FASTI ONLINE DOCUMENTS & RESEARCH

The Journal of Fasti Online ● Published by the Associazione Internazionale di Archeologia Classica ● Piazza San Marco, 49 – I-00186 Roma
Tel. / Fax: ++39.06.67.98.798 ● http://www.aiac.org; http://www.fastionline.org

Recovering evidence for the use of marble and coloured limestone in the first century AD in excavations at the sanctuary of Venus at Pompeii

Maureen Carroll - Giuseppe Montana - Luciana Randazzo - Renato Giarrusso

Introduction and aims

The sanctuary of Venus in Pompeii was first excavated between 1898 and 1900, when the site was cleared of ancient pumice and ash from the eruption of Vesuvius in AD 79 (fig. 1). The aim of these excavations and later occasional interventions was to reveal the architectural remains of the temple and the colonnades around it.[1] The minimal investigation of the subsoil in the sanctuary courtyard during any of these campaigns left many questions pertaining to the social, political and architectural development of Pompeii unanswered. By the same token, the lack of post-Roman disturbance gave the site great potential for new and focused archaeological exploration. In view of this, a research project was designed by the Department of Archaeology at the University of Sheffield with the primary objective of retrieving evidence for the date and layout of the city's principal Roman sanctuary and its possible landscaping with a sacred grove. The investigations in 1998, 2004 and 2006 involved excavation, clearing, surveying, recording, geophysical survey and sediment coring.

Furthermore, the project aimed to explore the evidence for subsequent building work on the temple and the possible provenance of building materials. To address this latter archaeological and historical aspect, a minero-petrographic and geochemical study was conducted in 2007/2008 in co-operation with the Dipartimento di Chimica e Fisica della Terra (C.F.T.A.) of the University of Palermo in order to obtain information about the nature, provenance and periods of use of white marble and coloured limestone in the sanctuary. Samples for scientific analysis were selected from hundreds of fragments recovered during the last season of excavations in 2006.

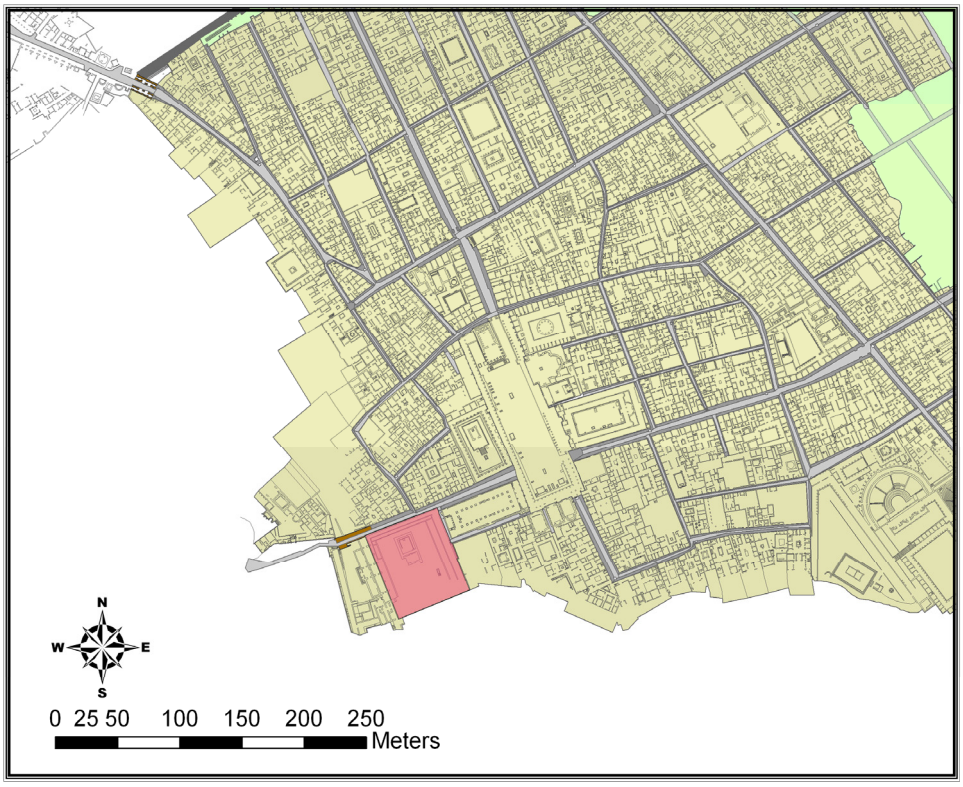

Fig. 1. Location of the Temple of Venus in Pompeii. Plan E. Poehler.

Archaeological background

The excavations have shown that shortly before or around the mid-first century BC a terrace of re-deposited building debris and soil was created in the south-west corner of the city on which a large temple complex for Venus was built. The material dumped here covered the remains of earlier structures, some of which appear to have been demolished for the new buildings. The tuff-built temple (Temple 1) of

[1] MAU 1900; MAIURI 1960.

the patron goddess of the Roman colony of Pompeii was erected on this terrace and it became the principal sanctuary of the Roman city.

Roman sanctuaries often were planted with trees to create a sacred grove, although archaeological evidence for them, even in Campania, is extremely rare[2]. No effort had ever been made to explore the subsoil at the site for traces of plantings, but the association of Venus with vegetation and fertility encouraged us to look for them. Our excavations uncovered a series of planting pits, some with intact terracotta planting pots still *in situ* in them, for trees and/or shrubs. After several seasons of fieldwork, it is clear that the sanctuary was carefully laid out as a sacred grove of trees and shrubs planted parallel to the three porticoes surrounding the temple (fig. 2). A preliminary report has been published recently and a more expansive discussion of our results is in preparation[3].

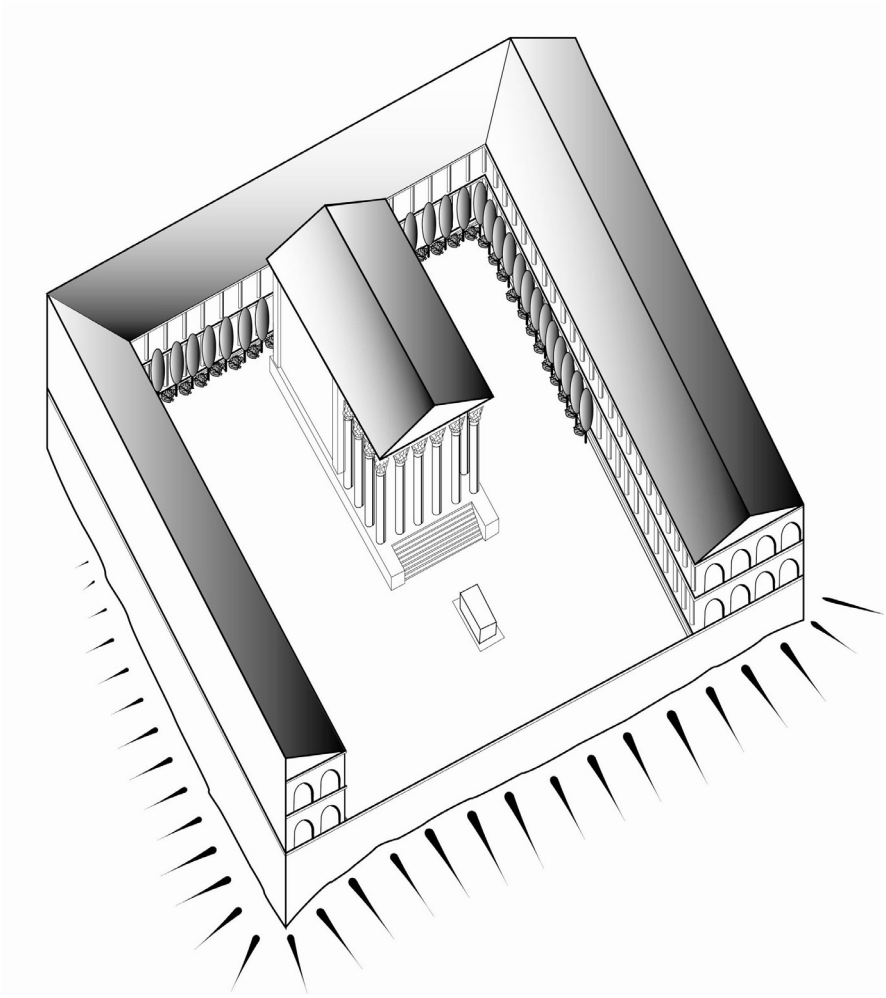

Fig. 2. Bird's-eye view of the reconstructed Temple of Venus and its sacred grove of trees planted in front of the porticoes in the first century BC (Drawing O. Jessop).

The archaeological evidence also indicates that the original temple and its porticoes were refurbished (Temple 2) in the early first century AD making generous use of marble for decorative elements, a material that was increasingly being employed for public and sacred buildings in Pompeii and elsewhere in the Augustan period. A study by L. Jacobelli and P. Pensabene of the surviving column capitals, bases and cornices from the excavations in 1900 offered stylistic corroboration of this date[4]. M. Wolf, in an architectural study of the sanctuary, more recently has suggested that the temple and its colonnades were rebuilt in marble and completed before AD 30 on exactly the same alignment and on the same scale as the earlier buildings (Temple 1) constructed of tuff[5]. Finally, in a third construction phase, the temple and porticoes were in the process of being rebuilt (Temple 3) after a devastating earthquake in AD 62 when the eruption of Vesuvius in AD 79 put an end to all work at the site. Not only white marble, but also various types of coloured limestone were used in the first century AD in decorating the temple and in erecting votive monuments.

The marble and limestone artefacts on which these earlier observations and dating criteria were based are the decorative architectural elements that still lie scattered randomly all over the site. It was not known, however, where exactly they were found originally in 1900 or to which structure or building phase they actually belonged (fig. 3). The value of the scientific analysis of marble and limestone excavated by the University of Sheffield lies in the fact that all the examined fragments come from contexts that were stratigraphically excavated and recorded. They were retrieved in contexts dating to the second phase (Temple 2) and the third phase (Temple 3), and they form the basis of the present report.

Samples and analytical methods

A representative sample (9 individuals) of the white marble and coloured limestone fragments recovered in the excavations were analysed by petrographical, mineralogical and geochemical methods in order to be characterized

[2] CARROLL 2003: 69-71.
[3] CARROLL 2008; CARROLL in preparation.
[4] JACOBELLI and PENSABENE 1995-1996.
[5] WOLF 2004.

Fig. 3. The courtyard of the Temple of Venus with scattered marble, limestone, tuff and basalt architectural elements during the excavations in 2006 (photo Carroll).

in terms of composition and provenance. A macroscopic description of the studied samples and the applied methods are summarized in Table 1. Details about the analytical procedures followed in this paper are reported in Appendix 1.

The conventional approach aimed at recognising white marbles usually combines several analytical techniques, such as optical microscopy on thin sections, X-ray diffraction, chemical analysis (XRF and/or NAA) as well as C and O stable isotope analysis[6]. A methodical plan analogous to the one above described was followed in this study. The identification of coloured stones, in most cases, is traditionally done only on the basis of careful examination of structural features recognizable on a macroscopic scale and the autoptic comparison with reference-lithotypes published in specialist literature[7]. In this analysis further diagnostic features, such as petrography and chemical composition, were also appraised and proved useful for the identification of the lithotypes.

Table 1. Short description of the analysed samples and methodology applied for their compositional characterization

SAMPLE	MACROSCOPIC DESCRIPTION	ANALYTICAL METHODS
2006.1	fine-grained white marble (architecture)	OM, XRD, XRF, MS
2006.2	fine-grained white marble (architecture)	OM, XRD, XRF, MS
522	fine-grained white marble (architecture)	OM, XRD, XRF, MS
523	very fine-grained white marble (architecture)	OM, XRD, XRF, MS
546	fine-grained white marble (architecture)	OM, XRD, XRF, MS
2006.3	monogenic calcareous breccia with white-pinkish angular elements and red-brown cement (column?)	OM, XRD, XRF
2006.4	yellow-pinkish microcrystalline limestone (veneer)	OM, XRD, XRF
2006.5	pale yellow microcrystalline limestone (veneer)	OM, XRD, XRF
2006.6	monogenic breccia with white elements and greenish cement (veneer)	OM, XRD, XRF

OM = Thin section optical microscopy; XRD = X-Ray Diffractometry; XRF = X-Ray Fluorescence; MS = Mass Spectrometry.

Results and discussion

The analysed samples were separated into two different series for a constructive discussion: white marbles and coloured limestones. Results concerning mineralogical composition (major and accessory phases) as well as textural features (grain size and morphology), respectively carried out by X-ray diffraction analysis (XRD) and optical microscopy on thin sections (OM), are summarized in Table 2.

[6] GORGONI *et al*. 2002; CAPEDRI *et al.* 2004a; CAPEDRI *et al*. 2004b; ATTANASIO *et al.* 2000; ATTANASIO *et al.* 2003; LAZZARINI *et al*. 2003; POLIKRETI 2007; ATTANASIO *et al.* 2008.
[7] GNOLI 1988; BORGHINI 2001; LAZZARINI 2004.

Table 2. Summary of principal mineralogical and textural characteristics of studied marbles derived by X-ray diffraction analysis (XRD) and observation of thin sections by the polarizing microscope (OM)

	Sample code	XRD results				OM results			
		Cal	Qtz	Dol	Ch	MGS (mm)	Texture	GBS	Accessory minerals
WHITE MARBLES	2006.1	+++	tr	-	-	1,0	I, He	L, S	Qtz, Ms
	2006.2	+++	-	-	-	1,0	I, He	L, S	Qtz, Ms
	522	+++	-	-	-	0,7	I, Ho	St, Cr, L	Qtz, Plg, Ms, Op, Ap
	523	+++	-	+	-	0,6	I, Ho	St, L	Qtz, Plg, Ms, Op, Ap
	546	+++	-	-	-	1,0	I, Ho	St, L	Qtz, Ms
LIMESTONES	2006.3	+++	+	-	-	-	I, He	-	Qtz, He
	2006.4	+++	tr	-	-	-	A, He	-	Qtz , Ru
	2006.5	+++	-	-	-	-	A, He	-	Qtz, Kfs
	2006.6	+++	+	-	+	-	I, He	-	Qtz, Ch, He, Op

+++ = Predominant, ++ = Major, + = Minor ; tr = trace; - = not detected. Qualifiers indicate relative abundances based on peak heights and do not necessarily reflect true relative proportions. MGS = maximum grain size; Texture: He, heteroblastic; Ho, homeoblastic; I, isotropic; A, anisotropic. GBS (grain boundary shape): St, straight; Cr, curved; D, dentate; L, lobate; S, sutured; - = not detected. Ru = rutile; Ch = chlorite; Qtz = quartz; Ms = muscovite; Kfs = K-feldspar; Plg = plagioclase; He = Hematite; Op = opaque oxides; Ap = apatite.

White marbles

Mineralogy and petrography

Calcite was always the predominant mineralogical phase detected by XRD, while traces or minor amounts of quartz and dolomite were detected only in two cases (samples 2006-1 and 523). In relation to boundaries of calcite grains some differences were appreciated: samples 522, 523 and 546 show homeoblastic texture and are made of equidimensional grains, while samples 2006.1 and 2006.2 are characterized by heteroblastic texture. Maximum grain size (MGS) of the individuals of calcite was used to make a comparison with other typologies of white marbles with various provenances (fig. 4). The geometric relationships between the recrystallized grains of calcium carbonate, depending on the evolution of the metamorphic event, were also appreciated under the polarizing microscope by means of GBS (grain boundary shape).

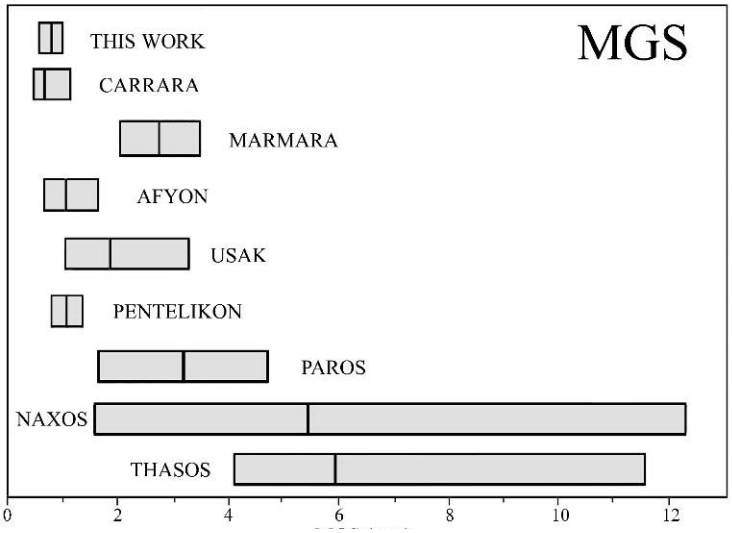

Fig. 4. Comparison between maximum grain size (MGS) of calcite crystals found in the samples studied in this work and values from literature concerning the most common white marbles used in Roman world (modified, after MOENS et al., 1988).

In particular, samples 522, 523, 546 show clear similarities and they may be classified as fine-grained white marbles characterized by homeoblastic-isotropic texture and intersection of grain boundaries with angle near 120° (triple-grain junctions). Calcite crystals show curved boundaries or else straight and lobate ones. There is no direct evidence of ductile deformations, other than primary polysynthetic twinning of calcite crystals (fig. 5a, 5b, 5c). Accessory minerals are represented by quartz, euhedral plagioclase, muscovite, apatite and opaque oxides. The

average grain size ranges from 0.25 mm (sample 523) to 0.4 mm (sample 546), while MGS achieves the value of 1.0 mm (sample 546).

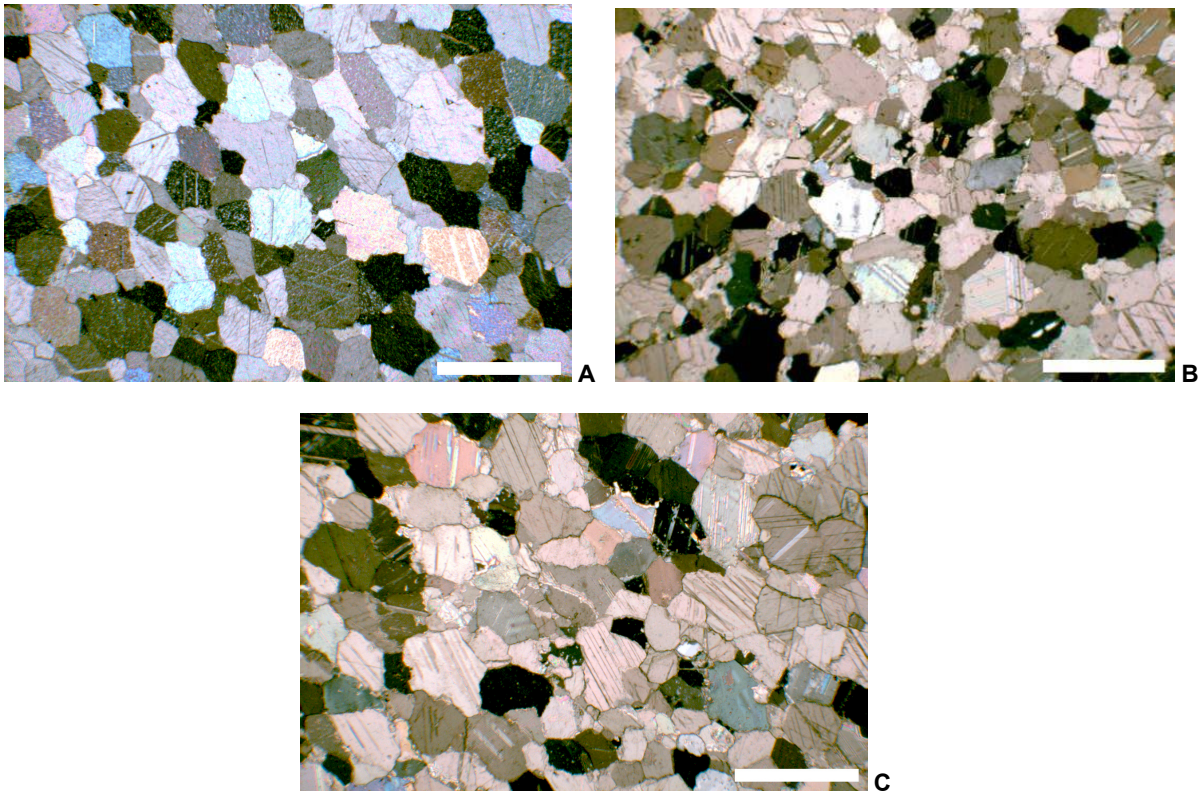

Fig. 5. Microphotographs showing textural features of samples 522 (A), 523 (B) and 546 (C) (crossed Nicol, scale bar = 0,5 mm).

Sample 2006.1 is a fine-grained heteroblastic marble showing signs of dynamic metamorphism. It is characterized by traces of cataclastic texture consisting of angular fragments of former carbonate grains (protoliths), commonly bent and strained, scattered into a matrix made of microcrystalline calcite. In the areas not affected by tectonic brecciation calcite grains show direct evidence of ductile deformation (lamellar twinning and ondulose extinction). This sample probably comes from an exploitation area very close to a fault line. The average grain size is 0.4 mm, while MGS achieves the value of 1.0 mm (fig. 6a). Sample 2006.2 can be described as a fine-grained heteroblastic calcite marble. It shows irregular crystal boundaries, from lobate to sutured, and in general a metamorphic grade lower than sample 2006.1 (fig. 6b). A higher frequency of accessory minerals is also evident. They consist of muscovite, quartz and rare plagioclase. Medium grain size is 0.4 mm, while MGS is 1.0 mm.

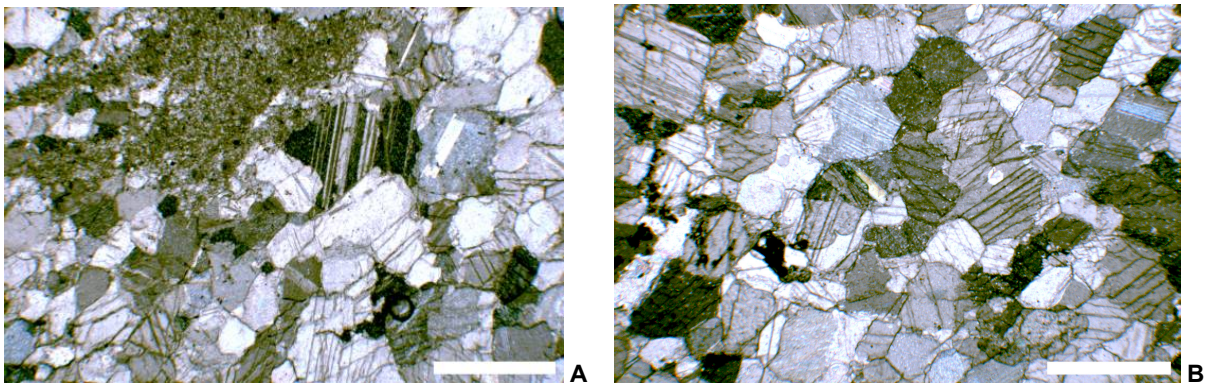

Fig. 6. Microphotographs of samples 2006.1 (A) and 2006.2 (B) (crossed Nicol, scale bar = 0,5 mm).

Table 3. Concentration of major, minor (% wt) and some trace elements (ppm) in white marble.

Sample		Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	TiO_2	Fe_2O_3	LOI	MnO	Cu	Zn	Sr
Detection Limit (ppm)		500	1100	900	1600	200	400	300	40	400	-	20	5	20	30
WHITE MARBLE	2006.1	LLD	1.01	0.19	0.67	LLD	0.06	53.94	0.02	0.10	43.53	20	11	LLD	153
	2006.2	LLD	1.67	0.87	0.48	LLD	0.07	53.43	0.02	0.19	43.40	80	14	LLD	166
	522	LLD	2.16	0.24	0.36	LLD	0.12	52.77	0.02	0.07	43.74	30	14	LLD	147
	523	LLD	2.05	0.27	0.44	LLD	0.08	52.71	0.03	0.08	43.53	32	9	LLD	150
	546	LLD	1.10	0.62	0.21	LLD	0.09	54.06	0.03	0.10	44.00	62	13	LLD	163
Mean		-	1.60	0.44	0.43	-	0.08	53.38	0.02	0.11	43.64	44	12	-	156
SD		-	0.53	0.30	0.17	-	0.02	0.63	0.01	0.05	0.24	25	2	-	9
Crisci *et al.*	Serie A	-	1.01	0.03	0.07	-	0.01	54.84	0.00	0.02	44.02	0	-	-	148
	Serie B	-	1.06	0.02	0.06	-	0.01	54.82	0.00	0.02	44.02	2	-	-	133
	Serie II	-	1.94	0.12	0.32	-	0.05	53.51	0.01	0.05	44.00	14	-	-	325
	Serie III	-	1.29	0.12	0.26	-	0.05	54.22	0.01	0.06	44.00	7	-	-	167
Herz *et al.*	Col.	0.05	3.26	0.24	0.26	-	0.03	54.26	-	0.04	42.66	27	-	7	178
	Mis.	0.04	2.25	0.17	0.45	-	0.02	50.92	-	0.02	43.53	22	-	6	149
	Tor.	0.37	2.79	0.34	0.55	-	0.08	51.69	-	0.17	43.46	43	-	20	160
	Ser.	0.04	2.95	0.13	0.14	-	0.02	52.26	-	0.03	43.25	39	-	7	161

LOI = loss on ignition; LLD = lower limit of detection; SD = standard deviation; - = not given; Col = Colonnata; Mis = Miseglia; Tor = Torano; Ser = Serravezza

C*hemistry and stable isotope analysis*

Major, minor and trace element concentrations of the selected samples of white marble are given in Table 3. Within the sample series, a reasonable compositional homogeneity for all the analysed elements can be appreciated, reflecting a limited range of variation.

Moving on to the stable isotope analysis, the studied samples demonstrated very similar $\delta^{13}C$ and $\delta^{18}O$ values, with a variation in the normalized $^{13}C/^{12}C$ and $^{18}O/^{16}O$ ratios ranging from +1.93 to + 2.11‰ and from -2.85 to -1.99‰ respectively (Table 4). As pointed out by Herz and Dean (1986), homogeneous isotopic signatures can be observed if the deposition and the subsequent diagenesis of the protolith occurred under uniform physico-chemical conditions, if isotopic equilibrium was attained and maintained during metamorphism and if the marble unit was homogeneous in bulk chemical composition and thickness. As first result, the values obtained demonstrate a notable similarity among the samples in terms of C and O stable isotopic composition.

Table 4. C and O stable isotopic composition of the analyzed samples

Sample code	$\delta^{13}C$ (‰)	$\delta^{18}O$ (‰)
2006-1	1.97 (0.01)	-2.3 (0.05)
2006-2	2.11 (0.01)	-2.85 (0.05)
523	1.93 (0.02)	-2.41 (0.04)
546	1.88 (0.02)	-2.19 (0.07)
522	2.03 (0.02)	-1.99 (0.04)

As standard references we used SRM IAEA CO1: $\delta^{13}C$ = 2.47 ‰ (0.01) and $\delta^{18}O$ = -2.42 ‰ (0.05). Standard deviations are shown in brackets.

Provenance

Mineralogical and petrographical features demonstrate the provenance of the samples 2006-1, 2006-2, 523, 546, 522 from the marble basin of Carrara[8]. In particular, samples 522, 523 and 546 might come from the same quarry because of a good fitting of textural characteristics (homeoblastic-isotropic). Concerning chemical patterns (Table 3), they are in an excellent agreement with several varieties of white marble cropping out in the district of the Apuan Alps which were previously studied[9]. Figure 7 shows that isotopic values of the analysed white marbles form a restricted cluster in the field pertaining to Carrara marbles.[10] This might also suggest a relative isotopic and genetic homogeneity of the correspondent exploitation area. A further comparison of $\delta^{13}C$ and $\delta^{18}O$ values found in this study with data obtained by Herz *et al.* 1986, which are specially focused on different sources in the Apuan Alps, corroborate this main provenance, although the attribution to any unambiguous quarry cannot be pointed out with sufficient reliability (fig. 8).

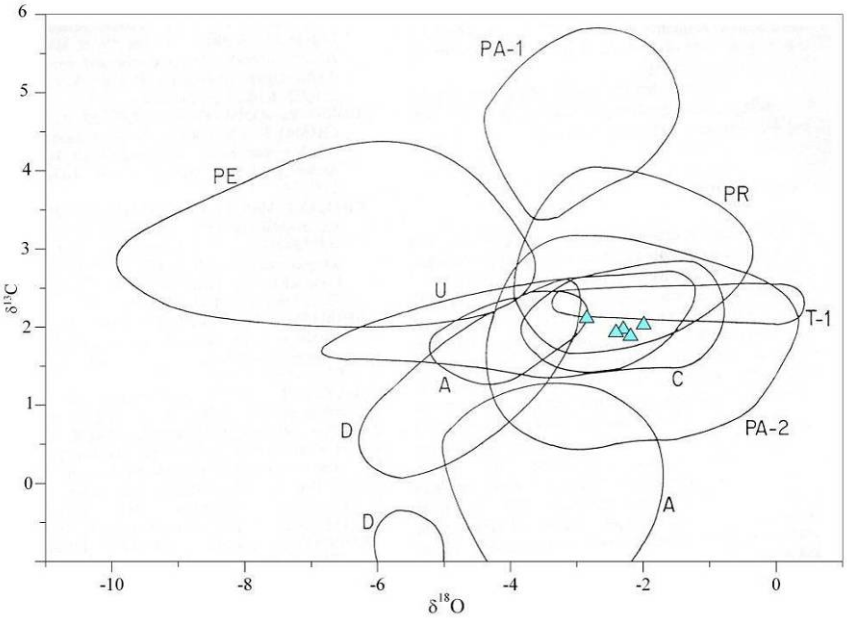

Fig. 7. ^{13}C and ^{18}O ratios of the samples of white marble objects of this study. Fields of the various historic quarries are reported according to Moens et al., 1992. A = Aphrodisias; C = Carrara; D = Dokimeion; N = Naxos; PA-1 = Paros Stefani; PA-2 = Paros Chorodaki; PE = Mount Pentelikon; PR = Proconnesos (= Marmara); T1, T2, T3 = Thasos and U = Usak.

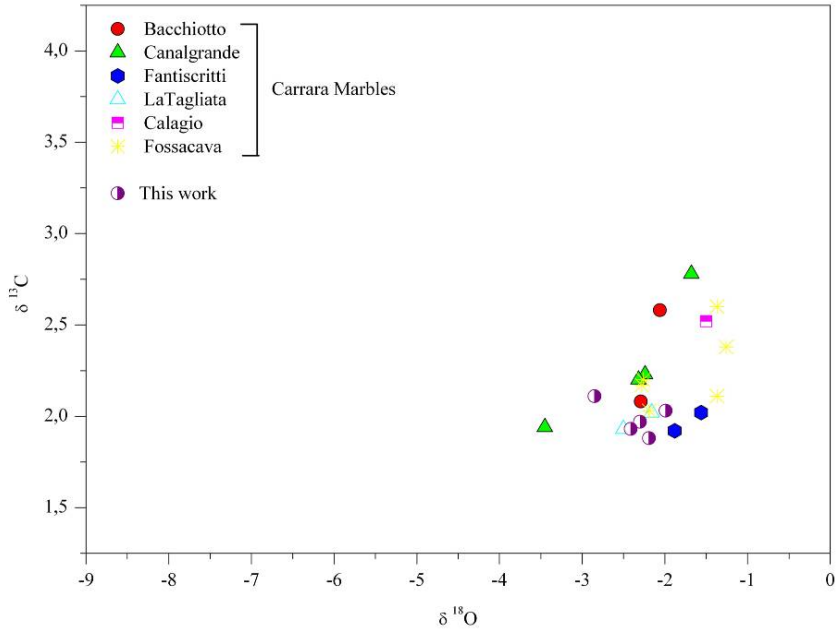

Fig. 8. $\delta^{13}C$ vs $\delta^{18}O$ plot where the studied samples are compared with Carrara white marbles from different quarries (after HERZ et al. 1986).

Coloured limestone

Mineralogy and petrography

By XRD calcite was detected to be the most abundant mineralogical phase. Minor amounts or traces of quartz were found in samples 2006.3, 2006.4 and 2006.6. The latter shows also traces of chlorite. Thin section microscopy allowed a more detailed classification of sample 2006.3 which macroscopically was already identified as a brecciated limestone. Angular breccia elements, independent of their colour, are composed by a micritic groundmass calcite affected by a restricted recrystallization process into coarse grained calcite. Stylolitic fractures can be observed in the micritic groundmass, sometimes also along the boundaries of the recrystallized areas. Reddish or fine-grained iron oxide is also evident (fig. 9a).

Samples 2006.4 and 2006.5 may be both classified as fine-grained limestones slightly metamorphosed, with incipient evidence of deformation. Their texture is characterized by irregular spots composed of aggregates of coarse crystals of calcite (size = 0.1-0.7 mm) scattered in a finer matrix with the same composition. Deformation is particularly evident in the polysynthetic twinning of coarser calcite grains. In some areas the presence of vague relicts of an originary bioclastic texture is suggested. Stylolites were discernible by the accumulation of iron oxides

[8] MOLLI *et al.* 2000.
[9] CRISCI *et al.* 1975; HERZ *et al.* 1986.
[10] MOENS *et al.* 1992.

which are also dispersed as ultrafine haematitic pigmentation in the fine-grained calcite matrix. Quartz (size range 0.1-0.2 mm) and rutile (rarely) were recognized as accessory minerals (fig. 9b and 9c).

Sample 2006.6 is a very fine grained limestone (from 0,02 to 0,04 mm) irregularly crossed by veins of coarser calcite crystals (up to 0.5 mm in size). It shows evidence of incipient recrystallization (fig. 9d). In the fine grained areas the originary texture with micritic intraclast may be still recognized. Sporadically it is possible to recognize relicts of echinoderm plates and aggregates of pseudopolygonal calcite that have replaced fossil shells during the diagenesis. Mineralization veins, irregularly distributed and composed of chlorite and iron oxides, are also frequent. Accessory minerals are represented by opaque oxides.

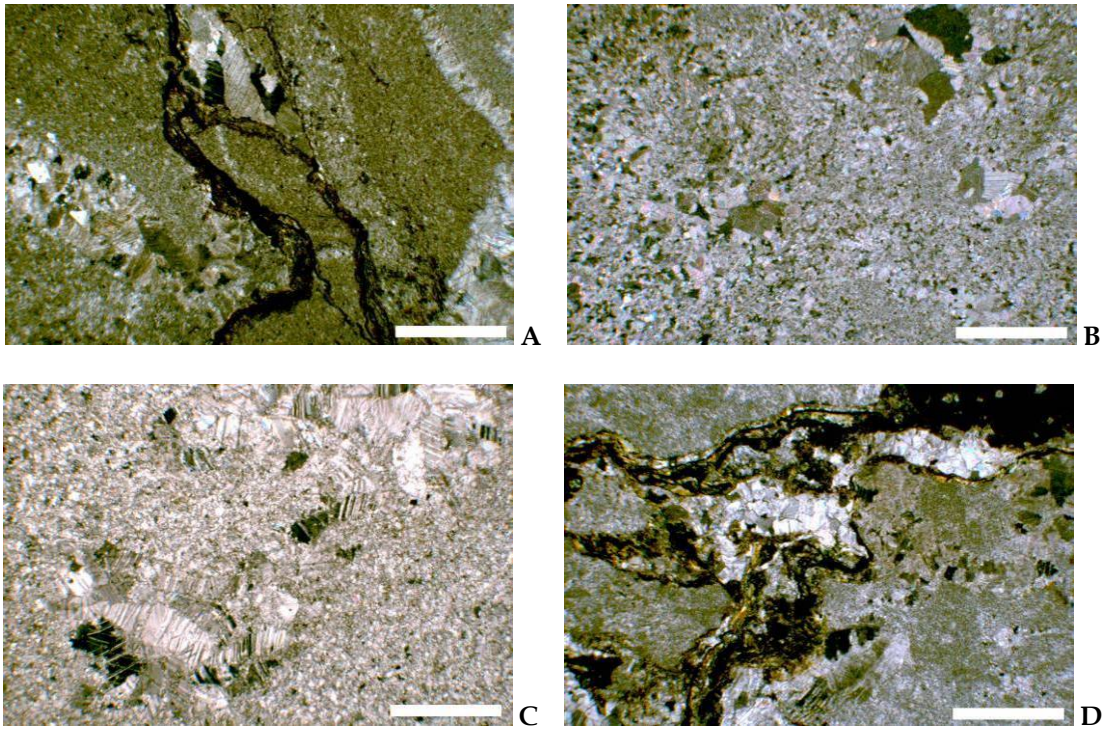

Fig. 9. Textural and compositional features of the studied coloured limestones seen by the polarizing microscope (crossed Nicol, scale bar = 0,5 mm). A: sample 2006.3; B: sample 2006.4; C: sample 2006.5; D: sample 2006.6.

Chemistry

Chemical compositions of coloured limestone obtained by XRF are summarized in Table 5. In all the samples, silicon oxide represents the most important of the secondary components, being clearly related to quartz and feldspars (accessory minerals). The aluminium oxide can be also associated with the presence of silicates. Sample 2006.6 shows a higher value of iron oxide (up to 6.27 wt %), probably due to the strong haematitic pigmentation of the stone, together with silicon and aluminum oxide (3.27 wt% and 8.05 wt%, respectively) because of the major incidences of accessory phases.

Provenance

The group of coloured limestone exhibits rather different macroscopic properties. Chemical and petrographic characteristics of sample 2006.3 match up very well to the ones reported in literature for the lithotype named Portasanta[11]. Sample 2006.6 may be classified on the basis of its macroscopic features as the variegated limestone well known as Africano[12]. The mineralogical and textural characteristics of both the pale yellow and pinkish-yellow samples (2006.4 and 2006.5) suggest a possible provenance from the Triassic limestone formations which are present in the area located in western Tuscany, to the south of the Apuan Alps, known as Montagnola Senese. In fact, the comparison of our observations and the already published petrographic descriptions concerning some lithotypes from the above mentioned area, such as Giallo Avorio, Giallo Venato and Rosato, confirm the existence of outstanding macroscopic and microscopic similarities with the lithotypes recovered at Pompeii[13].

[11] LAZZARINI 2007.
[12] BORGHINI 2001; LAZZARINI 2004.
[13] RODOLICO 1953; BRUNO *Et Al.* 1995; MUGNAINI *Et Al.* 2004.

Table 5. Concentration of major and minor elements (% wt) and some trace elements (ppm) of coloured limestone

Sample	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	TiO_2	Fe_2O_3	LOI	MnO	Cu	Zn	Sr
Detection Limit (ppm)	500	1100	900	1600	200	400	300	40	400	-	20	5	20	30
2006.3	LLD	0.64	1.56	3.64	LLD	0.27	51.45	0.03	0.44	41.33	0.23	20	15	249
2006.4	LLD	1.60	0.33	1.50	LLD	0.05	52.56	0.02	0.10	42.83	LLD	16	11	203
2006.5	LLD	0.69	0.51	0.32	LLD	0.18	54.51	0.02	0.27	43.08	LLD	8	5	164
2006.6	LLD	1.12	3.27	8.05	0.23	0.19	44.48	0.56	6.27	37.02	0.17	20	55	394
"Portasanta"*	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	TiO_2	Fe_2O_3	LOI	MnO	Cu	Zn	Sr
Min	0.02	0.08	0.14	0.56	0.01	0.03	-	0	0.07	-	13	0	3	117
Max	0.06	0.70	4.40	7.22	0.19	0.98	-	0.09	2.37	-	2245	6	33	965
Mean (n=24)	0.02	0.32	0.78	1.63	0.04	0.17	-	0.01	0.37	-	376	1	11	276

LOI = Loss on ignition.; LLD = Lower Limit of Detection; - = not given
*Chemical analysis after LAZZARINI, 2007.

Archaeological and historical considerations

White marbles are well documented in the first and second centuries AD in both public and private architecture (fig. 10). Carrara marble is very wide-spread in the Augustan period, with a marked drop in use in the second half of the first century AD[14]. Types of coloured limestone from a variety of Mediterranean locations also were widely distributed in the Roman period in the empire's capital and in provincial towns. According to R. Gnoli (1988), Portasanta was used at roughly the same time as Giallo Antico, Africano, Cipollino and Pavonazzetto. Together with these lithotypes, Portasanta is one of the coloured limestones most prevalent in Rome, being particularly evident in the second century in the Trajanic and Hadrianic periods. Africano is one of the first coloured limestones introduced into Rome as blocks and semi-finished columns. Its use (in Rome) increased from the Augustan period to reach a peak of popularity in the mid-second century in the Antonine period.

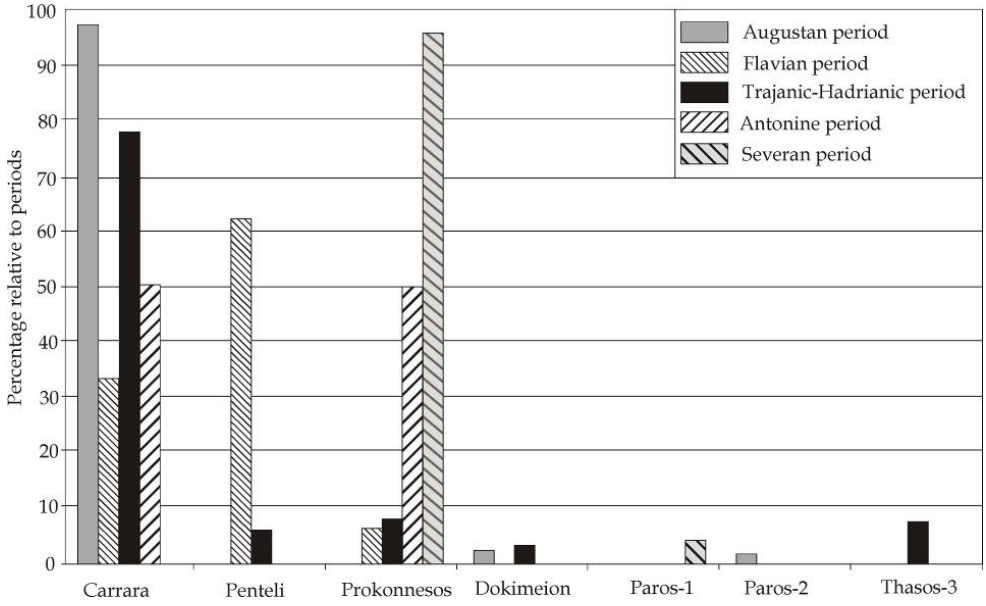

Fig. 10. Frequency diagram depicting the chronological distribution of the various marble varieties (after BRUNO et al. *2002).*

[14] ATTANASIO 2003: 165-168.

The employment and chronological distribution of white marbles and coloured limestone as building material outlined here in a general context are relevant to the site of Roman Pompeii. All the examined fragments recovered at the Temple of Venus come from contexts that were stratigraphically excavated and recorded, and they therefore allow us to recognise patterns of supply and use in building stone in the life of this major urban sanctuary. No marble or coloured stone was used in the construction of the first Roman temple in the middle of the first century BC. A noticeable change in the use of materials is evident in the early first century AD when the superstructure of the temple (Temple 2) and its surrounding colonnades were decorated with white marble. When this rebuild took place, the sacred grove of the earliest sanctuary was destroyed or intentionally abandoned. The builders then dumped a levelling layer of soil on the remains of the earlier grove, this layer containing broken wall plaster, tile and pottery, as well as numerous off-cuts and chips of white marble from work on site on the temple's decoration (fig. 11).

Fig. 11. Fragments and off-cuts of white Carrara marble left over from stone working on site in the early first century AD (photo Carroll).

Based on the grain size and stable isotope signatures, Carrara seemed to be the likely origin for the marble in samples 522, 523, 546, 2006.1 and 2006.2. In fact, combining the petrographic and isotopic data, Carrara marble is sufficiently well separated from all the similar important fine-grained marbles of antiquity. These marble fragments, then, confirm beyond any doubt that Carrara marble was being worked on the site for the architectural decoration of Temple 2 in the early first century A.D. After the earthquake in AD 62, the builders dug a broad and deep foundation trench around the ruined temple of Venus and they were in the process of erecting courses of large basalt blocks against the walls of the original building for the new, expanded structure (Temple 3). New porticoes were also in the process of being erected. Whether the financial resources needed for this last rebuild were supplied entirely through local private patronage or whether the civic treasury contributed or even imperial subsidies were granted is uncertain[15]. Rare and valuable evidence for the actual work-in-progress of stonemasons in this final phase between AD 62 and 79 is the debris that was left lying where it fell. Jacobelli and Pensabene recognised tool marks and cuttings on Carrara marble friezes and cornices of the Augustan to Julio-Claudian temple (Temple 2) and suggested that they were being reworked for this latest rebuild.[16] Until now there was no tangible archaeological evidence for this, but the significant amounts of white Carrara marble off-cuts we found in this debris suggest that either the older temple decoration (Temple 2) was being reworked or that new elements in Carrara marble were being brought in to complete the structures after AD 62.

Fig. 12. Veneer of various types of coloured limestone from statue bases and votive monuments (photo Carroll).

In the late Augustan and early Julio-Claudian phase of the sanctuary (Temple 2), votive monuments and statues were set up in the courtyard. Of these only the foundations or bases survive, but in some cases thin plaques of coloured

Fig. 13. Fragments and off-cuts of Portasanta limestone (pinkish fragments) from on-site building work between AD 62 and 79 (photo Carroll).

[15] On possible sources of funding in Pompeii after the earthquake see DOBBINS 1994: 693; DE CARO 1998: 242-243; WOLF 2004: 198.
[16] JACOBELLI and PENSABENE 1995-1996.

stone used as veneer still adhered to the bases (fig. 12). These could be identified as Breccia Dorata (samples 2006.4 and 2006.5) from western Tuscany and Africano (sample 2006.6) from Teos in the eastern Mediterranean.

Finally, in the last building campaign after AD 62, Portasanta limestone (sample 2006.3) from the island of Chios was being imported and worked on site, as chips and off-cuts in various contexts related to this last phase of work indicate (fig. 13). Its use at the Temple of Venus is apparent long before this type of coloured limestone achieved maximum popularity in Rome. It should be pointed out that there is a shaft of a Portasanta column for a votive offering with an unfinished base still on site, as well as a rough, unfinished column drum of the same material (fig. 14a-b), and it can be reasonably assumed that the stone-working debris stems from these or similar monuments.
The analysis of imported marbles and coloured limestone, from securely dated and archaeologically excavated contexts at the sanctuary of Venus, contributes significantly to an understanding of the architectural development of the complex and sheds light on the relationship between the builders of this principal temple of Pompeii's tutelary goddess and the suppliers of costly stone from distant quarries.


A


B

Fig. 14. Unfinished votive column of Portasanta limestone (A) on an unfinished column capital of probable Proconnesian marble, and an unfinished column drum (B) of Portasanta limestone (photo Carroll).

Appendix 1

Petrographic observations were carried out on thin sections of the studied samples by using a polarizing microscope Leica DM LSP.

Mineralogical composition was obtained by X-ray diffractometry (XRD) in the angular range 2-60° 2θ by a Philips X'Pert-Pro diffractometer, using CuKα radiation (graphite monochromator) at 40 KV and 40 mA.

Major, minor and trace elements analysis was carried out by an X-ray fluorescence spectrometer (Rigaku, ZSX Primus) using a Rh X-ray Tube at 4.0 KW). Several standard reference materials (SRM) were used for calibration lines (Standard No. 400, 401, 402, 403). The following element standard deviations were calculated by repeated measurements on the above mentioned SRM: SiO_2 0.3%, TiO_2 1.5%, Al_2O_3 0.3%, Fe_2O_3 0.7%, MnO 2.7%, CaO 11.0%, Na_2O 5.2%, K_2O 0.5%, P_2O_5 2.1%, Cu 1,1%, Zn 0,1%, Sr 0,5%.

Isotopic determinations on carbon and oxygen were performed by the Isotope Laboratory of the Institute of Geology and Mineralogy, University of Erlangen-Nürnberg, under the direction of Dr. Michael Joachimski. Rock sample powders were reacted with 100% phosphoric acid, according to Wachter and Hayes (1985), using a Kiel III carbonate preparation line connected to a Thermo-Finnigan 252 Mass Spectrometer. All values are reported in per mil units (‰). The oxygen and carbon isotope ratios are referred to the *Pee Dee Belemnite* standard or PDB (from the Cretaceous Pee Dee Formation, South Carolina) by assigning a $\delta^{13}C$ value of +1.95‰ and a $\delta^{18}O$ value of -2.20‰ to NBS19 and expressed as:

$$\delta^{18}O\ (‰) = 103[(^{18}O/^{16}O)_{sample} - (^{18}O/^{16}O)_{VPDB}]/(^{18}O/^{16}O)_{VPDB}$$
$$\delta^{13}C\ (‰) = 103[(^{13}C/^{12}C)_{sample} - (^{13}C/^{12}C)_{VPDB}]/(^{13}C/^{12}C)_{VPDB}$$

BIBLIOGRAPHY

ATTANASIO D., 2003, *Ancient White Marbles. Analysis and Identification by Paramagnetic Resonance Spectroscopy*, Rome.

ATTANASIO D., ARMIENTO G., BRILLI M., EMANUELE M.C., PLATANIA, R. and TURI B., 2000, "Multi-method marble provenance determinations: the Carrara marbles as a case study for the combined use of isotopic, electron spin resonance and petrographic data", in *Archaeometry* 42, 2: 257-272.

ATTANASIO D., DE MARINIS G., PALLECCHI P., PLATANIA R. and ROCCHI P., 2003, "An EPR and isotopic study of the marbles of the Trajan's Arch at Ancona: an example of alleged Hymettian provenance", in *Archaeometry* 45, 4: 553-568.

ATTANASIO D., BRILLI M. and TURI B., 2008, "The properties and identification of marble from Proconnesos (Marmara island, Turkey): a new database including isotopic, EPR and petrographic data", in *Archaeometry* 50, 5: 747-774.

BORGHINI G. (ed), 2001, *Marmi antichi*, Rome.

BRUNO M., LAZZARINI L., 1999, "Discovery of the Sienese provenance of Breccia Dorata, and Breccia Gialla Fibrosa, and the origin of Breccia Rossa Appenninica", in M. SCHVOERER (ed), *Asmosia IV. Archéomatériaux – Marbres et Autres Roches. Actes de la IV^{ème} Conférence Internationale de l'Association pour l'Étude des Marbres et Autres Roches Utilisés dans le Passé, Bordeaux, France, 9-13 octobre 1995*, Bordeaux: 77-82.

BRUNO M., CONTI L., PENSABENE P. and TURI B., 2002, "Pompeii after the AD 62 earthquake: historical, isotopic, and petrographic studies of quarry blocks in the Temple of Venus", in J.J. HERRMANN, N. HERZ and R. NEWMAN (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: 282-288.

BRUNO M., CANCELLIERE S., GORGONI C., LAZZARINI, L., PALLANTE P., and PENSABENE, P., 2002, "Provenance and distribution of white marbles in temples and public buildings of Imperial Rome", in J.J. HERMMANN, N. HERZ, R. NEWMAN (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: 289-300.

CAPEDRI S., VENTURELLI, G. and PHOTIADES A., 2004a, "Accessory minerals and $\delta^{18}O$ and $\delta^{13}C$ of marbles from the Mediterranean area", in *Journal of Cultural Heritage* 5: 27-47.

CAPEDRI S. and VENTURELLI G., 2004b, "Accessory minerals as tracers in the provenancing of archaeological marbles, used in combination with isotopic and petrographic data", in *Archaeometry* 46, 4: 517-536.

CARROLL M., 2003, *Earthly Paradises. Ancient Gardens in History and Archaeology*, London.

CARROLL M., 2008, "Nemus et Templum. Exploring the sacred grove at the Temple of Venus in Pompeii", in P.G. GUZZO and M.P. GUIDOBALDI (a cura di), *Nuove ricerche archeologiche nell'area vesuviana (scavi 2003-2006).* Atti del convegno Roma 1-3 febbraio 2007, Roma: 37-45.

CARROLL M., in preparation, "Politics, cult and identity in Roman Pompeii: Exploring the sanctuary of Venus and its sacred grove".

CRISCI M.G., LEONI L. and SBRANA A., 1975, "La formazione dei marmi delle Alpi Apuane (Toscana) Studio petrografico, mineralogico e chimico", in *Atti Società Toscana Scienze Naturali, Memorie,* Serie A, 82: 199-236.

DE CARO S. 1998, "La lucerna d'oro di Pompei: Un dono di Nerone a Venere Pompeiana", in *I Culti della Campania Antica. Atti del convegno internazionale di studi in ricordo di Nazarena Valenza Mele, Napoli 1995*, Roma: 239-244.

DOBBINS J. 1994, "Problems of Chronology, Decoration, and Urban Design in the Forum at Pompeii", in *American Journal of Archaeology* 98: 629-694.

GNOLI R., 1988*, Marmora Romana*. Rome (2nd Edition).

GORGONI C., LAZZARINI L., PALLANTE P. and TURI B., 2002, "An updated and detailed mineropetrographic and C–O stable isotopic reference database for the main Mediterranean marbles used in antiquity", in J.J. HERRMANN, N. HERZ and R. NEWMAN (eds), *Interdisciplinary studies on ancient stones*. London: 115-131.

HERZ N. and DEAN N.E., 1986, "Stable isotopes and archaeological geology: the Carrara marble, northern Italy", in *Applied Geochemistry* 1: 139-151.

JACOBELLI L. and PENSABENE P., 1995-1996, "La decorazione architettonica del Tempio di Venere a Pompei: contributo allo studio e alla ricostruzione del santuario", in *Rivista di Studi Pompeiani* 7: 45-76.

LAZZARINI L. and ANTONELLI F., 2003, "Petrographic and isotopic characterization of the marble of the island of Tinos (Greece)", in *Archaeometry* 45, 4: 541-552.

LAZZARINI L., 2004, *Pietre e Marmi antichi*, Padua.

LAZZARINI L., 2007, *Poikiloi lithoi, versicvlores macvlae: i marmi colorati della Grecia antica. Storia, uso, diffusione, cave, geologia, caratterizzazione scientifica, archeometria, deterioramento*, «Marmora» - Supplementi, Pisa-Roma.

MAIURI A., 1960, "Sterro dei cumuli e isolamento della cinta murale. Contributo all'urbanistica della città dissepolta", in *Bolletino d'Arte* 45: 166-179.

MAU A., 1990, "Der Tempel der Venus Pompeiana", in *Jahrbuch des Deutschen Archäologischen Insituts* 15: 270-308.

MOENS L., ROOS P., DE RUDDER J., DE PAEPE P., VAN HENDE J. AND WAELKENS M., 1988, "A multi-method approach to the identification of white marbles used in antique artefacts", in N. HERZ and M. WAELKENS (eds), *Classical marble: geochemistry, technology, trade*, Nato ASI series E, 153, Dordrecht: 243-250.

MOENS L., DE PAEPE P. and WAELKENS, M., 1992, "Multidisciplinary research and cooperation: keys to a successful provenance determination of white marbles", in M. WAELKENS, N. HERZ and L. MOENS (eds), *Ancient stones: Quarrying, Trade and Provenance*, Acta Archaeologica Lovaniensia, Monographiae 4, Leuven: 247-252.

MOLLI G., CONTI P., GIORGETTI G., MECCHERI M. and OESTERLING N., 2000, "Microfabric study on the deformational and thermal history of the Alpi Apuane marbles (Carrara marbles), Italy", in *Journal of Structural Geology* 1809-1825.

MUGNAINI S., CONTI P., GIAMELLO M., GUASPARRI G., SABATINI G. and SCALA A., 2004, "The Montagnola Senese marbles (Siena, Italy). Study of the microfabric and physical decay processes", in *Proceedings of the 10th International Congress on Deterioration and Conservation of Stone, 27 June - 2 July 2004*, Stockholm: 147-154. In Kwiatkowski, D. & Löfvendahl, R. (eds).

RODOLICO F., 1953, *Le Pietre delle città d'Italia*, Florence.

POLIKRETI K., 2007, "Detection of ancient marble forgery: techniques and limitations", in *Archaeometry* 49, 4: 603–619.

WOLF M., 2004, "Tempel und Macht in Pompeji", in E.L. SCHWANDNER and K. RHEIDT (eds.), *Architektur der Macht – Macht der Architektur*, Berlin: 190-199.

Acknowledgements

This small but important part of the project at the Temple of Venus would not have been possible without the permission granted by Pietro Giovanni Guzzo and Antonio D'Ambrosio to conduct our excavations in the sanctuary. We are grateful for their support. A generous grant awarded by the British Academy not only made the last season of fieldwork possible, but also the post-excavation analysis of the finds, and we are especially indebted to the Academy. We also thank our home institutions, the University of Sheffield and the Università di Palermo for their support of our research. The kind provision of the plan in Fig. 1 by Eric E. Poehler is gratefully acknowledged.

Maureen Carroll
Department of Archaeology, University of Sheffield
p.m.carroll@sheffield.ac.uk

Giuseppe Montana
Dipartimento di Chimica e Fisica della Terra ed Applicazioni alle Georisorse e ai Rischi Naturali (C.F.T.A), University of Palermo,
gmontana@unipa.it

Luciana Randazzo
Dipartimento di Chimica e Fisica della Terra ed Applicazioni alle Georisorse e ai Rischi Naturali (C.F.T.A), University of Palermo,
lrandaz@unict.it

Renato Giarrusso
Centro per la Protezione Ambientale e l'Analisi dei Materiali (CEPA s.r.l.), Palermo
renatogiarrusso@alice.it