ΠΑΝΕΠΙΣΤΗΜΙΟ ΑΘΗΝΩΝ, ΦΙΛΟΣΟΦΙΚΗ ΣΧΟΛΗ
ΤΟΜΕΑΣ ΑΡΧΑΙΟΛΟΓΙΑΣ & ΙΣΤΟΡΙΑΣ ΤΗΣ ΤΕΧΝΗΣ

ΑΛΑΣΑΡΝΑ
VI

ΓΛΥΠΤΙΚΗ – ΛΙΘΟΤΕΧΝΙΑ – ΕΠΙΓΡΑΦΕΣ

από το ιερό του Απόλλωνα Πυθαίου/Πυθαέως
και τον πρώιμο βυζαντινό οικισμό

Επιμελεια
Γ. Κοκκορου – Αλευρα

ΑΘΗΝΑ 2017

ΑΛΑΣΑΡΝΑ VI

ΕΘΝΙΚΟ ΚΑΙ ΚΑΠΟΔΙΣΤΡΙΑΚΟ ΠΑΝΕΠΙΣΤΗΜΙΟ ΑΘΗΝΩΝ

ΥΠΕΥΘΥΝΟΙ ΣΕΙΡΑΣ

ΓΕΩΡΓΙΑ ΚΟΚΚΟΡΟΥ-ΑΛΕΥΡΑ

ΣΟΦΙΑ ΚΑΛΟΠΙΣΗ-ΒΕΡΤΗ

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ΑΛΑΣΑΡΝΑ VI

ΓΛΥΠΤΙΚΗ – ΛΙΘΟΤΕΧΝΙΑ – ΕΠΙΓΡΑΦΕΣ

από το ιερό του Απόλλωνα Πυθαίου/Πυθαέως
και τον πρώιμο βυζαντινό οικισμό στην Αλάσαρνα

Επιμελεια

ΓΕΩΡΓΙΑ ΚΟΚΚΟΡΟΥ-ΑΛΕΥΡΑ

ΑΘΗΝΑ 2017

Η παρούσα έρευνα έχει συγχρηματοδοτηθεί από την Ευρωπαϊκή Ένωση (Ευρωπαϊκό Κοινωνικό Ταμείο – ΕΚΤ) και από εθνικούς πόρους μέσω του Επιχειρησιακού Προγράμματος «Εκπαίδευση και Διά Βίου Μάθηση» του Εθνικού Στρατηγικού Πλαισίου Αναφοράς (ΕΣΠΑ) – Ερευνητικό Χρηματοδοτούμενο Έργο: ΘΑΛΗΣ. Επένδυση στην κοινωνία της γνώσης μέσω του Ευρωπαϊκού Κοινωνικού Ταμείου.

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Συντονισμος εργου: Γεωργια Κοκκορου-Αλευρα

Ευρωπαϊκή Ένωση
Ευρωπαϊκό Κοινωνικό Ταμείο

ΕΠΙΧΕΙΡΗΣΙΑΚΟ ΠΡΟΓΡΑΜΜΑ
ΕΚΠΑΙΔΕΥΣΗ ΚΑΙ ΔΙΑ ΒΙΟΥ ΜΑΘΗΣΗ
επένδυση στην κοινωνία της γνώσης
ΥΠΟΥΡΓΕΙΟ ΠΑΙΔΕΙΑΣ & ΘΡΗΣΚΕΥΜΑΤΩΝ, ΠΟΛΙΤΙΣΜΟΥ & ΑΘΛΗΤΙΣΜΟΥ
ΕΙΔΙΚΗ ΥΠΗΡΕΣΙΑ ΔΙΑΧΕΙΡΙΣΗΣ

ΕΣΠΑ 2007-2013
πρόγραμμα για την ανάπτυξη
ΕΥΡΩΠΑΪΚΟ ΚΟΙΝΩΝΙΚΟ ΤΑΜΕΙΟ

Με τη συγχρηματοδότηση της Ελλάδας και της Ευρωπαϊκής Ένωσης

I. Γεωργια Κοκκορου-Αλευρα

σε συνεργασία με ΧΡΥΣΑΝΘΗ ΤΣΟΥΛΗ & ΕΦΗ ΡΗΓΑΤΟΥ

ΠΕΡΙΟΠΤΑ ΓΛΥΠΤΑ ΚΑΙ ΑΝΑΓΛΥΦΑ ΕΡΓΑ

♦

II. Ειρηνη Πουπακη

ΛΙΘΙΝΑ ΑΓΓΕΙΑ, ΧΕΙΡΟΜΥΛΟΙ ΚΑΙ ΑΛΛΑ ΛΙΘΙΝΑ ΑΝΤΙΚΕΙΜΕΝΑ (Β')

♦

III. Γ. Δουλφης & Γ. Κοκκορου-Αλευρα

ΝΕΕΣ ΕΠΙΓΡΑΦΕΣ (Β')

♦

IV. D. Tambakopoulos & Y. Maniatis

DETERMINATION OF THE MARBLE SOURCE OF SCULPTURE AND OTHER OBJECTS

♦

V. Α. Κατερινοπουλος & Κ. Μαυρογονατος

σε συνεργασία με ΕΙΡΗΝΗ ΠΟΥΠΑΚΗ

ΑΝΑΛΥΣΗ ΗΦΑΙΣΤΕΙΟΓΕΝΩΝ ΛΙΘΩΝ

Γενικό σχέδιο ανασκαφικού χώρου 2013

ΠΕΡΙΕΧΟΜΕΝΑ

IV.

DETERMINATION OF THE MARBLE SOURCE OF SCULPTURE AND OTHER OBJECTS FOUND IN HALASARNA, KOS

Dimitris Tambakopoulos & Yannis Maniatis

1. INTRODUCTION

Thirty nine (39) archaeological marble artefacts (Tables 1 and 2) from the site of the sanctuary of Apollo at ancient Halasarna and the Late Roman–Early Byzantine settlement that was established over the ruins of the earlier sanctuary were studied using scientific techniques and methodologies. The aim was to determine the provenance of their marble and identify the various marble sources used. These results could contribute to tracing the cultural and trade connections of Halasarna through all the periods of habitation and use.

In addition, and in order to successfully investigate the provenance of archaeological artefacts from Halasarna, it was considered crucial to explore the local ancient quarries at Kos and characterize the marble quarried there in antiquity by a combination of scientific techniques. A number of these quarries were known and published in the past,[1] but partially characterized scientifically, using only Petrographic and Stable Isotope Analysis.[2]

2. MATERIALS AND METHODS

2.1 LOCATION AND SAMPLING OF THE QUARRIES

The quarries of Kos were located using geological maps, data published in literature, and information from local people. Special thanks are due to Dr. Eirini Poupaki for joining in the search for the quarries and for bringing us in contact with Father Ioannis Koutantos, a priest in a local church at Zipari village, who guided us to the quarries on the north slopes of mount Dikaios. After the location of the quarries we recorded their coordinates, their approximate size, the presence of ancient tool marks and the macroscopic marble qualities to the extent that this was allowed by the weathering of the marble faces and the growth of vegetation. Samples were obtained from the quarry fronts and abandoned blocks covering as larger area as possible. Spots with remaining ancient tool marks were avoided.

2.2 ARCHAEOLOGICAL ARTEFACTS AND SAMPLING

According to the archaeological categorization and classification the studied artefacts were divided into two groups: a) The non-utilitarian artefacts, consisting of sculptures, altars and

[1] Chatziconstantinou and Poupaki 2009.
[2] Lazzarini and Malacrino 2010.

architectural elements, which we shall call the "KS" group, represented by 22 objects (KS1–KS22) (Table 1), and b) The utilitarian artefacts consisting of vessels, pestles, weights etc., which we shall call the "KO" group represented by 17 objects (KO1–KO18, KO6 was not marble and was omitted from the study) (Table 2). The samples were obtained in the form of a small chip with the use of a thin chisel, from selected points at old breaks with no effect to the archaeological information or aesthetic appearance of the artefacts.

2.3 TECHNIQUES AND METHODOLOGY

The marble of the collected samples from the quarries and the samples from the archaeological artefacts was examined and analysed using the following techniques:[3]

- Measurement of Maximum Grain Size (*MGS*) and qualitative examination of the marble crystalline features
- Electron Paramagnetic Resonance Spectroscopy (*EPR*)
- Stable Isotope Analysis of carbon and oxygen using Isotope Ratio Mass Spectrometry (*IRMS*).

2.3.1 *MGS* MEASUREMENTS AND SAMPLE PREPARATION

Prior to sampling of the archaeological artefacts, an in-situ, non-invasive, examination was performed at the storerooms of the Halasarna excavation. With the use of a portable light source, a millimetre scale and a magnifying glass (10x) the *MGS* (largest diameter of the biggest grain) and *MFS* (Most Frequent grain Size — largest diameter of the most frequent grain size) were measured. In addition, the crystallisation characteristics of the marble were assessed on the whole object. Whenever it was possible due to the geometry and size of the artefacts, the translucency was also measured as depth in cm of light penetrating the marble from the surface, by applying the light-source perpendicular to the surface.

The obtained samples from the artefacts were again examined under the optical microscope and the *MGS*, *MFS*, as well as, the marble crystallisation features were measured and compared against those from the in-situ examination of the whole objects. The same optical examination was performed for the geological samples, measuring their *MGS*, *MFS*, translucency, and recording their marble crystallisation features.

The samples were then cleaned mechanically from any weathered layers, and a small clean sample of each was ground gently in an agate mortar and sieved to retrieve fractions between 63 and 180 μm for the *EPR* analysis. Fine aliquots, below 63 μm, were also collected during the sieving for the Stable Isotope Analysis.

2.3.2 *EPR* ANALYSIS

As described in Polikreti and Maniatis (2002) and in Tambakopoulos (2013), three spectra (Fig. 1) were taken for each powder sample at different operating conditions using an X-Band EPR spectrometer (EPR BRUKER ER-200) operating at 9.47 GHz frequency: 1) The first spectrum (Fig. 1A) is that of the sextet of the Mn^{2+}, i.e. the 6 lines formed by the spin transition with electronic spin projection M_S = -1/2 to 1/2 and nuclear spin projection M_I taking values from –5/2 to 5/2, i.e. $\left|-\frac{1}{2}, M_I\right\rangle \rightarrow \left|\frac{1}{2}, M_I\right\rangle$. At the measurement conditions, in between the 6 main lines, the so called forbidden lines of Mn^{2+} that are occurring by the transitions $\left|-\frac{1}{2}, M_I\right\rangle \rightarrow \left|\frac{1}{2}, M_I \mp 1\right\rangle$ are

[3] Maniatis 2004.

also well formed. From this spectrum the height of the first peak is measured in relative units (parameter Mn^{2+}), the type of marble is evaluated (calcitic or dolomitic), and the percentage of dolomite when present in the sample is measured from the low magnetic field peak of the sextet[4] in the mixed dolomite/calcite marbles. 2) The second spectrum (Fig. 1B) is taken in order to achieve a better resolution for peaks with g-value around 2.00 that are occurring due to organic radicals, lattice defects etc. The spectrum consists of the 5th and 6th "forbidden" peaks in the center of the sextet. The presence of characteristic peaks in this area is recorded, as well as the half width at half maximum of the peak $\left|-\frac{1}{2},-\frac{1}{2}\right\rangle \rightarrow \left|\frac{1}{2},1\right\rangle$ (5th "forbidden" peak) in Gauss (parameter *Width*). 3) Finally, the third spectrum (Fig. 1C) consists of the low magnetic field peaks from 200 G to 3200 G which are due to paramagnetic ions, such as Fe^{3+} originating from the calcite lattice and replacing Ca ions. The height of the peak with g=14.25 is measured in relative units in this region as a standard parameter (parameter Fe^{3+}), but other peaks due to iron ions in oxides or in clay minerals (e.g. muscovite) are recorded if present.

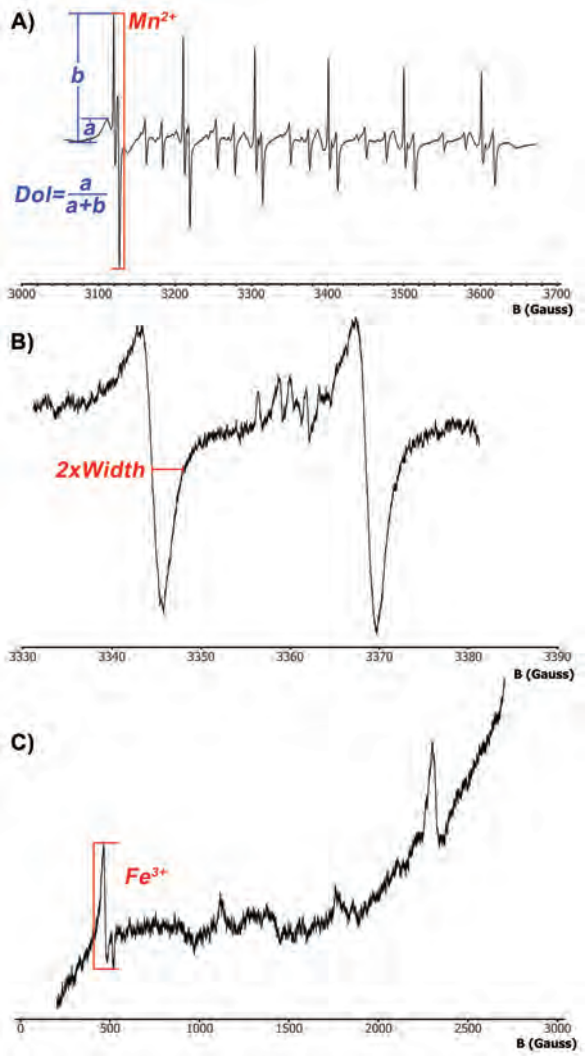

Fig. 1: The three spectra obtained by *EPR* spectroscopy showing the measured parameters.

In order to enlarge the *EPR* database we amalgamated the published *EPR* data by Attanasio (2003) with the database of the Laboratory of Archaeometry of NCSR "Demokritos". For making the two databases compatible we used as a theoretical standard the Mean value

[4] Attanasio 2003.

of Mn^{2+} of all the Penteli samples, given the large number of the analysed samples from Penteli at both laboratories (161 for Attanasio and 277 for Demokritos). The Mn^{2+} values in our database were divided by the Mean of Mn^{2+} value of our Penteli samples (2468 r.u.). Equally, Attanasio's H parameter, the height of the first peak of the last doublet of the Mn^{2+} sextet, was divided by the Mean of H parameter of Attanasios' samples from Penteli (8019.7 r.u.). The results are directly comparable since the height of both the first doublet peak and the last peak of the last doublet are proportional to the Mn^{2+} content of the measured sample, since all other instrumental parameters are kept constant for each measurement, at both laboratories.

For simplicity and continuity of published results, the presented Mn^{2+} values in this work are converted back to the "Demokritos" database range of values, i.e. the standardized measurements are multiplied by 2468.

2.3.3 STABLE ISOTOPE ANALYSIS

The isotopic ratios of carbon-13/carbon-12 (parameter $\delta^{13}C‰$) and oxygen-18/oxygen-16 (parameter $\delta^{18}O‰$) compared to the international standard PDB (Pee Dee Belemnite) were measured at the Department for Applied Geosciences and Geophysics, University of Leoben, Austria, by Prof. Walter Prochaska, using an IRMS analyser with a multiple collector.[5]

2.3.4 DATABASES

The results of analyses for the archaeological artefacts are compared to the data for known ancient marble quarries from Greece, Turkey, Italy, Portugal, Spain, and Morocco accumulated over the last 25 years by measurements at the Laboratory of Archaeometry, NCSR "Demokritos"[6] and by data published in literature.[7]

2.3.5 METHODOLOGY FOR PROVENANCE DETERMINATION

The first step is the statistical treatment of the results from the archaeological samples against the isotopic signatures and the *EPR* Mn^{2+} and *MGS* parameters from known ancient sources/quarries contained in the databases. This treatment is represented by three diagrams. The first are the diagrams of the *IRMS* parameters, $\delta^{18}O‰$ and $\delta^{13}C‰$, which for convenience and simplicity is constructed in two versions, once for the fine grained marbles ($MGS \leq 1.5$ mm) and then for the coarse grained marbles ($MGS > 1.5$ mm). The third diagram is that of the natural logarithms of *MGS* and Mn^{2+} parameters. The quarries that are excluded from the isotope diagrams, i.e., the quarries that their ellipses don't include any samples, are omitted from this diagram.

The next step involves only the samples that from the first step have more than one possible quarry of origin, i.e. the samples that fall in the overlapping region of two or more quarry ellipses in both diagrams. For each of these cases, Discriminant Analysis is performed using all the parameters, in order to best discriminate the possible quarries and exclude as many as possible of them, focusing to the minimum possible number of sources.

In the final step, the optical examination characteristics of the marble, such as colour, translucency, veins and crystalline features, as well as the date of the object if available, are taken into account to verify or exclude quarries of possible origin for each sample studied.

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[5] Craig and Craig 1972; Allison et al. 1995; Attanasio et al. 2006.
[6] Polikreti and Maniatis 2002; Maniatis et al. 2012.
[7] Herz 1987; Gorgoni et al. 2002; Lazzarini and Antonelli 2003; Attanasio 2003; Attanasio et al. 2006; Lazzarini and Malacrino 2010.

3. RESULTS AND DISCUSSION

3.1 THE MARBLE QUARRIES OF KOS

According to the literature[8] and the IGME maps the only area where marble formations exists in Kos is the south and north slopes of mount Dikaios in the area between village Lagoudi (NW) and the Piso Therma beach (SE) (Fig. 2). On the south slopes in the area with a toponym *Marmara* (meaning "marbles" in Greek), above the Piso Therma beach, there is a set of quarries visited previously and published by Lazzarini and Malacrino (2010). On the north slopes of Mt. Dikaios, there also exists an extended quarry area with several small and large quarries, not examined or analysed before, which we visited and studied within this project.

3.1.1 THE QUARRIES ON THE SE SLOPES OF MT. DIKAIOS

The Marmara location quarries are at a very upright mountain slope dropping down to the sea. Unfortunately, we were unable to reach the ancient quarry fronts due to very hostile landscape where the erosions have created vertical fronts that were impossible to climb. The

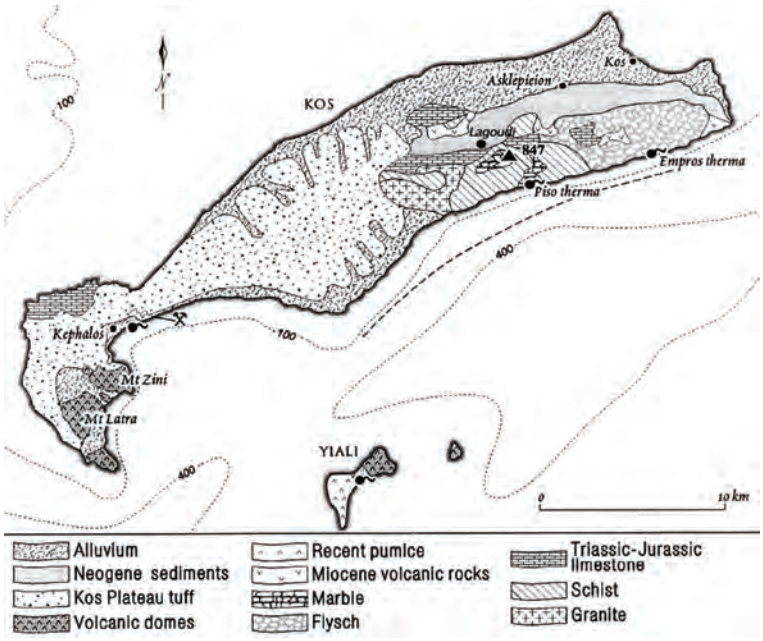

Fig. 2: Geological map of Kos. Two marble deposits can be seen between Lagoudi and Piso Therma, on the south and north slopes of Mt. Dikaios (highest peak at 847 m) (Higgins and Higgins 1996).

rift, however, that comes down from the quarries is full of smaller or bigger marble blocks of regular or irregular shapes, most probably carried down from the mountain by the stream waters during heavy storms or abandoned in ancient times on their transportation down the slopes to the sea — a typical ancient method of transportation of blocks from a quarry to their destination. Between the small and big marble blocks, we were able to locate blocks clearly cut in antiquity — bearing ancient tool marks from pickaxe and wedges, and a small semi-finished column (Figs 3 and 4). Sixteen (16) samples were collected from the blocks in the rift.

[8] Higgins and Higgins 1996; Chatziconstantinou and Poupaki 2009; Lazzarini and Malacrino 2010.

The marble of all the samples was whitish/greyish with darker greyish/blue diffused veins, similar to the marble of many monuments in Kos (Fig. 5).

The results from the optical examination and analyses with the scientific techniques are shown in Table 3 and in Figures 13–19 in box plot diagrams and in comparison with all the quarries studied. The marble in this location exhibits frequently lineated grains, *MGS* from 1.0 mm up to 2.0 mm with one sample having a few grains up to 4.0 mm, and transparency from very low to high, usually depending on the colour which varies from grey to white (Table 3). The texture can be homoblastic, but also heteroblastic, or both in different areas of the same sample.

The coordinates of the rift at the sea front are N 36°49′29.35″, E 27°13′30.04″.

3.1.2 THE QUARRIES ON THE NW SLOPES OF MT. DIKAIOS

On the north-west slopes of Mt. Dikaios several quarries were located exhibiting ancient tool marks. Worked marble blocks were seen abandoned in many locations. The quarries are high up the mountain (between 590 and 680 m from the sea level), not so easy to reach and in rather steep slopes that would have made the quarrying and carrying the blocks down a demanding task in antiquity.[9]

- *Dumping area*: It is a site located at N 36°50′36.33″, E 27°13′32.83″. It is actually a *landfill* covering a large area (more than 20 mx20 m) full of scattered big and small blocks of marble in irregular shapes, most probably produced by dynamite explosion in modern

Fig. 3: A Block with ancient tool marks inside the rift at Marmara (photo by R. Poupaki).
Fig. 4: A small column inside the rift at Marmara (photo by R. Poupaki).

Fig. 5 a, b: (Left) A marble rock from the rift at Marmara (photo by R. Poupaki). (Right) A marble slab from Asklipieio at Kos bearing the same vein pattern as the rock on the left (Photo by D. Tambakopoulos).

[9] Poupaki 2004; Poupaki under publication.

exploitation times (Fig. 6). However, a large number of blocks have ancient tool marks (pickaxe traces and wedge holes) (Figs 7 and 8) which means that all this material comes from ancient quarries under or very close to the scattered pieces of marble. We were unable however to locate any exposed ancient quarry fronts in this area. Fifteen (15) samples were collected from blocks covering the whole area. The marble is different from the qualities found at Marmara, as it is whiter, more translucent and coarser grained, usually with thin yellow veins. The crystals exhibit similar lineation as in Marmara, but there is also a curved foliation. All the details from the optical examination and the analytical

Fig. 6: The general view of the *Dumping Area* (Y. Maniatis and D. Tambakopoulos sampling, Father I. Koutantos standing on the right, Photo by R. Poupaki).
Fig. 7: A block of marble from the *Dumping Area* with pickaxe traces (Photo by D. Tambakopoulos).

Fig. 8: A block of marble from the *Dumping Area* with pickaxe traces (Photo by R. Poupaki).
Fig. 9: The ancient quarry front of the *Kako Skali* quarry (Photo by R. Poupaki).

Fig. 10: Ancient traces of pick axe forming the "fishbone" pattern (known as "a festoni" technique) at the front of the *Kako Skali* quarry (Photo by R. Poupaki).
Fig. 11: A cut block bearing ancient tool marks at the *Kako Skali* quarry (Photo by E. Poupaki).
Fig. 12: A quarry front on the slopes of Mt. Dikaios between the *Dumping Area* and *Kako Skali* (Y. Maniatis is sampling, Photo by D. Tambakopoulos).

techniques are presented in Table 4 and in Figures 13–19 in box plot diagrams.

- *Kako Skali* or *Kakoskalo*: It is the toponym of a quarry SW of the *Dumping area* located at N 36°50′28.13″ and E 27°13′39.23″. This is a large quarry with high vertical fronts measuring about 30 m wide and 20 m high (Fig. 9), exhibiting extensive ancient tool marks at the fronts and on abandon marble blocks (Figs 10 and 11). The variety of marble in this quarry is grey or greyish with thin dark grey or black veins, and low translucency. A couple of samples were white and with high translucency. In total, fifteen (15) samples were collected and studied. The results of the analyses are presented in Table 5 and in Figures 13–19 in box plot diagrams.
- Between the *Dumping area* and *Kako Skali*: A number of smaller quarry fronts were located along the North slopes of Mt. Dikaios from the Dumping area to Kako Skali (Fig. 12). Similar qualities of marble to the above sites were located and sampled in these quarries, but also black limestone with veins of white marble, and a black/grey cipolino variety were also found. Six (6) samples in total were obtained from these fronts. The results are presented in Table 6 and in Figures 13–19 in the form of box plot diagrams.

3.1.3 DISCRIMINATING THE LOCAL MARBLES

The analytical parameters of the collected samples from the quarries overlap in a great degree (Figs 13–19), which makes impossible the discrimination between the quarries of Kos based on these. The macroscopic characteristics, however, are quite variable and can be used to assign a marble of Koan origin to a quarry or a quarry region in Kos. In particular, a greyish marble with grey/blue diffused veins, closely spaced, is most probably coming from the Marmara region (SE Slopes), while a white marble with high translucency or a grey marble with dark thin veins is most probably coming from the Damping area/Kako Skali region (NW slopes).

In Figures 20 and 21 the graphs of $LnMn^{2+}$ vs *LnMGS* and $\delta^{13}C‰$ vs $\delta^{18}O‰$ for the Koan marble (all regions grouped together) and the most important ancient marble quarries of eastern Mediterranean are presented. In Figure 20 there is a great overlap with many other ancient quarries, but in Figure 21, due to the unique combination of carbon and oxygen isotopes, there is no overlapping with any quarry. However, the published data of Lazzarini and Malacrino (2010) show 3 samples with much lower $\delta^{13}C‰$ than the rest of their data and also the data of this work. One of these samples falls in the Penteli and Naxos-Apollonas field overlap, and the other 2 plot lower than the Naxos-Apollonas field. All three samples have very abundant dolomite content (using the terminology of Lazzarini and Malacrino) and very low *MGS* (0.4-0.6 mm) which could mean that they are dolomitic marbles of low quality (perhaps semi-crystallized) and they should be presented separately or omitted. Therefore, a full discrimination of the Koan marbles from all other known ancient quarries is possible by Stable Isotope Analysis.

3.2 MARBLE PROVENANCE OF HALASARNA ARTEFACTS

The results of the optical examination and the scientific techniques (*EPR* and *IRMS*) are presented in Tables 7 and 8 for the KS group and Tables 9 and 10 for KO group respectively. All the samples were found to be almost pure calcitic. Dolomite impurities (if any) were under the detection limit of *EPR* spectroscopy, which in general varies depending on the Mn^{2+} content in calcite versus that in dolomite. Empirical evidence has shown that dolomite content less than 2% is non-detectable by *EPR* spectroscopy.

The two diagrams, one for the KS and one for the KO group, of the isotopic parameters, $\delta^{18}O$‰ and $\delta^{13}C$‰, for fine grained samples (*MGS* ≤ 1.5 mm) are presented in Figures 22 and 23, respectively, and for the coarse grained marbles (*MGS* > 1.5 mm) in Figures 24 and 25. The diagrams of the natural logarithms of *MGS* and Mn^{2+} parameters are presented in Figures 26 and 27, for the KS and KO groups respectively.

- ***Kos***

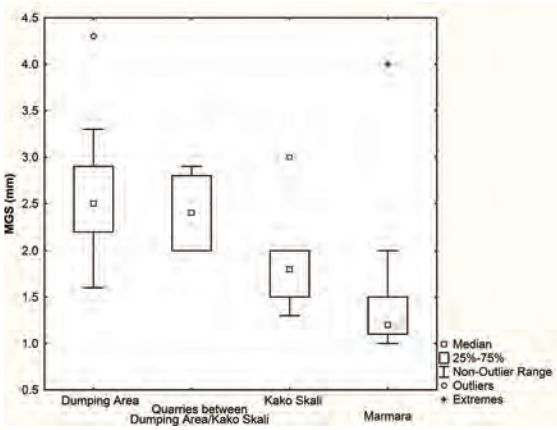

Fig. 13: Results of *MGS* parameter from the Optical examination for the different quarry regions of Kos.

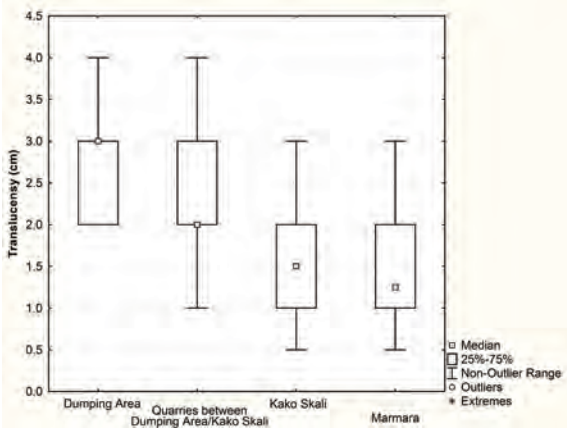

Fig. 14: Results of *Translucency* from the Optical examination for the different quarry regions of Kos.

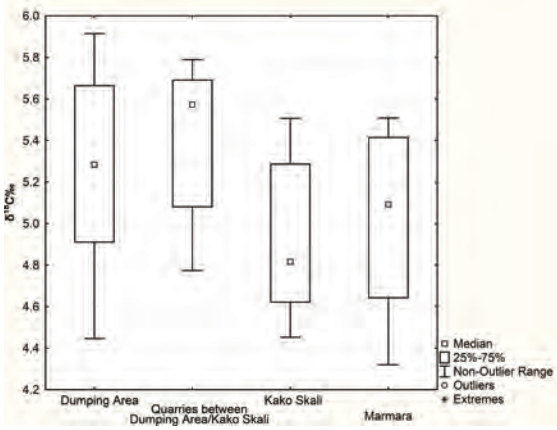

Fig. 15: Results of $\delta^{13}C$‰ parameter from the Stable Isotope Analysis for the different quarry regions of Kos.

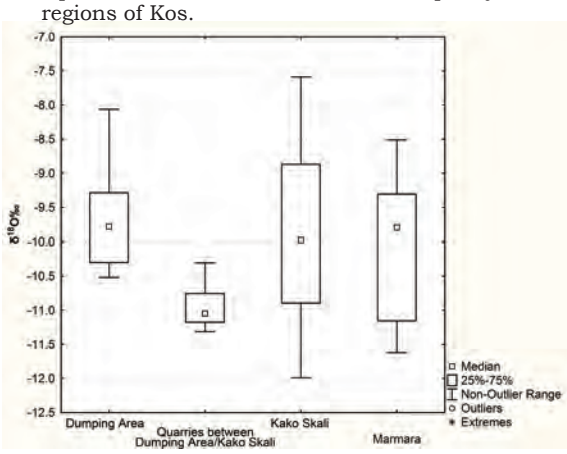

Fig. 16: Results of $\delta^{18}O$‰ parameter from the Stable Isotope Analysis for the different quarry regions of Kos.

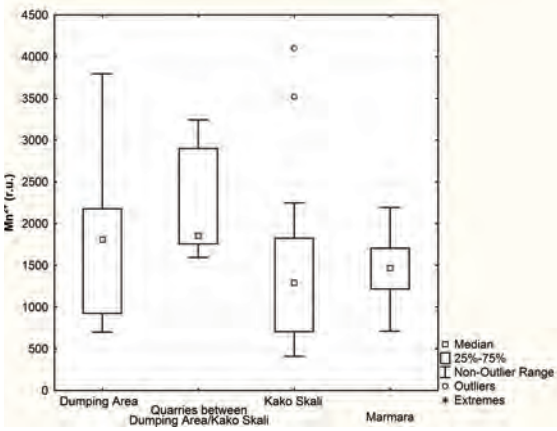

Fig. 17: Results of Mn^{2+} parameter from *EPR* for the different quarry regions of Kos.

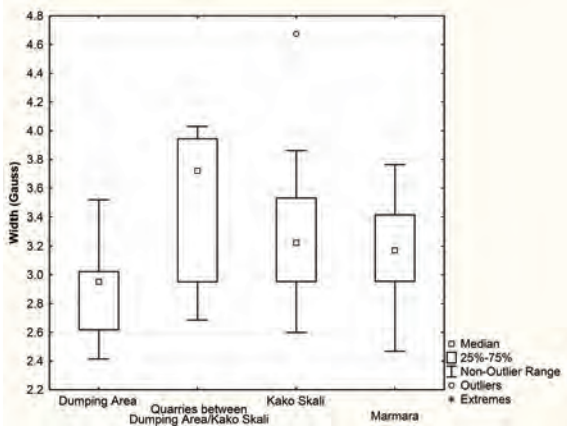

Fig. 18: Results of *Width parameter* from *EPR* for the different quarry regions of Kos.

From Figures 22, 24, and 25 it is evident that five samples of the KS group, namely KS16, KS17, KS18, KS20, and KS21, and two samples of the KO group, namely KO2 and KO5, are falling in the Kos ellipse. All these samples are also falling in the Kos ellipse of the equivalent *EPR* diagrams in Figures 26 and 27. KS19 is outside of the Kos ellipse in Figure 24, but since no other quarry has samples in that area, we have to assume that it is made in Koan marble and it comes from a source in Kos that we did not sample during the field work. This assumption can be validated by the fact that in Figure 26 falls inside the Kos ellipse, but also from its macroscopic characteristics which are similar to the marble of the quarries we sampled on mount Dikaios at Marmara and Kako Skali, i.e. grayish marble with grey veins. The heavy soil deposition made impossible to identify the vein pattern of this artefact and thus distinguish the provenance between Marmara and Kako Skali. By following the identification process discussed in paragraph 3.1.3 a suggestion for possible quarry region was made for all the artefacs of Koan origin (Tables 11 and 12).

The KS artefacts made in koan marble are three cylindrical altars (KS17, KS18, KS20), an orthostate of an altar or a pedestal (KS19), a grave relief fragment (KS16), and an arm fragment (KS21). The two KO artefacts (KO2 and KO5) are bowl fragments.

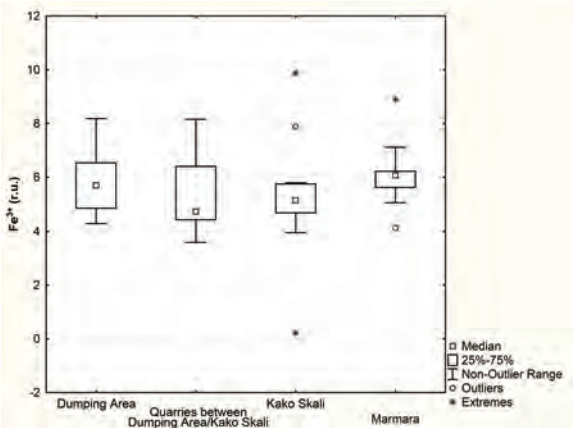

Fig. 19: Results of Fe^{3+} parameter of *EPR* for the different quarry regions of Kos.

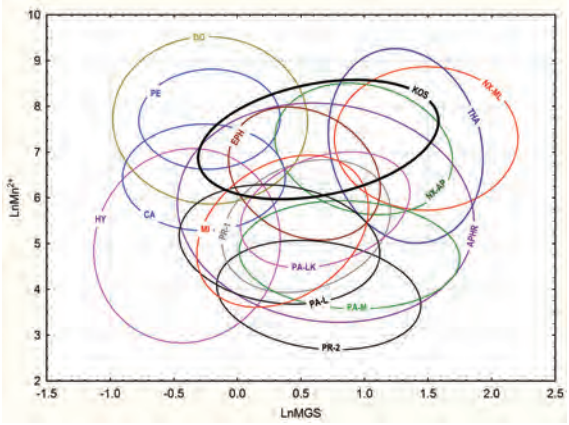

Fig. 20: Diagram of $LnMn^{2+}$ vs *LnMGS* for the Koan quarries and Ephesos (EPH), Paros (PA-M = Marathi, PA-L = Lychnitic, PA-LK = Lakkoi), Proconnesos (PR-1, PR-2), Miletos (MI), Aphrodisias (APHR), Naxos (NX-AP = Apollon, NX-ML = Melanes),Thasos (THA), Carrara (CA), Hymettos (HY) and Dokimeion (DO).

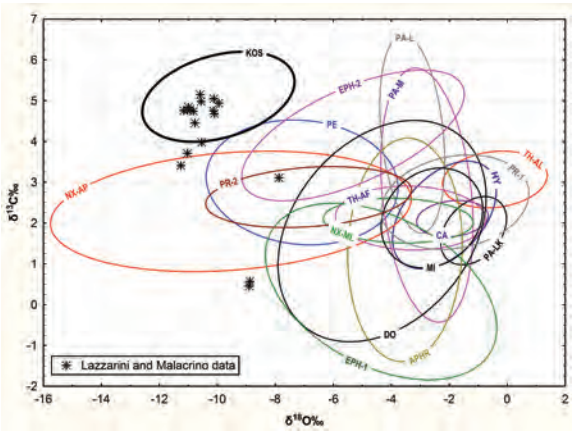

Fig. 21: Diagram of $\delta^{13}C‰$ vs $\delta^{18}O‰$ for the Koan quarries and Ephesos (EPH-1, EPH-2), Paros (PA-M = Marathi, PA-L = Lychnitic, PA-LK = Lakkoi), Proconnesos (PR-1, PR-2), Miletos (MI), Aphrodisias (APHR), Naxos (NX-AP = Apollon, NX-ML – Melanes), Thasos (TH-AL = Aliki, TH-AF = Acropolis/Fanari), Carrara (CA), Hymettos (HY), and Dokimeion (DO). The data of Lazzarini and Malacrino (2010) is plotted with asterisks.

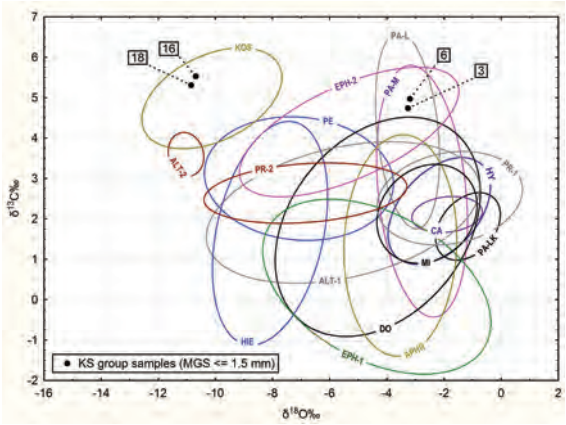

Fig. 22: Diagram $\delta^{18}O‰$ vs $\delta^{13}C‰$ for fine grained (MGS ≤ 1.5 mm) samples of the KS group and quarries with fine grained marble: Kos, Altintas (ALT-1, ALT-2), Penteli (PE), Ephesos (EPH-1, EPH-2), Paros (PA-M = Marathi, PA-L = Lychnitic, PA-LK = Lakkoi), Proconnesos (PR-1, PR-2), Hymettos (HY), Carrara (CA), Miletos (MI), Dokimeion (DO), Aphrodisias (APHR) and Hierapolis (HIE).

• *Paros-Marathi/Lychnitic*

In Figures 22 and 24 samples KS1, KS3, KS5, KS6, KS9, and KS15 are falling in the ellipses of Paros-Marathi (PA-M), Paros-Lychnitic (PA-L), and Ephesos (EPH-2). In Figure 26 however, only KS3 and KS9 are falling in the Ephesos ellipse, while the rest are very close to the Ephesos except KS15 which is quite far from Ephesos, but also far from Paros-Lychnitic as well. In order to clarify these cases we performed discriminant analysis using four parameters simultaneously, *MGS*, Mn^{2+}, $\delta^{18}O$‰, and $\delta^{13}C$‰. The results can be seen in Figure 28, which discriminates in a great degree the Paros and the Ephesos quarries. Therefore, from this diagram Ephesos can be excluded, leaving as source of marble for these samples the Marathi Valley on Paros, in which, besides the open quarries (PA-M), also the famous Lychnitic marble (PA-L) was quarried in the underground quarries of Nymph and Pan.

In the Marathi Valley of Paros various varieties of marble were quarried in Antiquity. In the earlier stages of marble provenance research scholars thought that the marble of the

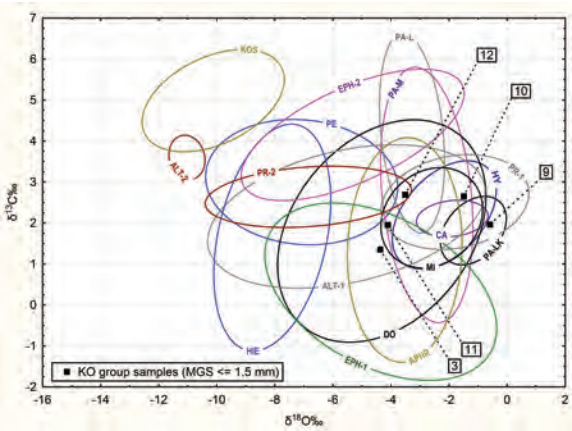

Fig. 23: Diagram $\delta^{18}O$‰ vs $\delta^{13}C$‰ for fine grained (*MGS* ≤ 1.5 mm) samples of the KO group and quarries with fine grained marble: Kos, Altintas (ALT-1, ALT-2), Penteli (PE), Ephesos (EPH-1, EPH-2), Paros (PA-M = Marathi, PA-L = Lychnitic, PA-LK = Lakkoi), Proconnesos (PR-1, PR-2), Hymettos (HY), Carrara (CA), Miletos (MI), Dokimeion (DO), Aphrodisias (APHR) and Hierapolis (HIE).

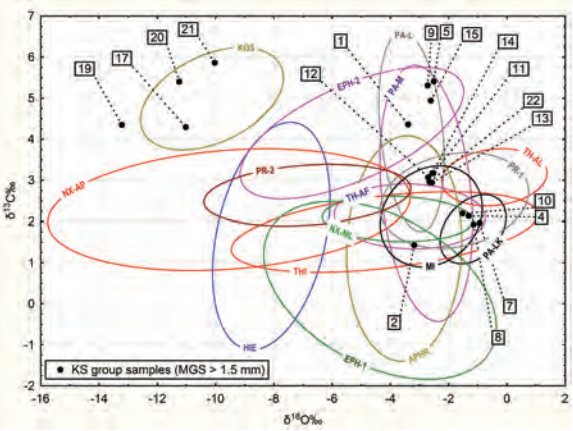

Fig. 24: Diagram $\delta^{18}O$‰ vs $\delta^{13}C$‰ for coarse grained (*MGS* > 1.5 mm) samples of the KS group and quarries with coarse grained marble: Kos, Ephesos (EPH-1, EPH-2), Paros (PA-M = Marathi, PA-L = Lychnitic, PA-LK = Lakkoi), Proconnesos (PR-1, PR-2), Miletos (MI), Aphrodisias (APHR), Hierapolis (HIE), Naxos (NX-AP = Apollon, NX-ML = Melanes), Thasos (TH-AL = Aliki, TH-AF = Acropolis/Fanari), Thiountas (THI).

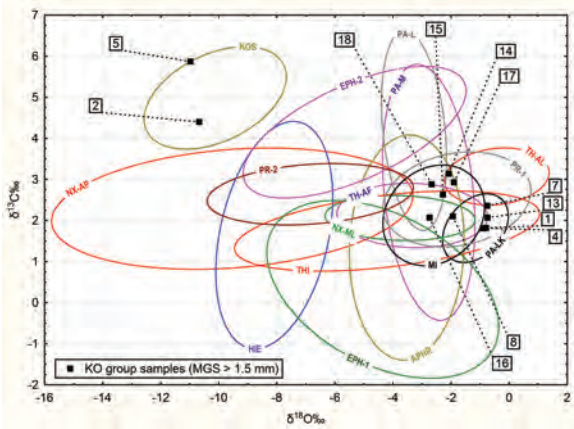

Fig. 25: Diagram $\delta^{18}O$‰ vs $\delta^{13}C$‰ for coarse grained (*MGS* > 1.5 mm) samples of the KO group and quarries with coarse grained marble: Kos, Ephesos (EPH-1, EPH-2), Paros (PA-M = Marathi, PA-L = Lychnitic, PA-LK = Lakkoi), Proconnesos (PR-1, PR-2), Miletos (MI), Aphrodisias (APHR), Hierapolis (HIE), Naxos (NX-AP = Apollon, NX-ML = Melanes), Thasos (TH-AL = Aliki, TH-AF = Acropolis/Fanari), Thiountas (THI).

underground quarry of Nymphs (the only underground quarry known at that time) is fine grained and of exceptional quality, which is not far from the truth for this particular quarry. This "uniqueness" was further emphasized as the first analyses showed that the isotopic values for carbon were quite higher than the rest of the open Marathi quarries, discriminating the two areas.[10] However, as the research in the Marathi valley progressed[11] new evidence showed that: a) there was a second underground quarry (Pan's quarry) in the same valley, b) the marble in the underground quarries can also be of inferior quality (greyish or grey, which was most probably not extracted but left over in Antiquity), c) the good quality marble with high translucency from the underground quarries can be also coarse grained with *MGS* reaching even more than 3 mm, and exhibiting lower carbon values, and d) marble with qualities similar to the so called "Lychnitis" marble has been located in the open quarries, exhibiting also the higher carbon values. This has created a huge overlapping of the "Lychnitic" and the "rest" of the Marathi marbles, making the old approach of assigning the exceptional quality marble with high carbon values solely to the underground quarries of the Marathi valley rather uncertain.

All the samples discussed in this paragraph exhibit similar to the "Lychnitic" quality characteristics, i.e. white colour, high translucency and good crystallization (except KS3 which is quite weathered), but not as much as to be granted the "Lychnitic" quality "certificate" without any doubt, despite the fact they all exhibit the higher carbon values. In the past, the higher

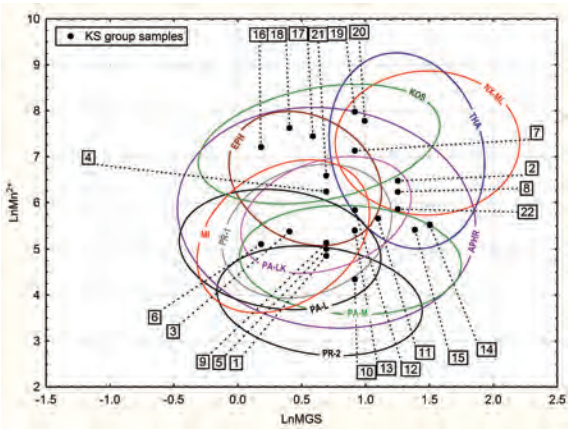

Fig. 26: Diagram of *LnMGS* vs *LnMn*$^{2+}$ for the KS group samples and the possible quarries as concluded from Figures 22 and 24: Kos, Ephesos (EPH), Paros (PA-M = Marathi, PA-L = Lychnitic, PA-LK = Lakkoi), Proconnesos (PR-1, PR-2), Miletos (MI), Aphrodisias (APHR), Naxos (NX-ML = Melanes), Thasos (THA), and Aphrodisias (APHR).

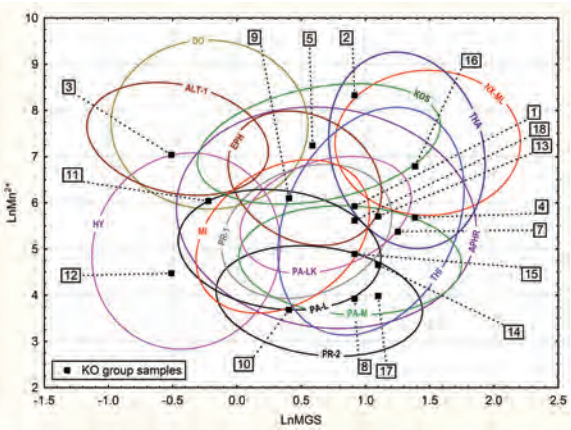

Fig. 27: Diagram of *LnMGS* vs *LnMn*$^{2+}$ for the KO group samples and the possible quarries as concluded from Figures 23 and 25: Kos, Ephesos (EPH), Paros (PA-M = Marathi, PA-L = Lychnitic, PA-LK = Lakkoi), Proconnesos (PR-1, PR-2), Miletos (MI), Aphrodisias (APHR), Naxos (NX-ML = Melanes), Thasos (THA), and Aphrodisias (APHR), Dokimeion (DO), Altintas (ALT-1), Hymettos (HY), and Thiountas (THI).

carbon values would be enough to set the origin of these samples to the underground quarries in the Marahti Valley. However, as stated above this could be wrong, as they could be coming from open quarries at the same valley. Thus, a second discriminant analysis was performed in an attempt to approach this problem. The results are shown in the Figure 29. From this graph only KS6 could be assigned to the underground quarries and only KS15, due to its large *MGS*, could be assigned solely to the open quarries. Therefore, samples KS1, KS3, KS5, KS9 are assigned to the Marathi valley with a high probability to be coming from the underground quarries, i.e. Paros-Marathi (Lyhnitic?), KS6 is assigned with a higher probability than the rest

[10] Herz 1987; Attanasio et al. 2006.
[11] Polikreti 1999; Maniatis and Polikreti 2000; Attanasio et al. 2006.

to the underground quarries, i.e. Paros-Lychnitic (Open quarries?) and KS15 is assigned to the open quarries of Marathi, i.e. Paros-Marathi.

All these samples from Paros-Marathi/Lychnites are statues or statuettes fragments, in contrast to the utilitarian objects (KO group) that none of them was made in Paros-Marathi/Lyhnitic marble, a fact that is compatible with the typical use of high quality marble for fine sculptured objects.

• *Paros-Marathi*

In addition to sample KS15, the tight group of samples KS11, KS12, KS13, KS14, and KS22 falls in the overlapping region of Paros-Marathi and Paros-Lychnitic fields of Figure 24. These samples also fall in the Proconnesos, Miletos and Aphrodisias ellipses. Aphrodisias can be safely excluded as, despite the extent of the 95% probability ellipse, there are not actual quarry samples with $\delta^{13}C$ value higher than 2.55‰, which is much lower that the carbon values of the above group of archaeological samples. Miletos can also be excluded as it is known for the grey and greyish varieties of marble[12] in contrast to the pure white and of high translucency marbles of this group. For the same reason, Proconnesos can also be excluded or at least be assigned with a very low probability as the marble of Proconnesos is light greyish and darker according to the colour values given by Attanasio et al. (2006). In Figure 26, all the samples fall relatively close, as in Figure 24, mainly due to similar Mn^{2+} parameter and inside the Paros-

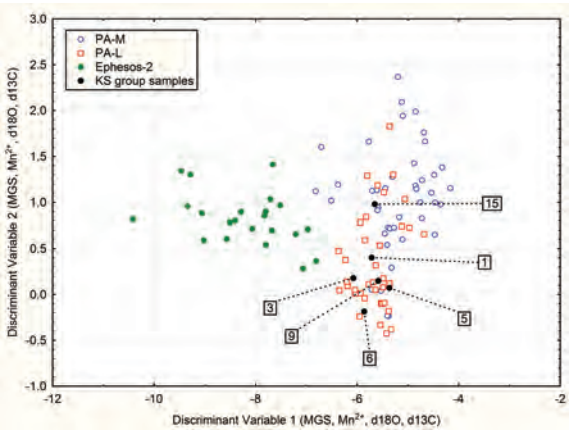

Fig. 28: Discriminant analysis for Paros-Marathi (PA-M), Paros-Lychnitic (PA-L), and Ephesos (Ephesos-2). The KS group samples fall in the Paros quarries.

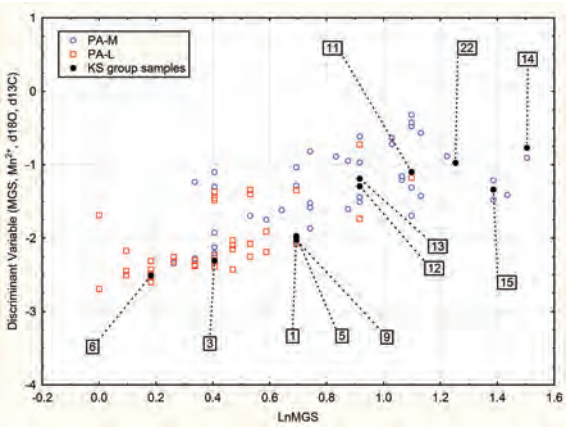

Fig. 29: Discriminant analysis for Paros-Marathi (PA-M) and Paros-Lychnitic (PA-L) and the KS group samples that fall in their overlapping area in the diagram of Figure 22.

Marathi ellipse, except KS14 and KS22 which are just outside of the probability ellipse. Thasos could be an alternative provenance possibility for these two samples, since although they plot outside of the 95% probability ellipse there are a few quarry samples from Thasos-AL that fall outside of the Thasos ellipse and close to KS14 and KS22 in Figure 24. However, the whiteness of these marble and the high translucency can perhaps exclude Thasos. Additionally, KS14 and KS22 are outside of the Proconnesos ellipse. In Figures 29 and 30 the discriminant analysis for these two samples points to a Paros-Marathi origin with higher probability than Paros-Lychnitic or Proconnesos.

In Table 9, a firm similarity can be noticed in EPR and isotopic parameters for this group of samples (KS15, KS11, KS12, KS13, KS14, and KS22). This fact could point to the same single

[12] Attanasio et al. 2006.

source of marble for all the samples with a variation in *MGS* between 2.5 and 4.5 mm, which strengthens further the Paros-Marathi possibility.

Sample KO10 in Figure 23 falls inside the ellipses of Proconnesos, Paros-Marathi (however outside the overall distribution of the actual quarry points), and Miletos. In Figure 27 it falls outside the Paros-Marathi, and just outside the Miletos ellipse (and also outside of the distribution of the actual quarry points). Although the analytical results point only to Proconnesos, the whiteness and high translucency of its marble is in favor of a Paros-Marathi origin. For this reason we cannot exclude the Paros-Marathi provenance as an alternative origin to Proconnesos, i.e. Proconnesos or Paros-Marathi.

In conclusion KS11, KS12, and KS13 are made in marble from Paros-Marathi with minor

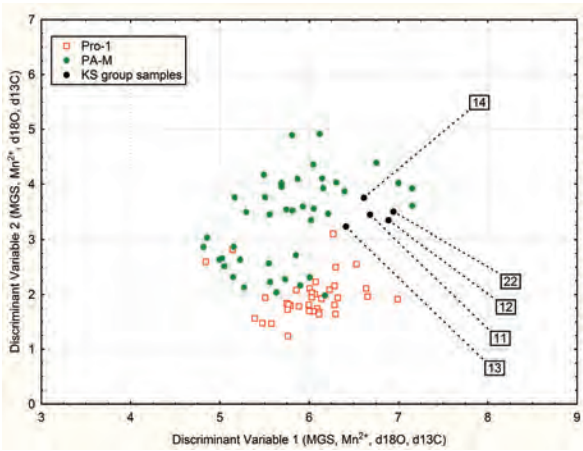

Fig. 30: Discriminant analysis for Paros-Marathi (PA-M) and Proconnesos (PR-1) and the KS group samples that fall in their overlapping area in the diagram of Figure 22.

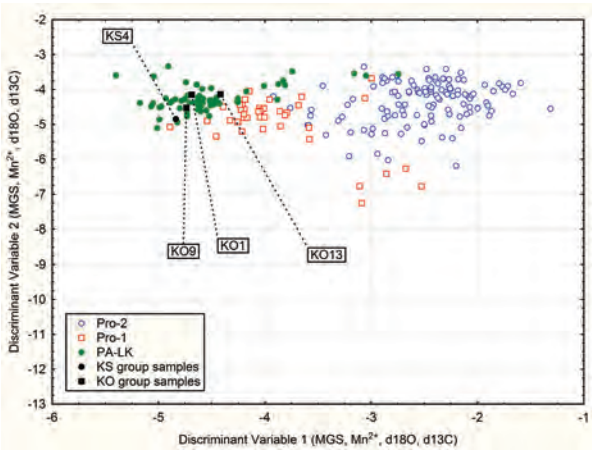

Fig. 31: Discriminant analysis for Paros-Lakkoi (PA-LK) and Proconnesos (PR-1, PR-2) and the samples that fall in their overlapping area in diagram of Figure 24 and 25.

probabilities to be made in marble from Proconnesos, i.e. Paros-Marathi (Proconnesos?), while KS14 and KS22 are made in Paros-Marathi marble without any other options.

Only one utilitarian artefact, KO10 — a semi-finished pestle fragment, has a possibility to be made in Paros-Marathi marble but with equal probabilities to be made in proconnesian marble (see in Proconnesos discussion below for more samples falling in the Proconnesos-Paros-Marathi overlap).

All the samples, except KS13 which is probably a fragment of an altar, and KO10 which is a pestle fragment, are statue fragments.

- *Paros-Lakkoi*

In Figures 23, 24, and 25, there is a number of samples falling mainly in the ellipses of Paros-Lakkoi and Proconnesos, while some of them fall also in other ellipses. These are KS4, KS7, KS8, and KS10 from the KS group, and KO1, KO4, KO7, KO8, KO9, and KO13 from the KO group. In Figures 26 and 27, KS8, KO4, and KO7 fall outside of Proconnesos. For KS8 and KO7 besides Paros-Lakkoi a possible provenance from the Figures 24, 25, 26, and 27 is also Thasos, but as discussed above, due to whiteness of the samples Thasos could be excluded, leaving only Paros-Lakkoi as the possible provenance. KO4 in Figure 27 falls outside of Paros-Lakkoi due to higher *MGS* than Paros, and since Thiountas and Thasos are excluded as well; the first due to its oxygen values being less than –2.85, much less than KO4, and Thasos due to both carbon and oxygen values, there are not possible quarries left as origin for this

sample. However, in a recent study presented in ASMOSIA XI International Conference,[13] Archaic Kouroi from Sounion made in Parian marble exhibited *MGS* more than 4 or 5 mm, thus making possible an assignment to the Paros-Lakkoi quarries for KO4 as well. Similarly to KO4, the sample KS7 is outside of the Paros-Lakkoi ellipse in Figure 26 and inside the ellipses of Ephesos, Aphrodisias, Kos, Thasos, and Naxos-Melanes, all of which can be excluded either due to carbon and oxygen values in Figure 24 for the first three of them, or due to *MFS* for the last two, excluding any possible quarries for KS7. However, the sample mass of KS7 was only 65 mg, which is much less than the necessary 220 mg for the standard measurements. The conversion of the measurement to a 220 mg equivalent one[14] introduces extra errors that may lead to an overestimate or underestimate of the final calculated value. By calculating the upper and lower limits for the $LnMn^{2+}$, its value can range from 7.0 to 7.25, and the lower value is just inside the Paros-Lakkoi.

Samples KS10 and KO8 are outside of Paros-Lakkoi in Figures 26 and 27 and inside Proconnesos and Paros-Marathi which is not excluded by oxygen and carbon values. However, both samples are greyish in colour with parallel veins that excludes Paros and verifies Proconnesos.

The remaining samples have only Paros-Lakkoi or Proconnesos possibilities and to clarify them we again performed discriminant analysis, presented in Figure 31. From this analysis it is clear that Paros-Lakkoi is the most probable origin for all of them, while Proconnesos is almost excluded. Furthermore, the whiteness, high translucency and *MFS* of KS4 and KO9 can entirely exclude Proconnesos, while the dating of KO13 being between 400 and 350 BC, makes it very early for Proconnesos[15] although cannot be entirely excluded based only on this reason. Finally, KO1 is the most distant sample, of the last group, from Proconnesos, and well within the main distribution of Paros-Lakkoi in Figure 31. However, the faint grey background and the medium translucency, cannot exclude entirely the Proconnesos possibility.

In conclusion KS4, KS7, KS8, KO4, KO7, KO9, are made in marble from Paros-Lakkoi. KO1 and KO13 are also most probably made in marble from Paros-Lakkoi, but there is a slight possibility for them to be made in marble from Proconnesos, i.e. Paros-Lakkoi (Proconnesos?). KS10 and KO8 are clearly made in marble from Proconnesos.

All KS group artefacts made in Paros-Lakkoi marble are statue fragments, while the KO group artefacts are three bowl fragments (KO1, KO7, and KO13), one basin fragment (KO9) and a table fragment (KO4).

- *Proconnesos*

Samples KO14, KO15, KO17, and KO18, in Figure 25, form a similar group to the Paros-Marathi group of samples in Figure 24 (KS11, KS12, KS13, KS14, and KS22) and fall in the same area of the overlapping ellipses of Paros-Marathi/Lychnitic and Proconnesos, as well as Thasos and Miletos. In contrast to the Paros-Marathi group which are all white marbles of high translucency (Table 7), these samples are greyish or whitish, of low translucency, and with dark grey parallel veins or bands (Table 8), hence safely excluding Paros-Marathi as a possible origin. In Figure 27, KO14, KO15, KO17, and KO18 are outside of Thasos, and KO14 and KO17 outside of Miletos. Due to the colour of Miletos, being mostly grey or greyish, and due to the lack of discriminant analysis in separating Miletos and Proconnesos, the final provenance for this group is: only Proconnesos for KO14 and KO17, Proconnesos or, with minor probabilities,

[13] Palagia et al. 2015.
[14] Tambakopoulos 2007.
[15] Maniatis et al. 2012.

Miletos for KO15, due to the dark grey parallel veins, i.e. Proconnesos or Miletos?, and Proconnesos or Miletos with equal probabilities for KO18.

Finally, KS10 and KO8 from Paros-Lakkoi discussion have already been assigned to Proconnesos, while KO10 from Paros-Marathi discussion has been assigned to Proconnesos or Paros-Marathi.

From the KS group only KS10, an arm fragment from a female statue, is made in proconnesian marble, while samples KS11, KS12, and KS13 (two statues and one altar respectively), only have minor probabilities to be made in marble from Proconnesos in addition to the most probable Paros-Marathi. From the KO group, three bowls are made in marble from Proconnesos; another two bowls have a possibility to be made in Miletos marble in addition to proconnesian; another bowl has only minor probabilities to be made in proconnesian marble instead of Paros-Lakkoi which is the most probable provenance; and finally a semi-finished pestle fragment is made in marble coming from Proconnesos or Paros-Marathi, with only a slightly higher probability for the Proconnesos provenance.

- *Dokimeion*

The very fine grained samples KO3 (*MGS* = 0.6 mm) from a fragment of a ring-based plate and KO11 (*MGS* = 0.8 mm) from a weight, in Figure 23, fall in the ellipses of Dokimeion and Altintas, as well as in other quarries that can be excluded due to small *MGS*. In Figure 27 they fall again in the Dokimeion ellipse, but only KO3 falls also in Altintas ellipse. Altintas however, is a quarry area in the modern Afyon Karahisar province of Turkey where the ancient Dokimeion quarries are located. Altintas and the rest of the Dokimeion quarries have the same marble varieties, mostly pavonazzetto but also good quality fine grained white marble.[16]

Additionally, KO11 is very close to Hymettos ellipse and within 2 outliers of Hymettos in Figure 23, and at the same time inside the Hymettos ellipse in Figure 27. Goette at al. (1999) reports that the white marble of Hymettos was exploited during Archaic and Classical times and the grey-blue during Roman times. This makes a hymettian provenance of this roman weight of white colour and medium translucency rather unlikely.

The provenance for both samples is therefore the Dokimeion quarries, while for KO3 there is a possibility to be from the Altintas quarries in the Dokimeion area, i.e. Dokimeion/Altintas. The Roman or later period date for these samples is compatible with their Dokimeion provenance.

- *Other provenances*

The very fine grained sample KO12 (*MGS* = 0.6 mm), in Figure 23, falls in the ellipses of Dokimeion, Altintas, Aphrodisias, Miletos, Proconnesos, Paros-Marathi, and Paros-Lychnitic, which due to *MGS*, all but Dokimeion and Altintas are excluded. In Figure 27, it falls only in Hymettos ellipse. The parameters would fit with Doliana but the microscopic features of the Doliana marbles (not good crystallization and a lot of mylonitised material between the grains) as opposed to the very good crystallization of sample KO12 excludes Doliana. The same can be true for the Hymettos poorly crystallised marbles. These make the determination of provenance for this sample very ambiguous. The next closest possible provenance for KO12 is Miletos, although marble with so fine grain distribution have not been found in Miletos. The same holds also for Proconnesos with the sample falling in the PR-1 and PR-2 isotope fields

[16] Attanasio et al. 2006.

but its *MGS* being too low for Proconnesos although a major sampling campaign on the island produced *MGS* values in certain areas which could approach the value of KO12.[17] We can therefore leave the provenance for this sample open for the time being but suggest tentatively Proconnesos as a probable option.

Sample KS2 comes from a Peplophoros statuette of Classical period. Its isotopic signature compared against known ancient quarries (Fig. 24) falls inside the ellipses of Paros-Marathi, Thasos-Acropolis/Fanari, Proconnesos, Aphrodisias, Ephesos, and Thiountas. In Figure 26, it falls inside the ellipses of Thasos, Aphrodisias, Thiountas and Paros-Lakkoi. Thiountas can be safely excluded as these quarries are only used locally in the nearby ancient city of Hierapolis.[18] Paros-Marathi, Paros-Lakkoi, Ephesos, and Proconnesos can also be excluded as they are not verified by both diagrams. This leaves as possible origins the quarries of Thasos and the quarries of Aphrodisias.

The marble of the head is heavily weathered. This makes the correct assignment of colour quite challenging, although it seems white, judging from the collected sample. Consequently, it is difficult to use colour for exclusion of Thasos, which is known for its light greyish and darker marble,[19] or Aphrodisias which is known for white marble with pinkish, reddish, or greenish shades.[20] Aphrodisias, however, can be excluded as the quarries were originally connected with the city of Aphrodisias and the marble was not exported abroad before the 1st c. AD.[21] Additionally, although the sample was taken from a deep, less weathered layer, and the collected sample was carefully cleaned from any weathered grains even under the microscope, a certain shift in the analytical parameters may have been introduced.[22] This means that Paros could also be a possible provenance due to an overestimation of Mn^{2+} parameter.

Given the above results the marble provenance for KS2 can be Paros or Thasos.

Finally, from Figures 25 and 27, sample KO16 simultaneously falls in the ellipses of Thasos, Naxos-Melanes, Thiountas, and Aphrodisias. Thiountas as stated above is only used locally in the ancient city of Hierapolis, and Aphrodisias can also be excluded due to the dating of this object (see sample KS2 discussion).

KO16, an Archaic to Early Classical period bowl made in white of high translucency marble, is assigned to Thasos or Naxos-Melanes as two possible provenances.

The provenance results for all the samples are summarized in Tables 11 and 12 for the KS and the KO group respectively. A graphical representation of the sources that supplied Halasarna with marble artefacts as concluded from this work is showing in Figure 32.

4. CONCLUSIONS

The local marble of Kos and a large number of ancient marble artefacts (39) coming from the excavation at Halasarna in the modern village of Kardamaina at Kos were studied with the use of scientific techniques and methodologies.

First, the database for ancient marble quarries of the Laboratory of Archaeometry of NCSR "Demokritos" was expanded with the new data from the local Kos marble. A new region of quarries —the NW slopes of Mt. Dikaios— was studied and characterized, together with the Marmara region on the SE. The analytical data were proven unable to discriminate the quarries of Kos between each other, but the macroscopic characteristics (colour, veins, trans-

[17] Attanasio et al. 2008.
[18] Attanasio et al. 2006.
[19] Attanasio et al. 2006.
[20] Long 2012.
[21] Long 2012.
[22] Tykot et al. 1999; Polikreti and Maniatis 2004.

parency) can help in distinguishing the NW from the SE slopes of Mt. Dikaios. However, the unique isotopic signatures of the Kos marbles as a whole can clearly distinguish them from all the other ancient quarries globally.

Second, using a combination of techniques and parameters the marble provenance of the ancient artefacts from Halasarna was determined. For the 28 of the 39 objects assignment to single marble source was successfully achieved. For the rest of the artefacts (11) the determination of their provenance was achieved with an accuracy of two alternative origin locations.

The provenance results revealed a strong relationship with Paros. From the 39 objects analysed, 21 are made in marble clearly from Paros or have Paros as one of their possible provenances.

The Paros provenance is more pronounced particularly in the non-utilitarian artefacts (statues, altars, stelae, and architectural elements). From 22 of these artefacts, 15 are made in marble from Paros or Paros together with a second origin option but Paros remaining the most probable origin.

The preference in Parian marble is also evident for the utilitarian artefacts (bowls, basins, mortars and pestles), but not as prominent as for the non-utilitarian ones. From the 18 utilitarian artefacts, 5 are made in marble from Paros (2 of them have also a slight probability to be made in proconnesian marble) and a 6th has also Paros as an alternative provenance probability besides Proconnesos.

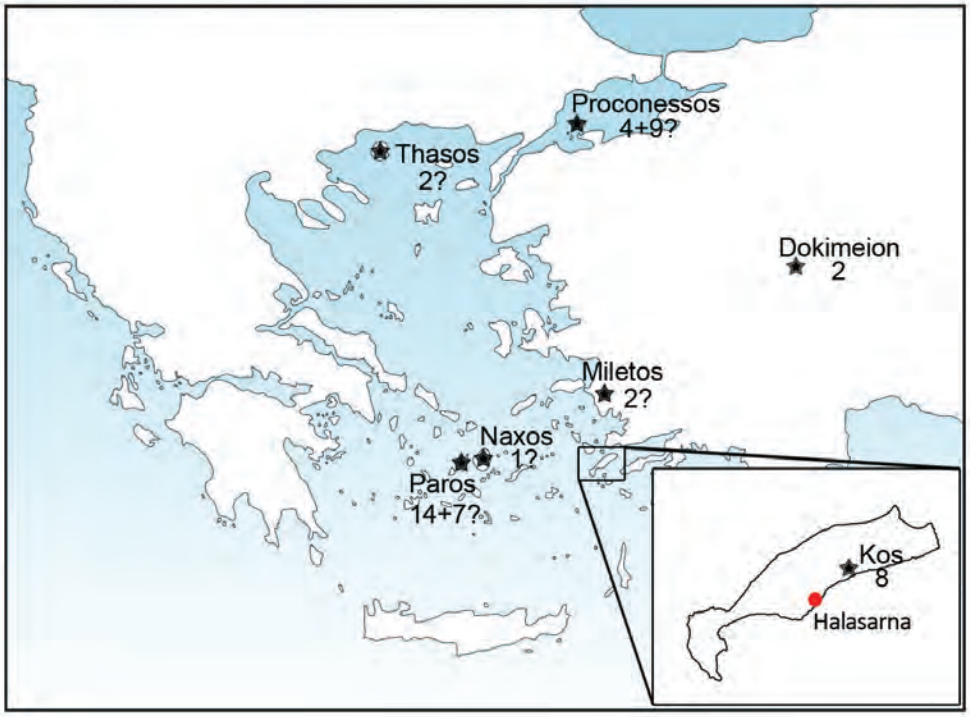

Fig. 32: Map of Greece and Asia Minor, showing the quarries that supplied Halasarna with marbles. The number without a question mark under each quarry is the number of artefacts made in marble from this quarry without an alternative option. The number with a question mark is the number of artefacts that has also other options for provenance.

The second most popular source is the local quarries of Kos at mount Dikaios. In total 8 of 39 studied objects are made in local marble from Kos. In particular, 6 assignments for the non-utilitarian artefacts and 2 for the utilitarian objects are made of this local marble. It is clear from Tables 11 and 12 that the local sources on Dikaios mountain are "discovered" and used at the later phases of Halasarna, from Hellenistic to later times, although other sources are also used simultaneously with the local marble. Contrary to this, none of the earlier artifacts

is made of local marble. This sets the time for opening of the Dikaios mountain quarries to the Hellenistic period, yet its extensive use occurs in Roman times.

The third most popular source of marble is Proconnesos. One non-utilitarian artefact is made in marble from Proconnesos and another three have a small probability to be from Proconnesos, but their most probable origin is Paros. Three utilitarian artefacts are made in marble from Proconnesos and six more have a possibility to be made in marble from Proconnesos.

The last safely assigned group of artefacts consists of two utilitarian objects made in marble from Dokimeion (Phrygia).

Other sources, such as Thasos, Miletos and Naxos appear as alternative possibilities for a small number of artefacts.

5. ACKNOWLEDGMENTS

We want to thank Professor Georgia Kokkorou-Alevras of the National Kapodistrian University of Athens for giving us the opportunity to investigate this interesting archaeological material and to extend our database with the local marble quarries of Kos. Sincere thanks are also due to Dr. Eirini Poupaki of the Greek Archaeological Service for her support in the study of the utilitarian objects and also for providing invaluable information on the Koan quarries and for arranging our trips and accompanying us to the quarries. We also like to thank Father Ioannis Koutantos, a priest in the church of Zipari village for guiding us to the quarries on the NW slopes of Mt Dikaios. In addition, we want to thank Georgios Doulfis for providing every necessary help in locating the archaeological objects in the storerooms and facilitating greatly our work. Finally, we would like to thank the student archaeologists and the rest of the personnel with which we share our stay in the Halasarna storerooms and the archaeological site.

Table 1. The archaeological information for the KS group — the statues, altars and architectural elements. In the inventory number «ΠΡΣΛΓ» stands for «Περισυλλογή-Collection». The numbers in parenthesis are from Kokkorou-Alevras (in this volume) except KS17 which is from Kokkorou-Alevras (2004).

Sample	Inv. No.	Details	Dating
KS1	Θ28–Ι28/Γ1/2002 (K 7)	Pelvis area of an Aphrodite's statuette	Late Hellenistic
KS2	K25/Γ1/2002 (K 2)	Fragment of a Peplophoros statuette	Classical
KS3	Θ27–28/Λ1/2011 (K 14)	Male head fragment	Hellenistic
KS4	Γ20/Γ1/1992 (K 11)	Fragment of an Aphrodite-Eros undersize group (base and feet)	Late Hellenistic
KS5	B25/Γ1/2009 (K 12)	Undersize Aphrodite head	Late Hellenistic
KS6	B27/Λ1/2008 (K 38)	Undersize arm fragment	Hellenistic
KS7	B22/Γ1/2009 (K 9)	Pelvis area and arm of a naked Aphrodite's statuette	Late Hellenistic
KS8	ΠΡΣΛΓ/Γ1/2013 (K 3)	Fragment of a female torso	Late Hellenistic
KS9	ΠΡΣΛΓ /Γ4/2013 (K 16)	Fragment of a male head	Late Hellenistic
KS10	B21–22/Γ1/2009 (K 34)	Arm fragment of a female statuette	Probably Late Hellenistic
KS11	Λ26–27/Λ3/2012 (K 22)	Shoulder fragment of a dressed figure	Probably Hellenistic
KS12	Π28–29/Γ2/2012 (K 33)	Forearm fragment of a dressed figure	Hellenistic
KS13	K26–27/Γ1/2012 (K 64)	Fragment of an Altar (?)	Uncertain
KS14	IK27–28/Γ2/1998 (K 19)	Fragment of a dressed figure	Hellenistic
KS15	ΠΡΣΛΓ /Γ2/2013 (K 20)	Fragment of a dressed male figure	Probably Hellenistic
KS16	K28–Λ28–Λ27/2011 (K 59)	Grave relief fragment	Late Hellenistic
KS17	E184 (αρ. K. 17)	Altar with bucrania and garlands	200-150 BC
KS18	ΠΡΣΛΓ /Γ5/2013	Fragment of an Altar	Late Hellenistic
KS19	P27–Π27/Λ14/2012	Orthostate of an Altar or a pedestal	Hellenistic (?)
KS20	ΠΡΣΛΓ/Λ2/2008 (K 63)	Altar fragment with bucrania and garlands	1st c. BC–1st c. AD
KS21	I29/Γ2/2013 (K 32)	Arm fragment	Uncertain
KS22	I29/Λ46/2013 (K 27)	Fragment of a dressed statue (?)	Probably Hellenistic

Table 2. The archaeological information for the KO group — the utilitarian objects. The numbers in parenthesis are from Poupaki (2011), except KO5 and KO9 which are from Poupaki (in this volume).

Sample	Inv. No.	Details	Dating
KO1	ΛΣ27 (9)	Bowl fragment	Hellenistic
KO2	ΛΣ95 (23)	Bowl fragments	5th c. AD
KO3	ΛΣ68 (2)	Fragment of a ring - based plate	Roman-Late Roman
KO4	ΛΣ30 (1)	Fragment of a table	"Severe style"/Early Classical
KO5	ΛΣ148 (K 7)	Fragment of four handled bowl	Roman to Early Byzantine
KO7	ΛΣ46 (3)	Fragments of two handled bowl	500–350 BC
KO8	ΛΣ116 (98)	Fragment of four-handled bowl	5th–6th c. AD
KO9	ΛΣ153 (K 6)	Fragment of a basin	Roman to Early Byzantine
KO10	ΛΣ117(99)	Semi-finished Pestle	Late Hellenistic to Roman
KO11	ΛΣ55 (83)	Weight	Roman/Early Byzantine
KO12	ΛΣ19 (13)	Base fragment of a basin	Archaic–Early Classical
KO13	ΛΣ45–ΛΣ51 (4)	Fragment of two handled bowl	400–350 BC
KO14	ΛΣ92 (22)	Fragment of four-handled bowl	5th c. AD
KO15	ΛΣ77 (18)	Fragment of four-handled bowl	5th c. AD
KO16	ΛΣ86 (7)	Fragment of a ring - based vessel	Archaic to Early Classical
KO17	ΛΣ85 (19)	Fragment of four-handled bowl	5th c. AD
KO18	ΛΣ90 (21)	Fragment of four-handled bowl	5th c. AD

Table 3. Results of examination and analyses for the marble from the south slopes of Mt Dikaios (*Marmara* location).

Sample	Details	Colour	Transl. (cm)	*MGS* (mm)	*MFS* (mm)	$\delta^{18}O$‰	$\delta^{13}C$‰	Mn^{2+} (r.u.)	Width (Gauss)	Fe^{3+} (r.u.)	Dol.
KSM1	Light greyish background, homoblastic	White	2.0	1.6	1.0-1.5	-11.16	5.28	1282.13	2.47	4.13	0.00
KSM2	Heteroblastic	Grey	1.5	1.4	0.5-0.8	-10.43	4.51	1472.02	3.14	6.12	0.00
KSM3	Homoblastic/ heteroblastic, lineation	Grey	1.0	1.2	0.5	-9.87	4.90	1381.81	3.70	6.26	0.00
KSM4	Areas with darker colour, heteroblastic?, Lineation	Greyish	1.0	1.2	0.5-1.0	-11.43	4.35	852.65	2.99	5.74	0.00
KSM5	Homoblastic, lineation	Greyish	1.5	1.0	0.5-0.8	-11.15	4.32	1535.96	3.38	5.66	0.00
KSM6	Lighter grey layers, lineation (Anisotropic)	Greyish	1.0	1.2	0.2-0.8	-11.62	4.93	1750.41	3.03	6.16	0.00
KSM7	Fine grained, lineation	Greyish	1.0	1.2	0.5	-8.51	5.47	1463.63	3.45	5.04	0.00
KSM8	Dark grey vein and stretched layers, lineation, heteroblastic, non-metamorphosed material in between the grains	Grey	1.0	1.2	0.1-0.8	-	-	1658.37	3.16	7.11	0.00
KSM9	Light greyish background, high transparency, well crystallized, homoblastic, lineation	White	3.0	1.2	1.0	-9.56	5.51	1754.90	2.92	6.95	0.00
KSM10	Light greyish background, homoblastic, lineation	White	2.0	1.0	0.8	-9.31	5.48	2193.65	2.60	6.02	0.00
KSM11	Darker thin vein	Greyish	1.5	4.0	1.0-2.0	-9.79	4.64	1173.25	3.45	8.88	0.00
KSM12	Greyish background (from weathering?), homoblastic, lineation	White	2.0	1.0	0.8	-9.80	5.24	1606.02	2.78	5.75	0.00
KSM13	Light greyish background, high transparency, iron pyrite inclusion, anisotropy in grain sizes	White	3.0	2.0	0.8-1.5	-9.59	4.93	1981.86	3.76	5.52	0.00
KSM14	Homoblastic, low translucency, iron pyrite inclusion	Greyish	0.5	1.0	0.5-1.0	-9.41	5.25	711.22	3.25	6.18	0.11
KSM15	Homoblastic, low translucency, iron pyrite inclusion, lineation	Greyish	0.5	2.0	0.8-1.5	-8.93	5.41	1262.11	3.18	6.16	0.14
KSM16	Darker areas, heteroblastic	Grey	1.0	1.4	0.5-0.8	-9.07	5.09	894.11	3.19	5.56	0.00

Table 4. Results of examination and analyses for the marble from the *Dumping Area* at the north slopes of Mt Dikaios.

Sample	Details	Colour	Transl. (cm)	*MGS* (mm)	*MFS* (mm)	$\delta^{18}O$‰	$\delta^{13}C$‰	Mn^{2+} (r.u.)	Width (Gauss)	Fe^{3+} (r.u.)	Dol.
KSP1	Well crystallized, heteroblastic/ homoblastic	White	2.0	2.2	1.0-2.0	-10.30	4.45	2177.48	3.19	4.95	0
KSP2	Well crystallized, homoblastic/ heteroblastic, foliated, lineation	White	2.5	2.9	0.5-2.0	-9.00	5.37	1808.85	2.51	7.49	0
KSP3	Homoblastic/ heteroblastic	White	2.5	2.5	1.0-2.0	-9.78	5.28	1098.78	3.22	4.29	0
KSP4	Homoblastic, foliated and lineation	White	2.0	2	1.0-1.5	-10.00	4.91	1824.31	3.52	5.87	0
KSP5	Slightly foliated, homoblastic	White	3.0	2.6	1.0-2.5	-9.64	5.91	700.59	2.53	5.69	0
KSP6	Slightly foliated, homoblastic/ heteroblastic, yellow veins	White	2.0	2.5	1.0-2.5	-10.37	4.45	1937.59	3.02	5.70	0
KSP7	Foliated-curved, lineation, homoblastic	White	3.0	2.9	1.5-2.5	-9.68	5.49	2819.39	2.62	5.19	0
KSP8	Foliated-curved, lineation, homoblastic/ heteroblastic	White	3.0	2.7	1.0-2.5	-9.78	5.66	894.47	3.00	4.84	0
KSP9	Whitish marble, foliated, lineation, yellow veins, homoblastic	Whitish	2.0	1.6	1.0-1.2	-9.95	5.00	1965.36	2.76	6.53	0
KSP10	Foliated, slight lineation, yellow veins, homoblastic	White	4.0	2.5	2.0-2.5	-9.38	5.18	924.85	3.00	4.73	0
KSP11	Light greyish background, foliated, lineation, homoblastic/ heteroblastic	White	2.0	3.3	1.5-2.0	-9.28	5.33	1300.27	3.01	4.63	0
KSP12	Foliated, lineation, homoblastic	White	3.0	4.3	2.0-2.5	-10.52	4.99	3075.64	2.72	7.00	0
KSP13	Yellowish background and gray thick veins, foliated, lineated homoblastic	Whitish	3.0	3	2.0-2.5	-10.51	4.78	3793.99	2.94	8.18	0
KSP14	Foliated, lineation, homoblastic	White	3.0	2.5	1.0-2.0	-8.06	5.68	1088.34	2.41	5.46	0
KSP15	Foliated, lineation, homoblastic	White	3.5	2.1	1.0-1.5	-9.09	5.72	796.86	2.95	6.02	0

Table 5. Results of examination and analyses for the marble from the *Kako Skali* quarry at the north slopes of Mt Dikaios.

Sample	Details	Colour	Transl. (cm)	*MGS* (mm)	*MFS* (mm)	$\delta^{18}O$‰	$\delta^{13}C$‰	Mn^{2+} (r.u.)	Width (Gauss)	Fe^{3+} (r.u.)	Dol.
KSB1	Heteroblastic	Greyish	2.0	1.5	0.01-1.5	-7.59	4.74	683.09	2.60	5.00	0.0
KSB2	Heteroblastic	Grey	1.5	2.0	0.5-1.0	-10.29	4.97	705.82	3.07	4.67	0.0
KSB3	Heteroblastic	Grey	1.5	1.8	0.5-1.0	-9.00	5.45	644.83	3.51	5.36	0.0
KSB4	Heteroblastic/ homoblastic	Grey	1.5	1.5	1.0	-7.77	5.29	817.89	3.22	5.19	0.0
KSB5	Dark grey striations, iron-pyrite inclusions, homoblastic	Grey	1.0	2.0	1.0-1.5	-10.46	4.48	890.44	3.80	3.95	0.0
KSB6	Brownish background, high transparency, heteroblastic	Whitish	3.0	1.9	0.8-1.5	-11.63	5.05	3521.43	3.23	9.87	0.0
KSB7	Brown argillaceous veins, heteroblastic	Greyish	2.0	1.5	1.0	-9.94	5.51	1291.02	3.86	5.79	0.0
KSB8	Dark grey veins and spots, heteroblastic	Grey	0.5	1.3	0.5-1.0	-8.45	5.46	410.31	2.95	4.21	0.1
KSB9	Well crystalized, homoblastic	Greyish	1.5	1.8	1.0-1.5	-10.89	4.65	1537.99	2.64	5.36	0.0
KSB10	Well crystalized, homoblastic	Greyish	2.0	2.0	1.0-1.5	-11.99	4.70	1826.21	3.29	5.13	0.0
KSB11	Homoblastic/ heteroblastic	Greyish	2.0	1.5	1.0	-10.15	4.60	760.02	2.95	0.22	0.0
KSB12	Homoblastic, well crystallized, areas with grain size ~2.5 and areas with 1.5, lineation, two argillaceous yellow/ brown veins?	Whitish	2.0	3.0	1.5	-9.98	4.45	4102.05	4.67	4.84	0.0
KSB13	Well crystallized, iron-pyrite inclusions	Greyish	0.5	2.0	1.0-1.5	-11.28	4.82	1411.09	3.21	5.74	0.0
KSB14	Well crystallized	Greyish	1.0	1.6	1.0	-9.24	5.14	1581.10	3.05	4.99	0.0
KSB15	Well crystallized, homoblastic	Greyish	1.0	1.9	1.0-1.5	-8.87	4.62	2248.54	3.53	7.88	0.0

Table 6. Results of examination and analyses for the marble from quarries between the *Dumping Area* and *Kako Skali* quarry at the north slopes of Mt Dikaios.

Sample	Details	Colour	Transl. (cm)	MGS (mm)	MFS (mm)	$\delta^{18}O$‰	$\delta^{13}C$‰	Mn^{2+} (r.u.)	Width (Gauss)	Fe^{3+} (r.u.)	Dol.
KSI1	Foliation, lineation, homoblastic/ heteroblastic, thin yellow argillaceous veins	Whitish	2.0	2.3	1.0-2.0	-11.04	5.79	1594.33	3.77	6.4	0
KSI2	Foliation, lineation, homoblastic/ heteroblastic, grey veins	White	2.0	2.9	1.0-2.0	-11.31	5.08	1920.51	4.03	4.5	0
KSI3	Slightly foliated, homoblastic/hetero-blastic	Grey	1.0	2.5	1.0-2.0	-10.75	4.77	2899.92	3.94	4.4	0
KSI4	Foliation, lineation, homoblastic/hetero-blastic	White	3.0	2.8	1.0-2.5	-10.30	5.69	3244.94	2.95	8.2	0
KSI5	Foliation, lineation, homoblastic	White	4.0	2.0	1.0-1.5	-11.05	5.61	1756.64	2.69	5	0
KSI6	Greyish background, foliation, lineation, homoblastic, thin argillaceous veins	White	2.0	2.0	1.5-1.8	-11.18	5.54	1788.53	3.68	3.6	0

Table 7. The results of the optical examination for the KS group – Sculptures, altars and architectural elements.

Sample	Colour	Marble	Transl. (cm)	*MGS* (mm)	*MFS* (mm)
KS1	White	Fine grained; high transl.; homoblastic; well crystallized	2.5	2.0	0.8-1.5
KS2	White	Coarse grained; high transl.?; calcite grains of ~ 6 mm; weathered	1.5-2.0	3.5	~2.0
KS3	White	Very fine grained; medium transl.; weathered; Homoblastic?	1.5	1.5	0.5
KS4	White	Fine grained; high transl.; seems light grayish at some areas	2.0	2.0	<1.0
KS5	White	No veins; no inclusions	2.5	2.0	0.8-1.5
KS6	White	Fine grained; high transl.; well crystallized	2.5	1.2	0.5-0.8
KS7	White	Maybe light grayish background; high transl.; well crystallized	2.0	2.5	1.0-2.0
KS8	White	High translucency; well crystallized; homoblastic	2.5	3.5	1.0-2.0
KS9	White	High translucency; homoblastic	3.0	2.0	1.0-1.5
KS10	Grayish	Weathered; low transl.; 2 dark parallel veins; well crystalized	0.5	2.5	1.5-2.0
KS11	White	High transl.; well crystalized	4.0	3.0	2.0
KS12	White	Medium transl; excellent crystallization; homoblastic	1.5	2.5	1.5-2.0
KS13	white	Wide faint brownish/greyish vein/band; homoblastic; high transl.	3.0	2.5	1.0-2.0
KS14	White	Coarse grained; high transl.; wide gray vein; Heteroblastic?	3.0	4.5	~4.5
KS15	White	No veins; coarse grained; high transl.; heteroblastic?	2.5	4.0	~4.0
KS16	White	Fine grained; high transl.; homoblastic	3.0	1.2	1.0
KS17	Grayish	Thin parallel darker veins; low to medium transl.; medium grained; homoblastic	1.0	1.8	1.0
KS18	Grayish	Thin parallel darker veins; high transl. on white areas; medium grained; heteroblastic (one piece of the samples has grains < 0.1 mm)	2.0	1.5	1.0
KS19	Grayish	Wide black vein on the left edge; homoblastic; very well crystalized	2.0	2.5	2.0
KS20	Grayish	Medium transl.; well crystallized	2.0	2.7	1.5-2.0
KS21	White	High transl.; heteroblastic?	2.5	2.0	1.0-1.5
KS22	White	High transl.; well crystalized	4.0	3.5	1.5-2.5

Table 8. The results of the optical examination for the KO group – the utilitarian marble objects.

Sample	Colour	Marble	Transl. (cm)	*MGS* (mm)	*MFS* (mm)
KO1	White	Faint gray background; very well crystallized; medium transl.	1.5	2.5	~2.5
KO2	Whitish	Medium transl.; well crystalized (a few translucent-clear grains)	1.0	2.5	1.0
KO3	White	Faint gray background; translucency assessed from small chips	>2.0?	0.6	~0.6
KO4	White	High transl.; very well crystallization; homoblastic/heteroblastic	3.5	4.0	1.0–3.0
KO5	White	High translucency; well crystallized	>3.0?	1.8	~1.8
KO7	White	Beige background (weathering?); elongated grains; high transl.; heteroblastic	2.0	3.5	~3.5
KO8	Grayish	Thin black parallel veins; low transl.; well crystallized; brittle	1.0	2.5	~2.5
KO9	White	Fine grained; high transl.	>2.0	1.5	1.0
KO10	White	No veins; fine grained; high transl.	>2.0	1.5	1.0
KO11	White	1-2 thin gray veins; fine grained; medium transl.	1.5	0.8	~0.8
KO12	Grayish	Very fine grained; no transl.; homoblastic	0.0	0.6	0.5
KO13	White	Coarse grained; high transl.; no veins; well crystallized; homoblastic?	2.5	3	2.0
KO14	Grayish	Medium grained; low trans.	0.3	3.0	2.0
KO15	Grayish	Medium grained; low transl.; 2 parallel dark gray thin veins	0.5	2.5	2.0
KO16	White	High transl.; no veins; medium grained; well crystallized.; heteroblastic	3.0	4.0	1.0–2.0
KO17	Whitish	Low to medium Translucency; dark gray diffused, thin or thick, veins; heteroblastic; well crystallized	1.0	3.0	2.0
KO18	Grayish	Low transl.; maybe a darker band; medium grained; schistolithic vein	0.5	2.5	1.0–2.0

Table 9. Results of *EPR* spectrometry and Stable Isotope analysis together with colour and grain size analysis for the KS group – the sculptures, altars and architectural elements.

Sample	Colour	*MGS* (mm)	*MFS* (mm)	Mn^{2+} (r.u.)	Width (Gauss)	Fe^{3+} (r.u.)	$\delta^{18}O$‰	$\delta^{13}C$‰
KS01	White	2.0	0.8-1.5	128.60	1.78	4.29	-3.39	4.36
KS02	White	3.5	~2.0	649.01	1.40	18.35	-3.18	1.43
KS03	White	1.5	0.5	217.88	1.64	8.10	-3.26	4.74
KS04	White	2.0	<1.0	513.18	2.90	4.35	-1.31	2.13
KS05	White	2.0	0.8-1.5	148.58	1.49	8.52	-2.51	5.41
KS06	White	1.2	0.5-0.8	165.44	1.47	9.54	-3.19	4.97
KS07	White	2.5	1.0-2.0	1249.70	2.20	0.25	-0.93	1.96
KS08	White	3.5	1.0-2.0	510.04	2.37	6.18	-1.14	1.93
KS09	White	2.0	1.0-1.5	170.15	1.90	4.53	-2.72	5.31
KS10	Grayish	2.5	1.5-2.0	77.01	2.57	2.69	-1.52	2.19
KS11	White	3.0	2.0	284.91	1.75	6.40	-2.52	3.17
KS12	White	2.5	1.5-2.0	342.71	1.71	8.84	-2.70	3.07
KS13	white	2.5	1.0-2.0	223.14	1.60	11.08	-2.57	2.94
KS14	White	4.5	~4.5	250.20	1.76	3.85	-2.56	3.17
KS15	White	4.0	~4.0	226.27	1.79	0.00	-2.61	4.94
KS16	White	1.2	1.0	1352.36	2.81	3.03	-10.69	5.53
KS17	Grayish	1.8	1.0	1714.12	3.77	3.16	-11.02	4.29
KS18	Grayish	1.5	1.0	2048.09	3.62	0.00	-10.85	5.31
KS19	Grayish	2.5	2.0	2917.28	2.54	4.94	-13.22	4.35
KS20	Grayish	2.7	1.5-2.0	2395.95	3.01	3.62	-11.25	5.40
KS21	White	2.0	1.0-1.5	727.68	3.14	0.00	-10.03	5.86
KS22	White	3.5	1.5-2.5	350.59	1.79	7.26	-2.66	2.95

Table 10. Results of *EPR* spectrometry and Stable Isotope analysis together with colour and grain size analysis for the KO group – the utilitarian marble objects.

Sample	Colour	*MGS* (mm)	*MFS* (mm)	Mn^{2+} (r.u.)	Width (Gauss)	Fe^{3+} (r.u.)	$\delta^{18}O$‰	$\delta^{13}C$‰
KO1	White	2.5	~2.5	374.02	2.60	5.61	-0.79	1.82
KO2	Whitish	2.5	1.0	4128.62	3.33	5.10	-10.68	4.40
KO3	White	0.6	~0.6	1140.20	1.46	11.17	-4.37	1.35
KO4	White	4.0	1.0-3.0	293.87	1.74	4.65	-0.90	1.81
KO5	White	1.8	~1.8	1395.05	2.71	6.04	-10.98	5.87
KO7	White	3.5	~3.5	216.24	1.78	14.44	-0.75	2.36
KO8	Grayish	2.5	~2.5	50.53	1.99	3.87	-1.94	2.10
KO9	White	1.5	1.0	445.40	2.01	6.88	-0.59	1.96
KO10	White	1.5	1.0	39.86	2.09	5.83	-1.49	2.65
KO11	White	0.8	~0.8	420.20	1.77	9.17	-4.11	1.95
KO12	Grayish	0.6	0.5	87.73	2.56	0.00	-3.51	2.69
KO13	White	3	2.0	300.62	1.89	6.42	-0.74	2.07
KO14	Grayish	3.0	2.0	105.37	2.42	6.39	-2.08	3.14
KO15	Grayish	2.5	2.0	133.52	2.20	10.04	-2.28	2.63
KO16	White	4.0	1.0-2.0	888.76	1.65	11.58	-2.74	2.07
KO17	Whitish	3.0	2.0	53.77	2.35	5.01	-1.90	2.93
KO18	Grayish	2.5	1.0-2.0	275.14	1.83	8.86	-2.67	2.88

Table 11. Provenance results for the KS group — the statues, altars and architectural elements. In the inventory number «ΠΡΣΛΓ» stands for «Περισυλλογή-Collection». The numbers in parenthesis are from Kokkorou-Alevras (in this volume) except KS17 which is from Kokkorou-Alevras (2004).

Sample	Inv. No.	Details	Dating	Provenance
KS1	Θ28–Ι28/Γ1/2002 (K 7)	Pelvis area of an Aphrodite's statuette	Late Hellenistic	Paros-Marathi (Lychnitic?)
KS2	K25/Γ1/2002 (K 2)	Fragment of a Peplophoros statuette	Classical	Paros or Thasos
KS3	Θ27–28/Λ1/2011 (K 14)	Male head fragment	Hellenistic	Paros-Marathi (Lychnitic?)
KS4	Γ20/Γ1/1992 (K 11)	Fragment of an Aphrodite-Erosundersizegroup (base and feet)	Late Hellenistic	Paros-Lakkoi
KS5	B25/Γ1/2009 (K 12)	Undersize Aphrodite head	Late Hellenistic	Paros-Marathi (Lychnitic?)
KS6	B27/Λ1/2008 (K 38)	Undersize arm fragment	Hellenistic	Paros-Lychnitic (Open quarries?)
KS7	B22/Γ1/2009 (K9)	Pelvis area and arm of a naked Aphrodite's statuette	Late Hellenistic	Paros-Lakkoi
KS8	ΠΡΣΛΓ/Γ1/2013 (K 3)	Fragment of a female torso	Late Hellenistic	Paros-Lakkoi
KS9	ΠΡΣΛΓ/Γ4/2013 (K 16)	Fragment of a male head	Late Hellenistic	Paros-Marathi (Lychnitic?)
KS10	B21–22/Γ1/2009 (K 34)	Arm fragment of a female statuette	Probably Late Hellenistic	Proconnesos
KS11	Λ26–27/Λ3/2012 (K 22)	Shoulder fragment of a dressed figure	Probably Hellenistic	Paros-Marathi (Proconnesos?)
KS12	Π28–29/Γ2/2012 (K 33)	Forearm fragment of a dressed figure	Hellenistic	Paros-Marathi (Proconnesos?)
KS13	K26–27/Γ1/2012 (K 64)	Fragment of an Altar (?)	Uncertain	Paros-Marathi (Proconnesos?)
KS14	IK27–28/Γ2/1998 (K 19)	Fragment of a dressed figure	Hellenistic	Paros-Marathi
KS15	ΠΡΣΛΓ/Γ2/2013 (K 20)	Fragment of a dressed male figure	Probably Hellenistic	Paros-Marathi
KS16	K28Λ28Λ27/2011 (K 59)	Grave relief fragment	Late Hellenistic	Kos (NW slopes)
KS17	E184 (αρ. K. 17)	Altar with bucrania and garlands	200–150 BC	Kos (Marmara)
KS18	ΠΡΣΛΓ /Γ5/2013	Fragment of an Altar	Late Hellenistic	Kos (Marmara)
KS19	P27–Π27/Λ14/2012	Orthostate of an Altar or a pedestal	Hellenistic (?)	Kos (Marmara or Kako Skali)
KS20	ΠΡΣΛΓ/Λ2/2008(K 63)	Altar fragment with bucrania and garlands	1stc. BC–1st c. AD	Kos (Marmara?)
KS21	I29/Γ2/2013 (K 32)	Arm fragment	Uncertain	Kos (NW Slopes)
KS22	I29/Λ46/2013 (K 27)	Fragment of a dressed statue (?)	Probably Hellenistic	Paros-Marathi

Table 12. Provenance results for the KO group — the utilitarian objects. The numbers in parenthesis are from Poupaki (2011), except KO5 and KO9 which are from Poupaki (in this volume).

Sample	Inv. No.	Details	Dating	Provenance
KO1	ΛΣ27 (9)	Bowl fragment	Hellenistic	Paros-Lakkoi (Proconnesos?)
KO2	ΛΣ95 (23)	Bowl fragments	5th c. AD	Kos (Marmara?)
KO3	ΛΣ68 (2)	Fragment of a ring - based plate	Roman-Late Roman	Dokimeion/Altintas
KO4	ΛΣ30 (1)	Fragment of a table	"Severe style" / Early Classical	Paros-Lakkoi
KO5	ΛΣ148 (K 7)	Fragment of four handled bowl	Roman to Early Byzantine	Kos (NW Slopes)
KO7	ΛΣ46 (3)	Fragments of two handled bowl	500–350 BC	Paros-Lakkoi
KO8	ΛΣ116 (98)	Fragment of four-handled bowl	5th–6thc. AD	Proconnesos
KO9	ΛΣ153 (K 6)	Fragment of a basin	Roman to Early Byzantine	Paros-Lakkoi
KO10	ΛΣ117(99)	Semi-finished Pestle	Late Hellenistic to Roman	Proconnesos or Paros-Marathi
KO11	ΛΣ55 (83)	Weight	Roman/Early Byzantine	Dokimeion
KO12	ΛΣ19 (13)	Base fragment of a basin	Archaic–Early Classical	Unknown or Proconnesos?
KO13	ΛΣ45-ΛΣ51 (4)	Fragment of two handled bowl	400–350 BC	Paros-Lakkoi (Proconnesos?)
KO14	ΛΣ92 (22)	Fragment of four-handled bowl	5th c. AD	Proconnesos
KO15	ΛΣ77 (18)	Fragment of four-handled bowl	5th c. AD	Proconnesos or Miletos?
KO16	ΛΣ86 (7)	Fragment of a ring - based vessel	Archaic to Early Classical	Thasos or Naxos-Melanes
KO17	ΛΣ85 (19)	Fragment of four-handled bowl	5th c. AD	Proconnesos
KO18	ΛΣ90 (21)	Fragment of four-handled bowl	5th c. AD	Proconnesos or Miletos

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ΠΕΡΙΛΗΨΗ

Στην παρούσα μελέτη διερευνήθηκε με φυσικοχημικές τεχνικές η προέλευση του μαρμάρου 22 γλυπτών και 17 χρηστικών αντικειμένων (Tables 1 και 2), από την ανασκαφή του Ιερού του Απόλλωνα Πυθαίου/Πυθαέως στην αρχαία Αλάσαρνα της Κω, αλλά και του υστερορωμαϊκού–πρώιμου βυζαντινού οικισμού που χτίστηκε επάνω στα ερείπια του ιερού. Ταυτόχρονα, έγινε επίσκεψη, εξέταση και λήψη 60 αντιπροσωπευτικών δειγμάτων από τα τοπικά λατομεία μαρμάρου στο όρος «Δίκαιος», τα οποία είχαν εν μέρει μόνο μελετηθεί στο παρελθόν.[1] Ο σκοπός της μελέτης είναι η επιστημονική τεκμηρίωση των πολιτισμικών και εμπορικών επαφών της Αλάσαρνας κατά τις διάφορες περιόδους κατοίκησης.

Για την εξέταση και ανάλυση χρησιμοποιήθηκε συνδυασμός ισοτοπικών, φασματοσκοπικών και οπτικών τεχνικών. Αρχικά τα αρχαιολογικά αντικείμενα εξετάστηκαν οπτικά στις αποθήκες της ανασκαφής στην Κω και μετρήθηκαν το Μέγιστο Μέγεθος Κόκκου (*MGS*) και το πιο Σύνηθες Μέγεθος Κόκκων (*MFS*) του μαρμάρου καθώς και η διαφάνεια, ενώ εκτιμήθηκε το χρώμα και άλλα μικρο- και μακροσκοπικά χαρακτηριστικά (Tables 7–8). Η ίδια εξέταση έγινε και για τα 60 δείγματα από τα αρχαία λατομεία (Tables 3–6). Όλα τα δείγματα, αρχαιολογικά και γεωλογικά, αναλύθηκαν περαιτέρω με τις τεχνικές της Φασματομετρίας Ηλεκτρονικού Παραμαγνητικού Συντονισμού (Electron Paramagnetic Resonance – *EPR*) και της ανάλυσης των Ισοτοπικών Λόγων άνθρακα και οξυγόνου με Φασματοσκοπία Μάζας (Isotope Ratio Mass Spectroscopy - *IRMS*) (Tables 3–6 και 9–10).

Τα αποτελέσματα για τα αρχαία λατομεία της Κω έδειξαν ότι ο διαχωρισμός μεταξύ των τοπικών λατομείων δεν είναι εύκολος (Figs 13–19), ωστόσο είναι εφικτός ο διαχωρισμός του τοπικού μαρμάρου εν συνόλω από τα υπόλοιπα γνωστά λατομεία μαρμάρου της αρχαιότητας λόγω των διαφορετικών ισοτοπικών παραμέτρων (Fig. 21). Η επιπλέον αξιολόγηση των μακροσκοπικών χαρακτηριστικών (φλέβες, χρώμα, διαφάνεια) βοηθά στον διαχωρισμό μεταξύ των νοτιοδυτικών και νοτιανατολικών κλιτύων του όρους.

Η ανάλυση και επεξεργασία των αρχαιολογικών δειγμάτων σε σχέση με τις εκτενείς βάσεις δεδομένων από μεγάλο αριθμό λατομείων της Ανατολικής Μεσογείου του Εργαστηρίου Αρχαιομετρίας του ΕΚΕΦΕ «Δημόκριτος» έδειξαν ότι:

Από τα 39 αρχαιολογικά δείγματα 8 ήταν φτιαγμένα από μάρμαρο των τοπικών λατομείων στο όρος Δίκαιος της Κω (Tables 11–12). Τα αντικείμενα αυτά είναι από τις νεότερες φάσεις της Αλάσαρνας (ελληνιστική και νεότερες περίοδοι), και σηματοδοτούν την ανακάλυψη και χρήση των συγκεκριμένων λατομείων.

Τα περισσότερα αντικείμενα, ωστόσο, συνολικά 21 από 39, προέρχονται με βεβαιότητα από τα λατομεία της Πάρου ή έχουν ως πιθανό τόπο προέλευσης την Πάρο (Tables 11–12). Η προτίμηση στο μάρμαρο της Πάρου εμφανίζεται πολύ περισσότερο στα μη χρηστικά αντικείμενα όπως αγάλματα, βωμούς, στήλες και αρχιτεκτονικά στοιχεία και λιγότερο στα χρηστικά.

Από τα λατομεία της Προκοννήσου προέρχονται 4 αντικείμενα, ενώ άλλα 2 από τα λατομεία στο Δοκίμειον (Αφιόν) της Φρυγίας.

Για ένα μικρό αριθμό αντικειμένων δίνονται ως εναλλακτικές περιοχές προέλευσης η Θάσος, η Μίλητος ή η Νάξος.

Συνολικά για τα 28 από τα 39 αντικείμενα προσδιορίστηκε η προέλευση με βεβαιότητα σε μία περιοχή, ενώ για τα υπόλοιπα 11 δίνονται δύο εναλλακτικές πιθανές προελεύσεις (Tables 11–12).

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[1] Chatziconstantinou και Poupaki 2009· Lazzarini και Malacrino 2010.