ARCHAEOMETRY ON STONES. MULTI-METHOD APPROACH TO INVESTIGATE STONE PROVENANCE. STUDIED CASES FROM ROMAN HISPANIC MARMORA

KÖVEK ARCHEOMETRIÁJA: TÖBB MÓDSZER EGYÜTTES ALKALMAZÁSA SZÁRMAZÁSI HELY VIZSGÁLATOKRA. ESETTANULMÁNYOK HISPANIAI RÓMAI MÁRVÁNYOKON

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Abstract

This contribution aims to expose a number of considerations regarding the reliability of the analytical results in the investigation of the quarry source of stones used as raw material in archaeological pieces. In many cases, a sequential selection of common petrological techniques achieves a positive result in provenance identification. Together with petrography and the determination of C and O stable isotopes, the study must often be complemented by the application of an additional technique to increase the rate of success, especially with certain white marbles. In some cases, however, even with a multi-method approach, the analytical results only guarantee an uncertain provenance between two possible marble sources. Additional remarks are reported after the archaeometric studies carried out on marble pieces found in Roman Hispania, where the presence of both, local and imported marbles, makes provenance study more difficult.

Kivonat

Ez a tanulmány a bányahely azonosítás problémáival, az anyagvizsgálati eredmények megbízhatóságával foglalkozik. Sok esetben, különféle kőzettani technikák megfelelő sorrendben történő alkalmazása jó eredményeket hozhat a származási hely vizsgálatok tekintetében. A kőzettani vizsgálatokkal együttesen alkalmazott stabil izotóp vizsgálatok mellett további technikák alkalmazására is sort kell keríteni a hatékonyság növelése érdekében, különösen bizonyos fehér márvány típusok esetében. Egyes esetekben azonban még a többféle vizsgálati technika is csak bizonytalan azonosítást tesz lehetővé, például két lehetséges márványbánya azonosítása tekintetében. További példákat mutatunk be a római kori Hispánia márvány leletein, ahol mind a helyi, mind a távolsági eredet felmerülhet a márványok tekintetében, ami a vizsgálatok körét kiszélesíti és megnehezíti.

KEYWORDS: MARBLE, QUARRY, ARCHAEOMETRY, IBERIAN MARBLES

KULCSSZAVAK: MÁRVÁNY, KŐBÁNYA, ARCHEOMETRIA, IBÉRIAI MÁRVÁNYOK

Introduction and aims

Stone and stone artefacts are common in archaeological remains, not only from Roman times, but also from many other periods. It is clear that a wide variety of stones were used for artefacts at different times and in different parts of the world. In general terms, throughout History, man has taken advantage of stone resources that were readily available. Since prehistoric times, man has known how to select stone depending on its quality to be used as a tool, a noble decorative element or perhaps for its special symbolic value. The archaeometrical study of stone pieces helps to understand the way of life of the ancient communities as the results can be of considerable value in establishing the provenance of artefacts and in elucidating exchange mechanisms, as well as providing geographical and chronological evidence of man's activities.

The study of the original geological source, or provenance study, is approached using different petrological, physical and chemical methods, depending on the stone element being under investigation. Dealing with building and decorative stones, it is undertaken through petrographical analyses that make it possible to determine their origin and to identify the quarry from which they were extracted. In general and for economic reasons, local stones were always widely used. The macroscopic and petrographical description of the stone provides a detailed characterization of the lithology, which is indispensable to address a successful identification. The extensive field survey around the archaeological site allows for checking the existence of the stone extraction fronts or locating previously unknown quarries. The type of quarry, number of extraction fronts, tool marks, type and size of the obtained elements, quarrying techniques, are all aspects that facilitate an

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understanding of the implications of stone resource exploitation.

In recent years the scientific community has been paying great attention to the archaeometrical study of archaeological marble pieces from the Hellenistic-Roman world (Maniatis, 2009; Gutiérrez Garcia-M et al., 2012 and other Asmosia proceedings). This survey focuses on the identification of the original stone raw material through the comparative analyses of rocks from ancient quarries. The results not only help to certify their authenticity, but contribute to the identification of copies, to match fragmented pieces and help with the planning of the work of conservation and restoration. In addition, they provide a better historical knowledge of the taste for certain varieties of marble, the preference of use by the sculptural workshops and the intercultural connection of the different artists, not to mention the economic impact arising from the exploitation and trading networks, including the use and distribution of local marbles.

In the sphere of Roman stone artefacts found in Hispania, not only the classical marbles were imported but also different white and coloured marbles were quarried from local sources, increasing the difficulty in discriminating the stone provenance (Àlvarez et al, 2009a; Lapuente 1995; Lapuente et al, 2014). In most cases, the statuary quality of Iberian marbles cannot compete with that of the classics. However, those marbles exploited in the SW of the Iberian Peninsula, particularly from different districts of the Ossa Morena geological unit, were highly appreciated in Roman times with excellent results of carving (Nogales & Beltrán, 2008; Nogales et al, in press). They are the so-called marbles of the Estremoz Anticline district, located in Lusitania, and those from the Almadén de la Plata district, in the Baetica Roman province (**Fig. 1**). Being originally from the same geological unit, the Ossa Morena of the Iberian Massif, both exhibit similarities in physical and compositional parameters, which make it more difficult to ascertain the marble origin of Hispanic artefacts. Additionally, in the Alpine Betic Chain, south of Iberia, pure dolomitic marbles were exploited in Mijas-Coín (quarries of the Málaga district). Their compositional and textural parameters are similar to those of Thasos dolomitic (Lapuente et al, 2000; 2002), increasing even more the complexity of provenance identification. Furthermore, Estremoz, Almadén de la Plata and Coin-Mijas together with other minor quarries from the Malaga district, have recently been identified in archaeological remains outside Iberia (Antonelli et al, 2009; 2015; Origlia et al, 2011). These identifications in the North of Africa open a new perspective for consideration in marble provenance analyses, as until now, these marbles were thought to be destined exclusively for local markets. A wide variety of physical and chemical techniques exist today to establish the nature and provenance of the stone artefacts. Databases, such as The Miss Marble database, (Zöldföldi et al, 2009) of combined mineralogical as well as chemical and physical parameters aim to help discriminate between ancient quarrying areas.

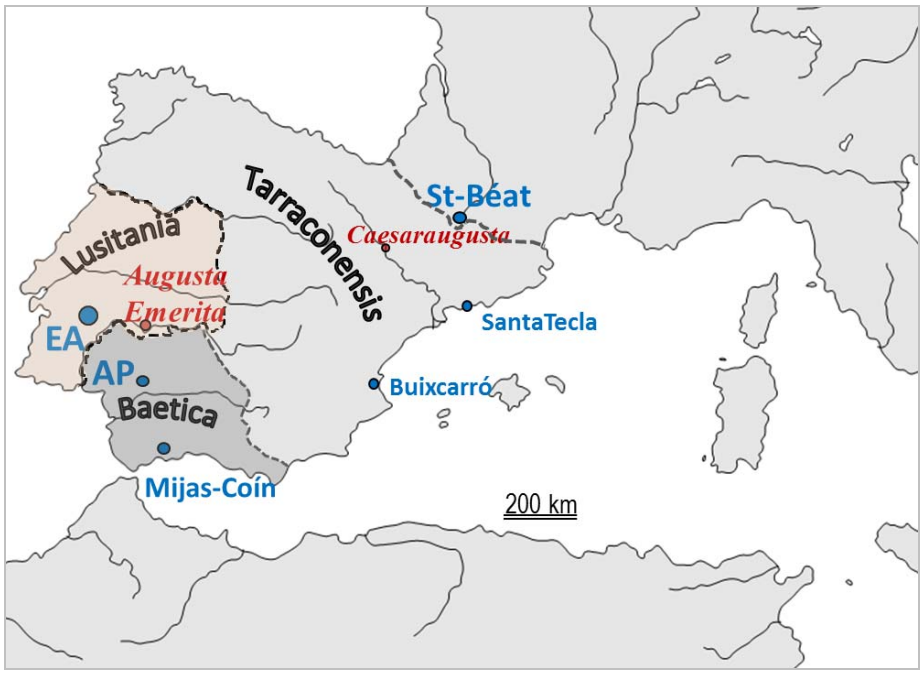

Fig.1.

Geographical setting of the Hispanic archaeological sites, the Roman provinces and the principal Iberian quarries named in the text. EA: Estremoz Anticline district. AP: Almadén de la Plata.

1. ábra

A szövegben említett lelőhelyek, a római provinciák és bányahelyek térképe. EA: Estremoz Antiklinális körzet. AP: Almadén de la Plata.

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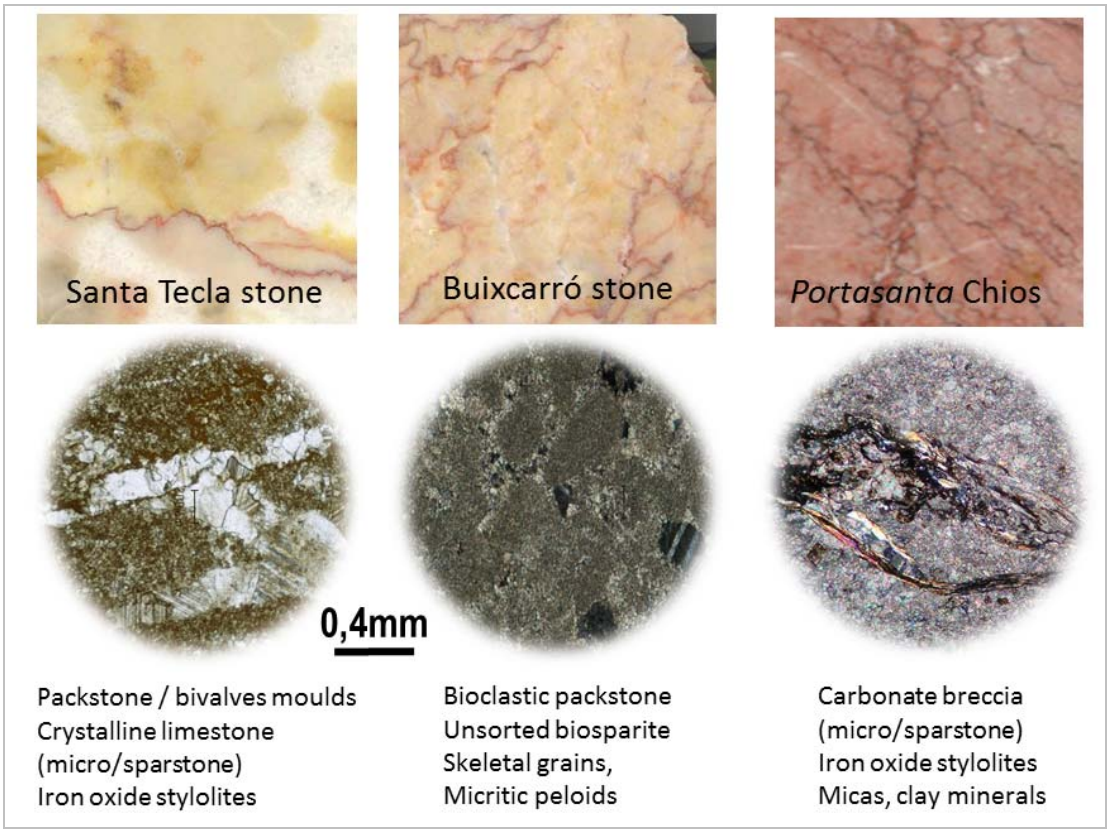

Fig. 2.: The yellow variety of Santa Tecla, exploited by Romans in the city of Tarraco visually resembles the appreciated *Giallo antico*, or *marmor Numidicum* from Tunisia. Additionally, the pink variety of Santa Tecla is quite similar not only to other Hispanic stone, the Buixcarró (*marmor Saetabitanum*) exploited near Xativa in Barxeta (Valencia), but also to the *Chium marmo*r known as Portasanta from the island of Chios. As both classical marmora were usually imported into Hispania, the petrographic approach is needed to discriminate the imported from the local stones. All these carbonate varieties are well identified using optical microscopy (Àlvarez et al, 2009a,b).

2. ábra: A Santa Tecla típusú kőzet sárga változata amelyet Tarraco környékén bányásztak a római időszakban szabad szemmel erősen hasonlít a tunéziai *Giallo antico*, más néven *marmor Numidicum*-ra. A Santa Tecla rózsaszín változata emlékeztet más hispániai bányászott kőzetekre, pl. a Xativa környéki Buixcarró márványra (*marmor Saetabitanum*), de a Chios szigetéről származó Portasanta vagy *Chium marmo*r-ra is hasonlít. Miután mind a két területről importáltak márványokat Hispániába, a megfelelő forrásterületek elkülonítéséhez kőzettani mikroszkópos vizsgálat szükséges

Macro- and microscopic examinations are always recommended as a starting point, yielding the basic information related to the nature of the stone being studied, on which to build a plan for more detailed examination. Rather than the methodological aspects, widely commented elsewhere (Attanasio, 2003; Lazzarini, 2004), this paper means to offer a series of guidelines intended to serve as a clarification for those not familiar with the archaeometrical study of marbles and who consider that the fact of having analyzed a piece is always sufficient guarantee to certify their quarry of origin.

Marble, marmor in Roman times

The term "*marmor*" used by the Romans, has a similar meaning to that of commercial marble, today. Mainly a proper metamorphic marble, but also whatever sedimentary carbonate rock, even stones of another nature such as serpentines, alabasters, basalts, granites, porphyries, jaspers, etc., which have enough quality to exhibit attractive coloured patterns after polishing. Pompey, Caesar, Cicero all succumbed to the fascination for the architectural and sculptural Hellenistic marbles. During and after Augustus, there was great enthusiasm for marble monuments and ornaments in both public and private spaces as a symbol of the power and image of the Empire. Coloured *marmora* were quarried from many different places around the Mediterranean. Most of their quarries were the property of the Emperor himself and their exploitation and stone trading was kept under strict administrative control.

The accessibility of the quarries to the nearest port for sea transport was obviously essential. They are well known to scholars because they were documented by the classic sources such as Pliny and even their high prices are known through Diocletian´s edict. *Marmora* used as pavements, opus sectile or walls covered with slabs became synonymous of power and richness, all over the Roman territories. The most important *marmora*, including white marbles, were exploited from the eastern Mediterranean area of Greece and Asia Minor, including their islands, together with Carrara in Italy. Other quarries were those of the conquest territories in the North of Africa, Gallia and Hispania (Àlvarez et al, 2009a).

The archaeometrical study of coloured marmora

The provenance study of coloured *marmora* can be a relatively easy task after a first visual inspection and a later comparison with well-known catalogues (Mielsch, 1985; Gnoli, 1988; Borghini, 1992; Napoleoni, 2001, etc). Additionally, the approach can be carried out by checking historic collections like that of Faustino Corsi found on display at the Museum of Natural History in Oxford and recently available on-line (www.oum.ox.ac.uk/corsi/).

However, the heterogeneity of colour patterns, the state of fragmentation, the existence of diverse varieties extracted from the same quarry and also the imitation with local stones, makes their study more difficult. It is in these cases where petrography is essential to avoid misidentification (**Fig. 2.**).

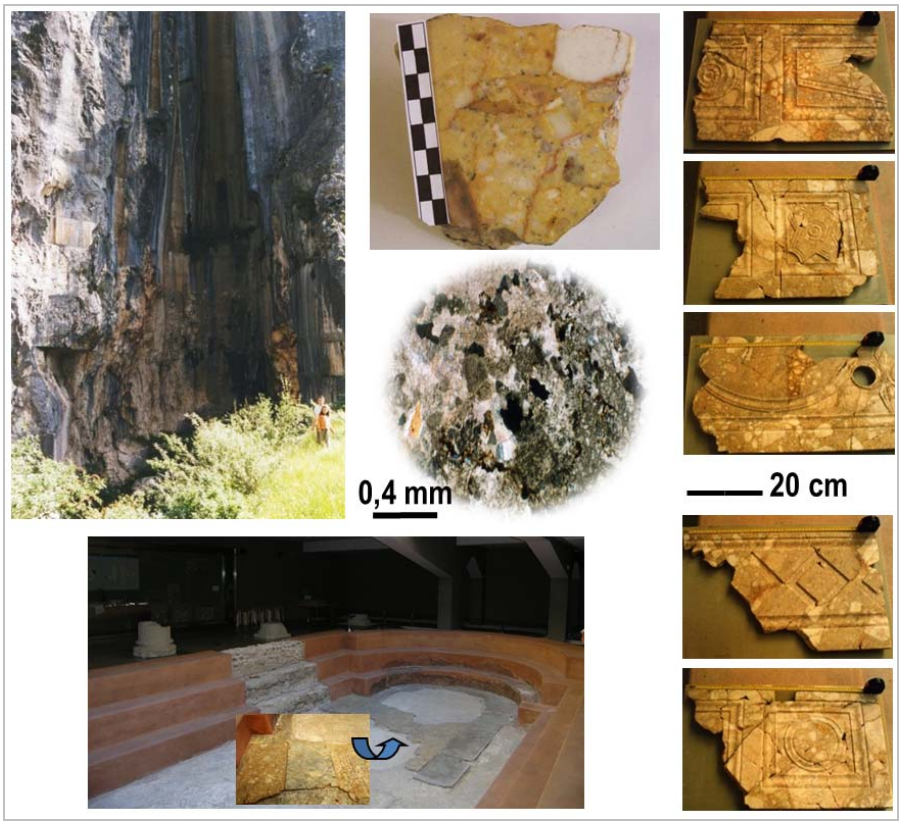

Fig. 3.: In Caesaraugusta, a yellow breccia with some golden shades which recall the precious Giallo antico brecciato was used in different buildings. In the public baths, rectangular slabs of this material covered the ground of a large open air swimming pool and also, with ornamental geometric figures, veneering the south wall. After macro and microscopic examination the stone was identified as the Roman breccia from Saint Béat (place called "La Péne-Saint-Martin) in the French Pyrenees, a marble district where white, grey and banded marbles were also exploited in Roman times.

3. ábra: Caesaraugusta-ban a Giallo antico brecciato-ra emlékeztető sárga breccsát használták a különféle épületeknél; pl. a közfürdőkben Makroszkópos és mikroszkópos vizsgálatok szerint a kőzet Saint Béat-ból származik (Francia Pireneusok, La Péne-Saint-Martin környéke), ahol fehér, szürke és szalagos mintázatú márványok egyaránt előfordulnak..

A guideline to take into account in the provenance study is the association of different *marmora*. White and coloured marbles jointly exploited from the same area reinforce their mutual identification when both were used in the same architectural decorative programmes. This is the case of certain white and coloured marbles used in Caesaraugusta. An enormous range of several *marmora*, in large and small slabs, covered the orchestra of its Roman Theatre. Their provenance was studied to discover the source area, which at first was only known not to be local. A yellow breccia with some golden shades which recall the precious *Giallo antico brecciato* from Tunisia, but quarried in the French Pyrenees, was the key to identifying many other varieties in white, grey and banded marbles exploited in the same district (**Fig. 3.**).

White marbles

Regarding white marbles, a multi-method approach must be applied in order to discriminate their provenance. A previous step is needed, a database with as many identifying parameters or «finger prints» as possible of the ancient quarry marbles obtained through the application of the same techniques. The identification of the marble source used in one archaeological piece involves a parallel analytical study which may be more or less complex, depending on different factors, from which the existence of local-regional marbles increases the uncertainty. Unlike the multicoloured *marmora,* white marbles need to be analysed following a step by step protocol and even their determination may be unsettled despite applying different analytical methods.

Analytical databases with quarry marbles

The initial phase of the provenance study is based on the elaboration of an analytical database of ancient marble quarries. Each research group works mainly with their own samples and their own analytical database, complemented with additional information from literature. However, not all databases include the same samples and the same methods, while some are based on mineralogical X-ray power diffraction (XRD), optical microscopy (OM) and stable C-O isotopic data; others deal with electron paramagnetic resonance (EPR) data, stable isotopes and certain petrographical parameters such as the maximum grain size (MGS). Cathodoluminescence (CL) microscopy, combined with stable isotopes, has been used for known classical quarrying areas (Barbin et al, 1989, 1992), as well as in Central Europe (Jarč & Zupančič, 2009; Št'astná et al, 2009) and in Iberia (Lapuente et al, 2000, 2014).

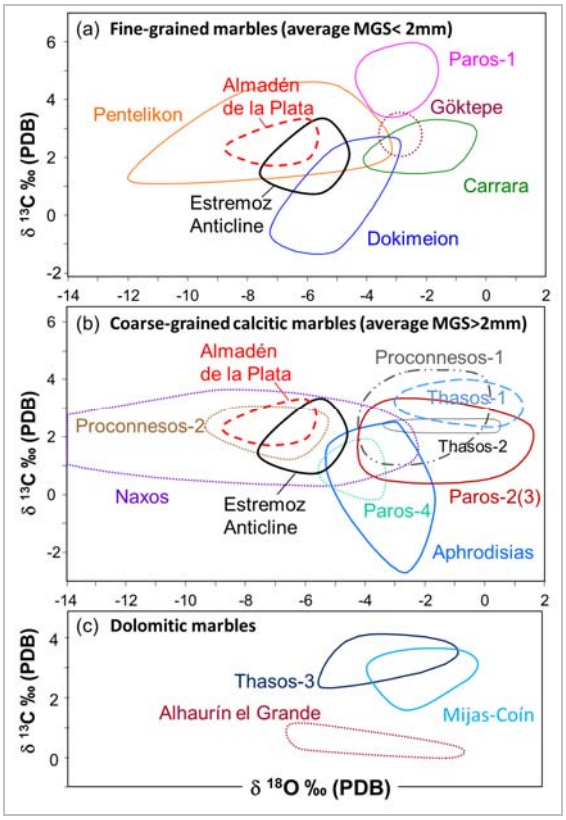

Fig. 4.: Isotopic signature of the most important Roman Hispanic white marble quarries compared with the classical marbles.

4. ábra: A legfontosabb római kori hispániai fehér márvány bányahelyek stabil izotóp adatai a klasszikus antik márványokhoz hasonlítva

Although it is true that each research team applies their available methods, most of them select the parameters established from a common group of techniques, (OM, XRD and stable C and O isotopes), which are the basis of the characterization of many marbles used in antiquity (e.g. Lazzarini et al, 1980; Herz, 1987; Moens et al, 1992). Marbles from one district of quarries usually have an isotopic signature distinctive from the rest of the marble sources. To improve comparison and discrimination, two different isotopic signature diagrams are commonly used (Gorgoni et al, 2002), one for fine grained marbles (MGS<2mm) and another for the coarse grained ones (MGS>2mm). Although much overlapping is common, especially for the coarse grained marbles, it is by far one of the most popular techniques, whenever it is combined with other techniques like thin-section microscopy. The recent discovery of ancient quarries of Göktepe, in Asia Minor (Attanasio et al., 2009) offers an additional marble source to be considered in the study of marble origin, whose isotopic signature partially overlaps those of Carrara and Dokimeion (Attanasio et al, 2015). Regarding the stable C and O isotopes of the most important Hispanic quarry marbles, updated

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isotopic diagrams for the Estremoz Anticline district in Lusitania and for Almadén de la Plata in Seville, have been reported (Lapuente et al, 2014). In both marble districts, the intra-quarry variation of features affects from macro- to microscale and it is not unusual to find different petrographical characteristics in one single marble block.

In **Fig. 4.**, both Iberian Estremoz Anticline and Almadén de la Plata isotopic fields are plotted in the reference isotopic diagrams for the classical marbles according to Gorgoni et al, (2002) in which the Göktepe field has also been included after data by Attanasio et al (2009, 2015). Pure dolomitic marbles from Mijas-Coín and dolomitic from Alhaurín el Grande together with Thasos dolomitic are also drawn in the same figure. Both Malaguese white marbles have been recently identified in archaeological pieces from Banasa, Morocco (Antonelli et al, 2015).

Secondly, other additional techniques such as the CL or EPR have been applied with success to identify classical marbles (Barbin et al, 1992; Attanasio et al, 2000; 2006; Polikreti & Maniatis, 2002). The use of additional CL features facilitates the discrimination of both mentioned Hispanic districts, whose marbles are similar –looking metamorphic rocks derived from comparable carbonate sequences subjected to a complex structural tectono-metamorphic evolution. Recent studies focused on the characterization of Hispanic marbles, lead us to draw attention to the similarity in visual and petrographical characteristics of white and coloured marbles of Estremoz Anticline and Almaden de la Plata. However, the combined use of Almadén de la Plata with dolomitic marble of Mijas-Coin found (Málaga), in different archaeological remains along the Guadalquivir Valley (Beltrán & Loza, 2008) facilitates their identification. The association of both Baetican materials gives great advantage to address the marble database comparison (Origlia et al, 2011; Antonelli et al, 2015). On the other hand, although both types of marble from the Ossa Morena unit share physical and compositional parameters, the additional combination of CL and isotopes is proving advantageous in their discrimination helping to improve knowledge about the dissemination of both types of marble and corroborating the minimal use of marbles originally from a different administrative Roman province (Lapuente et al, 2014).

Finally, despite this battery of techniques, certain marbles like some varieties of the recently discovered quarries of white Göktepe in Asia Minor (Attanasio et al, 2009) require additional parameters to be distinguished from Carrara marbles (Lapuente et al, 2012). Fortunately, the combination of different content of strontium seems to be useful for their discrimination (Attanasio et al, 2015).

The application of the database

In determining the marble quarry origin of one archaeological artefact, the analyst is faced with a number of difficulties that may affect the final interpretation of the results. On the one hand, sampling the archaeological artefact can be a difficult task and to avoid defacing the piece, a sample is not always taken from the most representative area to identify the marble source. The visual inspection of the complete piece is always recommended to observe any macroscopic characteristic not registered on the sample taken. The natural patina and even the sulphurous smell when being crushed can be useful qualitative features to help in the provenance study.

On the other hand, the more parameters the database contains, more likely it becomes to find the match, though at the same time, more difficult is the step by step comparison due to the common overlapping of features. The results sometimes fail to match well with the comparative parameters due to the lack of certain samples in the databases, either because some ancient quarrying sources still remain undiscovered or because they have become erased after years of intensive quarrying activity. In addition, some “finger prints” may not be exclusive to a single quarry and conversely, the intra-quarry variation from macro to micro-scale, can negatively affect the study of fragmented pieces, especially if great differences are detected in one single marble block. Moreover, the multiplicity of databases and the diversity of analyses with a different presentation of results make the correlation and comparison difficult among samples of different research groups.

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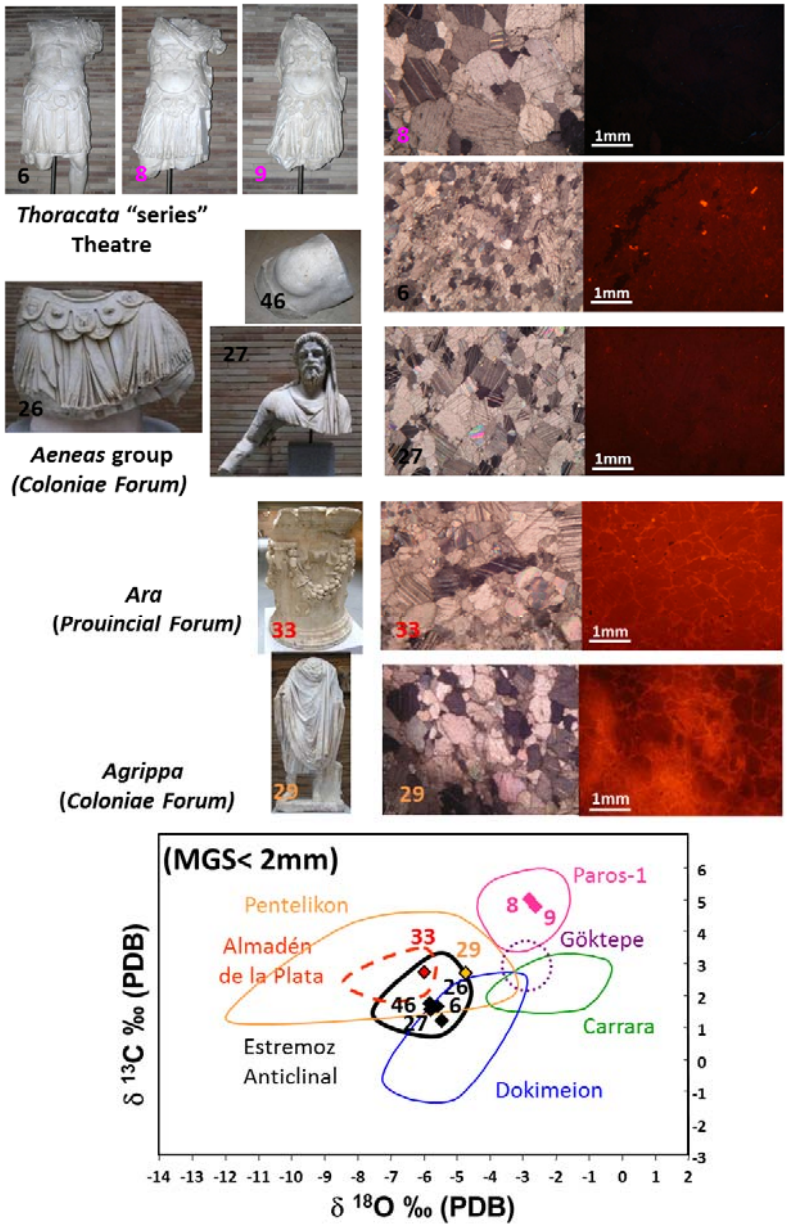

Fig. 5.:Three fragmented pieces of the Aeneas group from the Coloniae Forum of Augusta Emerita (capital of Roman Lusitania) were assigned to the same type of fine grained marble of the local Estremoz Anticline district, confirming the hypothesis of being a replica sculpture following a model from the Metropolis (Samples 26, 17 and 46). In the «series» of Thoracata Emperor from the scaenae frons of the Theatre of Augusta Emerita, only the archaeometric analyses reveals which marbles were local and which were imported. In this case, the quality of the local Estremoz Anticline marble allowed the skilful artist to achieve an excellent result, following the style of the other pieces carved in marble from the island of Paros (lychnites) (Samples, 6, 8 and 9). In sample 33, the petrographic features and the moderately strong CL intensity are compatible with two Iberian marble sources, Estremoz Anticline and Almadén de la Plata. Both provenances are also possible through its isotopic signature. Both marble sources are located in the same geological unit, the Ossa Morena, but in a different Roman administrative province, Estremoz in Lusitania and Almadén de la Plata in the Baetica province. Both were widely used in the SW part of Hispania, but each one was particularly used in each respective administrative province. In sample 29, the petrographic and CL features along with the isotopic signature are compatible with a local marble (Estremoz Anticline) and an imported marble (Pentelikon).

5. ábra: Három töredék Lusitania Augusta Emerita forumáról, amelyet a helyi Estremoz Antiklinális márványaihoz kötöttek.. További vizsgált márvány töredékek, ahol archeometriai vizsgálat tisztázta a márványok eredetét.

In general, over the last decade, studies on the origin of marbles have progressed with great success. In principle, the implementation of the first group of techniques (OM, XRD and stable isotopes) may be enough to find the origin of the marble used for an archaeological piece. The combination of mineralogical-petrographical features with the isotopic, works relatively well to discriminate a lot of classical marbles and many Hispanic marbles. This is the case applied to distinguish certain archaeological pieces from Augusta Emerita with common petrographical parameters, but their different isotopic signatures serve to be assigned to a different marble source, one local (Estremoz Anticline district) and the other a Lunense marble (Lapuente et al, 2000; 2014).

The presence of local marbles in addition to the imported increases the difficulty of discovering marble provenance of Hispanic artefacts. Moreover, the high quality of the finished sculpture work should not presuppose the idea of an imported marble having been used. Conversely, the technical quality of certain Iberian white statuary marbles made excellent carving works possible in the hands of skilful sculptors. Even using a combination of different techniques, certain doubts arise with the marble provenance of some cases, such as an *ara* from the Prouincial Forum of Augusta Emerita or the case of the Agrippa Statue (**Fig. 5.**).

Conclusions

Although there is no single reliable satisfactory method for matching the marble source of an artefact, the puzzle of information to distinguish one marble from another is gradually being completed using a combination of techniques. The provenance of Hispanic white marble artefacts is an even more difficult task. Not only does it require the application of several techniques, but also the archaeological criteria must not be overlooked since, together with imported marbles, extensive use was made of high quality local marbles such as those from the Estremoz Anticline district.

The interdisciplinary study with an archaeological hypothesis, regarding the nature of local or imported from the piece, based on the association's materials, their chronology, style, iconography, together with knowledge about the geographical distribution of local material, lies in a better interpretation of analytical results. Research involving new discriminating parameters has been leading towards the strontium isotopes and others more specific such as fluid inclusions. But currently, C and O isotopes combined with petrography and CL holds our greatest attention due to its successful application in many cases.

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