

The complex of S. Eustachius in Göreme, Cappadocia

reading the relationship between the landscape and a very articulated underground settlement

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Abstract: The settlement of the St. Eustachius church is excavated in the volcanic stones in the back part of the Tokalı church. The latter is a second monument is a very well-known rupestrian church in the Cappadocia area, but the structure of the whole settlement in which the Tokalı is inserted it's still subject of studies and hypothesis. So the St. Eustachius church, with its small room, covered with a vault enriched by a beautiful mural painting, its sepultures and its very articulated system of secondary rooms and tunnels, creates a rich and very challenging subject for the scholar and the surveyor. In fact the St. Eustachius settlement is carved in the peaks closing the plateau over the back of the Tokalı, because of its higher level it looks directly toward the Uçhisar Castle, placed at a linear distance of four kilometers, creating all the conditions to communicate with this important outpost using visual signals. In the remains of its tunnels, crossing the stone from the plateau to the rear "sword valley" there is the possibility to read the defensive system of the people from that time, where the church, the houses, the farms were working together to guaranty the security to its inhabitants. The digital survey, done using phase shift laser scanner all along the tunnels and all around the stones along the plateau and the "valley of the swords" has created the first complete and detailed documentation of this settlement, allowing the first in deep studies about this meaningful church.

Keywords: Rupestrian, Turkey, digital survey, Mural paints, 3D Laser Scanner.



Fig. 1 – Göreme valley: pinnacle. (Copyright: C. Crescenzi)

Rupestrian Heritage, introduction

The site of S. Eustachius in Göreme (Cappadocia, Turkey) is a fragment of the rupestrian culture heritage. It is a distinctive feature of the Mediterranean landscape. It has continuity in time, places and involves all social stratum. Man has excavated structures in the rocks from the Anatolian highlands to the Egyptian deserts, from the Balkans to Italy, from France to Spain. In this anthropological and ethnographic context, the artificial cave is the “common house” of Mediterranean cultures. Medieval caves - rupestrian houses and churches - massively characterize the landscape of the plateau of Cappadocia in Turkey, several regions of Spain, Greece and the Loire Valley in France, and many other places in the Mediterranean area and in other regions in the world. The cultural unity of rupestrian settlements was, in some cases, damaged or destroyed, but its relevance as open air eco-museums has never been underestimated, despite anthropogenic deterioration and erosion caused by weather conditions.

Recently, the attention was focused on urban settlements, on their different typologies, and on subterranean shelters. These structures are certainly less monumental than churches, but they are more numerous and more extensive and, perhaps, sometime more ancient. (BIXIO et al., 2002; CRESCENZI 2012)

Common requirement of the rupestrian sites are the geological and morphological characteristics that have allowed and still allow the excavation of rocks to create spaces for daily activities. As you can see in the five sites examined by the project EU CRHIMA-cinp, the characteristics of the rocks are due to volcanic eruptions that have deposited soft materials (such as tuffs like in Cappadocia and Santorini) or to water sedimentation, sometimes; all of which resulted in deposits of limestone, sandstones (in Italy) or gypsum (in France), even if there are cavities dug in hard rocks, too, like gneiss, schist and granite (TRIOLET, 2013, p.152).



Fig. 2 – The geological and morphological characteristics of some rupestrian sites in Mediterranean area
(1-3 Copyright: C. Crescenzi, 4 www.planetmountain.com, 5 G.M. Vampa, N. Pacini)

The settlement of St. Eustachius in Göreme

The complex of St. Eustachius and the Maryemana churches in Göreme: two case studies of documentation about rupestrian heritage in Cappadocia, technical approach from the digital survey to the restoration hypothesis. (ANDALORO et Al, 2013)

Generality

Cappadocia, located in the center of Turkey; is a historical region extended in a wide territory away from the sea located in a zone of volcanic origin that has been excavated and eroded until it became a landscape morphologically impossible for harsh life, but wonderful and at the same time mind-boggling for visitors. The natural plasticity of the territory and the environmental roughness motivated the ancient inhabitants to build through excavation their urban settlements for a very long period of time. The framers of the beauty of these places, however, are the same who constitute its end: the human pressure and climate actions lead to the collapse of the settlements built over the centuries. The drama of the state of degradation has become itself an added value of the landscape. The collapse of the structures has transformed the interior sculpture of the places such as external fronts and shows the beauty of details in the dissolution process: it is a rich collection of fleeting wonders. In this context, rich and complex, there are a large number of exceptional

monuments; some of them are well preserved and offer a great opportunity for research to improve the knowledge of that period.



Fig. 3 – On the left: Göreme valley, pinnacles. On the right: settlement of Çavuşin. (Copyright: C. Crescenzi)

The research project

The PRIN 2010-2011 (Italian National Project Relevance) approved in 2013 in the Italian Education, University and Research Ministry, by triennial project takes to heart the study, investigation and documentation of these rupestrian monuments with a project called “Rupestrian art and habitat in Cappadocia (Turkey) and in central and southern Italy. Rock, excavated architecture, painting: between knowledge, preservation and enhancement”.

The research was carried out following an interdisciplinary methodology, which combines humanistic knowledge with scientific and technical investigations and with the latest developments in new technologies applied to Cultural Heritage. As a result, the team includes architects, historians, archaeologists, speleologists, geologists, chemists and photographers¹.

The work here presented was organized by the unity of the DISBEC (Department of Cultural Heritage Science, UNITUS, Viterbo), the unit DIDA (Department of Architecture, UNIFI, Florence) and the CSS (Centre for Underground Study of Genoa)². The units have a significant long experience in the field of

¹ The research project involved the universities listed below: DSCC – UniBa resp. G. Bertelli, UniSalento- DBBCC resp. M. Falla, UniRoma1- DSDRA resp. Marco Carpiacci, UniRoma3 -DSU resp. M. L. Fobelli, UniCal resp. GM Crisci, UniMoRe-DSCG resp. P. Baraldi e CNR/Roma resp. F. Antinucci; still participating in the project the UniMe-DRP and the Centro Studi Sotterranei di Genova.

² The research mission in Cappadocia of the University of Tuscia “Rock paintings in Cappadocia. For a project of knowledge, conservation and enhancement”, directed Maria Andaloro, is composed by multiple research units. The group working on this research from the DISBEC (Department of Cultural Heritage Science, Viterbo) is composed by M. Andaloro (coordinator); M. Benucci, C. Bordino, P. Pogliani, D. Sgherri, M. Viscontini (art historians); C. Pelosi (chemistry); G. Alfano, D. Ventura (photographers); S. Amato, A. Levi (student) and G. Bordi (art historian from the Roma Tre University). For the DISBEC at the 2012 campaign took part: A. Bixio, R. Bixio, A. De Pascale, A. Maifredi; G. Mirocle Crisci, N. Rovella, S. A. Ruffolo, S. Marabini, L. Alberti, F. Acikgöz, A. Arcudi, S. Borghini, C. Caldi, G. Dikilitaş, S. Scioscia, M. C. Tomassetti, Öslem Toprak Cihan, V. Valentini, U. Yalçinkaya.

The group working on this research from the DIDA (Department of Architecture, Florence) is composed by C. Crescenzi (coordinator), M. Scalzo, G. Verdiani, S. Di Tondo, A. Pasquali, C. Giustiniani (architects). The Digital Survey of St. Eustachius was operated by G.

research and action on the rupestrian architecture: the CSS is carrying out researches in Cappadocia since 1991; the DISBEC has been working in the territory of Nevşehir since 2006, conducting the research mission "Rock painting in Cappadocia. For a project of knowledge, conservation and enhancement"; for the DIDA this is the prosecution of the previous experiences developed inside the European CHRIMA-cinp Project (Cultural Rupestrian Heritage in the Circum Mediterranean Area Common Identity, New Perspective) completed in 2012.



Fig. 4 – Göreme valley, southwest side. (Copyright: C. Crescenzi)

For the current project PRIN there are two roads of research that are particularly connected and focused on the area of Göreme. By the 2012 campaign, in fact, in addition to the monuments of the Göreme Open Air Museum, the investigation is focused on the surrounding valleys of Göreme and Kılıçlar. The goal is the realization of a comprehensive study of all the painted churches in this area but consolidated by a research anchored in the indissoluble union between the natural landscape, the urban planning dug, monuments and decorative art. The project aims at helping to improve their knowledge to a deeper understanding of civil and religious functions, buildings carved into the rock and the stages of development of the cave settlement. Within this work, correct documentation through digital survey and digital photography, added to other research methods, is a fundamental base for knowledge, conservation and valorization of the anthropic environment.

The first common activities of "fieldwork" among DIDA -UniFi, Disbec-UniTus e CSS took place in the large area upstream of Tokalı Kilise (the Church of the Buckle); it is one of the most beautiful churches of the Göreme Park, a World Heritage Site since 1985.

In this first meaningful collaboration the creation of 3D digital models, starting from an accurate digital survey, is aimed to display the paintings in the excavated churches that host them, allowing a deeper and clearer knowledge of the rupestrian habitat in all of its components. It will also be very useful for the realization of innovative instruments of fruition, suitable for a presentation of the rock monuments and

Verdiani, S. Di Tondo, C. Giustiniani. The data treatment and the post processing phases on the whole dataset from the digital survey campaign were operated together with the PRIN by G. Verdiani, S. Di Tondo, C. Crescenzi, T. Pignatale, A. Charalambous, V. Niccolini.

The successful development of our work in Cappadocia was made possible by the permission and support accorded to the mission by the General Direction of Monuments and Museums of the Turkish Republic and Murat Gulyaz director of the Archeological Museum of Nevşehir. For the 2012 survey, in particular, we are greatly indebted to the two Cultural Ministry Deputy, Metin Çakar from the Archaeological Museum of Çorum, and Gultekin Yanbeyi from the Department of Archaeology of the General Direction of Monuments and Museums.

pictorial decorations scientifically correct and diversified according to different communication levels: virtual reality installations and other multimedia products for the visitors of Open Air Museum.

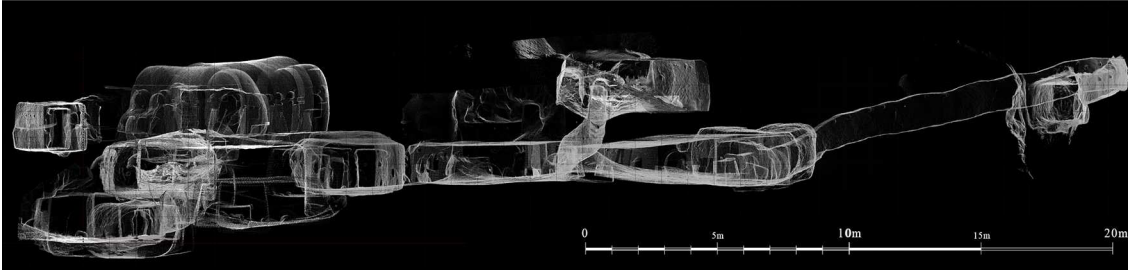


Fig. 5 – 3D survey of St. Eustachius settlement – laser scanning.

The St. Eustachius Kilise

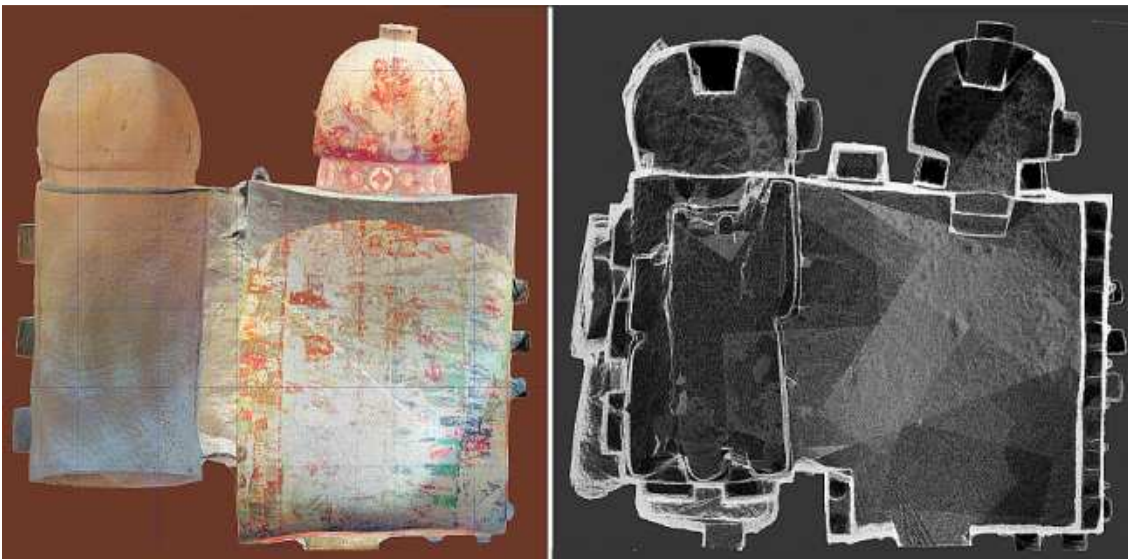


Fig. 6 – Vault projection and plan of St. Eustachius church – laser scanning

The settlement of St. Eustachius is hollowed out along the ridge between the Göreme Vadisi (Valley of Göreme) and the Kılıçlar Vadisi (Swords Valley), eighty meters NE of the Tokalı church. This second monument is one of the most precious rupestrian testimonials of Cappadocia.

The settlement takes his name from the church of St. Eustachius hollowed on top of the pinnacle, from where it dominates the area. The south-western face of the complex overlooks the valley of Göreme and its church could communicate visually with the rupestrian settlement of Uçhisar (the “Pointed Castle”) excavated in a natural tuff tower, three kilometres south-west, at the head of the erosion valleys district, perhaps used as sighting point (BIXIO et al., 1995). Besides Uçhisar, the last castle, the defensive system of territorial could still to rely on Başhisar (the first castle) and Ortahisar (the middle castle) this is about 100 meters high (CRESCENZI, 2012).

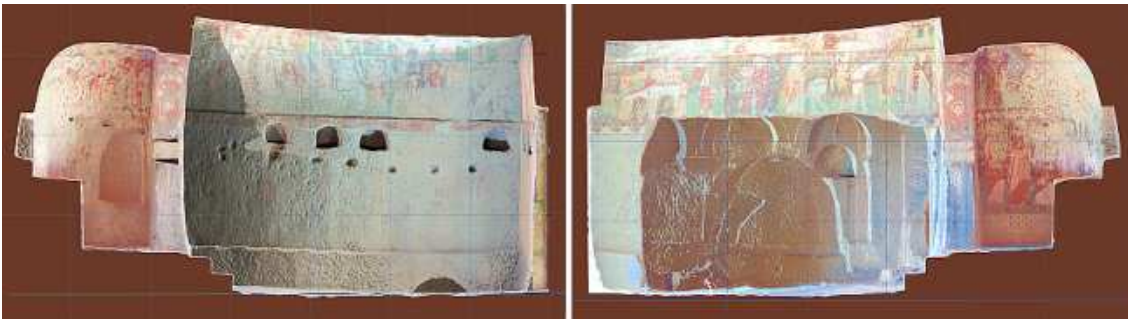


Fig.7 – Longitudinal sections of St. Eustachius church – laser scanning

The church is constituted by two naves, both barrel vaulted; the vault of the principal nave is frescoed, while the aisle is a funeral endonarthex (figs. 6, 7), the latter communicates with other rooms variously articulated (fig. 8); the naves have an apse with iconostasis and altar oriented east.

At a lower level is hollowed an elaborate system of housing with numerous structures supplied with defensive devices (figs. 11, 12, 13), stimulating for the scholars and the surveyors.

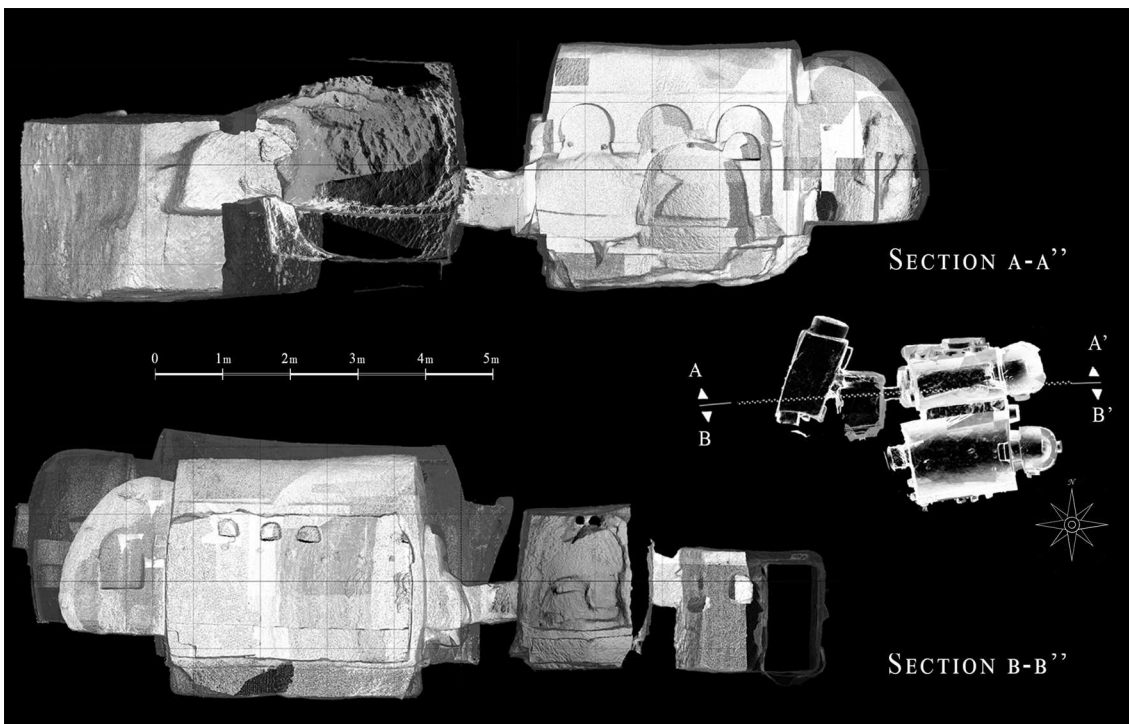


Fig.8 – St. Eustachius: longitudinal sections of funeral narthexes– laser scanning

The intragrate underground system

Thanks to the surveys, both traditional and innovative, it is evident that the underground settlement of St. Eustachius is an example of an ancient integrates system for living, worship, farming and defensive activities (DE PASCALE et al., 2013).

The remains of the underground rooms of the complex located back to Tokalı Kilise, show a linear system of defense that ran along the ridge overlooking the cliff in the left bank of the deep and narrow Kılıçlar Vadisi. The innermost rooms (redoubts), equipped with simple but efficacious defensive devices (millstone doors,

narrowings, loopholes) (BIXIO, DE PASCALE, 2012), were conceived to protect the inhabitants regularly living in the rooms closest the most accessible pathways winding through the slope of Göreme valley. The four shelters till now localized and surveyed (maybe there is a fifth shelter not yet explored because of the difficulty to attain it on the vertical wall of the cliff) were also in communication with the water supply structures (tunnel-shaped cisterns) excavated in the riverbed of the Kılıçlar Vadisi, on the opposite side of Göreme Vadisi (DE PASCALE et al., 2013). Besides, this canyon is crossed through the longitudinal axis by draining artificial tunnels, still in use, that allowed to utilize the bottom of the stream, free of flowing water, partially for farming and, in the meantime, as emergency way in case of attack (BIXIO, CALOI et al., 2012, pp. 147-150).

Digital survey of the St. Eustachius underground settlement

The survey of orography and of the articulated buildings with laser scanner is the first complete and detailed documentation of this settlement with an advanced technology, and will enable exhaustive studies and to integrate the studies in progress of the church and of the defensive system of the settlement.

The complex survey of the settlement has required a large number of scans because of narrow passages and the low levels of the ceilings, claustrophobic spaces and powdery paths at times the operator and the instrument crawled on the bottom. The arrival points (views) of the tunnel to the "Valley of the Swords" required specific configuration, to collect useful data to the alignment of the opposite side of the valley; indeed, both sides of the valley are heavily eroded, therefore unviable to useful distances for the survey with the tool in use, they are also devoid for collimation of easy references.

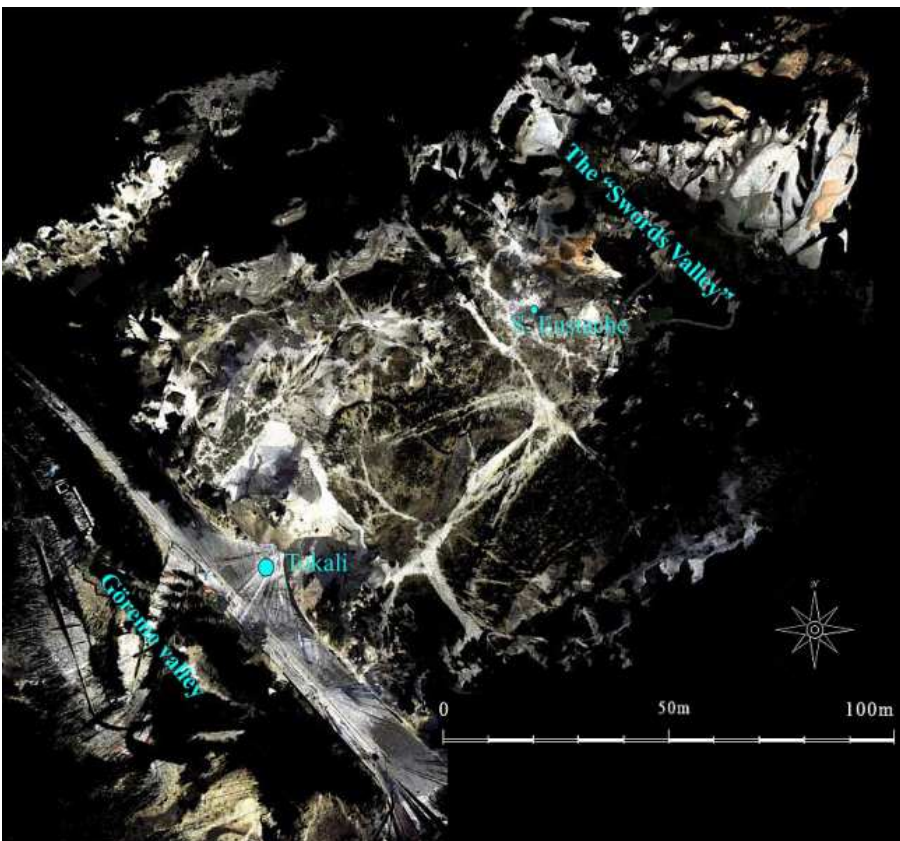


Fig.9 – Digital survey of the St. Eustachius settlement – laser scanning

The fieldwork has produced one hundred and forty scans. The point density at 5 m distance is 3 mm and the quality achieved +/- 2mm. Outside, the complex morphology of the pinnacles were needed many station points to cover the corrugated surfaces and to have sufficient natural targets for the registration of files; they (stations) were close to the surface from 60 cm for the lower parts to 25/30 m for the upper parts of the pinnacles, and they have integrated with those next and previous. The same definition of quality has been used to the interior, whose amplitudes didn't exceed 7 linear meters. Only for small rooms, narrow tunnels and passage the point density at 5 m distance is 6 mm and the quality achieved +/- 5mm. Each scan had an overlap, with one or more of them, of approximately 50%.

The external routes of the scans have been tracked with a GPS unit palm and waypoints taken out of each tunnel. In addition, to make the natural points and the temporary markers, it have been mainly used the flat type black and white for their small size and minimal bulk. Natural and paper targets, at least 5 for each individual registration, are used to register multiple individual scans each one on their own coordinate system, into a single aligned coordinate system.

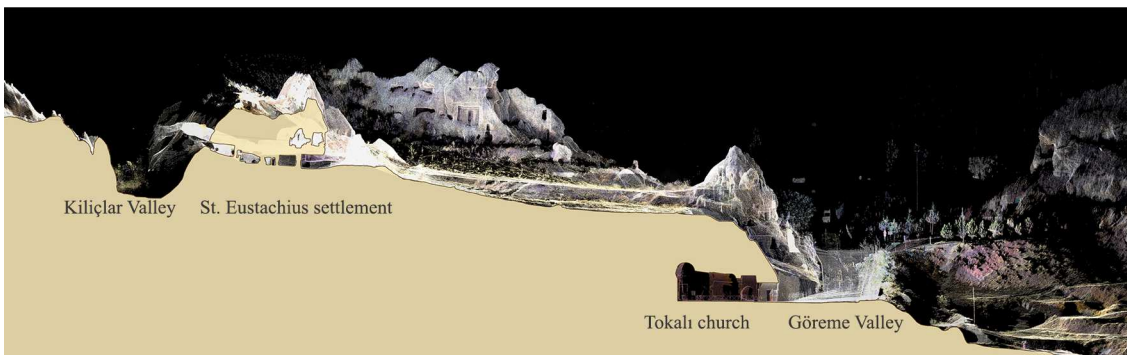


Fig.10 – Cross section between the whole surveyed area– laser scanning

The overall dataset scans was organized in eight thematic set: 1) the plateau, 2) the front of the church of settlement, 3) the side and tops, 4) first series of rooms and the main tunnel, 5) second series of rooms and tunnels, 6) third series of rooms and tunnels, 7) the inside of the church, 8) the Valley of the Swords.

The same organization has been maintained in the alignment of individual 8 groups of data, to create a complete model of the area.

3 D data treatment for settlement

The first data processing was performed with Faro Scene: scan files (*. FLS) were processed and were collimated with images taken by the same instrument, and then exported in PTX format.

The register setting of the files PTX was performed with Cyclone. They were selected at least 5 points (markers), natural and / or artificial, easily and clearly visible by multiple scans; these points were chosen not aligned, with different heights and distances, conveniently distributed in the scanned area; the points have been chosen manually. The maximum error accepted was 0.009 m in the pre-alignment of the markers; later was made the cloud-costraints for the error distribution and the realization of an optimal cloud-mesh.

Afterwards it was created some layers for each building in rock and parts of outdoor. This data management,

the careful selection of the "reference planes", associated to the "cut planes", the correct view with the many snapshots have allowed extracting clear images.

Also has been called the size of the images (pixels/cm at 300 dpi), and have been performed the necessary snapshots with 60/80 ml of points, to obtain the desired size and definition.

The architectural and environmental data representation has followed an established practice.



Fig.11 – Plan of underground shelters of St. Eustachius – integration of laser scanner with the expeditious scanning survey.

For all environmental snapshots have been created orthogonal views that reflect the established traditional graphics, useful for an easy reading of environments that were impossible even to be photographed. Afterwards, to get a good quality performance for representative and monumental architectures, our team will proceed to the mapping of the surfaces to make models more captivating, taking advantage of the innovative applications.

However, the greatest challenge will be to make images eye-catching and readable of structures that are dark and of difficult access, using only the points clouds of scansions without color.

Furthermore, a thorough photographic survey describes every single architectural element and its relationships with the landscape and the environment, and in turn, an interactive route with virtual tour reveals the landscape and architecture.

The different photographic surveys (punctual, 2D and 360 panoramas) and 3D models, related to each other, they respond to the cultural needs of different users and of different requirements of knowledge and of upgrade of the environment.

Considerations on the St. Eustachius underground settlement

The amount of data has been collected in just 7 days of work; results unreachable with traditional survey even if supported by technological tools. It was also appreciated the ease of Faro Focus; In fact, its low

weight and its small size made it possible the survey of spaces and environments with arduous accessibility, for example the tunnels or the steep slopes and sides of the canyons.

The alignment of 3D point clouds allowed viewing and understanding the overlaps and trends of the buildings closed into rocks and with difficult access, and made them measurable and investigable. Moreover, most of these buildings, close to collapse, are (closed) to the public for the difficult and dangerous access and visitable only from expert speleologists.

Therefore the survey with laser scanners, for its ability and quality to collect data, has been invaluable: the 3D models being produced allow to measure and investigate, to all interested studios, the existing with extinction carved urban system.

The 3DS survey, in cases of objective environmental difficulties, has been integrated with the expeditious archaeological survey. The crosschecking between the two techniques of survey, expeditious and 3DS has shown, in the case of Saint Eustace, the validity of the result of measurements made with caving techniques.

The work carried with the scanner has been highly appreciated. The results are visible to everyone.

The 3D shows the external paths, totally in rock, supplying a valid support to all investigations finalized to a clear interpretation of the insediative complex and of the articulated defensive system.

The scans made possible to understand the architecture of the places and structures, and first images extracted from the point cloud were invaluable to start studying this settlement.

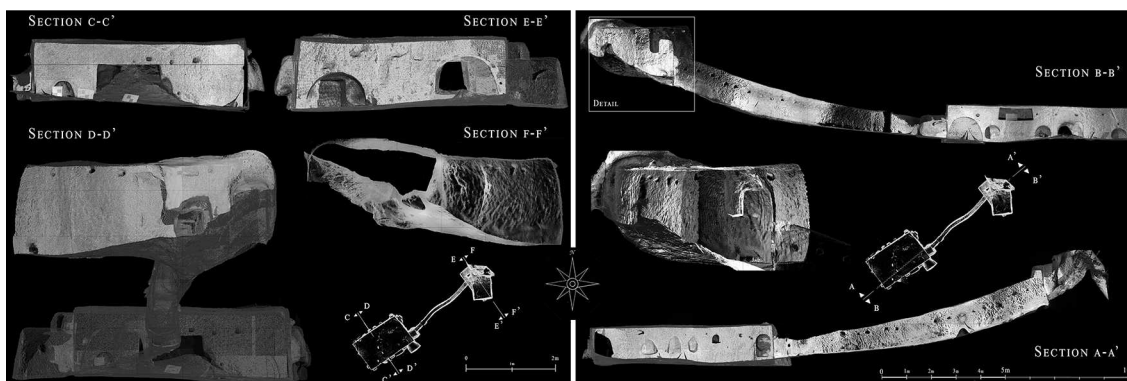


Fig.12 – Shelter 2: longitudinal and transversal sections.



Fig.13 – Shelter 1: longitudinal section.

Conclusions

The importance and possibilities of 3D Scanner survey are now well established. However, it is necessary to underline the use irreplaceable in archaeological areas or in areas in which is difficult to obtain data such as the local context and landscape, which represent the site of our research.

The survey by the 3D scanner, integrated with the topographic survey realized with speleological technique, two-dimensional and three-dimensional digital models, such as the double orthogonal projection of the buildings carved into the rock allow to: 1) analyze and define the relationships of the interpenetrating spaces; 2) Supply an efficacious support to the documentation originated from the analysis of the underground morphologies and excavation techniques, from the archaeometric data, and from the identification of manifold phases of utilization (three, at least), collected during the spelaeo-archaeological and geological surveys, still in progress; 3) Study the state of preservation of the rock-cut structures and prepare a plan for their consolidation; 4) Prepare projects for the accessibility of monumental structures, now closed to the public, and to reduce the risks of all users who have authorized access to them.

Besides, the survey and 3D model, extended to the surrounding external area, although widely deteriorated, will be useful to: 1) Deepen the knowledge of the relationships with the extant urban fabric and those destroyed over time, to interpret the original general urban context and life system in which the churches have been conceived and realized; 2) Develop an accessibility project able to saving the environmental and cultural peculiarity of this exceptional rupestrian heritage, improving the fruition standards in the respect of the security reasons.

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