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A multi-analytical approach for determining the provenance of the marbles from Ruspina Roman baths (Monastir, Tunisia)

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Abstract Although most of the ancient monuments found in *Ruspina* Roman town situated near the town of Monastir in the Sahil region of Tunisia were built with local materials, the Roman baths in this site were mainly decorated with imported marbles from Greece, Asia, Numidia, Italy and Algeria, indicating the important trade relationships between *Ruspina* and the other Mediterranean Roman towns. Among the seven types of marbles used in the decoration of *Ruspina*'s Roman baths, four have been characterized in previous studies: white Proconnesian from Asia, Penthelic and green cipolin from Greece, and Antique yellow from *Simitthus* in Tunisia. To characterize and identify the other three types, series of analytical methods had to be applied: minero-petrographic analysis of thin sections, chemical analysis, and isotopic analysis of oxygen and carbon. Used together, the methods enabled to identify the marbles studied: the white fine-grained marble corresponds to Carrara white marble from Italy, and the spotted dull grey and greco scritto came from Cap de Garde

quarries in Algeria. With the exception on one type (antique yellow), the other six types were imported marbles.

Keywords Ruspina · Tunisia · Roman baths · Marble provenances · Petrographic analyses · Isotopes

Introduction

Since the end of the second century/beginning of the third century, urban construction and renovation were a quite general phenomenon in Ancient Africa, essentially due to economic growth and the influence of Roman civilization (Picard 1990; Mahjoubi 2000). During this period, urbanization and urban development were encouraged leading to the proliferation of cities in which intense public and private building activities were undertaken. Inevitably, this led to the growing demand for building and decorating materials which were not only found locally but were also imported from other Roman provinces.

In ancient Tunisia, many private and public constructions were built with different types of stones (sandstones, limestones, sand-limestones and marbles) extracted from local ancient quarries (Gaied et al. 2010; Younès et al. 2012; Younès 2014). Nevertheless, numerous other public constructions, and sumptuous private dwellings, especially situated in harbour towns, were built and decorated with marbles imported from other Roman provinces (Younès 1999; Agus et al. 2007; Stone et al. 2011).

The archaeological excavations in *Ruspina*'s site located near the town of Monastir in the Sahil region of Tunisia (Fig. 1) tended to focus on the medium-sized Roman baths, nearly 1486 m² and dating back from the second century A.D. They were situated in the south-south-west of the archaeological site where a great amount of ceramic and marble

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fragments were discovered. Most of the marbles used in the decoration of the baths have been studied and analysed macroscopically in a recent article (Younès 2013). Yet, the characterization and the exact provenance of three marble types (white, spotted dull grey, and greco scritto) could not have been determined with the sole experienced eye.

The aim of this paper is to identify and determine the provenance of these three types of marbles used in the baths decoration through multi-analytical analyses: minero-petrographic analysis, together with chemical and isotopic analyses of oxygen and carbon.

Presentation of the site of Ruspina

The site of the Ancient Punic-Roman harbour town of *Ruspina* is located at Henchir Tennir, about 5 km west-south-west from the modern town Monastir in the Sahil region of Tunisia (Kallala 1998) (Fig. 1). The Latin and Greek sources located *Ruspina* in Eastern *Byzacium* between two important ancient harbour towns, *Hadrumetum* (modern town of Sousse) and *Leptiminus* (modern town of Lamta).

Compared to these two harbour towns and others such as *Thapsus*¹ (modern town of Békalta) where systematic archaeological studies were carried out and published, *Ruspina* did not enjoy the same treatment and only limited studies have been published so far. Indeed, no systematic archaeological field surveys have been carried out to identify the still visible constructions and to collect the archaeological remains including marble fragments scattered on the ground. With the exception of the Roman baths where five excavations had been carried out during five different periods (in 1987, 1988, 1991, 2001 and 2002), the archaeological site has not revealed all his past secrets yet (Fig. 2). These baths have an area less than 1500 m² and date from the second century A.D. (Fig. 3). The marble fragments collected during the last period of excavations (2002) were analysed macroscopically leading to the identification and provenance of four types of marbles out of seven² (Table 1). To identify the other three fragments, further analytical analyses have to be applied to discriminate and assign these fragments to their corresponding sources.

¹ Among the archaeological studies published on Ancient harbour towns in the Sahil region of Tunisia, see: Foucher 1964; Ben Lazreg and Mattingly 1992; Younès 1999.

² During the 2002 excavation campaign, I (Professor Ameer Younès) was responsible for studying the collected marble fragments. I would like to express all my acknowledgments to Professor N. Kallala for granting me this study.

Sampling and analytical methods

Sampling

A total of seven fragments collected from the Roman baths were sampled and analysed in terms of composition and provenance (Fig. 4). Moreover, six fragments extracted from working fronts of two known ancient quarries (respectively, two from Fossa Cava, in Italy, and four from Cap de Garde, in Algeria) were also sampled for further analyses (Fig. 5a, b). The samples identified only through the experienced eye represent the majority of them (4/7) and were not submitted to other analyses, whereas several analytical procedures had to be applied to discriminate the other three samples (F31, F33 and F42).

Minero-petrographic analyses

The three samples have been studied mineralogically in thin sections under the polarizing microscope Leica DM 500 P and their mineralogical composition evaluated by means of a swift point counter. Thin sections observations permit to determine the fabric of the marbles and to identify the accessory and secondary minerals in addition to calcite. These main petrographic characteristics were compared with those of the samples taken from Cap de Garde and Fossa Cava ancient quarries.

Chemical analysis

The samples have also been submitted to chemical analysis and their chemical compositions were performed under atomic absorption spectroscopy (AAS) at the Mineral Resources and Environment Laboratory, Faculty of Sciences, Tunis. The results of their chemical composition have been compared with those of the samples collected from Cap de Garde and Fossa Cava ancient quarries.

Isotopic analyses

Oxygen and carbon analyses of the sampled marbles were conducted at the Cornell Isotopes Laboratory, Ithaca, New York, USA. Isotopic ratios of either two elements (¹⁸O/¹⁶O and ¹³C/¹²C) were measured by either elemental analyser/isotope ratio mass spectrometry (EA/IRMS: carbon ($\delta^{13}\text{C}$) or by thermal chemical conversion-EA/IRMS (TCEA/IRMS: oxygen: ($\delta^{18}\text{O}$)). Reproducibility (internal precisions) is better than 0.05‰ for both isotope ratios ($\delta^{13}\text{C}$ and $\delta^{18}\text{O}$). The results of the isotopic analysis were expressed as δ (‰) values relative to the international PDB standard and compared with isotopic diagrams of the most important fine-to-coarse grained Mediterranean ancient marbles (Moens et al. 1992; Gorgoni et al. 2002).

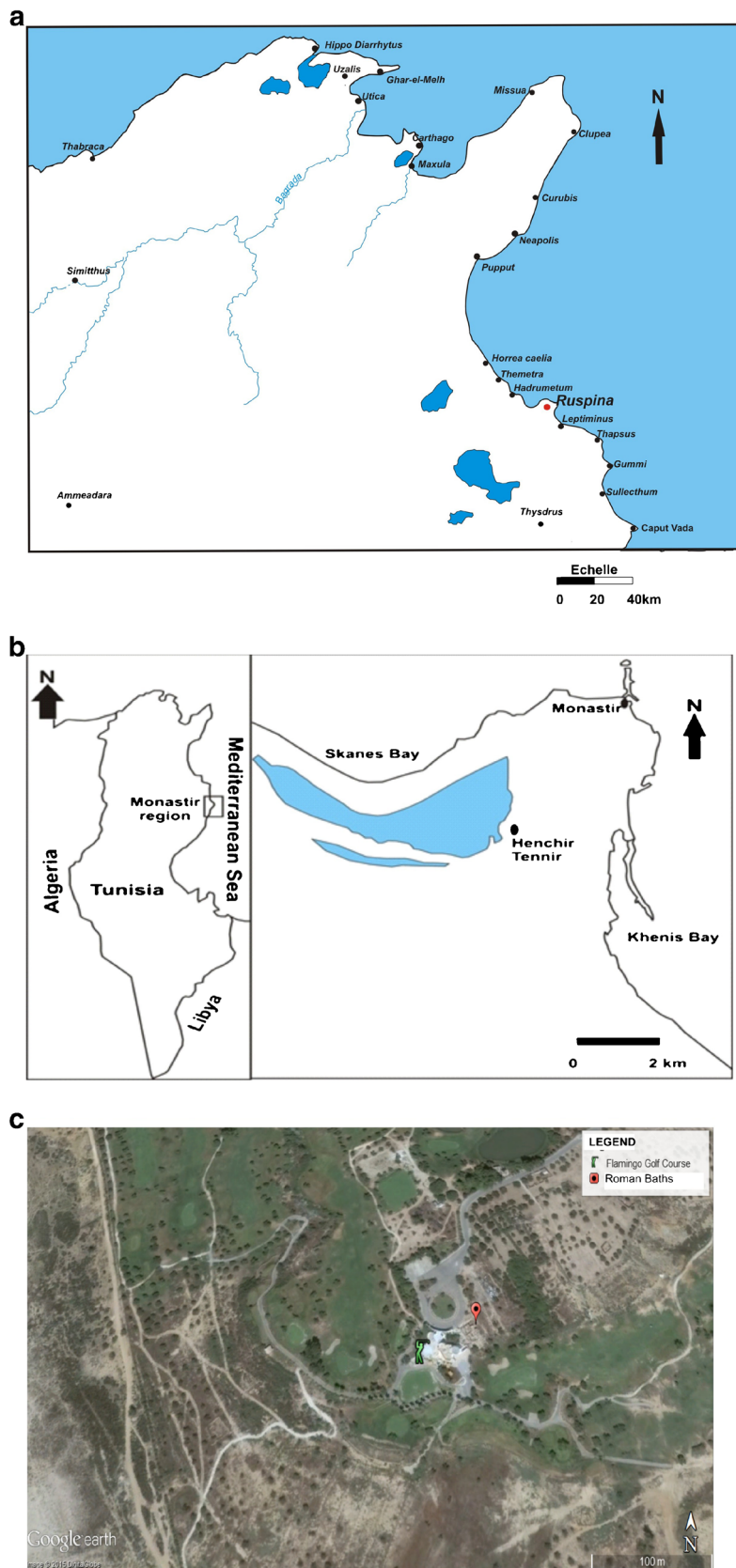


Fig. 1 Location of *Ruspina* Roman town (a), situation of Monastir modern town (b), and the studied archaeological site (c)

Fig. 2 View of a part of the excavated *caldarium* in the Roman baths



Results of the analytical procedures

Minero-petrographic results

The minero-petrographic analyses of thin sections performed on the three samples from Ruspina baths (F31, F33, and F42) reveal that calcite is the main component for all of them. The texture of the medium-to-coarse grained greco scritto sample (F33) is heteroblastic formed by interlocked crystals of calcite. Abundant black particles of graphite are found concentrated in

irregular veins and dispersed in the carbonated mass. Slightly deformed traces of polysynthetic twinning planes can also be seen (Fig. 6). The maximum grain size (MGS) of the grains of calcite varies from 2.08 to 3.02 mm with an average value at about 2.5 mm. Accessory minerals include graphite which is particularly abundant and responsible for the black coloured areas of the marble and quartz which is the other common accessory phase (Table 2).

The texture of the medium-to-coarse grained spotted dull grey sample (F31) is heteroblastic formed by crystals of

Fig. 3 Preliminary plan of Ruspina Roman baths (based on R. Hanoune's sketch), (excavation state 2002)

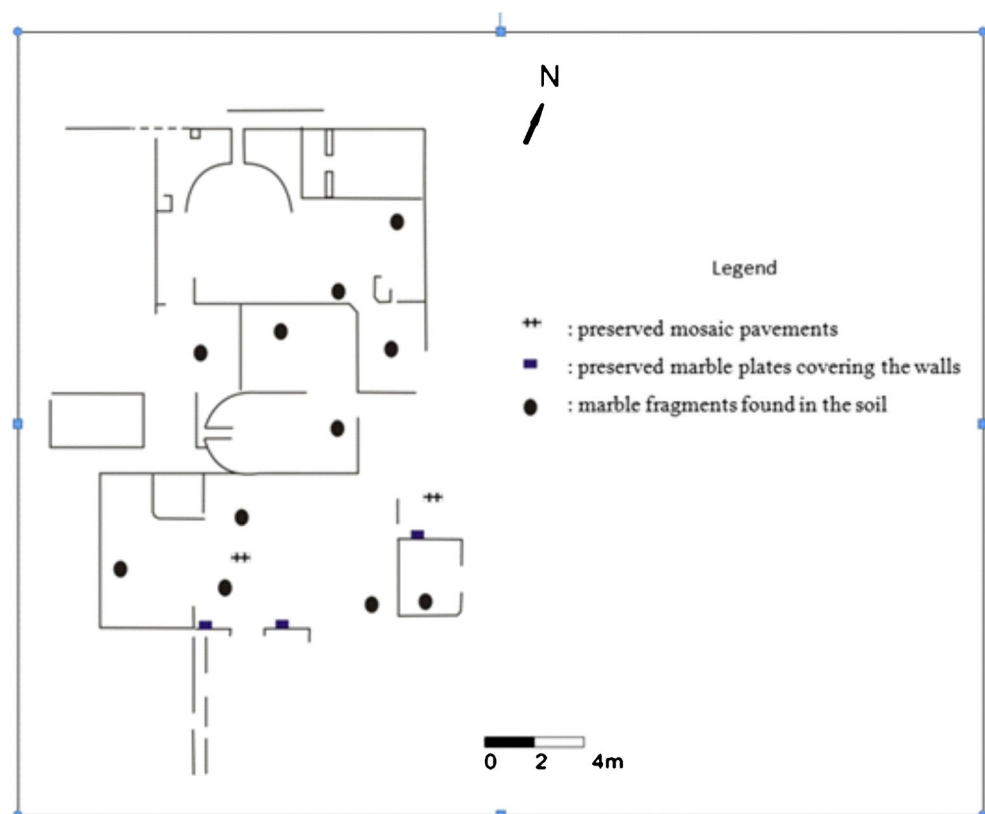
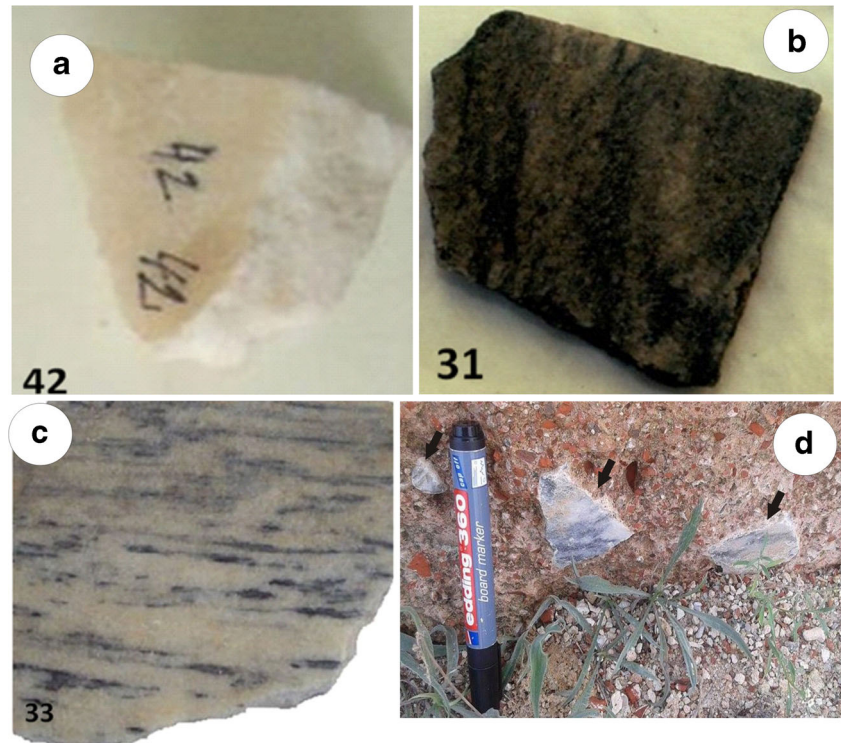


Fig. 4 Examples of collected sample. **a** White marble. **b** Dull grey marble. **c** “Greco scritto” marble. **d** Wall covered with fragment of greco scritto marbles



calcites, and the grey colour could be due to a small amount of dispersed organic carbon (Schmid et al. 1980). The MGS of the grains of calcite ranges from 1.6 to 2.4 mm with an average value of 2.04 mm. Accessory minerals include amphibole (essentially tremolite), chlorite and muscovite (Fig. 6 and Table 2).

These two samples (F31 and F33) reveal to be impure graphitic marbles since accessory minerals are distinctive indicating that the initial rock has experienced low grade of

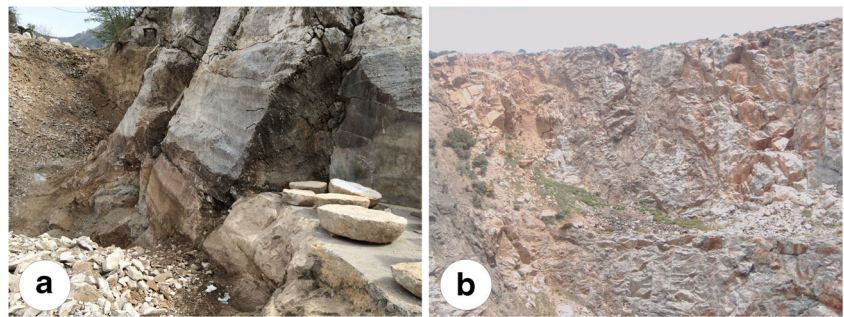
metamorphism in the area. However, calcite crystals, in the two samples, show mainly straight and embayed boundaries.

The white marble sample (F42) is characteristically fine-grained, with a homeoblastic texture with sometimes a lepidoblastic local schistosity and has granoblastic microfabric mostly made of calcite grains commonly forming polygonal grains with triple junctions meeting at about 120° angles. Its MGS is ranging from 0.5 to 1 mm (Fig. 6 and Table 2). These features are a characterization of marbles that

Table 1 Types, number, dimensions and location of the recovered studied marbles

Type of marble	Number of Fragments recovered	Dimensions (length × width × thickness)	Location in the baths (Fig. 4)
1/Greco scritto	276	26.77 m × 18.24 m × 0.7 to 2.9 cm	8 fragments in the <i>caldarium</i> , and 268 fragments in the <i>frigidarium</i> .
2/ <i>Marmor Pentelicum</i> , Pentelic marble	22	273.5 cm × 158.9 cm × 0.6 to 3.1 cm	<i>Frigidarium</i>
3/ <i>Marmor Carystium</i> , <i>marmor styrium</i> , green cipolin marble	19	147.3 cm × 87.9 cm × 1 to 2 cm	18 fragments in the <i>frigidarium</i> , and 1 fragment in the <i>caldarium</i>
4/ <i>Marmo bianco di Carrare</i> , Carrare white marble	9	104.7 cm × 66.1 cm × 1.05 to 2.05 cm	<i>Frigidarium</i>
5/ <i>Proconnesium marmor</i> , Proconnesian white marble	10	90.5 cm × 63.1 cm × 1.1 to 3 cm	<i>Frigidarium</i>
6/Dull grey white spotted marble	4	32.8 cm × 26.2 cm × 1.2 to 1.6 cm	<i>Frigidarium</i>
7/ <i>Marmor numidicum</i> , <i>Simithus</i> yellow marble	2	17 cm × 11.5 cm × 1.9 to 2 cm	<i>Frigidarium</i>
	Total = 342	Total = 33.45 m × 22.38 m × 0.6 to 3.1 cm	

Fig. 5 A partial view of the ancient quarries **a** Fossa Cava and **b** Cap de Garde



have suffered a late static recrystallization (Molli et al. 2010; Antonelli and Lazzarini 2015; Antonelli et al. 2015a, b).

Chemical results

The results of the chemical analysis led on the three samples are presented on Table 3. In general, the three marbles reveal a high content of CaO ranging from 52.09 % (F33) to 55.60 % (F42), with elevated LOI value (loss on ignition representing the sum of CO₂ and H₂O), and containing minor and traces of others elements.

The fine-grained white marble, essentially composed of calcite (F42), has the highest content of CaO. The insignificant content of silica is mainly explained by the slight amount of MgO, Al₂O₃ and K₂O.

Greco scritto sample (F33) reveals a significant content of MgO due to the presence of ferromagnesian components as well as dolomite. Both greco scritto and dull grey marbles are rather rich in SiO₂ due to the presence of free quartz and other silicates. These impurities confirm the results of mineralogical study which highlights the presence of quartz, amphibole (essentially tremolite), chlorites and muscovite.

Isotopic results

The results of the isotopic analyses conducted on the three samples (F31, F33 and F42) are reported on Table 2. The isotopic ratios showed positive values of $\delta^{13}\text{C}$ and negative values of $\delta^{18}\text{O}$ for the three samples concerned. Their isotopic composition was compared with the isotopic diagrams of the most important fine-to-coarse grained Mediterranean ancient marbles (Moens et al. 1992; Gorgoni et al. 2002).

Determination of the provenance of Ruspina's baths ancient marbles

The macroscopic and microscopic analyses, as well as the isotopic signatures of the samples collected from Ruspina's baths led to identify their provenances. The origin of the majority of the studied marbles (4/7) could have been identified

only through macroscopic analyses and the concerned marbles are as follows:

- Green cipolin from Karystos (Greece)
- Penthelic white marble from the Mt of Penteli (Greece)
- Antique yellow from *Simitthus* (Tunisia)
- White Proconnesian from Asia

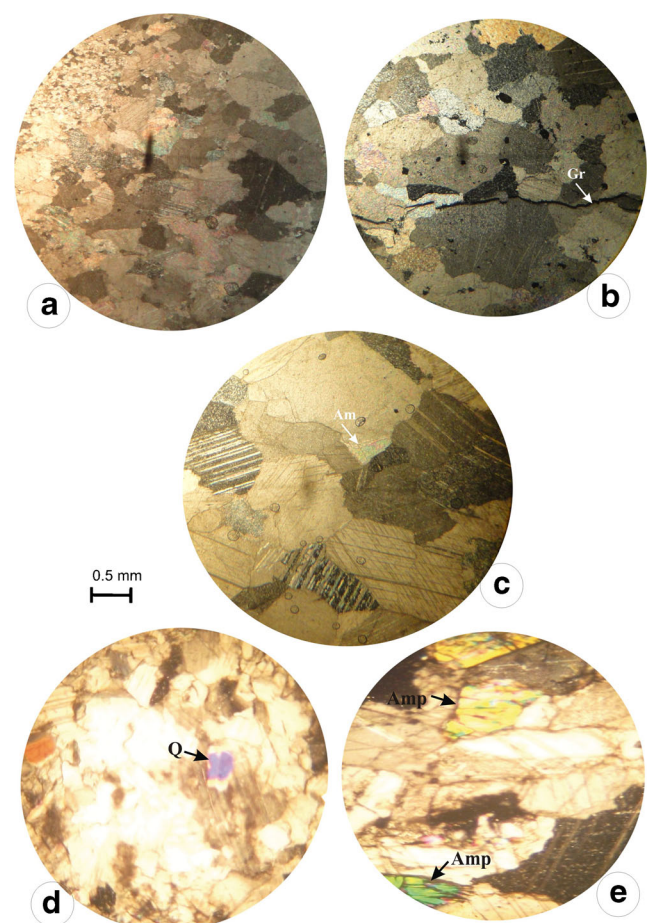


Fig. 6 Photomicrographs of thin sections of studied marbles in crossed polarized light **a, b** Carrara marble, sample 44. **c** dull grey marble, sample 31. **d, e** greco scritto marble, sample 33. (*Am* amphibole, *Gr* graphite, *Q* quartz)

Table 2 Macroscopic characteristics, mineralogical composition, texture and isotopic compositions of the studied samples

Sample	Macroscopic characteristics	Mineralogical composition	Texture	Shape of the crystal boarders	Maximum grain size (MGS)	Isotope ratio	
						$\delta^{18}\text{O(PDB)}$	$\delta^{13}\text{C(PDB)}$
F42 white marble	Thin grained with welded glittering white crystals. No putrid odour appears at its fracture.	Essentially carbonate fraction: calcite → 100	Granoblastic	Polygonal grains with lightly curved grain boundaries and, triple points.	1.20	-1.18	2.20
F31 dull grey	Medium to coarse-grained marble with scarce white spots.	Carbonate fraction: calcite → 95.5 Non-carbonate fraction: Quartz → 1.5 Oxides → Amphibole → 2.1	Heteroblastic, mosaic texture	Straight embayed	2.04	-10.05	3.27
F33 greco scritto	Medium-to-coarse grained, with white background; thin graphitic grey-blakish veins or dark grey to bluish stains (spots)	Carbonate fraction: calcite → 97 Non-carbonate fraction: Quartz → 3	Heteroblastic, mosaic texture	Sutured, embayed	2.50	-10.10	2.38
Carrara	Fine-grained marbles	Carbonate fraction: calcite Accessory phase : graphite, muscovite oxides plagioclases	Homeoblastic	polygonal mosaic of small to very small calcite crystals somewhere forming triple points	0.50 to 1	1.65 to 3.06	-0.29 to -3.45
Cap de Garde	Medium to coarse grained marbles	Carbonate fraction: calcite Accessory phase: graphite, amphibole oxides plagioclases	Heteroblastic	Sutured, embayed	0.60 to 6.60	-10.70 to 2	0.80 to 3.50

Table 3 Chemical composition of the analysed samples

Sample	LOI	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	MgO	CaO	Na ₂ O	K ₂ O	TiO ₂	P ₂ O ₅	Total
F42	43.19	0.10	<0.01	0.04	0.87	55.60	0.36	0.03	<0.01	<0.01	100.1
F31	42.95	2.50	0.13	0.19	1.34	53.08	0.00	0.02	<0.01	<0.01	100.2
F33	42.61	2.20	<0.01	0.03	1.91	52.09	0.36	0.01	<0.01	<0.01	99.2
Recrystallized marble Carrara (Molli et al. 2010)	43.70	0.05	0.09	0.11	1.24	54.66	–	–	–	0.12	99.97
Annealed marble Carrara (Molli et al. 2010)	43.50	0.15	0.08	0.12	1.08	54.92	–	–	–	0.11	99.96
67/07 PP0 (Cap de Garde)	41	3.2	2.3	0.78	2.17	49.57	0.08	0.07	0.049	0.023	99.24
67/07 PP1 (Cap de Garde)	44	0.0	0.1	0.06	1.57	53.65	0.03	<0.01	<0.01	<0.01	99.41
67/07 PP13 (Cap de Garde)	41	3.6	1.5	0.72	1.58	50.51	0.11	0.12	0.053	0.027	99.22
67/07 PP14 (Cap de Garde)	41	3.3	2.4	0.87	2.12	49.45	0.12	0.12	0.041	0.027	99.44

The minero-petrographic and isotopic results carried out on the other three samples enabled to identify their identification (F31, F33 and F42). Concerning the white fine-grained sample (F42), the minero-petrographic and chemical results, as well as the isotopic signatures are comparable with the same features observed in Carrara white marbles.

On the minero-petrographic point of view, both marbles (Carrara white marble and Ruspina's white marble) correspond to the same microfacies. In both marbles, calcite is plainly the main component. The presence of quartz, dolomite and silica was also slightly distinctive in both marbles, and no mineral of high temperature was detected indicating that both

Fig. 7 Isotopic signatures of studied marbles superimposed with the data bank proposed by Gorgoni et al. (2002) with supplementary data after Antonelli et al. (2009), Attanasio et al. (2012); Herrmann et al. (2012). Legend: *Aph* Aphrodisias, *C* Carrara, *CG* Cap de Garde, *D* Docimium, *N* Naxos, *Pa* Paros, *Pe* Penteli, *Pr* Proconnesos, *T* Thasos

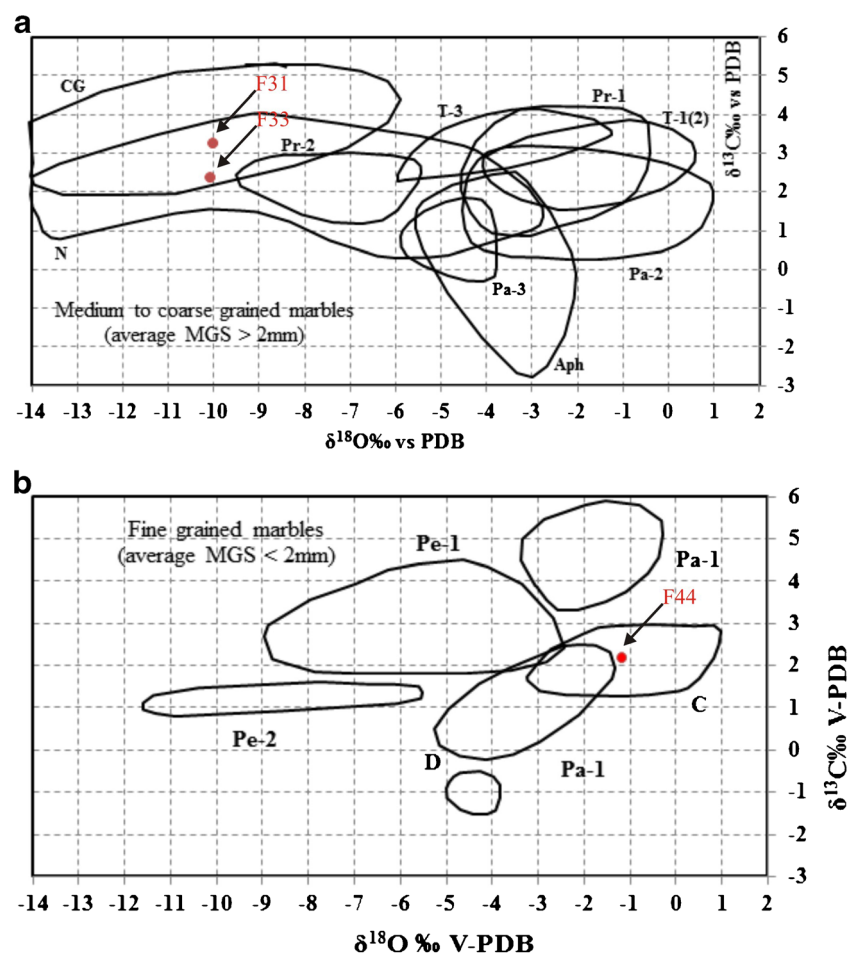
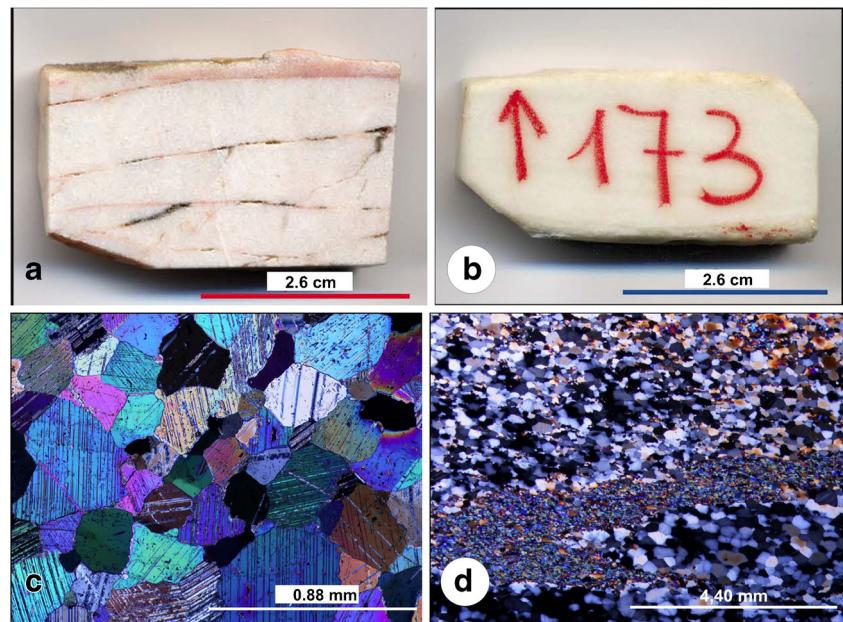


Fig. 8 a, b Fragments from Carrara quarry. c, d Photomicrographs of thin sections of Carrara marble



marbles result from a prograde metamorphism of low pressure and low metamorphism. Finally, both marbles show polygonal textures with triple grain junctions meeting at about 120° angles which indicate a good recrystallization under equilibrium condition (Figs. 7 and 8).

The chemical results, in agreement with petrographic analyses, reveal that both marbles have a high content in CaO (superior to 50 %), and impurities such as SiO_2 , MgO and Fe_2O_3 are very scarce, indicating that both marbles are very pure.

The isotopic ratios ($\delta^{13}\text{C}$ and $\delta^{18}\text{O}$) of the studied marble are shown in the diagrams of Fig. 7. Plotted in the comparative diagram for fine-grained classical marble varieties (Gorgoni et al. 2002), its isotopic values fall into the isotopic area of Carrara marbles.

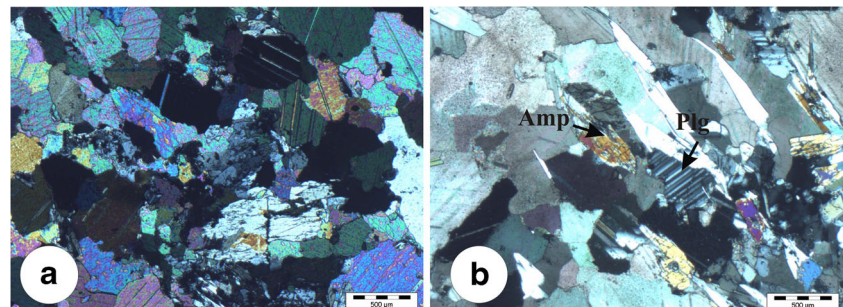
As far as greco scritto and dull grey marbles are concerned (F31 and F33), their minero-petrographic and chemical results, together with their isotopic signatures are comparable with the same features observed in Cap de Grade marbles.

The minero-petrographic results reveal that calcite is the main component of these both medium-to-coarse grained marbles and accessory minerals are also distinctive such as quartz, chlorite, muscovite and tremolite indicating that both samples are impure graphitic marbles and that the metamorphic sequence was formed in a prograde metamorphism (Hadj Zobir et al. 2014). Their MGS varies from 2.04 to 2.5 mm and such a microfabric is a characterization of Cap de Grade quarries (Yavuz et al. 2011; Herrmann et al. 2009; Antonelli et al. 2009, 2010; Attanasio et al. 2012) which were known to have produced a coarse grained marble (Fig. 9), which frequently has grey markings with a maximum grain size (MGS) higher than 2 mm.

The chemical results, in agreement with minero-petrographic analyses, reveal that both samples (F31 and F33) have a high content in SiO_2 , due to the presence of impurities such as free quartz and other silicates.

The isotopic ratios of greco scritto sample fall into the general Cap de Grade field (Fig. 7a), whereas the isotopic

Fig. 9 a, b Photomicrographs of thin sections of greco scritto marble from Cap de Grade quarry. Cross-polarized light



signatures of the dull grey-stripped sample overlap with Naxos and Cap de Garde fields. However, the petrographic characteristics of the sample F31 are quite different from those of the Naxos lithotype characterized by a very coarse grain (MGS arranging from 2 to 10 mm) (Gorgoni et al. 2002; Polikreti and Maniatis 2002; Ebert et al. 2010; Attanasio et al. 2012).

Conclusions

An archaeometric approach has been undertaken to determine scientifically the provenance of the marbles used in the decoration of Ruspina's baths. Hence, the macroscopic results, together with minero-petrographic, chemical and isotopic results indicate six different sources for the seven samples analysed. According to previous studies, there are four sources that have been identified: Green cipolin from Karystos (Greece), Penthelic white marble from the Mt of Penteli (Greece), Antique yellow from *Simitthus* (Tunisia), and White Proconnesian from Asia. However, two new origins arise in the present investigation: white marble from Carrara (Italy), greco scritto and the dull grey white spotted marble both from Cap de Garde (*Hippo Regius*, Algeria).

The results also reveal that Ruspina's baths were mainly decorated with imported marbles from Greece (Karystos and Mt of Penteli), Italy (Carrara), Asia (Proconnesia) and Numidia (Cap de Garde); only one fragment came from local quarries (*Simitthus*).

According to the number of collected marble fragments, greco scritto marble was the most used for covering the walls of the *caldarium* and *frigidarium* rooms, whereas the least used was the local *Simitthus* marble, the Antique yellow.

The important number of imported marbles used for decorating *Ruspina* Roman baths reveals the town's economic prosperity, its cultural relationships with other Eastern and Western Roman towns and also its integration into the Mediterranean commercial network (Ben Russell 2014).

Further studies on marbles used in public constructions and sumptuous dwellings situated in Eastern *Byzacium* harbour towns will permit to increase the data not only on the imported marble types but also concerning the trade relationships between this region and the rest of the Mediterranean world.

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References

Agus M, Cara S, Lazzarini L, Corda AM (2007) I marmi colorati di Uthina. In Sotgiu G, Ben Hassen H, Corda AM (éds) Fouilles

archéologiques à Uthina (2001–2007). Rapport préliminaire de l'activité de recherche de l'Institut du Patrimoine de Tunis et de l'Université de Cagliari, Italie, 2 vols, Ortacesus (Ca)-Tunis, 1, p 375–394

- Antonelli F, Lazzarini L (2015) An updated petrographic and isotopic reference database for white marbles used in antiquity. *Rendiconti Lincei* 1–15
- Antonelli F, Lazzarini L, Cancelliere S, Dessandier D (2009) Minero-petrographic and geochemical characterisation of “greco scritto” marble from Cap de Garde near Hippo Regius (Annaba, Algeria). *Archaeometry* 51(3):351–365
- Antonelli F, Lazzarini L, Cancelliere S, Dessandier D (2010) On the white and coloured marbles of the Roman town of Cuicul (Djemila, Algeria). *Archaeometry* 52(4):575–596
- Antonelli F, Santi P, Renzulli A, Santoro Bianchi S (2015a) The architectural reuse of Roman marble and stone Spolia in the early medieval Monte Sorbo Church (Sarsina, Central Italy). *Archaeometry*. doi:10.1111/arcm.12170
- Antonelli F, Lapuente MP, Dessandier D, Kamel S (2015b) Petrographic characterization and provenance determination of the crystalline marbles used in the Roman city of Banasa (Morocco): new data on the import of Iberian marble in Roman North Africa. *Archaeometry* 57(3):405–425
- Attanasio D, Yavuz AB, Bruno M, Herrmann JJ Jr, Tykot RH, van den Hoek A (2012) On the Ephesian origin of greco scritto marble. In Gutiérrez García A, Lapuente P, Rodà I (Eds) *Interdisciplinary studies on ancient stone. Proceedings of the IX ASMOSIA Conference (Tarragona 2009)* 245–254
- Ben Lazreg N, Mattingly DJ (1992) Leptiminus (Lamta): a Roman port city in Tunisia, Report n°1. Ann Arbor, MI
- Ben Russell B (2014) *The economics of the Roman stone trade. Oxford studies on the Roman economy*, Oxford University Press
- Ebert A, Gnos E, Ramseyer K, Spandler C, Fleitmann D, Decrouez D (2010) Provenance of marbles from Naxos based on microstructural and geochemical characterization. *Archaeometry* 52(2):209–228
- Foucher L (1964) *Hadrumetum*. Tunis
- Gaied ME, Younés A, Gallala W (2010) A geoarchaeological study of the ancient quarries of Sidi Ghedamsy Island (monastir, Tunisia). *Archaeometry* 52(4):531–549
- Gorgoni C, Lazzarini L, Pallante P, Turi B (2002) An updated and detailed minero-petrographic and CO stable isotopic reference database for the main Mediterranean marbles used in antiquity. *ASMOSIA 5*: 115–131
- Hadj Zobir S, Altenberger U, Günter C (2014) Geochemistry and petrology of metamorphosed submarine basic ashes in the Edough Massif (Cap de Garde, Annaba, northeastern Algeria). *Compt Rendus Geosci* 346(9):244–254
- Herrmann JJ, Attanasio D, Tykot RH, Van Den Hoek A (2009) Characterization and distribution of marble from Cap de Garde and Mt. Filfila, Algeria. *Interdisciplinary studies on ancient stone: Proceedings of the IX Association for the Study of Marble and Other Stones in Antiquity*, (ASMOSIA), Tarragona
- Herrmann JJ Jr, Attanasio D, Tykot RH, van den Hoek A (2012) Characterization and distribution of marble from Cap de Garde and Mt. Filfila, Algeria. In: Gutiérrez García A, Lapuente P, Rodà I (Eds.) *Interdisciplinary Studies on Ancient Stone. Proceedings of the IX ASMOSIA Conference (Tarragona 2009)*, p 300–309
- Kallala N (1998) La localisation du site de Ruspina d'après une prospection récente dans la presqu'île de Monastir. In 113^{ème} congrès national des sociétés savantes, IV^{ème} colloque sur l'histoire et l'archéologie de l'Afrique du Nord, Strasbourg, CTHS, II, p 525–533
- Mahjoubi A (2000) *Villes et structures urbaines de la province romaine d'Afrique*. Centre de publication universitaire, Tunis
- Moens L, Roos P, De Paep P, Lunsingh Scheurle R (1992) Provenance determination of white marble sculptures from the Allard Pierson

- Museum in Amsterdam based on chemical, microscopic and isotopic criteria". In: Waelkens M, Herz N, Moens L (eds) *Ancient stones: quarrying, trade and provenance*. University Press, Leuven, pp 269–276
- [Molli G, Cortecchi G, Vaselli L, Ottria G, Cortopassi A, Dinelli E, Mussi M, Barbieri M \(2010\) Fault zone structure and fluid–rock interaction of a high angle normal fault in Carrara marble \(NW Tuscany, Italy\). *J Struct Geol* 32\(9\):1334–1348](#)
- Picard Ch G (1990) *La civilisation de l'Afrique romaine*, 2^{ème} éd. Paris
- Polikreti K, Maniatis Y (2002) A new methodology for the provenance of marble based on EPR spectroscopy. *Archaeometry* 44(1):1–21
- [Schmid SM, Paterson MS, Boland JN \(1980\) High temperature flow and dynamic recrystallization in Carrara marble. *Tectonophysics* 65: 245–280](#)
- Stone DL, Mattingly DJ, Ben Lazreg N (2011) *Leptiminius (Lamta)*, Report No. 3: The Field Survey. Portsmouth, Rhode Island
- Yavuz AB, Bruno M, Attanasio D (2011) An updated, multi-method database of Ephesos marbles, including white, Greco scritto and Bigio varieties. *Archaeometry* 53:215–240
- [Younès A \(1999\) Recherches sur la ville portuaire de Thapsus et son territoire en Byzacène dans l'Antiquité. C.E.R.E.S., 2 tomes, Tunis](#)
- [Younès A \(2013\) Les marbres des thermes de Ruspina \(Henchir Tennir, Monastir, Tunisie\). *Marmora* 9:45–52](#)
- Younès A (2014) Les pierres marbrières antiques au nord de la dorsale tunisienne: état de la question et mise au point. Les ressources naturelles au Maghreb durant l'Antiquité et le Moyen Âge : exploitation, gestion et usage. V^e colloque international, Tunis, p 161–192
- [Younès A, Gaied ME, Gallala W \(2012\) Identification of stone blocks used for the building of the *Thysdrus* and *Thapsus* amphitheatres in Tunisia. *Archaeometry* 54\(2\):213–329](#)