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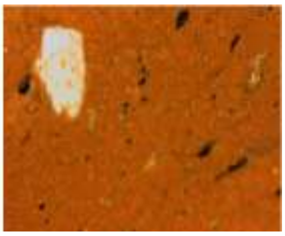

Late classical and Hellenistic pottery from Asclepieion of Ancient Messene, Greece: An Archaeometric approach

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ABSTRACT

Ancient Messene is an ancient city of the Messenia region, in South Western Peloponnese. Today belongs in the municipal unit of Ithomi. This particular research focuses on the archaeometric analysis of a large assemblage of pottery fragments from the deposits in the south terrace of the Asclepieion (Sector XV1/2) , at Ancient Messene. Based on the typological characteristics the pottery is dated between the second half of the 4th century and the 3rd century B.C. The pottery analysed consisted of coarse wares (such as cooking pots and table wares), transport amphorae and fine wares, mainly drinking and food-serving vessels. In addition, this assemblage included a large number of miniature drinking cups, primarily skyphoi, which probably had a votive character. Similar miniature cups are common findings in several sanctuaries of chthonic deities in the Greek world, indicating a similar cult in this area in the south terrace of the Asklepieion..

The research was carried out in the Laboratory of Archaeometry of the University of the Peloponnese. The study has focused on a) the macroscopic and microscopic examination of 283 pottery samples with the use of LED, in order to identify the visual properties of the clay, like the colour, the coarseness, the frequency of the inclusions and b) the chemical analysis of 26 representative clay fabric samples and 3 geological samples with a combination of XRF and SEM analysis, in order to define and classify different clay groups and explore their likely provenance.

Based on the macroscopic and microscopic observation the clay matrix was divided in eight (8) main fabrics, based on a) the colour of clay matrix, b) the coarseness c) the frequency of the inclusions. From this examination the following fabrics were presented a) Fabric I (Munsell 5YR7/3; pink), b) Fabric II (Munsell 5YR7/4; pink), c) Fabric III (Munsell 2.5YR 5/8; red), d) Fabric IV (Munsell 2.5YR (6/6, 6/8, 7/8; light red), e) Fabric V (Munsell 5YR 5/6,7/6; reddish yellow), f) Fabric VI (Munsell 2.5YR 5/4; reddish brown) g) Fabric VII (Munsell 5 YR 6/1; reddish gray), and h) Fabric VIII (Munsell 2.5YR 5/1; reddish black). From the above categorization, twenty six(26) pottery fragments, representative of the eight fabric groups, were chosen for chemical analysis.

From the microscopic examination of the 26 pottery samples and of the 3 geological, clay samples the following research questions were investigated: a) the number of fabric groups based on their chemical concentrations and the possible

correlation between the macroscopic and the chemical information, b) the likely provenance of the pots with the use of both geological and bibliographic data, c) technological parameters that had to do with the firing temperature of samples and the presence of slip/glaze. A future, more thorough analysis of the geology of Messenia along with the use of petrographic techniques for the better identification of pottery provenance, which will be based on this preliminary study, could be valuable for understanding how ancient Messenians manufactured their pots and, ultimately, shed some light on aspects of their everyday life.

1. DISCUSSION

Ancient Messene is one of the most significant city of the antiquity in size, shape and preservation (Θέμελης, 2010). Moreover, the fact that the archaeological space has not been covered up with today's structures and settlements and also it is in a par excellence Mediterranean and undamaged environment, can ''supply'' us with valuable findings through years.

A large assemblage of 283 pottery sherds of the Late Classical- and Hellenistic period from the south terrace, sector XVI/2 of Asclepieion was visually examined. The information from the typological examination was correlated with the data resulted by the use of non invasive analytical techniques, such as the scanning electron microscopy (SEM/EDS) and portable XRF(p-XRF). Based on the chemical characterization of the clay fabrics, important information was drawn regarding to technological issues such as the quality of the Messenian slip/glaze and the firing process in correlation with the typology of the vessels. Finally, three geological, clay samples collected from Valyra, an area close to ancient Messene, were microscopically and chemically analyzed in an effort to locate the clay resources used for the production of the studied pottery.

2. INTRODUCTION

Messene was established in the bank of the Pamisos river, in the downhill of the Messenian valley. The city took its name from Messene, the first mythical queen of Messenia, , daughter of the king of Argos Triopas. The ancient city was founded by the Theban general Epaminondas in 369 B.C., after his victory in the battle of Leuktra against the Spartans. Despite the fact that the city is mainly known from its architectural monuments of the Hellenistic and Roman periods, the earliest occupation within the area of the fortified city is dated back to Early Bronze Age (3000-2500 B.C.), while there are traces of habitation in the Geometric period (9th-8th B.C.). Messene had a great sociopolitical and economic development during the Hellenistic period and specifically when Messenia allied with Macedonia, under the domination of Philip II, to support the resistance against the Spartans (Farrington, 2012).

Messene is a very important ancient city for several factors. The most notable is the great size of the city, with a well-preserved grid plan and an imposing fortification system. The good preservation and the fact that the city was never totally destroyed, are things that contribute to the restoration processes around the archaeological site. Besides the archaeological remains, the descriptions of Pausanias enrich our knowledge about ancient Messene. The traveler visited the city during the kingship of the emperor Antoninus Pius, between the years 155 and 160 A.D., 530 years after the Messene's foundation. In his book, *Messeniaka* he presented the history of Messene and described its monuments (Themelis, 2010)**.**

The first excavations in ancient Messene started in 1828 under the auspices of the members of the French Scientific Expedition in the Peloponnese (Expédition Scientifique de Morée).Thanks to this expedition, Peloponnese was mapped and the ancient monuments were thoroughly investigated. The excavation was continued by Philippe Lebas in 1844. In 1895 the Archaeological Society of Athens assigned the systematic excavation of this archaeological site to the Samian archaeologist and politician afterwards, Themistocles Sofoulis . Between 1909 and 1925 at the head of the excavation is George Oikonomou, while from 1957 and up to 1975, Anastasios Orlandos who managed to reveal the biggest part of the Asclepieion complex (Θέμελης, 2010). Since 1987 and up to the present, Professor Petros Themelis has been in charge of a systematic program of excavation, restoration and promotion of the site of ancient Messene. This long-standing work has been sponsored by the Archaeological Society of Athens along with several private donors.

Though the excavation of the archaeological site of ancient Messene is one of the oldest excavations in Greece, it is only the last 30 years when the study of the monuments and of the movable archaeological finds has become more systematic, and related publications have appeared in print. Regarding the Hellenistic pottery from the site, P. Themelis has made important contributions (e.g. Themelis, 2005 on the early Hellenistic pottery from a deposit below the floor of the orchestra of the Ecclesiasterion), while systematic references to pottery finds from ancient Messene have been made in the yearly preliminary reports of the excavations published in the *PAE* since mid-1980's. His collaborators have also published a couple of articles about Hellenistic pottery from the site, such as Rogl 2005 who studied the Hellenistic pottery from the grave monument K3, along the west stoa of the *gymnasium*). The burials of K3 reveal a continuous use up to early Roman times. Besides the glass, iron, bronze objects and coins, numerous ceramic grave offerings were also excavated and about 60 complete vessels were preserved. Typologically the vessels belong to cylindrical pyxides, plain cups, small plates, oinochoai, lekane, biconical white-ground lagynoi, prochoi and amphoriskoi. In addition, drinking vessels like kantharoi and a considerable number of cooking pots such as chytrai, were found.

It is worth noting here that Rogl's article included a few observations about the clay fabrics of the pots found in K13. The clay of the fine wares is the typical Messenian clay, as defined in this study, which chromatically ranges from orange to brown orange or reddish yellow (Munsell 7.5YR 7/6), and macroscopically has very little mica and small white inclusions which have been identified as quartz. The same clay was also observed in the coarse wares and in the only thing that differentiated is in the large size of the inclusions. On the other hand, a small number of imports from Athens, Eastern Mediterranean and Asia Minor have been identified. Of course these imports have been identified on a typology base; since no chemical criteria have been applied, no safe conclusions about provenance study can be drawn.

Regarding Hellenistic pottery from the wider region of Messenia, it has so far only sporadically been published in the Proceedings of the Hellenistic pottery conferences, between 1976 and 2016 (e.g. for the pottery from the 'Tsopani Rachi' site, near Pylos, see Danali, 2005). Similarly, studies on Messenian pottery clay fabrics, of any period, appear only occasionally (e.g. Matson, 1972; Γιαννοπούλου, 2002). As a result, the definition of ‘Messenian’, in both pottery typology and clay fabrics, requires further exploration and study.

My present study focuses on the pottery which was found in a deposit in the south terrace of the Asclepieion, often linked with the earliest phases of the temple of Asclepius. This assemblage includes a considerable number of black-glazed pots (such as drinking vessels, primarily skyphoi, bowls of various sizes with outturned and incurved rim and fish-plates), tableware (e.g. jugs, lekanai, etc.), cooking ware (e.g. chytrai and lopades) and a few transport amphorae, dated according to the excavator between the Archaic and the Hellenistic period (Themelis 1994).

As far as the black-glazed pots from the assemblage are concerned, the following common features support the regional/local production of most of them: a) a thin, mat black to dark brown glazed which is often partly or completely flaked off, b) a limited stamped decoration, c) the emulation of forms that were produced in big centers like Athens and Corinth, or in cities and regions linked to Messenia, such as Argos, Arcadia, Achaia and Elis. The characteristics of the pottery reveal a socially closed society and economically self-sufficient. On the other hand, the Messenian pottery workshops depended on their allies like Elis not only for geographical reasons but also for political ones (Themelis, 2005). In general, the geographic area of Western Peloponnese and specifically Achaia, Elis and Messenia share common stylistic features because they belong to the same cultural unity (Kyriakou, 2005).

The prime goal of this thesis is the archaeometric study of 26 pottery fragments and the information that can be provided about their origin and technology through the chemical examination of the clay fabric. The following will be thoroughly presented a) the macroscopic examination of their clay fabrics, b) the microscopic examination of the samples with the use of SEM/EDS and p-XRF in order to draw information on aspects of the manufacturing process, like the firing conditions and firing temperature and the presence of slip/glaze. Moreover, for the identification of the pottery provenance a) 3 geological clay samples from Valyra region were collected b) relevant bibliographic data was studied.

The present study consisting of 10 chapters and is accompanied by 5 appendices.

In Chapter 1, a brief report about what will be discussed in the following chapters is presented.

In Chapter 2, a brief presentation of the excavations of ancient Messene, the importance of the site and the history of research on Hellenistic pottery from the site are presented. the sanctuary of Asclepius.

In Chapter 3, a brief presentation of the Asclepieion with detailed presentation of the pottery, found in the south terrace of the Asclepieion complex (Sector XVI/2).

In Chapter 4 the under examination samples are analytically presented. In addition, focus is also given in the 2 geological, clay fabrics which collected from Valyra, an area closed to Ancient Messene in order the locality of the understudy pottery been identified.

In Chapter 5, the methodological criteria along with the laboratory equipment and the exact laboratory conditions used for the chemical analysis of the samples are analytically presented.

In Chapter 6, the qualitative analysis of the large assemblage of pottery is thoroughly discussed and important conclusions from the visual traits examination are presented.

In Chapter 7, the chemical analysis used for the examination of the 26 pottery samples and the 3 geological, clay samples re analytically discussed. The two analytical techniques used for this study is presented. More specific, the major elements of SEM/EDS were used for the examination of the fabric groups while the trace elements of p-XRF were used for the provenance study.

In Chapter 8, the manufacture process of the pottery samples is presented by examining visually and chemically the quality of the slip/glaze.

In Chapter 9, basic parameters that affect the firing process are examined chemically and possible correlations with the utility of the vessels are presented.

In Chapter 10, the conclusions of this primary research are thoroughly presented. Moreover, emphasis is given in the importance of qualitative analysis in correlation with reliable analytical techniques for the better evaluation of pottery material. Finally, suggestions for further research are provided.

In Appendix A, a detailed catalogue of the visual traits of the pottery samples is presented. In Appendix B, the chemical data from the SEM/EDS and p-XRF analysis are presented. In Appendix C, the chemical concentrations from the analysis of the slip/glaze are presented. Appendix D includes analytical information about the samples which were chosen for the examination of firing process. Finally, in

Appendix E the typology of the vessels from which the samples have been taken are analytically presented.

3. THE ASCLEPIEION COMPLEX

The Asclepieion is an important architectural complex at Messene and along with the nearby Agora consisted the most ‘’neuralgic’’ spot of the public life of the city. The temple was dedicated to both Asclepius and the mythical queen Messene as the related numerous votive figurines indicate. According to Pausanias the Asclepieion was a kind of an art museum, full of superb statues of the Messenian sculptor Damophon. In addition, the place was sacred because Asclepius had also a healing aspect. Around the temple, there were about 140 stands for bronze statues, mainly of political figures (Themelis, 2010). The erection of the Asclepieion complex seems to fit in a great architectural program, in a model of the Athenian Acropolis, with a main purpose the projection of the Messenia’s as a distinct ethnos of the Peloponnese, which had paid tribute to their Doric and pre-Doric past (Themelis, 2014).

The main buildings of the Asclepieion complex are the following: **a) the large Doric Temple (Z), b) the Altar (Z1), c) the Ekklesiasterion (A), d) the Bouleuterion (Γ), e) the Archeion (Γ-Γ) and the f) Oikoi (K,M,N,Ξ,Y,X)** of the West side. In Figure 2. an analytical plan of the archaeological buildings of Asclepieion complex is presented. In the Ekklesiasterion took place various sociopolitical, religious or music events. Bouleuterion served as the main room for the meetings of the representatives of the city council (*synedroi*) while in the Archeion all formal documents of the Bouleuterion were kept. The Oikoi which were lined up from the North to the South of the Asclepieion were rooms for the exhibition of remarkable sculpture masterpieces of the Messenian sculptor Damophon (Themelis, 2010).

The Asclepieion has three architectural phases according the archeological stratigraphy. The first phase is dated in the Archaic period (7^{th}-6^{th} century B.C.). The sanctuary was linked to the town planning as an organized temenos in the 4^{th} century B.C. The third construction phase dated in the 3^{rd} century B.C. The dating of the phases of the Asclepieion is based on movable finds, such as pottery, figurines and votive tiles. Rebuilding continued in the temple and the surrounding buildings until the late antiquity (3^{rd}-4^{th} century A.D.). The sanctuary was finally abandoned in the last decades of the 4^{th} century A.D. after the catastrophic earthquake of the 375 A.D.

(Themelis, 1995). In Figure 1. An aerial photo of the excavation of the archaeological space of Asclepieion is shown.

Figure 1. Aerial photograph of the Asclepieion complex

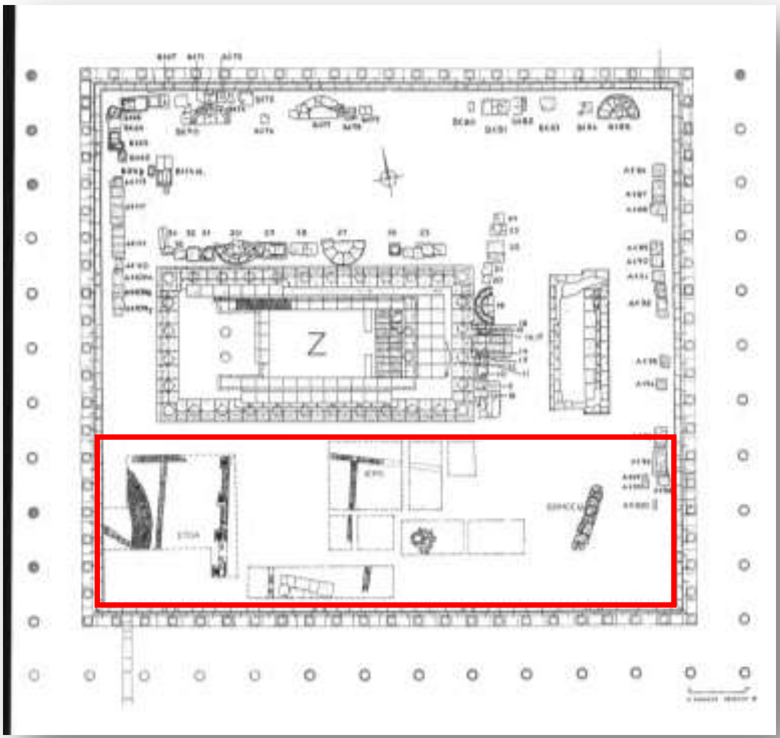


Figure 2. Ground plan of architectural remains of the early phase of the sanctuary in the south terrace of Asclepieion (the area where the pottery was found is in a red rectangular)

3.1 THE SOUTH TERRACE OF THE ASCLEPIEION(SECTOR XVI/2)

Air photographs of the Asclepieion complex revealed a cavity in the ground in the shape of a horseshoe , 4 meters southeast of the altar, which had been determined as a subterranean deposit. The excavation revealed a shallow pit (4,50x3,50 meters) which contained pottery sherds, a large number of stones, fragments of tiles, animal bones, carbonized wood, fired clay, iron and copper masses, 9 copper coins, copper nails, a few fragments of copper laminas and a fragment of a terracotta relief plaque, clay figurines, and miniature drinking vessels, such as skyphoi and kantharoi (Themelis, 1990a). Similar finds such as several small votive cups (skyphoi and kantharoi), terracotta figurines and tiles of the Archaic and Classical period, were also yielded from the area above a circular votive pit for liquid offerings between the stoa and the cult building (Themelis 1996).

Further excavations in the south terrace of the Asclepieion that took place in the 1990's brought to light more structures: part of a stoa of a sacred enclosure which predates the temple of Asclepius, and architectural remains of a cult building which had three phases (a wall of the Archaic period, a two-chambered construction of the early 4th century BC which was partly rebuilt after fire in the late 4th or early 3rd century BC and was, eventually, abandoned in the beginning of the 2nd century BC) (Themelis, 1995). The wide and shallow pit in the vicinity of the cult building, which appeared in the air photograph as aforementioned, seemed to have been used as a destruction dump of the second, Classical, phase of the sacred building. Only few miniature cups (skyphoi,) and a clay/terracotta relief plaque found inside the pit have a votive character, correlated with chthonic deities which cannot be identified (Themelis, 1990; 1993).

The pottery from the south terrace of the Asclepius temple date broadly between the Archaic, 7th -6th c. BC and the Hellenistic period, before the 2nd century BC (Themelis 1994, 87-88; the pottery assemblage is under publication by E. Zimi). Pottery fragments include coarse wares such as cooking pots (chytrai and lopades) and tableware (jars, oinochoai, lekanai), transport amphorae and fine wares, primarily drinking vessels (skyphoi and kantharoi), but also *unguentaria* (perfume bottles), echinus bowls, bowls with outturned rim. plates, etc. Most of the fine wares bear either black or brownish-red glaze.

4. SAMPLES

The 26 pottery samples which are studied and analysed in the current thesis were selected after examining a corpus of 283 samples (taken by Eleni Zimi in 2000's), from contexts in the south terrace of the Asclepieion (Sector XVI/2), dated between the last quarter of the 4th and the beginning of the 2nd century BC. These samples belong primarily to coarse wares, such as cooking pots, lekanai, a jar and a mortar as well as to transport amphorae. Fine wares are represented by fragments of a skyphos, a kantharos and an unclassified open form. The selection was based on the macroscopic and microscopic observation of the clay samples of the total corpus and the 26 representative samples were chemically analysed. Both the clay fabric and the presence of slip/glaze were examined, as will be thoroughly presented in the following chapters.

Furthermore, 3 geological, clay samples were collected and analyzed chemically in the Archaeometry Laboratory of the University of the Peloponnese. These samples were collected from Valyra, a village in the immediate vicinity of the site of ancient Messene, which has natural clay soils and a long-standing pottery tradition, and were chemically analysed for comparative purposes in relation to pottery provenancing. Between the 1920s and 1990s this area, along with neighboring villages, had a flourishing ceramics production (Viniou, 1990). Due to the pottery manufacture, throughout the 20th century the area had many pottery furnaces which are now half-destroyed or buried in the ground. Nowadays the pottery manufacturing in this area has vanished.

Regarding clay collecting, the clay was gathered from two spots in Valyra. The first geological, clay sample came from a location called Palaiokamina (C2 sample, Table 1). The Greek name *Palaiokamina* means old furnaces and the area took its name from the presence of pottery furnaces in the old times. The colour of this clay is gray with a very fine and sandy texture as is shown in Figure 3.

Figure 3. Imaging of the gray clay soil from Palaiokamina

Figure 4. Imaging of the red clay soil from Goubes

The second clay sample was collected from the area named Goubes (C1 sample, Table 1) which means big hole and took its name from the depth of the hole around 3 meters. When the pottery tradition was blooming the potters were digging in this spot in order to collect the clay soil for the manufacture of their ceramics. The colour of this clay is reddish as is shown in Figure 4. and it is more plastic in texture thanks to the presence of moisture. It is also worth noting that in the spot that the two clays were collected there was availability of water either with the form of a well or as natural stream.

After the collection of the clay soil, the clay was purified in the Laboratory of Archaeometry of the University of the Peloponnese. In Figure 5 are presented the two clay fabrics before and after the purification with the sieve.

For the purification a fine sieve with the diameter of 0,466 mm. was used. After the removal of all the impurities the clays were mixed with water for the manufacture of small clay briquettes. The two clays were mixed together in different contents because the gray clay was too sandy to be used just on its own. The different contents of the two clays are followed in the next table.

Figure 5. Imaging of the two clay fabrics after the purification with the sieve (top), the unrefined clay soils (bottom)

Table 1. Mixing quantities of the clay pastes used in this study

Name of clay briquettes	Contents of clay powder	Photo before firing	Photo after firing
C1	30 gr. red clay powder		
C2	30 gr. gray clay powder		
C3	➢ 30 gr. red clay(C2) powder ➢ 20 gr. of gray clay powder (C1)		
C4	➢ 15 gr.		

	red clay(C2) ➢ 15 gr. gray clay powder (C1)		

The C2 due to its sandy texture, had not the plasticity required and for that had to be put into a plate. Also for this reason this sample was not appropriate to be selected for chemical analysis and thus only the C1, C3 and C4 geological, clay samples were chosen for further examination.

After the manufacture of the clay briquettes, they were left to dry and then they were fired in an electrical furnace in the 960 C^{o}, in oxidizing atmosphere for 10 hours. Table 1 is shown the clay briquettes before and after the firing process. All the process of the manufacture and the firing of the clay briquettes took place in a local pottery workshop in the historical center of Kalamata.

5. METHODOLOGY

In this research the main aspects that need to be discussed are a) the visual traits of a large assemblage of 283 pottery samples and to see if there is a correlation with the mechanical properties of the vessels b) the chemical analysis of 26 representative, archaeological, pottery samples and 3 geological, clay samples with the use of analytical techniques in order to draw information about the provenance and the manufacture technology.

The techniques that were used for the examination of pottery were the followings: a) macroscopic observation in 283 pottery samples with the use of Munsell Soil Colour Chart of 2000, b)microscopic examination of 283 pottery samples with the use of Optical Microscopy, LED I-SCOPE, of Moritex device, using a fiber optics system(Palamara et al., 2016) c) SEM/EDS chemical analysis in 26 representative of the large assemblage archaeological samples and in 3 geological, clay samples, C1, C3 and C4, as is mentioned in Table 1 d) p-XRF analysis in 26 representative samples and 3 geological, clay samples. In Table 2 the values of clay standard, soil 7 that was used for the calibration of SEM/EDS and p-XRF devices are presented. Clay standard soil 7 was used for the determination of precision for both SEM/EDS and p- XRF. According to Table 2, the precision is good, with the exception of SiO2 which is underestimated by p-XRF while CaO is overestimated.

Table 2. Values of the clay standard soil 7

		Na_2O	**MgO**	**Al_2O_3**	**SiO_2**	**K_2O**	**CaO**	**TiO_2**	**Fe_2O_3**
Soil 7	**XRF**	0.83	1.43	12.44	46.68	1.82	31.44	0.68	4.69
	SEM	0.38	2.40	14.03	48.02	2.14	27.69	0.62	4.72
	Real values	0.42	2.40	11.38	49.35	1.87	29.23	0.64	4.71

The preparation of the samples for the two analytical techniques were slightly different depended on what needed to be examined. Thus, for the chemical examination of the 26 archaeological samples and the 3 geological clay ones, with the use of Scanning Electron Microscope (SEM/EDS) and non-destructive X-Ray Fluorescence (p-XRF), selected areas of the samples were polished using a Dremel

Rotary tool with a grinding tool prior to the analysis. Based on that preparation clean and smooth cross sections were created appropriate for the chemical analysis.

On the other hand, in order to draw information about the firing process and the slip/glaze, the following stages were presented: a) polished sections were prepared b) coated in resin c)fired in an electric furnace at 750 ^{o}C for a one hour and a half d) several grindings of the samples with a use of a wheel in order to remove the resin. For the examination of firing stage from the 29 samples(both archaeological and geological), 9 sherds were decided to be examined with the use of SEM/EDS analysis, based on specific parameters. These are a)the calcareous content b)the mascroscopic observation. Regarding to the macroscopic observation the samples were examined based on the the colour variations of their core as it is described in the Appendix B.More details about the firing process are prsented in chapter 8.During the analytical procedure, with the use of SEM/EDS, Backscattered electrons were used and a Low Vacuum in an effort to reduce the electron charge and to have as clear picture as possible. For the examination of slip/glaze five (5) samples were choosen. The slip/glaze will be dicussed thorougly in chapter 7. Again, the samples preparation took place in the Laboratory of the Univesrity of the Peloponnese.

Regarding to the instrumentation used for the SEM/EDS analysis, this was of JEOL (JSM-6510LV) coupled with EDS (Oxford Systems). The analytical data were obtained by INCA software. The analyses were conducted at 20 kV accelerating voltage, under a magnification of ×200 and with a count time of 180 s. At least 3 measurements were taken for each sample on different areas of polished fresh cuts (Palamara, et al 2016)The detailed SEM/EDS data is presented in the Appendix B-1.In addition, the p-XRF was a Bruker Tracer III SD set with a beam diameter of 3mm (analytical conditions are given in detail by Palamara, et al. 2016).

Portable XRF analysis was applied on all samples using a portable Data quantification was made using S1PXRF software and the built-in calibration curve for soil and clays. In order to optimize the analytical range, two settings were used: (1) an unfiltered low-energy excitation mode (high voltage set at 15 kV and current of 24 μA, analyses carried out under vacuum) was used for the analysis of major and minor elements with an atomic number, Z, between 11 and 29 and (2) an Al/Ti filtered (0.012 inches Al plus 0.001 inches Ti) high-energy excitation mode (high voltage set at 40 kV and current of 12 μA) was used for the analysis of minor and trace elements with an atomic number Z>29. At least 3 measurements were taken for each sample.

Generally, the precision for the XRF equipment was monitored based on specific soil and clay standards. The results and evaluation of the method are presented in detail in the Palamara et al., 2016.

6. VISUAL TRAITS

In this study qualitative analysis was accomplished in a large assemblage of 283 pottery fragments. More specific, the samples were examined based on their visual traits. The research took place in the Laboratory of the University of the Peloponnese. Moreover, with the use of statistical analysis these large dataset was able to be interpreted. The assemblage was divided in different fabric groups based on specific parameters as will be thoroughly presented in this chapter.

The clay samples were examined with the use of Munsell Soil Colour chart, of 2000 in order the colour of clay fabric being identified. The microscopic examination of the samples was accomplished with the use of optical microscopy, LED. Based on that observation, the 283 samples were separated in 8 main, clay fabric groups taken into account specific parameters.

This chapter will focus on the physical properties of fired ceramic materials, which can provide us with important technological information. In addition, all that factors which were chosen for this particular research had to be organized in an excel in order to be easier to work with. As a next stage, for that pottery classification all the parameters were analyzed statistically. Many different diagrams were examined in order to find the most suitable ways of representation in order to draw secure conclusions. In Table 3 the parameters that were chosen for this qualitative research are presented along with relative information that were draw and the instrumentation that was used. Except from these factors, hardness is also an important parameter for the pottery research but was not evaluated at the present study.

Table 3. Parameters determined from the examination of the visual traits

PARAMETERS	INFORMATION	INSTRUMENTATION
<u>Colour</u>	➢ Use of different type of clay ➢ Firing Process	➢ Munsell Soil Colour Chart
<u>Porosity</u>	Mechanical properties	➢ LED microscope (I Scope model of

		Moritex)
<u>Coarseness</u>	Mechanical properties	➢ LED microscope (IScope model of Moritex)
<u>Inclusions</u> **a)** Colour **b)** Shape and size **c)** Frequency	➢ Information about the quality of the clay ➢ **(a,b)** The use of temper, non-plastic inclusions intentionally added by the potters, or not. ➢ **(b,c)** Coarseness	➢ LED microscope (I Scope model of Moritex) ➢ Munsell colour chart (characterization of shape and size)

Based on the parameters that were presented in the previous table, specific charts were designed in an effort for this large qualitative dataset being quantified. In Figure 6 the eight based colour groups of clay matrix are presented. The examination of the clay matrix is based on the Munsell Soil Colour Chart. According to the pie chart the under study pottery assemblage can be dived in eight (8) main fabric groups. The variations in the colour of clay is generally affected by a number of parameters, primarily the clay concentration in FeO and the firing conditions (Rice, 1987). Regarding to the firing process and the possible correlation with the colour, Rice suggests that colours of low-fired natural clays can be limited to white, black, orange, red or some mixture of these colours such as shades of cream, brown or gray. On the other hand colours like yellow, blue and green are virtually impossible to achieve on low-fired pottery except by specials additives (usually added to high-fired clays or glazes) or as post firing pigments (Rice, 1987). Moreover, as will be thoroughly discussed in the Firing temperature chapter, the shape of the vessels, namely the close or open forms also affect the colour of the final product, by leaving a macroscopic fingerprint in the core of the materia l(Fabric V, Table 4). In Table 4representative LED photos of the eight fabric groups are presented.

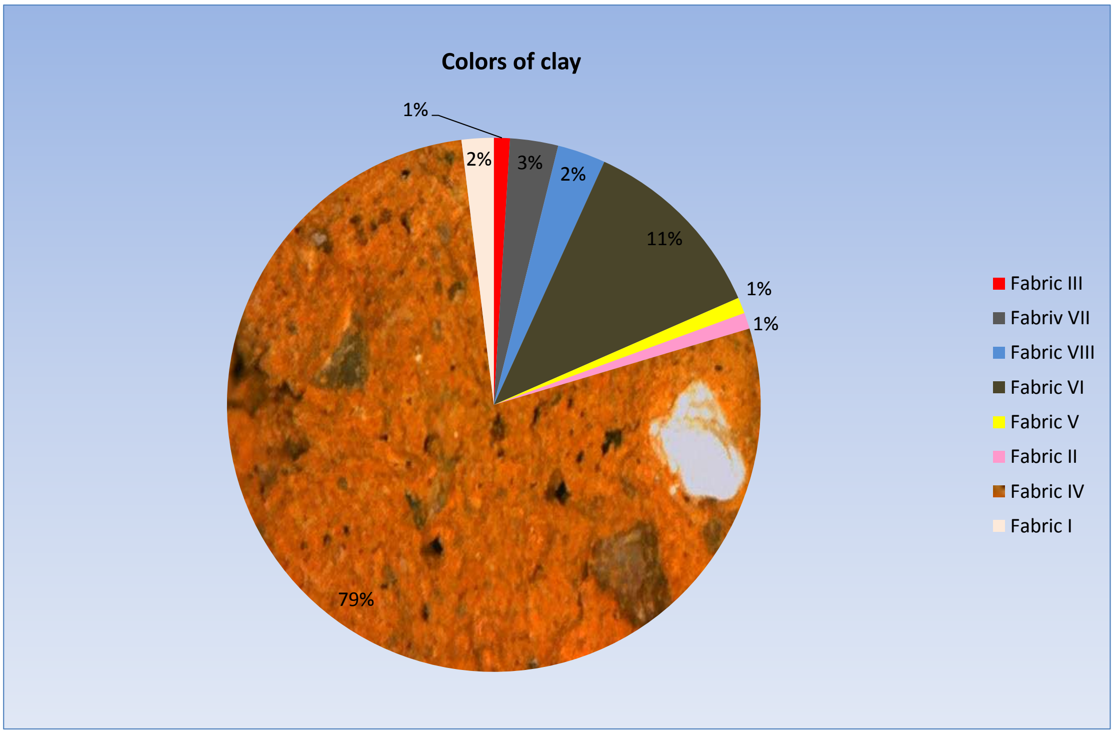
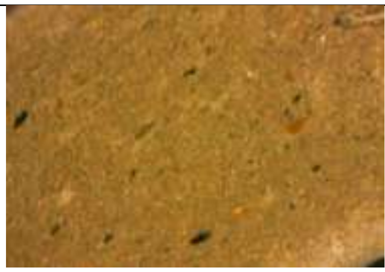
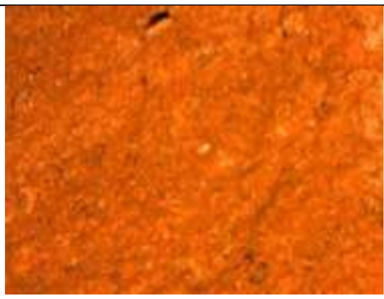
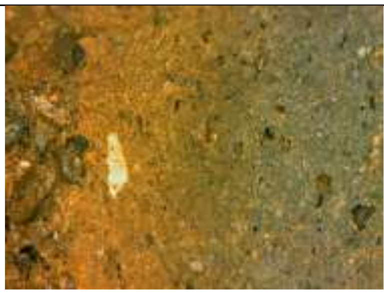
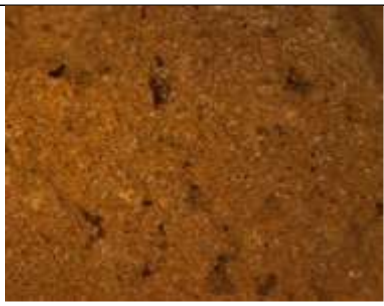
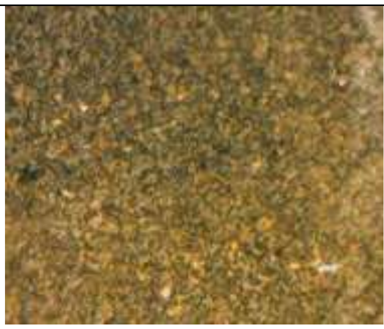


Figure 6. Pie chart of the basic clay fabrics

Table 4. LED photos of the basic fabrics

Fabrics	Munsell Soil Colour Chart	LED photo(magnification x 50)
Fabric I	5YR7/3 Pink	
Fabric II	5YR 7/4 Pink	

Fabric III	2.5YR 5/8 Red	
Fabric IV	2.5YR (6/6, 6/8, 7/8) Light red	
Fabric V	5YR (5/6,7/6) Reddish yellow	
Fabric VI	2.5YR 5/4 Reddish brown	
Fabric VII	5YR 6/1 Reddish gray	

Fabric VIII	2.5YR 5/1 Reddish black	

In Figure 7 the frequency of inclusions bar chart is presented. By examining this chart, we can have a broad idea of the quality of the clay. According to the frequency of inclusions we see that the biggest part of the pottery presents high frequency of inclusions. This can also be certified from the Fabric IV, which constitutes the biggest part of the assemblage, with a 68% percentage of high frequency of inclusions. Moreover, the Fabric VII appears the highest ratio of frequency of inclusions with percentage of 80%. Based on that frequency we can extract the following technological information: this high frequency of inclusions along with their big size of them must be temper, non-plastic inclusions, intentionally added by the potters.

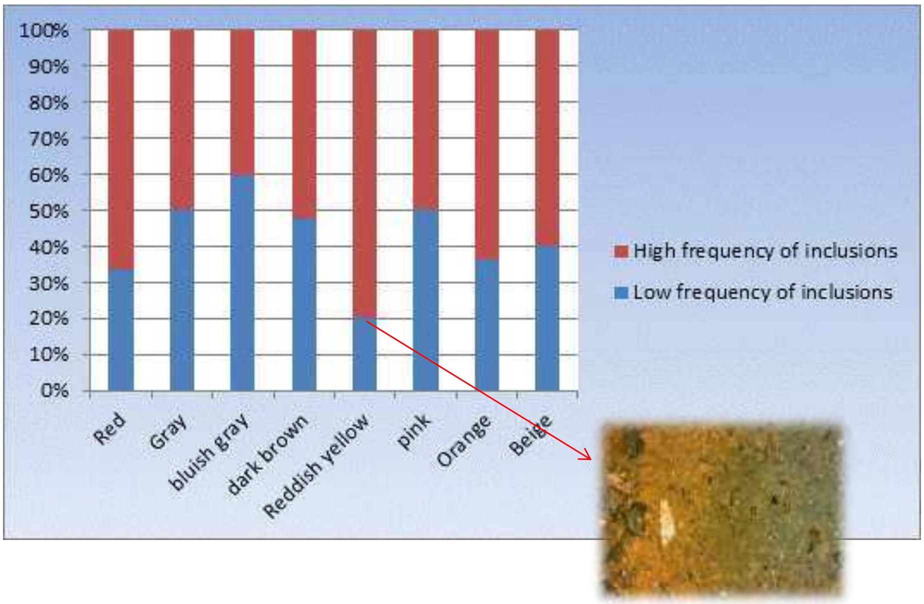


Figure 7. Frequency of inclusions bar chart in each of the eight Fabrics and characterized LED photo (magnification X50) of the microstructure of Fabric VII

In Table 5 information combined from the colour pie chart (Figure 6) and the frequency of inclusions bar chart (Figure 7) is presented.

Table5. Combined information from the colour pie chart and frequency of inclusions bar chart

Fabrics	**Munsell Soil Colour Chart**	**Percentage of samples**	**Type of pot**	**Low frequency of inclusions percentage**	**High frequency of inclusions percentage**
Fabric I	5YR7/3 Pink	2%	Open vessels Drinking cups Skyphoi	35%	68%
Fabric II	5YR 7/4 Pink	1%	Bowls Lekanai Plates	40%	60%
Fabric III	2.5YR 5/8 Red	1%	Open vessels Drinking cups Kantharos	32%	68%
Fabric IV	2.5YR (6/6, 6/8, 7/8) Light red	79%	Bowls Lekanai, Drinking cups Skyphoi, Cooking pots Lopades Amphorae	50%	50%

			Plates Pithoi		
Fabric V	5YR (5/6,7/6) Reddish yellow	1%	Cooking pots Lopade, Bowls Lekanai	60%	40%
Fabric VI	2.5YR 5/4 Reddish brown	11%	Open vessels, Bowls Lekanai, Plates Drinking cups Skyphoi	48%	52%
Fabric VII	5YR 6/1 Reddish gray	3%	Open vessels, Drinking cups Skyphoi	20%	80%
Fabric VIII	2.5YR 5/1 Reddish black	2%	Bowls Lekanai Cooking pots Lopade Lids	50%	50%

In Figure 8 bar chart the dominant colour of inclusions along with their frequency rate are presented. According to that, white inclusions are the dominant in the pottery and come first not only in the samples with high frequency of inclusions but also in those with low frequency. Then the red inclusions follow, while the black inclusions seem to have the lowest presence in the clay matrix. Moreover, has to be underlined that the colour of inclusions combined with the frequency in the clay matrix, can give us information about the quality of the clay and maybe can distinguish which inclusions are in the clay itself and which are intentionally added by the potter. The high frequency of the white inclusions along with the large-size of some of them as are observed in LED microscope, are Ca-rich inclusions which are very commonly added as temper by the potters (Shepard, 1985). The chemical analysis which will be presented in the following chapter proves that samples with coarse fabric and high frequency of large-size white inclusions are characterized at the same time as calcareous.

The red inclusions can be Fe-rich minerals or even red shale, which according to literature sources is a common rock of the Messenia region (Matson, 1972). However future detailed geological and mineralogical analysis is necessary in order to draw clear conclusions.

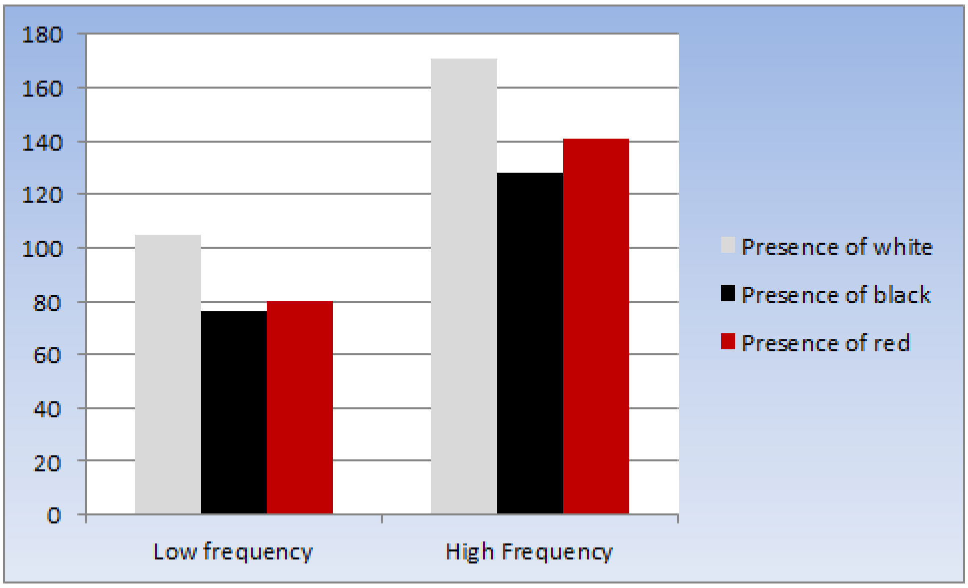


Figure 8. Bar chart that shows the three basic colours of inclusions along with their frequency rate

In Figure 9. pie chart the coarseness rate of the pottery assemblage is presented. From this chart we can draw information about the texture of the clay. As we can see the biggest part of the pottery (84%) can be characterized as fine while only 16% is described as coarse. This is not random but it relates to the fact that the biggest part of the pottery consists of fine wares primarily drinking vessels. On the other hand, the lower percentage of pottery which presents a coarse fabric (16%) represents coarse wares such as cooking pots. These kind of vessels in order to maintain heat needs to have thicker walls and that is why it appears coarser.

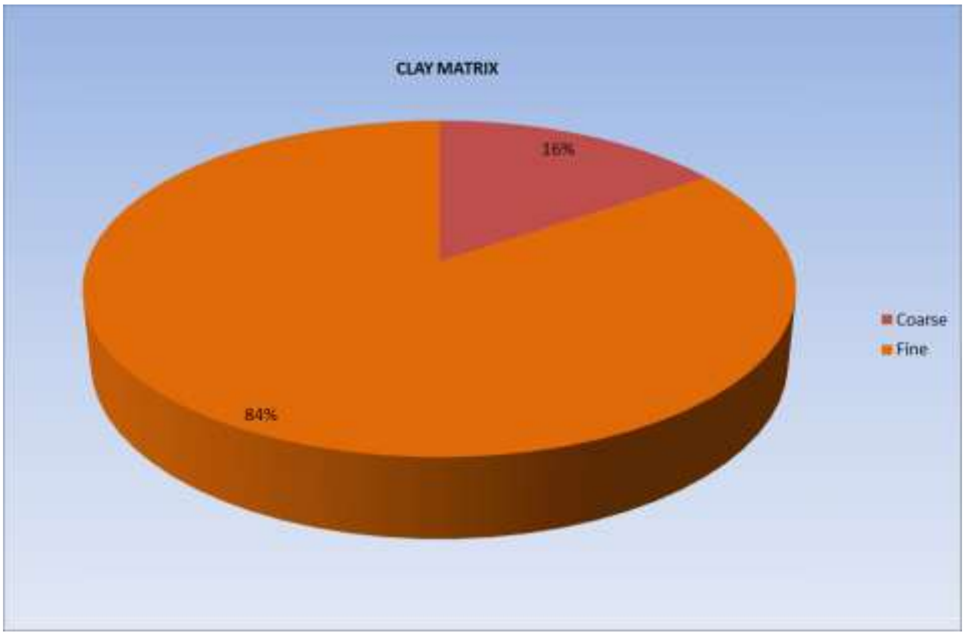


Figure 9. Coarseness pie chart

In Figure 10, pie chart the porosity rate of clay body is presented. Based on that, the highest percentage of the pottery (77%) can be characterized as porous while only 23% of the clay samples can be characterized as solid. The separation of the clay fabric into these two parameters can be very helpful in extracting important information about the mechanical properties of the pottery. For instance especially for the drinking vessels, porosity helps to maintain the liquid cool. In general and according to Rice porosity in some cases is necessary for the durability of the vessels and their use (Rice, 1987).

On the other hand, vessels that microscopically examined and their clay matrix has been characterized as solid, belong to the cooking pots. A possible explanation is that the solid clay matrix in this type of vessels increases the fire resistance.

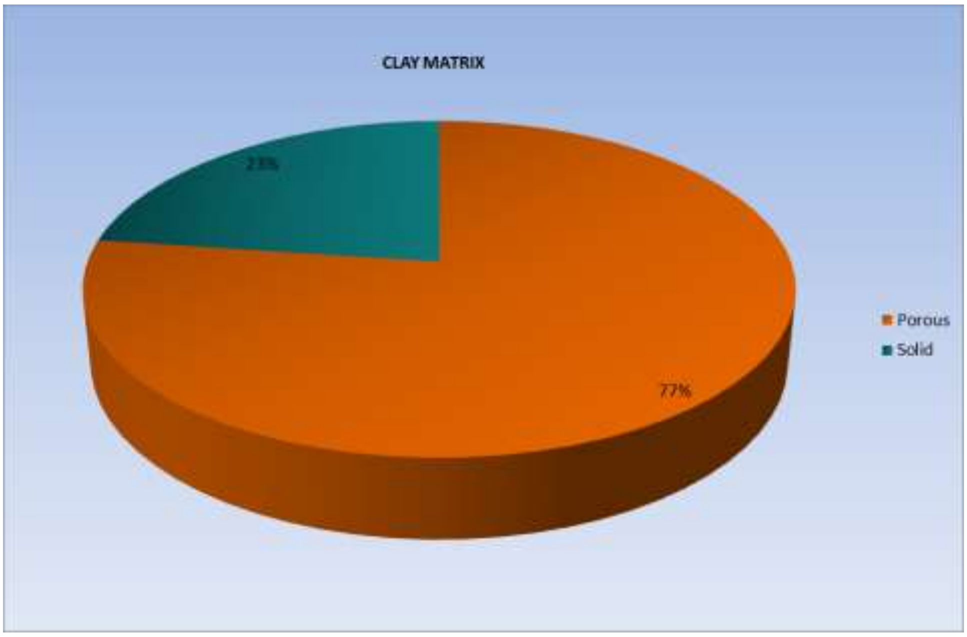


Figure 10. Porosity pie chart

6.1 PCA ANALYSIS

PCA analysis can help you to organize large datasets, comparing all the information that you can extract from your data in one diagram. The advantages of that is that you can have a more "clear" image of data's and based on that you can see if there are possible correlations or not.

In this research in order to be able to conduct a PCA, we had to think a hypothetical scale in which we could "translate" the parameters, into numbers. The parameters were the following: **a)** Size and shape of white inclusions **b)** Size and shape of red inclusions **c)** Size and shape of black inclusions **d)** Colour of clay matrix **e)** Porosity **f)** Frequency of inclusions **g)** Coarseness.

a) The shape of the three different inclusions (red, white, black) based on the Munsell colour chart categorization, varied between granular, angular and platy as it shown in

Table 6. Keeping in mind the hypothetical scale, the inclusions were given numbers from 1 to 3. For the samples where both granular and angular inclusions appeared), another 'intermediate' value was given.

a) Table 6. Shape of inclusions

granular	Granular/angular	**angular**	Angular/platy	**Platy**
1	2	3	4	5

Instrumentation used: Munsell Colour chart categorization, LED microscope

b) Table 7. Size of inclusions

Very fine	Very fine/fine	**Fine**	Fine/ medium	**Medium**	Medium/coarse	**Coarse**
1	2	3	4	5	6	7

Instrumentation used: Munsell Colour chart categorization, LED microscope

c) Table 8. Based colour groups

Fabric I (Munsell, 5YR7/3) Pink	**Fabric II (Munsell 5YR 7/4) Pink**	**Fabric III (Munsell 2.5YR 5/8) Red**	**Fabric IV (Munsell 2.5YR (6/6, 6/8, 7/8) Light red**	**Fabric V (Munsell 5YR (5/6,7/6) Reddish yellow**	**Fabric VI (Munsell 2.5YR 5/4) Reddish brown**	**Fabric VII (Munsell 5YR 6/1) Reddish gray**	**Fabric VIII (Munsell 2.5YR 5/1) Reddish black**
1	2	3	4	5	6	7	8

The colour of the clay matrix ranged among shades of pink, red, light red, reddish yellow, reddish brown, reddish gray and reddish black, according to the Munsell Soil Chart categorization.

Instrumentation used:Munsell Colour chart

d) Table 9. Porosity

Porous	Solid
1	2

The clay matrix also can be characterized as porous or solid. The porosity though, cannot be ''counted'' with the LED microscope. Although, with the use of optical microscope you can have a broad idea of the clay fabric.

Instrumentation used:LED microscope

e) Table 10. Frequency of inclusions

High	Low
1	2

The frequency of the inclusions was divided between high and low.

Instrumentation used: LED microscope

f) Table 11. Coarseness

Fine	Coarse
1	2

The clay matrix was characterized based on its texture and varied between fine and coarse.

<u>Instrumentation used</u>: LED microscope

The differentiations between the values have as main purpose to show in an easily understandable way how much the parameters differ between them. For example, if we look at the table of colour parameters we understand that the more the values differ between them the more different the group of colour is. According to that, the pink(shade 5YR7/3 of Munsell) **(1)**, pink (shade 5YR 7/4 of Munsell) **(2)** and red (shade 2.5YR 5/8 of Munsell) **(3)** is closer to light red (shades 2.5YR 6/6, 6/8, 7/8 of Munsell) **(4)** but vary significantly from the reddish gray (shade 5YR 6/1 of Munsell) **(7)** and the reddish black(shade 2.5YR 5/1 of Munsell) **(8)**. So by choosing different values, we understand how close or far are any of the values from the rest and according to that, the ratio of heterogeneity in our pottery samples is expressed. All this information about the parameters can be gathered in only one chart. PCA analysis can help us to gather all the parameters in only one chart, as Figure 11 is shown.

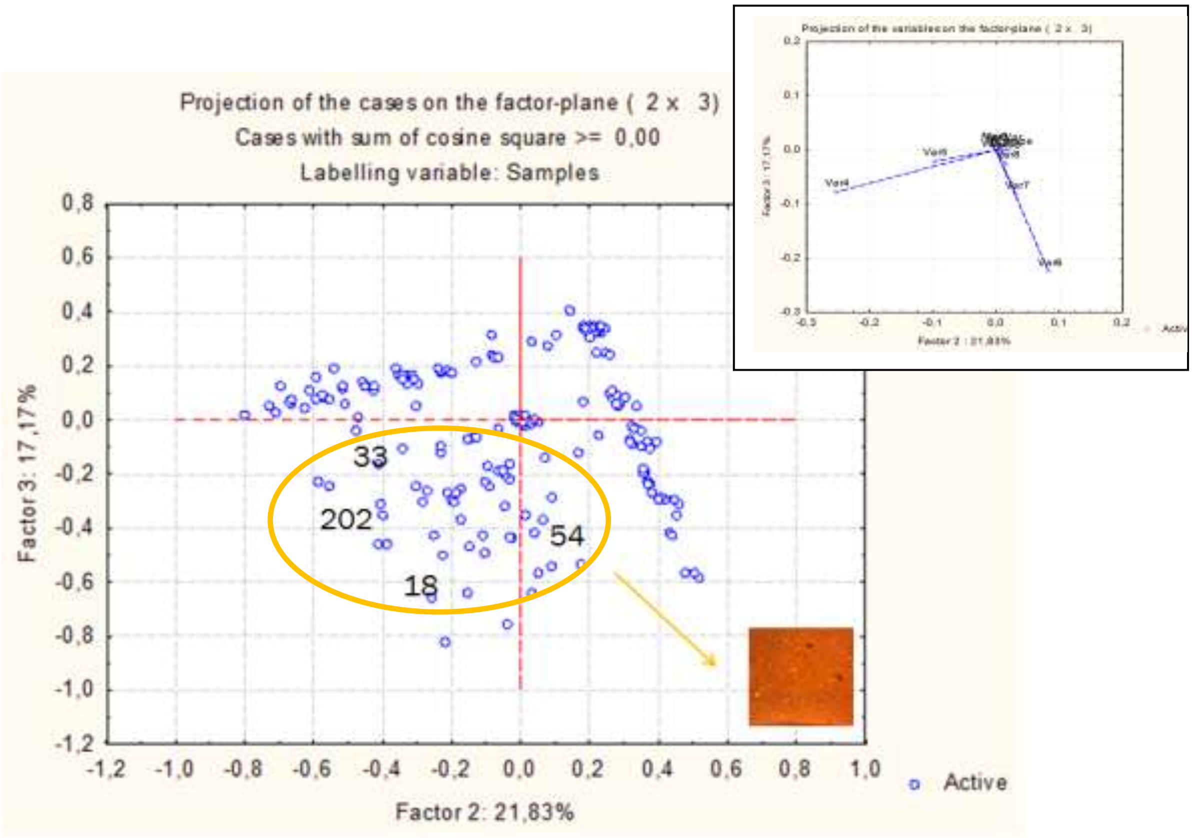


Figure 11. PCA plot (inlay plot: PCA vectors plot)

From the PCA chart we can see that the samples present heterogeneity. Some chemical groups can be distinguished like the samples 33, 202, 18 and 54 which belongs into the light red category of clay (Fabric IV). So, we could say that this Fabric IV which is the dominant fabric of the understudy pottery was also statistically confirmed by the PCA plot. Nevertheless, at least for now we cannot make any other grouping or draw any other conclusion. That has to do with our PCA scale which needs future improvement, and possible redefinition of the parameters that were chosen.

7. CHEMICAL ANALYSIS

In this chapter the chemical analysis followed for the examination of the pottery samples will be thoroughly presented along with the analytical techniques. The chemical analysis of the pottery samples with the use of SEM/EDS and portable XRF took place in the Laboratory of Archaeometry of the University of the Peloponnese (Kalamata).

7.1 CHEMICAL GROUPS

The concentration of the major elements of the fabric groups was determined with the use of SEM/EDS. As aforementioned, the microscopic examination led to the identification of 8 fabrics(Fabric I-Fabric VIII), whereas five chemically diverse groups (A, B, C, D and E) were determined based on the chemical examination(Figure 12). It is worth mentioning that the fabrics and the groups could generally not be correlated. By examining the CaO+MgO-Al_2O_3/SiO_2 (wt%) biplot (Figure 12) we can investigate the different chemical groups of our pottery. These are the following groups **a)** Group A samples M1, M17, M26, M9, C3 **b)** Group B samples M5, M7, M10, M11, M15, M6, M2, M4, M14, C4 **c)** Group C samples M8, M22 d) Group D samples M19, M12, M23, M3, M13, M16, M18 **e)** Group E samples M24, M20, M25, M21, C1.

More specific, Group A consists of five samples with the highest CaO content (>14 wt%). Two samples, M1 and M17, also present microscopic similarities, as they both belong to the Fabric I. The light colour of their fabric is affected by their high calcium content (close to 18 wt%), as it is known that the combination of high calcium content along with proper fire conditions can lead to whiter clay pastes (Molera *et al.,* 1985). Generally the addition of sea water(NaCl)in calcareous pastes can also affect the colour of the final product giving more white pastes (Matson, 1972). Of course, in this study this was not testified by the chemical examination.

Group B is characterized as calcareous (CaO>6 wt%) (Table A-1) and presents both chemically and macroscopically homogeneity, as it includes most of the samples that belong to the Fabric IV, with the exception of the M15 sample which belongs to the Fabric III.

Group D is characterized as non-calcareous (CaO<6 wt%) (Table A-1). From Group E two samples, M24 and M25, present both microscopical and chemical homogeneity as they belong to the same Fabric VIII and are non-calcareous (CaO<6 wt%). It is also microscopically testified that, these samples present high coarseness, with high frequency of inclusions. As a general comment regarding to the importance of calcareous clays (Group A, B, C) in comparison with the non-calcareous ones (Group D,E) is of ''technological nature'' and the improvement of the mechanical properties of the vessels (Rice,1987). Also, the determination of the calcareous content is based on the Maniatis et al, 1981 paper.

The Al_2O_3/SiO_2 (wt%) ratio, can inform you about the exact percentage of coarseness in the pottery. Based on the biplot (Figure 12) , it was verified that the under examination pottery samples belong to the coarse wares with a Al_2O_3/SiO_2 content ranges from 0.30 to 0.40 (wt%). Slightly coarser are the M8 and M22 samples (Al_2O_3/SiO_2 0.50 wt%).

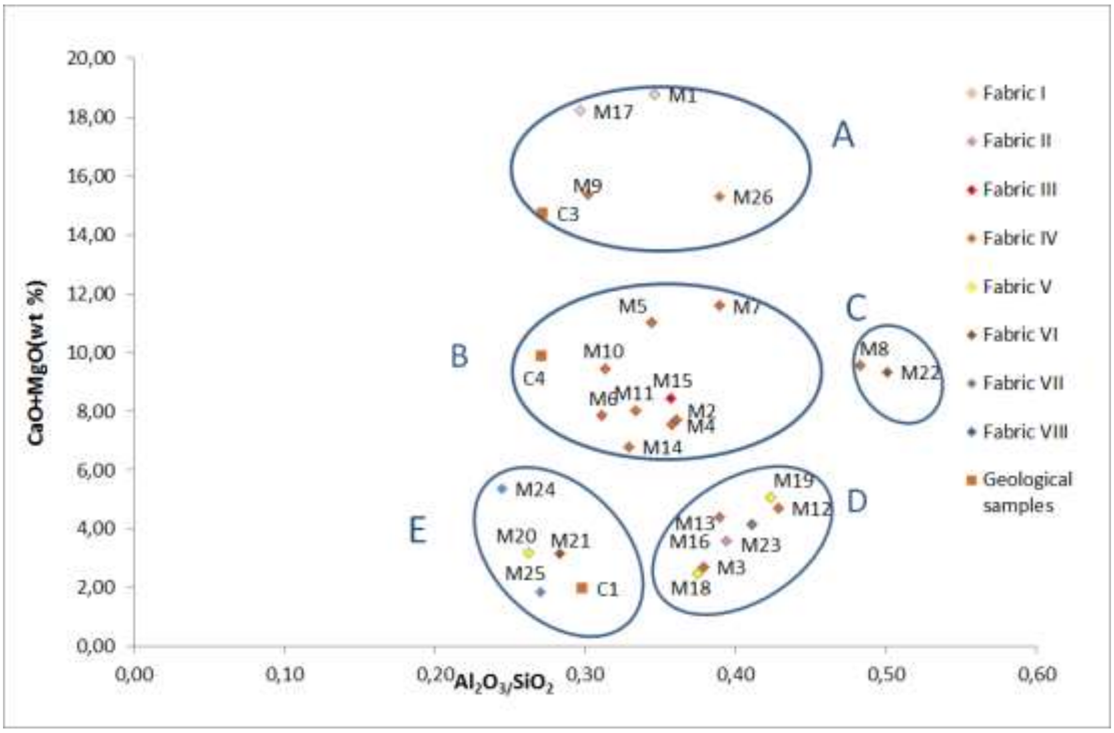


Figure 12. Concentrations of Al_2O_3/SiO_2 versus CaO+MgO

Table 12. Clustering groups

Chemical groups	Samples	Calcareous-non calcareous
A	M1,M17,M9,M26,3 clay	>6%(calcareous clay)
B	M5,M7,M10,M11,M15,M6,M2,M4,M14,4 clay	>6%(calcareous clay)
C	M8, M22	>6%(calcareous clay)
D	M19,M12, M23,M3,M13,M16,M18	<6%(non- calcareous clay)
E	M24, M20,M25,M21,1 clay	<6%(non- calcareous clay)

The TiO_2/FeO (wt%) biplot can show us the colour variation in the understudy pottery. The colour of pottery is generally affected by a number of parameters, primarily the clay concentration (FeO content) and the firing conditions (Rice,1987). In this case and according to TiO_2/FeO biplot (Figure 13) no clear correlation can be verified between the FeO content and the fabric hue. The biplot verified that samples which belong macroscopically to the same fabric, like Fabric V(Munsell 5YR 5/6,7/6, reddish yellow) present deviated values of FeO (wt%) content, that varies from 7 to 18%. This proves that the color variation correlated mainly with the firing conditions, as it will be thoroughly examined in the Firing Temperature chapter.

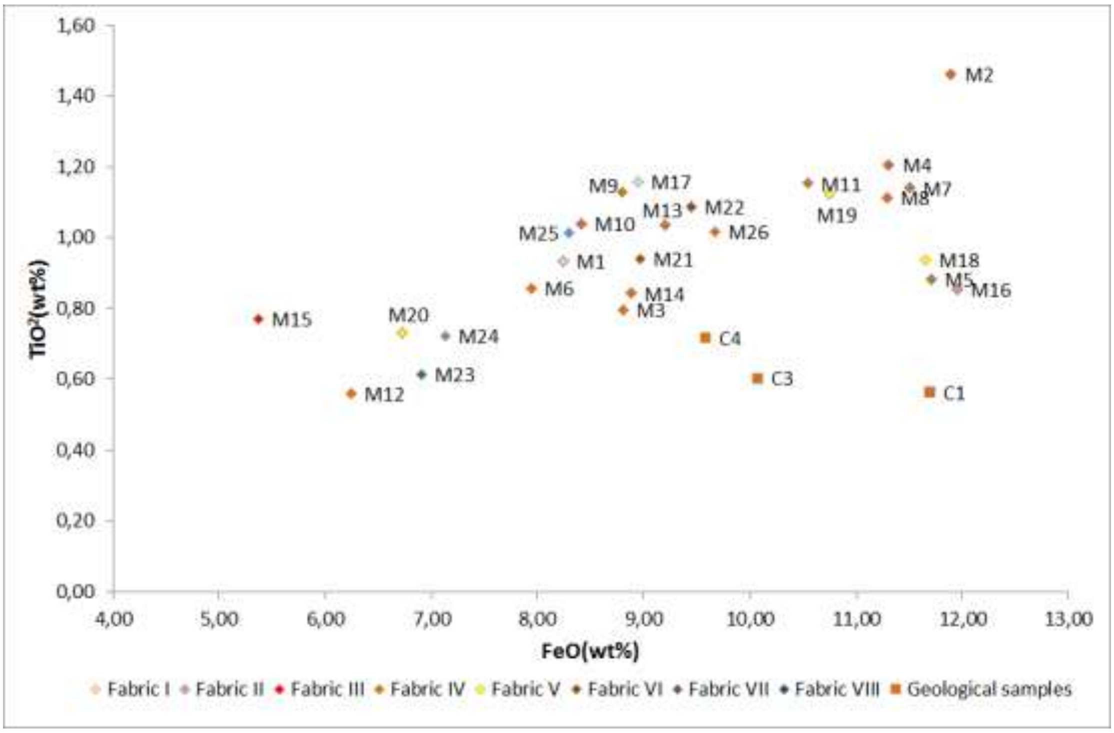


Figure 13. FeO versus TiO_2 ratio

7.2 PROVENANCE

In order to identify the provenance of the understudy pottery both bibliographic data and geological, clay samples were used. For the chemical analysis non-destructive p-XRF was used. The geological, clay samples that were used, selected after relevant research, from an area closed to ancient Messene, named Valyra, which is known for the long time tradition to handmade pottery, in an effort to detect the ancient clay sources. The procedure that was followed for the manufacture of clay briquettes was thoroughly described in previous chapter. Besides the geological, clay samples bibliographic data were also used. In the following table will be presented the macroscopic characteristics of clay fabrics from areas which selected based on the strong network of economic and social exchange developed with ancient Messene, during the late Classical, early Hellenistic period (Themelis, 2005).

In Table 13 clay fabrics from different areas of Peloponnese which have been macroscopically examined will be presented in an effort to have a broad idea about the type of clay these areas were used for the manufacture of their products. From this table we can say that the clays from these areas present more or less the same characteristics and that's why a detailed chemical examination needed to be done. Especially the clays from Patras and Elis are no easy to be distinguished because they belong in the same geophysical unity (Kyriakou, 2005).

Table 13. Visual traits of reference data

Selected Area	Macroscopic observation of clay	Time period
Messenia	Based on the qualitative analysis, the Messenian clay is characterized as dense and fine grained, with few mica and little visible temper. The clay is really soft with a chalky texture and that's why it is not preserve the glaze well. The colour varies from a light reddish yellow5YR 7/8 to a light orange 5YR 6/8 and in some cases to a light brown7,5YR 7/6-8/6. Especially the colour of the cooking wares varies from light yellow brown 7.5YR 7/6 to light pink 5YR 7/6. The vessels present thick walls, up to 2 cm. and in the most of the cases have a gray firing core. The colour of the inclusions varies from white, red, gray and brown, the size from small, medium, large and the shape from rounded and angular. Matson supports	Hellenistic- Late Roman

	that most of the small and medium rounded inclusions are probably sand. In the under examination samples with the use of SEM/EDS both quartz and calcium temper were detected (Alcock et al, 2005; Matson, 1972).	
Achaia	The clay from the region of Patras, Achaia based on the qualitative analysis present similarities with the Messenia clays. The colour varies from reddish yellow 7.5YR 6/6 to pink 7.5YR 7/4, and light yellowish brown 10YR 6/4 to pale brown 10YR 7/3, 7/4. Regarding to the texture is fine grained. The sherds present sandwich and bicoloured cores as a result of the firing temperature (Rathossi, 2005).	Archaic-Late Hellenistic
Elis	The clay is characterized as coarse grained, soft, reddish yellow 7.5TR 7/6. The clay that was used in pottery was in the most of the cases local because from the same clay was manufactured the	Late Classical-Early Hellenistic

	terracotta's of ancient Olympia sanctuary. The temper which was used in the clay consisted mostly of gravels and clay chunks (Μουστάκα, Χαντζή-Σπηλιοπούλου, 1991.)	
Argos	The clay is characterized as hard, with a lot of visible temper and mica. Regarding to its colour it varies from light red, light reddish brown to ashes gray (Κόλλια, 2000).	Early-Late Hellenistic

As has already been mentioned in order to identify the provenance of the understudy pottery, both geological and bibliographic data were used. In Table 14 the bibliographic references are thoroughly presented. Based on the combination of both the chemical and the reference data, the provenance part was able to be investigated. More specific, it is compared trace elements from **a)** the 3 geological, clay samples, **b)** 26 archeological samples **c)** relevant bibliographic data as described in the Table 14. From this combined information the Ni/TiO_2 biplot was created (Figure 14). For the bibliographic data the mean value (m) of the samples was used. The detailed p-XRF data is presented in the Appendix A-2, A-3.

Table 14. References table of bibliographic data

Bibliographic reference	Number of samples	Time period	Provenance
Magnone *et al.*, 2008:1533-1541 ''Technological	30	5^{th}-4^{th} century B.C.	Apulia

features of Apulian red figured pottery			
Aquilia *et al.*, 2015:3-11 ‘’Petro - archaeometric characterization of potteries from a kiln in Adrano, Sicily ‘’	26	4^{th}-2^{nd} century B.C.	Sicily
MacPhee *et al.*, 2010:114-143 ‘’Red-Figure pottery of uncertain origin from Corinth’’	12 Samples from Corinth 9 samples from Athens	Late 5^{th}-early 4^{th} century B.C.	Corinth Athens
Rathossi *et al.*, 2004:313-326 ‘’Technology and composition of Roman pottery in northwestern Peloponnese, Greece’’	29 samples from workshop A 22 samples from Workshop B	1^{st}-early 3^{rd} century A.D.	Patras

From this combined information the Ni versus TiO_2 biplot was created (Figure 14). According to this biplot the archaeological samples can be divided into two main clusters. The 3 geological clay samples (C1, C3, C4) are not correlated chemically with the archaeological samples which means that the possibility for the ancient clay sources being found, is excluded. In addition, none of the 26 Messenian samples have Attic or Corinthian provenance. On the contrary, some of the archaeological samples seem to be correlated chemically with the Apulian and the Sicilian ones. The M8 and M22 samples are outliers, with distinct chemical composition form all reference samples. The Patras data are not included in this bi-plot since the Ni concentration was not provided by Rathossi, *et al.* (2004). The Ni/TiO_2biplot cannot verify clearly the provenance of the understudy pottery samples. For that reason, more detailed geological investigation need to be done in order safe conclusions to be drawn.

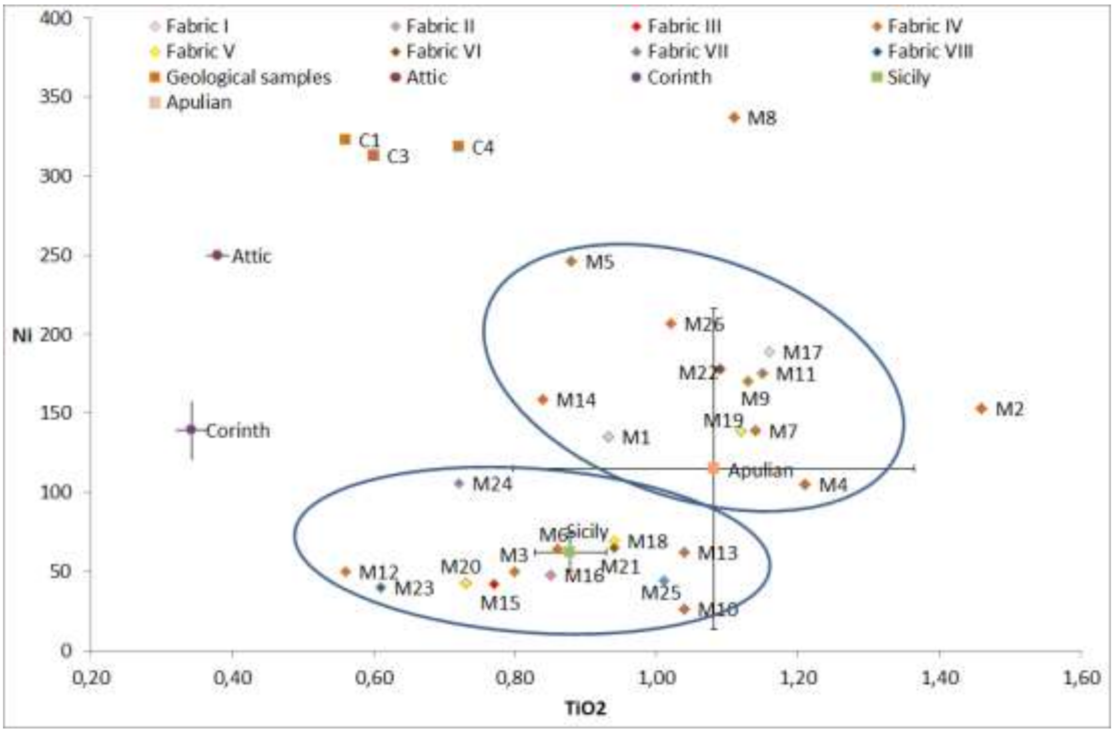


Figure 14. Concentrations of Ni versus TiO_2

7.3 PCA CHARTS

The analytical data from the SEMS/EDS and p-XRF chemical analysis were submitted to two Principal Component Analysis plots (PCA) according to the following table. In the statistical analysis the logarithms of the Major elements of the SEM/EDS and the Trace elements of the p-XRF were used. The statistical program used was the commercial statistical package STATISTICA 8.0.

Table 15. Table which shows the types of data used for the PCA plots

PCA	Data	Chemical elements
Figure 15.	Archaeological, geological	Major/Trace
Figure 16	Archaeological, geological, bibliographic	Major

In Figure 15 and 16 the two PCA charts which were emerged from the combined information of the major data of SEM/EDS device and the trace data of p-XRF device are presented. More specific in Figure 15 PCA plot we see that the pottery samples cannot easily be distinguished. The C3 and C4 geological, clay samples are clustered in comparison to the C1 because in these samples the same manufacture recipe was used as it has already been thoroughly described in chapter 3 (Table 1).

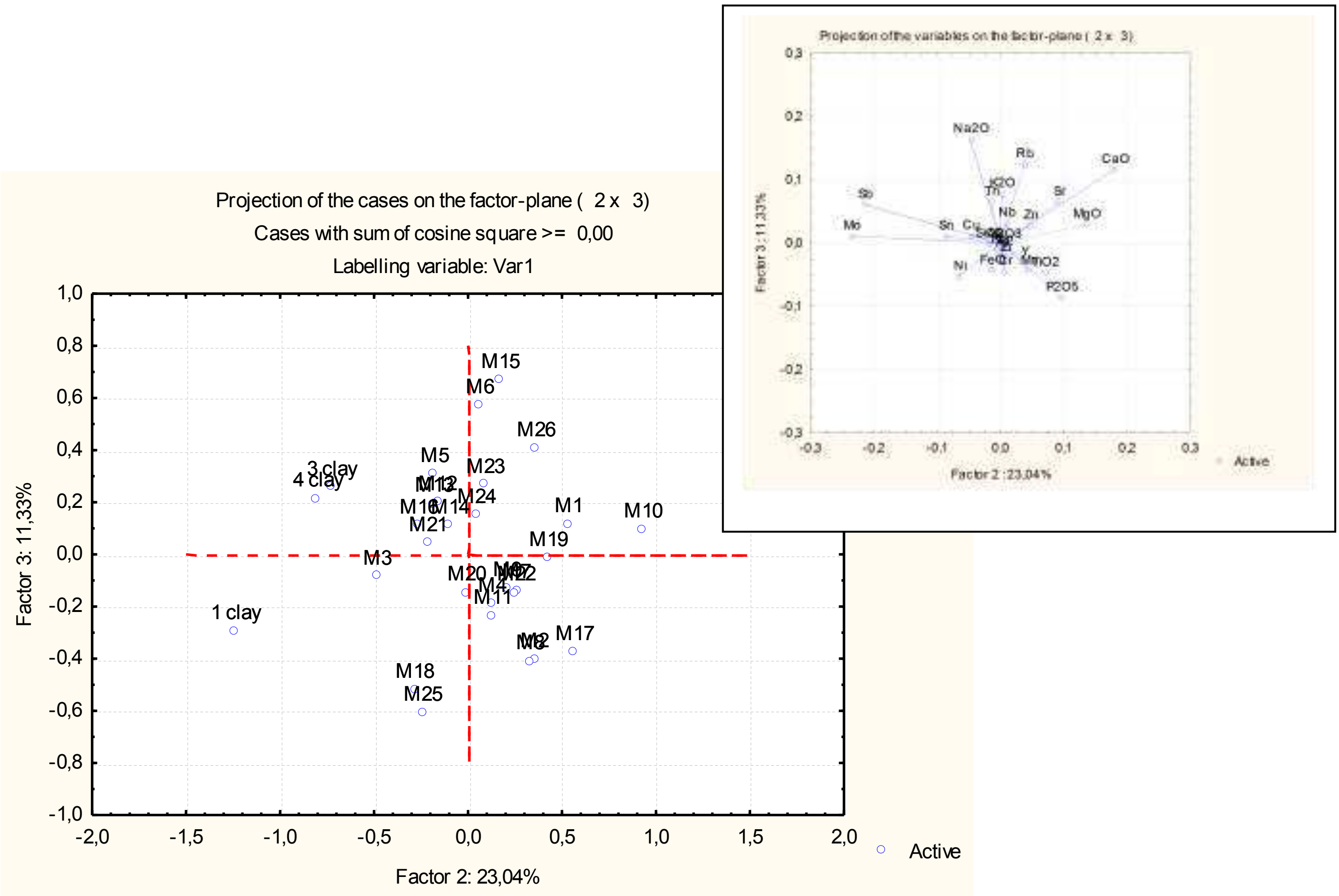


Figure 15. PCA plot (inlay plot: PCA vectors plot) showing the fluctuation between the archaeological and geological data

According to Figure 15 PCA plot, provenance is not easy being identified because the samples cannot easily be separated with the exception of the Attic, reference sample. One again, can be statistically verified that none of the Messenian samples have Attic provenance while Apulia, Sicily, Corinth and Patra present similar traits with the under study sample s(Figure 16, bilplot). Moreover, the Na_2O which affect the samples in vectors plot of Figure 16, could be reveal that the chemical variation and the heterogeneity of the samples connected perhaps with a different clay source. The fluctuation of both the CaO+MgO (wt%) might be revealing a different calcium source. Of course, more detailed research needs to be done to draw safer conclusions.

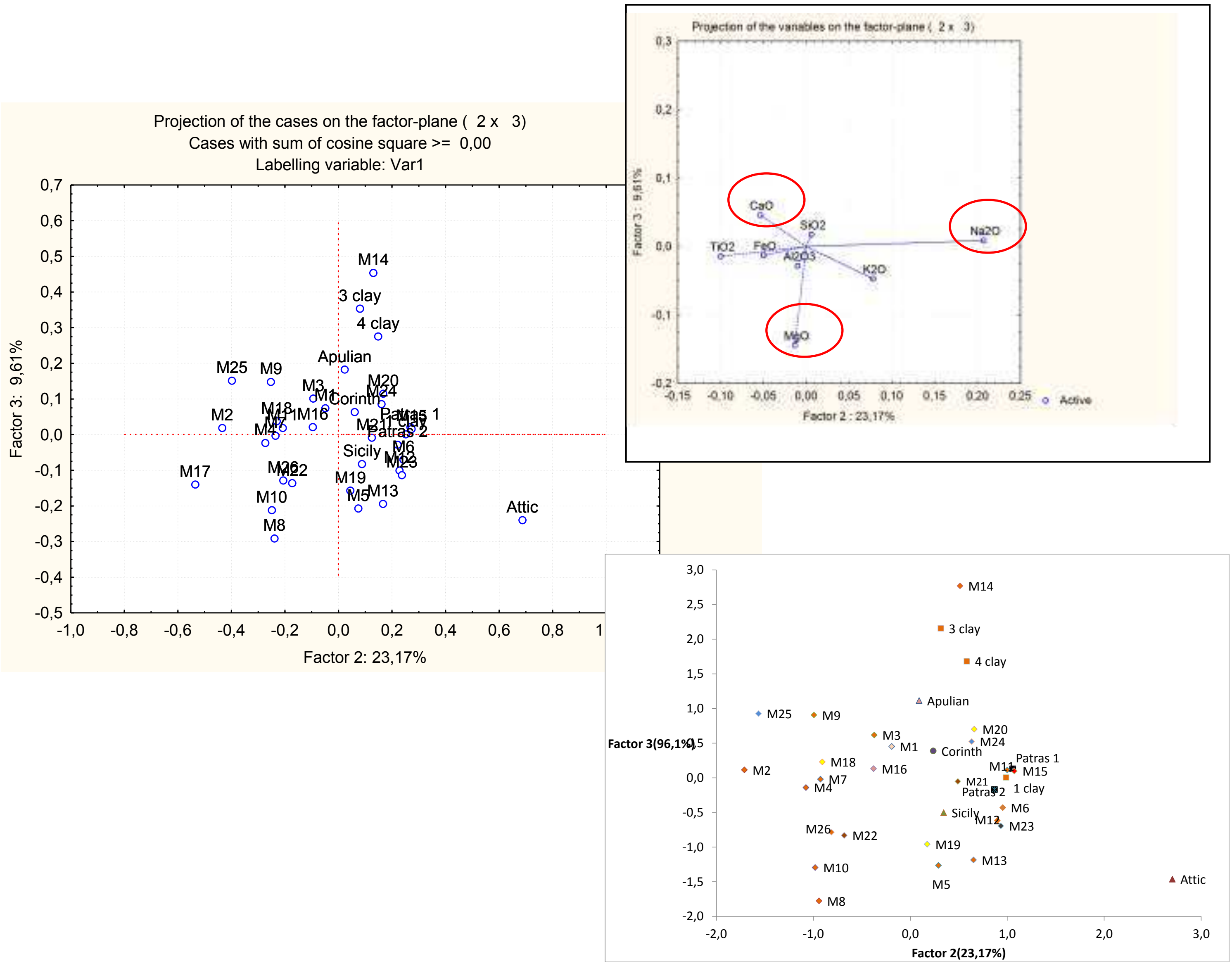


Figure 16. PCA plot(inlay plot: PCA vectors plot)showing the fluctuation between the archaeological, geological and bibliographic data, and biplot of the factors)

8. PRESENCE OF SLIP/GLAZE

In fine wares research was pursued beyond the macroscopic and microscopic observation of the fabric samples, to include examination of the glaze that covered the surface of these pots. The term slip was used for the 2 coarse wares(M1, M12) while the term glaze for the 3 black-reddish brown glazed fine wares(M3,M6,M15) (Chaviara and Aloupi, 2015). Detailed chemical concentrations of the slip/glaze were presented in the Appendix D.

8.1 VISUAL EXAMINATION

Through the macroscopic observation was verified that the colour of the glaze ranges between black-reddish black (Munsell 7.5YR 2.5/1, 2.5YR 5/1) to reddish brown and light red(2.5YR 5/3. 2.5YR 6/6). Black-glazed pottery was produced to the Greek world during the Hellenistic period (Mirti, 2000). The production of brown-red glazed was indicated from the 2nd quarter of the 2nd century B.C. and up to the 1st century B.C. (Gravani, 2004). In addition the slip of the M1, and M12 and the glaze of M15 sample can be characterized as dull and fugitive. However, the glaze of M6 appear to be shinier. Also, in all the cases the glaze seems to be absorbed by the clay fabric something that perhaps has to do with the quality of the Messenian clay soils.(Rogl, 2005).

8.2 ANALYTICAL EXAMINATION

The slip/glaze was examined also chemically with the use of SEM. Based on that the following outcomes were drawn:

- In most of the cases the glaze was very thin and that’s why in some of the SEM photos it is not easy recognizable.
- The thickness of the glaze varies and diffusion of grains through its width was observed according to Table 16(M6, M15).
- The glaze of M6 and M15 both macroscopically and microscopically appeared to be thick enough.(Table 16). Moreover, in M1 sample a high content of MnO (7.01 wt%) was detected which resulted in the red hue of the slip. Detailed chemical concentrations are presented in Appendix D.

- According to the following biplot (Figure 17), the slip/glaze appear homogeneity, as the Na_2O+K_2O ranges to from 3 (wt%) 5 (wt%) and the CaO+MgO (wt%) from 2 (wt%) to 8(wt%). On the other hand, clay body is more heterogeneous with a CaO+MgO (wt%) ranges from 2 (wt%) to 13 (wt%). Based on that we can assume that the potters used the same slip/glaze ''recipe'' for different clay bodies.
- High levels of potassium are usually observed in clayey slips/glazes and has to do with the use of natural K-rich illitic clays or reveals the addition of wood ash which correlates with the enrichment in potassium (Hoffman, 1962).
- Chemical analysis determined something commonly accepted both for red and black glazes, that in glazes in contrary with the clay bodies usually detected higher concentrations of aluminum and iron and lower concentrations of silicon and calcium. This happens, because potters used to choose a refinement clay for coating, which at the same time could reduce the vitrification more quickly in comparison with the body (Mirti 2000).
- Regarding to the high iron content of the glaze (Appendix D), it helps both red and black glazes to increase the intensity of colour (Hoffman, 1962). In most of the cases black and red-glazed vessels were mostly made using calcareous clays for the body (Mirti, 2000).

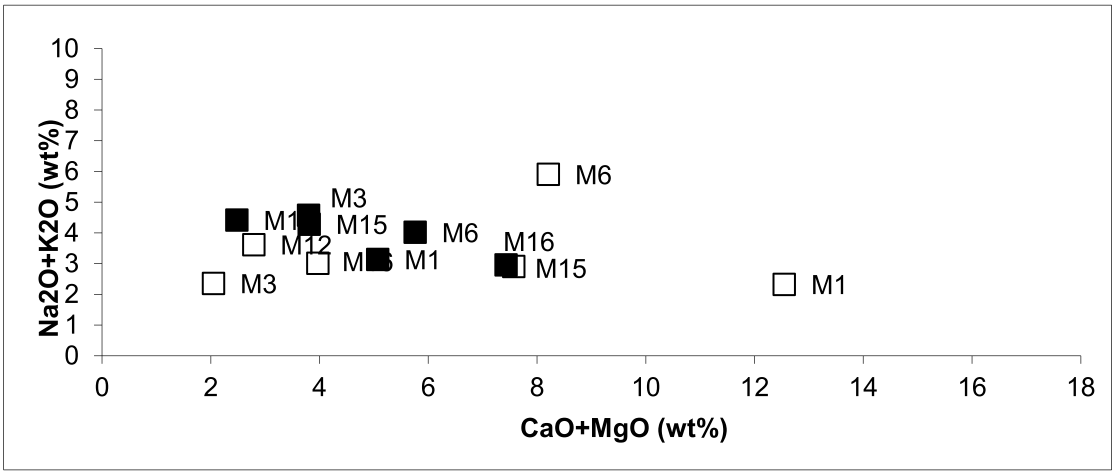
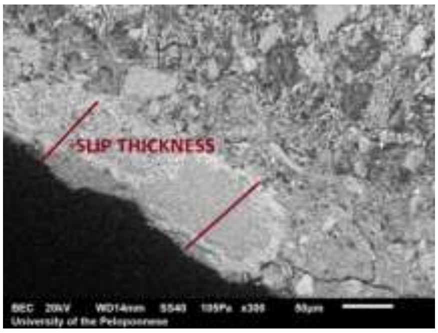
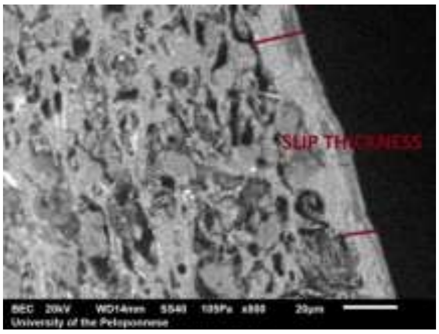


Figure17. Na_2O+K_2O to CaO+MgO ratio. Black symbols denote slips; white symbols denote clay bodies.

In the following table gathered information from the visual examination and the chemical analysis of the slip/glaze were presented.

Table 16. Slip/Glaze characterization

Sample code	Slip/Glaze Colour	Thickness	Comments	SEM/EDS photos
M1	Light red (Munsell 2.5YR 6/6)	Varies from 15 to 20.0 µm.	Coarse slip Diffusion of grains	 *Magnification x300 BEC.*
M6	Reddish black (Munsell 2.5YR 5/1)	Varies from 11.3 to 20.0 µm.	Fine glaze Diffusion of grains	 *Magnification x600 BEC.*
M15	Dark red (Munsell 2.5YR 3/6)	Varies from 12.0 to 20.0 µm.	Fine glaze Diffusion of grains	 *Magnification x800 BEC.*

9. FIRING TEMPERATURE

In this chapter the importance of firing temperature in the manufacture technology and how this can be investigated with the use of analytical techniques will be discussed.

Firing temperature and firing conditions are very important parameters in the pottery reseach because affects the mechanical properties of the vessels and correlate also with the colour variation in the clay fabric. In the archaeological research clay colour plays an important role in the classification procedure as it has already been discussed in Chapter 2. The utility of the colour classification in pottery study will be understandable if it is correlated with differences in chemical composition or in firing process. Moreover, most of the times the pottery colour might be correlated with specific biological conditions of the burial environment (Pradell *et al.,* 1995).

More specifically, in our research from the 29 pottery samples, 9 samples were choosen to be examined, 6 archaeological and 3 geological. Typologicaly the samples belongs to the coarse wares and consisting from big open vessels (lekanai) and an amphora. The selection of samples was based on a) the colour variation of the clay fabric and especially the colour of the core b) the calcarous content c) the shape of vessels(open or close). Moreover, will be discussed how the colour and microscopic traits are affected by the firing temperature, the calcarous content and the firing conditions. The SEM/EDS analysis was shown that the samples C1, C3, C4, M1,M10 M22, M19 and M5 were fired in oxidizing conditions, in an extensive vitrification state and their firing tempearure ranges from 900 to 960 ^{o}C(Rathossi *et al.,* 2010). Regarding to the colour of the core the M5 and M19 samples present a sandwich core. On the contrary, the M13 sample was fired in a reducing atmoshere in a higher firing temperature, which ranges from 1050 to 1100 ^{o}C, in a continious vitrification state with medium bloating pores (Maniatis and Tite, 1981). The high temperature of this sample was also visualy imprented in a 3 coloured core (red-blue-black).

The clay relief of the samples which has been fired in oxidizing conditions appear to be more compact with many big Qz (quartz) inclusions. On the other hand, sample M13 which has been fired in reducing conditions has a spoongy relief.

Regarding to the calcareous content of the samples, the major differentiation was spotted in sample M13, in which the low calcarous content seems to be correlated with its reducing firing stage. The groups of calcium concentration were defined by

Maniatis and Tite, 1981. In Appendix D, all this information was gathering in a relevant table allong with the relevant SEM/EDS photos.

Beside the temperature variation and the calcareous content, the shape of the vessel plays a crucial role to the clay paste colour. Based on that, was verified that the M19 and M5 sample which typologically belong to the open vessels present sandwich core while the M10 sample which is a close vessel has a biocoloured core (Molera *et al.,* 1998). Relevant photos presented at Appendix A-1.

Also, if we focuced on the different colours of clay pastes we could say that change from creamy pastes, like the sample M1 (Fabric I, 5 YR 7/3, pink) and sample M19 (Fabric V 5YR 5/6, 7/6, reddish yellow) to more red clay pastes is associated with the incorporation of Fe3q in several calcium silicates and aluminosilicates that developed during the firing process. Creamy colour pastes are related to the complete decomposition of calcite, along with the development of pyroxenes and the lower presence of iron oxides, in an oxidizing firing stage (Molera *et al.,* 1998). This is something which has also been verified in the case of M1 sample, in which the light colour of the clay matrix correlated both with the high calcareous content (close to 18 wt%) and the oxidizing firing conditions.. In addition, according to bibliography the use of sea water in calcareous paste has also been shown to yield whiter pastes (Matson, 1972). According to Tite and Maniatis the NaCl content of the sea water helps to the decomposition of calcite, and to the simultaneous formation of the minerals phases which are able to incorporate iron (Tite and Maniatis, 1975).

Regarding to how the firing temperature affects the mechanical properties of the vessels we could say that this depends on the type of the vessel. The under examination pottery samples belong to the coarse wares, consisting of large bowls (lekanai) and an amphora, sample M10. From bibliographic references we know that vessels like the amphorae, fired at higher temperatures from 800-to 950^{o}C and that contributes to the increasing of toughness and the suppressing of crack propagation (Hein et al, 2008). In this case the M10 sample has been fired in a temperature closed to 930^{o}C (Rathossi *et al.,* 2010). In addition, important role in the mechanical properties of the vessels along with the increasing toughness plays the Qz temper, that chemically was determined as a major inclusion of the understudy pottery (Kilikoglou *et al.,* 1998).

10. CONCLUSIONS

In this research 3 techniques were used for the examination of the pottery samples. These are the following: a) LED microscopy for the observation of the clay fabric b) p- XRF and c) SEM/EDS for the microscopical and chemical examination. The p-XRF is a well-established method of analysis and particular famous for the analysis of both archaeological and museum artifacts, where the study of pottery stands as one of the main applications in archaeometry and archaeological science (Liritzis and Zacharias, 2011). On the other hand images from scanning electron microscopy (SEM) are now-days quite common and is of a great value in archaeology field (Pollard *et al.,* 2007). Regarding to the evaluation of the two techniques and according to the chemical data (Appendix A1-A2), the SEM/EDS was preferred for the following reasons, a) There was evidences that for some chemical elements there was significant deviations: e.g. in p-XRF the SiO2 values were significantly higher compared to those from SEM/EDS due to the inhomogeneous nature of the pottery matrix, caused by large Qz grains embedded in the matrix and scanned by the set-up. b) under SEM the operator has a clear view of the studied area and therefore subsequent EDS analysis is more representative, plus spotted to e.g. mineral inclusions, if needed. For more information about the evaluation of the techniques been used, the following table is presented (Table 17).

Table 17. Total evaluation of techniques being used

Techniques	Applications	Advantages	Disadvantages
LED	Microscopic observation of clay matrix	A general idea about the clay matrix can be given	
p-XRF	Provenance study	• Chemical information • It is ideal for fine pottery • The size and shape of the pottery samples covers the XRF beam helping in this way to the better signal and penetration of X-rays. • No samples preparation • Low cost • Portability	The slip/glaze cannot be examined because multiply layers can alter the final results.
SEM/EDS	• Determination of fabric groups • Examination of firing temperature • Characterization of slip	• Information of both the chemical composition (Backscattered electrons) and the topography (Secondary electrons) • Use of Vacuum which give chemical, thermal	• Samples preparation for the • examination of slip/glaze and firing temperature • High cost • Non portable

		stability and better signal • High magnification X50.000 • Combination of imaging and analysis • Simpler calculation of quantitative results	

From the qualitative analysis of the clay fabric of the large assemblage of 283 pottery samples the following results were drawn regarding to the parameters of a) colour b) coarseness c) porosity d) size and shape of inclusions. First of all, eight (8) fabrics (Fabric I-Fabric VIII) were determined based on the Munsell Soil Colour chart. According to relevant pie charts was revealed that the biggest part of the pottery consists of fine wares, primarily drinking vessels while coarse wares, such as cooking pots cover the lower percent. In addition, the highest percentage of the pottery can be characterized as porous, which is something that improves the mechanical properties of the vessels like the durability and the maintenance of the temperature in cool conditions. This is something important especially for vessels, like drinking cups (skyphoi, kantharoi). Regarding to the inclusions, the big white inclusions present the highest frequency in the clay matrix and are correlated with Ca- rich minerals and Qz inclusions which have been chemically testified. All this macroscopically information was also statistically examined with the use of PCA analysis in order to see if there are possible correlations among the parameters. The PCA chart verified the general heterogeneity of the pottery.

The quantitative analysis was included chemical examination of 26 archaeological, pottery samples and 3 geological, clay samples with the technology of SEM/EDS and p- XRF. Based on that the following information was extracted: a) The $CaO+MgO-Al_2O_3/SiO_2$ (wt%) biplot was characterized the pottery as coarse and calcareous (CaO>6 (wt%). In addition, five chemical groups were determined in which in the most of the cases, the chemical information cannot be correlated with the microscopic examination. Exception presented four samples(M1,M17) which both belong to the Fabric I (5YR 7/3, pink) and chemical Group A and have high calcium content (closed to 18 wt%) and (M24, M25) from Fabric VIII (2.5YR 5/1 reddish black) and chemical Group E which have low calcium content (CaO<6 wt%).

On the other hand, the TiO_2/FeO biplot was shown that the colour variations in the pottery have to do primarily with the firing temperature or with a different clay source rather than the clay concentration in FeO content.

For identifying the provenance of the pottery samples with the use of p-XRF, both geological and bibliographic data were used. The geological data were collected from Valyra region which has natural clay soils. This was an effort in order the ancient clay sources been found. However, the chemical examination was showed that no chemical correlation with the archaeological samples could be done. On the other hand, bibliographic data from Sicily, Apulia, Corinth, Patra and Athens were chosen to be compared with the Messenian samples. These places were chosen because we know that ancient Messene had developed trade and cultural relationships with them during the Late Classical-Hellenistic period (Themelis 2005). The chemical information was shown that none of the examined Messenians samples have Attic provenance but this information is comparable with samples from Apulia, Siclily, Corinth and Patra in which present similar traits. The understudy pottery seems to be very heterogeneous. The 2 available techniques cannot investigate further the provenance and that is why for the moment no safe conclusion can be drawn. A more detailed geological research and the use of petrographic techniques could illuminate the provenance part, filling the gaps.

Regarding the firing temperature, all the samples were fired in oxidizing atmosphere, at a high temperature closed to 900-960^{o}C. Exception is constituted one sample(M13) which was fired in reducing atmosphere, at a higher firing temperature closed to 1100^{o}C, something that macroscopically was imprinted in a 3 coloured core. Also, the shape of the vessel affects the colour of the core. Based on that, it has been testified that open forms appear a sandwich core while closed forms a bicoloured core. This is something quite important that verified how the manufacture technology leaves a macroscopic ''fingerprint'' in the material.

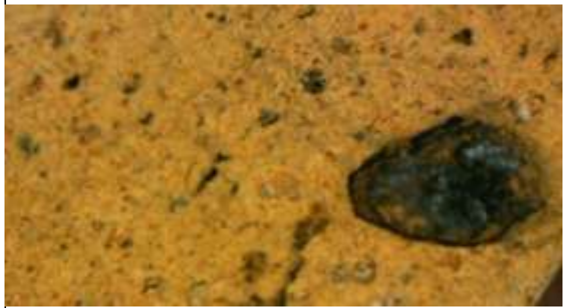
The slip/glaze was examined both macroscopically and microscopically. Regarding to the macroscopical observation the followings were observed a) the colour of the slip/glaze varies from black to reddish brown and light red based on the Munsell Soil Colour chart. Moreover b) its dull and fugitive and c) in some cases seems to be absorbed by the clay body. From the above we can say that the slip/glaze of the late Classical-Hellenistic period in Messene is of low quality something that can be correlated with the Messenian clay soils. The microscopically examination was shown that a) the slip/glaze thickness varies and diffusion of grains through its width were observed b) the $Na_2O+K_2O/CaO+MgO$ (wt%) biplot was verified that potters were used the same slip ''recipe'' for different clay bodies c) the high levels of potassium(K_2O closed to 3wt%) is something commonly found in clayey slips/glazes and testify the incorporation of wood ash in the final product. It has to be highlighted that the M1 sample had high MnO (7.01 wt%) which resulted in the red hue of the slip.

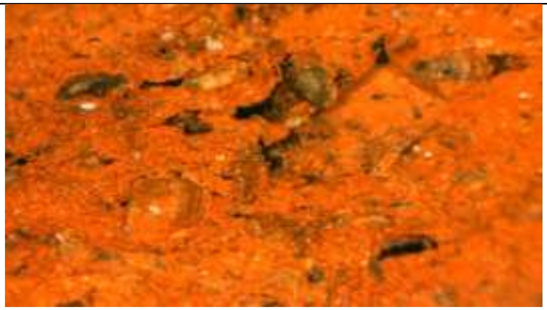
Through this interdisciplinary research was made clear how important is the combination of various techniques for the examination of pottery. The macroscopic and microscopic research in correlation with non-destructive analytical techniques gave us valuable information about pottery study, which from an archaeological point of view consist a basic ''trace'' of material culture. It is also important that the understudy pottery belongs chronologically to Late Classical-Hellenistic period, which is a period ''traditionally'' abandoned by many researchers because the vessels of that period had not the ''artistic'' value of the great black figured and red figured vessels of 5^{th} and 4^{th} century B.C. (Γραβάνη 2000). In addition, was proved how much information an archaeologist can take about the utility and production technology of pottery if meaningful combined the qualitative research of clay fabrics with appropriate chemical techniques.

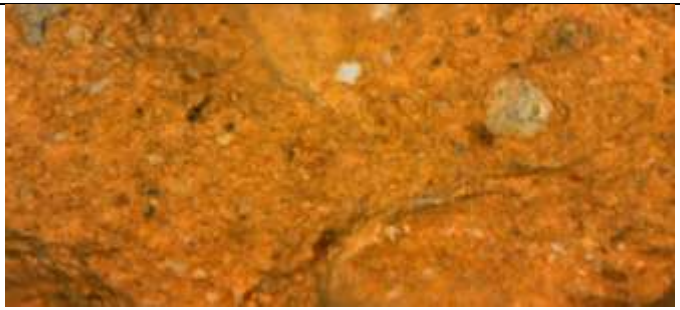
Additionally, provenance was studied. The available techniques were able to exclude the Attic origin for the Messenian samples. Provenance studies for ceramic materials consist a particular difficult research field, because a related set of questions need to be answered. Some of these are the discover of the origin of the material, the location that was produced or manufactured and moreover what purposes was served. In the case of ancient Messene the lack of enough archaeometric studies in Messenian clay fabrics and the sporadic similar research on Hellenistic pottery from neighboring areas creates a gap in the archaeological research. A future aim for the expansion of this project could be to pursue wider geological research in the area of Messenia along with the incorporation of petrographic techniques. A relevant research in Italy will be also valuable, as consist a trade route for Messenians during the 4^{th}-3^{rd} century B.C.

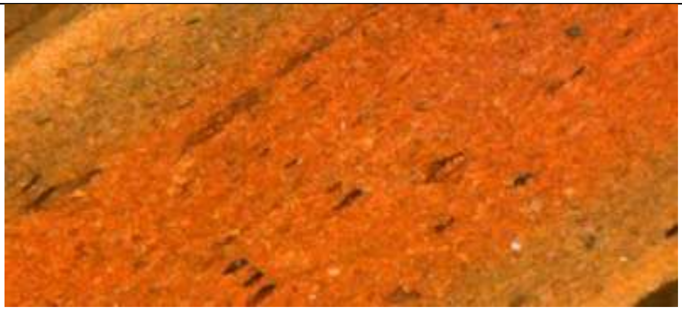
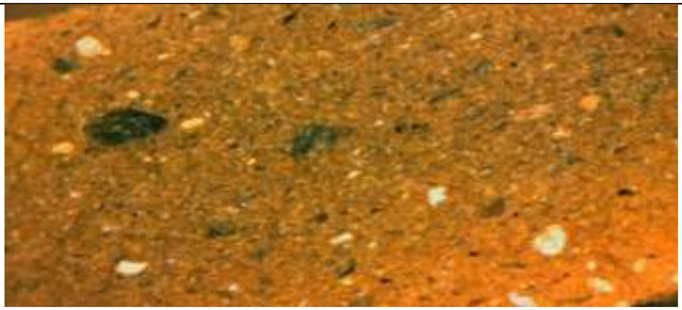
APPENDIX A

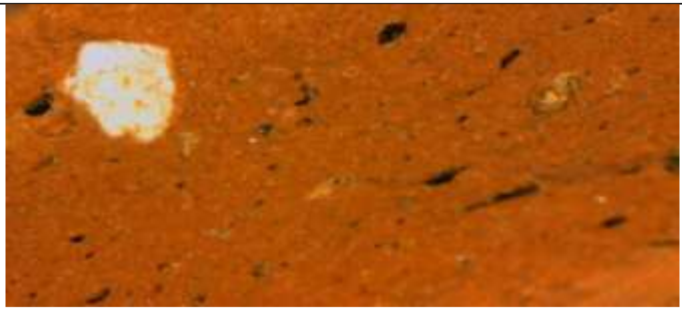
Table A-1 . Analytical table of Visual traits of the samples

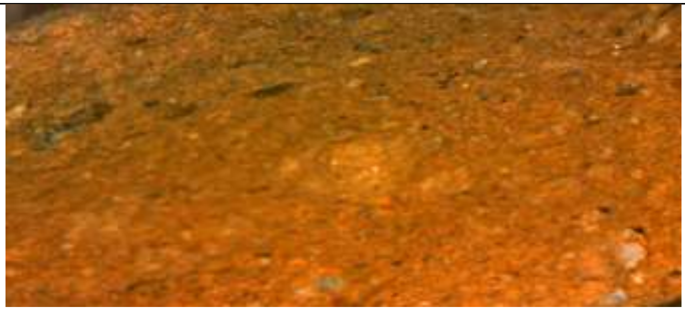
		Macroscopic observation	**Microscopic observation**					**Comments**
Sample Code	**LED photo(magnification X50)**	**Fabrics /Munsell Soil Colour Chart**	**Frequency of inclusions**	**Colour of inclusions**	**Size and Shape of inclusions**	**Coarseness**	**Porosity**	
M1		Fabric I 5YR 7/3	High	White Black Red	Fine to medium, granular	Coarse	Porous	

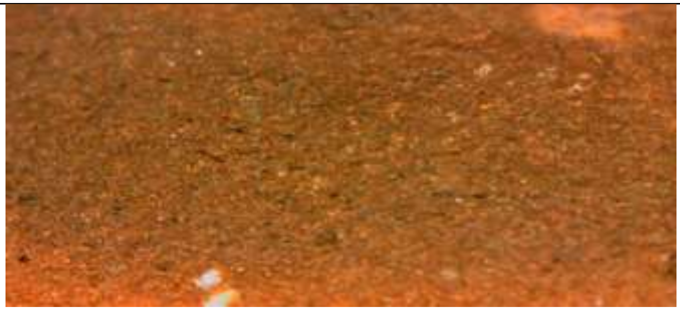
M2		Fabric IV 2.5YR (6/6, 6/8, 7/8)	High	White Red Black	Very fine to coarse granular and angular	Coarse	Porous	

M3		Fabric IV 2.5YR (6/6, 6/8, 7/8)	High	White Red Black	Very fine to fine granular	Coarse	Porous	

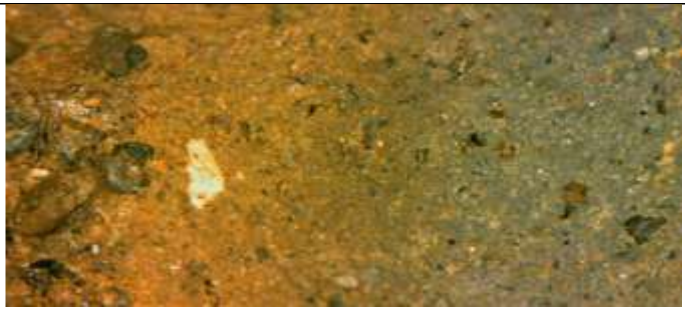
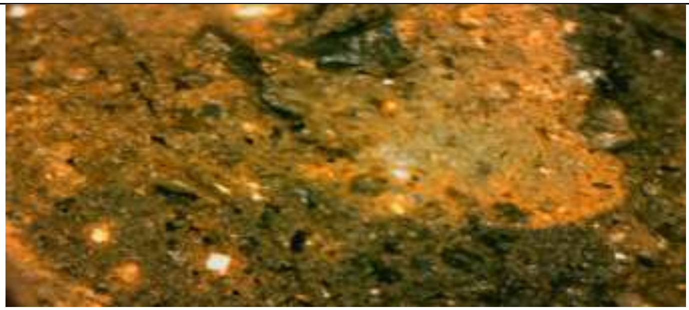
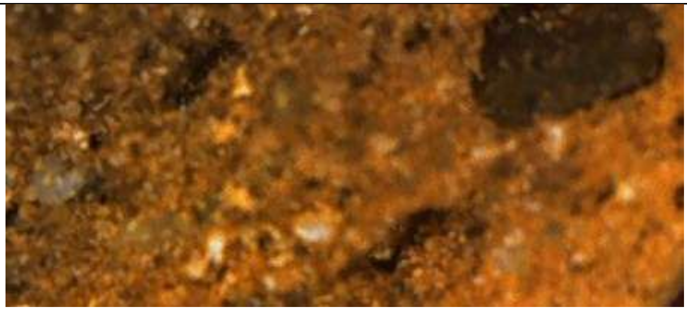
M4		Fabric IV 2.5YR (6/6, 6/8, 7/8)	High	White Red	Fine, medium and coarse granular, angular	Fine	Solid	
M5		Fabric IV 2.5YR (6/6, 6/8, 7/8)	Low	White Red Black	Fine granular and platy	Fine	Porous	Sandwich core (creamy-red-creamy)
M6		Fabric IV 2.5YR (6/6, 6/8, 7/8)	High	White Black	Fine to medium granular, angular	Fine	Solid	Slightly sandwich core(darker in the center)

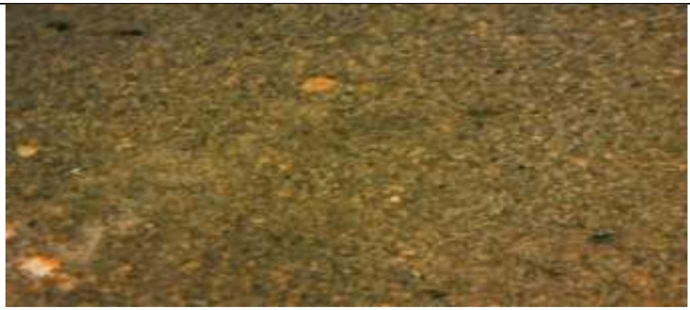
M7		Fabric IV 2.5YR (6/6, 6/8, 7/8)	High	White Red Black	Very fine, fine to medium granular, angular	Fine	Porous	
M8		Fabric IV 2.5YR (6/6, 6/8, 7/8)	Low	White Black	Very fine to medium granular, angular	Fine	Porous	
M9		Fabric IV 2.5YR (6/6, 6/8, 7/8)	High	White Black	Very fine to medium granular, angular	Fine	Porous	

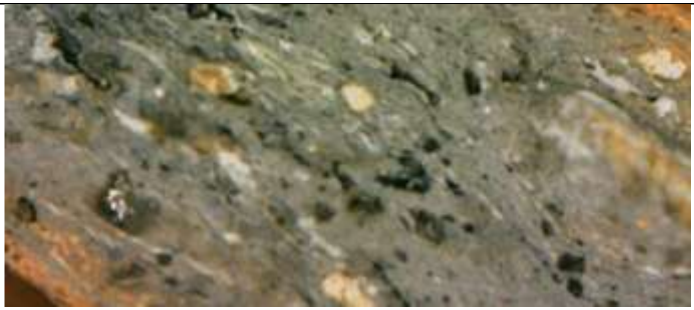
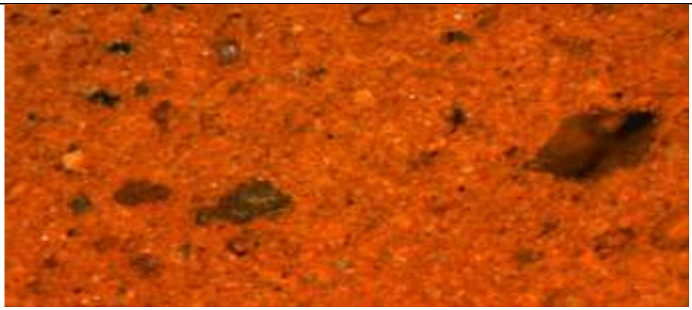
M10		Fabric IV 2.5YR (6/6, 6/8, 7/8)	High	White Black	Fine to medium, granular, angular	Coarse	Solid	Bicoloured core
M11		Fabric IV 2.5YR (6/6, 6/8, 7/8)	Low	White Red Black	Fine to medium granular	Fine	Porous	
M12		Fabric IV 2.5YR (6/6, 6/8, 7/8)	Low	White Red Black	Fine to medium granular	Fine	Porous	

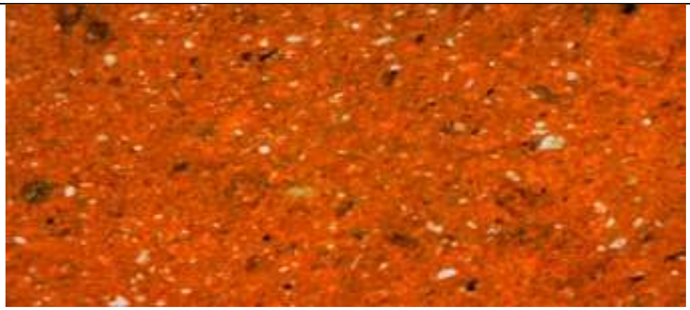
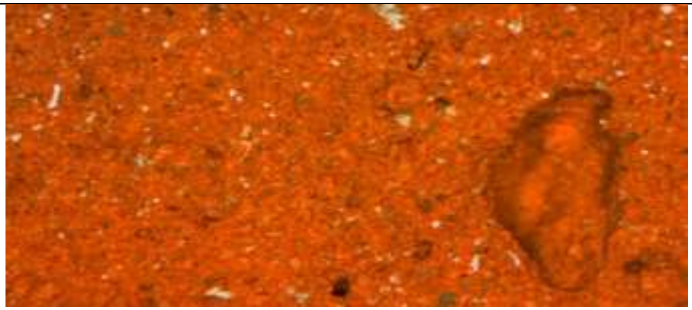
M13		Fabric IV 2.5YR (6/6, 6/8, 7/8)	Low	White Red Black	Very fine granular, Angular	Fine	Porous	3 coloured core(black-blue-orange)
M14		Fabric IV 2.5YR (6/6, 6/8, 7/8)	Low	White Red Black	Very fine granular	Fine	Porous	
M15		Fabric III 2.5YR 5/8 Red	High	White Black	Very fine to fine granular	Fine	Porous	

M16		Fabric II 5YR 7/4 Pink	Low	White Red Black	Fine granular	Fine	Porous	
M17		Fabric I 5YR7/3 Pink	Low	Black	Very fine granular	Fine	Porous	
M18		Fabric V 5YR (5/6,7/6) Reddish yellow	High	White Red Black	Fine, medium to coarse granular, angular	Coarse	Solid	Slightly sandwich core(darker in the center)

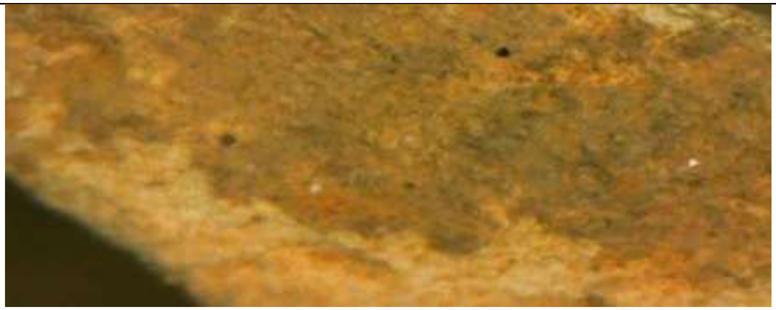
M19		Fabric V 5YR (5/6,7/6) Reddish yellow	High	White Red Black	Very fine to medium granular, angular	Coarse	Porous	Sandwich core(creamy-blue-creamy)
M20		Fabric V 5YR (5/6,7/6) Reddish yellow	High	White Red Black	Fine, medium to coarse granular, angular	Coarse	Porous	Black core
M21		Fabric VI 2.5YR 5/4 Reddish brown	High	White Red Black	Fine to medium granular, angular	Coarse	Solid	

M22		Fabric VI 2.5YR 5/4 Reddish brown	Low	White Red	Very fine granular	Fine	Porous	
M23		Fabric VII 5YR 6/1 Reddish gray	High	White Red	Very fine to fine granular	Fine	Porous	
M24		Fabric VIII 2.5YR 5/1 Reddish black	High	White Red	Fine to coarse Granular	Coarse	Porous	

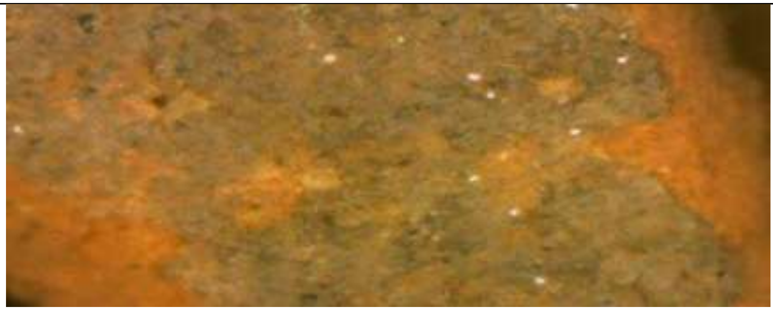
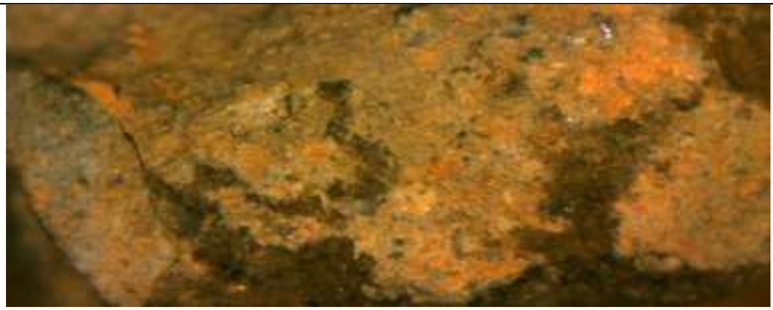
M25		Fabric VIII 2.5YR 5/1 Reddish black	High	White Red	Coarse granular, angular	Coarse	Solid	
M26		Fabric VIII 2.5YR 5/1 Reddish black	High	White Red Black	Fine and coarse granular	Coarse	Solid	Sandwich core(creamy-blue-creamy)
C1		Fabric IV 2.5YR 5/8 Red	High	Red Black	Fine to coarse granular, angular	Coarse	Porous	

C2		5YR 5/6 Yellowish red						
C3		Fabric IV 2.5YR 5/8 Red	High	White Red Black	Very fine to medium granular, angular	Fine	Porous	
C4		Fabric IV 2.5YR 5/8 Red	High	White Red Black	Very fine to coarse granular, angular	Fine	Porous	

A-2. Presence of slip/glaze table

Sample Code	LED photo(magnification X50)	Munsell Soil Colour Chart	Comments
M1		2.5YR 6/6 Light red	Low preservation
M3		2.5YR 3/3 Dark reddish brown	Low preservation

M6		2.5YR 5/1 Reddish black	High preservation
M8		2.5YR 5/1 Reddish black	Low preservation The slip seems to be absorbed by the clay body
M12		2.5YR 5/1 Reddish black	Low preservation

M14		2.5YR 5/3 Reddish brown	Low preservation
M15		2.5YR 3/6 Dark red	Low preservation
M18		2.5YR 5/3 Reddish brown	Low preservation

M22		7.5YR 2.5/1 Black	Low preservation
M23		2.5YR 5/3 Reddish brown	Low preservation

APPENDIX B

Table B-1. Bulk chemical compotation from the SEM/EDS analysis(m: average value; s:standard deviation)

Major oxides (oxides wt%, normalized to 100%)										
Sample code		**Na_2O**	**MgO**	**Al_2O_3**	**SiO_2**	**P_2O_5**	**K_2O**	**CaO**	**TiO_2**	**FeO**
M1	m	0.90	3.20	17.27	49.89	2.20	1.79	15.58	0.93	8.24
	s	0.05	0.19	1.06	1.47	0.40	0.14	1.44	0.12	0.79
M2	m	0.31	2.29	19.99	55.39	1.53	1.72	5.43	1.46	11.89
	s	0.17	0.05	0.18	0.88	0.43	0.05	0.93	0.25	1.60
M3	m	0.39	1.32	23.42	61.83	0.40	1.66	1.39	0.80	8.80
	s	0.06	0.15	1.28	1.03	0.10	0.16	0.47	0.09	1.59
M4	m	0.46	2.72	20.18	56.33	1.52	1.46	4.82	1.21	11.31
	s	0.29	0.63	0.86	2.89	0.36	0.31	1.71	0.21	1.71
M5	m	0.93	4.29	18.51	53.81	0.90	2.80	6.74	0.88	11.70
	s	0.18	0.26	0.68	2.44	0.16	0.28	0.78	0.24	3.49
M6	m	1.14	2.76	18.61	59.89	0.37	3.33	5.09	0.86	7.94
	s	0.03	0.15	0.39	0.69	0.20	0.23	0.48	0.18	0.27
M7	m	0.50	2.73	19.68	50.58	2.78	2.23	8.85	1.14	11.50

	s	0.07	0.33	0.46	1.54	0.22	0.11	0.65	0.00	0.93
M8	m	0.48	4.97	23.97	49.68	2.38	1.67	4.61	1.11	11.29
	s	0.22	0.44	0.54	0.53	0.12	0.12	0.35	0.16	0.53
M9	m	0.53	2.42	16.39	54.23	1.79	1.74	12.98	1.13	8.80
	s	0.16	0.22	0.54	0.36	0.38	0.06	0.42	0.19	0.77
M10	m	0.35	3.92	18.59	59.31		2.84	5.53	1.04	8.41
	s	0.23	0.06	1.01	1.44		0.32	0.57	0.22	0.13
M11	m	0.50	2.44	19.18	57.46	1.31	1.84	5.58	1.15	10.55
	s	0.09	0.40	0.87	1.66	0.23	0.50	0.53	0.25	0.88
M12	m	0.75	2.44	25.25	58.91	0.97	2.62	2.25	0.56	6.24
	s	0.18	0.26	0.78	1.00	0.05	0.20	0.17	0.20	0.25
M13	m	0.85	2.63	22.67	58.26	0.74	2.83	1.78	1.04	9.20
	s	0.24	0.21	0.40	2.09	0.02	0.08	0.03	0.11	1.77
M14	m	1.06	0.90	19.99	60.78		1.68	5.88	0.84	8.88
	s	0.06	0.21	0.32	0.50		0.17	0.85	0.06	0.38
M15	m	1.18	2.48	21.41	59.94		2.88	5.97	0.77	5.37
	s	0.06	0.04	0.57	0.96		0.15	0.56	0.33	0.31
M16	m	0.44	1.64	22.76	57.79	0.58	2.04	1.94	0.85	11.96
	s	0.38	0.56	2.32	6.85	0.33	0.94	1.69	0.09	3.60
M17	m	0.28	5.37	15.58	52.48	2.02	1.34	12.84	1.16	8.94
	s	0.07	0.62	1.11	2.78	1.26	0.13	0.72	0.12	0.53
M18	m	0.27	1.30	22.32	59.55	0.71	2.08	1.19	0.94	11.65
	s	0.20	0.08	1.20	1.14	0.49	0.06	0.14	0.14	2.16

M19	m	0.70	2.52	23.21	54.82	1.36	2.96	2.55	1.12	10.75
	s	0.30	0.31	1.98	3.36	0.78	0.24	0.50	0.36	2.01
M20	m	0.73	1.49	17.90	68.20	0.63	1.89	1.70	0.73	6.72
	s	0.08	0.04	1.44	2.58	0.32	0.11	0.31	0.13	0.66
M21	m	0.69	1.69	18.39	64.99	0.37	2.48	1.49	0.94	8.97
	s	0.36	0.22	1.49	3.47	0.03	0.38	0.22	0.26	1.14
M22	m	0.51	3.30	25.06	50.00	2.25	2.30	6.04	1.09	9.45
	s	0.08	0.14	0.61	0.90	0.17	0.20	0.26	0.09	0.21
M23	m	0.74	2.26	24.33	59.21	1.04	3.02	1.90	0.61	6.90
	s	0.03	0.22	0.71	0.26	0.16	0.41	0.48	0.01	0.54
M24	m	0.75	1.79	16.34	66.78		2.91	3.58	0.72	7.13
	s	0.22	0.09	0.78	0.97		0.10	0.28	0.08	0.53
M25	m	0.16	1.00	18.55	68.62		1.53	0.84	1.01	8.29
	s	0.09	0.13	1.41	1.29		0.30	0.06	0.14	2.59
M26	m	0.47	3.74	19.53	50.09	0.69	3.21	11.57	1.02	9.67
	s	0.01	0.36	0.28	1.24	0.37	0.23	0.95	0.05	0.80
1 clay	m	0.66	1.31	18.99	63.62		2.47	0.68	0.56	11.69
	s	0.23	0.05	0.38	0.22		0.20	0.19	0.25	0.40
3 clay	m	0.95	1.51	15.33	56.33		2.01	13.21	0.60	10.07
	s	0.28	0.07	0.69	1.62		0.08	1.25	0.11	0.61
4 clay	m	1.08	1.55	16.35	60.27		2.14	8.33	0.72	9.58
	s	0.11	0.03	0.18	2.24		0.10	2.80	0.18	0.64

Table B-2 Major elements concentrations from the p-XRF (m:average value; s:standard deviation)

Major oxides (oxides wt%)									
Sample Code		**Na_2O**	**MgO**	**Al_2O_3**	**SiO_2**	**K_2O**	**CaO**	**TiO_2**	**Fe_2O_3**
M1	m	1.02	1.15	15.47	54.36	1.95	17.32	0.91	7.82
	s	0.09	0.31	0.13	0.98	0.06	1.14	0.05	0.33
M2	m	0.87	1.23	17.66	64.24	1.43	4.91	1.12	8.53
	s	0.20	0.29	1.11	0.43	0.06	0.49	0.08	1.21
M3	m	0.94	0.94	20.76	57.58	2.56	8.12	0.82	8.29
	s	0.08	0.25	1.11	1.29	0.13	1.41	0.05	0.68
M4	m	1.06	1.12	17.16	61.68	2.13	10.02	0.89	8.91
	s	0.11	0.24	1.01	1.29	0.02	5.08	0.04	0.56
M5	m	1.26	0.85	18.59	59.51	3.09	5.53	0.91	10.25
	s	0.28	0.08	0.22	4.78	0.95	1.29	0.10	2.01
M6	m	0.97	0.78	18.51	62.26	3.20	5.16	0.84	8.27
	s	0.04	0.00	0.08	0.20	0.12	0.10	0.03	0.08
M7	m	1.02	1.03	14.51	64.04	1.51	9.29	0.88	7.71
	s	0.12	0.21	0.77	0.28	0.01	0.42	0.01	0.38
M8	m	1.20	0.93	22.43	55.73	1.60	5.15	1.30	11.68

	s	0.10	0.16	0.36	0.35	0.06	0.54	0.04	0.48
M9	m	1.06	0.81	16.14	61.56	1.38	10.18	0.83	8.04
	s	0.04	0.01	0.64	0.77	0.13	0.80	0.10	0.43
M10	m	0.94	1.20	16.59	65.33	2.56	5.07	0.93	7.39
	s	0.10	0.30	0.29	0.43	0.17	0.51	0.03	0.31
M11	m	0.96	0.95	18.89	62.57	2.11	4.39	0.98	9.16
	s	0.08	0.13	0.49	0.86	0.09	0.41	0.02	0.14
M12	m	0.98	1.10	21.41	57.95	2.89	5.29	1.07	9.32
	s	0.04	0.60	0.53	0.35	0.13	0.88	0.05	0.55
M13	m	0.78	1.17	22.32	61.52	2.77	1.74	1.05	8.65
	s	0.08	0.39	0.22	0.15	0.04	0.03	0.04	0.54
M14	m	1.06	0.90	19.99	60.78	1.68	5.88	0.84	8.88
	s	0.06	0.21	0.32	0.50	0.17	0.85	0.06	0.38
M15	m	1.02	1.37	19.18	60.90	2.70	5.11	0.88	8.84
	s	0.03	0.50	0.43	0.14	0.09	0.17	0.01	0.31
M16	m	1.01	0.80	18.72	57.06	2.64	11.72	0.81	7.24
	s	0.06	0.05	0.24	0.22	0.06	0.21	0.03	0.26
M17	m	1.11	1.26	17.38	56.62	1.21	12.19	0.88	9.34
	s	0.20	0.28	1.14	1.35	0.34	0.78	0.08	0.53
M18	m	0.89	0.89	18.34	66.88	1.42	0.90	0.79	9.90
	s	0.01	0.03	1.11	0.92	0.03	0.02	0.01	0.20
M19	m	1.04	0.79	19.19	60.67	3.06	3.17	1.15	10.93
	s	0.06	0.02	0.95	0.59	0.31	0.24	0.08	0.82

M20	m	0.75	1.08	17.65	66.90	1.63	7.62	1.77	9.56
	s	0.04	0.11	0.61	1.69	0.06	5.12	0.75	1.49
M21	m	0.94	1.19	17.50	68.28	1.89	1.21	0.87	8.11
	s	0.01	0.07	0.25	0.09	0.01	0.04	0.02	0.13
M22	m	1.14	0.74	24.71	54.15	1.98	5.30	1.13	10.85
	s	0.05	0.02	0.90	0.53	0.24	0.61	0.11	0.41
M23	m	0.88	0.92	18.02	53.95	2.70	14.82	0.85	7.86
	s	0.02	0.04	0.50	0.72	0.13	1.16	0.05	0.29
M24	m	0.88	1.16	15.59	69.19	2.19	5.20	0.99	7.21
	s	0.03	0.13	0.94	1.04	0.06	3.76	0.50	0.41
M25	m	0.83	1.48	16.43	70.05	1.25	0.77	0.98	8.22
	s	0.02	0.45	0.28	0.39	0.15	0.02	0.10	0.39
M26	m	0.98	1.29	20.23	52.59	2.90	11.26	0.83	9.92
	s	0.15	0.50	0.76	1.01	0.16	0.77	0.08	0.80
1 clay	m	0.83	0.81	17.70	68.11	2.02	0.61	0.69	9.24
	s	0.004	0.007	0.068	0.064	0.004	0.006	0.003	0.008
2 clay	m	1.23	1.19	7.83	59.97	1.37	23.30	0.53	4.59
	s	0.002	0.033	0.190	0.204	0.002	0.009	0.007	0.017
3 clay	m	1.00	0.83	14.98	64.47	1.74	9.04	0.65	7.28
	s	0.001	0.010	0.068	0.025	0.002	0.033	0.004	0.003
4 clay	m	0.92	0.85	15.94	65.40	1.84	6.86	0.71	7.49
	s	0.020	0.038	0.203	0.144	0.019	0.007	0.012	0.091

Table B-3. Trace elements concentration from the p-XRF (m: average value; s: standard deviation)

Trace elements (ppm)																						
Sample Code		P	S	V	Cr	Mn	Co	Ni	Cu	Zn	As	Rb	Sr	Y	Zr	Nb	Mo	Sn	Sb	Ba	Pb	Th	U
M1	m	5472	0	9	106	406	19	135	72	74	22	43	233	32	147	7	9	3	23	54	20	6	0
	s	463	0	4	2	1	1	4	3	1	6	2	3	2	1	0	2	0	2	93	2	1	0
M2	m	3236	0	58	155	316	25	153	91	82	7	49	105	31	176	8	11	2	14	268	13	6	0
	s	1522	0	20	11	11	1	3	9	8	1	2	6	1	8	1	3	1	4	465	1	1	0
M3	m	2523	9	24	89	263	19	50	129	88	8	78	75	29	119	7	23	3	32	954	14	7	3
	s	1294	16	18	6	32	1	5	15	3	1	2	2	5	4	1	3	0	1	425	1	1	4
M4	m	5265	0	30	76	485	21	105	119	109	16	52	127	31	120	7	17	3	24	539	17	6	1
	s	941	0	8	3	117	1	14	12	2	3	3	2	2	5	1	4	0	1	933	1	1	2
M5	m	665	393	17	116	356	33	246	141	117	13	86	105	26	110	7	23	4	49	5277	16	8	0
	s	141	76	17	10	18	10	41	5	3	1	16	17	1	8	2	6	0	6	9140	0	2	1
M6	m	1034	212	59	80	295	21	64	103	119	12	122	94	27	136	10	12	3	22	559	16	10	6
	s	58	46	6	8	5	2	5	2	6	1	8	8	2	7	1	7	0	7	660	1	1	1
M7	m	7469	0	40	76	905	18	139	99	88	8	29	374	39	121	8	21	3	34	0	14	5	0
	s	1256	0	9	14	82	1	5	8	8	2	2	85	2	7	1	1	1	5	0	1	0	0
M8	m	3319	0	34	138	486	35	337	151	149	13	27	236	46	142	8	12	3	21	199	15	5	0
	s	754	0	25	11	29	2	8	7	4	1	6	70	2	4	1	6	0	5	345	1	0	0
M9	m	4195	0	6	133	394	20	170	94	65	7	29	172	38	132	7	18	3	29	85	14	5	0

	s	725	0	10	19	69	0	5	4	9	1	3	8	1	11	1	2	0	2	147	1	0	0
M10	m	1133	251	91	114	217	17	26	33	89	5	89	192	27	246	10	4	2	8	21	13	9	2
	s	85	85	38	8	10	1	5	2	6	1	7	8	3	26	1	4	0	4	36	1	1	1
M11	m	5758	0	21	141	431	24	175	75	94	9	50	94	37	162	8	17	3	19	0	15	6	0
	s	1558	0	2	10	46	1	7	6	3	0	1	1	3	1	0	2	0	1	0	1	1	0
M12	m	4557	0	25	95	219	21	50	154	115	14	78	122	31	156	8	18	3	29	929	17	8	0
	s	1875	0	31	14	31	2	0	17	2	1	5	24	1	16	1	13	1	16	69	0	1	0
M13	m	1338	221	167	102	432	56	62	91	120	9	109	132	34	158	8	19	3	36	3396	14	9	0
	s	205	35	13	9	25	48	19	21	22	1	11	14	3	28	2	12	1	12	5881	1	1	0
M14	m	1578	98	2	98	240	25	159	137	105	13	52	158	31	146	7	13	3	29	189	16	6	1
	s	774	169	4	16	33	2	26	25	19	5	4	6	2	6	1	3	0	4	215	2	1	1
M15	m	465	476	20	74	200	20	42	110	105	8	119	267	27	148	10	14	3	29	374	13	10	3
	s	162	4	18	10	9	1	7	7	4	1	2	102	5	7	0	3	0	3	126	0	0	3
M16	m	2100	0	3	79	191	18	48	98	96	9	97	137	26	136	8	18	3	34	679	15	9	0
	s	90	0	5	6	7	2	5	8	9	1	6	13	2	10	1	8	1	9	612	1	1	0
M17	m	7098	0	0	81	478	27	189	127	95	9	22	185	38	125	6	10	3	20	294	14	4	0
	s	2932	0	0	15	139	2	20	23	7	1	3	20	3	12	1	4	0	9	510	1	1	0
M18	m	447	695	132	151	240	25	69	73	48	6	53	52	29	174	7	16	3	17	66	15	7	0
	s	25	76	24	5	9	1	1	4	3	1	3	3	1	5	1	1	0	7	83	1	1	0
M19	m	1836	9	147	119	887	30	139	95	130	10	105	235	34	177	11	6	3	15	499	14	9	2
	s	282	16	37	22	272	2	97	25	2	1	11	153	2	20	0	4	0	2	435	1	1	3
M20	m	1392	486	149	91	892	22	43	152	55	45	65	79	35	171	9	9	3	15	312	25	8	0
	s	56	37	16	1	91	2	4	2	2	8	3	3	3	6	1	5	1	3	385	1	0	0

M21	m	440	1125	14	111	195	19	65	94	69	6	79	94	30	200	9	14	3	17	96	12	7	1
	s	67	142	22	3	7	2	2	13	6	1	3	7	2	12	1	3	0	4	166	1	1	1
M22	m	3575	0	9	123	292	57	178	149	136	18	50	145	29	174	7	14	3	21	6158	17	7	0
	s	390	0	10	7	33	46	23	16	19	2	2	7	11	14	2	10	0	4	10546	2	1	0
M23	m	2482	0	51	102	169	30	40	55	87	6	113	142	26	146	10	9	2	25	1348	13	10	0
	s	125	0	5	2	5	19	4	20	15	1	4	6	2	19	2	6	1	12	2335	1	1	0
M24	m	207	777	41	79	344	19	106	120	91	8	102	89	33	144	10	14	3	15	186	14	9	2
	s	47	100	11	10	24	1	2	3	9	1	8	3	4	10	1	1	0	2	323	0	0	4
M25	m	199	933	85	128	175	21	44	75	99	17	75	57	25	204	8	14	3	19	0	18	8	0
	s	70	102	27	19	15	1	3	15	17	4	7	4	1	16	1	4	0	5	0	1	1	0
M26	m	1629	14	73	114	315	31	207	136	136	12	112	287	23	102	10	13	3	21	48	15	10	7
	s	499	24	13	6	34	1	6	9	8	1	1	6	1	4	1	2	0	1	84	1	1	4
1 clay	m						27	323	108	73	10	29		23			66	6	116	2867	15		
	s						1	3	2	1	1	0		0			1	0	0	69	1		
2 clay	m	0	1055	5	113	408																	
	s	0	127	1	5	1																	
3 clay	m						21	313	128	60	9	29		24			66	6	117	2349	15		
	s						0	2	1	1	0	1		1			0	0	0	199	0		
4 clay	m						22	318	124	64	9	29		24			67	6	118	2547	15		
	s						0	1	1	2	0	0		0			0	0	0	182	0		

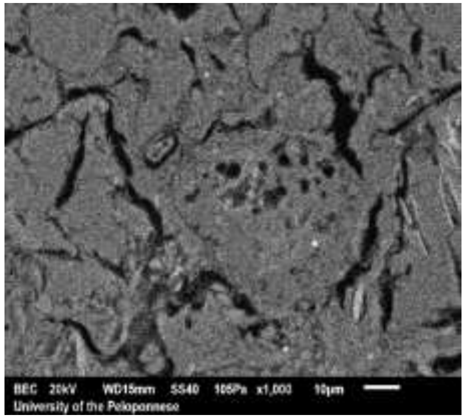
APPENDIX C

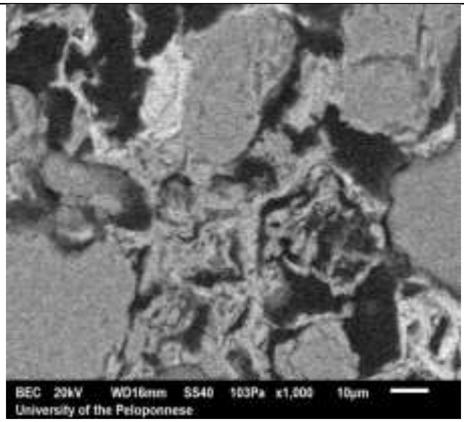
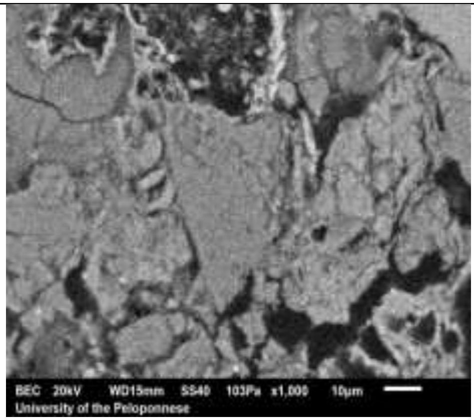
Table C-1. Bulk chemical analysis of the slip/glaze(S1: slip/glaze spectrum; S2:clay body spectrum)

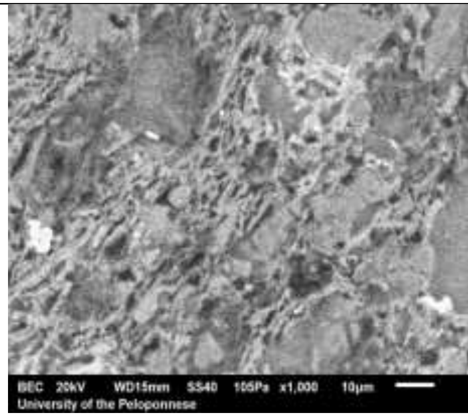
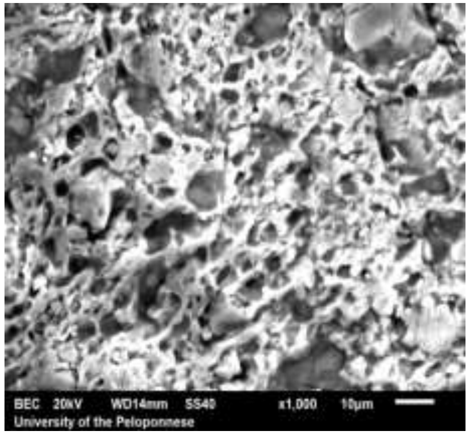
Sample		**Na_2O**	**MgO**	**Al_2O_3**	**SiO_2**	**P_2O_5**	**K_2O**	**CaO**	**TiO_2**	**FeO**	**MnO_2**
M1	**S1**	1.12	1.4	18.52	61.01	1.47	2.02	3.67	1.12	2.65	7.01
	S2	0.52	3.07	11.98	65.28	1.26	1.81	9.48	1.07		5.52
M3	**S1**	1.16	2.02	17.51	66.81	1.01	3.42	1.78	0.56	5.73	
	S2	0.32	1.07	12.21	78.11	0.59	2.04	0.98	0.38	4.3	
M6	**S1**	0.66	1.59	22.72	56.21	2	3.36	4.17	0.85	8.44	
	S2	1.36	1.82	16.37	62.55	1.52	4.55	6.39	0.57	4.87	
M12	**S1**	0.85	1.59	19.58	60.59	0.97	3.57	0.89	0.75	11.21	
	S2	0.47	1.8	17.77	66.82	0.74	3.15	0.99	1.53	6.73	
M15	**S1**	1.19	1.53	22.72	56.72	0.44	3.1	2.28	0.67	11.35	
	S2	0.56	2.12	15.56	65.36	0.84	2.35	5.45	0.7	7.05	

APPENDIX D

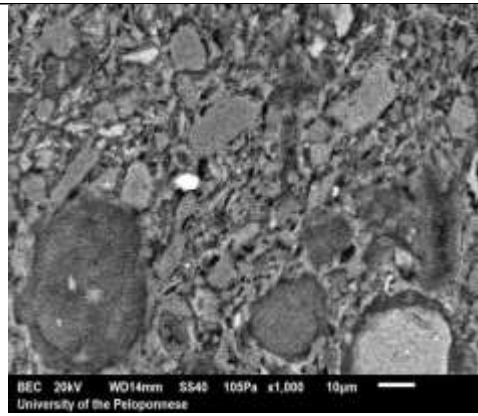
Table D-1. Table presenting analytical the parameters taken into account for the firing temperature (groups of calcium concentration defined by Maniatis and Tite, 1981

Sample Code	Typology	Comments	Calcareous/ Non Calcareous	Firing Conditions	SEM/EDS Photo (magnification X1000/Backscattered electrons (BEC e^-)
C1	Clay briquette (geological sample)	Fabric IV	Non calcareous	✓ Extensive vitrification ✓ Oxidizing 960-1000^{o}C	

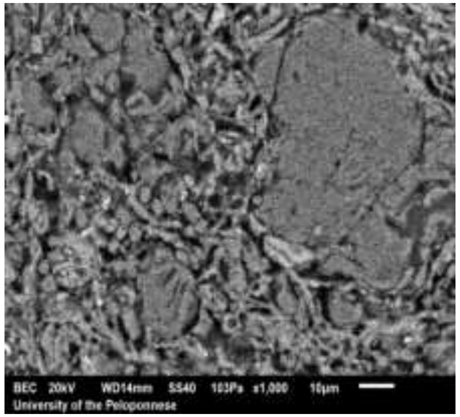
C3	Clay briquette (geological sample)	Fabric IV	Calcareous	✓ Extensive vitrification ✓ Oxidizing 960-1000^{o}C	
C4	Clay briquette (geological sample)	Fabric IV	Calcareous	✓ Extensive vitrification ✓ Oxidizing 960-1000^{o}C	

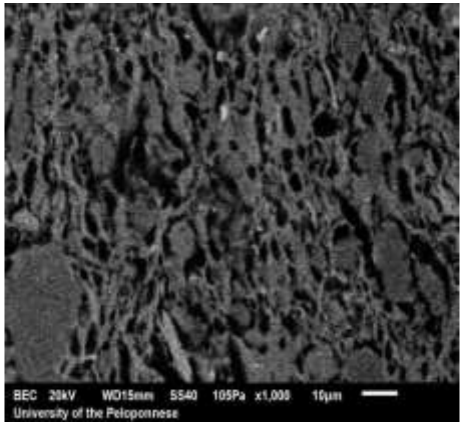
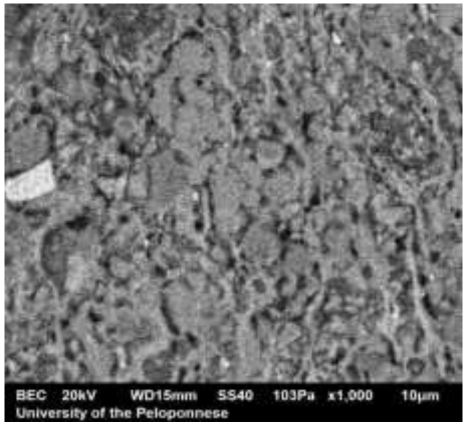
M1	Open vessel (lekane)	Fabric I	Calcareous Medium calcium oxide concentrations (15-25%)	✓ Extensive vitrification ✓ Oxidizing 960 ^{o}C	
M13	Open vessel (lekane)	Fabric IV 3 coloured core	Non calcareous	✓ Continuous vitrification with medium bloating pores ✓ Reducing 1050-1100 ^{o}C	

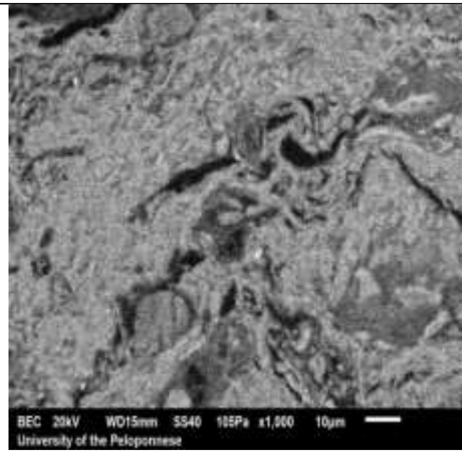
<table>
<tr><td>M22</td><td>Kantharos</td><td>Fabric VI</td><td>Calcareous</td><td>✓ Extensive vitrification

✓ Oxidizing
960 °C</td><td>
</td></tr>
<tr><td>M19</td><td>Fish-plate</td><td>Fabric V

Sandwich core
(creamy-
blue-creamy)</td><td>Non calcareous</td><td>✓ Extensive vitrification

✓ Oxidizing
960 °C</td><td>
</td></tr>
</table>

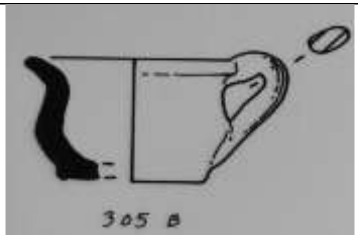
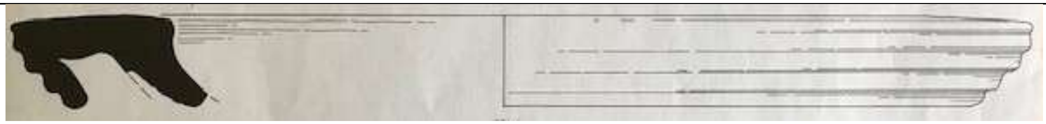
M5	Chytra (cooking pot)	Fabric IV Sandwich core (creamy-red-creamy) A small difference to the clay relief. The relief in the red spot is more porous in comparison with the creamy spot which appears more solid.	Calcareous Low calcium oxide concentrations (5-10%)	✓ Extensive vitrification ✓ Oxidizing 960 °C	Red area  Creamy area 

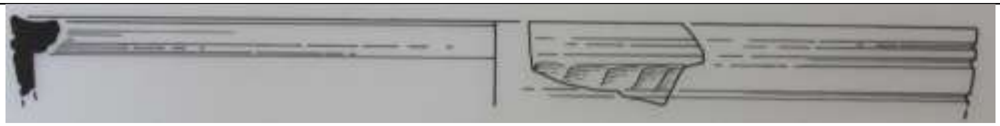
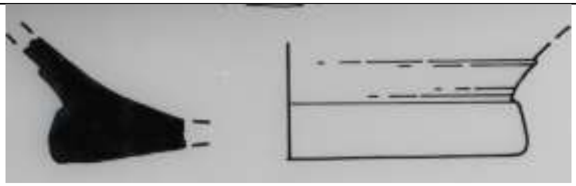
M10	Closed vessel (amphora)	Fabric IV Bicoloured core	Non Calcareous	Oxidizing 930 ^{o}C	

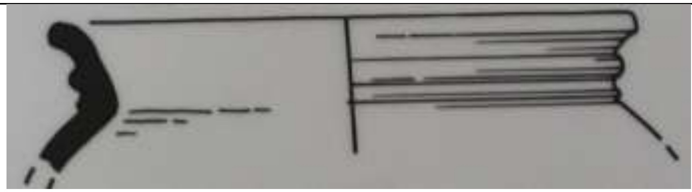
APPENDIX E

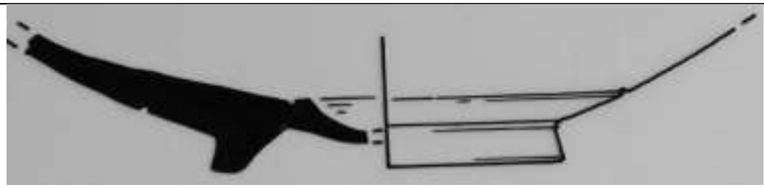
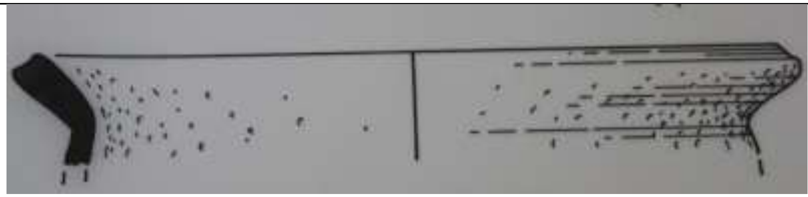
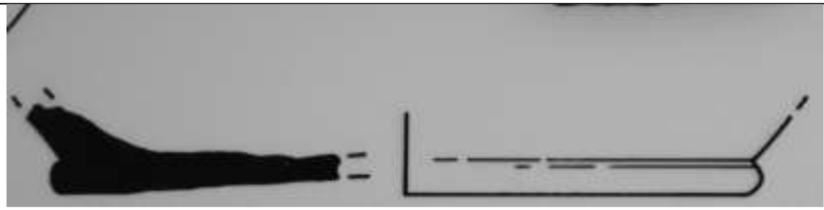
E-1 Typology table

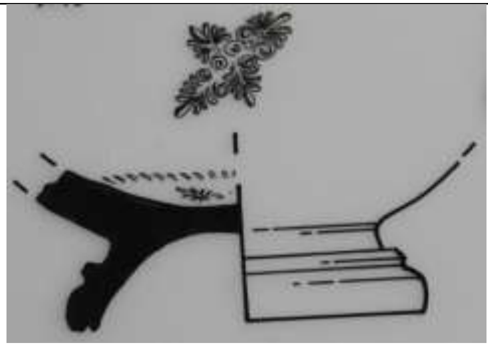
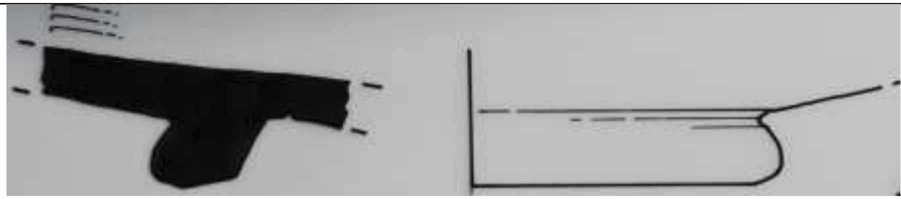
Sample Code	**Typology**	**Preservation state**	**Vessel drawing**	**Photo**
M1	Lekane	Flaring, ribbed rim and part of body		
M2	Lopas (cooking pot)	Part of angulat Offset lip, part of body and vertical handle		

M3	Miniature skyphos	Part of wall and flat base. One complete vertical handle.		
M4	Mortar	Ribbed overhanging rim and part of body		
M5	Chytra (cooking pot)	Nearly vertical rim and part of body		

M6	Open Vessel	In-curved ribbed rim and part of body		
M7	Cretan type Amphora	Not available		
M8	Koan type Amphora	Not available		
M9	Koan type Amphora	Not available		
M10	African type Amphora	Not available		
M11	Rhodian type Amphora	Not available		
M12	Roman Amphora	Not available		
M13	Open vessel (Lekane)	Ring shaped base and part of body		
M14	Skyphos base	Not available		

M15	Echinus bowl	Incurved rim		
M16	Open vessel (Jar?)	Flaring, ribbed rim and part of body		
M17	Lekane	Flaring, ribbed rim and part of body		
M18	Chytra (cooking pot)	In-curveded rim and beginning of body		

M19	Fish-plate	Splaying base with a central concavity, and part of lower body		
M20	Chytra (cooking pot)	Flaring rim and beginning of body		
M21	Oinochoe	Low, ring base and part of body		
M22	Kantharos	Raised base and beginning of body		

				
M23	Plate (*pinakio*)	Part of ring base and body		
M24	Lid	Part of lip and body		
M25	Chytra (Cooking pot)	Molded rim and part of handle		

M26	Chytra (cooking pot)	Flaring rim, start of handle and part of body		

BIBLIOGRAPHY

- Alcock, S., E., Berlin, A., M., Harrison, A., B., Sebastian Heath, Nigel Spencer and David L. Stone, (2005), Pylos Regional Archaeological Project, Part VII: Historical Messenia, Geometric through Late Roman:*Hesperia* 74.2:147-209 *(article published in an archaeological journal)*
- Aquila, E., Barone, G., Mazzoleni, P., Raneri, S., Lamagna, G., (2015), Petro-archaeometric characterization of potteries from a kiln in Adrano, Sicily: *Heritage Science*: 3-11 *(paper published in a scientific journal)*
- Αλούπη, Ε., (1993), *Φύση και Μικρομορφολογία των βαφών σε αρχαία κεραμικά, μια νέα προσέγγιση στη μελέτη της κεραμικής τεχνολογίας,* Ιωάννινα: 75-100 *(unpublished PhD thesis)*
- Βύνιου, Β., (1990), Μια οικογένεια τσουκαλιών στην Βαλύρα που έσβησε, *Εφημερίδα Βαλύρα*, 77-79, Απρίλιος *(newspaper article)*
- Γραβάνη, Κ., (2000), Προβλήματα στην έρευνα της ελληνιστικής κεραμικής: *Β΄Συνάντηση για την Ελληνιστική Κεραμική, Πρακτικά*, Ρόδος: 14 -19 (*paper published on the proceedings of a conference)*
- Chaviara, A., Aloupi-Siotis E.,(2015), The story of a soil that became a glaze: Chemical and microscopic fingerprints on the Attic vases: *Journal of Archaeological Science: Reports xxx-xxx(paper published in a scientific journal)*
- Danali, K., (2005), Ελληνιστική κεραμική από τον τάφο 3 του τύμβου της Τσοπάνης Ράχη στην Πύλο: *Ζ Επιστημονική συνάντηση για την Ελληνιστική* Κεραμική, Πρακτικά, Αθήνα:107-116 *(paper published on the proceedings of a conference)*
- Γιαννοπούλου, Μ. ,(2002), Η τεχνολογία των χειροποίητων αποθηκευτικών αγγείων στον ελλαδικό χώρο: Θεσσαλονίκη: 192-193*(book)*
- Farrington, A., (2012), Η Ελληνιστική και Ρωμαϊκή Μεσσηνία: Ι. Σπηλιοπούλου, Α. Δουλαβέρας (eds.), Μεσσηνία: συμβολές στην ιστορία και στον πολιτισμό της, Αθήνα: 135-152 *(chapter in a book)*
- Hein, A., Georgopoulou, V., Nodarou, E., Kilikoglou, V., (2008), Koan amphorae from Halasarna-investigations in a Hellenistic amphora production centre: *Journal of Archaeological Science* 35: 1049-1061 *(paper published in a scientific journal)*
- Hofmann, U., (1962), Die chemischen Grundlagen der griechischen Vasenmalerei: *Angewandte Chemie, Fortsetzung der Zeitschrift-Die Chemie herausgeben von der Gesellschaft Deutscher Chemiker* 74 (12):397-442 *(paper published in a scientific journal)*
- Kilikoglou, V., Vekinis, G., Maniatis, Y., Day, P.M., (1998), Mechanical performance of Quartz-tempered ceramics: Part 1, Strength and Toughness: *Archaeometry* 40.2: 261-279 *(paper published in a scientific journal)*

- Κόλια, Ε., (2000), Ταφικά σύνολα από την Ναύπακτο: *Στ΄ Επιστημονική Συνάντηση για την Ελληνιστική Κεραμική*, Βόλος: 388-389 *(chapter in a book)*
- Κυριάκου, Δ., (2005), Ελληνιστική κεραμική από τα νεκροταφεία της Πάτρας-Τυπολογική εξέλιξη: *Ζ΄ Επιστημονική Συνάντηση για την Ελληνιστική Κεραμική, Πρακτικά*, Αίγιο: 60-61 *(paper published on the proceedings of a conference)*
- Liritzis, I., Zacharias, N., (2011), *Portable XRF of Archaeological Artefacts: Current Research, Protocols and Limitations*, New York: 109-42 *(chapter in a book)*
- Matson, F. R., (1972), Ceramic Studies: W.A. McDonald-G.R. Rapp, Jr. (eds.), *The Minnesota Messenia Expedition. Reconstructing a Bronze Age Regional Environmen*t, The University of Minnesota Press, Minneapolis: 200-224 *(chapter in a book)*
- Tite, M. S., Maniatis, Y., (1975), Examination of Ancient Pottery using the Scanning Electron Microscope: *Nature* 257: 122-123 *(paper published in a scientific journal)*
- Maniatis, Y., Tite, M.S., (1981), Technological Examination of Neolithic-Bronze Age Pottery from Central and Southeast Europe and from the Near East: *Journal of Archaeological Science* 8: 59-76 *(paper published in a scientific journal)*
- Tite, M.S., Bimson, M., Freestone, I.C., (1982), An examination of the high gloss surface finishes on Greek Attic and Roman Samian wares: *Archaeometry* 24.2: 117-126*(paper published in a scientific journal)*
- Molera, J., Pradell, T., Vendrell-Saz, M., (1998), The colours of Ca-rich ceramic pastes: origin and characterization: *Applied Clay Science* 13: 187–188 *(paper published in a scientific journal)*
- Mirti, P., (2000), X-Ray Microanalysis Discloses the Secrets of Ancient Greek and Roman Potters: *X-Ray spectrometry,* 29: 63-72 *(paper published in a scientific journal)*
- Mangone, A., Giannossa L.C., Ciancio, A., Laviano, R., Traini, A.,(2008), Technological features of Apulian red figured pottery: *Journal of Archaeological Science 35*: 1533-1541 *(paper published in a scientific journal)*
- McPhee, I.D., Kartsonaki, E., (J2010), Red-figured pottery of uncertain origin from Corinth: Stylistic and Chemical analyses: *Hesperia*:79.1: 113-143 (*paper published in a scientific journal*)
- Μουστάκα, Α., (1991), Πρώιμη ανάγλυφη κεραμική από την Ηλεία*: Μελετήματα 13*, Αθήνα: 341-350 (*chapter in a book*)
- Pollard, A. M., (2007), *Analytical chemistry in Archaeology*, Cambridge University *(book)*
- Palamara, E., Zacharias, N., Xanthopoulou, M., Kasztovszk, Zs., Kovacs, I., Palles, D., Kamitsos, E. I., (2016), Technology issues of Byzantine glazed pottery from Corinth, Greece: *Microchemical Journal* 129: 137-204 *(paper published in a scientific journal)*

- Papachristodoulou C., Gravani,K.,Oikonomou, A., Ioannides, K.,(2010), On the provenance and manufacture of red-slipped fine ware from ancient Cassope (NW Greece): evidence by X-ray analytical methods, *Journal of Archaeological Science 37*:2145-2154(*paper published in a scientific journal)*
- Rice, M. P ,(1987), *Pottery analysis. A sourcebook*, University of Chicago Press: 232-233 *(book)*
- Rathossi, C., Tsolis-Katagas, P., Katagas, C., (2004), Technology and composition of Roman pottery in northwestern Peloponnese: *Applied Clay Science* 24: 313-326 (*paper published in a scientific journal*)
- Ραθώση, Ε. Χ., (2005), *Αρχαιολογικά κεραμικά ΒΔ Πελοποννήσου και προέλευση των πρώτων υλών τους: Πετρογραφική, Ορυκτολογική, Γεωχημική και Αρχαιομετρική προσέγγιση*, Πάτρα: 46-49 *(unpublished Phd Thesis)*
- Rathossi, C., Pontikes, Y., (2010), Effect of firing temperature and atmosphere on ceramics made of NW Peloponnese clay sediments: Part II. Chemistry of pyrometamorphic minerals and comparison with ancient ceramics: *Journal of the European Ceramic Society* 30: 1853–1866 *(paper published in a scientific journal)*
- Rogl, C., (2005), Hellenistic pottery from Grave monument K3, Messene: *Ζ΄ Επιστημονική Συνάντηση για την Ελληνιστική Κεραμική*, *Πρακτικά*, Αίγιο: 767-774 *(paper published on the proceedings of a conference)*
- Shepard, A., O. ,(1985), *Ceramics for the Archaeologists*, Carnegie institution of Washington *(book)*
- Shackley, M. S., (2011), *X-Ray Fluorescence Spectrometry in Geoarchaeology*, University of California. *(book)*
- Themelis, P., (1990), Ανασκαφή Μεσσήνης, *ΠΑΕ*: 69-71 *(paper published in an archaeological journal)*
- Themelis, P., (1993), Ανασκαφή Μεσσήνης, *ΠΑΕ*: 57-59 (*chapter in a book*)
- Themelis, P., (1994), Ανασκαφή Μεσσήνης *ΠΑΕ*: 86-89 *(chapter in a book)*
- Themelis, P., (1994), Ανασκαφή Μεσσήνης *ΠΑΕ*: 86-88 *(chapter in a book)*
- Themelis, P., (1996), Ανασκαφή Μεσσήνης *ΠΑΕ*: 144 *(chapter in a book)*
- Themelis, P., (2000), Πρώιμη ελληνιστική κεραμική από την Μεσσήνη: *Στ΄Επιστημονική Συνάντηση για την Ελληνιστική Κεραμική, Πρακτικά*, Βόλος:413-414*(paper published on the proceedings of a conference)*
- Themelis, P., (2005), Η ελληνιστική κεραμική της Μεσσήνης: *Ελληνιστική κεραμική από την Πελοπόννησο*, Αίγιο: 96-97*(chapter in a book)*
- Themelis, P., (2014), *Αρχαία Μεσσήνη*, Υπουργείο Πολιτισμού και Αθλητισμού ΤΑΠΑ, Αθήνα *(book)*

- Themelis, P., (2010), *Αρχαία Μεσσήνη: Ιστορία-Μνημεία-Άνθρωποι*, Αθήνα *(book)*
- Themelis, P., (2010), Ancient Messene, An important site in SW Peloponnese: *Bulletin of the Australian Archaeological Institute at Athens*, 7:28-29 (*paper in an archaeological journal*)
- Χαντζή-Σπηλιοπούλου, Γ., (1991), *Ταφικοί πίθοι στην Ηλεία κατά τον 4^{o} αι π.Χ. και τους Ελληνιστικούς χρόνους*: Μελετήματα 13, Αθήνα: 351-363 *(chapter in a book)*