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Archaeometric Studies on Hellenistic Period New Type Phaselis Amphorae

[HELLENİSTİK DÖNEM YENİ TİP PHASELİS AMPHORALARI ÜZERİNE ARKEOMETRİK ÇALIŞMALAR]

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ÖZET

Phaselis Merkezi Kule (PMK) Seramik Çöplüğü ve Amphora Üretim Alanı'nda yapılan çalışmalarda tespit edilen bir grup amphora üzerine yapılan arkeometrik analizler ve sonuçları bu çalışmanın ana tematiğini oluşturmaktadır. Bu kapsamda çalışmada 8 farklı örnek üzerinde Polarizan mikroskobu yardımıyla mineralojik-petrografik analizler, X-Işını Fluoresans analizi (PED-XRF) yardımıyla da kimyasal analizler gerçekleştirilmiştir. Petrografik incelemelerle, seramiklerin mikroskobik tanımlanmasıyla doku, mineral ve matriks bileşimleri belirlenmiştir. X-ışını Fluoresans analizi (PED-XRF) ile de kimyasal içerikleri tespit edilmiştir. Böylelikle kil yapısı olarak benzer, form olarak ayrışan 8 farklı amphora örneği; hem daha önceki Hellenistik Tapınak örneklerinin (APK) analiz verileriyle hem de lagünden (kil yatağından) alınan ham kil ile karşılaştırılarak köken benzerliği ortaya konulmaya çalışılmıştır.

Bu çalışmada, salt arkeometrik analiz verilerinden ziyade arkeoloji, jeoloji ve coğrafya disiplinleri kapsamda yapılan değerlendirmeler ön plana çıkarılmıştır. Nitekim birbirini destekleyen farklı disiplinlerin verileri sayesinde de bu çalışmanın, somut kanıtlarla desteklenerek hipotetik olmaktan çıkarılması amaçlanmıştır. Bu minvalde arkeolojik çalışmalarda ele geçen amphoralar üzerine yapılan arkeometrik araştırmalarla ortaya çıkan sonuçların, Phaselis'in yakın çevresinin jeolojisi ile de uyumlu olduğu görülmüştür. Ayrıca söz konusu yeni tip Phaselis amphoralarının, özellikle Lagün'den alınan ham kil ve diğer yerel gruplarla olan hamur benzerliği de ortaya konulmuştur. Böylelikle Arkeolojik, Arkeometrik, Jeolojik ve Coğrafi verilerle harmanlanan bu çalışma, disiplinler arası, birbirini destekleyen kanıtları da içermektedir. Netice itibariyle yapılan tüm bu çalışmaların sonuçlarının hem kentteki amphora çalışmalarına hem de seramik araştırmalarına önemli katkılar sunacağı düşünülmektedir.

Anahtar Kelimeler

Doğu Akdeniz, Phaselis, Merkezi Kule, Seramik Çöplüğü, Amphora Üretimi.

ABSTRACT

The primary theme of this study pertains to the archaeometric analyses and outcomes derived from a series of amphorae unearthed during the research conducted at the Phaselis Central Tower (PMK) Ceramic Dumpster and Amphora Production Area. In this study, a range of 8 samples were subjected to mineralogical-petrographic analysis using polarising microscopy and chemical analysis via X-Ray Fluorescence (PED-XRF). In order to determine the texture, mineral and matrix composition of the ceramics for microscopic identification, petrographic analyses were used. A total of eight distinct samples of amphora were thus subjected to a comparative analysis, encompassing both the analysis data of the earlier Hellenistic

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Temple samples (APK) and the raw clay extracted from the lagoon (raw clay). This approach was undertaken in order to ascertain the origin of the samples in question.

In this study, the focus was placed on evaluations within the context of archaeology, geology and geography, with the aim of expanding the scope beyond the limitations of archaeometric analysis data alone. Indeed, the objective of this study is to avoid the potential limitations of a hypothetical approach by providing a foundation of concrete evidence derived from diverse disciplinary perspectives. In this regard, the results of the archaeometric research conducted on the amphorae recovered during the archaeological excavations were found to be compatible with the geology of the immediate vicinity of Phaselis. Furthermore, the new Phaselis amphorae type exhibits a high degree of similarity with the raw clay from the Lagoon and other local groups. Consequently, this study, which integrates archaeological, archaeometric, geological and geographical data, is also significant in terms of its interdisciplinary, mutually supportive evidence. In conclusion, it is anticipated that the findings of these studies will make significant contributions to both the amphora studies in the city and the field of ceramic.

Keywords

Eastern Mediterranean, Phaselis, Central Tower, Pottery Dumpster, Amphora Production.

Introduction*

Phaselis, once a city on the western coast of the Pamphylia Gulf, is currently located within the borders of Tekirova Quarter, Kemer District, Antalya Province, just south of the modern Antalya-Kumluca highway. Due to its strategic location between the east and the west, some conservation and landscape projects have been initiated to protect the cultural legacy of Phaselis. During the Phaselis landscaping project, seven test trenches were opened on the flat field below the *Central Tower,* located on the northern slopes of the city center (Fig. 1).

During the course of the studies, finds were recovered from only three of the seven test trenches (Trenches DNM-D, G and F).[1] It was observed that these finds, which were recovered in the hundreds, presented a wide range of forms, including production waste and missfired amphora fragments, amorphous and slag fragments, parts of ceramic kilns, black glaze ceramic groups, coarse ceramics and amphora fragments.[2] A numerical superiority of amphorae was observed among the finds, and furthermore, among the amphorae recovered from the test trenches and identified in terms of form, Phaselis amphorae, which were previously identified as local, were numerically superior.

The main material of the study consists of a new variant thought to be of local production, and the studies carried out on this variant. Given the novelty of these findings and their analysis, both modern and classical archaeological methods were employed in this study. This new type of Phaselis amphorae, which exhibits a high degree of similarity in terms of clay structure to the amphorae found in the area and previously included in the literature as Phaselis Amphorae, is typologically divergent from other Phaselis forms. Archaeometric studies were conducted on 10 amphorae to ascertain whether these amphorae, which also demonstrate different characterisations based on the foot samples, exhibit local characteristics. The analysis revealed that, with the exception of 2 samples, the remaining 8 samples belonged to a local group. With regard to the remaining 8 amphorae, specimen number 1 (Fig. 5, PMK-B1) corresponds to Phaselis Type 1 specimen, while specimen number 8 (Fig. 5, PMK-B8) is an example of a type 3 production waste. The remaining 6 specimens represent new types of Phaselis amphorae (Fig. 5).[3] Archaeometric analyses were conducted on the Phaselis amphorae, which were determined to be of Phaselis origin and origin factory, based on the findings from previous studies conducted in the Hellenistic Temple Area.[4]

* Throughout the text, the abbreviation *PMK*: "*Phaselis Centre Tower*" is used for the newly studied examples, and *APK* for the *Hellenistic Temple Examples*: "*Antalya Phaselis Excavation*". Additionally, the term "B1" is employed to denote "*Amphora 1*", whilst the abbreviation "*APK-D1*" is used to refer to "*Raw Clay*".

2 For the findings and artefacts indicating production see Orhan 2023b: 47-60, Figs. 5-8.

3 The 6 amphorae selected for analysis represent the specimens which best illustrate the variety of forms encountered.

4 For the studies and finds from the Hellenistic Temple Area, see Orhan 2020: 75-86; 2023a: 27-36. For archaeometric analyses on the ceramics, see Orhan et al. 2022: 558-574.

In the course of this study, the following methodologies were employed:

-petrographic analysis (1 raw clay, 4 production waste and 43 amphora samples (48 in total),

-chemical analysis (XRF: X-Ray Fluorescence Spectroscopy) 1 clay, 3 production waste and 13 amphora samples (17 in total), some of which are previous samples and some new samples.

In the analyses conducted on raw clay, amorphous, production waste groups and amphorae, the raw clay was categorised into groups based on the rock of origin, namely basalt, diabase, serpentinite and pyroxenite. The analyses revealed that 26 amphorae (65%) out of 40 samples belonged to the same group, with their rock of origin being pyroxenite. The study thus determined that the clay sources of Phaselis Type 1, Type 2, Type 3a, Type 3b and Small Scale Phaselis samples were derived from serpentinite and pyroxenite rocks found in the vicinity. Previous studies have also revealed that these amphora groups are local amphorae produced in Phaselis and compatible with local clays.[5]

In this study, the amphorae retrieved from the Phaselis Central Tower Ceramic Dump and the Amphora Production Area were subjected to a petrographic analysis and categorised into 2 primary groups. The first group comprises predominantly gabbro and basalt rock fragments, exhibiting a denser paste matrix (samples PMK-B1, PMK-B7, APK-B30, APK-B6, APK-B38). The second group is characterised by a preponderance of pyroxene and serpentine minerals (PMK-B2, PMK-B3, PMK-B5). The distinction between these two groups can be attributed to the observation that the second group samples exhibit a reduced content compared to the first group. This reduction can be attributed to the presence of pyroxene and serpentine minerals, which are known to possess a smaller size paste structure in the second group samples (PMK-B2, PMK-B3, PMK-B5). Despite the establishment of two distinct groups based on mineral ratios and rock size, these samples exhibit characteristics indicative of ophiolitic rocks, and their provenance is found to be highly analogous. The objective of the current study, as outlined above, is to ascertain the provenance of the amphora samples. To this end, with the exception of the 8 amphora specimens from the PMK, the APK 40 specimens were subjected to extensive analysis in a preceding study. Consequently, the present study focuses on novel specimens and compares them with the groups examined in the preceding study.[6]

Methods of Analysis

In the course of the study, mineralogical-petrographic analyses were conducted with the assistance of a polarising microscope, whilst chemical analyses were performed with the aid of X-Ray Fluorescence analysis (PED-XRF). The application of petrographic analyses enabled the determination of the texture, mineral composition, matrix composition and chemical content of the samples by X-Ray Fluorescence analysis (PED-XRF).[7] The petrographic clay (matrix) and content (rock and mineral) properties of the samples were determined by means of thin section optical microscope analysis. For this purpose, the samples were cut with a suitable cutter, placed on slides, thinned to 0.25 mm, and thin sections were prepared. The thin sections of the samples were analysed using a LEICA Research Polarising Microscope DMLP Model, which is a bottom and top illuminated polarising microscope. Photographs were taken with a Leica DFC280 digital camera connected to the microscope (single and double nicol with appropriate magnification), and evaluations were made using the "*Leica Qwin Digital Imaging Programme*". Determination of the matrix and the clay, rocks and minerals forming the matrix was achieved using the "*Point Counting Method*".

The investigation of a sample as a form of spectroscopy is predicated on the analysis of X-rays emitted by a substance when it is struck by charged particles. In essence, this process entails the interactions of electromagnetic radiation and matter. The characterisation capacity

5 For the archaeometric analyses on the Hellenistic temple samples in previous studies, see Orhan et al. 2022: 558-574.

6 Orhan et al. 2022: 562-563, Figs. 7a-b; 2023a: 167-168, Fig. 43.

7 X-ray Fluorescence analysis (PED-XRF); this is a variant of X-ray Fluorescence (XRF), which is defined as the technique of emission of characteristic secondary (fluorescence) X-rays from a substance excited by bombardment with X-ray or gamma rays.

is largely based on the principle that each component has its own atomic structure and that the X-rays specific to these atomic structures can be distinguished from each other.[8]

The XEPOS-III PED-XRF brand spectrometer functions within the polarised energy dispersive X-ray (PED X) system. The spectrometer library contains a total of 92 types of standards, including those designated for geology, mining, materials science and oil solutions. The XEPOS-III PEDXRF spectrometer is capable of analysing elements ranging from sodium (Na) with atomic number 11 to uranium (U) with atomic number 92. The instrument's sensitivity threshold is 0.5 ppm for heavy elements and up to 10 ppm for light elements. Furthermore, the device is property of receiving powder, powder pellet, glass pellet, rock fragment and solution.[9]

PMK Ceramic Dumpster and Amphora Production Area: Excavations and Finds

A total of seven test trenches were scheduled during the course of excavations on the flat part of the building known as the Central Tower in Phaselis (Fig.1).[10] However, only three of these trenches, excavated at varying depths and widths, yielded significant archaeological finds. In addition Archaeological remains were absent from Trenches *21DNM-A*, *21DNM-B*, *21DNM-C* and *21DNM-E*. Conversely, a substantial quantity of amphorae, in addition to a modest number of pottery fragments, was recovered from trenches *21DNM-D*, *21DNM-F* and *21DNM-G*. The research conducted at the Ceramic Dumpster and Amphora Production Area has yielded a variety of materials, including kiln bricks that are either plastered or unplastered, amorphous and slag samples, pottery that exhibit firing or production defects, and amphora fragments that have experienced both structural and physical deterioration due to exposure to elevated temperatures (Fig. 2-4).

The trenches 21DNM squares "D", "F" and "G", which are the trenches mentioned above, contain a workshop or a group of archaeology artefacts thought to have a production-related function. In the context of the ceramic workshops, it has been observed that the terracotta bricks retrieved from these areas exhibit a rectangular configuration, characterised by a substantial and well-fired paste composition. Furthermore, it has been observed that certain of these bricks have been exposed to elevated temperatures, and evidence of lime pits is present on their surfaces.[11] In fact, despite the absence of precise functional data, it is considered that the bricks[12] may have been utilised externally in ovens or kilns (Fig. 2a).[13] Amorphous and slag wastes constitute one of the most dense groups among the find groups identified in PMK. (Fig. 2b). It was observed that some of these wastes, which had no shape and reached a glassy lustre by exposure to high temperatures, could belong to kiln plaster, while others were deformed ceramic fragments (Fig. 3a).[14] In addition to these amorphous and slag groups, some defective sherds of pottery and amphorae, fused together during the production phase, were also unearthed (Fig. 3b).[15] As a matter of fact, it can be said that the shards of the misfired pottery sample and the misfired amphorae are the clearest evidence of the production in this area.[16] Moreover, the presence of a shell on the tondo part of the ceramic vessel during

8 Alkan et al. 2011: 70.

9 İnal et al. 2008: 46; Zhan 2005: 207.

10 The labelling of the seven test trenches follow the alphabetical order starting from 21DNM abbreviation A to G. For the preliminary report of this work, see Arslan and Tüner-Önen 2021: 153-58, Figs. 15-25.

11 For further information regarding the analogous examples found in the Hellenistic Temple Area Production Area, refer to the relevant literatüre, see Orhan 2020: 82, Fig. 10b; Orhan et al. 2022: 561, Fig. 5; Orhan 2023a: 211, Fig. 28.

12 Only a few of the hundreds of bricks identified in the area were included in the study and analysed. Also for the use of bricks see Vargas and García 2004: 322, Fig. 31.

13 The substantial quantity of bricks identified during the course of the study suggests that they were used in the operation of ceramic kilns. For some examples of ovens using bricks, see also Swan 1984: 30-80, Figs. 2-20, Pls. 1-9. For ceramic kilns with this function, see Hasaki 2002: 468, Pls. I-II; İren 2003: 43, Fig. 47.

14 For kiln waste and slag samples from Seleukeia Sidera, see Hürmüzlü et al. 2020: 153, Figs. 7, 9.

15 The substantial accumulation of mismanufactured amphorae and ceramics fused together is of great importance as direct evidence of production activities.

16 For a similar context of finds from the Production Area of the Hellenistic Temple, see Orhan et al. 2022: 561, Fig. 4b. Also the excavation at Hasankeyf for production waste samples, see Çeken 2007: 250, Fig. 6. For examples in Crete, see Van de Moortel 2001: 77, Fig. 42.

the firing phase, which is indicative of production, provides compelling evidence of production in this area (Fig. 4a). Amphorae are the most important finds that help to date both the general context and this production area. In fact, the most important find indicating local amphora production is the foot fragment of a Phaselis type 3 amphora with production waste/ misfired among the defective examples summarised above, indicating direct production (Fig. 4b, Fig. 5, PMK-8).[17] The clay colour of the Phaselis amphora in question has undergone a change to grey tones during the firing process, a consequence of the application of unstable high temperatures. Furthermore, the slip texture has almost completely deteriorated. In addition, deep fractures, splits and lime punctures were formed on the foot of the amphora during the firing process, a likely consequence of temperature differences (Fig. 4b).[18] Despite this deformation on the amphora, it was possible to type and date the amphora thanks to the well-produced examples recovered from different sites at Phaselis.[19] In this context, the misfired amphora foot (Fig. 4b) is similar to Phaselis Type 3b within the Phaselis amphora groups and has been dated to the third or fourth quarter of the IVth century BC.[20] As previously stated, the results of the excavations suggest that this area was a ceramic dumpster or amphora production site, and that amphorae or pottery were produced in the vicinity. It has been observed that the Phaselis Type 3a and 3b forms of amphorae were particularly prevalent in this area from the middle of the IVth century BC. Furthermore, it is proposed that production in this area persisted from the middle of the IVth century BC to the beginning of the IIIth century BC.

17 For similar examples of production waste at different sites in Phaselis, see Orhan 2020: 82, Figs. 10c-d; Orhan et al. 2022: 561, Figs. 4c and 6; Orhan 2023a: 208, Fig. 17. Also for similar production waste at Rhodiapolis, see Çetintaş 2016: 123-136, Figs. 1-32.

18 The presence of fractures, splits and punctures on the Phaselis amphora is attributable to exposure to elevated temperatures. Examples of such deterioration on amphorae have been identified in excavations within the Hellenistic Temple Area, see Orhan 2020: 82, 10d.

19 For all types and subtypes of Phaselis amphorae, see Orhan 2023a: 249-261, Cat. Nos. 88-610, Pls. 2-4.

20 Orhan 2023a: 102-103, 534-565, Cat. Nos. 496-557, Pls. 2-4.

As a consequence of the research undertaken at the PMK Ceramic dumpster and the Amphora Production Area, it is hypothesised that these amphorae (Fig. 5, PMK-B2-B7), which are designated as new types, were also manufactured at Phaselis. For this reason, archaeometric studies were carried out on fabric and structurally similar groups. 8 different samples were analysed by means of PED-XRF and petrographic analyses (Fig. 5-11). All analyses are presented in detail under separate headings.

Petrography of clay samples

A clay sample was collected from the vicinity of the lagoon in the proximity of the ceramic dumpster and amphora production area within the city of Phaselis. This clay sample provides information about the geological formations of the area and is also compared with the ceramics.

In this particular context, the clay sample designated APK-B40 has been observed to contain gabbro (Fig. 6e-f), basalt (Fig. 6g), diabase and serpentinite rock fragments (Fig. 6a-d), along with pyroxene, plagioclase and opaque minerals. The presence of mafic minerals in the rocks indicates a process of opacification, with a transition from dark brown to reddish hues, and ultimately to opaque black. It was observed that in some samples, both opacified and unopacified mineral phases were present within the same mineral, with half of the minerals exhibiting opacification, while the remainder were completely opacified (Fig. 6. f, h). Serpentine samples demonstrate the presence of sieve texture. In certain samples, the presence of pyroxene remains between the sieve texture is discernible. These serpentine fragments are also partially opacified. In addition to opacification, opaque mineral chromium and magnetite are also encountered.

The analysis samples were divided into two groups. Accordingly, the similarities and differences between the production waste samples (APK-B35, APK-B37, APK-B39 and PMK-B8) and the presumed local amphorae are analysed and their origins are discussed. The production waste samples and the misfired amphorae (APK-B35, APK-B37, APK-B39 and PMK-B8) are also compared and discussed (Fig. 7).[21]

21 For comparison, see Orhan et al. 2022: 562-563, Figs. 7a-b; Orhan 2023a: 167, Fig. 43a.

Petrography of Amphora Samples

The Hellenistic temple samples were previously divided into several groups. In general, however, 26 of the 38 samples (68.43%) were originally associated with harzburgite or pyroxenite rocks. These samples also contain pyroxene and plagioclase minerals and gabbro rock fragments were also observed (Group 1).[22] In another group (group APK-B26, 28, 30, 32, 33) basalt, shale fragments and quartz, chert, plagioclase and muscovite minerals were identified.

Some of the samples in the study contain intense pyroxene minerals together with serpentinite rock fragments. In these samples (PMK-B1, B4, B6, B7), the density of the clay constituents was also found to be composed of pyroxene minerals (Fig. 8).

Provenance of the Amphorae

PMK-B3, one of the new type Phaselis amphora samples, and the production waste APK-B35 sample similarly contain basalt, diabase and gabbro rock fragments. In both samples, basalt fragments are observed in a very clean clay. Partial opacification is a common feature in both samples. Sample APK-B34 contains dense serpentinite rock fragments and these serpentinite fragments are partially opacified. Similarly, this is also seen in the partially opaque serpentine APK-D1(Raw clay) sample.[23]

The amphora samples in study have a clean clay and mostly red serpentine fragments are found inside. In this context, PMK-B5 and APK-B9, as well as the production waste PMK-B8, also have red coloured serpentine fragments (Fig. 9). PMK-B4 and PMK-B6, representing a new type of Phaselis amphora, and the previously studied type 3b form (APK-B10) were found to contain petrographically similar contents, characterised by the presence of dense serpentinite rock fragments. Similar serpentinites were also identified in the raw clay (APK-D1) sample (Fig. 10).

Phaselis type 3b amphorae (APK-B27), Phaselis type 1 (APK-B11) and APK-B26 contain gabbro rock fragments with pyroxene with partial opacification and opacification. This feature is analogous to the raw clay (APK-D1) from Lagoon (Fig. 11). Furthermore, the contents of the clay and production waste samples are analogous to those of amphorae APK-B14, APK-B7, APK-B31, APK-B19, APK-B30, APK-B6, APK-B38, APK-B33 and APK-B31 (Fig. 11). Moreover, observations of the amphorae containing serpentinite and iron fragments revealed the formation of a void surrounding the serpentine and iron components. These materials did not react with the clay, nor did they fuse (Figs. 9-10). This distinctive characteristic is of paramount importance in distinguishing the Phaselis amphorae from other imported amphora groups.

It is known that the serpentinite rock fragments in ceramics are sometimes oxidised to a red colour during firing. It is also known that clays in ophiolite areas have high iron, magnesium, chromium and nickel values. In this respect, in some of the ceramic samples in study, iron grains are large enough to be seen macroscopically.[24] Apart from these coarse iron oxide particles, the raw clay sample and ceramics contain rocks and minerals associated with ophiolite formation and very few fine limestone fragments.

With regard to the production sites of the amphorae mentioned above, the clay taken from the lagoon at the central site of Phaselis and the defective production and amphora samples recovered from the excavations were petrographically analysed. As a result, it was found that the rock fragments and minerals that were observed in the clay samples and the production waste samples were also observed in a similar way in the amphora samples. This demonstrated the petrographic similarity between the raw clay and defective production samples taken from the lagoon and the amphorae.

22 Orhan 2023a: 170, Fig. 45.

23 Orhan et al. 2022: 562, Fig. 7a.APK-D1; Orhan 2023a: 168, Fig. 43c.

24 Furthermore, the iron grains that were identified on a macroscopic level in the clay sample and the crushed ceramic samples were distinguished with a magnet. These iron grains were also detected by means of the Portable XRF analysis method. However, the results were not included in the scope of this study because they were outside of its remit, see Orhan 2023a: 168-169, Figs. 43b-d.

Chemical Analysis (XRF)

Chemical analyses (XRF) were carried out on 4 samples selected from a total of 8 samples examined within the scope of the study. This approach was adopted in order to ascertain the production sites by illuminating their chemical as well as their petrographic properties. The new analyses were compared with the chemical values of the clay and production waste samples analysed in previous studies. In addition to these studies, the main and trace element values of the amphora samples were obtained (Table 1-4). It is evident that the raw clay, production waste, misfired amphora and amphorae samples exhibit comparable content characteristics and are categorised into five distinct subgroups, exhibiting subtle disparities in elemental composition. As is evident in the grouping made according to CaO+MgO+Al203 values, the data show minor variations according to Ca, Mg and Al values. Accordingly, Group 1 (APK-B37 and APK-B39) had the highest calcium value. The closest example to this group is Group 2 (APK-B3), in which calcium value decreased, but aluminium value increased. Group 3 samples (PMK-B1, PMK-B2, PMK-B3, APK-B10, APK-B22, APK-B32, APK-B34), in which the calcium value decreased, the magnesium value increased and the aluminium value did not change, differ from group 1 and group

Element	PMK-B1	PMK-B2	PMK-B3	PMK-B4	APK-D1	APK-B3	APK-B6	APK-B7
Na_2O	0.050	0.053	0.051	0.046	0.940	0.045	0.047	0.052
MgO	4.678	3.331	3.994	5.546	6.902	2.009	5.807	5.539
Al_2O_3	12.430	10.570	8.509	11.830	11.570	15.080	13.250	11.740
SiO_2	55.290	62.490	47.060	56.050	50.300	46.540	55.940	58.590
P_2O_5	0.176	0.177	0.111	0.154	0.069	0.155	0.260	0.219
SO_3	0.195	0.086	0.134	0.125	0.130	0.068	0.057	0.074
Cl	0.043	0.017	0.044	0.022	0.361	0.008	0.004	0.014
K2O	1.968	1.986	1.772	2.262	0.940	1.507	1.831	1.787
CaO	10.990	8.961	10.490	8.586	8.391	15.160	6.554	8.038
TiO_2	0.723	0.780	0.668	0.752	0.521	0.754	0.894	0.717
V_2O_5	0.027	0.026	0.019	0.025	0.027	0.020	0.023	0.024
Cr_2O_3	0.051	0.062	0.051	0.064	0.047	0.038	0.016	0.183
MnO	0.138	0.146	0.107	0.121	0.087	0.138	0.108	0.162
Fe_2O_3	6.684	7.131	6.413	7.068	8.514	6.002	7.214	7.591
LOI	6.840	4.590	21.480	7.940	11.580	11.830	8.840	5.330

Table 1. Main element values of Phaselis PMK, Clay and APK samples (%)

Element	APK-B10	APK-B18	APK-B22	APK-B27	APK-B28	APK-B32	APK-B34	APK-B37	APK-B39
Na_2O	0.053	0.048	0.044	0.048	0.042	0.049	0.056	0.054	0.052
MgO	3.949	3.171	3.812	3.875	3.818	3.152	4.496	3.563	3.271
Al_2O_3	14.070	13.830	11.540	14.920	13.800	11.640	13.415	9.022	9.766
SiO_2	53.750	55.250	51.420	56.870	57.360	52.360	47.760	47.490	48.020
P_2O_5	0.189	0.162	0.221	0.278	0.234	0.222	0.148	0.122	0.167
SO_3	0.066	0.032	0.091	0.056	0.053	0.052	0.031	0.034	0.046
Cl	0.004	0.006	0.013	0.002	0.003	0.010	0.010	0.011	0.008
K2O	1.665	1.865	1.846	1.933	1.918	1.978	1.832	1.881	1.740
CaO	11.330	8.980	10.200	7.974	5.496	10.099	12.200	17.710	18.220
TiO_2	0.860	0.861	0.782	0.959	0.936	0.841	0.588	0.677	0.705
V_2O_5	0.025	0.018	0.021	0.026	0.021	0.020	0.019	0.025	0.022
Cr_2O_3	0.056	0.022	0.073	0.016	0.015	0.014	0.203	0.293	0.079
MnO	0.165	0.173	0.133	0.132	0.134	0.123	0.149	0.127	0.107
Fe_2O_3	7.704	8.205	6.809	8.067	7.256	6.662	6.646	6.156	5.972
LOI	6.840	6.980	12.740	3.880	8.830	11.840	12.840	11.850	11.750

Table 2. Main element values of Phaselis APK samples (%) (continued)

Element	PMK-B1	PMK-B2	PMK-B3	PMK-B4	APK-D1	APK-B3	APK-B6	APK-B7
Co	50.9	37.8	48.5	81.5	45.2	55.7	53.5	70.7
Ni	172.8	209.6	284.4	317.1	380.5	121.3	235.4	327.3
Cu	54.7	42.5	41.7	44.6	40.6	42.7	60.1	47.8
Zn	93.1	100.6	72.2	98.4	48.7	103.1	97.2	84.8
Ga	18.6	17.8	15.8	19.1	13.9	15.5	16.0	16.9
Ge	2.0	0.9	1.3	1.0	0.4	0.6	1.3	0.7
As	4.6	4.4	5.6	4.8	0.5	7.1	4.7	4.6
Se	0.3	0.3	0.3	0.3	0.2	0.3	0.3	0.3
Br	5.6	0.3	4.5	1.8	17.5	2.2	8.1	3.4
Rb	69.9	82.2	67.9	84.2	23.5	45.0	52.1	58.5
Sr	169.7	204.7	149.7	187.3	129.2	139.6	122.0	127.0
Y	23.8	25.8	22.0	22.8	17.8	21.2	26.4	25.3
Zr	136.1	137.6	121.4	134.0	67.2	151.7	182.4	144.1
Nb	15.5	21.1	16.7	21.5	3.2	21.2	20.2	19.6
Mo	3.0	6.8	3.0	3.0	3.0	3.6	3.7	3.9
Cd	0.8	1.1	0.9	0.8	0.9	0.7	0.8	2.9
In	0.8	1.1	0.9	0.8	0.8	1.0	0.8	1.0
Sn	2.3	2.1	1.6	1.0	2.0	1.2	2.9	4.0
Sb	0.8	1.3	1.0	0.9	0.8	1.0	0.9	1.7
Te	1.1	1.7	1.4	1.2	1.2	1.3	1.3	1.2
I	3.3	2.8	2.5	1.3	2.0	2.8	2.2	2.1
Cs	3.1	5.1	5.5	7.4	3.5	4.1	3.9	3.2
Ba	198.2	313.9	175.5	205.4	42.0	279.9	235.2	139.9
La	23.9	37.7	26.6	39.7	18.0	39.3	27.4	34.5
Ce	56.1	86.0	65.9	46.7	10.0	75.3	64.6	29.2
Hf	3.6	2.8	3.4	3.5	3.4	4.8	3.7	3.5
Ta	4.6	4.9	4.5	4.7	4.6	4.0	4.7	4.8
W	3.4	3.8	3.9	4.0	4.0	3.1	3.6	4.1
Hg	0.8	0.8	0.8	0.8	0.8	0.8	0.8	1.9
Tl	0.8	0.9	0.9	0.9	0.8	0.5	0.9	0.9
Pb	41.7	42.0	16.5	40.8	9.5	69.3	63.3	40.1
Bi	0.8	0.7	0.5	0.6	0.6	0.6	0.7	0.6
Th	7.9	8.4	5.7	7.1	0.7	9.2	9.5	4.2
U	7.4	8.5	6.5	8.1	6.9	22.7	10.5	14.7

Table 3. Trace element values of Phaselis PMK, Clay and APK samples (ppm).

Element	APK-B10	APK-B18	APK-B22	APK-B27	APK-B28	APK-B32	APK-B34	APK-B37	APK-B39
Co	45.8	65.7	75.1	25.7	55.9	51.2	62.1	41.7	45.9
Ni	202.2	286.3	271.3	153.8	144.2	132.3	310.7	105.6	99.2
Cu	45.4	47.1	45.5	56.5	76.5	52.7	36.8	36.1	43.6
Zn	111.4	117.6	110.1	103.2	100.9	106.3	86.8	64.8	82.1
Ga	22.0	18.9	16.1	19.7	20.1	17.9	16.2	17.8	18.2
Ge	1.4	1.1	1.4	2.2	2.2	0.9	0.5	0.9	1.4
As	3.7	4.7	8.4	4.3	4.4	4.2	3.7	2.6	3.1
Se	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Br	1.7	4.7	4.6	4.3	2.8	6.5	0.2	1.7	2.7
Rb	55.4	64.9	60.8	51.3	51.7	72.2	58.7	70.7	64.0
Sr	243.1	174.2	147.6	179.5	111.1	155.0	235.1	201.2	227.4
Y	25.7	25.7	22.5	28.3	29.7	25.7	20.1	22.1	23.6

Zr	136.1	137.6	121.4	134.0	67.2	151.7	182.4		144.1
Nb	15.5	21.1	16.7	21.5	3.2	21.2	20.2		19.6
Mo	3.0	6.8	3.0	3.0	3.0	3.6	3.7		3.9
Cd	0.8	1.1	0.9	0.8	0.9	0.7	0.8		2.9
In	0.8	1.1	0.9	0.8	0.8	1.0	0.8		1.0
Sn	2.3	2.1	1.6	1.0	2.0	1.2	2.9		4.0
Sb	0.8	1.3	1.0	0.9	0.8	1.0	0.9		1.7
Te	1.1	1.7	1.4	1.2	1.2	1.3	1.3		1.2
I	3.3	2.8	2.5	1.3	2.0	2.8	2.2		2.1
Cs	3.1	5.1	5.5	7.4	3.5	4.1	3.9		3.2
Ba	198.2	313.9	175.5	205.4	42.0	279.9	235.2		139.9
La	23.9	37.7	26.6	39.7	18.0	39.3	27.4		34.5
Ce	56.1	86.0	65.9	46.7	10.0	75.3	64.6		29.2
Hf	3.6	2.8	3.4	3.5	3.4	4.8	3.7		3.5
Ta	4.6	4.9	4.5	4.7	4.6	4.0	4.7		4.8
W	3.4	3.8	3.9	4.0	4.0	3.1	3.6		4.1
Hg	0.8	0.8	0.8	0.8	0.8	0.8	0.8		1.9
Tl	0.8	0.9	0.9	0.9	0.8	0.5	0.9		0.9
Pb	41.7	42.0	16.5	40.8	9.5	69.3	63.3		40.1
Bi	0.8	0.7	0.5	0.6	0.6	0.6	0.7		0.6
Th	7.9	8.4	5.7	7.1	0.7	9.2	9.5		4.2
U	7.4	8.5	6.5	8.1	6.9	22.7	10.5		14.7

Table 4. Trace element values of Phaselis APK samples (ppm) (continued)

2 in this characteristic. Group 4 (Raw clay, APK-B4, APK-B6, APK-B7), which has the same aluminium value but an increased magnesium value and a decreased calcium value, and group 5 (APK-18, APK-B27, APK-B28), which has magnesium and calcium values close to these groups, but an increased aluminium value, seem to form an association within themselves with similar values with very small differences. The contents and analytical values of all these groups indicate that they have a similar clay structure (Fig. 12a).

Chemical analyses revealed that the amphorae contain largely similar ingredients. However, these samples, which are composed of the same rocks and minerals, exhibit minor discrepancies in the proportions and values of the constituent elements. These variations imply that the raw material may have been sourced from disparate regions within the clay deposit (lagoon) during the fabrication of the amphorae.[25]

In addition, according to the results of the chemical analyses on the amphorae; the other most important finding supporting the compatibility of these samples with the clay resources of the region is the chromium (Cr_2O_3) values of the raw clay, production waste and amphora samples. It is evident that the clays in these regions exhibit elevated concentrations of iron, magnesium, chromium, and nickel, indicative of ophiolite formation.

According to the analyses of the clay samples in previous studies, values of 400-500 ppm and above (Fig. 12b) were found to be associated with ophiolites.[26] It is noteworthy that the chromium (Cr_2O_3) value in some of the clay samples taken from ophiolitic areas was found to be below 0.04-0.05% (400-500 ppm).[27] The

25 In light of the fact that ceramics were produced within these geographical areas during the specified period (ranging from the mid-5th century BC to the 3rd century BC), it is imperative to acknowledge that minor variations may emerge across different regions within the same geological formations.

26 Eroğlu et al. 2019: 168; Eroğlu et al. 2022: 72.

27 It is important to note that these results may be related to clays taken from areas where chromium minerals are not concentrated, but it is also possible that chromium

values of chromium (Cr_2O_3) above these ratios are definitely an indication of its relationship with ophiolitic areas. It is evident that the elevated chromium levels observed in the samples analysed in this study are of significant geological significance, as they indicate that these regions are ophiolitic in nature.

The region where Phaselis is located is geologically located in the area where the Tekirova ophiolite is surfaced (Fig. 13).[28] Petrographic and chemical analyses demonstrated that the raw clay, production waste, misfired amphora and amphora samples analysed in this direction were related to this formation. Indeed, raw clay (APK-D1), production waste- misfired amphora (APK-B37, APK-B39) and the new Phaselis amphora types (PKM-B1, PMK-B2, PMK-B3 and PMK-B4), which are the main subject of this study, as well as the previously studied local Phaselis types (APK-B7, APK-B10, APK-B22, APK-B34) were found to contain high levels of chromium according to the results of chemical analysis (Fig. 12b, Table 1). These ratios show the relationship of both raw clay and amphorae to ophiolite formation. This is one of the most important pieces of evidence showing that raw material was taken from different areas of the lagoon and that ceramics/amphoras were produced at Phaselis.

Evaluation and Conclusion

The petrographic method is the main analysis used to determine the origin of building materials and archaeological finds used in stone based historic buildings, such as stone, brick, mortar and ceramics, and other analyses support petrographic analyses. Consequently, in this study, petrographic and chemical analyses have been carried out on the raw clay sample taken from the lagoon and on the production waste, misfired amphorae, amorphous, slag and amphorae found during the excavations, in order to determine the origin of the amphorae. In this particular context, following a thorough analysis of a clay sample extracted from the lagoon, the presence of ophiolitic formations characterised by elevated magnesium, iron and chromium concentrations was revealed. It was ascertained that APK-B37, a defective production sample, exhibited the highest chromium content, with a value of 2929 ppm.[29] A comparison of this defective specimen with the unprocessed clay indicates that the clay resources in the region were utilised in the manufacture of ceramics and amphora at Phaselis.

The Tekirova ophiolite, which is visible in the region where Phaselis is located, is associated with oceanic formation and consists of ophiolite series and ophiolite melange. Accordingly, the ophiolite series comprises basal metamorphites, upper mantle peridotites (harzburgites, pyroxenites and gabbros), ultramafic-mafic cumulates and marine sediments (pelagic limestone, radiolarite), along with basalts and ophiolite melange. The ophiolite melange, which is a constituent of this formation, comprises serpentine harzburgite, gabbro, basalt, diabase, granite, mudstone and chert rocks.[30]

Therefore, in instances where rock fragments containing serpentine, basalt, gabbro and radiolaria are present in ceramics, consideration should be given to regions containing ophiolite series and ophiolite melange. In the context of the Tekirova ophiolites in and around Phaselis, olivine diabase has been identified in three areas: firstly, between Kemer and Çıralı; secondly, at the entrance of Çamyuva; thirdly, in the coastal area of Çıralı-Tekirova; and fourthly, south of Tatlısu Bay and west of Üç Adalar.[31] A dyke comprising olivine diabase was identified at the entrance to Çamyuva, situated approximately 1 kilometre northwest of Phaselis.[32] Furthermore, the detection of olivine in the production waste sample APK-B35 from Phaselis provides additional evidence that strengthens the origin of these amphorae (Fig. 13).

It is evident from the examination of the general petrographic features observed in the raw clay, production waste and amphora samples that serpentinisation, uralitisation, chloritisation, clayification and opacification are observed in

does not show a homogeneous distribution.

28 Şenel 1997: 10-15.

29 An analysis of the clay deposits in regions exhibiting ophiolite formations, in conjunction with the examination of the ceramics retrieved from these areas, has revealed that chromium and nickel concentrations are typically elevated, see Eroğlu et al. 2019: 168; Eroğlu et al. 2022: 72.

30 Sarıfakılıoğlu et al. 2017: 56.

31 Güneş, 2018: 36.

32 Güneş, 2018: 18.

pyroxenites-hazburgites. Mafic minerals show alteration starting with opacitisation and progressing to opacification. In some minerals, both processes are seen together, some of the minerals are opacitisationed while the other part is completely opaque. This is a common feature of both the clay sample and the ceramics (Fig. 6, 11).

In certain instances, pyroxenes exhibit a propensity for cleavage along a particular crystallographic axis. While some of these structures are observed to be pseudomorphs, it is also noted that they are uralitised and serpentinised from the margins and slitting surfaces (Figs. 7-8, 10). Olivine was observed in some samples, and in addition to olivine, basalt was also observed in a number of samples. Furthermore, some of these samples exhibited a sieve texture by virtue of the fact that they had been subjected to serpentinisation in small amounts. In addition to these findings, opaque minerals were identified as mafic in nature, and chromite and magnetite were distinguished among the opaque minerals.

As previously stated, in addition to pyroxenites, serpentinite rock fragments were identified in the clay sample, production waste, misfired amphora and the amphora samples. Serpentinites, which are the product of the alteration of pyroxenes and olivines, were also found to have a sieve texture. In serpanites, olivine and pyroxenes were found in voids as relics (Figures 6-7, 10). Furthermore, diabase rock fragments were identified in raw clay, fproduction waste, misfired amphora and amphora samples. Pyroxene, plagioclase and opaque minerals were detected in these rocks. Diabases are defined by two distinct textures: ophitic and subophitic. Alteration features indicative of processes such as uralitisation, serpentinisation and chromitisation have been identified in diabases.

In previous studies, Phaselis Type 1, Type 2, Type 3a, Type 3b and Small Scale Phaselis specimens were identified as locally produced. The new type of Phaselis amphorae (PMK-B2, B3, B4, B5, B6, B7), Type 1 (PMK-B1) and misfired amphora (PMK-B8) samples are the subject of this study. These were evaluated as a whole, in conjunction with raw clay and other production waste samples. Indeed, the results of petrographic and chemical analyses of raw clay a taken from a distance of 200 m from the PMK Ceramic Dump and Amphora Production Area in Phaselis, have been revealed by analytical methods to be related to Tekirova ophiolites. In addition to the raw clay, the production waste, the missfired amphora and amphora samples were also analysed according to these analyses, and their relationship to the Tekirova ophiolites was revealed by the analytical methods.

Consequently, a series of petrographic and chemical analyses were conducted on 8 distinct samples of amphora. The results of these analyses on the amphorae are consistent with the geology of the region. Furthermore, the findings of the analyses conducted on the raw clay sample, when compared to those of the amphora samples, revealed that the contents and minerals of the amphora and the raw clay were similar to each other. Therefore, it was observed that the aforementioned ingredients and minerals are in accordance with the geology of Phaselis and its surroundings (Fig. 13).[33] In this respect, the new type of Phaselis amphorae in study (Fig. 5, PMK-B2, B3, B4, B5, B6, B7) are demonstrably consistent with previous analyses and have been shown by archaeological, archaeometric and geological evidence to be locally produced like other Phaselis amphorae types.[34]

33 Şenel et al. 1981: 40; Öner 2018: 352-354.

34 For further information pertaining to the ceramic/amphora production areas and artefacts unearthed at Phaselis, see Orhan 2020: 75-86; 2023a: 27-34; 2023b: 47-60; 2024: 86-116.

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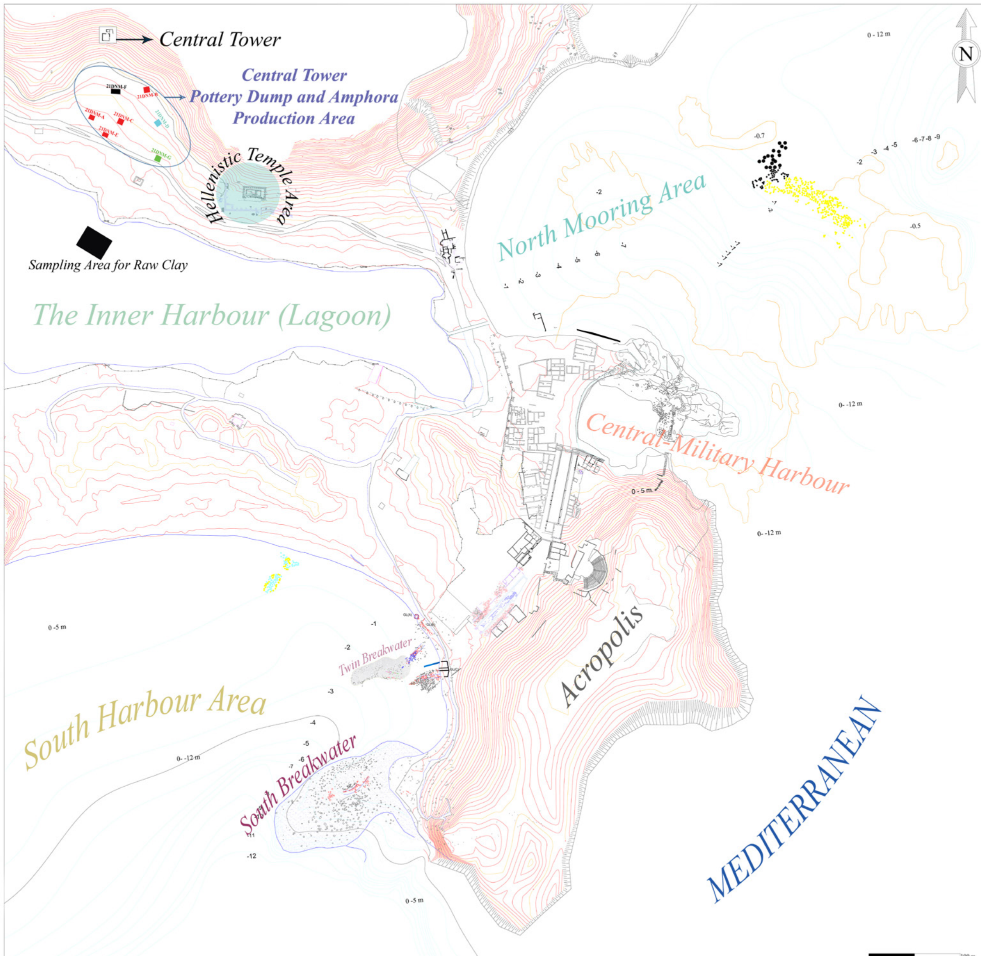


Fig. 1. Phaselis plan.

a b

Fig. 2a-b. Kiln bricks (a) and Amorphous-slag finds (b).

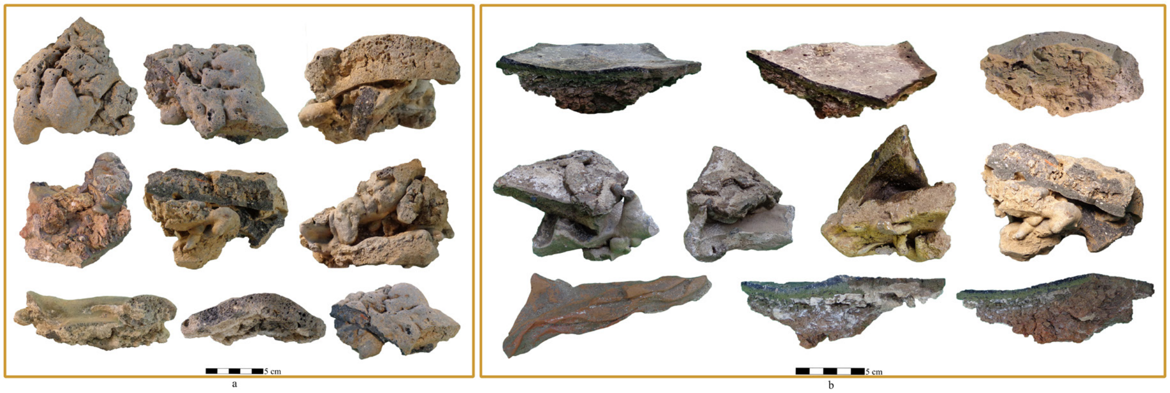


Fig. 3a-b. Examples of ceramic finds exhibiting flaws during the firing and production process.

Fig. 4a. Pottery shard with seashell on the tondo.
Fig. 4b. Misfired amphora foot.

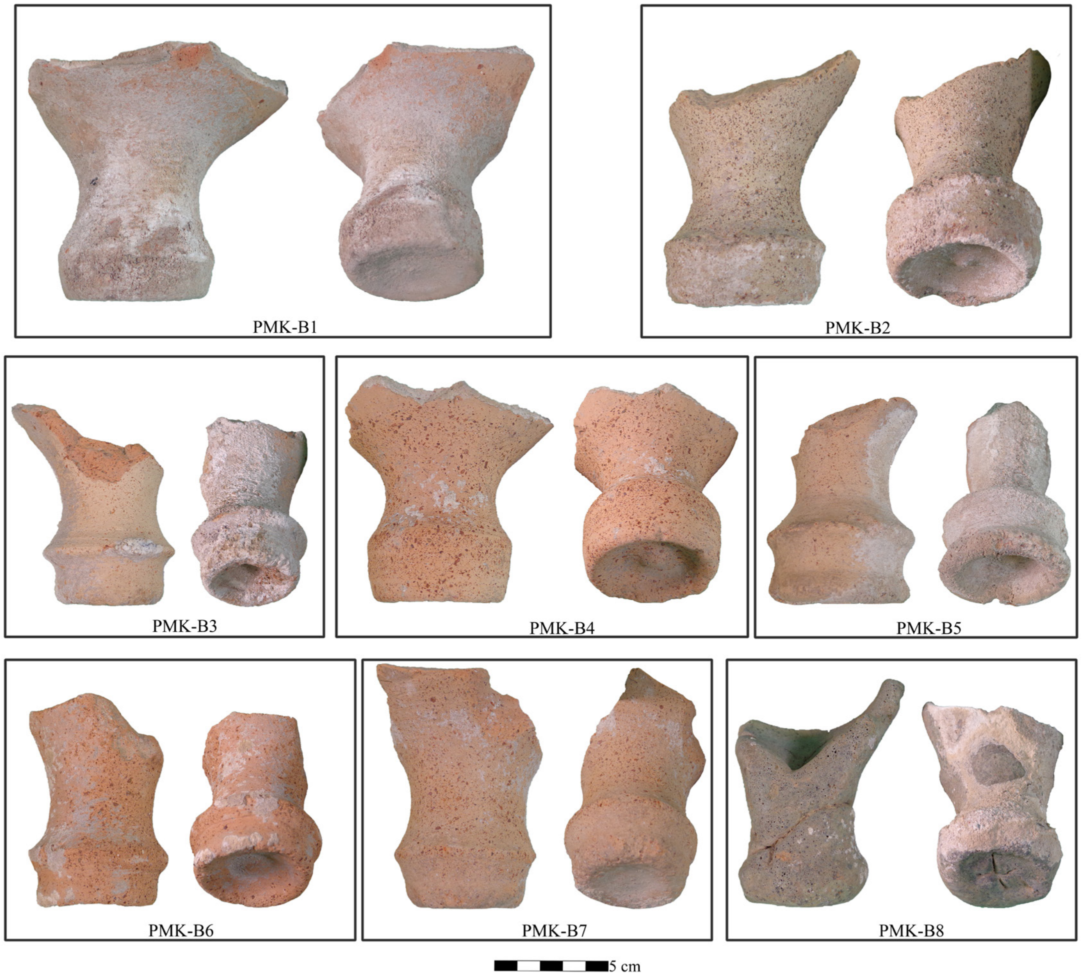


Fig. 5. Sampled amphorae.

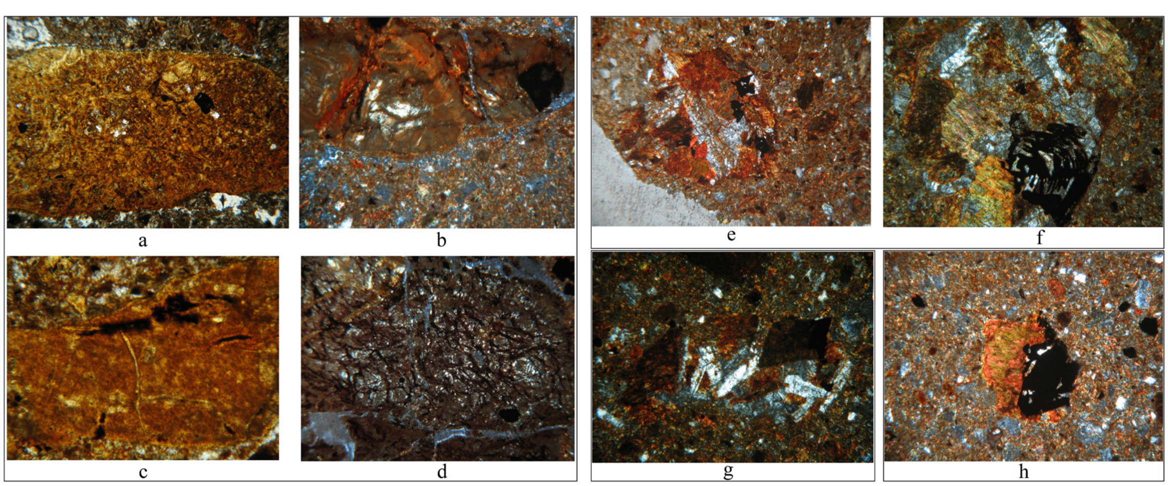


Fig. 6. Clay sample (APK-B40/D1) serpantinite (a,b,c,d), gabbro (e-f), basalt (g), partly opacitised and partly opaque pyroxene mineral (h).

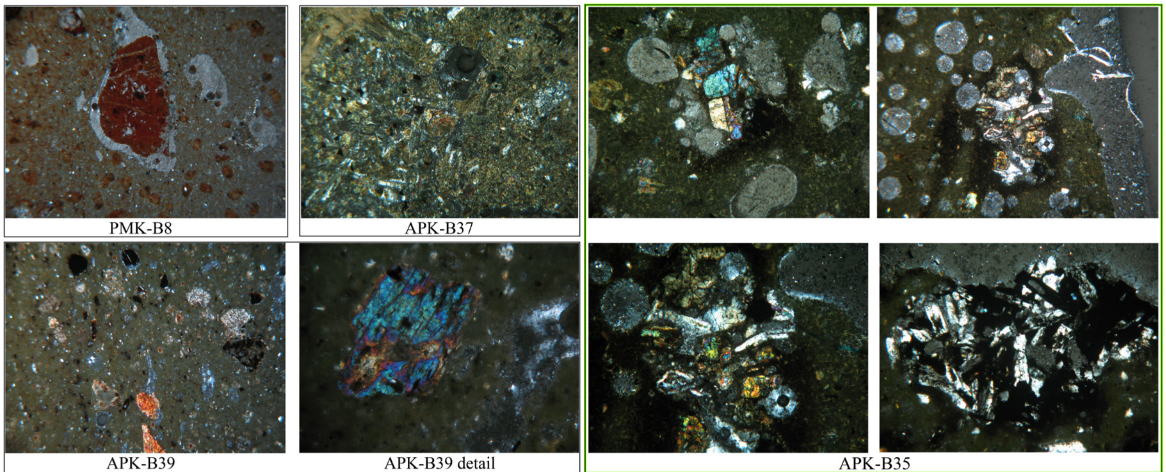


Fig. 7. Misfired amphora samples (APK-B39-PMK-B8) and production waste samples (APK-B35- APK-B37).

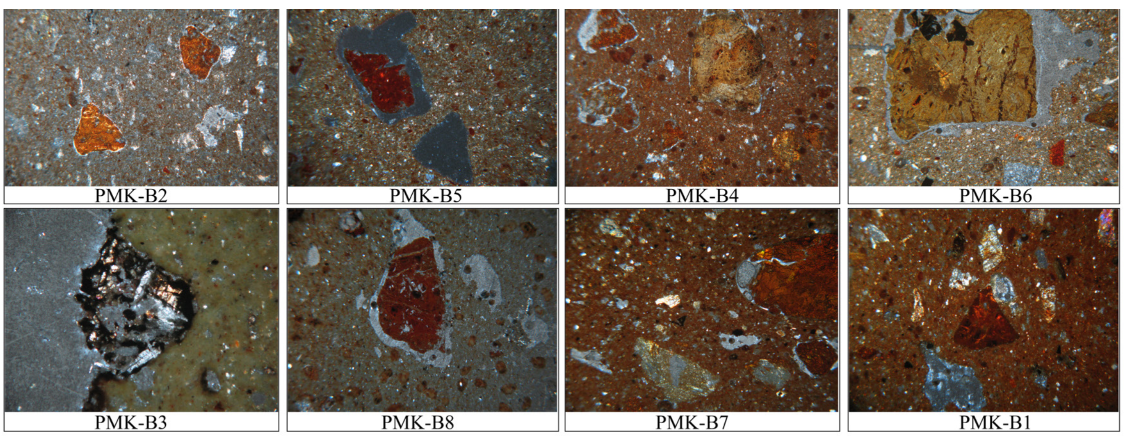


Fig. 8. Phaselis Centre Tower (PMK) samples.

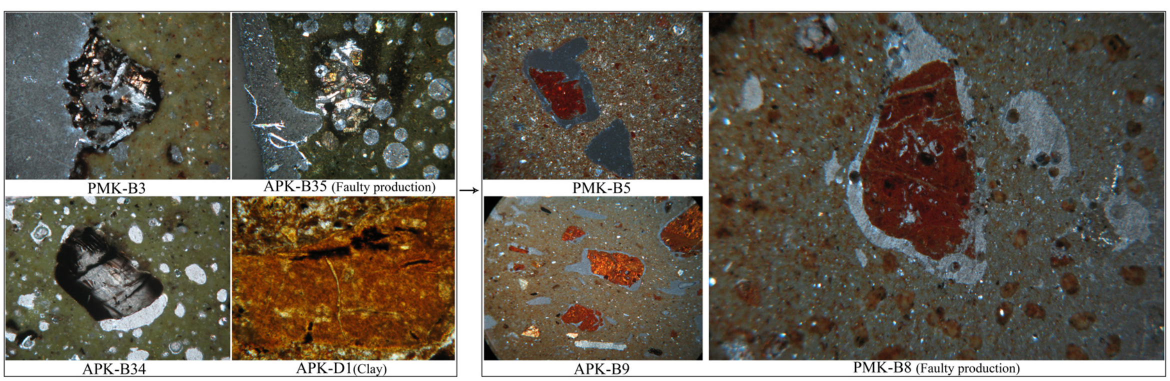


Fig. 9. Compared samples PMK-B3, APK-B35 (Misfired amphora), APK-B34, APK-D1(Raw clay), PMK-B5, APK-B9 and PMK-B8 (Misfired amphora samples).

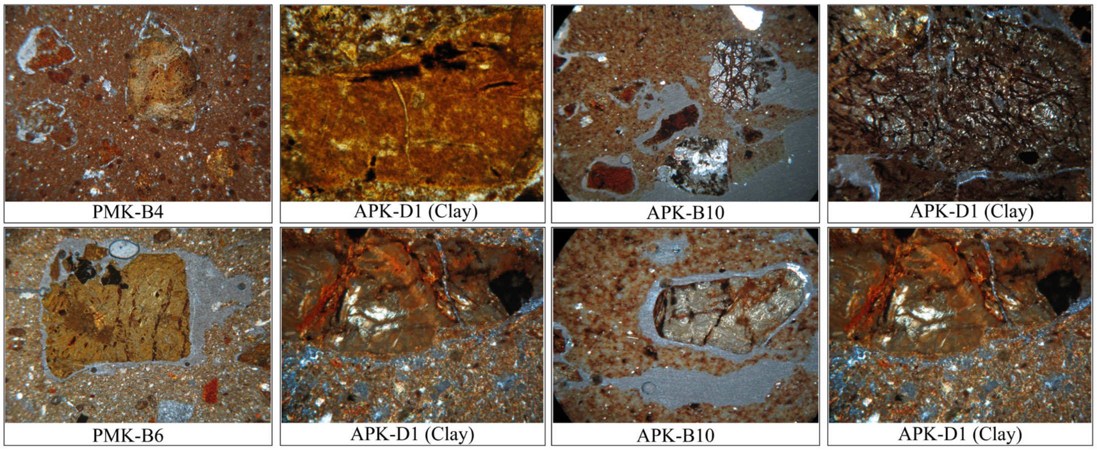


Fig. 10. Comparison of PMK and APK samples.

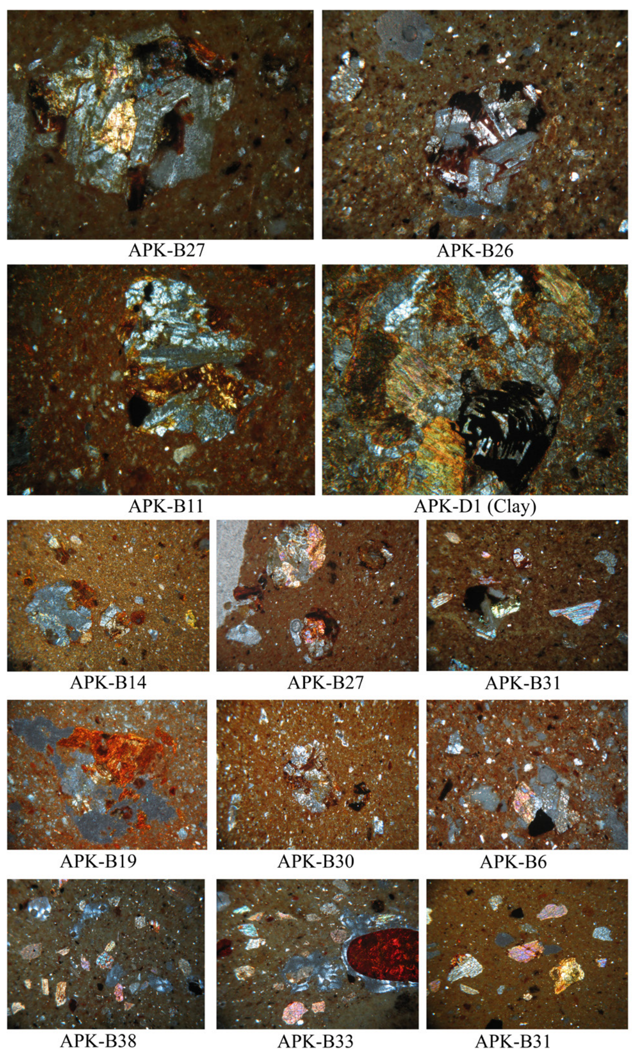
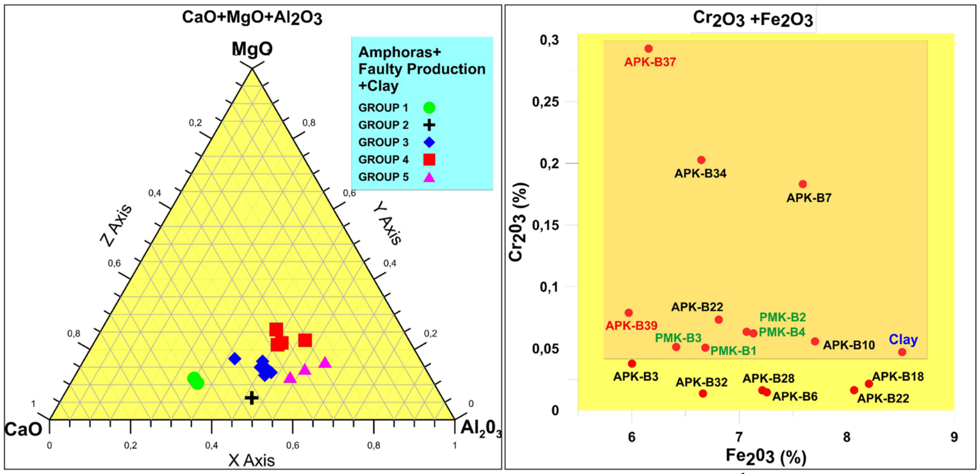


Fig. 11. Comparison of samples.



a b

Fig. 12a. Graph illustrates the correlation between raw clay, production waste and misfired amphora samples according to CaO+MgO+Al203 values (Group 1 (APK-B37, APK-B39), Group 2 (APK-B3), Group 3 (PMK-B1, PMK-B2, PMK-B3, APK-B10, APK-B22, APK-B32, APK-B34), Group 4 (Raw clay, APK-B4, APK-B6, APK-B7), Group 5 (APB18, APK-B27, APK-B28).

Fig.12b. Graph illustrates the relationship between Cr203 +Fe203 values and samples of raw clay, production waste and misfired amphora samples.

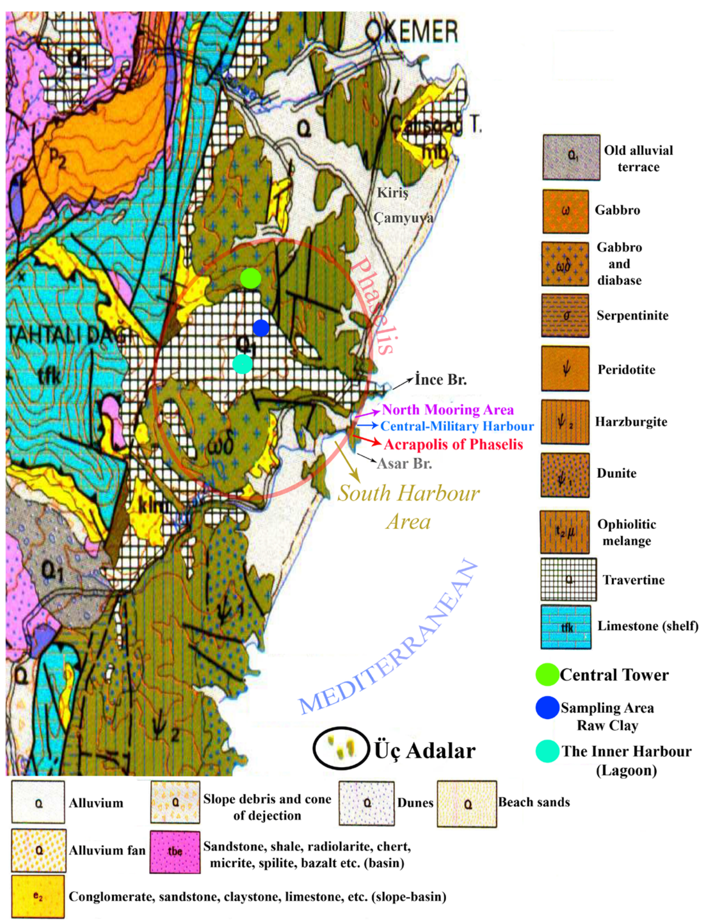


Fig. 13. A Generalised and edited geological map of the ancient city of Phaselis and its Surroundings (Şenel 1997; Öner 2018: 353, Fig. 3).