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Historical Use of Travertine in the Tuscan Architecture (Italy)

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Abstract: The landscape of an area is not only made up of natural elements but also of man-made elements represented by civil and agricultural artefacts and much more. These elements used to blend aesthetically and harmoniously with the landscape itself thanks to the use of local building materials. Particularly, this contribution examines the use of the travertine in the architecture of the Tuscany region from the Etruscan time to the contemporary age. In Tuscany, travertine is a remarkable example of an identity stone of the territory, so rich in thermal springs that favoured the formation of large deposits of this stone widely used in public and private buildings both in interior design and urban furnishing. The work was carried out through a survey in the Tuscan territory and collection of bibliographic information on the architectural web sites. The survey made it possible to collect a photographic documentation and to assess the state of conservation through the empirical observation of the morphologies of decay when present. Indeed, this stone material in the Mediterranean climate, which characterises Tuscany, shows a good durability against atmospheric agents but may be affected by a chromatic alteration that tends to give the surfaces a greyish appearance. This aesthetic issue is more evident in the Tuscan travertine due to is classic whitish colour.

Keywords: travertine; Tuscany; architecture; Etruscan age; contemporary age

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1. Introduction

The landscape of a territory is most often the result of human action, not only through agricultural and forestry practices, but it is also determined by the inhabited centres that populate it. These centres in the past blended aesthetically and harmoniously with the natural landscape thanks to the use of local building materials [1–5]. However, in the course of time, traditional building materials have often been abandoned (for economic reasons, depletion of resources, etc.) in favour of stone materials from other areas or of industrial production, which have homologated the appearance of urban centres. However, the use of historical materials has not been completely abandoned but restricted to restoration work on listed buildings, with supply problems for certain types whose quarries have been closed, or as cladding materials in private or public building works of a certain value where local administrations have wished to maintain a continuity of identity with the territory. This is the case for travertine, a rock resulting from the precipitation of carbonate dissolved in the waters of hot springs (travertines) or cold (limestone tuffs), under the influence of physico-chemical and/or biological processes. As reported by Plinio il Vecchio and Strabone, the name derives from Lapis tiburtinum, that is the stone of Tibur, the Latin name of Tivoli, a city located near Rome, from which this stone has been extracted from the Roman time until today. Travertine is a medium-hard material, easy to polish, with a good resistance to atmospheric agents especially in the Mediterranean climate, with a beautiful classic whitish colour, but other colorations are present [6–9]. Thanks to these characteristics, over the centuries, it has been used in architecture with both structural and decorative functions, particularly in the northern-central Italian peninsula where many deposits of this rock are present [10]. The Etruscans used travertine for the city walls, stones and funerary urns. In ancient Rome, travertine was the stone of monumental buildings (bridges, triumphal arches, theatres and amphitheatres, arcades, tombs façades) and flooring, but it was also used in private buildings [11]. In the Middle Ages, it was the monumental building material of Ascoli Piceno, Perugia, Ancona, Rieti, in relation to a local extraction [12]. Travertine then became the stone of the Roman Baroque and rationalist architecture, significant examples of which are the University City of Piacentini and the E.U.R complex (Universal Exposition of 1942) [13,14].

Travertine deposits are widespread not only in Italy but almost all over the World [15,16]. Deposits are not necessarily exploited for building materials or cladding but have sometimes become nature-protected geosites [17–19]. In fact, in some countries, although there are travertine deposits, these are often not commercially viable because they are typically small. Therefore, travertine is imported from the more famous quarries located elsewhere. Italian quarries are the most renowned, but equally well known are those in Turkey and Iran and also in Peru, Mexico, Croatia, Hungary, Ecuador and Spain [20–23]. Travertines with colours ranging from classic white and light cream to silver, red, chocolate and dark colours can come from these quarries [6–9]. In countries with a long exploitation history, travertine was also widely used as building material in those localities sited close to the deposits of this stone material. These countries include Spain, Hungary and Turkey, where travertine has been extensively used since the Roman times in various applications, such as buildings, monuments and roads. Valuable testimonies are the Roman Theatre of Carthago Nova whose red travertine came from the quarries of Mula (Murcia-Spain) [20,24] and the city of Hierapolis, founded in the 4th century B.C. by Seleucid kings, located in the Pamukkale area, surrounded by thermal springs and white travertine deposits [22].

The following are some examples of architecturally valuable buildings located in various parts of the World, built since the early 1900s, in which travertine has been used mainly as exterior and interior cladding.

The Berlin Shell-Haus, or Shell Building, on the Reichpietschufer is a symbol of modernist architecture designed by architects Emil Fahrenkamp and Atelier Christof Fischer. It was built in 1930–1932, during the Weimar Republic, to house the central offices of the Rhenania-Ossag mining company. The building is made of Italian travertine from Tivoli [25].

The Barcelona Mies van der Rohe Pavilion, also called the German Pavilion, was designed for the Barcelona International Exhibition in 1929, dismantled a year later and rebuilt in 1986. The Barcelona Pavilion is considered a benchmark for modern architecture thanks to its rigorous geometry and skilful use of materials like glass, steel and four different stones (Roman travertine, green Alpine marble, green marble from Greece and golden onyx from the Atlas Mountains) [26].

The Edith Farnsworth House, formerly the Farnsworth House, is a historical house designed and constructed by Ludwig Mies van der Rohe between 1945 and 1951 in Plano (Illinois). The house is an architectural masterpiece owned by the National Trust for Historic Preservation that is also one of the most acclaimed Modernist buildings in the World. The residence is a white rectangular pavilion with a travertine podium and steps [27].

Willis Tower in Chicago, projected by architects Skidmore, Ownings and Merrill and Bruce Graham, which used to be known as the Sears Tower, was the tallest building in the world when it was built in 1974. The lobby was built with high, polished travertine walls that visitors still admire today [28].

The Getty Center in Los Angeles, projected by architect Richard Meier, was built in 1984–1997 with 1.2 million square feet of travertine imported from Italy [29].

In Manhattan's Far West Side (in New York), the BIG architect studio projected the Twisting One High Line Skyscrapers that take up an entire city block. Client HFZ Capital expressed their desire to clad the two towers with real stone material in the same manner as the Lincoln Center (1959–1968) [30] and the Solow (1968–1974) [31] and Grace Buildings (1971–1974) [32]. All of these buildings are valuable examples of Roman travertine in the United States [33,34].

Museo Jumex in Mexico City (Mexico) was built between 2009 and 2013, by David Chipperfield Architects. The museum is located in the New Polanco area and is a redevelopment of a former industrial area in Mexico City. The Jumex Museum consists of a white reinforced concrete structure suspended on massive columns and clad on all sides with cream-coloured travertine slabs, except for the columns and ceilings. The travertine comes from a quarry in Xalapa in the state of Veracruz on the coast of the Gulf of Mexico [35].

More recent designs highlight both the interest in the use of this material as an alternative to better known and more expensive materials (like marble) and how the installation and particular solutions adopted by designers can enhance the aesthetics of the travertine surface. Examples are the façade of a residential building in the Swiss village of Crans-près-Céligny built by Group8asia (completed in 2014) [36], a public building near Cannes (France) completely clad in travertine (completed in 2019) [37], the residential suburbs of Mahallat (Iran) by Studio CAAT (completed in 2018) with travertine from the nearby quarries of Hajiabad and Abbasabad [38], the Travertine dream house in Serangoon (Singapore) by Wallflower Architecture + Design (completed in 2011) [39], the House in Faiha, Kuwait, by Studio Toggle (completed in 2022) [40], and the House at Gulmohar Greens (Ahmedabad city -India) by Studio 4000 (completed in 2023) [41].

Two examples of the sustainable use of waste from travertine processing or the re-use of travertine slabs in a new construction are shown in the following:

- The residential and commercial building, built between 2007 and 2010, in Mahallat (Iran) by architect Ramin Mehdizadeh (Architecture by Collective Terrain), uses processing stone waste from local quarries as cladding. This sustainable and cost-saving project was selected for the 2013 Aga Khan Award for Architecture. Ramin Mehdizadeh found many tons of stone scraps of different shapes and proportions but with the same thickness and designed a cladding for exterior and interior overlapping pieces of travertine, marble and granite [42].
- The Tidal House, a project by studio to po ma, in Den Burg (The Netherlands), was completed in 2023. The house is situated on Texel Island on the border of a rural area that passes into woods, dunes and the North Sea. The house has several sustainable implementations: a timber structure, façade cladding and window frames of sustainable modified wood, a roof of recycled aluminium, natural ventilation, a concrete floor to retain the heat with floor heating and re-used travertine floor tiles [43].

2. Methods and Data Sources

This contribution examines the use of travertine from the Etruscan time to the contemporary age in the architecture of Tuscany, a region rich in hydrothermal springs that gave rise to the formation of this carbonate rock. The work was carried out through a survey in the Tuscan territory and a collection of bibliographic information on architectural web sites. The survey of the territory took into consideration both those places indicated by Francesco Rodolico in his work "Le Pietre delle Città d'Italia" [1], as well as the sites known to the authors themselves. Over the years, the authors have visited the region extensively and acquired information on the use of travertine throughout Tuscany. Sources for the most recent monuments were also acquired through research on the websites of local travertine producers, where the realisations were indicated by selecting the most important ones. All newly used sites were visited by the authors.

A sheet was not used for these surveys, but general information documented by photographs was acquired.

The survey also made it possible to assess the state of conservation through the empirical observation of the morphologies of decay, when present. Indeed, this stone material in the Mediterranean climate, which characterises Tuscany, shows a good durability against atmospheric agents but may be affected by a chromatic alteration that tends to give the surfaces a greyish appearance. This aesthetic problem can be particularly evident in the Tuscan travertine due to is classic whitish colour.

3. Genesis of Travertine

Travertines are "continental carbonate rocks" which are formed in relation to the presence of springs fed by supersaturated calcium carbonate waters coming from a deep hydrothermal circuit [44,45]. The presence of normal faults that allows for the rise of deep fluids heated both by the geothermal gradient and by the possible presence of magmatic bodies, as is the case in southern Tuscany, favours this circulation [46,47]. Rainwater rich in carbonic acid (HCO_3^-) of meteoric origin (due to the presence of dissolved CO_2) and pedogenetic, circulating in deep circuits (geothermal) through carbonate or sulphatic rocks, brings in solution calcium ions in the form of calcium bicarbonate (Ca^{2+} + $2HCO_3^-$) [48,49]. These waters flow to the surface as supersaturated solutions. The decrease in pressure, which occurs at the source, determines the release of CO_2, which in turn causes the decomposition of the bicarbonate with precipitation of calcium carbonate (Figure 1). The environmental conditions of the thermal springs (evaporation speed, degassing, cooling) are reflected on the structure of the travertine with deposition rates that can reach 80 mm/year [50]. Crystalline crusts formed in the areas close to the source's outflow are formed by fans of radiated crystals [51] or in the shape of a feather. In the distal areas and in the areas of water stagnation, crystalline laminae associated with bacterial/cyanobacterial laminae are observed [52].

Figure 1. Precipitation of travertine from the thermal spring of Bagno Vignoni (province of Siena) (credit Fabio Fratini).

Large vacuoles due to gas bubbles, encrusted with microcrystalline calcite, are distributed along surfaces. Overall, these travertine deposits are compact, well stratified and, if forming in active hydrothermal systems, have a whitish colour that indicates the absence of life in the immediate vicinity of the source [53].

Carbonate deposits derived from "fresh" waters rich in calcium carbonates are also part of the "continental carbonate rocks". Calcium carbonate is acquired during circulation through limestone rocks in a shallow karst circuit that flow at a lower temperature than ambient. Calcareous tufa is the name of these deposits [54,55]. These are very porous, poorly stratified deposits, containing abundant traces of macrophytes and invertebrates [56,57].

The precipitation of calcium carbonate, generally slow and with low growth rates, occurs in the points where, due to an obstacle or a jump, the water assumes a turbulent motion and the vaporization and evaporation of the water favours the loss of CO_2. In this way, micro- and macrocrystalline encrustations are formed around the stems of aquatic plants until the bushes of rushes or the cushions of moss or cyanobacteria filaments are totally encrusted and petrified, giving rise to massive phytothermal or stromatolite structures. Fragments of encrusted stems can accumulate due to flood flows, forming small dams that delimit tanks in which a sedimentation of phytoclastic mud and sand develops.

4. Travertines and Thermal Sites in Tuscany

In the Italian territory, Tuscany is the region richest in hydrothermal manifestations and travertine deposits, some of which are still in formation. This is because Tuscany has been affected by important extensional tectonics that gave rise to the formation of intermountain basins delimited by normal fault systems that favoured the upwelling of magmas, significantly increasing the geothermal gradient [44,45,57].

The Etruscans and later the Romans already took advantage of this natural heritage of the region. Famous are the Fontes Clusinae (today's Terme di Chianciano), the thermal baths of Saturnia, Roselle, the Aquae Volaterrae and the Aquae Populaniae, represented in the "Tabula Peutingeriana", a medieval copy of a military road map of the imperial Roman age and sited near Sasso Pisano, the baths of San Giuliano, those of San Casciano dei Bagni.

Regarding the most important deposits of travertine and calcareous tufa, the following sites are worth mentioning in Figure 2 and Table 1. Particularly, Table 1 shows the locations of travertine deposits (in Tuscany) exploited in the past for the extraction of the stone material used in historical architecture. Some of these deposits are still exploited today.

Table 1. Most important deposits of travertine/calcareous tufa in Tuscany exploited in the past as building materials.

Locality	Province	Typology	Excavation
Rapolano	Siena	travertine	active
Colle Val d'Elsa	Siena	calcareous tufa	not exploited
Chiusdino-Frosini	Siena	calcareous tufa	not exploited
Sarteano	Siena	calcareous tufa	not exploited
Bagno Vignoni	Siena	travertine	not exploited
Sant'Albino-Chianciano	Siena	calcareous tufa	not exploited
Bagni San Filippo	Siena	travertine	not exploited
Castelnuovo dell'Abate	Siena	travertine	not exploited
Massa Marittima	Grosseto	calcareous tufa	not exploited
Saturnia-Montemerano	Grosseto	travertine	active
Monsummano	Pistoia	calcareous tufa	not exploited
Casciana Terme	Pisa	calcareous tufa	not exploited
Pignano	Pisa	travertine	not exploited

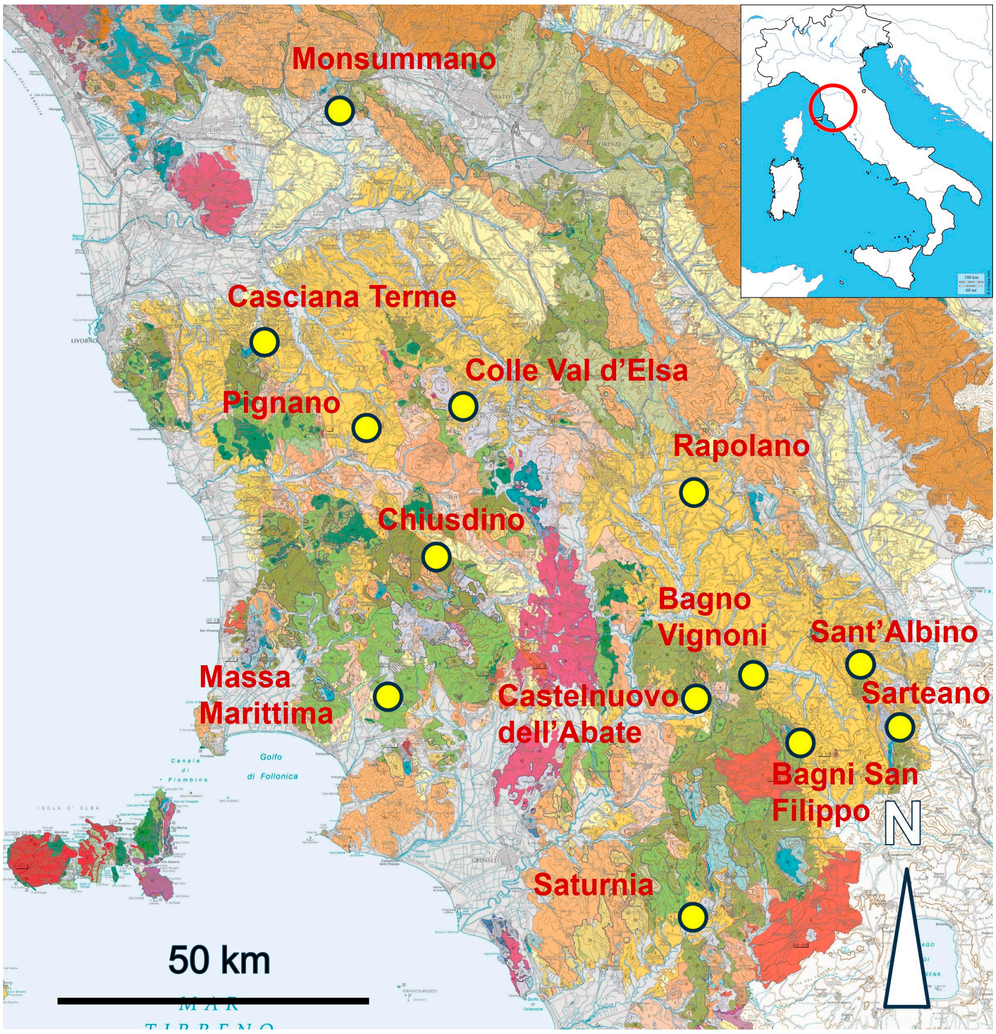


Figure 2. Most important deposits of travertine and calcareous tufa in Tuscany (reported on the geological map 1:250,000 edited by Carmignani et al., 2004 [58], modified).

5. Use of the Travertine in the Tuscan Architecture

In Tuscany (Figure 3 and Table 2), the most ancient use of travertine is that of Saturnia and Volterra.

In Saturnia, which stands on a travertine plateau, on the left bank of the Albenga river, in the hilly hinterland of Maremma, travertine is the main material used in architecture. Built by the Romans during the 2nd century BC, along the Via Clodia, which connected Rome to the inner Etruria, it preserves the remains of the ancient Roman city walls, with only one gate left (Porta Romana) of the four originally present and the imposing ruins of the Rocca Senese. In the small village, there is also a section of the Via Clodia with irregular travertine paving stones and vertical containment margins and the remains of a large rectangular travertine basin, called Bagno Secco.

In Volterra, travertine is present in the Porta dell 'Arco (Figure 4). Volterra is one of the main cities of ancient Tuscany (Etruria) with the name of Veláthri and a seat in the Middle Ages of an important bishopric. The gate, which is part of the city walls, dates back to the Etruscan period (4th and 3rd century BC). The piers of the door are made in the local Pietra Panchina [59,60]. The arch is made of perfectly squared travertine ashlars in excellent conservation condition coming from Pignano, which also provided the material for the seats of the Roman Theatre.

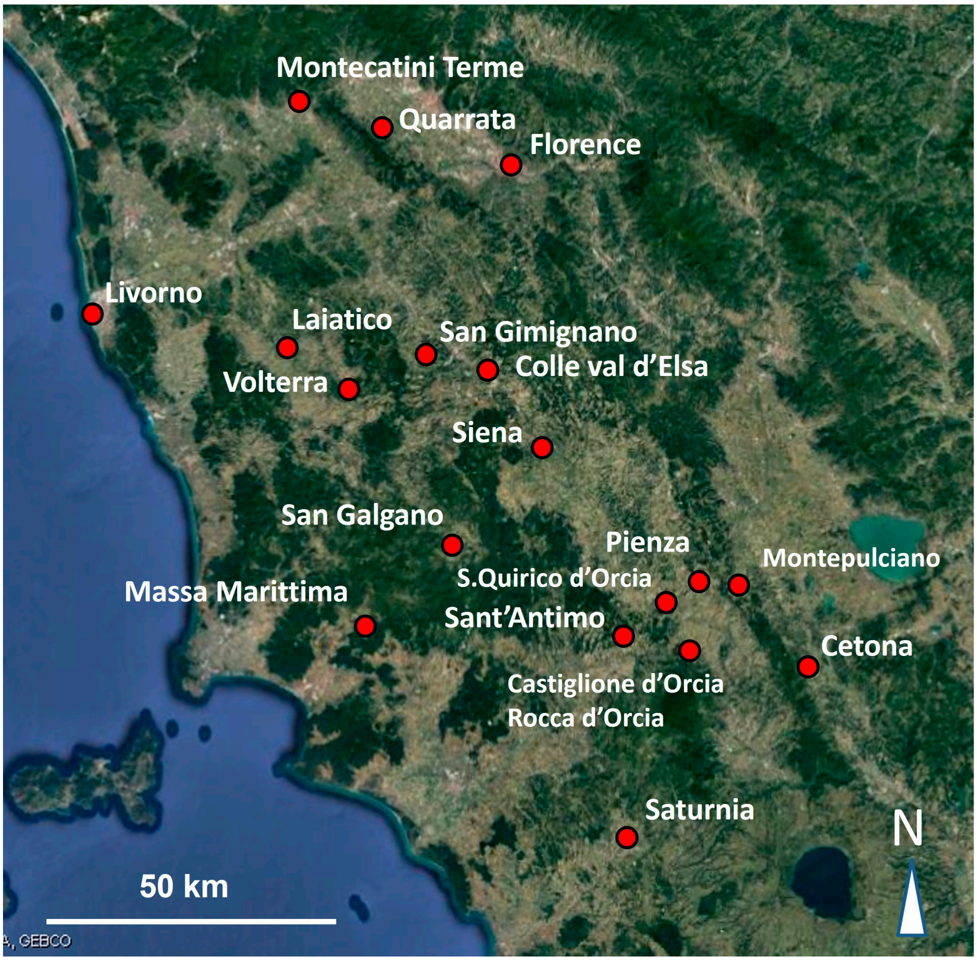


Figure 3. Localities mentioned in the text where travertine has been extensively used (from Google Earth Pro V 7.3.4, (14 December 2015), 43°30′23′′ N 10°41′13′′ E, Google Landsat/Copernicus Data SIO, NOAA, U.S. Navy, NGA, GEBCO [61], modified).

Table 2. Main localities of Tuscany where travertine has been used.

Locality	Buildings	Age	Use in the Buildings	Quarries
Saturnia	Roman city walls, Rocca senese	2nd century BC, XIIth–XVth c.	ashlars of the masonries, architectural decoration	Saturnia
Volterra	Porta dell'Arco	4th and 3rd c. BC	ashlars of the arch	Pignano
San Gimignano	numerous buildings, crowning of wells and cisterns	since the XIIth c.	dressed stones, corner stones, cladding of façades, as architectural decoration	Colle Val d'Elsa
S. Quirico d'Orcia	Church of Santi Quirico and Giuditta, Chigi Zandonari Palace	XIIth–XIIIth c.	cladding of façades and architectural decoration	Bagno Vignoni
Abbey of Sant'Antimo	the church	XIIth–XIIIth c.	ashlars of the masonry, architectural decoration	Castelnuovo dell'Abate
Massa Marittima	the building material of the town, Cathedral of San Cerbone	XIIth–XIIIth c.	ashlars of the masonries, architectural decoration	Massa Marittima
Siena	Papesse Palace, S. Maria di Provenzano, etc.	since the XIIIth c.	cladding of façades and architectural decoration	Rapolano

Table 2. *Cont.*

Locality	Buildings	Age	Use in the Buildings	Quarries
Colle Val d'Elsa	numerous buildings and tower houses	since the XIIIth c.	cladding of façades and architectural decoration	Colle Val d'Elsa
Abbey of San Galgano	the church	XIIIth c.	ashlars of the masonry	Chiusdino-Frosini
Montepulciano	Palazzo del Capitano del Popolo, Palazzo Comunale, S. Biagio	XIVth–XVIth c.	ashlars of the masonries, architectural decoration	Sant'Albino
Pienza	cathedral façade, the bell tower, Piccolomini Palace	XVth c.	cladding, paving of the streets, columns, architectural decoration	Bagno Vignoni
Castiglione d'Orcia	crowning of wells and cisterns	XVIIth c.	paving of the streets, corner stones, architectural decoration	Bagno Vignoni
Montecatini Terme	Terme del Tettuccio, railway station	XXth c.	cladding of façades and architectural decoration	Monsummano
Livorno	Government Palace, Municipal Stadium, Casa del Portuale	XXth c.	cladding of façades and architectural decoration	
Florence	Manifattura Tabacchi, Institute of Aeronautical Sciences	XXth c	cladding of façades, architectural decoration	

Figure 4. Porta dell' Arco in Volterra, gate of the city walls, dating back to the Etruscan period (4th and 3rd century BC) (credit Fabio Fratini).

San Gimignano is part of the UNESCO World Heritage Sites. Despite some XIXth–XXth century restorations, the village is substantially intact in its XIIIth–XIVth century appearance, evidence of the urban organization of the municipal age. In San Gimignano, the travertine comes from the outcrops of Colle Val d'Elsa area that extend for over 50 km^2. It was used since the XIIth century together with the cavernous limestone and lacustrine limestones of the Quaternary age. It is present as building material in dressed stones, sometimes finely hewn and rustic ashlars, in numerous buildings and tower houses and often as cornerstones. It is found also as architectural decorations and for the crowning of wells and cisterns.

San Quirico d'Orcia, a walled village on the ridge that separates the Orcia and Asso valleys, owes its development to its strategic position, in fact, it is located along the Via Francigena (the medieval route that pilgrims walked from France to Rome), at the connection with the route to Valdichiana. Travertine, from the nearby Bagno Vignoni outcrop, was used in many constructions as the only building material in finely hewn ashlars, as it can be observed in the Church of Santi Quirico and Giuditta (XIIth–XIIIth century) with three finely decorated portals (Figure 5) and in the small Romanesque church of Santa Maria Assunta (XIth century). In the baroque Palazzo Chigi Zandodari, travertine was used as a decoration to define the different elements of the façade.

Figure 5. The finely hewn ashlars of the Church of Santi Quirico and Giuditta (XIIth–XIIIth century) in San Quirico d'Orcia (province of Siena). The portal is surmounted by a porch supported by caryatids resting on lions made of Pliocenic sandstone (credit Barbara Sacchi).

Isolated in the countryside south of Montalcino, the abbey of Sant'Antimo stands out among the olive trees for the whiteness of its travertine, a great example of Romanesque-Lombard architecture. The travertine, both as finely hewn ashlars of the masonry and in the decorative architectural elements (columns, capitals), comes from the small outcrop of Castelnuovo dell'Abate.

The village of Massa Marittima dominates the hilly landscape, covered by dense Mediterranean shrubs, which slopes down towards the Gulf of Follonica. The ancient Massa Metallorum developed thanks to the intense mining activity linked to the deposits of pyrite, iron and mixed sulphides, known since ancient times and particularly exploited in the XIIth–XIVth century. The first European mining code, the lex mineraria, was drawn up here. The city bears a great urbanistic as well as monumental interest. In fact, next to the primitive nucleus (Massa Vecchia), seat of the bishopric and municipal powers, in 1228, with the affirmation of the new entrepreneurial class linked to mining, an urban expansion was planned on the plateau above. An urban layout with streets crossing at right angles, a unique feature in the medieval centres of the peninsula, characterizes this expansion. Both of these nuclei rest on a large travertine bench, which was the only building material [59]. Travertine was used as a building stone in carefully squared ashlars for religious and public buildings, in the frames of the openings, in the decorations and in the columns and pillars. An admirable example of the use of travertine is the Cathedral of San Cerbone, an outstanding expression of Romanesque-Gothic architecture of the XIIth–XIIIth century (Figure 6).

Figure 6. Particular of the Cathedral of San Cerbone in Massa Marittima (XIIth–XIIIth century) (credit Fabio Fratini).

Siena is another ancient town where travertine was widely used. It is included by UNESCO in the World Heritage List for its substantial stylistic unity of the medieval architectural heritage linked to a very rich artistic heritage, to a still intact surrounding rural landscape and to the tradition of the Palio (horse race bareback) and its 17 districts (contrade), which are the true soul of the city. The travertine, coming from the Rapolano area, was used, together with the cavernous limestone (from the Triassic age) and bricks, since the XIIIth century, with particular frequency from the XVth century to the present, as cladding of façades and as architectural decoration (thresholds, string courses, windowsills, columns) [62]. Among the most important buildings, it can be found in the rustic ashlar of Palazzo delle Papesse, in the cladding and architectural decorations of the façades of Santa Maria di Provenzano (Figure 7), San Giorgio and San Martino, as architectural decorations in the brick façade of San Vigilio, as cladding of the façade of Santa Maria delle Nevi, and in the crowning of the tower of the Palazzo Pubblico.

Figure 7. The travertine cladding of the façade of Santa Maria di Provenzano (Siena, XVIIth century) (credit Fabio Fratini).

Colle Val d'Elsa developed on three nuclei between the Xth and XIIIth centuries: the plain, the castle and the village. Since the Middle Ages, it was the site of an important production activity linked to the processing of wool and paper mills, thanks to the driving force obtained from the waters of the Elsa River, the same water that in the past allowed the abundant deposition of calcareous tufa. Travertine was used, together with bricks, as building material in ashlars, sometimes finely hewn and rustic ashlars, in numerous buildings and tower houses, often also as cornerstones.

San Galgano is another isolated Cistercian abbey in the countryside south of Chiusdino (province of Siena). The abbey is in a state of ruin and is occasionally used in summer for cultural events. Here, the travertine from the nearby outcrops on the left bank of the Merse river is used together with bricks.

Montepulciano, located on a high hill between Valdichiana and Val d'Orcia, has extensively used travertine from the nearby quarries of Sant'Albino. Travertine is present in the pointed arches of the Palazzo del Capitano del Popolo (XIVth century) and in the Palazzo Comunale which recalls the Palazzo della Signoria in Florence with the tower in the centre of the façade. In the XVIth century, great architects worked in the town such as Sangallo, Vignola, Peruzzi dello Scalza, with the realization of elegant architectures, sometimes entirely clad in travertine or simply decorated. Travertine is also the material of minor works such as wells and columns. Just outside of the historic centre of Montepulciano, in an isolated position, stands the church of San Biagio. Masterpiece of Antonio da Sangallo the elder, with a Greek cross plant, it is entirely clad in travertine and represents a fine example of XVIth century Renaissance architecture (Figure 8).

Figure 8. The church of San Biagio in Montepulciano, fine example of XVIth century Renaissance architecture, entirely clad in travertine (credit Fabio Fratini).

Pienza, an exquisitely Renaissance village founded by Pope Pio II Piccolomini in the XVth century, is built with the local cemented Pliocene sands, but travertine from Bagno Vignoni was used for paving the streets and for the cladding of the Cathedral façade and of the bell tower. Palazzo Piccolomini, built by Bernardo Rossellino, shows a façade in finely hewn Pliocene sandstones, but the window frames and columns of the internal courtyard are made from travertine, allowing it to lighten the slightly dark tone of the masonry (Figure 9) [63]. As in San Gimignano, there are beautiful wells made of travertine.

Castiglione d'Orcia and Rocca d'Orcia, perched a short distance away on a high hill overlooking the Val d'Orcia, were strategic control centres on the Via Francigena. The materials used in the construction of the two villages are limestone of the Cretaceous-Eocene age and bricks, but travertine was used in Rocca d'Orcia for the construction of a cistern, a true jewel of the small village, delimited by a circular wall that delimits a floor where the parapet of the opening is located. Likewise, in Castiglione d'Orcia, there is a wonderful travertine well dating back to 1618, located in a suggestive triangular sloping square paved with cobble stones dedicated to the painter and sculptor Lorenzo di Pietro, known as Il Vecchietta, born in the village (Figure 10).

From the villages and towns of ancient foundation, we pass to Montecatini Terme, a renowned spa town built starting from the second half of the XVIIIth century on the initiative of the Grand Duke Pietro Leopoldo to enhance the springs used already in the Middle Ages. The affirmation of Montecatini as an international tourist centre was accompanied, at the beginning of the XXth century, by the construction in eclectic forms of large hotels and leisure facilities (casino, café-concert, theatres) which were followed by villas and hotels in Art Nouveau style. The most representative thermal building is the Tettuccio, built in neoclassical forms in 1779–1781 and completely renovated in 1918–1928, based on the concept of the Roman baths with grandstands, exedras and imposing travertine colonnades from the nearby Monsummano (Figure 11).

Figure 9. Pienza, Palazzo Piccolomini (XVth century), with the façade in finely hewn Pliocene sandstone and window frames in travertine. On the left, part of the Cathedral façade can be seen, with its travertine cladding (credit Barbara Sacchi).

Figure 10. Travertine well dating back to 1618 in Castiglione d'Orcia (province of Siena) (credit Fabio Fratini).

Figure 11. Thermal baths of Tettuccio in Montecatini (first half of XXth century) (credit Fabio Fratini).

The railway station, built in 1937 according to the spirit of rationalist architecture, represents the last phase of the development of the spa town. The project was by Angiolo Mazzoni, one of the major designers of public buildings, railway stations and postal buildings in the first half of the XXth century. In the building, with the characteristic clock tower, Monsummano travertine was widely used as rustic ashlars cladding, in association, for decorative purposes, with stone materials such as granite and porphyry from Trentino (Figure 12).

The rationalist architecture in Italy had great development during the fascist regime, which, giving great impulse to the realization of public works, testified to the incisive and concrete presence in the country.

In this period, within the framework of a strictly national production policy that tended to minimize trade with foreign countries, new quarries were opened together with the reopening of the disused ones giving great impulse to the use of marbles, granites and stones in the façades and paving. The exteriors are usually white, while in the interiors, the material takes on decorative values in terms of its colour and grain. Marble is used in thin slabs for the cladding and in blocks for particular pieces and finishes. From Tuscany, particularly from the marble basin of the Apuan Alps, comes 8/10 of the national production of stones [64].

The fascist regime created new urban areas and new cities such as Littoria (now Latina), Pomezia, Sabaudia and Aprilia. Some of these works have a pure propaganda function, others represent masterpieces, and others are havoc (as in the case of via della Conciliazione in Rome). This architectural current, with the reduction in forms to an essentiality which corresponds to maximum functionality (elimination of decorations, simplification of shapes to pure volumes, the use of fundamental colours including above all white), extensively used travertine as a cladding and definition of the architectural elements.

Figure 12. Montecatini Terme railway station (credit Fabio Fratini).

In Tuscany, Livorno is one of the cities that bears important evidence of this architecture. It is the main port of Tuscany, on the Tyrrhenian Sea. It owes its birth to a project of an "ideal city", wanted by the Florentine Medici dynasty in the mid-XVIth century entrusted to the architect Bernardo Buontalenti, who thought of the construction of a pentagonal "fortress-city" surrounded by water and imposing walls with five bastions at the top of the pentagon. The advent of the Fascist regime and the political rise of Costanzo Ciano led to the creation and conception of massive plans for the gutting of the city. Thus, in parallel with the construction of a new and larger hospital (the Spedali Riuniti) and the municipal stadium, ancient buildings were demolished in the historic centre to make way for the palaces of the regime, such as the Government Palace based on the project of Alberto Legnani and Armando Sabatini. The architectural complex is of a dazzling white being completely covered with travertine and is enriched by two bas-reliefs, also in travertine, one by the sculptor Vico Consorti depicting Italy in peace and in war, and the other, by Tommaso Peccini, almost 40 m long on the main façade, representing the history of Livorno (Figure 13). The palace has been the location of numerous movies.

In Livorno, the Second World War caused extensive damage. In addition to the targets of strategic interest, much of the historic town and sites of artistic and historical interest were destroyed, such as the Duomo, the Synagogue, the San Marco Theatre and many other churches and historic buildings. In the area adjacent to the Government Palace, devastated by pre-war demolitions and war damage, between 1953 and 1957, under the impulse of the Port Workers Company, the Casa del Portuale was built (also known as Palazzo del Portuale) in rationalist style according to the project of Giovanni Salghetti Drioli, which with its brick facing and the slightly inclined walls recalls the Old Fortress sited nearby. The travertine, in contrast with the red of the bricks, was used to frame both the volume of the building (corners, base, upper frame) and the frames of the openings (Figure 14). This building has also been the location of numerous movies. Nearby, in front of the town hall, is the Palazzo Granducale, built in the first half of the XVIIth century. In the Second World War, it was completely destroyed and rebuilt in 1948 with a part that reflects the characteristics of the old building and a modern one. Travertine is used as cladding and in the pilasters of the front porch of the reconstructed part in an old style, while it constitutes the entire cladding of the modern part.

Figure 13. Livorno, the Government Palace with the bas-relief by Tommaso Peccini, representing the history of the city (credit Fabio Fratini).

Figure 14. Livorno, the Casa del Portuale (1953–1957), that with its brick facing and the slightly inclined walls recalls the Old Fortress (credit Fabio Fratini).

In Florence, the capital of Tuscany, travertine finds its most significant use in the Manifattura Tabacchi (tobacco manufacture building), a distinguished example of rationalist architecture together with the railway station of Giovanni Michelucci, the stadium of Pier Luigi Nervi and Gioacchino Luigi Mellucci and the Institute of Aeronautical Sciences of Raffaello Fagnoni. The project is by Giovanni Bartoli and Pier Luigi Nervi, and the construction was completed in 1940. The courtyard of the clock is bold and modern, just behind the curvilinear head building and the socialization spaces (later transformed into a cinema) with the glazed tower reminiscent of the Marathon Tower of the Florence Stadium (Figure 15).

Figure 15. The socialization spaces (now transformed into a cinema) of the Manifattura Tabacchi in Florence (credit Fabio Fratini).

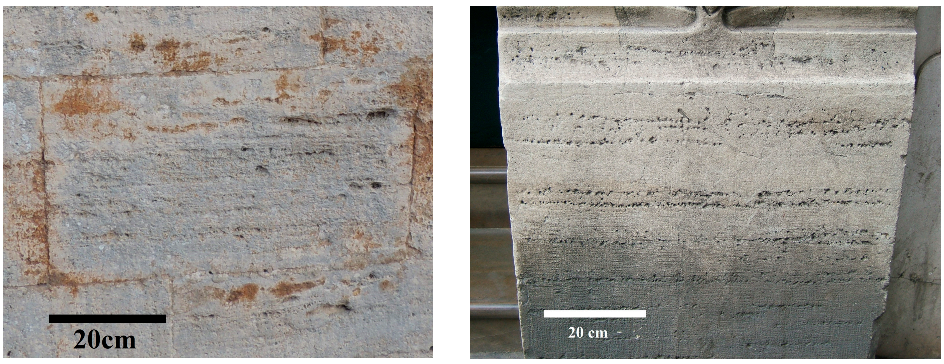
Regarding the first half of the XXth century, another interesting example of the use of travertine is found in Piombino, a city of Etruscan origin located in front of Elba Island, where this material was used in the balustrade with benches of the scenic pedestrian terrace located on the tip of the homonymous promontory (Figure 16).

In the 1960s, travertine continued to be used in civil buildings both for cladding the entire building and as a baseboard, frames for openings and thresholds. Subsequently, there has been a rapid decline, with, in recent years, a resumption of its use as an object of architectural design and interior design.

At the end of this excursus regarding the use of travertine in Tuscany, it must be remembered that this noble material was imitated in the so-called artificial stones between the end of the XIXth and the beginning of the XXth century. In this period, the advent of new hydraulic binders made it possible to create elements of considerable hardness and durability.

Figure 16. The balustrade with benches of the scenic pedestrian terrace in Piombino (credit Fabio Fratini).

The creation of artificial stone products made it possible to respond to the strong demand of materials for architectural ornamentation thanks to the ease of production of the artefacts and to the simplification of installation together with the cheapness of raw materials. These artificial stones were made of a mixture of binder and aggregate with the addition of stone powder and pigments and realized in moulds or on site with a purely decorative and/or coating function, never structural. To imitate true travertine (Figure 17a), white cement was used, and streaks of coarse salt were added to the bottom of the mould, which after dissolution left the characteristic cavities of this stone on the surface (Figure 17b). In Florence, an example of the use of "fake" travertine is in the Casa-Galleria Vichi, an Art Nouveau building built on a project by the architect Giovanni Michelazzi, completed in 1911. It is the most representative of the few Liberty buildings in the city. The very narrow façade is characterized by a marked verticality, with a fascinating mix of artificial stone, steel and glass (Figure 18).



(**a**) (**b**)

Figure 17. "True" travertine ashlar from Sarteano (Siena) (**a**) and fake travertine from Casa-Galleria Vichi (see Figure 17) (**b**).

Figure 18. The Casa-Galleria Vichi in Florence, an Art Nouveau building with a cladding in artificial travertine (credit Fabio Fratini).

6. Travertine in Contemporary Tuscany Architecture

In architecture, in urban furnishing, do the stone materials still represent an identifying character of the place? Are they current architectural materials? Is there still a monumental architecture that uses stones with the specific intent of using a material that represents the site, a material to which a value is attributed in economic, aesthetic and historical terms?

In the case of travertine, as indeed for many other stone materials, the relationship with the production areas is partly being lost in favour of an extra-territorial diffusion. Certainly, in interior design and urban furnishing, travertine is having considerable success. This is due to several factors: This material, compared to the more noble Apuan marble, has always had a lower cost, a high resistance to decay and a pleasant aesthetic appearance, which is noble in a certain sense. In addition, in the last few decades, the processing of travertine has changed from an artisanal to an industrial character and the advent of computerized processing techniques, both in terms of shape and surface texture, has made it possible to obtain surfaces with particular aesthetic effects, requested by architects who deal with design. In the quarry, it is possible to extract it with the least loss of material, which in any case is recovered for other uses, with a reduction in costs and greater environmental sustainability. Furthermore, thanks to the new surface treatments, like the complete filling of the porosity with resin, the accumulation of dirt within the porosity can be avoided favouring the use of this material indoors for flooring and bathroom/kitchen countertops. This is fostering the use of travertine, and this is particularly evident in Tuscany, where its widespread application for decorative purposes in the external facings of public and private buildings allows it to be recognised as the region's identifying material, recalling its ancient historical use.

As an example of contemporary urban furnishing, we recall the new Monte dei Paschi bank business centre in Siena built between the years 1993 and 1998 by Arch. Augusto Mazzini [65]. The architectural complex fills an urban "void" where the main station of the Leopoldina railway was sited (1848), demolished around 1930 when the new station was built not far from it. The building is compact and balanced in its articulation, in which the voids of the courtyard and the internal square seem to be inspired by the typical narrow streets of the historic city. The memory of the place is reflected both by the preservation of the old rails and the XIXth century façade of the locomotive depot and by the used materials that remain attentive and respectful of the context. Thus, the steel framed structure (partly in reinforced concrete) as well as the alucobond aluminium cladding blend well with the most classic construction materials: stone and brick. In fact, Mazzini chooses facing bricks fired in the last surviving Sienese furnace (the same as the neighbouring buildings) and the local Rapolano travertine with grey-blue veins for the side facing towards the historic city walls of Siena (Figure 19).

Figure 19. The new Monte dei Paschi di Siena bank business centre with the use of bricks and Rapolano travertine cladding (credit Silvia Rescic).

In Cetona, a medieval village in the province of Siena recognized as one of the "most beautiful in Italy", the renovation of the main square, Piazza Garibaldi, in the years 2003–2004 (curated by architects David Benedetti and Stefano Borsi) involved a few and targeted interventions aimed at giving the square a connotation of a social and collective place. In this vision, the local travertine of Sarteano was used in the light and dark colours (Figure 20).

Figure 20. The paving of Garibaldi square in Cetona (Siena), realized with regular slabs of the local travertine (credit Silvia Rescic).

In Laiatico (Pisa), the Casciana Terme travertine was used as a delimiting element for the Teatro del Silenzio (designed by Arch. Alberto Bartalini in 2006) [66]. It is a theatre that can be defined as "temporary" as the elements necessary for the performances are removed at the end of the event. The theatre is located in a natural depression among the hills one kilometre and a half from the village of Laiatico. It consists of a small lake in the centre of which stands a monumental sculpture by a contemporary artist, different for each year, and whose backdrop is made of travertine blocks which in the visual and constructive perception recall an ancient place of worship or a megalith of the Neolithic.

In Quarrata (Pistoia), a territory of ancient Roman centuriation, the Monsummano travertine was used in the renovation of Piazza Risorgimento, which took place between 2005 and 2007. The project also involved the restoration of the historic market area with the idea to give rise to a place for meeting, socialization and civil representation. Particular attention was paid to the design and materials of the paving which, in addition to guarantee functional performance, had to satisfy aesthetic needs linked to the local construction tradition and to the previous urban furnishing interventions carried out in the centre of the village. For these reasons, travertine and Pietra Serena sandstone were selected, realizing a decoration made of light-coloured bands (travertine) in contrast to the grey of the Pietra Serena (Figure 21).

In Castelnuovo dell'Abate (Montalcino, Siena), not far from the abbey of Sant'Antimo, the Tabor reception centre fits perfectly into the nature of the Starcia Valley. The centre was built on the occasion of the Jubilee of 2000 by the architect Stefano Lambardi as a place of welcome, a guesthouse dedicated to pilgrims passing through the Via Francigena [67–69]. The peculiarity of this realization is its immersion in nature obtained through an underground structure and "green" roofs, with the cladding of the walls being made of walnut travertine from the nearby quarries (Figure 22).

Figure 21. The paving of Risorgimento square in Quarrata (Pistoia), realized with a decoration of travertine light-coloured bands in contrast to the grey of the Pietra Serena sandstone (credit Silvia Rescic).

Figure 22. The Tabor reception centre near Castelnuovo dell'Abate, where the cladding of the walls has been realized with travertine from the nearby quarries (credit Silvia Rescic).

7. Durability and Conservation Methods for Travertine in Historical/Monumental Architecture

Travertine is a stone that if used in the Mediterranean climate, such as that of Tuscany, shows good durability to atmospheric agents. In other environments, it may suffer decay phenomena due to salt crystallization and freeze–thaw cycles [23,70–72]. As it was said before, during the 1900s and in the present time, the choice of travertine for architecture was mainly dictated by its texture and its wide range of shades, from the coloured variety of Spanish and Turkish travertines [7,73–75] to the white Italian and Turkish [76] varieties. Nevertheless, especially in this last case, the stone surface tends to darken over time. This fact generates chromatic alterations with considerable aesthetic damage to the artifacts. Studies on the long-term durability of travertine [77] have verified the frequent presence of black crusts in the polluted urban environment, made of gypsum accumulations with a laminar or framboidal morphology [78–83], especially on the surfaces with no direct contact with water. The greyish colour is instead the most common chromatic alteration of the travertine, being quite uniformly spread on large surfaces of the exposed stone as a consequence of the biological colonization and of deposit of mineral particles of micron size, usually clayey (Figure 23). The bio-receptivity of the travertine is highly dependent on its cavity presence, exposition to the solar radiation or cutting direction [84]. Cyanobacteria and black fungi are mainly responsible for the darkening phenomena [85–88]; however, other organisms belonging to microflora and macroflora can occur (Figure 24) [50,80,85]. The biological presence, along with other abiotic factors, contributes with different levels of decay to the paedogenic processes that may arise on this kind of stone [84].

Figure 23. Dark-grey biological colonization and predominantly clay-size mineral particles deposition in a travertine baseboard (credit Oana Adriana Cuzman).

Figure 24. Growth of lichens on the travertine architectural decorations of the Church of San Biagio in Montepulciano (credit Oana Adriana Cuzman).

With regard to the survey carried out in Tuscany, the presence of biological patinas was detected in both ancient monuments and contemporary architecture, while no problems of decohesion were ever observed. Occasionally, black crusts are present in historic buildings below overhanging architectonical elements which shelter from rainwater run-off.

The most frequent intervention in documented cases of conservation of travertine is cleaning, carried out with mechanical methods with regards to the higher plants and guano deposits [81,85]. On carbonate encrustations and black crusts, low pressure water is used [79,80,85], sometimes preceded by chemical cleaning by means of ammonium carbonate compresses [79–81,86]. A treatment with a biocide product is often necessary for a complete elimination of biological attacks [80,86].

With regards to any consolidation interventions, a distinction should be made between travertine used and exposed in geographical areas with high temperature and humidity variations and those exposed in more temperate areas, like in Italy. In the first case, some studies [89–91] have verified the improvement of mechanical and physical resistance of travertine by filling the porosity of the stone (with cement or polyester techniques). For travertine exposed to a temperate climate, such as the Mediterranean one, usual and long-known interventions are carried out: in cases where the travertine has cracks or fractures, applications of ethyl silicate can be carried out [81,85,86], and if necessary, injections of acrylic or acryl-silicone resins [82]. Interventions to replace compromised parts are also frequent together with the grouting of macroscopic lesions and fractures with specially prepared mortars containing travertine dust among the components.

Protective treatments are rarely applied on travertine (silanes and/or siloxanes as reported in in 79 and 85). Indeed, considering the low tendency to absorb water of most varieties of travertine, its treatment with hydrophobic products (that would easily alter the natural colour of the surface) is usually avoided.

8. Conclusions

Travertine is a medium-hard material, easy to polish and resistant to atmospheric agents in mediterranean climate that has been used in architecture with both structural and decorative functions, particularly in the northern-central Italian peninsula where many outcrops of this rock are present. Namely, this contribution examines the use of travertine from the Etruscan time to the contemporary age in the architecture of Tuscany, a region rich in hydrothermal springs that gave rise to the formation of this carbonate rock.

Unlike many other stone materials used historically, in Tuscany, travertine remains an identity stone of the territory as evidenced by its use in public and private buildings both in the interior design and urban furnishing. This is due to several factors: this material, compared to apuan marble, has always had a lower cost, a good resistance to decay in Mediterranean climate and a pleasant aesthetic appearance. In addition, along the XXth century, the processing of travertine has changed from an artisanal to an industrial character, and the advent of computerized processing techniques has made it possible to obtain surfaces with particular aesthetic effects, requested by architects who deal with design. Furthermore, thanks to the new surface treatments (i.e., the complete filling of the porosity with resin), this material can be used for many purposes (coating, flooring, masonry, ornaments) with a high guarantee of durability.

With regard to the survey carried out in Tuscany, the presence of biological patinas was detected in both ancient monuments and contemporary architecture, while no problems of decohesion were ever observed. Occasionally, black crusts are present in historic buildings below overhanging architectonical elements which shelter from rainwater run-off. For these problems, the intervention involves cleaning with mechanical methods, low-pressure water, sometimes preceded by chemical cleaning by means of ammonium carbonate compresses, and final biocide treatment for a complete elimination of biological attacks.

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