WHITE SCULPTURAL MATERIALS FROM VILLA ADRIANA: STUDY OF PROVENANCE

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Abstract
This contribution reports the archaeometric study of 62 fragmented sculptures from the collections stored in the reserves of Villa Adriana, Tivoli. They were carved in white fine to very fine grained marble, but also medium and coarse types were investigated. Provenance determination was carried out using a sequential approach, taking into account petrography and cathodomicrofacies as the first step, combined with the C and O stable isotopes. Complementary techniques, EPR and quantitative CL, were used to verify or specify from among the different options. The paper discusses the results of combining different analytical techniques in comparison to the most reliable databases. They confirm the use of Carrara but also point to a variety of classical marble sources in Greece and Turkey, including the recently discovered Göktepe quarries. Some results must be considered provisional, until the detailed petrography of Göktepe is published.

Keywords
Villa Adriana, sculpture, white marble, provenance study, quarry, Carrara, Göktepe.

Introduction and aims

The study of the origin of Roman white marble sculptures has been a line of interdisciplinary research that focuses more attention on the scientific community for its immediate historical implications. Databases of mineralogy, chemical and physical parameters are aimed at discriminating ancient quarrying areas through different parameters. Although there is no single satisfactorily reliable method for matching the origin of a marble artefact, the puzzle of information to distinguish one marble from another is gradually being completed using a combination of techniques. The difficulty that arises is the non-uniformity of data in the most reliable databases, while some are based on minero-petrographic and C-O stable isotopic data, others deal with EPR, isotopes and maximum grain size. Research involving new discriminate parameters has been leading towards Sr isotopes and other more specific ones such as fluid inclusions. But so far, C and O isotopes combined, at least to petrography, have attracted most attention for their successful applications. Pioneered by Craig and Craig (1972), C and O isotope ratios databases have been developed which have made the method a viable one (Herz 1987, 1988, 1992; Moens *et al.* 1988, 1992; Gorgoni *et al.* 1998, 2002; Attanasio *et al.* 2000, 2002, 2006).

A new perspective opened recently after the discovery of some imperial quarries in Asia Minor (Attanasio *et al.* 2008, 2009a; Yavuz *et al.* 2009). The high quality of these white marbles along with their location close to Aphrodisias, a centre of great sculptural tradition, offers a new outlook to consider in the study of marble origin. However, to date, the detailed petrography of these new sources remains unpublished, limiting the comparative studies. In this context, the present archaeometric paper discusses the results of combining different analytical techniques in order to investigate the marble provenance of a selection of white fragmented sculptures from Villa Adriana. Another paper in this volume deals with black sculptures (Lapuente *et al.* 2012).

The study of sculptural materials from the Imperial Villa constitutes a broad and intricate nucleus of investigation in which numerous researchers have been involved using different approaches (Sapelli 2010). In the past, much attention was devoted to architectural elements and ornamental building decoration using coloured and white marbles which were identified by visual inspection (Salvatori *et al.* 1988; Olevano *et al.* 1989). Recently (Attanasio *et al.* 2009b), the archaeometric study of 137 white architectural elements from three buildings at Villa Adriana has highlighted the predominance of Carrara marble (67%), with Pentelicon (26%), Proconesos (8%) and Thassian dolomitic (2%). In this volume, Pensabene and co-workers report the marble provenance of the Canopus statuary.

During the 2006 to 2008 archaeological expeditions of the Seville Pablo Olavide University project on Villa Adriana, diverse tasks of cataloguing and documentation were completed on the sculptured collections stored in the reserves of the Villa, always under the tutelage of the "Soprintendenza per i Beni Archeologici del Lazio". From all the documented collections, different cycles, programs and sculptured themes were recognized (León and Nogales 2008, 2010). One of the complementary scopes carried out during the final expedition was the selection of pieces for submitting to archaeometric analyses. These are evidently from diverse provenances, not only in their material but also in the features of manufacture and workshops. From the hundreds of examples, in different states of fragmentation, a set of 62 white marbles were sampled after visual examination.

Methodology

A multi-technique approach was used to avoid ambiguous or erroneous provenance determination. Thin section microscopy, cathodoluminescence, stable isotope

analysis and EPR were applied to identify their marble or stone provenance. Taking advantage of the fact that all the pieces were fragmented, it was possible to take a small chip without spoiling their visual appearance. Samples were freshly broken or abraded surfaces to avoid possible interference from weathering layers. Thin sections were made from all the samples and most of them were powdered for use with other techniques. Provenance determination was carried out using a sequential approach, taking into account petrography and cathodomicrofacies as the first step, combined with the C and O stable isotopes. Complementary techniques, EPR and quantitative CL, were used to verify provenance or clarify the differences. Results were compared with those of the published databases.

Analytical techniques

The polarizing microscope was systematically used for studying mineralogy and texture parameters. Particular attention was paid to fabric and grain size, measuring maximum grain size (MGS) and describing boundary grain shape (BGS). These parameters have a particular diagnostic significance for discriminating many ancient marbles since they are the consequence of their metamorphic record (Lazzarini *et al.* 1980, 1985; Moens *et al.* 1988; Lapuente 1995; Lapuente and Turi, 1995; Lapuente *et al.* 1998, 2000; Gorgoni *et al.* 2002; Capedri and Venturelli 2004; Capedri *et al.* 2004).

Cathodoluminescence analysis (CL) was carried out by using CL8200 Mk5-1 coupled with a NIKON Eclipse 50iPOL optical microscope[1] The electron energy applied to the thin-sections was 15-20 Kv and the beam current was operated at 250-300 μA. The observed luminescent colours, intensity and distribution of each sample were registered onto digital photographs using an automatic digital NIKON COOLPIX5400 camera. They were checked with the available CL microfacies applied to several classical quarrying areas in Greece, Italy and Turkey (Barbin *et al.* 1989, 1991, 1992a, 1992b).

A cathodoluminescence accessory for the SEM was used to register the CL emission spectrum and to measure the characteristic peak intensities of samples, in the form of 3 mg compressed powder tablets coated with C. Detailed information about devices and measurements is given in Lapuente *et al.* (2000). CL emission intensities were noted at 375 nm and at 620-650 nm, registering three spectra each second, on ten passages, and normalizing to Céret marble. The measurement units are in thousand parts of Céret emissions.

Oxygen and carbon isotopes were determined on dolomitic and calcitic samples by isotope ratio mass spectrometry with Finnigan MAT 252 equipment. A Finnigan MAT Kiel II automatic preparation device was previously used for phosphoric acid digestion at 72ºC and CO_2 purification. The results were expressed in terms of usual delta notation ($\delta^{13}C$ and $\delta^{18}O$) in ‰ relative to the international reference standard PDB.

EPR analyses were carried out with an X-band Varian E-9 spectrometer. The marble EPR spectrum is the standard spectrum of Mn^{2+} substitutionally diluted in the calcite lattice Attanasio *et al.* (2000). The parameters selected were the spectral intensity and the line width, following the available database[2] (Attanasio *et al.* 2002, 2008, 2009a; Yavuz *et al.* 2009).

Results and discussion

Preliminary petrographic analyses were applied to discriminate groups and subgroups of samples. They were investigated under microscope and cathodoluminescence equipment focusing special attention on all the known parameters and taking microphotographs. These different groups were checked by carrying out complementary analyses. They were verified with the isotope data, except in two cases through lack of enough samples. The quantitative cathodoluminescence and EPR were applied in some cases to compare results and confirm the previous groups. Note that the general petrographic study of recently discovered Göktepe remains unpublished, although the MGS is known. This obstacle hinders our comparative approach, which in some determinations should be taken as provisional pending the confrontation with the whole petrographic data.

Regarding the similarity in petrography and CLmicrofacies, 8 groups were differentiated from the white marbles, two in medium to coarse grain and 6 in very fine to fine grain. Table 1 shows the list of pieces, isotopic, CL, EPR values and the attributed provenance. After comparison with the available databases, different options are discussed in detail.

The established groups were as follows.

Medium-coarse (MGS> 2mm) marbles

Only two varieties were analyzed, one pure dolomitic and the other calcitic.

Dolomitic marbles

Focusing on petrography and CLmicrofacies, three samples (TI-VA 7, 20, 47) were distinguished as the typical heteroblastic dolomitic marble with microcalcite as an accessory, which came from **Thasos**, Cape Vathy or Saliara (Fig. 1a). Their isotopic signatures (Fig. 2), plotted on the diagram by Gorgoni *et al.* (2002), confirm the provenance.

1. At the ICAC (Institut Català d'Arqueologia Clàssica), Tarragona.
2. The authors are indebted to Dr Attanasio for making available the facilities of the EPR analyses.

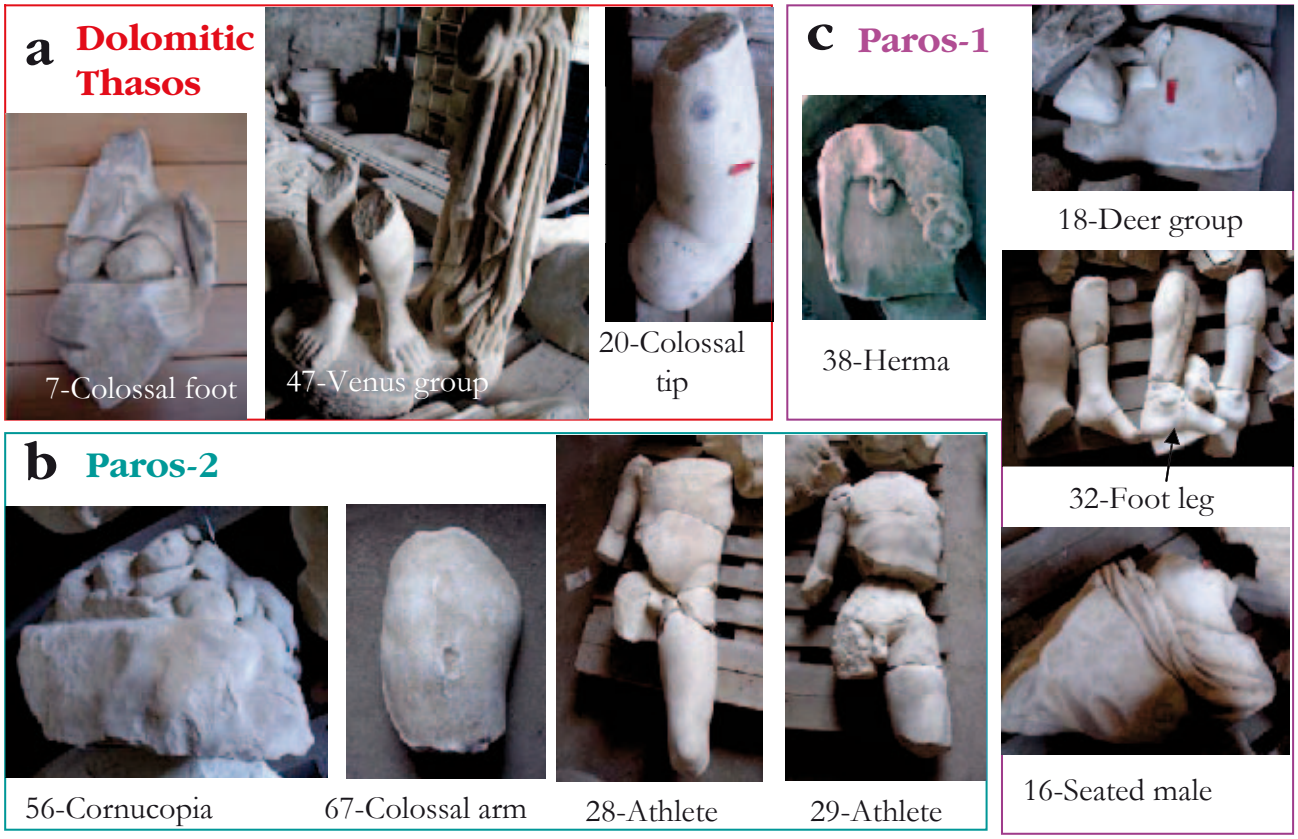

Fig 1. Provenance groups: (a) Dolomitic Thasos, (b) Paros-2, (c) Paros-1.

Calcitic marbles

The medium grained pure calcitic marbles (TI-VA 28, 29, 56, 67) with MGS<2,2mm show a slightly heteroblastic texture with the usual curved to sutured borders. They display a reddish brown faint to medium CL behaviour. This combination of features and their isotopic signature (Fig. 2) determine the provenance as Paros, Chorodaki, named Paros-2-3 (Fig. 1b)

Very fine (MGS<0,7mm) to fine (MGS< 2mm) marbles

From the very fine to fine-grained white marbles, 6 different groups have been formed. Two are calcitic with traces of dolomite, but the rest are pure calcitic marbles. C and O isotopes were plotted on a common diagram for marbles with MGS<2mm, after Gorgoni *et al.* (2002) (Fig. 3).

Their provenances are as follows:

Paros- Marathi

Four samples (TI-VA 16, 18, 32, 38) were assigned to Paros-1, Marathi (Fig. 1c). They show a mosaic of calcite heteroblastic to homeoblastic with curved to straight boundary shapes and MGS about 2mm long. CLmicrofacies exhibit their typical behaviour of very faint intensity. The isotopic signature confirms the Parian *lychnites* provenance (Fig. 3).

Afyon, Docimium

Samples TI-VA 1, 22, 25, 37, 48, 54 (Fig. 4a) are all fine grained calcite marbles (MGS≤1,5mm). They exhibit a typical heteroblastic texture with clear evidence of stress, in a strained fabric. Boundary grain shapes are mostly embayed, but also curved and straight ones can be recognized. The patchy CL reveals different behaviour in unaffected relicts by the stressed processes (Fig. 5b). C and O isotopic data (Fig. 3) confirm this Turkish provenance. One sample (TI-VA 21) exhibits a partially brecciated texture in transition to the general features described for the rest of the group. It displays the typical wine-red cement with hematite which ascribes the piece to a pavonazzetto typology.

Pentelicon

Five samples (TI-VA 17, 26, 43, 52, 59) were recognized as calcitic marbles from Pentelicon (Fig. 4b) due to their typical petrographic fabric with slight foliation along with the presence of white mica flacks and dolomite as accessories. Distinctive CLmicrofacies and isotopes confirm this Greek origin (Fig. 3).

Carrara

Regarding petrography, two groups (C1 and C2) were set aside, both with very fine grained calcite and the same range of sizes, (MGS< 0,7mm). **C1** was formed of six samples (TI-VA 8, 9, 11, 15, 34, 41) which display granoblastic to slightly heteroblastic texture, with patches of microdolomites and small scattered pyrites. Cathodomicrofacies with medium homogeneous intensity helps to enhance exactly where the dolomite is. Boundary grain shapes are straight to curved derived from almost stable conditions reached over long meta-

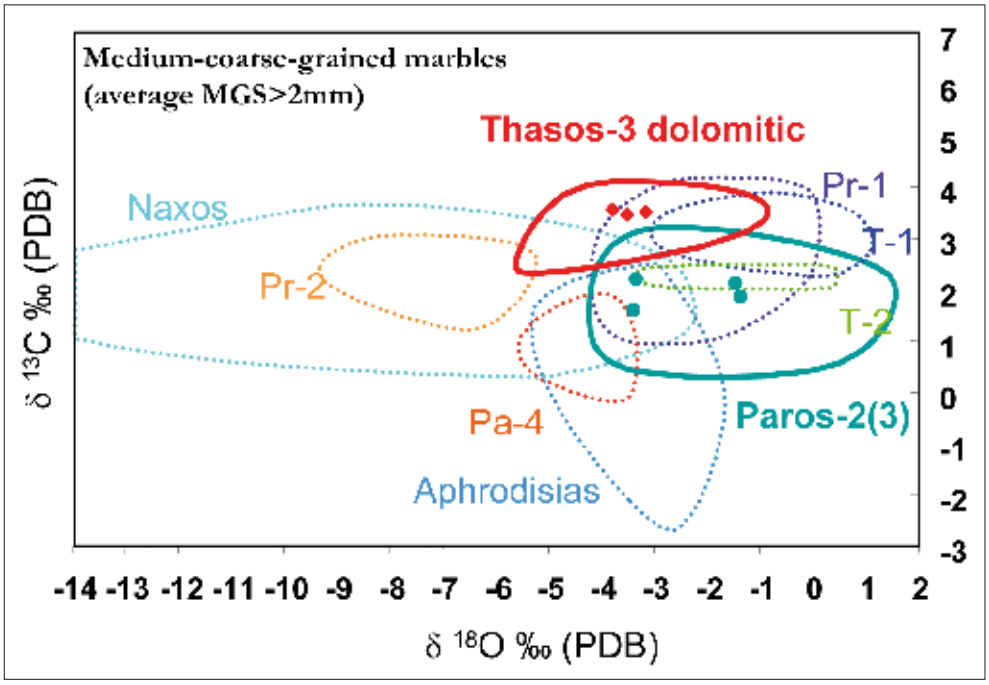

Fig 2. Isotopic signatures of TI-VA 7, 20, 47 dolomitic white marbles and TI-VA 28, 29, 56, 67 medium grained in the isotopic diagram after Gorgoni *et al.* (2002).

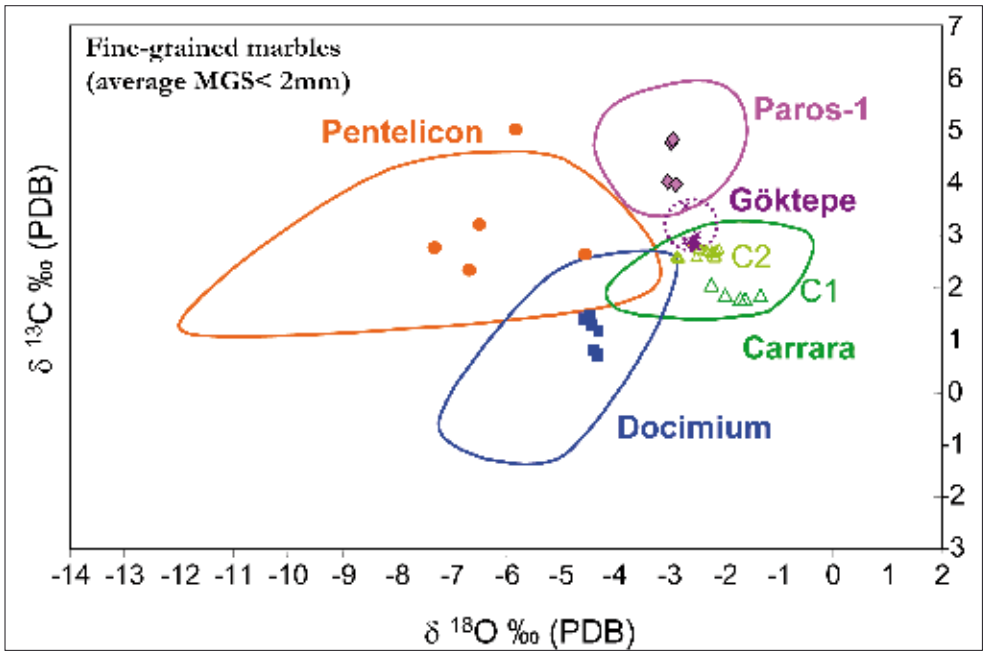

Fig 3. Isotopic signatures of TI-VA white marble petrographic groups in the general diagram after Gorgoni *et al.* (2002). 18 white Göktepe pieces are included and two different petrographic groups C1 and C2 are also differentiated inside the Carrara field. One sample of the Göktepe petrographic group is plotted in the Paros-1 isotopic field, however this sample is undoubtedly from the same petrographic group G.

morphic times (Fig. 5a). Isotopic values are discussed below, but from the results of all analytical tests carried out, a quarry from the Carrara district is the definite provenance (Fig. 6).

Group **C2** is made up of fifteen samples (TI-VA 3, 5, 14, 23, 30, 31, 35, 44, 45, 49, 60, 61, 62, 64, 65 shown in Fig. 7. Their texture is homeoblastic showing calcites with typical granoblastic in mosaic, polygonal with triple points revealing static recrystallization, which has always been described as representative of the *Lunense* Carrara. As their isotopic values fall into the general Carrara field (Fig. 4), this provenance should be taken as doubtless. The problem is their CL behaviour and therefore this also concerns EPR analyses. CLmicrofacies offer pictures with very faint intensity where only uncertain crystals show weak luminescence (Fig. 5b).[3] This conflicting point will be dealt with later, together with results from Göktepe white marbles.

3. CLmicrofacies applied to archaeological pieces manifested the problem of having blue luminescent with the same type of texture (Barbin *et al.* 1992a).

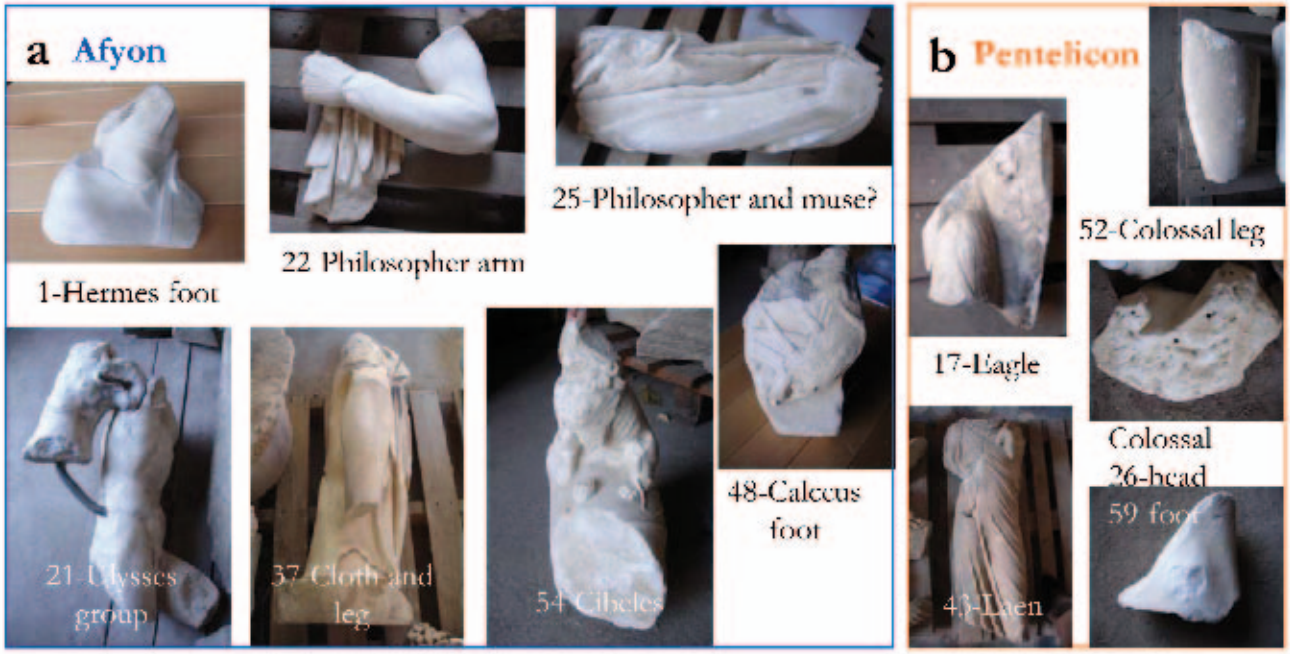

Fig 4. Provenance groups: (a) Afyon, (b) Pentelicon.

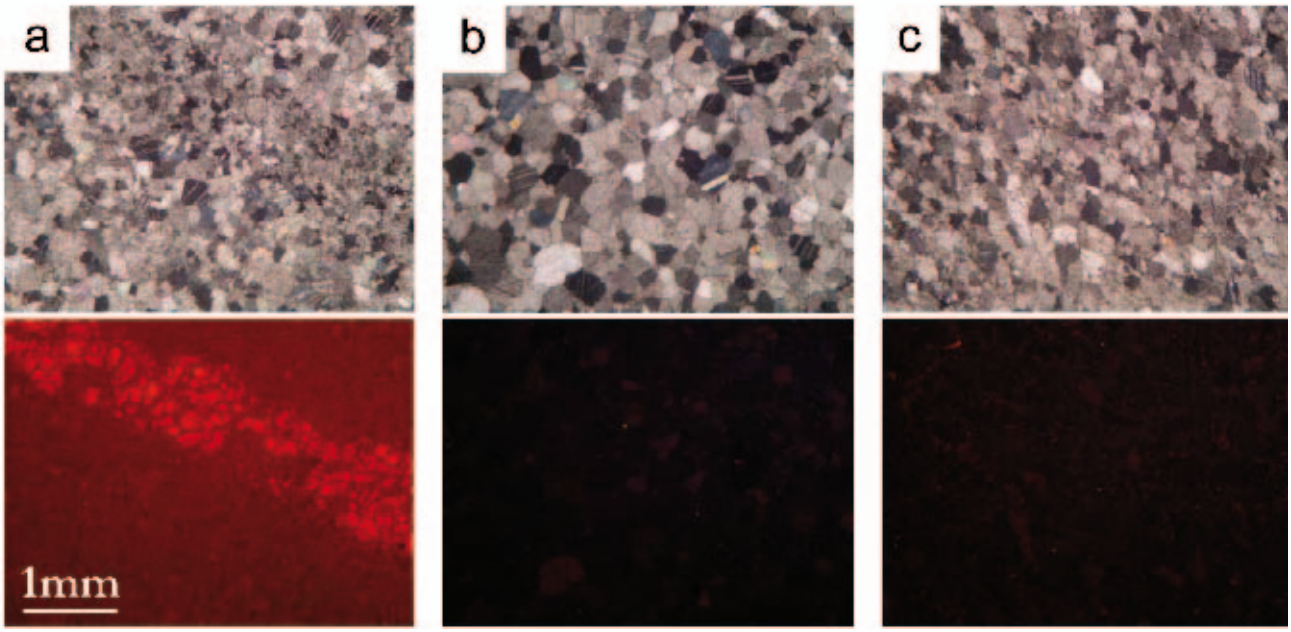

Fig 5. Representative photomicrographs in crossed-polarised light and CLmicrofacies: (a) Group C1, (b) Group C2, (c) Group G.

Göktepe White and the problem of discrimination from Carrara

Group (G) with 18 samples (TI-VA 2, 4, 10, 12, 19, 24, 27, 33, 36, 40, 50, 51, 53, 55, 57, 58, 63, 66) shown in figure 8, is composed of very fine grained marbles (MGS<0,5mm), homeoblastic to slightly heteroblastic, if subgrains were formed. Microstructures show from vaguely oriented calcites to clearly foliated fabric manifested by grain shape orientation, but characteristic crystallographic preferred orientation was also observed. Boundary grain shapes range from curved to interpenetrating, typical of diffusive mass transfer mechanism, when grains have no internal strain features. Sutured contacts were recognized as well, alongwith the presence of very small subgrains, formed by the deformation mechanism of intracrystalline plasticity (Blenkinsop 2000). There is no evidence of extensive deformation twinning but a few zoned undulatory extinctions were viewed. Accessory minerals are very scarce, tiny quartz and feldspars, and occasionally microdolomites are displayed by CL. With the exception of sample TI-VA 36 (medium intensity), all exhibit a faint heterogeneous CLmicro-

Fig 6. Pieces of petrographic group (C1).

Fig 7. Pieces of petrographic group (C2).

Fig 8. Pieces of Göktepe.

facies which often reveal a set of brighter points right at the calcite boundaries, and even a continuous bright line within each crystal encircling the relict nucleus. These CLmicrofacies are very characteristic and could be used to discriminate White Göktepe from others. Petrography and CLmicrofacies combination seem to be distinctive from the rest of the classical marbles (Fig. 5c).

C and O isotopes were plotted on a common diagram for marbles with MGS<2mm, after Gorgoni *et al.* (2002) (Fig. 3) where the 4 samples from Paros-1, 5 from Pentelicon and 6 from Docimium (above described) can be easily identified. However, within the usual Carrara isotopic field, three different groups are plotted (C1 and C2, but also most of the G group). An interesting feature to note is the relative isotopic homogeneity of each of these three distinguished petrographic groups. Group G, the most numerous with 18 samples, was attributed to white Göktepe in agreement with data by Attanasio *et al.* (2009a) which notes the Carrara and Göktepe isotopic signature overlapping. Bearing in mind another parameter which seems to discriminate white Göktepe marbles, such as their very fine grain MGS (0,66 mm), with an average grain size 0,291 ± 0,1mm (Attanasio *et al.* 2009a), our group G, with the smaller grain of all the samples studied (MGS<0,5mm), fits in well with data from Göktepe.

Isotopes of both, Carrara and Göktepe quarry references (Attanasio *et al.* 2006, 2009a) were plotted along with TI-VA archaeological samples in an overview diagram (Fig. 9). The reference Carrara isotopic fields of Gorgoni *et al.* (2002), was also drawn in the same figure. Note that the isotopic discrimination of Göktepe marbles is problematic since the majority of them cluster in the area of isotopes from the quarries of Carrara marbles.

Isotopic signature of those archaeological samples (TI-VA) were plotted inside the global Carrara field of Gorgoni *et al.* (2002), but clearly in three different groups which correspond to the petrographic C1, C2 and G. Group (G) follows the Göktepe data clue of quarry samples, with strongly superposed values with the exception of sample TI-VA 33 which has the higher $\delta^{13}C$ value (3,55) indicative of the Paros-1 isotopic area. However, through petrography it can undoubtedly be assigned to the same Göktepe group. Group C1 matches well with

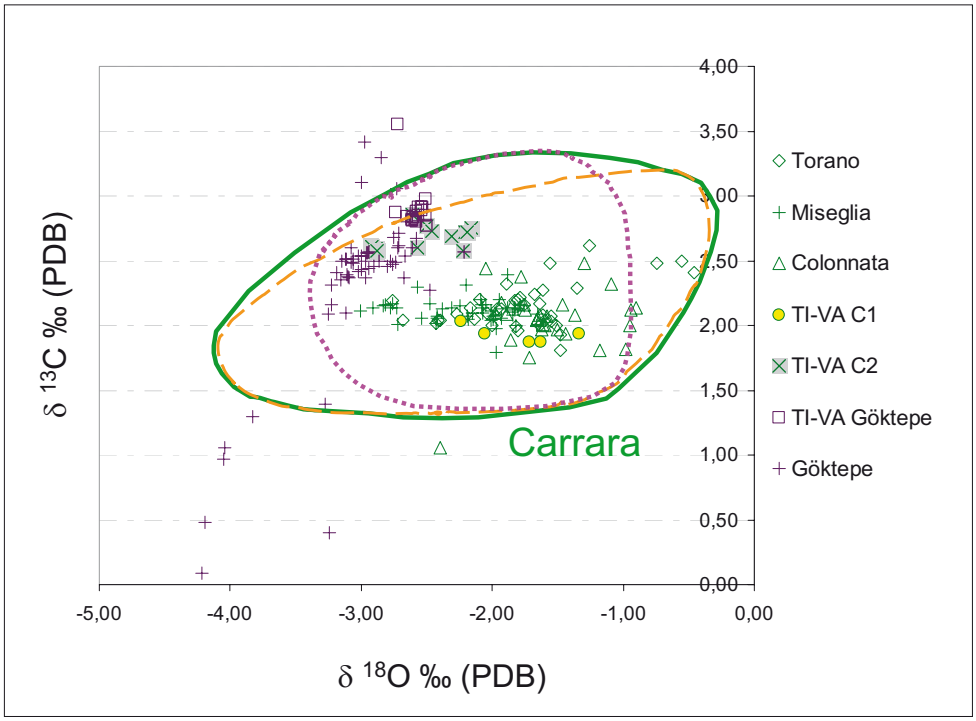

Fig 9. Overview of Carrara isotopic fields (lines) from Gorgoni *et al.* (2002) and data of Carrara quarries (Torano, Miseglia, Colonnata) from Attanasio *et al.* (2006). Bold green line is global isotopic field (quarrys and artefacts). Dashed orange line is quarry isotopic field. Dotted pink line is the area of isotopes from ancient artefacts known to be Carrara (Gorgoni *et al.* 2002). Most of the White Göktepe quarries (garnet cross) partially overlap the Carrara fields (Attanasio *et al.* 2009a). Archaeological samples (TI-VA) were separated in three different groups by petrography and CL (C1, C2 and G). All are plotted inside the global Carrara field. Group (C1) matches well with Carrara data of Attanasio *et al.* (2006). Group TI-VA Göktepe follows the Göktepe data clue, confirming this provenance. Group (C2) which has certainly typical Carrara texture, exhibits signatures closer to Göktepe quarries than those signatures of Carrara quarries plotted.

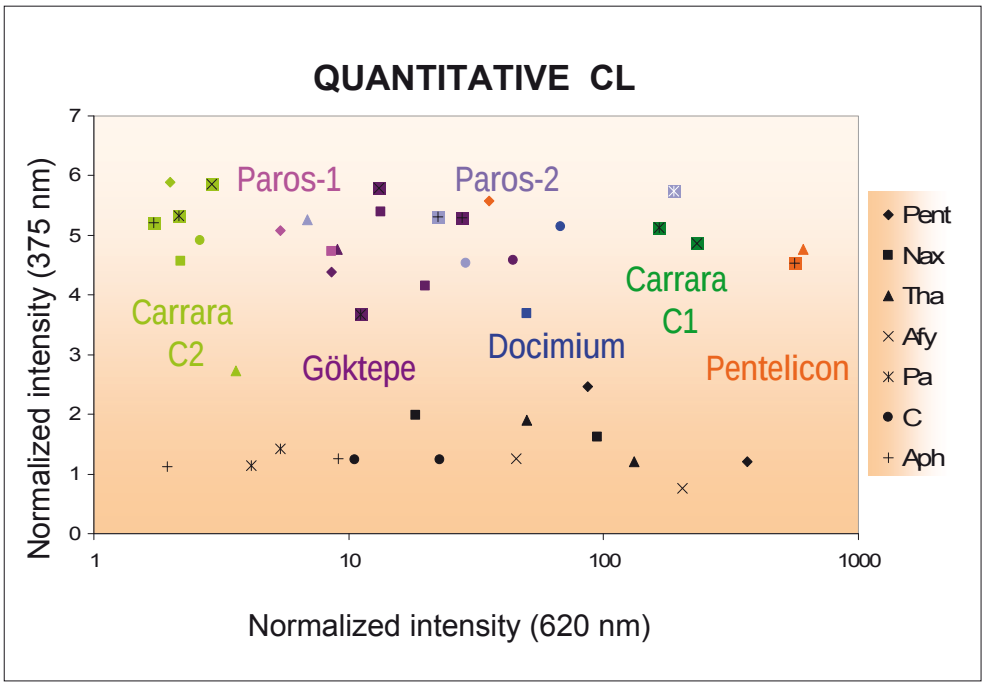

Fig 10. Quantitative CL values of seven calcitic groups of archaeological samples. Data are compiled in Table 1. Provenance is assigned trough petrography, CLmicrofacies, isotopes and EPR. Some classical calcitic marble values are plotted for comparison (Pentelicon, Naxos, Thasos, Afyon, Paros, Carrara, Aphrodisias).

Provenance	Referen. (TI-VA)	Store Ref.	Inventory	Archaeological description	$\delta^{18}O$	$\delta^{13}C$	CL QUANTITATIVE 620nm	375nm	EPR Int	W
Thasos	7	XXVII	829	Colossal foot	-3,57	3,50				
Dolomitic	20	XXI	1036	Colossal tip	-3,20	3,55				
	47	XIII	96	Venus group	-3,85	3,63				
Paros-2	28	XVIII		Athlete	-3,33	2,19	6,9	5,26		
Chorodaki	29	XVIII		Athlete	-3,43	1,70	28,8	4,54		
	56	X	44435	Cornucopia	-1,67	2,10	189	5,74		
	67	IX	40650	Colossal arm	-1,45	1,86	22,36	5,32		
Paros-1	16	XXII	777	Seated male statue	-2,98	4,90	5,4	5,08		
Marathi	18	XXI	543	Base group of deer	-2,81	3,92				
(*lychnites*)	32	XVIII	3350/1023	Foot leg	-2,99	4,83				
	38	XV	104 (2006)	Herma	-3,01	3,99	8,6	4,74		
Docimium	1	XXVIII	3203	Hermes foot	-4,42	1,51				
	22	XX	507	Philosopher arm	-4,51	1,46				
	25	XX	1062	Philosopher/muse group	-4,27	0,77	50,04	3,69		
	37	XV		Cloth and leg	-4,25	1,22	67,8	5,14		
	48	XII	42474	Calceus foot						
	54	X	44112	Cibeles	-4,38	1,34				
Doc/pavonazzetto	21	XXI		Ulysses Group	-4,33	0,85				
Pentelicon	17	XXII	867	Eagle	-7,38	2,72	165	5,13		
	26	XIX	45309	Colossal head	-5,82	5,03	35,6	5,57		
	43	XIV		Laen statue	-6,49	3,17	563	4,53	0,5686	0,7685
	52	XI	1024	Colossal leg	-6,72	2,38	607,7	4,76		
	59	X	41263	Colossal foot	-4,55	2,62				
Carrara (C1)	8	XXVII	2957	Decorated relief	-1,72	1,87			0,7472	0,637
	9	XXVII	2943	Deity-fountain relief	-1,63	1,87				
	11	XXVII	44983	Lion paw	-2,24	2,03				
	15	XXII	2694	Hercules base	-1,34	1,94			0,7781	0,4945
	34	XVI	2225	Large mask	-2,06	1,94	232	4,86	1,0037	0,5493
	41	XIV	2265	Colossal August?						
Carrara (C2)	3	XXVIII	895	Horse leg	-2,31	2,69				
	5	XXVIII	597	Antinous head	-2,91	2,58	2	5,89		
	14	XXVI	40453	Colossal hand	-2,61	2,86	3,6	2,73		
	23	XX		Statuary base	-2,22	2,58				
	30	XVIII	401	Pedestal with footstool	-2,93	2,62				
	31	XVIII	44000	Naked leg	-2,57	2,60				
	35	XVI		Fluvial deity	-2,19	2,72	2,15	5,33	0,0111	0,5108
	44	XIII	95	Plate with caryatid	-2,89	2,59				
	45	XIII	130	Antoninianus bust	-2,50	2,77				
	49	XII	2851	Apollo	-2,92	2,61	2,2	4,57	0,0123	0,49
	60	X		Colossal Hadrian	-2,21	2,72	1,72	5,21		
	61	X	41417	Female arm	-2,89	2,57				
	62	IX	402	Round with zodiac	-2,16	2,75	2,61	4,91	0,0223	0,58
	64	IX	721-740-3321	Antoninianus hole bust	-2,46	2,73	2,89	5,86	0,0276	0,54
	65	IX	42296	Female arm with peplum	-2,88	2,58				
Göktepe (G)	2	XXVIII	825	Decorated mulleus	-2,61	2,81				
	4	XXVIII	881	Swan neck	-2,54	2,89				
	10	XXVII	44491	Foot base	-2,58	2,88			0,0730	0,4156
	12	XXVI	558	Lucius Verus portrait	-2,65	2,84	20	4,16	0,0736	0,4492
	19	XXI	44451	Base on legs	-2,56	2,91	8,6	4,38		
	24	XX	781	Antoninianus bust	-2,61	2,82			0,0415	0,4612
	27	XIX	3073	Colossal foot	-2,74	2,87				
	33	XVIII	3354/4021	Naked legs	-2,72	3,55	9,07	4,76	0,0620	0,4976
	36	XV		Colossal dolphin	-2,56	2,85				
	40	XIV	3047	Lion paw	-2,54	2,91	44,2	4,58	0,1655	0,4049
	50	XII	43701	Female hand	-2,59	2,82				
	51	XII	44243	Relief/Herma and building	-2,51	2,98			0,0236	0,4158
	53	XI	2593	Child right foot	-2,60	2,83			0,0491	0,5431
	55	X	2623	Female statue with laen	-2,58	2,83	13,16	5,8		
	57	X	42495	Athlete	-2,53	2,91				
	58	X	40943	Male leg	-2,58	2,80	11,16	3,68		
	63	IX	2684	Statuary base	-2,50	2,77	27,8	5,3		
	66	IX	42552	Calceus foot	-2,51	2,85	13,38	5,4	0,0116	0,5164

Table 1. White marble sculptures from Villa Adriana.

the plotted Carrara quarry data (Attanasio *et al*. 2006). Group C2 (with the most typical Carrara texture) shows isotopic signatures closer to Göktepe quarries than those plotted of Carrara. In the absence of more information about textures from Göktepe, this C2 group must be assigned to Carrara, otherwise many previous provenance studies would require further reviewing.

Some additional analyses were carried out (Quantitative CL and EPR) on the available samples, to confirm CLmicrofacies groups (Table 1). Measurements based on the intensities of the CL spectra, by means of CL+SEM equipment, were taken at 375 nm and 620 nm and plotted on a quantitative CL diagram (Fig. 10). A small representation of classical quarries is also shown in order to compare their variability on the X axis.[4]

Though scattered, the identity of the 7 calcitic petrographic groups can be more or less recognized. Marbles (C1, C2 and G) under consideration show closer similarities among the samples of the same group. Comparing the global intensities of these three groups, some considerations may be noted: Values of the Y axis are similar in all groups. On the other hand, intensities at 620 nm peak show a wide dispersion. Samples from group C2 (with the typical Carrara texture) manifest the lower intensities in the spectrum at 620 nm (ranging from 1,72 to 3,6)[5] in agreement with their very weak CLmicrofacies.

Values of EPR intensity are in agreement to those at 620 nm CL intensity. The 8 samples measured from group G show relatively low intensity values at 620 nm (from 8,6 to 44,2; most of them <14). These values agree with the low EPR intensity (from 0,0116 to 0,1655), which match the EPR values of Göktepe quarries (Attanasio *et al*. 2009a) whose extreme values (in term of EPR Intensity) range from 0,0122 to 0,1324 (with 0,039±0,02 mean values) for the white Göktepe district 3 and from 0,1021 to 0,3011 (0,216±0,08 mean values), for the white Göktepe district 4.

Only one sample of the C1 petrographic group was measured under quantitative CL, but its intensity (232 agrees with the higher EPR intensity measured (1,0037), as shown in Table 1. EPR values of this C1 group range between 0,7472 and 1,0037 match the mean value of Carrara (0,685±0,63), after Attanasio *et al.* (2009a). Finally, EPR of 4 samples of C2 group show extremely low intensities (0,0111 to 0,0276) as they have also shown in the quantitative CL diagram (Fig. 10).

In brief, results from CL and EPR confirm the discrimination of three groups, one Carrara (C1), one Göktepe (G) and a third (C2) with samples showing the lowest intensities. At least two possibilities arise, this C2 is not a Carrara but a Göktepe with the same MGS and Carrara texture, or C2 is certainly a Carrara group from an area which was not sampled in the EPR databases and was not analyzed by CL or EPR in most isotopic databases.

Conclusions

The analytical results confirm that different classical white marbles were used for sculpturing purposes at Villa Adriana. From the 62 white samples analysed, different marble sources have been positively distinguished: Afyon, Pentelic, Paros-1, Paros-2 and dolomitic Thasos. Provisionally, for lack of Göktepe petrography to make comparisons, two different groups were discriminated from Carrara (C1 and C2), while one group (G) was definitely Göktepe.

These results confirm the presence of Carrara and emphasize the importance of Göktepe marble at Hadrian age, in agreement with the significant number of sculptures of Villa Adriana recently assigned to the black and/or white Göktepe quarries (Attanasio *et al.* 2009a).

Some doubts arise from the Carrara - Göktepe discrimination when compared with the available databases. Statistical treatments of discrimination should place more importance not only on the MGS but also on a parameter defining texture. Finally, the requirement of making available detailed petrographic data from Göktepe quarries could settle the doubts which have arisen from this archaeometric study.

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4. To match these with their provenance, further quarry data would be necessary, but this is beside the point.
5. Intensities are related to the emission of the standard Céret marble. Unit is the thousandth part of the standard emission.

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