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Revisiting the material evidence*

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THE PIGMENT PRODUCTION SITE OF THE ANCIENT AGORA OF KOS (GREECE): REVISITING THE MATERIAL EVIDENCE

Ariadne Kostomitsopoulou Marketou*

Keywords: Kos, agora, Hellenistic period, pigments, Egyptian blue, metallurgy, lead, silver, production site, manufacture

Parole chiave: Kos, agorà, età ellenistica, pigmenti, blu egiziano, metallurgia, piombo, argento, produzione, sito produttivo, manifattura

Abstract

A late-Hellenistic production site was found at the eastern stoa of the agora of Kos. The presence of destroyed fire-structures indicates pyrotechnological processes, related to pigment manufacture and metallurgy. Pigment production included the treatment of natural earths and the manufacture of the artificial material Egyptian blue. Among the excavation's finds were hollow tubular litharge rods, amorphous lead lumps and drops, and a small quantity of silver, which point to lead production and silver separation through cupellation. The co-existence of the two separate manufacturing activities at the same site may have been beneficial in supplying the workshop with raw materials and fuel. The strategic location of the production site in the commercial centre of the ancient town, with its connection to the port, would have facilitated trade. The production debris from the Koan site underlines the relationship between pigment manufacture and metallurgy.

Un sito produttivo risalente all'età tardo ellenistica fu messo in luce nel settore orientale dell'agorà di Kos. Resti di fornaci, pur se scarsamente conservate, testimoniano processi piro-tecnologici relativi alla metallurgia e alla manifattura di pigmenti. La produzione dei pigmenti includeva il trattamento di terre colorate e la manifattura del blu egizio, un pigmento artificiale. Alcuni tra i materiali rinvenuti nel sito (barre tubolari di litargirio, masse amorfe e gocce di piombo, e residui d'argento) indicano la produzione di piombo e la separazione dell'argento tramite coppellazione. La compresenza delle due diverse attività manifatturiere nello stesso impianto artigianale potrebbe essere stata vantaggiosa in termini di approvvigionamento di materie prime e combustibile. La posizione strategica della manifattura, situata nel centro commerciale della città antica e interconnessa con il porto, avrebbe facilitato la commercializzazione dei prodotti. Gli scarti produttivi suggeriscono una relazione tra la produzione di pigmenti e la metallurgia.

Introduction

The material remains of a production site, related to pigment manufacture and metallurgy, were brought to light in the central part of the agora of Kos¹ by the excavations conducted by the 22nd Ephorate of Prehistoric and Classical Antiquities of the Greek Archaeological Service (Fig. 1). The excavations were carried out in two phases. During the first phase (1984-1989), the largest part of the area was unearthed under the supervision of the archaeologist Charis Kantzia². The excavations of the second phase (2009-2011), undertaken by the archaeologist Eirini Papanikolaou from the Institute for Aegean Studies, expanded the uncovered area to the north and east as part of the restoration and reconstruction works at the central part of the agora³. The excavations revealed a section of the central part of the agora, with the *stylobate* of the eastern *stoa*, two rooms which belong to the eastern *stoa*, and the courtyard of the agora with the foundations of a Roman *tholos*⁴ (Figs. 1, 2).

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¹ Cadastral area No. 1293D, previously property of Damtsa.

² KANTZIA 1987; KANTZIA, KOUZELI 1987.

³ ELEUTHERIOU, NETTI 2011; GIANNIKOURI, SKERLOU, PAPANIKOLAOU 2011.

⁴ KANTZIA 1987.

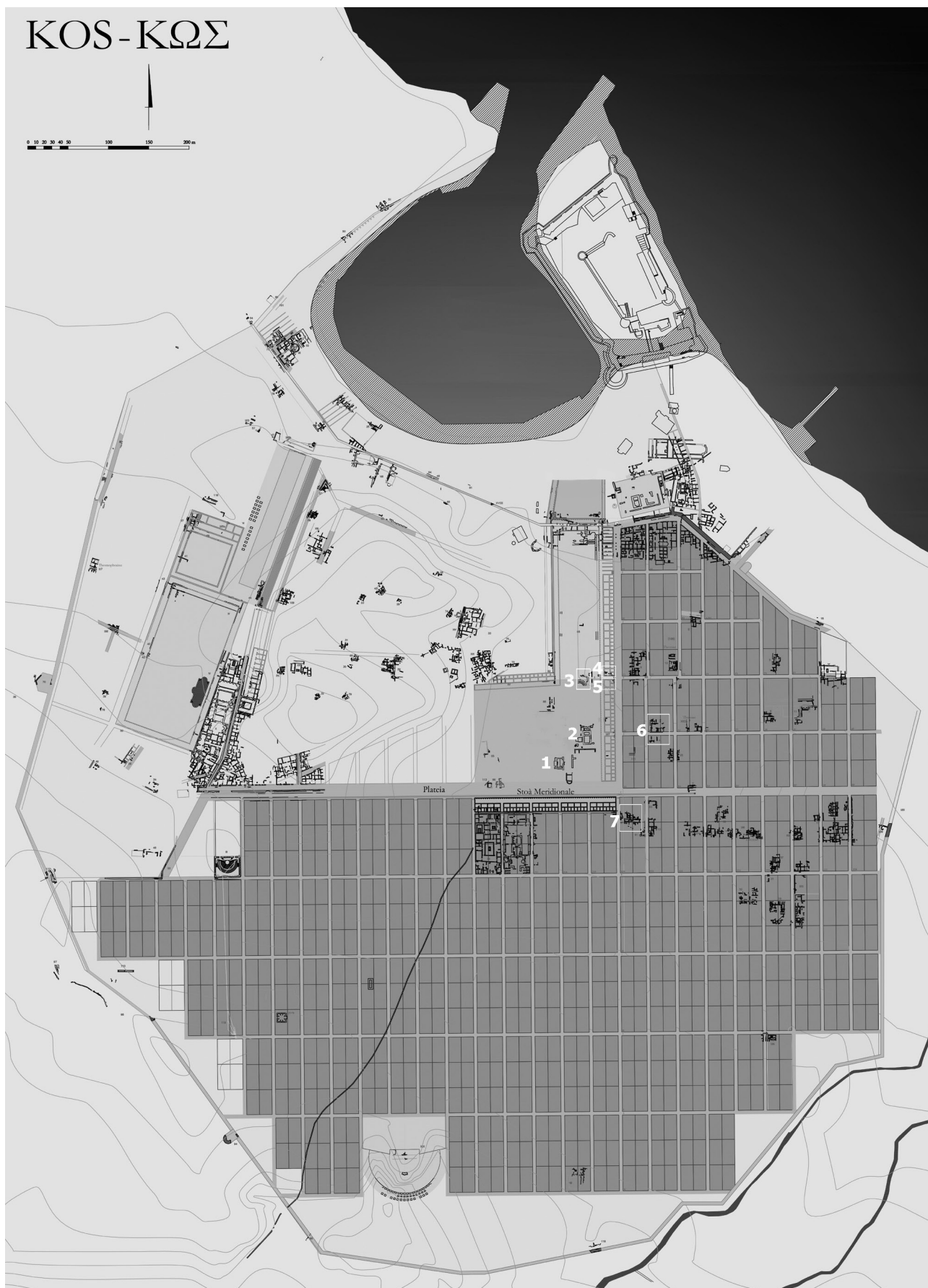


Fig.1. Town plan of Kos showing the agora after Rocco, Livadiotti 2011, with the Hellenistic temple of Attalides (1), the s. c. altar of Dionysus (2) and the Roman *tholos* (3). The pigment production site is located in a room of the eastern stoa (4), and a site related to metallurgical processes was also found to its south (5). The early Christian glass workshop is located at the eastern district of the city (6), and the late Classical-early Hellenistic amphora workshop was found to the south (7).

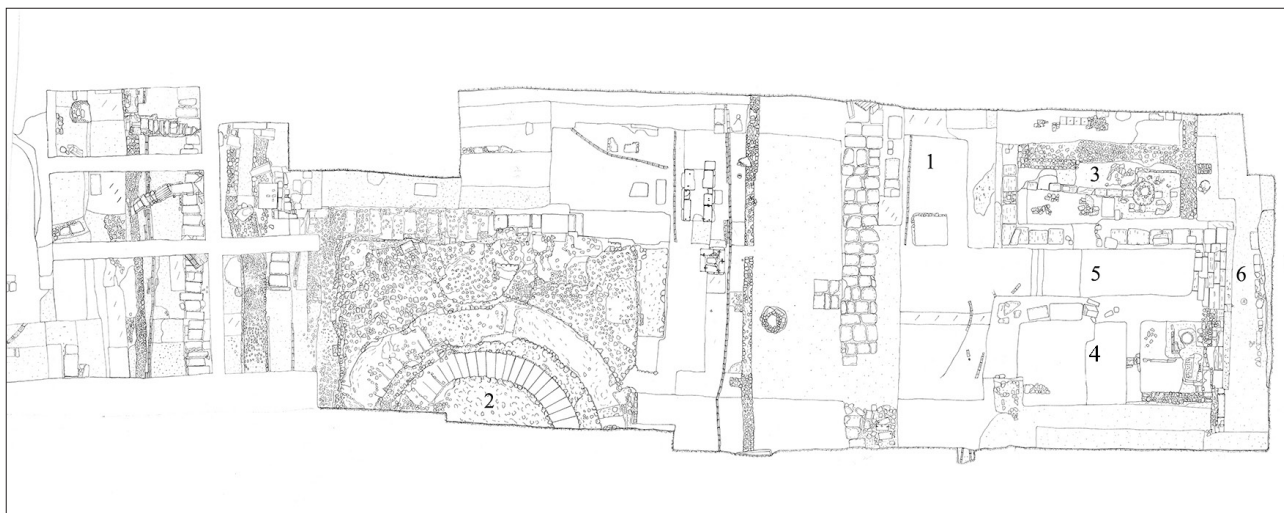


Fig. 2. The excavation on 1293 D (archaeologists: Ch. Kantzia, E. Papanikolaou, drawing E. Tsampouniari). Part of the eastern stoa is revealed (1), and to its west the foundations of a Roman *tholos* (2) were found. Two rooms of the eastern stoa were also found (3, 4). The two rooms are separated by an EW passage (5), connecting the agora's courtyard with the eastern part of the town. To their west, a NS street (6) was revealed, forming the agora's eastern border.

The production site was revealed in the area corresponding to the northern room (Figs. 1, 2). There, numerous earth pigments and Egyptian blue pellets were found in the context of destroyed fire-structures, along with amorphous lead, lead drops, and hollow tubular litharge rods (lead oxide, PbO). The findings of the first period have been preliminarily presented and published by Ch. Kantzia in collaboration with K. Kouzeli, with a special focus on successful and unsuccessful Egyptian blue products⁵. The present article aims to re-examine the material remains of the production site of the agora of Kos and to approach the intangible technological processes carried out at the site.

Research on ancient pigments, and especially on materials dated to the Hellenistic and Roman periods, shows a relatively uniform use of materials and techniques across different places (a material *koine*?), with slight variations depending on access to raw materials, local resources, and the symbolic connotations that the materials may bear⁶. The “artists’ palette” is comprised of numerous different materials, including natural pigments derived from the treatment of minerals or ores, synthetic materials such as Egyptian blue, and pigments derived from the treatment of metals such as lead white (*cerussa*), as well as organic dyes dispersed in an inorganic binder (lakes).

While pigments were abundantly used, material evidence for the organisation of their production in the Hellenistic and Roman periods is scarce⁷. The *nature* of pigments, with their variety of sources and production processes, makes the identification of production sites a demanding task, and calls into question the very existence of a single place dedicated to ‘pigment production’. Exceptional are the workshops — or the indications of workshops — for Egyptian blue production at the Greco-Roman sites of Memphis in Egypt and of Cumae, Liternum, and Puteoli in central Italy (Phlegraean Fields)⁸. An example of earth pigment treatment can be identified at a Hellenistic workshop on Agathonisi, an island neighbouring to Kos⁹. These production sites seem to have a specific focus: Egyptian blue in the first cases and earth pigments in the latter. It is for this reason that the production site of the agora of Kos, where earth pigments and Egyptian blue pellets were found in the same space with metallurgical remains, may be significant for our understanding of the organisation of pigment production.

The different manufacturing activities hosted at the production site of Kos are the focus of this article. In the first part¹⁰, the contextual setting of the site within its surroundings will be presented, followed by the presentation of the

⁵ KANTZIA, KOUZELI 1987.

⁶ The choice of uncommon, “precious” materials in antiquity and the symbolic connotations that these may bear in contrast to the most commonly used pigments is approached in a recent article by H. Brecoulaki. See BRECOULAKI 2014.

⁷ Pigments as raw materials have been found in several archaeological settings. See for example BEESTON, BECKER 2013, for the finds from a pigment shops in Rome from the Roman period, ESPOSITO

2016 and references therein for Pompeian painters’ workshops, and KARYDAS, BRECOULAKI, BOURGEOIS, JOCKEY 2009 for a study of raw pigments from Delos.

⁸ For a comparative review of Egyptian blue workshops in the Roman period see CAVASSA 2018.

⁹ TRIANTAFYLIDIS 2015.

¹⁰ See section *The agora of Kos and the development of mercantile and crafting activities*.

excavated site through its material remains¹¹. The archaeological evidence will be revisited through the study of the archival material, including the excavation diaries, photographic documentation, and drawings from the periods 1984-1989 and 2009-2011. The dating of the site will be reconsidered, complemented by the results from radiocarbon dating. In the second part¹², the excavation's finds will be re-examined, including the interpretation of preliminary results from the application of analytical techniques. The study of the finds and the identification of the materials treated *in situ* aims to improve our understanding of the production processes carried out at the site, i.e. pigment manufacture and metallurgy.

The agora of Kos and the development of mercantile and crafting activities

The pigment production site was brought to light in the eastern sector of the agora of Kos (Fig. 1), a place that seems to have hosted manufacturing activities throughout different periods¹³. The monumental complex of the Koan agora follows the island's historical development, with its form and functions shifting due to changing political circumstances and to the recurring and often catastrophic earthquakes that struck the island¹⁴. The early southern part of the agora, a centre for civic, civil and religious life, was constructed shortly after the synoecism and the foundation of the city of Kos in 366 BCE, including the monumental s. c. altar of Dionysus and, later, the Hellenistic temple of the Attalides¹⁵. A renovation at the end of the 4th c. expanded the complex of the agora, connecting the southern agora to the northern harbour area and thereby favouring the advancement of trade¹⁶. Indeed, commercial trade flourished on the island of Kos from the 3rd c. BCE onwards, with exports of various goods, such as the famous Koan silk garments, perfumes, wine, and pottery, bringing wealth and prosperity to the society¹⁷. To the south, the agora was connected to the rich inlands of Kos and the road leading to the *Asklepieion*, the island's most important sanctuary.

The agora dominated the northern part of the city and was incorporated in the Hippodamian urban plan, occupying 16 *insulae*¹⁸. It is considered to be one of the largest agora complexes in the ancient Greek world, shaped in the form of an L and approximately 350 m in length. Long stoas lined the east, west and south sides of the agora, which were incorporated into the urban plan by several passages¹⁹. The location of a site for pigment manufacture and metallurgy at the centre of the eastern stoa (Figs. 1, 2) may be significant for the interpretation of its organisation and its importance in the life of the ancient city²⁰.

Directly to the south of the site, and likewise incorporated in the stoa complex, a second room was brought to light by the excavations (Figs. 1, 2). Here, several bronze artefacts in various states of preservation and large quantities of corroded copper objects were found, along with bronze statues and statuettes of great artistic value, leading to its interpretation as a shop and/or metallurgical workshop²¹. The two workshops of the eastern stoa are located on either side of a 4.50 m wide, EW-oriented passage, which connects the agora to the eastern part of the town (Figs. 1, 2). An 8.80 m wide, NS-oriented street, which stands as the agora's eastern border, was revealed east of these rooms (Figs. 1, 2). This NS street is considered to have been important for the commercial and manufacturing activities of the city of Kos²².

Beyond the above two production sites of the eastern stoa complex, there are further indications of workshop activities in the eastern part of the ancient city of Kos. Kos is known from ancient treatises for the production of murex purple, and according to Kantzia, the excavations in the area indicate the operation of a murex workshop in proximity to the agora²³. Further, the unearthing of three clay figurine moulds at the eastern part of the agora supports the presence of

¹¹ See section *The material remains of the pigment and metal production site*.

¹² See *Discussion*.

¹³ LIVADIOTTI 2018, pp. 58-67.

¹⁴ GIANNIKOURI, SKERLOU, PAPANIKOLAOU 2011; ROCCO, LIVADIOTTI 2011.

¹⁵ STAMPOLIDIS 1987; GIANNIKOURI, SKERLOU, PAPANIKOLAOU 2011; ROCCO, LIVADIOTTI 2011.

¹⁶ SHERWIN-WHITE 1978, p. 24; ROCCO, LIVADIOTTI 2011; HÖGHAMMAR 2016.

¹⁷ SHERWIN-WHITE 1978, pp. 233, 236-241, 242-243, 378-383. This prosperity favoured the development of arts and sciences on Kos, the home of the painter Apelles, with a local School of Sculpture and the Hippocratic School of Medicine.

¹⁸ ROCCO, LIVADIOTTI 2011.

¹⁹ GIANNIKOURI, SKERLOU, PAPANIKOLAOU 2011; ROCCO, LIVADIOTTI 2011; ROCCO 2018.

²⁰ For an overview of the metallurgical and metal-working sites

organised in the area of the Athenian agora from the 6th c. BCE to the 6th c. CE see MATTUSCH 1977 and references therein.

²¹ The site has not yet been studied in detail. The presence of a statuette depicting Caligula is indicative of a 1st c. CE dating, or later. According to the excavation diaries (Diary 22, p. 5), the deposit of bronze finds was at the same level as the upper course of wall 2 of the northern room (see Figs. 6, 10 for wall 2). GIANNIKOURI, SKERLOU, PAPANIKOLAOU 2011, p. 368, and references therein.

²² The NS street was used continuously from the early 4th c. BCE until late antiquity (7th c. CE). See GIANNIKOURI, SKERLOU, PAPANIKOLAOU 2011, pp. 373-378. For the importance of the street to commercial and manufacturing activities see LIVADIOTTI 2018, pp. 61-62.

²³ For information about the production of murex purple on Kos see SHERWIN-WHITE 1978, p. 242, 383. The presence of murex dye workshops in the city is considered unlikely, due to the notorious malodour that is produced during the processing of the murex; however, the archaeological evidence indicates that at least part of the production was carried out in proximity to the agora. See KANTZIA 1987 pp. 237-238.

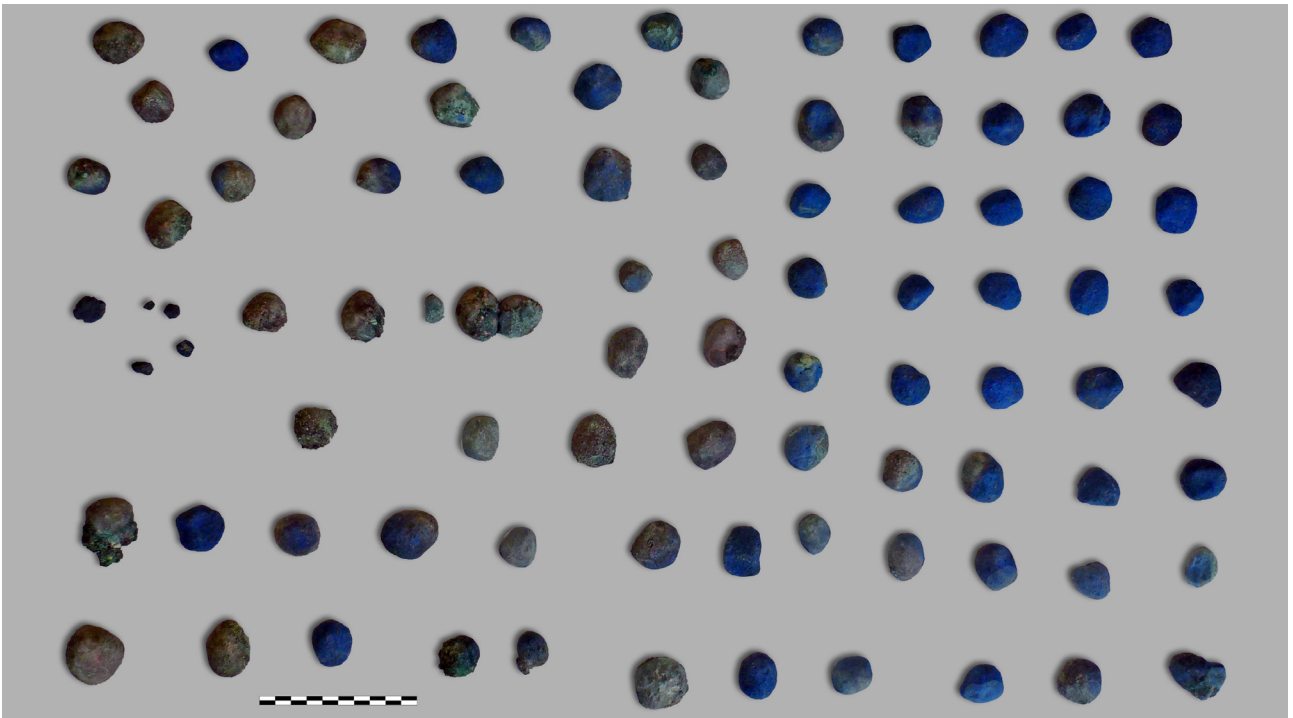


Fig. 3. Compilation of successfully (blue) and unsuccessfully produced EB pellets from FS1 (AE 714), with colours varying from blue to brown and from green to greyish purple.



Fig. 4. A selection of earth pigments from the Koan workshop after (Kostomitsopoulou Marketou, Kouzeli, Facorellis 2019).

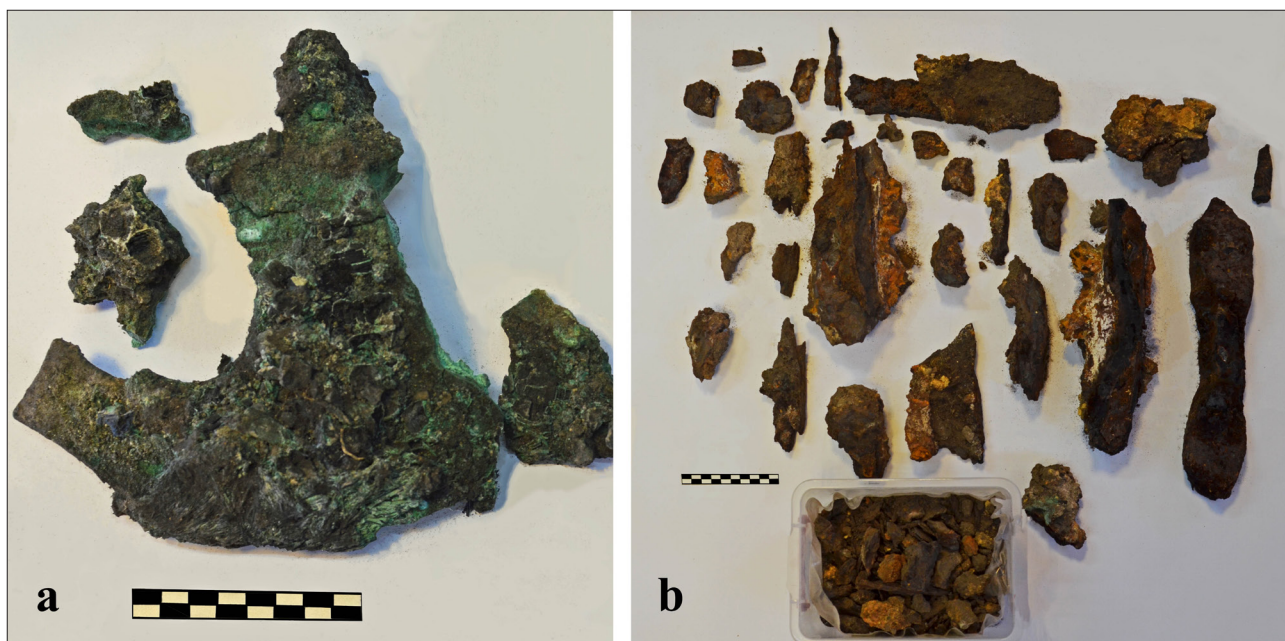


Fig. 5. a. Bronze object (AE 713) from FS1 with burnt pinecones adhered to its surface; b. a large piece of corroded iron (AE 705, original dimensions m 0.38 x 0.14 x 0.12) from the same layer of FS1. Fig. 6. a. Bronze object (AE 713) from FS1 with burnt pinecones adhered to its surface; b. a large piece of corroded iron (AE 705, original dimensions m 0.38 x 0.14 x 0.12) from the same layer of FS1.



Fig. 6. a. Hollow, tubular litharge rods from the deposit on the south of the well (AE 535). The rods have slightly varying dimensions, and their colour varies between pink and white; b. Amorphous lead lumps and drops from a deposit on the south of wall 2 (AE 878).



Fig. 7. Lime lumps from the hearth of fire-structure 1 (AE 715).

coroplastic workshops in this area²⁴. Finally, to the east of the agora and in proximity to the pigment production site, a late Classical-early Hellenistic (1st half of the 4th c. BCE) amphora workshop and late Roman-early Christian glass-working sites²⁵ have been found (Fig. 1), indicating a long-term crafting tradition in the area east of the agora.

²⁴Two moulds were found at the NS street that defines the eastern limit of the agora, while the exact location of the third is not specified. The moulds are related to the worship of Demeter and support the existence of local coroplastic workshops, possibly organised in the agora; GIANNIKOURI, SKERLOU, PAPANIKOLAOU 2011, p. 369; SKERLOU, GRIGORIADOU 2014. The need of pigments for

the decoration of the products of coroplastic workshops is indicated by the rich polychromy of the surviving figurines, on which one can observe blue, pink, white and red colours (personal observation).

²⁵For the amphora workshop see KANTZIA 1994; for the glass workshops see SKERLOU 2013, p. 1154; BROUSKARI 2002, p. 136.

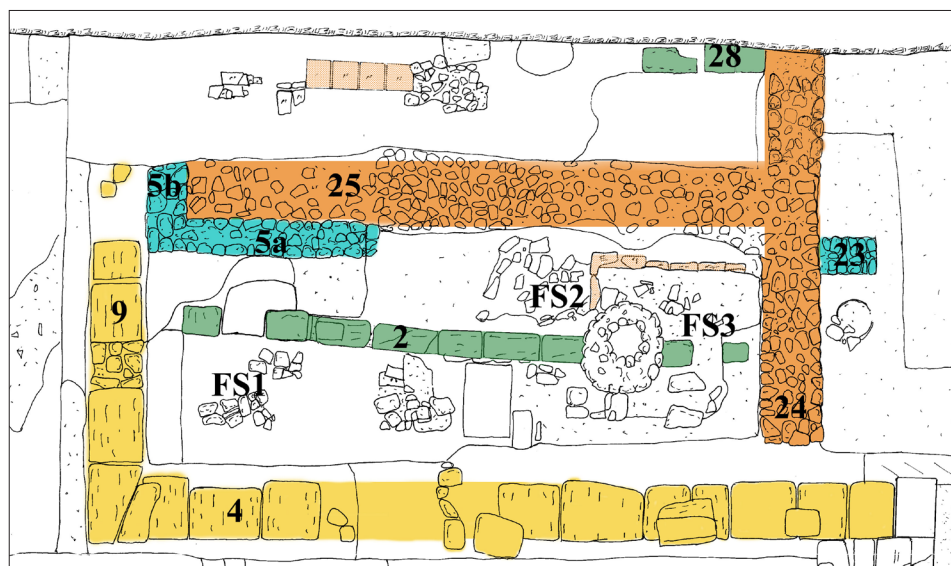


Fig. 8. Detail of the excavation plan (drawing by E. Tsampouniari) with the different architectural phases represented by different colours. Blue: walls possibly belonging to the 4th century BCE private houses, which were later demolished to enlarge the agora; yellow: foundations from the first phase of the agora (ca. end of 4th century BCE); orange: middle Hellenistic walls (2nd century BCE), green: late Hellenistic (1st century BCE) walls associated with pigment production.

The material remains of the pigment and metal production site

The excavations of the room to the north of the EW passage (Fig. 2), which is associated with pigment and metal production, brought to light approximately 130 Egyptian blue pellets along with numerous pigment lumps of red, brown, yellow and green colour (Figs. 3, 4). The pigment lumps were mainly found in relation to fire-structures. The presence of “unsuccessfully produced” Egyptian blue pellets among the finds points to local production of this artificial material. Moreover, the hypothesis that metallurgical processes were carried out at the site in parallel with pigment production is supported by the presence of corroded iron and bronze (Fig. 5), tubular litharge rods (Fig. 6 a), amorphous lumps and drops of lead (Fig. 6 b), lumps of lime (Fig. 7), and relevant equipment such as a trachyte quern.

The excavated area of the workshop extends 7.15-7.90 m NS and 12 m EW (Fig. 8). However, one should note that the today’s picture of the workshop is fragmented. The excavations of 2009-2011 indicate that the workshop stretched further north, with fire-structures organised beyond wall 28²⁶ (Fig. 8); unfortunately, the area north of wall 28 has been built over without prior archaeological investigations. Moreover, during the first trial trenches of the area, a Turkish wall was found at a level only 10 cm above the preserved architectural remains of the site (wall 2), indicating the degree of disturbance in the area. The deposit above the level of Turkish wall was removed by mechanical means and no further information is provided for the layers above it²⁷. In the following paragraphs, I aim to define the dating and the spatial organisation of the site. Further, I aim to relate the material remains from the excavations to the production processes carried out at the site.

Dating and spatial organisation

The severe disturbance of the stratigraphy, partly due to the spoliation of the agora’s structural materials during the Knights’ domination of the island (ca. 14th c. CE)²⁸ and partly to the consecutive earthquakes striking the island, complicates the dating of the production site. The description of the four distinguishable chronological phases through their architectural remains will follow. The last phase, *phase 4*, is related to manufacture, while the use of the room in the previous phases remains unknown²⁹. According to Ch. Kantzia, the production site was established in the late Hellenistic period, and most likely during the second half of the 1st c. BCE³⁰. Kantzia based the chronology of the workshop on the typology of a fragmented *olpe* which was found among undisturbed layers of the fire-structure related to Egyptian blue (Fig. 9). The late Hellenistic dating of the site will be re-evaluated, taking into account different elements and including the radiocarbon dating of materials from FS1.

Phase 1: The earliest building phase that can be identified through the site’s architectural remains, walls 5a-23 and 5b, belongs to a period before the construction of the eastern stoa of the agora, and most likely to the construction

²⁶ Unpublished excavation diary 199, p. 23.

²⁷ Unpublished excavation diary n. 22, pp. 1-2.

²⁸ MORRICONE 1950, p. 58; KANTZIA, KOUZELI 1987; GIANIKOURI, SKERLOU, PAPANIKOLAOU 2011.

²⁹ According to Kantzia, the early Hellenistic strata of the fillings

found directly to the west of the workshop, revealed metal scrap, indicating the use of the area for metallurgy even before *Phase 4*. See KANTZIA, KOUZELI 1987, p. 217.

³⁰ KANTZIA, KOUZELI 1987, pp. 210, 234.

of private houses in the 4th c. BCE, which were demolished towards the end of the century to enlarge the agora (Fig. 8)³¹. Walls 5a-23 and 5b are constructed of irregular blocks and are approximately 0.56 m wide.

Phase 2: After the renovations of the late 4th c. and the enlargement of the agora, this area was incorporated into a room of agora's eastern stoa. The direct contact of walls 5a-23 and 5b to wall 9 and 25 indicates their destruction before the construction of the latter. The room is limited to the south by the EW passage, which is defined by the foundations of wall 4 (Fig. 8). Wall 9 forms the western border of the room and at the same time serves as the front wall of the rooms of the eastern stoa. The two walls (9 and 4) are coeval and belong to the first building phases of the agora. During this so-called "amygdalopetra phase", which begins shortly after the foundation of the city in 366 BCE and continues until 275 or 230 BCE³², the foundations were built with a type of local tuff (*malakopetra*). The elevation of the walls was made with local travertine (*amygdalopetra*) and to a lesser extent with local white marble and limited inserts of local black or light blue marble³³. Only the foundations of walls 4 and 9 are preserved, built with rectangular *malakopetra* blocks with average dimensions of 0.90 × 1.20 m. The foundations are based on a solid layer of soil mixed with pebbles and pottery fragments, dated to the first phase of the agora (late 4th c. BCE)³⁴.

Phase 3: The eastern border of the workshop is defined by wall 24, while wall 25 was most likely used to divide the rooms of the stoa and at the same time support its structure. These walls, built of irregular stone blocks bound with mud, were constructed later than walls 4 and 9, and their foundations are laid on deposit of yellowish-brown soil³⁵. The preserved height of walls 24 and 25 is 0.67 m and 0.78 m respectively.

A partially preserved terracotta tile floor, constructed of square tiles approximately 0.43 × 0.43 m on the surface and 0.04 m in thickness, extends on both sides of wall 25 and could (hypothetically) be limited by walls 4, 9 and 24 (Fig. 5). The floor is based on a layer of lime-mortar, beneath which Hellenistic pottery sherds datable as late as the beginning of the 1st c. BCE were found among pottery belonging to earlier phases³⁶. The tile floor is located at 3.46 m.a.s.l.³⁷.

Phase 4: During the phase in which the space was active as a workshop, the area is characterised by the establishment of several fire-structures³⁸ immediately on top of the tile floor, in a unified space extending north from the EW passage³⁹.

In the original plan of the 4th c. agora, the EW passage and the NS street were situated at different levels, due to the natural inclination of the hill of the acropolis west of the agora (Fig. 1). A monumental travertine and marble staircase was constructed to bridge the height difference during the Hellenistic renovations of the agora⁴⁰. The height of the highest step of the staircase is 3.45 m.a.s.l.⁴¹ Therefore, during this phase the EW passage was situated approximately at this level. Further, Ch. Kantzia mentions that there is a strong inclination on the 13 m EW passage to the west, where the stoa of the agora is situated⁴².

According to Giannikouri and co-authors, the first stratum of the NS street, dated from the first half of the 4th c. to the second half of the 2nd c. BCE⁴³. This stratum is 54 cm thick and its upper surface is at the same level with the lowest step of the staircase, at approximately 2.55 m.a.s.l.⁴⁴. From the 2nd until the beginning of the 1st c. BCE the surface of the street was elevated 65-77 cm, reaching a height of approximately 3.32 m.a.s.l. During the 1st c. BCE a deposit of 45 cm was accumulated in three separate stratigraphic layers and the NS street gradually reached 3.80 m.a.s.l. By the end of the 1st c. BCE, the NS street rose to the level of the EW passage and the monumental staircase was completely covered. During the Roman period, the eastern end of the passage was located at 3.90 m.a.s.l., inclining slightly towards the west and the portico at 3.96 m.a.s.l.⁴⁵.

³¹ Monica Livadiotti and Giorgio Rocco, personal communication.

³² MORRICONE 1950, p. 56; LAURENZI 1959; ROCCO, LIVADIOTTI 2011, p. 386.

³³ LIVADIOTTI 2005.

³⁴ During the second excavation phase, the foundation layer of the stylobate was revealed: this was an artificial substrate that consisted of a solid soil layer, laid partially on a pozzolanic layer, which extends beneath the walls of the stoa's rooms. GIANNIKOURI, SKERLOU, PAPANIKOLAOU 2011, p. 372.

³⁵ Unpublished excavation diary n. 199, pp. 191-192.

³⁶ I am grateful to Dr Søren Handberg, Associate Professor at the Department of Archaeology, Conservation and History of the University of Oslo and Ms Dora Grigoriadou, archaeologist of the Municipality of Kos, for dating the pottery from the layers beneath the tile floor. The pottery of the excavation remains unpublished.

³⁷ The heights in m.a.s.l. are based on Schedio 7 (drawing 7, scale 1:100) of 1293D by M. Gnani, L. Mastropasqua, R. Netti, D. Tinel, G. Ventura, M. Zaza, M. Livadiotti, G. Rocco, V. Eleutheriou, and K. Charitonidis (2009) and on Figure 5 from the article of ELEUTHERIOU, NETTI 2011.

³⁸ The state of preservation of these structures does not allow their reconstruction. It is likely that they belong to metallurgical furnaces or to kilns, but in the best cases only the hearth is preserved. Therefore, for their presentation and the discussion I will use the more general term "fire-structure".

³⁹ Phase 4 is described in the following section "The material remains of pigment and metal production".

⁴⁰ KANTZIA 1987.

⁴¹ The height of the highest step of the staircase is comparable to the level of the northern room's tile floor (3.46 m.a.s.l.).

⁴² KANTZIA 1987, p. 637.

⁴³ GIANNIKOURI, SKERLOU, PAPANIKOLAOU 2011, p. 373.

⁴⁴ The calculation of the height for the lowest step was made taking into consideration that each step has a difference of approximately 0.24 m and that the height of the lowest step but one is 2.79 m.a.s.l. (see footnote 27 and KANTZIA 1987, p. 637). This height of the lowest step (2.54 m.a.s.l.) is approximately the same as that of the threshold in the neighbouring room to the south in Schedio 7 (2.57 m.a.s.l.).

⁴⁵ GIANNIKOURI, SKERLOU, PAPANIKOLAOU 2011, pp. 370-377.



Fig. 9. The late Hellenistic *olpe* from the hearth of fire-structure 1 (AE 706).

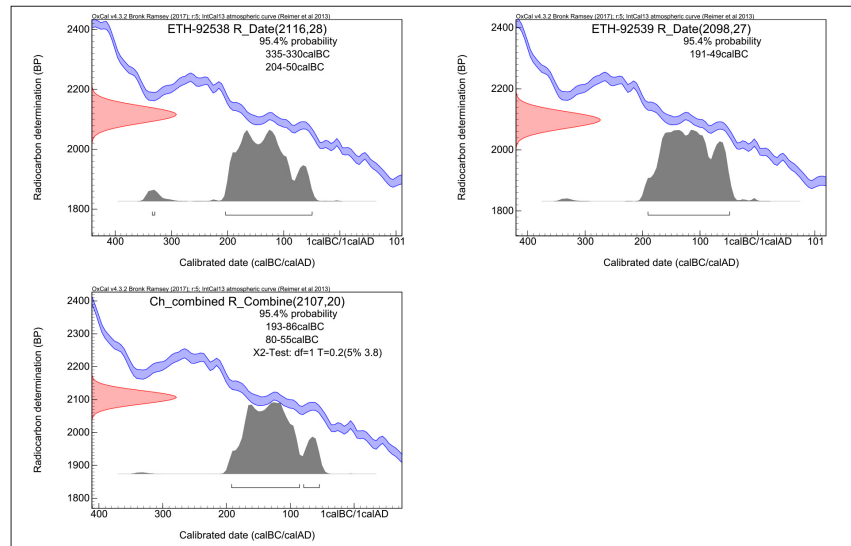


Fig. 10. Calibrated dates for two samples of pinecones from FS1. The analysis was carried out by Dr I. Hajdas at the Laboratory of Ion Beam Physics, ETH Zürich.

Therefore, it is safe to say that the level of the NS street in the early 1st c. BCE was comparable to the height of the tile floor, which, according to the typology of the pottery beneath it, was laid after 100 BCE⁴⁶. The production site, organised in the northern room after the construction of the tile floor, could therefore be entered from the NS street⁴⁷. The dating of the site to the late Hellenistic period is confirmed by the results of radiocarbon dating of samples retrieved from the undisturbed layers of the fire-structure related to Egyptian blue production (FS1), where the *olpe* was also found (Fig. 9). Two burnt pinecone samples from FS1 were analysed using Accelerator Mass Spectrometry (AMS) radiocarbon dating at the Laboratory of Ion Beam Physics by Dr. Irka Hajdas (Fig. 10)⁴⁸. The results show that the first sample can be dated between 204 and 50 BCE (94.8%) and the second between 191 and 49 BCE (95.4 %), with the combined results between 192 and 55 BCE (95.4%). The above results are in agreement with the first publication and Kantzia's interpretation that the workshop was organised on the—most likely already destroyed—tile floor during the second half of 1st c. BCE⁴⁹.

The material remains of pigment and metal production

The site is characterised by the presence of destroyed fire-structures, which were placed directly on the late Hellenistic tile-floor, destroying it at some points. Wall 2, dominating the workshop area, was also laid directly on the level of the tile-floor (Fig. 11, sections a-a' and b-b'). The second excavation period revealed wall 28, parallel to and on the same level as wall 2 (Figs. 8, 12). Walls 2 and 28, traversing the area of the workshop, are crucial for the understanding of the architectural organisation and the structure of the workshop. The absence of substantial foundations for the walls indicates their usage: they were not expected to bear the weight of a large structure. Rather, these walls are directly associated with the fire-structures revealed across their length, acting as their support.

The openings on the level of the second and first courses of wall 2 are considered to have facilitated the ventilation of the fire-structures supported by the wall (Fig. 11, sections a-a' and b-b'). The two walls are constructed of *malakopetra*, the same material used for the foundations of walls 4 and 9. It is likely that the same foundation blocks were used for the construction of the workshop's two parallel walls (2, 28), following the trend for removal and reuse of structural materials belonging to previous phases⁵⁰. The partially processed block found in the fillings of wall 9 may support this hypothesis (Fig. 13). The eastern part of wall 2 was disturbed due to the posterior construction of a circular well⁵¹ (diameter approximately 0.5 m with walls constructed of small stones and lime-mortar, see Figs. 8, 11). The well was most likely constructed after the collapse of FS2 and FS3 and without severely disturbing wall 2 (Fig. 11).

⁴⁶ See footnote 36.

⁴⁷ The height of the tile floor, which was constructed as described above during the beginning of the 1st c. BCE, is at 3.46 m.a.s.l. Therefore, the level of the room during the late 2nd and early 1st cs. BCE is comparable to the level of the NS street.

⁴⁸ The radiocarbon dating and the interpretation of the results were carried out by Dr I. Hajdas at the Laboratory of Ion Beam Physics,

ETH Zürich. For sample treatment see HAJDAS 2008. All calibrations were done with the program OxCal version 4.3.2, RAMSEY 2017. The atmospheric dates for calibration are according to REIMER *et al.* 2013.

⁴⁹ KANTZIA, KOUZELI 1987 p. 217.

⁵⁰ Livadiotti 2005.

⁵¹ KANTZIA, KOUZELI 1987.

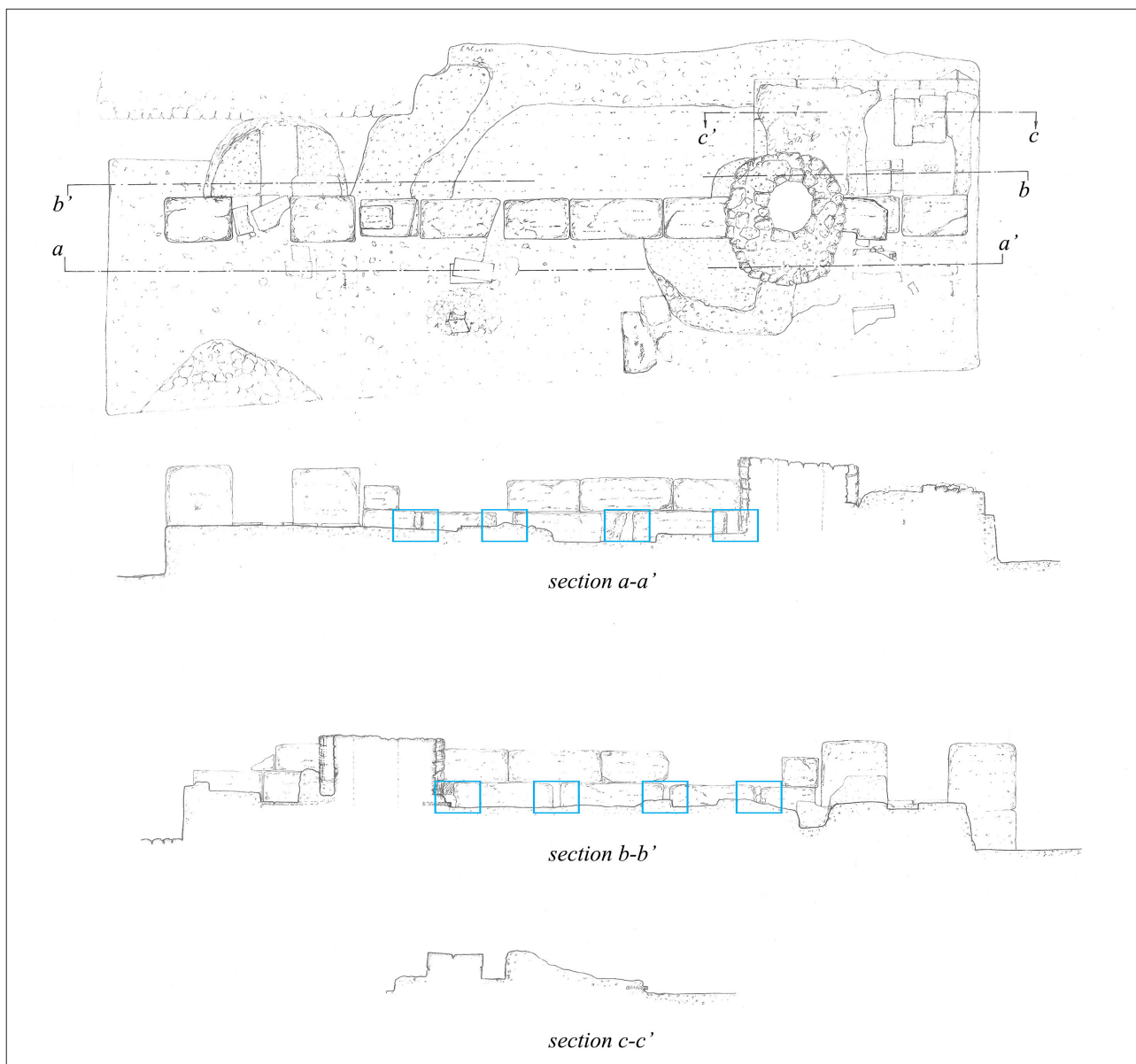


Fig. 11. Plan and section of wall 2 (drawing by M. Sandalos, 22nd Ephorate of Antiquities). The wall is laid directly on the tile-floor, partially destroying it. Wall 2 served as a support for the fire-structures that were organised across its length. The openings highlighted in the section of wall 2 are thought to have facilitated air ventilation for the kilns.

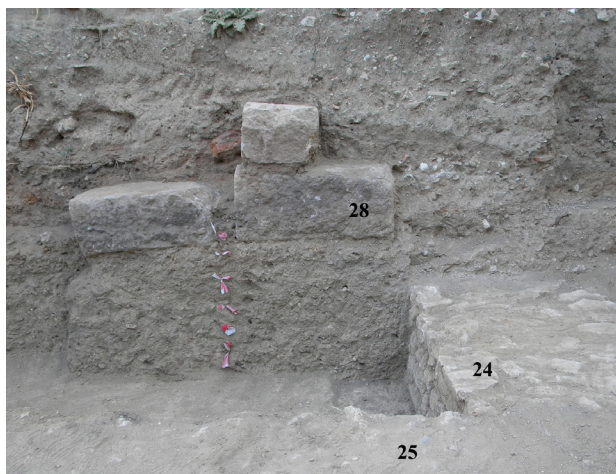


Fig. 12. Walls 28, 24 and 25 (partially covered) from the south (unpublished photograph by E. Papanikolaou, 2010).

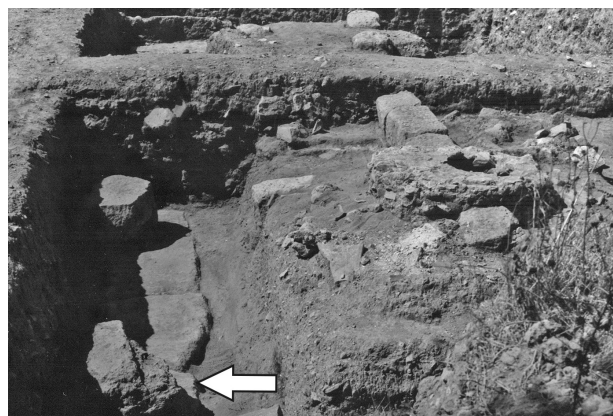


Fig. 13. Wall 4 from the east (unpublished photograph by Ch. Kantzia, 17/9/1986). The partially shaped stone can be distinguished. Its upper surface is shaped to a smaller size, with dimensions 0.90 m x 0.40 m.

The production site is therefore limited by the EW passage to the south and by the NS street to the east. Wall 9, the rear wall of the portico of the eastern stoa, divided the workshop's space from the agora. During *Phase 4*, there is no evidence for walls that would support a roofed structure. Rather, the workshop was probably organised in an open- or semi-open-air space, where the fire-structures were operated.

The presence of burnt soil, vitrified clay, fragmented and burnt cover tiles, corroded bronze objects with charcoal attached to them, lead drops, and tubular litharge rods (Figs. 5, 6) indicate pyrotechnological processes and point to the use of metallurgical furnaces. The remains of at least three fire-structures can be identified at the site (see Fig. 8, where the approximate locations of the fire-structures are indicated by FS). The vast majority of the pigments, including both the earth lumps and the Egyptian blue pellets, were found in relation to these fire-structures.

The descriptions of the three best-preserved fire-structures associated with wall 2 will follow (FS1, FS2, FS3). Unfortunately, their current state of preservation does not allow a straightforward reconstruction, a case typical for metallurgical remains⁵². The debris of vitrified and burnt clay throughout the workshop, along with burnt soil and gangue material, points to the presence of more such structures, already destroyed in a previous phase. For example, a deposit of burnt, worn and fragmented mud bricks covering an area of 1.00 × 0.70 m was revealed southwest of the well⁵³. Additionally, on the south of wall 28 the remnants or the waste of another fire-structure were found⁵⁴.

The first fire-structure from the west (**FS1**) is located south of the opening of wall 2 (Figs. 8, 14). This structure is related to the production of Egyptian blue, with 98 successful and unsuccessful pellets unearthed in its context (see Fig. 3 for a selection of the Egyptian blue pellets).

Two rectangular porous stones based on a compact, bright-coloured layer of soil and in line with wall 2, form the northern border of this structure. The two stones, 0.66 and 0.70 m in height respectively, have a 0.66 m opening between them. Their south-facing sides are burned, and their upper surface is particularly worn and rounded, indicating the extensive use of fire in the area to their south. A semi-circular stone mound, made of irregularly shaped stones, was revealed approximately 1 m south of the two rectangular stones, defining the southern limit of the fire-structure (Figs. 8, 14)⁵⁵. The mound is constructed of irregularly shaped stones of various types, including *amygdalopetra*, porous stones (possibly *malakopetra*), and marble. The external stones of the mound, and especially those facing towards the north, to the hearth of the fire-structure, are burnt. The mound and the two rectangular stones are based on the level of the tile floor, where only a couple of fragmented tiles are preserved (Figs. 11, 14, 15). The mound's foundation forms a curve with an internal diameter of 0.45 m, which is filled with clean soil showing no traces of fire, indicating that the hearth was limited to its north.



Fig. 14. Fire-structure 1 (photograph taken from the south, after Kantzia, Kouzeli 1987).



Fig. 15. The section of FS1 from the north, before the excavation of the area (photograph by Ch. Kantzia, 22nd Ephorate of Antiquities). The upper layer consists of burnt soil, followed by the burnt pinecones. The layers of burnt material are laid on top of a layer of small limestones, following west-to-east inclination.

⁵² TYLECOTE 1964, p. 29; CRADDOCK 1995, p. 200; KAKAVOGI-ANNIS 2005, p. 263; MERKEL 2007, p. 47.

⁵³ See unpublished excavation diary 35, entry 6/6/1988.

⁵⁴ See unpublished excavation diary 193, entries 17-18/9/2009.

⁵⁵ See also KANTZIA, KOUZELI 1987, p. 214-215, Fig. 1, for a more elaborate plan of the excavated site.



Fig. 16. Fragment from the tile-floor that was revealed at the bottom of the hearth of FS1, which preserves charcoal and copper oxides on its surface (AE 716 β).



Fig. 17. Attic west-slope *kantharos* (3rd c. BCE) incorporated in a clay mass from fire-structure 2.

⁵⁶ KANTZIA, KOUZELI 1987.

⁵⁷ The bronze objects included a rectangular copper sheet with dimensions 0.35x0.225x0.005 m, on which azurite and malachite have been formed (identified by Raman spectroscopy by the author and K. Kouzeli, unpublished data).

The deposit in the area defined by the two stones and the mound contains numerous burnt clay lumps and cover tiles, possibly belonging to a kiln's structure. A layer of burnt pinecones and twigs, intermixed with black burnt soil, was revealed beneath the burnt clay. The burnt pinecone layer is approximately 0.15 m thick and covers an area 1×3 m⁵⁶. There, numerous finds, including the 98 successful and unsuccessful Egyptian blue pellets (Fig. 3), corroded bronze objects with pinecones and charcoal adhered to their surface (Fig. 6a)⁵⁷ and iron objects (Fig. 6 b) were brought to light. Beneath the layer of the burnt pinecones, a layer of lime lumps, ranging in size from approximately 2 to 5 cm in diameter, formed the bottom of the fire pit (Fig. 7). The debris of the fire-pit features an inclination from west to east (Fig. 15). The presence of fragmented square-shaped tiles, with sides measuring 0.43 m and a thickness of 0.04 m, shows that the fire-structure was placed on the (already destroyed?) tile-floor (Fig. 16). Sporadically and throughout the area of the fire, smaller tile-fragments and lime lumps were found. The soil under the fire exhibits a brighter hue due to the persistent use of fire on this area.

The fragmented *olpe* (Fig. 9) in the layer of the burnt pinecones in the fire pit dates the fire-structure to the late Hellenistic period⁵⁸. Ch. Kantzia's interpretation for the dating of the "Egyptian blue fire-structure" (FS1) was confirmed by the results of AMS radiocarbon dating, giving a time span from the early 2nd c. BCE to the first half of the 1st c. BCE (see pp. 68-69).

The second fire-structure (FS2) is located to the north of wall 2 and extends to the west of the area later occupied by the well (Fig. 8). The remains of this structure consist of numerous clay bricks, which are constructed of coarse clay with colours ranging from orange to greenish, containing hay and small twigs, clay tiles, irregularly shaped stones, burnt soil, and fragments of marble architectural elements. A characteristic fragment of a 3rd c. BCE Attic west-slope *kantharos* with a painted X⁵⁹ was found incorporated in a burnt clay mass, possibly belonging to the walls of FS2 (Fig. 17).

A rectangular hearth belonging to FS2 (approximately 2.05 m EW and 1.05 m NS) is defined by wall 2 from the south and a compact wall constructed of soil from the west (noted in the diaries but removed during the excavation process and not preserved today). The structure sits directly on the square-tile floor, which remains preserved beneath it (Fig. 11). Wall 2 features an aperture on the level of its second course (Fig. 11,

⁵⁸ KANTZIA, KOUZELI 1987. See also HADJIDAKIS 2017, p. 339 for a similar *olpe* from the second half of the 1st c. BCE.

⁵⁹ Personal communication with V. Patsiada; PATSIADA 1983 Table 60, pp. 165-166; Table 61a-b, pp. 167-168. The pottery from the excavation remains to be studied, but this particular fragment was considered important for the present paper because it belongs to a fire-structure.

sections a-a' and b-b'), which corresponds to the "centre" of the fire-structure's hearth. The aperture is 0.22 m in height and has a smaller opening on the northern bank of wall 2 (0.13 m), widening towards the southern bank (0.33 m). A second similar aperture is located 1 m west of it (Fig. 11, section a-a' and b-b').

On the south side of wall 2 and directly in contact with this aperture, a large amount of amorphous lead lumps and lead drops were found (Fig. 6 b), while a deposit consisting of approximately 50 tubular litharge rods was found directly to the south of the well (Fig. 6 a). Directly to the west of FS2, a deposit of lime and burnt wood/charcoal was revealed. Within the debris of FS2, iron nails, oxidised iron lumps, corroded bronze objects, lime lumps and red earth intermixed with burnt soil were revealed.

The third fire-structure (**FS3**) was constructed against the eastern end of wall 2 (1.60 m east of FS2), in direct contact with its northern bank (Fig. 8). The structure sits on top of the square tile floor and features an east-to-west inclination. The area is characterised by black/burnt soil and numerous greenish, porous, lightweight lumps (possibly vitrified material from the collapsed walls of a kiln). The hearth occupies a rectangular space extending 0.55 m NS and 0.93 m EW. Tiles, made of coarse clay with inclusions of hay, with approximate dimensions of $0.53 \times 0.48 \times 0.11$ m, were revealed in the deposit of FS3, along with severely burnt marble architectural elements and vitrified clay from the furnace's walls.

As described above, the state of preservation of the workshop's fire-structures unfortunately does not allow their comprehensive reconstruction, nor do the descriptions of the remains retrieved from the archaeological diaries. Further research is required to detect the possibility of their reconstruction.

To summarise, the production site can be dated to the late Hellenistic period (1st c. BCE). The fire-structures are organised on a square-tile floor from a previous phase, dated to the early 1st c. BCE, which they partially destroyed. The archaeological finds, including numerous pigments, lead lumps and litharge rods, can be related to metallurgical processes and pigment production. In the following section (*Discussion*) the preliminary evidence which supports these different types of production will be presented with a view to illustrate the technological processes carried out at the workshop.

Discussion

Metallurgy

The most distinctive material remains of metallurgical processes are the more than fifty fragments of tubular litharge rods (Fig. 6 a) revealed directly to the south of the well along wall 2, in the context of burnt earth, drops of lead, and burnt and deteriorated clay bricks. Moreover, large quantities of lead were found in the form of drops and amorphous lumps (Fig. 6 b). These finds are associated with the destroyed fire-structures, pointing to *in situ* re-smelting for the reduction of litharge (PbO) to metallic lead (Pb)⁶⁰. The metallurgical furnaces associated with these processes cannot be directly identified among the above presented fire-structures and further research is required⁶¹. However, the location of the finds related to metallurgy points to their association with FS2 and FS3.

During the Hellenistic and Roman periods, litharge, the major by-product of the lead-silver separation process, was exported from the areas of the mines or the principal metallurgical workshops (e.g. Laurion and the workshops organised around the mines) to be further processed and/or recycled in remote workshops, in order to meet the increasing demand for lead⁶². Lead had several applications, among which its *transformation* into pigment can be pinpointed within the context of pigment production.

Cerussa, or *psimythion*, is a basic lead carbonate (cerussite, PbCO₃) that was commonly used as a white pigment. Vitruvius (*De arch.* 7.7.1) describes how the pigment was produced on the neighbouring island of Rhodes, and Pliny the Elder mentions the Rhodian lead workshops as the best source for *cerussa* (Plin. *HN* 34.175)⁶³. *Cerussa* workshops have not yet been brought to light, and there is no concrete material evidence for the production of *cerussa* at the Koan workshop or on Rhodes. However, Hellenistic lead-working sites have been found by excavations on Rhodes⁶⁴. According to geological and archaeological evidence, it is rather unlikely that Rhodes was actually the source of the lead⁶⁵,

⁶⁰ REHREN 2012 p. 33.

⁶¹ It is common for metallurgical furnaces to be found in such conditions. See CRADDOCK 1995, pp. 169-174. Further research, including possible experimental reconstructions of the fire-structures, would help to shed light on the specificities of the metallurgical processes.

⁶² The export and processing of ores and litharge in places distant from the mines is considered to be related to extensive deforestation and lack of fuel (see KAKAVOGIANNIS 2005, pp. 263, 282-286) in

combination with the increasing need for lead (see BOULAKIA 1972; REHREN, VANHOVE, MUSSCHE, OIKONOMAKOU 1999).

⁶³ The texts were read from the following editions: Vitruvius Pollio M., *The ten books on architecture*, translated by Morgan M.H., Dover Publications, 1960 New York; Pliny the Elder, *Natural history: With an English translation by H. Rackham*, 1958 London.

⁶⁴ KAKAVOGIANNIS 1985; FARMAKIDOU, MARKETOU 1995.

⁶⁵ DAVIES 1935, p. 266; HEALY 1978, p. 19.

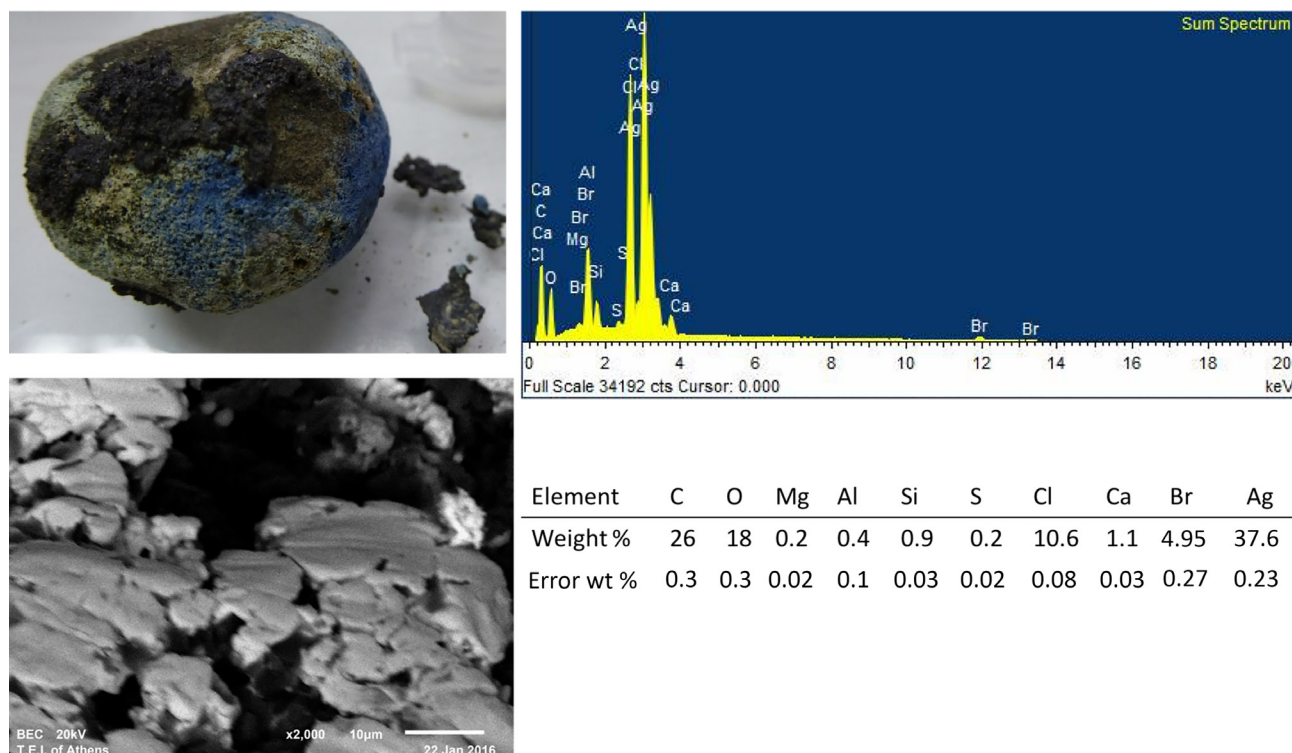


Fig. 18. Corroded silver was detected on the material loosely adhered to one of the EB pellets from FS1. a) The EB sphere with the detached black crust. b) Backscattered electron micrograph (2000 x) of an uncoated sample from the detached material under the scanning electron microscope (JEOL JSM-650 SEM, equipped with an Oxford X-act Energy Dispersive X-ray Spectrometer, using the INCAenergy software). The microscopic observation was performed in low vacuum (30 Pa) and with 20 kV accelerating voltage, without conductive coating of the samples. c) Semi-quantitative elemental composition of the sample from the EDS analysis.

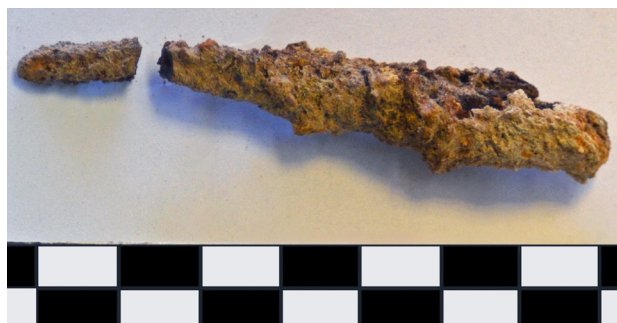


Fig. 19. Iron nail from the deposit of lead masses, possibly related to the cupellation process (AE 778).

sis of a cupellation process carried out *in situ*⁶⁸. Further, the adhesion of the corroded silver crust to the Egyptian blue pellet indicates the co-processing of these materials in time and space. The term “cupellation” is used to describe the metallurgical process employed for the separation of precious (gold and/or silver) from base metals. During this process the alloy of the precious metal with lead is melted in a crucible or pot (the *cupel*) and is exposed to a strong air current. In that way, metallic lead is oxidised to litharge (lead oxide, PbO). The base metals present in the ore (for example tin, copper etc.) dissolve in litharge and are carried away, leaving the precious metals (silver or gold) unaltered⁶⁹. The best-attested

indicating the import of ores from other places. Lead sources have, however, been identified on Kos. The galena (PbS) deposits of Mt. Dikaioi (location *Metalleio*) were exploited during the 20th c., but their exploitation in antiquity is still uncertain⁶⁶.

During the conduction of preliminary research on the Egyptian blue finds, an interesting observation was made. A type of black crust adhering to one of the Egyptian blue pellets, when examined under a scanning electron microscope equipped with an energy dispersive spectrometer (SEM-EDS), was identified as a type of silver chloride/silver bromide (Fig. 18)⁶⁷. This finding, combined with the presence of iron nails in the area of the fire-structures (Fig. 19), could support the hypothe-

⁶⁶ For the modern exploitation of the mines see MPELAVILAS, PASTEFANAKI, FRAGKISKOS 2009, p. 266. For the possibility of ancient mines see DAVIES 1935, pp. 265-266, SHERWIN-WHITE 1978, p. 228.

⁶⁷ The SEM-EDS analysis was carried out at the Laboratory of Instrumental Chemical Analysis of the Faculty of Applied Arts and Culture,

Department of Antiquities and Works of Art Conservation, University of West Attica, in collaboration with professor Y. Facorellis.

⁶⁸ CRADDOCK 1995, pp. 211-214, 216-231; KAKAVOGIANNIS 2005, pp. 273-286; MERKEL 2007, p. 47.

⁶⁹ TYLECOTE 1964, p. 31; HEALY 1978, pp. 152-153; CRADDOCK 1995, pp. 221-231.

application of the cupellation method is perhaps the recovery of silver from the argentiferous lead ores of Laurion, namely galena (PbS) and cerussite (PbCO₃)⁷⁰. In the metallurgical workshops of Rio Tinto (Spain), silver was mainly recovered through cupellation from sulfate deposits, namely jarosite⁷¹. In this case, lead was added intentionally into the melt, allowing the cupellation process to be carried out⁷².

With the development of cupellation, silver refinement advanced, facilitating the recovery of silver from alloys, such as the silver-containing alloys of coins⁷³. The presence of significant quantities of jarosite at the workshop⁷⁴ could be related to silver extraction, in a way similar to that employed in Spain. The presence of several bronze objects at the site as well as in the neighbouring southern room (see above: *The agora of Kos and the development of mercantile and crafting activities*) might point to metal recycling, possibly including silver recovery. The possibility of local ore exploitation should be further researched to elucidate the relationship between the litharge rods, the metallic lead lumps from the excavation and the local ores.

Pigment production

The hypothesis of local pigment production in the context of the workshop is supported by the unearthing of raw pigment lumps, including yellow, red, brown and green *natural* earth pigment lumps and the *artificial* Egyptian blue pellets. The presence of both successful and unsuccessful Egyptian blue pellets, as well as earth pigments in various stages of production⁷⁵, is considered characteristic of a production site, where the waste products would co-exist with the successfully produced materials⁷⁶. However, the presence of raw pigments alone may not be self-evident of pigment production at the site.

In a recent article on the production of Egyptian blue in the Hellenistic and Roman periods, L. Cavassa questions the production of this artificial blue material at the Koan workshop, arguing a) that the presence of saggars is crucial for the identification of a production site, and b) that the fire-structures are too small for this production⁷⁷. However, the absence of containers that can be readily identified as *saggars* does not necessarily exclude the possibility of a local Egyptian blue production. Their absence from the excavation record can be attributed to the fragmented nature of the archaeological process, or to our own limitations in identifying them in this specific context. Interestingly, in the production sites that we so far know, in Memphis and central Italy, two types of saggars can be identified⁷⁸, illustrating the variability within the different workshops in their technological choices. Further, despite the lack of identified furnaces in other cases that would be comparable to the Koan workshop, it is likely that the scale of the production, and therefore the size of the furnaces, could vary depending on the local context. In this section, preliminary evidence in support of the local production of Egyptian blue alongside the treatment of earths and metallurgical processes is discussed.

The heterogeneity of the *natural* earth pigments from the workshop was underlined in a recent study, in which a selection of iron-containing pigment lumps was analysed (Fig. 4)⁷⁹. The analysed yellow pigments were found to be of two types, with their colour attributed to the minerals jarosite and goethite respectively. Two types of red pigments were identified: a hematite-based red earth and a red pigment containing both hematite and lead tetroxide. The colour of the brown earths was attributed to a complex mixture of iron oxides, while the single green earth lump found through the excavations was identified as a type of celadonic rock. Among the finds, a significant variation in terms of shape, purity and colour saturation can be observed, indicating treatment processes carried out at the site⁸⁰.

When it comes to the Egyptian blue finds, the heterogeneity of materials can be readily observed (Fig. 3). A total of 138 Egyptian blue finds (total weight 1575.34 g) were brought to light, out of which 98 were found in the context of FS1. From the primary observation of the 122 complete pellets that are not covered with soil, 72 are successfully produced and feature throughout their surface the characteristic deep blue colour of Egyptian blue, while 29 are unsuccessful products, with colours varying from grey to green and purple to brown. In between these two main categories stand 21 pellets that are partially successful, i.e. more than half of the material is deep blue and the rest varies from green to grey and purple.

⁷⁰ CONOPHAGOS 1980, pp. 160-165; KAKAVOGIANNIS 2005, pp. 91-95; CRADDOCK 2014.

⁷¹ CRADDOCK 1995, pp. 216-221; ANGUILANO, REHREN, MUELLER, ROTHENBER 2007.

⁷² *Ibidem*.

⁷³ REHREN, KRAUS 1999, CRADDOCK 1995, p. 232; CRADDOCK 2014, p. 1091.

⁷⁴ A yellow lump that was analysed by means of powder X-ray diffraction (XRD), scanning electron microscopy-energy dispersive X-ray spectroscopy (SEM-EDS), Fourier transform infrared spectroscopy (FTIR) and pRaman spectroscopy was characterised as potassium jarosite [KFe₃³⁺(OH)₆(SO₄)₂]. See KOSTOMITSOPOULOU

MARKETOU, KOUZELI, FACORELLIS 2019 (forthcoming).

⁷⁵ The production of Egyptian blue on the site is supported in KANTZIA, KOUZELI 1987, and is the subject of the ongoing research conducted by the author. The treatment of earth pigments at the site is supported in KOSTOMITSOPOULOU MARKETOU, KOUZELI, FACORELLIS 2019 (forthcoming).

⁷⁶ KANTZIA, KOUZELI 1987.

⁷⁷ CAVASSA 2018.

⁷⁸ *Ibidem*.

⁷⁹ KOSTOMITSOPOULOU MARKETOU, KOUZELI, FACORELLIS 2019.

⁸⁰ *Ibidem*.



Fig. 20. Successful, partially successful and unsuccessful pellets of Egyptian blue from FS1.

Besides the classification into successful, unsuccessful, and semi-successful products, the finds vary in size (Fig. 20). For the majority of the pellets (74 of the 117 pellets with distinguishable dimensions), the size ranges from 2 to 3 cm across; 31 pellets are larger than 3 cm across, while 11 pellets are between 1 to 2 cm across and only 1 is smaller than 1 cm across. Studies of Egyptian blue samples from various Hellenistic and Roman sites show that the pellets enter the commercial cycle in the form of small pellets up to 2 cm across⁸¹, smaller than but similar in shape to those revealed in the Koan workshop.

The production of Egyptian blue is a complicated process that requires sophisticated knowledge and skilled craftsmanship. Egyptian blue is a multicomponent material, with copper calcium tetrasilicate ($\text{CaCuSi}_4\text{O}_{10}$) crystals being its main component to which its blue colour is attributed. It is produced by firing a finely ground mixture essentially containing the elements copper, silicon and calcium and an alkali flux in temperatures ranging from 850 to 1050 °C⁸². The sources of the starting materials can vary depending on the accessibility of raw materials. The presence of the starting materials for this production – copper in the form of corroded bronze objects and a bronze sheet, silicon as quartz pebbles (SiO_2)⁸³, and calcium in the form lime lumps (CaCO_3) – supports the possibility of local production⁸⁴. The presence of corroded bronze objects in the context of FS1 indicates the use of bronze filings for the production of Egyptian blue⁸⁵.

According to F. Delamare, the synthesis of Egyptian blue seems to require an exact stoichiometric ratio between copper and calcium, which could be achieved by the controlled addition of the latter in the mixture⁸⁶. Therefore, the presence of lime in the workshop would facilitate the production of Egyptian blue. The production of lime in this context would be very convenient, since it could be used for the production of plasters and mortars, but also as a flux for the metallurgical processes⁸⁷. Lime (CaO) could be produced by the calcination of limestone (CaCO_3) or other types of calcareous stones for several days, in temperatures ranging from 800 to 1000 °C⁸⁸. The kilns used for the production of lime resemble the metallurgical furnaces, with a single chamber for both the fuel and the limestone⁸⁹. Lime lumps have also been documented in the faience kilns of Memphis⁹⁰, a site known also for the production of Egyptian blue.

According to Ch. Kantzia, Egyptian blue was produced in FS1 (Figs. 8, 14), where a large flattened vessel containing the Egyptian blue pellets would be placed on top of the stone mound and the two rectangular stones⁹¹. Would this structure allow the firing of the starting mixture in the controlled oxidising atmosphere and the high temperatures (850-1050 °C) required for the synthesis of Egyptian blue⁹²? The presence of silver adhering to an Egyptian blue sphere (Fig. 18), as well as the discovery of an iron nail and copper oxides adhering to two different pellets (Fig. 21), might point to the contemporaneous use of FS1 for different activities, combining metallurgical processes with some stages of the production process for Egyptian blue, highlighting in that way the intertwined relationship between these productions. Due to the severe disturbance of the site and the state in which the remains of FS1 were brought to light, the reconstruction of the fire-structure requires further studies, including the experimental reconstruction of the kiln and the production process.

Beyond the primary manufacture of Egyptian blue and the categorisation into successful, unsuccessful and semi-successful pellets, a variance in the hue of the successful pellets is evident, with the brighter pellets being notably brittle in comparison to the darker ones. This, in addition to the presence of a pottery sherd with ground blue material on its surface (Fig. 22), indicates the further processing of the primary Egyptian blue pellets in order to produce different hues.

⁸¹ DELAMARE 2013, p. 20; TITE, HATTON 2007, p. 75.

⁸² See DELAMARE 2013 pp. 6-8 and references therein.

⁸³ That silica pebbles are mentioned in KANTZIA, KOUZELI 1987, but the author has not yet identified them in the storerooms.

⁸⁴ KANTZIA, KOUZELI 1987. The quartz pebbles mentioned both in the diaries and in the publication were not located in the storerooms.

⁸⁵ HATTON, SHORTLAND, TITE 2008.

⁸⁶ DELAMARE 2013, pp. 8, 21-22.

⁸⁷ MARECHAL 1985.

⁸⁸ WRIGHT, WRIGHT 2005, pp. 146-147.

⁸⁹ WRIGHT, WRIGHT 2005, p. 154.

⁹⁰ NICHOLSON 2013, p. 77.

⁹¹ KANTZIA, KOUZELI 1987.

⁹² ULLRICH 1987; PRADELL, SALVADO, HATTON, TITE 2006; DELAMARE 2013, p. 8.

Conclusion

The excavations at the eastern part of the Koan agora have brought to light a late Hellenistic production site. There, an assemblage composed of the material remains of pigment manufacture and metallurgy was unearthed. The production site is most likely oriented towards the eastern part of the ancient town, ‘functionally’ belonging to this area with a long crafting tradition. The proximity of the site to the port of Kos would secure the supply of the workshop with raw materials and the fuel necessary for the pyrotechnological processes involved in the productions⁹³.

Lead metallurgy is supported by the presence of hollow tubular litharge rods and amorphous lead lumps, found in the context of fire-structures. Silver recovery is indicated by the presence of a corroded silver crust adhering to an Egyptian blue pellet which was found in the context of a fire-structure. The manufacture of Egyptian blue is supported by the archaeological finds, and especially the unearthing of successful and unsuccessful pellets in the context of a fire-structure. Therefore, Kos can be included among Memphis, Cumae, Liternum, and Puteoli in the constellation of known Greco-Roman Egyptian blue production sites⁹⁴. The co-existence of different manufacturing activities could be beneficial for both types of production. In this context, Egyptian blue is produced in conjunction with metallurgical activities and the treatment of earth pigments, illustrating a close relationship between the two productions⁹⁵. Further research, including the physicochemical characterisation of the production debris found at the site, may illustrate the different productions and add pieces to the fragmented picture of the technological processes involved in the productions.

The types of pigments found in the workshop, earth pigments and Egyptian blue, are neither extraordinary nor unexpected. On the contrary, the materials from the workshop are consistent with the pigments commonly composing the painter’s palette during the Hellenistic period. Future work, including the identification of pigments preserved in ancient Koan polychrome figurines and statues, or the study of raw pigment lumps, a common find in Koan excavations⁹⁶, could to our understanding of the use of colour on the island of Kos.

⁹³Kakavogiannis 2005, pp. 284, 313-314.

⁹⁴Egyptian blue was produced at the production site of Memphis in Egypt, dated from the 3rd c. BCE to the 3rd c. CE, alongside other vitreous materials (faience and glass). See NICHOLSON 2003, 2013; TITE, HATTON 2007; RODLER *et al.* 2017; CAVASSA 2018. Puteoli, Cumae and Liternum are located in the Phlegraean Fields of central Italy. Puteoli (today’s Pozzuoli) is in fact the place indicated in the famous passage of Vitruvius (*De Arch.* 7.11) as the location of Vestorius’s workshop. The production sites have not been identified by excavations in the areas. However, saggars with adhered Egyptian blue have been found and are interpreted as the waste products of

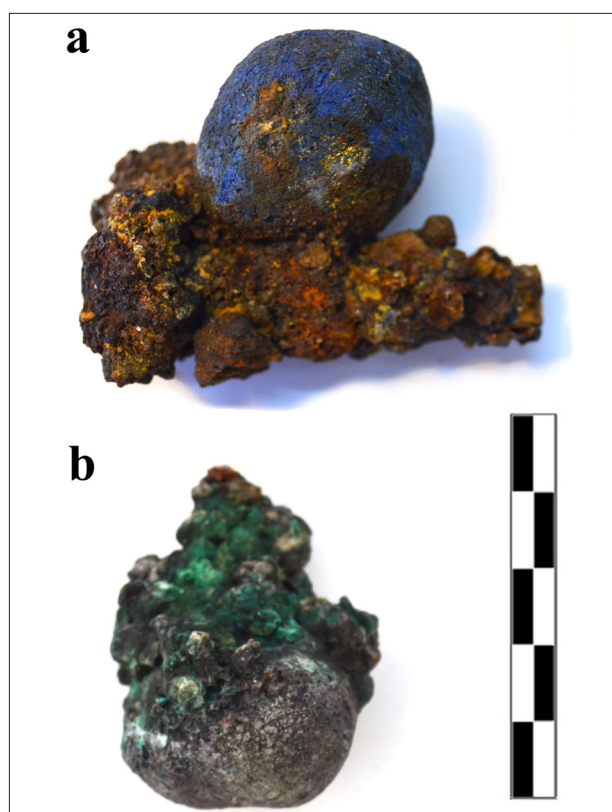


Fig. 21. a. Successfully produced EB sphere from FS1, adhered to a corroded iron nail (AE 714); b. unsuccessfully produced EB sphere (greyish colour) adhered to corroded copper material (AE 714).



Fig. 22. Pottery sherd with ground Egyptian blue adhered to its interior surface (AE 1844).

production sites. For Puteoli see DELAMARE 2013 p. 17 and references therein. For Liternum see CAVASSA, DELAMARE, REPOUX 2010; LAZZARINI, VERITÀ 2015, CAVASSA 2018. For Cumae see CAVASSA 2018 and GRIFA *et al.* 2016.

⁹⁵An Egyptian blue sphere was found in the context of a Hellenistic lead metallurgical workshop in Pherai, resembling the situation found on Kos. For the workshop of Pherai see ASDERAKI-TZOUERKIOTI, REHREN 2007. The Egyptian blue sphere from this context is very similar in size and shape to the ones from Kos (3 cm).

⁹⁶KANTZIA, KOUZELI 1987.

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Bibliography

- ANGUILANO, REHREN, MUELLER, ROTHENBERG 2007 = ANGUILANO L., REHREN T., MUELLER W., ROTHENBERG, B., *Roman jarosite exploitation at Rio Tinto (Spain)*, in *Archaeometallurgy in Europe 2007*, pp. 21-29.
- ASDERAKI-TZOUMERKIOTI, REHREN 2006 = ASDERAKI-Tzoumerkioti E., REHREN T., *Ελληνιστικό εργαστήριο μολύβδου στις Φερέες. Μια πρώτη αρχαιομετρική προσέγγιση*, YPEREIA 4. *Proceedings of the 4th International Conference. Pherai-Velestino-Rigas. October 2003*, Athens 2006, pp. 79-87.
- BEESTON, BECKER 2013 = BEESTON R. F., BECKER H. *Investigation of ancient roman pigments by portable x-ray fluorescence spectroscopy and polarized light microscopy*, in *ACS Symposium Series 1147*, 2013, pp. 19-41.
- BOULAKIA 1972 = BOULAKIA J.D., *Lead in the Roman world*, *American Journal of Archaeology*, 1972, pp. 139-144.
- BRECOULAKI 2014 = BRECOULAKI H., “Precious colours” in *Ancient Greek polychromy and painting: material aspects and symbolic values*, in *Revue archéologique* 1.57, 2014, pp. 3-35.
- BROUSKARI 2002 = BROUSKARI E., *Παλαιοχριστιανικό εργαστήριο ναλουργίας στην Κω: Μια πρώτη παρουσίαση*, in *Το γυαλί από την αρχαιότητα έως σήμερα, Β’ Συνέδριο Μαργαριτών Μυλοποτάμου Πεδιάχνης Κρήτης*, 26-28 Σεπτ. 1997, Μαργαρίτες Μυλοποτάμου 2002.
- CAVASSA 2018 = CAVASSA L. *La production du Bleu Égyptien durant l’époque Hellenistique et l’Empire Romain (III s. av. J.-C.-I s. apr. J.-C.)*, in JOCKEY P. (ed.), *Les arts de la couleur en Grèce ancienne... et ailleurs*, BCH, Suppl. 56, Athens 2018, pp. 13-34.
- CAVASSA, DELAMARE, REPOUX = CAVASSA L., DELAMARE F., REPOUX M., *La fabrication du bleu égyptien dans les champs phlégréens (Campanie, Italie) durant le I^{er} siècle de notre ère*, in *Aspects de l’artisanat en milieu urbain: Gaule et Occident Romain*, *Revue Archéologique de l’Est*, Suppl. 28, 2010, pp. 235-249.
- CONOPHAGOS 1980 = CONOPHAGOS C. E., *Le Laurium antique et la technique grecque de la production de l’argent*, Athens 1980.
- CRADDOCK 1995 = CRADDOCK P.T., *Early metal mining and production*. Edinburgh 1995.
- CRADDOCK 2014 = CRADDOCK P.T., *Production of silver across the ancient world*, in *ISIJ international*, 54.5, 2014, pp. 1085-1092.
- DAVIES 1935 = DAVIES O., *Roman mines in Europe*, Oxford 1935.
- DELAMARE 2013 = DELAMARE F., *Blue pigments: 5000 years of art and industry*, (Y. Rouchaleau, trans.), London 2013.
- ELEUTHERIOU, NETTI 2011 = ELEUTHERIOU V., NETTI, R., *Η Αγορά της Κω: Το έργο αποκατάστασης του Νοτίου Τμήματος*, in GIANNIKOURI 2011, pp. 425-438.
- ESPOSITO 2016 = ESPOSITO D., *The Economics of Pompeian Painting*, in FLOHR, M., WILSON A.I. (eds), *The Economy of Pompeii*, Oxford 2016, pp. 263-292.

- FARMAKIDOU, MARKETOU 1995 = FARMAKIDOU E., MARKETOU T., *Ελληνιστική Ιαλυσός, Οικόπεδο Αλούπη*, in *ArchDelt* 45, *Chronika*, 1990 (1995), pp. 489-491.
- GIANNIKOURI 2011 = GIANNIKOURI A. (ed.), *The agora in the Mediterranean from Homeric to Roman times, Proceedings of the International Conference, Kos. 14-17/04/2011*, Athens 2011.
- GIANNIKOURI, SKERLOU, PAPANIKOLAOU 2011 = GIANNIKOURI A., SKERLOU E., PAPANIKOLAOU E., *Η Αγορά της Κω. Ανασκαφικά δεδομένα*, in *Giannikouri* 2011, pp. 357-382.
- GRIFA *et al.* 2016 = GRIFA C., CAVASSA L., BONIS A.D., GERMINARIO C., GUARINO V., IZZO F., KAKOULLI I., LANGELLA A., MERCURIO M., MORRA V., *Beyond Vitruvius: New Insight in the Technology of Egyptian Blue and Green Frits*, in *Journal of the American Ceramic Society* 99.10, 2016, pp. 3467-3475.
- HADJIDAKIS 2017 = HADJIDAKIS P.I., *A small tavern on Delos: Catalogue of Objects*, in STAMPOLIDIS N., TSANGARI D., TASOULAS Y. (eds.), *Money: Tangible symbols in ancient Greece*, Catalogue of the Exhibition, Athens 2017, pp. 323-349.
- HAJDAS 2008 = HAJDAS I., *Radiocarbon dating and its applications in Quaternary studies*, in *Eiszeitalter und Gegenwart Quaternary Science Journal* 57.2, 2008, pp. 2-24.
- HATTON, SHORTLAND, TITE 2008 = HATTON G.D., SHORTLAND A.J., TITE M.S., *The production technology of Egyptian blue and green frits from second millennium BC Egypt and Mesopotamia*, in *Journal of Archaeological Science* 35.6, pp. 1591-1604.
- HEALY 1978 = HEALY J.F., *Mining and metallurgy in the Greek and Roman world*, London 1978.
- HÖGHAMMAR 2016 = HÖGHAMMAR, K., *International Networks of an Island Port in the Hellenistic Period. The Case of Kos*, in HÖGHAMMAR K., ALROTH B., LINDHAGEN A. (eds.), *Ancient Ports. The Geography of Connections. Proceedings of an international conference at the Department of Archaeology and Ancient History, Uppsala University, 23-25 September 2010. Boreas. Uppsala Studies in Ancient Mediterranean and Near Eastern Civilizations* 34. Uppsala 2016, pp. 95-165.
- KAKAVOGIANNIS 1985 = KAKAVOGIANNIS E., *Παραγωγή Μολύβδου από Λιθαργύρους στην Ελληνιστική Ρόδο*, in *Athens Annals of Archaeology* XVII, 1984 (1985), 1-2, pp. 124-139.
- KAKAVOGIANNIS 2005 = KAKAVOGIANNIS E., *Μέταλλα Εργάσιμα και Συγκεχωρημένα. Η οργάνωση της εκμετάλλευσης του ορυκτού πλούτου της Λαυρεωτικής από την Αθηναϊκή Δημοκρατία*, Athens 2005.
- KANTZIA 1987 = KANTZIA Ch., *Οδός Βύρωνος, Μεροπίδος και Πεισιάνδρου (Κ.Μ. 1293 F) (οικόπεδο αφών Δάμτσα)*, in *ArchDelt* 42, 1987 (1992), pp. 635-640.
- KANTZIA 1994 = KANTZIA Ch. *Ενα κεραμικό εργαστήριο αμοφρέων του πρώτου μισού του 4^{ου} αι. π.Χ. στην Κω, Γ' Επιστημονική συνάντηση για την Ελληνιστική Κεραμική*, Athens 1994, pp. 323-354.
- KANTZIA, KOUZELI 1987 = KANTZIA Ch., KOUZELI K., *Το εργαστήριο παρασκευής χρωμάτων στην Αρχαία Αγορά της Κω. Το Αιγυπτιακό μπλε*, in *Athens Annals of Archaeology*, 1987, pp. 210-250.
- KARYDAS, BRECOULAKI, BOURGEOIS, JOCKEY 2009 = KARYDAS A.G., BRECOULAKI H., BOURGEOIS B., JOCKEY Ph., *In situ X-Ray Fluorescence analysis of raw pigments and traces of polychromy on Hellenistic sculpture at the archaeological museum of Delos*, *BCH Suppl.* 51, 2009, pp. 811-829.
- KOSTOMITSOPOULOU MARKETOU, KOUZELI, FACORELLIS 2019 = KOSTOMITSOPOULOU MARKETOU A., KOUZELI K., FACORELLIS Y., *Colourful earth: Iron-containing pigments from the pigment production site of the ancient agora of Kos (Greece)*, *Journal of Archaeological Science: Reports*, forthcoming 2019.
- LAURENZI 1959 = LAURENZI L. (1959), s.v. *Coo*, *EAA* II, Roma 1959.
- LAZZARINI, VERITÀ 2015 = LAZZARINI L., VERITÀ M., *First evidence for 1st century AD production of Egyptian blue frit in Roman Italy*, in *Journal of Archaeological Science* 53, 2015, pp. 578-585.
- LIVADIOTTI 2005 = LIVADIOTTI M., *Note preliminari sulle tecniche costruttive di Coo in età ellenistica e romana*, in ADEMBRI B. (ed.), *Acimnistos. Miscellanea di studi par Mauro Cristofani, Prospettive*, I, 2005, pp. 178-187.
- LIVADIOTTI 2018 = LIVADIOTTI M., *The infrastructure of a Hellenistic town and its persistence in Imperial period: the case of Kos*, in HÖGHAMMAR K., LIVADIOTTI M. (eds.), *Sacred and civic spaces in the Greek poleis world, Uppsala seminars, 15-16 February 2017*, in *Thiasos* 7.2, 2018, pp. 39-75.
- MARECHAL 1985 = MARECHAL J.R., *Methods of ore roasting and the furnaces used* (Craddock P.T., trans.), in CRADDOCK P.T., HUGHES M.J. (eds.), *Furnaces and Smelting Technology in Antiquity, British Museum Occasional Paper* 48, London 1985, pp. 29-41.
- MATTUSCH 1977 = MATTUSCH C.C., *Bronze-and Ironworking in the Area of the Athenian Agora*, in *Hesperia* 46.4, 1977, pp. 340-379.
- MERKEL 2007 = MERKEL J.F., *Imperial Roman production of lead and silver in Upper Moesia (Serbia)*, in *Journal of the Serbian Archaeological Society* 23, 2007, pp. 39-78.

- MORRICONE 1950 = MORRICONE L., *Scavi e ricerche a Coa (1935-1943). Relazione preliminare*, in *BdA* XXXV, 1950, pp. 54-75, 219-246, 316-331.
- MPELAVILAS, PAPASTEFANAKI, FRAGKISKOS 2009 = MPELAVILAS N., PAPASTEFANAKI L., FRAGKISKOS A., *Ορυχεία στο Αγαίο: Βιομηχανική Αρχαιολογία στην Ελλάδα*, Athens 2009.
- NICHOLSON 2003 = NICHOLSON P.T., *New excavations at a Ptolemaic-Roman faience factory at Memphis, Egypt*, in *Annales du 15^e Congrès de l'Association Internationale pour l'Histoire du Verre. AIHV*, Nottingham 2003.
- NICHOLSON 2013 = NICHOLSON P.T., *Working in Memphis: the production of faience at Roman period Kom Helul*, Excavation Memoir 105, Egypt Exploration Society, London 2013.
- PATSIADA 1983 = PATSIADA V., *Κεραμική του τύπου της "Δυτικής Κλιτύος" από τη Ρόδο*, in *ArchDelt* 38, 1983, Part A-Studies (1990), pp. 105-210, tables 49-84.
- PRADELL, SALVADO, HATTON, TITE 2006 = PRADELL T., SALVADO N., HATTON G.D., TITE M.S., *Physical Processes Involved in Production of the Ancient Pigment, Egyptian Blue*, in *Journal of the American Ceramic Society* 89.4, 2006, pp. 1426-1431.
- RAMSEY 2017 = RAMSEY C.B., *Methods for summarizing radiocarbon datasets*, in *Radiocarbon* 59.6, 2017, pp. 1809-1833.
- REHREN 2012 = REHREN T., *Roads to riches: making good the silver ore at Laurion in Greece*, in *Archaeology International* 4, 2000, pp. 31-34.
- REHREN, KRAUS 1999 = REHREN T., KRAUS K., *Cupel and crucible: the refining of debased silver in the Colonia Ulpia Traiana, Xanten*, in *Journal of Roman Archaeology* 12, 1999, pp. 263-272.
- REHREN, VANHOVE, MUSSCHE, OIKONOMAKOU 1999 = REHREN T., VANHOVE D., MUSSCHE H., OIKONOMAKOU M., *Litharge from Laurion: A medical and metallurgical commodity from South Attika*, in *L'Antiquité Classique* 68, 1999, pp. 299-308.
- REIMER et al. 2013 = REIMER P.J., BARD E., BAYLISS A., BECK J.W., BLACKWELL P.G., RAMSEY, C.B., BUCK C.E., CHENG H., EDWARDS R.L., FRIEDRICH M., GROOTES P.M., *IntCal13 and Marine13 radiocarbon age calibration curves 0–50,000 years cal BP*, in *Radiocarbon* 55.4, 2013, pp. 1869-1887.
- ROCCO 2018 = ROCCO G., *Monuments of Kos I: the Southern Stoa of the Agora*, Thiasos Monografie 3, Roma 2018.
- ROCCO, LIVADIOTTI 2011 = ROCCO G., LIVADIOTTI M., *The agora of Kos. The Hellenistic and Roman phases*, in GIANNIKOURI 2011, pp. 383-424.
- RODLER et al. 2017 = RODLER A.S., ARTIOLI G., KLEIN S., PETSCHICK R., FINK-JENSEN P., BRØNS C., *Provenancing ancient pigments: Lead isotope analyses of the copper compound of Egyptian blue pigments from ancient Mediterranean artefacts*, in *Journal of Archaeological Science: Reports* 16, 2017, pp. 1-18.
- SHERWIN-WHITE 1978 = SHERWIN-WHITE S.M., *Ancient Cos. An historical study from the Dorian settlement to the Imperial period*, Göttingen 1978.
- SKERLOU 2013 = SKERLOU E., *Οδός Αόρδου Βύρωνος (KM 1293H, οικόπεδο Αφών Δάμψα)*, in *ArchDelt* 60, 2005 (2013) Χρονικά, pp. 1152-1154.
- SKERLOU, GRIGORIADOU 2014 = SKERLOU E., GRIGORIADOU D., *Ειδώλια προερχόμενα από αποδέτες του ιερού της Δήμητρας στην Κω. Μια πρώτη προσέγγιση*, in GIANNIKOURI A. (ed.), *Διεθνές συνέδριο στη μνήμη της Ηούς Ζερβουδάκη, Ρόδος, 26-29 Νοεμβρίου 2009*, Athens 2014, pp. 119-148.
- STAMPOLIDIS 1987 = STAMPOLIDIS N., *Ο Βωμός του Διονύσου στην Κω*, Ταμείο Αρχαιολογικών Πόρων, Athens 1987.
- TITE, HATTON 2007 = TITE M.S., HATTON G.D., *The production technology of, and trade in, Egyptian blue pigment in the Roman world*, in GOSDEN Ch., HAMEROW H., LOCK G., DE JERSEY Ph. (eds.), *Communities and Connections: Essays in Honour of Barry Cunliffe*, Oxford 2007, pp. 75-92.
- TRIANAFYLLIDIS 2015 = TRIANAFYLLIDIS P., *Archaeological researches on Milesian Agathonisi in the Dodecanese, Greece*, in LAFLI E., PATACI S. (eds.), *Recent Studies on the Archaeology of Anatolia*, BAR International Series, Archaeopress, Oxford 2015, pp. 95-104.
- TYLECOTE 1964 = TYLECOTE R., *Roman lead working in Britain*, in *The British Journal for the History of Science* 2.1, 1964, pp. 25-43.
- ULLRICH 1987 = ULLRICH D., *Egyptian blue and green frit: characterization, history and occurrence, synthesis*, in *Pact* 17, 1987, pp. 323-332.
- WRIGHT, WRIGHT 2005 = WRIGHT G.R.H., WRIGHT M., *Ancient building technology: Materials*. Leiden 2005.