

Article

Geological and Cultural Heritage in Urban Areas: Interconnections, Challenges and Opportunities

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Abstract

This study examines the challenges of conserving and enhancing geological and historical cultural heritage in urban areas of the southern Apennines, focusing on the Basilicata region in Southern Italy. The area's complex geological evolution has produced diverse landscapes shaped by outcropping lithologies with different characteristics. Many urban centers are surrounded by rugged terrain where geological and geomorphological features remain visible and accessible. The research analyzes several urban geosites through four case studies: Pietragalla, Laurenzana, Brienza, and Lagonegro, located in northeastern and central Basilicata. These sites display significant geological features closely connected with historical structures and urban development, offering strong potential for geoheritage interpretation. By combining a bibliographic review of geological and socio-cultural contexts with detailed field surveys, site-specific features and potential threats can be identified. The main objectives are to document and analyze geological characteristics, assess conservation conditions, and propose geoconservation measures for protection and sustainable use. The study also supports valorization strategies, promoting sustainable geotourism and increasing public awareness. The results emphasize the importance of integrating restoration actions with educational initiatives to ensure sustainable management, provide guidelines for site enhancement, encourage community involvement, and show how valorization of urban geological heritage can strengthen identity and support heritage conservation.

Keywords: geoconservation; geological and cultural heritage; urban areas; valorization; southern Italy



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1. Introduction and Aims

In recent decades, the valorization and conservation of geological heritage have been examined from various perspectives. Several papers discuss the definitions of geoheritage, as well as the quantification of its intrinsic and/or extrinsic value, and geoconservation concepts and actions [1–18]. The term “geoheritage” encompasses natural geological features with significant scientific and human value [3], with elements of

high scientific value linked to geosites [14], and refers to significant geological features and processes that contribute to the Earth's natural history and biodiversity (UNESCO <https://www.unesco.org/en/query-list/g/geoheritage>, accessed on 10 October 2025). So, geoheritage refers to relevant elements of high scientific value (geosites) that must be properly managed to preserve their natural and ecological importance (geoconservation). Beyond the indisputable importance of relevant geosites, another kind of sites includes locations that may not possess significant or relevant scientific value but have other important qualities, such as educational, aesthetic, or touristic significance, defined as geodiversity sites by Brihla [14]. In this paper, we use the term “geoheritage” in its broadest sense, applying it not only to elements of high scientific value but also to geodiversity sites or sites of geological interest, acknowledging that these sites may also warrant conservation actions for their abiotic features. This choice aims to enhance the territory by highlighting areas that, while not scientifically prominent or relevant, can benefit from the promotion of their natural heritage, highlighting the connections between natural heritage and human factors, and subsequently planning the necessary actions for geoconservation. These actions can be both material and tangible, as well as creative and intangible, with a focus on preserving the memory of these sites. There is extensive literature on quantitative geoheritage valorization, defined as the assessment and assignment of a value to geoheritage. This value can be scientific, cultural, educational, or aesthetic, rather than tangible or intangible, and is determined through various parameters, factors, values, and scores ([4,5,7,10,16] among others). In this paper, we use the term “valorization” not in a quantitative sense, but to refer to actions aimed at increasing understanding of and promoting sites, so they are appreciated and known by tourists and even by those who live and experience them daily, and sometimes do not fully know or understand their value. Valorization is a preliminary step to enhancing a site, understood as recognizing its value and emphasizing its potential for use and development.

The Basilicata region is situated within the southern Apennines and encompasses key geodynamic domains including the fold-and-thrust belt, the Bradano foredeep, and the Apulian foreland. This geotectonic complexity has resulted in a remarkable level of geodiversity as defined by Gray [15], making the region home to a significant geological heritage. Such a heritage demands scientific study, appropriate geoconservation measures, and strategies for its sustainable enhancement. These actions are especially relevant in marginal areas [19,20], where geoheritage can provide a valuable opportunity for local development and identity reinforcement [21–23]. In urban contexts, geological features are often highlighted or made more accessible through their interaction with anthropogenic structures, particularly buildings and infrastructures of historical and cultural value. This interplay creates a unique urban geoheritage that deserves specific attention. The present study addresses the identification, protection, and enhancement of urban geological and historical–cultural heritage sites, aiming to promote their visibility and understanding. In this context, geoconservation intersects with scientific, technical, administrative, educational, and policy frameworks [20]. The proposed actions are oriented towards:

- (i) basic and applied research;
- (ii) protection of geological and cultural heritage;
- (iii) dissemination and valorization of knowledge concerning sites of geoscientific interest.

This paper presents a selection of geo-cultural sites embedded within urban areas of the Basilicata region that are currently in need of geoconservation to ensure proper management and future valorization (Figure 1). In particular, four urban sites of geological and historical significance, included in the Basilicata regional list of Landscape assets art. 143 c.1, let. e of Legislative Decree 42/2004 (<https://rsdi.regione.basilicata.it/geonetwork/srv/ita/catalog>).

[search#/metadata/r_basili:-17d03679:1732f2731b9:-6e0a](#), accessed on 10 October 2025), have been studied in detail.

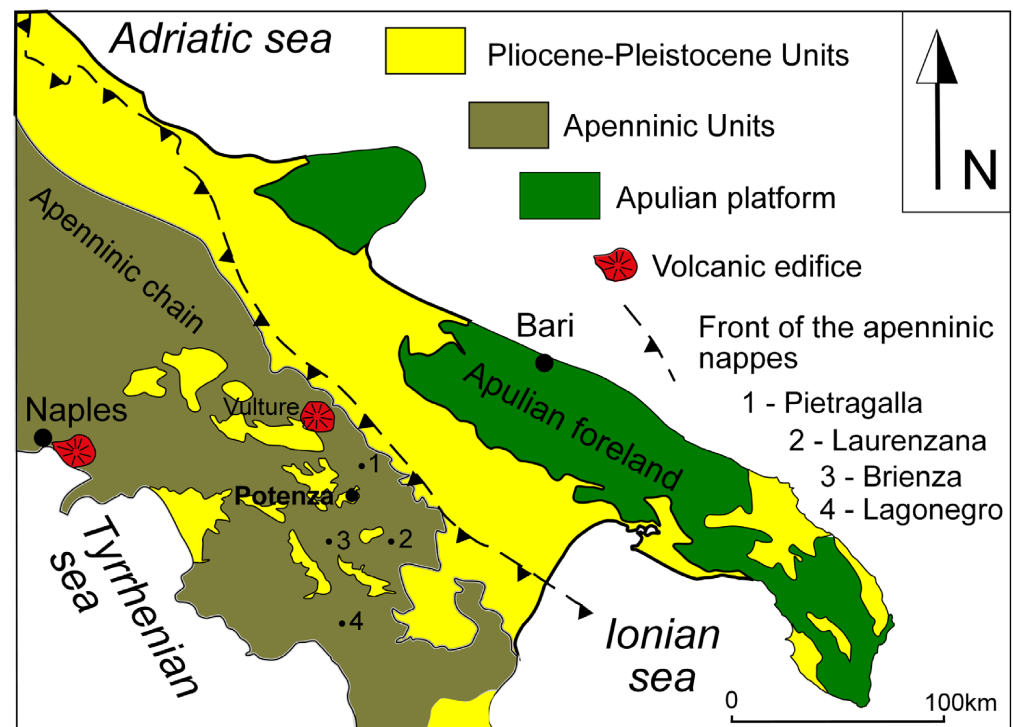


Figure 1. Sketch map of the southern Apennines with the location of the three studied sites (Modified after [24]).

Pietragalla—The *palmenti* and cellars. Located in the north-central part of Basilicata, this site is characterized by outcrops of quartzarenites, which host anthropogenic rock-cut structures such as *palmenti* (wine presses) and caves. These are located along the eastern and northern slopes of the ridge on which the town stands. Some of these structures are currently in a state of deterioration, and this study aims to identify necessary geoconservation interventions and potential strategies for their enhancement.

Laurenzana—The Castle and the Mother Church. Situated in the central sector of Basilicata, outside the main regional transportation corridors, the geosite includes two prominent conglomerate towers belonging to the Gorgoglione Formation, upon which the town's castle and main church are built. Highlighting the geological and cultural features of this site may promote its inclusion in sustainable tourism networks.

Brienza—The overthrust under the Castle. Located in the central-western portion of the region, this site lies on the northeastern slope of a hill crowned by a medieval castle. The slope features tectonic structures that are critical for understanding the geological evolution of the area. The integration of structural geology with cultural landmarks makes Brienza a notable candidate for geotouristic development.

Lagonegro—The Calabro-Lucana Railway bridge. This site is situated within a highly complex geological setting where the Lagonegro Units, the Apennine Platform, and the Liguride Units are exposed. The damaged state of a railway bridge in this area has revealed a Deep-Seated Gravitational Slope Deformation (DSGSD), serving as an illustrative case of geological processes impacting infrastructure.

The goal of this study is to promote awareness of the geological features of these sites and their connections with historical-cultural assets, ultimately increasing their attractiveness for visitors. Moreover, by informing local populations, the study seeks to promote stewardship of this heritage, encouraging urban residents to become active participants in

its protection. Its ultimate aim is to transform geological and cultural features into accessible and valuable resources for education, tourism, and sustainable territorial development. By doing so, it contributes to breaking the isolation of these often-marginal areas, aligning with broader goals of regional regeneration through geoheritage-based initiatives.

2. Materials and Methods

Geoconservation actions involve the management and preservation of geological, geomorphological, and soil features, as well as the natural processes that shape them [3]. To achieve these goals, it is essential to have a comprehensive understanding of the objects considered, both geological and non-geological, including their characteristics and the natural and human-related dynamics that affect them. In Table 1, the categorization proposed by Pescatore et al. [20] is presented. Basic Geoconservation focuses on the baseline identification and inventorying of geological and non-geological aspects present in a study area. Applied and Popularizing Geoconservation involves the practical integration of geoheritage into broader territorial, socio-economic, and cultural frameworks. It focuses on sustainable use, such as geotourism, geo-cultural dissemination, and environmental education, creating socio-economic benefits for local communities while fostering geo-awareness. Technical Geoconservation focuses on the specific engineering, scientific, and technical methodologies required to physically protect, restore, or manage geoheritage and sites of geological interest. This includes implementing stabilization techniques against hydrogeological hazards (e.g., landslides or rock-falls), developing specialized databases for site monitoring, and creating proper infrastructure to make sites accessible and safe for end-users without damaging the geological assets. The main themes presented in this paper are highlighted in red. The repetition of some themes in Applied and Popularizing Geoconservation results from their emergence in distinct contexts: the former being academic and sector-specific, while the latter is popular and broad. This paper examines mainly the first two aspects of geoconservation (Basic; Applied and Popularizing) with the aim to show and enhance the value of the analyzed sites. Technical Geoconservation is presented in preliminary form as the first results of observations made and possible actions to be taken for the purposes of geoconservation.

Following the procedure outlined by Pescatore et al. [20], for geoconservation actions, the text is organized as follows.

Section 3 provides a summary of Basic Conservation actions, referring to geological and non-geological contexts. Aerial photographs provided by the Military Geographic Institute (IGM) were used to analyze the considered areas. Observations made during field surveys, as well as through photogeological interpretation were subsequently mapped using topographic base maps at appropriate scales, obtained from the Regional Spatial Data (RSD) portal of the Basilicata Region. All geographic data were managed within a GIS environment using the open-source software “Quantum GIS” (version 4.0.3). To enhance documentation and facilitate the visual understanding of specific features at the four sites, aerial imagery was also acquired using a Phantom 4 Pro V2.0 drone. Selected high-resolution images were integrated into the study to support both analysis and communication of the results. The study began with an in-depth bibliographic review of the geological and historical-cultural contexts of the selected sites, drawing on various scientific databases and archival sources. Subsequently, detailed geological and geomorphological field surveys were carried out within the urban areas of interest. These surveys formed the basis for the creation of updated geological maps and, where necessary, detailed geomorphological maps of the investigated sectors. All collected data were synthesized to produce materials that are also accessible to non-specialist audiences, to foster broader understanding and appreciation of the unique geoheritage features present in these urban

environments. The non-geological contexts and features considered are also reported and described.

Table 1. Main actions and related themes in Basic, Applied and Popularizing, Technical Geoconservation. Modified after [20,21]. The main themes discussed in this paper are highlighted in red.

Geoconservation	Main Actions	Main Themes	
Basic Data collection	Definition and characterization of	1. physical landscape 2. natural and human-related dynamics 3. geo and non-geo contexts	
Applied and Popularizing Data processing Actions planning Actions implementation	Production of materials and proposals aimed at	Applied	Popularizing
		1. geoheritage evaluation and classification 2. geoheritage vulnerability assessing 3. geoheritage management 4. guidelines production for geoconservation actions 5. database production 6. geoheritage dissemination 7. citizen science	8. geoheritage, scientific and territorial knowledge dissemination 9. environmental issues dissemination 10. citizen science
Technical Actions planning Actions implementation Active and passive monitoring	Production of materials and proposals aimed at	1. geoconservation actions 2. territorial planning 3. support activities to geoconservation actions carried out in geo and non-geo contexts	

Section 4 focuses on Applied and Popularizing Geoconservation actions. These actions are aimed at: (i) assessing the vulnerability of various sites; (ii) evaluating the tourism and geotourism potential of these sites; and (iii) suggesting promotional activities targeted at both local and broader audiences.

Section 5 focuses on Technical Geoconservation actions. These actions aim to assess and propose necessary methods to physically protect, restore, or manage geological heritage and sites of geological interest. Additionally, it addresses the preservation of built heritage where applicable.

3. Basic Geoconservation

Basic geoconservation involves identifying and describing both geological and non-geological elements within a designated study area. The goal of this process is to establish a baseline of various natural features, formations, and processes, as well as human artifacts. Below, the main geological and non-geological contexts of the four studied sites are presented. Note that these descriptions are synthesized to provide a broad overview.

3.1. Geological and Geomorphological General Background

The Southern Apennines constitutes a northwest-southeast trending fold and thrust belt formed by the westward subduction of the Adriatic plate [25,26]. The deformation involved a complex paleogeographic domain characterized by alternating carbonate platforms and deep-sea basins [27–32]. The contractional tectonic deformation began in the late Oligocene and continued into the Pleistocene, producing a tectonic pile composed of various superimposed tectonic units [30,32].

The Southern Apennines comprise three main sub-parallel zones: the inner, axial, and outer zones. The inner zone, located on the Tyrrhenian side, consists of Cretaceous to Miocene deep-water pelagic deposits, pertaining to the Internal Units (Ligurids and

Sicilids), together with related syn-orogenic Miocene siliciclastic successions, which overthrust the Mesozoic Apennine Platform carbonates. The axial zone is largely occupied by the Mesozoic—Cenozoic Lagonegro Units [31,33] and the associated Miocene-Pliocene thrust top deposits (i.e., the Gorgoglione Formation). In this zone the Lagonegro Units are tectonically overlain by the Apennine Platform carbonates [33]. The outer zone predominantly includes Miocene thrust-top successions stratigraphically overlain by the Pliocene–Pleistocene clastic deposits of the Bradano Foredeep.

The four sites considered in this study are located in the outer and axial zones of the Southern Apennines. They represent key geological areas, belonging to different tectonic units, which show clear tectonic and stratigraphic relationships. Each of them is characterized by distinctive, well-exposed geological features.

The first site, corresponding with the village of Pietragalla (1 in Figure 1), is characterized by numerous traditional wine presses (*palmenti*) and cellars excavated into quartzarenite deposits pertaining to the Miocene Numidian Flysch, part of the Lagonegro succession cropping out in the outer zone. These features are not only of geological significance but also testify the local viticultural heritage, showing a strong link between geological substratum and cultural practices.

The second site corresponds to the village of Laurenzana (2 in Figure 1), located along the axial-outer zone of the Southern Apennine. Here, two prominent conglomeratic towers of the Miocene Gorgoglione Formation, served as the foundations for the medieval castle and the main parish church. The striking integration of these structures with the surrounding rocks exemplifies the close relationship between geology and historical architecture in the region.

The third site corresponds to the hill hosting the mediaeval quarter Brienza (3 in Figure 1), situated in the axial zone of the Southern Apennines. The site exposes an overthrust contact juxtaposing Triassic dolomites of the Apennine Platform Units over the Cretaceous–Eocene Flysch Rosso Formation. At the hilltop stands the medieval castle of Brienza. This tectonic contact is a remarkable example of compressional deformation, reflecting the complex geological history of the Southern Apennines.

The final site is the Calabro-Lucana Railway bridge at Lagonegro (4 in Figure 1), located in the axial portion of the Southern Apennine chain. Here, the bridge abutments rest within the Vallone della Serra Valley where deposits related to both the Lagonegro Basin and the Apennine Platform units crop out. The bridge was damaged by a Deep-Seated Gravitational Slope Deformation (DSGSD) affecting the right side of the valley. This case shows how slow and hardly detectable geological processes can be highlighted by the deformation of an infrastructure.

Together, these sites not only contribute to a deeper understanding of the geological history and tectonic evolution of the region but also provide insights into the cultural identity and historical development of the associated urban areas.

3.2. The *Palmenti* and Cellars of Pietragalla

- Geo context

Pietragalla is a small town of approximately 3700 inhabitants in the province of Potenza, Basilicata (southern Italy). The historical center extends predominantly along a NE–SW-oriented ridge, reaching a maximum elevation of about 853 m a.s.l. From a geological perspective, the area surrounding Pietragalla lies in the frontal sector of the Southern Apennine thrust belt and comprises several key tectonostratigraphic units (Figure 2a). The Lagonegro Units are represented by the Flysch Rosso Formation (Upper Cretaceous–Oligocene), consisting of alternating red shales and limestones, and by the Numidian Flysch Formation (Aquitani–Lower Langhian) [30,33,34], characterized by alternating medium-

to coarse-grained quartzarenites and brown clays. The Irpinian Units are represented by the Serra Palazzo Formation (Langhian–Tortonian), which comprises sandstones, lens-shaped microconglomerates, calcarenites, and clays. Pliocene Thrust-Top deposits: consisting of clays, sands, sandstones, and conglomerates, unconformably overlie these units. These formations have been significantly affected by compressional tectonics from the Middle Miocene to the Middle Pleistocene. Subsequently, Plio-Quaternary NW–SE-oriented extensional faults have overprinted and dissected the earlier compressional structures.

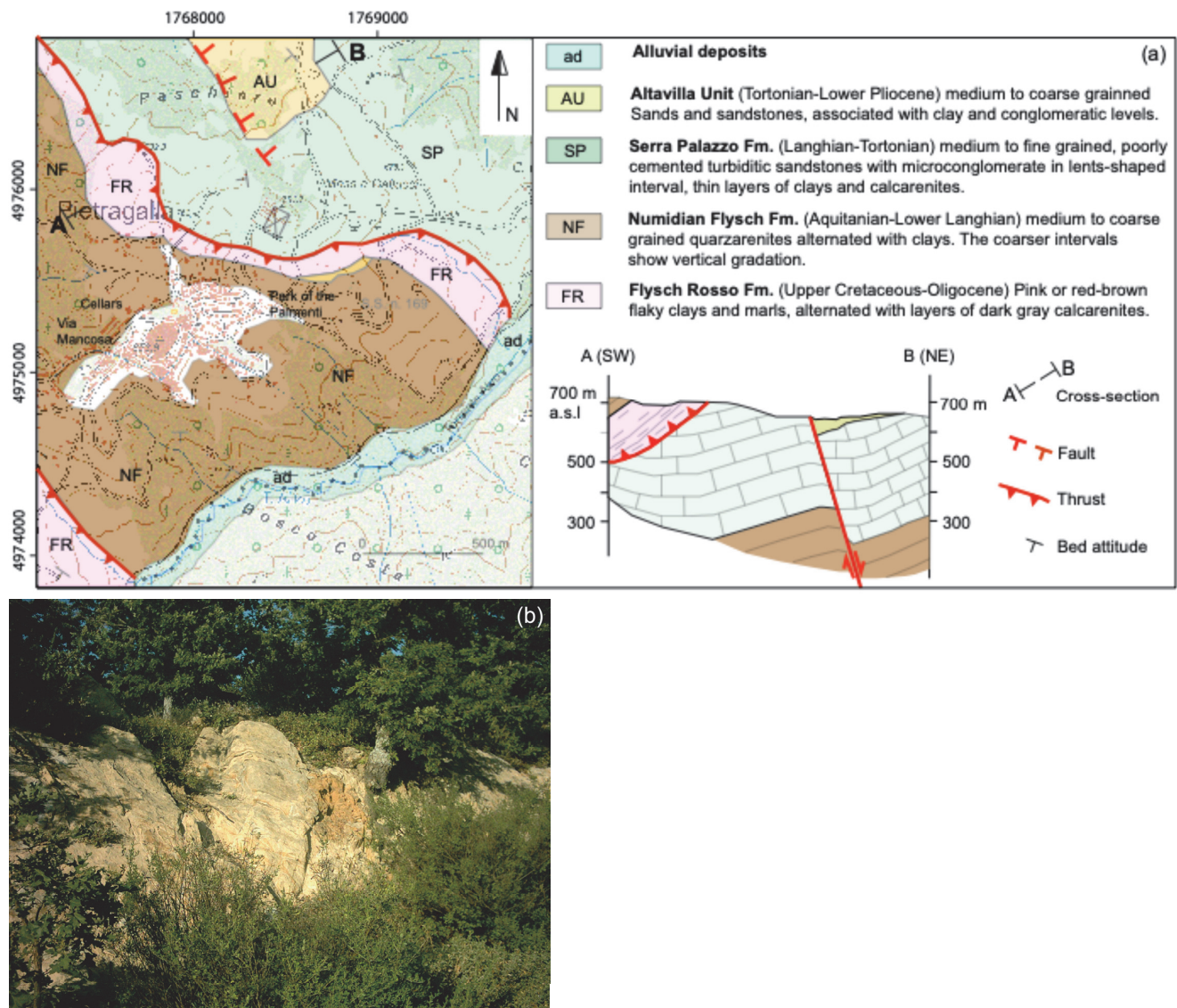


Figure 2. (a) Geological map of the Pietragalla area; (b) outcrop of quartzarenites of the Numidian Formation.

The town of Pietragalla itself is built directly upon deposits of the Numidian Flysch, which provided the ideal lithological conditions for the excavation of the *palmenti* (Figure 2a,b).

- Non-geo context

Within the urban area, numerous traditional *palmenti*, rock-cut wine presses and cellars, have been excavated into the quartzarenite bedrock. While a few structures are located beneath residential buildings in the town center, the majority are located on an east-facing slope near State Road 169 (S.S. n. 169), where approximately 200 units extend over an area

of about two hectares (Figures 2a and 3b). The *palmenti* of Pietragalla represent a rare and significant example of rural rock-cut architecture, regarded as unique for their dense spatial arrangement and architectural coherence. These semi-subterranean units are arranged side-by-side in a highly organized layout, blending seamlessly into the surrounding landscape. The location of the *palmenti* was conditioned by both geological and agricultural factors specifically, the presence of quartzarenite outcrops and the proximity to vineyards that historically covered the eastern slopes of the Pietragalla territory. Each *palmento* consists of a small rock-cut chamber containing at least two basins used for grape pressing and must fermenting. Collectively, these structures form the “Parco dei Palmenti” (775 m a.s.l.) (Figure 3a–c).

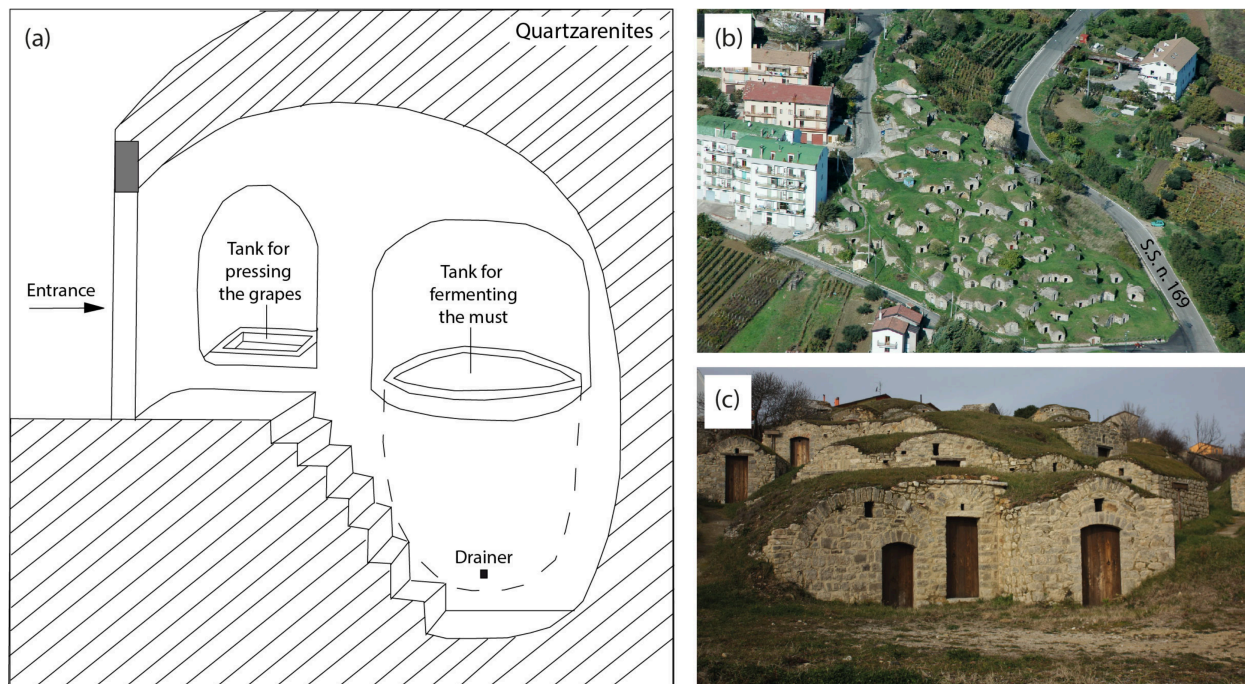


Figure 3. (a) Scheme of a *palmento*; (b) aerial view of the “Parco dei palmenti” area; (c) external appearance of the *palmenti*.

Until the late 1970s, they were actively used during the grape harvest, although most have since fallen into disuse, a few families continue to produce wine using these traditional facilities, thus preserving both the architectural heritage and the associated cultural practices. One remarkable feature of the *palmenti* is their ability to maintain a relatively stable internal temperature throughout the year. This thermal consistency is observed even in structures not fully excavated into the bedrock, where a stone-vaulted roof, built using ashlar masonry, was cambered and subsequently covered with a thick layer of soil, now supporting natural vegetation. The construction materials vary: walls may consist of quartzarenite and limestone blocks, or of mixed of stone-and-brick masonry. Interior architectural solutions also differ: the atrium is often covered by either barrel or cross vaults, while fermentation tanks are typically entirely carved into the quartzarenite, with rock-cut barrel roofs (Figure 3a,c). Each *palmento* features a rational internal layout, including a pressing basin, a fermentation tank, a designated space for the palm’ntedd (a small pressing tool), niches carved into the walls for oil lamps or candles, and in some cases, a fireplace used to heat the must during fermentation.

The *palmenti* constitute a complex system of structures representing a distinctive form of rural architecture associated with historical winemaking practices (Figure 3a,b). After the harvest, grapes were pressed and the must underwent partial fermentation within these

installations. The units were constructed adjacent to one another and are distributed across multiple levels along the slope (Figure 3b,c).

Inside the *palmento*, between one and four basins may be present for grape pressing and must fermentation (Figure 4a,b).

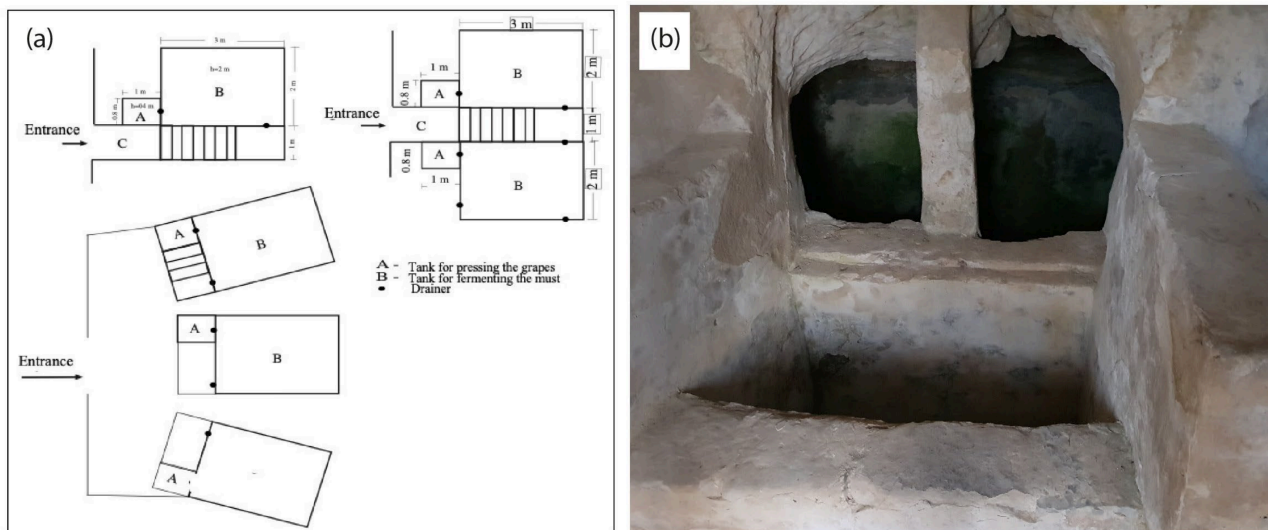


Figure 4. (a) Scheme of *palmenti* with one and multiple fermentation tanks; (b) picture of *palmento* with two fermentation tanks.

More common are *palmenti* comprising two pressing tanks and two fermentation tanks; one set was used for white grapes and the other for red grapes, and these facilities were often shared among several families. The *palmenti* were excavated at the beginning of the 16th century and continued to be developed over the subsequent three centuries. Between the 18th and 19th centuries, the so-called ‘little house’, the elevated structure covering the tanks and the hypogeal spaces, was added [35]. In recent years, the municipal administration has initiated a program aimed at restoring and enhancing the site, including public events designed to increase awareness of the cultural and historical value of the *palmenti* and associated cellars. After fermentation, the must was drawn off and transported to cellars located in the historic center and along the north-facing slope of Pietragalla Hill, in via Mancosa (Figures 2a and 5a–c), where it was transferred into wooden barrels for aging.

The cellars were constructed concurrently with the *palmenti* to meet the need for wine storage following the initial stages of fermentation, in an environment offering stable and suitable temperature conditions. Excavated into the quartz-rich sandstones, the cellars typically house one or two rows of wooden barrels, owned by one or more families. Each cellar is approximately 3 m wide, with their lengths vary considerably. Currently, most of the cellars excavated in the quartzarenites, outcropping along the northern slope of Via Mancosa (Figure 5a), are in an advanced state of decay (Figure 6a,b).

This progressive deterioration has recently led to the collapse of portion of the overlying road and may compromise the stability of the entire slope. The “Parco dei Palmenti” and the cellar area are frequently the focus of initiatives aimed at promoting and enhancing the geocultural heritage of Pietragalla.



Figure 5. (a) Cellars dug along the north-facing slope (via Mancosa); (b) entrance to a cellar dug into the foundations of a house; (c) inside the cellar.



Figure 6. Interiors of abandoned cellars where there are still barrels made by local craftsmen. (a) damaged barrels; (b) barrels and other containers that can be recovered.

3.3. The Castle and the Mother Church of Laurenzana

- Geo context

Laurenzana is located in the central-eastern sector of the Southern Apennines, near the frontal zone of the orogenic belt. In the study area, the outcropping units belong to the Sicilide Units, represented here by the Corleto Perticara Formation [25,36–39]. This

formation consist of marls, marly limestones, calcilutites, calcarenites, shales, and, less frequently, sandstones and calcirudites. These units form the pre-Miocene substratum onto which the thrust-top deposits rest, namely the Irpinian Units and the Plio-Pleistocene successions. The former includes the Gorgoglione Formation (Upper Langhian–Lower Tortonian), composed of turbiditic claystone, sandstone, and conglomerate successions [40,41], while the latter comprise the Calvello Basin deposits, consisting of marine to transitional sediments [42,43]. The Sicilide Units were regionally overthrust onto the Gorgoglione Formation as a result of the compressional tectonics that shaped the Apennine chain. Along this major tectonic contact, isolated conglomeratic slices of the Gorgoglione Formation are exposed. These outcrops were historically exploited as foundation substrate for the construction for key architectural structures, including the Mother Church and the medieval Castle of Laurenzana (Figure 7).



Figure 7. The two conglomerate towers that house the castle and the mother church at the top.

The area is bounded by two major strike-slip fault zones: a NE-SW oriented right-lateral strike-slip fault coinciding with the Camastra Stream, and a WNW-ESE oriented left-lateral strike-slip fault, commonly referred in the literature as the Scorciabuoi Fault. The most recent tectonic phases in the area are represented by N110° oriented left-lateral strike-slip faults and SW-NE oriented normal faults. The south-western conglomerate tower, located at 855 m a.s.l., was selected as the site for the medieval castle, whereas the north-eastern tower, at 820 m a.s.l., hosts the Mother Church [44] (Figure 8).

- **Non-geo context**

The Laurenzana Castle, like the Mother Church, is closely integrated with the underlying bedrock. Designed to defend the village, its walls follow what is known in military terminology as the “tactical edge of the terrain,” thereby enhancing the natural defensive advantages provided by the rock while optimizing the use of available space, as demonstrated by the architectural plans of both structures (Figure 9).

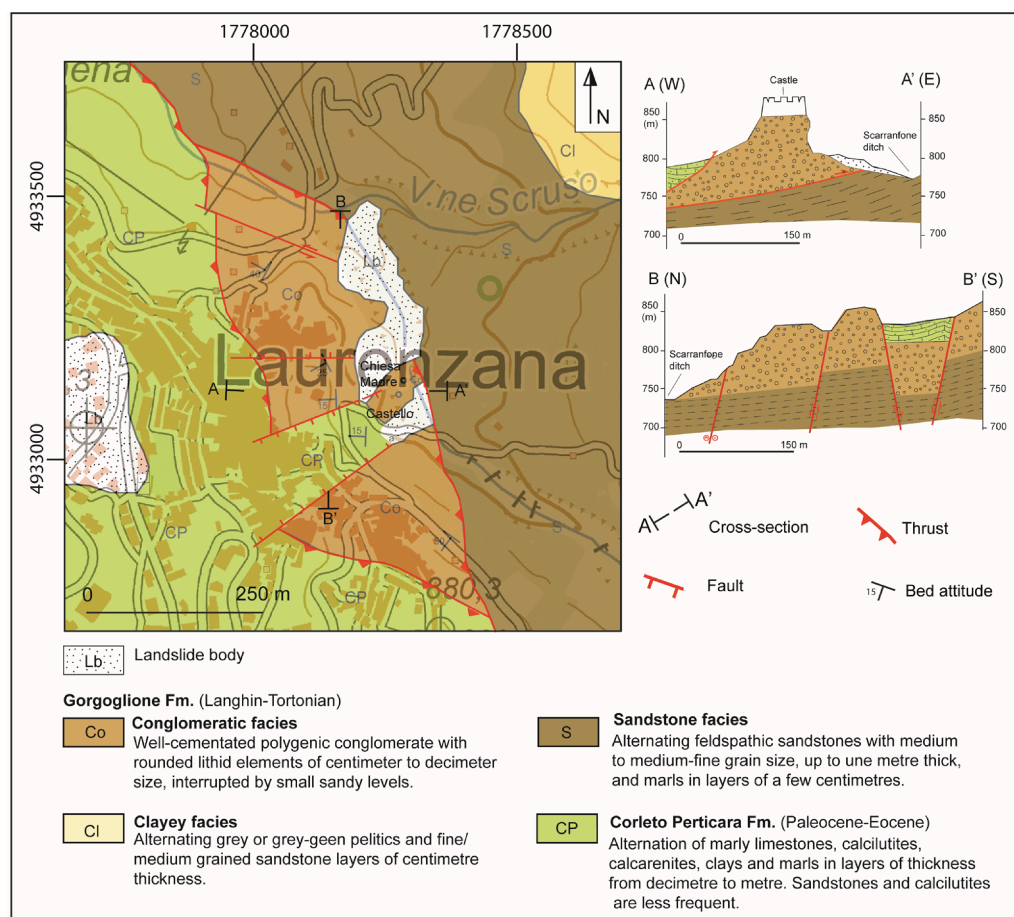


Figure 8. Geological map of the Laurenzana area [44].

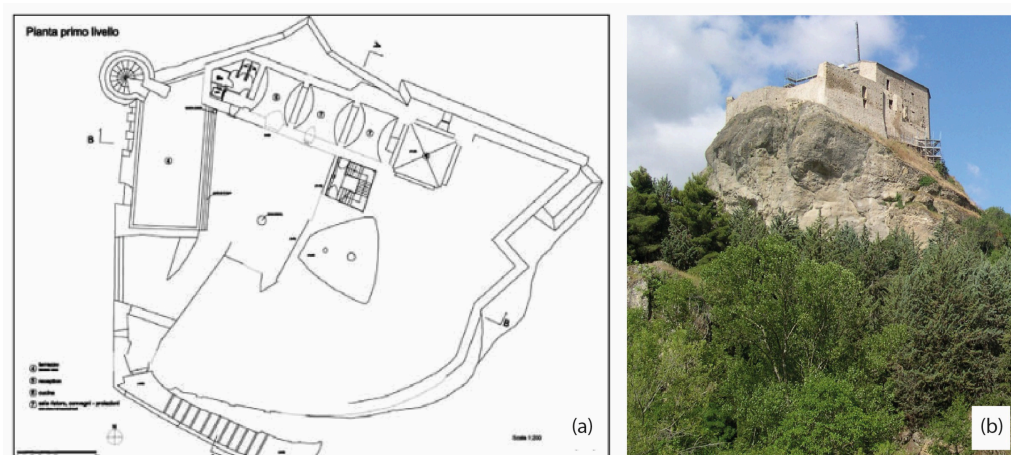


Figure 9. (a) planimetry the castle; (b) view of the castle.

The underground rooms, historically used as stables and cisterns, extend across two levels entirely excavated into the bedrock. The castle dates to the Norman period (1040–1190), when it was granted in fief to Guglielmo, son of Matteo da Tito, and underwent significant renovation during the Angevin period (1250–1450). Subsequently, the Aragonese (1400–1500) extensively modified the structure to accommodate firearms and to reflect emerging Renaissance architectural tastes [45]. Between the eighteenth and nineteenth centuries, the castle was transformed into its current palace-like configuration, marking a shift away from its original defensive role. During this phase, the building was vertically expanded on all sides and enlarged by incorporating the remaining small spaces at the

top of the tower. Numerous collapses affecting the tower's perimeter were documented, prompting early stabilization interventions such as the construction of buttresses. The castle's abandonment began in the early 20th century and accelerated markedly after World War II. Major restoration efforts commenced in the 1980s, initially focusing on the consolidation of the conglomerate tower and later extending to the overlying structures [46] (Figure 10).



Figure 10. Consolidation work on the conglomerates and the buildings.

The Mother Church of Santa Maria Assunta was originally constructed at the beginning of the 13th century and expanded in 1583 (Figure 11a,b).

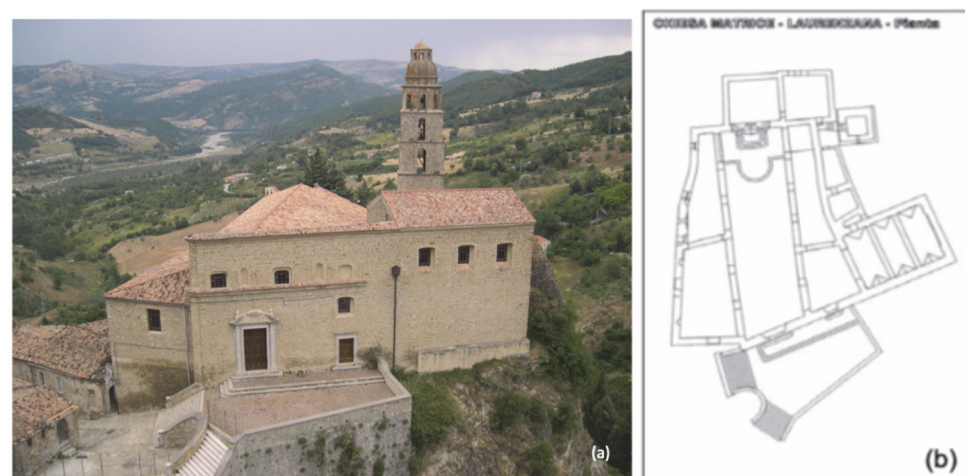


Figure 11. (a) Mother Church of Santa Maria Assunta seen from SE; (b) planimetry.

It attained its current configuration in the 18th century with the addition of the lateral chapel, completed in 1780, which complemented the basilica's three-nave plan. The monumental double-ramp entrance staircase, characterized by an oval layout, together with the main and secondary portals, represents a notably example of late Baroque architecture. From the 1980s onward, the Mother Church has undergone structural reinforcement to improve its seismic performance, followed by several restoration campaigns aimed at preserving and enhancing its historical and artistic value [46]. Since their restoration, both the castle and the Mother Church have attracted numerous visitors. The castle, in particular, hosts exhibitions, conferences, and various cultural events designed to promote and valorize these heritage sites.

3.4. The Overthrust Under the Brienza Castle

- Geo context

The study area corresponds to a major thrust system responsible for the tectonic superposition of the Apennine Carbonate Platform onto the Lagonegro Basin Units [31]. The carbonate platform succession consists of Triassic dolostones and dolomitic breccias, which grade upward into Ellipsactinia Limestones (Upper Jurassic). These are unconformably overlain by Miocene sandstones belonging to the Monte Sierio Formation. The Apennine Carbonate Platform is tectonically emplaced above the Lagonegro Units, represented in this area by the Flysch Rosso Formation (Upper Cretaceous–Eocene), a turbidite succession composed of calcarenites alternating with red to green marls. Above the Overlying the Mesozoic substratum in angular unconformity are Pleistocene alluvial deposits associated with the Pergola–Melandro intermontane basin. These basin-fill deposits consist of alternating reddish matrix-supported polygenic conglomerates and coarse-grained yellowish sands, reaching a maximum thickness of approximately 100 m. The thrust plane is a top-to-the-E–NE vergent structure. The footwall unit displays typical semi-ductile deformation features, including S–C tectonites and boudinage, whereas the hanging wall carbonates are pervasively fractured and locally affected by cataclastic zones exhibiting a flour-like texture. This thrust contact is dissected by a network of younger, high-angle faults predominantly oriented NW–SE, which fragment the original thrust surface and produce a stepped morphology that progressively dips toward the E–NE. The presence of syn-tectonic calcite fibres on fault planes indicates a general transtensional to extensional tectonic. The Plio-Quaternary activity of these faults is inferred from the deformation of the alluvial deposits within the Pergola–Melandro Basin. The thrust surface is well exposed near the confluence of the Pergola and Fiumicello streams, which encircle the village of Brienza. Continued regional uplift has enabled these streams to incise into the alluvial fill, gradually exposing the underlying Mesozoic substratum. This fluvial incision has produced an asymmetric valley profile: the steeper valley side corresponds to the more competent carbonate rocks, whereas the gentler slope has developed within the more erodible Lagonegro Units (Figure 12).

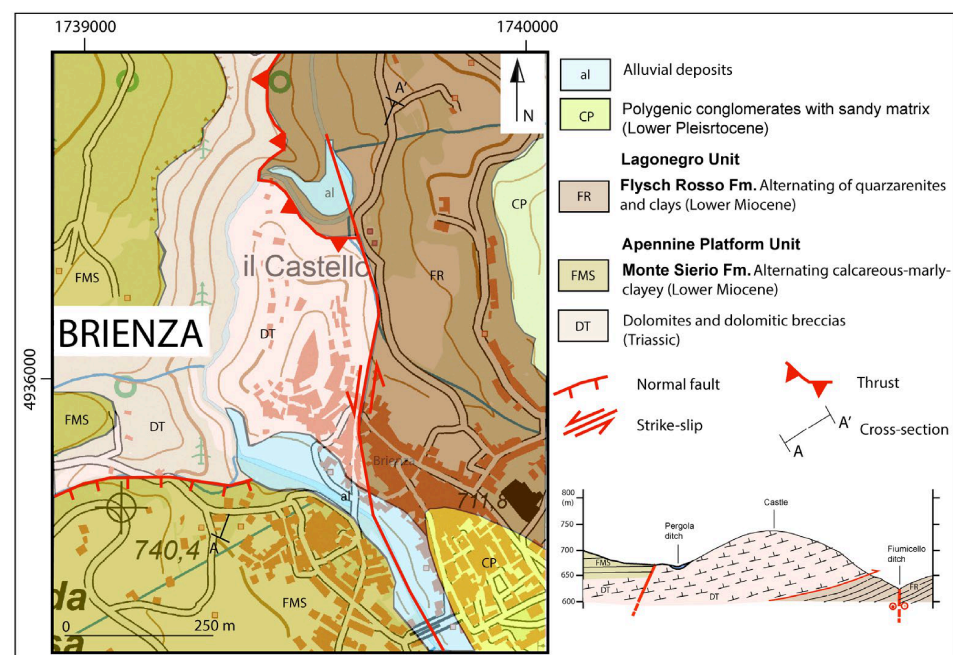


Figure 12. Geological map and cross-section of the northern part of the Brienza.

Remnants of the original alluvial surface are preserved at approximately 750 m a.s.l., forming flat surfaces or, along the margins, narrow ridges with sub-horizontal longitudinal profiles. Multiple episodes of tectonic uplift and periods of stasis are recorded by a sequence of fluvial terraces at different elevations relative to the modern Pergola and Fiumicello streams. The landscape is characteristic of a mountainous region, with surface drainage patterns strongly influenced by recent tectonic activity. The medieval castle of Brienza is strategically located above the carbonate succession in the hanging wall of the thrust fault (Figure 13a,b).



Figure 13. (a) View of the Brienza Castle from the NE; (b) overthrust (red line) along the eastern slope of the hill on which the Brienza castle was built.

- Non-geo context

The castle is located in the northern part of the town, atop a steep hill flanked by two streams called the Pergola torrent and the Fiumicello. Its origins date back to a Lombard fortification, although the current structure has medieval roots, as evidenced by a 1237 record from Emperor Frederick II, which attests to the building's existence. During the Angevin period (13th–14th century) the fiefdom and the castle assume prominent defensive functions. In the 15th century, ownership of the castle changed hands several times before acquired by the Caracciolo family of Naples. Under the Caracciolo family, in 1783, the castle underwent modernization and embellishment works [47,48]. The castle sustained severe damage during the 1857 earthquake and subsequently remained in a prolonged state of abandonment [49–51]. Following the 1980 earthquake, restoration efforts began to consolidate the structure and enhance its value as a cultural and tourist asset [52]. Today, the castle is open to visitors, hosts cultural events, and form part of a broader initiative to promote the historic village of Brienza as a “city of art.”

3.5. The Calabro-Lucane Railway Bridge of the Lagonegro Village

- Geo context

The Calabro–Lucane Railway bridge, situated on the outskirts of the Lagonegro urban area, represents a clear example of the impact that slope gravitational processes can have on infrastructure (Figure 14).

The Lagonegro area is located within the western sector of the Southern Apennine Chain and comprises several tectono-stratigraphic units that belong to three primary paleo-geographic domains: the Liguride Units, the Apennine Platform Unit, and the Lagonegro Unit [25,53] (Figure 15).



Figure 14. View of the Calabro-Lucane railway bridge in Lagonegro.

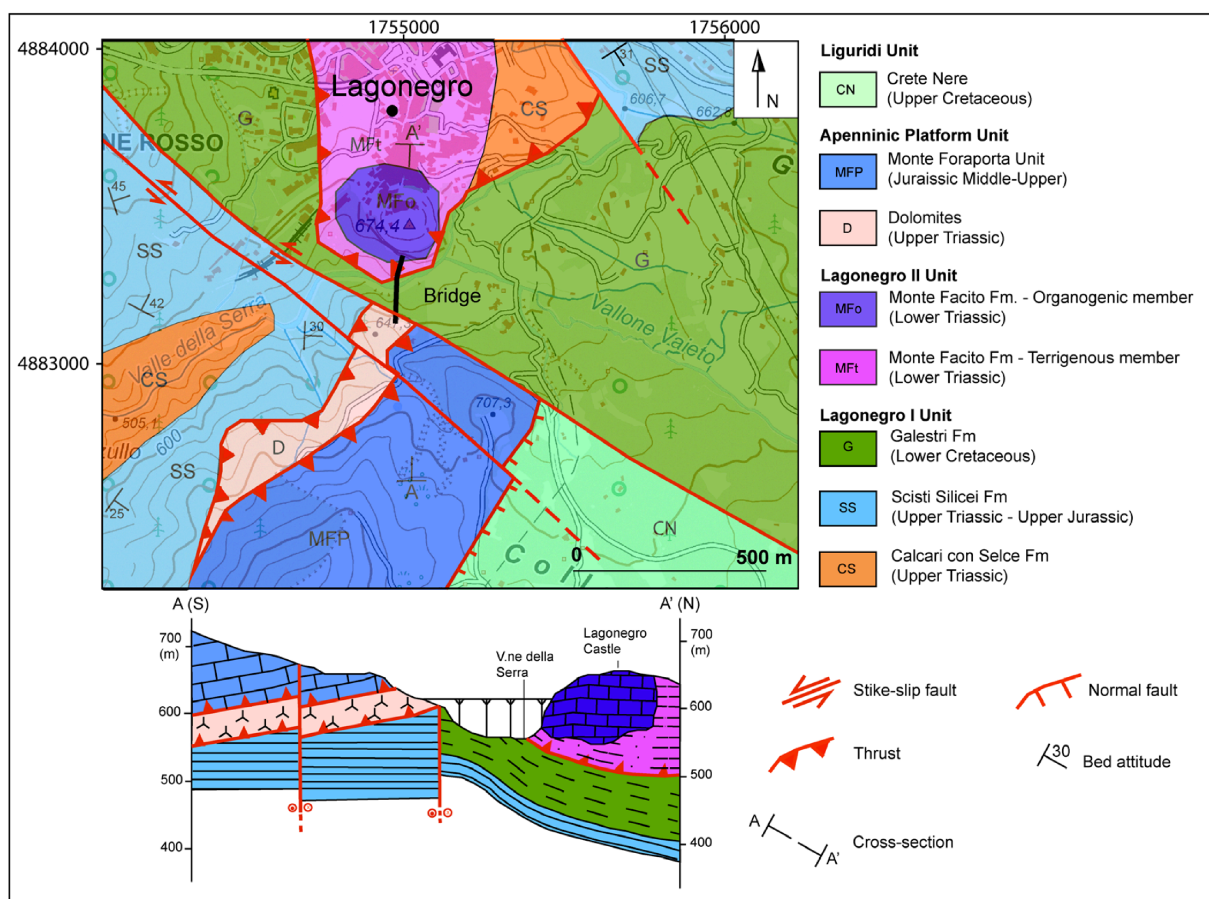


Figure 15. Geological map and cross-section of the Lagonegro area.

The topmost unit is represented by the Crete Nere Formation (Liguride Units), which tectonically overlie the carbonates of the Campanian–Lucanian Platform [53,54]. The deepest units are represented by the Lagonegro Basin successions [55,56].

During the Miocene, compressional deformation caused the carbonate platform units to overthrust onto the Lagonegro succession, resulting in duplication of the Lagonegro units [56]. This compressive phase produced widespread folding with a predominant NW–

SE orientation [57]. During the Quaternary, this compressional regime was overprinted by a brittle tectonic phase, marked by the activity of both normal and strike-slip faults. The normal faults trend approximately N–S, N130°, and N40°, whereas the strike-slip faults, characterized by left-lateral motion, trend around N130° [58].

- Non-geo context

The Calabro–Lucane Railway bridge crosses a major N140-oriented left-lateral strike-slip fault, juxtaposing the Lagonegro Unit formations to the north with the Apennine Platform carbonates to the south (Figure 15). The northern abutment of the bridge rests on a carbonate block based on a siliciclastic succession belonging to the Monte Facito Formation (Middle Triassic), at the base of the Lagonegro succession. Close to the fault zone, the dark shales and silicified marls characteristic of the Galestri Formation are also involved. On the southern side, the bridge is founded on the Apennine Platform carbonates composed of Triassic cataclastic dolomites and the Jurassic limestones. The pronounced lithological contrast between the carbonate block and the terrigenous deposits at its base likely plays a key role in promoting the slope instability responsible for the deformation observed in the bridge structure. The viaduct, approximately 200 m in length and reaching a height of about 60 m, features a mixed structural design composed of masonry piers and reinforced concrete parabolic arches. Its construction required the expertise of highly specialized engineering firms. Notably, a French company—one of the few at the time possessing the necessary technical capabilities—was contracted to build the arches [59]. The railway section was officially opened to service on 28 October 1929 (Figure 16).

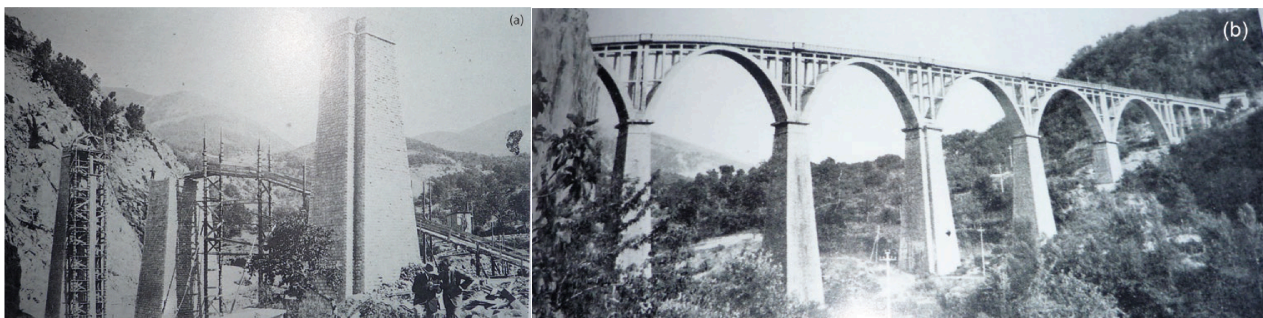


Figure 16. (a) Photo of the bridge during the construction; (b) View of the bridge just finished.

The effects of the deformation were clearly reflected in the structural displacements of the viaduct. As shown in Figure 17, an initial compressive phase, generated by the thrust of the downslope-moving carbonate block, was followed by a tilting of the structure, producing a vertical displacement of approximately one meter along the railway line (Figure 17a–c).

Progressive deformation affecting all six arches ultimately led to the suspension of railway operations on 1 March 1952. Field investigations indicate that the deformation was primarily caused by a Deep-Seated Gravitational Slope Deformation (DSGSD) [60–64]. This DSGSD developed along a listric slip surface located at the interface between a rigid limestone block supporting the northern abutment of the bridge and the underlying terrigenous deposits (Figure 17a). The gravitational process initially manifested as translational sliding and subsequently evolved into rotational movement of the carbonate block. This evolution was facilitated by the strong mechanical contrast between the competent limestone and the underlying, more deformable terrigenous units. The pronounced lithological discontinuity also acted as a preferential pathway for water infiltration, further promoting slope instability. The bridge lies along the route of numerous field excursions involving school

groups, researchers, and enthusiasts. These excursions traverse an area particularly rich in geological heritage, contributing to its valorization and to the promotion of geotourism.

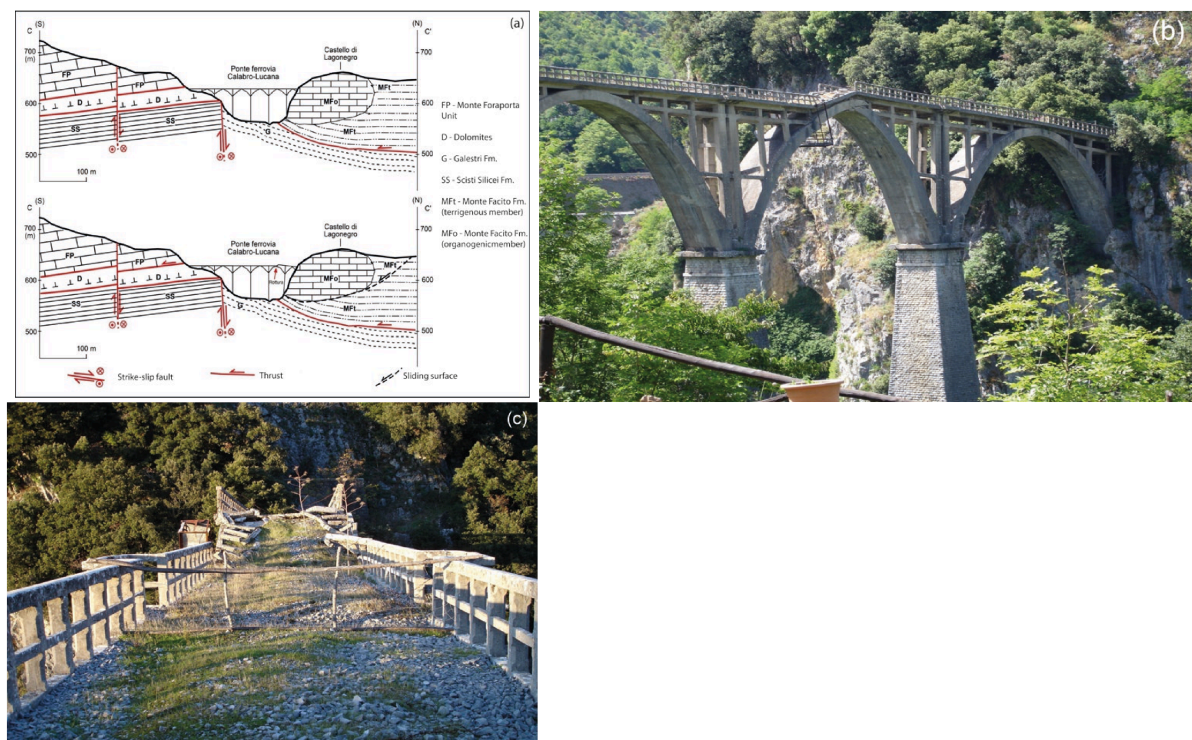


Figure 17. (a) Geomorphological sections created along the Calabro-Lucane railway bridge, before and after DSGSD [64]; (b) Photo of the bridge after the break; (c) difference in level of the railway track.

4. Applied and Popularizing Geoconservation

Applied and popularizing geoconservation involves a thorough analysis of the key themes that define the study sites, as well as the practical integration of geoheritage into broader territorial, socio-economic, and cultural contexts. As mentioned above, we use the term “valorization” not in a quantitative sense, but rather to describe a set of actions aimed at enhancing understanding and promoting specific sites. Through valorization, our goal is to raise awareness about the cultural, historical, geological and environmental significance of these locations. This process involves educational initiatives and community engagement to highlight the unique features associated with these places. To achieve geoconservation goals, it is crucial that the local communities are actively involved, as they represent the first stakeholders. Moreover, valorization is an important first step in enhancing a site. It involves recognizing the site’s inherent value and its potential for development, leading to better utilization, sustainable tourism, and thoughtful conservation efforts. This applies to both geological and non-geological contexts. Contacts are currently underway with local administrations to establish collaboration protocols, specifically tailored to the characteristics of the sites. Note that the arguments related to site valorization are only briefly mentioned to provide an idea of the potential of these locations. Their development will depend on local needs, considering both residents’ and tourists’ perspectives. The common objective of the various proposals is to enhance geological and environmental knowledge and awareness. In Table 2, the main geological and non-geological issues and themes identified in the analyzed sites are presented.

Table 2. Main geological issues and themes, both fundamental and specialized, present in the analyzed sites.

Geo-context Main issues							
Basic geology, physical geography and geomorphology	Rocks and Mineral		Difference between rock and mineral. Recognizing different types of rock. Interactions between different rock types throughout the rock cycle. Main characteristics of sedimentary rocks. Hydrographic network definition and evolution. Landscape definition and evolution.				
	The rocks cycle						
	Sedimentary rocks						
	Hydrographic network						
	Landscape and landforms						
Advanced geology	Regional geology		Analyzing geological features, series, formations, and units on a large scale within a specific geographic area provides a comprehensive understanding of a region's geological evolution, structural architecture, and the distribution of rock formations.				
	Structural geology		Analysis of mineral or rock arrangement and deformation at micro-, meso-, and macroscale, including their original and current shapes, and the forces that caused their deformation.				
	Applied geology		Using geological principles for site assessment, foundation design, and analysing potential hazards like slope instability and earthquakes				
	Rocks and Minerals	The rocks cycle-Sedimentary rocks	Hydrographic network	Landscape and landforms	Regional Geology	Structural geology	Applied Geology
Pietragalla	X	X			X		
Laurenzana	X	X	X	X	X	X	X
Brienza	X	X			X	X	
Lagonegro	X	X	X	X	X	X	X
Non-Geo context and related geo context							
Pietragalla	Ancient rural rock-cut architecture		Carved stones		Building stones		
Laurenzana	Medieval architecture		Building stones		Buildings constructed on or integrated into bedrock		
Brienza	Medieval architecture		Building stones		Buildings constructed on or integrated into bedrock		
Lagonegro	Industrial architecture		DSGSD		Buildings constructed on rock		

As previously described, the selected sites clearly represent basic geological themes, thereby allowing the association of specialised themes.

Furthermore, each site is characterised by unique and peculiar objects closely linked to both the human and geological context. In all analyzed cases, aspects of the geological context have significantly influenced human presence, the establishment of places for human activity, and continue to affect their conservation. In this paper, we have highlighted the architectural features of various constructions and their connections to the geological context. This emphasis stems from the recognition that these features are essential in drawing tourists and enhancing their overall experience. In Pietragalla, the *Palmenti* Park and the cellar area are often focal points for numerous cultural initiatives. In Brienza, the “Vivi il Medioevo” Medieval Festival is a historical reenactment that features the reconstruction of a medieval village. This event includes artisan workshops, markets, court life, spirituality, dances, taverns, games, and scenes depicting daily life. The historic center of Laurenzana features various local religious and folkloric events. Cultural and musical events are organized in Lagonegro, attracting many tourists. These situations highlight the importance of asset enhancement and protection. Before exploring these topics, it is crucial to highlight that effectively enhancing and safeguarding an asset necessitates a comprehensive understanding of it at the local level. It is crucial to engage local communities and raise awareness about their historical and cultural heritage, as well as its fragility, and

also providing the essential tools needed for enhancing and conserving this heritage. To achieve this, we believe it is crucial to provide free, appropriate informational materials to local schools and individuals involved in the area's enhancement efforts. Although this paper will not discuss this aspect, as it focuses on the general aspects of geoconservation, it is important to emphasize that effective geoconservation actions require the involvement and participation of the local community. Gaining a deep understanding of the rich natural and cultural heritage that exists within the territory people belong to, along with its importance in a larger context, is an essential first step toward its preservation. By recognizing its value, people cultivate a sense of pride and responsibility in safeguarding this common good for future generations. For each site, the main critical issues and potential solutions will be introduced, starting with geoconservation concerns and then addressing enhancement issues. As regards the latter, in many instances, the urban landscape, along with its architectural and natural features, presents opportunities for on-site enhancement efforts [65,66]. It's essential to distinguish between temporary initiatives that occur during specific events throughout the year, which attract tourists, and more extensive initiatives that involve schools and residents. These broader initiatives aim to raise awareness and foster participation in promoting and caring for the community's cultural heritage.

4.1. Pietragalla

The *Palmenti* Park and the cellar area are excellent examples of ancient rural rock-cut architecture. The availability of a material that is both durable and workable, namely Numidian sandstone, contributed significantly to the development of this area. Numidian sandstones are highly mature quartzarenites, with a SiO₂ content comprising 93 weight percent (wt%), occurring in beds that range in size from one to several meters and often exhibit dense local fracturing. From a geotechnical perspective, their behaviour is influenced by the high quartz content, the degree of cementation or alteration, and the presence of fracturing systems, which can lead to severe physical weathering in outcropping conditions. Generally, intact rock exhibits good strength characteristics, and is considered a durable and versatile material, commonly used as building stone. When excavated, they also serve as natural containers. The underground chambers created by this excavation maintain a constant temperature and environmental conditions, making them ideal for wine processing and storage.

- Vulnerability

Most of the *Palmenti* and cellars are in good condition, thanks to the nature and composition of the sandstone, which provides strong resistance to environmental elements and human impact. The latter is mainly linked to the abrasive effects of tourists's footwear and the environmental changes that can occur in underground spaces when crowded. However, some cellars are experiencing significant abandonment and deterioration. Notably, rainwater infiltration has been observed; if left unaddressed, it can cause severe damage to cellars and, consequently, to the surrounding urban area.

- Valorization

The area of *Palmenti* Park is well-suited for displaying informative panels that focus on both historical and cultural aspects, as well as geological themes. These panels could provide information about the characteristics of the rocks, their formation and origin, and introduce concepts such as geological time, the deformative history of the territory, geodiversity, and biodiversity, among others. Furthermore, specific historical and cultural issues can be addressed, such as the use of quartzarenite as a building stone at this site and others in Basilicata. The site offers an opportunity to explore various aspects, including the rock's characteristics, its different behaviors regarding weathering both underground

and on the surface, and the potential for engaging residents in citizen science initiatives to actively monitor the weathering process. The site is ideal for hosting sensorial experience stations where visitors can engage with the sandstone. Various points throughout the area invite guests to touch the rocks, allowing them to appreciate the texture and grain size. Additionally, installing magnifying glasses at strategic locations would enhance the experience by enabling visitors to closely examine the rock's various components, providing both a tactile and visual encounter. These installations should ideally be placed at various heights to ensure that even children can interact with them independently. Additionally, each installation should include brief descriptions of what can be observed, tailored to different age groups—using simpler language for children and more complex language for adults.

4.2. Laurenzana

The Castle and the mother church of Laurenzana are built on two natural towers that represent distinctive elements of the landscape. They consist of well-cemented conglomeratic-arenaceous and sandstone deposits. From a geotechnical perspective, sandstones exhibit medium to high compressive strength. They are quite dense rock, despite being highly porous and prone to water absorption, particularly through capillarity. The building's base walls are constructed on the natural bedrock, which consists of the same sandstone used as building stones. The buildings feature rooms carved into the rock, which were used as stables and cisterns in the castle and as burial places in the church. During restoration work, archaeological excavations in the church uncovered fragments of paper, fabric, and leather, along with shoes and other footwear, preserved thanks to the high humidity that characterizes these spaces [67]. The towers underwent consolidation and stabilization work to preserve the historic buildings above them. These interventions focused on securing the sites rather than geoconserving their geological features. The consolidation interventions performed enhanced the stability of rock bodies while maintaining their porosity and permeability characteristics.

- Vulnerability

The presence of fracture systems affecting the deposits negatively impacts their stability. Over time, collapses along the walls and detachments of boulders of various sizes have occurred. This situation emphasizes the need to monitor the existing surface rainwater drainage system to limit infiltration, which could damage the towers and, consequently, put the buildings' stability at risk.

- Valorization

Throughout the year, various events attract primarily local tourists. The Castle and the Mother Church are listed by the FAI (Italian Environment Fund). In July, a medieval historical reenactment occurs, featuring an impressive parade. During this event, the four *contrade* (districts) of the village compete in medieval-style games. The winning *contrada* presents a lily to the Madonna, who is enshrined in the Chiesa Mare, and carries it in a procession on 16 July. Both the Castle and the Mother Church feature large areas that could be dedicated to temporary installations focused on geological and environmental themes. The streets of the village would be transformed into a journey showcasing various themes, guiding visitors to enhance their understanding of the area from geological, geographical, physical, and naturalistic perspectives. Ideally, the routes would feature panels for adults as well as interactive panels specifically designed for children, making their experience engaging and enjoyable.

4.3. Brienza

The historic center of Brienza retains its medieval architecture. The houses and castle were built using limestone, readily available locally and sourced from the calcareous portions of the Flysch Rosso and the Apennine Platform formations. The castle was constructed in a strategic location, situated on a narrow hill. This position provided excellent visibility over the surrounding territory while also offering a defensible stance, as the rugged terrain made it difficult to access. At the base of the hill, where Brienza Castle is located, the tectonic contact between two significant geological formations that characterize this area of the southern Apennine chain, belonging to different paleogeographic contexts, is observable. Here, carbonate deposits from the carbonate platform paleogeographic domain (Apennine Platform) overlie deposits from the basin paleogeographic domain (Lagonegro Basin). The carbonate deposits include dolomites, dolomitic limestones, breccias, and calcarenites, while the basin deposits are composed of calcarenites and calcilutites, alternating with predominantly red marlstones from the Flysch Rosso Formation. This is one of the crucial sites for understanding the evolution of the southern Apennine chain. It is well known by the geological scientific community, and is an object of study. It can be accessed via a path. The overhanging rock face exhibits various fracture systems and shows signs of collapses ranging from small to medium-large dimensions.

- Vulnerability

Regarding geoconservation issues, essential measures must be taken to ensure the safety and integrity of the site. These measures include removing unstable rock blocks, strengthening the rock wall, and carefully maintaining the trail. These actions can significantly reduce risks and enhance the overall safety of all visitors. Currently, wearing a safety helmet is recommended and mandatory for geology students approaching the site during educational excursions.

- Valorization

If adequately explained, this site offers a valuable opportunity to educate the public about the large-scale evolution of the southern Apennines, the concept of geological time, and how it differs from human perceptions of time. The urban layout of the historic center is well-suited for thematic itineraries. These itineraries can include temporary panel installations that guide tourists along routes highlighting not only the historical and cultural aspects of the area but also broader geological and environmental topics, tailored to the site characteristics. Similar to Laurenzana, we envision panels for adults and interactive panels designed specifically for children, allowing them to interact independently and in a fun, engaging way.

4.4. Lagonegro

The Lagonegro area is well-known within the geological community. Several studies have outlined the main stratigraphic characteristics of the rock formations in this region, beginning with the work of De Lorenzo [68–70] and Scandone [55,56], and extending to the most recent research conducted by the CARG project [71]. These successions are derived from deposition within a basinal domain (The Lagonegro Basin) located between the Apennine and Apulian carbonate platforms. Additionally, successions from another basinal domain, separated from the Lagonegro Basin by the Apennine carbonate platform, are also present. The Lagonegro railway bridge was built between 1916 and 1929, and inaugurated in October 1929. The bridge is notable for being one of the first uses of reinforced concrete in Italy. The bridge spans a deeply incised valley (Vallone della Serra), which has formed in a complex structural zone characterized by NW-SE oriented strike-slip faults and geological thrusts. Shortly after its inauguration, the bridge began to experience

deformational problems. Within less than ten years, the first pylon lifted by approximately 40 cm. This progressive deterioration impacted the northern arch of the structure, leading to the closure of the railway in 1952. The deformation is now significant and noticeable even from a distance. This issue is attributed to a DSGSD affecting the limestone block supporting the bridge to the north.

- Vulnerability

The deformed bridge serves as a clear example of how geological instabilities can adversely affect infrastructure. It underscores the importance of having a thorough understanding of the local geological conditions to prevent material damage. It's worth noting that the bridge was constructed at a time when DSGSD was not known, and it represents a significant engineering building. In this site, there are few, if any, options to slow the DSGSD's movement.

4.5. Valorization

Lagonegro and its surrounding areas are a popular destination for geology students. They come here for in-depth study of stratigraphy, structural geology, and regional geology, as well as for applied geology. Each year, cultural events are held to honor Giuseppe De Lorenzo, a renowned geologist, philosopher, and deep connoisseur of the region. Cultural and musical events are held year-round, drawing many tourists and providing an excellent opportunity to install temporary panels with historical, cultural, and geological-environmental information. In this case too, we plan panels for adults and interactive panels dedicated to children.

5. Technical Geoconservation

Technical Geoconservation aims to identify best practices for geoconservation, tailored to specific objects and the context involved. Table 3 showcases the main purposes in Technical Geoconservation actions.

Table 3. Main purposes in Technical Geoconservation actions.

Technical Geoconservation					
Main Purposes					
		Ensure	Prevent	Promote	Monitor
		at an appropriate time/dimensional scale			
Geosities and/or sites of geological interest	site	✓ integrity ✓ equilibrium ✓ visibility ✓ accessibility	✓ damage ✓ increase and acceleration of natural morpho-evolutionary processes	✓ geodiversity ✓ use of environmentally friendly and sustainable technologies and techniques	✓ evolution over time
Physical landscape	system	✓ safety			

The four study sites show significant differences in their geological and geomorphological characteristics. This text presents potential geoconservation actions based on initial observations.

5.1. Pietragalla

The area of *Palmenti* Park is vulnerable to both natural and human-induced factors. The exposed rocks are subject to weathering, which needs to be monitored to evaluate any acceleration due to climate change. The presence of fracture systems can allow rainwater to infiltrate more easily, leading to further deterioration of both the cavities and exposed sections. These systems should be carefully Significant measures and interventions are necessary at the site to ensure its safety and integrity, including the removal of unstable rock blocks, the consolidation of the rock face. Additionally, in several locations, these fracture

systems are characterized by open fractures and are occupied by plants, whose roots may contribute to further deterioration. The rainwater drainage system seems inadequate, resulting in the formation of pools and unchanneled flow ways even during moderate rainfall. As regards the human-related factor, it is mainly related to the abrasive effects of tourists' footwear on the sandstones and the environmental changes that can occur in underground spaces when crowded. The main geoconservation actions proposed include monitoring surface weathering, analyzing fracturing, and managing rainwater and greenery. For the first two aspects, once the condition of the site and the potential rate of deterioration is assessed, suitable technologies to help slow down the process can be identified. These technologies may involve the use of new materials that can temporarily enhance site conditions. A short-time solution includes utilizing non-synthetic materials, which have a low environmental impact, even though their effectiveness is temporary.

5.2. *Laurenzana*

The presence of fracture systems at this site also highlights the need to monitor their presence and extent. It is also advisable to inspect and monitor the existing surface rainwater drainage system to limit infiltration, which could damage the building foundations and, consequently, compromise their stability. Furthermore, the use of transparent synthetic material could be evaluated to increase the stability of the rock walls without compromising their visibility.

5.3. *Brienza*

The overthrust area under the Brienza castle is characterized by an overhanging rock face that displays several fracture systems. The intersection of these fracture systems creates blocks of varying sizes that may be at risk of collapse, particularly following heavy rainfall events. To address this, a comprehensive field survey and mapping of these systems, along with a 3D drone survey of the entire wall, serve as a base for developing safety measures at the site. A careful maintenance of the path is also necessary.

5.4. *Lagonegro*

As mentioned above, there is no possibility of slowing down the movement of the DSGSD and preserving the bridge. However, preserving its memory is possible. By implementing continuous monitoring, aerial photography, 3D analysis and modelling reconstruction, and deformation analysis, an archive could be created that documents its evolution over time. This represents another form of geoconservation: preserving the memory of an object linked to a natural geological event.

6. Discussions

Geoconservation issues involve a wide range of actions covering scientific, technical, administrative, educational, and political aspects. These actions start with the answer to "Why?" (Figure 18a) and the definition of "Who?", proceed with the proposal of "What to do?", and end with the answer to "How to do it?" (Figure 18b).

The term "Why" refers to defining the study area or site and providing a justification for its selection. When considering the reasons for choosing a particular area, both locations recognized for their high scientific, cultural, or aesthetic value and those that are lesser-known or unacknowledged should be viewed as equally important. The planning of conservation actions should not rely solely on the pre-existing awareness of an area; rather, the outcomes—such as territorial valorization, enhancement, protection, conservation, and sustainable management—can generate a significant local impact, regardless of the site's initial reputation. The four sites chosen for this study, while not presenting unique geological features or significant scientific relevance, display distinctive characteristics

that can be placed within different contexts, both geological and non-geological. They were selected due to the coexistence of geological and architectural features within an urban setting. The “Who” phase addresses the fundamental description of the geological framework and the related non-geological elements (Basic Geoconservation). To this end, the sites were analyzed within the regional context of the Southern Apennines and in terms of their local geological settings, detailing the specific urban features of each area. Once these contexts and the selected objects have been defined, the next step involves determining how to utilize the available data effectively—namely, defining what to do (Applied and Popularizing Geoconservation). The “What” phase addresses a thorough analysis and description of the key themes that define the study sites. In this paper, the vulnerability of the selected objects and potential tourist-related valorization actions are addressed. Several themes can be developed, ranging from general geological issues to more specific, detailed aspects related to both geology and human activity. This includes understanding the criteria behind choosing where to build settlements; for instance, the castles of Brienza and Laurenzana, along with the Mother Church of Laurenzana, were strategically located on elevated ridges to maintain territorial control and serve defensive purposes. Similarly, in Lagonegro, although only a few ruins remain of the Norman castle, they still illustrate the strategic reasons behind the site’s original selection. Furthermore, water is a crucial element for addressing various geological and environmental issues, including the protection of water resources, managing their declining availability compared to the past, and implementing strategies to minimize waste while promoting recycling. These themes, however, are not exhaustive of the sites’ full potential. Although the initial approach is common to all sites (Basic Geoconservation), the follow-up phase of Applied and Popularizing Geoconservation must be customized based on the specific goals and unique characteristics of each locality. This tailored approach allows for the exploration of the most relevant elements and topics on a case-by-case basis. All selected sites are suitable for hosting both temporary and permanent installations, enabling the development of informational and promotional materials aimed at a wide range of audiences, including tourists and local residents. It is important to highlight, however, that most information panels currently in use are primarily designed for an adult demographic, both in terms of viewing height and content complexity. This setup contributes to the alienation of children from the topics being presented; only in rare instances do parents lift their children to see a panel while explaining its content. To address this issue, it would be highly beneficial to create signage installed at a child’s eye level, utilizing age-appropriate language and illustrative methods. Additionally, dedicated educational paths could be established where younger visitors do not feel excluded or inadequate due to an inability to access or understand the information shared. Finally, the “How” phase concerns identifying best practices for geoconservation actions tailored to specific objects and their respective geo and non-geo contexts. The four sites selected for this study vary significantly in terms of landscape, geology, and human land-use characteristics; consequently, their geoconservation priorities differ. At Pietragalla and Laurenzana, the main issues are related to the inadequate regulation of surface rainwater, which produces two different effects linked to the nature of the outcropping rocks. In Pietragalla, the sandstones have low primary porosity and permeability, which contributes to surface weathering phenomena. However, the presence of fracturing systems increases their secondary permeability; this means that fractures can become preferential waterways, but also—on topographic surfaces or along exposed walls—suitable habitats for herbaceous plants, shrubs, and trees. The latter, if left unchecked, can cause the widening of these fractures, leading to greater water penetration and worsening the stability of the rock mass. These issues are particularly evident in the urban areas where historical cellars (palmenti) are located; as these cellars are gradually being abandoned by

residents, it results in the deterioration of both road infrastructure and buildings. Proper management of rainwater, combined with targeted greenery maintenance, appears to be the priority intervention for ensuring the geoconservation of these cellars, some of which remain in good condition. In Laurenzana, the sandstones exhibit high primary porosity and permeability, making them highly susceptible to water absorption. Moreover, the existence of fracture systems significantly contributes to their secondary permeability. As a result, if not managed effectively, rainwater runoff from the Castle and the Mother Church can easily infiltrate the rock mass, potentially compromising the stability of the cliffs and towers supporting them. Although the stabilization efforts implemented thus far have enhanced the mechanical strength of the rock masses, underestimating the impact of infiltrating rainwater could lead to future structural damage. Conversely, in Brienza, geoconservation requires focusing on technical engineering measures to secure the overthrust site. Lastly, in Lagonegro, acquiring data and digital images to create a virtual archive is the proposed geoconservation action. In conclusion, the proposed multi-step framework highlights how geoconservation actions can be effectively associated with a site's tailored methodology. This study is part of a broader project devoted to enhancing local geoheritage by connecting it to other cultural contexts. Furthermore, it emphasizes that while basic geoconservation steps remain uniform, the applied phases must diverge to address the unique geological and structural realities of each urban area.

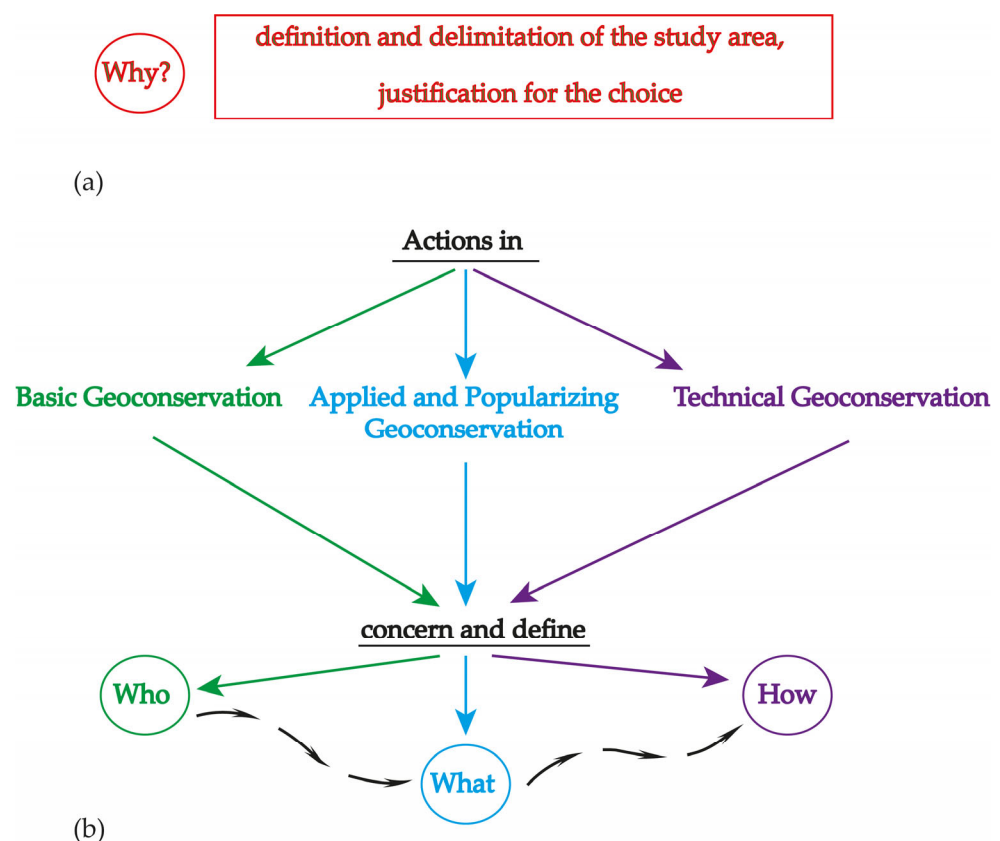


Figure 18. Diagram illustrating: (a) the study area definition, and (b) the geoconservation action workflow.

7. Conclusions

This study demonstrates that the urban geological heritage of Basilicata represents a valuable territorial and cultural resource, capable of strengthening the connection between the natural environment, historical development, and local identity. The case studies of Pietragalla, Laurenzana, Brienza, and Lagonegro show that, even in the absence of

geosites with exceptional scientific significance, the coexistence of geological, architectural, and landscape features can create considerable potential for heritage enhancement and sustainable development.

The findings confirm that geoconservation should not be limited to the protection of geological elements alone but must integrate scientific, technical, administrative, educational, and social dimensions. In this regard, the proposed “Why–Who–What–How” framework proves to be an effective methodological approach for guiding conservation planning, from defining objectives and contextual characteristics to identifying appropriate management and enhancement actions.

A key outcome of the research is the recognition that geoconservation strategies must be tailored to the specific conditions of each site. While the initial stages of documentation and assessment are common to all locations, the applied measures need to reflect the different geological settings and conservation challenges. In Pietragalla and Laurenzana, priority should be given to rainwater management and vegetation control to reduce weathering processes and protect both geological features and historical structures. In Brienza, geoconservation efforts should focus on engineering solutions aimed at slope stabilization and site safety. In Lagonegro, the creation of digital archives and virtual documentation emerges as a valuable strategy for preserving and promoting the site’s heritage.

The study also highlights the crucial role of education and public engagement in ensuring the long-term success of geoconservation initiatives. The development of accessible interpretative tools, inclusive information panels, and educational activities designed for different age groups—particularly children—can increase public awareness and foster a stronger connection between local communities and their geological heritage.

Overall, the research emphasizes that the sustainable enhancement of urban geoheritage can serve as an effective tool for territorial development, supporting geotourism, strengthening community identity, and promoting the long-term conservation of both natural and cultural heritage. Consequently, urban geoconservation should be regarded not only as a conservation objective but also as an opportunity to generate cultural, educational, social, and economic benefits for local communities while ensuring the preservation of geoheritage for future generations.

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