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SCIentific RESearch and Information Technology
Ricerca Scientifica e Tecnologie dell'Informazione
Vol 14, Issue 1 (2024), 79-96
e-ISSN 2239-4303, DOI 10.2423/i22394303v14n1p79

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DIGITAL SURVEYING, AUGMENTED TREKKING AND VALORISATION STRATEGIES FOR INLAND AREAS. THE GRANDI PIETRE VALLEY

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Abstract

The paper deals with a study about the geosite of Grandi Pietre Valley, located in the Aspromonte National Park, aimed at digitizing and enhancing its heritage. The landscape is characterized by rocky emergencies placed as natural landmarks. They are flanked by hermitic caves and ruins from the Byzantine era. The main naturalistic and archaeological features have been surveyed through *image-based* and *range-based* techniques. The acquired data have permitted to elaborate 3D digital models, which are useful both for a geometric and morphological analysis intended for experts and for the elaboration of a multimedia apparatus usable through ICT and aimed at a project of interactive fruition of the territory. Currently, part of the data has been entered on Wikiloc, an app for hiking activities that also allows to display multimedia documentations, but a specific app with more interaction possibilities is planned. Its logical structure and graphical interface have been designed.

Keywords

Digital Survey, Byzantine Architecture, Rock Architecture, Landscape, Interactive Fruition, Augmented Trekking.

1. *Introduction*

In recent years, the use of new surveying and 3D modelling techniques, in addition to the diffusion of ICT[1], have provided effective instruments for knowledge and valorisation of the Cultural Heritage (Mendoza, De La Hoz Franco, & Gómez, 2023). These tools have been frequently used for data acquisition and the elaboration of projects predominantly aimed at the built historical heritage, while the use of ICT for the valorisation of landscape assets is less common. However, even in this field, the past three decades have witnessed a progressive development of methods and technologies that today offer unexplored opportunities.

Digital techniques have been applied to landscape representations as early as the 1990s (Bishop & Lange, 2005), but over the years the possibility of data integration and relationship between different representation software have contributed to the development of increasingly immersive and interactive communication models (Balestrieri & Cicalò, 2020, p. 62). This has made it possible to offer calibrated responses to different types of users: on the one hand, representations intended for the staff have continued to maintain a scientific character; on the other hand, new technologies have allowed to meet the needs of a broader number of users and the growing demands for the valorisation of the territory and marginal areas. This includes a specialization of a field called *Visual Landscape Science* (Nijhuis, van Lammeren, & van der Hoeven, 2011), which integrates multiple representation tools –GIS, 3D models, geomatics, digital visualizations etc.– and gives a relevant contribution "[...] to the identification and communication of landscape resources, promoting not only their physical accessibility" (Balestrieri & Cicalò, 2020, p. 63).

Even the concept of landscape itself has been undergoing a significant transformation in recent years. From a purely aesthetic and contemplative perspective, there has been a shift to an approach that considers it under other multiple aspects: ethical, social, environmental, legal, economic, and so forth.

Such a complex and articulated conception necessarily implies a non-exclusive use of the landscape. Thus, the notion of landscape as a common good begins to gain ground (Settis, 2013). This approach is enshrined in the *European Landscape Convention* (2000), which defines it as

[1] Information and Communication Technologies.

Fig. 1: Grandi Pietre Valley, view from Pietra Castello. Photo by Domenico Mediati.

"[...] a key element of individual and social well-being". This is a crucial point that marks the shift from a purely aesthetic and conservative conception to a new approach characterized by a growing need to guarantee a "right to landscape" (Strecker, 2011), through a healthy balance between development, conservation and enjoyment[2].

Every landscape context is the result of multiple stratifications in which naturalistic elements and anthropic transformations operate and interact. Thus, the landscape becomes "an indivisible entity that differs from the trivial sum of each component" (Balestrieri & Cicalò, 2020, p. 22). Through the mixture of cultural, natural, morphological and aesthetic values, this complex system represents the identity character of each territorial reality, but is also a resource to be exploited, albeit in a manner commensurate with its degree of fragility. Therefore, landscape can be considered as the result of an individual and collective vision (Carneiro, Joanna, & Lavrador, 2015), where historical and cultural components play a role that is as decisive as that of environmental ones.

These features are particularly evident in the study area and enhance a territory that is often considered marginal, but, on the contrary, possesses remarkable landscape and cultural qualities.

2. *The study area*

The study refers to the Goal 11.4 (Strengthen efforts to protect and safeguard the world's cultural and natural heritage) of the UN 2030 Agenda for Sustainable Development. In fact, the paper deals with an area of particular landscape interest, located within the Aspromonte National Park, which, since 2021, is one of the 11 Italian parks included in the UNESCO Global Geoparks Network. In particular, the surveys, studies and experiments proposed in this paper have involved the Grandi Pietre Valley, a geosite of historical and landscape interest located in the northeastern quadrant of the park, between the villages of San Luca, birthplace of the writer Corrado Alvaro, and Natile Vecchio (fig. 1).

The landscape is dotted with rocky emergencies, shaped by meteoric and wind erosion and placed as spontaneous landmarks. Exclusively naturalistic emergencies such as Pietra Cappa and Pietra Lunga are joined by splendid examples of the combination of natural elements and anthropogenic transformations. The Miocene

[2] The "Habitat" Directive 92/43/EEC, establishing the "Natura 2000 Network", makes it clear in Article 2 that areas included in the network are not rigidly protected reserves that exclude human activities, but places where economic, social and cultural needs can be reconciled.

conglomeratic complex of the Rocche di San Pietro with the small rock settlement, the massif of Pietra Castello with the ruins of an ancient Byzantine fortification and the remains of the small church of San Giorgio testify the richness of an area where history and archaeological heritage add value to an essentially unspoiled landscape (Picone Chiodo & Venoso, 2021). The environment in which these archaeological assets are found is extremely impervious and can only be reached through cart roads and trekking routes. It is a context which is completely different from the traditional tourist itineraries but, for this very reason, it has a relevant potential: it is the ideal area where to apply techniques of landscape digitization and innovative strategies of communication and enhancement through ICT (Silva, Jesus, & Jorge, 2023; van Nuenen & Scarles, 2021; Tommasi, 2021).

3. Research path and objectives

The research focuses on the digitization and valorisation of a cultural, landscape and archaeological heritage that is too often forgotten. There are few historical studies on this context and are mainly conducted by Domenico Minuto and Sebastiano Venoso. The surveys and graphic documentations are even rarer[3]. Therefore, the digital elaborations and 3D models obtained are an unprecedented and useful heritage for the morphological analysis of the naturalistic and anthropic context. They have permitted to document the signs left by man in the environment and carry out morphological analysis and verification of hypotheses of the original configuration of some ruins.

Digital processing has been carried out in compliance with the criteria of the 2008 *London Charter* and the 2011 *Seville Principles* (Brusaporci & Trizio, 2013). In particular, Principle 6.1 of the first document has been considered. It urges the use of digital technologies for an inclusive fruition of cultural heritage, giving the concept of accessibility a broader meaning that is not only limited to the barriers of physical disability but also includes those of a cultural, social, economic, and political nature.

This paper illustrates the digitization process of a substantially unexplored archaeological and landscape heritage, creating a new database for this area.

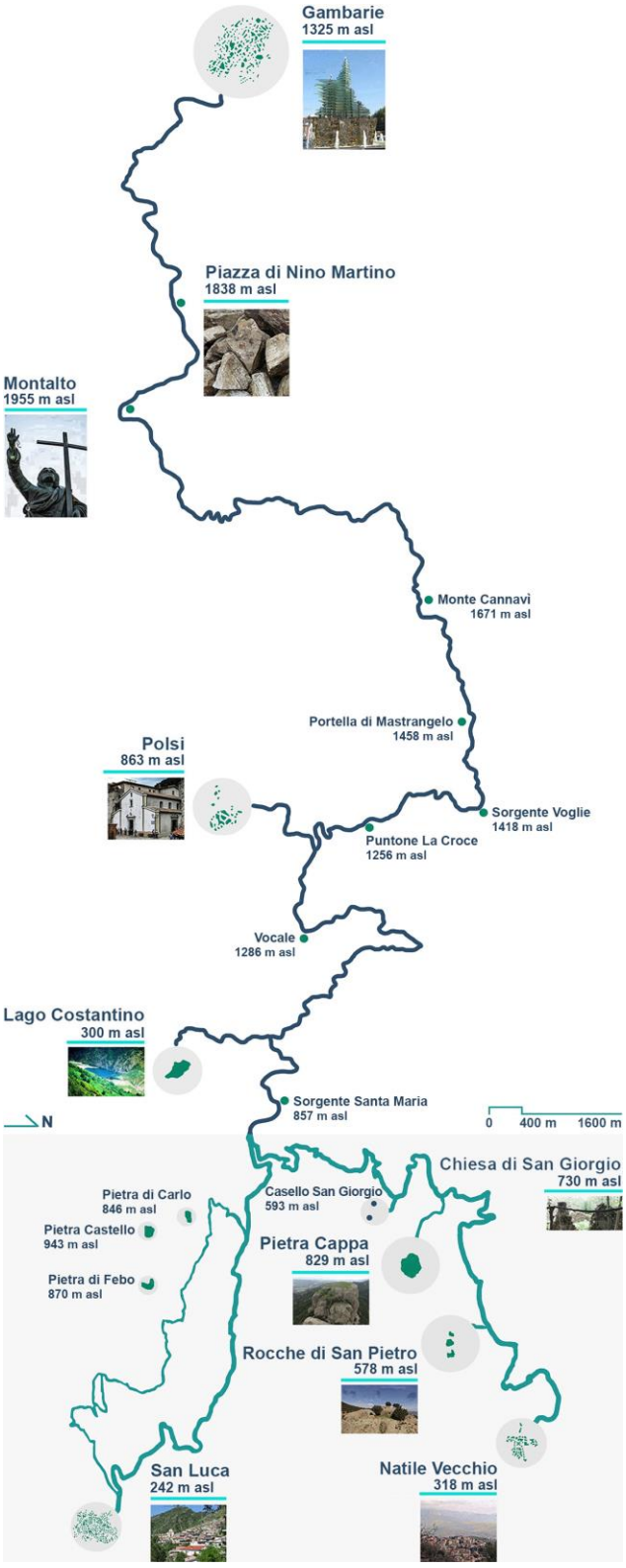

Fig. 2: Hiking route from Grandi Pietre Valley to Gambarie. In green there is the path between San Luca and Natile Vecchio. Major tourist destinations are highlighted along the route. Drawing by Paolo Sergi.

[3] Gaetano Ginex, Stefania Raschi, Gabriella Falcomatà and Domenico Tosto carried out some digital elaborations of the Asceterio located in the Rocche di San Pietro (Picone Chiodo, 2005, p. 89-95).

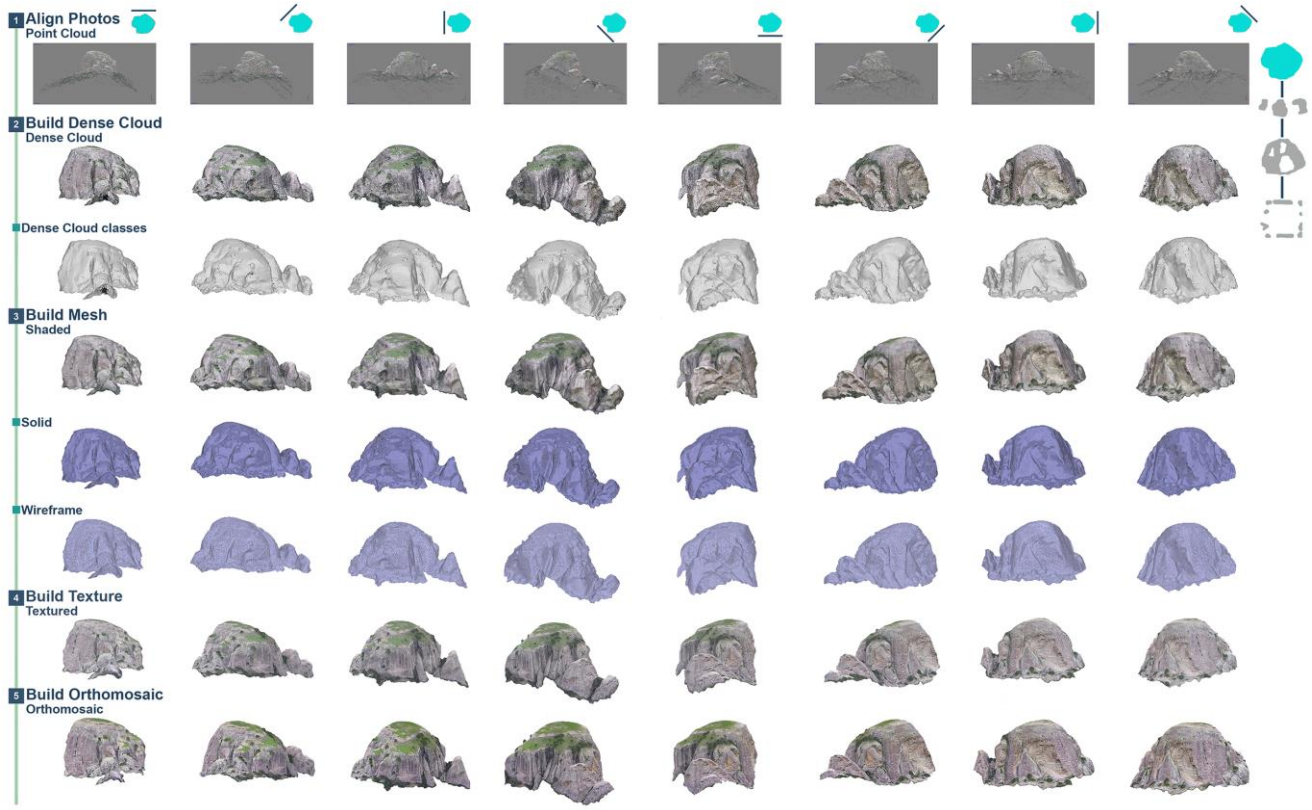

Fig. 3: Pietra Cappa, workflow of photogrammetric processing. Drawing by Paolo Sergi.

In addition to scientific and morphological analysis on the emergencies examined, it aims at using this digital heritage for an enhancement project for the Grandi Pietre Valley through ICT. To this end, it is proposed to use existing apps on the web and a schematic logic of a specific app, which is still in a conception phase. The final result will be an "augmented" trekking route, i.e., a hiking trail in which digital mobile devices show the path and provide infographic information on the historical, geological and naturalistic features of the sites. The identified route connects San Luca with the small village of Natile Vecchio, runs for about 15 km within the valley and is part of the Integrated Local Development Project (ILDP) - POR Calabria FESR 2007-2013. This route intercepts the path that leads from the Pietra Cappa monolith to Gambarie. It extends for about 50 km and is part of the *Sentiero Italia*, one of the longest treks in the world[4] (fig. 2).

4. *Surveying and digitization*

The naturalistic and archaeological features involved in the study has been surveyed with an integrated methodology, using both range-based and image-based instrumentation (Remondino, 2011, p. 91-93; Wen, et al., 2018). The Pietra Cappa monolith and the Rocche di San Pietro have required photogrammetric instrumentation, which are the most suitable to ensure an adequate coverage of such large and articulated portions of the territory. Processing has been made with a Structure from Motion[5] software obtaining point clouds, textured models and orthophotos.

For the construction of the 3D model of Pietra Cappa, we have used 668 georeferenced 20.1 Mpx (5472 x 3648 pixels) aerial photos: 63 with nadiral shot; 605 with inclined shot. Projective alignment of the photos found 213.294 constraint points. Once the area of interest has been delimited, we have

[4] The *Sentiero Italia* trail covers 7,960 km, running along the entire Apennine ridge and the southern side of the Alps. Much of the *Sentiero Italia* is part of the European long-distance hiking trail E1 that connects North Cape (Norway) with Cape Passero in Sicily (Italy).

[5] The aerial photos were taken by Dr. Forestry (PhD) Francesco Manti through UAS/drone Dji Mavic 2 Pro, in September and October 2023, subject to the permission of Aspromonte National Park (No. 77 of 16/05/2023). Dr. Elvira Castiglione, Official and Exclusive Guide of the Aspromonte National Park, collaborated on the aerial shots and accompaniment to the sites. The photogrammetric processing was carried out by Arch. Paolo Sergi with Metashape 1.8 software.

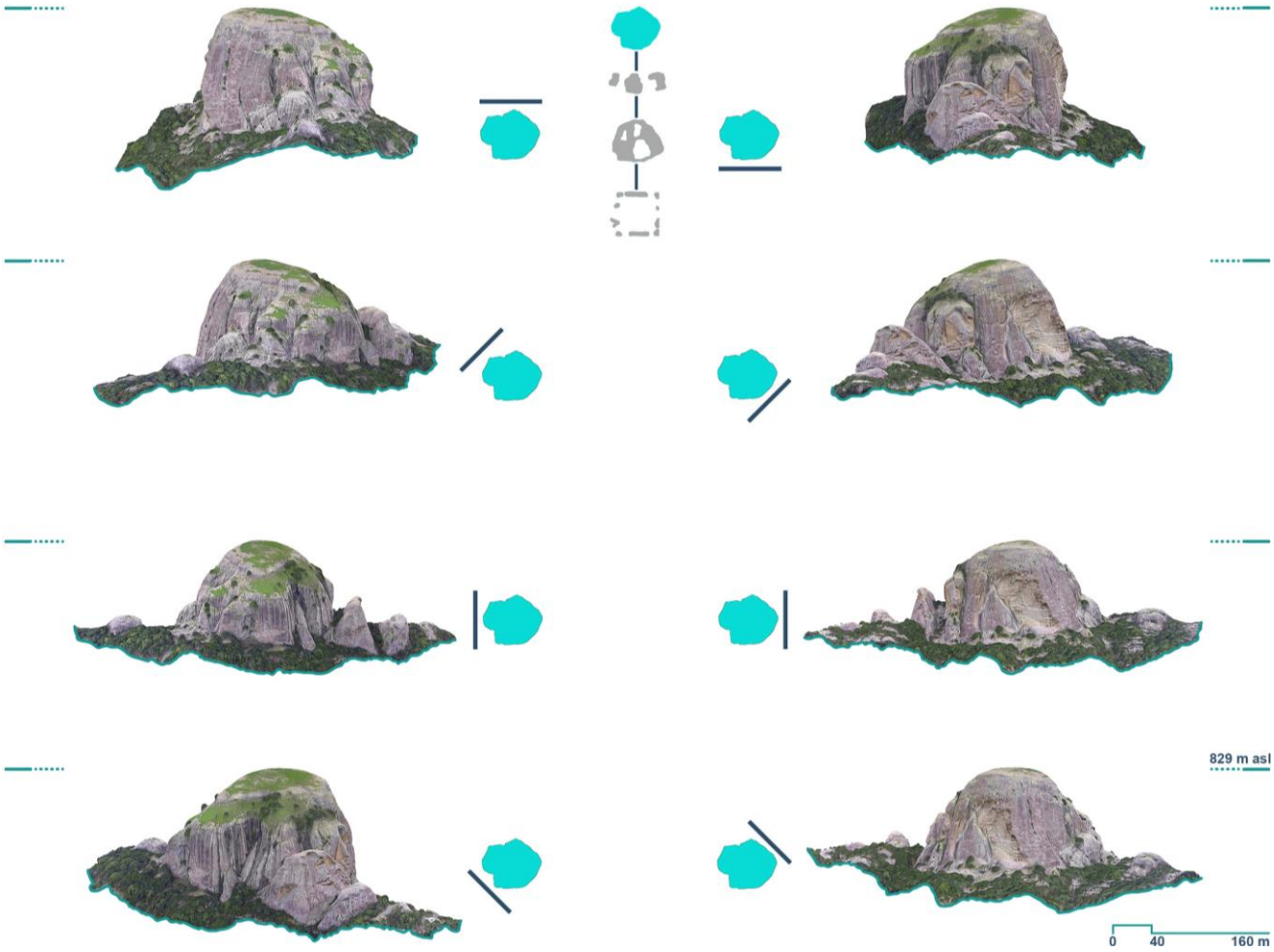

Fig. 4: Pietra Cappa, orthophotos of the 3D model. Drawing by Paolo Sergi.

generated a point cloud consisting of 164,961,885 points. Then, we have constructed a textured 3D mesh of 32,992,150 faces and 16,541,652 vertices, from which graphical processing and a navigable 3D model have been extracted (figs. 3, 4). The same process has been used for the Rocche di San Pietro using 396 photos[6]: 147 with nadiral shot; 249 with inclined shot. From the obtained photogrammetric survey, we have extracted an excerpt with the main promontory, where there are traces of ancient hermitic remains (figs. 5, 6).

The emergencies on an architectural scale, such as the ruins of the church of San Giorgio and the Asceterio located on the southern slope of the Rocche di San Pietro, have been surveyed with range-based methodology (Faro Focus X 330 phase-difference laser-scanner)[7]. This has allowed us to obtain detailed surveys that were particularly suitable for a historical-morphological analysis of the artifacts.

For the Asceterio we have used eleven survey stations[8]. Seven georeferenced scans have been taken outside, around the cave, from southeast to northwest. The first five are located near the Asceterio, while the other two, given the complex orographic articulation, have been placed at greater distances: one about 22 meters to the north, at the top of a nearby promontory, so as to cover part of the outer canopy from above; the seventh about 65 meters, beyond the deep valley that surrounds the Asceterio plateau to the northwest (fig. 7). The south side, undetectable by laser-scanner, has been

[6] The projective alignment of the Rocche di San Pietro photographs has identified 100.779 constraint points. The point cloud, restricted to the area of interest, has 60,079,877 points; the resulting 3D mesh consists of 12,015,560 faces and 6,025,910 vertices.

[7] Range-based surveys were carried out by Domenico Mediati and Paolo Sergi and then processed on *Scene* software.

[8] The point cloud obtained after the alignment of the scans records a value of the "average tensions" of the scan points of 9.8093 mm (for 52.2% of the points, this value is less than 4 mm). The "average tensions" of the targets are 0.0056.

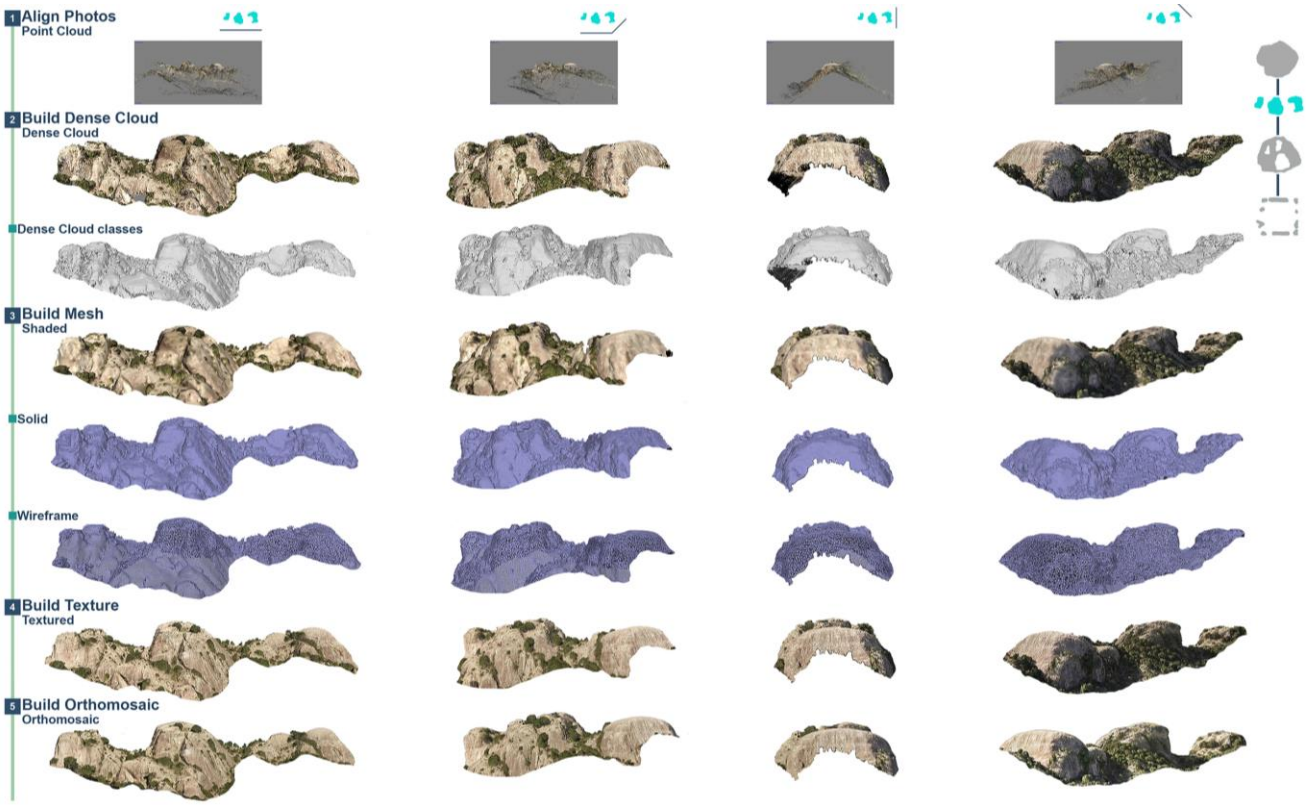

Fig. 5: Rocche di San Pietro, workflow of photogrammetric processing. Drawing by Paolo Sergi.

surveyed by aerial photogrammetry. In addition, we have surveyed the two inside and overlapping spaces of the cave with four laser scans: two for the lower level and two for the smaller, more articulated upper level. Two outdoor stations have been placed in front of the two access passages located to the north and east, so that the indoor and outdoor scans could be aligned.

The ruined state of the small church of San Pietro in Pietra Cappa and the very low height of the remaining wall fragments made it possible to cover all the findings with only nine georeferenced laser scans: two placed inside the wall perimeter, in the north and south corners, and seven others around the artifact to allow the acquisition of the outer surfaces of the ruins[9] (fig. 8).

The photogrammetric and laser-scanner surveys complemented each other, providing comprehensive, multi-scale digital documentation of the analyzed environmental and archaeological context. Thanks to them, we have been able to elaborate 3D digital models, detailed graphic documentations, orthophotos and orthomosaics useful both for in-depth scientific investigation with morphological and architectural analysis and for digital visualization and fruition.

5. Pietra Cappa and the environmental background

The geosite of the Grandi Pietre Valley is dominated by the Pietra Cappa monolith. It is located between the Careri and Bonamico valleys, about 12 km as the crow flies from the Ionian coast. The environmental context in which it is located is characterized by olive groves and arable lands that, as they rise in altitude, are replaced by Mediterranean scrub and holm oak and chestnut woods[10].

Pietra Cappa is known to be among the largest monoliths in Europe, although it is actually a huge polygenic conglomerate[11] from a lithological point of view. It covers an area of about 4 hectares and

[9] The "average tensions" of the scan points are 5.1752 mm (this value is less than 4 mm for 44% of the points). Those of the targets are 0.0054. For the alignment of the scans, we used spherical targets Ø 145 mm.

[10] There are also some specimens of monumental chestnut trees.

[11] A conglomerate is a sedimentary rock composed of clasts (pebbles) of varying size and nature. They are bound by a cement (matrix) that can be of various kinds: calcite, dolomite, silica etc.

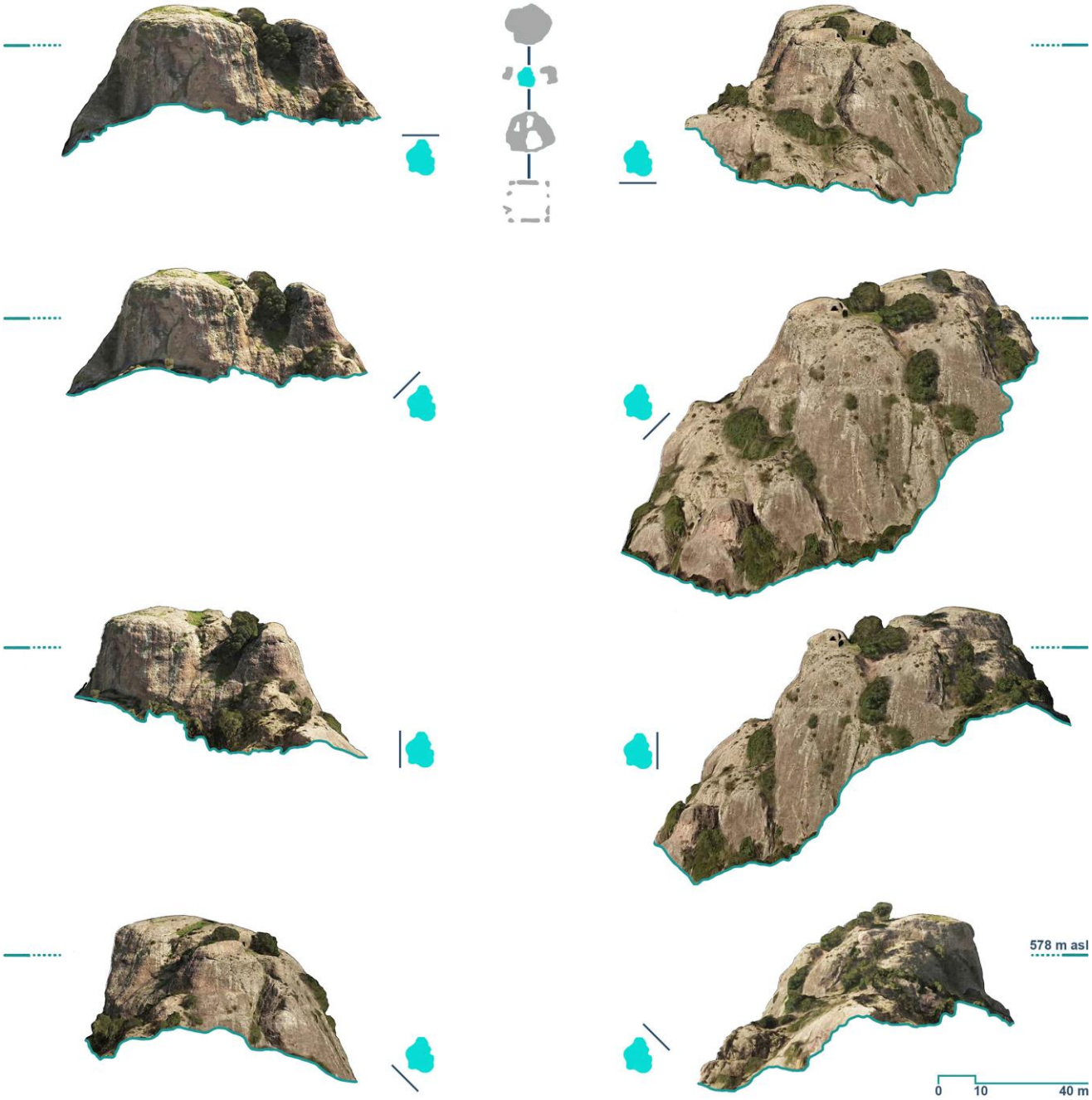

Fig. 6: Rocche di San Pietro, orthophotos of the 3D model. Extract of the portion where the Asceterio is located. Drawing by Paolo Sergi.

rises almost 140 meters. Geomorphologically speaking, Pietra Cappa is a *butte*, that is, a relief with steep walls and a semi-flat summit in which the diameter of the summit surface (about 70 meters) is less than the height of the walls (figs. 9, 10). The base of the monolith is at an elevation of almost 700 meters asl while the summit is at 829 meters. Ancient religious, civil and fortification buildings are present in the surrounding area.

The origin of its name is found in some medieval documents bearing the inscription "Pietra Cauca", i.e., hollow stone. This appellation derives from the conformation of the monolith which, at its base, has a crossable fissure generated by weathering. However, the toponym extends to the entire surrounding area in which the presence of small caves carved into the rock is reminiscent of the landscapes of Cappadocia.

6. Byzantine ruins and the historical background

The Byzantine conquest of Calabria took place in 554 and established a power that lasted until the Norman conquest (1059). During these five centuries

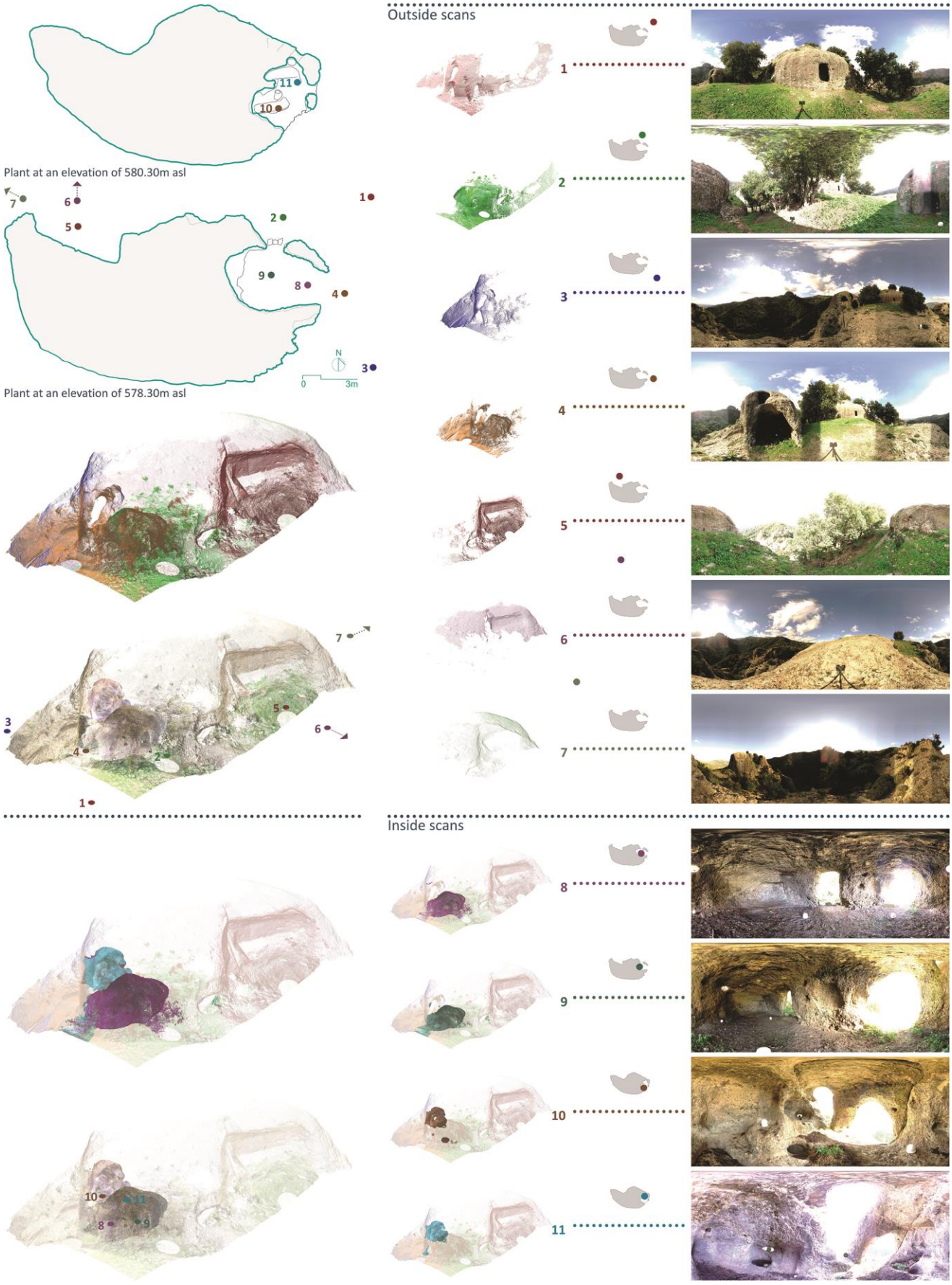

Figure 7: Asceterio, range-based survey process workflow. Drawing by Domenico Mediati.

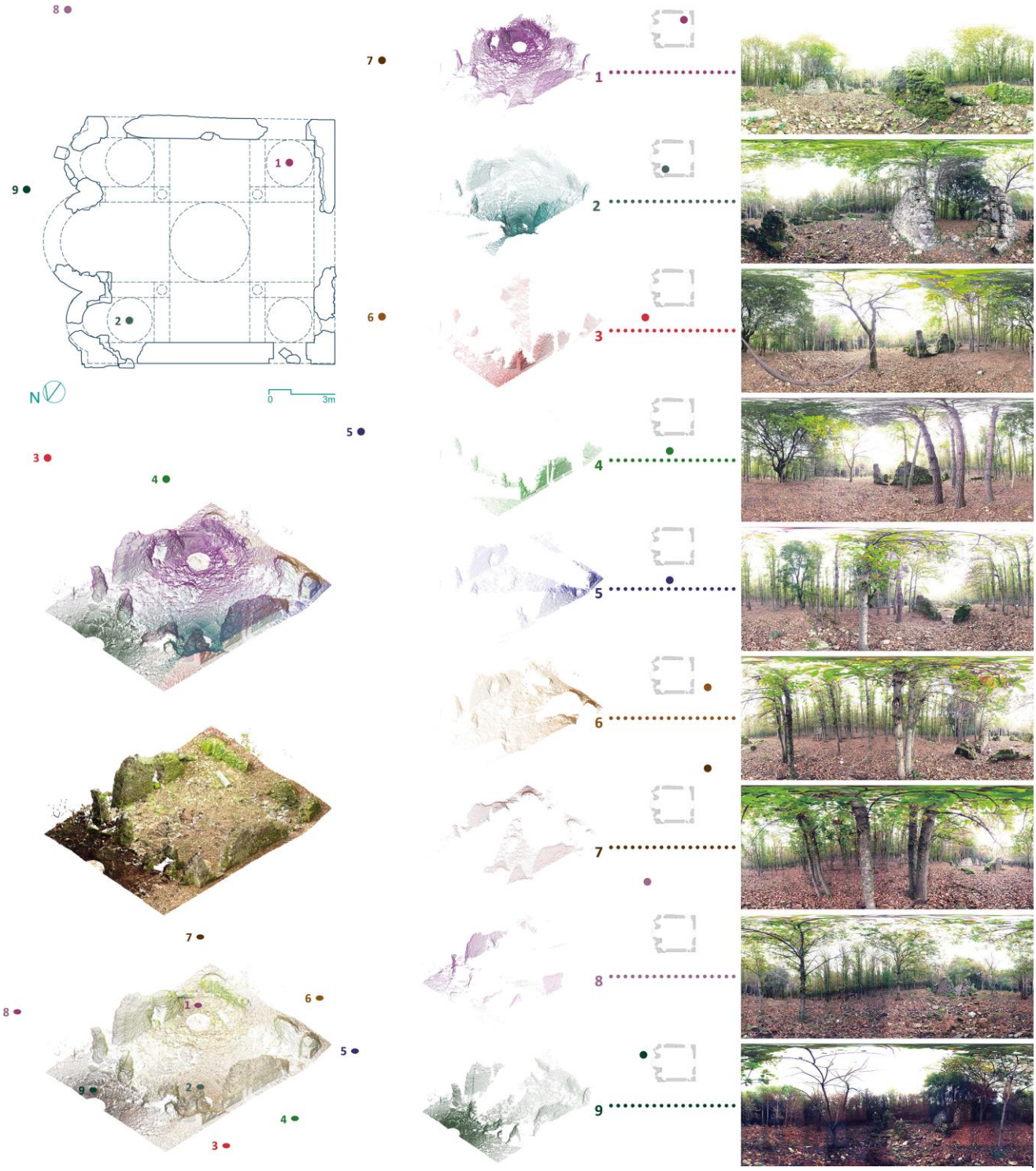

Fig. 8: Church of San Giorgio in Pietra Cappa, range-based survey process workflow. Drawing by Domenico Mediati.

many monks from the East moved to southern Italy, contributing to the flourishing of a fervent ascetic life in *Calavria*[12] territory.

Between the 7th and 8th centuries, following the Arab invasion of the Byzantine Empire, there was an initial exodus of Greek-speaking Melkite monks who found refuge in Sicily and southern Italy from Syria, Palestine, and Africa. The flow intensified following the iconoclastic struggles that began in 726. To escape persecution, the monks abandoned

[12] Byzantine name of ancient *Brutium*.

Fig. 9: Pietra Cappa, aerial drone photo by Francesco Manti.

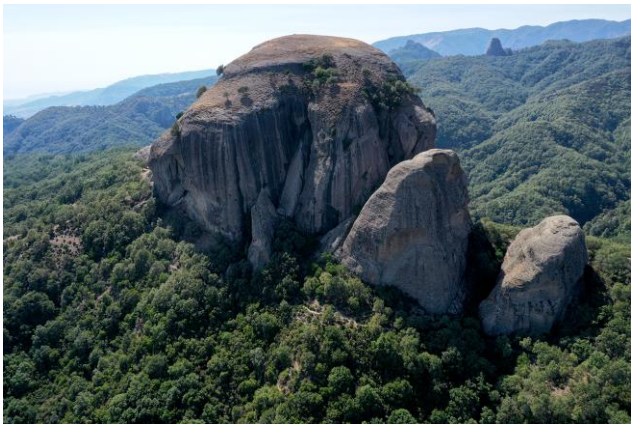

Fig. 10: Pietra Cappa, aerial drone photo by Francesco Manti.

the hermitages and monasteries of Asia Minor – often located in rocky environments– and moved to the western Mediterranean regions, finding in the rugged mountain slopes of Apulia, Calabria and Sicily an environment similar to that of Cappadocia. Meanwhile, Islamic occupation began in Sicily. In 704 the first Maghrib expedition took place, followed by a slow conquest of the island that was completed in the 9th century. Under the pressure of Arab occupation, the monks who had found refuge in Sicily from the East were forced into new migrations. Many crossed the Strait of Messina taking refuge in territories which were still protected from Byzantine rule (Calabria, Basilicata and Apulia). Some of them chose the rugged mountains of Calabria.

Between the 7th and 9th centuries, the slopes of Aspromonte, rich in *laure* and hermit caves, became a true place of spirituality.

6.1 The Asceterio and the Rocche di San Pietro

The Rocche di San Pietro are located in the northeast of Pietra Cappa, on the eastern slope of the Ménica stream, and consist of a system of conglomeratic matrix cliffs in which a number of caves are excavated. They housed small hermit communities of Greek rite. Historian Domenico Minuto hypothesizes that "[...] the Asceterio was frequented in a very remote age, presumably around the 7th or 8th century" (Minuto, 1999, p. 358).

The hermitic complex consists of a main cave (578 m asl) located on the southern side of the rock, overhanging the valley, and two other smaller caves nearby. The main cave opens on a small plateau, has a curved profile shaped by weathering and develops over two levels (fig. 11). The lower hypogeal space has a height of about 1.60 m and an oblong planform with a maximum dimension of about 5.70 m in the east-west direction and about 3.70 m in the north-south direction. It is accessed through two openings: the wider and irregular one is located on the east side; the second one, narrower and squarer, is located on the north side. Two small holes with a maximum width of about 40 cm connect the lower level with the upper one. The latter is more irregular and smaller in size, with a maximum dimension of about 3.20 m and a very variable height that reaches up to about 2.20 meters. On the side placed toward the cliff face there is a small ovoid hole with a major axis of about 40 cm, from which it is possible to overlook the small plateau in front of the Asceterio. Two other larger openings, one facing east and the other toward the valley, provided access to the space. Its ground plane is extremely irregular and spreads over several elevations. Within two pseudo-niches, one to the north and the other to the west, two elongated cavities, which probably served as beds for the monks, were excavated (figs. 12, 13).

On the rock face located in the north of the Asceterio there is a second cave which is accessed by a very regular entrance, 93 cm wide and 160 cm high. Its interior space has a pseudo hemispherical canopy with a diameter of about 2 meters. Behind the main cave Domenico Minuto identifies possible traces of a third chamber. Here there is a trapezoidal platform –with a length of 4.70 m and a width varying between 1.00 and 1.60 m– that could be the trace of a cave that later collapsed (Minuto, 1977, p. 372).

All the rock caves illustrated are the result of anthropogenic excavations, probably begun on pre-existing natural cavities. The presence of beds, the way the rock surfaces are modelled to obtain

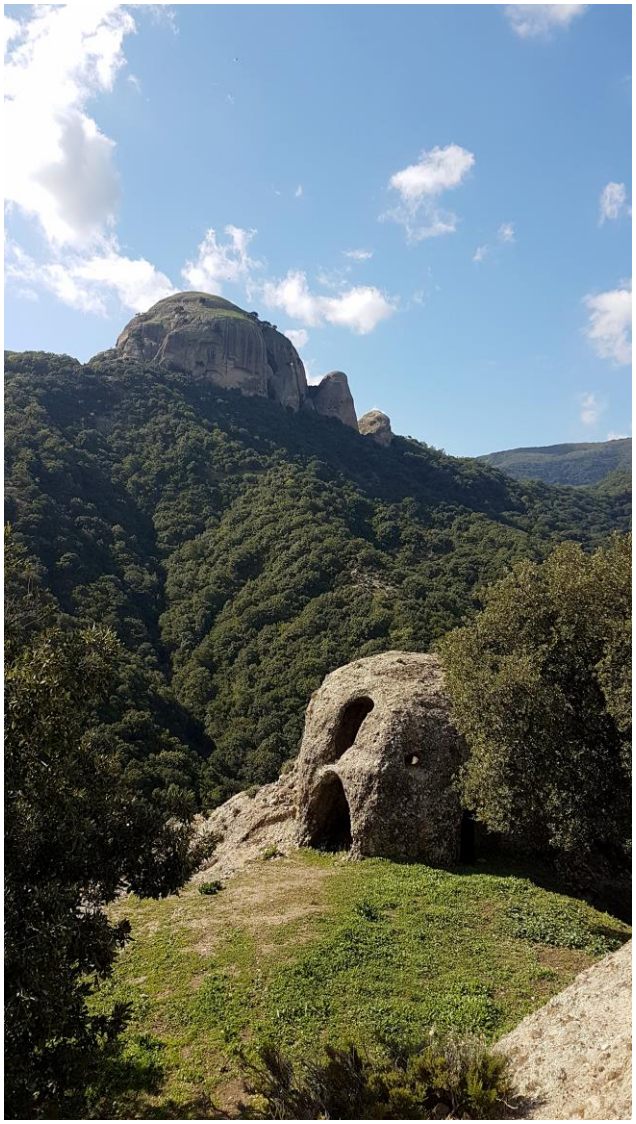

Fig. 11: Asceterio (in the foreground) and Pietra Cappa (in the background). Photo by Domenico Mediati.

shelves and passageways appropriate to the various functions, as well as the presence of obvious signs of excavation with metal tools, are clear evidence of an aspiration to turn apparently inhospitable spaces into habitable places.

6.2 Church of San Giorgio in Pietra Cappa

The ruins of the church of San Giorgio (730 m asl) are located west of Pietra Cappa, about 500 meters as the crow flies, immersed in a dense forest of ancient chestnut trees. In August 1935 archaeologist Gennaro Pesce conducted an excavation campaign and proposed a date of the 10th century (Pesce, 1936, p. 365). The same hypothesis is also put forward by Arnaldo Venditti (Venditti, 1967, p. 873, 874). Some more recent studies on the wall facings, carried out by Domenico Minuto in collaboration with Sebastiano Venoso, hypothesized that they belong to the 7th and 8th century (Minuto, 2014, p. 195).

The perimeter of the plan is quadrangular with three apses facing northeast. The outer width is about 11.15 m on the southwest side and 11.26 m on the side of the apses. Even the side walls are about 11.26 m in size. The difference of 11 cm between the opposing fronts of the southwest and the apses is due to the 1-degree rotation of the southeast wall with respect to the orthogonal scheme on which the plan layout is set. The central apse, deeper than the two side apses, projects about 1.75 m above the hypothetical plane of the facade. The internal dimensions are 9.23 m on the entrance front and 9.35 m on the apses side; in the opposite direction the internal dimension is 9.76 m, excluding the apses. The latter have different internal diameters: 3.20 m for the central apse, while the lateral ones differ from each other by 20 cm (1.60 m the one on the left at the *pròthesis*; 1.80 m the one on the right at the *diaconicòn*).

The typological layout is a *quincunx* scheme, that is, an inscribed Greek cross pattern, widely used in Greece, mainly in the middle and late Byzantine period. In southern Italy the *quincunx* pattern has other better-known examples: the nearby Cattolica di Stilo; the church of San Marco in Rossano (later converted to a longitudinal plan church); and the church of San Pietro in Otranto. A further example was the church of the Ottimati in Reggio Calabria, which no longer exists because it was demolished after the 1908 earthquake.

The church of San Giorgio in Pietra Cappa is larger in size than the Cattolica and the original core of San Marco in Rossano, whose exterior dimensions are about 7 meters. This, probably, influenced the detail of the plan scheme. In fact, in the Cattolica and San Marco, given their small extensions, it was not possible to differentiate the size of the central space from the corner ones, otherwise the lateral spaces would have been too small. The greater width of the Otranto church –and even more that of Pietra Cappa– has allowed a greater hierarchy, giving more weight to the arms of the Greek cross and a smaller size to the corner compartments.

A further aspect concerns the number of domes. The Cattolica and San Marco have five of similar diameter, while San Pietro in Otranto has only one central dome and four vaults on the corners. As for the growth in height of the church in Pietra Cappa, there is no certain information

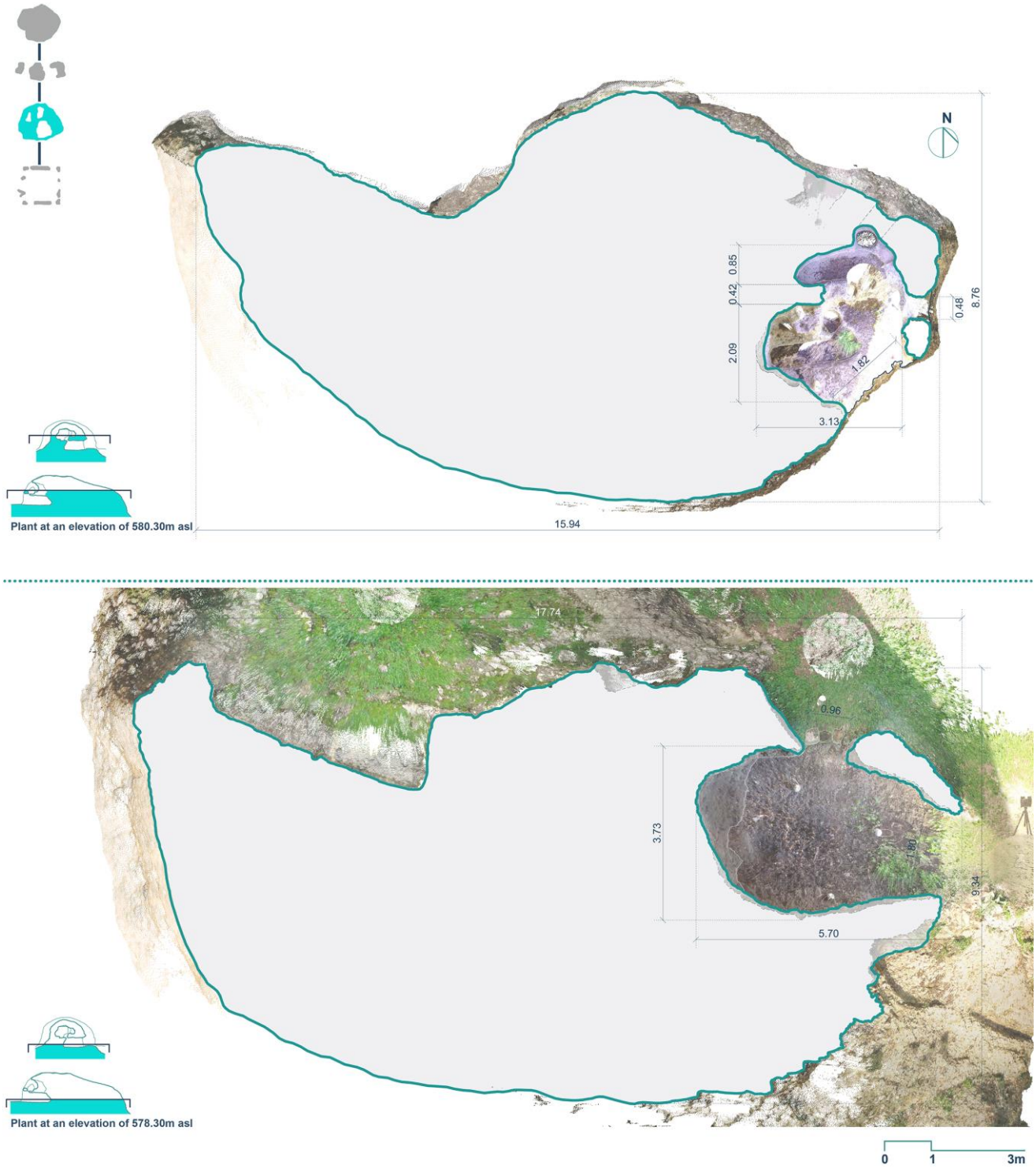

Fig. 12: Asceterio, plans of the two levels. Drawing by Domenico Mediati.

(Venditti, 1967, p. 873, 874). However, on the basis of the discovery of many fragments of white marble columns on the outside of the southwest wall, in his report on the excavations Gennaro Pesce hypothesizes the presence of several double lancet windows distributed over five domes, similar to what happens in the nearby Cattolica di Stilo. This hypothesis of spatial configuration, put in relation to the planimetric articulation with a central nave wider than the lateral ones, allows us to assume a scheme of five hierarchically differentiated domes, as occurs in other churches in Greek lands. In Calabria this solution is unusual, in fact both the Cattolica di Stilo and the church of San Marco in Rossano have five domes of similar size to each other.

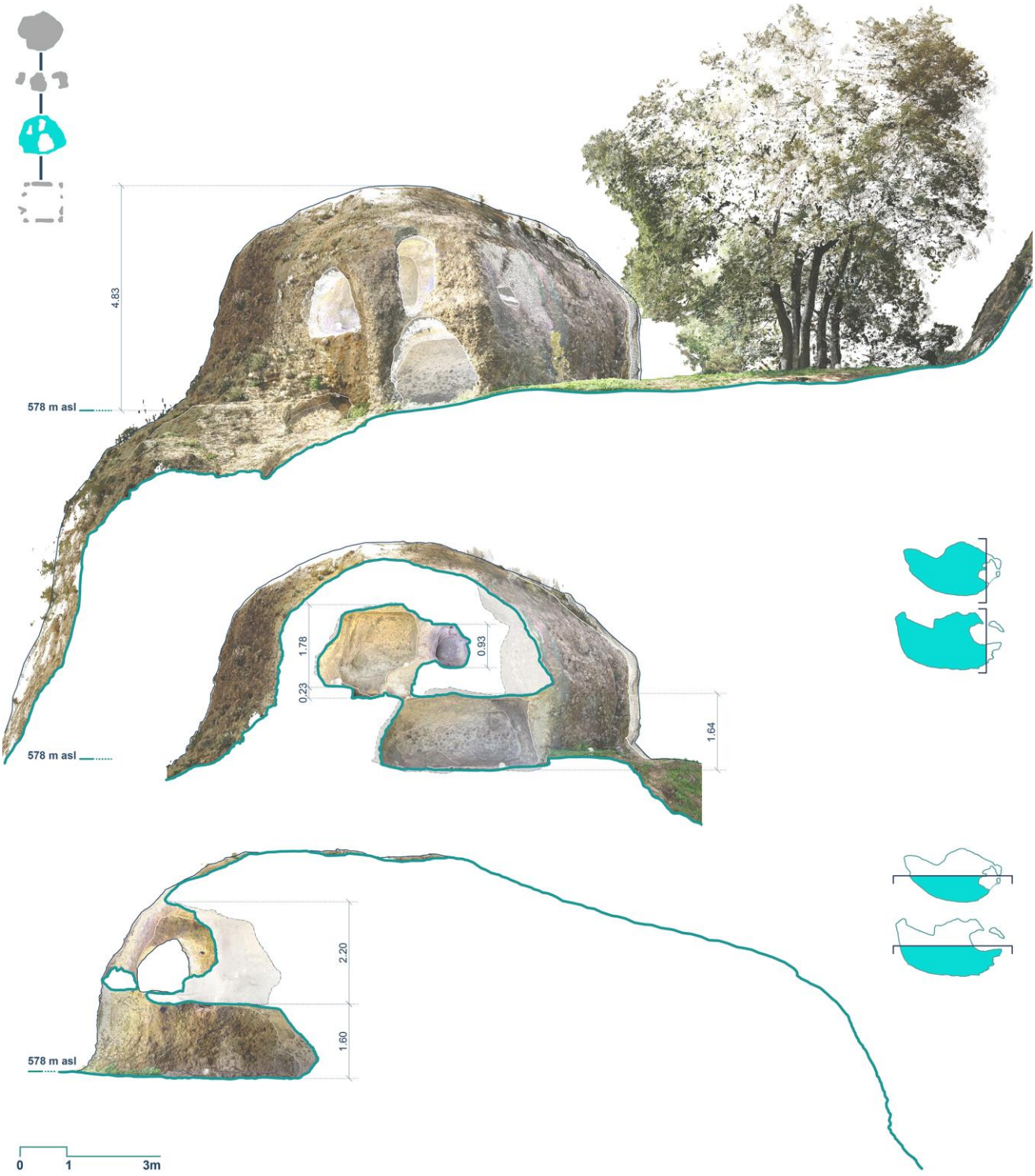

Fig. 13: Asceterio, from top to bottom: elevation; cross section; longitudinal section. Drawing by Domenico Mediati.

The ruins also include some fragments of the four columns which supported the central dome, two in granite and the other two in crushed stone. They had a smooth shaft, a collar at the top of the scape and a diameter of 45 cm. According to Gennaro Pesce, they should be 4.05 m high (Pesce, 1936, p. 361). The masonry is composed of sandstone, squared ashlars, bricks and mortar and has a thickness of about 90-95 cm in the rectilinear walls and about 75-80 cm in the apses. The fragments which have remained standing are principally located in the side walls: they are 3.00 m high in the northwest and 3.30 m in the southeast. Their presence in the southwest and in

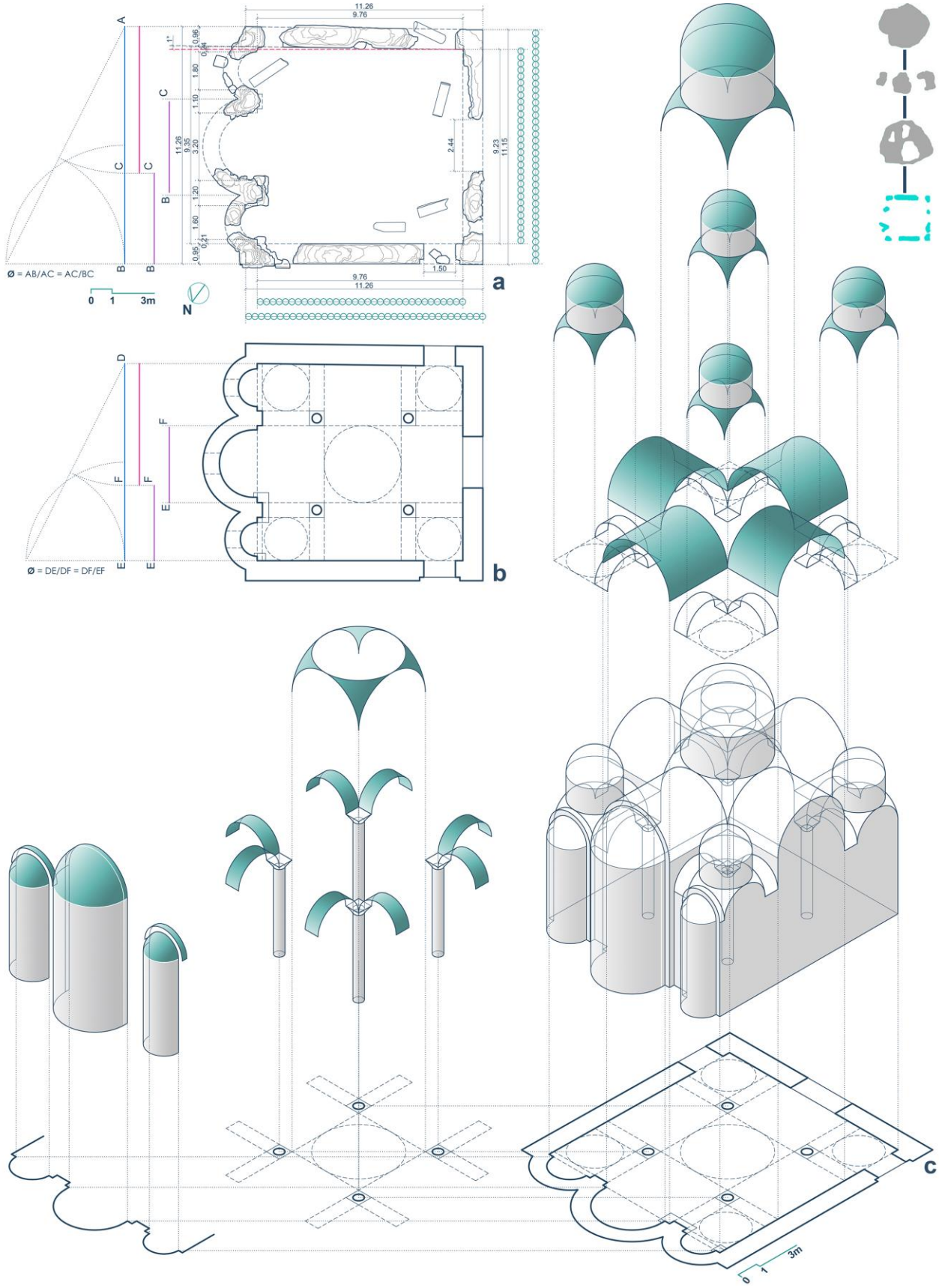

Fig. 14: Church of San Giorgio in Pietra Cappa: a) survey restitution plan with modular subdivision according to Byzantine foot; b) plan with original configuration hypothesis; c) spatial configuration hypothesis. Drawing by Domenico Mediati.

the apses is scarce. However, the ground traces allow us to identify the perimeter of the church. It had a front entrance on the southwestern wall and two side entrances on the adjacent one. These last two openings led Venditti to suggest the presence of a narthex, like in the Church of Ottimati in Reggio Calabria.

Graphical analysis of the survey (fig. 14) shows that the outer width of the main apse (BC) is very close to the size of the minor segment obtained by dividing the width of the church on the side of the apses (AB) in its golden section. Thus, we have used a similar geometric relation to assume the width of the central nave (EF). In fact, in our reconstruction it is equivalent to the smaller portion of the subdivision according to the golden section of the inner width of the church (ED). This hypothesis seems to be confirmed by the rare remains. The presence of such geometric relationships reveals a pronounced sensitivity to proportional relationships, which were probably unconscious for the workforce who operated in the periphery of the Byzantine Empire.

As documented by Gennaro Pesce, in 1935 there was still a quarter of the *opus sectile* pavement (Pesce, 1936, p. 362). The Neapolitan archaeologist decided to dismantle the pavement in order to safeguard it and exhibit it at the future National Archaeological Museum of Reggio Calabria, but its location is currently unknown[13] (Pesce, 1936, p. 364; Minuto, 1977, p. 361).

Analysis of the ruins of the Pietra Cappa church suggests that it belongs to a very important historical and architectural background. The typological pattern connects it to a Byzantine architectural tradition, widespread between the two shores of the Mediterranean, of which only a few examples remain in southern Italy. Its size is even greater than the best-known examples of Stilo, Rossano and Otranto and makes us believe that for centuries it was the center of an intense ascetic life, probably linked to a monastic community. Therefore, the ruins of San Giorgio's Church are clear evidence that the abandoned forests and landscapes around Pietra Cappa have had a fervent anthropic and spiritual presence that can be an opportunity for knowledge and appreciation today.

7. Valorisation and interactive fruition

The Report "Natura e cultura. Le aree protette, luoghi di turismo sostenibile" in 2017[14] suggests that nature tourism in Italy had about 30.5 million presences in 2015 with a growing trend[15]. At the same time, it shows that in southern Italy, the Aspromonte National Park has a lower digital awareness index than the average of other National Parks, although the number of Google searches is slightly lower. This highlights ample room for improvement in the appeal of the park through a wider use of digitalization.

Extensive studies on the characteristics of the "nature tourist" show that they are generally a more demanding users, with a high educational background, good economic availability and marked environmental sensitivity (Balestrieri & Cicalò, 2020, p. 81). These data lead us to hypothesize communication and valorisation strategies that combine interest in nature with opportunities for in-depth historical and cultural study through interactive and inclusive fruition techniques. However, such approach should be understood not only from the perspective of a tourism and economic revitalization of the area but especially as a tool for active conservation: "what is accessible, visible and known to the wider public can be more easily protected" (Balestrieri & Cicalò, 2020, p. 63).

The present study fits into this perspective and offers an approach based on an integrated relationship between fruition and conservation. It has produced a relevant amount of digital data, multimedia content and historical-morphological analysis on the heritage of the area. Surveys carried out through TLS and photogrammetric techniques have produced detailed point clouds, from which 3D models of the landscape context and archaeological findings have been generated. The software used have been Scene, Metashape, Rhino, and Geomagic. Initially, the digital models contained overabundant data, so we decimated and optimized them, minimizing the number of graphic primitives and achieving smoother visualization for the web and mobile apps. Architectural-scale models have been reduced to about 50,000 faces, landscape-scale models to about 100,000. The 3D models have been

[13] Checks made at the museum show no evidence of the deposit of such flooring.

[14] The document was produced by the Italian Ministry of Environment in collaboration with *Unioncamere*, *Fondazione sviluppo sostenibile* and *Federparchi*.

[15] Source: *Osservatorio Nazionale delle Filiere del Turismo*, *UNIONCAMERE-SICAMERA* data, February 2015.

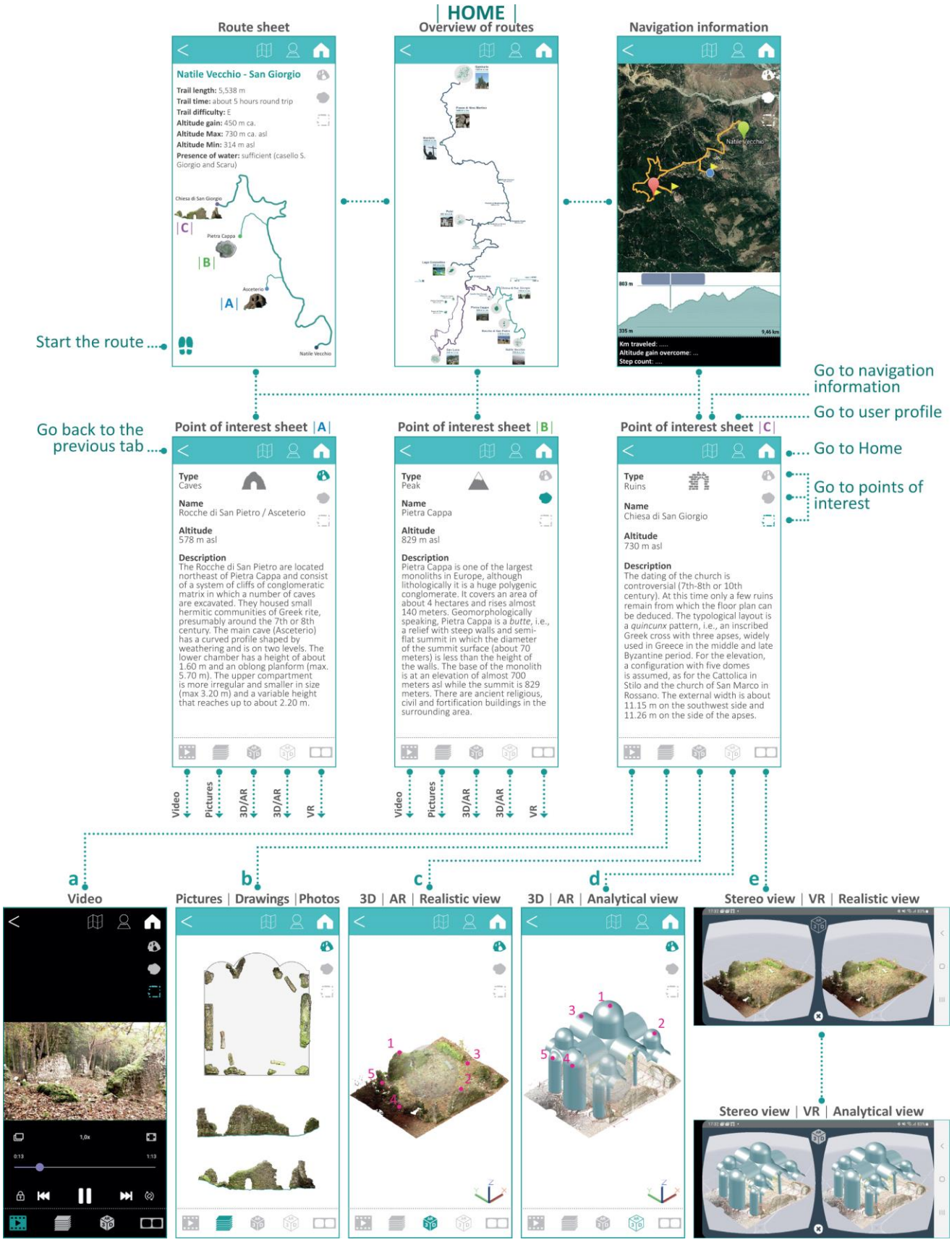

Figure 15: Logical scheme and graphical interface for an "augmented" Trekking App in the Grandi Pietre Valley. Detail of the Natile Vecchio-San Giorgio trail. Bottom: example of viewable content for each point of interest.

finally exported in OBJ format with corresponding textures. The hiking route has been recorded in a GPX (GPS Exchange Format) file usable on GPS navigators or specific hiking apps.

At present, the GPX track and some of the multimedia content have been put on Wikiloc, a trekking app that also allows to display multimedia documentations related to the route. However, currently available hiking apps offer limited capabilities, generally not allowing the display of 3D model viewing and the use of VR/AR. In addition, they are subjected to rapid obsolescence with frequent configuration changes and they are sometimes withdrawn from the market. This does not guarantee long-term sustainability of digital documentation[16]. Therefore, it is aimed to create a specific app that will allow to break loose from third-party digital tools and offer more possibilities for interaction, including in VR/AR mode. The logical scheme of this app, currently in the design phase, envisions two different modes of use: on-site and remote. The two modes will be interconnected and will have actionable contents with GPS proximity sensing or through appropriate links. The app provides the common functions of GPS location, map display, route tracking and statistics, position and elevation data, etc. Furthermore, five sections can be activated for each landscape, archaeological or architectural point of interest: a) aerial and terrestrial videos; b) images with in-depth metric-morphological analysis and photographic documentation; c) navigable 3D model in realistic mode with additional information in AR (historical information on archaeological finds, descriptions on geological nature of geosites, tree species and fauna, etc.); d) navigable 3D model with visualization by surfaces, possible hypotheses of the original configuration of the finds, and descriptions in AR; e) stereoscopic visualization (VR) of 3D models in both realistic and conceptual modes (fig. 15). This app may be later implemented with other attractions of the same Grandi Pietre Valley and other hiking trails in the Aspromonte National Park.

8. Conclusions

The digitization process proposed in this paper is a new experience for the study area and can contribute to experiment with good practices for its valorisation. It is a multi-scale and multidisciplinary approach, which on the one hand, involves the difficulty of relating heterogeneous content, but on the other hand offers an effective tool to enhance the complexity of this area. Information on the navigation of the trail is combined with additional multi-sectoral data. Thus, an "augmented" trekking route, in which virtual content becomes an incentive for a direct use of the territory, has been created: it is a conscious hiking activity that promotes and enhances the hidden resources of a landscape, which is fascinating and evocative as well as wild and forgotten.

Credits

The paper is the result of a collaboration between the two authors. The paragraphs *1. Introduction*; *3. Research path and objectives*; *4. Surveying and digitization*; *6. Byzantine ruins and the historical background* with related sub-paragraphs; *7. Valorisation and interactive fruition* are by Domenico Mediati. The paragraphs *2. The study area*; *5. Pietra Cappa and the environmental context* are by Rosario Giovanni Brandolino. *Conclusions* were written by both authors.

The research has been authorized by the Aspromonte National Park with clearance No. 77 of May 16, 2023.

Acknowledgements

For the scientific contribution and support provided to the research we would like to thank: Dr. Agronomist Alfonso Picone Chiodo for his consultancy on the hiking trails; Dr. Forestry (PdD) Francesco Manti and Aspromonte National Park Guide Dr. Elvira Castiglione for aerial shots, escorting to the sites and consultancy in the environmental and forestry sector; Dr. Alessandro Milardi for his contribution on the geological topics; Arch. Paolo Sergi for photogrammetric processing and some drawings. Finally, our special thanks go to the Aspromonte National Park for its interest in the research and for supporting an opportunity of knowledge and valorisation of one of the most fascinating naturalistic areas of Calabria.

[16] See *Seville Principles* (2011), principle 6.2; *London Charter* (2008), principle 5; *Charter on the Preservation of the Digital Heritage* (2003), art. 1.

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