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RESEARCH

Geochemical and petrographic investigation of the provenance of white marble decorative elements from the Roman Villa Armira in south-eastern Bulgaria

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Abstract
The paper presents evidence of Roman marble production in the Balkan region, specifically from the south-eastern Rhodope Mountain area (modern Bulgaria) and Armira. Although the Roman marble trade and production in antiquity are well known in Prokonnesos, Thasos, and several other production sites, marble deposits from inland Thrace have received far less attention. In 2018–2019, a systematic survey of south-eastern Bulgaria (Roman Thrace) was carried out by our team in collaboration with the National Archaeological Institute with Museum in Bulgaria. White marble quarries and outcrops were investigated in situ with the goal of characterizing the macroscopic qualities of the stone. Quarry samples were collected and analyzed through various techniques—petrography, isotopic, and chemical analyses—and compared with the architectural decorative marble and artifacts from the Roman villa at Armira. We demonstrate that the geochemical and petrographic features of these samples indicate a marble provenance restricted to a few selected sources. We conclude that the local marble from the Armira and Kamilski Dol quarries was widely used for the complete architectural program of the Roman villa of Armira.

Keywords Provenance of white marble · Bulgaria · Thrace · Villa Armira · Rhodope Mountains · Roman Period · Architectonical decoration

Introduction

The Roman province of Thrace experienced an upsurge in urbanization and monumentalization, leading to the construction of new infrastructure during the imperial period. The detailed study of the provenance of the marble objects provides an opportunity to investigate the usage of the material, the commercial and social relations between producers and clients, and insights into the political, commercial, and social relations of each city and province. The key actors involved in these processes were the emperor, the provincial governor, and the urban elites, all involved both as owners of the quarries and as well as its clients (Cancik et al. 2006).

Some of the most prominent, renowned, and best-investigated marble sources from antiquity surround the territory of the province of Thrace. They include sources from the

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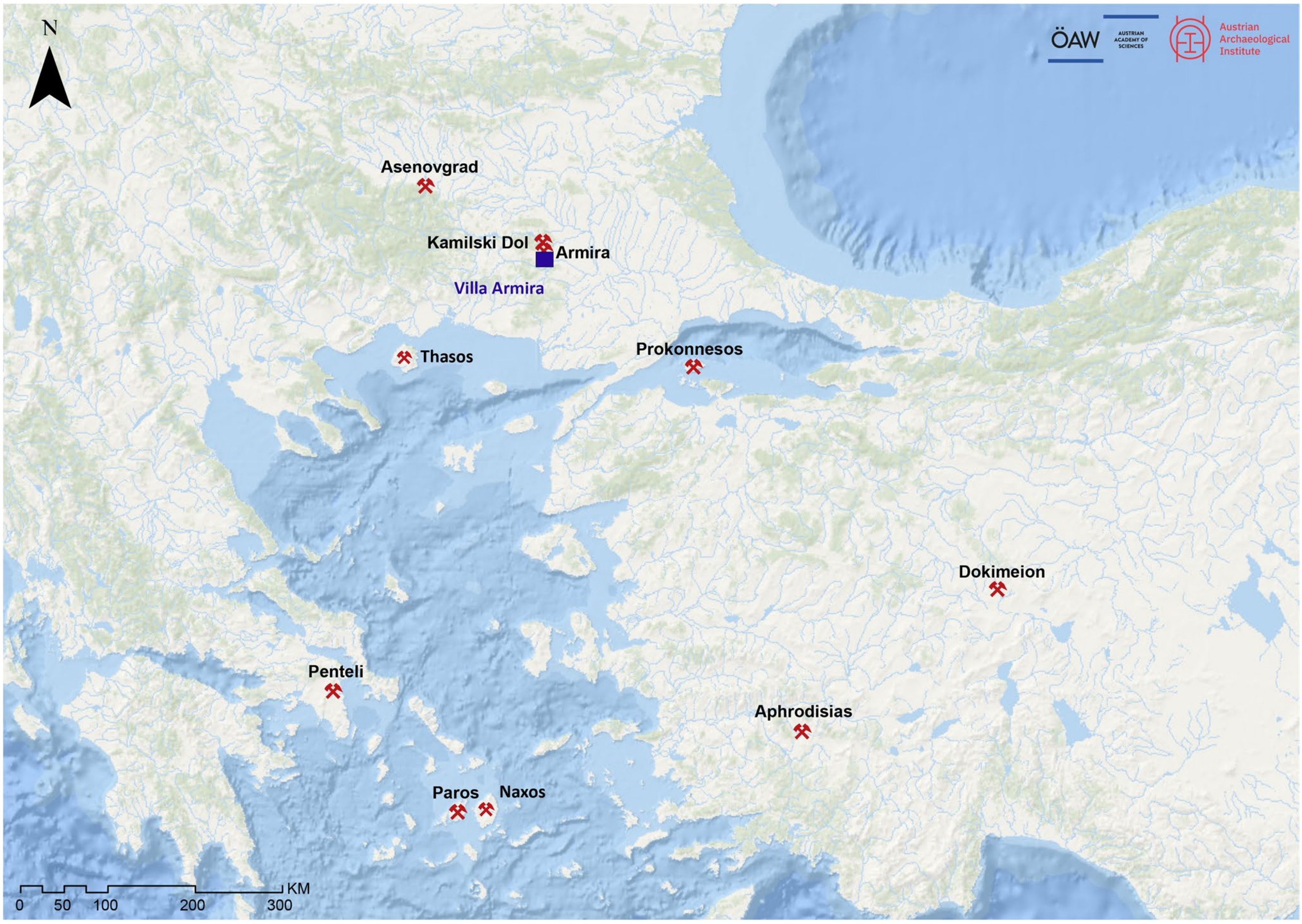

Fig. 1 Geographic distribution of the most significant roman marble sources (in red mark) and the location of the Villa Armira (blue mark) (Ed. N. Math, ÖAI/ÖAW)

islands of Prokonnesos[1] (Marmara) and Thasos[2] (Fig. 1), located in the provinces of Asia and Thrace respectively (Cenati and Ladstätter in press). The marble from these quarries spread throughout the empire, but was also used in the main inland cities of Thrace (Vanderheyde and Prochaska 2011) (on Thracian quarries, see below). The topographical and geological limitations played a critical role in the organization and administration of these quarries (Hirt 2010).

By contrast, numerous marble deposits in the interior, specifically around present-day Bulgaria, received far less attention. Scientific information on the chemical and petrographic characteristics of this marble is limited to a few examples, although local material was widely used for the monumentalization and embellishment of Roman cities. For example, marble from Asenovgrad, approximately 15 km south of present-day Plovdiv, was extensively used in the second century for the construction and urbanization of Roman Philippopolis (Kovachev 2010; ongoing FWF project). Evidence for Roman marble production in inland Thrace is also known from the Strandzha Mountains; the north-western Balkans near the town of Berkovitsa; Topolovgrad, in south-western Bulgaria at Ilindentsi, Pirin, Petrovo; and from various other areas in the Rhodope Mountains (Petrova and Ivanov 2009). Many of these ancient quarries may have been exploited during the second-century AD urbanization phase, providing building material for the Roman building programs in Thracian cities (Andreeva et al. in press). These massive-scale developments can be well observed in the cities of Philippopolis,[3] Augusta Traiana,[4]

[1] For Prokonnesian quarries, see the following: Asgari 1978, 1990, 1992.

[2] For Thasian quarries, see the following: Koželj et al. 1982; Κουκούλη—Χρυσανθάκη et al. 1999.

[3] Ivanov 2012; Topalilov 2011.

[4] Ivanov 2012

Deultum,[5] and Hadrianopolis.[6] At the same time, marble from Thracian quarries may have been used to embellish the luxurious villas of provincial elites, such as Villa Armira near Ivaylovgrad, Kasnakovo,[7] and Chatalka[8] (Andreeva et al. in press).

The analysis of the production and distribution of Thracian marble sources is of particular interest, especially considering that written sources regarding the marble trade within and outside the province are limited (see Andreeva et al. in press). Striking craft connections in architecture and sculpture can be specially recognized with Asia Minor, although this close connection between Asia Minor and Thrace cannot be fully explained (Dimitrov 2018). A systematic sampling of the Thracian quarries and Roman objects from various sites can contribute to larger questions regarding the trade of marble and the cultural and technological transfer between these Roman provinces. More broadly, identifying the provenance of ancient marble artifacts can provide new perspectives on larger archaeological questions relating to commercial enterprise in antiquity, social relations between producers and clients, and trade and exchange. Our research demonstrates that the regional and long-distance trade of white marble was important historically and economically for Thrace during the Roman imperial period (first to third century AD).

Previous investigations

From an archaeological point of view, a systematic investigation of the use of marble in Thracian cities, villas, and sanctuaries is an absolute desideratum, especially since the region constitutes a terra incognita for marble studies (Russell 2013). For example, various studies have focused on marble research on sculptures (Koleva 2005, 2017a, 2017b; Popova-Moroz 1996), architecture and architectural decoration (Dimitrov 2007, 2018), sarcophagi (Ivanov 2002), unfinished objects (Cherneva 2009; Minchev 2012), and workmen and trade (Cherneva 2006; Getov 2002) all published in the last two decades. These also include research on limestone as the main building material in antiquity at Marcianopolis (Dimitrov 2015). In Bulgaria, the state of research lacks homogeneity, with limited investigation and analytical work on marble quarries and outcrops in the region. Although Petrova and Ivanov (2009) compiled a general list of ancient quarries, describing their location and material type, the geochemical and isotopic data necessary for a databank are still lacking. We contend that this represents a significant gap in scholarship, highlighting the need for an analytical investigation and acquisition of such data from these quarries. The larger aim of this publication and the future project (see below) is the development of a geochemical analysis database for future archaeometrical marble provenance studies (Andreeva et al. in press).

Working towards this goal, in 2018–2019, approximately 30 white marble and limestone artifacts from the so-called Sanctuary of the Nymphs of Aphrodite and a villa near the Bulgarian village of Kasnakovo (Dimitrovgrad Municipality) were analyzed.[9] This large villa complex, situated on a small hill in the Rhodope Mountains, is one of the largest of its kind in Roman Thrace. The results of the marble analysis revealed the selective use of local marble and limestone for architectural elements (Klokonitsa, Kamilksi Dol, and Armira) in the residential part of the complex, indicating the desire of the owners of the estate to show their wealth and position in provincial society (Anevlavi et al. 2019).

The architecture of the villa and its reconstruction

In this paper, we focus on the so-called Villa Armira, a luxurious Roman estate, whose remarkable planning scheme, lavish marble decoration, and original floor mosaics characterize it as a unique specimen of Roman provincial art and architecture. Villas in the Roman province of Thrace varied and included simple *villae rusticae* and *villae urbana* combining production sectors with residential and representative parts. They were owned by members of the provincial elite who, after the founding of the Roman province, contributed to the economy of the region. Villas in Roman Thrace are known from the territories of Serdica, Pautalia, and Augusta Traiana (Bâltâc 2011; Dinchev 1997). Among these, the large complex of Chatalka[10] (region of Augusta Traiana), built probably in the first century AD, is famous for its marble decoration in the residential part (Dinchev 1997, pp. 60–67). Next to it, the villa located near modern-day Kasnakovo is an example of a residential complex that utilized both local and imported marble decoration (see above).

The Villa Armira, with a known area of 3600 m^2, is situated in a particularly attractive area in the eastern Rhodope Mountains in the valley of the small and not navigable

[5] Preshlenov 2015; Sharankov 2017

[6] Yıldırım 2007

[7] For marble use in Kasnakovo see Anevlavi et al. 2019.

[8] Nikolov 1976; Mladenova 1991; Dinchev 1997; Kabakchieva 2005; Katsarova/Petkova 2016. The marble of the Villa Chatalka is under investigation. (ongoing FWF project). Primary data show the use of Rhodope marble.

[9] For archaeological information on Kasnakovo see Aladzhov 1962; Katsarova 2013, 2017, 2018; Petkova 2018.

[10] Marble provenance studies on Villa Chatalka will be conducted in 2022/2023.

Armira river, a tributary of the larger river Arda. With a mild climate and fertile territory (Baltakova 2008), this region was in pre-Roman times part of the Odrysian kingdom (Fol and Spiridonov 1983a, b); thereafter, it belonged to the region of Hadrianopolis (Mladenova 1975).[11] The villa was discovered in 1964 during the building of a dam. Construction was immediately halted resulting in the preservation of this archaeological complex (Fig. 2).

The excavators date the first building stage between the first century (approximately 70 AD) (Kabakchieva 1995, 2005) to the second quarter of the second century (Late Hadrianic period).[12] The main building was articulated around a peristyle with a central pool (impluvium). Representative rooms, such as the triclinium, were incorporated with a hypocaust heating system. Existed facilities for agricultural production were also identified near the residential part of the villa, although these have only been partially excavated.

Substantial renovations in the second century AD saw the replacement of the polychrome fresco paintings with a white marble wall cladding. This phase is extraordinary due to the exclusive use of white marble and the absence of statuary (except herms) and colored marble. The replacement of frescoes with marble is not an unknown phenomenon, occurring in residential buildings in other parts of the Roman world during the second century AD (Zimmermann and Ladstätter 2011). The motivation for this change most likely lies in the adoption of imperial forms of representation within the private sphere. For Armira, it is striking that colored marble objects are also missing. This was uncommon in Roman architecture, where prestigious private houses incorporated multiple colored stones and patterns (Bradley 2006). It is doubtful that the walls were monochrome white, and it is far more likely that they incorporated at least partially painted or colored stucco infills. While the lack of colored marble can presumably be linked to a stylistic choice, the lack of statues might be explained by their removal in Late Antiquity and/or post-Roman times or modern looting activities. In the third century, a new triclinium with a mosaic floor and new service rooms were added to the main building. The villa was finally abandoned in the fourth century during the Gothic wars (Mladenova 1991a; Kabakchieva 2012).

The identity of the owners of the Roman villa who lived here between the first and second centuries remains unknown; however, a mosaic floor portrait might show a patron with his children (Urbankova 2013). Scholars have assumed that the foundation of the complex can be attributed to a member of the Thracian aristocracy, whose tumulus burial place was not far from the villa (Kabakchieva 2008, 2010). Nonetheless, the lack of inscriptions or other documentary sources regarding the villa or the burial site makes it impossible to support this Thracian identity.

Fig. 2 Marble-plated wall with pilaster capitals at the Peristilium of the villa (Ph. V. Anevlavi, ÖAI/ÖAW)

Quarries in the south-eastern Rhodopes

The extensive use of white marble in the residential part of Villa Armira might relate to the exploitation of marble quarries in the area. These would have significantly increased in the second century, as a systematic urbanization process took place in the province, resulting in the expansion of existing cities and founding of new ones (Andreeva et al. in press).

Two sampling campaigns in 2018 and 2019 were carried out in south-eastern Bulgaria. From a geological point of view, the region is comparatively well-studied. In the last few decades, intensive prospection directed towards the discovery of precious metals sources, and quarrying of gneiss, marble, limestone, schist, and other non-ore minerals has also been carried out. Following the preliminary collection of information, marble quarries in the Eastern Rhodope Mountains were visited and sampled, under the assumption that modern marble sources were also exploited in antiquity. The registration and mapping of possible traces of ancient marble extraction were undertaken during the second stage of the project beginning in 2019 (Georgiev et al. 2020). The campaigns investigated 16 quarries and outcrops located in the vicinity of Villa Armira[13] (Table 1). The quarries around the villa (Armira 1, 2, 3, 4) are located within a radius of 3 to 4 km. The quarries

[11] For a more detailed history of research on Villa Armira, see Mladenova 1991a.

[12] The first person to research the villa, Yanka Mladenova, dated the surviving part of the sculptural decoration and architectural details to the late Hadrianic period through the rule of Antoninus Pius. Her interpretation was based on stratigraphic and numismatic evidence, as well as stylistic analysis. Regardless of which dating is accepted, both Villa Armira and the villa near Chatalka, in the Stara Zagora region, remain until now the earliest and the most representative villa complexes in the Roman province of Thrace.

[13] Located in the modern territory of Ivaylovgrad.

Table 1 The coordinates of the analyzed quarries and archaeological sites. The information was collected during the sampling campaigns of 2018 and 2019, with the use of a GPS device (Ed. V. Anevlavi ÖAI/ÖAW)

Quarry	Coordinates
Dyadovitsi	41.60296–025.13998
Pordivitsa	41.32911–025.63926
Egrek	41.33329–025.64376
Lensko	41.44094–025.95058
Klokonitsa	42.00066–025.52878
Krepost	41.99305–025.57146
Kamilski Dol 1	41.60139–026.06303
Kamilski Dol 1A	41.60712–026.05536
Kamilski Dol 2	41.60676–026.05612
Kamilski Dol 3	41.61557–026.05603
Kamilski Dol 4	41.60753–026.05882
River Armira Valley	41.51191–026.08516
Armira 1	41.50602–026.09191
Armira 2	41.50854–026.09143
Armira 3	41.50001–026.09764
Armira 4	41.51372–026.08405
Archaeological sites	
Villa Armira	41.49974498426678, 26.106150007939966
Kasnakovo	42.00370421541764, 25.5076253426652

of Kamilski Dol, Dyadovitsi, Pordivitsa, Egrek, and Lensko were also investigated (Fig. 2) since, until a few years ago, many were still in operation. Due to modern marble exploitation, ancient tool marks or other traces are no longer visible. In some cases, the owners of the quarries or local guides referred to ancient semi-finished artifacts on-site, but these could not be presently identified. According to archaeologists, abandoned objects were found around Kamilski Dol 1 and brought to the Regional Museum. In Armira 1 and 2, debris and tool marks were observed and recorded (Anevlavi et al. in press) (Figs. 3 and 4). The 2019 campaign at the Villa Armira and its surroundings provided the first concrete evidence of ancient marble exploitation. These quarries were located in the west and southwest, on the edge of the Eastern Rhodope Mountain slopes, and along the steep banks of the Armira river and its tributaries (Fig. 5). The distance to the villa varies, ranging from several hundreds of meters up to one and a half to 2 km. In some cases, waste heaps of fragments of antique pottery were also found among these possible ancient exploitation activities (Georgiev et al. 2020).

From a geological perspective, Villa Armira is situated in the eastern Rhodopes. The mountain range was formed by the collision of the Drama continental block in the south with the Moesian platform in the north. This tectonic activity started in the Middle Jurassic and resulted in intense overthrusting and stacking of the clasts and metamorphism of the area at various degrees up to eclogite facies temperatures. Extension and cooling of this crustal segment began in the Upper Cretaceous and were associated with a magmatic activity. Retrograde metamorphic overprinting is a characteristic feature of these rocks (Burg et al. 1996; Ricou et al. 1998; Wüthrich 2009).

The regional host rocks are metamorphic rocks with various metamorphic degrees. Gneisses, metabasic rocks, and eclogites with marble beds of limited size are common. The marble in the area is generally coarse-grained and shows clear characteristics of the retrograde overprinting mentioned above.

The investigated quarries are characterized by various lithotypes. The Kamilski Dol is a marble with a white to light grey color and medium to coarse grain size. The marble in quarries Armira 1 and 2 are of white, slightly greyish color, and medium grain size. Armira 3 is a very white and extremely fine-grained marble (tectonized), while coarse to very coarse-grained, white, slightly greyish

Fig. 3 The quarry Armira 4. Modern extraction has destroyed possible ancient marks (ph. V. Anevlavi, ÖAI/ÖAW)

Fig. 4 The quarry Kamilski Dol 1a. Modern extraction has destroyed possible ancient marks (ph. V. Anevlavi, ÖAI/ÖAW)

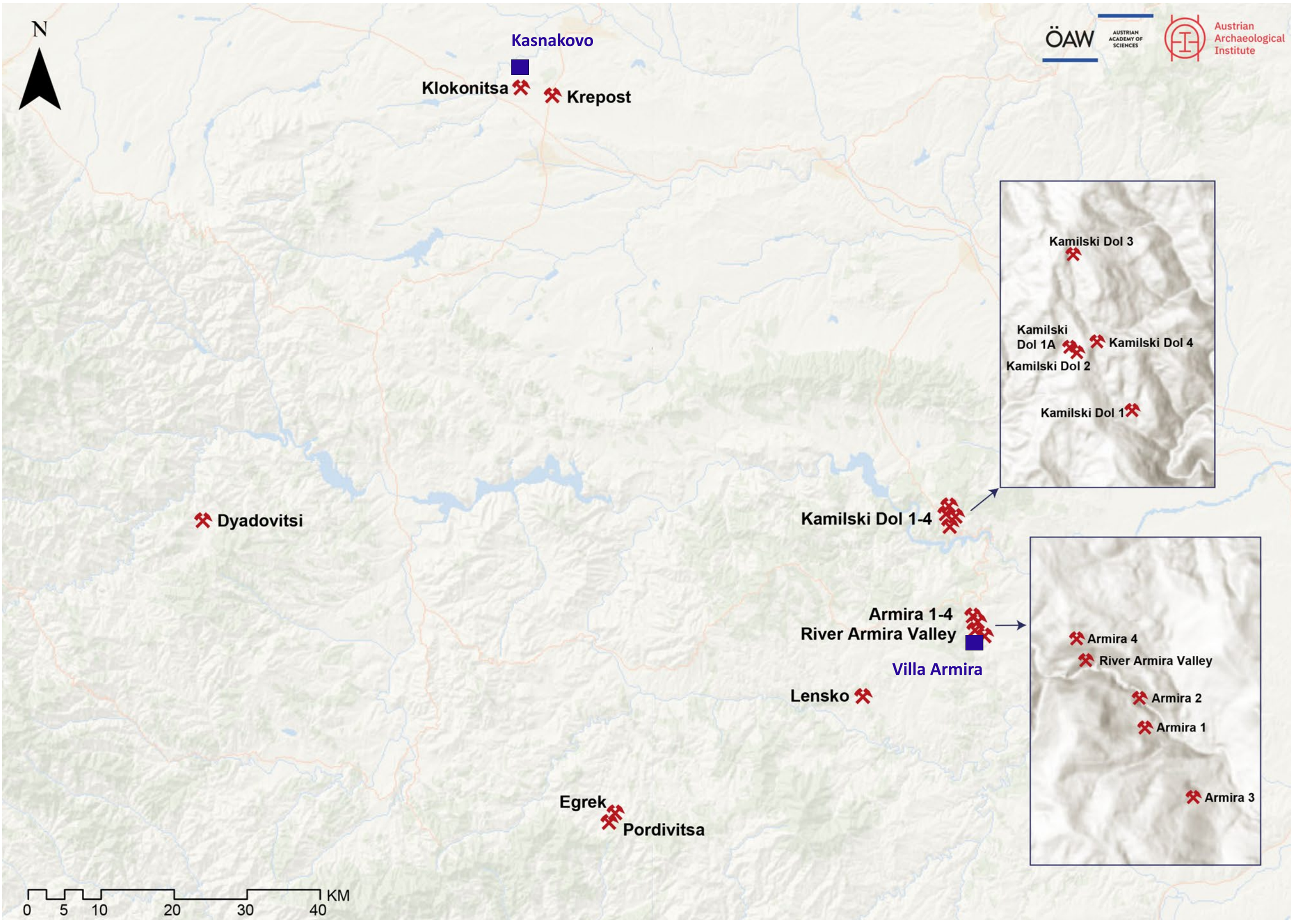

Fig. 5 The detailed map of the sampled quarries and archaeological sites in south-eastern Bulgaria (Ed. N. Math, ÖAW/ÖAI)

marble is found in Armira 4.[14] Large amounts of debris, probably waste rock piles, were observed at short distances (Armira 1, debris 1–4) (Anevlavi et al. in press).

Research questions and methodology

The marble revetment used in the villa of Armira is an intensely debated topic in archaeology. Scholars have hypothesized that it was a product of the Aphrodisias workshop in Asia Minor (Kabakchieva 2012). This interpretation was based on the high level of craftsmanship and the extraordinary quality of the marble utilized. Two proposed scenarios consider the importation of the finished pieces from Asia Minor or the migration of specialized craftsmen who would have worked locally. While the former would presuppose a marble origin from Asia Minor, specifically from the region around Aphrodisias, the latter scenario would have to involve local raw materials that were processed on-site. An identification of the origin of the marble can therefore provide decisive clues to the economic and social processes behind it.

The heterogeneity of analytical data and the large number of quarries and sources for marble production in antiquity require a methodological approach that combines a range of methods for provenance analysis (Maniatis 2004). For reliable results, petrographic investigations need to be combined with different chemical and isotopic data and statistical analysis (Shackley 2008).

With an increase in the number of studied objects, a reliance on exclusively petrographic methods becomes limiting. One of the main reasons for this limitation is the restricted number of textural features appearing in pure white marble. For this study, thin sections were prepared for both geological and archaeological samples from both the local quarries and the villa. The petrographic examination provided an opportunity to study the texture of the different objects and compare them with petrographic material from the subregional quarries, discussed below.

[14] Remarks on grain sizes: 0,5-1,2 mm - fine grain; 1,2-2,5 mm - medium grain; > 2,5 mm - coarse grain.

The use of stable isotope analysis for marble provenance studies is well-established, widely used, and a basic premise for any marble provenance analysis (Attanasio et al. 2006). However, the exclusive use of stable isotope analysis without other methodological approaches leads to satisfactory results only in very rare cases. All the artifacts and new quarry samples were also investigated isotopically.[15]

The application of trace element analysis in marble analysis started earlier than the introduction of isotopic analysis. In this context, it is important to highlight that the elements incorporated in the carbonate lattice (Mg, Fe, Mn, Sr, and Zn) have a rather homogeneous and uniform distribution and can be advantageously used to distinguish between different types of white marble. Distinguishing several important ancient marble sources through stable isotope analysis is problematic, with considerable overlap in the corresponding compositional range. In the last few years, ICP-MS analysis has been used as a new method for marble provenance studies, extending the number of chemical variables into the low or sub-ppm levels. The encouraging results obtained with this method show several trace elements that discriminate very well among the studied marble from different sources (e.g., Vola et al. 2022). These elements are Mg, Mn, Sr, Fe, La, Ce, Cd, Ba, Y, Yb, U, etc. Together with the conventionally obtained analytical variables and the evaluation by multivariate statistical analysis, very good discrimination between the archaeological and geological samples can be achieved (Prochaska and Attanasio 2021, 2022). All the artifacts and new quarry samples were also chemically investigated, and the complete data can be accessed in the supplementary material.

Fluid inclusion analysis is based on a "crush and leach" method of extractable total dissolved solids (TDS) from marble and carbonate rocks in general. These solutes occur mainly in very small fluid-filled voids, called fluid inclusions, found in all marble. The results of studies on fluid inclusions in carbonate rocks show that the fluid phase is usually relatively uniform in terms of its chemical composition. Using ion chromatography, several chemical parameters (cations and anions) can be detected simultaneously. In recent years, this method has been used repeatedly to distinguish between different marble when other methods failed (Prochaska and Grillo 2010). All the examined artifacts and new quarry samples were also investigated by this method.

The collection and application of many variables require statistical data processing. The results of bulk rock isotopic, trace element, and fluid inclusion chemical analysis were treated by multivariate discriminant analysis for statistical evaluation and data processing.[16] STATISTICA and SPSS computer software was used for these calculations.[17]

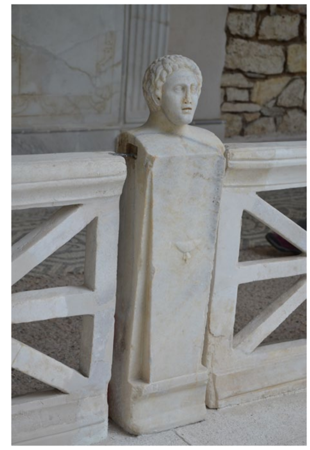

Fig. 6 PM-BG-132: Herm stele from the impluvium of the villa (ph. V. Anevlavi, ÖAI/ÖAW)

The sampled artifacts

The high-grade white marble deposits in inland Thrace have not yet been systematically explored. The 2018 and 2019 sampling campaigns investigated the marble quarries and outcrops in the eastern Rhodopes and white marble from the Roman Villa Armira.

Samples were taken in the form of small chips (approximately 1 g) from a suitable location of an existing old breakage, without destroying the archaeological/art-historical information and the aesthetic value. Artifacts were sampled mainly from the architecture of the peristyle: 17 pilaster capitals, 10 revetment plates, 7 blocks of the balustrade, 5 hermae, etc. (Figs. 6, 7, 8). Most of the artifacts are still in situ in the partly reconstructed villa, while other pieces are located at the National Archaeological Institute with Museum in Sofia (NAIM) and the Regional Historical Museum of Ivaylovgrad (RHMI). The samples, their marble description, and the results are presented below (Table 3).

[15] For complete data, see the supplementary material.

[16] For the detailed instrumentation reference and the sample preparation procedure, preparation: see Prochaska. Attanasio 2021 and Prochaska, Attanasio 2022.

[17] The supplementary material of this paper includes the analytical data from the archaeological samples of Villa Armira and Kasnakovo, as well as a series of SE Rhodope quarries. The Supplementary material provides the data with the lab and sample number (including the quarry locations). From columns C – N the ion-chromatography data are displayed (including Lithium, Sodium, Potassium, Magnesium, Calcium, Fluorine, Chlorine, Bromine, Iodine-Jod, Nitrate, Sulfite Ion in rations and DS is the amount of sodium. potassium and chlorine in ppb referring to the extracted solution). Columns P and Q show the stable isotopic values of Carbon and Oxygen. The columns S – U provide the chemical values from the ICP-MS analysis (including Magnesium, Manganese, Iron, Strontium, Chromium, Vanadium, Yttrium, Cadmium, Boron, Lanthanum, Cerium, Praseodymium, Dysprosium, Holmium, Ytterbium, Lead, and Uranium, data in ppm).

Fig. 7 PM-BG-110/111/112: The door in the peristyle of the villa (ph. V. Anevlavi, ÖAI/ÖAW)

Fig. 8 PM-BG-126/127/128: A Corinthian capital, column, and base at the corner of the impluvium (ph. V. Anevlavi, ÖAI/ÖAW)

Petrographic analysis

The ubiquitous textural feature of the marble used for the architectural and decorative artifacts at the villa Armira includes a penetrative deformation to highly differing degrees. This phenomenon can be observed in all marble sources from the Rhodope Mountains. The lithological units have been metamorphosed up to the amphibolite facies degree during Cretaceous crustal thickening and nappe-stacking (Burg et al. 1996). Crustal extension and detachment faults in Upper Eocene to Oligocene resulted in rapid cooling. The strongly deformed texture of the investigated marble results from multiple syn- to post-crystalline deformational events (Dimov et al. 2000; Ovtcharova et al. 2003). This extreme deformation, up to ultramylonites, can be observed at every scale with the degree of deformation varying within a few centimeters. In the case of the Lensko

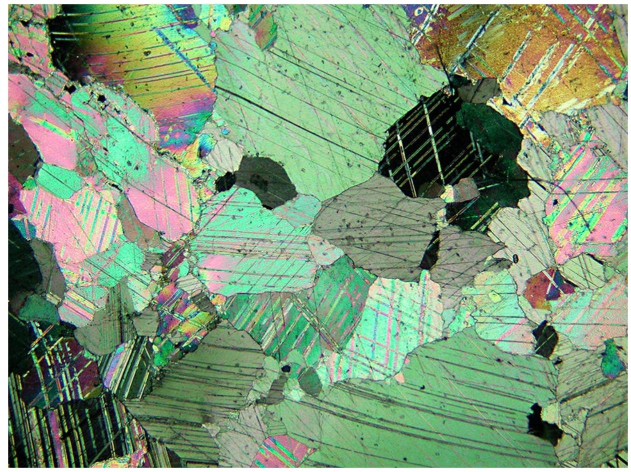

Fig. 9 Micro-photograph of the frieze marble (PM-BG-117) as an example of one of the less deformed marbles of the villa where signs of post crystalline deformation are rare (cross-polarized light, length of the image is 6 mm) (Ph. W. Prochaska, ÖAI/ÖAW)

quarry (Anevlavi et al. in press), this type of marble can cover an entire quarry. In general, all investigated marble sources around Villa Armira are calcitic, although a few outcrops of dolomitic marbles were also found.

The marble artifacts from the villa are white, and the amount of minor or accessory minerals is generally very low. The least deformed textures among the investigated artifacts are coarse- to very coarse-grained marble with an average grain size of 6 mm or more. This suggests that the investigated marbles underwent a high metamorphic degree (amphibolite facies), prior to deformation. The following section will present the microtextures of a series of samples with increasing deformational fabrics.

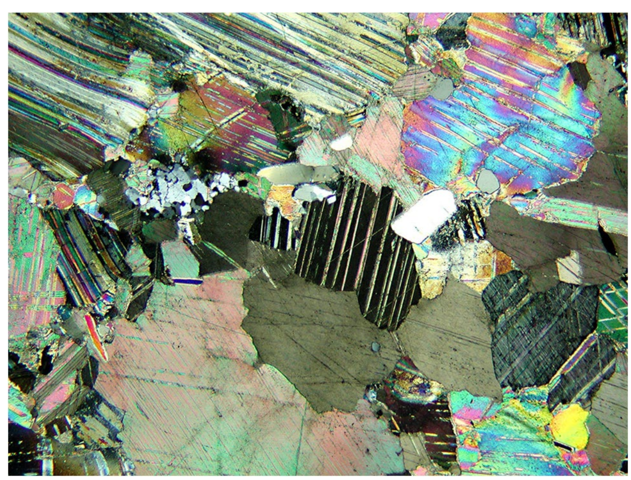

Fig. 10 Micro-photograph of sample no. PM-BG-147, a relatively slightly deformed marble from a revetment plate at Villa Armira. Quartz, mica, chlorite, apatite, and sphene are present in subordinate amounts (cross-polarized light, length of the image is 6 mm) (Ph. W. Prochaska, ÖAI/ÖAW)

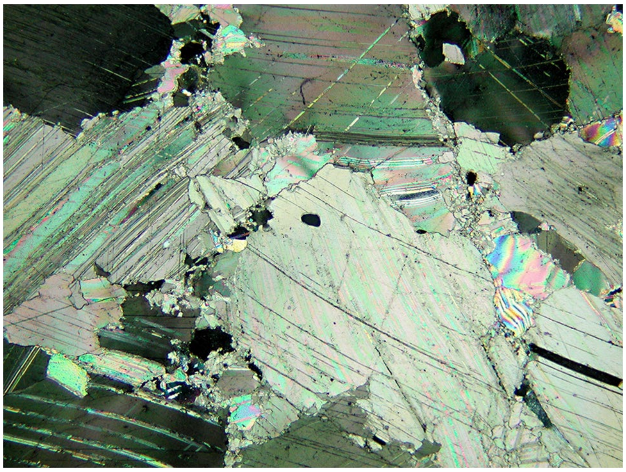

Fig. 11 Micro-photograph of marble of a herm from Villa Armira (sample no. PM-BG-130), exhibiting progressing deformation and formation of subgrains at the grain boundaries of the large calcite porphyroblasts (cross-polarized light, length of the image is 6 mm) (Ph. W. Prochaska, ÖAI/ÖAW)

Of the investigated archaeological samples, one of the least deformed examples comes from a villa frieze (sample no. PM-BG-117), although clear signs of substantial deformation, such as deformed twin lamellae, are also detected here (Fig. 9). The maximum grain size is approximately 6 mm. The grain boundaries are slightly intermeshed, and a beginning formation of small sub-grains between the big porphyroblasts can be observed. This process progresses continuously, resulting in a highly serrated texture (Collerson 1974). Quartz occurs as a minor constituent in the archaeological marble samples at Villa Armira. Slightly deformed mica with very weak brownish pleochroism also occurs (phlogopite).

The silicate mineral content is generally low in the Armira marble, both from geological and archaeological samples. One example with minor amounts of non-carbonate impurities comes from a revetment plate (Fig. 10), and this again shows some signs of deformation. The maximum grain size is approximately 6 mm. Quartz occurs in this sample as a minor constituent. Slightly deformed mica with very weak brownish pleochroism also occurs (phlogopite), as does a fractured grain of sphene. The overall silicate mineral content of this sample is approximately 2%, which is exceptionally high for marble from the Villa Armira.

Further progressing deformation is indicated in the decay of the large calcite porphyroblasts. The formation of smaller subgrains starts at the grain boundaries of the bigger calcite crystals (Figs. 11, 12) resulting in abundant serrated grain boundaries. This is the prevailing texture of the Villa Armira marble artifacts and is used in all kinds of decorative architecture. The tectonic deformation and the formation of subgrains are overprinted by extensive recrystallization resulting in a very strong and tough fabric very well suited for sculptural purposes. Figure 11 presents the marble of a herm at the villa.

The process of increasing deformation and grain size reduction finally leads to an extremely fine-grained texture where larger relic grains can only be observed occasionally. Macroscopically, the varieties with the most intense deformation exhibit a vitreous fracture and a porcelain-like appearance. Usually, these extremely fine-grained varieties were not used in decorative architecture; however, in Villa Armira, the white tesserae were made of this type of marble (e.g., sample PM-BG-146, Fig. 13) (Ph. W. Prochaska, ÖAI/ÖAW).

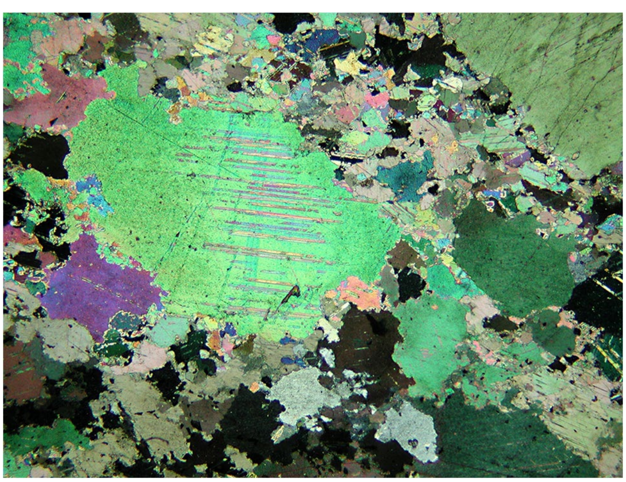

Fig. 12 Micro-photograph of marble of a pilaster (sample PM-BG-122) from Villa Armira. Increasing grain size reduction is due to tectonic deformation and results in serrated grain boundaries of the calcite porphyroblasts and the formation of a fine-grained calcite groundmass (cross-polarized light, length of the image is 6 mm) (Ph. W. Prochaska, ÖAI/ÖAW)

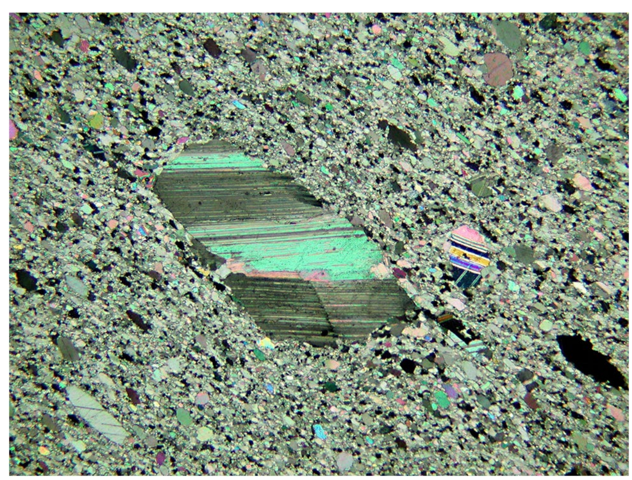

Fig. 13 Micro-photograph of a tessera (PM-BG-146) from the Villa Armira. Extreme tectonic deformation results in an ultramylonitic calcite texture. Displayed are relicts of calcite porphyroblasts in a very fine-grained groundmass (cross-polarized light, length of the image is 6 mm) (Ph. W. Prochaska, ÖAI/ÖAW)

Results

The archaeological samples we compared against a database of 4700 geological samples from marble quarries and outcrops from the ancient world, including Aphrodisias, Carrara, Prokonnesos, Dokimeion, Pentelikon, Paros, Thasos, Miletos/Heraklea, and Ephesos. Locations in their vicinities such as Greek Macedonia, Thrace, and North Macedonia were also explored. The following diagrams provide the final selection of quarries with the closest chemical similarities to the examined archaeological examples.

From the petrographic analysis, all Villa Armira artifacts were made of calcitic marble, and this is corroborated by their Mg values (see supplementary material) (Table 2). Due to the small size of the specimen from each sampled artifact, a limited collection was selected for the preparation of thin sections. The most characteristic samples are presented in this paper. The data (isotopic values, chemical and fluid data) were evaluated with the assistance of statistical programs. For each group of artifacts, a primary isotopic diagram was performed, following a multivariate diagram. Below are the final and representative diagrams.

The new data show the presence of two distinct groups of marble in the region with a distinct isotopic composition (Fig. 14). One group (Armira 1, Kamilski Dol 1, and 3) is exceptionally ^{13}C enriched, ranging between + 5 and + 6‰. The group with the lighter C-isotopic composition has a wide range of O-isotopic values, probably due to different degrees of metamorphic overprinting and recrystallization.

Table 2 Collective results from the petrographic analysis

Sample number	Petrographic description
PM-BG-117	Calcitic marble; An example of one of the less deformed marbles of the villa, where signs of post-crystalline deformation are rare
PM-BG-122	Calcitic marble; Increasing grain size reduction is due to tectonic deformation and results in highly serrated grain boundaries of the calcite porphyroblasts and the formation of a fine-grained calcite groundmass
PM-BG-130	Calcitic marble; Exhibiting progressing deformation and formation of subgrains at the grain boundaries of the large calcite porphyroblasts
PM-PG-146	Calcitic marble; Extreme tectonic deformation results in an ultramylonitic calcite texture. Displayed are relicts of calcite porphyroblasts in a very fine-grained groundmass
PM-BG-147	Calcitic marble; A relatively slightly deformed marble from a revetment plate at Villa Armira. Quartz, mica, chlorite, apatite, and sphene are present in subordinate amounts

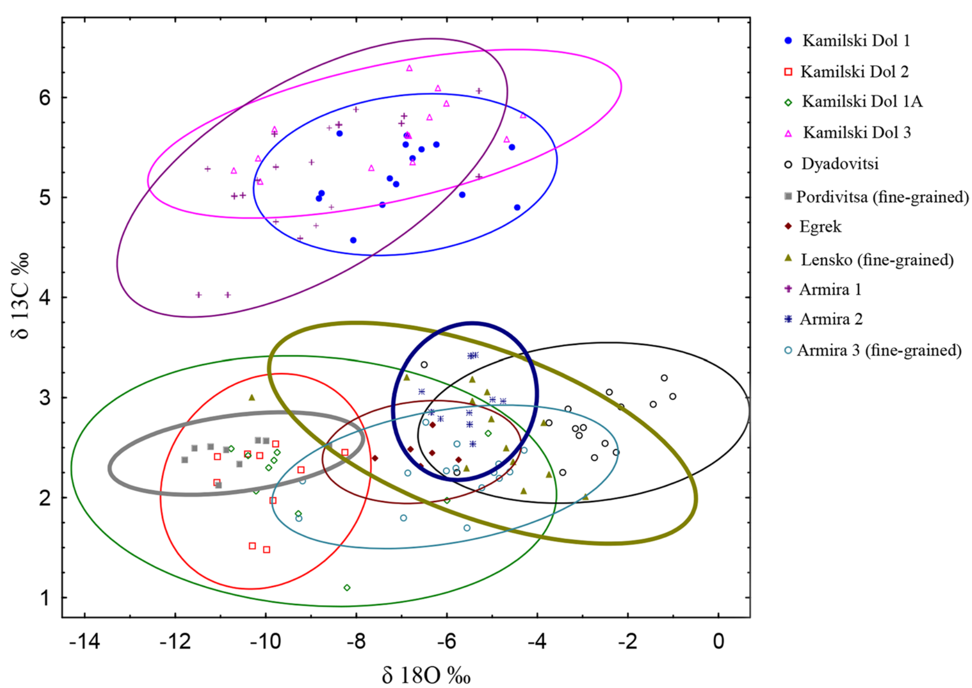

Fig. 14 Isotope diagram of the quarries of the Eastern Rhodopes. Pordivitsa, Lensko, and Armira 3 are fine-grained, white marble quarries. The rest of the locations are medium to coarse-grained, white to greyish marble quarries (ed. V. Anevlavi, ÖAI/ÖAW)

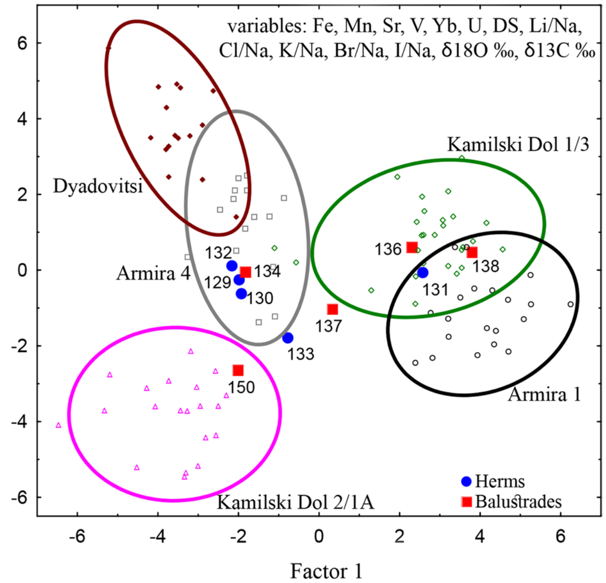

Fig. 15 The multivariate diagram of the hermae and the balustrades. The results show the use of Armira 4 and Kamilski Dol 1/3. The used variables are Fe, Mn, Sr, Cd, V, Y, La, Ce, Yb, U, DS, Li/Na, Cl/Na, K/Na, Br/Na, I/Na, $\delta^{18}O$ ‰, and $\delta.^{13}C$ ‰ (ed. V. Anevlavi, ÖAI/ÖAW)

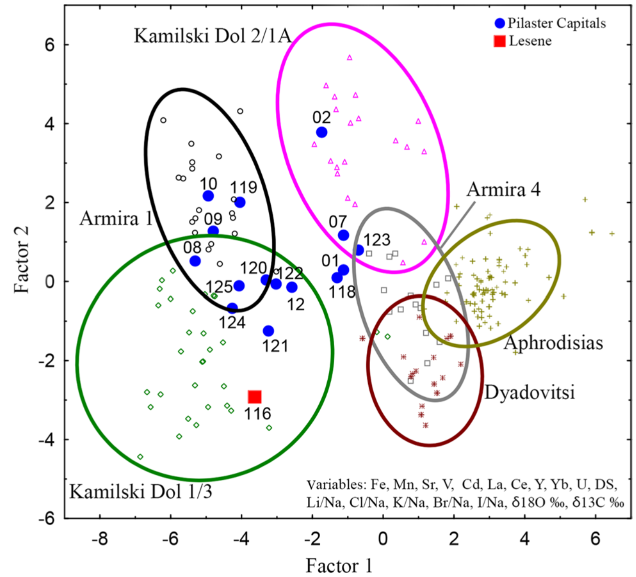

Fig. 16 The pilaster capitals originate from the Kamilski dol and Armira quarries. The used variables are Fe, Mn, Sr, Y, La, Ce, Yb, DS, Li/Na, Cl/Na, K/Na, Br/Na, I/Na, δ18O ‰, and δ13C ‰ (ed. V. Anevlavi, ÖAI/ÖAW)

The results of the analyses on archaeological objects indicated the exclusive use of local sources.[18] More specifically, the studied hermae are made of Armira marble, and the balustrades decorating the impluvium in the central peristyle can be classified into two groups, Armira and Kamilski Dol. While previous studies suggested an Aphrodisian origin of the white marble used for the decoration of the villa, the analytical results demonstrate a local origin of the featured materials. The samples with high $d^{13}C$ values originate from Kamilski Dol 1/3, while the samples with low $d^{13}C$ values of this group derive from Armira 4. The multivariate diagram of this group shows a clear separation of the presented quarries (Fig. 15).

In decorative architecture, two quarry sources appear Kamilski Dol and Armira. A larger number of pilaster capitals (9) originate from the Armira area (Fig. 16). Majority of the architectural elements (including a Corinthian capital, a column, stylobate fragments, bases, and doors) originate from Armira 1 (Fig. 17 and Table 3). The examined tesserae made of white fine-grained marble were compared with the relevant fine-grained quarries. The results showed that the marble source was Pordivitsa, approximately 80 km from the villa (Fig. 18).

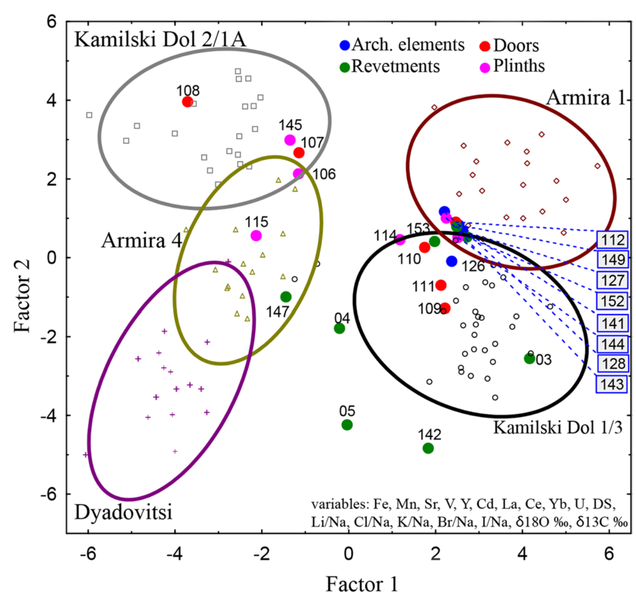

Fig. 17 The multivariate diagram of the architectural elements of the villa. The results show the use of Kamilski Dol 1/3 and Armira 1. The used variables are Fe, Mn, Sr, Cd, V, Y, La, Ce, Yb, U, DS, Li/Na, Cl/Na, K/Na, Br/Na, I/Na, δ18O ‰, and δ13C ‰. (ed. V. Anevlavi, ÖAI/ÖAW)

[18] Each quarry field is represented by an 90% ellipse.

Table 3 The sampled artifacts, their marble description, and the provenance results (Ed. V. Anevlavi, W. Prochaska, ÖAI/ÖAW)

Project Nr	Inv. Nr	Lab Nr	Object	Findspot	Location	Marble description	Relat. Prob[a]	Results
PM-BG-001	8460	7701	Pilaster capital	Peristylium	NAIM	Medium to coarse-grained; white color	**93.6**	**Armira 4**
PM-BG-002	8461	7702	Pilaster capital	Peristylium	NAIM	Medium coarse-grained; white color;	**100.0**	**Kamilski Dol 2/1A**
PM-BG-003	8455b	7703	Revetment plate	Peristylium	NAIM	Medium to coarse-grained; grey color	**99.9**	**Kamilski Dol 1/3**
PM-BG-004	8465b	7704	Revetment plate	Peristylium	NAIM	Medium to coarse-grained; white color	**96.9**	**Armira 4**
PM-BG-005	8465a	7705	Revetment plate	Peristylium	NAIM	Medium to coarse-grained; white color	**95.6**	**Kamilski Dol 1/3**
PM-BG-007	8462	7707	Pilaster capital	Peristylium	NAIM	Medium to coarse-grained; white color	**97.0**	**Kamilski Dol 2/1A**
PM-BG-008	8458	7708	Pilaster capital	Peristylium	NAIM	Medium-grained; white color	**99.3**	**Armira 1**
PM-BG-009	8464	7709	Pilaster capital	Peristylium	NAIM	Medium-grained; white color	**100.0**	**Armira 1**
PM-BG-010	8459	7710	Pilaster capital	Peristylium	NAIM	Medium-grained; white color	**100.0**	**Armira 1**
PM-BG-011	8457	7711	Pilaster capital	Peristylium	NAIM	Medium to coarse-grained; white color	**100.0**	**Kamilski Dol 2/1A**
PM-BG-012	8463	7712	Pilaster capital	Peristylium	NAIM	Medium to coarse-grained; white color	**93.9**	**Armira 1**
PM-BG-014	K8488	7714	Frieze Architrave	Impluvium	NAIM	Medium to coarse-grained; white, greyish color	**93.4**	**Armira 1**
PM-BG-106	No inv	7806	Door lintel	Peristylium	Peristylium	Medium to coarse-grained; white color	**81.0**	**Armira 4**
PM-BG-107	No inv	7807	Door lintel	Peristylium	Peristylium	Medium to coarse-grained; white color	**98.2**	**Kamilski Dol 2/1A**
PM-BG-108	No inv	7808	Door frame	Peristylium	Peristylium	Medium to coarse-grained; white, grey color	**100.0**	**Kamilski Dol 2/1A**
PM-BG-109	No inv	7809	Door frame	Peristylium	Peristylium	Medium to coarse-grained; white, grey color	**100.0**	**Kamilski Dol 1/3**
PM-BG-110	No inv	7810	Door frame	Peristylium	Peristylium	Medium to coarse-grained; white, grey color	**98.8**	**Armira 1**
PM-BG-111	No inv	7811	Door frame	Peristylium	Peristylium	Medium to coarse-grained; white, grey color	**100.0**	**Kamilski Dol 1/3**

Table 3 (continued)

Project Nr	Inv. Nr	Lab Nr	Object	Findspot	Location	Marble description	Relat. Prob[a]	Results
PM-BG-112	No inv	7812	Door lintel	Peristylium	Peristylium	Medium to coarse-grained; white, grey color	**99.2**	**Armira 1**
PM-BG-113	No inv	7813	Plinth	Peristylium	Peristylium	Medium to coarse-grained; white, grey color	**91.3**	**Kamilski Dol 1/3**
PM-BG-114	No inv	7814	Plinth	Peristylium	Peristylium	Medium to coarse-grained; white, grey color	**69.1**	**Armira 1**
PM-BG-115	No inv	7815	Plinth	Peristylium	Peristylium, West wall	Medium to coarse-grained; white, grey color	**96.7**	**Armira 4**
PM-BG-116	65 (old)	7816	Lesene	Peristylium	Peristylium, West wall	Medium to coarse-grained; white, grey color	**100.0**	**Kamilski Dol 1/3**
PM-BG-117	No inv	7817	Frieze Architrave	Peristylium	Peristylium;	Medium to coarse-grained; white color	**96.9**	**Armira 4**
PM-BG-118	224a old	7818	Pilaster capital	Peristylium	Peristylium	Medium to coarse-grained; white color	**95.2**	**Armira 4**
PM-BG-119	No inv	7819	Pilaster capital	Peristylium	Peristylium	Medium to coarse-grained; white color	**43.5**	**Kamilski Dol 1/3**
PM-BG-120	No inv	7820	Pilaster capital	Peristylium	Peristylium	Coarse-grained; greyish color	**73.4**	**Armira 1**
PM-BG-121	226 old	7821	Pilaster capital	Peristylium	Peristylium	Medium to coarse-grained; white color	**97.5**	**Kamilski Dol 1/3**
PM-BG-122	No inv	7822	Pilaster capital	Peristylium	Peristylium	Coarse grain grey	**97.9**	**Armira 1**
PM-BG-123	No inv	7823	Pilaster capital	Peristylium	Peristylium	Coarse-grained; white color	**90.1**	**Kamilski Dol 2/1A**
PM-BG-124	No inv	7824	Pilaster capital	Peristylium	Peristylium	Coarse-grained; white color	**55.8**	**Kamilski Dol 1/3**
PM-BG-125	No inv	7825	Pilaster capital	Peristylium	Peristylium	Coarse-grained; white color	**96.6**	**Kamilski Dol 1/3**
PM-BG-126	No inv	7826	Corinthian capital	Peristylium	Peristylium	Medium to coarse-grained; white color	**80.8**	**Armira 1**
PM-BG-127	No inv	7827	Twisted column	Peristylium	Peristylium	Medium to coarse-grained; white color	**96.0**	**Armira 1**
PM-BG-128	No inv	7828	Stylobate block	Peristylium	Peristylium	Medium to coarse-grained; white to greyish color	**99.8**	**Armira 1**
PM-BG-129	No inv	7829	Herm	Peristylium	Peristylium	Coarse-grained; white color	**99.3**	**Armira 4**
PM-BG-130	No inv	7830	Herm	Peristylium	Peristylium	Coarse-grained; white color	**93.5**	**Armira 4**

Table 3 (continued)

Project Nr	Inv. Nr	Lab Nr	Object	Findspot	Location	Marble description	Relat. Prob[a]	Results
PM-BG-131	No inv	7831	Herm	Peristylium	Peristylium	Coarse-grained; white color	**99.7**	**Armira 1**
PM-BG-132	No inv	7832	Herm	Peristylium	Peristylium	Coarse-grained; white color	**99.9**	**Armira 4**
PM-BG-133	No inv	7833	Herm	Peristylium	Peristylium	Coarse-grained; white color	**78.2**	**Armira 4**
PM-BG-134	No inv	7834	Balustrade block	Peristylium	Peristylium	Coarse-grained; white color	**98.4**	**Armira 4**
PM-BG-135	No inv	7835	Balustrade block	Peristylium	Peristylium	Coarse-grained; white color	**93.1**	**Armira 4**
PM-BG-136	No inv	7836	Balustrade block	Peristylium	Peristylium	Coarse-grained; white color	**83.5**	**Kamilski Dol 1/3**
PM-BG-137	No inv	7837	Balustrade block	Peristylium	Peristylium	Coarse-grained; white color	**57.2**	**Armira 4**
PM-BG-138	No inv	7838	Balustrade block	Peristylium	Peristylium	Coarse-grained; white color	**90.8**	**Armira 1**
PM-BG-139	386 old	7839	Frag, of a Corinthian capital	Peristylium	Peristylium (porticus)	Coarse-grained; white to greyish color	**62.9**	**Kamilski Dol 1/3**
PM-BG-140	No inv	7840	Frag. of frieze architrave	Peristylium	Peristylium (porticus)	Coarse-grained; white to greyish color	**75.9**	**Armira 1**
PM-BG-141	424 old	7841	Revetment plate	Peristylium	Peristylium (porticus)	Coarse-grained; white to greyish color	**93.3**	**Armira 1**
PM-BG-142	432 old	7842	Revetment plate	Peristylium	Peristylium (porticus)	Coarse-grained; white to greyish color	**100.0**	**Kamilski Dol 1/3**
PM-BG-143	1329b	7843	Plinth	Room 6	Room 6	Coarse-grained; white to greyish color	**99.5**	**Armira 1**
PM-BG-144	1331	7844	Plinth	Room 6	Room 6	Coarse-grained; white to greyish color	**99.6**	**Armira 1**
PM-BG-145	1105	7845	Plinth	Room 6	Room 6	Coarse-grained; white to greyish color	**91.4**	**Kamilski Dol 2/1A**
PM-BG-146	No inv	7846	Tessera	Villa	Mosaic	Fine-grained; white color	**100.0**	**Pordivitsa**
PM-BG-147	No inv	7847	Revetment plate	Main Entrance from W	Main Entrance from W	Coarse-grained; white color	**88.4**	**Kamilski Dol 1/3**
PM-BG-148	No inv	7848	Column	Main Entrance from W	Main Entrance from W	Coarse-grained; white color	**91.5**	**Kamilski Dol 1/3**
PM-BG-149	No inv	7849	Column base	Main Entrance from W	Main Entrance from W	Medium to coarse-grained; white color	**98.2**	**Armira 1**
PM-BG-150	1141 old	7850	Balustrade block	Peristylium	Depot	Medium to coarse-grained; white color	**100.0**	**Kamilski Dol 2/1A**
PM-BG-151	No inv	7851	Revetment plate	Villa	Depot	Breccia	**88.2**	**Kamilski Dol 2/1A**
PM-BG-152	No inv	7852	Revetment plate	Villa	Depot	Coarse-grained; white color	**68.8**	**Armira 1**

Table 3 (continued)

Project Nr	Inv. Nr	Lab Nr	Object	Findspot	Location	Marble description	Relat. Prob[a]	Results
PM-BG-153	No inv	7853	Revetment plate	Villa	Depot	Coarse-grained; white, grey color	**99.4**	**Armira 1**
PM-BG-156	393 new	7856	Frag. of frieze architrave	Peristylium	RHMI	Medium to coarse-grained; white color	**82.6**	**Armira 4**
PM-BG-157	98a old	7857	Frag. of frieze architrave	Peristylium	RHMI	Medium to coarse-grained; white color	**86.3**	**Armira 4**
PM-BG-158	257 old	7858	Frag. of frieze architrave	Peristylium	RHMI	Medium to coarse-grained; white color	**87.9**	**Armira 4**
PM-BG-159	237 old	7859	Frag. of pilaster capital	Peristylium	RHMI	Coarse-grained; white color	**88.7**	**Armira 1**
PM-BG-208	No inv	7908	Tessera	Large room	Large room	Fine-grained, grey color	**–**	**Unknown**
PM-BG-209	No inv	7909	Tessera	Large room	Large room	Fine-grained; white color	**99.9**	**Pordivitsa**

[a]Relative (posterior) probability: Probability of the sample belonging to some group within the assumption that it originates in any case from one of the groups in the selection. The threshold is 60%. Low values indicate that the sample's assignment is in doubt between two or more groups

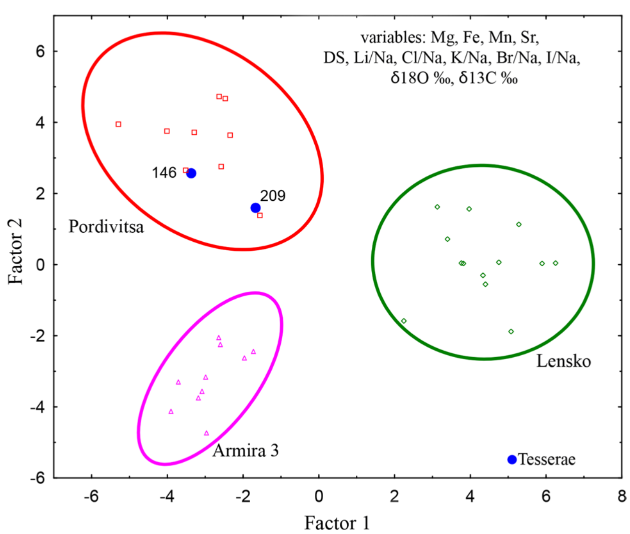

Fig. 18 The multivariate diagram of the tesserae. The results showed the use of Pordivitsa marble. The used variables are Fe, Mn, Mg, Sr, DS, Li/Na, Cl/Na, K/Na, Br/Na, I/Na, δ18O ‰, δ13C ‰ (ed. V. Anevlavi, ÖAI/ÖAW)

Discussion

The analyses of the marble inventory from the villa of Armira clearly demonstrate that all architectonical and decorative elements originated from regional sources. Their importation from Asia Minor (or elsewhere) can be confidently ruled out. Their origin includes ancient quarries next to the villa and larger ancient quarries near Kamilski Dol at approximately 27 km. The importance of Kamilski Dol in antiquity is highlighted by the presence of in situ ancient artifacts, such as a stele now kept at the Kardzhali Regional Museum of History. Quarry sources in the south-eastern Rhodope Mountains were all close to main road networks and rivers, the preferred method of transportation. This faster and cheaper transportation method helped facilitate the construction of marble buildings in cities like Philippopolis and Augusta Traiana, which were laid along navigable rivers (Russell 2013). At Armira, the situation is different. The rivers were not navigable, and the stone had to be transported overland. This applies both to the nearby Armira quarries and to the more distant mining areas of Kamilski Dol, and it is striking to conclude that marble from Kamilski Dol and Armira was used for the same groups of objects. This observation is a sure indication that raw blocks or semi-finished products were delivered from the two quarries to the villa and finished herespeak. The most important and striking result of our analysis demonstrates that practically, no imported marble was used in the construction of the Villa Armira, although the owners were certainly high-ranked members of the provincial elite.

Marble from Kamilski Dol might have been transported to main inland Thracian cities and contributed to the monumental shaping of these centers. It was also used for the decoration of private estates such as the villa Armira (Fig. 19). The use of Kamilski Dol marble has also been recognized

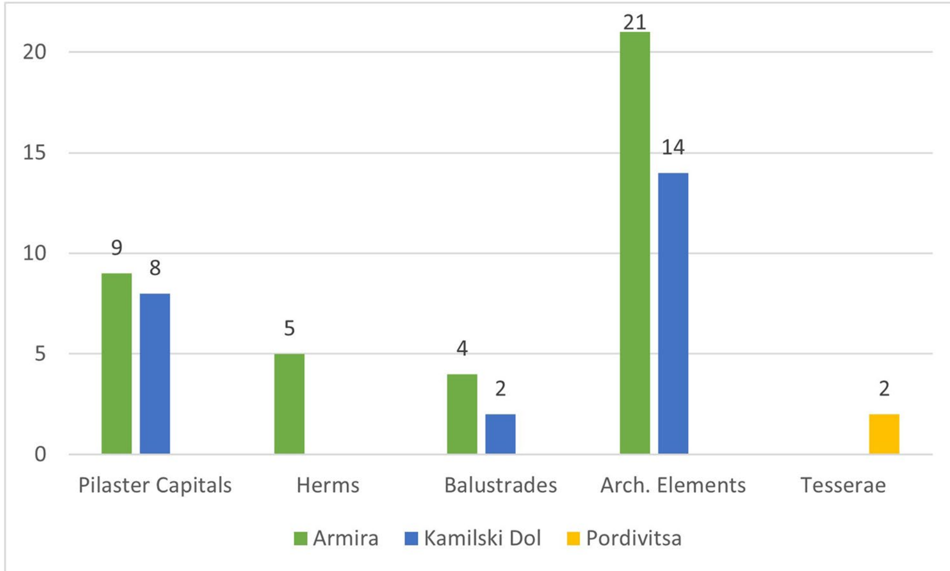

Fig. 19 The general charts of the results show the marble distribution among the three locations Kamilski Dol, Armira, and Pordivitsa (ed. V. Anevlavi, ÖAI/ÖAW)

in the few surviving white marble decorative elements at the Roman villa in Kasnakovo (Anevlavi et al. 2019). Everything seems to indicate that the quarries of Kamilski Dol and Armira were of particular importance in the Roman Imperial period and supplied marble across the province of Thrace. Due to the high quality of this raw material, it was used in representative elaborate contexts and to produce decorative building elements. The proven use and processing of regional marble for the production of exquisite artifacts speak to the presence of highly specialized craftsmen. It is possible that this went hand in hand with the development and use of quarries and that a link existed between quarrying activities and ownership of the villa. In addition to a representative wing, the villa of Armira also had a *pars urbana*, i.e., a production area. Looking at the topographical location of the villa and its catchment area, it becomes clear that it is situated at a crossroads between large agricultural production areas in the south and raw material deposits in the mountains in the north. On the territory of the villa, there were also mining sites, which, according to Roman custom, were operated either by the villa owners themselves or by tenants through subcontracts. The elaborate and quite unusual decoration of the peristyle with its emphasis on local marble can be taken as an indication that marble quarrying was an economic mainstay of the family that owned the villa of Armira (Kabakchieva 2012). The luxurious marble furnishings of the representative products, part of their large estate, would thus be an expression of their business. This would also explain why imported white or colored marble is missing.

The areas around Kamilski Dol and Armira seem to have been important economic regions for Roman Thrace. We draw this preliminary conclusion on the basis of the current marble source results and the geological and archaeological research conducted in the last few decades, resulting in the identification of precious metal mining activities in the eastern Rhodope Mountain region (Milev et al. 2007; Popov et al. 2011). This is especially true for Kamilski Dol where the remains of large goldmines were found in the vicinity of known marble quarries. Its preliminary dating places it in Roman Antiquity (Nakov et al. 2001; Popov and Tsintsov 2010). These observations were confirmed and significantly amplified during our team's fieldwork in the region (Georgiev et al. 2020).

The development of the economic branches related to the Roman period's exploitation of important raw materials in the eastern Rhodope Mountains corresponds to the development of a related road network. The natural communication between the eastern periphery of the Rhodope Mountains in the regions of Armira and Kamilski Dol is open to the east towards the valley of the Maritsa River. As noted, Armira was administered by Hadrianopolis. The use of marble from Pordivitsa for the tesserae might suggest the presence of a workshop specializing in the production of mosaics in the area (for mosaics production see Scheibelreiter-Gail 2011; Urbankova 2013), tying this location to the larger network in this area.

Future investigation

The present study motivated further exploration of Roman Thrace under a new FWF project (no: P 33,042) at the Austrian Academy of Sciences. In the summer of 2020, the project started with the aim of determining the geochemical-petrographic fingerprint of white marble in Roman

Thrace from the first to the third century AD. The focus is on cities, quarries, and especially marble prestige objects, artifacts, and building materials. In the second century AD, during the urbanization of Thrace, the demand for marble increased drastically. The project examines white marble in this province with a focus on identifying local resources and imports. The project also explores the economic foundations of the stone trade, the logistics of the marble trade, and the monumentalization of urban spaces. In the spring of 2021, an overflight of seven areas in the south-eastern Rhodope Mountains was arranged, and LiDAR scans were made of the marble quarry areas. As a result of the information provided by this non-destructive method, the registration and mapping of old quarries in densely forested and inaccessible regions can actively continue. This method provided us with field information about possible marble quarries and mining of precious metals and gneiss. Future work will incorporate the sampled artifacts from the current project and the quarries of Armira and Kamilski Dol, into an investigation on the production and exportation of materials from these sources to nearby sites (e.g., archaeological samples from the sanctuary of Lozen), and across larger Roman complexes (e.g., cities of Philippopolis, Augusta Traiana, Pautalia). The expansion of the existing database is ongoing and includes white marble quarries from the areas of Asenovgrad, Topolovgrad, and Malko Tarnovo.

Moreover, extensive research by Andrianou and Lazzarini around Greek Thrace and Macedonia provided new avenues for exploring marble trade networks and discussions around trade and connectivity between provinces. The analytical work on local quarries and a large group of grave monuments highlighted the local, Thasian and Prokonnesian use of marble (Andrianou and Lazzarini 2013, 2020; Lazzarini 2017). The research at Villa Armira, the ongoing project on the use of marble in inland Trace, and the results presented by Andrianou and Lazzarini all emphasize the necessity of investigating these important sites located along the lower reaches of the Maritsa/Evros River in modern Greece and Turkey.

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Author contribution All authors contributed to the study's conception and design. Material sampling, cataloging, and photographing were conducted by VA, WP, CC, SL, HP, PG, and GK. The preparation, data collection, and analysis were performed by VA and WP. All authors read and approved the final manuscript.

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