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Remains of a sacred past: archaeometric characterization of Protogeometric to Archaic ceramics from the sanctuary of Apollo *Pythios* in Gortyn, Crete

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For myth changes while customs remain constant; men continue to do what they did before them, though the reasons on which their fathers acted have been long forgotten. The history of religion is a long attempt to reconcile old custom with new reason, to find a sound theory for an absurd practice.

James George Frazer, *The Golden Bough*

You (Apollo) who know the appointed end of all things, and all the paths that lead to them? And how many leaves the earth puts forth in spring, and how many grains of sand in the sea and in rivers are dashed by the waves and the gusting winds; and that which will be, and from where it will come, all this you clearly see.

Pindar, *Pythian Ode 9*

To my mom.
We speak to different gods now,
but you are the one who taught me how to pray.

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And for that, I thank the Driving-force that has pointed me in the right direction throughout all this time. You help me go further, and we will keep going, will keep rising.

You are what you love.

Coragem, força e humildade.

Abstract

The sanctuary of Apollo *Pythios* was built in the mid-7th century BCE in Gortyn, located in the central-southern portion of the island of Crete (Greece). Its construction marks the beginning of a new phase in the history of Gortyn, as it goes together with the transferring of the city's settlements from the hilltops to the Messara plain, which became the nucleus of the urban life in the Archaic period and the further development of the *polis*.

The scope of this research is to analyze the ceramic material recovered in the 2019 excavations from the Protogeometric to the Archaic period. The presence of ceramic material from the Protogeometric and Geometric periods — earlier than the foundation of the sanctuary of Apollo — attests the presence of human activity in the area prior to the construction of the temple, thus inferring an earlier use of the plain than previously thought. The typology of the material, mostly corresponding to table and kitchen wares, as well as storage jars, hints into a use of the area for communal gathering and festivities. This work represents an important step towards the reconstruction of the history of the sanctuary and the city of Gortyn, as it can potentially enable the identification of continuities or discontinuities in the ceramic preparation that may hint at changes in local production techniques and the social dynamics of the region.

An archaeometric analysis was performed on 46 ceramic sherds dating from the Protogeometric to the Archaic period, and aiming towards a characterization of the ceramic fabric that would allow the identification of continuities or transformations in the production technology throughout the centuries, as well as potentially hinting on the provenance of the pottery. A petrographic characterization through optical microscopy was applied in 17 of the samples, corresponding to the coarse grained material. Chemical analysis through X-Ray Fluorescence was applied to identify the major and trace elements of 20 of the samples, and the data were statistically treated with the software Statgraphics to analyze patterns of clustering and the chemical variables responsible of data variability by principal component analysis. Lastly, all the samples were characterized in terms of mineralogical composition through X-Ray Powder Diffraction. The results were combined with the typo-chronological data of the material undertaken by the Universities of Padua and Bochum in previous research, as well as with those obtained by the macroscopic analysis of the fabric in the early stages of this work and that enabled the identification of some characteristics of the ceramic body that allowed an initial classification of the material into macrofabric.

From this multi-analytical research, it was possible to evaluate the continuities or discontinuities in the paste preparation from the Protogeometric to the Archaic period, potentially hinting changes in local production techniques, cultural and social dynamics of the region. This research represents an important step towards the reconstruction of the history of the city of Gortyn,

as it can provide new insights into the spatial organization of the region prior to the foundation of the sanctuary of Apollo, which later evolved as a major center for communal gathering in Gortyn.

Abstract in Italian

Il santuario di Apollo Pitio fu costruito a metà del VII secolo a.C. a Gortina, situata nella parte centro-meridionale dell'isola di Creta (Grecia). La sua costruzione segna l'inizio di una nuova fase nella storia di Gortina, poiché coincide con il trasferimento degli insediamenti dalle sommità delle colline alla piana di Messarà, che divenne il nucleo della vita urbana durante il periodo arcaico e favorì lo sviluppo della polis.

L'obiettivo di questa ricerca è analizzare archaeometricamente parte del materiale ceramico recuperato negli scavi del 2019, risalente dal periodo Protogeometrico a quello Arcaico. La presenza di materiale ceramico dei periodi Protogeometrico e Geometrico — precedente alla fondazione del santuario di Apollo — attesta l'attività umana nell'area prima della costruzione del tempio, suggerendo così un utilizzo della pianura anteriore a quanto precedentemente ipotizzato. La tipologia del materiale, costituita principalmente da vasellame da mensa e da cucina, oltre che da anfore, indica un utilizzo dell'area per riunioni comunitarie e festività. Questo lavoro rappresenta un passo importante per la ricostruzione della storia del santuario e della città di Gortina, poiché può potenzialmente consentire l'identificazione di continuità o discontinuità nella preparazione della ceramica che potrebbero suggerire cambiamenti nelle tecniche di produzione locali e nelle dinamiche sociali.

L'analisi archeometrica è stata eseguita su 46 frammenti ceramici databili dal periodo Protogeometrico a quello Arcaico, con l'obiettivo di caratterizzare il materiale ceramico e permettere l'identificazione di continuità o trasformazioni nelle tecnologie produttive attraverso i secoli, oltre a suggerire potenzialmente la provenienza della ceramica. Una caratterizzazione petrografica tramite microscopia ottica è stata applicata a 17 campioni, corrispondenti al materiale a grana grossa. L'analisi chimica mediante fluorescenza a raggi X è stata applicata a 20 campioni per identificare gli elementi principali e in tracce, e i dati sono stati trattati statisticamente con il software Statgraphics per analizzare i pattern di clustering e le variabili chimiche responsabili della variabilità dei dati mediante analisi delle componenti principali. Infine, tutti i campioni sono stati caratterizzati in termini di composizione mineralogica tramite diffrazione di raggi X su polveri. I risultati sono stati combinati con i dati tipocronologici del materiale ottenuti dalle Università di Padova e di Bochum in ricerche precedenti, nonché con quelli ricavati dall'analisi macroscopica del tessuto nelle fasi iniziali di questo lavoro, che ha permesso l'identificazione di alcune caratteristiche del corpo ceramico per una classificazione iniziale del materiale in macro-fabbricati.

Grazie a questa ricerca multi-analitica, è stato possibile valutare le continuità o discontinuità nella preparazione delle paste dal periodo Protogeometrico a quello Arcaico, suggerendo potenziali cambiamenti nelle tecniche di produzione locali, nelle dinamiche culturali e sociali della regione. Questa ricerca rappresenta un importante passo verso la ricostruzione della storia della città di Gortina, poiché può fornire nuove prospettive sull'organizzazione spaziale prima della fondazione del santuario di Apollo, un importante centro di aggregazione comunitaria a Gortina.

TABLE OF EQUIVALENCE

SAMPLE’S ID AND EXCAVATION NUMBER

The samples will be referred to in this work by an identification number that was created to enable a more fluid workflow and data management during the archaeometric analysis. The table below shows the equivalence between the new identification number (column 1) and their original identification code (column 2).

ID number	**Excavation number**
G1	GONA19 1664/3314
G2	GONA19 1663/3216
G3	GONA19 1649/3591
G4	GONA19 1663/3215
G5	GONA19 1631/4000
G6	GONA19 1631/4004 + 4021
G7	GONA19 1631/4020
G8	GONA19 1631/4148
G9	GONA19 1664/3335
G10	GONA19 1664/3315
G11	GONA19 1664/4172
G12	GONA19 1641/4037
G13	GONA19 1649/3629
G14	GONA19 1649/3593
G15	GONA19 1641/3635
G16	GONA19 1631/4382
G17	GONA19 1649/4207
G18	GONA19 1631/4146
G19	GONA19 1631/4381
G20	GONA19 1649/3590
G21	GONA19 1631/3986

G22	GONA19 1631/4008 + 4012 + 4030 + 4017
G23	GONA19 1664/3373
G24	GONA19 1649/3592
G25	GONA19 1663/3204
G26	GONA19 1276/1282
G27	GONA19 1649/3514
G28	GONA19 1655/4212
G29	GONA19 1649/3533
G30	GONA19 1631/3994-4101
G31	GONA19 1631/3985
G32	GONA19 1649/3553
G33	GONA19 1649/3571-3541
G34	GONA19 1631/3997
G35	GONA19 1640/2842
G36	GONA19 1663/3177
G37	GONA19 1649/3567 + 3562 + 3670
G38	GONA19 1635/4187
G39	GONA19 1663/3217
G40	GONA19 1649/3508
G41	GONA19 1635/4185 + 3518
G42	GONA19 1649/3526
G43	GONA19 1631/4055 + 4070 + 4369 + 4061
G44	GONA19 1635/4193
G45	GONA19 1649/3569
G46	GONA19 1649/3575

CHRONOLOGICAL TIMESPAN OF THE ARCHAEOLOGICAL PERIODS IN CRETE

Bronze Age		
Name	**Equivalence**	**Timespan**
Early Minoan I - Middle Minoan IA	Prepalatial	Ca. 3200 - 1900 BCE
Middle Minoan IB - Middle Minoan IIA	Protopalatial	Ca. 1900 - 1700 BCE
Middle Minoan IIIB - Late Minoan IB	Neopalatial	Ca. 1700 - 1450 BCE
Late Minoan II - Late Minoan IIIB	Third/Final Palatial	Ca. 1450 - 1200 BCE
Late Minoan IIIC	Postpalatial	Ca. 1200 - 1050 BCE
Iron Age		
Name	**Abbreviation used in this work**	**Timespan**
Protogeometric	PG	Ca. 1050 - 900 BCE
Geometric	G	Ca. 900 - 700 BCE
Orientalizing	Or	Ca. 700 - 600 BCE
Archaic	Ar	Ca. 600 - 480 BCE

Introduction

One of the most important cities of ancient Crete, Gortyn has part of its history marked by the construction of the sanctuary of Apollo *Pythios*. The temple is among the many pieces of evidence of a process of large-scale urban reorganization that took place not only in Gortyn, but among other Cretan cities during the 7th century BCE.

The situation found in Gortyn is a perfect case-study to disclose the broader scenario of the Cretan Early Iron Age (1000 - 700 BCE), especially in regard to these 7th century urban transformations. The transferring of the city's nucleus from the earliest settlements on the hills of Profitis Ilias and Aghios Ioannis — where the *acropolis* and the sanctuary of Athena is found — to the plain occurred at the time, in a similar pattern observed among other Cretan cities on the period. These urban-landscape transformations are deeply characterized by the abandonment of hilltop settlements in favor of coastal sites or fertile lowlands, as well as the construction of civic buildings and intensification of cultivation (Kotsonas, 2002, p. 50). In this regard, the foundation of the sanctuary of Apollo in the mid-7th century BCE marks this transition to the city's new urban layout, now centered around the plain (Kotsonas, 2002, p. 50).

But the finding of ceramic evidence from earlier periods casts some doubt on the long-held assumption that it was only with the construction of the sanctuary that the plain started to be used. This material, recovered on the 2019 excavations led by the Italian Archaeological School and the University of Padova, is dated from the Protogeometric, Geometric, Orientalizing, and Archaic periods, and thus part of them are prior to the foundation of the temple of Apollo. These pottery sherds were extracted from the trenches nearby the so-called *Edificio* C, under a pink-colored floor layer Highly fragmented and found on a limited area of 1x1.5 m, it was likely that this material was placed for ground-levelling purposes or for the preparation of the floor layer — therefore, on a secondary deposit. Interestingly, the extreme degree of fragmentation, the association with sacred objects such as figurines, an arrow-head and an *horos*, as well as the old age of the fragments — with over 50% belonging to the Protogeometric period — raises the hypothesis of whether this pottery came originally from a nearby deposit or pottery pit (Bonetto et al, 2023, p. 608).

The chronology and typology of this material — largely corresponding to table and kitchen ware, as well as storage jars — might be indicative of a frequentation of the area prior to the foundation of the sanctuary, potentially for communal gathering or festivities. Therefore, the study of these ceramic materials is crucial for understanding the early cultural and social dynamics in

Gortyn, raising fresh hypotheses and perspectives regarding the city's new urban layout centralized on the plain.

AIMS AND RELEVANCE OF THE RESEARCH

The initial aim of this analysis is to evaluate the transformations on the ceramic body of 46 of this newly-recovered material, dated from the Protogeometric (c. 1050 - 900 BCE) to Archaic period (c. 700 - 480 BCE) and focusing on changes in the composition and production techniques of the pottery from these earlier times. In the context of Gortyn, the identification of continuities and discontinuities on the paste recipe could potentially highlight the preservation of traditional practices or significant innovations, which is essential for understanding the long-term evolution of ceramic production techniques and social dynamics in Gortyn and, more specifically, in the context of the transferring of the city's nucleus from the hills to the plain. By this diachronic approach, it is possible not only to trace changes in ceramic preparation, but also to reveal continuities that connect earlier phases of human activity in the plain to the later establishment of the sanctuary of Apollo *Pythios*. Additionally, the identification of similarities on the ceramic recipe of sherds specifically from the Protogeometric and Geometric periods could indicate possible contact and cultural exchange between these early settlements, thus offering critical insights into the spatial organization and social use of the area.

This is interesting as it may reflect technological advancements, shifts in trade networks, or changes in local production practices. If the production recipes of the ceramic body remain consistent across the centuries, it could suggest a stable pottery tradition, possibly indicating strong cultural continuity or limited external influences. On the contrary, significant changes in the fabric composition might point to the introduction of new techniques, external contacts, or the movement of potters and craftspeople from other regions.

The second aim of this research is to compare whether the fabric of sherds belonging to the same typology class evolved chronologically, presenting transformations or similarities on the clay preparation throughout the centuries. Through an analysis of the ceramic body of sherds from different classes of typology, it is possible to identify if specific paste recipes are being used according to the desired function of the resulting pot. Moreover, the identification of specific typology-driven pastes might hint into the existence of specialized pottery workshops, which once more points into the social organization of ancient Gortyn.

Lastly, by examining the mineralogical and petrographic properties of the ceramics, a first hint into the provenance of raw materials used in pottery production is aimed. This can provide insights into the extent of resource exploitation and trade routes, as well as the level of interaction between Gortyn and neighboring regions.

RELEVANT CONCEPTS

Two important definitions are central for this analysis. First, it is essential to define the conceptual connections between technique, technology, and culture. Through the established relationship between these concepts, it is possible to address the true potential of pottery and ceramic analysis to hint into the broader socio-cultural frameworks in which these vessels were created.

The often complex relationship between subjects (people) and objects (ceramics, in this case) reveals great details about past societies — in this sense, the concept of *chaîne opératoire* is a relevant conceptual tool. This methodological framework was first articulated by the French anthropologist André Leroi-Gourhan in his work *Le Geste et la Parole* (1964), in which he defines the concept of technique as "both the skill and the tool, organized into a sequence by a genuine syntax that gives operational series both their rigidity and their flexibility (Leroi-Gourhan, 1964, p. 164). In other words, technological processes are organized sequences of actions that reflect both cultural practices and social identities.

As this methodological framework is related to the complete range of technological choices applied to the raw materials, techniques, and operations involved in pottery production, the concept of *chaîne operatóire* enhances the understanding of the phases involved in ceramic production and its spaces, materials, and human resources (Santacreu, 2014, p. 50). In this interpretation, 'technology' is related to the social and symbolic characteristics that are typical from the societies in which they were found. If pottery vessels can be seen as "physical entities that are collected and studied by archaeologists as evidence of past societies", and techniques as "human actions performed in the production or use of these physical entities" (Santacreu, 2014, p. 50), the analysis of the social and cultural frameworks of past societies starting from tangible evidence — in this case, the ceramics — can be done (Santacreu, 2014, p. 50).

According to the idea of *chaîne opératoire,* specific ceramic recipes can be applied according to specific social dynamics "that regulate the whole production process, from the raw materials selected to the final product obtained" (Santacreu, 2014, p. 54). These are related to the range of techniques developed by a specific society, but also to the transmission of knowledge from one generation to another or between different distinguished societies. Therefore reconstructing technological choices enables the identification of social transformations and cultural exchanges.

The data acquired from archaeometric research can be of great use to the reconstruction of technological choices made by past societies, as it enables disclosure of elements and techniques of pottery production such as raw materials, paste preparation, and firing procedures (Santacreu, 2014, p. 55). Thus the application of this concept in this work makes it possible to trace the evolution of ceramic production practices over time, illuminating how these practices reflect broader social, economic, and cultural shifts within the society of Gortyn. By analyzing technological choices — such as material selection, paste composition, and firing techniques — this study can reveal the embedded social knowledge and skill transmission within the community.

MATERIALS AND METHODS

Once the cleaning and classification procedure of the materials retrieved by the excavations of 2019 has been carried out and the main chrono-typological characteristics of the ceramic fragments has been undertaken by a team from the Universities of Padova and Bochum, the research started. The analysis proceeded with a first macroscopic characterization on the field combined with an extensive literature review on the evolution of the city of Gortyn and the sanctuary of Apollo *Pythios*. In a second moment, the in-depth archaeometric analysis done through a multi-analytical and diachronic approach took place, undertaken in the laboratory facilities of the Department of Geosciences, at the University of Padova.

The initial macroscopic study was performed in 72 sherds dating from the Protogeometric to the Archaic period. It enabled disclosing the inclusions, color, hardness, and other macroscopically-observable characteristics of the ceramic body, supported by the use of a Dino Lite Microscope. This led to the first classification of the material into macrofabrics, and was an essential step in the first selection of the material.

The archaeometric analysis was applied to 46 of these initially studied ceramic sherds. All the samples were studied in terms of mineralogical composition through X-Ray Powder Diffraction (XRPD), combined with the use of the software HighScore Plus to identify the main mineral phases. This data was then statistically treated, with the application of cluster analysis following the methodology proposed by Maritan (2015).

Additionally, a petrographic characterization through optical microscopy was applied to 17 of the samples, corresponding to the coarse grained material. Samples were studied under plain and cross polarized light followed the methodology proposed by Quinn (2013) and revised by Maritan (2023), that foresees the characterization in terms of type, shape, and distribution of inclusions and voids, as well as a description of the groundmass.

Lastly, chemical analysis by X-Ray Fluorescence (XRF) was used in 20 of the samples. This number of samples was selected due to the scarce quantity of material available: as a quantity of at least 1.4 grams is needed for the XRF analysis and the material could not be entirely destroyed, only samples that met these measurements could be characterized in terms of chemical composition. The analysis was able to identify the sample's major, minor, and trace elements, and the data were statistically treated with the software Statgraphics to analyze patterns of clustering and principal component analysis.

Through the chrono-typological evaluation, mineralogical and chemical assemblage, and petrographic characterization of the Protogeometric, Geometric, Orientalizing and Archaic pottery, it is possible to outline the social dynamics and technological framework of Gortyn from these earlier periods to the time in which the city's nucleus is certainly oriented centered on the plain. This multi-analytical approach sheds light on the technological evolution and potential specialization within Gortyn's ceramic production, providing interesting insights into Gortyn's socio-cultural landscape.

HISTORY OF ARCHAEOMETRIC RESEARCH IN CRETE

Archaeometric research on ceramics on the island Crete began in the 1950s, focusing on understanding ancient pottery production and trade networks. Early studies employed techniques such as petrographic analysis to establish links between ceramic styles and local geology. In the 1960s and 1970s, more advanced techniques such as Neutron Activation Analysis (NAA) were introduced, allowing for more detailed chemical fingerprinting of ceramics.

By the 1980s and 1990s, interdisciplinary research combined techniques such as X-ray fluorescence (XRF) and Electron Microprobe Analysis (EMPA) to investigate the elemental composition of pottery. Relevant contributions came from scholars such as P.M. Day and D.E. Wilson, who analyzed pottery from East Crete and Knossos (Wilson - Day, 1994), identifying local production centers and revealing specialized production systems linked to palatial economies. Special attention must be paid to the studies held by H.W. Catling and J.N. Coldstream (1996) of the British School at Athens in the archaeometric characterization of the pottery from the North Cemetery of Knossos in relation to Levantine and Cypriot imports.

Archaeometric investigation on Iron Age ceramic has gained traction over the past few decades, with a focus on understanding the technological innovations and trade relationships that characterized the period. While much of the earlier research concentrated on the Minoan and Mycenaean periods, recent studies have started to shed light on the complexities of Iron Age ceramics, including their production techniques, raw material sourcing, and distribution patterns (Judson, 2018, p. 1).

Recent advances in archaeometric research have focused on technological analyses using methods such as X-ray Diffraction (XRD) and thin section analysis for petrographic characterization. Worth mentioning are the works on the sites of Eleutherna and Priniàs. In Eleutherna, a site known for its rich archaeological deposits, researchers have conducted detailed studies of ceramic assemblages from the Iron Age, utilizing techniques such as petrographic analysis and chemical characterization. These studies have revealed the influence of regional styles and trade networks, particularly the connections between Crete and the broader Mediterranean world.

A significant research conducted by A. Kotsonas (2008), in *The Archaeology of tomb A1K1 of Orthi Petra in Eleutherna: The Early Iron Age pottery*. In this volume, the author discusses the ceramic material from the site's necropolis, focusing on the chronological and typological framework as well as patterns of pottery production and consumption and fabric manufacturing (Kotsonas 2008). Similarly, at Priniàs, recent research was undertaken in 2021 by scholars of the Italian School of Archaeology in Athens (Pautasso et al, 2021), with the application of Scanning Electron Microscope (SEM) and Neutral Activation Analysis to study the ceramics from the site's necropolis.

While archaeometric studies on Cretan Iron Age ceramics are still emerging, the work at Eleutherna and Priniàs highlights the significant progress made in understanding this period. These works provide valuable insights into the production practices and trade networks that defined the Iron Age, with the continuity and transformation of technology, manufacturing, and styles.

The research led by the Institute for Aegean Prehistory Study center for East Crete (INSTAP SCEC) has been pivotal in advancing archaeometric studies of Cretan ceramics in general, particularly through detailed analyses of pottery production and raw material sourcing. The institute is dedicated to the investigation of the island's archaeology from the prehistoric period to the Early Iron Age, not only through the support of ongoing excavations but also through the scientific analysis on Cretan material culture in the institute's facilities. Founded in 2002, INSTAP's William A. McDonald Ceramic Petrography Lab has fostered extensively archaeometric research, with particular emphasis on the petrographic analysis of ceramic materials from the Neolithic to the modern times (William A. McDonald Ceramic Petrography Lab, INSTAP SCEC, accessed on 05/11/2024 https://instapstudycenter.net/archeological-science/ceramic-petrography/). The head of the laboratory, E. Nodarou, has conducted extensive mineralogical and petrographic studies that have refined the understanding of Cretan local ceramic production techniques, with the identification of clay sources, firing techniques, and the compositional signatures of ceramics across different archaeological periods (Nodarou, 2003).

Archaeometry in Crete holds enormous potential for expanding and deepening the understanding of the island's archaeology. The analysis presented in this work is the first archaeometric study conducted in materials from an archaeological site of Gortyn — and given the importance of the city to the history and archaeology of Crete, poses as a crucial step for help uncovering the island's social and cultural dynamics. As the ceramic material from Gortyn and from the sanctuary of Apollo *Pythios* have already been subject to extensive chrono-typological investigation (Bonetto et al 2023, Pegoraro 2021; Garattini, 2023), the possibility to further characterize the sherds in terms of petrographic composition, mineralogical assemblage, and chemical characteristics presents a pivotal step not only to understand the evolution of the sanctuary and the city, but also to the archaeological knowledge of Crete as a whole.

Chapter 1
Archaeological Background

1.1 THE ISLAND OF CRETE

1.1.1. HISTORY OF RESEARCH

Located in the heart of the Mediterranean, Crete experienced centuries of cultural exchanges that shaped its history and archaeological record. Its position in an almost equidistant point from Europe, Asia, and Africa made the island a “stepping stone between the continents” (Pendlebury, 1939, p. 1) and transformed Crete into a melting pot of cultures from different societies and civilizations that have crossed the island since the Bronze Age.

Historical interest in Crete dates to the Renaissance, when the drawings of travelers reached wider audiences and inspired the 18th and 19th century works on Cretan botany, geology, and ancient ruins (Day, 2018, p. 1). Interest on the ancient inscriptions was common in the 19th century, with the works of the Italian archaeologist F. Halbherr becoming a pivotal point in uncovering the island’s epigraphic remains.

The extensive and large-scale archaeological excavations of the 20th century led by scholars such as Sir A. Evans bolstered European and global interest in Cretan archaeology, leading to an intense exploration of the island for archaeological purposes (Day, 2018, p. 1). However, the traditional archaeological fieldwork applied at the time often focused on specific areas such as Knossos and the Messara, mainly due to the investigation of palaces and settlements of Minoan origin. Western, southeastern, and upland regions are being more recently explored, as well as the investigation of other historical periods to counterbalance the early predominance of Bronze Age studies (Day, 2018, p. 1).

Scholarly research in the Iron Age has increased in the last three decades, with special emphasis on the patterns of developing urbanism. Recent surveys and excavation campaigns have brought to light new sites belonging to the Early Iron Age and especially to the Protogeometric period (Judson, 2018, p. 1), thus enhancing the archaeological interest in the matter. In the early 2000’s, the publication of works on sites such as Profitis Ilias near the hill of Smari, Prinias, Knossos, and Eleutherna, marked a renewed interest in Iron Age settlement sites (Haysom, 2013, p. 68). Recent scholarly interest in investigating developing models of urbanism and settlement organizations from the 12th century BCE onwards have aimed towards a reconstruction of the patterns of urban development in the island (Judson, 2018, p. 1).

1.1.2. CRETE FROM THE BRONZE TO THE IRON AGE

The Bronze Age in Crete initiated around 3200 BCE with an increase in the number of settlements and the appearance of villages of significant size by the mid-third millennium BCE (Day, 2018, p. 3 - 5). The Cretan Early Bronze Age is also named Early Minoan or Prepalatial, lasting until 1900 BCE. The Middle and Late Bronze Age testified the birth of the so-called palaces, namely the ones from Knossos, Malia, Phaistos, and Zakros, which were initially considered to be royal residences but are now believed to have hosted diverse functions (Day, 2018, p. 5). These structures were central to the Minoan culture that flourished in the island in the Bronze Age, and their construction are divided into two main phases: the Protopalatial (1900 - 1700 BCE) and the Neopalatial (1700 - 1450 BCE) periods, divided by an earthquake around 1700 BCE.

The transition from the Bronze to the Iron Age is marked by the same issues faced by other Mediterranean societies at that time, such as natural catastrophes and overseas raiders that eventually led to internal tensions and collapse of earlier civilizations. The appearance of upland settlements in relatively inaccessible locations marks the Cretan Early Iron Age (1050 - 700 BCE), with the abandonment or destruction of the earlier coastal Bronze Age settlements (Day, 2018, p, 7). The Early Iron Age saw the emergence of new social systems and is characterized by being a "crucial transformative phase in the historical and material transition" of the island (Judson, 2018, p. 1). The Protogeometric period in the 9th century BCE is traditionally seen as a period of societal re-emergence after the Late Bronze Age decline, and therefore central for the later development of Greek civilization (Judson, 2018, p. 1), with an increased social complexity and settlement sizes. This is also reflected in the rising number of imports, after the significant decline in the 13th and 12th centuries, indicating "an extension and diversification of regional economic networks" (Judson, 2018, p. 6). This pattern goes on through the Geometric period, with settlements achieving the largest extent and new constructions taking place during the 8th and 7th centuries.

The following Orientalizing period (ca. 700 - 600 BCE) is named after the increasing influence of Near Eastern cultures in Cretan society, translated into the 7th century pottery style. The dissemination of this style was fueled not only by oversea influence, but also by the increased circulation of this type of pottery within Crete (Kotsonas, 2013, p. 238 - 239). The Archaic period (600 - 480 BCE) is characterized by the expansion of some settlements, abandonment of others, and the further emergence of the polis.

Based on material evidence from cemeteries, sanctuaries, and settlements, A. Kotsonas (2002) proposes that the 7th century presents a particular pattern of urban development that suggests large-scale spatial re-organization.

The abandonment of extensive cemeteries with chamber tombs in favor of individual cremation, a practice that lasted until the 6th century, presents a change from collective to individual funerary practices hints into significant transformations in the status system. In this case, the increased practice of individual cremation would mean a decreased need to reinforce and distinguish social groups (Kotsonas, 2002, p. 43) and thus indicates a change in social mentality (Kotsonas, 2002, p. 44). This process is followed by an increase in the number of elaborated grave monuments, found in 7th century Eleutherna and Priniàs, and that could symbolize a competition between elite members (Kotsonas, 2002, p. 43).

Moreover, evidence of increased votive deposits and the construction of new sanctuaries and temples has been connected to further urban transformation. Some examples are the construction of the 7th century's temples in Gortyn — the temple of Athena, in the acropolis, and the temple of Apollo, in the plain (Kotsonas, 2002, p. 45).

Lastly, some transformation of settlement patterns can be attested in cities such as Knossos and Gortyn. The earlier presents a discontinuity between the 7th and 6th centuries settlements, while in the later, there is a shift from the early 7th century hilltop settlements (Kotsonas, 2002, pp. 48 - 49), with the transferring of the city center to the plain and a gradual nucleation of the settlement (Kotsonas, 2002, p. 50). In general, the evidence from settlements indicates a preference for the fertile lowland or coastal sites, in contrast to the earlier hilltop and highland settlements. The sites present an increased urbanization and erection of civic buildings, peaking around the end of the 7th century (Kotsonas, 2002, pp. 50). In synthesis, Kotsonas proposes that all these processes "should be interpreted as the reflection of an important phenomenon, usually described as the rise of the archaic polis" (Kotsonas, 2002, p. 50).

Evidence of contact with mainland Greece is attested in the Archaic period by ceramic evidence, namely the Laconian kraters, Corinthian aryballoi, and vessels in Attic black figure. Social organization is characterized by a preference for oligarchies and the public display of law codes on civic buildings — the Gortyn law code being one of the most famous and remarkable examples (Day, 2018, p. 7).

As for the Classic Period, Crete had an important role in the 5th century Mediterranean trade, although was not particularly active during the Greek-Persian conflicts and Peloponnesian wars. During Classical and Hellenistic times, however, there was an increased conflict within the island, with the expansion of the larger city-states — namely Knossos and Gortyn — over smaller ones, occasionally ending up in total destruction or abandonment (Day, 2018, p. 7 - 8). The island became a Roman province in 67 BCE, with settlements expanding to the countryside with the emergence of small farms and villages.

1.2 THE CITY OF GORTYN

The ancient city of Gortyn is located in the present-day village of Agioi Deka and is one of the most important urban centers of Iron Age Crete, experiencing centuries of expansion and transformation of its urban life. It has drawn attention from scholars since 1884, with the recovery of the inscribed law code dated between 480 and 450 BCE by F. Halbherr (Di Vita, 2010, p. 11). Following that initial discovery, the excavations by the Italian School of Archaeology began in 1898, with several campaigns aimed on the study of the odeion, the acropolis, the praetorium, and the ancient temples (Francis et al, 2003, p. 487). These initial works recovered numerous quantities of epigraphic evidence that enabled the reconstruction of the civil, economic, and social history of the city (Di Vita, 2010, p. 13).

The ancient tradition relates the foundation of the city to the invasion of colonizers from Arcadia and Laconia during the then so-called Greek Dark Ages (1200 - 800 BCE), introducing the doric language and culture. Mythologically, the foundation of the city is related in literature to the presence of Gortys, a character that is often described as grandson of Zeus and Europa, or as an Arcadian hero (Di Vita, 2010, p. 15).

Earlier history of the region can be dated back to protohistoric times. Although there are little archaeological traces for the early use of the territory, local human presence can be attested since at least the end of the Neolithic, with ceramic and lithic materials on the Hagios Ioannis hills in the south-eastern portion of the city, named as "Geometric village" (Di Vita, 2010, p. 15). The origins of this urban settlement date to the Tardo-Minoan III B-C (around 1200 BCE) and developed along the Subminoan, Geometric, and Orientalizing phases. Some of its most significant finds are the squared rooms, votive evidence such as idols and small terracotta animals, as well as an abundant quantity of ceramic material that was used in the first drafts of the site's chronology (Di Vita, 2010, p. 17 - 18). In the Orientalizing period, the construction of a temple dedicated to the goddess Athena took place in the region, becoming the acropolis of Gortyn around the 7th century (D'Acunto, 2002).

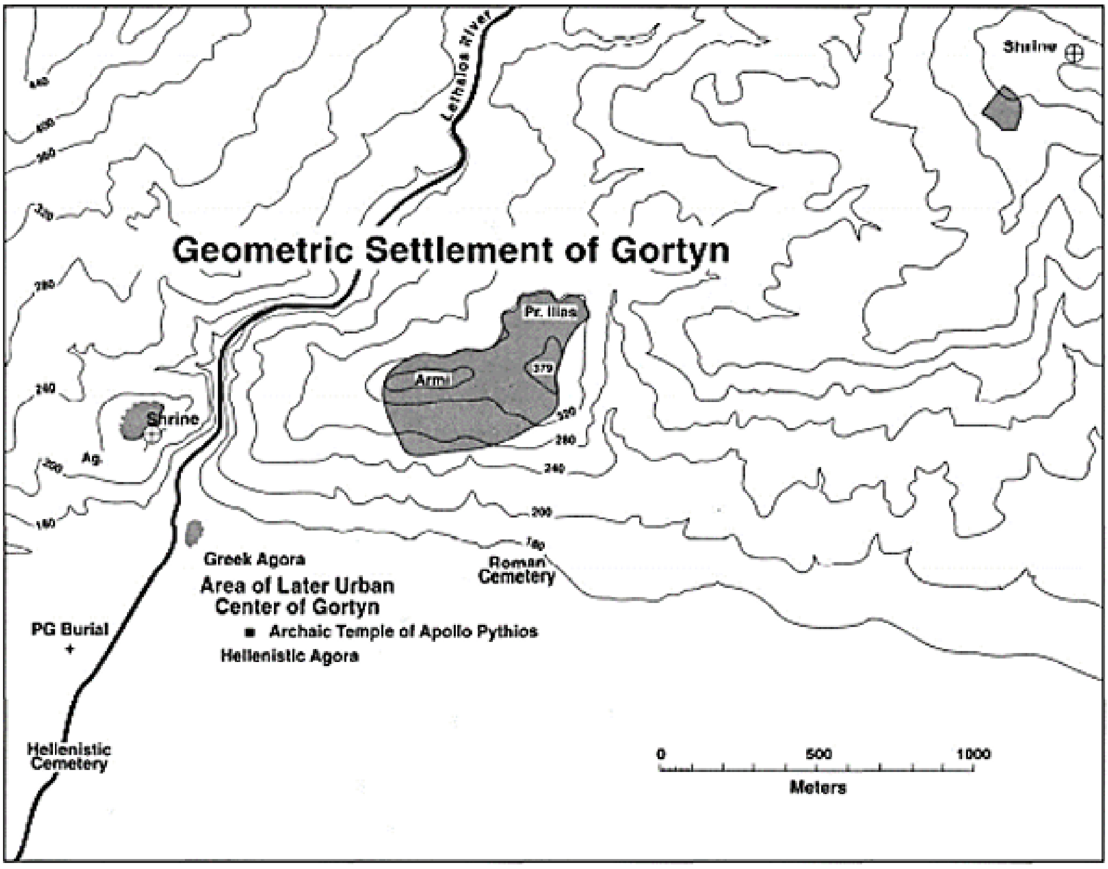


Figure. 1. Gortyn during the Geometric period (after Judson, 2018, p. 300)

These early settlements have increasingly expanded throughout the centuries. This is especially due to Gortyn's strategic position between the North-South and East-West routes of the island, as well as the easy access to the fertile lands on the south (Lippolis, 1995, p. 7).

It is by the 7th century BCE that the community of Gortyn seems to experience a process of political and territorial reorganization, with the first traces of urban activities. The construction of the sanctuary of Apollo in the Messara testifies the flourishing of the urban city, with its reorganization in the plain rather than the earlier hilltop settlements (Kotsonas, 2002, p. 48).

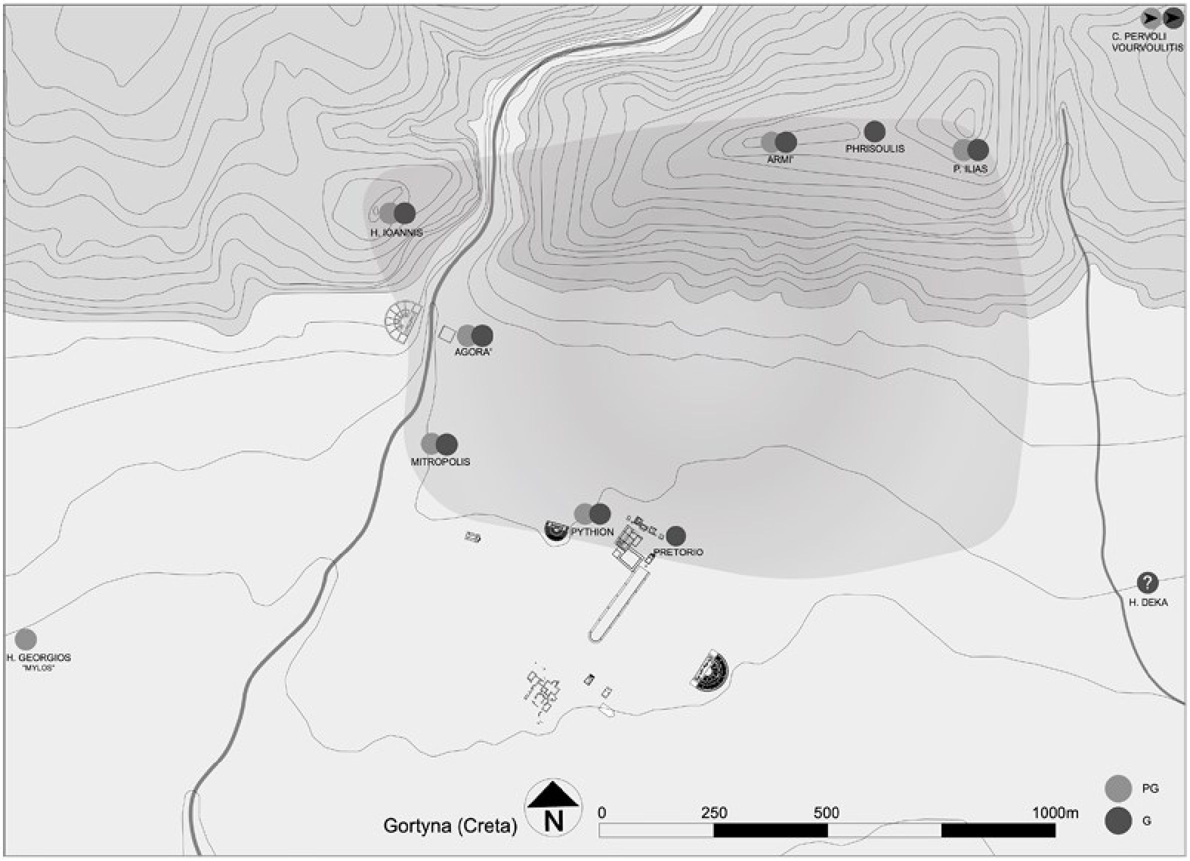


Figure. 2. Urban map of Gortyn with the distribution of the Protogeometric and Geometric material. The area occupied by the Greek and Early Imperial Roman city is highlighted in grey.
(after e. J. Bonetto; Archivi SAIA, NIG 8581).

The Archaic age brings up a significant territorial expansion to Gortyn, extending its control to all the Messara plain and finally taking over the Cretan political scenario in the Hellenistic period. It is by this time that the city's nucleus fully concentrates around the sanctuary of Apollo, establishing the new organization of the city around the Messara. According to Kotsonas (2002, p. 51), Archaic Gortyn presents a clear example of the process of polis formation of the period: "relocation of the settlement to an easily accessible area and/or nucleation, change in the focal point of the city, erection of public buildings among which the temple of the patron deity, with the inscription of laws, usually on that temple."

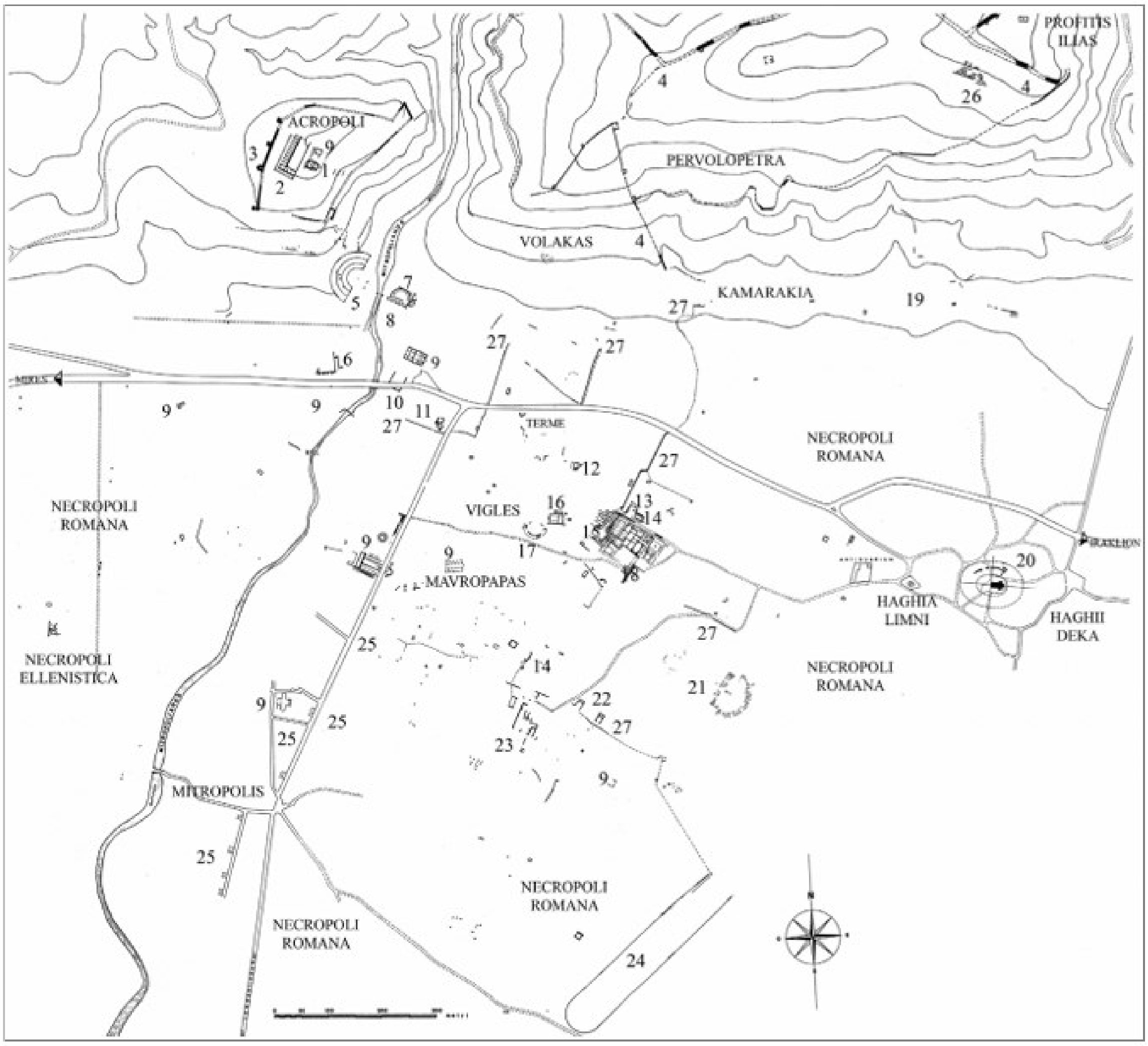


Figure 3. General plan of Gortyn. 1. Sanctuary of Athena; 2. Kastro building; 3. Byzantine fortification; 4. Hellenistic fortification; 5. *Acropolis* theater; 6. Terrace with votive finds (sanctuary?); 7. *Odeion*; 8. *Agora*; 9. Christian sacred place; 10. Public building (*Agoranomion*); 11. Byzantine baths; 12. Sanctuary of the Egyptian gods; 13. Temple A; 14. *nymphaeums*; 15. Quarter of the "Byzantine houses"; 16. Sanctuary of Apollo *Pythios*; 17. *Odeion* of the *Pythion*; 18. Gymnasium/baths of the Pretorio and Stadium; 19. Sanctuary of Demeter and Kore; 20. Amphitheater; 21. Theater; 22. Twin temples; 23. Baths of Megali Porta; 24. Circus; 25. Quarter of the *Latosion*?; 26. Settlement of Profitis Ilias (VIII - VII cent. BCE); 27. Aqueduct.
(after Lippolis, Caliò, Giatti 2019, p. 22, fig. 7)

1.3 THE SANCTUARY OF APOLLO *PYTHIOS*

As mentioned above, the foundation of the sanctuary of Apollo *Pythios* is an important mark for the restructuring of Gortyn in Archaic times. It can be related to the use of the Messara plain for community gathering, without the need of relying on the hilltop settlements for protection. Therefore, the temple attests the presence of an organized community, becoming the center of the communal and cultural life of Gortyn in the 7th and 6th centuries (Di Vita, 2010, p. 35).

Previous work placed the foundation of the temple between the Orientalizing and Early Archaic period, based on the inscriptions of the *krepidoma* (Bonetto el al, 2021, p. 55). It acquired a significant role in Hellenistic times, gaining remarkable political and religious importance during the expansion of the *polis* in the Late Hellenistic and Roman Imperial times (Bonetto et al, 2020, p. 452). Excavations on the site were first carried out in 1885, on its discovery by Federico Halbherr, with the main scope of recovering and collecting the inscriptions dating back to the Archaic period. Those were initially carved in the temple's original structure and later reused on the restoration of the walls by Roman builders in the 3rd century CE (Bonetto et al, 2020, p. 451).

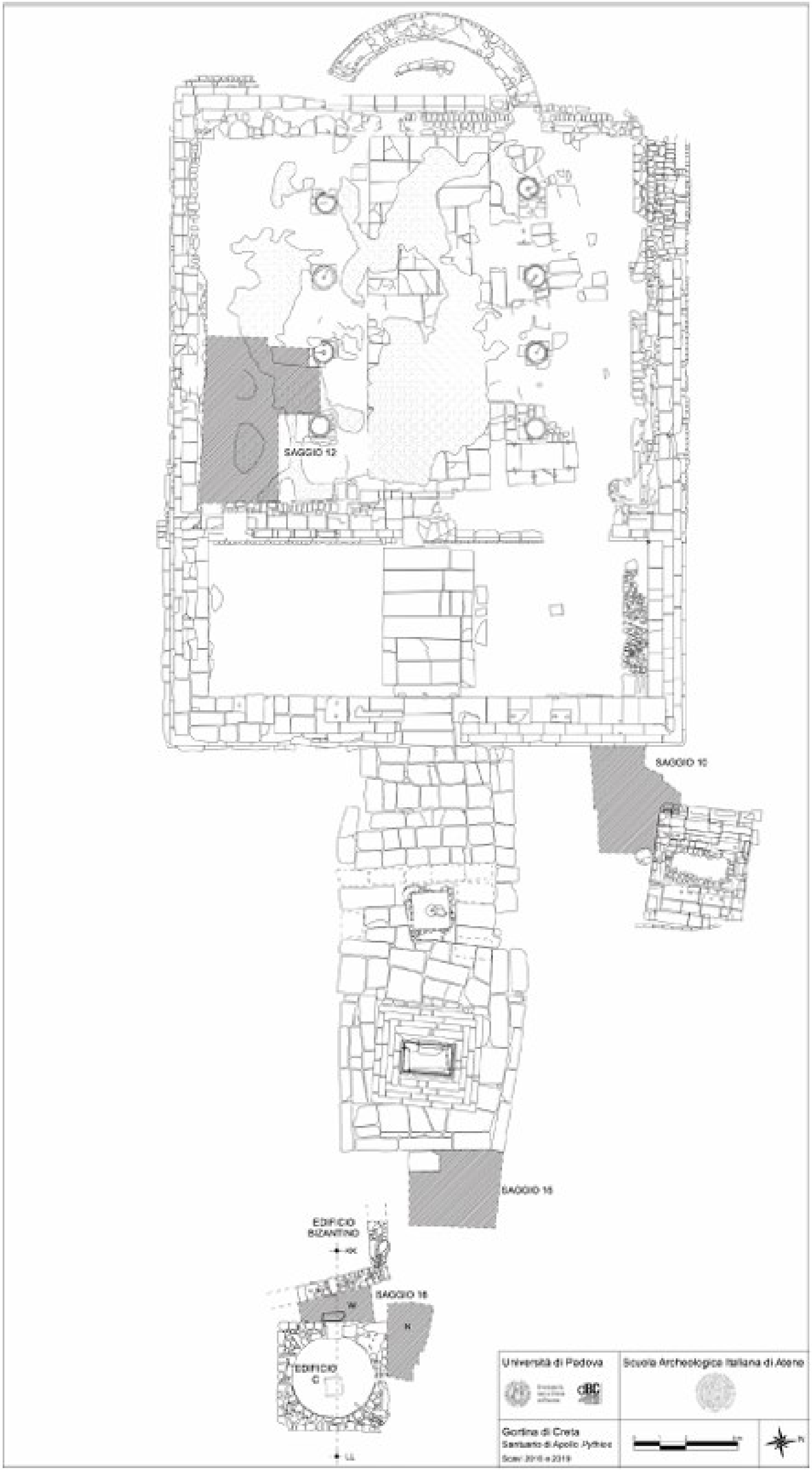
This initial work was focused on the interpretation of the recovered inscriptions. By doing so, Halbherr's research identified three main building phases of the temple, dated to the Archaic, Hellenistic, and Roman Imperial periods, a classification that, given the type of methodology applied at the time, seems too limited, schematic, and outdated (Bonetto et al, 2020, pp. 451-452). As common to the excavations of the time, little to no attention was paid to the architectural characteristics of the building, as well as to the stratigraphy of the site and small findings, such as ceramics (Bonetto et al, 2020, p. 451).

It was only several decades after the discovery of the site that further activities were carried out. Worth mentioning are the small-scale trial excavations led by Antonio Maria Colini between 1940 and 1974 (Colini, 1974), as well as an architectural examination made by Maria Ricciardi in the 1980's (Ricciardi, 1986-1987). Those works offered new information regarding not only the area of the sacred complex, but also the structures of the building.

Research focused on identifying and characterizing the historical assessment and stratigraphy of the site took place between 2013 and 2019, with the additional aim of creating an updated digital survey of the structure and studying the architectural elements of both the temple and its connecting buildings (Bonetto et al, 2020, p. 452). The 2016 campaign made it possible not only to complete the survey, but also draft the chronology of the site.

The oldest portion of the building is now dated to the mid-7th century BCE, based on the latest results of ceramic and stratigraphic data. This conclusion is drawn thanks to the finding of a black-glazed cup (Fig. 4) found on what is now interpreted as the foundation deposit of the sanctuary.

Located on the same level of the walls of the oldest portion of the sanctuary, the finding suggests that this deposition aimed at marking the completion of the building's lower foundations (Bonetto et al, 2021, pp. 57 - 58).



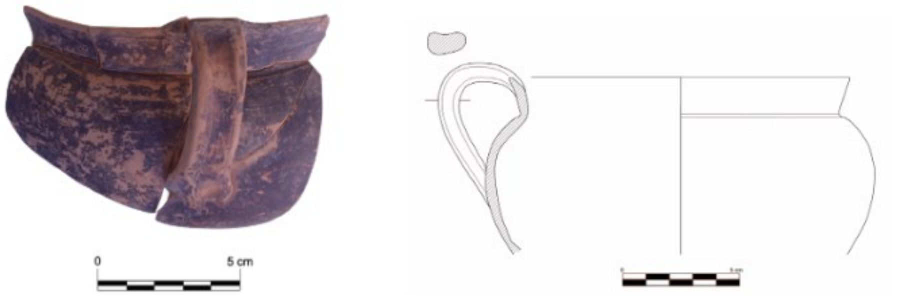


Figure. 4. Top: Floorplan of the sanctuary of Apollo with the indication of the excavation trenches (10, 12, 15 and 16) (after Bonetto et al, p. 607, © Archivio Università di Padova - Archivi SAIA, NIG 8580). Bottom: The black-glazed cup from the foundation deposit (courtesy of Università di Padova - Dip. Beni culturali; © Archivio fotografico SAIA U/12310).

The architectural project was likely based on a foot unit of 33.3 cm, suggesting the work of Eastern architects and artisans (Bonetto et al, 2020, p. 454). The difficulty in providing the existence of a roof in Archaic times — as the small pits that could hold the wooden supports of the roof date only to Roman times — might lead to the conclusion that the sanctuary was an open-air precinct (Bonetto et al, 2020, pp. 455-456).

As confirmed by the 2014 excavations, the temple's structures underwent significant modification between the 3rd and 2nd centuries BCE, with the building of a *pronaos* in the 3rd century BCE and the addition of six columns in a new façade (Bonetto et al, 2020, pp. 457-458). The theater, identified and excavated by the University of Padua between 2012 and 2013, became an adjunctive portion of the sacred area in the Early Imperial times, with its construction taking place in the first half of the 2nd century CE (Bonetto et al, 2020, p. 459). Further architectural transformations took place in the area, with a complete transformation of the layout of the temple in the Middle Imperial period that involved the reuse of the Archaic blocks with inscriptions on the newly built outer walls and the construction of a roof, standing over a double row of four monolithic marble columns over the attic bases (Bonetto et al, 2020, p. 459). After the renovation in the first half of the 3rd century CE, the temple probably collapsed due to the 356 CE earthquake (Bonetto et al, 2020, p. 462).

Special attention must be paid to the location of the site. Set in the Messara plain, it is apparently isolated from the nearby hills, which hosted several villages during the Late Minoan and Geometric periods, as previously mentioned. Although its construction is seen as the marker of the new plain-centered urban layout of Gortyn, the data recovered during the 2019 campaigns might propose a slightly different scenario to the evolution of the city. These pottery sherds were recovered from layers below a pre-Roman pavement and date back to Protogeometric and Geometric periods, and therefore are earlier than the foundation of the sanctuary. Their chronology is particularly rare to the temple and this region of Gortyn and therefore of great value for the research, as they indicate a use of this area for community or religious festivities prior to the foundation of the sanctuary (Bertelli, 2021, p. 66).

1.4 THE CONTEXT OF THE POTTERY SHERDS

The ceramic studied in this research was excavated from the so-called *Edificio* C (Fig. 5), located in the eastern portion of the temple (Bertelli, 2021, p. 64). This building was found during the excavations of the Byzantine quarter (Zanini et al, 2009) and corresponds to a squared area of 420m size, with a circular space of 3.16 m of diameter in the center, and a single opening towards the direction of the *Pythion* (Zanini et al, 2009, p. 1110) (Fig. 5, top). Its peculiar shape and the typology of materials found in the internal portion of the building — 36 Roman lamps, bones and animal remains, (Bertelli, 2021, p. 64) as well as traces of combustion — could indicate a ritual use (Zanini et al, 2009, p. 1111).

In 2019, the excavation opened three adjuncting areas next to the building. Trenches were opened in the western and northern external parts of *Edificio* C, as well as on the internal part of the building (Bertelli, 2021, p. 65). The western and northern area is the most relevant for the scope of this research, as it contains the layers from where the ceramic fragments here analyzed were excavated.

Figure 5. Top: The *Edificio* C with the sanctuary on the back (after Zanini et al, 2009, p. 1113). Bottom: Aerial view of *Edificio* C (courtesy of Università di Padova - Dip. Beni culturali; © Archivio fotografico SAIA U/12316).

A layer of *battuto* (compacted floor), corresponding to the stratigraphic unit 1636, was cut from the foundation trench of the building, and is therefore earlier than the building itself. A large amount of highly fragmented ceramic sherds was found, which may imply that they were intentionally used to compact the floor's foundation. Despite being in a secondary context, the association with items like miniature terracotta shields from the Orientalizing period, an arrowhead, and a boundary marker (*horos*) found far from the sacred area suggests that these might have been discarded or deposited intentionally in the area. Initial analysis of the fragments points to a single event of material deposition, probably occurring between the 5th and early 4th century BC, as indicated by the presence of black-glazed cup bases and radiocarbon dating results (Bonetto et al, 2023, p. 608).

The impressive number of ceramic fragments recovered from the stratigraphic layers 1641 and 1649, which corresponds to 1663 and 1664 in the southern expansion of this area, are of particular interest for the understanding of the development of the sanctuary. The US 1631, which was already identified in the beginning of the campaign, was enlarged 12 cm thick and excavated for an extension of 1 m² (Fig. 6), and presented numerous small ceramic fragments from the Geometric and Orientalizing period, as well as a wall of *oinochoe* that can be related to some ceramic findings from the temple of Athena on the *acropolis* (Bertelli, 2021, p. 68).

Figure 6. Stratigraphic unit 1631, in area 16.
(courtesy of Università di Padova - Dip. Beni culturali; © Archivio fotografico SAIA U/12319).

Even though the findings come from later stratigraphy and have been probably reused in classical or hellenistic period, the presence of such an amount of ceramic materials dating to the

Protogeometric, Geometric and Orientalizing periods indicates that they probably come from a nearby area and therefore that an use of the area prior to the construction of the temple is probable (Bertelli, 2021, p. 69). Moreover, the typology of the fragments — mainly related to cooking and tableware — might as well indicate the use of the area for feasts and community gathering (Bertelli, 2021, p. 66). Therefore, the area has been frequented since, at least, the Protogeometric period, perhaps already with a sacred function. In this regard, the archaeometric analysis of the ceramic evidence from a diachronic perspective can hint into the evolution of the sacred area by identifying possible continuity and/or changes in the paste's recipe, manufacturing and firing technology.

1.4.1. CHRONO-TYPOLOFGICAL INVESTIGATION OF THE MATERIAL ANALYZED

The general picture of the social and cultural transformations of the Bronze to Iron Age transition in Crete is translated in the ceramic styles of the time. It is possible to detect an increase in the technological quality of the ceramic, with larger application of figured decoration, freely painted naturalistic elements, and the spread of imports (Pappalardo, 2021, p. 12). Additionally, the emergence of new decoration trends in the beginning of the Iron Age is related to the influence of Attic imports, which can be seen in the gradual adoption of concentric circles drawn with compass and multiple brush from the Subminoan to the Early Protogeometric age. These are particularly present in *amphorae* and bell-*kraters*, while small open vessels often lack decoration or display a single wavy line (Coldstream et al, 2001, p. 65).

Geometric pottery often displays an eclectic mixture of Attic and local styles, combining triangles, arcs, and circles (Coldstream et al, 2001, p. 66). The Middle Geometric style displays a dark-ground pattern, strongly influenced by Attic imports, while the Late Geometric displays a gradual advance of white-on-dark decoration and narrow horizontal strips (Coldstream et al, 2001, p. 69). Transitioning to the Orientalizing period, it is possible to detect the adoption of freehand curvilinear ornaments, partially of oriental origin. These were already present in earlier periods, but increased significantly by the end of the 8th century BCE (Coldstream et al, 2001, p. 70).

Finally, the later Archaic pottery displays local developments that reflect the island's interactions with both mainland Greece and broader Mediterranean influences. This period attested a transformation in decorative techniques and motifs, influenced by Cretan social and political transitions. Pottery from this era displays a move toward more geometric designs, with local workshops incorporating styles from neighboring regions while retaining distinctly Cretan characteristics (Erickson, 2010).

The identification of the typology and chronology of the sherds excavated in the sanctuary of Apollo in the 2019 campaigns was made on the research campaigns of 2021, 2022, and 2023, in a joint-mission by the Universities of Padua and Bochum (Bonetto et al, 2023, p. 609). Despite the small dimensions and noticeable fragmentation of the material, the identification of the general chronology was possible through the analysis of the morphology, paste, and type of decoration of slip/glaze that was characteristic of certain periods, as well as the comparison with the evidence from neighboring sites such as Knossos, Festòs, Kommos, and Priniàs (Bonetto et al, 2023, p. 625).

The decoration pattern in parallel lines and bands of different width made with black or dark brown glaze and in concentric circles, both typical of the Early Iron Age, was largely present among the fragments. Additionally, it was possible to verify the presence of the typical Geometric white-on-dark decoration, present in fragments of *amphorae*, *pixides*, and *oinochoai* (Bonetto el al, 2023, p. 625).

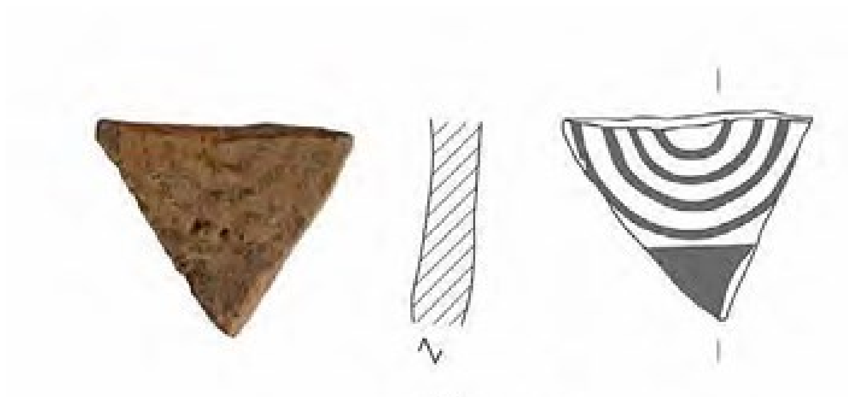


Figure 7. Fragment GONA 19 1649/4207 (equivalent to G17), displaying the curvilinear decoration typical of the Geometric period (modified after Bonetto et al, 2023, p. 647)

Samples without decoration were not classified in terms of specific chronology, since the lack of diagnostic traces made it impossible to assign them specific periods within the broader timeframe. However, as they were excavated from the same stratigraphic layers as the others, it is certain that they fall into the timespan from the Protogeometric to Archaic period.

Combined with the decoration analysis, the method of the ‘sum of the weighted average’ was applied, chosen due to the broad date ranges of some of the fragments. This quantification method was based on the works of Terrenato and Ricci (1998), which, in simpler terms, involves splitting the total number of fragments with the same dating across the period they span, then assigning a proportional fraction to each year in that range. For instance, if there are 14 fragments dated between the years 30 and 130, the total (14) should be divided by the time period (100 years), giving each year from 30 to 130 a fraction of 14:100, or 0.14. Once all the classifications are done, the fractions for each year are added up, creating a curve that closely reflects the chronological distribution of the materials. This approach ensures that each fragment has an equal impact on the curve while preserving the detailed chronological information (Terrenato - Ricci, 1998, pp. 92 - 93).

The application consisted of the split of centuries into 25-year periods. The value of each fragment was divided across these periods, and the resulting fractions were summed to create a curve showing the chronological distribution of the fragments. In this curve, all pieces contributed equally, with the horizontal axis showing the timeline and the vertical axis representing the sum of these fractions per quarter-century.

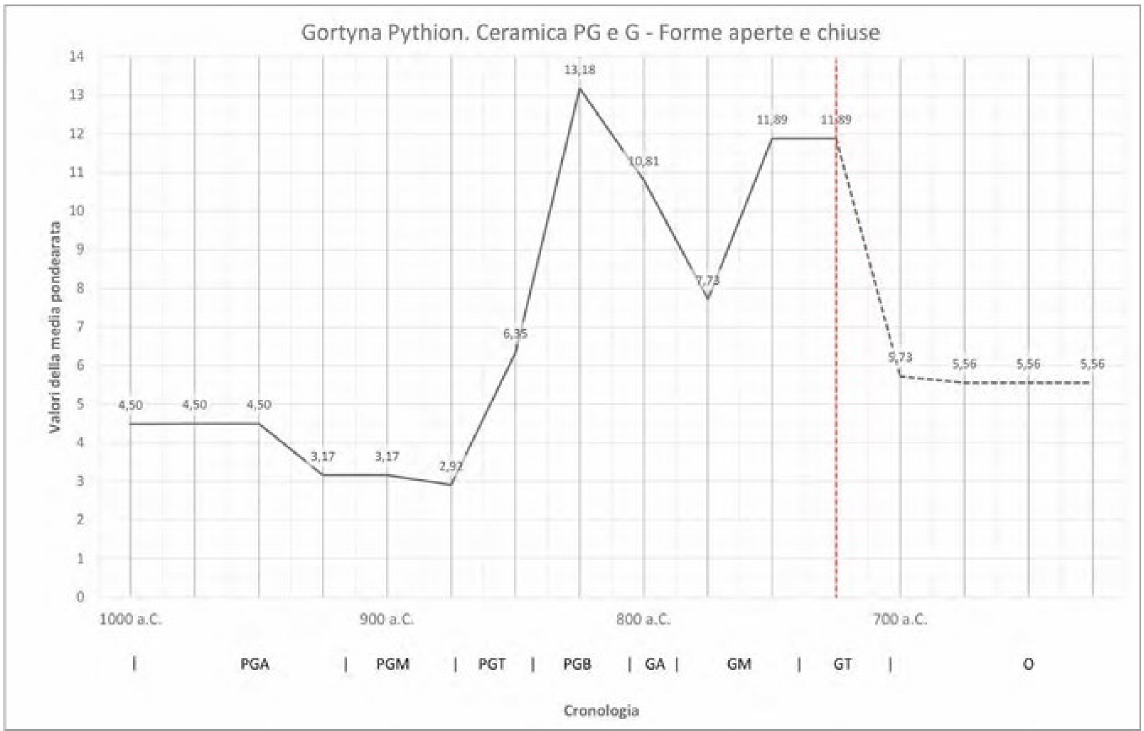


Figure 8. Sum of the individual weighted average of the fragments (open and closed forms). Abbreviations: PGA, PGM, an PGT = Early, Middle, and Late Protogeometric, respectively; GA, GM and GT = Early, Middle, and Late Geometric, respectively; O = Orientalizing (after Bonetto et al, 2023, p. 627).

It is possible to observe a significant presence of ceramic fragments dating back to the Early Protogeometric period, which could indicate possible activity in the area as early as the 10th century BCE, which increased in number through the Middle and Late Protogeometric. The presence of these ceramic fragments remains constant throughout the centuries and confirms the early frequentation of the area, suggesting a continuous presence in the area prior to the monumentalization of the temple of Apollo *Pythios*. Lastly, the increase in ceramics during the Late Geometric and Orientalizing periods can be related to the appearance of structural evidence in the sanctuary during the 7th century BCE (Bonetto et al, 2023, p. 626).

From the 46 samples selected for the archaeometric analysis, 8 were identified as Protogeometric, 7 as Geometric, 14 as Orientalizing, and 2 as either Orientalizing or Archaic. As the remaining 15 fragments did not contain diagnostic decoration patterns, they remained unidentified in terms of chronological specificity. Most of the samples correspond to fragments of pouring vessels (*hydria*, *oinochoe* and *lekythos*), that make up the total of 20 samples, followed by 8 storage vessels (*krater*, *pithos* and *amphorae*), 4 vessels for eating and drinking (cup, bell *skyphos*, *kotyle* and *lekane*) 2 cooking ware (jugs), and 2 tableware (lids). In addition, a fragment of a shield was identified, as well as a figurine, which combined with the presence of vessels used mainly for eating, drinking and cooking, could hint into a ceremonial use of the area.

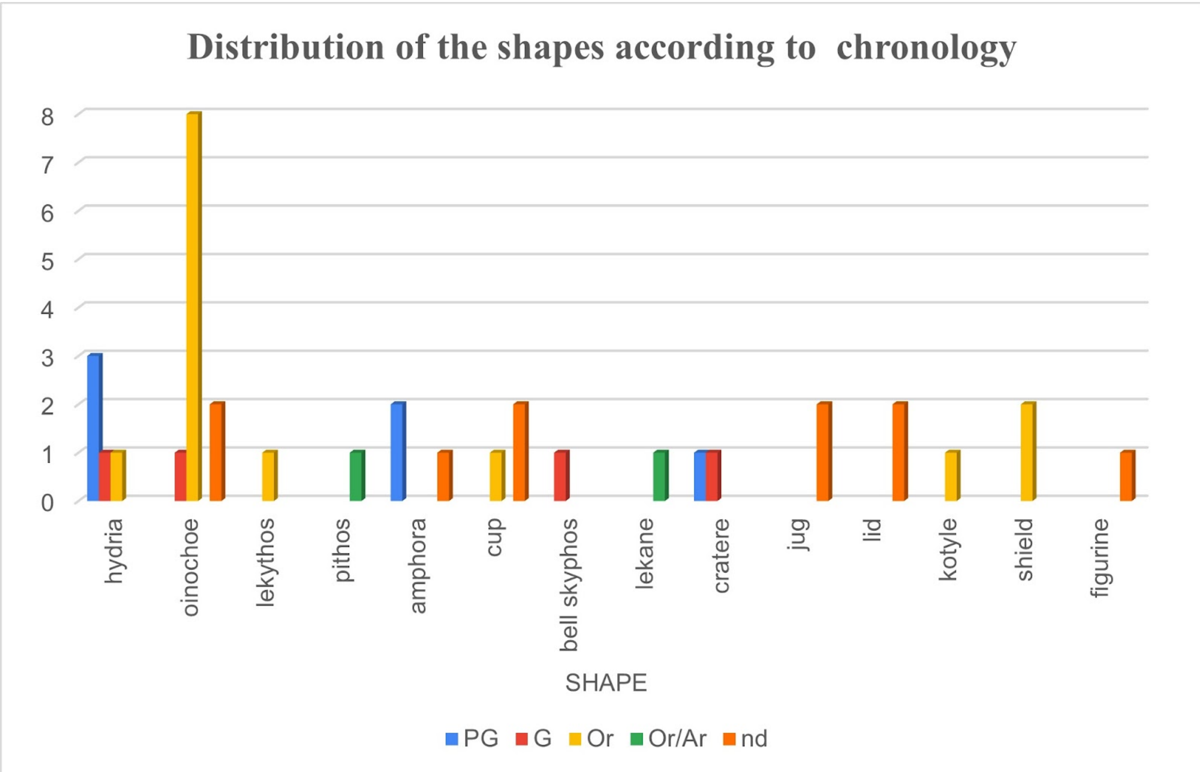


Figure 9. Distribution of the shapes according to the chronology.

Finally, it should be pointed out that the initial works on this ceramic hypothesized that 9 of the excavated material could possibly be imported, and not locally produced. This assumption was made based on the macroscopically-observable aspects of the ceramic body such as color, hardness, inclusions, and feel. Through the comparison with ceramics from other Cretan sites, with special regard to the stylistic features that are characteristic of these other locations, this material was first speculated to be Knossian. Archaeometric analysis can therefore be a useful tool to help disclosure the provenance of these sherds — if, of course, the data available is sufficient to provide a scientific basis for that.

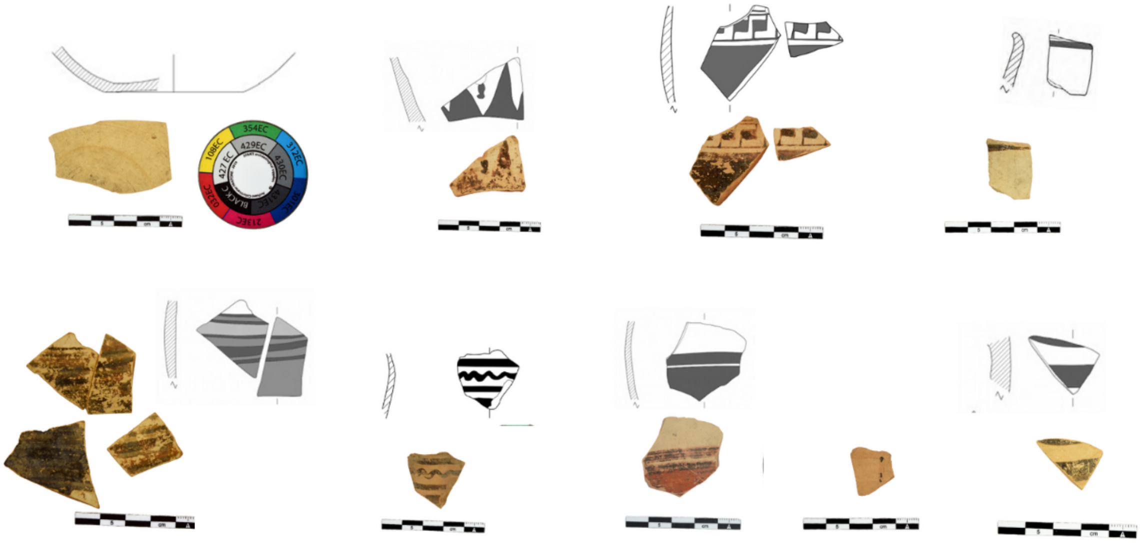


Figure 10. Pictures and drawings of the possible imports. Top to bottom and left to right: G23, a bottom of an *oinochoe*; G29: wall of a shield; G33: wall of an *oinochoe*; G35: wall of a bell *skyphos*; G37, G38, G42, G44 and G45: wall of an *oinochoe*. All fragments are from the Orientalizing period, except for fragments G35 and G38, that are Geometric, and G44 (unknown chronology).

Chapter 2
Geological Background

2.1. GEOLOGICAL BACKGROUND OF CRETE

The island of Crete is an elongated, horst-like structure that is part of the islands of the Aegean arc. Its landscape is characterized by gentle hills, wide alluvial plains, and high mountainous chains that divide the island into three main parts (Mentesana et al, 2016, p. 300). Crete is marked by seven recognized depositional intervals, corresponding to combinations of “sedimentary patterns, tectonic movements and palaeogeographic configurations” (Fortuin, 1978, p. 451). The island is a fragment of the peri mediterranean Alpine orogenic belt, which consists of a “pile of thrust-nappes deriving from the deformation of Mesozoic to Cenozoic paleographic domains related to the progressive Africa-Eurasia convergence” (Tortorici et al, 2011, p. 320).

Its position at the intersection of the African and Eurasian tectonic plates resulted in significant changes in Crete’s geological structure, caused by the ongoing subduction processes of the region. This phenomenon led to the formation of the Ophiolite series and the uplift of the Carbonate plateaux that characterizes the geology of south-central Crete (Mentesana et al, 2016, p. 300). The Hellenic subduction zone, located to the south of Crete, is responsible for the current tectonic activity in the region. This area has been shaped by multiple episodes of faulting and metamorphism, particularly during the Oligocene and Miocene epochs, leading to the exposure of high-pressure, low-temperature metamorphic rocks (Rahl et al, 2004).

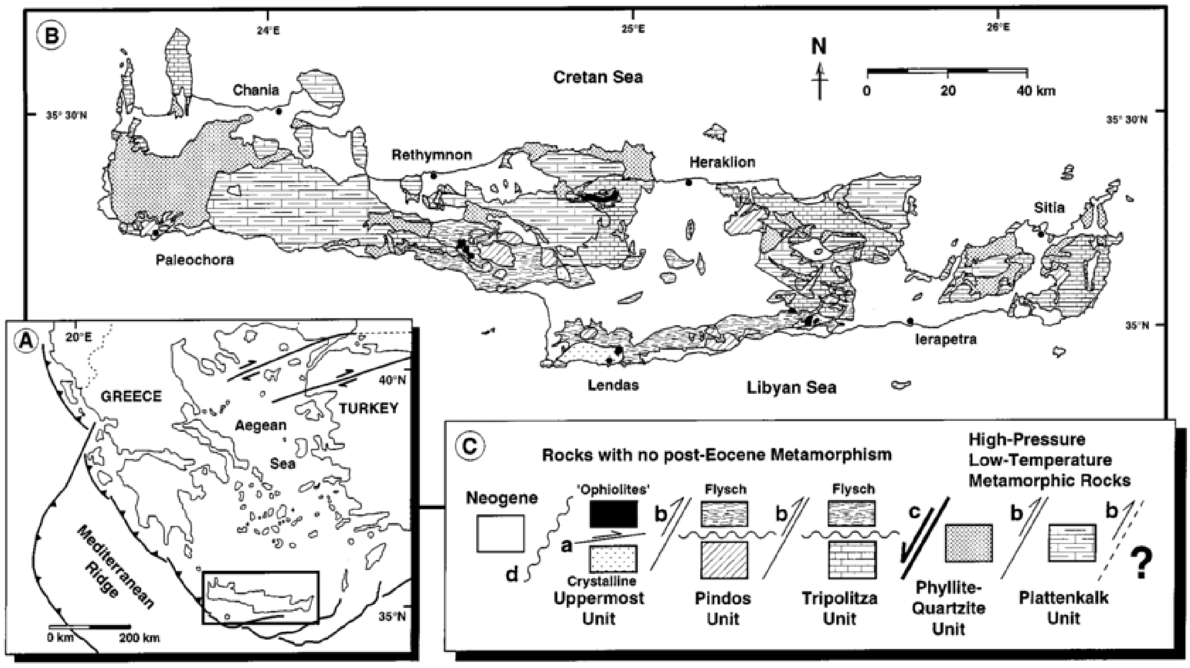


Figure 11. Geological sketch of Crete (modified after Creutzburg and Seidel, 1975; taken from Thomson et al, 1998, p. 260)

2.2. THE MESSARA PLAIN

Of main relevance to this research is the geological setting of the Messara plain, where Gortyn is located. It is a west-east oriented tectonic depression (graben) located in the southern sector of Crete, 25 and 5 km wide and with a total area of 112 km². The Messara's present landscape is a result of geomorphological transformations that occurred in the span of millenia, with short and long term climatic variations, sea level changes, tectonic episodes, and the alternation of processes of erosion and deposition, as well as recent anthropic activity.

The Messara is cut by the Yeropotamos river, flowing between the Psiloritis Mountains to the north and the Asteroussia Mountains to the south in the direction of the Lybian Sea (Amato et al, 2012, p. 133). To the west, the plain is initially confined by the Phaistos hills before extending into the alluvial coastal plain of the Timbaki Gulf. To the north, the Messara is divided from the Heraklion basin by the carbonate plateaux, with alternating deposits of carbonate formations and the Ophiolite (Mentesana et al, 2016, p. 300); while in the south, schist and limestone formations from the Mesozoic era are predominant (Tsanis et al, 2014, p. 69).

The Messara is bordered and intersected by steep faults and embedded between deposits Mesozoic, Miocene, and Plio-Quaternary in age (Amato et al, 2012, p. 133). The plain hosts Crete's largest alluvium aquifer (Liard et al, 2018, p. 740) and is mainly composed of Quaternary deposits

(Tsanis et al, 2014, p. 69). Its topography consists of a flat basin morphology modified by river terraces and alluvial fans (Tsanis et al, 2014, p. 69).

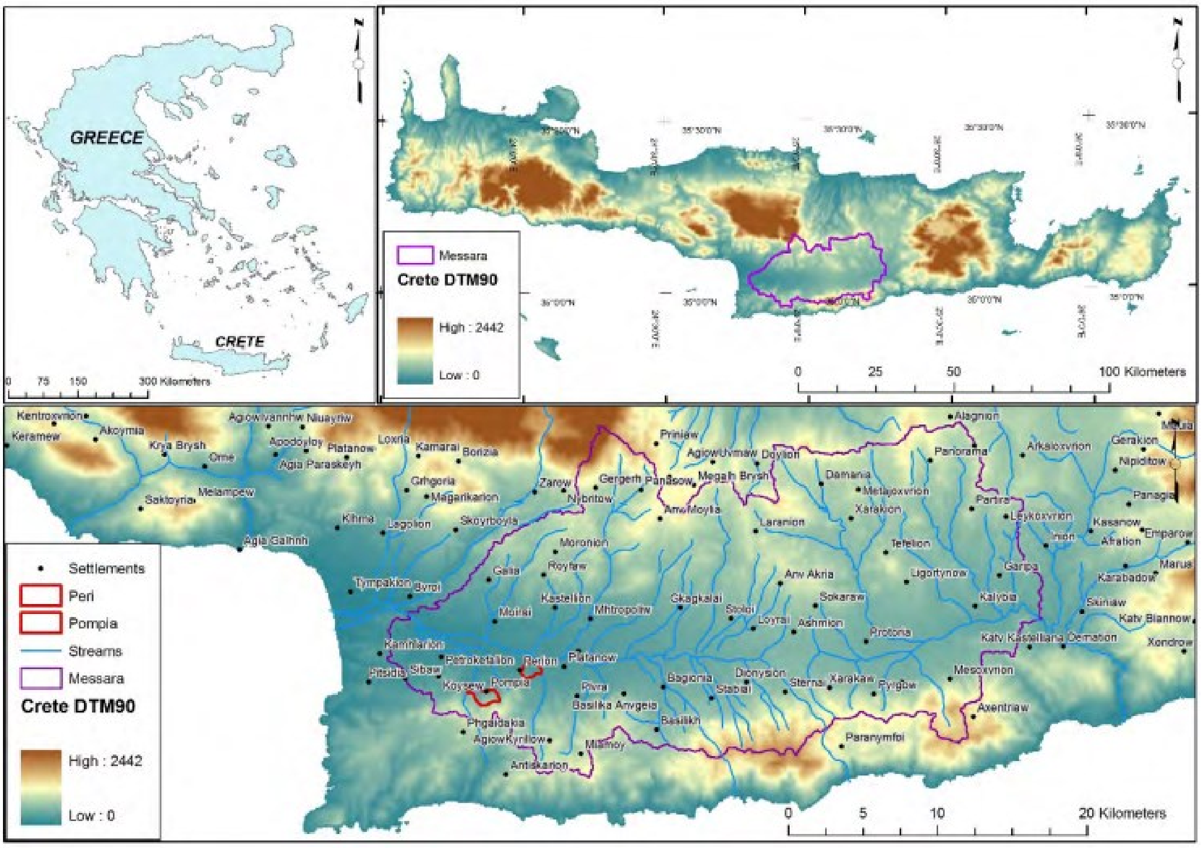


Figure 12. Location of the Messara with topographical relief (after Tsanis et al, 2014, p. 68).

The geological composition of the deposits of the Messara are, according to Amato et al (2012, p. 133), the following:

- metamorphic rocks (ophiolites, gneiss, shales) and flysch deposits of Mesozoic-Cenozoic age, outcropping only in small areas on high mountain slopes;
- marls and marly limestones, sandy and gravelly deposits of Miocene and Plio-Pleistocene age, outcropping mainly along the borders of the basin and in the Phaistos hills;
- alluvial, fluvial, marshy, scree and marine deposits of the Pleistocene and Holocene, constituted by an alternation of loose gravels, sands and clays.

The latter two make most of the sediment filling the Messara plain (Amato et al, 2012, p. 133), covered by Quaternary alluvial clays, silts, sands, and gravels (Tsanis et al, 2014, p. 69). At the base of the Phaistos hills and the Psiloritis and Asteroussia mountains on the valley's edges, the alluvial sequences exhibit heterotopic relationships with the deposits from the foothill aggradation zone. The formation of this zone was likely influenced by tectonic activity along the adjacent slopes, Holocene climate changes, and anthropic land-use modifications (Amato et al, 2012, p. 133).

The particular heterogeneity of rocks and sediments found in the Messara plain is the result of the coexistence of morpho-stratigraphical units displaying erosional and depositional morpho-dynamical processes (Amato et al, 2012, p. 133). Along the plain it is possible to find:

- hilltops of planar palaeo-surface at the top of the Messara hills, with flat areas ranging from small to large and bordered by both steep and gentle slopes with in situ and superficial archaeological material;
- aggradation, formed as a result of Late Quaternary climatic changes and anthropic changes in the Holocene, located mainly zones of alluvial fans, rock-falls and debris cones;
- the alluvial plain, formed by fluvial morphodynamics transformations resulting from climatic changes, land-use, and tectonics that are correlated with two aggradation periods in the Holocene;
- the coastal alluvial plain of the Yeropotamos River, with layers of sandy dunal barriers that are partially covered with riverine marshy deposit (Amato et al, 2012, p. 134).

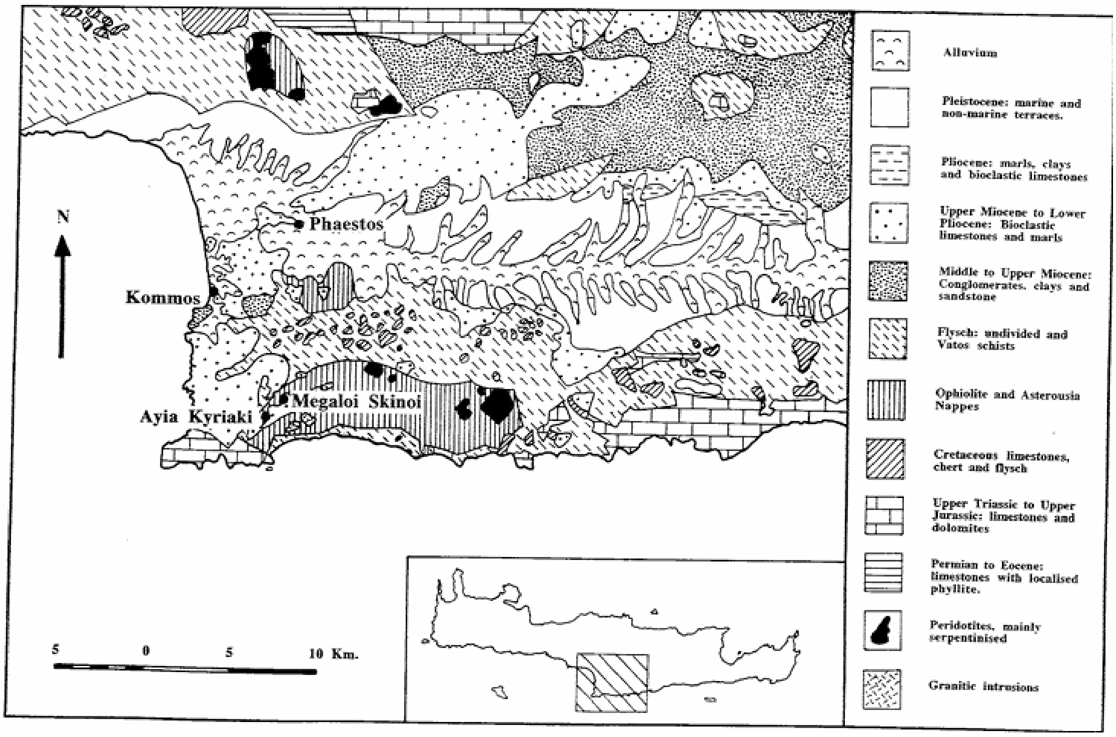


Figure 13. Geological sketch of South-central Crete and the Messara plain (after Wilson & Day, 1994, p. 56).

2.3. THE GEOLOGY OF GORTYN

The village of Agioi Deka where the ancient Gortyn is located is in the center of the Messara Plain and near its western edge. It is between two mountain chains — the Psiloritis in the north and Asterousia mountains in the south. The city is delimited by the Lassithi mountains eastwards, opening towards the Libyan Sea to the west, and crossed by the river Mitropolianòs, a tributary of the Yeropotamos. This river flows through the plain, passing between the westernmost of the low hills, which are extensions of the Ida range and form the northern boundary of the Messara: the hill of Aghio Ioannis (267 m above sea level), where the *acropolis* was established, and the more easterly hills of Peripetrea (296 m), Armi (348 m), and Profitis Ilias (379 m) (Di Vita, 2010, pp. 3 - 5).

Agioi Deka/Gortyn is located on a fertile plain primarily composed of Neogene marine sediments, including marls, clays, and silts (Fig. 14 and 15). It is noticeable the presence of the following geological formations:

- metamorphic rocks formed during the Oligocene and early Miocene, which include schists and quartzites;
- sedimentary rocks, such as carbonate rocks coming from ancient marine environments and including limestone and dolostone; as well as alluvial deposits;
- volcanic rocks, less prominent than the earlier two but still present in the region (Rahl et al, 2004).

Additionally, the presence of hornblende-rich amphibolites has been attested on the region of Agioi Deka, composing a part of the geology of the central Messara (Liard, 2018, p. 740).

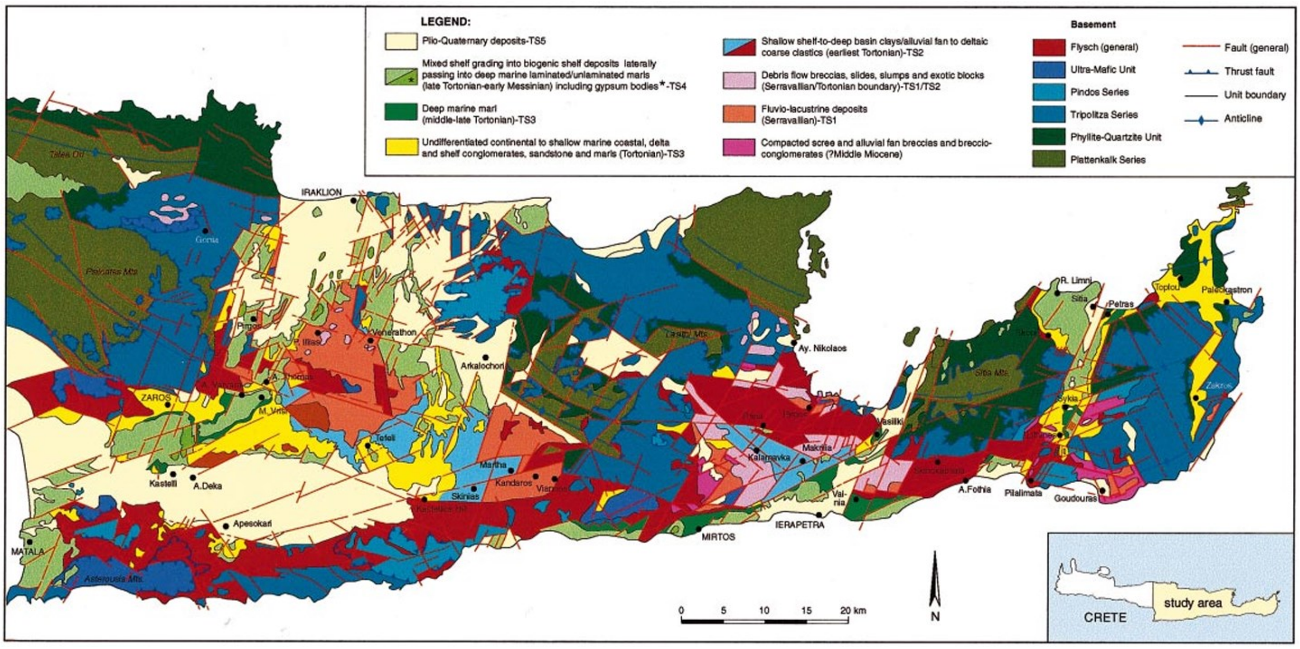


Figure 14. Geological sketch of central and eastern Crete, with the indication of the village of Agioi Deka (after ten Veen et al, 1999, p. 226).

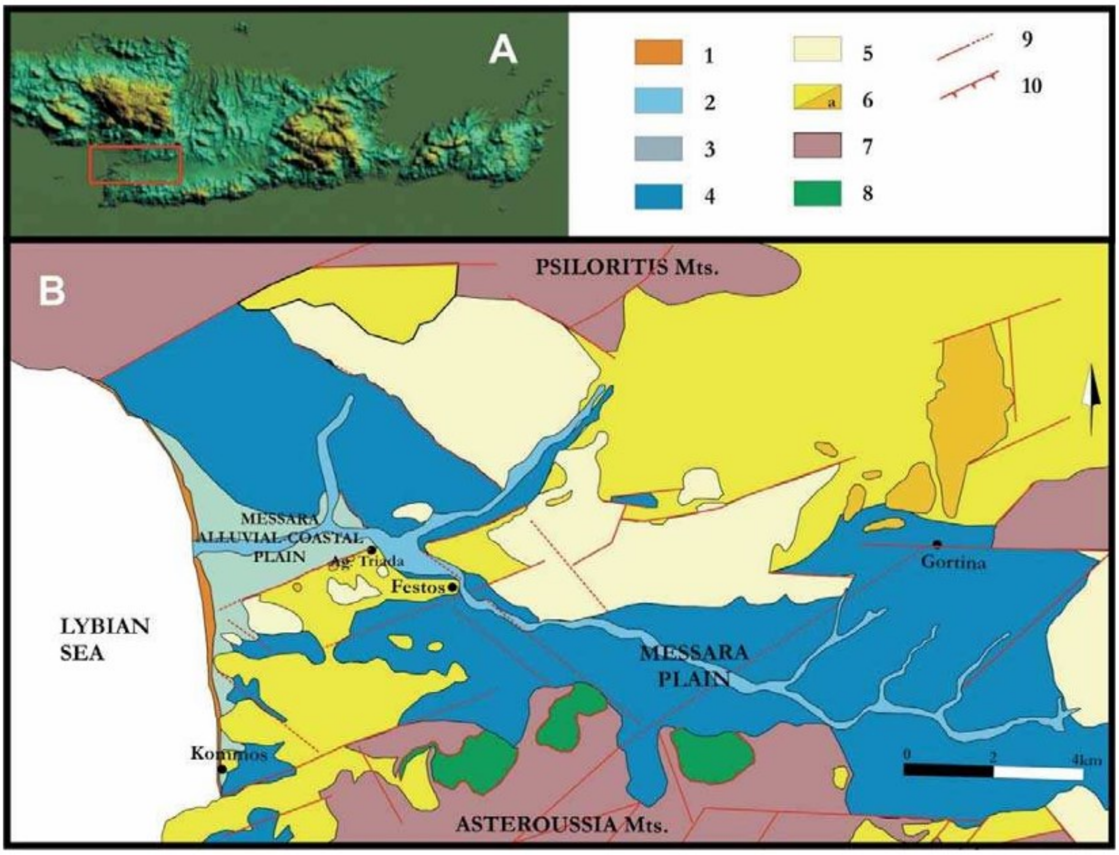


Figure 15. Location (A) and schematic geological map (B) of the Messara. Geological units: 1) present day sandy coastal ridge; 2) present day alluvial deposits of the main rivers; 3) alluvial coastal-plain deposits (Holocene); 4) alluvial plain and slope deposits (Upper Pleistocene-Holocene); 5) Pliocene and Pleistocene marly, sandy and gravelly deposits; 6) Miocene marly and calcareous marly deposits with interbedded gypsum layers; 7) Cenozoic Flysch deposits; 8) Mesozoic metamorphic rocks; 9) main faults, dashed when inferred; 10) main thrusts (after Amato et al, 2014, p. 143).

Chapter 3
Macroscopic characterization

3.1. DESCRIPTION OF THE ANALYSIS AND TYPOLOGICAL CLASSIFICATION

Macroscopic characterization of ceramic material is an essential part of the archaeological work. Through the observation of features identifiable on the naked eye, it is possible to disclose some key features of the material studies and that enable the characterization of aspects such as typology, surface treatment, decorative patterns, and modeling techniques (Santacreu, 2014, p. 11). The study represented a crucial step towards the scope of this work, enabling the identification of characteristics that were useful for the further study of the paste through archaeometric methods. Combined, macroscopic and microscopic observations provide a powerful tool for an in-depth approach of the ceramic paste and the technologies applied (Santacreu, 2014, p. 11).

The macroscopic characterization of 72 fragments excavated in 2019 was carried out in a field campaign between July and August of 2023. A Dino Lite microscope was used to identify the macrofabric and some of the macroscopically identifiable inclusions, allowing an initial classification of the ceramic bodies. This device consists of a small microscope connected to the computer through an USB cable that acts as a magnifier and allows to better macroscopically describe the various textural features of the ceramic body (micromass, inclusions, and voids). It enables the identification of coarser grains constituting the inclusions in terms of composition (when possible), grain-size distribution, shape and proportion in respect to the micromass. Observations also on the micromass can be done for the color and quantity of the matrix, voids or pores (Druc, 2018, p. 14).

The fragments were analyzed according to the following categories:

1. FRAGMENT ID:

with the code and identification number of each fragment, as attributed by the 2019 excavation.

2. MACROFABRIC DESCRIPTION:

General description of the fabric, grain size, and inclusions identified macroscopicallY; this work was done by the researchers University of Padova and the University of Bochum during the material study campaigns 2020-2023.

3. CHRONOLOGY:

The chronology of the fragments was identified by the research of University of Padova and University of Bochum during the material study campaigns 2020-2023.

The period to which the fragments belong to are the following:

- Protogeometric period (9 samples)
- between Protogeometric and Geometric periods (1 sample)
- Geometric period (8 samples)
- Orientalizing period (14 samples)
- between Orientalizing and Archaic periods (1 sample)
- Archaic period (1 sample)

The chronology of some fragments remains unidentified, as the decoration pattern was insufficient to enable a chronological diagnostic.

4. FABRIC COLOR:

based on the Munsell Color Chart. This method was developed by the Munsell Color Company based on the theory of color by A.H. Munsell. It uses three color attributes — hue, value, and chroma — in order to set colors into numerical scales, which also predicts a logical visual relationship between all other colors (Munsel, 2024. https://munsell.com/about-munsell-color/how-color-notation-works/ Accessed 24/07/2024). The method is widely used for color characterization in archaeology and other material sciences.

5. FUNCTION AND SHAPE:

The classification was made based on the description of shapes and types from the Knossos Pottery Handbook (Coldstream et al, 2001). This work was done by the researchers of University of Padova and University of Bochum during the material study campaigns 2020-2023.

The ceramic material analyzed was classified as follow:

Storage Vessels:

10 fragments, classified according to their specific shapes as:

a) *Amphorae*: 4 fragments. Those are containers of wine and other liquids, usually found as fragments in domestic deposits – whereas in tombs some complete examples of these types of vessels can be found (Coldstream et al, 2021, p. 23). Greek-styled *amphorae* can be made with two vertical handles from neck to shoulder, or two horizontal handles attached to the vase's belly. In settlements, examples of the neck-handled pots are usually more frequent. It is worth mentioning that from the 9th century BCE onwards this style was significantly influenced by Attic imports, with the adoption of a dark-ground body and ornaments concentrated in the pot's shoulders, mainly during the Early and Medium Geometric period. On the Late Geometric period, the decreased Attic influenced led to a reduced size and increased shape of the pots, whereas the only complete known example of Early Orientalizing *amphora* is tall, slim, and containing decorative motifs typical of the Orientalizing style (Coldstream et al, 2021, p. 23).

b) *Kraters*: 2 fragments. Those are vessels used commonly for wine and water mixtures. It can be defined as an open vessel with a rim of 20 cm or more. The deep-bell *krater* was common in the Protogeometric period, and can be easily recognized due to the double curve on the profile, a trait commonly associated with the Minoan inheritance of those pots (Coldstream et al, 2021, pp. 46 - 47). The Attic shape served as an inspiration for the *kraters* belonging to the geometric period.

c) *Pithoi*: 1 fragment. This type of container was normally used as storage containers in domestic contexts, whereas in funerary sites these vases can be found used as crematory urns (Coldstream et al., 2021, p. 24).

d) Closed form: 1 fragment.

f) 1 fragment was left unidentified in terms of shape.

Fast pouring vessels:

23 fragments, classified according to their specific shapes as follow:

a) *Hydriae*: 9 fragments. These pots were normally used as containers for pouring water. Its shape usually concerns a plump, with the ones found in funerary contexts with a smaller size and more decorations than those coming from domestic contexts (Coldstream et al, 2021, p. 37).

b) *Oinochoai*: 14 fragments. Those are distinguished by the trefoil lip, used to facilitate wine pouring and, in the case of smaller vessels, their more narrowed necks can indicate an use as slow-pouring containers of unguents or oil (Coldstream et al., 2021, p. 39). The vessels from the Protogeometric period display carefully decorated motifs, with the shape progressively changing from the LPG plump ovoid to the PGB slimmer ovoid. Like the *amphorae*, those vessels were also influenced by Attic imports in the 9th century BCE and towards the 8th century BCE, with local pots tending to display an imitation of both technique and style, with carefully prepared clay fired to a pinkish-brown Attic resembling color and dark ground, austere decoration. As for the Orientalizing *oinochoai*, their flat base, round handle and low and broad neck indicate a more mundane and frequent use (Coldstream et al., 2021, p. 40).

c) 1 fragment was indistinguishable between *hydria* and *oinochoe*.

Figurine:

1 handmade fragment.

Kitchenware:

5 fragments, presenting the following shapes:

a) 2 fragments are closed forms/cooking jug, corresponding to the bottom of a plate;
b) 1 rim of a pot;
c) 1 rim of a lid, with a shield shape, which could have had a votive function;
d) 1 foot of a tripod pot.

Pots and vessels for eating and drinking:

corresponding to the following shapes:

a) *Kotyle*: 2 fragments. This was a Corinthian late-geometric creation. The shape evolved from the *skyphos* through a gradual elimination of the lip, with the oldest examples following a Corinthian form, with an hemispherical flat-base and slight nick on the lip. In the Orientalizing period – to which the fragment corresponds to – these pots still followed a Corinthian model, imitating their decoration (Coldstream et al, 2021, p. 55).

b) Cup: 2 fragments. These were the main form of drinking vessel during the Geometric and Orientalizing periods, replacing the *skyphos* (Coldstream et al, 2021, p. 55).

c) *Lekane*: 3 fragments. This is a deep bowl typical of the Archaic and Classical periods, and common in households of the Hellenistic period (Coldstream et al, 2021, p. 106).

d) Bell *skyphos*: 1 fragment. This is a specific type of *skyphos*, characterized by its bell-shaped body and typically features two horizontal handles.

Pouring vessel, undistinguishable whether fast or slow pouring:
1 fragment.

Slow pouring vessel:
1 fragment, corresponding to a wall of a *lekythos* from the Orientalizing period. Those are fragments to which there is little information about, due to their scarcity. Their use was related to unguents and perfumed oils (Coldstream et al, 2021, p. 87).

Tableware:
6 fragments, to which 5 are lids and 1 is a cup.

6. PART:
indication of the specific parts of the vase. Those consisted of walls, rims, handles, bottom, and foots (one of a conic section and one of a zoomorphic figure).

7. HARDNESS:

This parameter was analyzed referring to the fragment's resistance to scratching, based on the Mohs hardness scale (Whitney et al, 2017, p. 56). This scale consists of ranking the hardness of materials according to the objects they can be scratched with (fingernail, copper coin, steel knife, glass). In ceramic materials, the hardness can provide some hints about the firing temperature and raw materials used in ceramic preparation (Kim et al, 2001, p. 1437). 9 fragments were classified as hard (3 on Mohs scale), meaning that they cannot be scratched with a fingernail. The remaining 63 were classified as soft — able to be scratched with a fingernail (2.5 on Mohs scale).

8. FEEL:

although this criteria is quite subjective, identifying the feel of a ceramic material can help distinguish specific properties of the fabric when dealing with large quantities of material (Whitbread, 2017, p. 204), and represents the combination of hardness, inclusions, and surface treatment (Orton et al, 1993, p. 70). The fragments here analyzed ranged from smooth (no irregularities felt) to rough (some irregularities felt). No fragment was identified as harsh (abrasive to the finger).

9. FRACTURE (see fig. 16):

Analyzing the fracture (possibly through the section of the potsherds) can provide some hints into the firing techniques applied to the vase, as the firing atmosphere can cause a change in the color of the paste (Orton et al, 1993, p. 133). The fragment's fracture was identified following the parameters of Rye (1981).

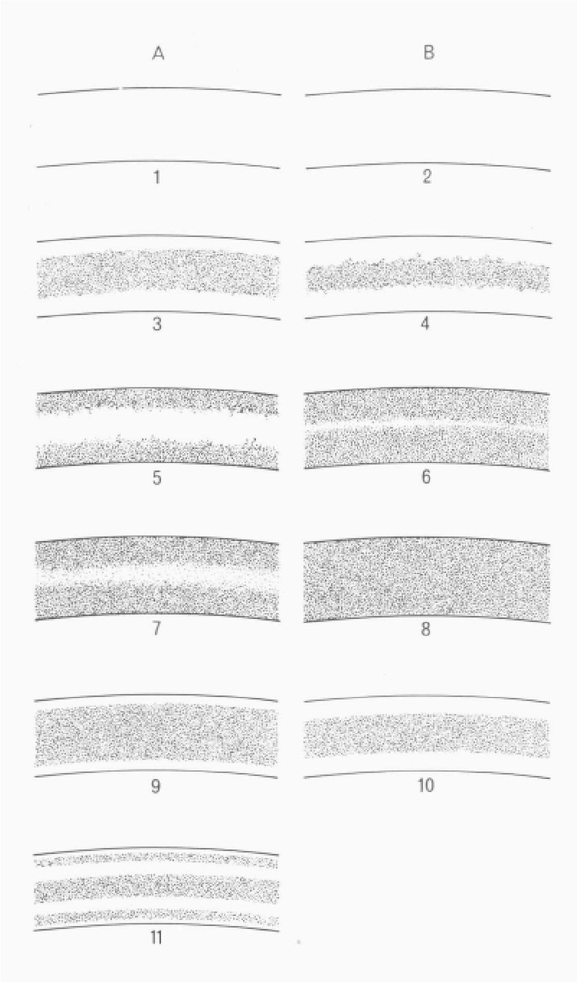


Figure 16. Colors distribution in cross section of the ceramic, showing the possible different patters with indication of the firing process they experienced. 1) oxidized, organics not originally present, no core; 3 and 4) oxidized, organics originally present, diffuse core margins; 5) reduced, organics not originally present, diffuse core margins; 6) reduced, organics not originally present, black or gray may extend completely through the wall leaving "no core"; 7) reduced, organics originally present, diffuse core margin; 8) reduced, organics may or may not have been originally present, no core; 9 and 10) reduced, cooled rapidly in air, sharp core margin; 11) reduced, cooled rapidly in the air, reduced again, cooled rapidly in the air again, sharp core margins, "double core" (after Rye, 1981, p. 116).

10. WEIGHT:

measured in terms of grams.

11. SIZE:

measured in terms of centimetres, with the measurements taken from the length, height, and thickness of each fragment.

12. INCLUSIONS:

With the use of the Dino Lite, it was possible to tentatively identify the mineral inclusions of the fragments, categorizing them in terms of grain size, percentage, roundness, and sorting. Roundness ranges from very angular to well rounded, and can provide some hints about the nature of the used clayey material — or possible added temper —, as the amount of roundness can indicate the length, type, and intensity of transport, as the roundness increases with distance.

On the other hand, the presence of angular inclusions can indicate not only a little transportation, but also a possible deliberate adding of crushed materials to the clay paste (Maritan, 2023, p. 4). The sorting corresponds to the homogeneity of the grain size, so that well sorted inclusions are those corresponding to a specific restricted grain size, while a poorly sorted one is when inclusions cover a wider grain-size distribution, and was evaluated based on the comparative charts proposed by Mathews et al (1991), and can provide information about the used clay material and/or the production recipes (Maritan, 2023, p. 4).

This part of the study also enabled the identification of some pores — empty spaces that result from the "evaporation of the paste water and to the loss of volatile materials during firing (structural water and carbonates, as well as organic materials)" (Maritan, 2023, p. 4). Their presence, as well as the evaluation of their shape, size, and quantity, can hint into the addition of organic materials into the paste, as well as the firing temperature (estimated by the shape of the voids) and production technique (estimated by pore distribution) (Maritan, 2023, p. 4).

This was an important step towards the classification of the fragments in terms of paste, enabling a macroscopic categorization of the types of minerals in the paste that made possible to organize the fragments in distinguished macrofabrics.

12. PICTURES:

Finally, the final rows of the table contain the pictures of each fragment with a scale and color chart.

A complete catalogue with the macroscopic characterization of the 46 samples selected for the archaeometric analysis is available on Appendix 1 (p. 116).

3.2. MACROFABRICS

The final step of the macroscopic characterization was to divide the fragments into macrofabrics. This classification was made based on the characteristics observed on this initial analysis, mainly taking into account the grain size of inclusions, minerals that were recognized, and color of the ceramic body.

This was an important first step into the identification of key-features of the material, enabling their initial classification and enabling the selection of the materials that were later sampled and analyzed with further archaeometric methods.

MACROFABRIC VERY COARSE (Fig. 17):

This group contains fragments with large inclusions, mainly visible on the naked eye. The macroscopic analysis enabled the identification of an abundance of limestone, grog, quartz, and oxides.

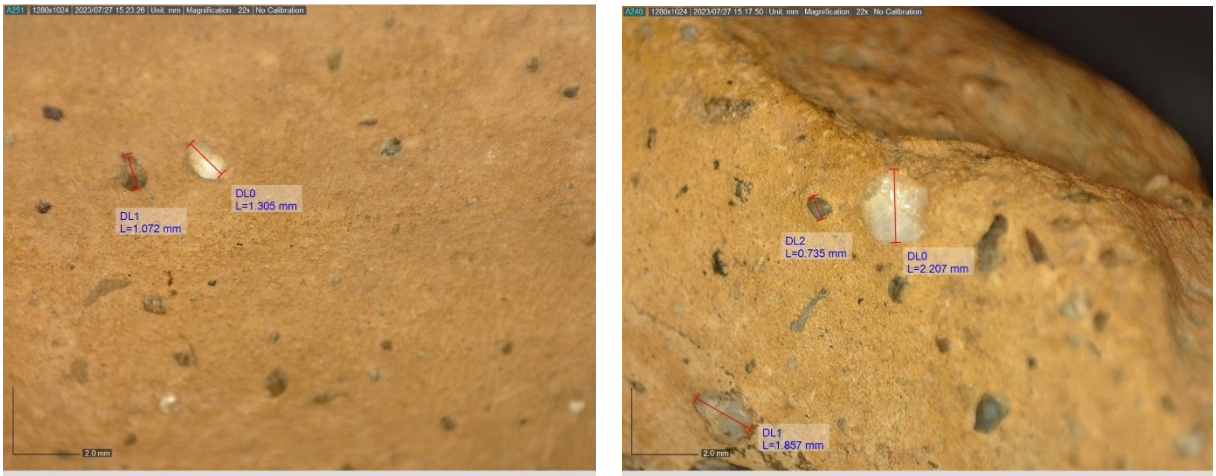


Figure 17. Photograph taken with the Dino Lite of fragment G5, classified as very coarse microfabric.

MACROFABRIC COARSE (Fig. 18):

Light colored coarse A:

those fragments present a rough surface, with poorly sorted inclusions such as quartz, white and dark inclusions, as well as pores.

Light colored coarse B:

those presented a more orangish color, with a fair/good sorting of the inclusions such as quartz, white and dark inclusions, and pores.

Pinkish coarse:

fragments with a more pinkish paste, with large quartz, white inclusions, and abundant pores.

Orange coarse:

very bright orange color, with abundance of dark inclusions — that could be grog or oxides — as well as white inclusions.

Dark colored coarse A:

those contain fairly sorted inclusions, with many dark and white inclusions, pores, some quartz, and a slightly rough surface.

Dark colored coarse B:

those contain a very dark paste color, with grayish to brownish inclusions, as well as white inclusions with a milkish aspect, and quartz. These inclusions present a more angular aspect.

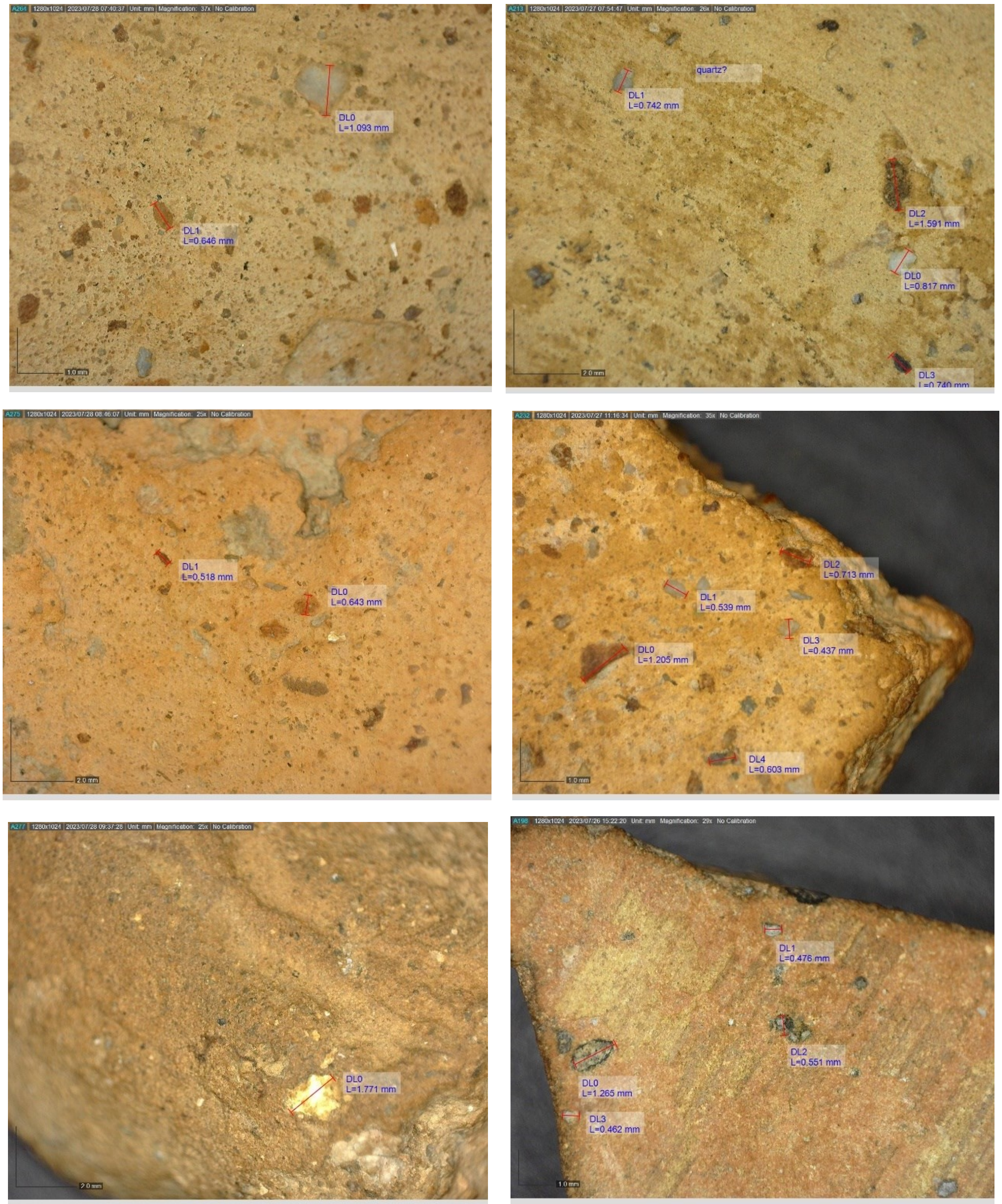


Figure 18. Photograph taken with the Dino Lite images of fragments. Top to bottom and left to right: G3, G4, G9, G8, G1, and G13, classified as coarse microfabric.

MACROFABRIC MEDIUM COARSE (fig. 19):

These fragments contain inclusions that are not as coarse as the previous ones, but that could not be considered fine grained. They were divided into the following subfabrics, according to the color of the matrix and the minerals identified:

Light brown medium coarse A:
rounded and sub-rounded white inclusions and oxides.

Light brown medium coarse B:
abundance of dark inclusions and few white inclusions.

Light red medium coarse:
contained white inclusions, rounded voids, and mica.

Dark red medium coarse:
Contained mica, some white inclusions, oxide, and maybe quartz. Inclusions were particularly well sorted.

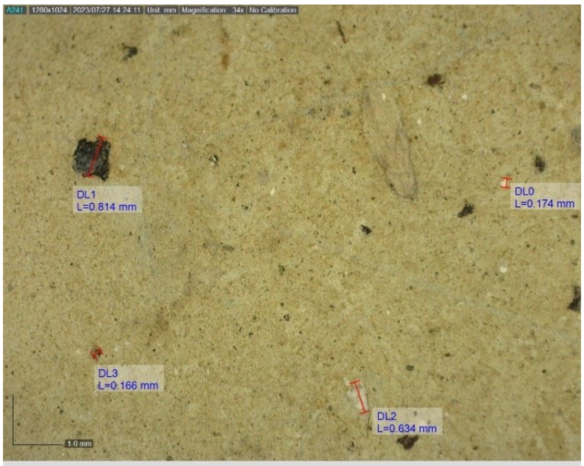


Figure 19. Photograph taken with the Dino Lite of fragment G28, classified as medium coarse microfabric.

MACROFABRIC SEMI FINE (fig. 20):
Those were fragments that contained a mainly fine matrix, but with the presence of some significant coarse inclusions, visible on the naked eye. They were divided in the following subfabrics, regarding the matrix color and inclusions observed:

Light semi fine:
light orange color with a smooth surface. White and dark inclusions, and rounded unidentified grains were observed.

Light brown semi fine:

contain some coarse inclusions of white and green inclusions.

Dark semi fine:

rough surface, with abundant dark and some white inclusions.

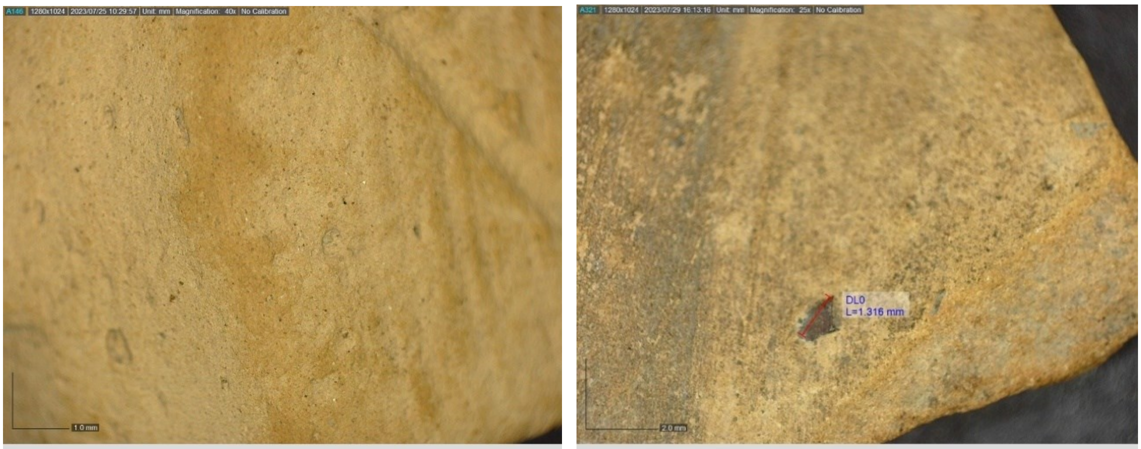


Figure 20. Photographs taken with theDino Lite images of fragments G20 and G21, classified as semi fine microfabric.

FINE (fig. 21):

These fragments were the hardest to characterize given the small dimension of their inclusions — which difficulties the study of the fragments on the macroscopic scale. They were divided into the following subgroups, according to their color and inclusions that could be observed:

Light fine:

this is the largest group, given the difficulty in spotting differences in the composition of its fragments that could lead to further subclassifications. It presents a smooth surface, with some calcite and pores.

Light fine B:

contains only one fragment, with one coarse grain of white inclusion, mica, and some pores.

Light brown fine:

it contains very fine white inclusion, dark spots, and an overall darker paste color.

Medium orange fine:

the only fragments in this group are part of a mug. Contains some mica, as well as voids that indicate the presence of organic residues.

Medium brown fine:

also contains only one fragment. Its inclusions are one large sub-angular white inclusions, and some oxide.

Dark fine:

these fragments have a dark brown/grayish color, with few inclusions.

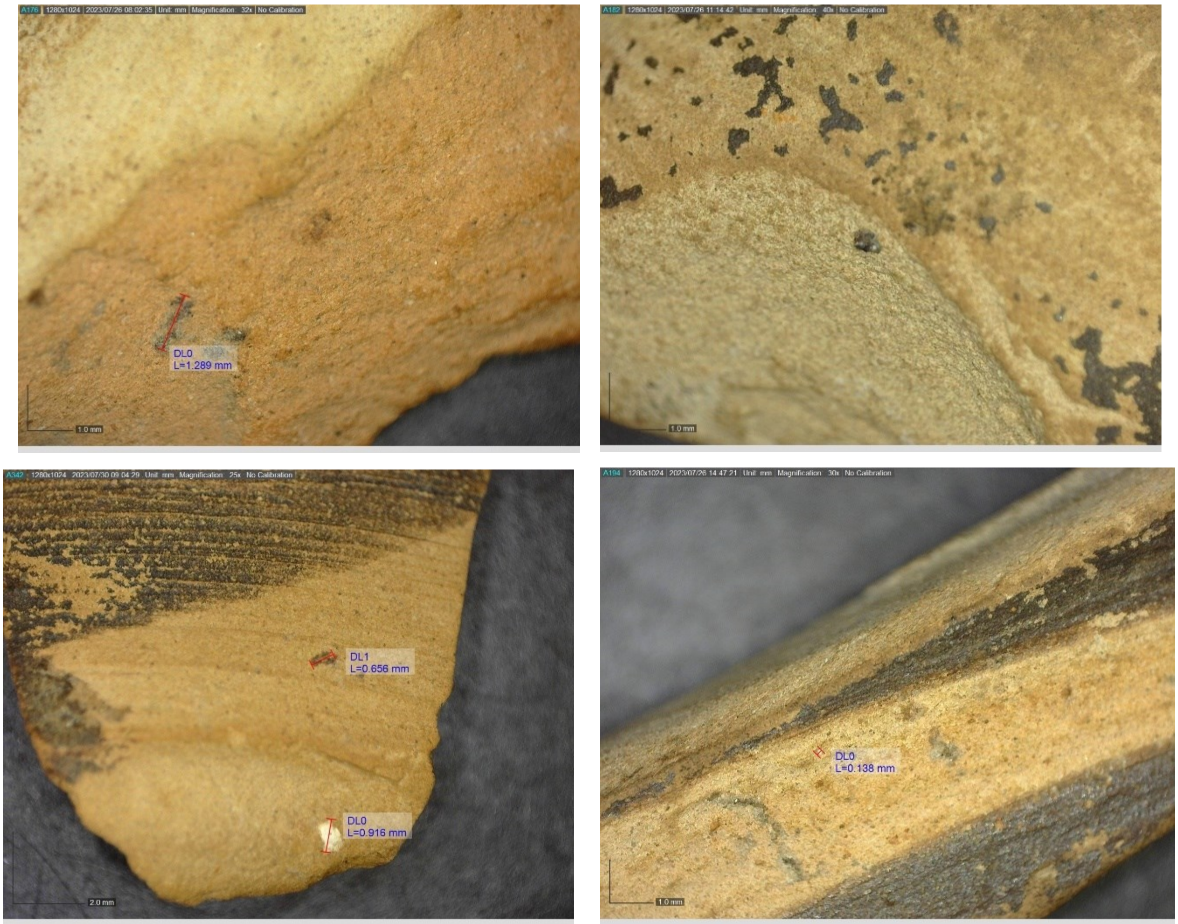


Figure 21. Photograph taken with the Dino Lite of fragments G22, G27, G37, and G30, classified as fine grained.

Chapter 4
Archaeometric characterization

4.1. PETROGRAPHIC ANALYSIS

4.1.1. DESCRIPTION OF THE METHOD

Thin-section ceramic petrography has along stiry story since it was first used at the end of the 19th century. But was only in the late eighties that a consistent method, correlated also with a specific terminology, was proposed by Whitbread (1989), later revised by Quinn (2013), and comprehends the analysis of 30 μm thick slices of material fixed on a glass microscope slide. The sections are studied with a polarized light microscope, which enables the use of plane polarized light (PPL) and cross polarized light (XPL). In archaeological sciences, the method is widely used to identify the mineral and rock inclusions on a given material, incorporating the methodology from sedimentology and sediment petrography (Quinn, 2013, p. 4).

Under PPL, minerals are described by their habit (external shape), color (response to visible light), potential pleochroism (color change when rotating the microscope stage), relief (the extent to which mineral grains stand out based on refractive indices), cleavage (easy splitting along flat planes), and fracture (breaking along irregular surfaces), according to the specific characteristics that depend on the interaction between the light and the crystal structure of the mineral and that allows them to be distinguished and classified. In XPL, minerals are analyzed based on interference colors and potential twinning (symmetrical intergrowth of crystals) (Maritan, 2023, p. 3).

This research followed the guidelines proposed by Quinn (2013) and Maritan (2023), in which the study of the thin sections is done in terms of clay matrix, inclusions, and voids.

The matrix or micromass is the main component of the fabric or paste of the archaeological ceramics, often constituting over 50% of a sherd's volume. It consists of fine-grained material with a size finer than 10μm, and appears as a translucent mass under the microscope. In thin section analysis, it is possible to describe the matrix in terms of optical state and orientation, observing variations in terms of composition, color, and texture that may hint into a natural heterogeneity in the raw clay that did not become fully homogeneous during the clay processing, manufacture, and firing (Quinn, 2013, pp. 39 - 43).

Inclusions are “often the most distinctive component of the paste” (Quinn, 2013, p. 44). Given that they tend to stand out from the matrix, inclusions can provide important information especially in terms of provenance, since their mineralogical and petrographic nature, and in particular thir association, can be univocally linked to specific geological contexts and therefore geographic regions/areas. Inclusions can be studied and described in terms of their mineral-petrographic nature, shape, grain size, abundance, and spatial distribution (Maritan, 2023, p. 4).

The shape of inclusions in ceramics can vary from angular to well-rounded, which changes according to factors such as the distance, type, and intensity of transport from their geological source, as well as the deposition environment — alluvial, coastal, marine, or desert. The identification of the degree of angularity of the inclusions can provide some information on the provenance of a material — as inclusions become more rounded the farther they have traveled — and production technology — as angular inclusions often suggest they were intentionally crushed by the potter before being mixed into the clay paste (Maritan, 2023, p. 4).

Grain-size distribution is another key factor, with well-sorted and unimodal distributions typically indicating natural sediments, while bimodal distributions — meaning, poorly sorted (Quinn, 2013, p. 85) — suggest the mixing of different materials, such as base clay and sand or ground minerals/rocks. This latter case often points to the deliberate addition of inclusions as a temper, enhancing the clay’s properties (reducing their plasticity). Additionally, the quantity of inclusions — often expressed as the percentage of the ceramic body they occupy — provides insights into production techniques. This percentage can be estimated using comparative charts, helping to understand the materials and methods used in ceramic production (Maritan, 2023, p. 4). The characterization of the texture is done by the analysis of the space-distribution of the inclusions, which can range from close-spaced — when the inclusions have points of contact —, single-spaced — the distance between inclusions is equivalent to their average diameter —, or double- or open-spaced — the distance is twice the diameter or more (Quinn, 2013, p. 83).

Lastly, the identification of voids — textural features that appear colorless in PPL and black (in extinction) in XPL — can hint into the production process of the ceramic material. Voids are formed by the loss of free, adsorbed, interlayer, and structural water during drying and/or the burning of volatile materials — such as organics — on firing (Maritan, 2023, p. 4). They influence physical properties such as weight, toughness, thermal conductivity, permeability, and insulation (Quinn. 2013, p. 61). The shape of the voids can hint into the production technology of a ceramic material — for instance, the presence of vesicles and well-rounded voids indicate high firing temperatures, while channels are usually indicative of a lower firing temperature (Maritan, 2023, p. 4). Additionally, voids well parallel to the wall indicate the use of slab or molding rather than wheel throwing or coiling for the formation of the pot (Maritan, 2023, p. 4).

4.1.2. GENERAL DESCRIPTION OF THE SAMPLES UNDER THIN SECTION MICROSCOPY

In the present thesis research were analyzed 17 samples in thin section, and in particular those corresponding to the very coarse and coarse grained macrofabrics. They were selected for this analysis due to the enlarged possibility to disclose the inclusion types that could link them to specific geological units, providing a hint into the provenance of the sherds and paste recipes applied.

Generally, the samples exhibit a variety of inclusions, including quartz, metamorphic rocks, limestone, and claystone. While the mineralogical composition of the sherds is similar, noticeable differences in the percentage and space distribution of the inclusions, as well as shape and orientation of the voids, enabled the classification of the samples into three main petrographic groups (petro-group or petro-fabric) and a loner/outlier.

4.1.3. PETRO-FABRICS

PETRO-GROUP 1: INCLUSION-RICH POTSHERDS

The samples of this group are characterized by a heterogeneous optically inactive matrix and a very abundant inclusions, ranging from 25% to 30%. These inclusions vary in size from sand to silt, with single space related distribution (the distance between inclusions is generally equivalent to the diameter of the inclusions) and bimodal (poorly sorted) grain-size distribution, and a degree of roundness varying from well-rounded for the sand-sized inclusions to angular for the silt-sized fractions.

The type of inclusions is diverse, including coarse grains (larger than the size of sand, 2000 μm) of sandstone, quartz, carbonatic rocks, micritic limestone, claystone, siltstone, opaque minerals (probable oxides) and inclusions of metamorphic rocks. Additionally, the presence of voids, primarily in the form of vughs, constitute approximately 10% of the overall sample volume.

The identification of some differences in the percentage of inclusions and void shapes enabled the further classification of the samples into two subgroups:

Petro-group 1a (Fig. 22): marked by a particularly high inclusion content, with around 30% of the sample volume, and a distinct dark brown matrix and vugh-shaped voids. A small bone fragment was identified among the typical inclusions. The subgroup is composed by sample G1, a *hydria* from the Protogeometric period.

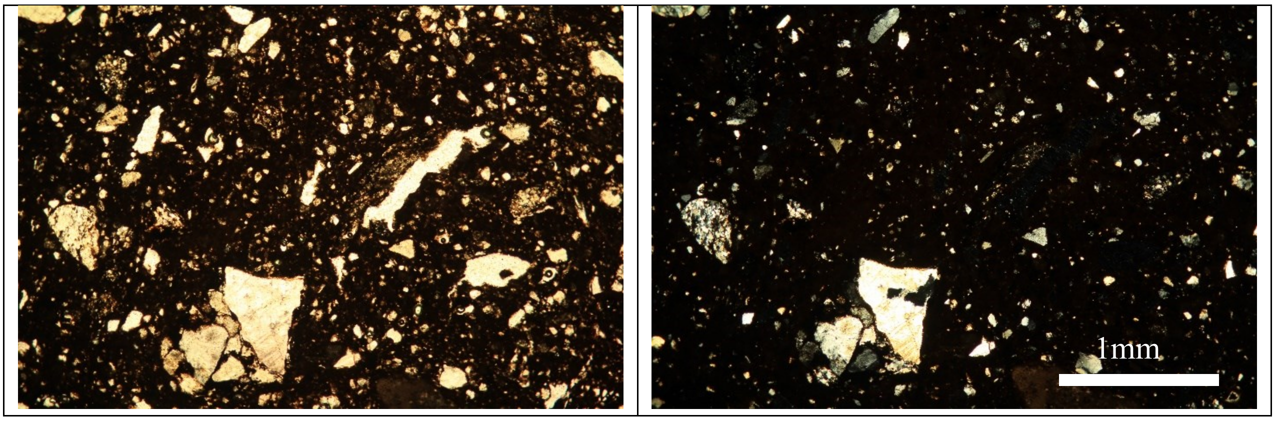


Figure. 22. Photomicrographs in plain-polarised light (left) and crossed-polarized light (right) of potsherd of group 1a (sample G1) in 5x magnification.

Petro-group 1b (Fig. 23): shows a slight reduction in inclusion's abundance, corresponding to 20% - 25% of the volume. The subgroup is composed of samples G3 (cooking jug), G8 (lid/tableware), G9 (figurine), and G14 (cooking jug).

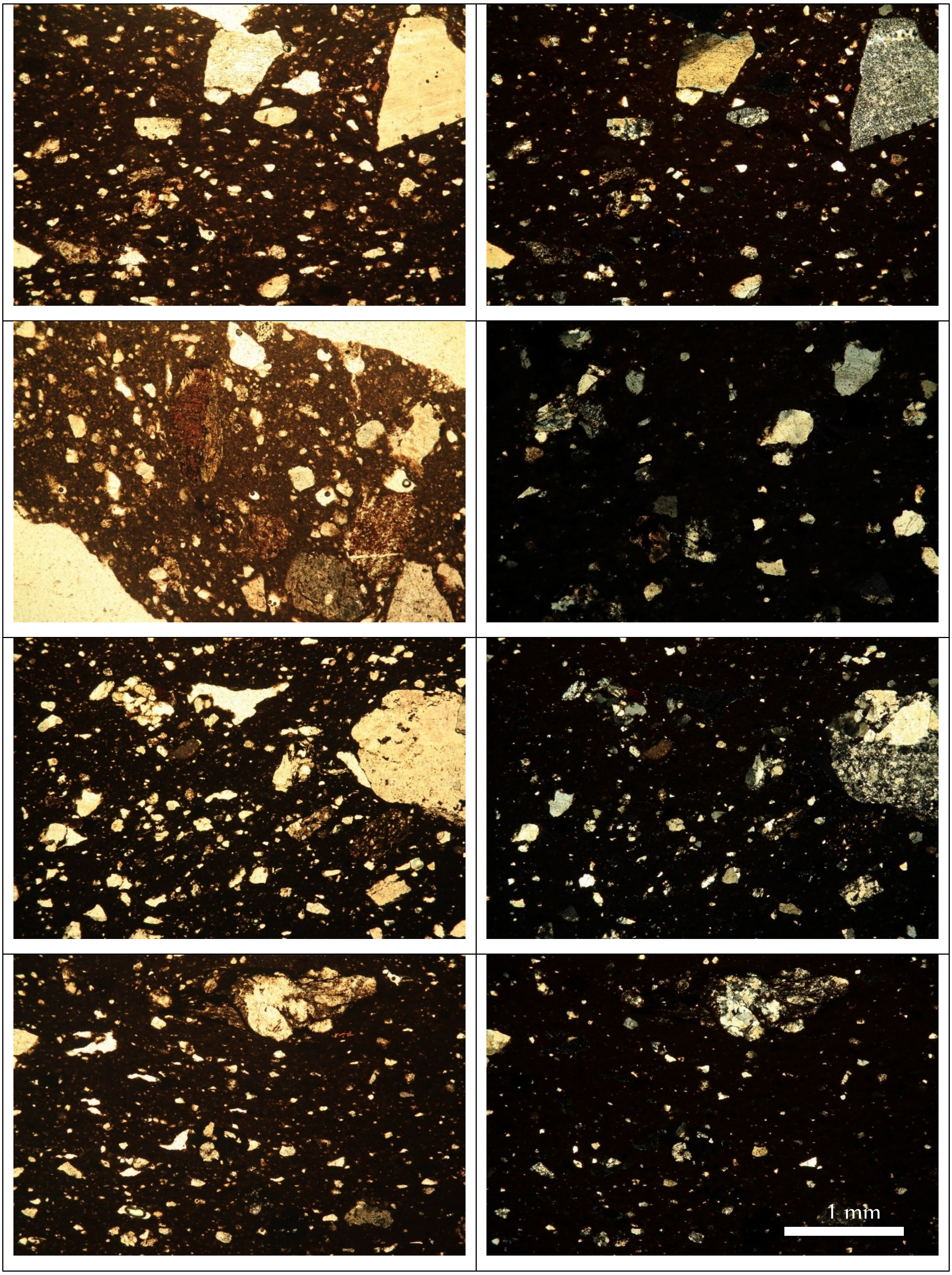


Figure. 23. Photomicrographs in PPL (left) and XPL (right) of potsherds of group 1b in 5x magnification. From top to bottom, samples: G3, G8, G9 and G14.

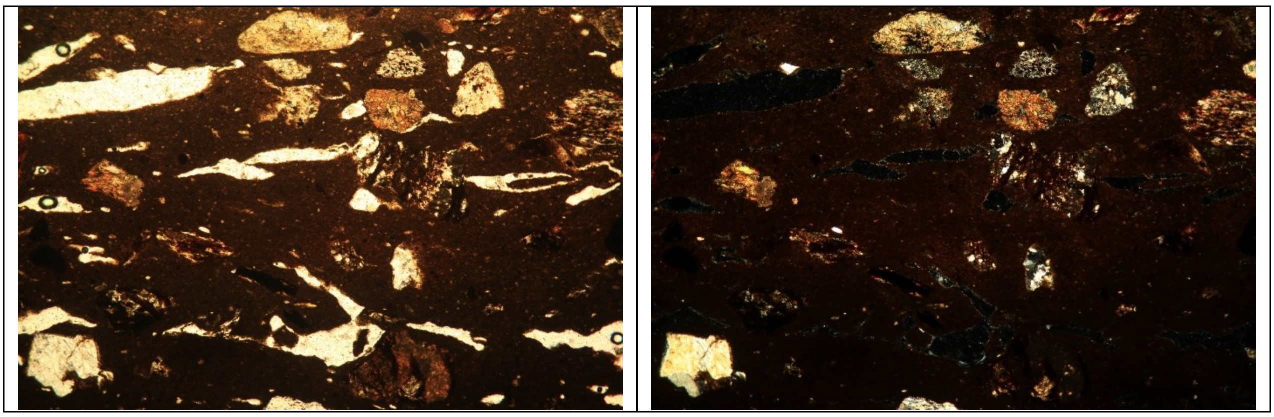
PETRO-GROUP 2: ARGILLACEOUS SAND-BEARING POTSHERDS

The second petro-fabrics is characterized by a more homogeneous, optically active matrix, predominantly consisting of an argillaceous matrix with adding of sandy inclusions into the paste. The inclusions are primarily well-rounded and are mainly silt-sized, and feature a distribution that ranges from double-spaced to open-spaced distribution (the distance between the inclusions is twice the mean diameter of the inclusions or more). Compared to petro-group 1, samples from this petro-fabric present a significant reduction in inclusions content, which represent about 5% to 10% of sample volume.

It was possible to identify inclusions of metamorphic rocks, limestone, mudstone, siltstone, and muscovite. The voids are mainly channels, well oriented parallel to the wall, but a few vughs and vesicles were also identified. The voids represent 5% to 10% of the sample's volume.

Differences in grain-size and angularity of the inclusions enables the identification of the following subgroups:

Petro-group 2a (Fig. 24): distinguished by the presence of coarser and very well-rounded inclusions, as well as a few silt-sized inclusions, in a bimodal and double-space related distribution. Large vesicles, vugh, and channels voids well parallel to the wall. The group is composed by samples G2 (*lekane*) and G4 (*pithos*), both from the Orientalizing or Archaic periods.



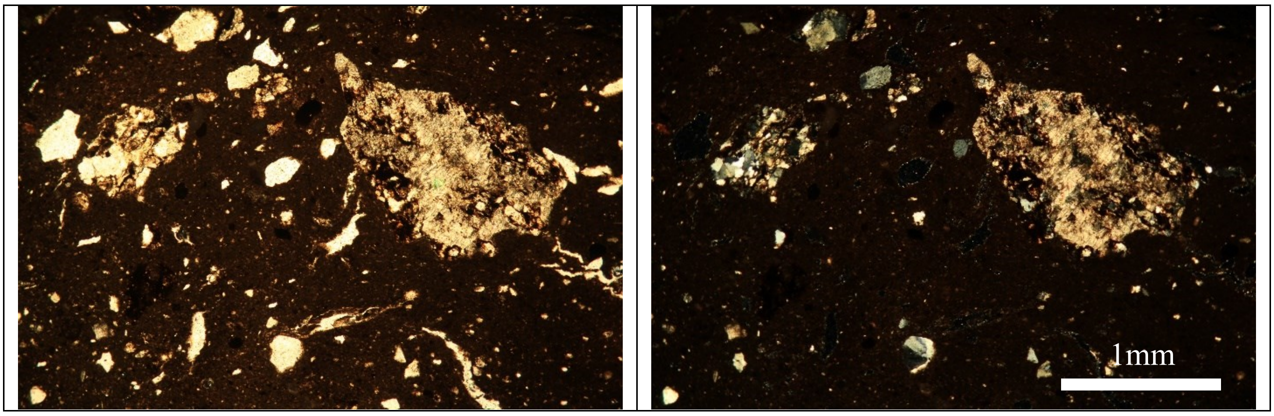
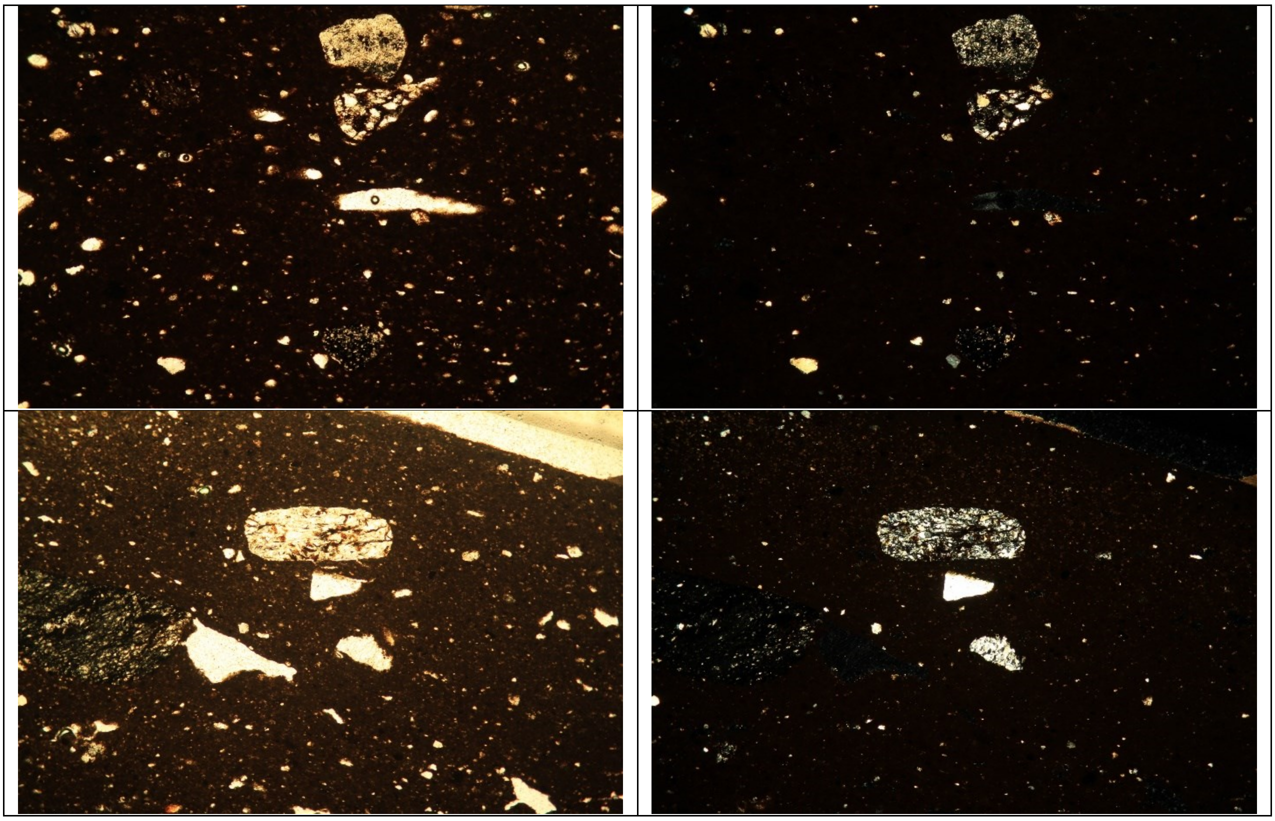


Figure. 24. Photomicrographs in PPL (left) and XPL (right) of potsherds of petro-group 2a in 5x magnification. From top to bottom: samples G2 and G4.

Petro-group 2b (Fig. 25): distinguished by the predominance of silt-sized inclusions and a couple on sand-size. Inclusions are more fairly sorted and display an open-space related distribution. Voids are mainly vughs and channels, occupying 3% to 5% of the volume. The group is composed of samples G5, G6 (Protogeometric *amphorae*), and G7 (storage vessel).



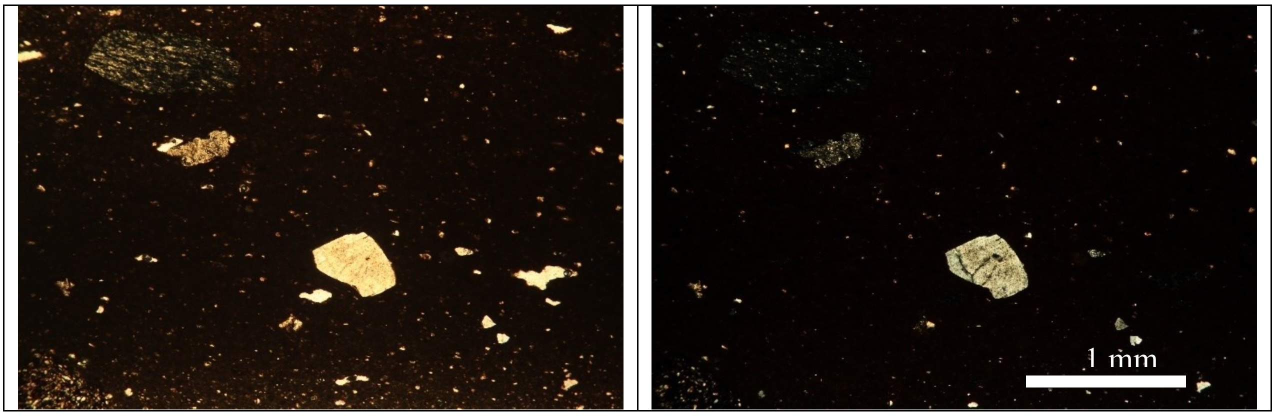
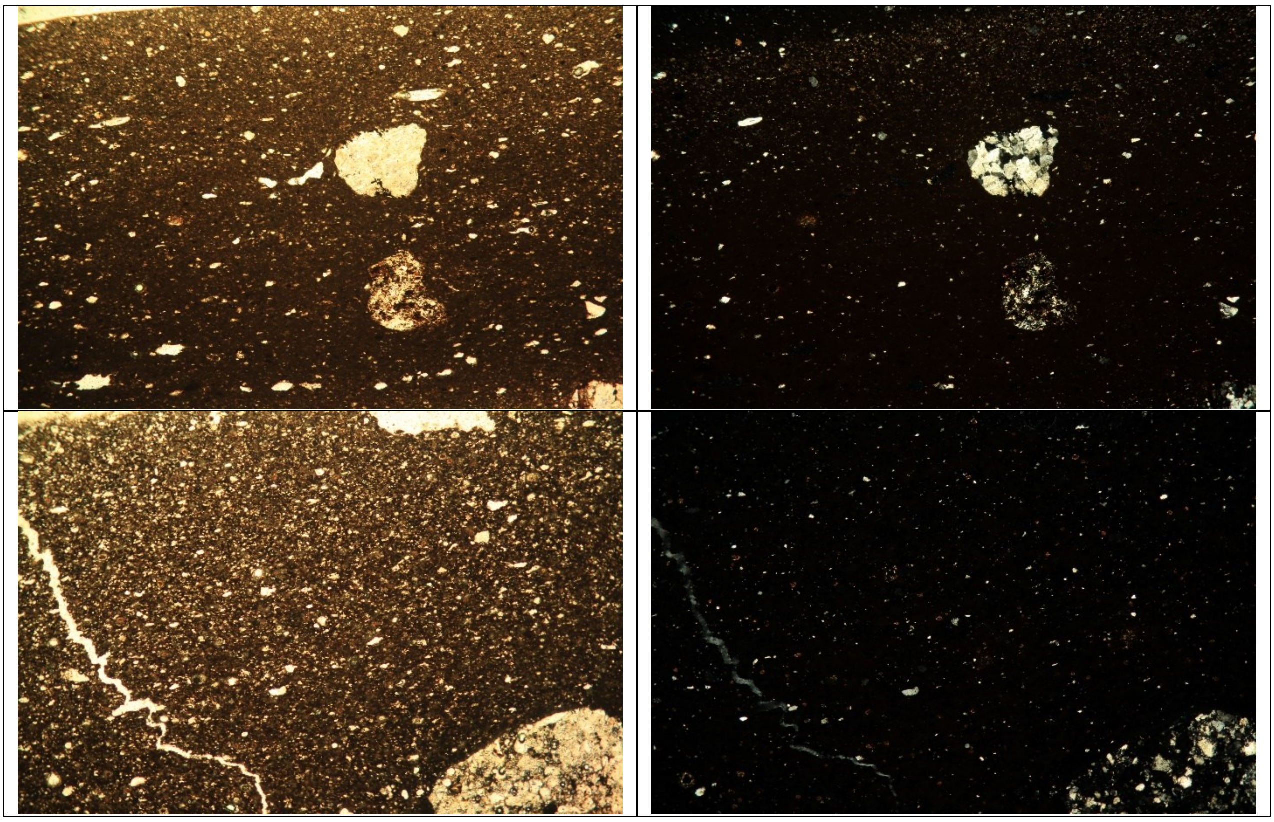


Figure. 25. Photomicrographs in PPL (left) and XPL (right) of potsherds of group 2b in 5x magnification. From top to bottom: samples G5, G6 and G7.

Petro-group 2c (Fig. 26): a seemingly more heterogeneous matrix with predominantly silt-sized inclusions, but few coarse and medium sand-sized inclusions, in a double-spaced related distribution. The voids are mainly vughs, channels and vesicles. It is composed of samples G12 (Protogeometric *krater*), G13 and G16 (Protogeometric *hydriae*).



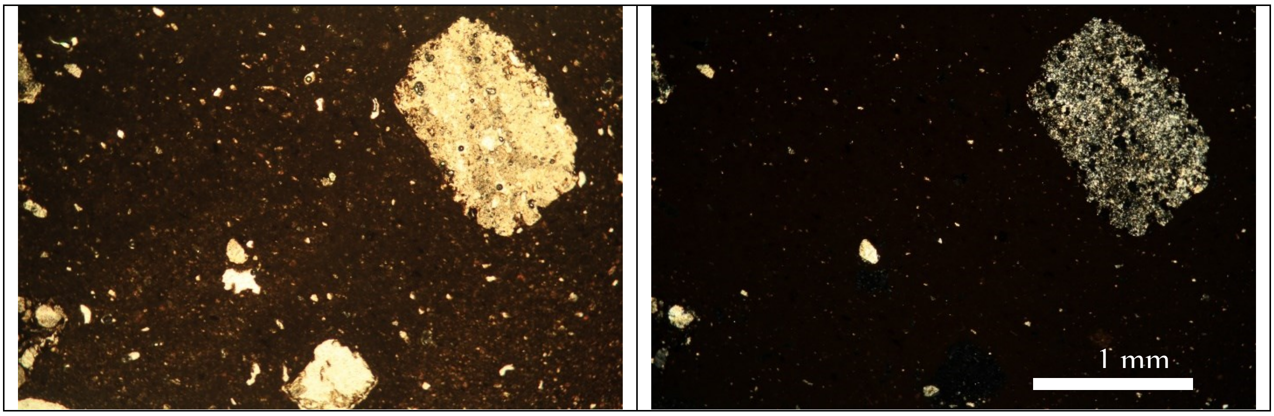


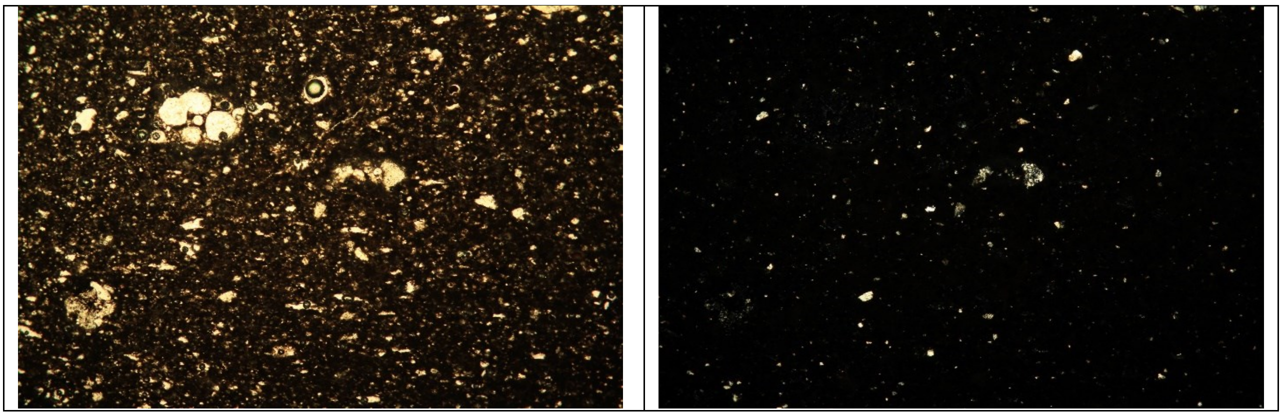
Figure. 26. Photomicrographs in PPL (left) and XPL (right) of potsherds of petro-group 2c in 5x magnification. From top to bottom: samples G12, G13 and G16.

PETRO-GROUP 3: FINE SAND-SIZED INCLUSION POTSHERDS (Fig. 27)

The presence of samples displaying characteristics that fall in between the two previous groups prevented their classification into either category. Therefore, they were assigned into a new, intermedium group, with unique features that do not fully align with groups 1 and 2.

The samples in this group present a distinct combination of a dark matrix with an abundance of well-rounded silt-sized inclusions and some sand-sized, occupying 30% of the volume, and displaying single-space and double-space related distribution. It was possible to identify pores produced by the decomposition of organic material (probably temper), sandstone, mudstone, and metamorphic rocks. The voids are relatively small and correspond to channels and vughs, occupying around 3% to 5% of the volume.

The group is composed of samples G10 (Protogeometric hydria), G11 (Geometric *hydria*), and (Geometric *krater*).



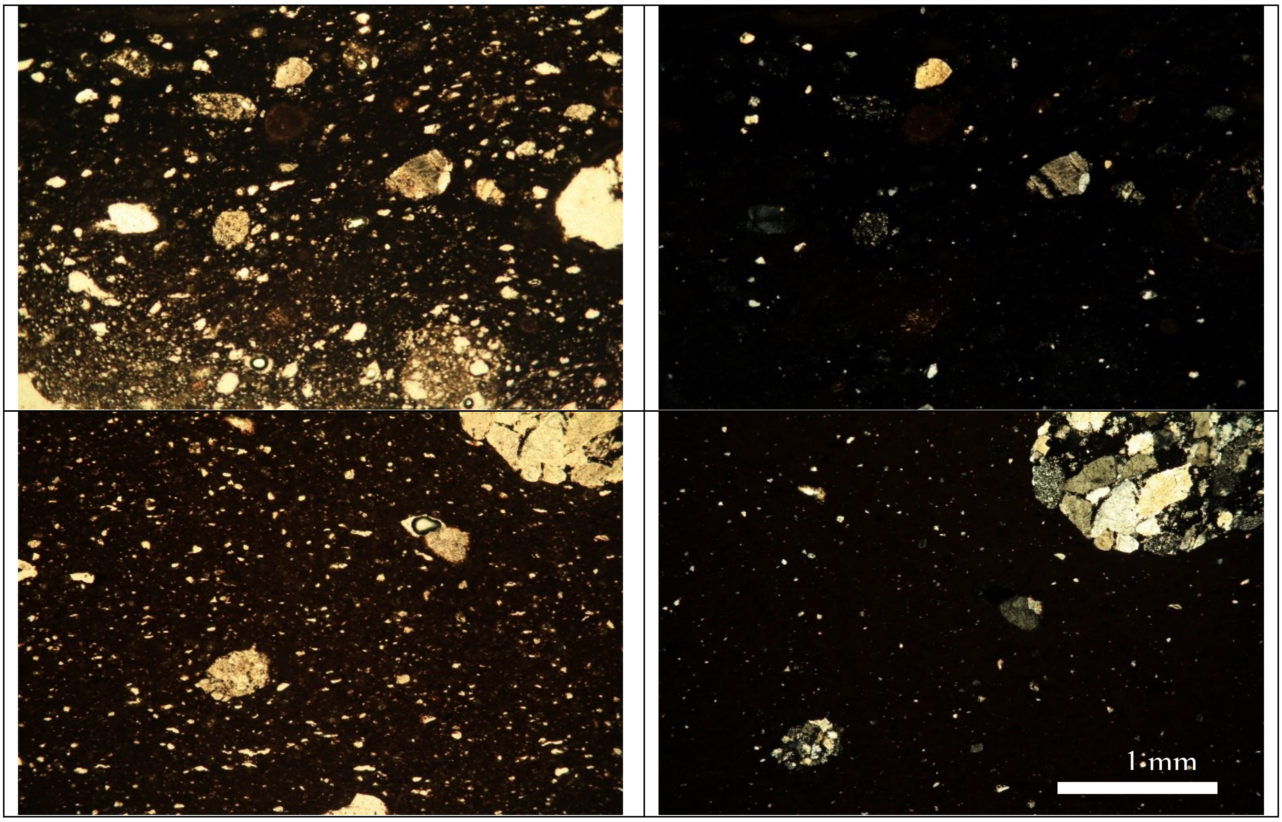


Figure. 27. Photomicrographs in PPL (left) and XPL (right) of potsherds of petro-group 3 in 5x magnification. From top to bottom: samples G10, G11 and G17.

LONER (OUTLIER) (Fig. 28):

Characterized by a clean, almost depurated clay, but with the presence of some rounded inclusions (1 to 3%) in open space related distribution. It was possible to identify a grain of metamorphic rock.

Composed by sample G15, an *oinochoe* from the Orientalizing period.

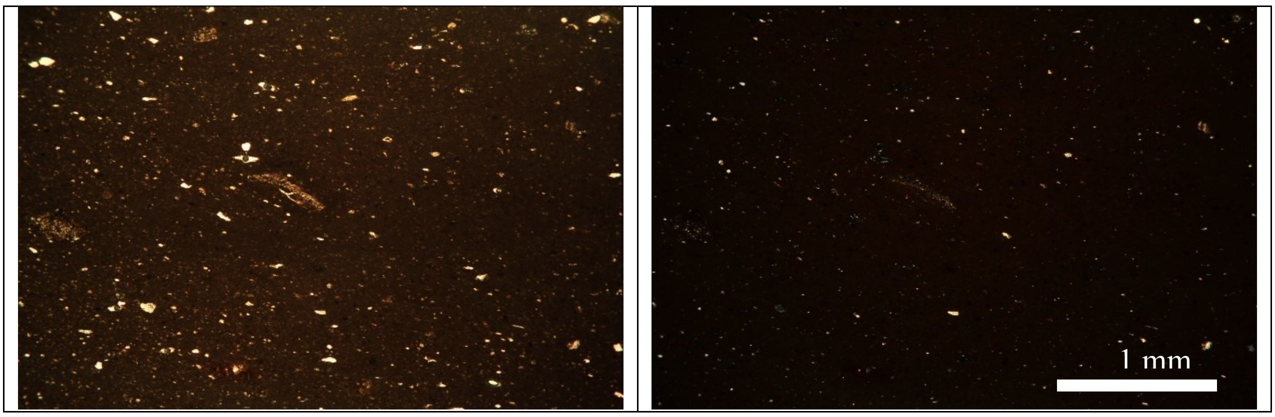


Figure. 28. Photomicrographs of potsherds of the outlier (loner) in 5x magnification. Sample G15 in PPL (left) and XPL (right).

4.2. MINERALOGICAL ASSEMBLAGE THROUGH X-RAY POWDER DIFFRACTION

4.2.1. DESCRIPTION OF THE METHOD

X-Ray Powder Diffraction (XRPD) enables the identification of crystalline phases of a material, thus allowing the disclosure of its mineralogical composition (Artioli, 2010, p. 47). The method is widely applied to characterize the mineralogical components, production technology, and raw material of ancient ceramics (Maritan et al, 2015, p. 540; Maritan, 2019). As some mineral phases crystallize or decompose during firing, the presence or absence of such phases in a sample may hint into firing temperature and conditions.

XRPD was applied on all the 46 samples selected for the archaeometric analysis. A quantity of about 1 g was produced grinding the sample after it was cleaned with a Dremel micro-drill to remove the outer layer, avoiding contamination and enabling the analysis of the ceramic body only. Samples were ground in an agate mortar and pestle that was cleaned to avoid cross contamination, and the resulting powders were prepared on spinning steel back-loading sample holders. They were analyzed on a PANanalytical X'Pert PRO diffractometer in Bragg-Brentano geometry equipped with a cobalt X-ray tube and X'Celerator detector, with the working conditions of CoKa radiation, 40 kV voltage, 30 mÅ current, 3-70° 2θ range, step size 0.02° and 1s counts per step. Lastly, the mineral phases were identified with the software X'Pert HighScore Plus.

4.2.2. MINERALOGICAL COMPOSITION OF THE SHERDS

The analysis was able to disclose the main mineralogical components of the samples, which were presented on a complete table (Appendix 2, p. 158).

It is possible to identify that all the samples are composed of quartz and albite. The latter is a mineral of the feldspar group, specifically of the plagioclase series, and is found in sedimentary and metamorphic rocks — therefore, it is consistent with the geology of the region.

It is important to mention that the mineralogy of ceramic materials reflects both the type of clay used, its processing, and the firing method applied, as well as possible post-depositional transformations. In this case, the presence of mineral phases such as muscovite/illite, calcite, diopside, and gehlenite enabled the estimation of the firing temperature.

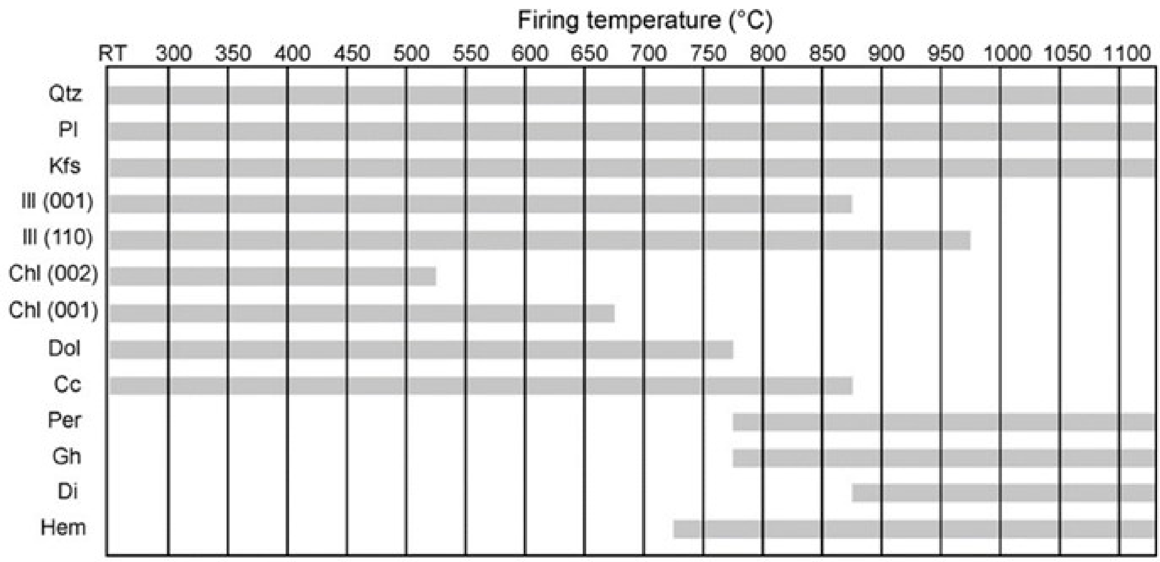


Figure 29. Bar diagram showing the mineralogical evolution of a chloritic-illitic clay rich in carbonates (calcite and dolomite) with increasing firing temperatures (after Nodari et al, 2007).

According to the table above (Fig. 29) muscovite decomposes around 950º, and its presence within a representative number of samples indicate the maximum firing temperature that they were exposed to. Secondly, the presence of calcite indicated a minimum limit for the firing temperature, as this mineral decomposes around 850º. The identification of diopside and gehlenite among some of the samples in which the calcite was not identified enables to infer that these samples were fired on a higher temperature, ranging from 900º to 950º as this is the temperature in which these minerals crystallize. The sherds in which calcite was identified have a firing temperature close to 850º — as this mineral decomposes at higher temperatures (Pérez-Montserrat et al, 2022). Fig. 30 shows that the ranges of firing temperatures are widely distributed across the periods, which implies that the firing techniques do not seem to change chronologically.

Samples containing olivine indicate a firing temperature that exceeded 850º. As chemical analysis identified a high content of magnesium (Appendix 4), this element could have been transformed into olivine from this temperature upwards. Interestingly, from the 8 olivine-bearing sherds identified, 4 are from the Protogeometric period and the other 4 do not have a specific chronological assignment. This detail might hint into a specific firing procedure or the existence of different clay source that was used simultaneously in the period, or the existence of a specialized pottery workshop.

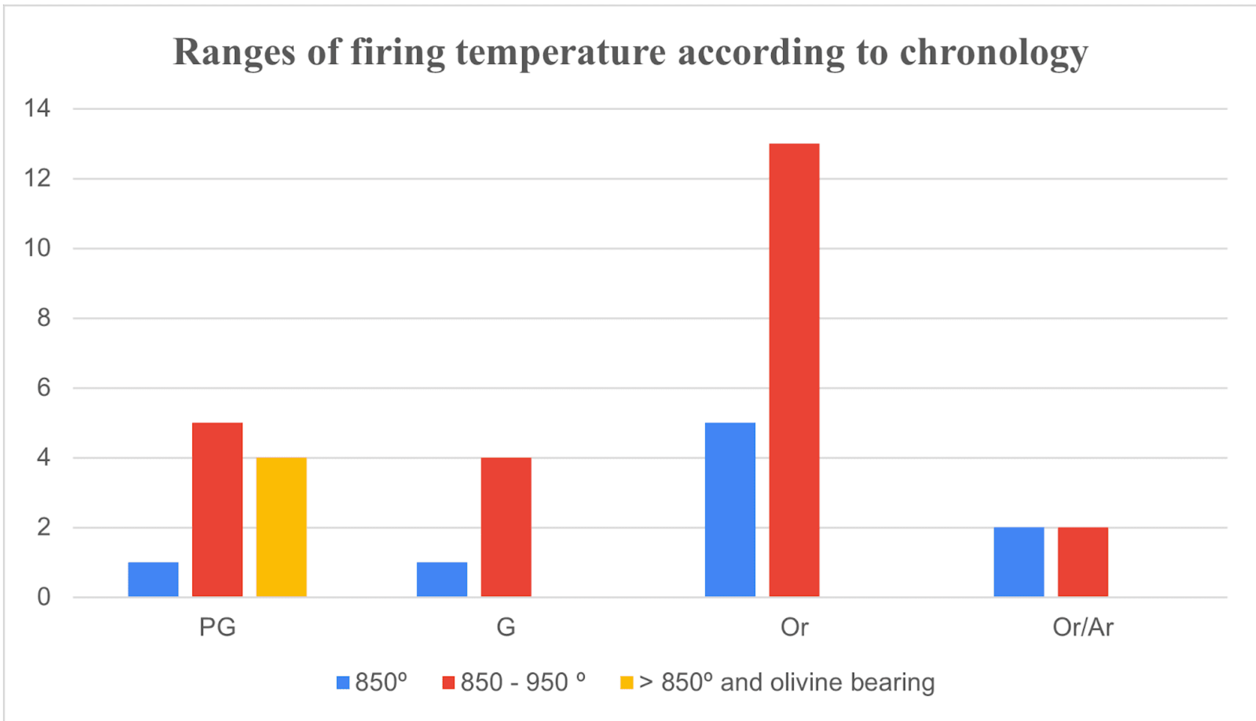


Figure 30. Graph showing the distribution of the ranges of firing temperature according to the chronology of the samples.

Another interesting outcome of the XRPD analysis is the disclosure of analcime in 7 of the samples. This mineral is a sodium-zeolite that corresponds typically to secondary mineral phases in ceramics, and crystallizes during burial on post-depositional processes (Buxeda i Garrigós et al, 2001, p. 21). These transformations occur as the fragments interact with fluids in the deposits that may lead to a change in their original mineralogical and chemical composition, as well as the ceramic's structure in a micro-scale level (Maritan, 2020, p. 1).

Analcime results from post-depositional alteration of the glassy phase (Schwedt et al, 2006, p. 238). Buxeda et al (2002) explains that the phenomenon occurs as an unstable glassy phase containing large amounts of potassium forms during the firing. The weathering processes during burial leads to a partial leaching of this potassium, thus causing a crystallization of the remaining silicate material through the fixation of the sodium from the burial environment.

4.2.3. CLUSTER ANALYSIS

Diffraction data acquired through XRPD analysis was further processed with the software High Score Plus. Cluster analysis gathered the data into a dendrogram with the cluster groups, following the methodology proposed by Maritan et al (2015). Cluster analysis of XRPD data enables the grouping of homogeneous samples, which further allows the identification of groups of samples with structural similarities as well as the main differences between the samples (Maritan et al, 2015, p. 540). When applying this method it's essential to consider that mineralogical similarities between samples are influenced by various factors, particularly the raw materials used, the textural composition of the clay and any added temper, as well as firing conditions (maximum temperature and firing atmosphere) (Maritan et al, 2015, p. 541).

It was possible to identify the presence of 10 clusters, according to the dendrogram reported (Fig. 31). Two samples were not clustered and are considered as outliers in the analysis. Those are samples G39, an Orientalizing cup, and G22, an Orientalizing *kotyle*. An overview of the dendrogram enables one to see that the clusters do not necessarily follow the chronology of the samples, but rather a tendency to cluster the samples according to their typology. This can be seen, for instance, in cluster 2, made mainly of *oinochoai*, cluster 5, entirely composed of *hydriae*, or cluster 9, with four out of the five *amphorae* analyzed.

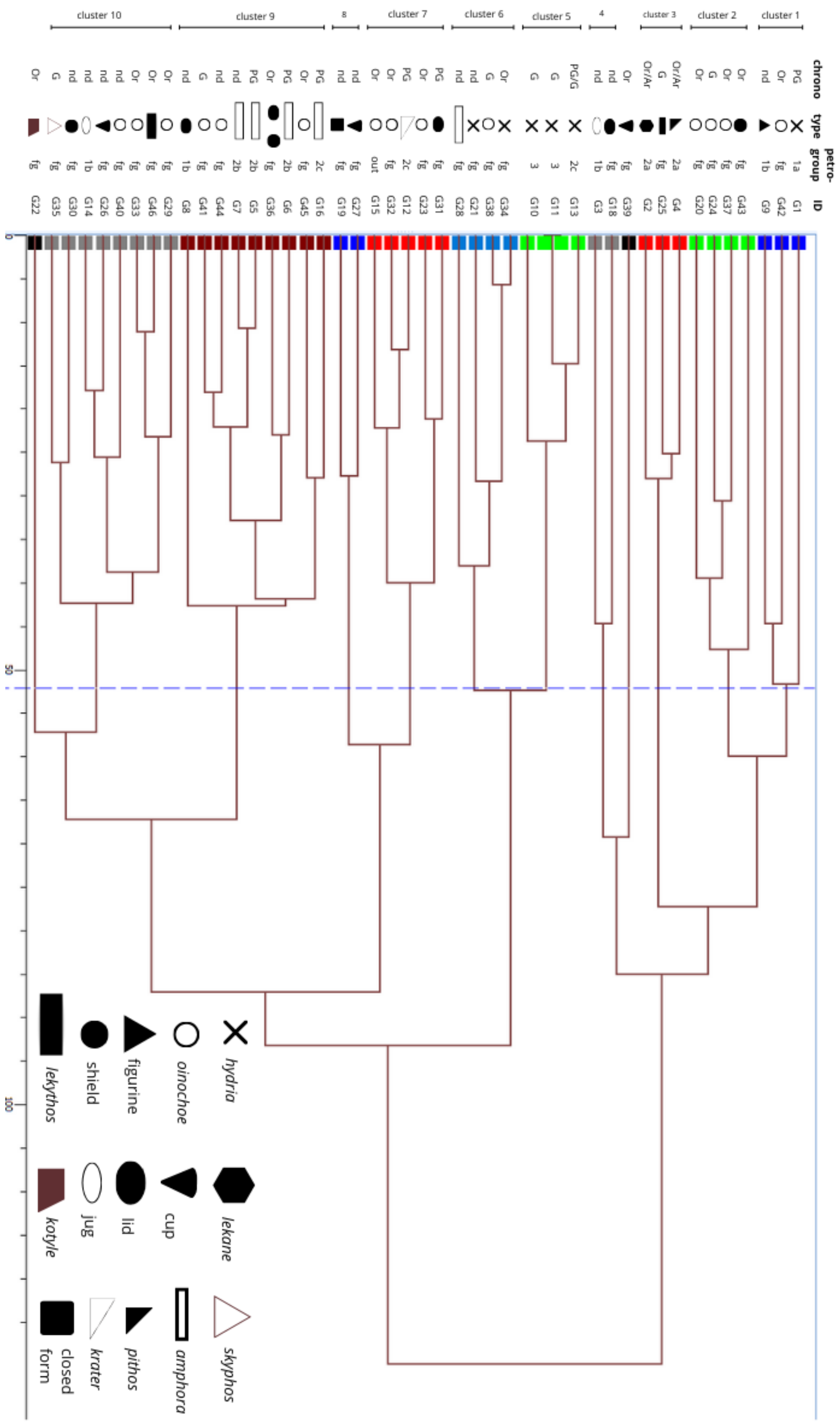


Figure 31. Dendrogram obtained by the cluster analysis of the Gortyn ceramics, with the indication of (right to left, starting from the dendrogram) sample’s ID, petro-group (the fine-grained samples are indicated as ‘fg’) typology (indicated by a symbol; legend on the corner of the dendrogram), and chronology.

The software assigned a representative sample for each cluster, which contains the dominant characteristics of the group it belongs to.

The representative for cluster 1 is sample G9, a figurine without specific chronology and from the petro-fabric 1b. Its mineralogical composition (Fig. 32) is characterized by the presence of peaks of quartz, albite, diopside and illite/muscovite.

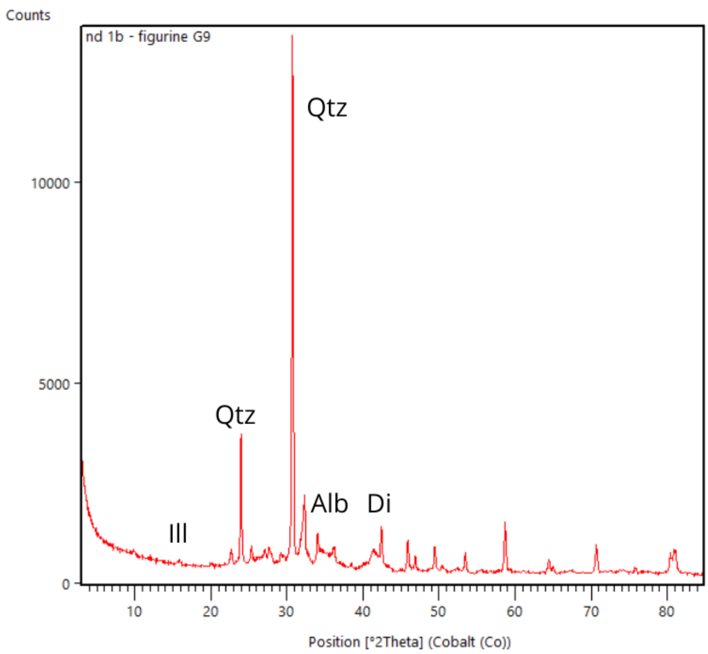


Figure 32. XRPD pattern of sample G9, representative of cluster 1. Mineral abbreviations: Qtz: quartz; Ill = illite/muscovite; Alb = albite; Di = diopside.

The representative of cluster 2 is sample G24, a fine-grained *oinochoe* from the Geometric period. The sample's mineralogical composition is composed of quartz, albite, and muscovite (Fig. 33).

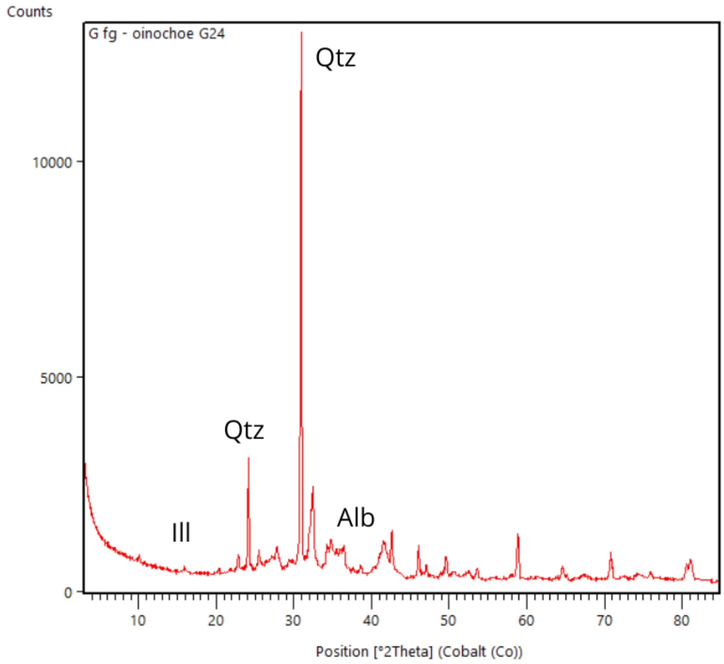


Figure 33. XRPD pattern of sample G24, representative of cluster 2. Mineral abbreviations: Qtz: quartz; Ill = muscovite; Alb = albite.

Cluster 3 is represented by sample G3 (Fig. 34), a cooking jug from the petro-group 1b and without specific chronology. It is characterized by peaks of quartz, albite, calcite, and illite/muscovite.

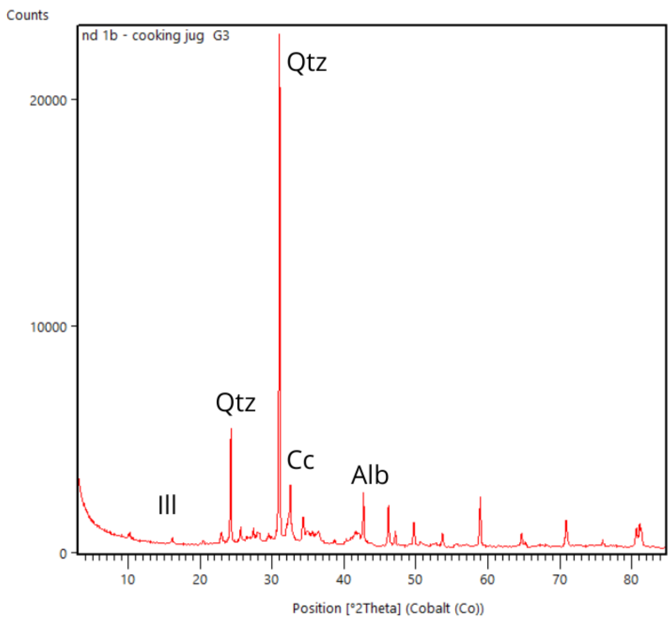


Figure 34. XRPD pattern of sample G3, representative of cluster 3. Mineral abbreviations: Qtz: quartz; Ill = illite/muscovite; Alb = albite; Cc = calcite.

Clusters 4 and 5 are the largest ones, and are represented by samples G7 (Fig. 35), a storage vessel with no specific chronology, and G29 (Fig. 36), an Orientalizing fine-grained *oinochoe,* respectively. Both show peaks of quartz, albite, and microcline; sample G7 also contains diopside, gehlenite, and olivine, while sample G29 contains illite/muscovite.

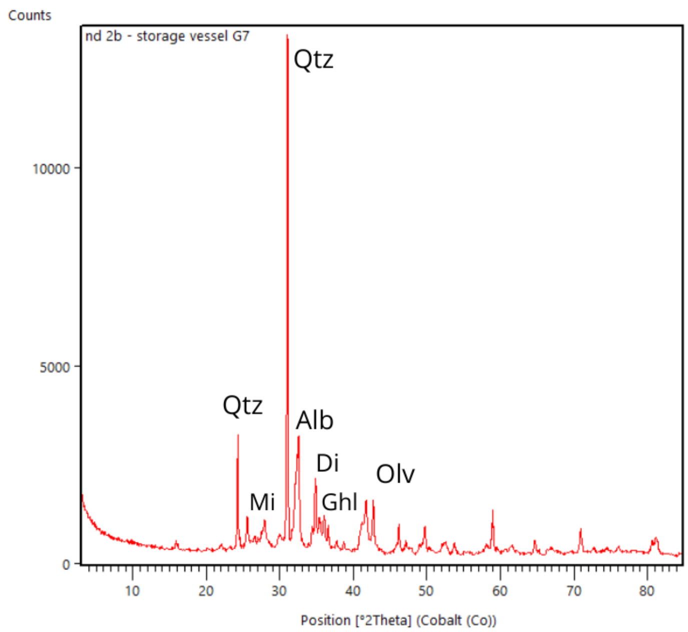


Figure 35. XRPD pattern of sample G7, representative of cluster 4. Mineral abbreviations: Qtz: quartz; Alb = albite; Mi = microcline; Di = diospide; Ghl = gehlenite; Olv = olivine

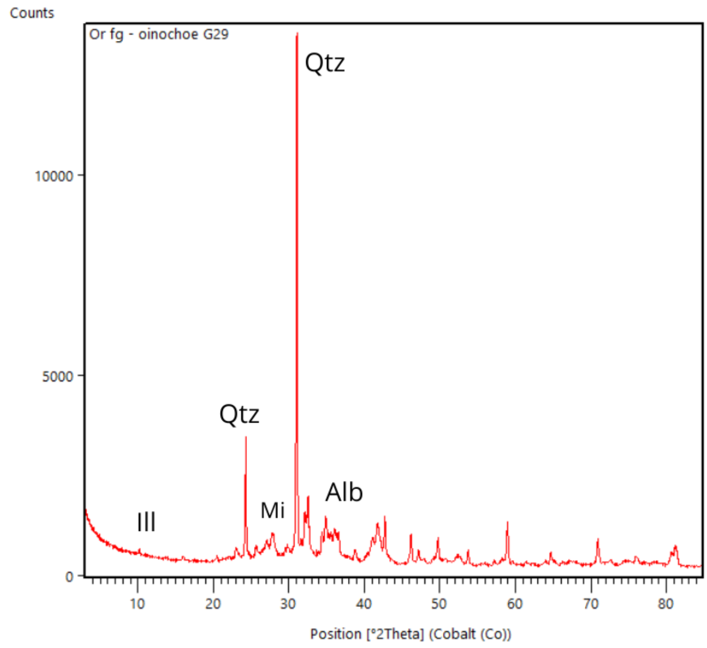


Figure 36. XRPD pattern of sample G29, representative of cluster 5. Mineral abbreviations: Qtz: quartz; Alb = albite; Micro = microcline; Ill = illite/muscovite.

Cluster 6 is represented by sample G12 (Fig. 37), a Protogeometric *krater* from petro-fabric 2c. Its mineralogical composition is characterized by the presence of quartz, albite, and augite (pyroxene)

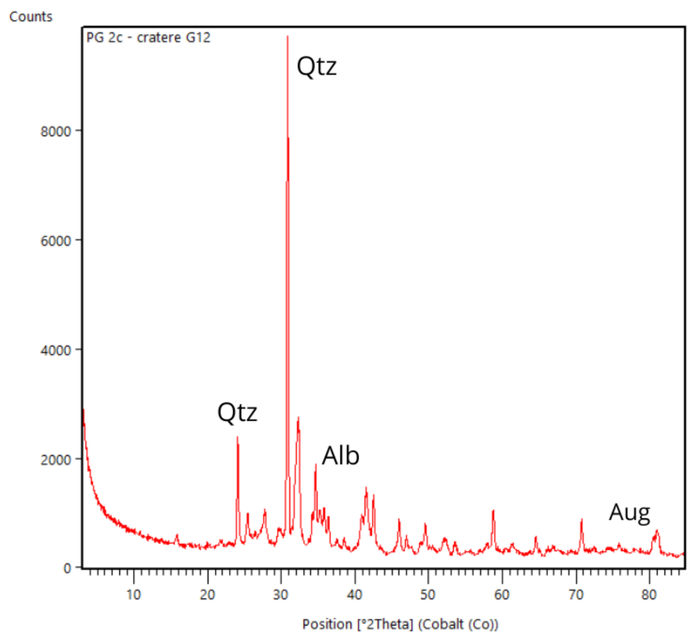


Figure 37. XRPD pattern of sample G12, representative of cluster 6. Mineral abbreviations: Qtz: quartz; Alb = albite; Aug = augite

The representative of cluster 7 is sample G34 (Fig. 38), a fine grained *hydria* from the Orientalizing period. The mineralogical composition is characterized by the presence of quartz, albite, illite/muscovite, and augite.

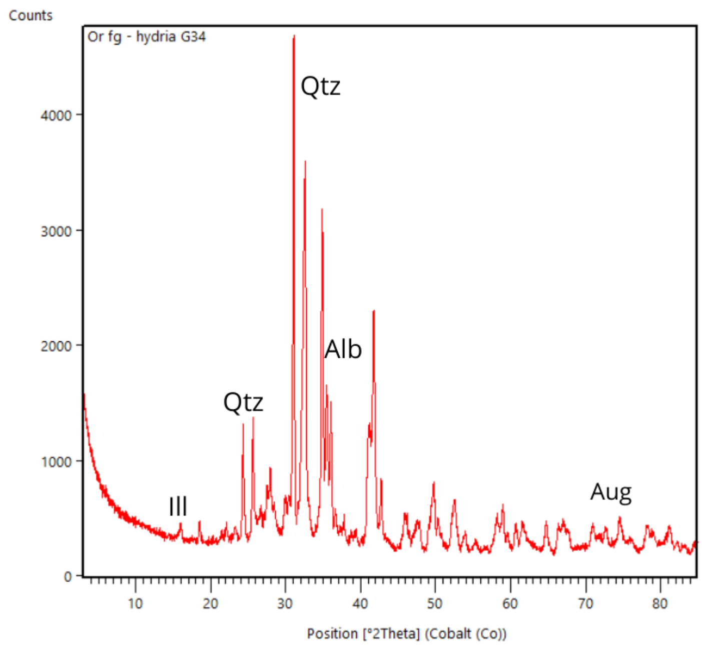


Figure 38. XRPD pattern of sample G34, representative of cluster 7. Mineral abbreviations: Qtz: quartz; Alb = albite; Aug = augite; Ill = illite/muscovite.

The representative sample of cluster 8 is G25 (Fig. 39), a *lekythos* from the Geometric period. It displays peaks of quartz, albite, and illite/muscovite.

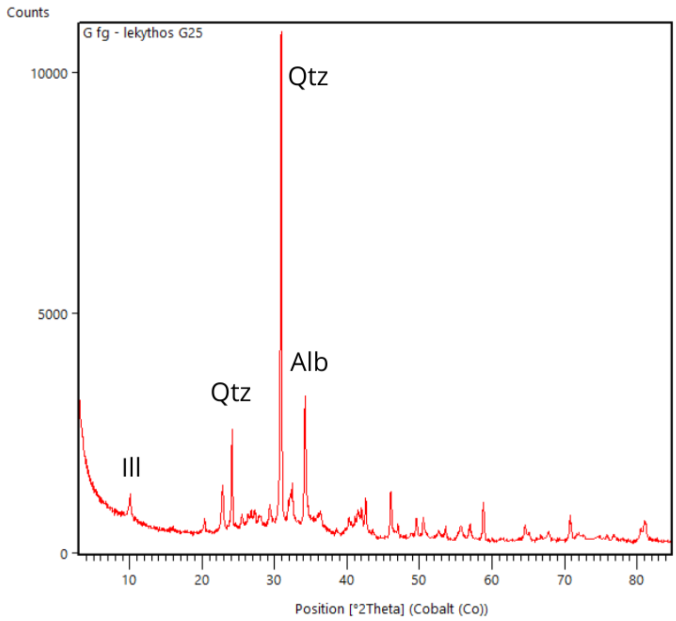


Figure 39. XRPD pattern of sample G25, representative of cluster 8. Mineral abbreviations: Qtz: quartz; Alb = albite; Ill =illite/ muscovite.

Finally, clusters 9 and 10 are represented by samples G27 (Fig. 40) and G11 (Fig. 41), respectively. The first is a fine-grained cup with no specific chronology, while the latter is a Geometric *hydria* from the petro-group 3. Their mineralogical composition is made of quartz, albite, and olivine; sample G27 also contains diopside and analcime, while G11 contains augite.

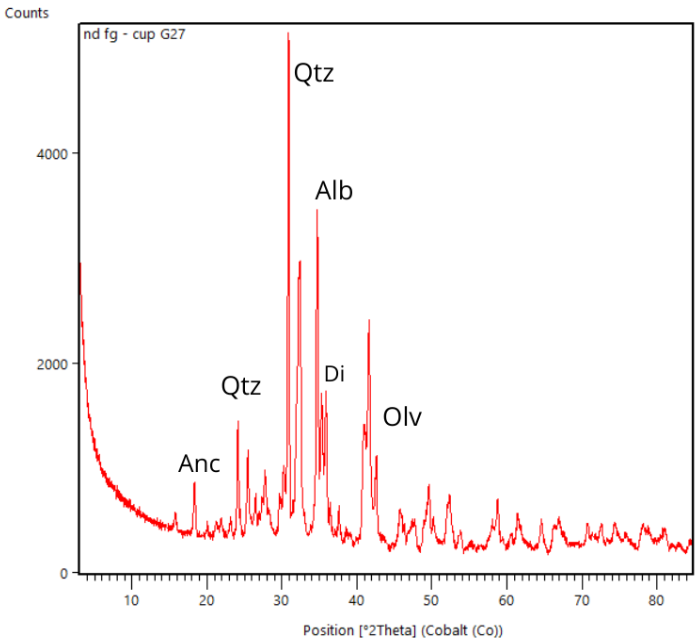


Figure 40. XRPD pattern of sample G27, representative of cluster 9. Mineral abbreviations: Qtz: quartz; Alb = albite; Anc = analcime, Olv = olivine, Di = diopside.

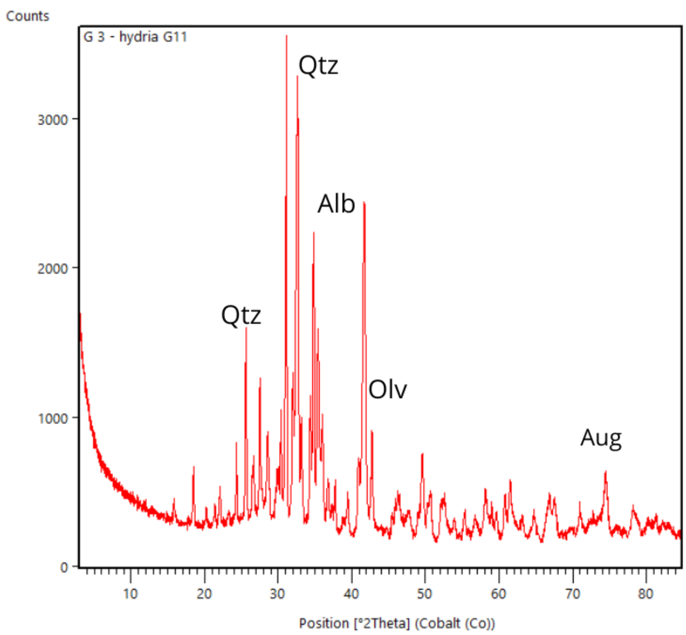


Figure. 41. XRPD pattern of sample G11, representative of cluster 10. Mineral abbreviations: Qtz: quartz; Alb = albite; Aug = augite, Olv = olivine.

4.2.4. CLUSTER ANALYSIS OF THE XRPD DATA OF SAMPLES STUDIED UNDER THIN SECTION PETROGRAPHY

Cluster analysis was applied on the 17 samples that underwent thin-section petrography. This was done to evaluate the relationship between the production recipes and the raw material used and the mineralogical association, which can be also affected by the firing process (Holakooai et al, 2014; Maritan et al, 2015). The resulting dendrogram (Fig. 42) shows that the samples tend to group according to their assigned petrographic group.

Additionally, the clusters displayed a relative correlation between petrographic groups and typologies. This can be seen, for instance, in the predominance of *hydriae* on cluster 2 and *amphorae* on cluster 3. This points to the hypothesis that the ceramic recipes could have been typologically or functionality driven rather than chronologically influenced, which will be further elaborated in the next chapter (p. 97).

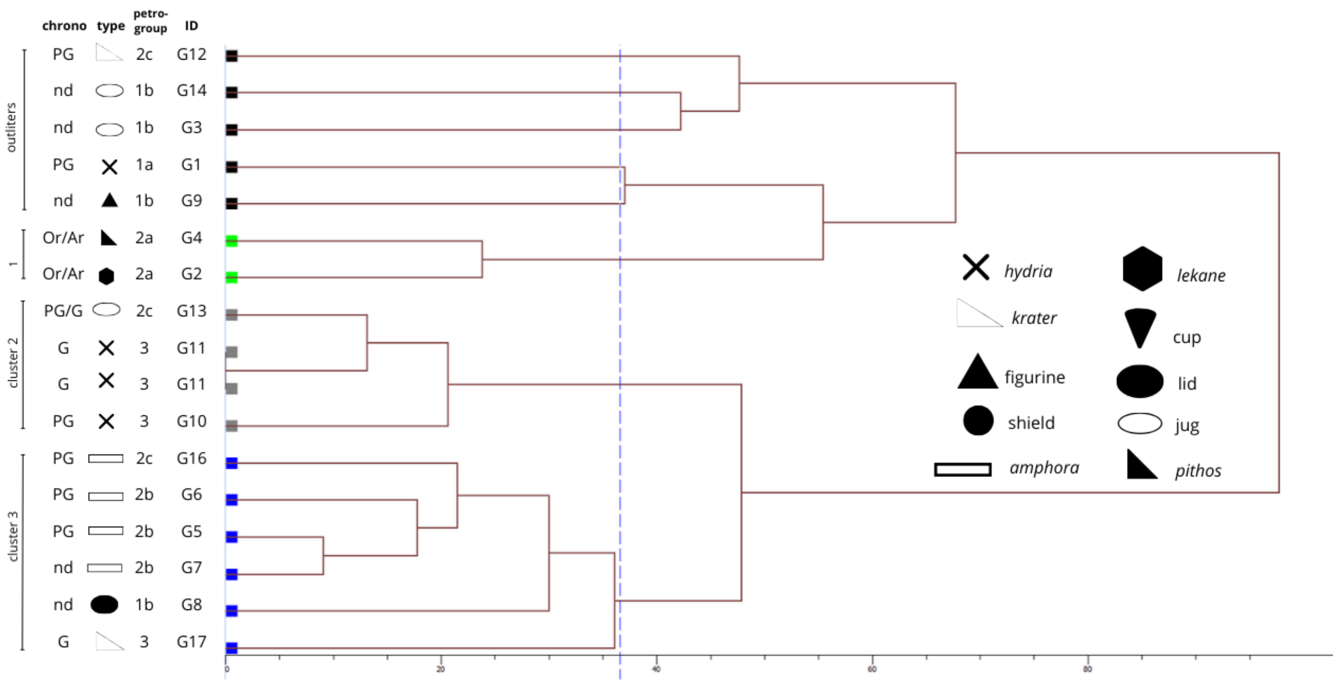


Figure 42. Dendrogram of the coarser-grained potsherds, studied also in thin sections, with indication of (right to left, starting from the dendrogram): sample ID, petro-group, typology (indicated by a symbol; legend in the corner of the dendrogram), and chronology.

A total of five sherds were considered as outliers. Those are:

- Sample G12, a Protogeometric *krater*;

- G14 and G3, two jugs of no specific chronologies;
- Sample G1, a Protogeometric *hydria*;
- Sample G9, a figurine of no specific chronology.

4.2.5. CLUSTER ANALYSIS OF THE FINE GRAINED SHERDS

The XRPD data of the fine grained samples were also studied under cluster analysis, resulting in an interesting pattern. Even as most of the fine-grained sherds belong to the Orientalizing period, they do not tend to be clustered together (Fig. 43), and are widely distributed across the dendrogram following a similar pattern as the one identified on the clustering of all 46 samples (Fig. 31). Given that a large number of these samples are from *oinochoai*, their wide distribution throughout the graph could indicate the use of different ceramic recipes or firing temperature even to vessels of the same typology. This could point to a higher degree of experimentation during the Orientalizing period, in which Crete was exposed to influences from other cultures — especially from the East (Kotsonas, 2013).

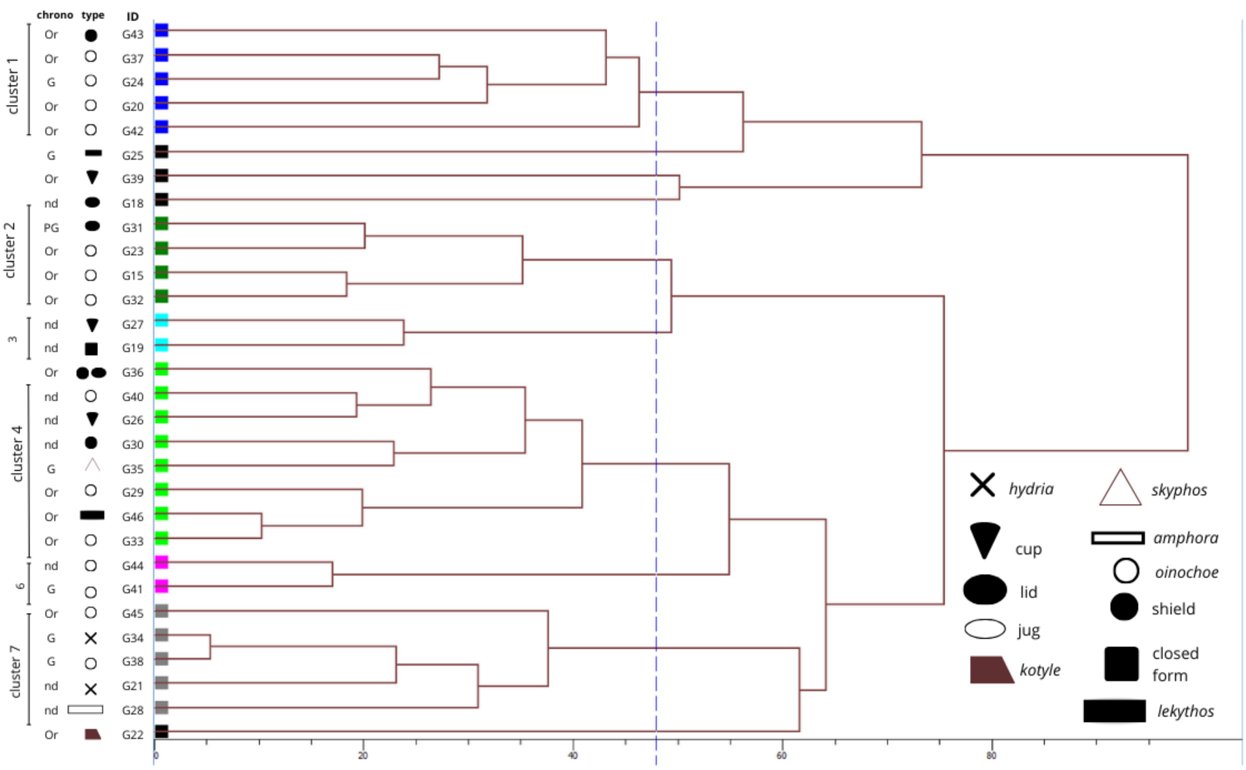


Figure 43. Dendrogram of the cluster analysis of the fine grained sherds, with the indication of (right to left, starting from the dendrogram): sample ID, typology (indicated by a symbol; legend on the corner of the dendrogram), and chronology,

The outliers identified are samples:

- G25, a Geometric *lekythos*;
- G39, an Orientalizing cup;
- G36, an Orientalizing lid or shield;
- G22, an Orientalizing *kotyle*.

4.3. CHEMICAL CHARACTERIZATION THROUGH X-RAY FLUORESCENCE SPECTROMETRY

4.3.1.DESCRIPTION OF THE METHOD

Investigating the chemical composition of archaeological ceramics is a powerful way of disclosing and characterizing the raw material used on production, helping to identify the provenance and production technique used on ancient ceramics (Maritan, 2023, p. 5).

The samples were chemically characterized through X-Ray Fluorescence (XRF). The method consists of the identification and quantification of major, minor, and trace chemical elements in the samples through the expulsion of core atoms by high energy X-rays, causing the emission of fluorescence photons that represent the characteristic spectrum of the atom (Artioli, 2010, pp. 34 - 35). The analysis identified the presence of major and minor elements expressed in wt% of SiO2, TiO2, Al2O3, Fe2O3, MnO, MgO, CaO, Na2O, K2O and P2O5, as well as trace elements expressed in parts per million (ppm) of S, Sc, V, Cr, Co, Ni, Cu, Zn, Ga, Rb, Sr, Y, Zr, Nb, Ba, La, Ce, Nd, Pb, Th and U.

Chemical analysis was applied in 20 of the samples from both coarse and fine ware. As stated earlier, the selection criteria was the representativeness of the material, with samples with at least 1.4 g selected for the XRF. As the other 26 samples were smaller than this minimum amount, they could not be chosen for the chemical analysis. Despite this initial difficulty this analysis was an important step towards the further characterization of the material, and the data could successfully complement the results acquired from earlier work.

The powder was prepared following the same preparation procedures adopted on the powder preparation for the XRPD analysis: the initial removal of the inner and outer layers with a Dremel micro-drill enabled the analysis solely of the ceramic body, followed by the grinding of the samples with a cleaned agate mortar and pestle. The XRF data was processed on the software Statgraphics and analyzed in terms of cluster analysis (CA) and principal component analysis (PCA).

A table with the full chemical composition of the 20 samples analyzed on XRF is available on Appendix 4 (p. 168).

4.3.2. STATISTICAL TREATMENT OF THE DATA: CLUSTER ANALYSIS

The results of the cluster analysis exhibited three clusters (Fig. 44).

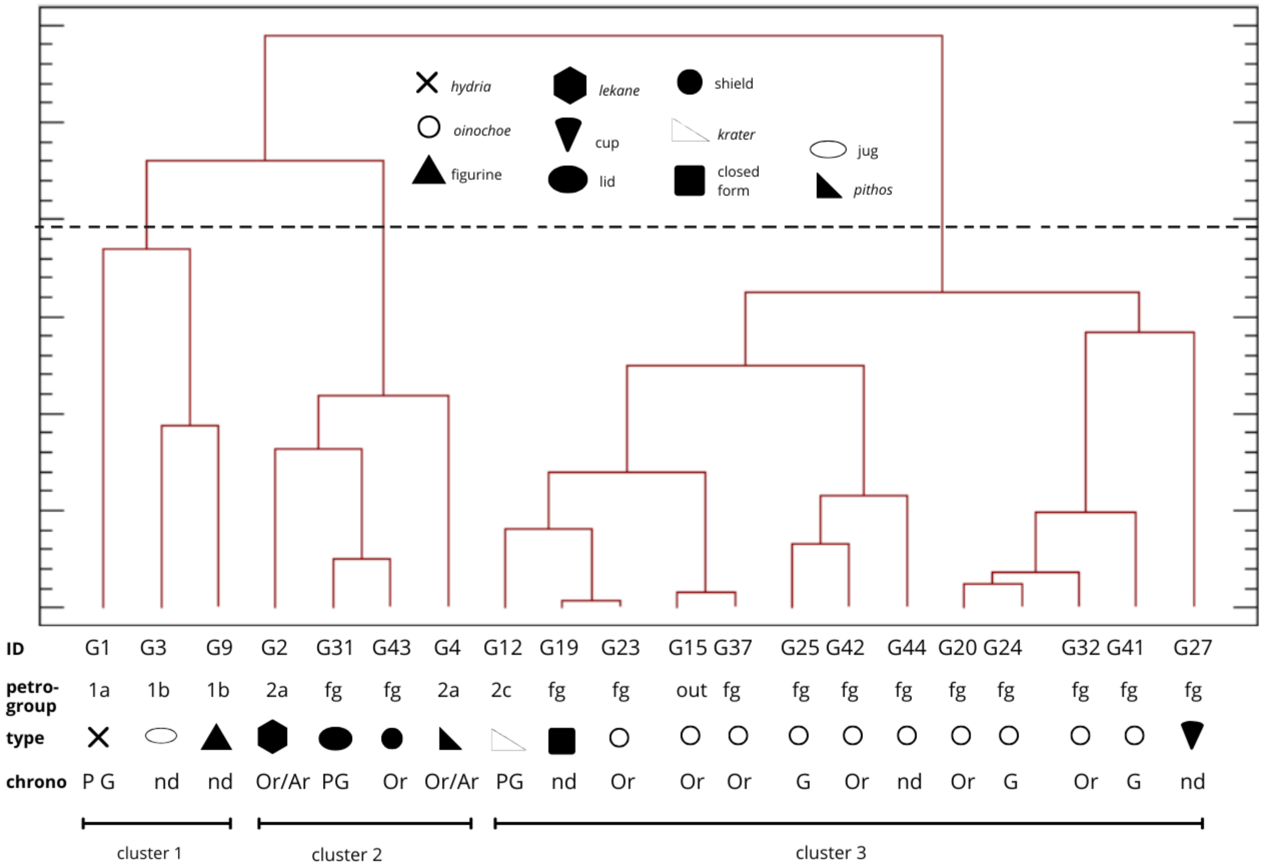


Figure 44. Dendrogram obtained by the cluster analysis of the samples, performed with the Square Euclidean Distance and the Ward's Method, with the indication of the sample's ID, petro-group, typology (indicated by a symbol; legend in the top of the dendrogram), and chronology.

Cluster 1 consists of two fragments with unknown specific chronology, corresponding to a cooking jug (G3) and a figurine (G9), both from petro-fabrics 1b, and a Protogeometric *hydria* from petro-group 1a (G1).

Cluster 2 is made of four samples. Their typo-chronological characterization is varied, corresponding to one Orientalizing or Archaic *lekane* (G2) from petro-group 2a, one fine grained Protogeometric lid (G31), one fine-grained Orientalizing shield (G43), and one Orientalizing or Archaic *pithos* (G4) from petro-fabrics 2a.

Very interesting is to note that, despite cluster 3 is quite large, three main sub-clusters can be identified:

i) one grouping four samples, three of which are fine grained (fg), one from the petro-fabric group 2c, and one from the outlier petrographic group (clean clay). They are three Orientalizing *oinochoai* (G23, G15, and G37), and one Protogeometric *krater* (G12) from petro-group group 2c, and a fine grained closed form without specific chronology (G19);

ii) another one formed of three samples of fine-grained oinochoe, the chronology of each of them is diverse: one is Geometric, one is Orientalizing, and one does not contain a specific chronology (respectively, samples G25, G42, and G44);

iii) the last group is made of four fine-grained oinochoe from different chronologies (two Orientalizing and two Geometric, respectively G20 and G32, and G24 and G41), and a fine-grained cup without specific chronology (G27).

As the three clusters contain samples spanning different chronological periods, an analysis of the dendrogram allows one to see that they seem to be grouped together based on similarities in their typological features, such as vessel shape or function, rather than their age. This as can be seen specially on clusters 3, composed mainly of *oinochoai* from both the Orientalizing and Geometric periods. This may indicate that the ceramic body was created based on specific typological-driven recipes that remained consistent over time, with specific variations introduced based on function and shape. Overall, these results suggest a continuity in ceramic production techniques, with changes driven by the functional requirements of the vessels rather than chronological evolution.

Additionally, cluster 1 is composed by samples from petro-fabrics 1b, while cluster 3 is mainly composed of fine-grained samples. This reflects the correspondence between their chemical composition and petrographic characteristics. The sherds, regardless of their varied chronologies, demonstrate a clear petrographic and chemical alignment, similarly to the dendrogram of the XRPD data of the samples studied under thin section microscopy (Fig. 42, p. 89).

4.3.3. STATISTICAL TREATMENT OF THE DATA: PRINCIPAL COMPONENT ANALYSIS

Principal Component Analysis (PCA) was also applied on the statistical treatment of the chemical data. The analysis consists of "the correlation among the data variables, in order to construct a new set of variables, the principal components with some good statistical properties" (Papageorgiou, 2020, p. 210).

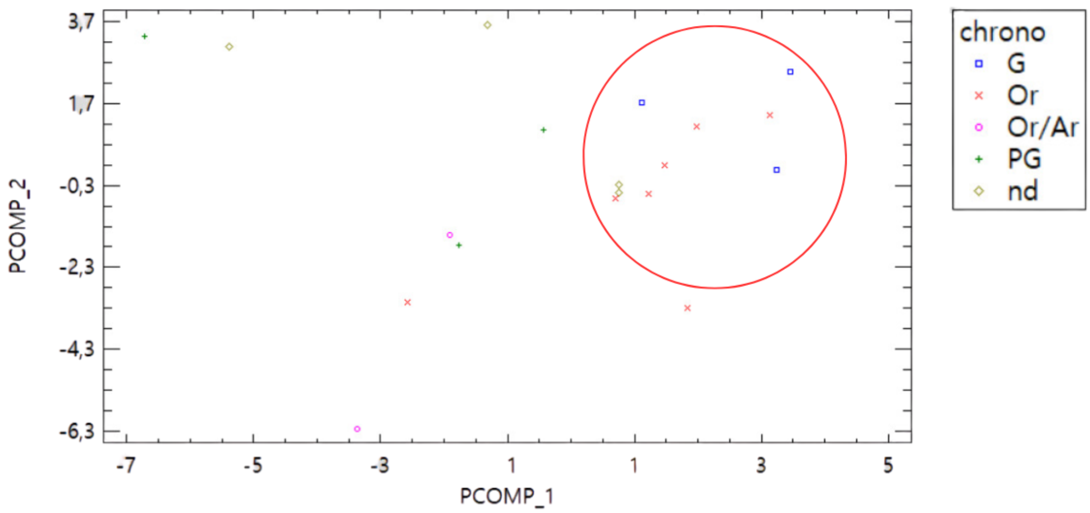


Figure 45. Scare plot of the PCOMP1 and PCOMP2 obtained from the XRF data with the indication of chronology (Abbrevations: PG = Protogeometric; G = Geometric; Or = Orientalizing; Ar = Archaic; nd = no specific chronology). PCOMP 1 and PCOM2 represent, respectively, the eigenvalue of 8,49301 and 5,98532, a percent of variance of 27,397% and 19,307%, and a cumulative percentage of 27,397% and 46,704%.

When principal component analysis is applied to the samples and analysed according to their chronology, no systematic grouping can be seen, except for the Orientalizing ceramics that tend to group all together. When typology is considered, it can be seen that the sherds display a relatively higher degree of variability. Fig. 46 shows that the *oinochoe* tend to be grouped together, which might indicate some similarity in their chemical composition despite the general low variability in the system,

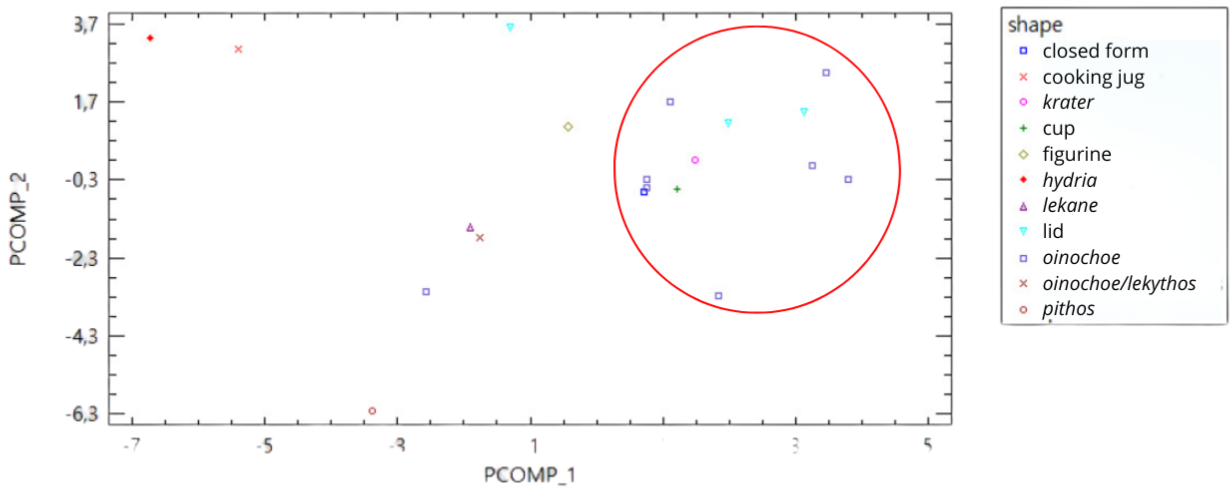


Figure 46. Scare plot of the PCOMP1 and PCOMP2 obtained from the XRF data, with the indication of the typology (shape).

Chapter 5

Discussion: results of the archaeometric characterization and archaeological implications

The combination of the chrono-typological and archaeometric characterization of the ceramic material enabled an interesting evaluation of aspects regarding their production processes, which can hint into the early dynamics of Gortyn. As part of these sherds date from a period prior to the construction of the temple of Apollo in the mid-7th century BCE while others are contemporaneous to its foundation, the patterns of composition and production technology observed may hint into the cultural and social landscape of the city — specifically if the relationship between technology, culture, and society, enabled by the concept of *chaîne operatóire*, is taken into consideration.

The results gathered from the data available and their possible interpretations and archaeological implications are presented below, with the aim of answering broader questions to help to disclose the complex scenario of Gortyn's early urban layout.

5.1. MINERALOGICAL AND CHEMICAL COMPOSITION, PETRO-FABRICS AND CERAMIC RECIPES: CHRONOLOGICAL CONTINUITY, TYPOLOGICAL CHANGE

The cluster analysis of the mineralogical assemblage gathered from the XRPD (Fig. 31, p. 81) analysis showed that the samples belonging to the same chronological periods are not necessarily clustered together. On the other hand, the dendrogram showed a tendency to cluster the samples according to their typology. It thus seems that the mineralogical composition of the sherds varies according to their typology, but the specific typology-based recipes tend to stay rather consistent throughout the different periods — explaining why there is not a significant chronological variation on the ceramic composition. Typology, rather than chronology, seems to drive the paste preparation procedures and diversity within the ceramic technology of Gortyn, with certain functional classes of pottery being created using distinct ceramic recipes that remained stable across different periods.

The stability in ceramic composition across time may suggest a deliberate preservation of established ceramic practices, potentially indicating a strong cultural continuity and a stable local pottery tradition. This consistency in production recipe could imply that the community in Gortyn valued long-standing techniques, which may have been tied to local identity or cultural practices. The lack of substantial change in ceramic technology throughout the chronological periods may reflect a strong preference for maintaining local methods rather than adopting new influences. Although the Iron Age marks Crete with significant economic, socio-political, and cultural transformations, as well as increasing contact with external influences (Prent, 2005, p. 623), there seems to be a significant retention of traditional practices — at least in Gortyn. While stylistic changes occurred, many foundational techniques remained consistent from earlier periods.

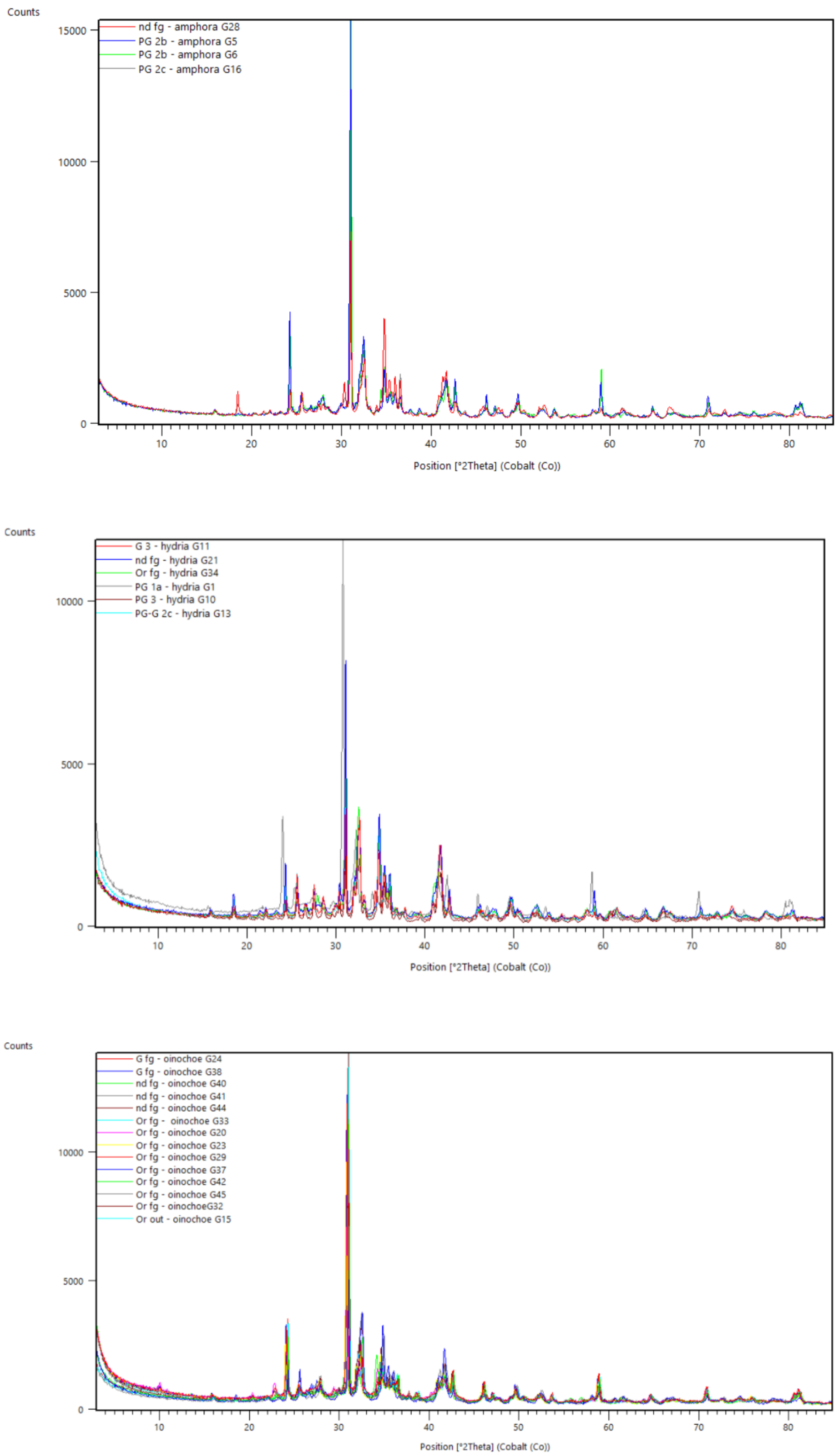


Figure. 47. Comparison of the XRD spectrum of samples of (top to bottom) *amphorae*, *hydriae*, and *oinochoai*. It is possible to see similarities in the spectrum pattern of sherds of the same type. The chronology, petro-fabric, and sample ID are indicated in the images (the abbreviation 'fg' refers to the fine grained sherds, that were not characterized in terms of petro-fabric)

When compared to the cluster analysis performed with the XRF data (Fig. 44, p. 93), it is noticeable that this pattern is somehow maintained. One special aspect of the dendrogram is the relation between different sherds of *oinochoai,* grouped on cluster 3. Although most of the *oinochoai* samples are, in general, from the Orientalizing period, they were clustered next to two sherds from the Geometric period, as well as with two sherds with no specific chronology. Additionally, principal component analysis performed with the XRF data (Fig. 45, p. 95) showed a low degree of variability among the chemical composition of the analyzed samples from different periods, which is consistent to the hypothesis of a chronological continuity of the same ceramic recipes. As the PCA approximated the samples of *oinochoai* in the graph (Fig. 46, p. 96), it once more points to the possibility of specific ceramic recipes being chosen for different types of pots regardless on the chronological period — once more indicating the retention of these typology-driven recipes across the centuries.

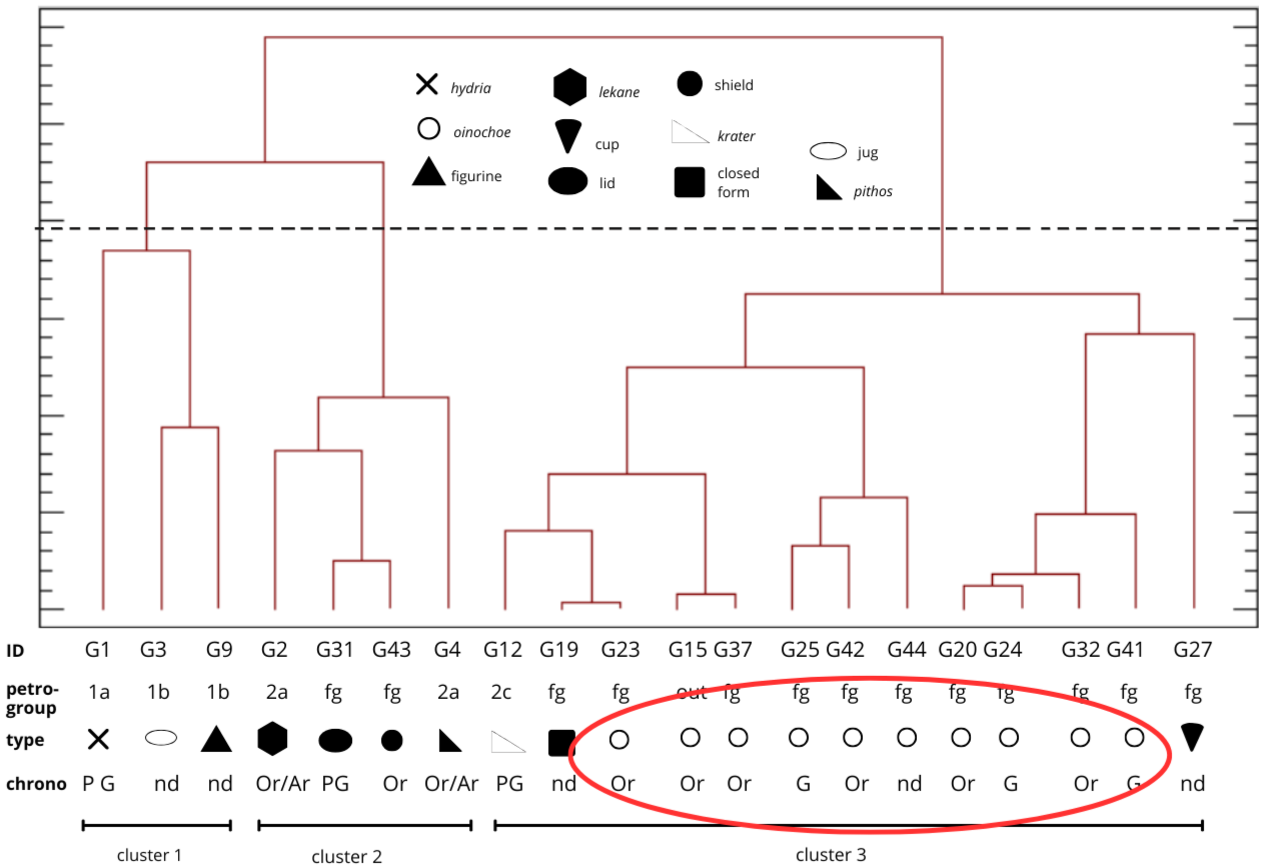


Figure 48. Cluster analysis made with the chemical data with the samples of *oinochoai* highlighted.

When analyzed in terms of petro-fabrics, the samples displayed an interesting clustering pattern. The analysis of the 17 coarse-grained samples revealed that the clustering patterns respect almost perfectly the petro-fabrics identified with thin section petrography (Fig. 42, p. 89). In addition to following the assigned petro-fabric, the three clusters on the dendrogram also grouped the samples according to their typology, once more pointing out the use of specific ceramic recipes to vessels of the same type.

Finally, the macrofabrics identified by the macroscopic characterization of the sherds (p. 61) can also point to some typological variations. Even as the main criteria for the macrofabric classification was the color of the ceramic body and inclusion's grain-size — which are rather subjective criteria — it could be seen, for instance, that all the *oinochoai* were put in the macrofabric groups of light-colored sherds — also, they were all fine-grained — while all the *hydriae* and shields were darker in color and classified on the dark-colored groups. Once more, these patterns indicate a typological orientation of the process of paste preparation, that is seen here on the color of the ceramic body.

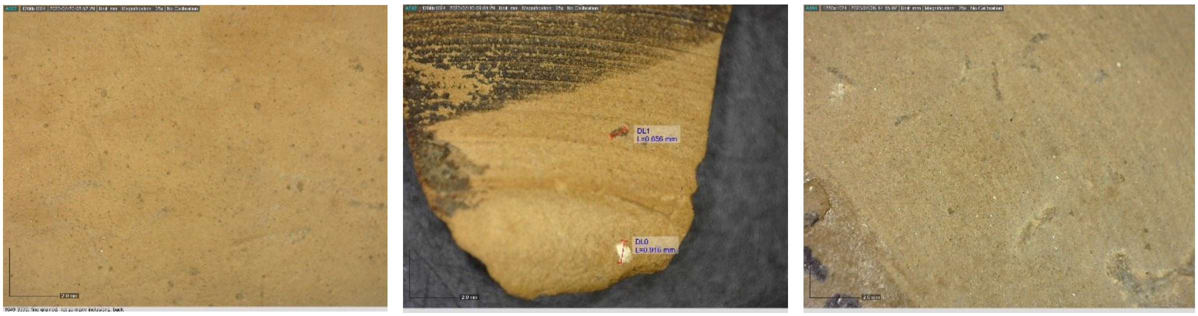


Figure 49. Dino Lite pictures of fragments G20 (*oinochoe*), G34 (*hydria*), and G43 (shield), showing slight differences in the color of the ceramic body.

This consistency of the typologically-driven ceramic recipes across time within suggests a specialized and systematic approach to ceramic production in Gortyn, possibly reflecting the presence of skilled workshops or artisans with established techniques related to specific pottery functions.

The presence of specialized pottery workshops is attested in Gortyn in the Orientalizing period — more specifically, from the second half of the 7th century to the 6th century BCE. This identification was made thanks to the finding of discarded material on a pottery pit in 1992. Located on the south slope of the hill of Profitis Ilias, this large pit was filled with poorly fired pieces, furnace fragments, vitrified sherds, and so on — in summary, consisting of evidence of discarded material. The study of this sherds pointed to a significant homogeneity on the patterns production technique and a noticeable standardization of the fragment's shapes, which enabled researchers to conclude that this was the discarded material coming from one or more local pottery workshops (Santaniello, 2012, p. 253).

The finding of typology-driven ceramic recipes in the sherds from the sanctuary of Apollo may reinforce the notion of specialized craft traditions in ancient Gortyn. Although there is no reference for the existence of Protogeometric or Geometric workshops in the city, the presence of workshops in later periods may be an indication that these specialized industries might have existed in a period prior to what was initially thought. Similarly, is is possible that the same workshop carried out its activities throughout the next archaeological periods, following a similar trend of raw material procurement, clay preparation and firing techniques.

Figure 50. Map of Gortyn with the identification of the pottery pit, dated between the 7th and 6th centuries BCE (after Santaniello, 2012, p. 253).

These results are relevant as they provide insights into the social organization of Gortyn's pottery craftsmanship. The constant use of the same typology-specific recipes over time hints at an established structured organization of the ceramic production sector, where the function and form of the vessel dictated the choice of ceramic preparation. Such organization points to a stable and socially structured pottery tradition in Gortyn, with the same ceramic recipes used consistently for different types of vessels throughout the centuries.

But although there is indeed a chronological continuity on the ceramic recipes applied to the pottery, another interesting outcome of the cluster analysis is the identification of a slight variability on the ceramic recipe of the sherds from the Orientalizing period. This can be seen on the dendrogram of the XRPD data of the fine-grained sherds (Fig. 43, p. 89). Even as the cluster analysis of the chemical data showed a similar chemical composition of the samples of *oinochoai* — seen in their grouping either on the same clusters or in neighboring clusters — the dendrogram of the XRPD data reveals a wide distribution of the Orientalizing *oinochoai*. Also, little to no macroscopic variability was observed among the different samples of *oinochoai* analyzed, with most of then being characterized as either light colored or light brown colored (all fine grained).

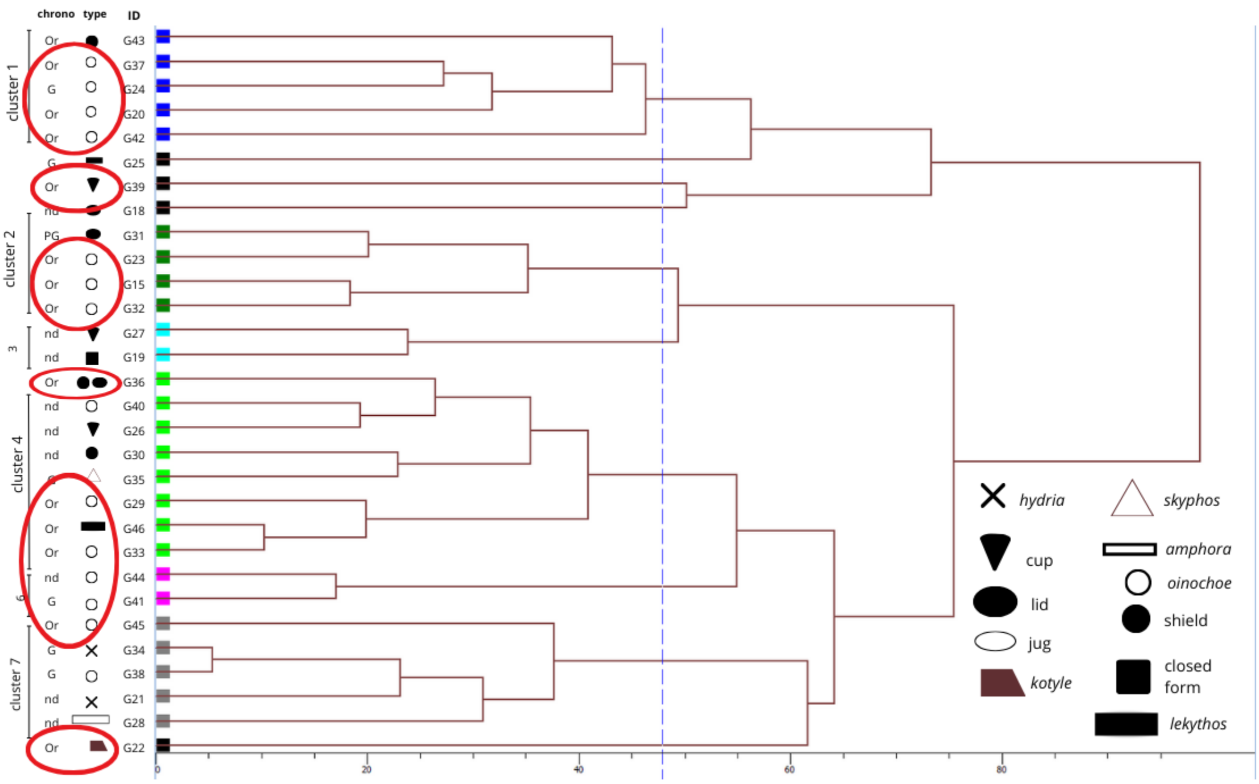


Figure 51. The dendrogram of the fine grained sherds with the Orientalizing sherds circled in red. It is possible to see a wide distribution of the samples throughout the dendrogram, even of those from the same typology.

This may hint into some variations on the ceramic recipe for the *oinochoe* and hence a degree of experimentation during the Orientalizing period. It could be the result of a somehow regional diversity in production methods or adaptations in response to foreign influences and changing aesthetic preference. As elaborated by Kotsonas (2013, p. 238), pottery from the Orientalizing period is deeply marked by the "introduction of a range of techniques and the adoption of varied morphological elements". Thus the broad distribution pattern for the Orientalizing samples might showcase a period of innovation and diversification in ceramic production, likely influenced by these cross-cultural exchanges in the Iron Age Mediterranean. Moreover, this diversity could be a symptom of Gortyn's expansion during the Orientalizing period (Kotsonas, 2002, p. 50), introducing new trends of ceramic production and technology.

In summary, while there is a clear chronological continuity in the patterns of ceramic production technology from the Protogeometric through the Archaic periods, with the same ceramic recipes being applied throughout the centuries and indicating a strong adherence to local traditions, there is also evidence of experimentation and diversification during the Orientalizing period, as observed in the slight variability between the sample of *oinochoai*. This balance between continuity and innovation highlights how Gortyn's potters maintained some of their core practices while integrating new influences, which might pose an interesting response to the dynamic culture of the period.

5.2. FIRING-INDUCED MINERALOGICAL VARIABILITY: MORE EVIDENCE OF A PROTOGEOMETRIC WORKSHOP?

Another curious outcome of the archaeometric research is the estimation of the firing temperatures to which the pots were exposed to. As previously detailed, the temperature ranges were of around 850º for the calcite-bearing sherds and higher than 850º for diopside and gehlenite bearing sherds. Samples that contained calcite were fired around 850º, due to the melting temperature of this mineral. As seen (Fig. 30, p. 79), the ranges of firing temperature are fairly distributed throughout the chronological periods.

However, the eight olivine-bearing sherds could indicate a crystallization of the magnesium content in a temperature also higher than 850º. As all these olivine-bearing samples date either from the Protogeometric period or do not have a specific chronological assignment, two possible interpretations can be made: firstly, the olivine content could indicate the exploitation of a different clay source during the period. Secondly, it could be another evidence for the presence of a

Protogeometric pottery workshop. Both hypotheses point to the presence of a specialized recipe that is not used afterwards.

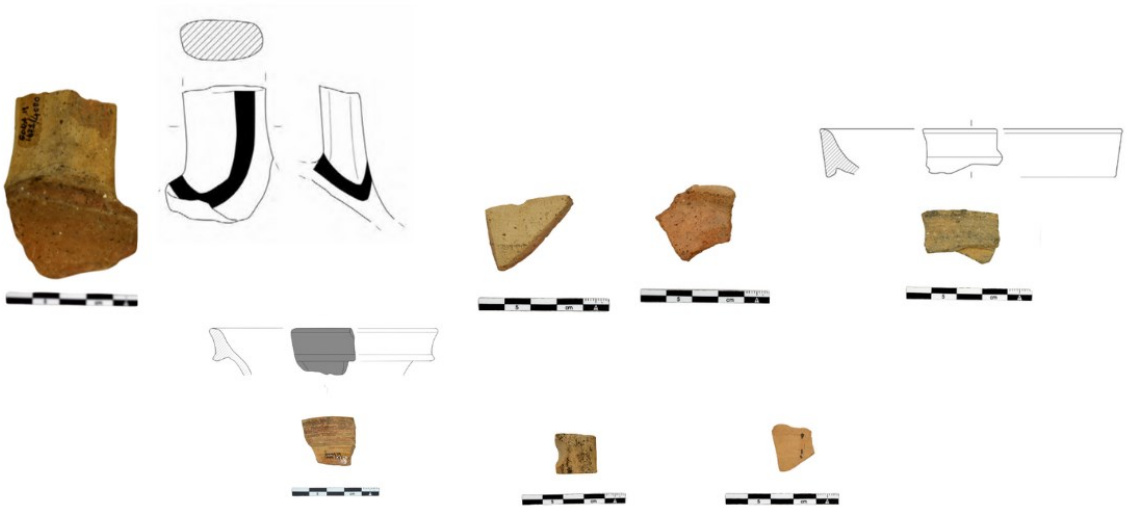


Figure 52. Olivine-bearing sherds. Top to bottom and left to right: G5 (*amphora*), G7 (*amphora*), G8 (lid), G10 (*hydria*), G11 (*hydria*), G13 (*hydria*), G27 (cup) and G44 (*oinochoe*).

5.3. HINTS INTO PROVENANCE AND POSSIBLE IMPORTS

The data acquired by this research was insufficient to fully determine the provenance of the analyzed material. However, the findings support the hypothesis of local ceramic production, which is evidenced by a close correspondence between the mineralogical composition of the ceramics and the geological profile of the Messara Plain and Gortyn.

As mentioned, the Messara is characterized by metamorphic rocks, marly limestones, and sandy and alluvial deposits (Amato et al, 2012), and Gortyn spans over a plain of marine sediments and an abundance of marls, clays, and silts, as well as metamorphic and sedimentary rocks. The ceramic samples here analyzed show mineral characteristics consistent with local clay sources, specifically calcite-rich clay, which align well with the mineralogy of clays occurring in this area. The presence of inclusions of quartz indicates the addition of sand as a temper; this can be observed particularly in petro-group 2, but also in the abundant inclusions of petro-group 1. This alignment suggests that the ceramics were likely made using local clay sources, following production practices rooted in the region's geological resources. Additionally, pottery production in the Messara has traditionally relied mainly on the use of local calcareous clays often tempered with sand (Liard, 2018, p. 739) — once more matching the petrographic composition of the analyzed sherds.

The data acquired by this analysis was also compared with the archaeometric research on two Cretan sites: Eleutherna and Priniàs (respectively Kotsonas, 2008; and Pautasso et al, 2021), in an effort to search for similarities or differences in the petrographic composition of Gortyn's ceramic material that may hint into possible exchanges between the cities. But while both researches have published the results of the scientific analysis made on the ceramic material uncovered by their excavations, the data is insufficient for a reliable comparison between the Gortyn's ceramics and the technology and petrographic composition of the material of these neighbor sites. In Eleutherna, for instance, the results of the thin section microscopy reported some petro-fabrics with similar inclusions as those found in the Gortyn samples, with the presence of inclusions of metamorphic rocks and clay pellets (Kotsonas, 2008, p. 348). Future work could properly compare the samples between the two locations to try to establish any possible correlations.

It is important to say that the data collected on this research was insufficient to conclude whether the 9 fragments that were considered as possible Knossian imports by the initial chrono-typological evaluation (Fig. 10, p. 46) can be indeed classified as so. The cluster analysis of the XRD data has not pointed out any particularity among the mineralogical composition of these samples that would place them in a separated cluster or as outliers. Therefore, the use of similar raw material, clay preparation and firing techniques impossibilities to distinguish these sherds archaeometrically, at least at the present moment of the research. Further analysis would have to be made to properly understand if the provenance of these samples is indeed different from the others — potentially, through the comparison of the data with geological references and petrographic databases from Knossos and/or other Cretan sites.

Finally, one last remark must be made in regard to sample G22, a fragment of an Orientalizing *kotyle*. Identified as an outlier on the cluster analysis made with the XRPD data of all 46 samples, as well as on the cluster analysis of the fine-grained sherds, the fragment seems to contain a particular mineralogical composition that makes it stand out among the others.

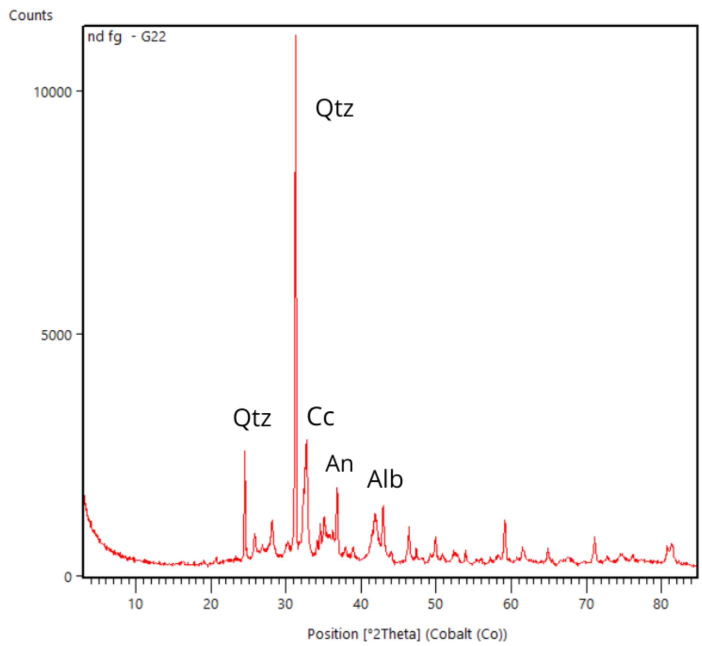


Figure 53. XRPD spectrum of sample G22. Mineral abbreviations: Qtz: quartz; Alb = albite; Cc = calcite; An = anorthite.

Three hypotheses can be raised to try to explain this pattern. Firstly, it is possible that this fragment is an import, explaining why it does not match the other fragments in terms of mineralogical composition. Alternatively, this outlier could be another indicative for the application of distinct ceramic recipes for particular vessel types. As this sample is the only fragment of *kotyle* analyzed archaeometrically, it is possible that the vessel was made following a particular ceramic recipe that would explain why its composition is distinct from that of the other sherds — once more pointing to the existence of typologically-driven ceramic recipes in Gortyn. Lastly, as the sample is from the Orientalizing period, it would once more point to the degree of experimentation led by cultural exchange of the time. It would be necessary, however, to compare this sample with others from the same type, period, and from different production sites to either confirm or refute the hypotheses.

Figure 54. Pictures and drawing of fragment G22.

5.4. SOCIAL IMPLICATIONS: NEW PERSPECTIVES ON THE EARLY URBAN LANDSCAPE OF GORTYN THROUGH THE ANALYSIS OF THE CERAMIC MATERIAL

In an effort to understand the connections between materiality, knowledge, and culture, it is useful to go back to the concept of *chaîne operatóire* to better address the relations between the results of this research with a broader scenario. Defined earlier in this work as the chain of actions and operations involved in pottery production from the selection of the raw materials to the production techniques (Leroi-Gourhan, 1964, p. 164), the *chaîne operatóire* approach can be used as a methodological framework to properly contextualize Gortyn's ceramic production within Crete's socio-economic and cultural landscape, as well as with the patterns of urban development of the city.

The continuities observed in the typological-driven ceramic recipes showcase an interesting pattern of transmission of knowledge throughout the centuries. The identification of specific recipes according to the typology of the material is an interesting find, as it informs of a techno-functional concern and the existence of specialized procedures to guarantee specific functions of the pots created (Santacreu, 2014, p. 180). As previously detailed, this find might hint into the existence of early specialized pottery workshops in Gortyn, which would point to a more complex social and economic structure within the community from the early stages of the city. Such organized production somehow aligns with a social structure in which knowledge transmission was systematic, ensuring the continuity and refinement of specialized pottery techniques. The persistence of these traditional typologically-driven ceramic techniques suggests a stable and continuous human activity with specific technological choices that may have become part of the community's identity and daily practices.

Important to say is that the results presented so far cannot state that the presence of Protogeometric and Geometric ceramic material in the plain of Gortyn would indicate an earlier transferring of the city’s nucleus from the hilltops to the lower region. But what can be inferred is that these peoples were meeting in the plain seasonally, potentially to discuss social and political matters or for ceremonial gatherings, while drinking and eating. Moreover, it is noticeable the stable transmission of ceramic knowledge identified could potentially be an indicative of the presence of a somehow consistent community and established production practice. This continuity could suggest that, even prior to the foundation of the sanctuary of Apollo *Pythios*, the settlements could have had skilled artisans, contributing to a proto-urban fabric that laid the groundwork for Gortyn’s later urban center. The use of consistent recipes reveals a strong attachment to established methods, potentially reflecting cultural values and technological skills tied to these production choices.

In connecting these findings back to the aims of this research, the work has illustrated that ceramic production in Gortyn was somehow embedded in cultural practice. By tracking the differences in ceramic production both chronologically and typologically, and through the *chaîne opératoire* framework, this study has contextualized Gortyn’s pottery tradition within a wider scenario of social and cultural characteristics. The existence of these somehow traditional technologies point to a consistent human presence in the region from early periods onwards, which implies that these practices were integral to the local community's way of life.

Conclusions

This extensive and multi analytical study made possible to integrate the analysis of the ceramic sherds — macroscopic typo-chronological evaluation, petrographic analysis through thin-section optical microscopy, mineralogical characterization through X-Ray Powder Diffraction, and chemical characterization through X-Ray Fluorescence — to the available literature and ongoing studies on the evolution of the city of Gortyn and the sanctuary of Apollo *Pythios*. By adopting a diachronic approach, it was possible to verify that the patterns of continuity attested on the typologically-driven ceramic recipes from the Protogeometric to the Archaic periods showcase a local tradition on the ceramic production. Additionally, it is possible to raise the question of whether this typological specialization could hint on the existence of common pottery workshops prior to the establishment of the city.

Nevertheless, the concept of *chaîne operatóire* enables one to draw connections between the technological patterns displayed on the ceramic material studied and the social framework in which they were crafted. As technology is viewed in this work as an indicative of cultural patterns and an outcome of generational knowledge transmission, it can be inferred that these ceramic traditions in Gortyn showcases a stable community that maintained ceramic practices across generations, reflecting a cohesive social identity grounded in shared techniques and materials. In this way, the ceramic study not only reconstructs technological continuity but also enriches our understanding of how social and economic spaces could have been arranged in early Gortyn, shaping the foundation for the later urban landscape.

A solid ground for future research and collaborations is built by this work. Further analysis specifically focused on answering the question of provenance could combine the petrographic characterization of the ceramic material excavated from the sanctuary of Apollo with those coming from other sites of Gortyn. For the Protogeometric and Geometric period this applies specially to ceramics from the settlement of Profitis Ilias and the hilltop *acropolis*. If the material found on the plain displays the same composition as the one on the hilltop's settlements, it can hint onto a degree of connection between both sites. On the other hand, a low correlation between the material from the two sites could imply a degree of independence between the plain and hilltop communities — hence answering the question on whether there was a local workshop elsewhere.

Similar reasonings can be made regarding the Orientalizing and Archaic fragments. It would be noteworthy comparing them with the ceramics of the sanctuary of Athena on the hilltop *acropolis* and especially with the ceramics coming from the workshop area pit, establishing links or distinguishing them in terms of fabric and petrographic composition.

Additionally, a comparison with databases of ceramic and clay petrography available in facilities such as the INSTAP laboratories could be proven useful to understand patterns of economic exchange and socio-cultural interaction between the different regions of Crete. Finally, future research could expand the range of methodology applied on the ceramic material, selecting more samples for thin section and XRF analysis or using other methods such as Scanning Electron Microscopy (SEM) to acquire further information on the composition and production technology of the pottery sherds.

As these results corresponded to the first application of archaeometric methods on the ceramic material from Gortyn, this work is essential in providing the initial framework to expand the current understanding of the city's urban evolution. Considering the role of Gortyn in Crete's political, social, and cultural history, understanding its early dynamics and spatial organization is crucial to enhance the archaeological knowledge on the island. In that sense, the study of the ceramic material was of prime importance on disclosure of the city's technological expertise, cultural dynamics, and patterns of knowledge transmission, from its early times until its centralization around the sanctuary of Apollo.

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Appendix

APPENDIX 1: Catalogue of the macroscopic characterization of the 46 sherds archaeometrically analysed

Fragment G1

Excavation number: GONA19 1664/3314
Macrofabric description: local, gray with white inclusions of small dimensions and black inclusions of medium dimensions
Specific chronology: Protogeometric
color: pale brown 10YR 6/3
Function: fast pouring vessel
Shape: *hydria*
Part: rim
Hardness: soft
Fracture: no core
Weight (g): 9.15
Size (cm): 4.1 x 2,1 x 0.8
Feel: very rough
Inclusions: some pores, white inclusions, mica, quartz, oxide. Rounded and fairily distributed.
Macrofabric: dark colored coarse A

Figure 55. Picture and drawing of fragment G1.

Fragment G2

Excavation number: GONA19 1663/3216
Macrofabric description: gray, white, and black inclusions of various dimensions
Specific chronology: Orientalizing/Archaic
color: light yellowish brown 10YR 6/4
Function: vessel for eating and drinking
Shape: *lekane*
Part: rim and wall
Hardness: hard
Fracture: no core
Weight (g): 61.11
Size (cm): 9 x 4.2 x 1.2
Feel: rough
Inclusions: abundance of inclusions; quartz, oxide, and white inclusions. Poorly sorted and rounded, angular, and sub-angular.
Macrofabric: very coarse

Figure 56. Picture of fragment G2.

Fragment G3

Excavation number: GONA19 1649/3591
Macrofabric description: gray with few white inclusions of small dimensions and numerous black and dark inclusions of medium dimensions, slight presence of silver mica
Specific chronology: nd
color: light brown 7.5YR 6/4
Function: kitchen ware
Shape: cooking jug
Part: bottom
Hardness: soft
Fracture: no core
Weight (g): 22.62
Size (cm): 4.3 x 4,4 x 0.8
Feel: rough with a sandy feel
Inclusions: very coarse quartz and oxide, mica, and pores. Poorly sorted and rounded.
Macrofabric: dark colored coarse A

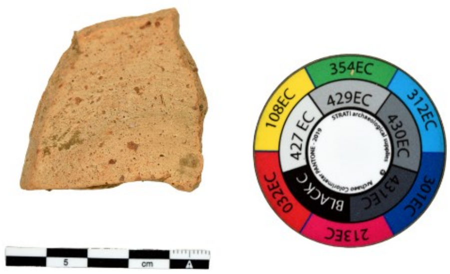


Figure 57. Picture of fragment G3.

Fragment G4

Excavation number: GONA19 1663/3215
Macrofabric description: gray, white, and black inclusions of various dimensions
Specific chronology: Orientalizing/Archaic
color: light brownish gray 10YR 6/2
Function: storage vessel
Shape: *pithos*
Part: vertical handle
Hardness: soft
Fracture: no core
Weight (g): > 65
Size (cm): 9 x 5.1 x 3.2
Feel: rough
Inclusions: quartz, oxide, white inclusions. Poorly sorted, rounded and elongated.
Macrofabric: very coarse

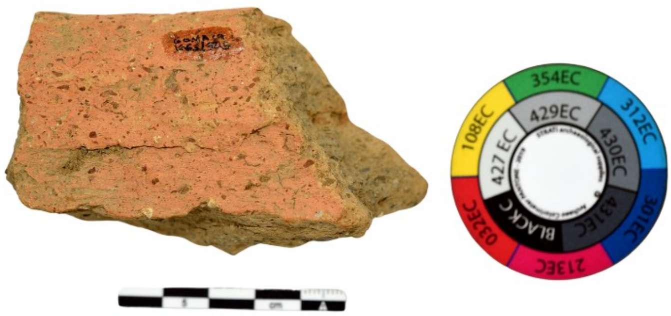


Figure 58. Picture of fragment G4.

Fragment G5

Excavation number: GONA19 1631/4000
Macrofabric description: gray with numerous white and brown inclusions of small, medium and big dimensions
Specific chronology: Protogeometric
color: strong brown 7.5 YR 5/6
Function: storage vessel
Shape: *amphora*
Part: vertical handle and wall, with traces of burning
Hardness: soft
Fracture: no core
Weight (g): 60
Size (cm): 6.3 x 4.4 x 1x8
Feel: smooth
Inclusions: abundant white inclusions, mica, and oxides. Poorly sorted and rounded, with few sub-angular.
Macrofabric: very coarse

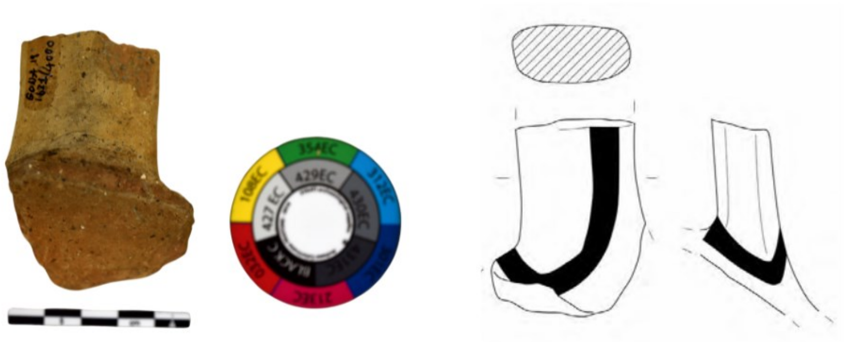


Figure 59. Picture of fragment G5.

Fragment G6

Excavation number: GONA19 1631/4004 + 4021
Macrofabric description: medium coarse with white, brown, and black inclusions of small and medium dimensions
Specific chronology: Protogeometric
color: light yellowish brown 10YR 6/4
Function: storage vessel
Shape: *amphora*
Part: wall
Hardness: soft
Fracture: no core
Weight (g): 20
Size (cm): 6.4 x 3x5 x 0x7
Feel: rough
Inclusions: quartz, gray inclusions, and pores. Good sorted and rounded.
Macrofabric: light colored coarse B

Figure 60. Picture and drawing of fragment G6.

Fragment G7

Excavation number: GONA19 1631/4020
Macrofabric description: medium coarse with white and brown inclusions of medium dimension
Specific chronology: Protogeometric
color: light brown 7.5YR 6/4
Function: storage vessel
Shape: unknown
Part: wall
Hardness: soft
Fracture: no core
Weight (g): 5.05
Size (cm): 3.4 x 2.5 x 0.6
Feel: smooth
Inclusions: gray and white inclusions, quartz and oxides. Good sorted and rounded/alongated.
Macrofabric: light colored coarse B

Figure 61. Picture of fragment G7.

Fragment G8

Excavation number: GONA19 1631/4148
Macrofabric description: medium coarse with white, brown, and black inclusions of small and medium dimensions; rare golden mica
Specific chronology: nd
color: reddish yellow 7.5 YR 6/6
Function: table ware
Shape: lid
Part: rim
Hardness: soft
Fracture: no core
Weight (g): 6.95
Size (cm): 3 x 3 x 0.7
Feel: soft
Inclusions: oxides, quartz, and gray inclusions. Very poorly sorted and angular/sub-angular.
Macrofabric: orange coarse

Figure 62 Picture of fragment G8.

Fragment G9

Excavation number: GONA19 1664/3335
Macrofabric description: coarse
Specific chronology: nd
color: reddish yellow 5YR 6/8
Function: figurine
Shape: handmade form
Part: nd
Hardness: soft
Fracture: no core
Weight (g): 24.87
Size (cm): 5 x 4.9 x 0.9
Feel: rough
Inclusions: coarse quartz, white inclusions, oxide, and abundant pores. Good sorted and rounded.
Macrofabric: pink coarse

Figure 63. Picture of fragment G9.

Fragment G10

Excavation number: GONA19 1634/3315
Macrofabric description: medium coarse local with white inclusions of small dimension and black inclusions of medium dimension, *stracotto*
Specific chronology: Protogeometric
color: pale brown 10YR 6/3
Function: fast pouring vessel
Shape: *hydria*
Part: rim
Hardness: soft
Fracture: no core
Weight (g): 5.24
Size (cm): 6.4 x 3x5 x 0x7
Macrofabric: dark colored coarse B

Figure 64. Picture and drawing of fragment G10.

Fragment G11

Excavation number: GONA19 1664/4172
Macrofabric description: gray, white and black inclusions of medium dimension
Specific chronology: Geometric
color: dark gray 10YR 4/1
Function: fast pouring vessel
Shape: *hydria*
Part: base
Hardness: soft
Fracture: no core
Weight (g): 4.36
Size (cm): 3.1 x 2.3 x 0.5
Feel: smooth
Inclusions: very coarse quartz, oxide, white inclusions. Fairly sorted and rounded, angular, and sub-angular.
Macrofabric: dark colored coarse B

Figure 65. Picture and drawing of fragment G11.

Fragment G12

Excavation number: GONA19 1641/4037
Macrofabric description: medium coarse with brown inclusions of medium dimensions
Specific chronology: Protogeometric
color: light yellowish brown 10YR 6/4
Function: storage vessel
Shape: *krater*
Part: wall
Hardness: soft
Fracture: no core
Weight (g): 3.1
Size (cm): 1.6 x 2.9 x 0.5
Feel: smooth
Inclusions: very coarse oxide, course quartz, and some pores. Fairly sorted and rounded/sub-rounded.
Macrofabric: dark colored coarse A

Figure 66. Picture and drawing of fragment G12.

Fragment G13

Excavation number: GONA19 1649/3629
Macrofabric description: semi fine with small white and black inclusions
Specific chronology: Protogeometric/Geometric
color: brown 10YR 5/3
Function: storage vessel
Shape: *hydria*
Part: rim, encounter between neck and wall with small line on the joining point.
Hardness: soft
Fracture: no core
Weight (g): 6.85
Size (cm): 2.7 x 2.8 x 0.5
Feel: smooth
Inclusions: one very coarse grain of mica, gray and white inclusions. Fairly sorted and rounded and sub-angular.
Macrofabric: dark colored coarse B

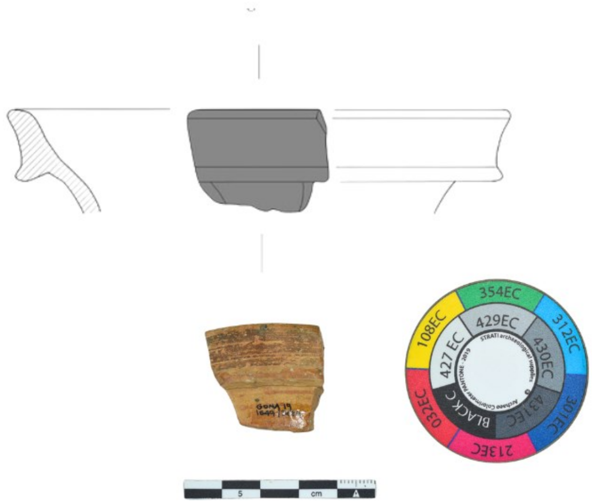


Figure 67. Picture and drawing of fragment G13.

Fragment G14

Excavation number: GONA19 1649/3593
Macrofabric description: gray with brown inclusions of small dimensions and silver mica
Specific chronology: unknown
color: reddish yellow 7.5YR 6/6
Function: kitchen ware
Shape: cooking jug
Part: bottom
Hardness: soft
Fracture: no core
Weight (g): 19.27
Size (cm): 3.1 x 4.7 x 0.9
Feel: rough
Inclusions: quartz, gray inclusions, mica and one very coarse oxide. Fairly sorted and rounded.
Macrofabric: light colored coarse B

Figure 68. Picture of fragment G14.

Fragment G15

Excavation number: GONA19 1641/3635
Macrofabric description: fine with rare inclusions of medium and small dimensions, white and brown
Specific chronology: Orientalizing
color: light brown 7.5YR 6/4
Function: fast pouring vessel
Shape: *oinochoe*
Part: wall
Hardness: soft
Fracture: no core
Weight (g): 14.29
Feel: smooth
Inclusions: some coarse white inclusions. Fairly sorted and rounded
Macrofabric: light colored coarse A

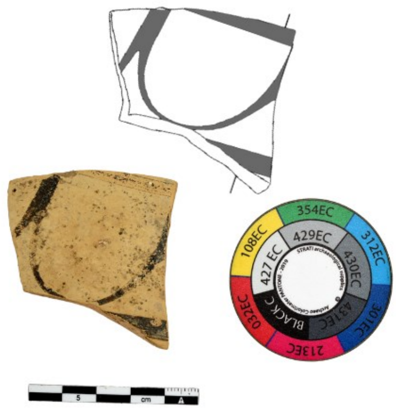


Figure 69. Picture and drawing of fragment G15.

Fragment G16

Excavation number: GONA19 1631/4382
Macrofabric description: fine with numerous inclusions of small and medium dimensions, white, brown and black
Specific chronology: Protogeometric
color: light yellowish brown 10YR 6/4
Function: storage vessel
Shape: *amphora*
Part: wall
Hardness: soft
Fracture: no core
Weight (g): 1.48
Feel: rough
Inclusions: quartz, oxides, and white inclusions. Fairly sorted and angular.
Macrofabric: light colored coarse A

Figure 70. Picture and drawing of fragment G16.

Fragment G17

Excavation number: GONA19 1649/4207
Macrofabric description: medium coarse with white and black inclusions of medium dimensions
Specific chronology: Geometric
color: light brown 7.5YR 6/4
Function: storage vessel
Shape: *krater*
Part: wall
Hardness: soft
Fracture: oxidized
Weight (g): 8.37
Size: 4 x 3.3 x 0.8
Feel: rough
Inclusions: quartz, gray inclusions, and mica. Rounded.
Macrofabric: dark colored coarse A

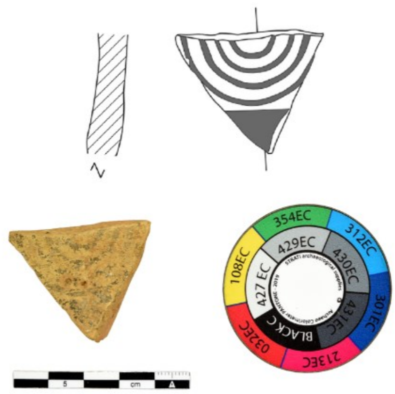


Figure 71. Picture and drawing of fragment G17.

Fragment G18

Excavation number: GONA19 1631/4146
Macrofabric description: medium coarse with brown and white inclusions of small and medium size, silver mica
Specific chronology: nd
color: yellowish red 5YR 5/6
Function: table ware
Shape: lid
Part: rim
Hardness: soft
Fracture: no core
Weight (g): 3.26
Size: 1.9 x 2.2 x 0.5
Feel: smooth, slightly rough
Inclusions: quartz, oxide, some mica. Fairly sorted and rounded.
Macrofabric: orange coarse

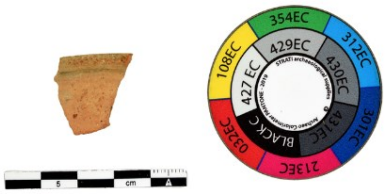


Figure 72. Picture of fragment G18.

Fragment G19

Excavation number: GONA19 1631/4381 + 4001 + 4380
Macrofabric description: fine grained
Specific chronology: nd
color: light brown 7.5YR 6/4
Function: storage vessel
Shape: closed form
Part: wall
Hardness: soft
Fracture: no core
Weight (g): 21
Feel: smooth
Inclusions: pores, which inclusions. Sub-angular and sub-rounded.
Macrofabric: light semi fine

Figure 73. `Picture of fragment G19.

Fragment G20

Excavation number: GONA19 1649/3590
Macrofabric description: fine with rare brown inclusions, silver mica
Specific chronology: Orientalizing
color: reddish yellow 7.5YR 7/6
Function: fast pouring vessel
Shape: *oinochoe*
Part: bottom
Hardness: soft
Fracture: no core
Weight (g): 5.76
Size: 3.7 x 2.7 x 0.4
Feel: smooth
Inclusions: white inclusions, some coarse pores (d = 0.242mm). Rounded.
Macrofabric: light semi fine

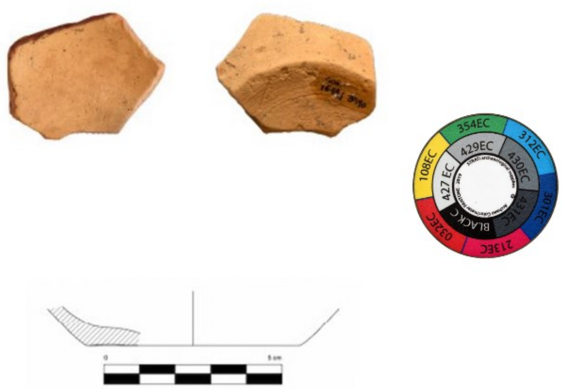


Figure 74. Picture and drawing of fragment G20.

Fragment G21

Excavation number: GONA19 1631/3986
Macrofabric description: fine with rare white and brown inclusions of small and medium dimensions
Specific chronology: nd
color: pale brown 10YR 6/3
Function: pouring vessel
Shape: *hydria*
Part: rim
Hardness: soft
Fracture: no core
Weight (g): 7.51
Size: 3.4 x 4 x 0.9
Feel: rough
Inclusions: quartz, oxides, white inclusions. Rounded and sub-rounded.
Macrofabric: dark semi fine

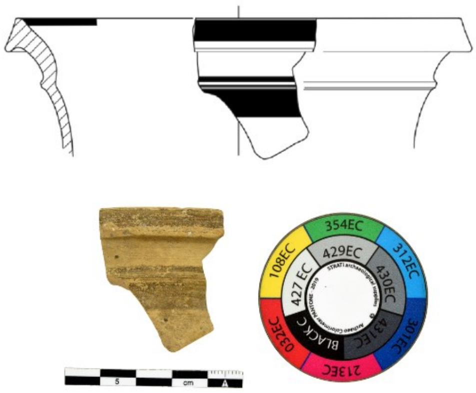


Figure 75. Picture and drawing of fragment G21.

Fragment G22

Excavation number: GONA19 1631/4008 + 4030 + 4012 + 4017
Macrofabric description: fine grained
Specific chronology: Orientalizing
color: brownish yellow 10YR 6/6
Function: vessel for eating and drinking
Shape: *kotyle*
Part: three wall fragments and one rim fragments with an attached handle
Hardness: soft
Fracture: oxidized with little core
Weight (g): 5
Feel: smooth
Inclusions: coarse gray inclusions, white inclusions. Rounded
Macrofabric: light fine

Figure 76. Picture and drawing of fragment G22.

Fragment G23

Excavation number: GONA19 1664/3373
Macrofabric description: fine grained
Specific chronology: Orientalizing
color: pink 7.5YR 7/4
Function: fast pouring vessel
Shape: *oinochoe*
Part: bottom
Hardness: soft
Fracture: no core
Weight (g): 7.46
Size: 5.6 x 3.7 x 0.4
Feel: smooth
Inclusions: few white inclusions and pores. Good sorting and rounded.
Macrofabric: light fine

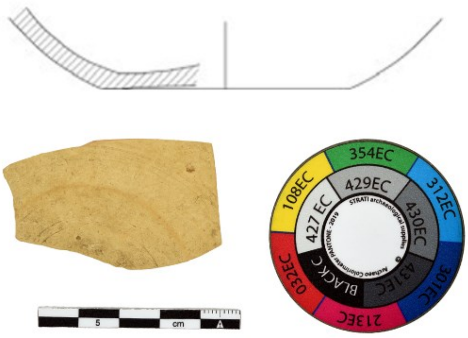


Figure 77. Picture and drawing of fragment G23.

Fragment G24

Excavation number: GONA19 1649/3592
Macrofabric description: fine grained
Specific chronology: Geometric
color: reddish yellow 7.5YR 7/6
Function: fast pouring vessel
Shape: *oinochoe*
Part: bottom
Hardness: soft
Fracture: no core
Weight (g): 7
Size: 4.6 x 2.7 x 0.3
Feel: smooth
Inclusions: pores, few white inclusions. Sub-rounded.
Macrofabric: light fine

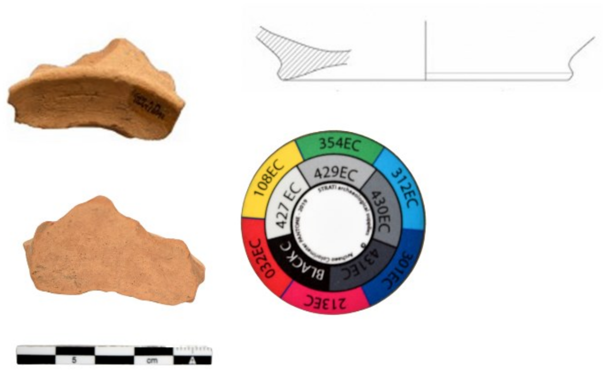


Figure 78. Picture of fragment G24.

Fragment G25

Excavation number: GONA19 1663/3204
Macrofabric description: fine grained, rare golden and silver mica
Specific chronology: Geometric
color: pale yellow 2.5YR 7/3
Function: fast pouring vessel
Shape: *oinochoe*
Part: bottom
Hardness: soft
Fracture: no core
Weight (g): 6.27
Size: 2.6 x 4.1 x 0.8
Feel: smooth
Inclusions: some white inclusions, oxide, some pores. Rounded
Macrofabric: light brown fine

Figure 79. Picture of fragment G25.

Fragment G26

Excavation number: GONA19 1276 + 1282/4384
Specific chronology: nd
Function: table ware
Shape: cup
Part: two rims, one handle and one wall
Hardness: soft
Fracture: no core
Weight (g): 60
Feel: smooth
Inclusions: some mica, a void left by the decomposition of an organic remain. Rounded.
Macrofabric: medium orange fine

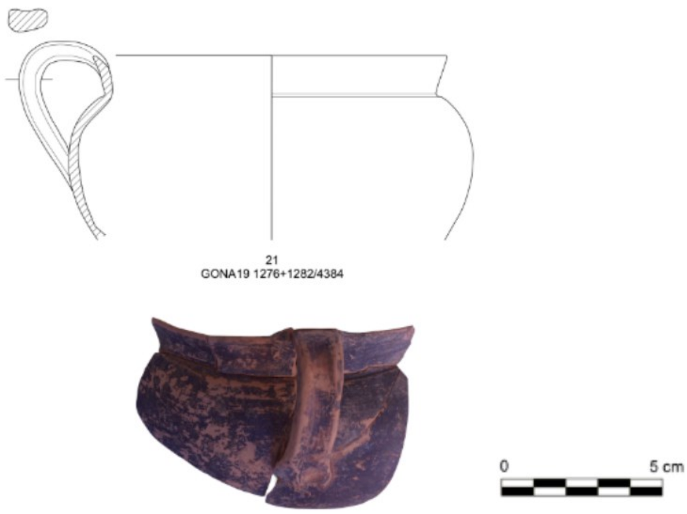


Figure 80. Picture and drawing of fragment G26.

Fragment G27

Excavation number: GONA19 1649/3514
Macrofabric description: fine grained
Specific chronology: nd
color: reddish yellow 7.5YR 7/6
Function: vessel for eating and drinking
Shape: cup
Part: handle
Hardness: hard
Fracture: no core
Weight (g): 2.56
Size: 2 x 1.9 x 0.6
Feel: smooth
Inclusions: quartz, mica, white inclusions. Rounded.
Macrofabric: light brown fine

Figure 81. Picture of fragment G27.

Fragment G28

Excavation number: GONA19 1655/4212
Macrofabric description: fine grained, rare light brown/greenish to dark brown inclusions; small white and black inclusions
Specific chronology: nd
color: light brown greenish to light brown
Function: storage vessel
Shape: *amphora*
Part: wall
Hardness: soft
Fracture: little core
Weight (g): 7.17
Size: 4.6 x 2.7 x 0.3
Feel: smooth
Inclusions: oxide, some white inclusions. Fairly sorted and rounded.
Macrofabric: light brown medium coarse B

Figure 82. Picture of fragment G28.

Fragment G29

Excavation number: GONA19 1649/3533
Macrofabric description: fine with silver mica
Specific chronology: Orientalizing
color: reddish yellow 7.5YR 7/6
Function: fast pouring vessel
Shape: *oinochoe*
Part: wall
Hardness: soft
Fracture: no core
Weight (g): 4.52
Size: 3.6 x 2.7 x 0.6
Feel: slightly rough
Inclusions: abundance of white inclusions, pores. Sub-rounded.
Macrofabric: light fine

Figure 83. Picture and drawing of fragment G29.

Fragment G30

Excavation number: GONA19 1631/3994 + 4101
Macrofabric description: fine grained
Specific chronology: nd
color: grayish brown 10YR 5/2
Function: lid
Shape: shield
Part: wall
Hardness: soft
Fracture: no core
Weight (g): 2.6
Feel: smooth
Inclusions: some white inclusions and pores. Sub-rounded and rounded.
Macrofabric: dark fine

Figure 84. .Picture of fragment G30

Fragment G31

Excavation number: GONA19 1631/3985
Macrofabric description: fine grained
Specific chronology: Protogeometric
color: graywish brown 10YR 5/2
Function: table ware
Shape: lid
Part: rim
Hardness: soft
Fracture: no core
Weight (g): 7.68
Size: 4.1 x 1.9 x 1
Feel: smooth
Inclusions: mica, pores, some white inclusions. Rounded
Macrofabric: dark fine

Figure 85. Picture of fragment G30

Fragment G32

Excavation number: GONA19 1649/3553
Macrofabric description: fine with rare white inclusions
Specific chronology: Orientalizing
color: reddish yellow 7.5YR 7/6
Function: fast pouring vessel
Shape: *oinochoe*
Part: wall
Hardness: hard
Fracture: no core
Weight (g): 1.77
Size: 2.2 x 1.4 x 0.4
Feel: smooth
Inclusions: white inclusions, some gray inclusions. Rounded
Macrofabric: light fine

Figure 86. Picture and drawing of fragment G32.

Fragment G33

Excavation number: GONA19 1649/3571 + 3541
Macrofabric description: fine with silver mica
Specific chronology: Orientalizing
color: reddish yellow 7.5YR 7/6
Function: fast pouring vessel
Shape: *oinochoe*
Part: wall
Hardness: soft
Fracture: no core
Weight (g): 4.89
Feel: smooth
Inclusions: white inclusions, and pores. Sub-rounded and sub-angular.
Macrofabric: light fine

Figure 87. Picture and drawing of fragment G33.

Fragment G34

Excavation number: GONA19 1631/3997
Macrofabric description: fine grained
Specific chronology: Orientalizing
color: brownish yellow 10YR 6/6
Function: fast pouring vessel
Shape: *hydria*
Part: rim
Hardness: hard
Fracture: no core
Weight: < 1
Size: 2.5 x 2.6 x 0.5
Feel: smooth
Inclusions: white inclusions and oxide. Rounded and sub-angular.
Macrofabric: medium brown fine

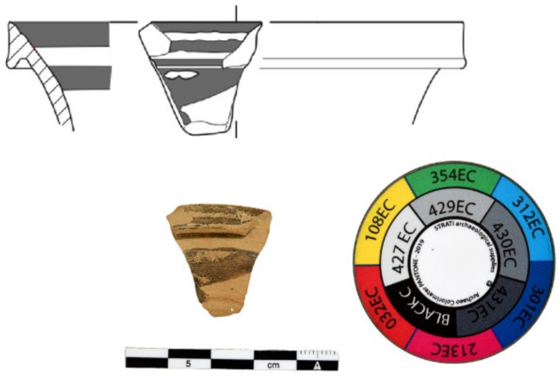


Figure 88. Picture and drawing of fragment G34.

Fragment G35

Excavation number: GONA19 1640/2842
Macrofabric description: fine with silver mica
Specific chronology: Geometric
color: light yellowish brown 10YR 6/4
Function: vessel for eating and drinking
Shape: bell *skyphos*
Part: wall
Hardness: hard
Fracture: no core
Weight (g): 3.16
Size: 1.6 x 2.1 x 0.3
Feel: rough
Inclusions: white inclusions, pores. Sub-rounded
Macrofabric: light brown fine

Figure 89. Picture and drawing of fragment G35.

Fragment G36

Excavation number: GONA19 1663/3177
Macrofabric description: fine grained
Specific chronology: Orientalizing
color: very pale brown 10YR 7/4
Function: lid/shield
Shape: *oinochoe*
Part: wall
Hardness: soft
Fracture: some core
Weight (g): 2.02
Size: 2.4 x 2,1 x 0.5
Feel: smooth
Inclusions: white inclusions, oxides, abundant pores. Very good sorting, rounded.
Macrofabric: light fine

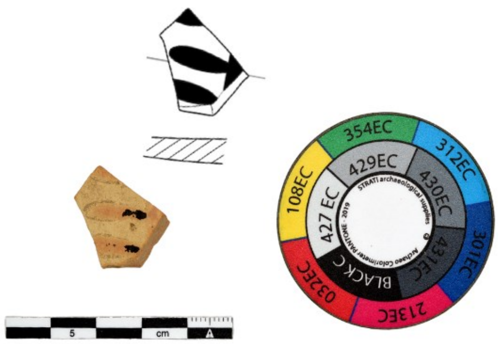


Figure 90. Picture and drawing of fragment G36.

Fragment G37

Excavation number: GONA19 1649/3567 + 3562 + 3670
Macrofabric description: fine grained
Specific chronology: Orientalizing
color: reddish yellow 7.5YR 6/6
Function: fast pouring vessel
Shape: *oinochoe*
Part: bottom
Hardness: soft
Fracture: no core
Weight (g): 7.7
Feel: smooth
Inclusions: white inclusions, oxides, pores. A coarse white inclusion in the core. Sub-rounded.
Macrofabric: light fine

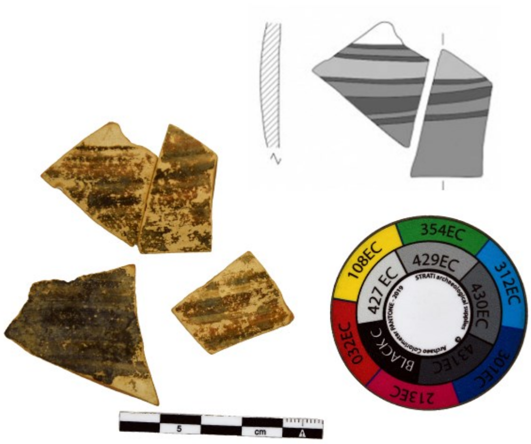


Figure 91. Picture and drawing of fragment G37.

Fragment G38

Excavation number: GONA19 1635/4187
Macrofabric description: fine, silver mica
Specific chronology: Geometric
color: very pale brown 10YR 7/4
Function: fast pouring vessel
Shape: *oinochoe*
Part: wall
Hardness: hard
Fracture: no core
Weight (g): 2.25
Size: 2.8 x 2.7 x 0.3
Feel: smooth
Inclusions: oxides, gray inclusions, and pores. Rounded.
Macrofabric: light fine

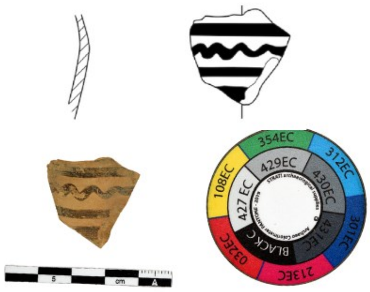


Figure 92. Picture and drawing of fragment G38.

Fragment G39

Excavation number: GONA19 1663/3217
Macrofabric description: fine grained
Specific chronology: Orientalizing
color: reddish yellow 7.5YR 7/6
Function: vessel for eating and drinking
Shape: cup
Part: rim
Hardness: soft
Fracture: no core
Weight (g): 3.11
Size: 3.6 x 2.5 x 0.3
Feel: smooth
Inclusions: white inclusions particularly elongated, gray inclusions and oxides. Rounded/Sub-angular.
Macrofabric: light fine

Figure 93. Picture of fragment G39.

Fragment G40

Excavation number: GONA19 1649/3508
Macrofabric description: fine grained
Specific chronology: nd
color: light brown
Function: fast pouring vessel
Shape: *oinochoe*
Part: handle
Hardness: soft
Fracture: no core
Weight (g): 4.32
Size: 2.4 x 2.4 x 0.6
Feel: smooth
Inclusions: pores and white inclusions. Rounded.
Macrofabric: light fine

Figure 94. Picture and drawing of fragment G40.

Fragment G41

Excavation number: GONA19 1635/4185 + 3518
Macrofabric description: fine grained
Specific chronology: Geometric
color: light brown 7.5YR 6/4
Shape: *pixide*
Part: rim of a plate and wall
Hardness: hard
Fracture: no core
Weight (g): 6.4
Size: 1.9 x 2.3 x 0.4
Feel: smooth
Inclusions: some white inclusions. Rounded.
Macrofabric: light fine

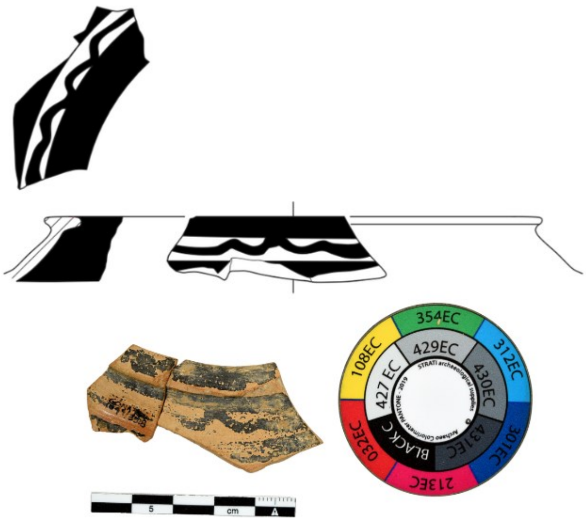


Figure 95. Picture and drawing of fragment G41.

Fragment G42

Excavation number: GONA19 1649/3526
Macrofabric description: fine with silver mica.
Specific chronology: Orientalizing
color: dark orange
Function: fast pouring vessel
Shape: *oinochoe*
Part: wall
Hardness: soft
Fracture: no core
Weight (g): 4.26
Size: 3.5 x 3.4 x 0.3
Feel: very smooth
Inclusions: one coarse white inclusions, mica, some pores. Good sorting, rounded.
Macrofabric: light fine B

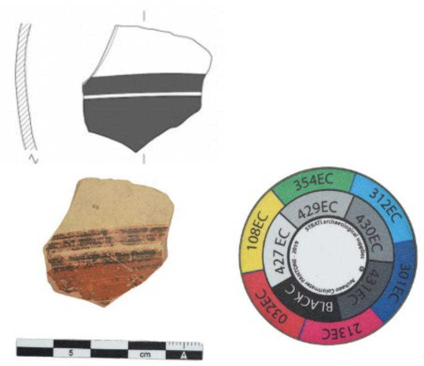


Figure 96. Picture and drawing of fragment G42.

Fragment G43

Excavation number: GONA19 1631/4055 + 4070 + 4369 + 4061
Macrofabric description: fine, *stracotto*.
Specific chronology: Orientalizing
color: grayish brown 10YR 5/2
Shape: shield
Part: rim and wall
Hardness: soft
Fracture: reduced
Weight (g): 15
Feel: smooth
Inclusions: some mica, one coarse white inclusion. Good sorting and sub-angular.
Macrofabric: dark fine

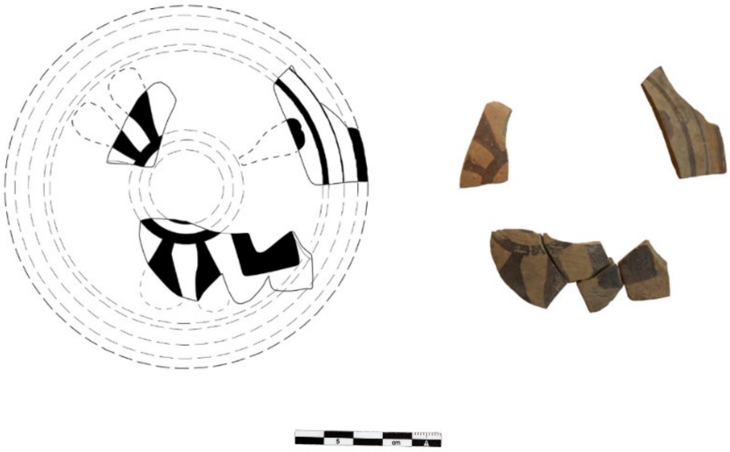


Figure 97. Picture and drawing of fragment G43.

Fragment G44

Excavation number: GONA19 1635/4193
Macrofabric description: fine, rare silver mica.
Specific chronology: nd
color: brown
Function: fast pouring vessel
Shape: *oinochoe*
Part: wall
Hardness: soft
Fracture: oxidized with some core
Weight (g): 1.36
Size: 2.1 x 1.6 x 0.4
Feel: smooth
Inclusions: some white inclusions and pores, oxides. Sub-angular.
Macrofabric: light fine

Figure 98. Picture of fragment G44.

Fragment G45

Excavation number: GONA19 1649/3569
Macrofabric description: fine grained.
Specific chronology: Orientalizing
color: light yellowish brown 10YR 6/4
Function: fast pouring vessel
Shape: *oinochoe*
Part: wall
Hardness: hard
Fracture: no core
Weight (g): 1.69
Size: 2.4 x 1.7 x 0.5
Feel: smooth
Inclusions: white inclusions, some pores, oxides. Rounded.
Macrofabric: light fine

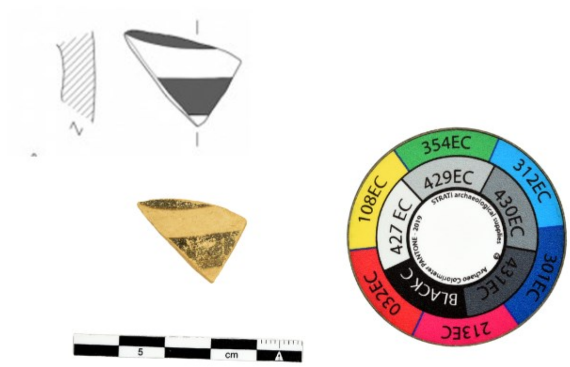


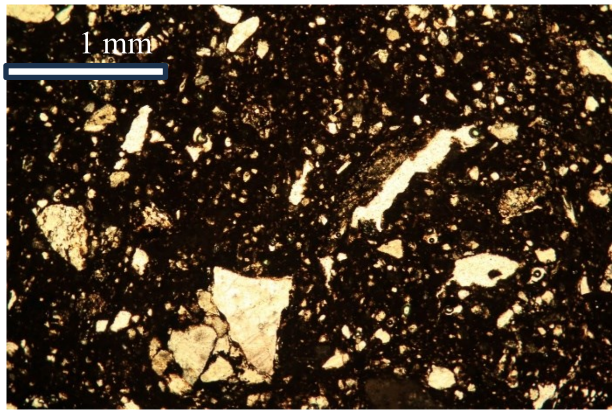
Figure 99. Picture and drawing of fragment G45.

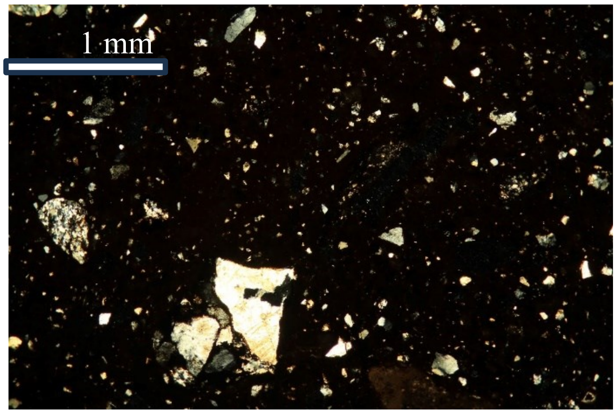
Fragment G46

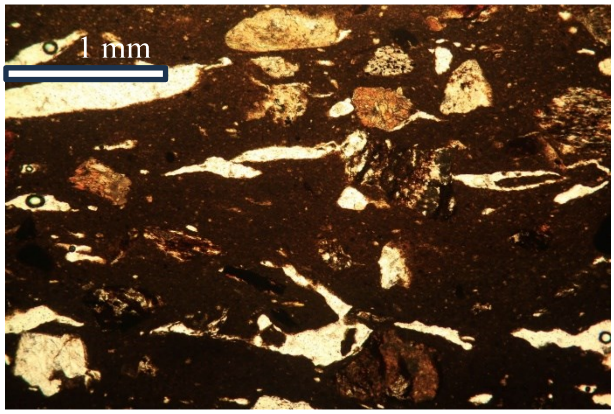
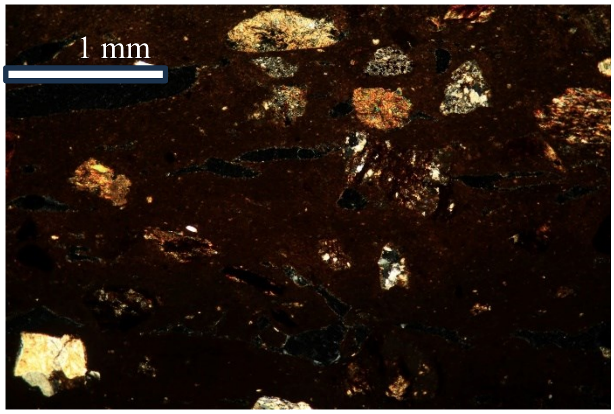
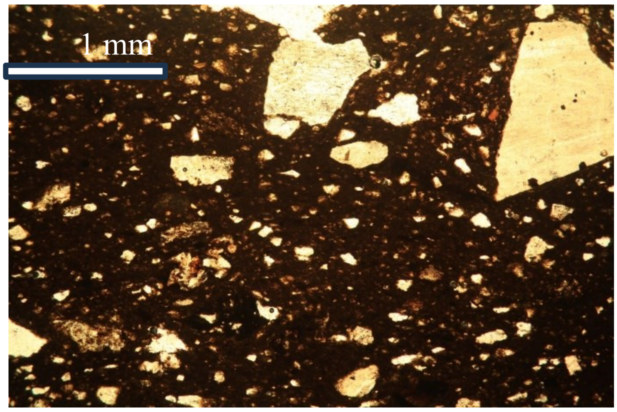
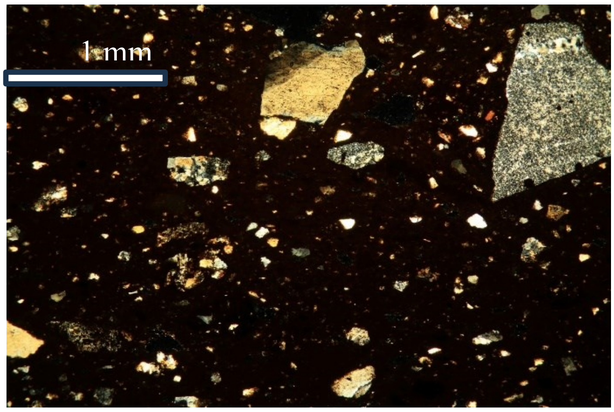
Excavation number: GONA19 1649/3575
Macrofabric description: fine with silver mica
Specific chronology: Orientalizing
color: light red 2.5YR 7/8
Function: slow pouring vessel
Shape: *lekythos*
Part: wall
Hardness: soft
Fracture: no core
Weight (g): 1.03
Size: 2.2 x 1.5 x 0.3
Feel: smooth
Inclusions: white inclusions, some gray inclusions, mica. Rounded.
Macrofabric: light fine

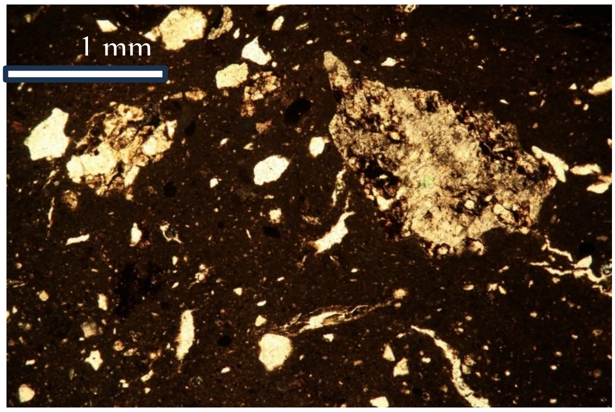
Figure 100. Picture and drawing of fragment G46.

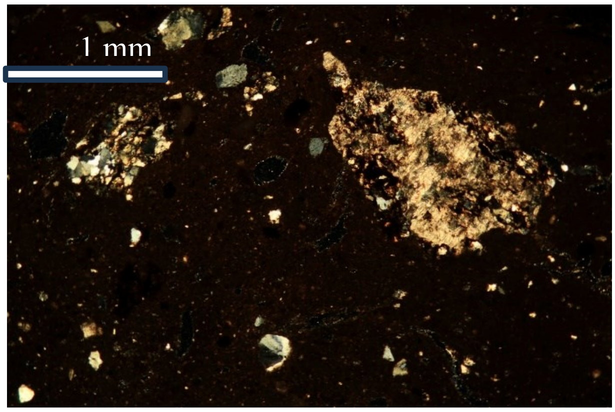
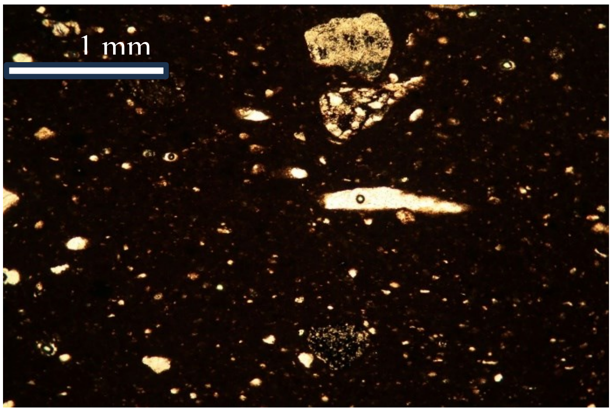
APPENDIX 2: Catalogue with the description of the thin sections

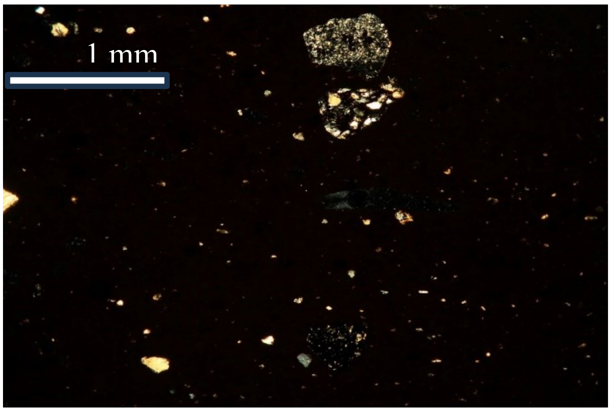
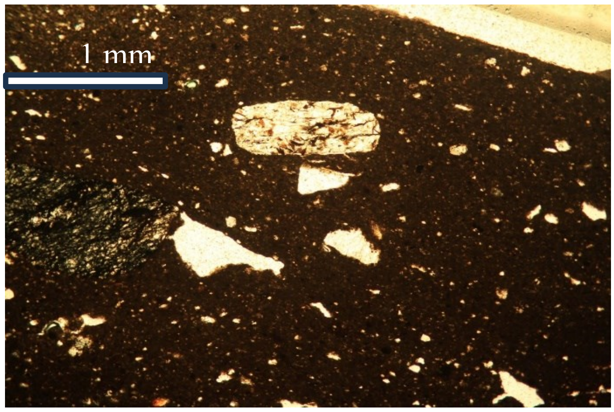
<table>
<tr><th>ID</th><th>PETRO-GROUP</th><th>C:f ratio</th><th>C:f quantity</th><th>Optical state</th><th>Inclusion types</th></tr>
<tr><td>G1</td><td>1a</td><td>Single space distribution</td><td>25 - 30%</td><td>Optically inactive</td><td>Quartz-made sandstone, carbonatic rock, micritic limestone, metamorphic rock, claystone, siltstone, opaque mineral (hematite, magnetite, oxides…), one small bone.</td></tr>
<tr><td colspan="3">

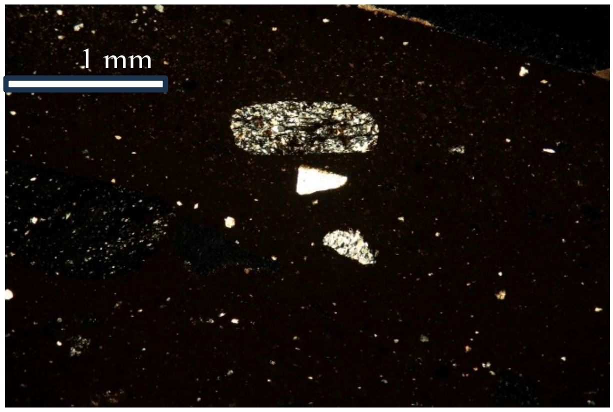
Photomicrograph of sample G1 in PPL (left) and XPL (right), in 5x magnification.</td><td colspan="3">
</td></tr>
<tr><td>G2</td><td>2a</td><td>Double-spaced distribution</td><td>5 - 10%</td><td>Optically active</td><td>metamorphic rocks, yellowish limestone (probably due to a lower firing temperature), biotite, muscovite, chlorite undergoing transformation, mudstone, siltstone, carbonates, and metapellites. It is is characterized by segments of argillicious matrix with little adding of sand into the paste.</td></tr>
</table>

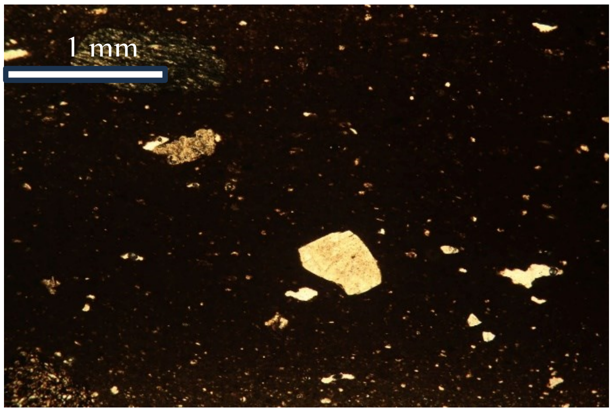
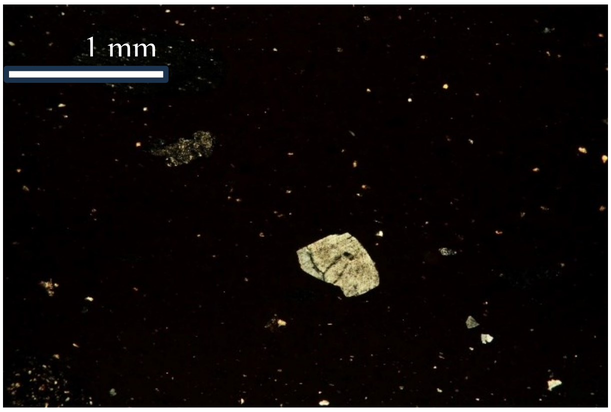
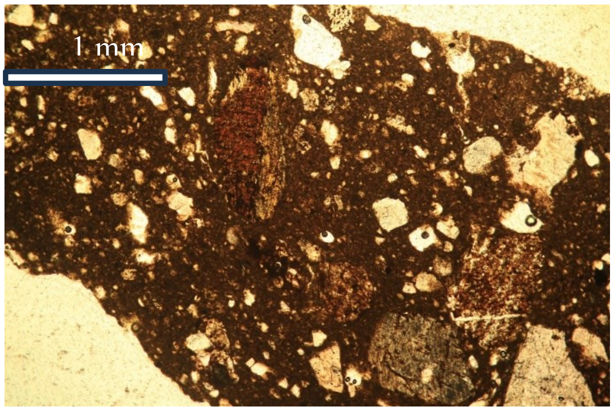
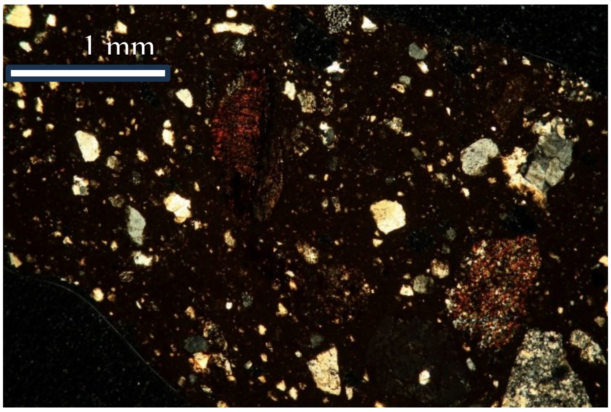
 Photomicrograph of sample G2 in PPL (left) and XPL (right), in 5x magnification.					
G3	1b	Single-space distribution	25%	Optically inactive	It was possible to verify the presence of a large fragment of chert, metamorphic quartz, oxide, and sandstone.
 Photomicrograph of sample G3 in PPL (left) and XPL (right), in 5x magnification.					
G4	2a	Double-space distribution	5 - 10%	Optically active	It was possible to identify the presence of sedimentary and metamorphic rocks, with inclusions of quartz, siltstone, carbonatic rock with some claystone, calcite, micritic limestone and spiritic limestone, as well as a fossil.

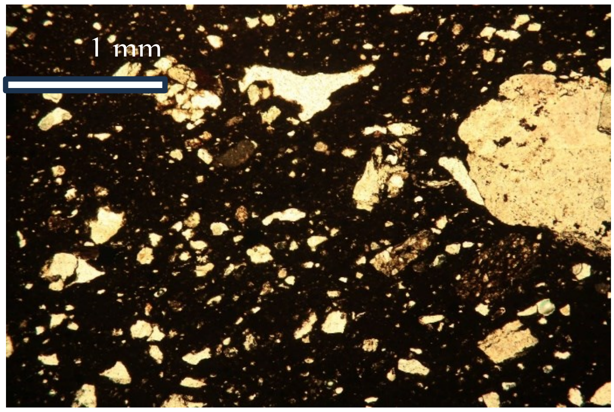
<table>
<tr><td colspan="3">

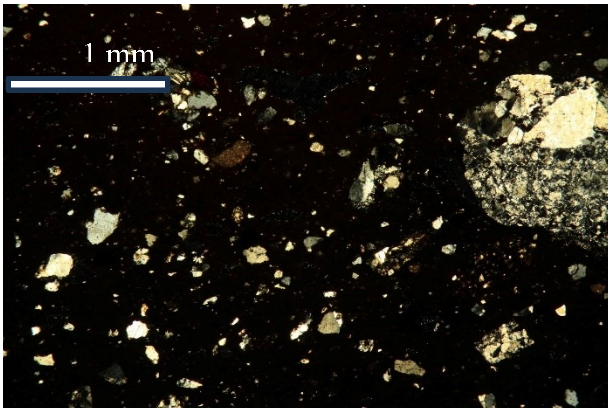
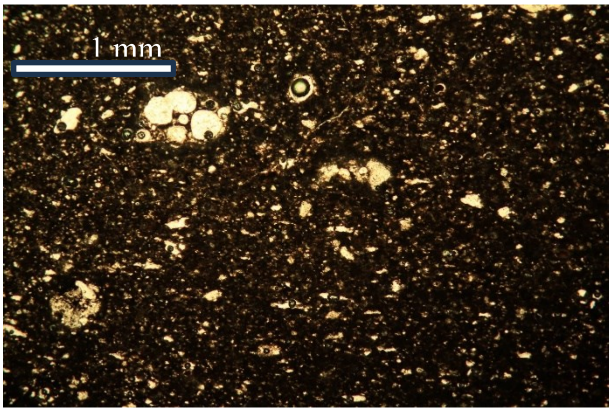
Photomicrograph of sample G4 in PPL (left) and XPL (right), in 5x magnification.</td><td colspan="3">
</td></tr>
<tr><td>G5</td><td>2b</td><td>Double-space distribution</td><td>10%</td><td>Optically active</td><td>Presence of quartz sandstone, metamorphic rock</td></tr>
<tr><td colspan="3">

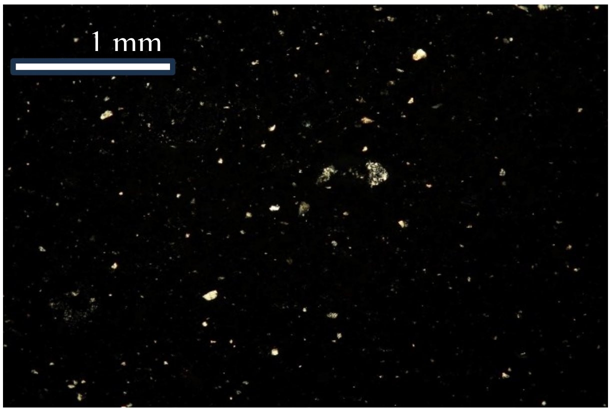
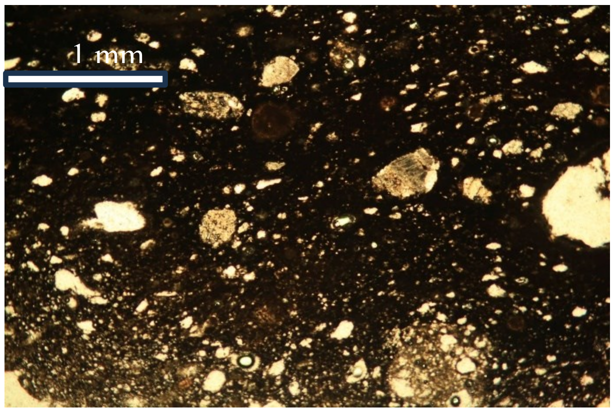
Photomicrograph of sample G5 in PPL (left) and XPL (right), in 5x magnification.</td><td colspan="3">
</td></tr>
<tr><td>G6</td><td>2b</td><td>Open space distribution</td><td>5%</td><td>Optically active</td><td>Presence of quartz sandstone, possibly a large oxide, metamorphic rock</td></tr>
<tr><td colspan="3">

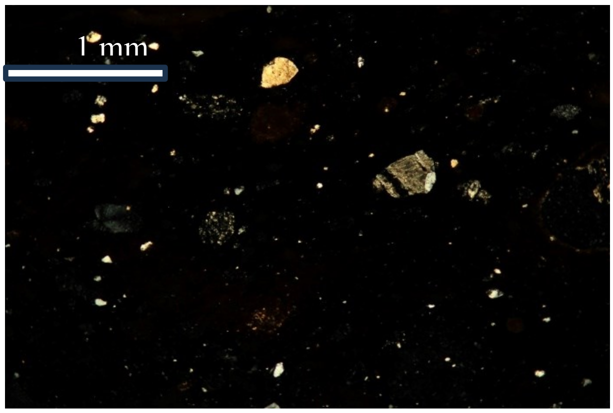
Photomicrograph of sample G6 in PPL (left) and XPL (right), in 5x magnification.</td><td colspan="3">
</td></tr>
</table>

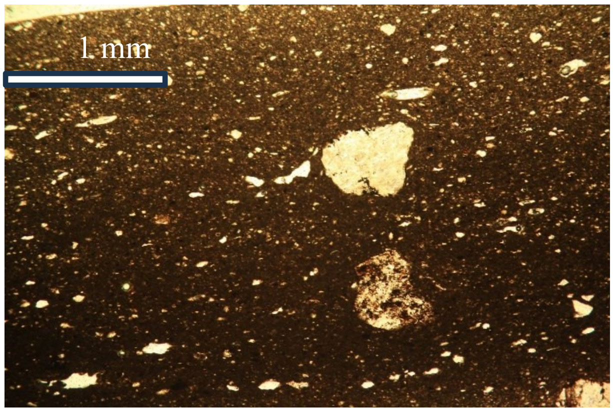
G7	2b	Open space distribution	3 - 5%	Optically active	It was possible to identify some large grains of metamorphic quartz, feldspar, and mudstone (argillite).
 Photomicrograph of sample G7 in PPL (left) and XPL (right), in 5x magnification.					
G8	1b	Single space distribution	25 - 30%	Optically inactive	It was possible to identify inclusions of metamorphic roks, feldspar, metamorphic quartz, acidic magmatic fusic rock and chert. Characterized by a more abundant presence of clay pellets/grog.
 Photomicrograph of sample G8 in PPL (left) and XPL (right), in 5x magnification.					
G9	1b	Single spaced distribution	25 - 30%	Optically inactive	It was possible to identify inclusions of sandstone, metamorphic rock, limestone, and some decomposed chlorite.

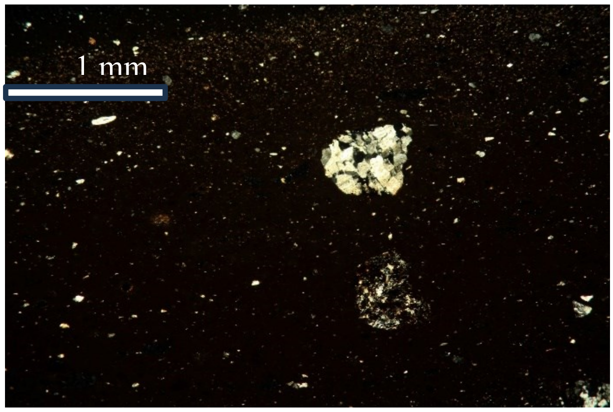
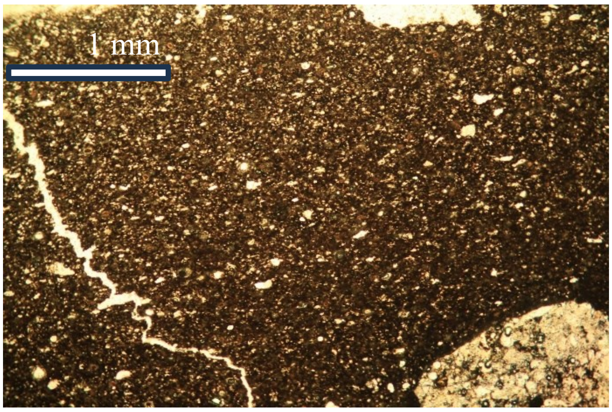
<table>
<tr><td colspan="3">

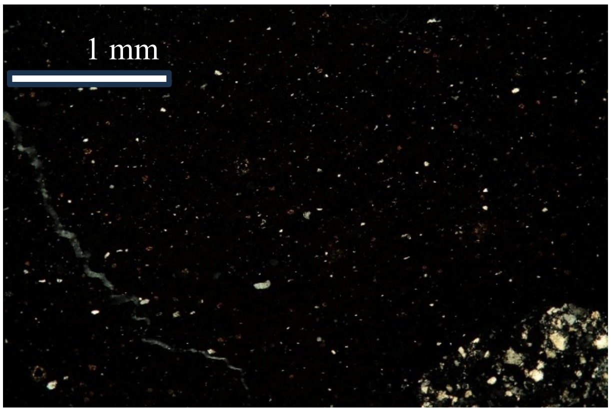
Photomicrograph of sample G9 in PPL (left) and XPL (right), in 5x magnification.</td><td colspan="3">
</td></tr>
<tr><td>G10</td><td>3</td><td>Single spaced distribution, almost close spaced</td><td>30%</td><td>Optically active</td><td>Small silt-sized grains on the, some decomposed organic</td></tr>
<tr><td colspan="3">

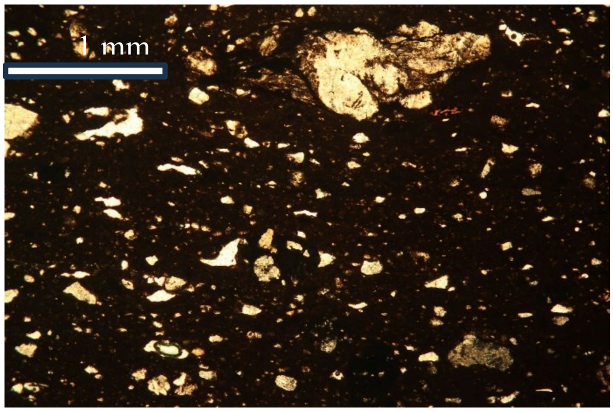
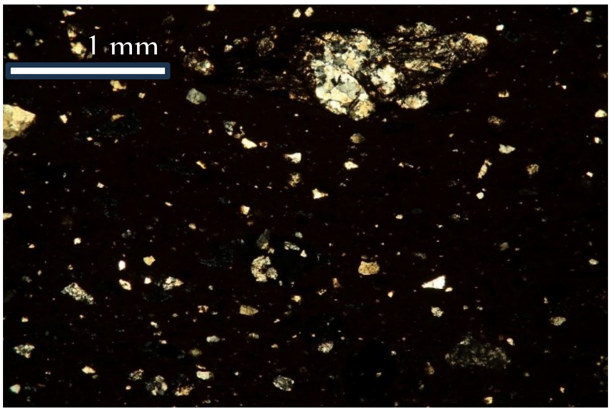
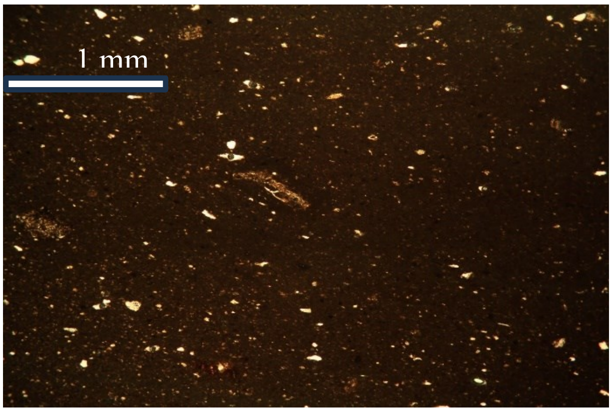
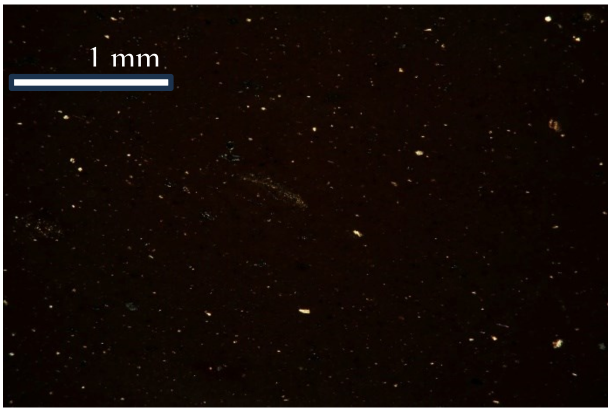
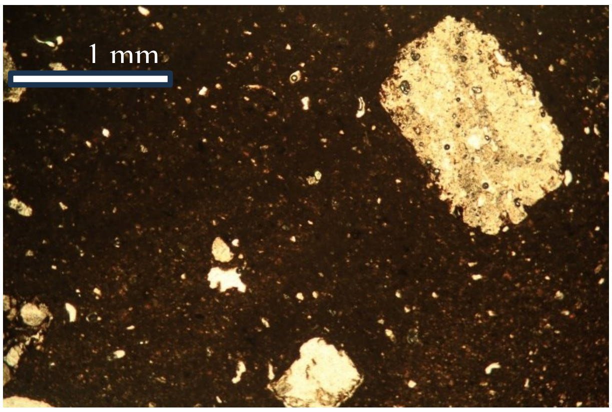
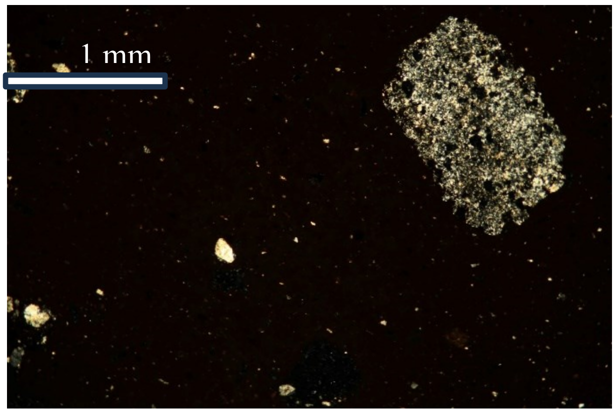
Photomicrograph of sample G10 in PPL (left) and XPL (right), in 5x magnification.</td><td colspan="3">
</td></tr>
<tr><td>G11</td><td>3</td><td>Single spaced distribution</td><td>30%</td><td>Optically active</td><td>sandstone, mudstone, grains of metamorphic rocks.</td></tr>
<tr><td colspan="3">

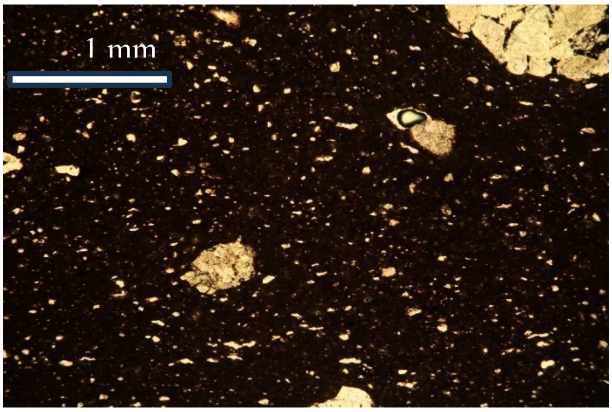
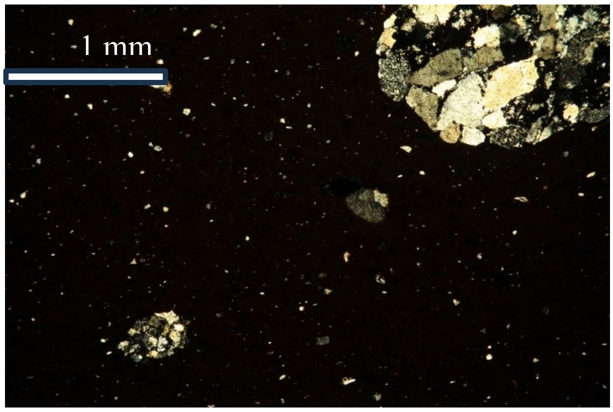
Photomicrograph of sample G11 in PPL (left) and XPL (right), in 5x magnification.</td><td colspan="3">
</td></tr>
<tr><td>G12</td><td>2c</td><td>Double, almost open spaced</td><td>5 - 10%</td><td>Optically active</td><td>Inclusions of quartz and limestone.</td></tr>
</table>

<table>
<tr><td colspan="3">

Photomicrograph of sample G12 in PPL (left) and XPL (right), in 5x magnification.</td><td colspan="3">
</td></tr>
<tr><td>G13</td><td>2c</td><td>Double-spaced distribution</td><td>10 - 20%</td><td>Optically active</td><td>Coarse inclusions of sandstone, metamorphic rocks, perhaps some decomposed organics</td></tr>
<tr><td colspan="3">

Photomicrograph of sample G13 in PPL (left) and XPL (right), in 5x magnification.</td><td colspan="3">
</td></tr>
<tr><td>G14</td><td>1b</td><td>Single-spaced distribution</td><td>20%</td><td>Optically inactive</td><td>It was possible to identify inclusions of large sandstone, carbonatic rocks, micritic limestone, metamorphic rocks, claystone, siltstone, opaque minerals (hematite, magnetite…)</td></tr>
</table>

 Photomicrograph of sample G14 in PPL (left) and XPL (right), in 5x magnification.					
G15	Loner/outlier	Open spaced	1 - 3%	Optically active	Almost depurated clay with an inclusion of metamorphic rock
 Photomicrograph of sample G15 in PPL (left) and XPL (right), in 5x magnification.					
G16	2c	Double to open spaced	3 - 5%	Optically active	Inclusions point to the addition of sand to the clay
 Photomicrograph of sample G16 in PPL (left) and XPL (right), in 5x magnification.					

G17	3	Double spaced	20 - 30%	Optically inactive	It was possible to identify sandstone from metamorphic origin.
 Photomicrograph of sample G17 in PPL (left) and XPL (right), in 5x magnification.					

APPENDIX 3: Complete mineralogical assemblage of the ceramic material

ID	quartz	albite	calcite	muscovite	diopside	Clino-enstatite	Augite	gehlenite	microcline	olivine	anorthite	Analcime
G1	x	x			x	x					x	
G2	x	x		X								
G3	x	x	x	X								
G4	x	x	x	X								
G5	x	x	x		x			X		x		
G6	x	x		X	x							
G7	x	x			x			X	x	x		
G8	x	x					X			x	x	
G9	x	x			x							
G10	x						X			x	x	x
G11	x	x					X			x		
G12	x	x					X					
G13	x						X			x	x	x
G14	x	x		X								
G15	x	x					X	X				
G16	x	x			x	x		X				x
G17	x	x			x						x	x
G18	x	x		X								
G19	x	x					X	X	x			
G20	x	x	x	X	x							
G21	x	x			x		X				x	x
G22	x	x	x								x	
G23	x	x		X				X				
G24	x	x		X								
G25	x	x	x	X								
G26	x	x						X				
G27	x	x			x					x		x

G28	x	x			x							x
G29	x	x	x	X					x			
G30	x	x	x									
G31	x	x		X	x							
G32	x	x		X	x							
G33	x	x		X		x						
G34	x	x		X			X					
G35	x	x						X			x	
G36	x	x			x							
G37	x	x		X	x							
G38	x	x					X				x	
G39	x	x	x	X								
G40	x	x						X			x	
G41	x	x			x							
G42	x	x	x	X	x							
G43	x	x	x					X				
G44	x	x		X						x		
G45	x	x			x		X	X				
G46	x	x		X								

APPENDIX 4: XRF data

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Tot		L.O.I.
G1	63,53	0,87	15,06	6,89	0,09	3,51	5,96	1,25	2,47	0,19	99,82		2,97
G2	57,53	0,84	15,19	7,97	0,10	6,04	8,56	0,97	2,29	0,18	99,67		6,71
G3	63,99	0,81	14,64	6,94	0,11	4,21	5,63	1,10	2,21	0,11	99,75		5,91
G4	53,41	0,76	14,84	7,00	0,13	5,93	14,36	0,92	2,15	0,19	99,69		14,56
G9	60,84	0,80	16,22	7,94	0,15	4,37	5,93	0,90	2,44	0,15	99,74		5,46
G12	56,03	0,85	16,40	7,62	0,11	5,58	9,59	0,96	2,48	0,13	99,75		3,86
G15	53,69	0,90	16,94	8,01	0,11	5,06	11,32	0,91	2,64	0,15	99,73		4,26
G19	52,10	0,87	16,48	7,92	0,11	6,94	11,82	0,84	2,56	0,12	99,76		2,20
G20	53,19	0,93	17,90	8,46	0,12	5,98	9,45	0,80	2,77	0,16	99,76		6,96
G23	52,87	0,89	16,58	7,93	0,11	6,24	11,58	0,89	2,51	0,15	99,75		5,06
G24	56,16	0,93	17,50	8,32	0,11	5,70	7,22	0,92	2,70	0,17	99,73		6,08
G25	53,58	0,93	17,66	8,14	0,11	5,32	10,26	0,84	2,69	0,16	99,69		8,89
G27	50,36	0,90	16,91	8,16	0,11	7,96	12,15	1,32	1,77	0,13	99,77		2,22
G31	52,57	0,85	16,17	7,71	0,11	7,18	11,62	0,96	2,41	0,16	99,74		6,78
G32	53,12	0,90	17,13	8,06	0,11	6,34	10,37	0,89	2,67	0,14	99,73		3,61
G37	56,11	0,91	17,26	8,24	0,11	5,31	7,95	0,91	2,77	0,16	99,73		3,69
G41	53,02	0,94	18,13	8,42	0,11	6,12	9,23	0,86	2,79	0,13	99,75		2,33
G42	51,20	0,86	16,51	7,96	0,11	5,77	13,88	0,74	2,49	0,18	99,70		9,13
G43	52,87	0,82	15,36	7,24	0,10	6,50	13,75	0,82	2,10	0,15	99,71		10,50
G44	51,92	0,92	17,24	8,30	0,12	6,68	10,87	0,82	2,71	0,14	99,72		4,01

ppm	**S**	**Sc**	**V**	**Cr**	**Co**	**Ni**	**Cu**	**Zn**	**Ga**	**Rb**	**Sr**	**Y**	**Zr**
G1	101	17	131	271	28	165	44	90	5	110	194	24	205
G2	548	21	145	396	31	322	56	131	4	101	477	22	140
G3	207	16	125	441	29	214	48	113	8	106	385	24	188
G4	590	31	132	269	26	208	53	134	<3	96	794	21	154
G9	144	17	145	405	34	240	49	113	11	117	372	27	158

G12	89	25	136	387	32	262	42	129	4	122	493	22	155
G15	148	28	132	336	33	273	53	131	9	130	527	24	161
G19	40	29	130	333	31	265	49	133	<3	127	360	21	161
G20	183	25	153	342	34	279	52	160	13	131	447	24	168
G23	113	28	119	326	30	249	56	142	<3	122	464	23	166
G24	109	21	143	357	34	268	46	153	13	131	488	23	169
G25	395	26	158	342	34	284	59	139	<3	131	516	23	162
G27	22	30	138	338	30	273	52	134	12	111	381	23	161
G31	248	26	132	326	32	259	42	152	<3	111	419	22	165
G32	122	28	139	329	31	260	54	146	10	132	623	22	167
G37	69	22	124	345	34	261	48	138	4	130	517	22	170
G41	35	25	159	352	37	298	48	186	11	140	361	24	157
G42	257	31	147	317	28	267	66	145	3	121	616	22	158
G43	443	31	131	319	31	244	44	152	8	98	602	22	164
G44	89	29	144	332	32	269	52	285	3	134	465	23	163

ppm	**Nb**	**Ba**	**La**	**Ce**	**Nd**	**Pb**	**Th**	**U**
G1	5	406	25	54	25	15	10	4
G2	7	550	24	50	19	22	8	4
G3	6	409	25	53	26	23	8	3
G4	6	576	23	49	29	28	6	5
G9	9	508	24	49	26	24	10	<3
G12	8	431	29	61	29	19	9	<3
G15	5	608	29	58	34	27	10	4
G19	9	416	25	54	26	25	15	3
G20	11	513	22	50	28	31	11	<3
G23	8	512	26	55	32	26	13	<3
G24	6	587	23	50	30	27	7	3
G25	11	617	27	56	36	24	13	3
G27	10	480	24	53	34	26	10	<3
G31	6	504	19	44	26	25	9	6

G32	8	444	23	51	30	26	5	<3
G37	9	676	29	59	31	32	11	3
G41	9	465	26	55	30	23	10	5
G42	10	664	28	56	30	24	6	<3
G43	4	482	25	52	26	23	8	4
G44	10	620	28	58	29	26	8	<3