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Pietra Serena: the stone of the Renaissance

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Abstract: The most frequently used material in Florentine Renaissance architecture was Pietra Serena, a sandstone that nowadays is found in a quite satisfactory state of conservation. The reason for this is that architects and stone cutters in the past made careful selections of the materials they employed. This conscientious picking out was very important because most sandstone layers have a composition that is not always suitable for assuring an acceptable durability. This paper deals with the mineralogical, chemical, petrographical and physical characteristics of the Pietra Serena sandstone quarried in the hills near Florence in order to verify what was affirmed by Vasari (1568), Tuscan painter, architect and historian of art of the 16th century, and other Tuscan naturalists regarding the quality of this sandstone.

As a matter of fact, analyses demonstrate that the Pietra Serena sandstones quarried in the hills of Settignano (to the northeast of Florence) and in the Gonfolina area (Lastra a Signa, to the west of Florence), are composed of layers particularly rich in calcite present mainly as sparitic cement. This calcitic cement gives great durability to the stone as is demonstrated by the good state of conservation of some Florentine monuments realized with Pietra Serena.

The city of Florence (Fig. 1) is located in the SE corner of the Firenze-Prato-Pistoia basin, one of the tectonic basins that evolved during the Neogene on the Tyrrenian side of the Apennines thrust and fold belt. The substratum of the basin is mainly formed of Ligurian Units that tectonically overlie the turbiditic formations of the Tuscan Unit (Boccaletti *et al.* 2001).

For centuries, the sandstone outcrops have provided the building material for the city. The particular colour of the city is due to the use of these sandstones: ochraceous shades for the aristocratic palaces, the public administration buildings and civil houses (Pietraforte), and cerulean colours for the large colonnades and the paved streets (Pietra Serena). Pietraforte was the primary building material of the city, while Pietra Serena was used chiefly for ornamental purposes, having its most exalted period during the Renaissance when large blocks of this sandstone were required to carve columns and capitals (Fratini & Rescic 2013). This distinct role (considering the name given to the two stones) suggests that Pietra Serena is a material definitely more workable than Pietraforte. In fact, although both sandstones are sandy sediments that have undergone a process of transformation into rock as a result of the physical process of compaction and cementation (diagenesis), Pietra Serena distinguishes itself with greater textural homogeneity and a clayey matrix that holds together the sand fraction, thus affording a reduced cohesion. Pietraforte, instead, is characterized by the presence of calcite veins and a predominantly carbonate cement that provides a greater compactness (Fig. 2). The easy workability of Pietra Serena is therefore linked to the stone's lower durability, which causes innumerable conservation problems for the city's monuments. Nevertheless, careful study suggests that some of the architectural elements made of Pietra Serena have favourable components that contribute to fairly good conservation conditions.

Pietra Serena from the Etruscans to the 19th Century

Pietra Serena is a material that can be utilized for architectural elements, ornaments, road paving, household furnishings, and even religious and civil objects. The cyclopean blocks of the Etruscan walls of Fiesole (Florence) evidence that Pietra Serena was put to use in the Archaic period. Since that time its use lasted almost continuously until the 19th century. Today, the depletion of many quarries and the consequent high cost of the stone, have determined the use of the Pietra di Firenzuola (Cantisani *et al.* 2013) and Pietra di Santa Brigida (both quite similar to Pietra Serena) where it is required by the historical stylistic context. Artificial stones made up of Portland cement are often utilized especially for road paving.

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Fig. 1. The fluvial lacustrine basin of Plio-Pleistocenic age formed in the post-orogenic distensive phase of the Apennine formation where Florence is located.

Fig. 2. The two types of sandstone in Florence: Pietraforte at the bottom, rich in convolute laminations and calcite veins; Pietra Serena on top. Pietraforte is the building material of the city while Pietra Serena is mainly employed as ornaments and architectonic decorations.

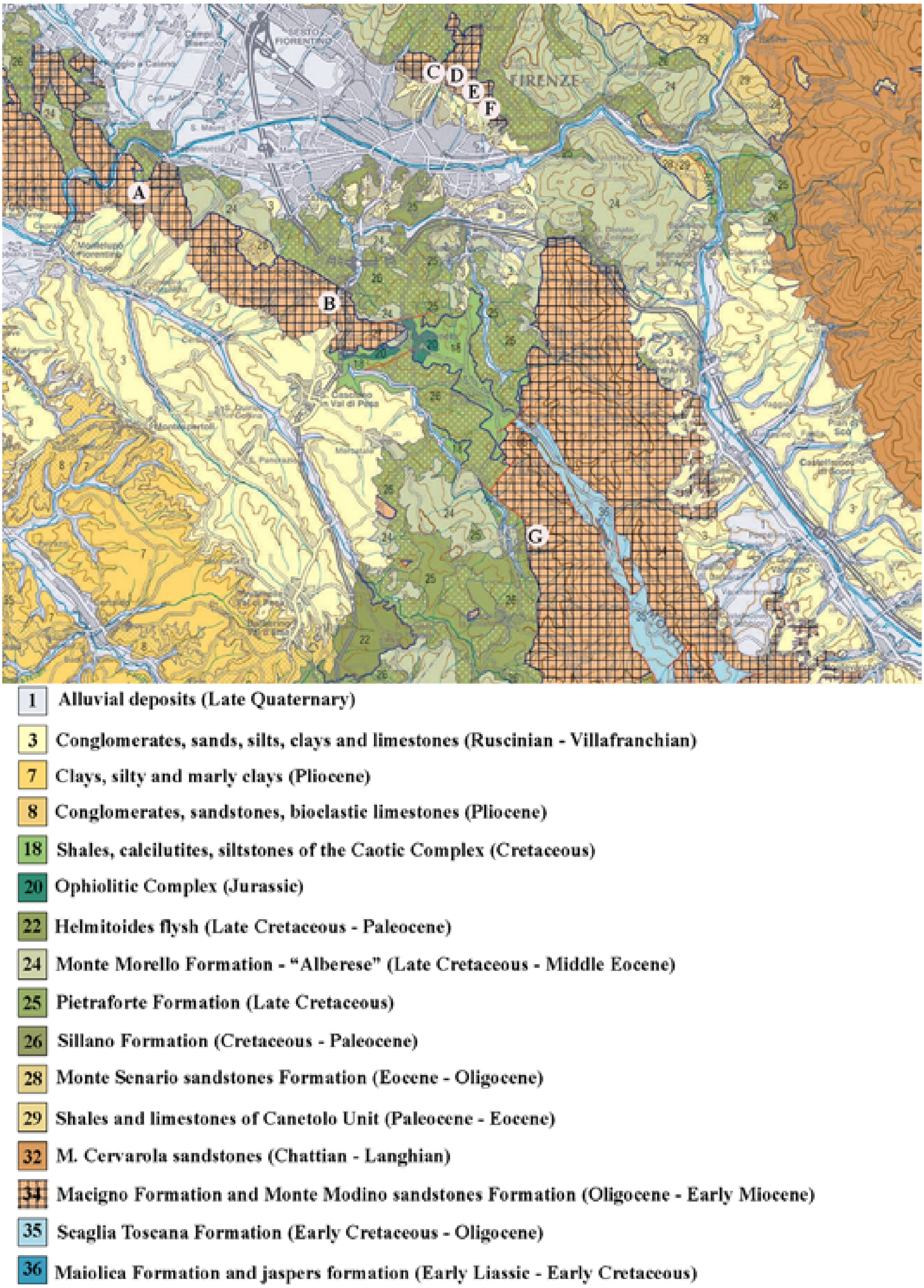

Fig. 3. Geological map of the outskirts of Florence with the locations of the ancient Pietra Serena quarries (geological map 1:250.000 modified after Carmignani *et al*. 2004). A = Gonfolina quarry; B = Tavarnuzze quarry; C = Bolognese quarry; D = Faentina quarry; E = Bonciani-Fiesole quarries; F = Fossato-Trassinaia, Settignano quarries; G = Greve quarry.

Fiesole, a small town on the hills to the north of Florence, gives irrefutable evidence of the use of Pietra Serena in antiquity. An abundance of outcrops attests to this. It should be remembered that some quarries, now almost completely hidden by buildings and/or vegetation growth, were located precisely in the city itself. In 1987, excavations in Piazza Garibaldi revealed the remains of a Roman quarry. Moreover, confirming the excessive exploitation of this material in and around Fiesole, Boccaccio (1313–1375), Tuscan scholar and author of the famous *Decameron*, referred to the hills as an immense heap of stones stained by the leaden colour of the quarries that loomed over Florence.

After the Etruscans and the Romans, the Longobards capitalized on the stone. The presence of some graves made of simple blocks put in place without mortar and covered with slabs, and by one or two capitals reused in the crypt of the Fiesole Cathedral (Salvianti & Latini 1988), corroborate the influence of the Longobards. There is little evidence of the continuing use of Pietra Serena during the early Middle Ages; but, from the 13th century on, with the birth and development of the free city of Florence, the Florentines employed this stone extensively because abundant quantities of the material was available and the quarries were very close to the city. It should be noted that in the past, roads were scarce and not always in optimal condition, and so the possibility of supplying material in areas close to the city was appreciated because it was inexpensive to do so. At first, the active quarries met the demand, but in the 15th century the opening of new quarries in the hills to the north of the city, precisely in the valley of Mugnone, and near the village of Settignano, became necessary (Fig. 3).

There are two reasons that explain this great demand: one was linked to the urban expansion of Florence; the other was due to the new stylistic requirements demanded by famous artists. Brunelleschi (1377–1446), in particular, envisaged the use of monolithic blocks (Fig. 4) and the contrast of grey stone with white plaster; he believed these were salient features for his artistic creations (Figs 5 & 6). Other quarries were opened in more remote areas such as Gonfolina, to the west of the city. For example, the monolithic columns of the San

Fig. 4. The colonnade in Pietra Serena in the second cloister of the Santa Croce Convent (Florence), created by Bernardo Rossellino in 1453.

Fig. 5. The Pazzi Chapel within the Franciscan Convent of Santa Croce (Florence), one of the most extraordinary examples of the Renaissance architecture, which construction was initiated by Brunelleschi in 1429. It is evident that the white plaster finishing contrasts with the grey of the Pietra Serena architectural elements.

Lorenzo Basilica were partly extracted in the Trassinaia quarry (Settignano area) and then some in Gonfolina (Ozzola 1903). The columns of the Loggia of the Innocenti would come from the Trassinaia quarry (De Fabriczy 1891) as reported in a Brunelleschi project. Vasari (1568) highlights the fact that Michelangelo (1475–1564) employed, for the Laurentian Library and the San Lorenzo sacristy, the so-called Pietra del Fossato, a fine-grained variety of Pietra Serena from the Mensola valley (Quarry of Pillars) (Fig. 7) with exceptional durability. According to Vasari, the Pietra del Fossato was selected for use in the constructions of the Uffizi and the Loggia del Mercato Nuovo (Eldmann 1950).

In the second half of the 16th century, during the Grand Duchy, this stone enjoyed such prestige that its use had been linked to the embellishment of the capital city of the Grand Duchy of Tuscany, Florence, to enhance the power of the ruling dynasty. At the time, Banned Quarries were established in which the stone, particularly beautiful and resistant to weathering, could be extracted but only with authorization. These quarries were located between San Francesco and Fontelucente, the hill to the west of Fiesole, and Mulinaccio, near Maiano, east of Fiesole (Targioni Tozzetti 1880).

From this time onwards, the use of Pietra Serena was conjoined with that of Pietra Bigia, a variety of the same sandstone whose most striking feature is a light brown colour and good durability that made it the preferred one for façades (Fig. 8). The most recently opened quarries were in the area of Greve in Chianti (Caprolo quarry) along with the Montebuoni and Tavarnuzze quarries, south of the city.

Nowadays, as we have already mentioned, the quarries of Pietra Serena are almost all closed due to depletion or landscape constraints related to urban planning ordinances and to the proximity of the quarries to Florence. The sandstone most commonly used in the new architectural realization and also in the restorations is quarried in the district of Firenzuola (Apennine north east of Florence) and is named Pietra Serena di Firenzuola. It is macroscopically similar to the Pietra Serena and belongs to the Marnoso Arenacea Formation (Cantisani *et al.* 2013). In addition, the Santa Brigida quarry has

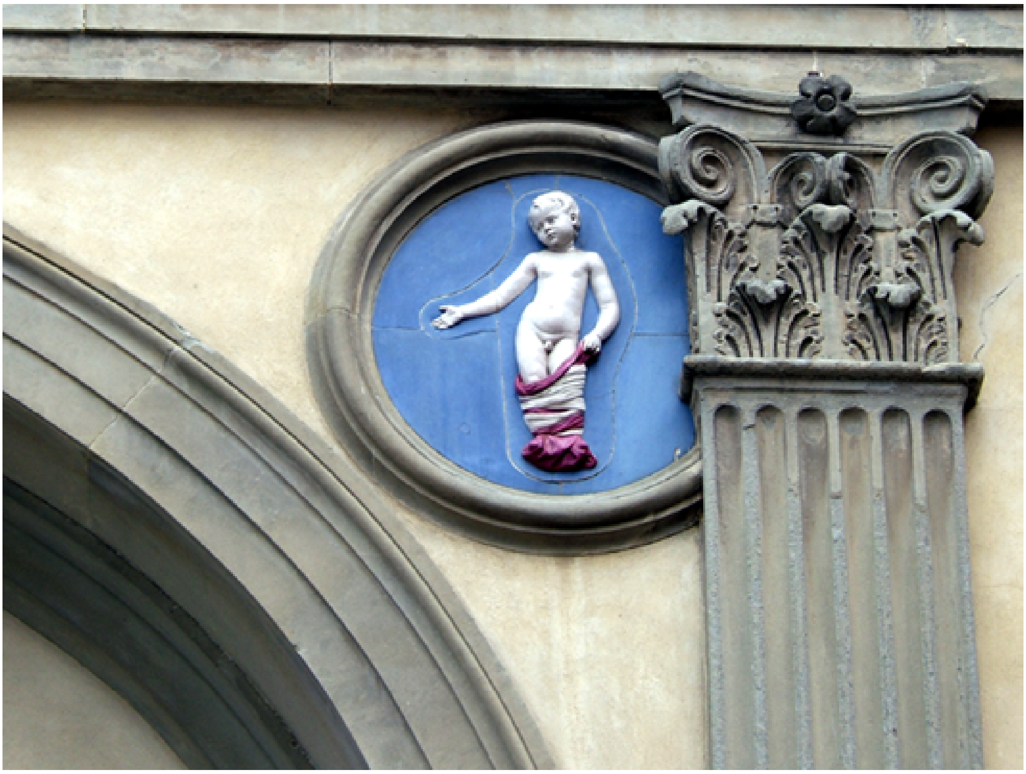

Fig. 6. The Spedale degli Innocenti (Florence) realized by Brunelleschi (1419–1445): a particular element of the façade with its white plaster finishing contrasting with the greyness of Pietra Serena. The façade is adorned with white and blue glazed *terracotta tondi* depicting babies in arms, works of Andrea della Robbia, added in 1487.

recently been reopened. It is located to the east of Florence from where is extracted the Pietra di Santa Brigida, a sandstone similar to the Pietra Serena and belonging to the Monte Senario Formation.

The varieties of Pietra Serena

At the beginning of the 19th century, Targioni Tozzetti (1712–1783), Florentine physician and naturalist, deduced from simple empirical observations that '... in contrast to the uniformity of the mineralogical constituents, is the variability, even in the same layer, of the quantity and quality of cement ... '. In reality, he realized that Pietra Serena and Pietra Bigia belonged to the same lithological type and differed in only several varieties based on colour and resistance to atmospheric conditions. Pietra Serena was described as '... cerulean coloured tending to bluish' and Pietra Bigia 'as earth coloured'. The Pietra Bigia was '... harder and more resistant to weathering even though there was a coarse grained variety of Pietra Serena, called "*ruspa*" being of strong resistance to weathering... '. Therefore, both types had a coarse grained variety of high durability and a fine grained variety that could not resist the effect of weather. Even with respect to chisel workability (i.e. toughness) there were two types: the strong and the soft.

Concerning this last feature, Targioni Tozzetti (1880) writes that the Fiesole quarries between San Francesco and Fontelucente and Mulinaccio-Maiano, belonged to the strong varieties and were included in the already mentioned Banned Quarries, 'but ... it is not known if some of the quarries in the Gonfolina area are included in this category...'.

Moreover Targioni Tozzetti, with enviable precision and almost modern descriptive phraseology, distinguished four varieties of Pietra Serena from Monte Ceceri (Fiesole) that were described as follows:

The first was a very hard stone with grains of various sizes and cement of clear calcite, very hard to work, with low porosity. This kind of sandstone

Fig. 7. Quarry of Pillars, nowadays occupied by a pond, sited below Monte Ceceri (Fiesole) where the Pietra del Fossato was extracted.

when exposed to weathering, takes on a dark patina without affecting its durability as demonstrated by the ancient walls of Etruscan Fiesole.

The second was the *Sereno ordinario* type in which the grain size was finer, but not uniform; the binder was abundant in quantity and mainly made up of clay minerals that do not provide the frost proof characteristics.

The third, called *Sereno gentile*, was fine-grained, with a uniform grain size, and a binder made of clay minerals with a slight amount of calcitic cement. This variety was easy to sculpt and took polishing very well.

The fourth type of *Sereno gentile* had an even smaller and more uniform grain size and a higher amount of calcitic cement. This variety was very favourable to sculpting, with an excellent polished aspect and a good durability even outdoors. This kind of *Sereno gentile* constitutes a particular *facies* of some rare zones of the sandstone formation.

The types of Pietra Serena described by Targioni Tozzetti have to be added to those mentioned in historical documents concerning the accountancy of the material order; for example, the Pietra di Trassinaia and the Pietra del Fossato, whose names are simply linked to the area of origin and not to a different lithotype from Pietra Serena, strictly speaking.

Geological setting and description

Pietra Serena is the name given by masons and architects to the sandstones of the Macigno and Monte Modino Formations (Upper Oligocene/Lower Miocene) cropping out in the Northern Apennines (Abbate & Bruni 1987; Bruni & Pandeli 1992). They were formed in turbidity currents, better known as submarine landslides and capable of moving and transporting large quantities of material from the coastal zone to great sea depths. The finest fraction of the turbidity current is represented by thin pelite levels that alternate with sandstone layers that can reach a thickness of 5 m (Fig. 9). These Formations are part of the Tuscan Sequence of the Northern Apennines in the stratigraphic succession with the Scaglia Toscana Formation (formerly Scisti Policromi). The maximum thickness (reaching about 3000 m) occurs along the Monte Orsaro-Monti del Chianti line (Fazzuoli *et al.* 1985).

Sandstone samples have been collected from the Chianti Mountains near Greve where the outcrops can be referred to the middle–lower Macigno, from the quarries to the south (Tavarnuzze) and to the west (Gonfolina) of Florence (belonging to the top Macigno), and from the quarries on the hills of Fiesole-Settignano belonging to the Monte Modino Formation (Pandeli *et al.* 1994).

Fig. 8. Architectural element in Pietra Bigia (Zuccari Palace-Florence 16th century), a variety of Pietra Serena which underwent an oxidizing process, which nevertheless did not affect the durability.

A petrographical study, performed with an optical microscopy under transmitted light (ZEISS Axio-Scope.A1) mainly reveals sandstones rich in clay matrix (Fig. 10) with a lower amount of carbonatic cement (calcite); while a high presence of calcite as sparitic cement can be observed in some layers of the Trassinaia, Gonfolina, Fiesole, Bolognese and Greve quarries (Fig. 11) (Cipriani 1958; Bruni *et al.* 1994). The clastic granules (coarse grained and fine grained varieties are present)

Fig. 9. The Braschi quarry, along the slopes of Monte Ceceri (Fiesole), one of the few quarries where the stone was extracted from the depths of the mountain, which left stone pillars in order to prevent the fall of the vault.

consist of quartz, feldspars, fragments of metamorphic and magmatic rocks, muscovite and biotite often transformed into chlorite. These sandstones can be classified, according to Folk (1974), as lithic arkoses (Fig. 12).

From the data obtained through mineralogical analysis (X-ray diffraction using a Philips PW 1050/37 diffractometer, with a Philips X'Pert data acquiring system) and calcimetry (Dietrich-Fruhling calcimeter) (Table 1), it is possible to

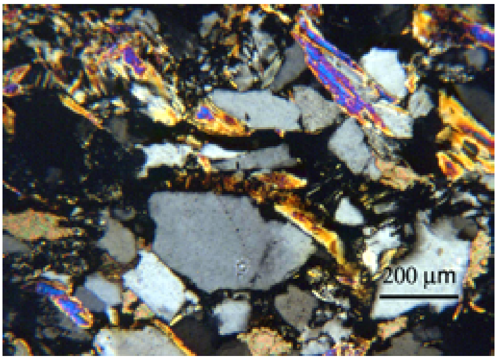

Fig. 10. The clay matrix that binds the sandy fraction of Pietra Serena of the Tavarnuzze quarry (image in thin section, under optical microscopy in transmitted light, xpl).

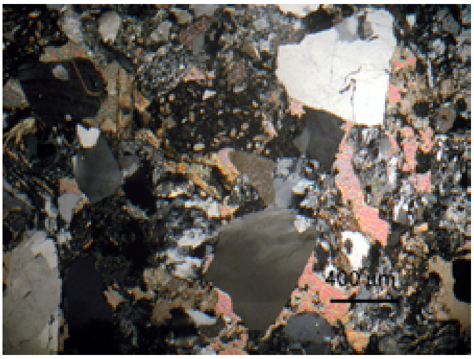

Fig. 11. Cement of sparitic calcite in Pietra Serena extracted from the Gonfolina quarry (image in thin section, under optical microscopy in transmitted light, xpl).

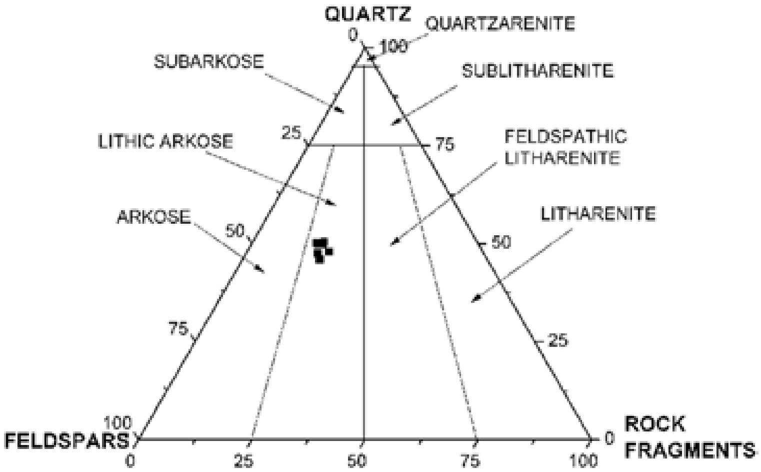

Fig. 12. Classification diagram for sedimentary rocks Q-F-RF (modified after Folk 1974). Black squares represent the analysed samples.

assert that the samples of Pietra Serena, taken from the different quarries surrounding Florence, are mainly differentiated on the basis of the clay mineral associations: the association illite/kaolinite/chlorite/chlorite-vermiculite is found in Greve, Tavarnuzze and Gonfolina. The other quarries are characterized by the illite/kaolinite/chlorite association. The quarries of Tavarnuzze, Faentina and the Quarry of Pillars are poor in calcite (5–7%), while the other quarries show an amount of calcite ranging from 7% to 10% up to 15%, as was found in the Trassinaia, Gonfolina, Fiesole, Bolognese and Greve quarries.

Concerning the Quarry of Pillars, the reduced amount of calcite is anomalous, considering that this quarry was ruled as Banned Quarry (the quality of the sandstone was considered excellent). A possible explanation could be that the sandstone layers of superior quality have been completely extracted.

Studies carried out by Banchelli *et al.* 1997, show that it is possible to distinguish, within the Macigno/Monte Modino Formations, cropping out around Florence, the source of the quarried sandstone according to the associations of the clay minerals contained in the matrix. Such different associations are linked to the location of the quarries in different positions of the stratigraphic succession.

The water accessible porosity (determined through the hydrostatic balance method using a Mettler Toledo balance) and the water absorption coefficient (UNI EN 15801:2010), disclose that the sandstone of the Trassinaia quarry has the lowest values of both parameters, while the Pietra del Fossato (Quarry of Pillars) is the most porous, having also the greater absorption coefficient, followed by the sandstones of Greve, Gonfolina, Faentina, Fiesole, Bolognese and Tavarnuzze (Table 1). No significant correlations of an increase of the absorption coefficient with the presence of swelling clay minerals have been evidenced. These data offer important details about the decay phenomena and the durability of each sandstone.

The chemical analysis of the major elements (Franzini *et al.* 1975) were realized by X-ray Fluorescence on pressed powder pellets using a Philips PW 1480 wave length dispersive spectrometer with Rh anode, while total volatile components were determined as loss on ignition (L.O.I.) at 950 °C on powder dried at 110 °C. This analysis confirms (Table 2) the data obtained with the calcimetry with higher levels of CaO in the samples rich in calcite. The total iron content (expressed as $Fe_2O_3^T$), which is responsible for the chromatic alteration of the stone in place, shows great variability.

Samples have also been collected from architectural elements (columns) found in the cloisters of the Badia Fiorentina and the Church of the Carmine. Petrographical observations of the thin section under a polarizing microscope as well as testing of the content in calcite through calcimetry, were carried out on these samples.

These samples exhibit a good correlation between the state of conservation and the quantity of calcite despite the limited number of analysed samples. The columns of the Orange Cloister in the Badia Fiorentina (15th century) and those of the second cloister of the Carmine Church (16th–17th century) present a calcite amount of 14–15% (Table 3), close to the values of some quarries showing a high content of sparitic calcite (see the Trassinaia, Gonfolina, Bolognese quarries, etc.).

Table 1. *Semi-quantitative mineralogical composition and average of physical characteristics on five samples of sandstone for each quarry*

Quarries	Stratigraphical position (Pandeli *et al.* 1994)	Quartz	Calcite	Plagioclases	K-feldspars	Micas	Clay minerals	Range Calcite/ calcimetry	ICw%	Pw%
Greve	Macigno middle low	xxx	x	xx	x	x	I-Cl-K-ClV	7–10	1.75 ± 0.16	4.51 ± 0.41
Quarry of Pillars Pietra Fossato/ Settignano	Modino-Fiesole intermediate	xxx	x	xx	x	x	I-Cl-K	5–6	1.91 ± 0.24	4.89 ± 0.57
Tavarnuzze	top Macigno	xxx	x	xx	x	x	I-Cl-K-ClV	5–7	1.17 ± 0.17	3.08 ± 0.44
Gonfolina	top Macigno	xxx	x	xx	x	x	I-Cl-K-ClV	7–10	1.57 ± 0.03	4.08 ± 0.83
Bonciani/Fiesole	top Modino-Fiesole + chips of clay	xxx	x	xx	x	x	I-Cl-K	6–10	1.29 ± 0.25	3.36 ± 0.63
Trassinaia/ Settignano	top Modino-Fiesole	xxx	xx	xx	x	x	I-Cl-K	9–15	1.00 ± 0.10	2.63 ± 0.26
Faentina	medium base Modino-Fiesole	xxx	x	xx	xx	x	I-Cl-K	7	1.44 ± 0.01	3.73 ± 0.04
Bolognese	medium top Modino-Fiesole	xxx	x	xx	x	x	I-Cl-K	5–11	1.24 ± 0.45	3.21 ± 1.14

xxx = high content; xx = average content; x = low content; I = Illite; Cl = Chlorite; K = Kaolinite; ClV= Chlorite-Vermiculite; ICw = water absorption coefficient; Pw = effective porosity.

Table 2. *Average chemical composition (% in weight) on five samples of sandstone for each quarry*

Quarries	SiO_2	TiO_2	Al_2O_3	$Fe_2O_3{}^T$	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	L.O.I.
Greve	58.71 ± 088	0.43 ± 0.01	12.78 ± 0.53	4.35 ± 0.08	0.07 ± 0	8.60 ± 0.60	5.80 ± 1.56	1.73 ± 0.01	2.35 ± 0.04	0.09 ± 0	5.13 ± 0.57
Fossato	63.43 ± 3.40	0.47 ± 0.06	13.68 ± 0.95	4.36 ± 0.55	0.006 ± 0	5.60 ± 0.96	3.35 ± 0.62	2.49 ± 0.35	2.58 ± 0.11	0.13 ± 0.03	3.59 ± 0.67
Tavarnuzze	62.37 ± 1.02	0.46 ± 0.06	13.98 ± 0.72	4.30 ± 0.42	0.06 ± 0.01	6.89 ± 0.65	3.30 ± 0.50	2.25 ± 0.14	2.47 ± 0.08	0.10 ± 0.01	3.82 ± 0.27
Gonfolina	58.40 ± 5.98	0.47 ± 0.09	14.51 ± 1.12	4.55 ± 0.73	0.07 ± 0.01	6.95 ± 1.25	5.21 ± 1.68	1.86 ± 0.48	2.64 ± 0.22	0.10 ± 0.01	5.28 ± 1.36
Bonciani	60.49 ± 3.31	0.44 ± 0.02	13.80 ± 0.88	4.28 ± 0.43	0.08 ± 0.02	5.05 ± 1.02	5.30 ± 2.05	2.28 ± 0.26	2.57 ± 0.15	0.11 ± 0.01	4.72 ± 0.76
Trassinaia	57.65 ± 2.61	0.50 ± 0.04	13.79 ± 0.43	3.94 ± 0.34	0.11 ± 0.05	4.50 ± 1.64	7.79 ± 3.05	2.38 ± 0.24	2.14 ± 0.38	0.11 ± 0.02	7.08 ± 2.08
Faentina	59.56 ± 1.05	0.47 ± 0.08	13.96 ± 0.50	4.58 ± 0.41	0.08 ± 0.04	6.68 ± 0.70	5.60 ± 1.75	2.15 ± 0.21	1.30 ± 0.15	0.12 ± 0.01	4.26 ± 0.58
Bolognese	64.93 ± 4.84	0.22 ± 0.27	14.86 ± 2.53	1.89 ± 2.33	0.06 ± 0.08	5.96 ± 2.95	3.39 ± 4.28	2.50 ± 1.99	1.30 ± 1.56	0.12 ± 0.03	4.80 ± 1.64

LOI = Loss On Ignition.

As previously mentioned, the main characteristics that differentiate the four types of *Sereno* from that of the Monte Ceceri described by Targioni Tozzetti are the grain size, grain size distribution and the nature and quantity of the calcitic cement. These features also explain the close link with the quality of the stone itself particularly as regard to its durability (Eldmann 1937, 1950). The amount of calcitic cement is of the greatest importance in terms of durability because it is closely connected with the mechanical characteristics of the stone.

The decay of the stone is essentially linked to natural physical and physical-chemical processes due to the concomitant action of two factors: sudden temperature changes and humidity. Water can perform in several ways: by removing the clay matrix via a purely mechanical washing action, leaving the stone completely disaggregated, and, by causing swelling of the crystal lattice of clay minerals thus leading to the typical exfoliation and superficial disintegration (Fig. 13). The action of water on the calcite interstitial fraction of the stone can cause dissolution and precipitation which leads to crust formation that has greater cohesion with less porosity. The crusts that have been formed tend to fall off and then reform with the progressive destruction of the affected architectural element. The effect of water penetrating into the pores is also relevant because it can freeze during low temperatures leading to the disintegration of the stone (Malesani *et al.* 2003).

These aspects lay out how the processes of decay of this sandstone are regulated by its mineralogical-petrographical characteristics and physical properties. In fact, an increase in the percentage of calcitic cement produces a lower material porosity. This means, in general, that there will be less water circulation inside the stone and therefore a reduced chance of calcite dissolution-precipitation, leaching of clay minerals, and the development of internal stresses linked both to the freezing-thawing phenomena and the swelling of clay minerals.

Therefore, it is reasonable to surmise that the varieties of Pietra Serena, famed for their good durability, were those in which a greater amount of calcitic cement was present (Eldmann 1937, 1950). However, it is important to point out that within the Macigno Formation there probably existed zones and layers, today completely depleted, in which the amount of calcitic cement was still higher than the average. For example, the materials used for the ancient Etruscan walls extracted from the so-called Banned Quarries in the area of Fiesole, seem to belong to these varieties; and also those used for the columns of Santo Spirito and San Lorenzo, some of which came from the

Table 3. *Content of calcite % (calcimetry) in the samples of sandstone from historical artefacts*

Historical artefacts	Number of samples	$CaCO_3$
Badia Fiorentina	23	12 ± 3
Chiesa del Carmine	31	10 ± 2

Quarry of Pillars (Pietra del Fossato) and the Trassinaia and Gonfolina quarries.

Our studies, carried out on the apparently more resistant layers existing in some of the earliest utilized quarries, were finalized in order to verify this hypothesis. Regrettably, it was not possible to sample some of the quarries cited in historical sources (Targioni Tozzetti 1880), such as Fontelucente and Molinaccio, because of inaccessibility. The Quarry of Pillars, where the Pietra del Fossato was extracted, has been sampled only partially because of the existence of an artificial lake at the bottom of the quarry face. Also to be noted is the fact that in these quarries the layers more resistant to decay might not have been sampled because they were completely extracted. For this reason, the analytical data of the sampled quarries, do not always justify the high durability found on ancient works of art.

Conclusions

The mineralogical, petrographical, chemical and physical data of several quarries of Pietra Serena sandstone located around Florence have highlighted some differences related to the durability of this material. The cerulean and airy colonnades that have made famous the architecture of the Florentine Renaissance are today in a relatively good state of conservation primarily because very careful selection by architects and craftsmen of the stone material had been effectuated. They chose the sandstone layers that were richer in calcite. The reason was that most of the sandstone layers that constitute the Pietra Serena outcrops have a composition that does not guarantee sustainable durability.

This research confirms, with analytical data, what Vasari (1568) and, later on, Targioni Tozzetti

Fig. 13. Decay of Pietra Serena along the columns of the cloister of San Marco Convent (15th century, Florence): the process develops mainly through exfoliation and detachment of crusts.

(1880) alleged concerning the quality of some outcrops of Pietra Serena. Nevertheless, the analyses showed that some of the quarries that according to Vasari (1568) produced a very durable stone nowadays do not have good material. Such incongruity may be explained either by the fact that the layers quarried in the past have been exhausted, or because the ancient quarry fronts, in some cases (for example the Quarry of Pillars) are now inaccessible.

The data collected show that in the Trassinaia Gonfolina, Fiesole, Greve and Bolognese quarries there are sandstone layers significantly richer in calcite and mainly present as sparitic cement. Analytical data on samples taken from Florentine architectural artefacts that still exhibit a satisfactory state of conservation confirm that this characteristic affords the stone adequate durability.

Please note that all authors of this chapter should be considered as principal authors.

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