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The Triassic marble from the Punta Bianca promontory (La Spezia, Italy). Did Roman quarrying of "Lunensis marble" begin here?

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ABSTRACT. — A marble body belonging to the Triassic low-grade metamorphic sequence of the «Punta Bianca Unit» outcrops on the coastal cliff of the Punta Bianca promontory (La Spezia, Liguria, Italy). The macroscopic features of this marble are described and its chemical, mineralogical and physical data presented, as resulting from measurements on 25 samples. Punta Bianca marble is easily distinguished from the better-known Jurassic Carrara marble on the basis of the fine grain size of the former (70 μm), the presence of muscovite flakes and, especially, of winding ankerite veins which take on a characteristic rust colour when altered. A number of architectural elements made of Punta Bianca marble and dating from the first century B.C. to the second century are found at the archaeological site of Luni, about 4 km north-east of Punta Bianca. The possibility that quarrying of Punta Bianca marble began before that of Carrara marble is considered.

RIASSUNTO. — Sulla falesia del promontorio di Punta Bianca (La Spezia) affiora una lente di marmo appartenente alla sequenza Triassica, di basso grado metamorfico, della «Unità di Punta Bianca». Si riportano le caratteristiche macroscopiche ed i dati chimici, mineralogici e fisici misurati su 25 campioni prelevati sulla falesia. La grana minuta (70 μm), la costante presenza di muscovite nella massa, la presenza di vene contorte di ankerite che assumono color ruggine per alterazione, permettono di distinguere facilmente questo marmo da quello ben più noto dei vicini giacimenti giurassici di Carrara. Nella zona archeologica di Luni (La Spezia), circa 4 km a nord-est di Punta Bianca e una volta in riva al mare, sono stati osservati numerosi elementi architettonici in marmo della Punta Bianca, datati fra l'inizio del primo secolo prima di Cristo ed il secondo dopo Cristo. Si indica la possibilità, da verificare, che l'estrazione del marmo di Punta Bianca, in epoca romana, sia iniziata prima di quella dei marmi del bacino di Carrara.

KEY WORDS: *Lunensis marble, Punta Bianca Promontory, Roman Age quarrying*

INTRODUCTION

The many marble varieties from the Jurassic layers outcropping in the Apuan Alps (Northern Tuscany) are renowned, the world over, under the generic name of «Carrara marble». Three main quarrying sites have long been established in the Carrara area, located in the Colonnata, Fantiscritti and Lorano valleys.

Although the exact period and sites in which these marbles were first quarried are unknown, it is now certain that quarrying began well over 2000 years ago in the vicinity of the ancient Roman colony, Luna, after the Roman conquest of the Apuan territories in 180 B.C.

The Luna settlement (now the Luni archaeological site; fig. 1) was established in 177 B.C. near the seacoast about 5 km west of

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the present-day city of Carrara. Because of its strategic position as a seaport, Luna had access to a far-flung market for locally excavated marble, and in time became famous throughout the Mediterranean basin. Classical literature always refers to Carrara marble as «Lunensis marble», because it was marketed and shipped from Luna. Today, this term is used only historically to refer to marble quarried during Roman times in the Carrara area; since the Middle Ages, this marble has been known as Carrara marble.

There are in fact two different marble formations outcropping in the area near Luna:

– Triassic «Punta Bianca marble» (PBM), outcropping on the coastal cliff of the Punta Bianca promontory on the eastern side of the Gulf of La Spezia (Liguria), near the mouth of the Magra River and about 4 km south-west of Luna;

– Jurassic Carrara marble.

The aims of this paper are to present chemical, mineralogical and physical data on PBM, to furnish macroscopic criteria to distinguish PBM from Jurassic Carrara marble, and to discuss problems related to its use in ancient times.

GEOLOGY

The Punta Bianca marble (PBM) (Fig. 1) is a meta-limestone, bearing Diplopores (Elter and Federici, 1964; Federici, 1965) and Gasteropods (Federici, 1966). It belongs to the Triassic metamorphic sequence of the «Punta Bianca Unit» (Storti, 1995). Martini *et al.* (1986) provide detailed stratigraphic and sedimentological data, and Franceschelli *et al.* (1986) give petrographic data. A wedge-shaped marble body (Fig. 2) outcrops in the coastal cliff of the Punta Bianca promontory, starting at sea level and extending within the mountain. Its maximum thickness is about 20 metres and its lateral extension about 200 metres. It lies over a layer of shale and is bounded upwards by a pink breccia layer.

Macroscopically, PBM is fine-grained, dull, and pure white to ivory-white in colour. Small muscovite flakes are obvious to the naked eye by their visible sparkle. Numerous irregularly winding white veins, varying in thickness from about 1 mm to 10 cm, are a characteristic feature of PBM. They are made up of large carbonate crystals, rust-coloured on their altered surfaces. A number of thinner straight veins also occur and are made up of spathic calcite, which maintains its white colour on the altered surfaces as well.

The exposed marble surfaces show loss of cohesion, revealed by superficial roughness and increased porosity. This weathering, described as «*marmo cotto*» («cooked marble»; Franzini, 1995), is limited to an irregular external cover only a few decimetres thick.

SAMPLING AND STUDY METHODS

Nineteen marble and 6 vein samples were collected along a 25 m-long profile extending throughout the thickness of the marble body outcropping at Punta Bianca. Three samples were collected from its weathered external layer.

Chemical analyses were performed by X-ray fluorescence (XRF) (Franzini *et al.*, 1975); the detection limit for Na_2O is 0.02 wt.%. Loss on ignition (LOI) was determined at 950°C on powders dried at 105°C. Qualitative mineralogical compositions and petrographic features were derived from X-ray Powder Diffraction (XRPD) and optical microscope investigation of thin sections.

Six white marble samples (three weathered, three unweathered) were then selected for measurement of physical properties. Bulk densities (γ_d) and total immersion water imbibition coefficients (IC) were measured on cylinders 3 cm in diameter and 5 cm high (NORMAL 7/81, 1981).

Normative compositions were obtained computing first orthoclase and albite from K_2O

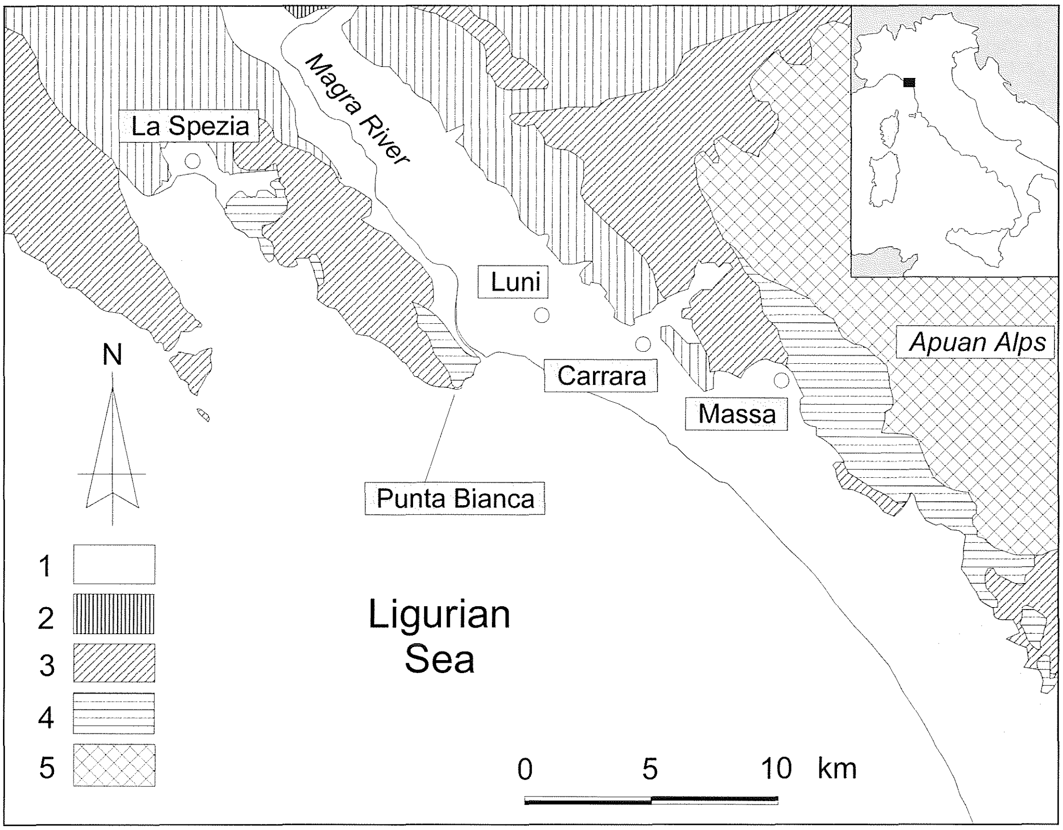

Fig. 1 – Structural setting of Northern Apennines between Massa and La Spezia (redrawn and modified from Martini *et al.*, 1986). 1= post-Alpine sediments; 2) Ligurian Nappe s.l.; 3) Tuscan Nappe s.l.; 4) Massa Unit s.l.; 5) Apuan (Carrara) Unit.

and Na_2O. The remaining Al_2O_3 was combined, to exhaustion, first with orthoclase to obtain muscovite, then with albite to obtain paragonite, and lastly with silica to obtain pyrophyllite. The remaining silica was computed as quartz. CaO and MgO were computed as calcite and magnesite, respectively. Fe_2O_3, recomputed to FeO, yielded siderite. At this computing step, the remaining LOI was negative for all samples. Hence, some siderite was converted to hematite until the remaining LOI was zero. Lastly, magnesite and siderite were combined with calcite to obtain ankerite, and the Fe/(Fe + Mg) mole ratio in ankerite was calculated.

Results and discussion of data

Chemical data

Table 1 lists average values and variability ranges of chemical and normative compositions computed separately for the 19 marble and 6 vein samples. For all 25 samples, major components are calcium oxide and LOI.

Two groups containing strongly correlated elements may be singled out (Table 2). One group includes LOI and CaO; the other includes Al_2O_3, SiO_2, K_2O and TiO_2. A strong negative correlation exists between the components of groups 1 and 2. MgO and Fe_2O_3

Fig. 2 – Photograph of wedge-shaped marble body outcropping from coastal cliff of Punta Bianca promontory.

show a weak positive correlation (0.5< r <0.8) with group 2 constituents. P_2O_5 and MnO show no correlation either with each other or with the other components. Expressing the data in moles, and assuming LOI to be entirely represented by CO_2, a very strong correlation (r = 0.998) is observed between CO_2 and the sum of MgO + CaO + Fe_2O_3 (second row in Table 2). Na_2O was present in measurable amounts (0.04 %) in only one sample.

The Al/Alk molar ratio between alumina (Al) and total alkalis (Alk) yielded an average value of 4.1 and ranged from 3 to 5.2 in 18 out of the 19 samples. The only sample having a lower value (1.84) is the same one containing a little Na_2O. Considering that the samples were collected on the cliff of the promontory, it is possible that this sodium content is due to contamination by seawater. Disregarding the Na_2O content, this sample yielded an Al/Alk ratio of 4.07.

The six vein analyses revealed similar features, although with much greater variability, samples being richer in MgO, MnO and Fe_2O_3 and poorer in CaO. The linear correlation coefficient between MnO and Fe_2O_3 was high (r = 0.98) and the Al/Alk ratio low in three out of the six samples.

Mineralogy and petrography data

As revealed by optical microscopy and XRPD on total samples, the mineralogical composition of PBM is dominated by calcite, with very small amounts of muscovite and dolomite-type carbonates. Quartz, chlorite, iron oxides and hydroxides were sometimes observed. XRPD revealed trace amounts of

TABLE 1

Chemical and normative compositions of Punta Bianca marbles and veins.

	Marble (19)			Veins (6)		
	Average	Min.	Max.	Average	Min.	Max.
LOI	42.77	40.74	43.77	40.22	35.86	44.26
Na_2O	<0.02	<0.02	0.04	0.10	<0.02	0.19
MgO	0.25	0.14	0.45	6.53	1.27	13.78
Al_2O_3	1.03	0.16	3.05	1.91	0.59	7.31
SiO_2	1.53	0.30	3.94	2.92	1.08	10.45
P_2O_5	0.02	<0.01	0.15	0.01	<0.01	0.03
K_2O	0.22	0.05	0.61	0.46	0.12	1.88
CaO	53.84	50.75	55.45	37.42	31.34	45.39
TiO_2	0.03	0.01	0.09	0.06	0.02	0.24
MnO	0.07	0.04	0.10	0.71	0.39	1.18
Fe_2O_3	0.24	0.07	0.67	9.66	4.10	17.08
Total	100.00			100.00		
Al/Alk	4.10	1.84	5.19	3.03	1.33	5.54
Muscovite	1.87	0.39	5.16	3.71	0.58	15.90
Pyrophyllite	0.31	0.12	1.07	0.22	0.00	0.57
Quartz	0.67	0.05	2.25	0.67	0.00	2.50
Calcite	95.24	89.23	98.60	41.20	24.84	68.26
Ankerite	1.78	0.82	3.12	50.21	26.65	71.45
Hematite	0.00	0.00	0.00	2.14	1.03	3.65
Others*	0.02	0.00	0.48	1.08	0.00	3.75
Sum of minerals	99.89	99.77	99.95	99.23	98.90	99.56
Fe/(Mg+Fe) **	29.31	19.13	58.54	43.40	10.24	82.15

* orthoclase, albite, paragonite; ** mole %.
(n) number of samples; Fe_2O_3 = total iron expressed as Fe_2O_3.

pyrophyllite and paragonite in two samples. The normative compositions (Table 1) confirm these observations. On average, the marble samples are made up of 97% carbonate minerals (92-99.5%) and 3% silicates (0.5-8%). Seventeen out of the 19 samples contain small quantities (<1%) of normative pyrophyllite, fitting their high Al/Alk ratios. The great variability of computed ankerite compositions (Fe/(Fe+Mg) from 19 to 59 mole%) is probably not a true value, and may be due to small errors in LOI measurements or to the presence of unaccounted dolomite.

The PBM have a dishomogeneous granoblastic polygonal texture, with straight to slightly curved grain boundaries. Grain size is about 70 μm on average and ranges from 40 μm to 250 μm.

The mineralogy of the vein samples differs substantially from that of the marbles. They exhibit much broader variability ranges, greater amounts of ankerite and silicate minerals, and lesser pyrophyllite which, moreover, is present in only three out of the six samples. The veins generally have a xenoblastic texture, with a grain size averaging about 200 μm (range: 120-

TABLE 2

Best-fit equations and linear correlation coefficients.

	r	ε	n
$CaO = 1.5303 \cdot LOI - 11.51$	0.993	0.2 %	19
$MgO + CaO + FeO = 1.053 \cdot (LOI/44) - 0.05$	0.998	0.07%	19
$SiO_2 = 0.815 \cdot Al_2O_3 + 0.11$	0.993	7%	17
$K_2O = 0.201 \cdot Al_2O_3 + 0.014$	0.987	7%	19
$TiO_2 = 0.0319 \cdot Al_2O_3 + 0.0014$	0.938	17%	19

r = linear correlation coefficient; n = number of samples; ε = average absolute percentage difference between observed and computed data.

360 μm). Ankerite crystals have curved-embayed boundaries.

Physical data

The three unweathered samples furnished the following average results: $\gamma_d = 2.716$ g/cm³ and IC = 0.12% by weight; the three weathered ones yielded: $\gamma_d = 2.694$ g/cm³ and IC = 0.44% by weight. Assuming a saturation index of 100%, absolute densities computed from the measured data are 2.725 g/cm³ and 2.726 g/cm³, respectively, for unweathered and weathered samples.

The IC values measured on unweathered samples are comparable to high-quality marble from the Carrara area and guarantee good resistance to weathering by both soluble salts and temperature variations (Franzini, 1995).

USES AND DEGRADATION

Visual examination of marble pieces at the Luni Museum and Archaeological Site reveals that PBM was employed during Roman times to fashion structural components for buildings. Attribution of the stone to the PBM outcrop was based on the presence of the winding, rust-coloured veins. The main structural elements found are:

– some capitals belonging to the second stage of construction of «Capitolium», dated to the early first century B.C.;

– some steps of the Great Temple at the northern corner of the site, probably dating back to the turn of the first century (excavations are ongoing);

– a number of steps in the amphitheatre, dated to the second century.

Apart from these large pieces, a number of much smaller ones, the identification of which as PBM is not so certain, are present as shapeless masonry elements in the walls of the amphitheatre. They occur together with portions of shale and pink breccia with white marble elements over- and under-lying the marble in the Punta Bianca coastal cliff. No sculptured PBM statues have been found.

Apart from the rust colour of the veins, the blocks are well preserved, without visible signs of the progressive lack of cohesion so common in marble. Instead, weathering phenomena, with increased porosity and loss of cohesion, were observed in the Punta Bianca outcrop, where the marble underwent the action of brine and direct sunlight. However, even in such extreme conditions, the observed layer of decay is very limited.

A field survey of the marble outcrop did not reveal traces of quarrying on the cliff, apart from a single chisel-cut channel about 5 cm deep and 1 m long found in a hewn-out section. It is therefore impossible to make any reasonable estimate of the volume of marble quarried, if any.

On the south-west slope of Mt. Brugiana, overlooking the city of Massa, about 20 km south-east of Luni, marble pertaining to the «Massa unit» and indistinguishable from the PBM outcrops. This marble was used to a limited extent during the XVII century: an example is the fountain in the square at Bedizzano, near Carrara. The Mt. Brugiana marble outcrops 700 m above sea level; there is no archaeological evidence of Roman Age settlements in this locality. We are therefore confident that the marble found in the Luni archaeological site does not come from Mt. Brugiana.

CONCLUSIONS

The Triassic Punta Bianca marble (PBM), belonging to the metamorphic sequence of the «Punta Bianca Unit», is a fine-grained marble (average grain size 70 μm), characterized by winding ankerite veins. Macroscopically, it is distinguishable from the well-known «Carrara marble» by its smaller grain size and by the presence of muscovite flakes and ankerite veins, which turn rust-coloured when weathered. The main chemical and mineralogical characteristics are alumina prevailing over alkalis, an average of 3% silicate minerals, mostly muscovite, and the presence of ankerite veins. Unaltered PBM samples have very low water imbibition coefficients (about 0.1% by weight), which increase to about 0.4% in weathered samples. Lastly, PBM demonstrates good resistance to physical and chemical alteration.

Crafted PBM objects are found in the Luni archaeological site, and have been dated from the early first century B.C. (the Capitolium capitals) to the second century (amphitheatre steps). PBM has been observed only in structural elements (essentially capitals and steps); no statues have been found.

The data collected suggest that PBM began to be used before quarrying of Jurassic marble from the Carrara area. The date for the earliest quarrying of Carrara marble is usually drawn from an historical source: Pliny the Elder quotes Cornelius Nepos as saying that, in 48 B.C., Mamurra, a Roman nobleman, had a house with monolithic columns of Carystio or Lunensis marble. In the time of the Roman Empire, the adjective *lunensis* was used in the literature to refer to Jurassic Carrara marble.

Nevertheless, to our knowledge, the oldest known artefacts in Rome made of Carrara marble are the Gaio Cestio pyramid (Rome, 12 B.C., Steinby 1999) and the *Ara Pacis* (Rome), a monument erected in 9 B.C. by order of Augustus. The Gaio Cestio pyramid and especially the *Ara Pacis* contain huge, expertly quarried blocks of high-quality Carrara marble. Hence, marble quarrying in Carrara must have been well-established by that time, although information allowing more precise dating are lacking. Some Etruscan Age marble funeral steles are known, but they do not necessarily imply quarrying: funeral steles may be obtained from erratic marble blocks.

Carrara marble undoubtedly possesses many desirable features: the large number of different varieties, the availability of large single blocks, its beauty, high and constant quality, scarcity of defects and overall excellent physical and mechanical characteristics - all of which combine to make it superior, better-known, and much more frequently used than Punta Bianca marble. Unfortunately, available data do not allow us to define with certainty exactly when marble quarrying began in the Punta Bianca promontory, nor when it began in the Carrara region but, owing to the easily accessible seaside position of the outcrop, quarrying of Punta Bianca marble may have preceded that of Carrara marble by about 50 years.

A research project has therefore been set up with the aim of identifying the type of marble, Punta Bianca or Carrara, used in the marble elements from the Roman Luna settlement. Study will be made of as many structural components as possible - findings either still present at the Luni site or in museums, as well as those which have, over the ages, been re-used as building materials and placed in various buildings scattered all over the Luni area.

In the meantime, we emphasize that, strictly speaking, *lunensis* should best be used to refer to marble from Punta Bianca, rather than Carrara. More broadly speaking, it should at least be kept in mind that the term does comprise marble from two different geological formations.

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