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Provenance of marble sculptures from the National Museum of Carthage (Tunisia)

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The results of a combined minero-petrographic and isotopic study carried out on representative marble sculptures from the Museum of Carthage are presented. Pentelikon source has been identified for nine of the analyzed items, Carrara and Prokonnesos sources have been also identified for three and one items respectively, confirming in some cases previously-made hypothesis. Local Chemtou and Djebel Ichkeul stones present very different petrographic fabrics compared with the most recurrent marbles. The undertaken approach adds value to the descriptions of the studied artifacts and could be extended to other art pieces of this and other museums.

1. Introduction

The National Museum of Carthage is, along with the Bardo Museum, one of the main archaeological museums in Tunisia. The museum locates on the Carthage acropolis, on top of the Byrsa hill. It was founded at the end of the 19th century (Gandolphe, 1952) by the *Pères Blancs* (a society of Catholic missionaries), its building was originally a monastery, and indeed, the first archaeological works on the site were performed by the missionaries. After the independence of Tunisia from France, and the decommissioning of the religious functions of the building, the museum opened as a national museum in 1964. It was refurbished at the end of the 20th century and it is at present undergoing again major restructuring.

The history of the Carthage Museum is only the last chapter of the full story of Byrsa hill and its surroundings. On top of this hill, known as *l'esplanade*, there was, once on a time, the Punic city of Carthage (prosperous from the 6th century BC onwards) that was completely destroyed by the Romans after the Third Punic War (146 BC). A century later, a new Roman Carthage was built on its ruins under the rule of Julius Caesar. The Roman city became one of the biggest cities of the Empire and a center of early Christianity (4th to 7th century AD). Under the Vandals and the Muslims, the city was progressively abandoned, used as a quarry and finally forgotten until the arrival of the French missionaries.

Thought some of the finest finds from Carthage are now at the Bardo Museum and elsewhere, the National Museum of Carthage contains the largest collection of objects from this archaeological site, covering both the Punic and the Roman periods. The Punic objects include tomb and votive stones, inscriptions, sarcophagi, ossuaries and grave goods. From the Roman period there are mainly mosaics, funerary inscriptions, sculptures and architectural elements. Finally, among the early Christian objects are worth to mention the funerary inscriptions and sarcophagi.

The scope of this paper is to bring archaeometric data to identify, and in some cases to confirm, the provenance of several artifacts from the Carthage Museum. The presented approach will help to produce new explanatory notes for the visitors and could be extended to other art objects from the Museum.

2. Archaeological background

As a result of the old and complex history of the Carthage Museum (Ennabli, 1998; Gandolphe, 1952), some of the objects

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from its collections lack of a complete description of its archaeological setting. Basic information, as the provenance of the stone-made pieces is not mentioned or assumed without any rigorous archaeometric approach.

The marbles of a number of sculptures, see Fig. 1, (including low-reliefs and sculpted sarcophagi) have been subjected to petrographic, X-ray and isotopic analyses for identification of its provenance.

All the studied statues and low-reliefs belonged to the Roman city. From the iconographic point of view, they reflect the abundance and nourishing vocation of the city: three sculptures include representations of overflowing edibles as a symbol of wealth. Item #1 depicts a Genius Coloniae Cathaginis, i.e. a protecting spirit for the Carthaginians, holding a cornucopia or horn of plenty. This sculpture was found not far from the alleged emplacement of the Capitolium and presents all the features of the official imperial art from early 2nd century AD. Its face has some similarities with the known representations of Antinous (the favorite of the Roman emperor Hadrian). Item #2 is a torso of a standing woman holding what seems to be a basket full of fruits. The statue could represent Pomona, the goddess of fruit, usually associated to abundance. Item #3 is one of two colossal (3-m high) fine low reliefs from the Museum depicting Victoria, the goddess of victory, as a winged woman holding a cornucopia.

The two similar low-reliefs of Victoria were found scattered in many fragments by Delattre (1898) at the end of the 19th century nearby the Saint Louis cathedral that still today stands on top the Byrsa hill. Along with these low-reliefs, it was found item #4, also exceedingly fragmented, this one after reconstruction yielded another 3-m-high low relief of even finer manufacture. It depicts again Victoria, now as a winged woman holding a trophy of Roman arms. This statue is considered one of the masterpieces of the museum, and together with the other mentioned low-reliefs, has been interpreted to be part of a triumphal arch or a similar monument, perhaps to commemorate the victory over the Parthians in 166 AD (Picard, 1951).

Other mythological characters from the studied set include Silenius (item #5), the old fat satyr who tutored the wine-god Bacchus. The statue is a free-standing sculpture that depicts a drunken Silenius being supported by four satyrs. The statue dates from the 1st–3rd century AD, perhaps is a reproduction of a bigger statue and surely is an adaptation to a free-standing sculpture of this classical theme (Saumagne et al., 1964). It was found broken in 45 fragments and after reconstruction two of the satyrs are still missing. According to the excavators, it appeared intentionally broken (Saumagne et al., 1964), perhaps as a victim during the Christian destruction of pagan temples, in 399 (Lavagne, 2000). Item #6 is very incomplete, it was found in the 19th century behind the amphitheatre (Delattre, 1899) and consists of a torso fragment that could depict a young Bacchus or perhaps Apollo. Finally, item #7 is a Roman copy, possibly from the 3rd century AD, of a Hellenistic statue of a sleeping Eros (the god of love).

Besides mythological characters, other Roman sculptures from the studied set depict famous and anonymous people. Thus, item #8 portrays the head of co-emperor Lucius Verus, who ruled with Marcus Aurelius, from 161 AD to 169 AD, it was found during the 19th century at the southern side of Byrsa hill (Delattre, 1899). Item #9 and #10 are funerary statues that were found within the same mausoleum, in the Yasmina necropolis, 200 m south-west from the emplacement of the Carthage circus. Item #9 was found in 1981 (Annabi, 1981) and it is usually referred as an auriga (a slave that drove a biga chariot) though he could be an agitator (quadriga driver) as well. However, taking into account, among other features, that he is holding a small amphora, an alternative and plausible interpretation has turned him into a sparsor (stable hand who cooled Roman chariot horses with water) (Thuillier, 1999). In 1992, item #10 was retrieved and it is usually assumed that it depicts the spouse of the sparsor (Norman, 1993; Norman and Haeckl, 1993). Both sculptures would be from middle 3rd century AD. Item #11 is a statue of an idealized woman wearing a stola sculpted using the flowing drapery technique, and item #12 is the torso of an unknown figure wearing distinguished clothes.

In addition to Roman sculptures, materials from two sarcophagi were also studied. On one hand, item #13, known as the Sarcophagus of the Priest, depicts, carved in Greek style (Picard, 1951) on its lid, a bearded figure wearing a beltless tunic and thick sandals. This sarcophagus was retrieved in 1902 from the Punic necropolis in Bordj-Djedid (near Sainte Monique) along with the so-called Sarcophagus of the Priestess (Delattre, 1903a); both are central pieces of the Punic-dedicated area of the museum, other similar sarcophagi were found in the same necropolis, all of them are supposedly from the late 4th century BC to early 3rd century BC. Another simpler sarcophagus, item #14, was also studied. This is decorated with parallel s-shaped strigils like many other sarcophagi found in the early Christian basilicas of the site (Delattre, 1912; Béjaoui, 1985, 1987). These sarcophagi date from late-4th to early 5th century and have been described as being made either of local biosparitic limestone 'kadel' or Prokonnesos marble (Rodà, 2001).

3. Materials and methods

Small samples, in form of irregular chips of about 1 cm^3, were obtained from the fourteen listed items using a small chisel, always from hidden parts of the objects (the back side or the outer bottom) to minimize the damage on the artifacts. Besides samples from the artifacts, samples from two local quarries of recrystallized limestones (Chemtou, in northwestern Tunisia and Djebel Ichkeul, in northern Tunisia) were also obtained for comparison purposes. Part of the samples was powdered to be analyzed using both powder X-ray diffraction (XRD) and mass spectrometry. The remaining part of each sample was used for visual inspection and observation under a stereoscopic microscope and to produce thin sections to be viewed using a petrographic microscope. All samples were labeled according to the corresponding item number; samples from Chemtou and Djebel Ichkeul were labeled Ch and Dj respectively.

3.1. Minero-petrographic analyses

Standard thin sections of the samples were prepared at CEREGE. Petrographic descriptions were mainly performed using a NIKON Eclipse 50iPOL microscope in the Institut d'Arqueologia Clàssica, in Tarragona, pictures were taken using a NIKON COOLPIX5400 mounted on the microscope. Reference materials from the collection of classical marbles assembled by the LEMLA (Álvarez and Rodà, 1992) in the Universitat Autònoma in Barcelona were used for comparison purposes. Thin section observation permits to determine the fabric of the marble and to identify the accessory and secondary minerals, in addition to calcite. Analyses performed by experienced petrologists are known to be a successful method to identify different types of marbles and related rocks.

3.2. XRD analyses

XRD measurements were performed at CEREGE on powdered samples with a θ-θ Panalytical X'Pert Pro MPD diffractometer running at 40 kV and 40 mA using Co Kα radiation ($\lambda = 1.79$ Å) with a linear X'Celerator detector and a secondary flat monochromator. The 2θ range was 23–75° with a step size of 0.033° and a counting time of 3 s per step. Samples were finely crushed in an agate mortar

Fig. 1. Pictures of all the studied artifacts from the Museum of Carthage, numbers correspond to labels as defined in Section 2 and Table 1.

and sieved on "zero-background" silicon plate to avoid preferential orientation. Particles statistic was improved by spinning the samples at 15 rpm. Rietveld refinements (Rietveld, 1969) were performed in order to obtain semi-quantitative information about the mineral phases present in the samples. Rietveld analysis consists in simulating a diffraction pattern from the crystallographic parameters of each mineral phase (space group, unit cell), peak profile parameters and some instrumental parameters. The theoretical pattern is then iteratively compared to the experimental one adjusting the parameters to minimize the differences between the two patterns. X'Pert Highscore Plus (Panalytical) was used to obtain the contribution of each mineral phase fitting only the scale factor and the background. Maud software was also used refining furthermore some instrumental, profile and structural parameters. In particular, our target was the identification of dolomitic components.

3.3. *Isotopic analyses*

Isotopes analysis ($\delta^{18}O$ and $\delta^{13}C$) were conducted at CEREGE on crushed marble samples using a mass spectrometer (Finnigan Delta Advantage) equipped with a carbonate device. Measured isotopic values are normalized against international standard NBS-19. Mean external reproducibility was better than 0.03‰ for $\delta^{13}C$ and 0.05‰ for $\delta^{18}O$. Isotopic characterization has proven to be a very useful tool to identify marble provenance in artefacts (Gorgoni et al., 2002), specially when its use is combined with minero-petrographic results (Gorgoni et al., 2002; Pensabene et al., 2012). The isotopic signature is a measure of the deviation of $^{13}C/^{12}C$ and $^{18}O/^{16}O$ ratios found in the investigated sample with respect to a standard sample VDPB (Belemnitella americana from the Cretaceous Pee Dee Formation, South Carolina) (Capedri et al., 2004). The principal factors controlling the isotopic ratios in marbles are linked to the nature of the protolith, the temperature and interaction with water during metamorphism and later weathering history.

4. Results

Table 1 lists the essential features of the analyzed marble artifacts obtained from the different applied methods.

The minero-petrographic analyses of thin sections (Fig. 2) revealed textural and mineralogical information. Regarding the composition, calcite is plainly the main, if not the only, component in all samples. Rounded quartz crystals have been identified in samples #1, #4, #6, #9, #10, #12 and #13, whereas elongated mica crystals (possible muscovite) have been found in samples #4, #6 and #12. Finally the presence of dolomite was also distinctive in sample #7 (in form of zoned rhomboid crystals, Fig. 3a) and perhaps in sample #4 (in form of lamellar crystals with micas, Fig. 3b). As far as texture is concerned, all the samples, except one (sample #14), present mosaics of fine-grained crystals (MGS < 1 mm). A systematic counting of several digitized images of thin sections was performed to obtain crystal size distributions (CSD). Almost all samples exhibit rather large heteroblastic distributions covering at least the 0.15 mm–0.60 mm range, generally with slightly lineated crystals and sometimes (samples #1, #3, #7, #9 and #12) containing microcrystal aggregates (Fig. 3c) of microspar size (up to 20 μm). In contrast, samples #2 and #5 show no microcrystals at all and a narrower CSD (~0.12 mm–~0.42 mm) of equidimensional crystals with occasional triple point boundaries (Fig. 3d), which can be called as homeoblastic. Finally, sample #14, definitively different from the rest, has a wider CSD, from ~0.10 mm to ~2.28 mm. Other identified distinctive features are occasional strained crystals with undulating extinctions (samples #1 and #14) and intense twinning (again sample #14). Fabrics of samples from local quarries exhibit microcrystalline

Table 1
Analytical features of the materials sampled (all from the National Museum of Carthage but items Ch and Dj). XRD = X-ray diffraction. HE = heteroblastic. HO = homoblastic. MGS = maximum grain size. % Dol = Dolomite percentage. Attr. = Attribution. Pe = Pentelikon. C = Carrara. Pr = Prokonnesos.

Object	Item	Petrography			XRD	Isotopic ratio		Attr.
		Textural features	Accessory minerals	MGS (mm)	% Dol	$\delta^{13}C$	$\delta^{18}O$	
Genius Coloniae	1	HE, mosaic of lineated crystals, strained crystals, occasional microcrystal aggregates.	Quartz	0.67	Traces	2.63	−7.29	Pe
Pomona	2	HO, polygonal non-oriented, straight/curved boundaries, triple points.	–	0.42	–	2.21	−1.71	C
Victoria with cornucopia	3	HE, mosaic of slightly lineated crystals, elongated microcrystal aggregates.	–	0.60	6	2.64	−4.37	Pe
Victoria with arms	4	HE, mosaic of slightly lineated crystals, lamellar clusters with carbonate and micas.	Muscovite, quartz	0.55	Traces	3.25	−5.55	Pe
Silenius	5	HO, polygonal non-oriented, straight/curved boundaries, triple points.	–	0.43	Traces	2.12	−2.21	C
Bacchus	6	HE, mosaic of slightly lineated crystals, curbed boundaries.	Quartz, mica	0.60	Traces	2.43	−7.56	Pe
Eros	7	HE, dispersed and aggregated microcrystals, zoned rhomboid crystals (dolomite).	–	0.60	12	2.85	−6.48	Pe
Lucius Verus	8	HE, mosaic of slightly lineated crystals, curbed boundaries.	–	0.77	1	2.57	−4.17	Pe
Sparsor	9	HE, mosaic of slightly lineated crystals, microcrystal aggregates.	Quartz	0.61	2	2.36	−6.17	Pe
Sparsor's wife	10	HE, mosaic of slightly lineated crystals.	Quartz	0.72	–	2.58	−4.96	Pe
Woman with stola	11	HE, polygonal non-oriented, straight/curved boundaries, triple points.	–	0.62	–	2.14	−1.67	C
Unknown torso	12	HE, mosaic of slightly lineated crystals, occasional microcrystal aggregates.	Quartz, muscovite	0.61	12	2.97	−5.55	Pe
The Priest	13	HE, mosaic of slightly lineated crystals.	Quartz	0.85	2	2.80	−7.77	Pe
Christian sarcophagus	14	HE, xenoblastic structures, sutured boundaries, intense twinning, strained crystals and twinning lines.	–	2.28	–	3.28	−0.65	Pr
Chemtou sample	Ch	HO, microcrystalline, anhedral grains, twinning, occasional fine-grained crystals in veins.	–	0.04	–	1.24	−10.45	–
Ichkeul sample	Dj	HE, very fine grained, embayed boundaries.	Opaque minerals	0.38	Traces	1.46	−6.46	–

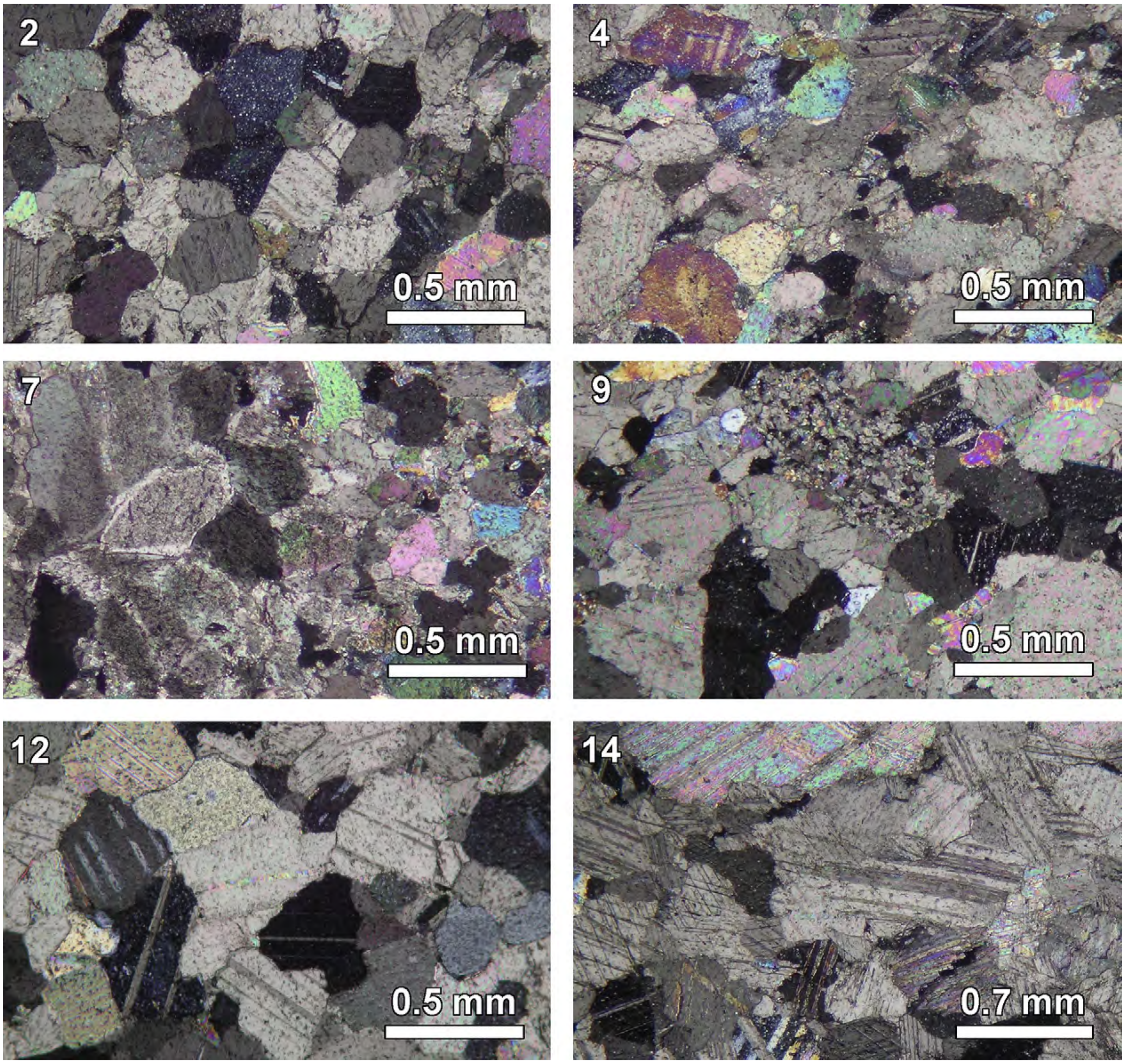

Fig. 2. Crossed polarized light photomicrographs of the thin sections of some of the objects studied. Numbers correspond to labels as defined in Section 2 and Table 1.

equidimensional anhedral calcite crystals with veins filled with coarser grains (Fig. 4a) and a very fine-grained mosaic of calcite and opaque crystals with embayed boundaries (Fig. 4b).

XRD analyses, in agreement with petrographic analyses, reveal that calcite is the main component of all the samples (representative patterns are shown in Fig. 5). However, there are slight discrepancies between XRD and petrographic data regarding the accessory minerals: XRD diffractograms indicate an important fraction of dolomite in samples #7 (Fig. 5b) and #12 (12%) and sample #3 (6%), though petrographic analyses only detected it in sample #7 (Fig. 3a) and thus, they went unnoticed in samples #3 and #12. In contrast, presumed dolomite lamellar crystals in sample #4 could be, after all, calcite crystals. XRD patterns have revealed the presence of quartz in all the samples, but only in a significant amount in samples #9 and #13 (2%) and #6 and #12 (1%), though quartz crystals were also seen in the thin sections of

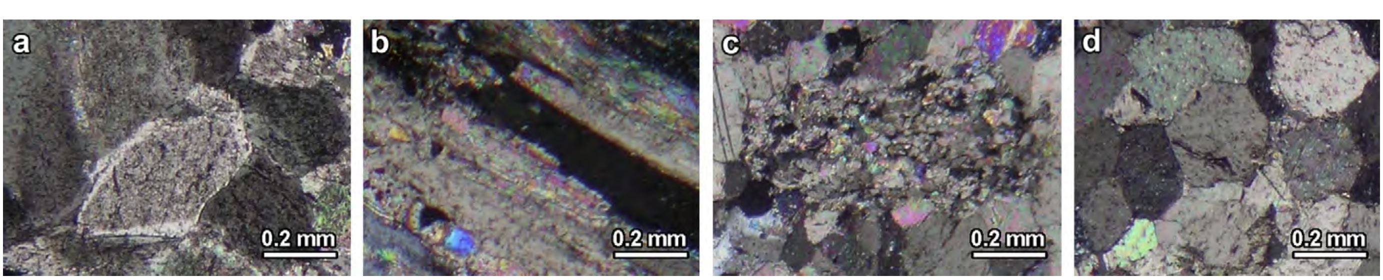

Fig. 3. Crossed polarized light photomicrographs of detailed fabric features found in the thin sections of some of the objects studied: (a) sample #7 – zoned rhomboid crystal of dolomite; (b) sample #4 – lamellar crystals of carbonate; (c) sample #9 – microcrystal aggregate; (d) sample #2 – homeoblastic mosaic with triple points.

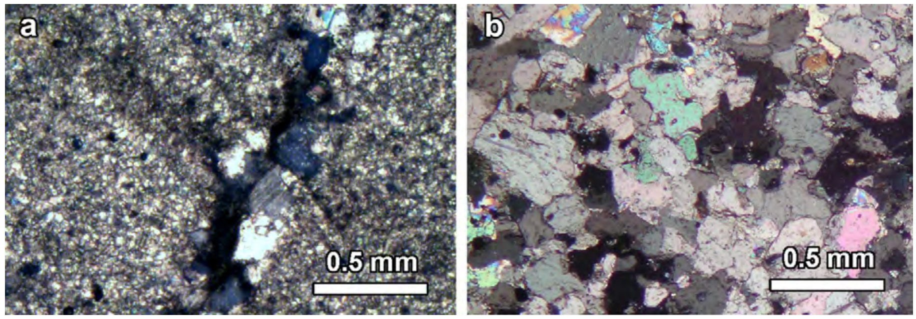

Fig. 4. Crossed polarized light photomicrographs of the thin sections of samples from two Tunisian quarries: (a) Chemtou and (b) Djebel Ichkeul.

samples #1, #4 and #10 and finally muscovite traces have been found in samples #4, #6 and #9, though petrographically this mineral went unnoticed in sample #9 but it appeared in thin sections of sample #12. Discrepancies between XRD and petrographic analyses reflect the natural variability of accessory components in the studied samples. In fact, the powdered XRD samples were not obtained from the material immediately adjacent to the cut slab.

The isotope ratios ($\delta^{18}O$ and $\delta^{13}C$) of the samples are shown in the diagrams of Fig. 6. According to the petrographic data, all the samples except one (#14) are plotted in the comparative diagram for fine-grained classical marble varieties (Gorgoni et al., 2002), whereas sample #14 is plotted separately in the diagram for medium- to coarse-grained classical varieties (Gorgoni et al., 2002). The majority of samples lie unambiguously within a given area, corresponding either to Carrara marbles (for samples #2, #5 and #11) or to Pentelikon marbles (for the rest of the samples, though sample #8 could also correspond to a Dokimeian marble). Finally, the coarse-grained sample (#14) should belong to a Prokonnesos-1 marble (from the island of Marmara) or a Thasos-2 marble (from the Aliki district, in the island of Thasos). Moreover, regardless of their grain size, all the samples have been also plotted in a comparative diagram with the isotopic areas of several known white marbles from Roman Hispania (Lapuente et al., 2000) and Morocco (Origlia et al., 2012; Antonelli et al., 2009a). All samples, except #6 and #13 lie within a given area of Hispanic marbles, sometimes with ambiguity between two different provenances. Samples #2, #5, #11 and #14 lie within the area of the Málaga marble district, samples #3, #8 and #10 within the area of the Macael group, in the Almeria marble district, though sample #10, along with samples #1, #4, #7, #9 and #12, also lie within the area of the Estremoz marble district. Finally samples #7 and #9 are also within the area of the Almadén de la Plata marbles.

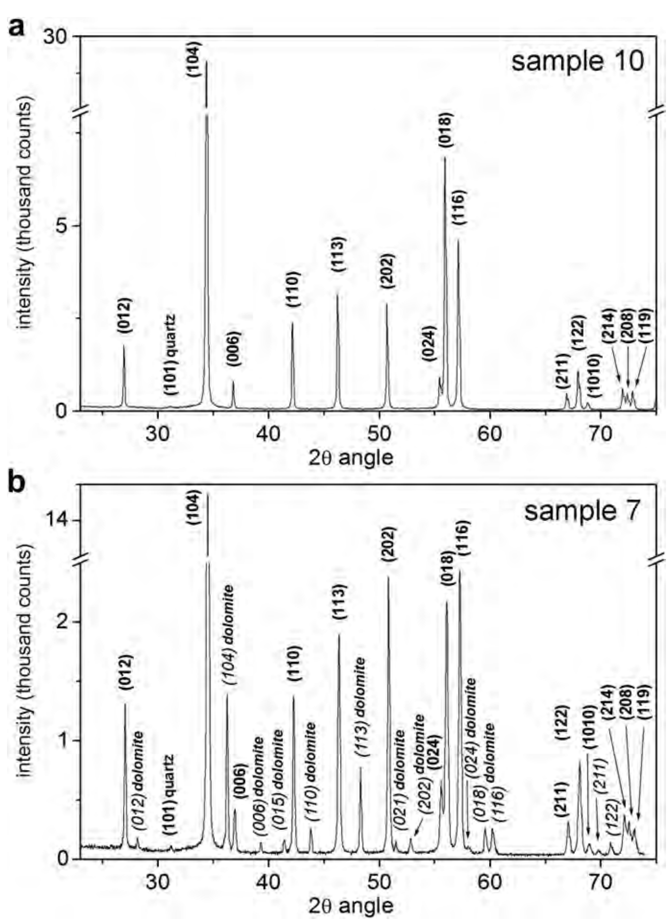

Fig. 5. Indexed X-ray diffraction patterns for (a) sample #10 – all the peaks correspond to calcite except the quartz-labeled (101) which is the main reflection of quartz; (b) sample #7 – same peaks as in sample #10 and extra dolomite-labeled peaks (in italics) that correspond to dolomite.

5. Discussion

The use of isotope diagrams is a good starting point to constraint the possible origin of the studied marbles. Considering classical marbles, our isotopic results indicate quite unambiguously that nine of fourteen investigated items are made of Pentelikon marble, three of them are made of Carrara marble (Fig. 6a), and only one item (#14) is ambiguously identified as a Prokonnesos-1 or Thasos-2 marble (Fig. 6b). Besides classical marbles, we have considered Roman Hispania marbles because some of its marbles have been identified in African sites (Antonelli et al., 2009a; Origlia et al., 2011) and several researchers have hypothesised that Hispanic marbles were not only used in Iberia but also exported (Morbidelli et al., 2007). We have also considered Moroccan marbles for proximity reasons though its isotopic signature resulted to be different from that of our studied marbles. Despite being quarried even closer to Carthage, we have disregarded the *greco scritto* marble (from Cap de Garde, Algeria) because its fine gray-blackish veining and dark gray-to-bluish patches/spots (Antonelli et al., 2009b) are absent in all our studied items.

The overlapping between the isotopic signature of classical and Hispanic marbles is a problem that has to be solved taking into account data from other techniques, mainly petrography. Indeed, the Hispanic origin of the samples can be excluded due to petrographic and mineralogical reasons. For the samples that lie within the area of the Málaga marble district (#2, #5, #11 and #14), this origin can be rejected because Málaga marbles are invariably dolomitic (Lapuente et al., 2000) and our samples are calcitic, thus

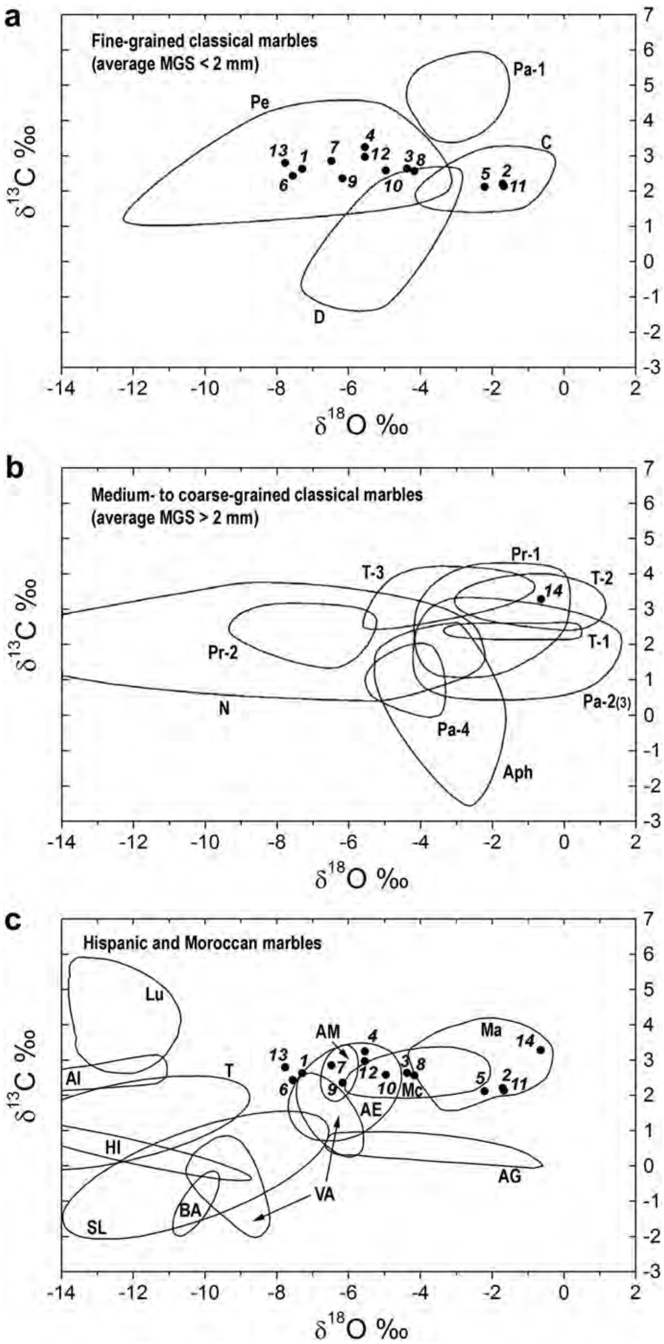

Fig. 6. Isotopic signatures of white marbles used for the studied artifacts; isotopic fields from Gorgoni et al. (2002), Lapuente et al. (2000) and Origlia et al. (2012). (a) Pa-1 = Paros Stefani; D = Dokimeion; Pe = Pentelikon; C = Carrara; (b) Aph = Aphrodisias; N = Naxos; Pa = Paros; Pr = Prokonnesos; T = Thasos; (c) Hispanic AE = Estremoz Anticline district. Ossa Morena Zone district: VA = Viana do Alentejo, Al = Alconera, AM = Almadén de la Plata. Almeria district: Lu = Lubrin, Mc = Macael group. Ma = Malaga district. AG = Alhaurin el Grande; and Moroccan T = Tiskram; SL = Sidi Lamine; HI = Hrent Ifou and BA = Bou Acila.

these samples would have a Carrara provenance (except for the coarse-grained #14). Moreover, samples within the isotopic area of the Estremoz district (#1, #4, #7, #9, #10 and #12) are fine-grained, whereas almost all lithotypes from the Estremoz district are medium- or coarse-grained, and often with pinkish veins (Álvarez et al., 2009). Among the Estremoz varieties, only the marbles from Borba are fine-grained, but they contain gray veins (Álvarez et al., 2009) and contrary to our samples, they have not lineated crystals and are texturally closer to Carrara marbles (Lapuente, 1997). Thus, Mount Pentelikon remains as the most probable provenance for these samples. Hypothetical Macael origin for samples #3, #8 and #9 can also be excluded because the larger grain size of the Macael marbles compared with our samples (Lapuente et al., 2000; Álvarez et al., 2009). Finally, marbles from Almadén de la Plata have a distinctive mortar and strained texture (Lapuente et al., 2000), very dissimilar to the samples that match their isotopic signature (#7 and #9).

Once excluded the Hispanic marbles, we can keep the results obtained from the isotopic diagrams of classical marbles, these in general point to Pentelikon and Carrara. The petrographic features of our samples are in agreement with these isotopic attributions. Despite being marbles with a similar tectonic setting (regional metamorphism), Pentelikon and Carrara have distinct isotopic signatures, for instance isotopic values for Carrara marbles are much more clustered indicating a static recrystallization that is also apparent by a petrographic homeoblastic texture.

The occurrence of Hispanic marbles in Carthage would have been surprising but the occurrence of both Pentelikon and Carrara marbles in Carthage during Roman times was expected. White-marble formations are quite scattered in the Mediterranean basin and some of them have been quarried since Antiquity, among the most renowned we find certainly those from Pentelikon and Carrara. The quarries of Mount Pentelikon (Greece) were worked from the 5th century BC (Korres, 1995) and from that time onwards its marbles were freely exported. Pentelikon exports reached Rome as early as the 2nd century BC and though its quarries never became an imperial property (Attanasio et al., 2006), it was widely used and distributed across the Roman Empire (Herrmann et al., 2009), including distant areas such as north-west Africa (Antonelli et al., 2009a). In Carthage, for instance, it was applied in the bases and the capitals of the Antonin thermae (2nd century AD) (Duval, 1971). Concerning Carrara, Pliny the Elder explained, in his Natural History (André et al., 1981), that the first works in the Carrara quarry were done in Julius Caesar's times (1st century BC) and soon became one of the main marble sources both for sculpture and building purposes and its exports reached the Roman colonies in Africa (Azedine, 2004) as well. We cannot make any chronological distinction between the use of Pentelikon or Carrara marbles. Both types of marbles were used in Rome preferentially during the 1st and 2nd centuries AD (Bruno et al., 2002) and quite consistently, the ages of the items according to artistic/typological features would be 2nd and 3rd centuries AD.

As previously mentioned, the overlapping between the fields of variability of the two isotopic parameters ($\delta^{18}O$ and $\delta^{13}C$) has been one of the problems of isotopic analysis applied to provenance studies. For classical marbles, this problem has been overcome by taking account of data from other techniques, such as the maximum grain size (MGS). However some overlapping persists. In the present study, sample #8, and perhaps #3 and #10 too, could be identified as Dokimeian as well as Pentelikon marble. Again, the petrographic information is essential to make the distinction, Dokimeion marble is fine-grained as Pentelikon but its fabric is completely different: the crystal boundaries are often sutured and include strained, often kinked, crystals indicating unstable conditions reached after quite brief metamorphic events (Gorgoni et al., 2002). Thus, samples #8, #3 and #10 are Pentelikon marbles and not Dokimeian.

Sample #13 deserves a separate mention because its origin is not Roman but Punic. According to the isotopic analysis this sample is made of Pentelikon marble. However, due to its pale yellow tint and its Punic origin we wondered if this could be made of a local stone. Our candidates were the yellowish recrystallized limestones from Chemtou and Djebel Ichkeul quarries. Looking at the isotopic ratios obtained from samples from these two quarries (see Table 1) we get values that lie within the field of variability of Pentelikon marble, though with quite low values of $\delta^{13}C$. Other data sources can help to identify the provenance of sample #13 marble. On one hand, Chemtou can be excluded because of historical reasons: its quarry produced the renowned *giallo antico* (Roman marmor numidicum) but it was worked from the second half of the 2nd century BC (Mezzolani, 2008) and thus, long after the presumed age of item #13 (the Punic sarcophagus), moreover its fabric is definitively not similar to sample #13. On the other hand Djebel Ichkeul, although it was quarried during Punic times (Mezzolani, 2008), can also be excluded taking into account petrographic data: the fabric of sample #13 is unequivocally that of a fine-grained marble (a material that has undergo complete recrystallization due to metamorphism) whereas the stone from Djebel Ichkeul, like that from Chemtou, is an intermediate type of rock between the sedimentary and metamorphic types. It has extensively recrystallized through diagenesis and low-grade metamorphism. Recrystallization has resulted in a marble-like fabric but with a significant lower grain size (see Table 1) compared to fine-grained marbles. The question remains as to where the yellowish tint of item #13 comes from. This could, in fact, be compatible with the Pentelikon attribution for some authors have referred on Pentelikon marble a golden tint due to weathering of iron compounds (Gardner, 1920). However, the opaque components seen in the thin sections of sample #13 are very small (<20 μm) and unseen in the diffraction patterns, and thus possibly amorphous. An extra source of tint could be the wooden coffins that lay on the sarcophagus as it has been pointed out for other items from the same site (Delattre, 1903b). In conclusion, sample #13 could be made of Pentelikon marble, its Punic origin is not an objection to this attribution. The Punic culture was strongly influenced by the Greeks; this has been specially remarked after revision of the findings from the necropolis in Bordj-Djedid where item #13 was found. Sarcophagi from this necropolis are carved in Greek style and its possible Greek origin was already hypothesized by Picard (1951).

Another marble with a different background is that of item #14. Petrographically, it is a marble with grains coarser than those of all other items and thus, its isotopic results are plotted in a different comparative diagram for classical marbles. Isotopic analyses point to two possible origins (Prokonnesos-1 or Thasos-2). Once more, petrographic data are the clue to narrow the attribution. The Thasian origin can be excluded because MGS for sample #14 is below 2.5 mm (Palagia et al., 2003). Moreover sample #14 shows xenoblastic structure with some crystals granulated along their borders (mortar texture), sutured boundaries and deformation elements that match with the typical features of Prokonnesos-1 marbles (Gorgoni et al., 2002). However, the lack of the typical gray veins of Prokonnesian could cast some doubts on this attribution, though these characteristic stripes are sometimes absent in Prokonnesos (Attanasio et al., 2008). Anyhow, this attribution is consistent with the early Christian character of the item as Prokonnesos largely replaced other marbles from the 2nd century BC onwards (Attanasio et al., 2006, 2008).

6. Conclusions

An archaeometric approach has been undertaken to determine scientifically the provenance of some artifacts from the Museum of Carthage. The obtained data add value to the characterization and descriptions of the studied items and the undertaken approach could be extended to other art pieces. Analytical results indicate that the most probable source for nine of the fourteen investigated items is Pentelikon marble, for three of them is Carrara and only one would be Prokonnesos-1 marble. These sources are consistent with the historical context and facts, and some authors had already correctly presumed them for some items: e.g. item #5 (Saumagne et al., 1964), item #9 (Thuillier, 1999) or item #14 (Rodà, 2001), even without a rigorous archaeometric approach.

Thanks to the compilation of isotopic databases, the fields of isotopic fractionation variability ($\delta^{18}O$ and $\delta^{13}C$) for the most recurrent marbles seem to be now well-established. This allows a fast identification of marble provenance that requires a very small amount of sample. However, isotopic values alone are of poor significance as they do not even discriminate between pseudometamorphic carbonates (like Ch or Dj samples) and marbles. It is known that metamorphism on carbonates can actually keep unaltered, to a certain extent, their original sedimentary isotopic signature (Valley et al., 1990). The combination of minero-petrographic and isotopic analyses has proved once again to be a reliable approach to identify the provenance of marbles.

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References

Álvarez, A., Domènech, A., Lapuente, P., Pitarch, A., Royo, H., 2009. Marbles and Stones of Hispania: Catálogo Exposición, IX ASMOSIA Conference, Tarragona. Institut Català d'Arqueologia Clàssica.

Álvarez, A., Rodà, I., 1992. Ciencias, metodologías y técnicas aplicadas a la arqueología. Fundació "la Caixa".

André, J., Bloch, R., Rouveret, A., 1981. Pline l'ancien: histoire naturelle, Livre XXXVI. Les Belles Lettres.

Annabi, M.K., 1981. Découverte d'un édifice et d'une sculpture près du cirque Romain. CEDAC Carthage Bulletin 3.

Antonelli, F., Lazzarini, L., Cancelliere, S., Dessandier, D., 2009a. Volubilis (Meknes, Morocco): archaeometric study of the white and coloured marbles imported in the Roman age. Journal of Cultural Heritage 10, 116–123.

Antonelli, F., Lazzarini, L., Cancelliere, S., Dessandier, D., 2009b. Minero-petrographic and geochemical characterization of 'Greco scritto' marble from Cap de Garde, near Hippo Regius (Annaba, Algeria). Archaeometry 51, 351–365. http://dx.doi.org/10.1111/j.1475-4754.2008.00408.x.

Attanasio, D., Brilli, M., Bruno, M., 2008. The properties and identification of marble from Proconnesos (Marmara island, Turkey): a new data including isotopic, EPR and petrographic data. Archaeometry 50, 747–774.

Attanasio, D., Brilli, M., Ogle, N., 2006. The Isotopic Signature of Classical Marbles. "L'Erma" di Bretschneider.

Azedine, B., 2004. Aspects de l'hellénisme africo-romain. Comptes-rendus des séances de l'Académie des Inscriptions et Belles-Lettres 148, 53–65.

Béjaoui, F., 1987. Nouveaux sarcophages à strigiles de Carthage. CEDAC Carthage Bulletin, 5–6.

Béjaoui, F., 1985. Sarcophages inédits de Tunisie. CEDAC Carthage Bulletin, 25–28.

Bruno, M., Cancelliere, S., Gorgoni, C., Lazzarini, L., Pallante, P., Pensabene, P., 2002. Provenance and distribution of white marbles in temples and public buildings of Imperial Rome. In: Hermmann, J.J., Herz, N., Newman, R. (Eds.), Asmosia 5. Interdisciplinary Studies on Ancient Stone. Proceedings of the Fifth International Conference of the Association for the Study of Marble and Other Stones in Antiquity. Boston, pp. 289–300.

Capedri, S., Venturelli, G., Photiades, A., 2004. Accessory minerals and $\delta^{18}O$ and $\delta^{13}C$ of marbles from the Mediterranean area. Journal of Cultural Heritage 5, 27–47.

Delattre, A.L., Commission de l'Afrique du Nord (France), 1899. Musées et collections archéologiques de l'Algérie et de la Tunisie: Musée Lavigerie de Saint Louis de Carthage. E. Leroux.

Delattre, A.L., 1912. Les fouilles de Damous-el-Karita. Comptes-rendus des séances de l'Académie des Inscriptions et Belles-Lettres 56, 460–476.

Delattre, A.L., 1903a. Carthage. Nécropole punique voisine de Sainte-Monique. Deux sarcophages anthropoïdes en marbre blanc. Comptes-rendus des séances de l'Académie des Inscriptions et Belles-Lettres 47, 23–33.

Delattre, A.L., 1903b. Carthage. Nécropole punique voisine de Sainte-Monique. Le septième et le huitième sarcophage de marbre. Couvercle anthropoïde. –

Épitaphes de prêtresses. Comptes-rendus des séances de l'Académie des Inscriptions et Belles-Lettres 47, 11–23.
Delattre, A.L., 1898. frLes Grandes statues du Musée de Saint-Louis à Carthage. imp. E. Petithenry, Paris.
Duval, N., 1971. Architecture et urbanisme à Carthage et à Utique. Journal des savants 4, 287–297.
Ennabli, A., 1998. Le musée de Carthage: un lieu de mémoire. Museum International. n 198, L, 25–32.
Gandolphe, P., 1952. Origines et débuts du Musée Lavigerie. Cahiers de Byrsa 2, 151–178.
Gardner, E.A., 1920. A Handbook of Greek Sculpture. Macmillan, London.
Gorgoni, C., Lazzarini, L., Pallante, P., Turi, B., 2002. An Updated and Detailed Mineropetrographic and C–O Stable Isotopic Reference Database for the Main Mediterranean Marbles Used in Antiquity, pp. 115–131.
Herrmann Jr., J.J., Tykot, R.H., DePaepe, P., Moens, L., 2009. Pentelic marble in central Italy: isotopic testing of neo-attic furniture. In: Jockey, P. (Ed.), Marbres et autres roches de la Méditerranée antique: études interdisciplinaires/Interdisciplinary Studies on Mediterranean Ancient Marble and Stones. Maisonneuve & Larose, Paris, pp. 309–328.
Korres, M., 1995. From Pentelicon to the Parthenon: the Ancient Quarries and the Story of a Half-worked Column Capital of the First Marble Parthenon. Melissa.
Lapuente, M.P., 1997. Problemas petrográficos en la identificación de mármoles clásicos: diferenciación de Carrara y Borba. Caesaraugusta 73, 279–288.
Lapuente, M.P., Turi, B., Blanc, P., 2000. Marbles from Roman Hispania: stable isotope and cathodoluminiscence characterization. Applied Geochemistry 15, 1469–1493.
Lavagne, H., 2000. La tolérance de l'Église et de l'État à l'égard des oeuvres d'art du paganisme dans l'Antiquité tardive. Études littéraires 32, 45–54.
Mezzolani, A., 2008. I materiali lapidei nelle costruzioni di età fenicia e punica a Cartagine. Analecta Romana Instituti Danici, XXXIII, pp. 7–25.
Morbidelli, P., Tucci, P., Imperatori, C., Polvorinos, A., Preite Martínez, M., Azzaro, E., Hernández, M.J., 2007. Roman quarries of the Iberian peninsula: "Anasol" and "Anasol"-type. European Journal of Mineralogy 19, 125–135.
Norman, N.J., 1993. The University of Georgia in the Yasmina Necropolis. CEDAC Carthage Bulletin 9.
Norman, N.J., Haeckl, A.E., 1993. The Yasmina necropolis at Carthage. Journal of Roman Archaeology, 238–250.
Origlia, F., Gliozzo, E., Gandin, A., Meccheri, M., Spangenberg, J.E., Turbanti Memmi, I., 2012. Marbles and carbonate rocks from central Morocco: a petrographic, mineralogical and geochemical study. Environmental Earth Sciences 66, 209–222.
Origlia, F., Gliozzo, E., Meccheri, M., Spangenberg, J.E., Turbanti Memmi, I., Papi, E., 2011. Mineralogical, petrographic and geochemical characterization of white and coloured Iberian marbles in the context of the provenancing of some artefacts from Thamusida (Kenitra, Morocco). European Journal of Mineralogy 23, 857–869.
Palagia, O., Maniatis, Y., Dotsika, E., Kavoussanaki, D., 2003. New investigations on the pedimental sculptures of the "Hieron" of Samothrace: a preliminary report. In: Proceedings of the 7th International Conference of Association for the Study of Marble and Other Stones in Antiquity. BCH Suppl. 51. École française d'Athènes, Athens, pp. 113–132.
Pensabene, P., Antonelli, F., Lazzarini, L., Cancelliere, S., 2012. Provenance of marble sculptures and artifacts from the so-called Canopus and other buildings of "Villa Adriana" (Hadrian's villa – Tivoli, Italy). Journal of Archaeological Science 39, 1331–1337.
Picard, C., 1951. Carthage, Société d'Édition. Les Belles Lettres, Paris.
Rietveld, H.M., 1969. A profile refinement method for nuclear and magnetic structures. Journal of Applied Crystallography 2, 65–71.
Rodà, I., 2001. Producción, materiales y circulación de sarcófagos en el Imperio Romano. In: Conde Guerri, M.E., Noguera Celdrán, J.M. (Eds.), El sarcófago romano: contribuciones al estudio de su tipología, iconografía y centros de producción. Universidad de Murcia, Murcia, pp. 51–78.
Saumagne, C., Poinssot, L., Pinard, M., 1964. Mélanges de Carthage: Section culturelle de l'Ambassade de France.
Thuillier, J.P., 1999. Agitator ou Sparsor? À propos d'une célèbre statue de Carthage. Comptes-rendus des séances de l'Académie des Inscriptions et Belles-Lettres 143, 1081–1106.
Valley, J.W., Bohlen, S.R., Essene, E.J., Lamb, W., 1990. Metamorphism in the Adirondacks: II. The role of fluids. Journal of Petrology 31, 555–596.