

# NEW INSIGHTS ON MATERIAL USE FOR ROMAN AND LATE ANTIQUE SARCOPHAGI IN THE BASILICA OF SAN APOLLINARE IN CLASSE (RAVENNA, ITALY)

## ÚJ ISMERETEK A RÓMAI ÉS KÉSŐ ANTIK SZARKOFÁGOK ANYAGHASZNÁLATÁRÓL A SAN APOLLINARE IN CLASSE BAZILIKÁBAN (RAVENNA, OLASZORSZÁG)•

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### Abstract

*This paper presents the provenance of white marble used in late antique sarcophagi from the Basilica of San Apollinare in Classe (Ravenna), challenging the long-held assumption that most marble came from the quarries of Proconnesos (Marmara Island, Turkey) in the Eastern Mediterranean. While previous studies have relied primarily on stylistic, typological analysis and historical presumptions, the research of this project uses a combination of non-destructive and minimally invasive methods, including macroscopic and microscopic examination, Raman spectroscopy, X-ray fluorescence spectroscopy,  $\delta^{18}\text{O}$  and  $\delta^{13}\text{C}$  stable isotope analysis. The analysis of sarcophagi from the Basilica of San Apollinare in Classe reveals the use of different types of marble, showing a combination of marbles from different quarries. The results of the analyses indicate that in addition to Proconnesos marble, material from quarries on Thassos and Paros was also used in the Ravenna region. The results emphasise the diversity of marble sources beyond Proconnesos, including quarries in Asia Minor, Thassos and Paros. This study contributes to a broader understanding of Mediterranean trade networks and artistic production in Late Antiquity, and also highlights the need for further research into the marble trade in the northern Adriatic.*

### Kivonat

*Ez a tanulmány a Ravenna közelében lévő San Apollinare in Classe bazilikából származó késő antik szarkofágokban használt fehér márvány eredetét vizsgálja, megkérdőjelezve azt a régóta fennálló feltételezést, hogy a legtöbb márvány a Kelet-Mediterrán térség keleti részén található Proconnesos (Marmara-sziget, Törökország) kőbányáiból származik. Míg a korábbi tanulmányok elsősorban stilisztikai, tipológiai elemzésekre és történelmi feltételezésekre támaszkodtak, addig a jelen projekt keretében végzett kutatás roncsolásmentes és minimálisan invazív módszerek kombinációját alkalmazza, beleértve a makroszkópos és mikroszkópos vizsgálatot, a Raman-spektroszkópiát, a  $\delta^{18}\text{O}$  és  $\delta^{13}\text{C}$  stabil izotópelemzést. A San Apollinare in Classe bazilikából származó szarkofágok elemzése különböző márványtípusok használatát tárja fel, néhány szarkofágon különböző kőbányákból származó márványok kombinációja látható. Az elemzések eredményei azt mutatják, hogy a prokonneszoszi márványon kívül a Thassos és Paros kőbányáiból származó anyagot is felhasználtak a prokonneszoszi bányákon kívül. Ez a tanulmány hozzájárul a mediterrán kereskedelmi hálózatok és a késő ókori művészeti termelés szélesebb körű megértéséhez, és rávilágít az Adria északi részén folyó márványkereskedelem további kutatásának szükségességére.*

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KULCSSZAVAK: MÁRVÁNY SZARKOFÁGOK; SZÁRMAZÁSI HELY MEGHATÁROZÁS; RONCSOLÁSMENTES ELEMZÉS; KÉSŐ ÓKOR; RAVENNA; SAN APOLLINARE IN CLASSE



**Fig. 1.:**

Ravenna with the port district of *Civitas Classis*. (Unless otherwise stated, the image attachments are the work of the authors.)

**1. ábra:**

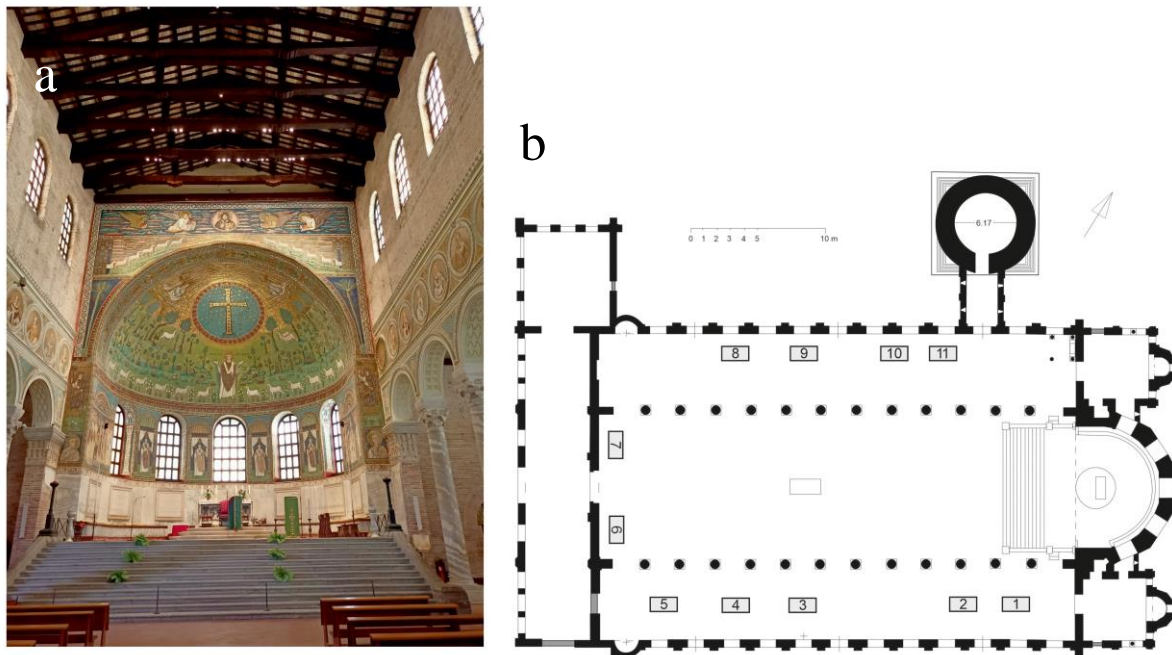
Ravenna a *Civitas Classis* kikötői negyeddel. (Eltérő hivatkozás hiánya esetén a képmelléletek a szerzők munkái.)

## Introduction

It is widely believed that Ravenna (**Fig. 1.**) sourced marble from Proconnesos and the Eastern Mediterranean between the 5<sup>th</sup> and 8<sup>th</sup> centuries. The theory that Proconnesos is one of the main sources of marble is supported by its competitive cost in Antiquity and its wide distribution in the Late Antique Mediterranean (Guidobaldi 2002; Pensabene 1986; Pensabene & Barsanti 2008; Sodini 2002). It is generally considered unlikely that the marble came from Italian quarries, such as Carrara. Thus, the provenance of white marble artefacts preserved in late ancient basilicas was historically attributed mainly to the imperial quarries of Proconnesos on the Marmara Island or, more generally, to some of the Greek or Eastern quarries, or it was left unspecified. However, there was no mention of the methodology of provenance determination, which was based only on macroscopic inspection, historical presumptions and references in the ancient sources (Farioli 1969, 1977, 1983; Angiolini-Martinelli 1968; Valenti-Zucchini & Bucci 1968; Andreas Agnellus XVII,26; XXI,50; XXVI,76; XXXVIII,149). Only the first attempts have been made to study the white and white-grey marble samples found in the basilica and monastery of San Severo in Classe (Tůmová 2013, Tůmová et al. 2016, 2021). The issue of marble provenance is closely linked to the question of commercial exchange and long-distance

trade in the whole of Mediterranean (Kingsley 2009; Laiou & Morriison 2007; Mazzocchin 2003; McCormick 2001; Morriison & Sodini 2002; Panella 1989, 1993; Rizzardi 2016; Walker 1988). The current research carried out on the eleven sarcophagi in the basilica of San Apollinare in Classe was based on macroscopical and microscopical observations, determination of the mineralogical composition using mobile Raman spectroscopy, determination of the chemical composition using X-ray fluorescence spectroscopy, taking small samples with a micro drill and measurement of stable oxygen ( $\delta^{18}\text{O}$ ) and carbon ( $\delta^{13}\text{C}$ ) isotope ratios.

From about the second half of the 19<sup>th</sup> century, the scientific community became interested in the sarcophagi in the basilicas in Ravenna (Garrucci 1881). Interest in the Ravenna sarcophagi continued throughout the first half of the 20<sup>th</sup> century (Wilpert 1929, 1932, 1936), and then especially in the second half of the last century, when they were studied more systematically (Angiolini-Martinelli 1968; Bovini 1954; De Francovich 1959; Deichmann 1969a, 1974, 1982; Dresken-Weiland, Bovini & Brandenburg 1998; Farioli 1966a, 1966b, 1968, 1972, 1975, 1983, 1989; Koch 1998, 2000; Kollwitz & Herdejürgen 1979; Lawrence 1970; Rizzardi 1994; Russo 1968, 1974; Schoolman 2013; Valenti-Zucchini & Bucci 1968).



**Fig. 2a.:** The basilica of San Apollinare in Classe; **Fig. 2b.:** The layout of the basilica of San Apollinare in Classe with evidence of 11 sarcophagi (sph): 1. sph of the Twelve Apostles; 2. sph of archbishop Theodorus; 3. sph of the archbishop Gratosius; 4. sph “a sei nicchie”; 5. Roman sph of Licinia Valeria; 6. sph “a tre e quattro nicchie”; 7. sph with the *adoratio crucis* and lambs; 8. sph of the archbishop Felix; 9. sph with the *adoratio crucis* and antithetic lambs; 10. sph with the lambs carrying crosses (“agnelli cruciferi”); 11. sph of IOHANNIS (modified after Deliyannis 2010, 262, Fig. 90).

**2a. ábra:** San Apollinare in Classe bazilikája; **2b. ábra:** A San Apollinare in Classe bazilika alaprajza 11 szarkofág leletével: 1. a tizenkét apostol szarkofágja; 2. Teodor érsek szarkofágja; 3. Gratosius érsek szarkofágja; 4. „a sei nicchie” szarkofág; 5. Licinia Valeria római szarkofágja; 6. „a tre e quattro nicchie” szarkofág; 7. „a tre e quattro nicchie” szarkofág. szarkofág az „*adoratio crucis*”-szal és bárányokkal; 8. Félix érsek szarkofágja; 9. szarkofág az „*adoratio crucis*”-szal és bárányokkal; 10. szarkofág a keresztet tartó bárányokkal („agnelli cruciferi”); 11. IOHANNIS szarkofágja (Deliyannis 2010, 262, 90. ábra után módosítva).

For a stylistic and iconographic analysis of the development of Western and Ravennate sculptural art, sarcophagi and Eastern (Byzantine) influences cf. Deichmann 1969a, b, 1974, 1982, 1989; Gerke 1959a, b, c; Russo 1974; Sodini 2002. On the basis of stylistic analysis and documented analogies with products of Eastern provenance, the thesis was formulated that some sarcophagi with figural decoration were imported into Ravenna in the early 5<sup>th</sup> century, before the establishment of an independent local workshop, mainly from the East (*Asia Minor*), and especially via Constantinople. We have almost no information about artists working in Ravenna. One exception is an artist called Daniel, who was active during the reign of the Arian, Ostrogothic king Theodoric (Cassiodorus, *Variae*, III, 19). However, it is not entirely certain whether he worked directly in Ravenna or only traded in sarcophagi (Koch 2000, 390). According to Rizzardi (1994, 189–202), it is very likely that he was one of the stonemasons of the Ravenna workshop. When we talk about imported sarcophagi, we primarily refer to the Pignatta

sarcophagus and the sarcophagus of Liberius III, but also other aspects of the architecture and iconography are undoubtedly influenced by the East. The parallels with Constantinopolitan sculpture (e.g., the base of the obelisk of Theodosius) and sarcophagi from Bakirköy, Silivri Gate, Saragüzel and Yedikule are well known (cf. Deichmann 1969b, 292–307; Gerke 1959c, 109–121; Rizzardi 2004, 2007). Ravenna’s favorable position on the sea and its port at Classe facilitated frequent trade contacts. Therefore, the hypothesis of the use of marble from the East makes more sense. The question remains whether the sarcophagi were finished before being imported to Ravenna or whether, as was the case with architectural decorations and sarcophagi imported from Eastern workshops and quarries, they were transported in prefabricated state and finished on site, either by foreign artists or later in a local workshop. A distinguishing feature of the Ravenna sarcophagi, as opposed to those produced by the Roman workshops, is the decoration on all four sides of the chest (as in the Eastern, Constantinopolitan and

Microasiatic sarcophagi). In addition, there are specific architectural decorations and compositional features, some of which show Eastern influences. In Ravenna, therefore, we find a synthesis of local, Roman and northern Italian traditions with the art of the Greek East, *Asia Minor* and Constantinople (cf. De Maria 1998, 485).

Only one of the thirteen Ravennate sarcophagi with figural decoration (“a figure umane”), known as the Sarcophagus of the Twelve Apostles, and nine of the forty-five Ravennate sarcophagi with purely symbolic decoration, as well as a small Roman sarcophagus, are now in the Basilica of San Apollinare in Classe (**Figs. 2a,b**), built and decorated with beautiful mosaics in the second half of the 6<sup>th</sup> century.

Most of the sarcophagi of the Ravennate circle are now in the basilicas of Ravenna, but some are also in Ferrara, Fusignano, Imola, Longana, Ostiglia, Padova, Pesaro, Milan, and in the Marche region (Mondolfo).

The sarcophagus of the Twelve Apostles (**Fig. 2b.1**) is of the “panel” type, featuring carved pilasters with cannellure, bases and leaf-spoon capitals at the corners. The architrave is adorned with stylized Lesbian (convex-concave) kyma. The decoration on the front side (**Fig. 3a**) depicts Christ seated on a throne, handing a scroll of the Law to the Apostle St. Paul, who receives it in hands covered by *pallium*. This iconography of *manibus velatis*, symbolising sacred respect and reverence, is not exclusive to Christian iconography, but is also found in imperial iconography. It can thus be seen that this represents the Eastern tradition of the *traditio legis* to Paul rather than to the Apostle Peter, who is depicted on the left of Christ, bearing a cross in the shape of a *crux patens* on his shoulder. In addition, Peter's hands are covered by a cloak on which is held a key, his symbol. The central *trinus* scene is surrounded by the figures of two apostles, both of whom are depicted with the gesture of *acclamatio*, with a disproportionately accentuated right hand. The composition is brought to a conclusion with the depiction of two apostles, each holding a crown in their cloaked hands. With the exception of the apostles Peter and Paul, who can be identified by their typological portrait (Paul with a pointed beard and Peter with a curly beard), the other apostles are unidentifiable. It is noteworthy that Christ is depicted with both the symbols of the open codex in His left hand and the iconography of the *traditio legis*. An analogous combination of these two iconographic elements can be observed in the Certosa/Bonacossi sarcophagus in Ferrara.

The sarcophagus is dated to the first half of the 5<sup>th</sup> century (De Francovich 1959; Farioli 1977;

Valenti-Zucchini & Bucci 1968, 35–36; see also Diehl 1928, 63–64). However, Gerke (1969) posits that it is the final Ravennate sarcophagus to feature a human representation, and thus considers it to be of a more recent date than the Barbacian sarcophagus (dated to 440–450 or to the mid to late 5<sup>th</sup> century: De Francovich 1959, 109; Farioli 1977, 40; Valenti-Zucchini & Bucci 1968) or the already mentioned Certosa/Bonacossi sarcophagus in Ferrara (dated 450–475; Kollwitz & Herdejürgen 1979, 68). He then draws a parallel with the Constantinopolitan sarcophagi of Bakirköy and Yedikule (Gerke 1959c, 113). However, this chronology appears to be inconsistent with the style of the Rinaldo sarcophagus, which is related in style and composition to the Twelve Apostles sarcophagus. The sarcophagus is stylistically and compositionally (central *trinus* group) related to the front wall of the Rinaldo sarcophagus, which dates from the first half of the 5<sup>th</sup> century and is located in the Cathedral of Ravenna. It is also related to the back wall, which features symbolic decoration – in terms of architectural composition, the style of floral motifs and symbolic decoration (front and back wall, lid) on the sarcophagus of Archbishop Theodore in the Basilica of San Apollinare in Classe exhibits stylistic similarities to the sarcophagi of Certosa/Bonacossi, particularly in the portrayal of Christ's throne on the front wall and the disproportionate representation of the hands in comparison to the body. Other pertinent analogies include the sarcophagus of Pietro Peccatore (or Pietro degli Onesti) and the sides of the sarcophagus of Exuperantius and Maximianus (the first half of the 5<sup>th</sup> century) in the Cathedral. Furthermore, the sarcophagus of the Twelve Apostles displays a compositional equilibrium that is absent in the Barbacian or Certosa/Bonacossi sarcophagi. It can therefore be concluded that the sarcophagus is most likely to date from the final decade of the first half of the 5<sup>th</sup> century (Sekavová 2006, 116).

The back side of the sarcophagus displays a symbolic decoration in the form of two peacocks, their heads oriented towards the central medallion, which features a Latin cross of the *crux patens* type. The aforementioned representation is circumscribed by vignettes of leaves and grapes. (**Fig. 3b**).

The lateral sides of the sarcophagus exhibit a similar architectural frame to that observed on the front, which depicts the three apostles. On the right, two apostles are depicted shaking hands in a gesture of *dextrarum iunctio*, while the third holds his right hand raised to his chest and grasps a globe in his left (**Fig. 4a**). The scene on the left side is analogous to that on the right, as both depict three apostles. The central figure is depicted holding an open codex and making an *adlocutio* gesture with his right hand.





**Fig. 3.:** The sarcophagus of the Twelve Apostles, San Apollinare in Classe: front (a) and back (b) sides.

**3. ábra:** A tizenkét apostol szarkofágja, San Apollinare in Classe: elülső (a) és hátsó (b) oldal.



**Fig. 4.:** The sarcophagus of the Twelve Apostles, right (a) and left (b) lateral sides

**4. ábra:** A tizenkét apostol szarkofágja, jobb (a) és bal (b) oldalfelület

The apostles depicted on the lateral sides are shown with the scrolls (*volumina*) in their hands. The semi-cylindrical lid of “a baule” type features a symbolic decoration consisting of three Christological monograms on either side (**Figs. 3-4**). Furthermore, the lunettes on the lid display Latin crosses flanked by doves in the composition of the *adoratio crucis* and vine tendrils.

The sarcophagus of Archbishop Theodorus (**Fig. 2b.2**) was relocated from the Santa Maria di Urano monastery in Bertinoro (Forlì) to the basilica of San Apollinare in Classe. The sarcophagus is categorized as the “panel” type, featuring carved

pilasters with canelure, bases and leaf-spoon capitals at the corners. These are similar in design to those seen on the Twelve Apostles sarcophagus. The architrave is adorned with a stylized representation of the Lesbian kyma. The front side’s decoration (**Fig. 5a**) features a Christological monogram comprising the Greek letters XP, with the letters AQ suspended below. Two rosettes are also depicted beneath the medallion. Furthermore, the composition features two peacocks facing each other. Two vine branches, bearing leaves and grapes, flourish behind the bodies of the peacocks. Two doves are observed below, engaged in the act



of refreshing themselves on the grapes. The back (Fig. 5b) exhibits a comparable compositional structure, albeit with a central cross in lieu of the medallion. It features peacocks, doves, and a small mammal with an elongated head and a long tail (sometimes identified as a small rabbit). The structural framework of the posterior is less complex than that of the anterior, lacking both cannellure and lesbien kyma. The lateral surfaces feature symbolic decorations in the form of floral tendrils, rosettes, doves and crosses. The decoration on the left lateral surface is almost entirely absent.

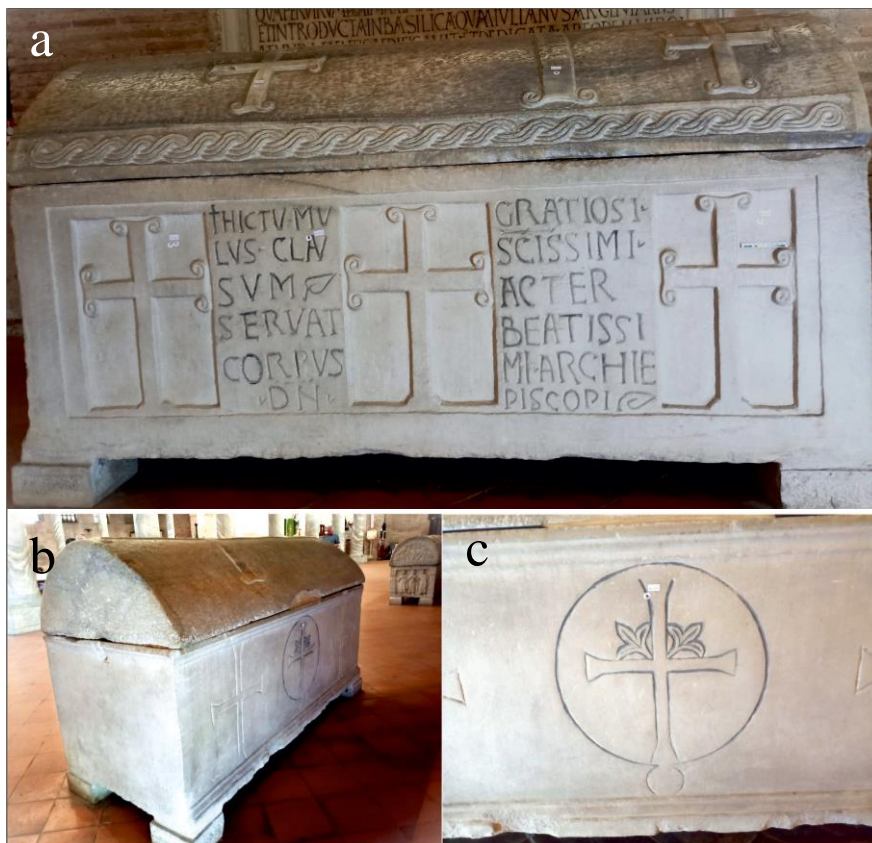
The semi-circular lid (Fig. 5.) features a symbolic decoration comprising two crosses and a *chi-iota* monogram with pendent Greek letters A and Ω

enclosed within a laurel wreath. On the front wall is a carved inscription HIC REQUIESCIT IN PACE THEODORVS V.B. ARCHIEPISCOPVS. The sarcophagus was erroneously dated according to the deposition of Theodorus' body in 688; however, this was a secondary use of the sarcophagus. A stylistic analysis and comparisons with other Ravennate sarcophagi indicate that the dating should be revised to the mid-fifth century or slightly later (Valenti-Zucchini Bucci 1968, 8, n. 4). Analogies of the sarcophagus, both in composition and style, can be drawn with the back of the S. Isacio sarcophagus (peacocks, monograms), the sarcophagus of Twelve Apostles, the sarcophagus in Fusignano, the right lateral side of the Rinaldo sarcophagus (grapevine tendrils), the sarcophagus



**Fig. 5.:** The sarcophagus of Archbishop Theodorus, San Apollinare in Classe: front (a) and back (b) sides

**5. ábra:** Teodor érsek szarkofágja, San Apollinare in Classe: előlő (a) és hátsó (b) oldal



**Fig. 6.:**

The sarcophagus of Archbishop Gratosus, San Apollinare in Classe: front (a), back side (b) and a detail of the central cross in clipaeum on the reverse side (c).

**6. ábra:**

Gratosus érsek szarkofágja, San Apollinare in Classe: előlap (a), hátoldal (b) és a hátoldalon a központi kereszt részlete a clipaeumban (c).

Certosa/Bonacossi and the front of the S. Gervasio sarcophagus in Mondolfo (Sekavová 2006, 148).

The sarcophagus of Archbishop Gratosius (**Fig. 2b.3**), which features decoration dated to the end of the 8<sup>th</sup> century, is regarded as a reworked sarcophagus intended for subsequent use, for which the date of secondary use is known: 788 AD, date of the death of Archbishop Gratosius (Farioli 1977, 138; Valenti-Zucchini & Bucci 1968, 58; Baldini, La Manna & Marsili 2021). The decoration on the front wall (**Fig. 6a**) is a purely symbolic and ornamental composition. It consists of three panels with Latin crosses with elaborate volutes on the arms (*crux patens*) and panels between them with a dedicatory inscription to Archbishop Gratosius in black polychrome in carved majuscule letters:

|           |           |
|-----------|-----------|
| †HIC TVMV | GRATIOSI  |
| LVS CLAV  | SCISSIMI  |
| SVM       | AC TER    |
| SERVAT    | BEATISSI  |
| CORPVS    | MI ARCHIE |
| DN        | PISCOPI   |

The lid of the “a baule” type is slightly flattened and bears three crosses engraved asymmetrically, similar to the crosses on the front. The lower part of the lid is decorated with a border with an interlaced motif. The reverse (**Fig. 6b**) shows remnants of black polychromy, including three partially engraved Latin crosses (*crux patens* form), which appear to be a preliminary sketch. The central one (**Fig. 6c**) is surrounded by a *clippaeum* standing on a small globe. Two lilies grow on the cross-beam of the cross. The left side of the coffin is also decorated with a Latin cross within a flat, bordered field. The right side was left without any decoration. This sarcophagus has a close analogy in the sarcophagus

of Archbishop Iohannes in the same basilica (**Fig. 14**).

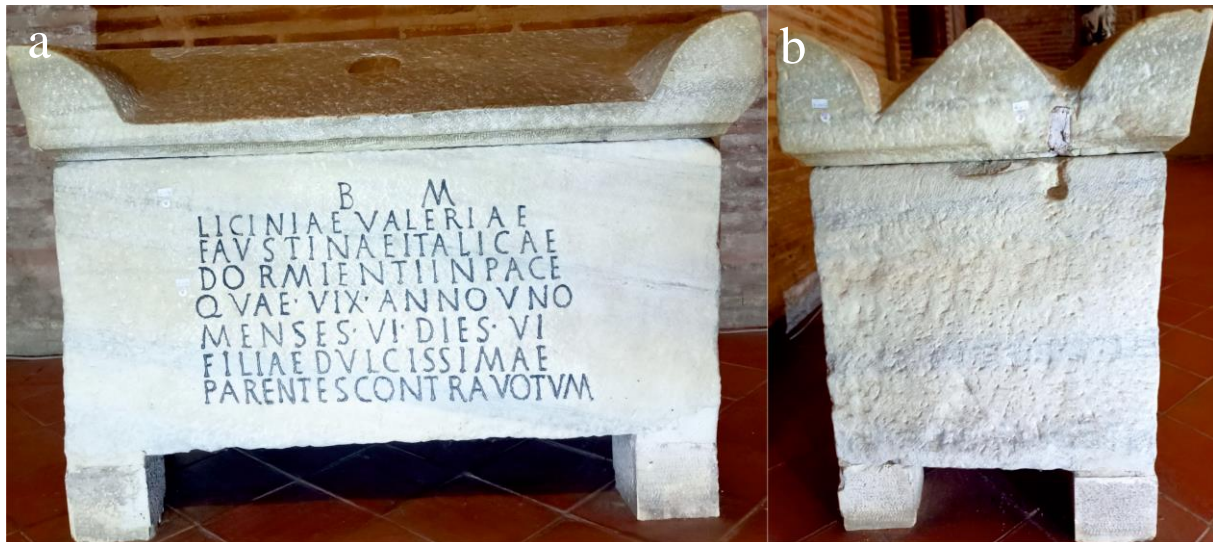
As the name “a sei nicchie” suggests (**Fig. 2b.4**), it is a type of sarcophagus with *aediculae*: the front and the back are divided into six niches in which the architecture of the central niches and the columns supporting their arches are abstracted and replaced by a symbolic scene. On the wall facing the interior of the basilica, two peacocks are drinking water from a kantharos (**Fig. 7a**), while on the back wall two lambs are refreshing themselves with palm fruits (perhaps dates) (**Fig. 7b**). In the niches adjacent to the central scene, on both walls, there are Latin crosses and palm trees on the edges. All these attributes have a strong early Christian symbolism. And in this sarcophagus we see a gradual move away from figurative representation towards purely symbolic representation in the Ravennate sarcophagi (cf. Gerke 1959c, 118–119). The row of niches is continuous throughout the sarcophagus, with two niches on each side decorated with Latin crosses. The lid of the sarcophagus is of the “a baule” type and is decorated with a matrix that resembles slices of pine cones or roof tiles. The cornice is decorated with an ovoid motif. The sarcophagus is dated to the end of the 5<sup>th</sup> – beginning of the 6<sup>th</sup> century (Valenti-Zucchini & Bucci 1968, 45; De Francovich 1959, 82–87) and it shows more compositional and stylistic similarities within the framework of the Ravennate art of the 5<sup>th</sup> and 6<sup>th</sup> centuries: the sarcophagus “a sei nicchie” in the Cathedral of Ravenna; two sarcophagi “a nicchie” and of Liberius III in the Basilica of San Francesco; the altar in the main apse in the Basilica of San Apollinare in Classe and San Giovanni Evangelista; the sarcophagus of Valentinian III in the Mausoleum of Galla Placidia; analogies of the sides are found in a tympanon of the sarcophagus “Traversari” in the Basilica of San Francesco. (Sekavová 2006, 149).



**Fig. 7.:** The sarcophagus “a sei nicchie”, San Apollinare in Classe: front (a) and back (b) sides.

**7. ábra:** Az „a sei nicchie” szarkofág, San Apollinare in Classe: elülső (a) és hátsó (b) oldal





**Fig. 8.:** Small Roman sarcophagus of Licinia Valeria, San Apollinare in Classe: front (a) and left (b) side.

**8. ábra:** Licinia Valeria kis római szarkofágja, San Apollinare in Classe: elülső (a) és bal (b) oldal

The small fourth-century Roman sarcophagus of Licinia Valeria (**Fig. 2b.5**) with a low gabled lid and angular acroteria is undecorated. On the front, there is an inscription dedicated by the parents to their daughter, to Licinia Valeria, a girl died at the age of 1 year, 6 months and 6 days (**Fig. 8.**).

The sarcophagus “a tre e quattro nicchie” (**Fig. 2b.6**) has a central tympanon and is decorated with three niches on the front and four *aediculae* on the back. The simple, undecorated lid is of the “a baule” type. The right lunette of the lid depicts two opposing peacocks picking the berries from the grapes hanging from the tendrils of the vine growing from the central kantharos (**Fig. 9b**). The left lunette shows a laurel wreath with *lemniscæ* on which two doves rest. In the centre of the crown there is a *chi-rho* monogram with outstretched arms at the ends (**Fig. 9c**).

The side of the sarcophagus facing the main nave of the basilica shows architectural features influenced by pagan sarcophagi from northern Italy of the 3<sup>rd</sup> century AD (**Fig. 9a**), and it is clearly a sarcophagus reworked in the Christian spirit in the late 5<sup>th</sup> or early 6<sup>th</sup> century (Sekavová 2006, 19, 36–37, 53). A typological analogy can be found in the sarcophagus of Valentinian III in the so-called Mausoleum of Galla Placidia in Ravenna. For the dating of the sarcophagus to the last decade of the 5<sup>th</sup> century see De Francovich 1959, 81; for the dating to the first decade of the 6<sup>th</sup> century see Valenti-Zucchini & Bucci, 1968, 47. Gerke (1959c, 119–120) also finds a model for this type of triple *aedicule* with a tympanum over the central niche in northern Italian pagan sarcophagi of the 3<sup>rd</sup> century, but attributes its origin to Greek production. The reworking can be seen on the front, where the deep relief of the architectural frame (pilasters, *aediculae*, tympanum)

contrasts sharply with the low relief of the Christian symbols in the niches (the central cross appearing under the open curtains and two lateral crosses with hanging letters *Alpha* and *Omega*). The symbolism of the cross appearing from behind the half-open curtains recalls the theophany, which is also represented in figurative form, for example on the Brescia ivory lypsantheque (where Christ *docens* is depicted in the Collegium of the Apostles) or, in its symbolic form as a *crux gemmata*, on the Milan ivory diptych (Sekavová 2006, 152). The analogy of the theophany of the cross appearing behind the open curtain can also be found in the central niche at the front of the sarcophagus in the tomb at the Silivri Gate in Constantinopol, discovered in the 1980s (Mathews 1994, 313, 317, Fig. 4). It is interesting to note that the crosses (*crux gemmata*) in the side niches are mirrored, as can be seen from the hanging letters or the decorative *rho* at the top of the vertical arm of the cross. It is also interesting to note an additional inscription, carved between two columns on the front, which refers to Archbishop Reparatus. (**Fig. 9f**).

On the right side, in an architectural framework consisting of two pilasters with cannellure and acanthus capitals, a large volute *kantharos* with a shell at the edge of the neck is displayed below the arch. Two doves rest on columns beside the *kantharos* (**Fig. 9b**).

On the left side, in a similar architectural frame to that on the opposite side, the *Agnus Dei* is depicted on a mountain from which flow the springs of the four rivers of Paradise. Behind the head of the lamb, facing backwards, is a nimbus inscribed with the Constantinian XP monogram (**Fig. 9c**).





**Fig. 9.:** The sarcophagus “a tre e quattro nicchie” with the central tympanon, San Apollinare in Classe: front (a), lateral (b, c) sides, the reverse wall (d, e), and the inscription between two columns on the front (f).

**9. ábra:** A „a tre e quattro nicchie” szarkofág egy központi timpanonnal, San Apollinare in Classe: előlap (a), oldalsó oldalak (b, c), a hátfal (d, e) és a felirat két oszlop között az előlapon (f).

The field of the back side (**Fig. 9d, e**) is divided by four niches supported by columns. The arches of the niches are filled with decorative shells. In the two central niches there are monogrammatic crosses with outstretched arms (*crux patens*) and internal plastic modelling; in the remaining niches there are date palms.

The monumental, symbolic sarcophagus with the *adoratio crucis* and the antithetic lambs (**Fig. 2b.7**) is of the panel type, with pilasters located at the edges. The lid, of “a baule” type, is adorned with a symbolic decoration of a laurel *corona* containing a central Latin cross with the Greek letters ΑΩ, flanked by two peacocks standing on *lemniscæ* ending in heart-shaped ivy leaves (**Fig. 10a**). The side lunettes of the lid are decorated with a beautiful symbolic motif of tendrils growing from the kantharos and the *adoratio crucis* motif with antithetic doves. The decoration on the front consists of a monumental composition of *adoratio crucis* with antithetic lambs. Behind the lambs are palm trees with fruit in low relief. The central cross is of Latin type with outstretched arms at the ends

(*crux patens*) and the letters ΑΩ hanging from it (**Fig. 10a**). One side is decorated with the symbolism of the *adoratio crucis*, with antithetic peacocks and the central cross on a mountain from which four apocalyptic rivers flow (**Fig. 10c**). The opposite lateral side is decorated with an *Agnus Dei* with a jewelled cross (*crux gemmata*) – as a symbol of the victory – in the form of a *crux patens* and a small dove with a *corona victoriae* in its beak (**Fig. 10b**). The dating of the sarcophagus varies: according to De Francovich and Chevallier it was made in the last decade of the 5<sup>th</sup> century, while Valenti-Zucchini & Bucci (1968, 48) date it to the beginning of the 6<sup>th</sup> century (Chevallier 1961; De Francovich 1959, 47).

The sarcophagus of the Archbishop Felix (**Fig. 2b.8**) belongs to the late group of Ravennate sarcophagi dated to the 8<sup>th</sup> century, whose artistic decoration is dated to the first quarter of the same century (around 723) and is considered by some authors to be “barbarian” (Angiolini-Martinelli 1992, 162; Valenti-Zucchini & Bucci 1968, 57; see also Godoli 1997, 25, n. 36).



**Fig. 10.:** The sarcophagus with *adoratio crucis* and the lambs, San Apollinare in Classe: front (a) and lateral (b, c) sides

**10. ábra:** A szarkofág az „*adoratio crucis*”-szal és a bárányokkal, San Apollinare in Classe: elülső (a) és oldalsó (b, c) oldal





**Fig. 11.:** The sarcophagus of Archbishop Felix, San Apollinare in Classe: front (a) and back (b) wall

**11. ábra:** Félix érsek szarkofágja, San Apollinare in Classe: elülső (a) és hátsó (b) fal

The manner of execution and the style of decoration show a distancing from the veristic representation, typical of the production of fifth-century sarcophagi, but we can nevertheless see a transition to early medieval artistic expression (cf. Gerke 1959c, 121). The typology of the front, on the other hand, is at first sight based on the early forms of the pagan architectural sarcophagi with *aediculae* of the 3<sup>rd</sup> century, produced in northern Italy, as we have seen also in the sarcophagus “a tre e quattro nicchie”. In fact, this sarcophagus was probably a pagan one, reused for the burial of the Archbishop in 723. The iconography of the *adoratio crucis* on the front side is reminiscent of the older figurative compositions of Ravennate art, but is purely symbolic. In the central niche, closed by a tympanum, there is the theophany of the Cross, flanked by the Apostles Peter and Paul in the form of antithetic lambs. Above them are the crosses as the *Vexillum Christi*. In the side niches there are hanging crowns (wreaths), while on the sides there are candelabras with lit candles. (Fig. 11a). The motif of lighted candles on a tall candelabra can be found in several other examples from Ravenna, such as on the sides of the Barbatian sarcophagus in the Cathedral, on the lunette of the lid of the sarcophagus in front of the Basilica of San Francesco, and on the Ravennate type sarcophagus in Ostiglia (Sekavová 2006, 93). Light, *illuminatio*, is an important element in Christian art as it represents divinity, regeneration, and new life (J 1,3–5. J 5,35. Mt 5,14–16). Candles lit on Holy Saturday symbolize the resurrection, and candles used at baptism symbolize new life in Christ. The candles adorning the sarcophagus hold both a funeral and a luminous significance, symbolizing the light of resurrection.

The lid is also very simplified and flattened, reminiscent of earlier monumental fifth-century “a baule” lids. This is a reused older lid, originally with a gabled roof. The border of the lid is decorated with a knitted pattern and is adorned with a large Latin cross running the length of the lid and two smaller ones in a floral *clippaeum* (repeated on

both sides of the lid), with the Greek letters ΑΩ suspended from the arms of both crosses and mirrored on each cross. A dedicatory inscription HIC TVMVLVS CLAVSVM SERVAT CORPVS DOMN FELICIS SCISSI AC TER BEATISS. ARCHIEPISCOPI is situated above the lid rim (Valenti-Zucchini & Bucci 1968, 57). The sides and back are without decoration (Fig. 11b).

The sarcophagus with the *adoratio crucis* with the antithetic lambs and the laurel wreath or “con agnelli e ghirlanda d’alloro” (Fig. 2b.9) is of the panel type with rather stylised angular pilasters with floral motifs and very schematic leaf-spoon capitals. It also belongs to the group of later sarcophagi already produced locally. The main scene on the front is in very deep relief, with two lambs and a laurel wreath with *lemniscæ* in the center, surmounted by oak leaves – or stylized vine leaves as some authors have suggested (Lawrence 1970, 39; Valenti-Zucchini & Bucci 1968, 53–54). In the center of the wreath there is the Latin cross with the inner profilations and outstretched arms. Behind the bodies of the lambs there are stylized palm trees (Fig. 12a). The stylistic analysis of the sarcophagus led to its different datings, showing that the sarcophagus was used more than once or over a longer period of time: the lid and the front of the chest are dated to the first quarter or the end of the 6<sup>th</sup> century or even to the 7<sup>th</sup> century (first quarter of the 6<sup>th</sup> century: De Francovich 1959, 119–121; the end of the 6<sup>th</sup> century: Valenti-Zucchini & Bucci 1968, 53–54; 7<sup>th</sup> century: Lawrence 1970, 39; cf. also Godoli 1997, 25, n. 38). Lateral sides are dated to the 8<sup>th</sup> (for dating to the 8<sup>th</sup> century see Lawrence 1970, 39, when she compares the capitals and the floral ornament with *transennae* from the 8<sup>th</sup> century in Bobbio, Bologna, Neapol, and Rome) or 9<sup>th</sup> century (for the first half of the 9<sup>th</sup> century see De Francovich 1959, 119–121 and for the turn of the 8<sup>th</sup> and 9<sup>th</sup> centuries see Valenti-Zucchini & Bucci 1968, 53–54). The back is without decoration. Both sides are decorated



**Fig. 12.:** The sarcophagus with *adoratio crucis* and the antithetic lambs, San Apollinare in Classe: front (a) and lateral (b, c) sides

**12. ábra:** A szarkofág az „*adoratio crucis*”-szal és a bárányokkal, San Apollinare in Classe: elülső (a) és oldalsó (b, c) oldal

in a similar manner (**Fig. 12b, c**): the composition field is divided by two arcades, the horseshoe arch of which is decorated inside with a pearl motif. The columns supporting the arches of the edicule are also decorated with a row of pearls. The arcades are filled with a dynamic spiral-flake motif, close to the Lombard style.

The lid of this sarcophagus is of the “a baule” type, made of a different type of marble from that of the chest, and it also has different dimensions, so it seems that the lid did not originally belong to the chest (as in the case of the sarcophagus of the Archbishop Felix) (De Francovich 1959, 120). The decoration of both, the lid and the front of the chest, is dated to the 6<sup>th</sup> or 7<sup>th</sup> century (De Francovich 1959, 119–121, Lawrence 1970, 39; Valenti-



Zucchini & Bucci 1968, 53–54); while the lateral sides are dated to the 8<sup>th</sup>–9<sup>th</sup> centuries (De Francovich 1959, 121; Lawrence 1970, 39). In the centre of the right lunette is a *kantharos* surrounded by floral tendrils. The lower edges are decorated with symmetrical lilies. The dominant decoration of the left lunette is a massive Latin cross with a central disc. The cross is in the form of a *crux patens*. Two lilies grow out of the lower corners, as in the right lunette. The scenes on the two lunettes are framed by a plastic border. On the back of the lid there is a *crux patens*. The style of the sarcophagus is based on the classical concept of the earlier Ravennate production and anticipates the characteristic expression of the early medieval art (schematization, ornamentation, stylization).

Sarcophagus with the cruciferous lambs (*agnelli cruciferi*) and a central monogram (Fig. 2b.10) is dated to the second quarter of the 8<sup>th</sup> century or to the beginning of the same century, but its lid of the more flattened “a baule” type, seems to be older

than a chest, probably dated to the 6<sup>th</sup> century (Godoli 1997, 25, n. 37; Valenti-Zucchini & Bucci 1968, 57–58). The decoration of the lid consists of the iconography of antithetic peacocks on the sides of the *kantharos*. The relief of the vase and the peacocks is in poor condition. The back side and the two side lunettes are without decoration. The decoration of the chest is limited to the *adoratio crucis* of the rather schematic lambs carrying the crosses (Fig. 13a). In the center of the scene is a star-shaped monogram composed of the Greek cross and the Greek letter X, the initial of Christ's name. A similar monogram can be found on the triumphal arch of the presbytery of the Basilica of San Vitale in Ravenna, dating to the second quarter of the 6<sup>th</sup> century. The sides are without decoration (Fig. 13b).

Sarcophagus of the Archbishop Iohannis (Fig. 2b.11), dated to the 8<sup>th</sup> century, finds its closest analogue in the sarcophagus of the Archbishop Gratosus and it is also reworked from



**Fig. 13.:** The sarcophagus with the cruciferous lambs, San Apollinare in Classe: front (a) and left lateral (b) side  
**13. ábra:** A szarkofág a keresztes bárányokkal, San Apollinare in Classe: elülső (a) és bal oldali (b) oldal



**Fig. 14.:** The sarcophagus of the Archbishop IOHANNIS, San Apollinare in Classe: front (a) and right (b) side  
**14. ábra:** IOHANNIS érsek szarkofágja, San Apollinare in Classe: elülső (a) és jobb (b) oldal

a pagan sarcophagus (Valenti-Zucchini & Bucci 1968, 58). The decoration on the front (**Fig. 14a**) is divided into three panels in lower relief, bearing a purely symbolic, ornamental composition of three Latin crosses with elaborate spiral finials on the arms. Between two panels of higher relief, there is an inscription dedicated to the Archbishop Iohannis. The inscription is also *de facto* identical to that on the sarcophagus of Gratosus, albeit in a different order:

|             |              |
|-------------|--------------|
| †HIC TVMV   | IOHANNIS     |
| LVS CLAVSVM | SCISSIMI     |
| SERVAT COR  | AC TER BE    |
| PVS DN      | ATISS ARCHEP |

The right side features the same decoration of the Latin cross (**Fig. 14b**), the left side and the back are without decoration. The lid of the “a baule” type is rather flattened, reworked from the original gabled roof lid. The lower part of the lid is decorated with a border with an interlaced motif, identical to that on the lid of the sarcophagus of Gratosus. Only the right lunette is decorated with a Latin cross within the medallion. The original gabled form of the lid is evidenced by a profiled border on the lunette (**Fig. 14b**).

### Methodology and sampling

Compared to other fields of archaeometry, such as ceramics or metals research, there is still very little research on the use of non-destructive methods to determine the provenance of marble (Careri et al. 1992, Tykot 2012, 2015, Herrmann et al. 2015). These methods are ideally preferable to those that require sampling, even if it is of limited size. In this study, we pursued the approach of obtaining as much information as possible *in situ* and non-destructively, thereby reducing the number and quantity of samples. In the course of the investigations macroscopic and microscopic properties were analyzed, the maximum grain size was determined, and the mineralogical and chemical composition was studied *in situ*. This was followed by the collection of drill dust samples using micro-diamond drills and the analysis of carbon and oxygen stable isotope ratios.

### Macroscopical and microscopical description and determination of maximum grain size (MGS) of the marbles

During the initial inspection, the macroscopic and microscopic characteristics were recorded, such as color, texture, structure, homogeneity of the material, veins, inclusions, but also the odor when scratched or drilled. One of the most commonly used parameters in marble provenance analysis is the maximum grain size (MGS). However, until a

few years ago, in most cases neither numerical results nor a description of the method used to determine this very important parameter were published on the subject. In recent years, some authors have published detailed results and statistical analyses of thin sections providing very good results (Attanasio et al. 2006; Cramer 2004; Csorba et al. 2015; Unterwurzacher et al. 2005; Morbidelli et al. 2007; Zöldföldi & Székely 2004, 2005, 2008; Székely & Zöldföldi 2009; Zöldföldi 2011). However, to conduct the analysis it is necessary to remove small fragments of a few cubic centimetres from the objects. This was avoided in the first phase of the project and the maximum grain size was determined using a watch loupe. It has a diameter of 25 mm and a 20 mm glass reticule that allows a clear view through the eyepiece and provides a magnification up to 10x. It is equipped with 8 LEDs that illuminate the field of view and the distance between the graduated glass retina and the magnifier is adjusted by turning the robust ring of the graduated magnifier so that a clearly focused image can be seen on the retina. The field of view is 25 mm, the graphic scale covers 20 mm, the minimum graduation of the scale is 0.1 mm and the light source is provided by 8 LEDs.

### Raman spectroscopy

Raman spectroscopy is one of the most effective methods for determining the mineralogical phase composition of a sample using Raman scattering. In this spectroscopic technique, the sample is excited by a monochromatic light source, such as a laser, and the Raman shifts are recorded. Raman shifts are frequency shifts that occur when monochromatic light is scattered by a sample and produces a different frequency to that of the original light source. This allows the energy change of the photon to be determined, which corresponds to the energy difference between the fundamental state and the excited state. This creates a unique fingerprint that can be used to identify the mineralogical phases. This spectroscopic technique is becoming increasingly popular in archaeometry and heritage conservation as it allows a sample to be analyzed non-invasively and its constituents identified. A major advantage of Raman spectroscopy is that it is a non-destructive method of analyzing samples without the need for sample preparation. In determining the origin of marble, one of the main questions is whether the marble is calcitic or dolomitic, or a mixture of both. A Metrohm MIRA XTR Raman spectroscope was used in this study. This uses a sensitive laser light with a wavelength of 785 nm and XTR algorithms to extract the Raman data from the sample fluorescence using advanced AI and machine learning. In addition, the MIRA XTR features Orbital Raster Scanning (ORS) technology to improve sample detection and increase the accuracy of results or avoid surface damage.



## Carbon and oxygen isotope analyses

The variation in the isotopic composition of carbon and oxygen in marble carbonates (i.e., mostly calcite,  $\text{CaCO}_3$  and dolomite,  $\text{CaMg}(\text{CO}_3)_2$ ) has a number of causes. These include the different ways in which the rock was formed; the isotopic composition of the water in contact with the carbonate minerals during their formation and subsequent history; the temperature at which metamorphism took place; and successive ageing processes. In other words, marble from a particular locality, formed by a unique geological history, will have isotopic characteristics that distinguish it from marble formed elsewhere with a very different geological history. It is also reasonable to assume that the same process that led to the formation of a particular type of marble has also caused it to become relatively homogeneous within a certain area. This is influenced by isotopic equilibrium during formation and metamorphism of the calcareous rocks by fluid phases. Both hypotheses have been shown to be correct and justify the use of the isotopic method (Herz 1985, Faure 1986). In this study, powder samples were taken using a diamond drill with a diameter of 1 to 3 mm, depending on the raw material of the investigated object. In order to prevent near-surface weathering or contamination from falsifying the stable isotopic geochemistry results, the near-surface layers were first removed using a diamond grinder before samples were taken for analysis.

In the laboratory, carbonate powders were reacted with 100 % phosphoric acid at 70 °C using a Gasbench II connected to a ThermoFisher Delta V Plus mass spectrometer. All values are expressed in parts per thousand relative to V-PDB. Reproducibility and accuracy were monitored by repeat analysis of laboratory standards calibrated by assigning a  $\delta^{13}\text{C}$  of +1.95 ‰ to NBS19 and -47.3 ‰ to IAEA CO9 and a  $\delta^{18}\text{O}$  of -2.20 ‰ to NBS19 and -23.2 ‰ to NBS18. Reproducibility for  $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$  was  $\pm 0.0\text{‰}$  and  $\pm 0.0\text{‰}$  (1 std.dev.; see data file for values), respectively. Standard NBS 19 was also analyzed as a quality control sample.

## Results

### Macroscopic and microscopic description and determination of maximum grain size (MGS)

The macroscopic and microscopic description of the objects examined is summarized **Table 1 in Appendix**. Macroscopically, the Ravenna marble can be roughly divided into two groups: the first is a white-grey, homogeneous but heteroblastic marble with typical long dark grey bands and a grain size of about 2 mm, with the darker bands tending to be of a smaller grain size. The other group is a more white, homogeneous, often spotted, coarse-grained variety with a maximum grain size

of about 3 mm. No fine-grained marble (i.e.,  $<0.8(?)\text{mm}$ , Attanasio et al. 2006) has been found, so quarries such as Carrara can be ruled out.

The box-plot diagram in **Fig. 15** shows the results for the maximum grain sizes. The background diagram contains a comparison of several thousand results from the MissMarble database (Zöldföldi et al. 2011). According to this, group 1 (green rectangle) with an MGS of about 2 mm can be assigned to the quarries of Proconnesos, Paros, Aphrodisias, Ephesos, possibly Miletus, while group 2 (blue rectangle) with larger MGS can be assigned to the quarries of Thassos, possibly Paros, Naxos and Thioúntas.

### Raman spectroscopy

In order to clarify the mineralogical composition, Raman spectroscopic analyses were carried out *in situ* at several points on the surface of the sarcophagi. The Raman spectroscopy analyses showed that all the sarcophagi are composed of calcitic marble (**Fig. 16.**, Raman peaks for calcite are 1087, 713 and  $1436\text{ cm}^{-1}$ ). In many sarcophagi the white and grey areas were compared. In some sarcophagi, dolomite (**Figs. 17-18.**; Raman peaks 1098 and  $719\text{ cm}^{-1}$ ) was found in addition to calcite, almost exclusively in the grey areas. Gypsum was also identified in some of the measurements (**Fig. 19.**, Raman peak at  $1008\text{ cm}^{-1}$ ). This indicates a surface transformation from calcite ( $\text{CaCO}_3$ ) to gypsum ( $\text{Ca}_2\text{SO}_4 \cdot 2\text{H}_2\text{O}$ ) due to the effect of an external sulphate source. Since the sarcophagi are located in protected indoor spaces, the cause of the transformation is mainly due to the use of candles in the basilica, since many (especially older) candles with a high sulfur content produce sulfur dioxide ( $\text{SO}_2$ ) when they burn, which forms gypsum ( $\text{Ca}_2\text{SO}_4 \cdot 2\text{H}_2\text{O}$ ) with the calcite ( $\text{CaCO}_3$ ) on the surface of the marble.

### Determination of $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ stable isotope ratios

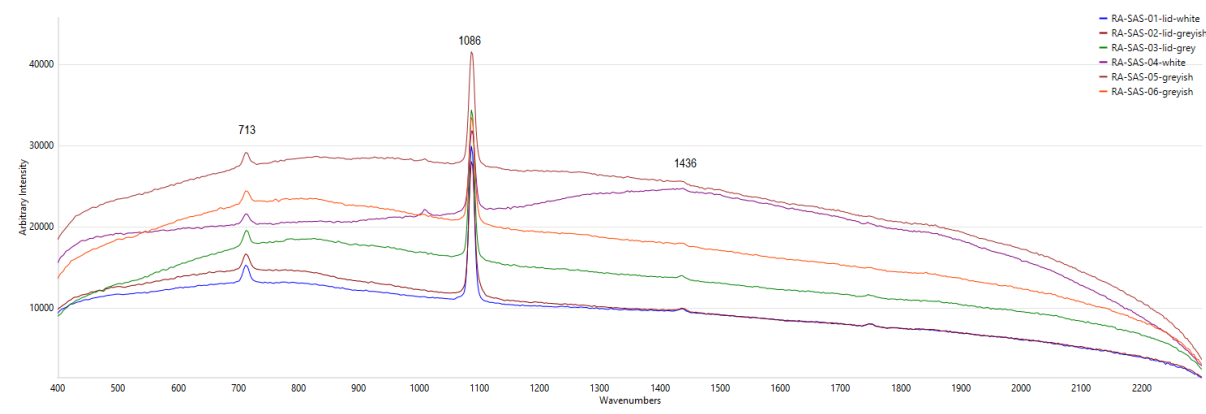
As far as isotopic data are concerned, the increasing number of analyses of ancient and modern marble quarries that have appeared in literature in recent years testifies to the great popularity of this technique in archaeometric research. Paradoxically, the large amount of data available has led to an extremely complex overall picture; indeed, in an overall diagram of  $\delta^{13}\text{C}$  versus  $\delta^{18}\text{O}$ , the fields characterizing each quarry overlap considerably, making the use of this method of investigation problematic, if not impossible (**Fig. 20.**). For this reason, these diagrams are rather used to confirm or deny the origin of possible quarries selected according to other criteria. Nevertheless, it is an important criterion because the methodology is standardized, little material is required and many



**Fig. 15.:** Boxplot showing the results for the maximum grain sizes. Group 1 with an MGS of about 1.2 to 2 mm (green rectangle) and group 2 with an MGS of about 2.8 to 3.7 mm (blue rectangle). The background plot contains a comparison of several thousand results from the MissMarble database (Attanasio et al. 2006; Cramer 2004; Zöldföldi 2011).

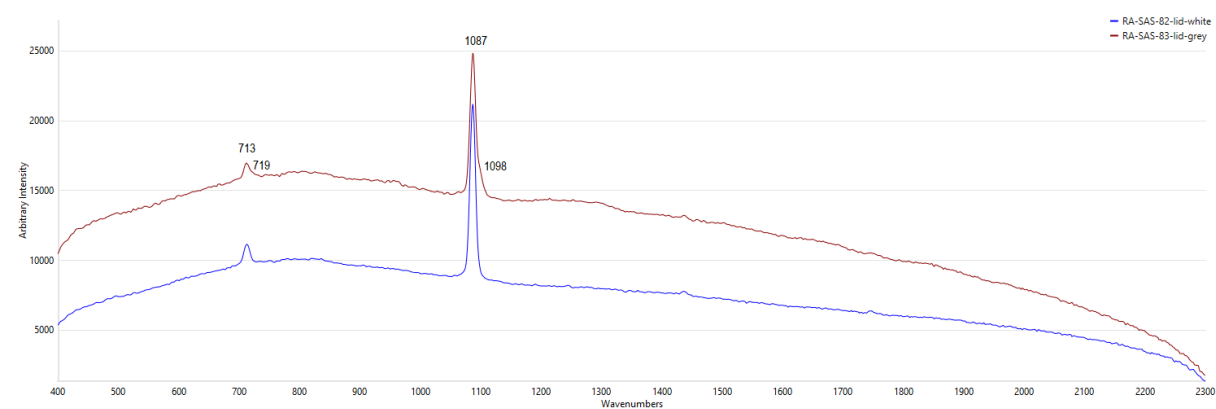
**15. ábra:** A maximális szemcseméreteket bemutató dobozdiagram. Az 1. csoport körülbelül 1,2–2 mm-es MGS-sel (zöld téglalap) és a 2. csoport körülbelül 2,8–3,7 mm-es MGS-sel (kék téglalap). A háttérkép a MissMarble adatbázis több ezer eredményének összehasonlítását tartalmazza (Attanasio et al. 2006; Cramer 2004; Zöldföldi 2011)





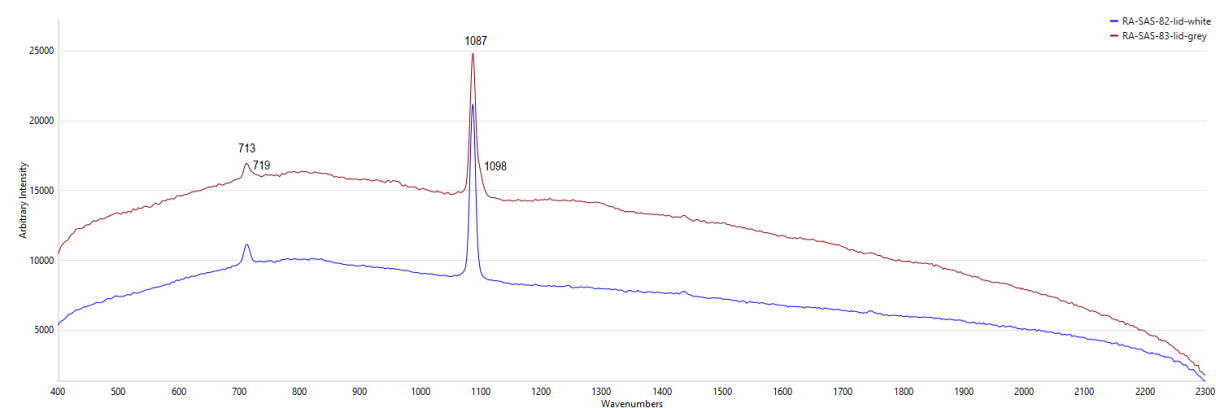
**Fig. 16.:** Raman spectra of several sarcophagi with calcite (1087, 713 and 1436 cm⁻¹) as the main mineral

**16. ábra:** A kalcitot (1087, 713 és 1436 cm⁻¹) fő közetalkotó ásványként tartalmazó szarkofágok Raman spektruma



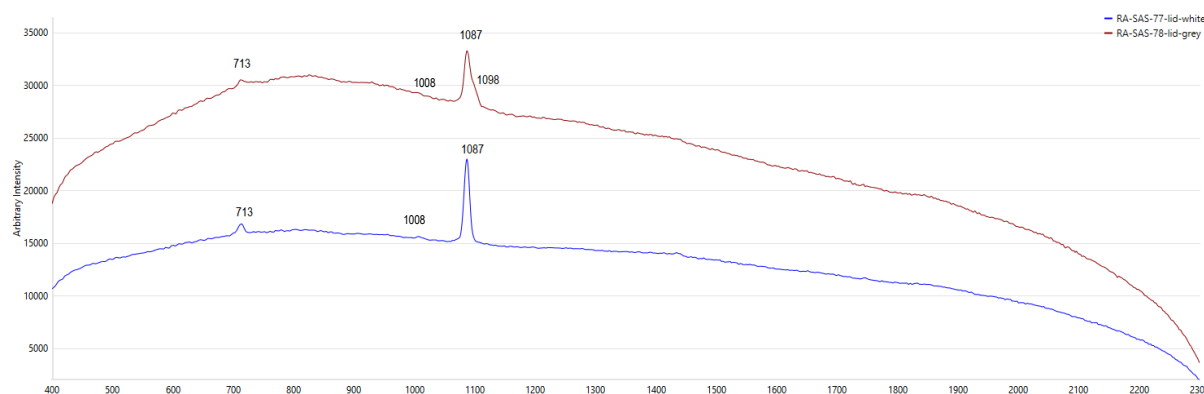
**Fig. 17.:** Raman spectra from the lid of the sarcophagus #11, sarcophagus of Iohannis, with calcite (1087, 713, 1436 cm⁻¹) as the main mineral and dolomite (1098 and 719 cm⁻¹) as the accessory mineral in the grey part

**17. ábra:** Raman spektrumok a 11. számú szarkofág, Iohannis szarkofágjának fedeléről, a szürke részen a kalcit (1087, 713, 1436 cm⁻¹) mint fő és a dolomit (1098 és 719 cm⁻¹) mint járulékos közetalkotó ásvány jelenik meg



**Fig. 18.:** Raman spectra from the lid of the sarcophagus #10, with the cruciferous lambs (“agnelli cruciferi”), with calcite (1087, 713 cm⁻¹) as the main mineral and dolomite (1098 cm⁻¹) as the accessory mineral in the grey part

**18. ábra:** Raman spektrumok a 10. szarkofág fedeléről, a keresztes bárányokkal („agnelli cruciferi”), a szürke részen a kalcit (1087, 713 cm⁻¹) mint fő és a dolomit (1098 cm⁻¹) mint járulékos közetalkotó ásvány jelenik meg



**Fig. 19.:** Raman spectra of various sarcophagi, with calcite ( $1087$ ,  $713$  and  $1436\text{ cm}^{-1}$ ) as the main mineral and gypsum ( $1008\text{ cm}^{-1}$ ) as a weathering product

**19. ábra:** A kalcitot ( $1087$ ,  $713$  és  $1436\text{ cm}^{-1}$ ) fő kőzetalkotó ásványként és a gipszet ( $1008\text{ cm}^{-1}$ ) felületi átalakulási termékként tartalmazó szarkofágok Raman spektruma

thousands of data are available (e.g. Herz 1985, Attanasio et al. 2006, Zöldöföldi et al. 2011).

Based on the results, the stable isotope compositions of the raw material of the sarcophagi overlap with the isotope signals of following quarries: Thassos and Paros (Greece, **Fig. 20.**), Proconnesos, Miletus, Muğla, Altintas, possibly Hierapolis (Asia Minor, modern Turkey, **Figs. 21-22.**). Based on the stable isotopes, Carrara/Serravezza could also be considered as a possible source (**Fig. 23.**), but this can be excluded due to the different grain sizes mentioned above. Four samples (11, 18, 19, and 27) are outside of these isotopic ranges, therefore, these values are checked first and the samples are analyzed further, possibly using samples from a second sampling or by determining the  $^{87}\text{Sr}/^{86}\text{Sr}$  isotope ratios, thin section microscopy, and cathodoluminescence analysis, in order to get more insights into their provenance.

To answer the provenance question and get more reliable information of the isotopic and MGS results, 3D diagrams were constructed. The trivariate assignment methods using isotopic signatures (MGS,  $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$ ) of Anatolian, Greek and other known marbles was used in this study to establish their provenance among of bivariate plots ( $\delta^{13}\text{C}$ ,  $\delta^{18}\text{O}$ ). Comparing the two methods, the trivariate method allows a better selectivity and a much more secure assignment of provenance. The major difficulty of the trivariate method is the scarcity of data in literature, where all three values are published on the very same sample. Significant differences can be observed using the 3D diagrams (MGS,  $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$ ) of the marbles in the Eastern Mediterranean Region (**Fig. 24.**). As **Fig. 25.** clearly shows, samples 7 and 8 can very probably be assigned to the so-called non-lychnitic

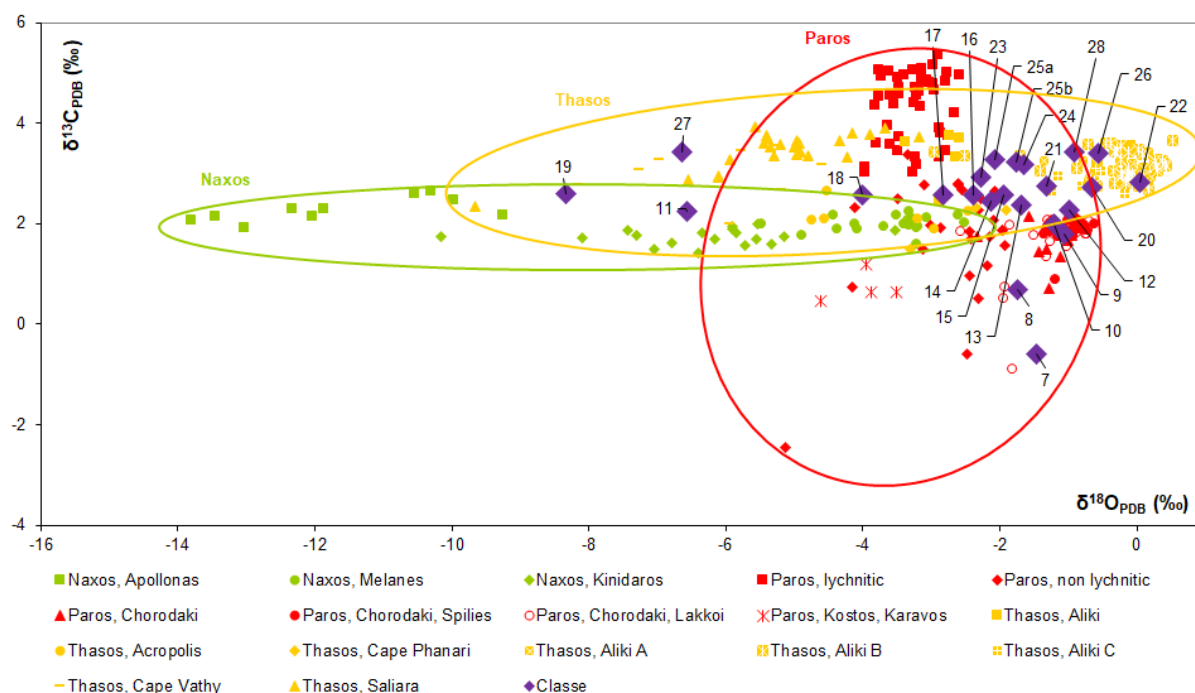
marble quarries on the island of Paros. Furthermore, with the help of the 3D diagrams, samples can be clearly assigned to the marble quarries on the islands of Marmara and Thasos (**Fig. 26.**).

### Conclusion

The provenance of the marble of eleven sarcophagi now in the basilica of San Apollinare in Classe near Ravenna was analyzed. The non-destructive investigations (macroscopic and microscopic description, determination of grain size analyses and mineralogical investigations by the means of Raman spectroscopy), combined with minimally invasive sampling and the determination of stable isotopes, have led to the following results.

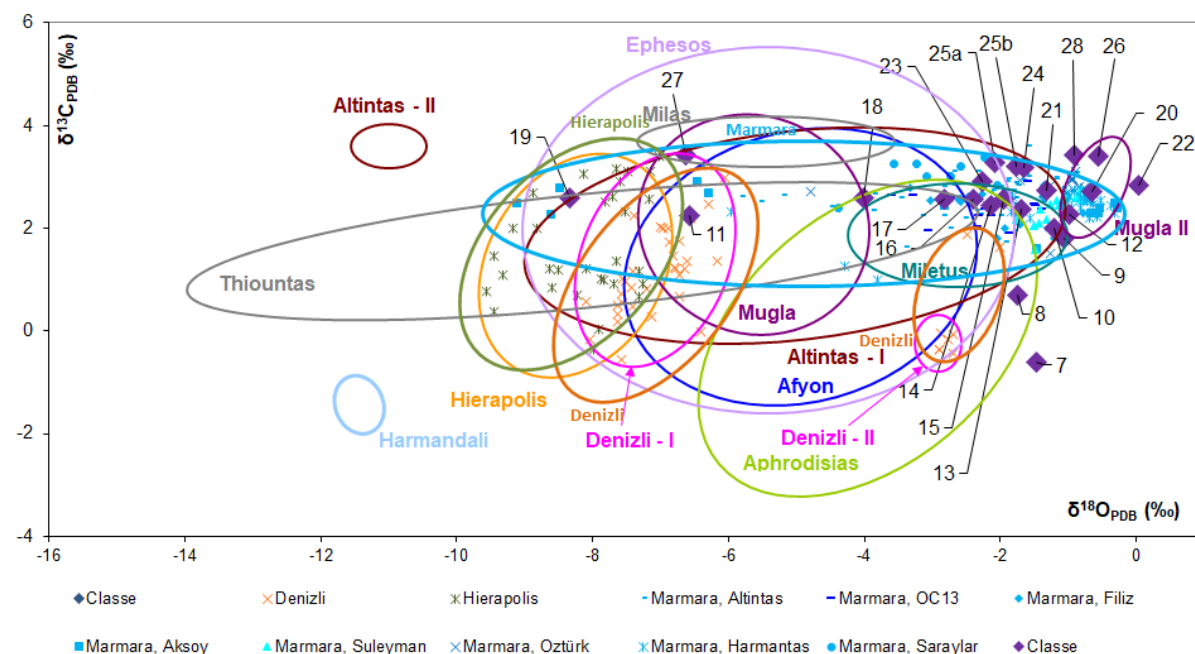
The results of the analyses suggested that the majority of the chests (8 out of a total of 11) were very probably made of Proconnesian marble, two were probably made of Paros marble and one was probably from the quarry in Denizli although this has to be confirmed by further analyses. As far as the lids of the sarcophagi are concerned, the dominance of Proconnesian marble is not as obvious as in the case of the chests: only four lids have been reliably identified as being made of Proconnesian marble, while the other three lids are made of Thassian marble and only two lids are made of Paros marble. Two lids can be identified as coming from the quarries of Marmara Island (Proconnesos) or from Thassos. However, as these two kinds of marble belong to the same geological unit, further investigations are required based on  $^{87}\text{Sr}/^{86}\text{Sr}$  isotope ratios, thin section preparation, statistical grain size distribution analysis and cathodoluminescence observations will confirm one of the proposed provenances.





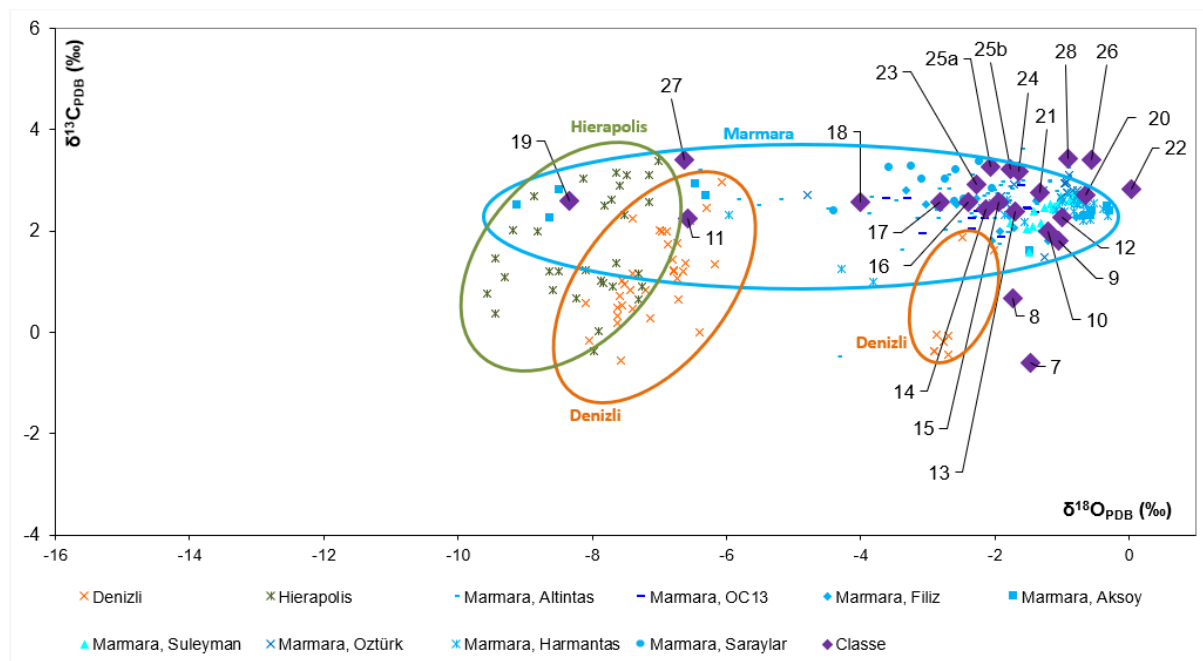
**Fig. 20.:** Data set of  $\delta^{13}\text{C}$  versus  $\delta^{18}\text{O}$  isotopic compositions (in ‰, relative to PDB) from the sarcophagi in San Apollinare in Classe compared with the data set of middle to coarse grained (MGS>1.5 mm) marble from Greece

**20. ábra:** A San Apollinare in Classe-i szarkofágok  $\delta^{13}\text{C}$  és  $\delta^{18}\text{O}$  izotópos összetételének adatai (‰-ben, a PDB-hez viszonyítva), összehasonlítva a Görögországból származó közepes és durva szemcséjű (MGS>1,5 mm) márványok adathalmazával



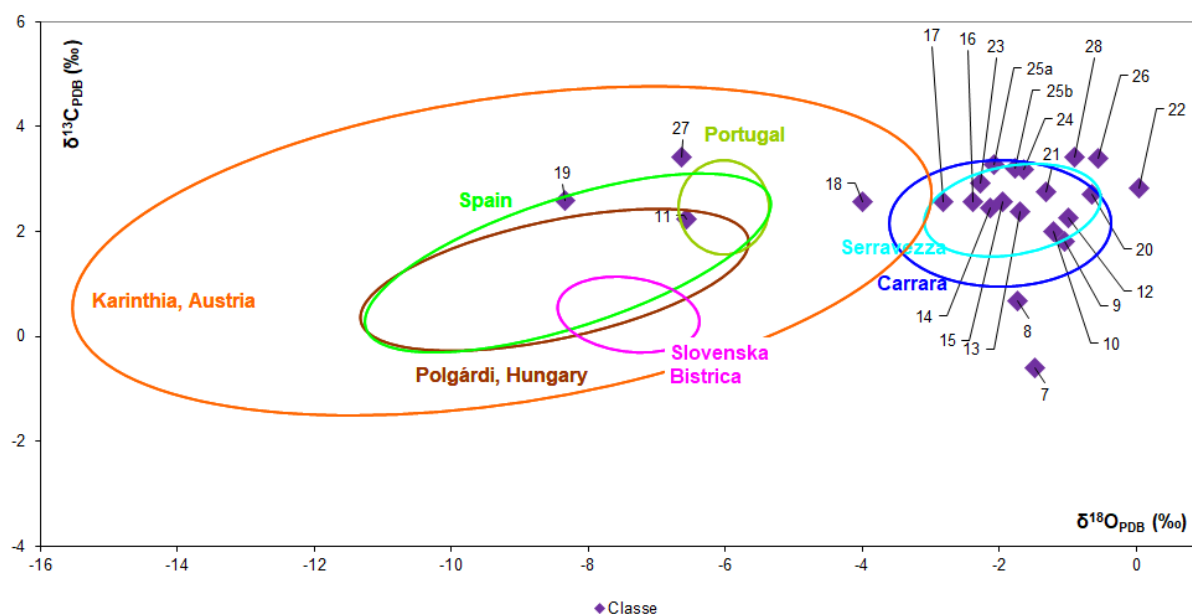
**Fig. 21.:** Data set of  $\delta^{13}\text{C}$  vs.  $\delta^{18}\text{O}$  isotopic compositions (in ‰, relative to PDB) from the sarcophagi in San Apollinare in Classe compared with the data set of middle to coarse grained (MGS<1.5 mm) marble from Asia Minor

**21. ábra:** A San Apollinare in Classe-i szarkofágok  $\delta^{13}\text{C}$  és  $\delta^{18}\text{O}$  izotópos összetételének adatai (‰-ben, a PDB-hez viszonyítva), összehasonlítva a Kis-Ázsiából származó, közép- és durva szemcsés (MGS<1,5 mm) márványok adathalmazával



**Fig. 22.:** Data set of  $\delta^{13}\text{C}$  vs.  $\delta^{18}\text{O}$  isotopic compositions (in ‰, relative to PDB) from the sarcophagi in San Apollinare in Classe compared with the data set of selected middle to coarse grained (MGS < 1.5 mm) marble from Asia Minor

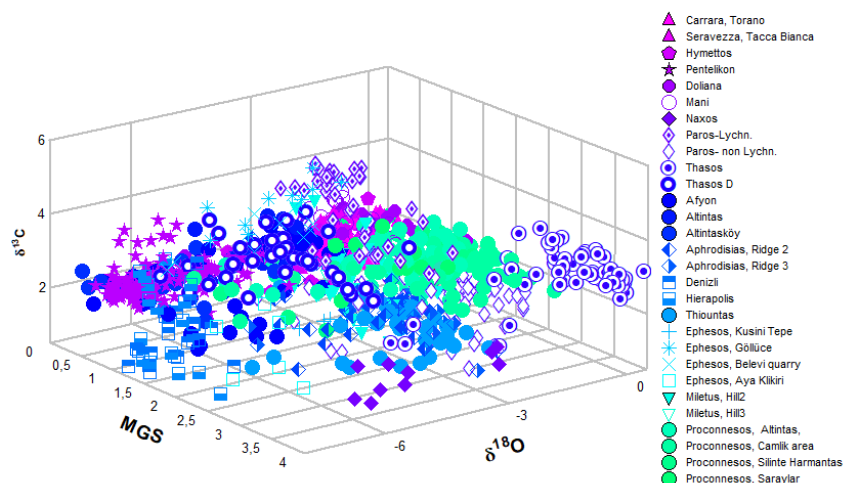
**22. ábra:** A San Apollinare in Classe-i szarkofágok  $\delta^{13}\text{C}$  és  $\delta^{18}\text{O}$  izotópos összetételének adatai (‰-ben, a PDB-hez viszonyítva), összehasonlítva néhány Kis-Ázsiából származó, közép- és durva szemcsés (MGS < 1,5 mm) márvány adathalmazával



**Fig. 23.:** Data set of  $\delta^{13}\text{C}$  vs.  $\delta^{18}\text{O}$  isotopic compositions (in ‰, relative to PDB) from the sarcophagi in San Apollinare in Classe compared with the data set of middle to coarse grained (MGS < 1.5 mm) marble from Europe

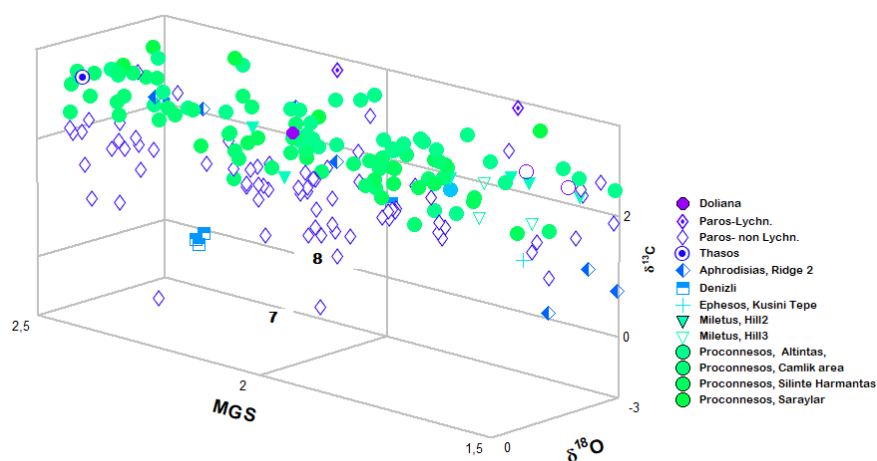
**23. ábra:** A San Apollinare in Classe-i szarkofágok  $\delta^{13}\text{C}$  és  $\delta^{18}\text{O}$  izotópos összetételének adatai (‰-ben, a PDB-hez viszonyítva), összehasonlítva az európai közép- és durvaszemcsés (MGS < 1,5 mm) márványok adathalmazával





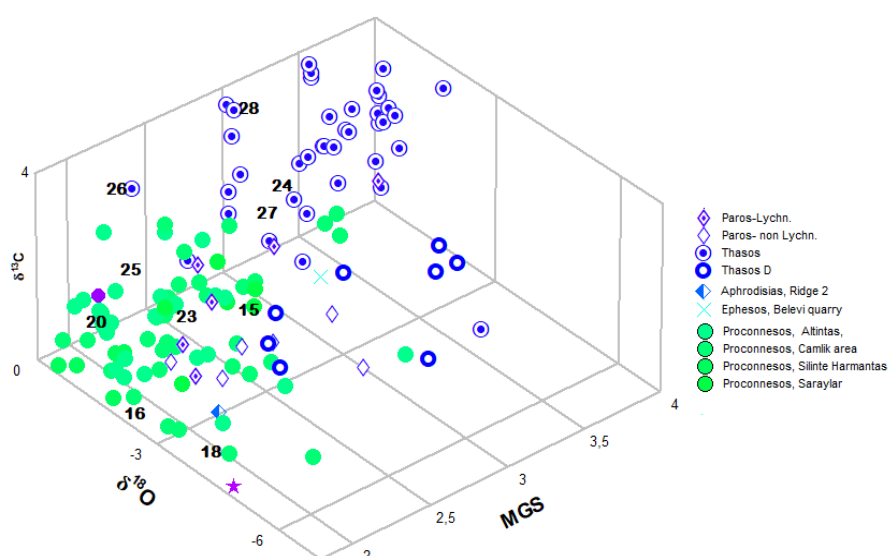
**Fig. 24.:**  
3D plots (MGS,  $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$ ) of marbles from the Eastern Mediterranean area

**24. ábra:**  
A Földközi-tenger keleti térségéből származó márványok 3D diagramja (MGS,  $\delta^{13}\text{C}$  és  $\delta^{18}\text{O}$ )



**Fig. 25.:**  
Comparative 3D diagram (MGS,  $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$ ) of samples 7 and 8 with the marble quarries of the eastern Mediterranean

**25. ábra:**  
A 7. és 8. minta, valamint a Földközi-tenger keleti részén található márványbányák összehasonlító 3D diagramja (MGS,  $\delta^{13}\text{C}$  és  $\delta^{18}\text{O}$ )



**Fig 26.:**  
Comparative 3D diagram (MGS,  $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$ ) of several sarcophagi from the Basilica of San Apollinare in Classe and the marble quarries of the Eastern Mediterranean

**26. ábra:**  
A San Apollinare in Classe bazilikából származó számos szarkofág és a Földközi-tenger keleti részén található márványbányák összehasonlító 3D diagramja (MGS,  $\delta^{13}\text{C}$  és  $\delta^{18}\text{O}$ )

On the basis of these analyses, it seems that in addition to the famous and widely used marble from Proconnesos, the calcitic marble from Thassos was also used in the northern Adriatic region in Late Antiquity. Even the quarries on the island of Paros and those in *Asia Minor* cannot be definitively ruled out. Future large-scale studies in Ravenna and other sites in the northern Adriatic are needed to continue to build a more complete picture of marble provenance and trade networks, but it is already possible to confirm that, in addition to the famous Proconnesse marble, more types of white or white-greyish marble were present in the Ravennate region.

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### Contribution of authors

**Helena Tůmová** Conceptualization, Investigation, Writing – Original text. **Zöldföldi Judit** Formal analysis, Investigation, Writing – Original text. **Enrico Cirelli** Supervision, Data curation, Resources.

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