

# The Church of Meryemana in Göreme, Cappadocia.

## New life in prototyping and augmented reality.

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**Abstract:** The submitted case study is about the rupestrian church of Meryem Ana in Göreme (Cappadocia, Turkey), a small church with mural paintings representing valuable heritage at risk due to the poor stability of the rock where it's excavated in.

In 2012 a team of researchers from DIDA – Dipartimento di Architettura, Università degli Studi di Firenze carried out a survey of the church that would show the artifact current conservation state and procedures to avoid the permanent loss.

The processing of data carried out by laser scanner and photographic survey made it possible to produce conventional drawings and to build a 3D reality based model of the church thanks to reverse modelling, retopology and texturing techniques. This now represents an important database of a no longer accessible cultural heritage and a useful tool for still-images or animation products, but also a helpful means for the development of research projects and restoration interventions for enhancement.

A scale model, build from 3D data with SLS technology (Selective Laser Sintering), and an augmented reality application, developed with Unity 3D and Vuforia are the way to achieve the main aims of the project, which is the reconstruction of the church through the integration of 3D print techniques and augmented reality technologies.

These applications properly programmed can be used for dissemination both in scientific and entertainment fields.

**Keywords:** Heritage at risk, Reality based models, 3D Print, Augmented reality.

## Introduction

The assets of Cappadocia today appears intended for a broad loss, in certain parts the rupestrian monument are well preserved, in other parts they are abandoned or overloaded by admiring tourists, this whole patrimony appears only partially preservable, and therefore it is even more exceptional in its late phase.

This case study takes care about the Meryemana church in Göreme (Cappadocia, Turkey), a small rupestrian church enriched by mural paintings from the life of Virgin Mary. This small monument represents a valuable heritage at risk because of the poor stability of the rock in which it has been excavated.

The study carried out here is aimed to revisit this case in light of a possible methodological path that goes from integrated survey technologies used on the field, with three-dimensional reconstructions of space, supplying a broader spectrum of quantitative and qualitative data.

The whole processing brought to the production of a model built from 3D data with SLS technology (Selective Laser Sintering). A solution created in scale for which it is even possible to speculate a reproduction made in the true scale (in part or in its entirety). The entire apparatus of the wall paintings is

displayed over the Physical model by an augmented reality system. This has been developed with *Unity 3D* and *Qualcomm Vuforia* used as a way to achieve one of the aims of the project: suggesting a possible reconstruction of the church through the integration of 3D print techniques and augmented reality technologies.

The connection system between real and virtual is based on a simple QR code that can be acquired directly from the device of the visitor. The ability to incorporate themes and the versatile versions of the model with augmented reality make it particularly effective and attractive for any fan of the Cultural Heritage and technologies, creating an interesting experience in the best tradition of the Digital Heritage.

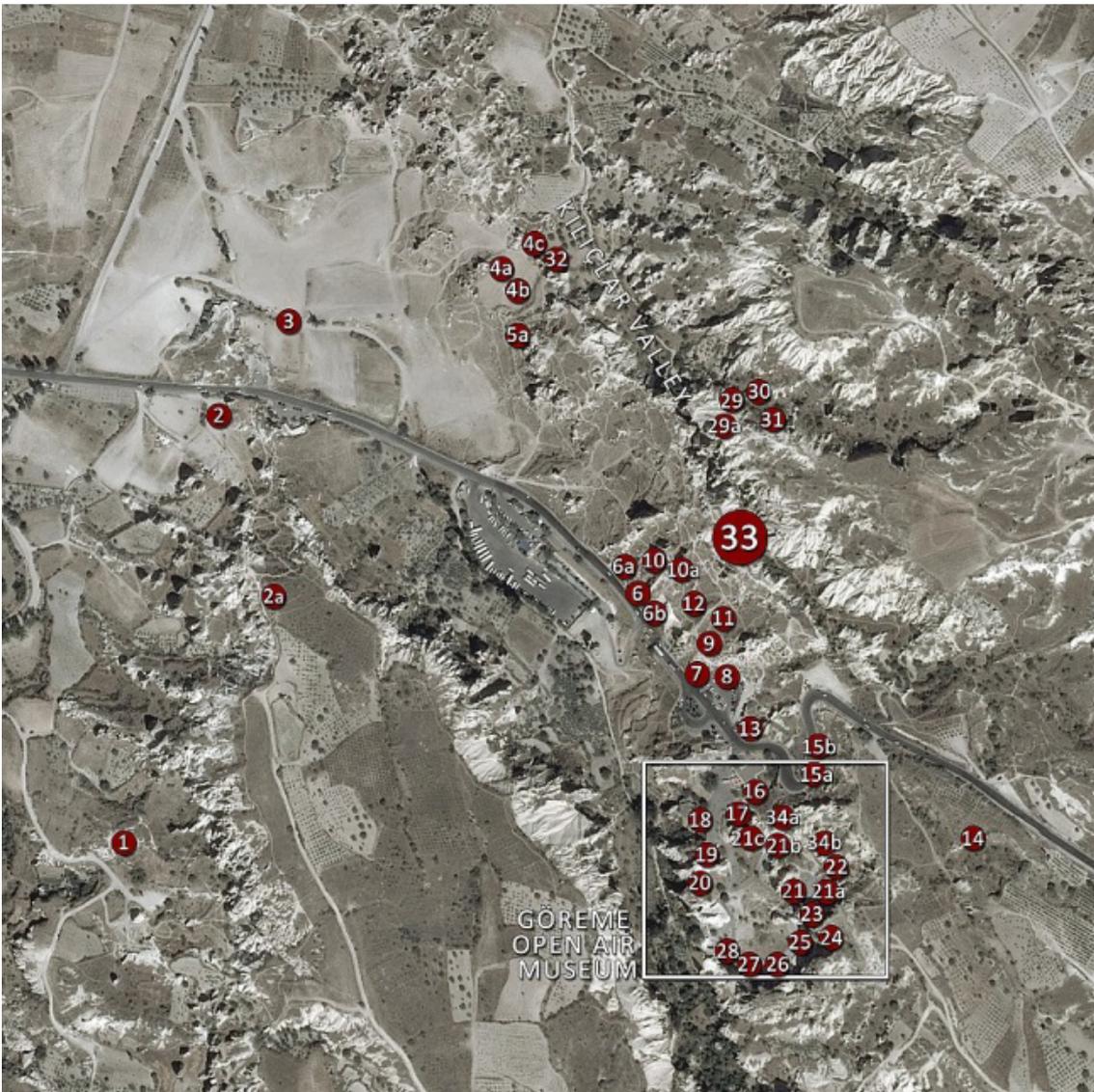


Fig. 1 – Map of the Churches in the "Swords Valley", Göreme, Turkey.

### The Church of Meryemana

The church of Meryemana (Kiliçlar Kuşluk - Göreme, No. 33), dating from the eleventh century, is part of a large monastic complex composed of dozens of rock churches (X-XIII c.), today organized in an "open air

museum" (Fig. 1). Located 1.5 km away from the center of the village of Göreme, in the valley of Kiliclar (in turkish it means "the swords valley"), this complex contains some of the finest rock-hewn churches (Fig. 2), decorated with beautiful frescoes and wall paintings, whose colors yet retain their original freshness.

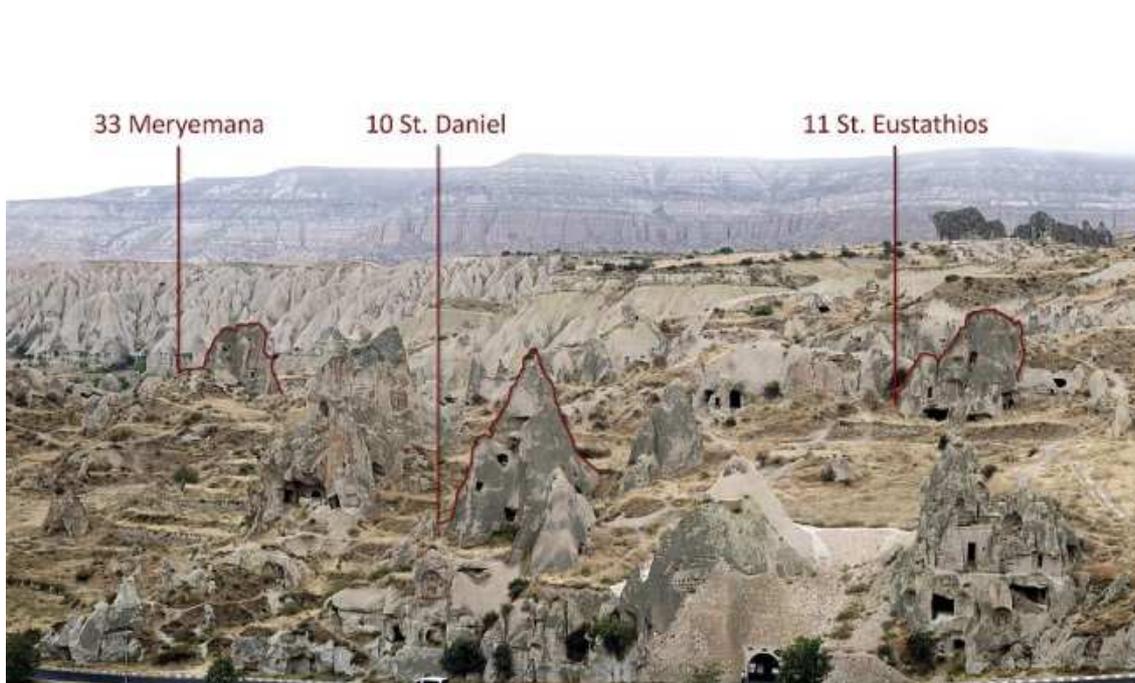


Fig. 2 – The "Swords Valley", Göreme, Turkey (Copyright: Giorgio Verdiani).

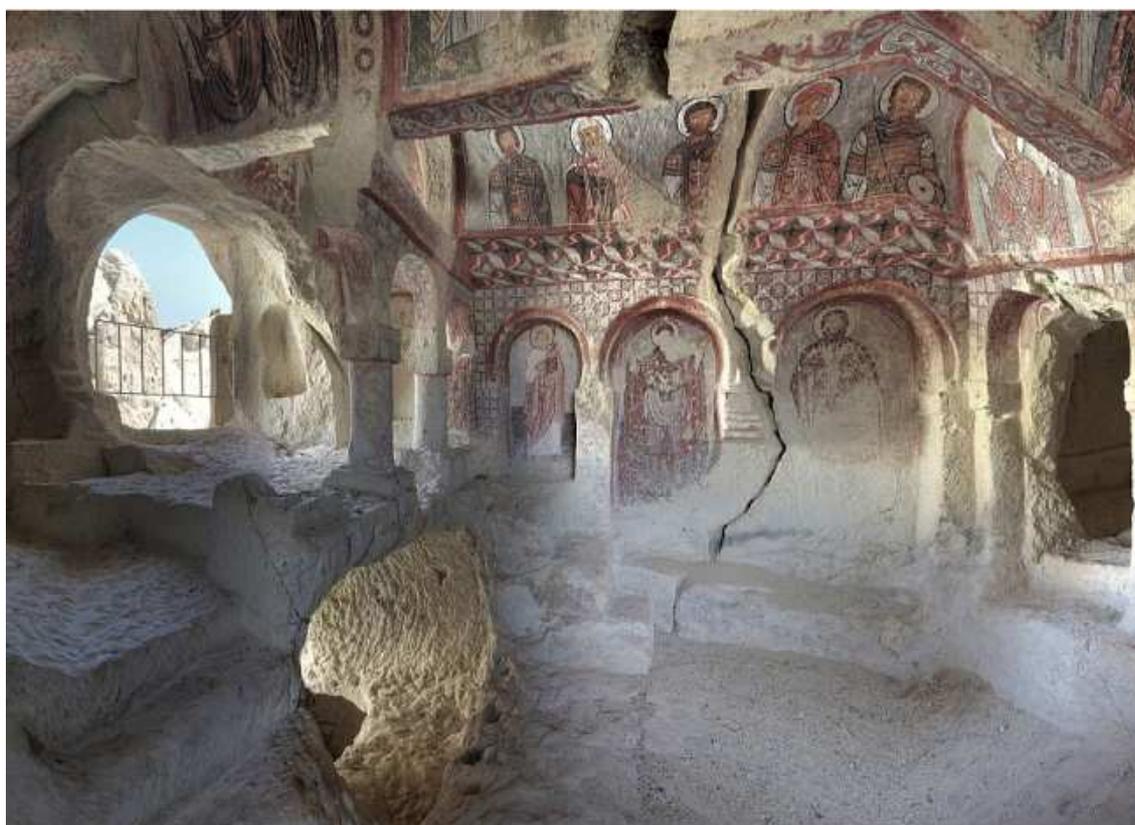


Fig. 3 – Meryemana Church, interior Photo (Copyright: Giorgio Verdiani, Claudio Giustiniani).

Despite the excavation technique provided the craftsmen of Cappadocia the opportunity to create new architectural forms; they remained true to Byzantine models. Thus, Meryemana churches entirely reflect Byzantine sacral architecture both for plan and elevation architectural elements, such as arches, pillars, columns, capitals, frames, vaults and domes.

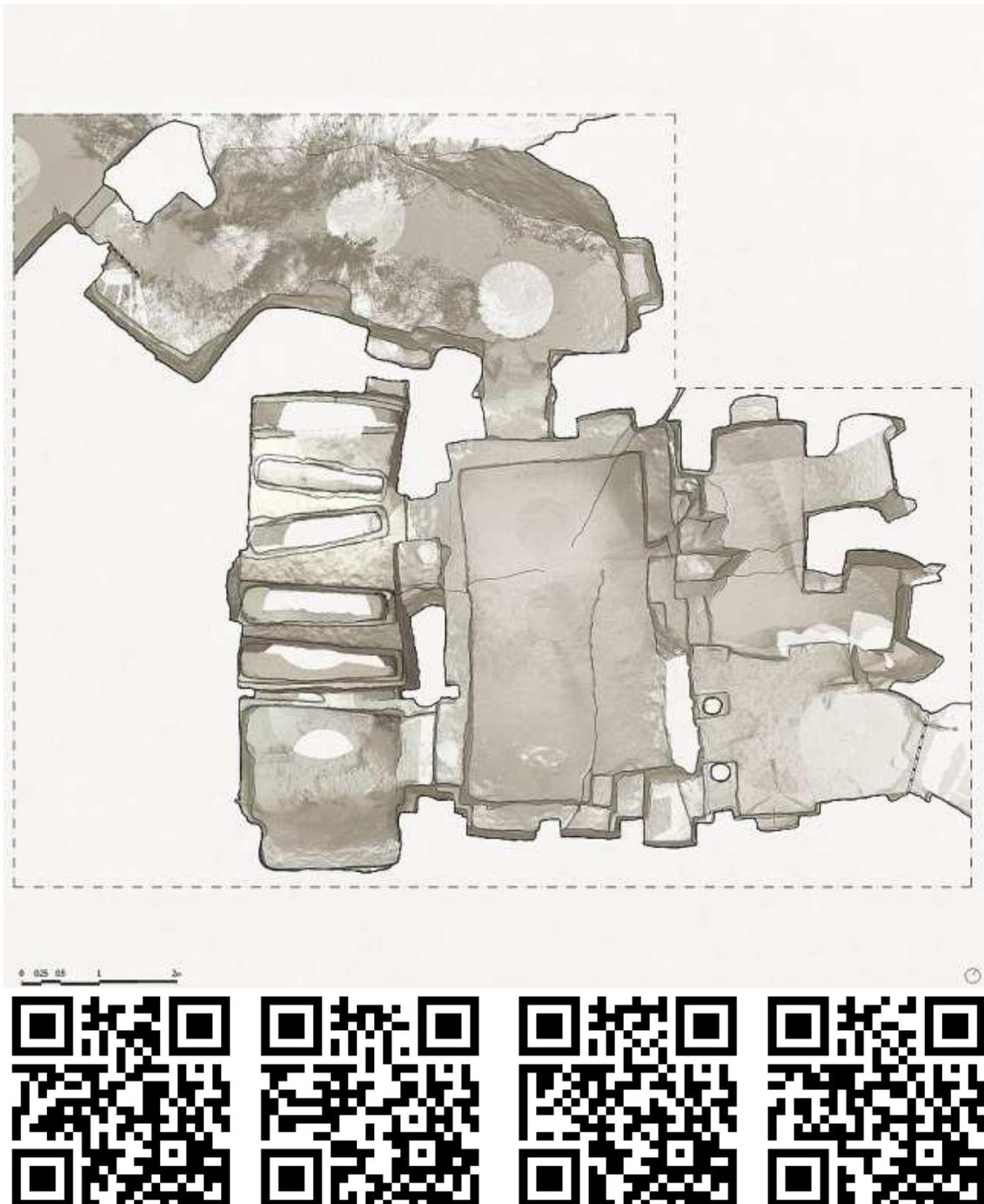


Fig. 4 – Meryemana Church, Planimetry. QR-Codes for panoramic Virtual Tour.

This kind of modest size buildings perfectly fit for small monastic communities needs. The main feature distinguishing Meryemana churches from the others in the area is due to the presence of a transept covered by two barrel vaults of different sizes, without any support to the ground.

The huge crack running through the entire compartment reveals the dreadful state in which Meryemana complex is (Fig. 3): it develops all along the vaults and the vertical walls, even touching the floor. The two extremities of the crack on the floor are only half a meter separated (Fig.4). The bema and the lower chambers are beyond the crack that divides the church into two parts. Each path on either side of the church is considered to be dangerous both for the structure and for the safety of the visitors.

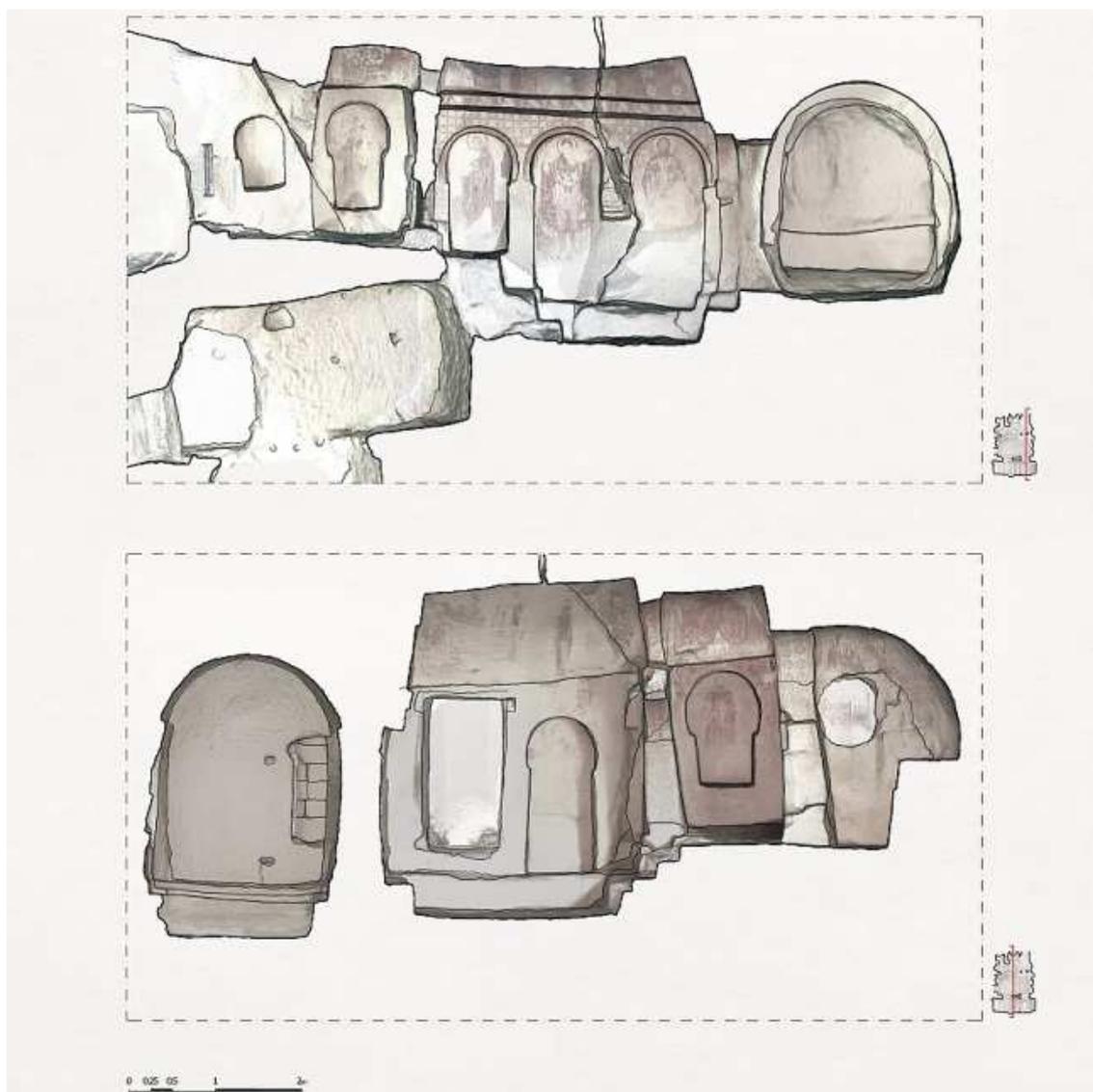


Fig. 5 – Meryemana Church, Longitudinal Sections from Point Cloud.

The sequence of spaces clearly shows a complex development of the Church in time. Aggressive interventions after its creation have indeed altered and destroyed part of the original frescoes, such as the one opening the connection with the chamber tombs.

Three apses open east of the naos, two of which are still preserved in good condition. The south one, called *diacoricon* (vestry), has almost completely disappeared and a large opening towards the valley allows an amazing view towards the opposite peaks. The north one, defined as *prothesis*, welcomes the space once used for the preparation of bread and wine.

Among the *bema* and naos the separation is clear; the first difference is in height, as can be seen in Sections; noticeable is the separation of the two spaces (Fig. 5). Also a hallway with raised ceiling opens on nave with a carved *iconostasis* in six strings and five columns. Three of the five columns have been lost; the missing part however creates an asymmetric perception of the church and emphasizes the value of the remaining columns (Fig. 6).

Below the *bema*, in the right part there are two other secondary rooms structured one on top of the other, probably excavated at a later time possibly to provide for a direct connection to the *naos* by way of wooden stairs.

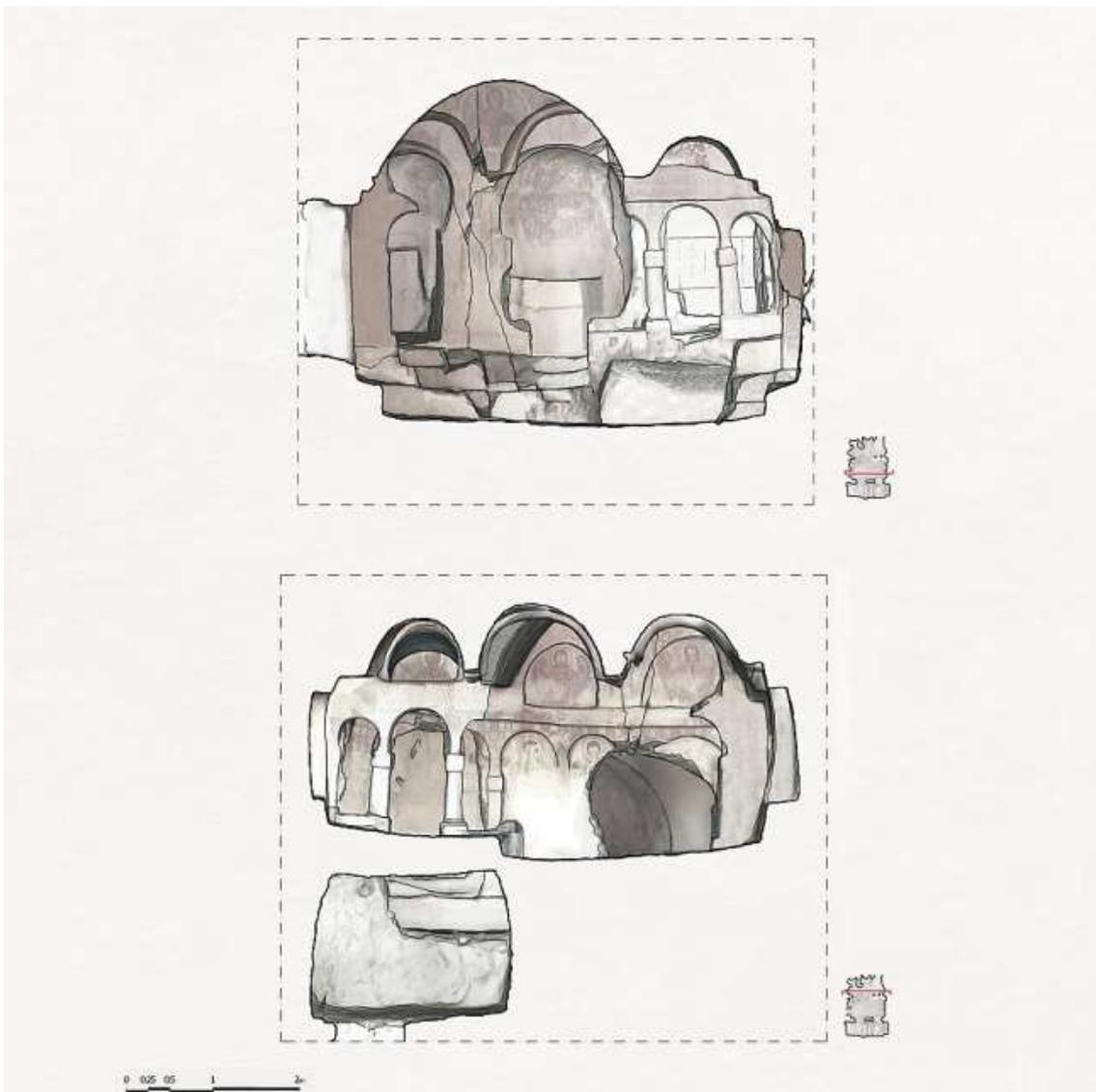


Fig. 6 – Meryemana Church, Cross Sections from Point Cloud.

The paintings of Meryemana represent, not only for specialists but also for a curious visitor, a valuable evidence of the art in the X-XIth century. Indeed only in Cappadocia, in all rock churches these frescoes can be appreciated, as in other regions of Byzantine world they are rare and often fragmentary. A copious

documentary material, cleverly orchestrated, reveals an eventful story and informs us about the community, its beliefs and religious practices.

### **Digital Survey and 3D data treatment**

In the summer of 2012 the Department of Architecture of Florence (DIDA), in collaboration with the Department of Cultural Heritage of Viterbo (DISBEC), has developed a project called "*Rupestrian Habitat and Arts in Cappadocia -Turkey- and in the Center-South of Italy. Stone, carved architecture, paintings: between the knowledge, the conservation and the enhancement*". Starting from an accurate survey campaign with digital camera of the churches of Saint Eustace, Meryemana and San Daniele, located on the back of the large area of Tokali Kilise, the research project aims to analyze the collected data and provide tools and models focused on understanding the causes of damage and degradation (time and climate change effects on architecture) of tangible cultural heritage (buildings, sites and landscapes).

The produced material is therefore essential for the recovery, the heritage conservation and a greater understanding of its cultural values.

Survey is the first step towards the acknowledgement of architectural heritage. In practice, subsequent analyses, whether metrical, proportional or structural, are based on geometric and chromatic collected data. The interesting developments we were given by technology in the last decades, including methods and tools for “contactless” three-dimensional data acquisition, have led to the conclusion of this important research phase in the best possible way. In fact, thanks to the use of a laser scanner (*Faro Focus3D CAM2*) a better knowledge of the geometric dimensions of detected rock settlements has been obtained. The result is a discontinuous 3D model, consisting of a series of point clouds (one for each station) preserving the real scale of the acquired object and thence allowing the operators to perform their survey operation (previously implemented in loco) directly in the laboratory through a dedicated software.

Laser scanner, being able to return objects of complex shape with a maximum error of 3mm (but especially in less time), has produced a result that has decisively contributed to the production of two- dimensional models (plans and canonical sections) and three-dimensional meshes on which carry out the virtual operations later.

### **Mesh and Retopology**

Point clouds, nonetheless the density, represent, as previously mentioned, a discontinuous pattern, which do not maintain perceptual features although metrically faithful to reality. Thanks to the use of tools and algorithms made available by specific software it has been possible to obtain a triangular mesh from acquired data on the field. Once you have a *hi-poly* model by simple triangulation, it is appropriate for the operator to treat any topological errors presented in the mesh through the use of semi-automatic tools. That allows always to keep control of the adherence of the geometric model to reality.

Any disclosure of the study conducted to date is related to methods and instruments that require further processing of a virtual elaboration. Augmented reality and real-time applications have yet to clash with the computational limits that characterize the majority of the hardware on the market. For this reason, it becomes essential to implement optimization procedures of 3D models. The simplification of geometric data lets the

operator keep the weight of the files in terms of megabytes and maintain at the same time the actual perception of characteristics of the article.

The best way to lighten the derived data from processing of point clouds (model mesh hi-poly) is the use of a technique known as *retopology*. The now available advanced tools permit the simplified use (semi- automatic) of this technique. The goal is to drastically reduce the number of polygons that describe the geometry of the object, from a million to a few thousands (Fig. 7), while keeping the control points of the original mesh. This process certainly simplifies the shape, but admit to use *low-poly* mesh for real-time rendering applications or for the video production. To a smaller number of polygons correspond a computational lightening of rendering engine in calculation phase.

After a texturing preliminary operation involving a *color-map* creation from photographs and a 3D painting (coloring the parts related to the external environment and undercuts directly on the model using tools brush), necessary operations were carried out for the production of a *normal-map*. To bake the *normal map* means to transcribe the geometric information taken from the *hi-poly* mesh into a 2D image (*UV-MAP*). These maps, appropriately combined, allow the operator to give the final model a photorealism useful to its disclosure and its reliability color (Fig. 8).

The models originated by this pipeline are much lighter in terms of bytes. Exploiting the techniques described they can be imported into software such as Unity 3D (working in the field of entertainment) for the production of real-time applications.

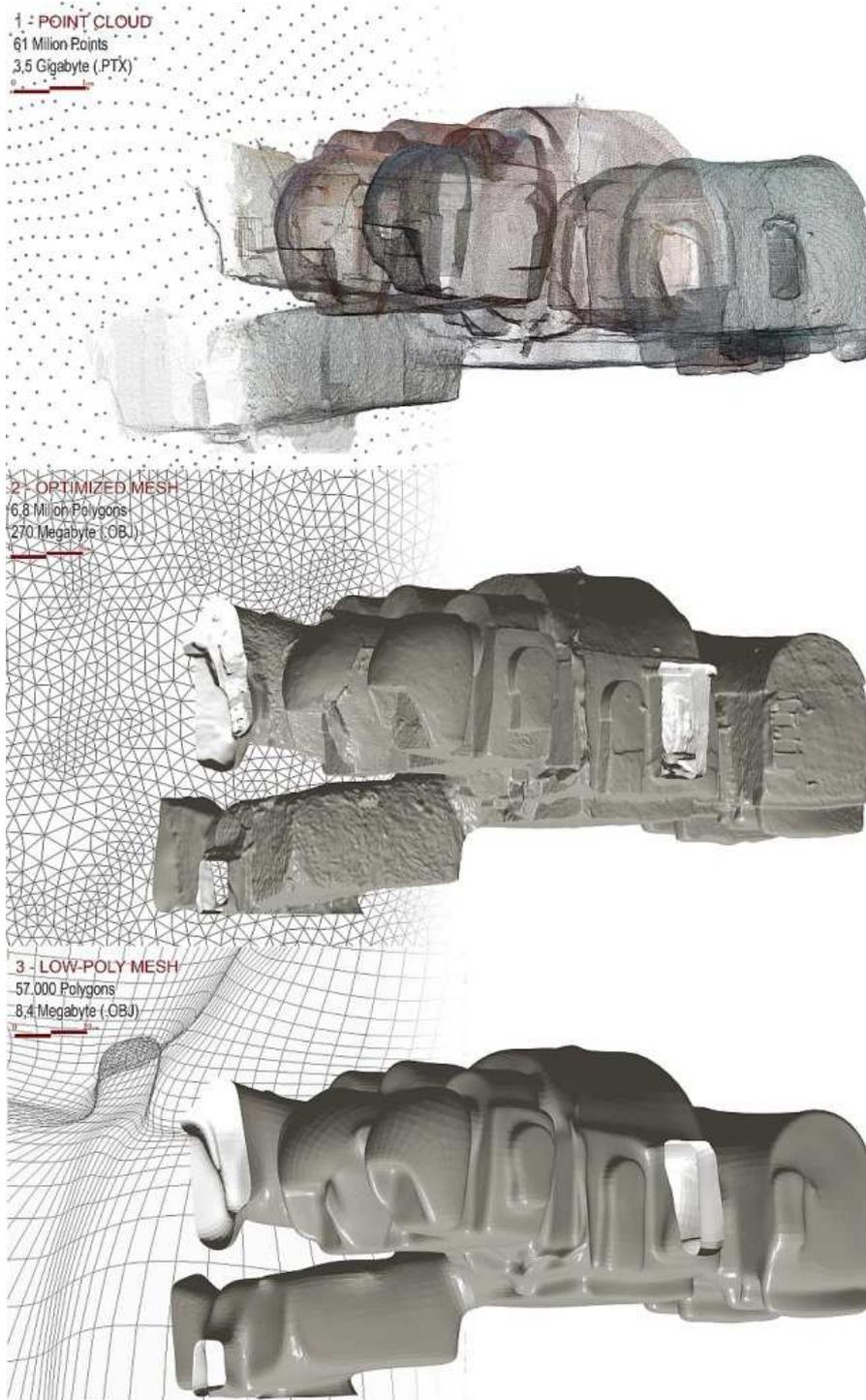


Fig. 7 – Reverse Modeling and Retopology.



Fig. 8 – Model Mapping.

### 3D print & Augmented Reality

In addition to the study and preservation of digital data, the goal is to propose a system for a faithful reproduction of the artifact that is both realistic and evocative, equal to a real experience. Therefore, to provide the visitor with a similar feeling, the new printing technologies have the ability to recreate the digital data holding minimum unnoticeable errors. This gives the church (now inaccessible) a new life.

After the production in 1:1 scale of the physical prototype, resulting from the processed dataset, the visitors can live a complete immersion experience in the architectural space, almost like in the original. In order to a practical demonstration of the potential prototyping technique for a detailed physical examination of the church, a prototype of the rock settlement has been designed in a 1:25 scale (Fig. 9, Fig. 10). Starting from the data produced by the *reverse modeling* techniques previously described two types of different mesh were produced:

- a *hi-poly* mesh (high number of polygons), suitably divided according to the architectural morphology of the church (optimization required for easy management of the individual file) for a 1:1 print scale;
- a simplified mesh (*mid-poly*) for prototyping in 1:25 (by reducing the size of the printed output it has been possible to reduce the density of polygons describing the geometry).

However, the current technologies focused on 3D printing are unable to restore and generate high color data quality, despite research in recent years having produced significant results in this regard.

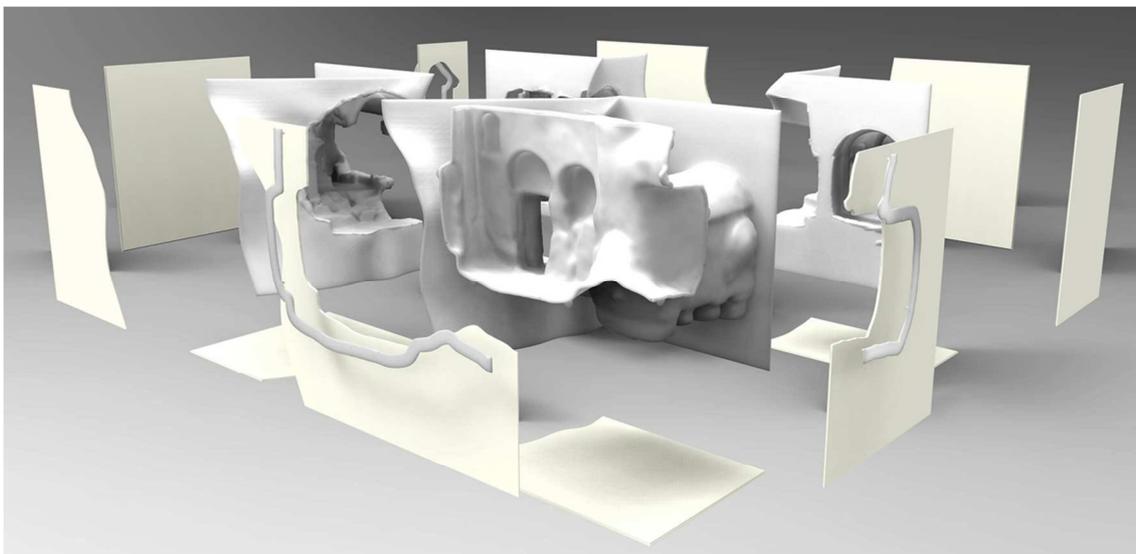


Fig. 9 – 3D Printed Model project.

The union between reality and virtual worlds using augmented reality is the key to the missing element that unites and defines the project. It represents the fusion between real and virtual, united in an experience of enriched enjoyment. The idea is then to combine the interactivity and communication possibilities we are offered, involving virtual worlds with the atmosphere of the environment faithfully reconstructed in three dimensions into one "augmented structure". The process of development of this application, thanks to the enormous diffusion that in the last four years has had this technology on the market, did not require special computer skills in the field of programming. In fact, using a *plug-in* for the software *Unity 3D*, *Qualcomm*

*Vuforia*, is very simple and straightforward, even for an inexperienced user, to load in the assets our *low-poly* mesh model with the *color-map* and the *normal-map*. A first result with an augmented reality directly using the computer webcam can be now achieved.



Fig. 10 – Realized 3D Printed Model - 1:25 (Copyright: PMD - Promo Design s.cons. a r.l.).

*Vuforia* has indeed released for free a simple interface to interact with the virtual reality: after loading its *plug-in* interface in the *Unity* software, we can immediately build and customize a simple but effective AR application from the recognition of specific target images. Target images are stored in a cloud database to which it connects the service, in order to save space for local storage.

*Qualcomm Vuforia* is already compatible with both *Apple iOS* operating system and *Google Android*.

Therefore the app, based on its new implementation, will become available for a very wide audience (Fig. 11).



Fig. 11 – Augmented Reality Application: 3D printed model mapped with 3D digital model. QR-Code for video demonstration.

Thanks to the software Unity3D it was also possible to develop solutions to use 3D virtual reality application as the "virtual tour" and "real time section". In the first case (Fig. 12), we pass from an augmented to a virtual reality exploration. Visitors, even those not physically present in the structure of the church, can virtually enter, while remaining in any part of the world. By making available such applications through the network, the system enables an exploration customized to the needs of the user's knowledge: a cultural experience that suggests and offers new opportunities for remote exploration.

In the second case (Fig. 13), the application (the real time section) makes it possible to dissect in real time (along the three axes) the model of the church of Meryemana by the movement of a cursor, or directly with a finger on the screen of the touchscreen device.

## Conclusions

The study carried out aims at revisiting the case of the Church of Meryemana in the light of a new methodological path. With three-dimensional reconstructions of space the methodological process supplies a broader spectrum of quantitative and qualitative data.

This work represents an important database of a no longer accessible cultural heritage, a helpful means for the development of research projects and restoration interventions for enhancement.

The right to transmit the results of such studies depends on a complex of different factors (for example : paper space, color and resolution of the photos, the limits of the design, completeness of texts etc.). This digital approach can capture the attention over a meaningful Cultural Heritage element at risk and can help in finding the needed resources and the appropriate reflections before operating any intervention on the monument.

It is essential, in the archeology of the third millennium, to create models of knowledge and open based interactive non-linear systems. Moreover in a full digital age is all the more a priority to try to find the best solution for the problem of archaeological information modelling, according to new standards of communication and representation to be devoted in the future.



Fig. 12 – Virtual Reality Tour Application for Android. QR-Code for the APK Download.



Fig. 13 – Real Time Section Application. QR-Code for the video demonstration.

### Acknowledgment

The digital musealization researches, prototyping/3D printing and multimedia extraction of the Meryemana church came from Carlo Gira's work in his Architecture degree thesis (Tutor: G.Verdiani, co-tutors: A. Aliperta, F.Susca).

The research mission in Cappadocia of the University of Tuscia “Rock paintings in Cappadocia. For a project of knowledge, conservation and enhancement”, directed by Maria Andaloro, is composed of multiple research units. The working group 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. The Digital Survey of Meryemana was operated by: G. Verdiani, 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, C. Gira, T. Pignatale, A. Charalambous.

The mission in Cappadocia was supported by the General Direction of Monuments and Museums of the Turkish Republic and Murat Gulyaz, director of the Archeological Museum of Nevsehir.

For the 2012 survey, in particular, we are greatly indebted to the two Cultural Ministry Deputies, Metin Çakar from the Archaeological Museum of Çorum, and Gultekin Yanbeyi from the Department of Archaeology of the General Direction of Monuments and Museums.

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**Imprint:**

Proceedings of the 19th International Conference on Cultural Heritage and New Technologies 2014 (CHNT 19, 2014)

Vienna 2015

<http://www.chnt.at/proceedings-chnt-19/>

ISBN 978-3-200-04167-7

Editor/Publisher: Museen der Stadt Wien – Stadtarchäologie

Editorial Team: Wolfgang Börner, Susanne Uhlirz

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