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Beyond Pentelikon: Imported white marbles in Athenian sculptural workshops of the Roman period

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ABSTRACT

This article presents the results of a provenance study of the marbles used for 58 sculptures from the excavations of the Athenian Agora (Greece), including numerous unfinished works. The sculptures were preselected for analysis because they did not match the visual characteristics of local Pentelic marble. All sculptures were studied noninvasively with a standard light source, and measurements of the Maximum Grain Size (MGS), the Most Frequent Grain Size (MFS), and translucency were taken. The sculptures were also analyzed for trace elements, such as strontium (Sr) and manganese (Mn), using a portable X-Ray Fluorescence (pXRF) instrument. Samples were collected from 44 sculptures for laboratory-based analyses, including verification measurements of MGS and MFS under a stereoscopic microscope, qualitative examination of crystalline features of the marbles, and Isotopic Ratio Mass Spectroscopy (IRMS) for measurements of the stable isotopes of carbon and oxygen. The results show that a range of imported white marbles were being carved in local Athenian workshops during the Roman period (1st century BCE to 3rd century CE), including marbles from Thasos (5 sculptures), Paros (as many as 16 sculptures), and Afyon, near Dokimeion in Phrygia (as many as 33 sculptures). Marble from Göktepe, near Aphrodisias in Caria, is also identified (3 or 4 sculptures), but it is present only among the finished works. This study highlights the extensive material networks to which ancient Athens belonged and underscores the importance of interdisciplinary methodologies, integrating archaeometry, archaeology, and art history, for reconstructing the artistic practices and aesthetic desires of past communities.

1. Introduction

Mount Pentelikon provided Athens with an abundance of high-quality white marble in antiquity. The quarries, located some 20 km northeast of the city, were exploited intermittently during the 6th century BCE for sculptural production. Large-scale extraction began in the 5th century BCE to supply materials for major building projects on the Acropolis and elsewhere in the city (Korres, 1995, pp. 62–100; Palagia, 2021, pp. 285–289). Quarrying activity continued throughout the Hellenistic and Roman Imperial periods at varying levels of intensity for a range of architectural and sculptural purposes, both within Athens and across the wider Mediterranean region. The extent of quarry operations during Late Antiquity remains insufficiently studied, but it seems to have been minimal. Pentelic marble was highly prized by sculptors for its uniformity, fine grain size, and receptibility for carved detail. Due to the dominant use of Pentelic marble in Athens, other sources of marble that supplied the city's thriving sculptural workshops have not been systematically studied using scientific techniques.

The storerooms of the excavations of the Athenian Agora present an opportunity to understand marble choices in the city. The present archaeological site, which includes the ancient civic center and its surrounding neighborhoods, has been excavated since 1931 by the American School of Classical Studies at Athens. The depots of the archaeological project now contain over 3800 marble sculptures spanning the Neolithic to Ottoman periods, including all phases of Greek antiquity. The Agora thus provides a wide cross-section of marbles in a city renowned for its sculptural output. Our research on this corpus has identified an important group of Roman-period sculptures (1st century BCE to 3rd century CE) carved from marbles that are visually inconsistent with stone from Mount Pentelikon. A key feature of this group is the presence of numerous unfinished works, which are of special significance because they document some of the types of marbles carved in

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Athenian workshops. In this article, we present the results of archaeometric analyses of 58 sculptures from the Agora, aiming to establish the provenance of the marbles used. Our study is, to date, the most extensive marble provenance investigation of an archaeological group of sculptures from Athens.

2. Samples and methods

Fifty-eight (58) sculptures were examined: 46 statuettes, 6 small-scale statues, 1 fragment of a life-size statue, 3 reduced-scale busts, 1 table support, and 1 small herm. Thirty-one (31) of these sculptures are finished works, while 27 are unfinished. All sculptures were examined and analyzed noninvasively. Of these, 44 sculptures were also sampled for laboratory examination and analysis (Table 1). As mentioned above, these sculptures were preselected for study because their stones did not match the macroscopic characteristics of Pentelic marble; in other words, they do not constitute a random sample set. Permission for the examination, sampling, and analysis was granted by the Ephorate of Antiquities of the City of Athens and by the Directorate of Conservation of the Hellenic Ministry of Culture. The procedures and methods used are presented below.

2.1. Noninvasive examination and analysis

2.1.1. Optical examination

All sculptures were examined noninvasively in the conservation laboratory of the Agora Excavations. A cold light source, a 0.5-mm scale, a magnifying lens (10×), and, when necessary, a stereoscopic optical microscope were used for measuring the Maximum Grain Size (MGS) and the Most Frequent grain Size (MFS). The measurements of these values were taken on a finished surface of each object under transmitting light (Fig. 1A) and have a minimum accuracy of ±0.5 mm, although estimates with a higher accuracy (half the above) are possible under a stereomicroscope. The procedure approximates, to a certain extent, measurements obtained from thin-sections. In addition, the optical examination helped in characterizing the color, marble fabric, and other qualitative features, such as translucency (Fig. 1B), veins, and inclusions (Maniatis et al., 2021). This initial non-invasive examination is essential because it permits the observation and recording of the physical characteristics of the marble in several parts of the whole object, obtaining an overall and average assessment of the marble features, and overcoming the limitations of the single collected sample, which is unavoidably small.

2.1.2. Analysis with portable X-ray Fluorescence (pXRF)

All objects were also analyzed noninvasively using a portable X-ray fluorescence instrument (ThermoFisher, Niton XL3t), utilizing a 50 kV x-ray tube with a gold anode. The analysis window is circular and has a diameter of 8.0 mm. The embedded program *Soils* was used to determine the concentration of strontium (Sr), primarily, and to a lesser extent manganese (Mn). Each measurement was taken for 2 min, at four different energy ranges by an automatic change of filters, so that enough data would be accumulated for statistical accuracy. The calibration was done with the internal standards of the Thermo-Niton instrument for the *Soils* program.

For Sr, accuracy was verified by comparison with a number of samples analyzed also with Atomic Absorption Spectroscopy (AAS). This resulted in differences ranging between 1 and 5 %, without systematic preference to higher or lower values compared to the AAS measurements. When the size of the sculpture permitted it, two or three measurements were taken at different locations on the sculpture, and the average was used in the final results presented in Table 1. The standard deviation between the different locations never exceeded 8.0 %, indicating the reliability of Sr measurements in marble, provided that the selected surface for analysis is as flat as possible and that care is taken so that the entire analyzed surface is within the 8.0 mm diameter of the instrument's aperture. The instrumental precision at 1σ for every measurement is very high (max: ±5 %); however, given the above checks and comparisons, we may take ± 8.0 % as an overall precision for the Sr measurements in Table 1. The detection limit for Sr is given by the instrumental specifications for a Si + Fe + Ca matrix to 5 ppm.

For Mn, the accuracy of the pXRF measurements is much lower. The detection limit is about 90 ppm, and the instrumental precision of the Mn measurements ranges between 20 and 40 %. Comparing the Mn values obtained with pXRF with published values of known quarries obtained with AAS or Inductively Plasma-Mass Spectroscopy (ICP-MS) (Attanasio et al., 2011; Prochaska and Attanasio, 2021, 2022), the pXRF values appear to be within the range of Penteli and Afyon, but higher than the low Mn values of Paros and Göktepe. The latter is due to the high detection limit for Mn (90 ppm), which is above the values measured for these quarries with AAS (appr. 5–25 ppm). Nevertheless, the relative values measured with pXRF between the different Agora sculptures were found to be helpful for use as an additional parameter in the assignment of provenance of some sculptures. The Fe concentration values measured with pXRF are highly variable depending on the surface soil contamination and therefore have not been included in this study.

2.2. Sampling and laboratory examination and analysis

A sample in the form of a very small marble chip or flakes was obtained from each of the objects selected for sampling. This required applying a small chisel on a preexisting break surface. The sampling procedure was as minimally invasive as possible with regard to the artistic, aesthetic, and historical integrity of the object. The following analyses were then carried out on the samples.

1. Examination of the marble flake/chip(s) under a stereoscopic optical microscope for the qualitative assessment of the crystalline features, and for confirming or adjusting the MGS and MFS values previously measured noninvasively for the whole object.
2. Stable Isotope Analysis (IRMS) for carbon and oxygen.

A description of the above techniques and the methodology for provenance determinations can be found in the relevant literature (Attanasio et al., 2006; Craig, 1957; Maniatis, 2004; Polikreti and Maniatis, 2002; Tambakopoulos, 2013).

Due to the small size of the objects, which forced us to remove only a small sample, it was not possible to use additional analytical techniques, such as petrography.

For the Stable Isotope Analysis of carbon and oxygen, small grains of marble were cleaned by rinsing them briefly in diluted HCl. They were then ground into a very fine powder, from which a sample of ca. 30 mg was submitted for isotope analysis to the GeoZentrum Nordbayern of the Friedrich-Alexander Universität Erlangen-Nürnberg, Naturwissenschaftliche Fakultät. The method involved reacting the marble powders with 100 % phosphoric acid at 70 °C using a Gasbench II connected to a ThermoFisher Delta V Plus mass spectrometer. All values are reported in per mil relative to V-PDB. Reproducibility and accuracy were monitored by replicate analysis of laboratory standards calibrated by assigning a $\delta^{13}C$ of +1.95 ‰ to NBS19 and -47.3 ‰ to IAEA-CO9 and a $\delta^{18}O$ of −2.20 ‰ to NBS19 and -23.2 ‰ to NBS18. Reproducibility for $\delta^{13}C$ and $\delta^{18}O$ was ±0.05 and ±0.05 (1 std. dev.), respectively. Standard NBS 19 was additionally analyzed as a quality control sample.

2.3. Databases

The results of isotopic analyses and MGS were compared with the data from known ancient marble quarries, assembled during more than 30 years of research at the Laboratory of Archaeometry, NCSR "Demokritos" (Mandi, 1993; Maniatis et al., 2012, 2021, 2012; Maniatis et al., Unpublished; Maniatis and Polikreti, 2000; Polikreti, 1999;

Table 1
Optical, isotopic and pXRF results of examined statuary from the Athenian Agora.

Sample no.	Inv. no.	Description	Marble and sample description	Transl. (cm)	MGS (mm)	MFS (mm)	Sr (ppm)	Mn (ppm)	$\delta^{18}O$‰	$\delta^{13}C$ ‰	Provenance
1	S 2446	Small-scale statue: female head	Fine-grained, white, pyrite inclusions?	2.0	1.5	0.5	129	181	−6.80	2.88	**Afyon**
2	S 1796	Small-scale statue: female figure (Aphrodite?)	Coarse-grained, greyish uniformly	2.5	3.0	1.5	89	b.d.l.	−1.00	1.84	**Paros-LK**
3	S 1683	Small-scale statue: female figure (Aphrodite?)	Coarse-grained, greyish uniformly	2.5	3.0	1.5	113	136	−2.70	5.23	**Paros-MA/LY**
4	S 674	Statuette: Apollo or Dionysos (unfinished)	Coarse-grained, snow white, typical Thasos-dolomitic grain-distribution	1.5	3.0	2.0	23	b.d.l.	−2.82	3.86	**Thasos-DOL**
5	S 559	Statuette: Pan(?) (unfinished)	Fine-grained, white, foliation (schist-veins)	3.0	1.3	0.8–1.0	149	155	−6.72	2.64	**Penteli**
6	S 271	Statuette: Artemis, Rospigliosi type(?)	Very fine-grained, white, almost opaque, subject to fire?	<1.0	0.8	0.5	137	136	−6.43	2.82	**Afyon**
7	S 160	Statuette: Aphrodite	Extremely fine-grained, light greyish, wax-like, no veins, one crack	3.5	0.4	0.2	52	88	−5.40	−0.66	**Afyon (Bacakale)**
8	S 2924	Statuette: male youth	Extremely fine-grained, white, not very translucent. On the back dark grey layer (two tone)	1.0	0.5	0.3–0.5	476	111	−3.54	2.38	**Göktepe**
9	S 409[a]	Statuette: Aphrodite, half-draped Anadyomene type (unfinished)	Extremely fine-grained, whitish/light greyish, wax-like appearance. Translucent.	3.5	0.4	0.2	59	125	−5,33	−0,37	**Afyon (Bacakale)**
10	S 1898[a]	Statuette: Hygieia, Trentham Hall type (unfinished)	Extremely fine-grained, whitish/light greyish marble, wax-like appearance. Translucent.	2.5	0.4	0.2	58	157	−6,98	−0,16	**Afyon (Bacakale)**
11	S 2108[a]	Statuette: Hygieia, Hope type (unfinished)	Extremely fine-grained whitish/light greyish marble.	2.0	0.5	0.1	66	157	−6,34	−0,20	**Afyon (Bacakale)**
12	S 3128[a]	Statuette: Striding male figure (unfinished)	Extremely fine-grained, whitish marble. Translucent.	3.5	0.2	0.1	62	158	−5,32	−0,34	**Afyon (Bacakale)**
13	S 2946[a]	Statuette: Apollo, holding the bow (unfinished)	Extremely fine-grained white marble. Translucent.	2.0	0.1	<0.1	59	125	−5,31	−0,49	**Afyon (Bacakale)**
14	S 3122	Statuette: Aphrodite	Extremely fine-grained, no veins, not very translucent, very light tint of grey	1.0	0.3	0.2	57	147	−5.00	−0.58	**Afyon (Bacakale)**
15	S 1813	Statuette: Artemis(?)	Extremely fine-grained, whitish	2.0	0.5	0.2–0.3	276	129	−2.40	2.69	**Göktepe**
16	S 3208	Statuette: Aphrodite, half-draped Knidia type	Coarse-grained, white, very translucent	3.5	4.5	2.0–4.0	87	123	−0.87	2.00	**Paros-LK**
17	S 3095	Statuette: Aphrodite, half-draped Knidia type	Fine-grained, white, translucent	3.0	1.4	1.0	160	154	−3.20	4.83	**Paros-MA/LY**
18	S 2004 + S 3140	Statuette: Aphrodite, half-draped Knidia type	Coarse-grained, whitish/greyish	2.0	4.5	1.0–3.0	98	133	−1.11	2.21	**Paros-LK**
19	S 700	Statuette: Herakles, Farnese type (unfinished)	Coarse-grained, snow white, typical Thasos-dolomitic grain-distribution	1.5	3.5	2.0–3.0	28	71	−2.67	3.76	**Thasos-DOL**
20	S 1415	Statuette: nude male (unfinished)	Medium-grained, whitish/greyish	2.5	1.7	0.5–1.2	116	133	−2.64	5.07	**Paros-LY**
21	S 1861	Statuette: Herakles(?) (unfinished)	Coarse-grained, white, typical Thasos-dolomitic grain-distribution	1.0	2.2	1.0–2.0	23	96	−4.99	3.61	**Thasos-DOL**
22	S 3350	Statuette: Aphrodite(?), half-draped	Medium-grained, greyish	1.5	1.8	1.0	148	137	−0.58	2.82	Prokon-1 or Paros-LK
23	S 2306	Statuette: Aphrodite, half-draped	Medium-grained, white	2.5	2.5	1.0–2.0	157	148	−1.76	2.09	**Paros-MA/LK** or Prokon-1
24	S 3511	Statuette: Aphrodite, half-draped Knidia type	Fine-grained, white, 1 large calcite or dolomite crystal	3.0	1.5	0.5–1.0	161	137	−4.70	2.20	**Penteli**, Afyon, Aphrodisias
25	S 3000	Statuette: Aphrodite, half-draped Knidia type	Medium to coarse-grained, whitish	2.0	2.7	1.0–2.0	92	116	−1.15	1.88	**Paros-LK**
26	S 3189	Statuette: Aphrodite (unfinished)	Coarse-grained, snow white, typical Thasos-dolomitic grain-distribution	2.0	2.7	2.0	27	91	−4.14	3.81	**Thasos-DOL**
27	S 523	Statuette: Aphrodite, half-draped (unfinished)	Extremely fine-grained, whitish/greyish, not very translucent	1.5	0.5	0.2	130	234	−7.67	2.95	**Afyon** or Penteli
28	S 2058	Statuette: Apollo	Extremely fine-grained, whitish, translucent	2.5–3.0	0.3	0.1–0.2	61	128	−5.96	−0.10	**Afyon (Bacakale)**
29	S 265	Statuette: Herakles	Coarse-grained, snow white, typical Thasos-dolomitic grain-distribution	1.5	1.8	1.5–1.8	26	91	−3.87	3.93	**Thasos-DOL**

(*continued on next page*)

Table 1 (*continued*)

Sample no.	Inv. no.	Description	Marble and sample description	Transl. (cm)	MGS (mm)	MFS (mm)	Sr (ppm)	Mn (ppm)	$\delta^{18}O$‰	$\delta^{13}C$ ‰	Provenance
30	S 1755[a]	Statuette: Aphrodite, baring the left leg (unfinished)	Extremely fine-grained, milky white, almost opaque. Orange vein?	<1.0	0.2	0.1	60	111	−4.94	−0.29	**Afyon (Bacakale)**
31	S 1656	Statuette: Aphrodite, Capitoline-Medici type (unfinished)	Medium-grained, white, translucent	3.0	2.7	1.0–2.0	100	105	−0.99	2.00	**Paros-LK**
32	S 1904	Statuette: nude youth (Apollo?)	Extremely fine-grained, white, wax-like, translucent	3.0	0.5	0.1–0.2	61	165	−6.62	0.02	**Afyon (Bacakale)**
33	S 3331[a]	Statuette: Asklepios, Giustini type (unfinished)	Extremely fine-grained, white	2.5	0.2	<0.1	56	164	−5.59	−0.14	**Afyon (Bacakale)**
34	S 3056	Statuette: Aphrodite, half-draped (unfinished)	Medium-grained, heavy soil deposition and weathering)	3.0	2.0	0.5–2.0	194	119	−3.60	4.84	**Paros-LY/MA**
35	S 2016	Statuette: Aphrodite (unfinished)	Extremely fine-grained, white, wax-like	2.5	0.5	0.2	134	185	−5.88	3.97	**Afyon**
36	S 854[b]	Statuette: Asklepios, Giustini type (unfinished)	Extremely fine-grained, whitish, fine purple veins	n.m.	0.1	<0.05	53	141	−6.06	−0.1	**Afyon (Bacakale)**
37	S 1807[b]	Statuette: Asklepios, Giustini type	Extremely fine-grained, whitish	n.m.	0.4	0.1–0.2	65	134	−5.35	−0.29	**Afyon (Bacakale)**
38	S 480[b]	Statuette: Asklepios, Giustini type	Extremely fine-grained, whitish, wax-like	2.5	0.4	0.1–0.2	625	128	−2.61	3.04	**Göktepe**
39	S 759	Small-scale statue: Asklepios(?)	Medium/coarse grained, white, fizzes but not vigorously	2.0	3.4	1.0–2.0	120	150	−1.56	2.04	**Paros-LK**
40	S 1805	Statuette: Asklepios, Velia type	Fine-grained, white, perhaps a vein or a structural defect on the back, translucent	3.5–4.0	1.0	0.7–0.8	190	127	−3.05	5.12	**Paros-LY**
41	S 727	Statuette: Asklepios, Giustini type	Fine-grained, white, translucent	3.0	1.0	0.7–0.9	120	145	−4.15	4.69	**Paros-LY**
42	S 2082	Statuette: Isis (unfinished?)	Extremely fine-grained, whitish/light grey, very translucent	3.5	0.4	0.2	65	137	−6.70[c]	0.11[c]	**Afyon (Bacakale)**
43	S 636	Statuette: Aphrodite, baring the left leg	Medium-grained, whitish, rare larger crystal	2.0	2.5	1.0	168	154	−2.64[c]	3.98[c]	**Paros-MA/LY**
44	S 376	Statuette: Hygieia, Hope type (unfinished)	Fine-grained, white, foliation (schist veins)	1.5	1.0	0.5	152	161	−5.60[c]	4.04[c]	**Penteli**
			In-situ examination only								***Most likely provenance***
45	S 1178	Statuette: Eros (unfinished)	Extremely fine-grained, white, wax-like, translucent	2.5–3.0	0.5	0.2	57	131	–	–	Afyon (Bacakale?)
46	S 1175	Life-size statue: hand (unfinished)	Extremely fine-grained, white, wax-like, translucent	3.0	0.5	0.2	63	166	–	–	Afyon (Bacakale?)
47	S 385	Small-scale statue: Athena (unfinished)	Extremely fine-grained, white, wax-like, translucent	3.0	0.5	0.3	90	140	–	–	Afyon (Bacakale?)
48	S 1723	Table support: male figure (unfinished)	Extremely fine-grained, white, wax-like, translucent	3.0	0.5	0.3	82	139	–	–	Afyon (Bacakale?)
49	S 1978	Reduced-scale portrait bust	Fine-grained, white, no veins, no foliation	3.0	1.5	1.0	128	149	–	–	Afyon or Paros-LY?
50	S 1977	Reduced scale portrait: Julia Domna	Fine-grained, whitish/light greyish, a bit dull	1.5	1.0	0.5	355	157	–	–	Göktepe or Afyon
51	S 1096	Statuette: Eros	Extremely fine-grained, white, wax-like, translucent	3.0	0.3	0.2	73	127	–	–	Afyon (Bacakale?)
52	S 3263	Statuette: Aphrodite, baring the left leg (unfinished)	Extremely fine-grained, white, translucent	3.0	0.5	0.2	63	166	–	–	Afyon (Bacakale?)
53	S 1806	Statuette: Aphrodite nursing Eros	Extremely fine-grained, white spots present	2.0–2.5	0.5	<0.5	53	102	–	–	Afyon (Bacakale?)
54	S 1537	Small-scale statue: Athena, Parthenos type(?)	Extremely fine-grained, whitish/light grey	2.0	0.5	0.2	59	162	–	–	Afyon (Bacakale?)
55	S 3358	Reduced scale bust: female figure	Extremely fine-grained, whitish/light grey, very translucent	4.0	0.2	<0.1	63	157	–	–	Afyon (Bacakale?)
56	S 3154	Statuette: Hermes (unfinished)	Extremely fine-grained, whitish/light grey, very translucent	3.5–4.0	0.3	<0.2	51	135	–	–	Afyon (Bacakale?)
57	S 757	Statuette: Aphrodite, baring the left leg	Extremely fine-grained, white, translucent	3.0	0.5	0.2–0.1	59	152	–	–	Afyon (Bacakale?)
58	S 1487	Small herm (unfinished)	Extremely fine-grained, white/light grey, translucent	3.0	0.4	0.2	61	151	–	–	Afyon (Bacakale?)

Note 1: MGS and MFS values below 0.5 mm are estimates.

[a] Statuettes published in the ASMOSIA XIII Proceedings at Vienna (Maniatis et al. 2025), included here for comparative purposes.

[b] Statuettes published in the ASMOSIA XII Proceedings at Izmir (Martens et al. 2023), included here for comparative purposes.

[c] Isotopic analysis performed by Norman Herz at the Geology Department, University of Georgia, USA.

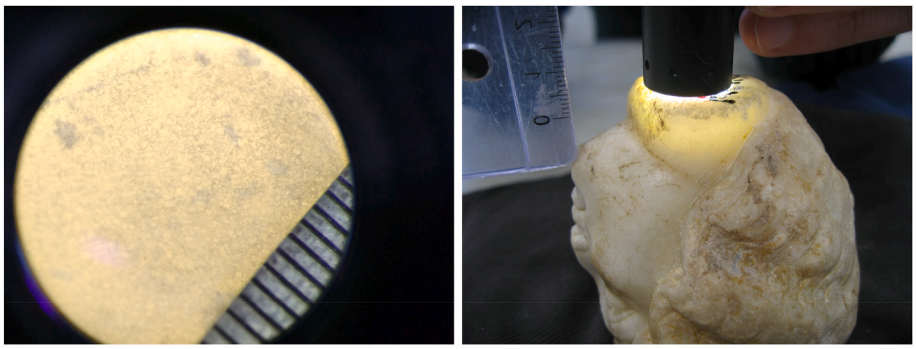

Fig. 1. A: Measuring the MGS and MFS noninvasively under a stereoscopic microscope in transmitted light (sample 28); 0.5 mm scale. B: Measuring the translucency of marble (sample 50).

Tambakopoulos, 2013; Tambakopoulos and Maniatis, 2012, 2017; Vakoulis, 2000), and by comparison with other published datasets (Attanasio et al., 2006, 2009, 2016, 2021; Bruno et al., 2002; Gorgoni et al., 2002; Herz, 1987, 2000, 2002, 2006, 2000; Pike, 2000, 2009). The data were gathered into a single isotope database. The physical properties and qualitative crystalline features of the marble obtained from the in-situ examination and the microscopic examination in the laboratory were also compared with the extensive sample bank of the Laboratory of Archaeometry's quarry regions. The Sr analysis results were compared with the published data (Attanasio et al., 2011, 2016; Calligaro et al., 2013; Gorgoni et al., 1992; Mandi, 1993; Poretti et al., 2017; Prochaska, Personal communication; Prochaska and Attanasio, 2021, 2022; Wielgosz-Rondolino et al., 2024), as were the Mn results (Attanasio et al., 2011, 2015; Magrini et al., 2016; Prochaska and Attanasio, 2021, 2022; Wielgosz-Rondolino et al., 2024).

3. Results and discussion

All measured parameters (quantitative and qualitative) of the examined and analyzed sculptures are presented in Table 1, together with the final marble provenance assignments. The preliminary results of 10 of the 58 samples (marked in Table 1) were presented at conferences of the Association for the Study of Marble and Other Stones in Antiquity (ASMOSIA) in 2018 and 2022; they are included herein for comparative purposes and to ensure a holistic approach to the presentation and interpretation of the data. A map of the quarries and sites discussed in this article is provided in Fig. 2.

3.1. Dolomitic marble

Five sculptures were carved from dolomitic marble (samples 4, 19, 21, 26, 29) (Fig. 3). The dolomitic nature was verified by two main procedures: (1) the fizzing test with dilute HCl acid (0.5N) at a very small point on a broken surface under a microscope (dolomitic marbles do not fizz, while calcitic marbles fizz vigorously); and (2) the measurement of calcium (Ca) with the pXRF (these samples produced low Ca content, 24–34 %, while the calcitic samples have higher contents, around 45–55 %). In addition, the Sr content was very low compared to the calcitic marble sculptures in this study, typically between 23 and 28 ppm (Table 1). Very similar Sr values have also been obtained

Fig. 2. Map of the Aegean region, showing locations discussed in the text.

noninvasively using a mobile XRF instrument on sculptures made of Thasian dolomitic marble in the Louvre (Calligaro et al., 2013). The isotopic signatures of the samples are plotted against the field of Thasian dolomitic marble (Attanasio et al., 2006) from the known dolomitic quarries at Vathy and Saliara in the northeastern part of the island (Fig. 4). As it is seen from this plot, all samples fall within this field. The MGS range (1.8–3.5 mm) and the characteristic grain-size distribution, together with the snow-white color, confirm the origin of the marble from the Thasian dolomitic quarries. Four of the statuettes (nos. 4, 19, 21, 26) are unfinished (Fig. 3), indicating that this marble was being worked in Athenian marble-carving studios during the Roman period.

3.2. Calcitic marbles

The remaining 53 sculptures were carved from calcitic marbles. The MGS of these sculptures ranges from extremely fine-grained (0.1 mm) to coarse-grained (4.5 mm) (Table 1). Fig. 5 shows their MGS distribution in a statistical percentile diagram. The majority (60 %) are an extremely fine-grained marble with MGS in the range 0.1–0.8 mm. Others (24 %) are a fine- to medium-grained marble (1.0–2.0 mm), and the rest (16 %) are a coarse-grained marble (2.5–4.5 mm). In what follows, we discuss each of these grain-size groups separately because they are compared to different quarry groups with equivalent grain sizes.

3.2.1. Very fine-grained marbles (MGS = 0.1–0.8 mm)

There are 32 sculptures in this group. The marble tends to be white or wax-like (or honey-like) in color, with high translucency; however, a few are milky white, with very low translucency. Twenty (20) sculptures were fully analyzed, and their isotopic signatures are plotted against the fields of the quarries known to have produced fine-grained marble (Fig. 6). The Paros-Marathi and Paros-Lychnites quarries are, in general, not so finely grained, but since their marble ranges from coarse-grained to fine-grained, they have been included for comparison. The isotopic diagram shows that the majority of the extremely fine-grained samples exhibit a very low $\delta^{13}C$ value, within a very narrow range (+0.11 to −0.66 ‰), which causes them to accumulate in the lower part of the overall Afyon (Dokimeion) field, and in particular, in the subfield of the Bacakale quarry at Afyon (dashed circle in Fig. 6), also known as the Röder I quarry (Attanasio et al., 2006; Röder, 1971) (Fig. 7). Some of the samples enter into the extreme lower end of the Göktepe ellipse (Fig. 6).

There are exceptions to the behavior of the samples in this group. In particular, samples 6, 27, and 35 exhibit higher $\delta^{13}C$ values than the others and fall in the Penteli isotopic field; samples 6 and 35 also fall

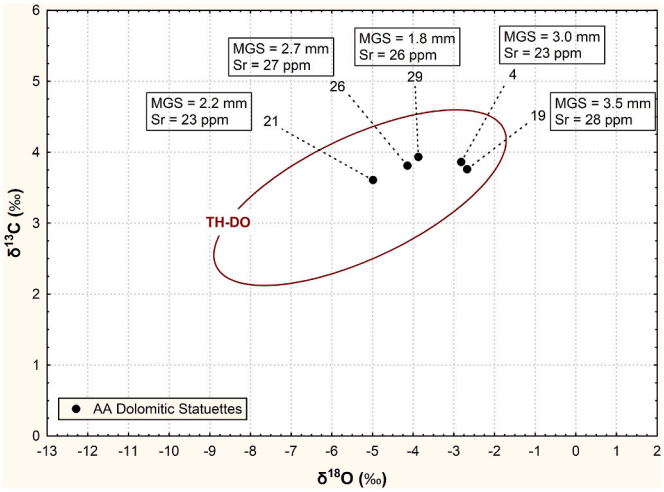

Fig. 4. The isotopic signature of dolomitic marble samples against the Thasian field of dolomitic quarries (Attanasio et al., 2006).

inside the overall Afyon field (Fig. 6). In addition, samples 8, 15, 38 fall in the center of the Göktepe field, but overlap with the Paros-Marathi, Paros-Lychnites, and Hymettos isotopic fields.

In order to distinguish the above quarries, we use the values of strontium (Sr), an element that differentiates them (Attanasio et al., 2011, 2015, 2021; Magrini et al., 2016; Poretti et al., 2017; Prochaska and Attanasio, 2022). Fig. 8 shows the Sr concentration versus MGS for the extremely fine-grained samples. Again, all samples that exhibit low $\delta^{13}C$ values and that fall in the Afyon-Bacakale isotope subfield exhibit very low Sr concentrations. This excludes the Göktepe origin for those that have an overlap with the Göktepe field. The very low $\delta^{13}C$ values, in combination with very low Sr values, characterize the marble extracted from the Bacakale quarry within the overall Afyon field (Attanasio et al., 2006, 2011). There are no other quarries within the Afyon district or the nearby Altintas quarries that exhibit $\delta^{13}C$ below 0 ‰. We can therefore safely assign the origin of these samples not only to the Afyon quarries, but specifically, to the Bacakale section. Taken together, the almost indistinguishable $\delta^{13}C$ values and the great similarity of the Sr values may indicate that the marble used for these sculptures could have come from blocks extracted in close proximity to one another, although blocks extracted further apart could also have similar values.

Samples 8, 15, and 38 fall in the center of the Göktepe isotopic field

Fig. 3. Sculptures carved from Thasian dolomitic marble; all are unfinished except no. 29.

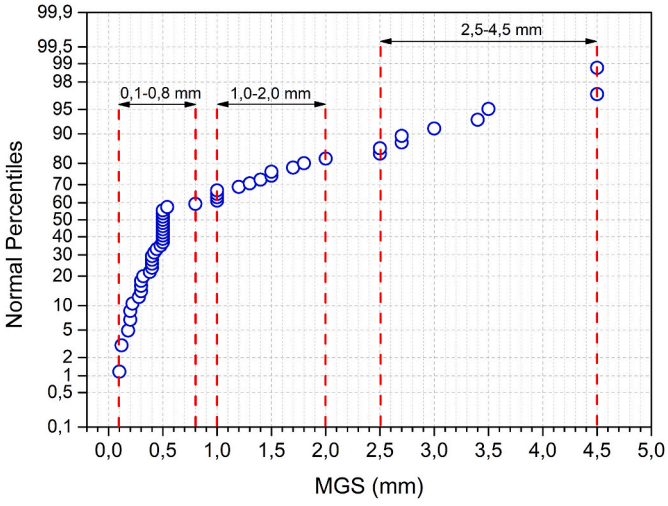

Fig. 5. MGS sizes frequency distribution graph with cumulative percentage of all calcitic marble sculptures examined.

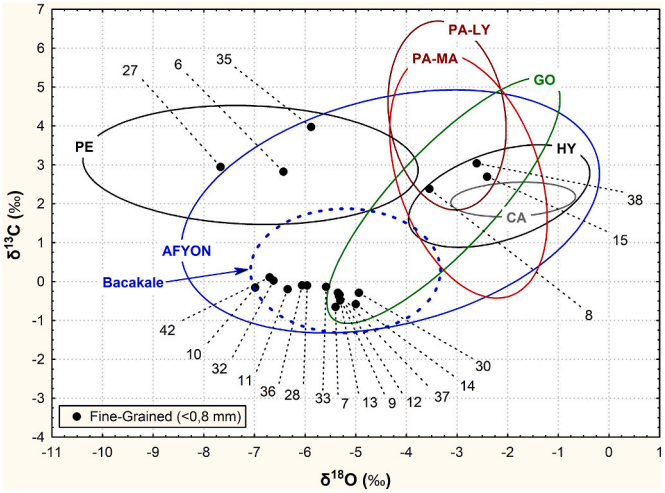

Fig. 6. Isotopic signatures of extremely fine-grained (below 0.8 mm) samples against quarries producing fine-grained marble. Quarry abbreviations: PE = Penteli, AF = Afyon (Dokimeion), Bacakale = Afyon-Bacakale, HY = Hemettos, PA-MA = Paros-Marathi, PA-LY = Paros-Lychnites, CA = Carrara, GO = Göktepe.

(Fig. 6). Samples 8 and 38 have a very high Sr concentration, above any other quarry than Göktepe; for this reason, they are undoubtedly from Göktepe (Fig. 8). Sample 15 has a Sr content which is close to the extreme values of the Afyon-All quarry range, but well inside the Göktepe range. Regarding the Mn values, as discussed in Section 2.1.2, the detection limit of the pXRF instrument is around 90 ppm. Therefore, the measured values of Mn for samples 8, 15, and 38 (111, 129, and 128 ppm, respectively) are close to the detection limit and cannot be considered corresponding to measurements taken with AAS or ICP Spectroscopy published in the literature for Göktepe (10–26 ppm) (Attanasio et al., 2021) or lower (Poretti et al., 2017). However, compared to the Mn measurements of the sculptures analyzed herein, it appears that the values measured for the above three sculptures are among the lowest, together with marbles identified as Parian. Therefore, despite the absolute values, samples 8, 15, and 38 correspond to marble with a low Mn concentration. In conclusion, the isotopic values, the high Sr values, the extremely fine grain size, and the relatively low Mn values verify the Göktepe origin for the marble of these three statuettes.

Samples 6, 27, and 35 are also extremely fine-grained. Samples 6 and 35 fall in the overlap of the Afyon and Penteli isotopic fields and sample 27 just outside the Afyon ellipse and in the Penteli field (Fig. 6). All three have identical Sr values (130–137 ppm), which fall in the extreme lower Sr range of the bulk of Penteli values (min: 131/133 ppm), but well inside the Sr range of Afyon (min: 44/64 ppm) (Poretti et al., 2017; Prochaska and Attanasio, 2022). These samples also have some

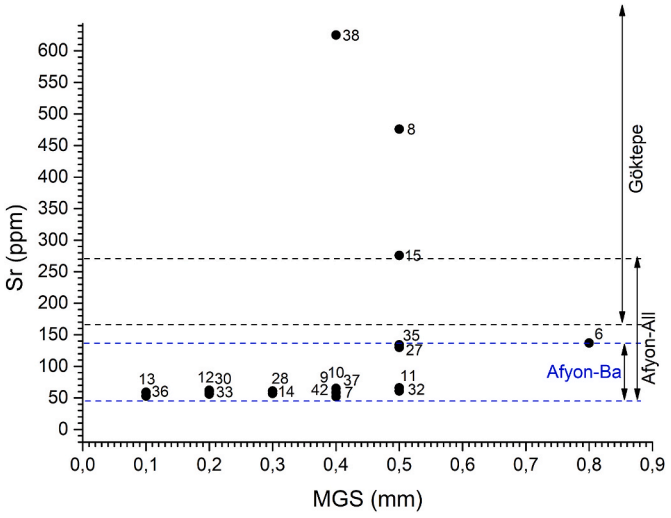

Fig. 8. Strontium versus MGS for the fully analyzed fine-grained samples (<0.8 mm). The 2σ Sr ranges for Afyon-All, Afyon-Bacakale, and Göktepe quarries are also shown with dashed line (for data sources see text). The error bars: ±4–5 ppm for all the low Sr samples; ±10–11 ppm for samples no. 6, 27, 35; and ±22 ppm, ±38 ppm, ±50 ppm for the samples no. 15, 8, 38 respectively.

Fig. 7. The extensive quarry district at Afyon, covering several km^2, with a yellow pin marking the location of the Bacakale quarry. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

distinctive features: sample 6 is almost opaque and sample 35 has a wax-like appearance (Table 1). These features are not exhibited by Pentelic marbles but are frequent in the Afyon ones. Sample 27, which falls only within the Pentelic field, is a bit puzzling. Its extremely fine grain size brings it below the Penteli range, and its Sr value is slightly below the minimum for Penteli, as with the other two samples discussed above; it is possible that sample 27 is an Afyon outlier. In addition, all three samples (6, 35, and 27) lack any sign of foliation or pyrite inclusions, features which are characteristic of Pentelic marble. In view of all the above, we would assign the provenance of samples 6 and 35 to Afyon with a high probability, and sample 27 also to Afyon, with an alternative identification as Penteli. Given their relatively high $\delta^{13}C$ value, if these three samples are indeed from Afyon, they cannot originate from the Bacakale quarry like most of the other extremely fine-grained samples in this study, but from within the overall Afyon quarry district.

In addition to the 20 fully analyzed samples in this group, we have another 12 extremely fine-grained marble sculptures, for which we conducted only optical examination and pXRF analysis. Their Sr values are all characteristically low and cluster together in the very low Sr values of the overall Afyon quarries range, together with the identified 14 Bacakale samples (Fig. 9). Beyond Afyon, there is no other known quarry with such extremely fine-grained marble and such low Sr values. Therefore, the provenance of the marble of these sculptures can be assigned with confidence to the Afyon quarry district. Furthermore, these additional sculptures have qualitative marble properties that are very similar to those whose marble origin has been traced specifically to the Bacakale quarry. It is therefore very likely that these additional 12 samples also come from the specific Afyon-Bacakale quarry; cautiously, however, this cannot be proven without measurement of the $\delta^{13}C$ isotopes.

In summary, from the 32 extremely fine-grained samples examined, only three come from Göktepe. The remaining 29 samples are traced to Afyon, and more specifically, 26 of them (14 securely and 12 most likely) to Afyon-Bacakale, making this specific section of the quarry an important source of marble for some of the workshops operating near the Agora in the Roman period. Three others may come from nearby quarries in the general Afyon quarry district. Among the group of Afyon samples, 17 are unfinished, indicating that marble from this quarry was imported to Athens as a raw material for carving in local workshops.

Regarding the samples from Göktepe (Fig. 10), it is interesting to note that sample 8 was probably quarried at the contact zone between white and grey/black marble in the Göktepe quarry (Attanasio et al., 2021). This has produced a two-tone statuette: white in the front and dark grey for the garment over the back (Fig. 10). The statuette is the first known example of a two-tone Göktepe sculpture in Athens and one of only several examples known worldwide (Attanasio et al., 2021, p.199-202).

3.2.2. *Fine/medium-grained marbles (MGS = 1.0–2.0 mm)*

Twelve (12) sculptures belong to this group. Ten (10) were fully analyzed, while two were examined optically and analyzed using pXRF. The isotopic signatures of the 10 fully analyzed samples are plotted against the quarries with marbles of equivalent grain size (Fig. 11).

Samples 1 and 5 fall in the overlapping fields of Afyon, Penteli, Prokonnesos-2, and borderline Ephesos-1. Ephesos is an unlikely source since the isotopic signature of these samples plot at the very edge of the 95 % ellipse and outside the distribution of the field points (not shown in the diagram for simplicity; see Supplementary). Regarding the Sr values, sample 1 plots much below the 2σ Penteli range and at the extreme lowest of the 2σ Prokonnesos-2 range (Fig. 12), a fact that makes these two origins very unlikely. Therefore, the most probable origin of sample 1, in agreement with the low Sr value, the isotopes, and the high Mn value (Table 1), is Afyon. Sample 5 has a Sr value that falls within both the 2σ Penteli and Prokonnesos-2 ranges, but the presence of foliation (Table 1) excludes the latter quarry; sample 5 is from Penteli.

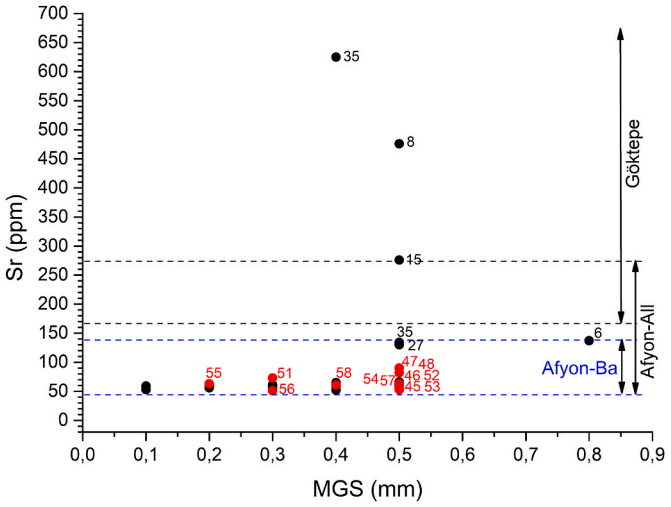

Fig. 9. Strontium versus MGS for all the fine-grained sculptures (below 0.8 mm) examined. The red dots and numbers are the ones examined only optically and analyzed with pXRF (see Table 1). The 2σ Sr ranges for Afyon-All, Afyon-Bacakale, and Göktepe quarries are also shown (for data sources see text). Error bars of samples as in Fig. 8, except samples 47, 48 than have ±7–8 ppm. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

Sample 44, whose isotopic signature falls in the overlap of Penteli, Ephesos-1, and Afyon (Fig. 11), also exhibits clear foliation (Table 1), which, in addition to its Sr value, leaves no doubt for its origin from Penteli.

The isotopes of samples 17, 20, 34, 40, and 41 fall within the overlap of the Paros-Lychnites, Paros-Marathi, Ephesos-1, and Afyon fields. Afyon must be excluded because the samples fall on the border of the ellipse and far away from the actual field points (see Supplementary). The Sr content of these samples (Fig. 12) clearly distinguishes the origin of sample 34 which falls outside the Ephesos-1 range and only in the Paros-Lychnites/Marathi range, therefore providing an unambiguous origin for this sample from Paros-Lychnites/Marathi. However, the Sr values of the other samples in this group fall within both the Ephesos-1 and the Paros-Lychnites/Marathi ranges (Fig. 12), making it difficult on the grounds of the analytical data alone to distinguish between these two quarry regions. Macroscopic features of the marble, such as appearance and translucency, as well as microscopic features, such as the clear marble fabric, all point to Paros. In particular, samples 20, 40, and 41, in conjunction with their Sr values, seem to belong to the Paros-Lychnites variety, while samples 17 and 34 could be either Paros-Lychnites or Paros-Marathi. The Parian origin of the marble is verified by stylistic analysis of the statuettes, which suggests production on Delos (see section 4.3, below).

Sample 22 is a greyish, somewhat fine-grained marble (MGS = 1.8 mm; MFS = 1.0 mm) with low translucency. Isotopically, it falls in the overlap of the Thasos-Aliki and Prokonnesos-1 fields, and just outside the Paros-Lakkoi field (Fig. 11). Its Sr value is in the range of all three of those quarries (Fig. 12); however, its MGS (1.8 mm) is below the range of Thasos (minimum: 2.0 mm) [Supplementary and also (Antonelli and Lazzarini, 2015; Attanasio et al., 2006)], and the generally fine grain size distribution (MFS = 1.0 mm) would exclude Thasos as a possible origin. The isotopic signature of this sample points to a Prokonnesos-1 origin because it falls outside (higher $\delta^{13}C$ value) of the present numerical values of the Paros-Lakkoi quarries field. However, the graphical presentation of the Paros-Lakkoi field (Paros-2) in Antonelli and Lazzarini (2015) shows that the $\delta^{13}C$ values may exceed 3.0 ‰, in which case the value of sample 22 ($\delta^{13}C$ = 2.82 ‰) would fall inside the Paros-Lakkoi field. This, taken together with its Sr-content, which is compatible with both Prokonnesos-1 and Paros-Lakkoi, leads us to

Fig. 10. Sculptures carved from Göktepe marble; no. 8 is a two-tone sculpture. An alternative provenance for no. 50 is Afyon.

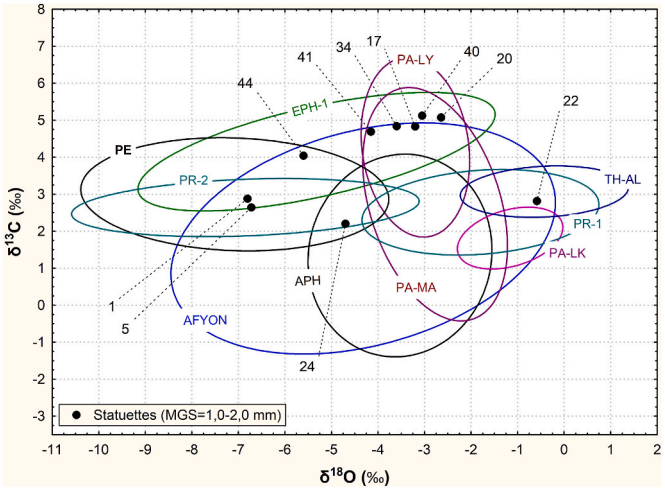

Fig. 11. Isotopic signatures of fine- and medium-grained (MGS = 1.0–2.0 mm) samples, against quarries producing equivalent grain size marble. Quarry abbreviations: PE = Penteli, AFYON = Afyon (Dokimeion), EPH-1 = Ephesos-1, PA-MA = Paros-Marathi, PA-LY=Paros-Lychnites, PA-LK=Paros-Lakkoi, APH = Aphrodisias, TH-AL = Thasos-Aliki, PR-1 = Prokonnesos-1, PR-2 = Prokonnesos-2.

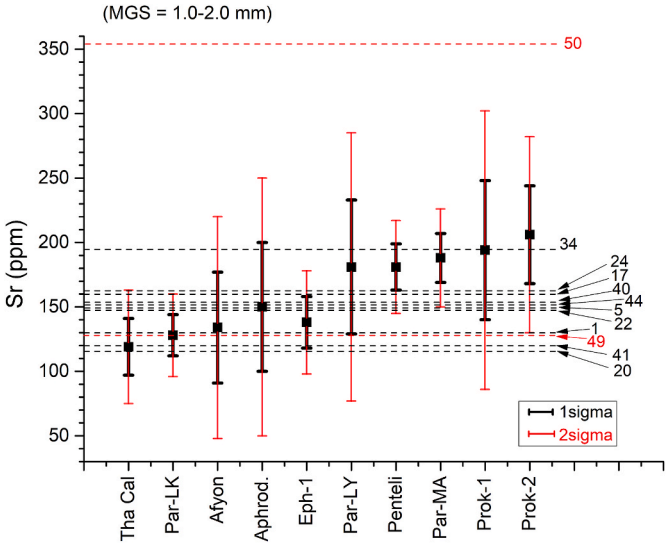

Fig. 12. Sr values of samples with MGS = 1.0–2.0 mm, against quarries with marble within the same range. Sculptures 49 and 50 in red are without isotopic analysis. Error bars: ±9–10 ppm for samples no. 20 to 1; ±11–13 ppm for samples no. 22 to 24; ±15 ppm for sample no. 34; and ±28 ppm for sample no. 50. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

cautiously assign sample 22 to either Prokonnesos-1 or Paros-Lakkoi.

Finally, sample 24 falls isotopically in the overlap of Penteli, Aphrodisias, and Afyon. This is a generally fine-grained marble (MGS = 1.5 mm; MFS = 0.5–1.0 mm) that would fall within the range of Penteli and Afyon quarries [Supplementary and (Antonelli and Lazzarini, 2015; Attanasio et al., 2011, 2021)], but outside (i.e., below) the 25–75 % range of the Aphrodisias quarries (Attanasio et al., 2006; Wielgosz--Rondolino et al., 2024). The Sr value of the sample (161 ppm) cannot differentiate it between the three quarries (Penteli, Afyon, and Aphrodisias). Mn tends to be lower than the other clearly Pentelic samples which may point more to Aphrodisias (Wielgosz-Rondolino et al., 2024), but both Penteli and Afyon have quarry regions with low Mn values (Prochaska and Attanasio, 2022). Perhaps the only feature than may shift its probability slightly toward a Pentelic origin is the presence of a single large calcite or dolomite crystal (about 2 mm) which has been observed in many sculptures of Pentelic marble (Tambakopoulos et al., 2019). In conclusion, we would leave this marble with three provenance options in order of probability: Penteli, Afyon, Aphrodisias.

Regarding samples 49 and 50, for which we have only optical qualitative examination and Sr analysis with pXRF, some provenance information can be deduced. Sample 49 is described as a fine-grained marble (MGS = 1.5 mm), white, and translucent, without any foliation or other features (Table 1). Its Sr value (Fig. 12) overlaps between the fine-grained quarries of Afyon and Paros-Lychnites. Its rather low grain size and rather high Mn value (149 ppm) reduce the Paros-Lychnites probability and point to Afyon as the most probable origin; still, Paros-Lychnites cannot be excluded. Sample 50, on the other hand, has a very fine overall grain-size distribution. In addition, it is dull and has a very high Sr value (355 ppm) (Fig. 12). All these are characteristic features of Göktepe, which is the most likely origin for this marble.

3.2.3. *Medium/coarse-grained marble (MGS = 2.5–4.5 mm)*

There are nine (9) samples in this range. The isotopic signatures are shown on Fig. 13, plotted against quarry fields producing marble with equivalent grain sizes. Sample 43 falls isotopically in the Paros-Marathi/Lychnites fields. No other quarry is possible, and its Sr value agrees within 1σ with both these Paros quarry regions. Therefore its origin is clearly from Paros-Marathi/Lychnites. Sample 3 plots within the Paros-Marathi/Lychnities fields, but it also plots at the right end of the Ephesos-1 statistical ellipse where there are no field points [Supplementary and (Prochaska et al., 2024)]; no sample in the Ephesos-1 dataset has a $\delta^{13}C$ value above 4.6 ‰. Its Sr value (Fig. 14) falls within the range of Paros but also in the 2σ Ephesos range, a fact that does not help much in the discrimination. Based primarily on the isotopes, we would assign the marble of this sculpture most probably to Paros-Marathi or Lychnites.

Samples 2, 16, 18, 25, and 31 cluster in the center of the Paros-Lakkoi field, although there is some overlap with the Prokonnesos-1 field and

the Thasos-Acropolis-Fanari field (Fig. 13). Thasos-Acropolis-Fanari is unlikely because there are no field points at that part of its statistical ellipse (see Supplementary). The Sr values of these samples also cluster together in a rather low range (85–100 ppm), and they seem to fall within the Thasos-Calcitic marble range, which includes the Thasos-Acropolis-Fanari locations where the isotopic signature of these samples fall. Their Sr values also fall at the lower end of the 2σ ranges of Paros-Lakkoi and Prokonnesos-1 (Fig. 14), quarries possible from the isotopic signatures. The Mn content of these samples is relatively low compared to other samples from known high Mn-content quarries (e.g., Thasos, Penteli, Afyon), ranging from below the detection limit of pXRF to 133 ppm, pointing to Paros or Prokonnesos (Prochaska and Attanasio, 2021), a fact that makes Thasos very unlikely. Apart from the high Mn-content, Thasos is also unlikely because of the lack of isotopic field values in the end part of the Thasos-Acropolis-Fanari ellipse where the isotopic signatures of these samples fall as discussed above. Therefore, given their characteristic position in the center of the Paros-Lakkoi isotopic field, we assign the provenance of these samples with high probability to the Paros-Lakkoi quarries or with lower probability to the Prokonnesos-1 quarries.

Samples 23 and 39 also fall isotopically in the Paros-Lakkoi field, as the previous group, but not in the center of it, and in a position that overlaps with the Paros-Marathi field, and further inside, the Prokonnesos-1 and Thasos-Acropolis-Fanari fields (Fig. 13). Sample 23 also falls marginally inside the Aphrodisias ellipse but outside the distribution of all field points [see Supplementary and (Attanasio et al., 2006; Prochaska and Attanasio, 2022; Wielgosz-Rondolino et al., 2024)]; the Aphrodisias dataset includes hundreds of samples, making the Aphrodisias origin highly unlikely. The Sr value of sample 23 (157 ppm) (Fig. 14) falls within the 2σ range of Paros-Lakkoi, Paros-Marathi, and Thasos-Calcitic, and within the 1σ range of Prokonnesos-1. Its MGS (2.5 mm) and MFS (1.0–2.0 mm) make the Thasos-Acropolis-Fanari (the only possible from the isotopes Thasian locations) origin highly unlikely. Thus, we assign the provenance of sample 23 either to Paros (Marathi or Lakkoi) or Prokonnesos-1. Sample 39 has a similar isotopic signature as sample 23, but it plots closer to the center of the Paros-Lakkoi field. However, its Sr value (120 ppm) (Fig. 14) excludes Paros-Marathi and falls more centrally in the Paros-Lakkoi and Thasos-Calcitic fields, and in the 2σ Prokonnesos-1 range. However, the MGS value (3.4 mm) of this sample would bring it to the extreme edge of the Prokonnesos-1 range (out of 167 samples, only two have values above 3.0 mm) (Attanasio et al., 2006, 2008), making its origin from Prokonnesos highly unlikely. Considering the MFS value of this sample (1.0–2.0 mm), Thasos-Acropolis-Fanari (very coarse-grained marbles) is highly unlikely. We therefore assign the provenance of sample 39 to the Paros-Lakkoi quarries.

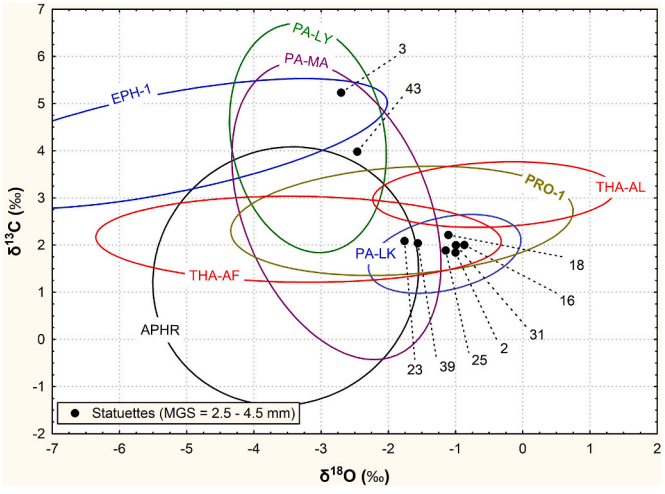

Fig. 13. Isotopic signatures of medium- and coarse-grained (MGS = 2.5–4.5 mm) samples, against quarries producing equivalent grain size marble. Quarry abbreviations: EPH-1 = Ephesos-1, PA-MA = Paros-Marathi, PA-LY=Paros-Lychnites, PA-LK=Paros-Lakkoi, APHR = Aphrodisias, THA-AF=Thasos-Acropolis/Fanari, THA-AL = Thasos-Aliki, PRO-1 = Prokonnesos-1.

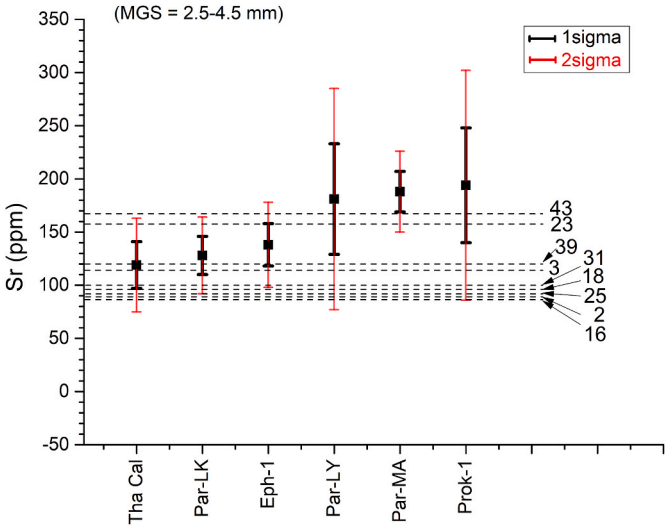

Fig. 14. Sr values of samples with MGS = 2.5–4.5 mm, against quarries with marble with equivalent grain sizes. Error bars: ±7–8 ppm for samples no. 16–31; ±9–10 ppm for samples no. 3 and 39; and ±13 ppm for samples no. 23 and 43.

4. Archaeological discussion

The results of this study demonstrate that sculptures carved from imported white marbles were available in Athens through local workshop channels, an aspect of production that has previously received little attention. Marbles imported from Thasos in the north Aegean, Paros in the Cyclades, and Afyon in west-central Asia Minor were being used in Athenian workshops during the Roman period, especially in the 2nd and 3rd centuries CE. Unfinished sculptures—that is, sculptures that were actively being carved in Athens and abandoned before completion—are present in all marble groups except Göktepe.

Our research focused on small-format works because they survive in large numbers and therefore provide a general index of the types of stones available in Athens. The small size of the unfinished works is of particular significance because it excludes a scenario wherein the sculptures were roughed out at distant quarries and sent to Athens for completion and final finishing—such a system would have been impractical for the numerous statuettes in this study that originally stood ca. 20–40 cm high, with some examples even smaller. Crucially, several unfinished sculptures can be associated with archaeologically attested studios (see section 4.2). Additional support for the conclusion is provided by the presence of iconographic types that belong firmly within the Athenian visual repertoire (e.g., samples 9, 10, 11, 30, 33) (Fig. 15).

Finally, it is unlikely that the sculptures were carved from recycled architectural blocks already present in Athens. It would be highly unusual to construct a building from statuary-grade marbles such as those from Paros or Afyon. More broadly, imported white marbles are very rare in the built environment of the city. The Stoa of Eumenes, constructed ca. 170 BCE on the south slope of the Acropolis from prefabricated blocks of Prokonnesian marble, is a main exception, being a benefaction of the Pergamene King Eumenes II (Korres, 2022, p. 66). For the unfinished sculptures presented herein, it is most reasonable to conclude that quarried blocks were delivered to Athens for the express purpose of carving new figures. To date, no squared blocks of imported

white marble have been documented in Athens or its port Piraeus.

4.1. Marble from Thasos

Harrison (Harrison, 1960, p. 387) established the presence of Thasian marble in Athenian sculptural workshops more than 60 years ago. The focus of her study, an unfinished bust excavated from the Post-Herulian Wall in the Agora, represents a heroized figure (Palagia, 2019). A profusion of tool-marks and a series of measuring points show that the sculpture was in the process of being carved. Although the bust has not been analyzed, it presents visual characteristics that are fully consistent with the dolomitic, snow-white marble from the quarries at Vathy and Saliara on Thasos. More recently, Stefanidou-Tiveriou (2022) has explored the wider uses of Thasian dolomitic marble in Athenian workshops, with attention to portraiture and architectural sculptures. Our results show that, in addition to those genres, sculptors also carved small, freestanding figures from the stone (Fig. 3). The four unfinished statuettes (samples 4, 19, 21, and 26) were found in secondary archaeological contexts, and given their small size and portable nature, it is not possible to anchor them to a specific workshop setting. Nevertheless, it seems certain they were being carved in studios near the Agora.

Limited amounts of Thasian marble reached Athens as early as the Augustan period, as an imperial portrait head demonstrates (Stefanidou-Tiveriou and Kaltsas, 2020, no. IV.1.5). Local use of the marble for imperial statues and busts is further documented in the 2nd century CE. The travel writer Pausanias (1.18.6), for example, recorded statues of the emperor Hadrian (117–138 CE) in the Olympieion that were carved from Thasian marble. The stone was presumably recognizable to Pausanias because it was the dolomitic type. A small-scale statue of Antinoös, who was deified after his death in 130 CE, was carved from Thasian dolomitic marble (Stefanidou-Tiveriou, 2019). A spectacular bust of the emperor Antoninus Pius (138–161 CE), found in a luxurious Late Antique residence near the Agora, where it had been later transferred for display, exhibits the macroscopic characteristics of Thasian dolomitic marble (Frantz, 1988, p. 41, pl. 40:a). Athenian workshops used Thasian marble for a range of formats and subjects during the 2nd and 3rd centuries CE. To our knowledge, Thasian calcitic marble has not been identified at Athens. Instead, the dolomitic type was preferred on account of its snow-white color, its hardness, and a grain size that allowed for crisp carving and polished surfaces (Stefanidou-Tiveriou, 2022).

4.2. Marbles from Asia Minor

Within the last two decades, a growing number of archaeometric studies have demonstrated the large quantity and wide dispersal of sculptures of the Roman Imperial period that are carved from fine-grained, white marbles quarried in Asia Minor. Two sources of white marble from this region were exploited extensively: the expansive quarries near Dokimeion in central Phrygia (İscehisar, Afyon province, Turkey) (Bruno et al., 2015; Röder, 1971) and the recently discovered quarries at Göktepe near Aphrodisias in Caria (southwest Turkey) (Attanasio et al., 2021). Marbles from both locations have been found throughout the Mediterranean basin, documented in their largest numbers in Asia Minor, and on the Italian peninsula and in Gaul (Attanasio et al., 2016, 2019, 2021). White marble from Dokimeion (Afyon) seems to have first been quarried for export in the Augustan period. The systematic exploitation of Göktepe marble, on the other hand, occurred later; the stone was circulating widely in the Mediterranean basin by the mid-2nd century CE. It remains to be considered how extensively white marbles from Asia Minor were deployed in Roman-period Greece, particularly in marble-rich Athens.

Thirty-one of the sculptures presented in this study (18 fully analyzed; 13 noninvasively examined and analyzed) were carved from marble quarried near ancient Dokimeion (Afyon). Eleven of the fully analyzed sculptures are unfinished (samples 9–13, 27, 30, 33, 35, 36, 42) (Table 1, Fig. 15), providing evidence that local sculptors were routinely carving the stone in Athens. The marble seems to have been used not only for statuettes (samples 6, 7, 9–14, 27, 28, 30, 32, 33, 35–37, 42, 45, 51–53, 56, 57), but also for a wider range of products, including small busts (samples 49[?], 55), herms (sample 58), table supports (sample 48), and small- (samples 1, 47, 54) and large-scale (sample 46) statuary (Table 1).

Although the spatial distribution of these sculptures is scattered throughout the zone of the Agora excavations, there is a general concentration at the south and southwest side of the site, where several marble-carving studios were located (Martens, 2025, p. 155, Fig. 84). The single life-size sculpture in this study, an unfinished hand (sample 46), was found in a layer of marble chippings laid down ca. 200–250 CE, in a sculptor's studio located in the west stoa of the Library of Pantainos (Lawton, 2006, pp. 22–23; Martens, 2025, no. H, p. 425). Two statuettes (samples 11 and 42) (Fig. 15) were used as construction material in the filling of the Post-Herulian Wall, where they were abandoned in the late 3rd century CE. Those statuettes were found alongside other unfinished works in Pentelic and Thasian marbles, and they seem to have originated from a workshop that operated in the South Square of the Agora. Finally, a statuette (sample 36) was found in a well on the north slope of the Areopagos, along with other unfinished works that had been discarded following the Herulian sack (Martens, 2021a). In sum, three separate workshop contexts from the Agora excavations contained sculptures being carved from Afyon marble in the early to mid-3rd century CE. The observation that some samples could come from blocks extracted near one another in the Bacakale sector of the quarries (see section 3.2.1) suggests that, on at least one occasion, a substantial shipment of the stone reached Athens.

Three statuettes (samples 8, 15, 38) (Fig. 10) are carved from Göktepe marble. Another probable example is a reduced-scale portrait of the Severan empress Julia Domna (193–ca. 210 CE) (sample 50) (Fig. 10). It seems that these sculptures were imported to Athens in a finished state; however, caution is needed regarding this hypothesis because Göktepe marble was exported as a raw material in squared blocks (Attanasio et al., 2021, pp. 266–268). In the case of a statuette of

Fig. 15. Selection of sculptures carved from marble from Afyon (Dokimeion).

Asklepios (sample 38), a Christian maker's mark, similar to those found at Aphrodisias, almost certainly marks out the piece as an import (Martens, 2018, pp. 584–585). Marble from Göktepe was favored for imperial portraits, most especially during the Severan period (Attanasio et al., 2021, pp. 155–156, 2019, pp. 188–212). The small head of Julia Domna (sample 50), probably broken away from a bust, was found in Herulian destruction debris in a bathing establishment southwest of the Agora square. A headless bust (sample 49), maybe representing another member of the imperial family and possibly carved from Afyon marble, was found alongside the head. A tentative conclusion is that both portraits might have been used for the purposes of imperial cult or ceremonial honors (Martens, 2025, pp. 5–6). Finally, a statuette of a youth wearing a short mantle (sample 8) employed the two-tone, black--and-white Göktepe marble. The dark portion of the stone was used to render the garment over the back. This is a unique example of the two-tone Göktepe stone in Athens. All four of the Göktepe marble sculptures analyzed from the Agora preserve very high, reflective polishes.

4.3. Marbles from Paros

Parian marble was used for a group of statuettes of Aphrodite that were probably carved on the Cycladic island of Delos during the late 2nd and early 1st centuries BCE, and then imported to Athens in a finished state (samples 16, 17, 18, 23) (Fig. 16). The sculptures in this group—united by size, iconography, style, and technique—find close parallels on Delos (Marcadé, 1969, pls. XLV, XLVIII; Martens, 2021b). Specifically, three figures represent Aphrodite in a highly distinctive half-draped version of the Knidia type, with the drapery rendered in an schematic, drawn-on style (samples 16, 17, 18). Another statuette (sample 23) represents Aphrodite with a mantle suspended around the legs, its folds rendered in a similar manner. The stylistic similarities affirm the Parian provenance of the marble and suggest that the alternative origin from Prokonnesos is unlikely (see section 3.2.2; Table 1). Sculptors working on Delos routinely carved marble from neighboring Paros and very rarely marble from Mount Pentelikon. Since another statuette belonging to this stylistic group was most probably carved from Pentelic marble (sample 24), it is reasonable to conclude that Athenian sculptors imitated the imported Delian works. Many Athenian sculptors worked on the island during the Late Hellenistic period, and the fortunes of the two cities were closely linked at that time. While the marble of this latter statuette could alternatively come from Afyon or Aphrodisias (see section 3.2.2), those quarries are highly unlikely since they were not producing stone for export at the time the sculpture was carved.

A final statuette of Aphrodite (sample 22) should be discussed here. The results of this provenance study suggest that the marble came from the Prokonnesos-1 or Paros-Lakkoi quarries (see section 3.2.2). From an archaeological point of view, the Parian provenance is preferable because the closest parallels again come from Delos (Marcadé, 1969, pl. XLII). If, however, the marble is indeed Prokonnesian, then it is a rare example of the stone for figured sculpture in Athens.

Parian marble, carved in Athenian workshops since the 6th century BCE, boasts a rich and lengthy local history (Palagia, 2021, pp. 283–284, 2000). Three unfinished statuettes (samples 20, 31, and 34) (Fig. 16), variously traced to the Marathi or Lakkoi quarries (Table 1), show that Athenian sculptors continued to deploy the stone for new sculptures during the Roman period. Two of the unfinished works (samples 31 and 34), both representing Aphrodite, were found removed from their ancient contexts. A statuette of a male figure (sample 20), however, was excavated from a stratified well, which provides a terminus ante quem of ca. 150 CE. A statuette of Aphrodite standing with her left leg bare (sample 43) belongs to an iconographic type that was popular in Athens, suggesting that, even though it is finished, it was produced in the city. It is not possible to establish if the other Parian marble sculptures (samples 2, 3, 25, 39–41) (Fig. 16, Table 1) were carved locally or imported from the Cyclades in a finished state.

5. Conclusions

This extensive marble provenance study of 58 sculptures has drawn attention to a variety of imported white marbles that were available in Athens through local workshop channels during the Roman period, an aspect of production that has not been sufficiently recognized. While the investigated sculptures comprise a small proportion of the overall assemblage from the Agora excavations (ca. 1.5 %), they are broadly representative of the main types of nonlocal marbles (i.e., not Pentelic) present in the city during this time, especially for small-format genres. The unfinished sculptures are of special importance because they demonstrate a range of marbles that were being worked locally. It has long been known that Parian and Thasian marbles were brought to the city for carving. This study adds new evidence, finding a substantial local use of marble quarried from Afyon (ancient Dokimeion) during the 2nd and 3rd centuries CE, and in particular, a concentration of stone from the Bacakale sector of those quarries. Continued archaeometric research on unfinished sculptures from Athens will help to establish the extent and frequency of imported stones in local workshops over time.

Imported white marbles were a special luxury, desired by consumers because of their famous and distant origins, in addition to their distinctive visual properties. A leading reason for the use of these imported marbles seems to have been a desire for the specific surface finishes they produced. The very fine-grained marbles from Afyon and Göktepe, for example, produced reflective polishes that were difficult to achieve with local marble from Mount Pentelikon. When highly polished, painted, and sometimes gilded, the figures could recall chryselephantine statuary, befitting for images of gods and goddesses. The use of the imported marbles identified herein emphasizes the wide material

Fig. 16. Selection of sculptures carved from Parian marble. Sample 22 could alternatively be from the Prokonessos-1 quarries.

connections within the art worlds to which Athens belonged. It also shows that identifying the place of carving of a marble sculpture must reach beyond marble provenance alone; it requires collaborative approaches that integrate archaeometry, archaeology, and art history.

CRediT authorship contribution statement

Yannis Maniatis: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation. **Brian Martens:** Writing – review & editing, Writing – original draft, Investigation, Funding acquisition, Conceptualization. **Dimitris Tambakopoulos:** Methodology, Investigation, Formal analysis.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jas.2025.106336.

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