

Serpentine and ophicalcite in the architecture of eastern Liguria and as decoration of Tuscan religious buildings

Highlights:

- broadening the knowledge related to the use of serpentine together with that of a reddish brecciate variety of this lithotype, an ophicalcite
- As for ophicalcite, a lower durability compared to serpentine can be observed
- this material (serpentine), despite to its apparent compactness, can show significant decay due to physical processes
- this material (serpentine) is no longer quarried in Liguria and Tuscany and for replacements, serpentinites from Alpine area are used
- the restoration interventions on this material foresee the replacement or plastering

**Serpentinite and opicalcite in the architecture of eastern Liguria and as decoration of
Tuscan religious buildings**

Fabio Fratini^a, Silvia Rescic^b, Daniela Pittaluga^c

^aCNR-ISPC (Institute of Heritage Science), via Madonna del Piano n10, 50019 Sesto F. (FI) Italy

^bCNR-ISPC (Institute of Heritage Science), via Madonna del Piano n10, 50019 Sesto F. (FI) Italy

^cArchitecture and Design Department (DAD), University of Genoa, School of Specialization in Architectural Heritage and Landscape (SSBAP), Stradone di Sant'Agostino 37, 16123 Genova

*Corresponding author: Silvia Rescic silvia.rescic@cnr.it

Declarations of interest: none

Funding: this research did not receive any specific grant from funding agencies in the public, commercial or not-for-profit sector

Serpentinite and ophicalcite in the architecture of eastern Liguria and as decoration of Tuscan religious buildings

Abstract

The serpentinite is a metamorphic rock with a particular texture and colour ranging from light to dark green that was used in the Middle Ages architecture of Eastern Liguria and Central Tuscany as an element of embellishment of high value. This value was in relation to its aesthetic aspect but also to the high processing cost due to its hardness, requiring specialized workers. This research aims at broadening the knowledge related to the use of serpentinite together with that of a reddish brecciate variety of this lithotype, an ophicalcite traditionally called “Rosso di Levante”. Conservation issues of these two materials, which are affected mainly by physical phenomena, will be highlighted.

Key words: serpentinite, ophicalcite, Rosso di Levante, Marmo verde

1. Introduction

Italy is a territory characterized by a great variety of landscapes: the sharp peaks and deep valleys of the Alpine chain, the flat Padan plain, the Apennine Mountains, often characterized by rounded tops, the gentle rounded hills of the Crete Senesi and Adriatic coast, just to recall some territories. All these landscapes reflect the complex geology of Italy, which is characterized by a great variety of lithological types. In these landscapes, each village and town have a unique identity given by the architecture typologies together with the colours of the building materials. Indeed, the use of these materials was dictated primarily by the local availability (Rodolico 1953) and favoured by the presence of many independent little states lasting until the unity of Italy, reached in the second half of the XIXth century. Regarding the Ligurian coast, the most used building stones in the western area (province of Imperia) were the marly limestones and calcareous sandstones of the Helminthoid Flysch sequences, whereas in the Albenga-Finale area the Oligo-Miocene organogenic limestones traditionally called “Pietra di

Finale” were utilized. In the Genoa area and in Tigullio the marly limestones of the Monte Antola Cretaceous flysch were used, whereas in the eastern area the Cretaceous sandstones of Monte Gottero and the Oligocene sandstones of the Tuscan Series were utilized. Furthermore, in the Gulf of La Spezia the black Triassic limestones were used. In addition, in most part of the region the roofs were realized with slate tiles quarried in Lavagna valley.

As for Tuscany, the urban areas grown at the foothills of the Apennines (Florence, Pistoia, Arezzo, Cortona), were characterised by the use of Oligocene sandstones (Pietra Serena) with the exception of Prato where a marly limestone called “Pietra Alberese” was extensively used (Fratini & Rescic 2013). The lithotypes cropping out in Monte Pisano, particularly quartzites, were widely used in Pisa and Lucca. The towns and villages of central-southern Tuscany are generally more heterogeneous regarding the building materials: Siena and San Gimignano, located close to large outcrops of Pliocenic clay, made extensive use of bricks. In these two towns, however, in the most ancient period (XII-XIIIth century), the Calcare Cavernoso (the stone for tower) was also used while more recently (from the XIVth century), Pliocenic sandstone and travertine were used (Giamello et al. 1992). Pliocenic sandstone and travertine also characterise the architecture of Volterra, Pienza and Montepulciano, while in Massa Marittima and Rapolano the principal building material is travertine.

Concerning these two regions, the aim of this research is broadening the knowledge related to the use of serpentinite and opicalcite linked to the presence of local outcrops.

The term “serpentino”, used in Tuscany for many centuries, refers to the appearance similar to a snake’s skin (in Italian “serpente” means snake) (Figure 1).



Figure 1. Serpentinite block with the appearance of snakeskin, “ranocchiaia” variety (Pavone strembed-Tuscany)

This rock was described by the Tuscan naturalist Targioni Tozzetti (1768) while Brongniart, in 1813, used the term “ophiolite” as Hellenism for “serpentino”. The serpentinite is a lithotype originated through the metamorphism, in an oceanic environment, of a peridotite, a magmatic rock belonging to the Earth mantle. The rock can be easily polished and shows different shades of green, from light to dark till black, sometimes with bluish reflexes, and a uniform texture, sometimes crossed by whitish/bluish veins. The “ranocchiaia” variety, (in Italian means “like a frog”) has a light green colour and it’s characterized by a network of thin dark veins (Figure 1).

The ophicalcite is a brecciate variety of serpentinite, often reddish in colour, traditionally called “Rosso di Levante”, widely used in the XVIIth-XIXth centuries for internal decoration and in the first half of XXth century for external cladding and paving (Figure 2).



Figure 2. Ophicalcite fragment: “Rosso Levante” variety

Serpentinite is no longer quarried in Liguria and Tuscany while little quarries of “Rosso di Levante” are still active near Levante, precisely in Montaretto (Eastern Liguria) producing a small amount of material.

2. Geological setting and petrographical characterization

The serpentinite utilized in the architecture of eastern Liguria and north central Tuscany belongs to the ophiolitic complexes of the northern Apennine, remnants of both embryonic and slow-spreading type oceanic lithosphere, exposed in the tectonic units of eastern Liguria and Tuscan-Emilian Apennine (Figures 3-4).

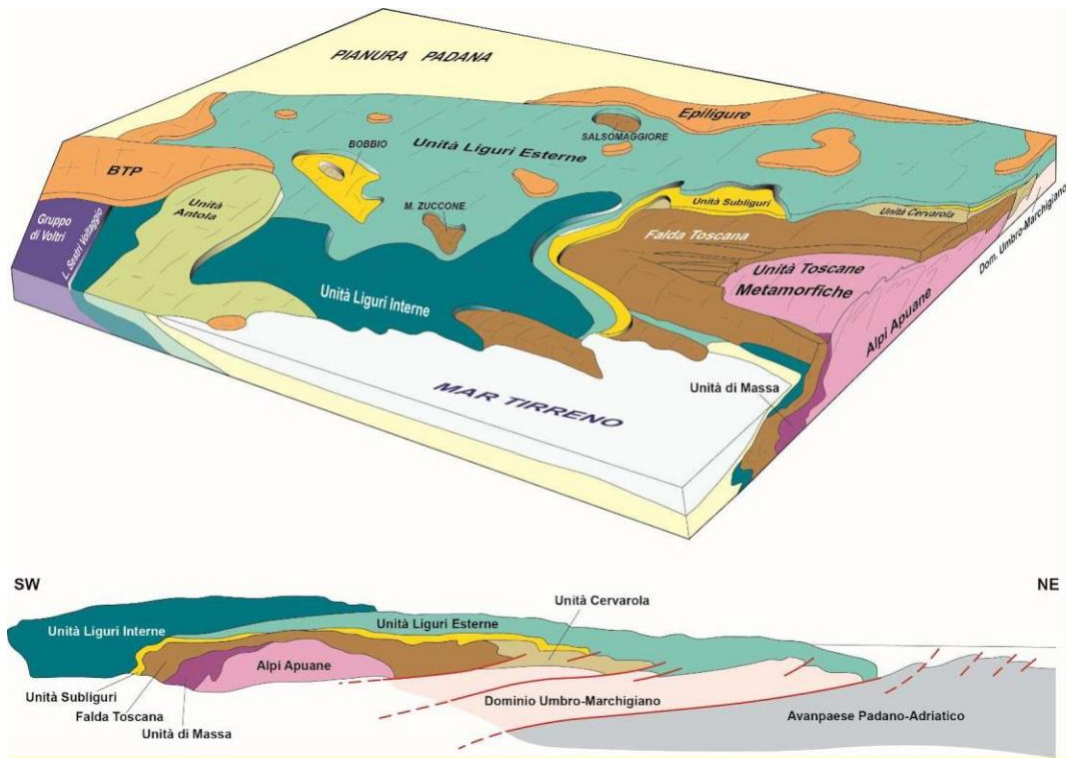


Figure 3. Tectonic scheme (after Elter 1994, modified)



Figure 4. Map with the location of the main ophiolite outcrops (market in black) (after Bortolotti & Passerini 1970, modified)

These ophiolite complexes, generally constituted by the association of serpentinite, gabbros and basalts, are found within the Ligurian tectonic units, which represent the uppermost nappes of the northern Apennine stack and are subdivided into two main groups (Marroni et al. 1998; Bortolotti et al. 2001):

- the ophiolites of the external Ligurian units are associated with rocks of continental origin and are attributed to a marginal ocean domain;
- the ophiolites of the internal Ligurian units show no relationship with continental material and are ascribed to an oceanward portion of the Ligurian-Piedmontese basin.

The serpentinites were formed through hydration of peridotites in a metamorphic process of quite low temperature (below 500 °C) during their uplift from the upper mantle to the bottom of a growing oceanic basin. Both the external and internal Ligurian units suffered a polyphase deformation during the Alpine orogenesis that led to their emplacement in the late Oligocene-Miocene (Marroni et al. 2004). Peak orogenic metamorphism of both the internal and external Ligurian ophiolites occurred under prehnite-pumpellyite facies conditions (Lucchetti et al. 1990). During the hydration process (serpentinization), the primary Mg-rich minerals (olivine, orthopyroxene, and clinopyroxene) were transformed in serpentine-group minerals (approximate formula $Mg_3Si_2O_5(OH)_4$). Secondary minerals are magnetite, chromiferous spinel, brucite, talc, pyrite, calcite, and magnesite.

The macroscopic structure of a serpentinite can be relatively uniform, interrupted by whitish/bluish veins of fibrous serpentine (chrysotile) or characterized by a dense intertwining of light veins as in the variety "rannocchiaia".

At the microscopic level, pseudomorphic bastite structure, mesh pseudomorphic structure and hourglass texture pseudomorphic structure are distinguished (Figure 5). The bastites are "ghosts" of the serpentinization process of pyroxenes while the mesh and hourglass structures represent the "ghost" of the serpentinization process of olivine (Wicks & Whittaker 1977; Evans et al. 2013) (Figure 6).

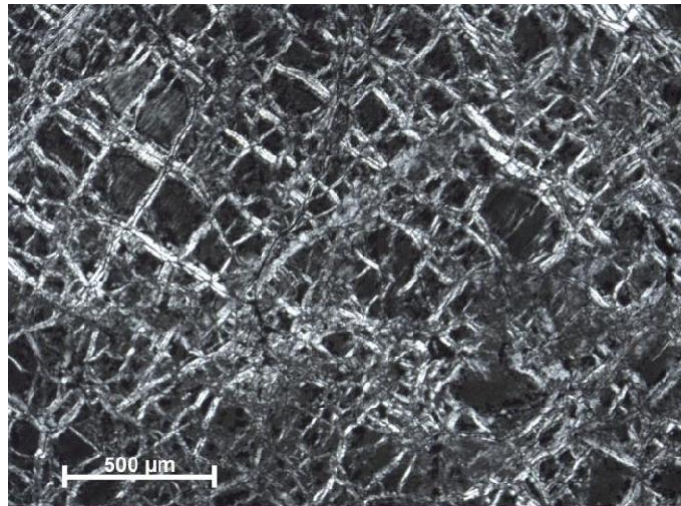


Figure 5. Mesh structure in a serpentine (image in thin section at the optical microscope, crossed nicols) (façade of the Cathedral of Florence)

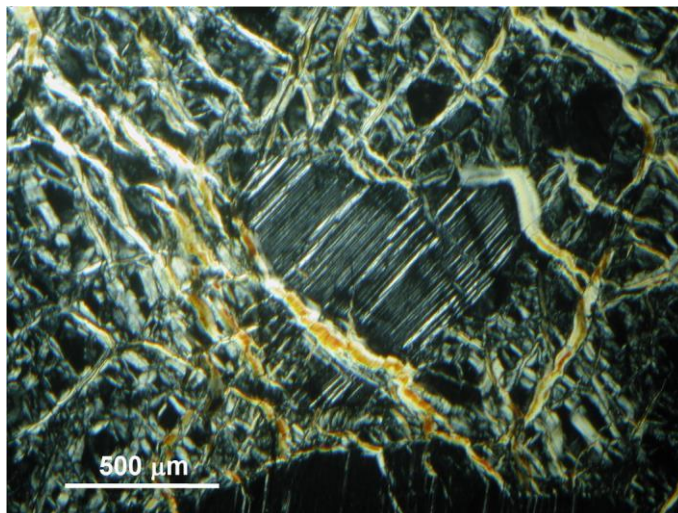


Figure 6. "Ghost" of the serpentinization process of a pyroxene in the centre of the image with surrounding mesh and hourglass structures (image in thin section at the optical microscope, crossed nicols) (façade of the Collegiata of Sant' Andrea-Empoli)

These structures are present in variable amounts and are in any case made up of lizardite type serpentine. There are also veins consisting of a chrysotile-like serpentine (Figure 7) which, when abundant, form the dense net that characterizes the "rannocchiaia" variety (see Figure 1). When

magnetite is present in small granules, the rock has a dark green colour while if the granules are larger, the colour is light green.

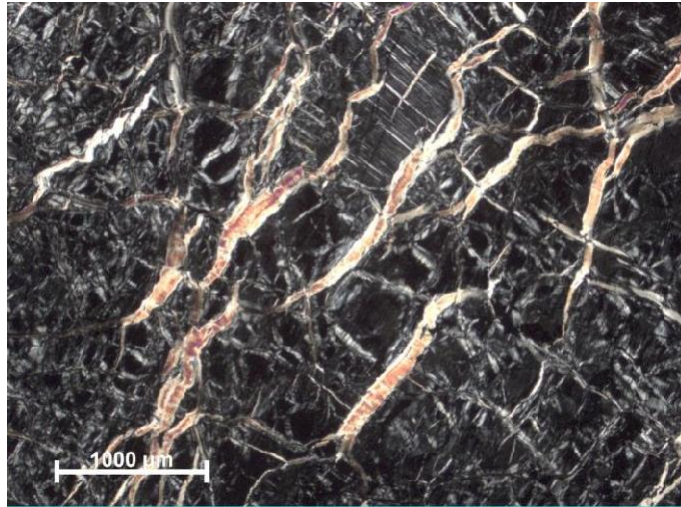


Figure 7. Chrysotile veins in a serpentinite (image in thin section at the optical microscope, crossed nicols) (façade of the Collegiata of Sant'Andrea-Empoli)

Ophicalcites are tectonic breccias which show evidence of ductile to brittle deformation under progressively lower temperature conditions. They consist of serpentinites disrupted by a polyphase network of calcite veins. Their genesis was referred to the detachment faulting that led to mantle uplift at the ocean floor (Treves & Harper 1994; Molli 1995; Principi et al. 2004). Among the ophiolite breccias of eastern Liguria, laying between the serpentinite basement and the overhanging sedimentary sequence, Cortesogno et al. (1980) distinguished different varieties according to fragments composition (“Breccia di Levante”, “Rosso di Levante s.s.”, “Breccia di Framura”, “Breccia di Rossola”).

As for “Rosso di Levante”, it occurs at the top of serpentinites and consists of highly fractured serpentinites with fractures filled with white sparry calcite, talc (in the most recent fractures), serpentinite fragments and microsparitic calcareous mud. Circulation of hydrothermal fluids along the fractures caused the partial carbonation of serpentine and oxidation of magnetite into hematite, with a

strong reddish hue. The microsparitic mud shows pink hue of various intensity. Thanks to its composition, texture and low porosity, this material can be polished obtaining slabs of aesthetic value.

3. Historical use of serpentinite in Liguria

The serpentinite was used since the Middle Ages as building material and for architectonic decoration in some villages of eastern Liguria, in relation to the presence of wide outcrops of this rock in the territory. In the remaining part of the region the serpentinite was used only for architectonic decoration of religious building, particularly in Genoa. Among these villages, the coastal localities of Levanto, Monterosso and Vernazza in La Spezia province must be reminded (Figure 8).

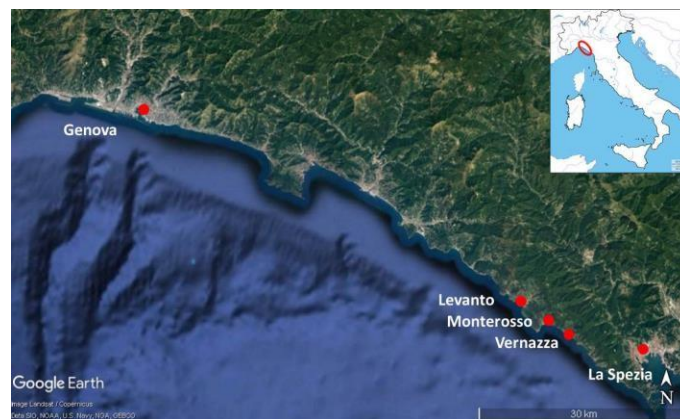


Figure 8. The villages of eastern Liguria showing a widespread use of serpentinite (after Google Earth, modified)

3.1 *Levanto*

Levanto is sited at the bottom of a small gulf which, much deeper in Middle Ages, was progressively filled with sediments. The birth of the village, as well as the other villages described in the following, dates to the XIth - XIIth centuries, following a widespread phenomenon that leads the populations originally settled in the mountains to migrate to the coast. However, the actual development of the village began in the XIIIth century when the city of Genoa decided to expand to the East looking for new trans-Appennine passes for its maritime traffic (Busco & Montagni 1995; Boato & Cagnana 1998). The geological characteristics of the Levanto territory have strongly influenced its architecture up to

the beginning of the XIXth century. The quarrying activity is documented since the XIIth century and the consequent skill in stone working had reflections in the choice of the materials to be used (Del Soldato & Pintus 1984, 1985). Indeed, the mountains bordering Levanto are mainly constituted by serpentinites and sandstones (Abbate 1969; Cortesogno et al. 1981, 1987; Bortolotti et al. 2008) that were adopted both for load bearing and not load bearing structures, depending on their mechanical characteristics and workability (Mannoni 1976, 1990, 1994). These materials were supplied both from rock outcrops and as pebbles from the Ghiararo stream. Nevertheless, also stone materials from abroad were used like slate for the roof tiles and Apuan marble for architectonic decoration.

The serpentinite is found (together with sandstones and bricks) as pebbles and irregular blocks, in the generally rendered mixed masonries characterizing most of the civil buildings. The same kind of mixed masonry is present in the city walls, dating back to the XIIIth century, and rebuilt in the XVIth century, and in the castle, which is included in the defensive walls. It is also found as corner stone in roughly shaped blocks. Nevertheless, the most interesting use of the serpentinite is in the noble, commercial, and public buildings where the material was cut and worked in regular blocks for the realization of architectural elements (arches, jambs, columns) and as dressed stone obtaining a special aesthetic effect (Figure 9). The use of serpentinite as dressed stones for load-bearing walls testifies to the wealth the village had achieved in the Middle Ages, thanks to the presence of the channel-port (buried in the XVIIth century) that favoured the maritime trade. Indeed, the processing of this lithotype to make regular blocks was quite expensive because time consuming and requiring expert stonecutters. The serpentinite outcrops are in fact characterized by a fracturing without preferential directions, from which only irregular shaped blocks are obtained. In addition, the sound material is very hard and tends to chip with processing (Fratini et al. 2019).



Figure 9. Merchant building of the XIIIth-XIVth century where the serpentinite was used as regular blocks in the masonry (Levanto)

A noteworthy public building is the “Loggia Comunale”, one of the few late medieval buildings of this type that survived in Liguria. The main façade consists of five brick arches that rest on two end pillars and four columns with Romanesque capitals, all in serpentine (Figure 10).



Figure 10. Loggia Comunale”, late medieval public building
with four columns in serpentine (Levanto)

As for the religious buildings, the serpentinite was used in the parish church of Sant'Andrea (Figure 11).



Figure 11. Levanto, interior of the church of Sant'Andrea,
characterized by the use of serpentinite in the two massive
pillars that delimit the presbytery and in the ribs of the vault, in
the arches of the central nave, in the capitals and the dark strip
of the columns

Built in the first half of the XIIIth century and enlarged in the XVth century, it is a remarkable example of Ligurian Gothic. The façade is characterized by a cladding in strips of white Apuan marble and green serpentinite. The interior, with five naves, is characterized by the use of serpentinite, present in the two massive pillars that delimit the presbytery, in the ribs of the vault of the presbytery itself, in the arches of the central nave, the capitals and the dark strip of the columns that recall the decoration of the façade. Another religious building is the former Augustinian Convent, dating back to the mid-XVIIth century. Built on a previous XIIIth century building which was part of the numerous warehouses located along

the channel–port, it has a serpentinite dressed stone façade with pointed arched portals, evidence of the transformations undergone (Figure 12).



Figure 12. Levanto, former convent of the Augustinians, where the serpentinite was used as regular blocks in the masonry

The construction of the railway Sestri Levante-La Spezia, inaugurated on 1874, and the realization of the road to Bracco pass, favoured, between the late XIXth- early XXth century, the touristic development of the village with the growing of an architecture characterized by palaces, villas, and buildings where the reference to the eclecticism rules is evident. Some of these buildings show the use of the local serpentinite generally in roughly shaped blocks (Figure 13).



Figure 13. Levanto, eclectic villa built in roughly shaped serpentinite blocks.

3.2 Monterosso and Vernazza

Monterosso and Vernazza, together with Corniglia, Manarola and Riomaggiore, are part of the Cinque Terre. These are five villages located along the coast southeast of Levanto. Since 1997 they are included in the UNESCO World Heritage Sites for being "a cultural landscape of exceptional value that represents the harmonious interaction established between man and nature", a landscape that is the result of a traditional way of life that continues to play an important socio-economic role for the inhabitants. In fact, man's work has shaped the steep slopes overhanging the sea with an infinite series of terraces, "fasce", in order to favour their practice of agriculture.

Until 1874, when the Sestri Levante-La Spezia railway line was inaugurated, these villages could only be reached by sea or through a network of steep paths and it was precisely this isolation that guaranteed the establishment of an economy of self-sufficiency with the products of agriculture and fishing which made possible the generation of the terraced landscape and the structure of the villages (Fregola & Stringa 1978). Monterosso is the westernmost village of the Cinque Terre. The village, of medieval origin, has a linear structure arranged along the Buranco stream and overlooks a large inlet bordered to the west by Mesco promontory.

As well as in Levanto, most of the civic buildings show masonries realized with pebbles and irregular blocks of serpentinite. Nevertheless, the serpentinite is also present as dressed stone in the medieval remains of the Loggia del Podestà, now incorporated in a modern building and in the bichrome façade of San Giovanni Battista parish church, built between the XIIIth-XIVth century and restored in the Baroque time. Next to the apse is the bell tower (originally the watchtower of the Genoese fortifications) where serpentinite is used as corner stones.

Vernazza, southeast of Monterosso, grew up along the Vernazzola stream, which forms its central axis, and flows into the sea in a small inlet bordered by a promontory. The village is suggestive with the square overlooking the marina rich in valuable architectural elements such as loggias, arcades, worked

portals, and masonries in green serpentinite ashlar (Figure 14), evidence of a particular wealth period the village went through, if compared to the other Cinque Terre villages.



Figure 14. Vernazza: the square overlooking the marina with buildings rich in valuable architectural elements and masonries in serpentinite dressed stones.

The parish church of Santa Margherita d'Antiochia (XIVth century) stands in the square facing the sea with the imposing octagonal belltower that rests on the four pillars of the presbytery, made of serpentinite. The ribs and pendentive of the cross vaults of the nave, part of the masonry of the apse and of the side facing the marina are also in serpentinite (Figure 15).



Figure 15. Vernazza, the apse of the church of Santa Margherita d'Antiochia, where the serpentinite has been used as regular blocks in the masonry

3.3 Other use of serpentinite

In this territory the use of serpentinite is not limited to civil and religious architecture, but it is interesting to observe that it also affects transport infrastructures and paving decoration. As for transport infrastructures, it is worth remembering the XIXth century railway artefacts between Monterosso and Deiva, a village north-west of Levanto: indeed, retaining walls, arches of the bridges, entrance arches of the numerous tunnels and their internal lining, were realized with rough-hewn blocks of the local serpentinite (Figure 16).

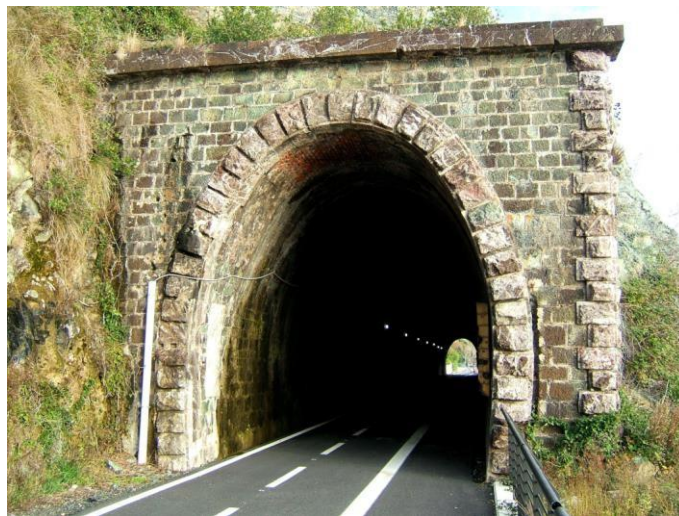


Figure 16. Entrance arch of a tunnel of the XIX railway in serpentinite and opicalcite blocks, now transformed into a cycle path after the construction of the new line

As regards paving decoration, a particular use of serpentinite is in the art of the "rissêu", term which in Genoese language means pebble. It is a particular mosaic made using pebbles that is typical of churchyards and gardens of villas and palaces in Liguria (Figure 17).



Figure 17. Bogliasco, churchyard of the parish church of Nativity with a "rissêu" decoration in white marble and green serpentinite pebbles dating back to 1767

This paving decoration developed in Liguria from the XVIth century, probably following contacts with the Byzantines in the Eastern Mediterranean. The "rissêu" is laid on a base consisting of a "dry mixture" of lime and sand where the design to be made is traced. The decoration is mainly two tone white- black. The original white pebbles are of quartz or calcite (now also of marble), the dark ones of serpentinite and are leveled on the laying side to better adapt them to the base on which they are fixed.

4. Historical use of serpentinite in Tuscany

The maximum use of serpentinite as an architectural decoration material can be found in the religious architecture of Tuscany. This use dates to the XIth century with the flowering of Romanesque architecture (Gurrieri, 1989; Ruschi 1989). It is always a local use linked to outcrops of limited extension widespread in the territory of the region (Gurrieri 1974). The serpentinite can be observed in Florence, Prato, Pistoia, Siena, Volterra (Figure 18), but also in the churches of the countryside villages.



Figure 18. Towns of north-central Tuscany where the use of the serpentinite is widespread (after Google Earth, modified)

It is generically called "Green marble" and locally, in the territory of Florence-Prato-Pistoia "Verde di Prato", "Nero di Prato" (Repetti 1839); "Black Marble" (Villani 1345; Guasti 1887), "Paragone" (which means "black of comparison") (Del Riccio 1597; Vasari 1546).

The use is mainly for polychrome cladding and for floors, more rarely as column drums. As defined by Nardini Despotti Mospignotti (1902), in the external cladding this polychromism can be "decorative/architectural", highlighting the architectural parties, or "lithotomic polychromism" which is expressed with alternations of light and dark stones in horizontal rows without respecting the architectural elements. The light stone is generally marble but in Prato is Pietra Alberese limestone and in Pistoia Pietra Alberese together with travertine.

4.1 Florence and Pistoia

In Florence the serpentinite can be found in the Baptistery, in the Santa Maria del Fiore Cathedral, in the churches of Santa Maria Novella (Figure 19), Santa Croce, San Miniato a Monte, in Badia Fiesolana and in the columns of the nave of the church of S.S. Apostles. In Pistoia the serpentinite was used in the decoration of the Baptistery, in San Zeno Cathedral, San Giovanni Fuorcivitas, Sant'Andrea, San Bartolomeo in Pantano, San Pier Maggiore, San Paolo, in the Palazzo dei Vescovi. The serpentinite used in these cities comes from the large outcrop of Mt. Ferrato, near Prato.

In the surroundings of Florence there is also the Franciscan church of Santa Croce in Figline Valdarno which serpentinite rows comes from Impruneta, a village south of Florence, famous for the production of earthenwares.



Figure 19. Particular of the Renaissance façade of Santa Maria Novella in Florence, realized by Leon Battista Alberti in the second half of the XVth century

4.2 Prato and Empoli

In Prato the serpentine can be found in Santo Stefano Cathedral (Figure 20) where it was used in the bichrome cladding of the façade and side walls and in the columns of the nave. Moreover, this stone was used in the columns and cladding of the Vescovado romanesque cloister (XIIth century), in the bichrome cladding of San Francesco, San Domenico and Santa Maria delle Carceri, in the gothic portal of San Niccolò di Bari, and in the Emperor Castle.

In the outskirts of Prato, the apses of the Church of Sant'Ippolito in Piazzanese are a unique example where the serpentinite was used as masonry material (Figure 21).

In Empoli the outstanding monument where the serpentinite was used as decoration material is the Romanesque façade of the Collegiata di Sant'Andrea (XIth century). As well as for Florence and Pistoia, the serpentinite used in these cities comes from the large outcrop of Mt. Ferrato.



Figure 20. Prato, the bichrome cladding of the Cathedral of Santo Stefano with the Donatello and Michelozzo pulpit dating back to the first half of the XV century (where: S = serpentinite; A = Alberese limestone; AW = wheatered Alberese limestone)



Figure 21. Church of Sant'Ippolito in Piazzanese where the serpentinite has been used as regular blocks in the masonry (Galciana- Prato) (XI century)

4.3 Siena and Volterra

In Siena, the serpentinite was used in the Gothic portals of the Palazzo Pubblico, in the bichrome cladding (together with the white marble of Montagnola Senese) of the Romanesque Gothic Assumption Cathedral, in the green strips of the nave columns, in its precious floor, in the bichrome cladding of the unfinished New Cathedral, in the Archbishop's palace, in the decoration of the pointed arches of the oldest part of the Spedale of Santa Maria della Scala, in the lunette of the entrance portal of San Donato. Moreover, the serpentinite constitutes the black half of the "Balzana", the emblem of Siena (Figure 22). Historically this serpentinite was quarried at Crevole and Vallerano, near Murlo, 25 km south of Siena (Giamello et al. 1992).



Figure 22. The Gothic portals of the Palazzo Pubblico with the "Balzana", emblem of Siena, where the dark half is made of serpentinite

In Volterra, the serpentinite is found in the bichrome cladding of the Baptistery, in the entrance portal and in the bichrome cladding of the apse of Santa Maria Assunta Cathedral, in the mullioned windows of the Palazzo del Podestà, in the arched decoration of the façade of San Michele. The stone material comes from the nearby outcrop of Uignano.

5. The use of ophicalcite

Stone materials related to the serpentinite are ophicalcites, serpentinite breccias with red and green elements cemented by white calcite veins and pink calcite matrix (Figure 2). These rocks can be found as little outcrops in a restricted area delimited to the southwest by the coast of Levanto-Bonassola-Framura-Deiva and to the north by the villages of Pavareto, Carro and Ziona, in the west side of Vara valley (Figure 23). Other outcrops are located near Pietralavezzara, in Polcevera valley, north of Genoa.



Figure 23. Ophicalcite outcrops in Eastern Liguria (after Google Earth, modified)

For its aesthetic characteristics, the ophicalcite was already quarried by Romans as ornamental stone as testified by its presence in the villa of Quintilio Varo located north of Tivoli (hence the name of Breccia Quintilina) and by a block at the Celio Antiquarium in Rome. At first scholars attributed the origin of these materials to the Levanto area (Pensabene 1998) but more recent studies indicate a provenance from Asia Minor. From Middle Ages to the XIX century, it was widely traded with the name of “Rosso Levanto” and “Breccia di Levanto” (Santamaria 2004). An ancient quarry, called columns quarry, now closed, is still visible near the church of Sant'Andrea in Levanto (Figure. 24). Another one is still visible on the seaside near Framura village, also testified by the toponime “Punta dei Marmi” (Marble cape) and called by locals’ people also “Porto delle colonne” (columns harbour),

evidence that the stone blocks were directly boarded there (Marchi 1993) (Figure 25). More recently quarries were opened near the village of Montaretto, close to Bonassola.



Figure 24. the ancient quarry of “Rosso di Levante” named columns quarry (Levanto)



Figure 25. The ancient quarry of opicalcite in Punta dei Marmi (Framura)

The most important historic buildings where opicalcite was used are the gothic portals of the façade of San Lorenzo Cathedral in Genoa (Figure 26) and the portals of the nearby Church of Jesus but it can be found also in many Genoese palaces and churches from Middle Ages to Baroque time (altars,

floors, facings and coatings, columns) (Pieri 1964). This material, called “Rosso Polcevera”, comes from the nearby outcrop of Pietralavezzara in Polcevera valley.



Figure 26. The gothic portals of the façade of San Lorenzo Cathedral in Genoa (XIII century) (where: S = serpentinite; O = ophicalcite)

A further diffusion of ophicalcite is in the early XXth century architecture as thresholds, sills, doorposts, lintels, baseboards, external facing of shops, staircases and paving of villas of many Ligurian towns. In Levanto it was widely used as cladding in the old railway station, rebuilt in 1949 after the destruction caused by an allied bombing in 1944 (Burrini 2014). In Florence it is found as decoration slabs of the bases of the two obelisks in Breccia Medicea located in Piazza Santa Maria Novella. These slabs were originally in Breccia Medicea and were replaced with Rosso di Levanto in the 1960s, a period of strong impulse of the extraction, which then returned to decrease drastically (Fiora & Alciati 2007).

As for the material quarried in Polcevera valley, beside the “Rosso Polcevera” there is also the “Verde Polcevera”, which consists of green serpentinite breccias cemented by white calcite veins. A similar green breccia was quarried near Voltaggio, in the Lemme valley (Piemonte region), about 10 km to the north of Pietralavezzara. These polishable rocks were extracted at least starting from 1572 (Quaini 1981) and were mostly intended for local churches and palaces but were also required outside Liguria both as cladding and as columns. In Genoa they were used in the first half of the XXth century to panel

main doors, banks, and shops, as well as in the opening of Cristoforo Colombo Tunnel in Dante Square (Cimmino et al. 2003). Yet in 1938, up to 1500 tons per year of this material were extracted (Santamaria 2004).

West of Genoa, precisely in Varenna valley near Pegli, there are other outcrops of serpentinite breccias from which in the past a material similar to “Verde Polcevera” called "Verde Pegli", was extracted. An example of its use in Genoa is in the chapel of San Liborio (church of Santi Vittore and Carlo) as columns and decorative elements (Santamaria 2004).

6. Deterioration and conservation

The Apennine serpentinites, despite their apparent compactness, nevertheless can suffer significant decay. From the mineralogic point of view these rocks are made of lizardite (from the serpentinization/hydration process of olivine and pyroxenes) and chrysotile (fibrous serpentine) veins with minor amounts of magnetite. The decay develops first with decohesion phenomena starting from the edges of the ashlar/cladding slabs; subsequently flakes few millimeters thick fall, then a crushing process is established with the detachment of fragments whose dimensions recall the original grainblastic structure, prior to the serpentinization process (Figure 27) (Ceccherini 1989; De Vecchi et al. 1991; Fratini et al. 1987, 1991; Vannucci 1989).

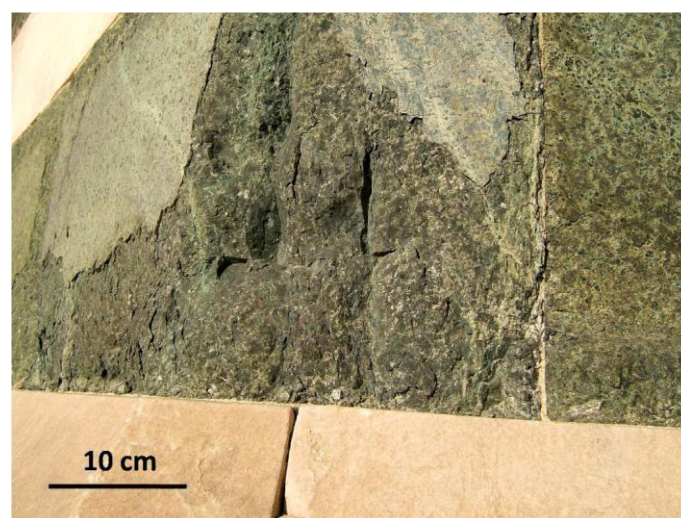


Figure 27. Decohesion phenomena starting from the edges in a serpentinite strip (Florence Cathedral)

Another element of "weakness" is represented by the veins of fibrous serpentine (chrysotile) where detachments of fragments can occur, even of moderate dimensions (Figure 28).

Regarding petrophysical characteristics, it was observed that the weathered Apennine serpentinites (taken from monuments) have a porosity between 3 and 10%, and a saturation index (% of porosity that can be filled by water) often higher than 100%. This means that water can enter also inside the crystal lattice of the minerals, which is dangerous for the tensions that can develop inside the material in the presence of humidity (Fratini et al. 1987, 1991; De Vecchi et al. 1991).



Figure 28. Veins of chrysotile which favour the detachment of fragments (Badia Fiorentina, Fiesole)

In Bralio et al. (1995) an attempt was made to explain this water absorption phenomenon. To this purpose weathered and unweathered Apennine serpentinites were compared to Alpine serpentinites (used for substitution in restoration interventions), because more durable. Alpine serpentinites have a

porosity comparable to that of Apennine serpentinites but are made of antigorite type serpentine (Figure 29) instead of lizardite+chrysotile and their saturation index is lower than 100% even after exposure to atmospheric agents. This is not the same for Apennine serpentinites that, starting from a saturation index lower than 100% in the "fresh" quarry material, reach a saturation index higher than 100% in the weathered material (Table 1).

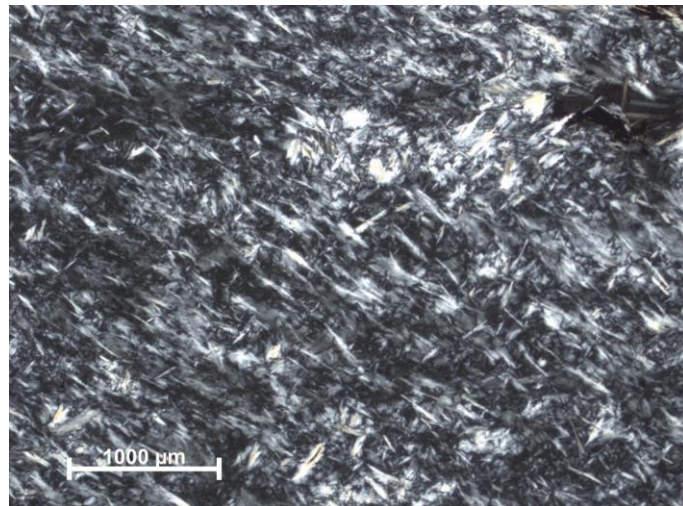


Figure 29. Alpine antigorite serpentinite (image in thin section at the optical microscope, crossed nicols)

Table 1. Main characteristics of Apennine and Alpine serpentinites

Lithotype	Mineralogical composition	Unweathered		Weathered	
		Porosity range (%)	Saturation index range (%)	Porosity range (%)	Saturation index range (%)
Apennine serpentinite	Lizardite	3-10	90-95	3-10	>100
	Chrysotile				
Alpine serpentinite	Antigorite	3-5	25-50	3-5	25-50

Lizardite has a tube structure and the model proposed to explain the saturation index higher than 100% assumes the presence, in this tube structure, of barriers with an amorphous structure that are chemically permeable to water but impermeable to gases. These barriers would form due to alteration processes lasting a few hundred years and would favour the generation of stresses inside the material. Moreover, the study of Bralio et al. (1995) did not highlight any chemical and mineralogical difference between the altered serpentinite from the Florence Cathedral and similar unweathered serpentinite from the Apennine quarries, meaning that the decay of this material is essentially physical. The following factors would be involved:

- physical discontinuities, such as chrysotile veins and the flaking planes of the bastites;
- the concomitance of the strong heat absorption (consequence of the dark colour) with the low thermal conductivity. This determines the generation of high thermal gradients between the surface and the interior of the material with consequent thermoclastic phenomena (fracturing of the material due to thermal cycles);
- the very high water saturation index. This determines swelling phenomena and consequent tensions of considerable entity, as evidenced by linear expansion measures.

In consideration of the intrinsic factors involved in the decay of this material, only interventions aimed to decrease the entry of water can be carried out (application of water repellents), but nothing can be done regarding the thermoclastic phenomena due to the dark colour. As matter of fact the most diffused interventions involve first plastering (Figure 30) and then the complete replacement of the altered slabs (Viciani 1989) (Figure 31).



Figure 30. Plastering of a serpentinite ashlar (Church of Santa Maria delle Carceri, Prato)



Figure 31. Substitution of a serpentinite ashlar with an Alpine serpentinite (Church of Santa Maria Novella, Florence)

As for opihalcite, a lower durability compared to serpentinite can be observed because further factors intervene, such as the heterogeneity due to the presence of calcitie veins and the calcitie-hematite matrix. This gives rise to differential decay phenomena due to the different thermal expansion coefficient and the different hardness (Figure 32).

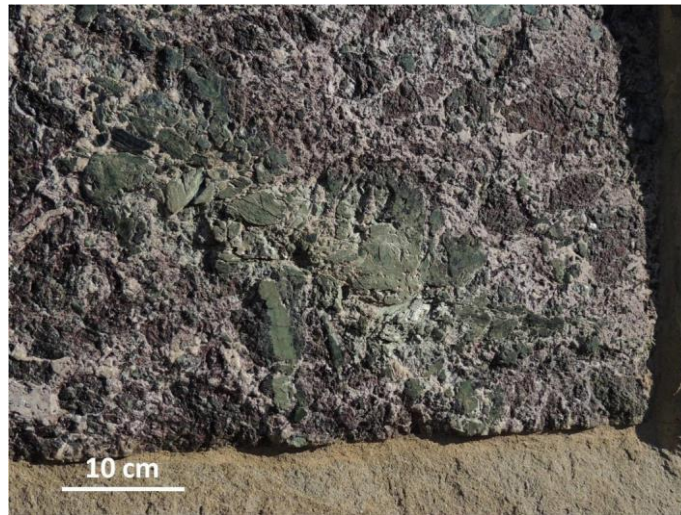


Figure 32. Ophicalcite decayed

Furthermore, the sporadic presence of talc, a mineral of very low hardness that can be easily eroded, must be pointed out.

7. Conclusions

The serpentinite is a stone material peculiar for its colour, showing different shades of green, sometimes with bluish reflexes, that can be polished. For this reason, since the Middle Ages, it was utilized in the bichrome architectonic decoration of many religious buildings in Tuscany. Nevertheless, in some villages of eastern Liguria it was also utilized in commercial and public buildings where the material was cut and worked in regular blocks for the realization of architectural elements (arches, jambs, columns) and as dressed stone with a very special aesthetic effect. This kind of use testifies to the wealth the villages had achieved in the Middle Ages considering that the processing of this lithotype to make regular blocks is quite expensive requiring expert stonecutters.

This material, despite to its apparent compactness, can show significant decay due to physical processes. Indeed, the high heat absorption (consequence of its dark colour linked to low thermal conductivity) and the high water saturation index give rise to stresses with consequent flaking and scaling of the cladding slabs. In consideration of the intrinsic factors involved in the decay of this material, only interventions aimed to decrease the entry of water can be carried out (application of water repellents), but nothing can be done regarding the thermoclastic phenomena due to the dark

colour. Normally the restoration interventions on this material foresee the replacement or plastering. Nevertheless, this material is no longer quarried both in Liguria and Tuscany and for the replacements, serpentinites from quarries located in the Alpine area are used, materials that have a different appearance and mineralogical composition compared to the Apennine serpentinites. There are many reasons explaining why these materials are no longer quarried, or the extraction has greatly decreased as in the case of Rosso di Levante. Regarding serpentinite, after the medieval period, the material was extracted only to make replacements and in the early part of the XXth century to extract material for aggregates. In addition, in the same period, quarrying activities in the Alpine area began to be carried out with technologies that made them economically sustainable. In the second half of the 1900s, particularly in Tuscany, faced with the devastation caused by the indiscriminate extraction of materials for aggregates, it was decided to prohibit any type of extraction. As for Rosso di Levante, after a strong increase in production between 1880 and 1929, a decrease and a following increase in the 1960s, given the small size of the outcrops, the material is almost exhausted.

This study is a first overview about use, decay, and conservation issues of serpentinite and related breccias in architecture. A wider study on the influence of the texture and mineralogical composition of the Apennine serpentinites on the behaviour towards atmospheric agents will be carried out.

References

- Abbate E. (1969) *Geologia delle Cinque Terre e dell'entroterra di Levante (Liguria Orientale)*, Società Geologica Italiana Memorie, vol. 8, 923-1014
- Boato A., Cagnana A. (1998) "Archeologia globale nel territorio del comune di Levante (SP): primi risultati e prospettive di ricerca", in *Atti della Prima Conferenza I di Archeologia Medievale*, (held in Cassino 14-15 December 1995)
- Bortolotti V., Passerini P. (1970) "Magmatic activity", in *Sedimentary Geology*, Special issue "Development of the Northern Apennine Geosyncline", 4 (3/4), 599-624

- Bortolotti V, Principi G, Treves B (2001) "Ophiolites, Ligurides and the tectonic evolution from spreading to convergence of a Mesozoic Western Tethys segment", Eds Vai G.B. & Martini I.P. *Anatomy of an Orogen: the Apennines and Adjacent Mediterranean Basins*, Kluwer Academic Publishers Dordrecht, 151-164
- Bortolotti V., Principi G., Leoni L. (2008) "Carta Geologica d'Italia 1:50.000 – Foglio 247 - Levante - Servizio Geologico Regione Liguria
- Brongniart A (1813) "Essaie d'une classification minéralogique des roches mêlangés" *Journal des Mines*, 199, 5-48
- Bralia A., Ceccherini S., Fratini F., Manganelli del Fà C., Mellini M, Sabatini G. (1995) "Anomalous water absorption in low grade serpentinites: more water than space?", *Europ. Jour. Min.*, 7, 205-215
- Busco G., Montagni C. (1995) "Guida al centro storico di Levante", Sagep, Genova
- Burrini M. (2014) "Da Sestri Levante a La Spezia: storia della ferrovia del litorale ligure", Ed. Effegi
- Ceccherini S. (1989) "L'alterazione dei materiali lapidei costituenti il portale laterale del Duomo Nuovo di Siena", Tesi di Laurea inedita, Università degli Studi di Siena.
- Cimmino F., Faccini F., Robbiano A. (2003) "Stones and coloured marbles of Liguria in historical monuments", *Periodico di Mineralogia*, vol. 73, Special Issue 3, 71-84
- Cortesogno L., Galbiati B., Principi G., Vercesi del Castellazzo G. (1981) Carta geologica delle ofioliti del Bracco - tra Lèvanto e Velva in scala I : 2 5. 000. Gruppo di Lavoro sulle Ofioliti Mediterranee. CNR, Firenze
- Cortesogno L., Galbiati B., Principi G. (1980) "Le breccie serpentinitiche giurassiche della Liguria orientale", *Arch. Sc. Genève*, 33, 185-200
- Cortesogno L., Galbiati B., Principi G. (1987) "Note alla "Carta Geologica delle ofioliti del Bracco" e ricostruzione della paleogeografia giurassico-cretacica", *Ofioliti*, 12, 261-342.
- Del Soldato M., Pintus S. (1984) "Levanto: geologia, ambiente, evoluzione storica", mostra a cura di Marco Del Soldato e Stefano Pintus, Tipolitografica La Spezia

- Del Soldato M., Pintus S. (1985) “Studio geologico-storico delle attività e delle tecniche estrattive nella Liguria orientale (area compresa tra Genova e La Spezia”, Memorie della Accademia Lunigianese di scienze Giovanni Capelli, La Spezia
- Nardini Despotti Mospignotti A. (1902) “Il Duomo di San Giovanni oggi Battistero di Firenze”, Alinari, Firenze
- De Vecchi G., Rossetti M., Vannucci S. (1991) “La serpentina della Cattedrale di S. Maria del Fiore a Firenze ed il suo degrado”, in Atti del Convegno Scienza e Beni Culturali: “Le Pietre nell’Architettura: struttura e superfici”, Bressanone 25-28 Giugno 1991, 247-256.
- Del Riccio A. (1597) “Istorie delle Pietre”, Ristampa a cura di P. Bazzocchi, S.P.E.S., Firenze 1979.
- Elter P. (1994) “Introduzione alla geologia dell’Appennino ligure-emiliano”, in G. Zanzucchi (Ed.) “Appennino ligure-emiliano, 10 itinerari, Guide geologiche regionali S.G.I., 6, 17-24
- Evans BW, Hattori K, Baronnet A (2013) “Serpentinite: What, Why, Where?”, *Elements*, 9, 99-106
- Fiora L., Alciati L. (2007) Rosso di Levanto e Portoro, “marmi” colorati dalle proprietà estetiche uniche, a cura di Luigi Marino, Cave storiche e risorse lapidee, ALINEA Firenze, 59-62
- Fratini F., Manganelli Del Fà C., Tiano P., Matteoli U., Camaiti M. (1987) “Indagine conoscitiva sullo stato di conservazione dei materiali lapidei presenti sulla facciata di S. Maria del Fiore, Firenze”, in: Due Granduchi, Tre re e una facciata", ed. Alinea, Firenze, 66-78.
- Fratini F., Ceccherini S., Pecchioni E., Manganelli Del Fà C., Scala A., Galletti G. (1991) “Alterazione del marmo e della serpentinite costituenti il rivestimento della facciata della Collegiata di S. Andrea in Empoli (Firenze)”, in Atti del Convegno Scienza e Beni Culturali: “Le Pietre nell’Architettura: struttura e superfici”, Bressanone 25-28 Giugno 1991, 323-334.
- Fratini F., Mattone M., Rescic S. (2019) “The stone materials in the historical architecture of Levanto and their durability (Liguria, Italy)”, in Edited by Daniela Pittaluga and Fabio Fratini “Conservation et mise en valeur du patrimoine architectural et paysagé des sites côtiers méditerranéens”, 807-820, Copyright © 2019 by Franco Angeli s.r.l., Milano, Italy

- Fratini F., Rescic S. (2013) “The stone materials of the historical architecture of Tuscany, Italy”, in Cassar, J., Winter, M. G., Marker, B. R., Walton, N. R. G., Entwisle, D. C., Bromhead, E. N. & Smith, J. W. N. (eds) *Stone in Historic Buildings: Characterization and Performance*. Geological Society, London, Special Publications, 391, 71-92
- Fregola A., Stringa P. (1978) “Le Cinque Terre nell’arco da Deiva all’isola del Tinetto”, Genova
- Giamello, M., Guasparri, G., Neri, R., Sabatini, G. (1992) “Building materials in Siena architecture: type, distribution and state of conservation”, *Science and Technology for Cultural Heritage*, 1, 55–65.
- Guasti C. (1887) “S. Maria del Fiore, La costruzione della Chiesa e del Campanile secondo i documenti tratti dall'Archivio dell'Opera secolare e da quello di Stato”, Arnoldo Forni Editore, Firenze 1887.
- Gurrieri F. (1974) “Il marmo verde di Prato nel policromismo architettonico”, in *Atti della Società Toscana di Scienze Naturali*, 81, 2-12
- Gurrieri F. (1989) “Lineamenti filologici dell’architettura policroma”, in proceedings of the congress “Il bianco e il verde: architettura policroma fra storia e restauro”, Firenze June 13-15 1989, Alinea Ed., 15-20
- Lucchetti G., Cabella R. & Cortesogno L. (1990) - Pumpellyites and coexisting minerals in different low-grade metamorphic facies of Liguria, Italy. *J. Metamorph. Geol.*, 8 (5), 539-550.
- Mannoni T. (1976) “L’analisi delle tecniche murarie medievali in Liguria”, in “Atti del Colloquio Internazionale di Archeologia Medievale”, Palermo 1976, pp. 291-300.
- Mannoni T. (1990) “La tecnica muraria preindustriale e la trasmissione del sapere empirico”, in *Tecnologia e tecnica delle murature antiche*, Padova, 6-10.
- Marchi P. (1993) “Pietre di Liguria: materiali e tecniche dell’architettura storica”, SAGEP, Genova
- Marroni M., Meneghini F., Pandolfi L. (2004) - From accretion to exhumation in a fossil accretionary wedge: a case history from Gottero unit (Northern Apennines, Italy). *Geodin. Acta*, 17, 41–53.

- Marroni M., Molli G., Montanini A. & Tribuzio R. (1998) - The association of continental crust rocks with ophiolites in the Northern Apennines (Italy): implications for the continent-ocean transition in the Western Tethys. *Tectonophysics*, 292, 43-66.
- Molli G. (1995) "Pre-orogenic High Temperature Shear Zones in a Ophiolite Complex (Bracco Massif, Northern Apennines, Italy)", in *Mantle and Lower Crust Exposed in Oceanic Ridges and in Ophiolites*, edited by Vissers R.L. & Nicolas A., Kluwer Academic Publishers, 147-161.
- Pieri M. (1964) - I marmi d'Italia, Hoepli Ed., Milano
- Principi G., Bortolotti V., Chiari M., Cortesogno L., Gaggero L., Marcucci M., Saccani E., Treves B. (2004) "The pre-orogenic volcano-sedimentary covers of the western Tethys oceanic basin: a review", *Ophioliti*, 29 (2), 177-211
- Quaini M. (1981) "Materiali liguri per la «Statistica» di G. A. Magini", in *La conoscenza del territorio ligure fra Medio Evo ed Età Moderna*, Genova, 211-214
- Pensabene P. a cura di (1998) "Marmi Antichi II", L'Erma di Bretschneider
- Repetti E., 1839 - Dizionario Geografico-fisico storico della Toscana - Firenze, Vol. III, 387-389
- Rodolico F. (1953) - Le pietre delle città d'Italia. - Le Monnier, Firenze.
- Ruschi P. (1989) "La policromia nell'architettura medievale toscana: influssi ed influenze", in proceedings of the congress "Il bianco e il verde: architettura policroma fra storia e restauro", Firenze June 13-15 1989, Alinea Ed., 29-43
- Santamaria R. (2004) "Pietre di «diversi colori come l'arco celeste»: le cave e i marmi di Liguria nei secoli XVI - XVIII, in *Couleurs d'éternité. Marbres et décors religieux XVI.e – XVIII.e siècles*, Actes du Colloque International de Rome 2004, c.d.s.
- Targioni Tozzetti G. (1768) "Relazioni di alcuni viaggi fatti in diverse parti della Toscana", Firenze, Stamperia Granducale 1768, Anastatic copy A. Forni Press Bologna Italy 1972
- Treves B., Harper D. (1994) "Exposure of serpentinites on the ocean floor: sequence of faulting and hydrofracturing in the northern Apennine ophiolites, *Ophioliti*, 19(2B), 435-466

- Vannucci S. (1989) “Degradato e problemi conservativi dei marmi e delle serpentine”, in: Atti del Convegno "Il Bianco e il Verde: architettura policroma tra storia e restauro" Firenze June 13-15 1989, Alinea Ed., 121-130.
- Vasari G. 1546, - Le vite dé più eccellenti pittori, scultori et architettori. - con annotazioni e commenti di Gaetano Milanesi, Sansoni printed edition of 1878-1885, Firenze
- Viciani E. (1989) “Il marmo verde di Prato nella cattedrale fiorentina: comportamenti nel tempo e problemi di restauro”, in proceedings of the congress “Il bianco e il verde: architettura policroma fra storia e restauro”, Firenze June 13-15 1989, Alinea Ed., 131-136
- Villani G., 1365, Cronaca, libro VIII, capitolo 3, printed edition of 1845, Firenze
- Wicks F.J., Whittaker E.J.W. (1977) “Serpentine textures and serpentization”, *Canad. Mineral.*, 15, 459-488.