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Article

The Marble of Campiglia: An Historical Cultural Heritage Ornamental Stone from Tuscany, Italy

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Abstract

This paper presents an outline of a historical stone: the Marble of Campiglia, from Tuscany (Italy). A comprehensive review of the literature and archival documents, combined with a new detailed field survey, allowed us to revise the geological setting and exploitation history of this cultural heritage marble, which has been sporadically used since Etruscan times up to the present day. The Campiglia Marittima Marble (CMM) has a thermal-metamorphic origin related to the intrusion of a granitic pluton dated at about 5.4 Ma. This gave rise to a marble with peculiar textural, grain-size, and fracturing features that influenced the cultivation approaches and methods. The main exploitation periods of the CMM as an ornamental stone were the Etruscan-Roman age, the Renaissance, and the nineteenth century; currently, it is used only for industrial purposes. A great number of ancient quarries are located on the western slope of Monte Rombolo, probably due to the high variety of commercial marble types that can be found in the area and to its strategic position with an easy transport way to the Tyrrhenian Sea. This research is aimed to recall to the memory this historical marble and can also support the possible reopening of a few quarries for conservation purposes, for ensuring the Authenticity of the historical artefacts in which it was used.

Keywords: Campiglia marble; cultural heritage; geological setting; historical uses; quarrying exploitation

1. Introduction

1.1. Civilization of Stone

Ours is a civilization of stone, without stone our civilization would not exist as it is, or we would be in the civilization of Wood and Raw Earth, as historically happened and as still present in various parts of the world. The relationship between built and stone was born in prehistory with the use of stone as a material that then becomes raw material in a chain of knowledge, know-how, techniques and social and economic organization that has allowed the development of our civilization and the creation of works of art, monuments and buildings in stone material, in other words the Stone Buildings of our civilization. In this process the Historic Stones have been outlined, that is, local stones used and characterize a site, a region, now supplanted by the omnipresent concrete, and whose technical and territorial knowledge has been lost and must now be recovered with scientific studies that give a trace of these roots of a territory. We must be aware that behind every Stone Building there is a quarry, which therefore represents a cultural place, the opening of which involves various knowledge, skills and coordinated actions [1].

The Building Stone itself has a cultural value as the local historical mining activity is a distinctive and characterizing feature of a territory, a culture of a civilization [2–4], but the current trend towards general globalization leads to forgetting these cultural, historical and economic roots of a territory [5,6], justifying the value of the scientific and technical recovery of the knowledge of these roots.

To reconstruct the history of a city, a territory, a region it is essential to also know the ownership conditions of the quarries, the type of contracts with the contractors who took on the task of extraction, the methods of supplying the construction site, without placing an excessive distinction between decorative and construction stones, as in many cases the two categories overlap; but also, the study of transport systems, since the proximity of a quarry to the place of use often determines the choice of materials [2,7,8].

Knowledge of the geological conditions of a territory and the possibilities it offered of stones of greater or lesser quality conditioned the historical significance of the importation of marble and stones from other regions or even from other countries.

It is in this perspective that the presence or absence of exotic marbles with a high media impact acquires a specific historical meaning.

Over time, there have been stones whose value does not depend on current market demand: these are the "historical stones"; which, often no longer in cultivation, are found in monuments, works of art, archaeological sites and as artefacts in common use, and which are part of the cultural heritage and in particular of the historical-artistic-architectural-archaeological heritage of a society [1].

In these events, the value of the stone resource lies not only in the meaning it assumes for the purposes of safeguarding and conserving, through conservation, this heritage, but, more generally, in the fact that the stones constitute a cultural legacy of an activity that is sometimes very relevant in the history and local and cultural traditions of a civilization, now too often lost.

1.2. The Campiglia Marittima Marble

This paper presents a general review of one of these historical stones: the Campiglia Marittima Marble (CMM), near the Campiglia Marittima village (southern Tuscany, Italy) (Figure 1), which had been exploited since the Etruscan time until XX century [9–11].

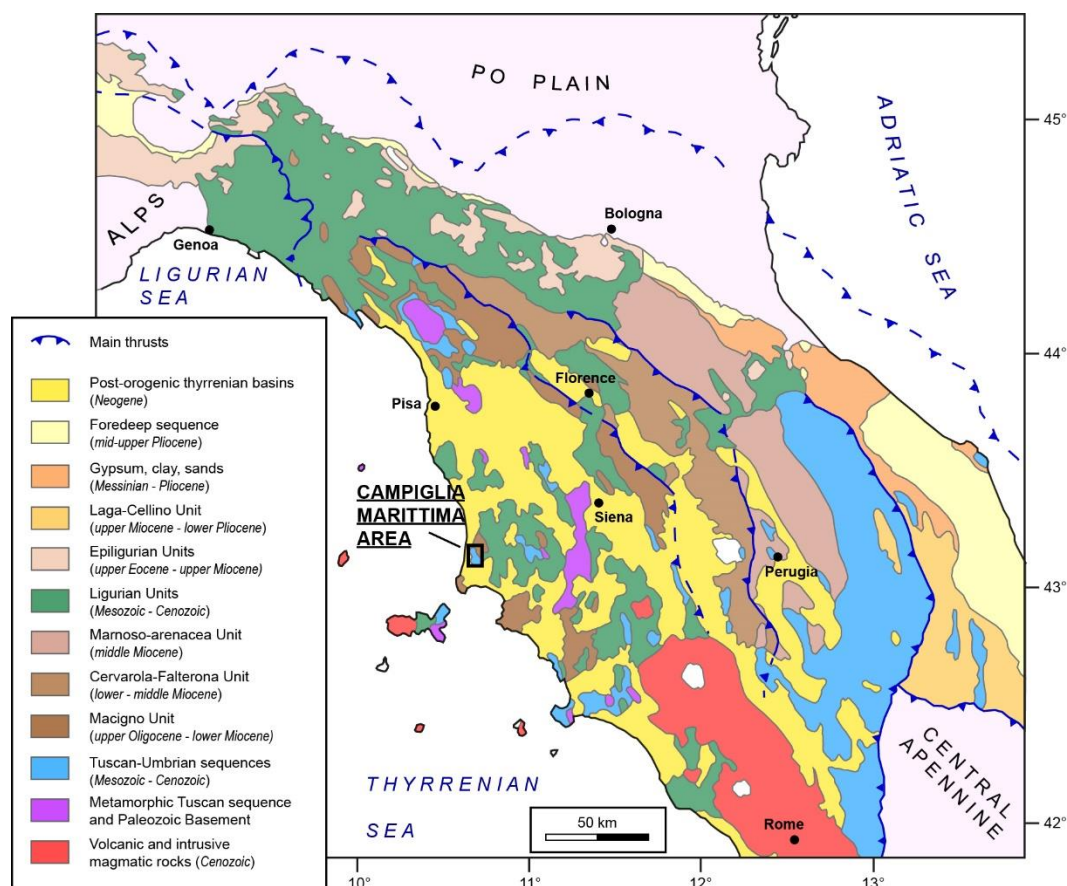


Figure 1. Location of the village of Campiglia Marittima in the frame of geology of Northern Apennine, Italy (elaboration G. Risaliti).

This marble is relatively little known compared to others, probably because of the competition with other marbles present in Tuscany, such as the one from Montagnola Senese or the most famous Carrara Marble [12–16].

At present, wondering inside Campiglia and in its countryside, is possible to see many CMM quoins and ashlar inserted in the masonries of medieval palaces and houses as reuse from previous edifices, presumably Romans. For example, on the façade of Palazzo Pretorio, the parish church of San Giovanni, or even the ancient city walls (Figure 2)[10].



Figure 2. Examples of some buildings in Campiglia Marittima where CMM were used as quoins, ashlars or coats of arms. (a) Palazzo Pretorio; (b) external door of the parish church of San Giovanni; (c) North gate of the city walls. (Photos by G. Risaliti).

This paper provides, for the first time, a map of the historical quarries of CMM, accompanied by a geological description and a resume of the main uses and exploitation phases, pasts and presents, which characterizes the history of this marble and its relationships with the human history.

2. Materials and Methods

The research had been articulated into bibliographic research concerning marble quarrying and extraction in the Campiglia Marittima area, integrating new data with an extent survey of all the marble quarries. Because of a matter of concept and interest, we only focused on the marble quarries, without considering other kinds of resources present in the area, such as mines or quarries of different materials [17–19]. For quarries particularly difficult to reach, an Unmanned Aerial Vehicle (UAV) was used to collect data.

The survey results are summarized in a map of the marble quarries present in the Campiglia Marittima area, correlated with a description of the involved lithologies. Even if some databases or publications exist, they are limited to restricted areas and focused only on a few quarries or to certain specific aspects.

Therefore, this is the first time that a full database of the state of the art concerning CMM quarries is presented.

2.1. Geological Setting

From a geological point of view, the Campiglia area is located in the inner sector of the Northern Apennine fold-and-thrust belt [20,21]. The area is tectonically represented by a N-S elongated, triangular shaped horst, mainly made up of carbonatic rocks whose age spans from Late Triassic to Late Jurassic (Figure 3). The horst is delimited on its western side by a N-S trending, W-dipping normal fault, on its eastern side by a series of NNW-SSE trending, ENE-dipping normal faults, and on its southern side by a series of normal faults, not univocally oriented (Figure 3) [22–25].

From bottom to top, the main tectonic units outcropping in the area are (Figure 3) [24,25]:

- Tuscan Nappe, constituted, from bottom to top, by platform carbonatites, pelagic limestone, marls and shales, and topped by turbidite sandstones (Late Triassic – early Miocene).
- Subligurian Units, mainly shales, marls and sandstones (middle Eocene – early Miocene).
- Ligurian Units, shales, marls, marly-limestones and limestones (Jurassic to Eocene).

Neogene sedimentary deposits, mainly sand and silt (middle-Late Pleistocene), unconformably cover the previous tectonic units.

In addition to the previous units, the Campiglia area is characterized by the presence of a magmatic complex, of the Tuscan Magmatic Province [26], made up by granite, porphyry dikes and rhyolite, dated to late Messinian – early Pliocene (Figure 3) [27,28]. This magmatic intrusion caused contact metamorphism and led to ore deposits in the intruded carbonates.

Tuscan Nappe, Subligurian Units and Ligurian Units, are tectonically stacked and override on top of each other during the main Apennine orogenic phase, between late Oligocene and early Miocene; the Neogene sediments unconformably cover these tectonic units [20,21 and references therein, 24,25,29].

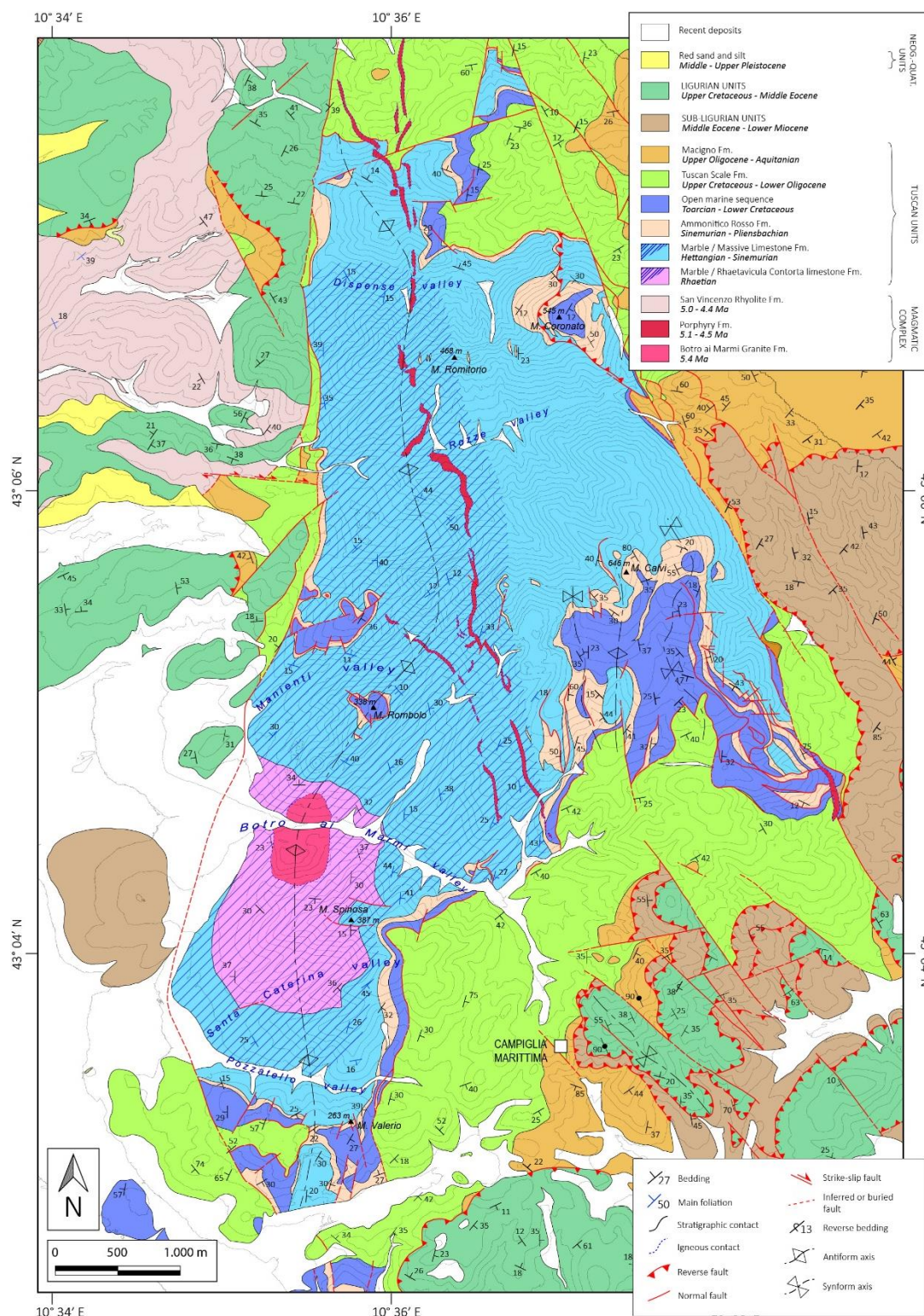


Figure 3. Geological map of the Campiglia Marittima area (elaboration G. Risaliti; modified from [24,25,30]).

After the establishment of an extensional tectonic regime in middle Miocene, since late Miocene – Pliocene, high angle normal faults affected the area, causing the formation of the horst of the Campiglia area [22,23]. Here, formations belonging to the Tuscan nappe outcrop; from bottom to top they are: *Rhaeticulica Contorta* Limestone Fm. (Late Triassic), *Calcarea Massiccio* Fm., *Ammonitico Rosso* Fm. and *Selcifero* Limestone Fm (Early Jurassic), *Posidonomya* Marls Fm. (Middle Jurassic) and *Diaspri* Fm. (Late Jurassic; Figure 3).

In late Messinian, an intrusive granitic body, the Botro ai Marmi Granite, intruded up to a shallow level causing the metamorphism of the host-rock around the intrusion. The main lithologies

affected by metamorphism were the Rhaetavicula Contorta Limestone Fm. and the Calcare Massiccio Fm., which shifted to marble (CMM), in the metamorphic aureole around the pluton (Figure 3) [22,23]. The age of the granite intrusion, which got rise to the metamorphism, has been estimated to 5,4 Ma [28].

The emplacement took place at 3-4 km of depth, corresponding to a pressure of 1-1,5 kbar [31]. Metamorphism temperature has been estimated in several areas of the metamorphic aureole, resulting in a maximum peak of 450° [31–33]. This value is in agreement with the metamorphic aureole thickness estimated to be around 500 m from the pluton contact [30].

After the pluton emplacement, porphyry dikes and San Vincenzo Rhyolite emplaced in several episodes, spanning from 5,1 to 4,4 Ma ago (Figure 3) [28], only locally affecting with metamorphism the host rocks.

The metamorphic aureole has a N-S elongated shape; its length is approximately 6,5 km along N-S direction and a few more than 2 km along E-W direction (Figure 3). The main structure correlated with the aureole is a large antiform with a N-S axial direction, given by the CMM layering attitude (Figure 3) [30,34,35]. The aureole is totally included within the horst that characterizes the area; its western boundary coincides with the main N-S trending fault that bounds the horst, while its northern, eastern and southern limits are given by the decreasing of metamorphic grade, thus not exactly definable. Aureole's shape reflects the one of the underlying granitic body, as it has been reconstructed, through boreholes, reflection seismics and gravimetric maps [17,30,35]. It results in a N-S elongated shape, with two main tops: the southernmost, major and more significant top outcrops at Botro ai Marmi (Figure 3), a second, northernmost, less prominent top, is between Poggio Ginepraie and Dispense valley, with the top about 100 m below the ground datum.

During last decades, several Authors proposed different interpretations about pluton emplacement mechanisms:

- Some authors [22,23,35] proposed an intrusive body rising and emplacing in a fully extensional tectonic regime;
- Others [34,36,37] suggested that magma rose by exploiting a releasing band associated with the activity of a dextral strike-slip fault;
- Recently, [30] proposed a compressive tectonic regime model, where the magma rises by filling the core of an enucleating antiform fold (i.e. the main antiform that characterizes the aureole).

2.2. The CMM

The main characteristics of the CMM vary depending both on the kind of protolith and metamorphic temperature (i.e. the distance from the pluton) it underwent.

Several commercial types of CMM have been recognized within the area, and quarried through times: *Bardiglio Fiorito*, *Bardiglio*, *White*, *Broccatello* [32,33,38]; a brief description of which is reported in Table 1.

CMMs present a strong to slight schistosity [30,34]. Even if the schistosity is not always visible at mesoscale, a defined Shape Preferred Orientation (SPO) of calcite grains can be visualized with the TOM, by cutting the marble sample properly (i.e. parallel to the XZ plane of the strain ellipsoid [39]).

Table 1. Description of CMM types. (elaboration G. Risaliti).

Commercial Marble type	Protolith	Color	Grain size	Schistosity
<i>Bardiglio Fiorito</i>	Raethavicula Contorta	Dark grey	Medium and coarse grained	Yes
<i>Bardiglio</i>	Raethavicula Contorta	Grey to brown-grey and pink-grey marbles	Medium and coarse grained	Yes

<i>White</i>	Calcare Massiccio	Mainly white, light grey, rarely pink	Fine, medium and coarse grained	Yes and No
<i>Broccatello</i>	Marble Breccia (Calcare Massiccio)	White-yellow, yellow and dark yellow	Fine grained, eterometric breccia	Yes

According to calcite flow laws [40,41], due to the estimated P/T conditions, the CMM grain size decreases by decreasing temperature from the pluton contact. Close to the Botro ai Marmi granite top calcite grains reach 3-5 mm [32], whereas in the outermost sides of the aureole crystals dimension have values around 20-40 μm [30].

Grain boundaries are generally curved to lobate in the whole aureole, sometimes even ameboid, rarely straight, and texture is mainly heteroblastic [30,32,33,38]; bulging structures are also present and at places texture appears to be homeoblastic [38,42].

Petrographically, CMM are almost always pure marbles, made up of calcite crystals more than 95 %. Dolomite can be present, mainly in the grey marble (*Bardiglio and Bardiglio Fiorito*), where it has been found occasionally up to 7 % or 10 % of compositional value [32]. Other minerals which have been recognized are Diopside, Talc, Quartz (mainly in veins), Phlogopite, Apatite, Tremolite, Chlorite, Fe-oxides, Pyrite, K-Feldspar [30–32,38].

The O/C isotope data for Campiglia have $\delta^{18}\text{O}$ ranging between -13 to -5 and $\delta^{13}\text{C}$ 0.5 to 2 (Figure 4) [32].

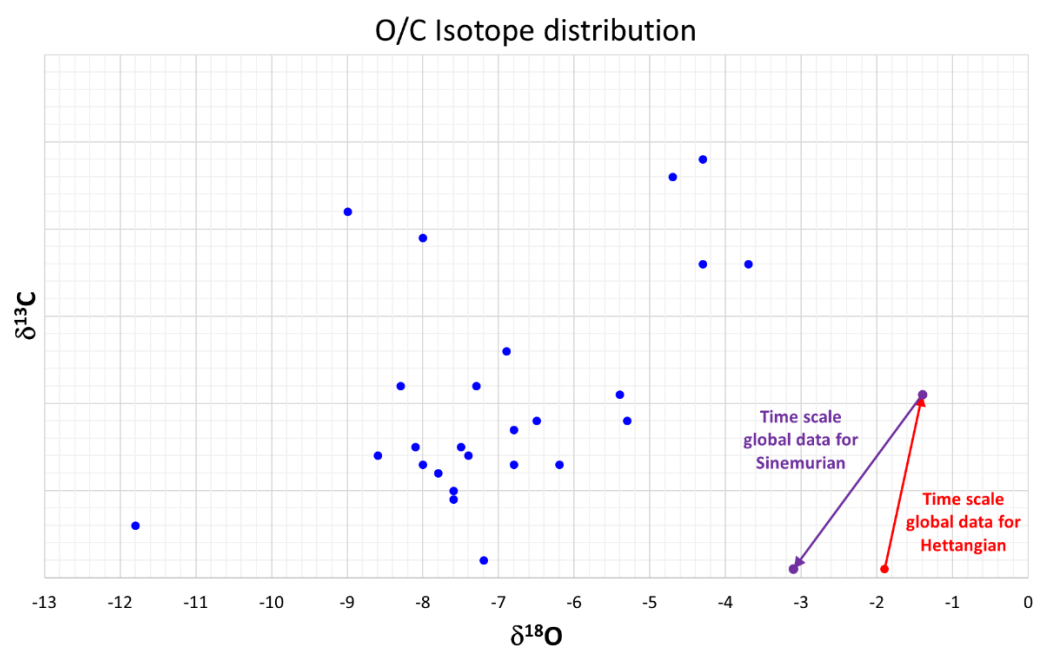


Figure 4. O/C Isotope data for the Campiglia marbles and the referring data for Hettangian and Sinemurian in the Global Time Scale (elaboration M. Coli, data from [32]).

This data presents no correspondence in the C/O isotope distribution with those from the same age no metamorphic platform carbonate rocks as reported in the Global Time Scale (GTS) [43]. This no correspondence between the GTS data and marbles was already outlined by [44] for the Carrara Marble, which derived by tectono-dynamic metamorphism of the same protolith.

3. Results

3.1. Areal Distribution of Quarries

A total number of 36 quarries (Figure 5) have been surveyed, even if some have more extraction fronts due to their large size. Quarries are here reported by their common name; for those that do not have one, numbering system used in the database (DB) of the San Silvestro Archaeological Mining Park had been used; this DB includes most of the quarries between the Monte Rombolo area and the Manienti valley. The details are reported in Table 2, and in the Supplementary Material as a .kmz file.

Most of the quarries are located in the area between Monte Rombolo and the Manienti valley. On the Monte Rombolo slopes, going anticlockwise from the northern slope to the southern one, there are quarries n. 197, 198, 206, 205, 204, 203, 202, 241, 242, 243, *Pari* quarry, *Fornelli* quarry, quarries n. 246, n. 232, *Bardiglio* quarry and quarry n. 226. The last three of the above cited are the only one were *Bardiglio* type, from *Raethavicula Contorta* Limestone Fm. protolith, had been extracted. The only other quarry within the same protolith is the *Black* quarry, located a little bit more to the South, at the northwestern slope of Monte Spinosa, which is the only one in this area where *Bardiglio Fiorito* type has been quarried.

All the other quarries cited, except for the *Broccatello* quarry, which will be discussed later, had been opened in the *White* marble type, whose protolith is the *Calcare Massiccio* Fm. Westward from Rombolo Mt., in the locality known as Campo alle Buche, quarry n. 209 and *Perdicary* quarry are present. This latter is a large quarrying area, which had been quarried in different ages, and where several fronts of extraction have been reported (quarries n. 210, 211, 238 and 239 in the DB of San Silvestro Archaeological Mining Park).

Northward, in the E-W oriented Manienti valley, going from West to East, quarries n. 208, 196 and 190 are close to the impluvium, whereas quarries n. 194, 183, 176, 175 and 174 are on the southern slope, on the right side of the valley.

Eastward of Monte Rombolo, on the western slope of Poggio ai Lanzi Hill, there is the *Poggio ai Lanzi* quarry, where the railway of the Park train runs today. Southward of Poggio ai Lanzi Hill, near the beginning of Botro ai Marmi valley, are ubicated the *Fucinaia* quarry, where it is visible the stratigraphic contact between the *Calcare Massiccio* Fm. and the *Ammonitico Rosso* Fm. (Figure 6c), and the quarry n.3, near the eastern boundary of the metamorphic aureole. Going from the eastern to the southern limit of the aureole, within the Pozzatello valley, there are the *Pozzatello* quarries, 1 and 2 from the easternmost to the westernmost, as they are named in the database of the Regional Quarries Plan of Tuscany [45].

Moving through the northern part of the area, the *San Carlo* quarry is located to the South of the Rozze valley, near the San Carlo locality, which gives it the name. More than 1 km to the North, there is the *Broccatello* quarry (also known as *Ortali* or *Romitorino* quarry), on the northwestern slope of the Romitorino Peak. This quarry is the only one where the protolith is not the *Calcare Massiccio* Fm. in a *strictu sense*, but it's an heterometric, approximately homogenic, sedimentary breccia, made up by clasts of *Calcare Massiccio* Fm., now aligned along the main schistosity (Figure 7, a and b). Northward, within the Dispense valley, are ubicated the last two quarries, in the proximity of the northern boundary of the metamorphic aureole, the *Roman* quarry and *Calasorbi* quarry (also known as *Valle delle Dispense* quarry).

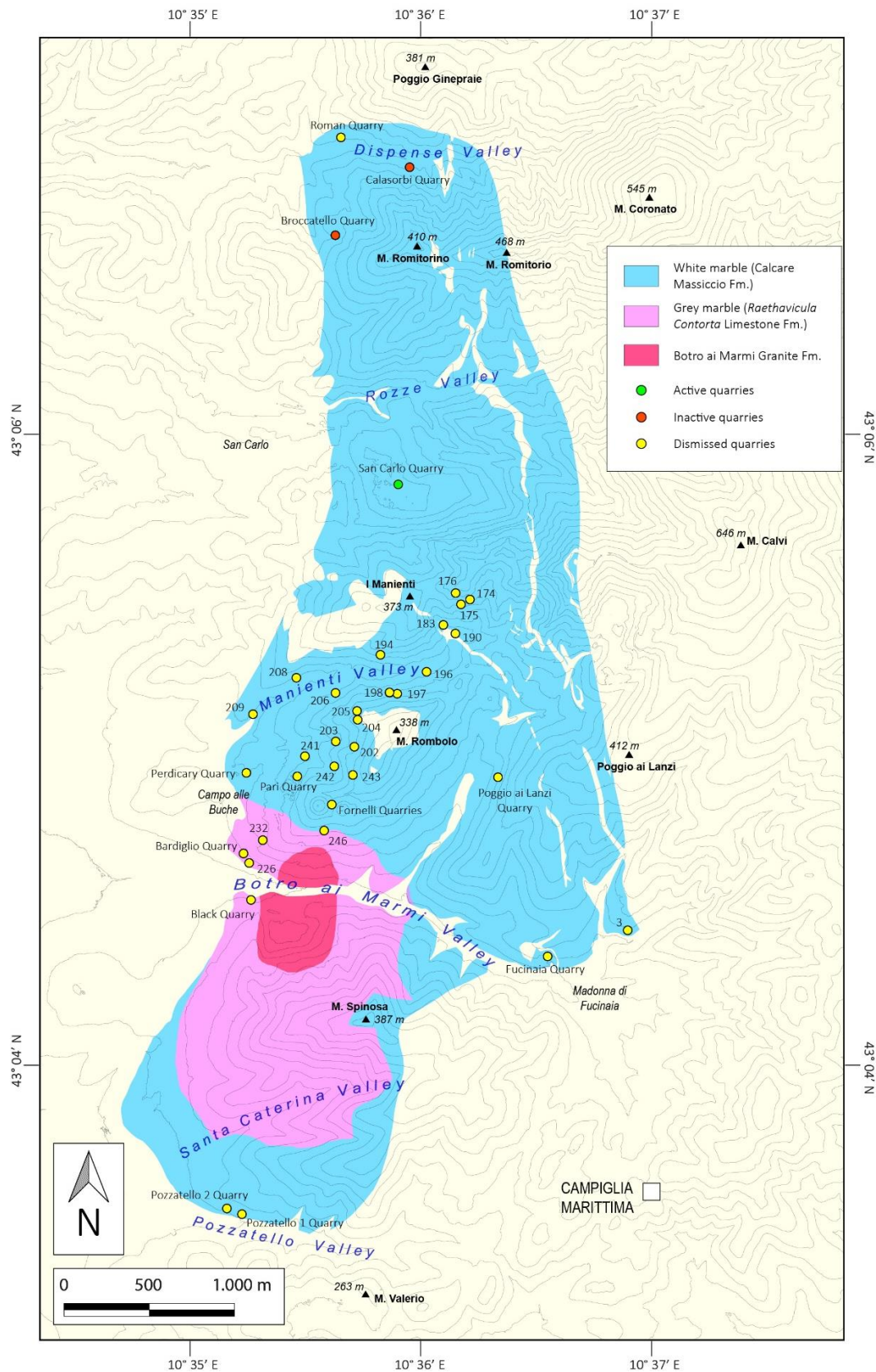


Figure 5. CMM quarries distribution in the metamorphic aureole; outlined the granitic outcrop of Botro ai Marmi and the distribution of the white and grey marbles (elaboration G. Risaliti).

Table 2. List of the quarries of CMM. Quarries' name is referred both to their common names, if they have one, or to the numbering of the database of the San Silvestro Archeological Mining Park (elaboration G. Risaliti).

Name	Marble commercial type	Protolith	Coordinates WGS84 Lat.- Long.	Altitude a.s.l.	Municipality	Current status
Bardiglio quarry – quarry n. 225	Bardiglio	Raethavicula Contorta	43.07797 N, 10.58798 E	119 m	Campiglia Marittima (LI)	dismissed
Black quarry	Bardiglio Fiorito	Raethavicula Contorta	43.07551 N, 10.58846 E	102 m	Campiglia Marittima (LI)	dismissed
Broccatello quarry (a.k.a. Ortali or Romitorino quarry)	Broccatello	Marble Breccia (Calcere Massiccio)	43.11054 N, 10.59545 E	197 m	Castagneto Carducci (LI)	inactive
Calasorbi quarry (a.k.a. Valle delle Dispense quarry)	White	Calcere Massiccio	43.11406 N, 10.6009 E	165 m	Castagneto Carducci (LI)	inactive
Fornelli quarries – quarry n. 244	White	Calcere Massiccio	43.08047 N, 10.59441 E	260 m	Campiglia Marittima (LI)	dismissed
Fucinaia quarry – quarry n. 2	White	Calcere Massiccio	43.07223 N, 10.60977 E	155 m	Campiglia Marittima (LI)	dismissed
Pari quarry – quarry n. 240	White	Calcere Massiccio	43.08199 N, 10.59196 E	200 m	Campiglia Marittima (LI)	dismissed
Perdicary quarry - quarries n. 210, 211, 238, 239	White	Calcere Massiccio	43.08223 N, 10.5883 E	149 m	Campiglia Marittima (LI)	dismissed
Poggio ai Lanzi quarry – quarry n. 134	White	Calcere Massiccio	43.08174 N, 10.60644 E	210 m	Campiglia Marittima (LI)	dismissed
Pozzatello 1 quarry	White	Calcere Massiccio	43.05891 N, 10.58738 E	105 m	Campiglia Marittima (LI)	dismissed
Pozzatello 2 quarry	White	Calcere Massiccio	43.05923 N, 10.5863 E	106 m	Campiglia Marittima (LI)	dismissed
Quarry n. 3	White	Calcere Massiccio	43.07352 N, 10.61558 E	193 m	Campiglia Marittima (LI)	dismissed
Quarry n. 174	White	Calcere Massiccio	43.09116 N, 10.60466 E	352 m	San Vincenzo (LI)	dismissed
Quarry n. 175	White	Calcere Massiccio	43.09091 N, 10.604 E	331 m	San Vincenzo (LI)	dismissed
Quarry n. 176	White	Calcere Massiccio	43.09152 N, 10.60363 E	380 m	San Vincenzo (LI)	dismissed
Quarry n. 183	White	Calcere Massiccio	43.08984 N, 10.6027 E	252 m	San Vincenzo (LI)	dismissed
Quarry n. 190	White	Calcere Massiccio	43.08938 N, 10.60356 E	240 m	San Vincenzo (LI)	dismissed
Quarry n. 194	White	Calcere Massiccio	43.08833 N, 10.59813 E	269 m	San Vincenzo (LI)	dismissed

Quarry n. 196	White	Calcare Massiccio	43.08738 N, 10.60143 E	216 m	Campiglia Marittima (LI)	dismissed
Quarry n. 197	White	Calcare Massiccio	43.08626 N, 10.59928 E	276 m	Campiglia Marittima (LI)	dismissed
Quarry n. 198	White	Calcare Massiccio	43.08633 N, 10.59873 E	367 m	Campiglia Marittima (LI)	dismissed
Quarry n. 202	White	Calcare Massiccio	43.0835 N, 10.59612 E	297 m	Campiglia Marittima (LI)	dismissed
Quarry n. 203	White	Calcare Massiccio	43.0838 N, 10.59478 E	238 m	Campiglia Marittima (LI)	dismissed
Quarry n. 204	White	Calcare Massiccio	43.08492 N, 10.59639 E	318 m	Campiglia Marittima (LI)	dismissed
Quarry n. 205	White	Calcare Massiccio	43.08539 N, 10.59636 E	297 m	Campiglia Marittima (LI)	dismissed
Quarry n. 206	White	Calcare Massiccio	43.08636 N, 10.59484 E	207 m	Campiglia Marittima (LI)	dismissed
Quarry n. 208	White	Calcare Massiccio	43.0872 N, 10.59203 E	181 m	San Vincenzo (LI)	dismissed
Quarry n. 209	White	Calcare Massiccio	43.08532 N, 10.58885 E	150 m	San Vincenzo (LI)	dismissed
Quarry n. 226	Bardiglio	Raethavicula Contorta	43.07746 N, 10.58838 E	109 m	Campiglia Marittima (LI)	dismissed
Quarry n. 232	Bardiglio	Raethavicula Contorta	43.07865 N, 10.58939 E	157 m	Campiglia Marittima (LI)	dismissed
Quarry n. 241	White	Calcare Massiccio	43.08305 N, 10.59254 E	197 m	Campiglia Marittima (LI)	dismissed
Quarry n. 242	White	Calcare Massiccio	43.08248 N, 10.59465 E	244 m	Campiglia Marittima (LI)	dismissed
Quarry n. 243	White	Calcare Massiccio	43.08201 N, 10.59597 E	319 m	Campiglia Marittima (LI)	dismissed
Quarry n. 246	White	Calcare Massiccio	43.0791 N, 10.59382 E	220 m	Campiglia Marittima (LI)	dismissed
Roman quarry	White	Calcare Massiccio	43.11571 N, 10.59599 E	147 m	Castagneto Carducci (LI)	dismissed
San Carlo quarry	White	Calcare Massiccio	43.10121 N, 10.60308 E	151 m	San Vincenzo (LI)	active

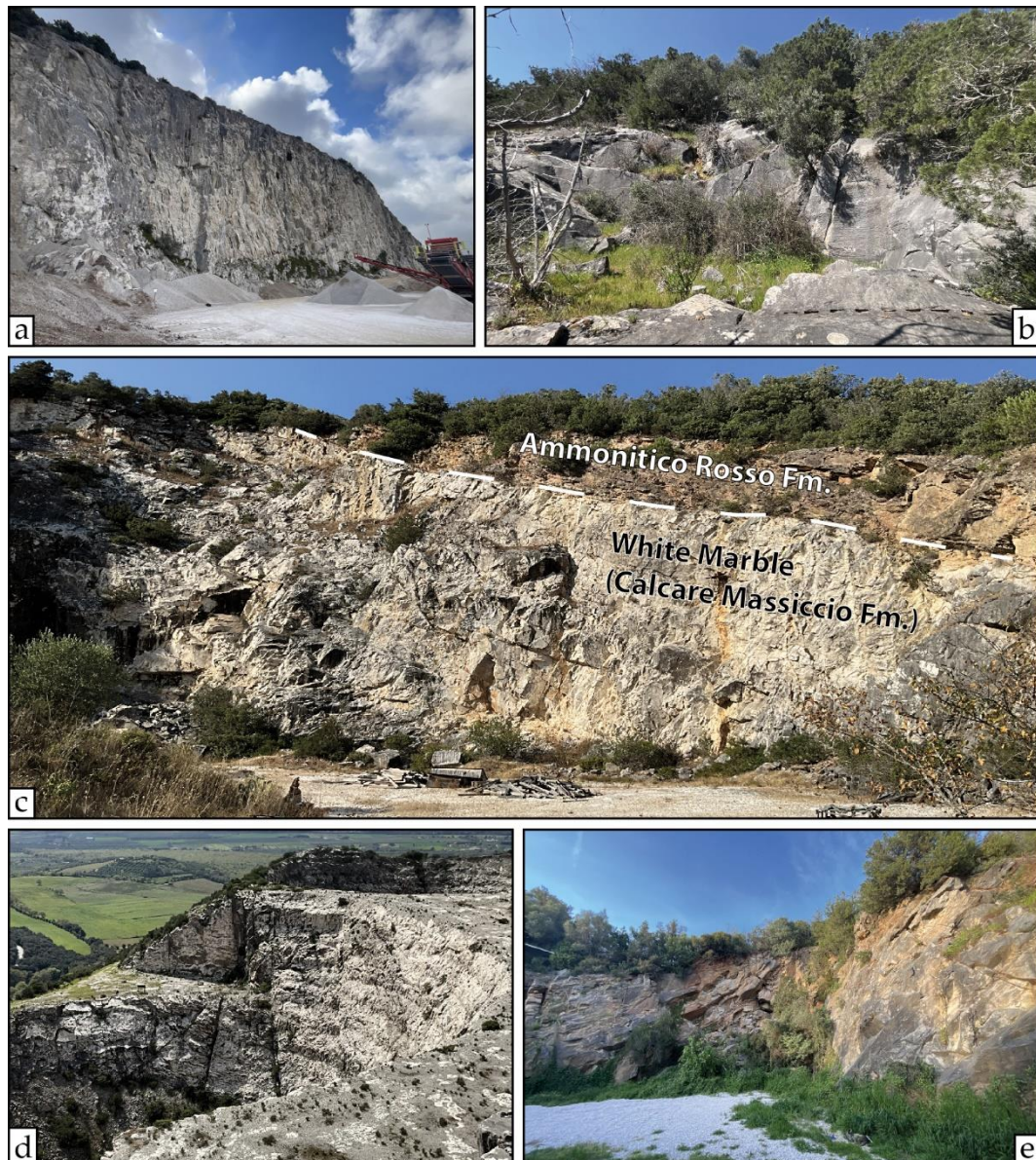


Figure 6. Prospects of some quarries surveyed in the central part of the area of interest: (a) *Pari* quarry; (b) quarry n. 208; (c) *Fucinaia* quarry, where it's visible the stratigraphic contact between *Calcarea Massiccio Fm.* (White marble) and *Ammonitico Rosso Fm.*; (d) *Fornelli* quarries, with their typical funnel shape; (e) quarry n. 226, one of the few quarries within the *Bardiglio* marble type. (Photos by G. Risaliti).

As above said, it is generally correct to assert that marble grain size decreases by moving away from the Botro ai Marmi Pluton top, (Figure 3; Franzini et al., 2010; Cavari et al., 2012; Lezzerini et al., 2021; Papeschi et al., 2025). Therefore, quarries located in the inner part of the aureole, like those within the *Raethavicula Contorta* Limestone Fm. (*Pari* quarry and *Fornelli* quarry), tend to have a bigger grain size than those close to the aureole limit, like *Pozzatello* 1 and 2 quarries, the *Roman* quarry or quarry n. 3.

San Carlo quarry is the largest one, as its E-W linear dimension reaches almost 1 km. Other quarries with an order of hundreds of meters in size are *Perdicary* quarry, *Pari* quarry and *Fornelli* quarry, which is composed of two excavation areas with a peculiar funnel shape, and the *Poggio ai Lanzi* quarry. All other quarries are of small size, and their linear dimensions vary from order of meters to some decades of meters.



Figure 7. Prospects of some quarries surveyed in the northern part of the area of interest: (a) *Broccatello* quarry; (b) detail of the *Broccatello* marble type within the *Broccatello* quarry, which is actually a metamorphic calcareous breccia, made up by clasts of Calcare Massiccio Fm.; clasts are aligned accordingly to the main schistosity; (c) *Roman Quarry*; (d) *Calasorbi* quarry. (Photos by M. Coli and G. Risaliti)

Of all quarries covered by the study, according to the Regional Quarries Plan of Tuscany [45] the *San Carlo* quarry is active, the *Broccatello* quarry and the *Calasorbi* quarry are inactive, but included as potential quarrying sites (Figure 5). All the other quarries are to be considered dismissed; of these the *Pari* quarry, hosted by the Cave di Campiglia S.p.a., actually is used as repository for quarry waste from the nearby quarries of Calcare Massiccio used as aggregates.

3.2. Exploitation History of the CMM

The CMM was quarried and used sporadically at least since Etruscan time. [46] and [47] assessed that Etruscans extracted the marble from the locality of Campo alle Buche, near the western flank of Mount Rombolo (than known as *Perdicary* quarry; Figure 5), during the IV and III century B.C. This period is correlated with an important expansion and prosperity time of the near Etruscan city of Populonia, on the coast. The hypothesis of an Etruscan excavation period had already been supposed by [48] and [9]. That was confirmed successively by [38,49], who compared marble from Campo alle Buche and some other quarries within the Manienti valley (Figure 5) with some artefacts from the city of Populonia, by adopting minero-petrographic and isotopic analyses. Results show that Etruscans quarried and used marble from (at least) those quarries, within a period which is described as Late-Etruscan to Early Roman time.

[50] wrote the Roman used the CMM to build milestones along the ancient Via Aemilia in 140 A.D., under Emperor Antoninus Pius (Figure 8), as well as they were used to build sculptures [9].



Figure 8. Milestone of CMM along the Roman Via Aemilia near Cecina. (Photo by M. Coli).

In the XV century Florence acquired the Campiglia area [50] and, given the problems of supplying marble from Carrara for economic reasons and belligerence with Lucca and Pisa, the Opera del Duomo of Firenze (OPA), which since 1296 has in charge the construction and the conservation of the Firenze Cathedral with the Brunelleschi's Dome and Giotto's bell-tower, in order to have marble slabs for cladding the aisle of the Cathedral, completed the following missions (see in the online archive of the OPA at [51]) in Campiglia:

- April 1434: First expedition to Campiglia to the old *Roman* quarry to take a few test blocks, with Battista d'Antonio (Master Builder) and Cecco Andrea Fraschetta from Settignano and a few masters present.

- June 1434: Second expedition to Campiglia, carried out by Cecco Andrea Fraschetta from Settignano (Master Builder), Baccio d'Antonio (Assistant Master Builder), Giovanni d'Antonio di Giusto from Settignano, Battista d'Antonio, Nicola, Nanni di Berto, Cecco di Meo di Cecchino.

- October 1434: Third expedition to Campiglia, present: Filippo Brunelleschi, Bindaccio d'Albertaccio da Ricasoli, Battista, plus others.

- 1470: Visit to the Campiglia quarries of Lorenzo de' Medici with the workers of the Opera.

According to [52] and [9], during that time CMM were used to clad the exterior walls of the back aisle and the eastern sides of the Tamburo of the Florence Cathedral, as well as for external slabs of the guard tower of San Vincenzo.

In the XVI century, four quarries were open in Campiglia, of which the OPA had the direct concession and worked with its workers; these quarries were visited by Cosimo I de' Medici, Grand Duke of Tuscany, in 1558 and 1561. He recommended the use of the CMM to the famous artists Giambologna and Bartolomeo Ammannati [9–11,53,54]. Ammannati requested the CMM to realize

the *Giunone Fountain* in Piazza della Signoria at Florence; but for unknown reasons, probably due to transport problems or issues during the excavation, then the artist used the Carrara Marble [55].

It is not clear which quarries were opened in those centuries [9,50,52,54,56], certainly the *Roman* quarry was partly reopened because on its cuts are engraved signatures and dates of that time and from which a beautiful *White* marble came (Figure 9). [56] reports of other quarries in the area near Monte Romitorio opened at that time, like the *Broccatello* quarry (Figure 5).



Figure 9. Engrave on a cut of the *Roman* quarry: “1418, Filippo Spina”. (Photo by M. Coli).

After more than 200 years, marble quarries in Campo alle Buche were re-opened by the affair man Vassili Perdicary, who invested and promoted CMM quarrying and selling between 1845 and 1878 [9–11,57]. This activity attracted the attention of numerous artists and sculptors over the world, who used this marble in their works: Lorenzo Bartolini, Pietro Tenerani, Giovanni Duprè, Anton Hautmann, Hiram Power, Max Ymkof, Albert Wolff, Johan Niclas Byström and Luigi Bienaimé are just some of them [9,58].

After Perdicary’s death, in 1878, Monte Rombolo quarries and the surrounding lands were acquired by the Lippi family from San Vincenzo village, who only sporadically sold the marble, between the end of XIX and the first decades of XX century [10,11]. In fact, until around 1930, the marble was still extracted from the locality of Campo alle Buche [9,47,59].

Starting from 1900, CMM are used as melting material in steel production at Piombino, first by the S.T.I.A.M. society and then by the ILVA s.p.a. [9–11]. For this reason, the *Fornelli* quarries were built, with their typical funnel shape, between 1940 and 1960 (Figure 5d).

As resulting by historical air photos [60], during the second half of the last century, the *Poggio ai Lanzi* quarry, the *Broccatello* quarry and the *Calasorbi* quarry were active, the latter two as CMM extraction sites for ornamental purposes.

Today, the only active quarry of CMM is the *San Carlo* quarry, opened in 1927 and managed by the Solvay enterprise for its industrial purposes (Figure 5).

In a near future, the *Broccatello* quarry is planned to be re-opened.

4. Discussion

The presented results show that most of CMM quarries is located in the area between the western slope of Monte Rombolo and the Manienti valley (Figure 5). The same area is the one where surely CMM has always been extracted, at least since Etruscan times [38,49]. The reason why this part of the Campiglia area has always been the preferred one to be quarried (despite our days) is due to at least two main aspects. The first one is the position, which is relatively close to the sea and to the main streets that link Campiglia Marittima with the coast, where major connecting roads exist since Etruscan and Roman times [9,58], and also with the possibility to be shipped away.

The second, is the high variability of marble commercial types that are present there; in fact, in this area, several commercial marble varieties had been actually proposed for the *White* marble through time, which should be added to the ones that we distinguished in Table 1. In the mid of XIX century, the famous geologist Paolo Savi, together with other geologists and sculptors, were sent to observe and evaluate the CMM in the quarries near Campo alle Buche by the owner Vassili Perdicary, to assess the quality of the marble marketed by his industry [58]. They all agreed that the *White* marble excavated in Campo alle Buche, where the grain size is coarse (the *Perdicary* quarry; Figure 5), was very similar, or even identical, to the classic *Pario* marble from Greece, for both esthetical and physical characteristics. Nevertheless, moving to the quarries in the upper part of Monte Rombolo, or on its north-western slope, or still in the Manienti valley (Figure 5), the *White* marble was classified by the same authors as the classical *Grechetto* from Africa, for its smaller grain size, or also as the *Statuario* or *Ordinario* types of the Carrara Marble [9,58]. Of course, these commercial varieties of *White* marble were added to the grey marbles *Bardiglio* (or *Bardiglio Turchino*) and *Bardiglio Fiorito* of the CMM [58]. The same varieties have been described for CMM even in recent times, in magazine specifically for marble workers and quarrymen [10]. Also in the case of the *Broccatello* marble type, different commercial names are actually used, such as "*Calacatta Gherardesca*" or "*Misto Gherardesca*" [61].

It is clear that the above-cited qualities and variabilities of CMMs are strictly related to its geological nature. Not only by considering the difference of protolith between the Grey Marble and the White Marble (i.e. *Raethavacula Contorta* Limestone and *Calcare Massiccio*, respectively), but also considering decreasing in grain size by increasing distance from the pluton [30,38], thus conferring to the marble different characteristics that can be translated in different commercial marble types.

According to [47], it is therefore reasonably probable that some of the marble that was sold and used as "Greek marble", especially during the excavation activities of the XIX century, was actually CMM, and not the original *Pario*. The same reasoning could be done for the *Grechetto* marble from Africa, or for the *Statuario* or the *Ordinario* marbles from the Carrara Marbles. Here comes the problem, today, to understand which buildings, statues, sculptors or other works of art are actually made with CMM rather than marble coming from other extraction sites, and vice versa.

A sure attribution of work arts to a certain type of marble can be made according with different approaches [44]:

- Archived documents data.
- Technical analyses regarding minero-petrology, O/C isotopes and EPR.
- Expert judgement.

Today, at the known state of the art, some of the monuments and buildings where the CMM surely results to have been used are:

- In Campiglia Marittima, as quoins and ashlar on Palazzo Pretorio, on the parish church of San Giovanni and on the city walls (Figure 2)[10,11].
- In San Vincenzo, for the external curtain on the Guard Tower and for the former Palazzo Lippi [9,10].
- At Livorno, for some tombs in the monumental cemetery of Montenero (Figure 10a) and, probably, in the Greek Orthodox cemetery.
- At Florence, as slabs in the cladding of the back aisle and the eastern sides of the Tamburo and the top cone of the Lanterna of the Brunelleschi's Dome of the Santa Maria del Fiore Cathedral (Figure

10b), for the head of Filippo Brunelleschi on its tomb in the same Cathedral, for the base of the Statue of Dante Alighieri by Enrico Pazzi, in the Cappella dei Principi at the San Lorenzo Church [9,52,56].

- At Pisa, for the external cladding of the Baptistery and the Santa Maria della Spina Church [56].

- At Siena, for the statue of Pio II within the Sant'Agostino Church [9].



Figure 10. Examples of some monuments made with CMM. (a) Tomb of Francesco Domenico Guerrazzi at the cemetery of Montenero, Livorno. (b) The Lanterna of the Brunelleschi's Dome of the Santa Maria del Fiore Cathedral in Florence; the top cone is made up with CMM. (Phots by G. Risaliti and M. Coli)

There is no doubt that CMM has always been appreciated by the people who worked with it; as proof, its history is linked with human history for more than 2300 years. In the letters written by the artists and the geologists sent by Perdicary to the CMM quarries, they confirm that CMM is a high-quality marble, and they are enthusiastic about the works of art they can produce with it (some of these are the ones listed above) [58]. Even [9], in 1936 already, was surprised by the fact that CMM was not exploited for stone uses at that time, despite its good quality.

Certainly, CMM suffered and suffers the competition with other local marbles through time, like the Carrara Marble or the Montagnola Senese Marble [15]. Probably, another important aspect is related to the high degree of fracturing affecting the CMM [33], which inhibits the chances to exploit large blocks, especially compared with Carrara Marble.

5. Conclusion

In this work, we provide an outline of an historical stone, the Campiglia Marittima Marble (CMM), from Tuscany, Italy. A first geological description of this material is accompanied by a resume of its main excavation periods and historical uses, and a complete map of all the quarries within CMM is presented.

CMM is a thermo-metamorphic marble; it has been quarried since Etruscan times until nowadays, even if currently it is used only for industrial purposes. The great number of quarries is in the central-western part of the metamorphic aureole, between the Botro ai Marmi valley and the Manienti Valley, where the higher variety of commercial marble types is present.

Despite currently being relatively little known, probably due to the historical competition with other local marbles, CMM has always been appreciated by the artists and the people who worked with it, and its history is unequivocally linked with the human one, especially in Tuscany and Italy. For these reasons, it deserves a special title, like all the stones which made a crucial contribution to progress and human civilization.

Hopefully, in the future it will be cultivated again, for historical, industrial or even dimensional stone; in fact, in the Regional Quarries Plan of Tuscany, the quarry sites of *Broccatello* and *Calasorbi* are included as potential extractive areas. Actually, the *Broccatello* quarry is planned to be re-opened soon.

To the authors knowledge, this is the first time that a complete, omni-comprehensive study on this material is published, with the aim of culturally restoring the memory of this marble.

Supplementary Materials: The following supporting information can be downloaded at: Preprints.org, Campiglia_quarries.kmz (.KMZ file).

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