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The Catacombs of San Giovanni in Syracuse: Surveying, Digital Enhancement and Revitalization of an Archaeological Landmark

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Abstract. This study is a cross-disciplinary research carried out by archaeologists, engineers and architects aimed at the knowledge and enhancement of the San Giovanni catacombs complex in Syracuse. The study uses the most innovative 3D surveying and virtual reproduction technologies and methodologies in order to broaden the understanding of the archaeological site's most peculiar features. The digital 3D models of the rooms studied here can be used to enhance the visiting experience and the online presence of the archaeological complex.

Keywords: Roman Catacombs, laser scanning, 3d modeling, knowledge, virtual fruition, virtual archaeology.

1 Introduction

This paper presents the first results of an interdisciplinary study aimed at extending our knowledge of the San Giovanni catacombs complex in Syracuse, as well as enhancing this archaeological landmark and improving its visibility.

The archaeological complex comprises the catacombs, the basilica of San Giovanni Evangelista and the crypt of San Marciano.

In Syracuse, the systematic study of collective cemeteries started many years ago and different archaeological surveys of the city's antique funerary settlements suggested many directions for research and investigation: historical-religious, economic and social. The results of the present study of the burial areas' architecture and layout will no doubt shed some new light on all these different aspects.

The study is based on general archival, bibliographical, documentary, literary and epigraphic data and it uses the most innovative 3D surveying and virtual reproduction technologies and methodologies. The digital 3D models of the rooms studied here can be used to enhance the visiting experience and the online presence of the archeological complex. The project also includes regular archaeological excavations.

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After giving a brief overview of the structural aspects of the Catacombs of San Giovanni in Section 2, Section 3 will focus on the digital enhancement and visitor experience. Section 4 will then offer an in-depth look into the actual surveying and 3D modeling methods used to create accurate and detailed virtual reproductions of some areas of the Catacombs, and Section 5 will examine the results of this study and consider future developments.

Fig. 1-2. The *decumanus maximus* (on the left) and the in situ survey (on the right)

2 Historical and Structural Aspects of the Catacombs of San Giovanni in Syracuse

The History of the area, which was going to hold the catacombs (San Giovanni, Vigna Cassia and Santa Lucia), spanned the centuries between the classical Greek and late antique ages, gradually giving evidence of quarries (Latomie), water supply systems to the city, characterized by cisterns and aqueducts [1: 682], handcraft workshops from the beginning of the 4th/3rd century BCE and burials datable to the early and mid-Roman Empire. It is no accident that if hydraulic systems and furnaces have been found inside the three biggest catacombs. The funerary evidences prior to the creation of monumental community cemeteries are columbaria, hypogea of different sizes inserted into the catacombs or isolated from them and *sub divo* burials, all datable to the first three centuries of the Roman Empire, if not beyond, and commissioned by pagans.

Several interest will be given to structural aspect of the catacombs of S. Giovanni, practice of funeral rituals, ethnic and cultural fruition's characters, transformation in the use, transformation in the way of using spaces for graves, to complete a general point of view about the phenomena of continuity and innovation as to previous sepulchral arrangements and, in the analysed periods, the facies belonging to the different settling, variegated in the committees'ideological and religious themes, in choosing monumental types (like rotundas) and decorations, in self-representative aspects, in burial uses. In this perspective we will give particular importance to the study of executing techniques, of material employed, of working funerary organization. Just as in Roman catacombs, but with a bigger monumentality, the project of the catacombs of S. Giovanni involves realizing a regular urban plan for the subterranean city of the dead. In the catacombs, indeed, the exploitation of pre-existent hydraulic structures is not unusual: aqueducts, private channels, circular section well and conical or bell-shaped cisterns [2,3].

Fig. 3. The plan of the catacombs where the areas of interest are highlighted

The same happens in the catacombs of San Giovanni, with the diversity due to a well-defined project; in several cases the *fossores* (gravediggers) were forced to demolish or amputate the cisterns that influenced the construction of the regular structure according to the project. It is feasible to see numerous cases of hydraulic installations reuse, which facilitated the realization of galleries, *lucernaria* (skylights) and private chambers (rotundas of *Marina, Adelfia* and *Sarcophagi*). It only remains to make a choice between two possible explanations: 1) it is a case of a *pantheon* constructed *ex novo* on the pattern of the mausolea above ground, as the rotunda of Antiochia to suit both the local and passing members of the élite, without any influence imposed by preexistent hydraulic structures [4: 764]; 2) the rotundas reuse hydraulic preexistences and adapt them to a private vision of the space. In this case the presence of previous structures (cisterns of large dimensions), probably increased even further and whose undeniable traces remain (openings for drawing water and inspection pit with platforms) and have been the input for creating subterranean *mausolea* [5: 81-83]. The alignment of the three rotundas would be, in this sense, related to their original utilization from above (for the system of the lined cisterns in Syracuse see [1]), more than the alignment of the roads and neighboring hypogea [4: 763]. The former explanation for the genesis of this sector does not convince, mostly because of the idea of an adjustment of the alignment of the three rotundas with a nearby road, 350 m away from the catacombs which served the theater area. The same central thread seems to link the three rotundas – of *Marina, Adelfia* and *Sarcophagi* – to the solution adopted in the catacombs called "Grotta di Fragapane" in Agrigento [6: 205,215], where preexistent granaries develop into circular chambers. The analysis of the funerary system certifies one hand the dependence on the Roman model, and other the debt in respect of local traditions.

3 Optimisation and Digital Enhancement

The Catacombs' digital enhancement project will see the creation of three integrated multimedia platforms:

- Online communication. The museum's website, which is under construction, will promote the Catacombs that are currently open to the public (through the creation of an *Itinerary of the Catacombs*) and offer "virtual access" to the areas that cannot be visited at the moment. It will also give visibility to other local cultural landmarks by introducing combined offers and touristic routes. The website will be available in various languages and it will feature extensive descriptions and a comprehensive collection of multimedia resources (photo galleries, videos, 360° visits, 3D reproductions), easy to share or save on the user's own device. The aim is to attract young visitors and schools to the museum by creating interactive games related to the Catacombs and building an online community through various forms of interaction and content-sharing via Facebook, Twitter, Flickr or YouTube.
- On-site communication. To enhance the visitor experience the museum will use innovative on-site communication methods:
  - multi-touch [7] multimedia tables featuring multiplayer interactive games that will make the visit more entertaining and fun, especially for young visitors and school excursions [8];
  - holographic projection [7] [8] of a 3D virtual reproduction *in situ* of Adelfia's sarcophagus (the original is currently on display at the Paolo Orsi Museum) at the centre of the eponymous Rotunda;
  - multimedia WiFiGuide [9] will provide multilingual information about different key items spread across the Catacombs and the Crypt. The information will be accessible on the visitor's own mobile device or on rented devices (iPod Touch) via an underground WiFi network.
- Monitoring attendance, feedback and interest. Two different platforms will be used to collect real-time statistical data that will help define appropriate strategies: *eFlowAccess* to monitor visitors' access at the entrance [10] and *eFlowFeedback* to monitor their feedback at the exit [10]. Both applications use highly customisable templates to generate multilingual feedback forms and multiple-choice questionnaires. The data thus obtained are processed to get statistics and reports (graphs, bar charts, pie charts) for each individual item. *WiFiGuide* allows users to send direct feedback, but it also provides valuable information about visitors' experience, both quantitatively (number of visitors, language, visitor flow by date and hour) and in terms of quality. WiFiGuide can indeed show the degree of interest towards different exhibits, but it also provides *performance indicators* such as the *attraction rate* (how many visitors were "attracted" to a specific exhibit) or the *sweep rate* (how much time they spent in front of each item). With all this information at hand, the museum has a powerful tool to monitor visitors' behaviour based on primary quantitative and qualitative data.

4 Extending Knowledge of the Catacombs of San Giovanni through Surveying and 3D Documenting

The past few years have seen a steady increase in demand for the surveying and mapping of monuments and archaeological sites by means of innovative 3D technology (range-based and image-based) [11,12,13,14,15,16].

As stated by Norbert Zimmermann [17,18], who coordinated the START project for the Domitilla catacombs in Rome, computer-based technology and 3D modelling can be extremely helpful and they can provide powerful research tools for archaeologists faced with historic sites whose geometry and space distribution is particularly complex.

The type of 3D models thus obtained will be a valuable high-quality resource for further cross-disciplinary research activities encompassing different methodological approaches. It also gives a good basis for developing a three-dimensional information system [19] which can include dimensions, archival, bibliographic, documentary, literary, epigraphic, historic-religious and socioeconomic information.

Moreover, 3D models can also help researchers create a space-time reconstruction of the different phases in the site's evolution [20], or they can be used to study the ventilation and lighting systems of these spaces, or to develop interactive 3D web applications [21] and augmented reality [22] to make better use of our cultural heritage.

4.1 Data Acquisition and Registration

With the digitisation project of the Catacombs of San Giovanni our research team had to tackle wide-ranging issues and challenges. The sheer size of the complex, the intricate layout of the rooms and galleries, as well as surface irregularities made it clear that Laser Scanning was the most appropriate technology. Indeed, considering the execution time and the precision and amount of data obtained, laser scanning was the best way to obtain a 3D model that reveals different historical spaces through virtual reality images. The archaeological site features an intricate network of communicating galleries and large rooms. In both the galleries and the rooms, there are innumerable burial niches and *arcosolia* cut perpendicularly into the rock walls and laid out side by side.

During the first stage of the project, we surveyed two rotundas (*Adelfia* and *Sarcofagi*), and two quadrangular cubicles (Eusebio and Paolo) and analysed all metric data obtained, to find empirical evidence showing that pre-existing hydraulic structure such as water tanks, aqueducts or private canals had been re-used.

We used the Leica HDS 3000 ToF Laser Scanner, whose technical specifications are as follows: accuracy of single measurement position 6 mm, distance 4 mm; scan rate up to 4,000 points/sec; field of view 360°x270°.

The surveying protocol involved 6 scans: 1 for each space to be surveyed (in barycentric position) and 2 “transition” scans. These last two were captured from the galleries so as to survey the numerous arcosolia in as much detail as possible, while also reducing the black areas inherent to the complex morphology of the site’s layout.

To ensure proper alignment of the different scans in a common reference system, 29 reflecting targets were scattered across the walls' surface and they were detected and registered by the scanner (minimum of 4 targeted control points for each point cloud).

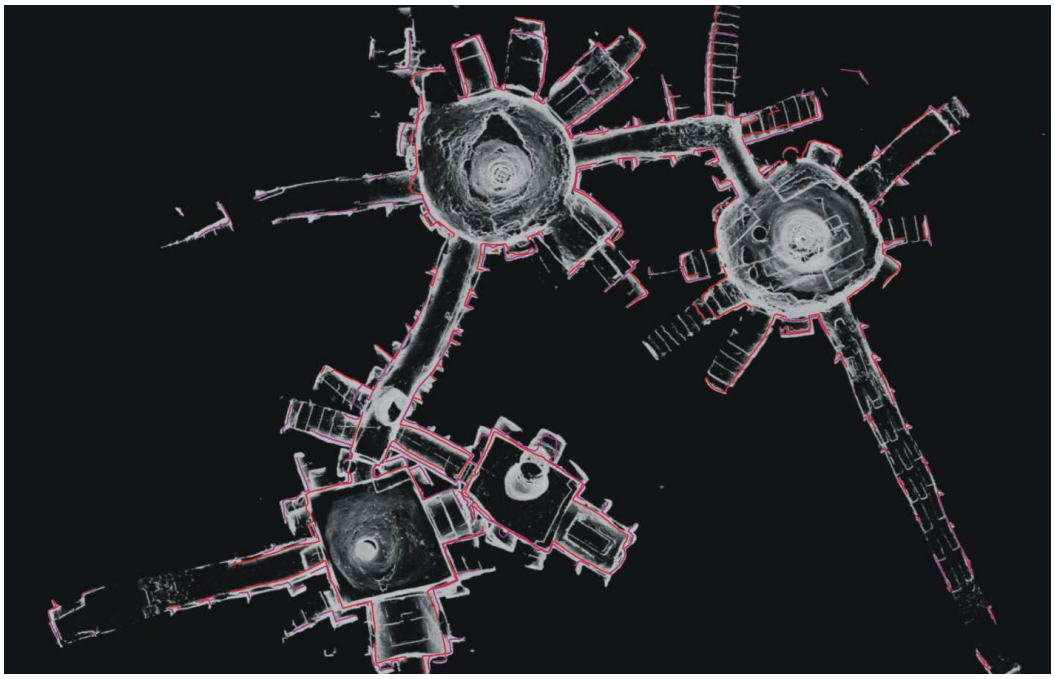

Fig. 5. The ground plane of the rooms (in red) overlapped on the point cloud

The comprehensive model thus obtained consists in 6 scans and a total of 46,940,251 points. Once all field survey data had been registered point clouds were post-processed using specific software, such as Leica's Cyclone, Gexcel's JRC Reconstructor or CloudWorks.

4.2 Revealing the Site's Complexity: Interpretation of 3D Data

Thorough graphic investigation of the point clouds was needed in order to document the geometry of the archaeological complex in plans and elevations without overlooking the site's spatiality and the complexities of its different areas. To draw the site plan we used two horizontal planes taken at different levels of the archaeological site, so as to be able to document its most outstanding features as accurately as possible.

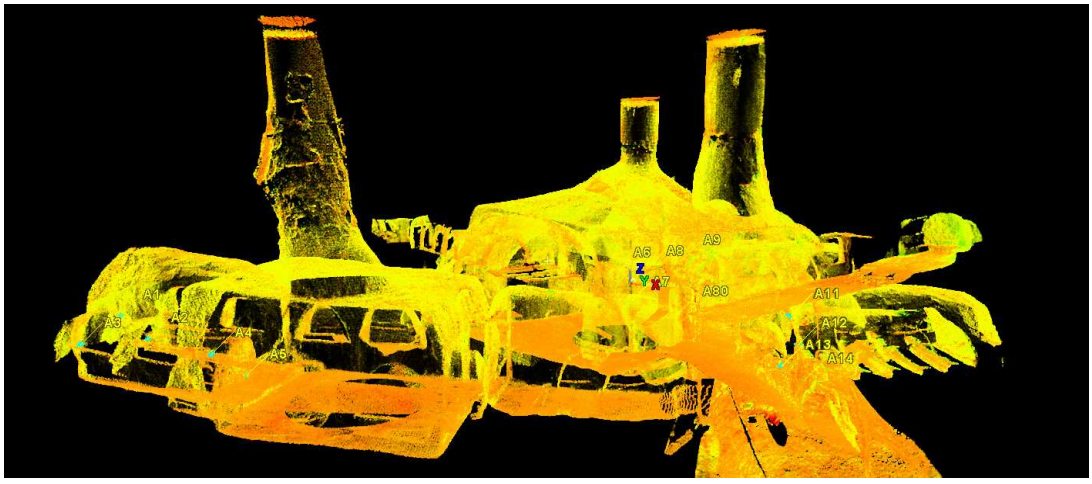

Fig. 6. The 3D model of the cubicles of Eusebius and Paul in false RGB visualization

Moreover, we also carefully selected several offset vertical cross-sections, each of them showing specific views of the complex: axis between the entrances to the galleries, in the skylights' axis, in the centre of the rotundas and the quadrangular cubicles. We also obtained section planes of the surface of the ceiling's intrados, as well as the amplitude and depth of the skylights. The arching of the intrados that covers the rotunda has the shape of a somewhat irregular, wrinkled inverted cone. This confirms the previous use of these spaces as cisterns, as can be noticed in comparison with other ones [23].

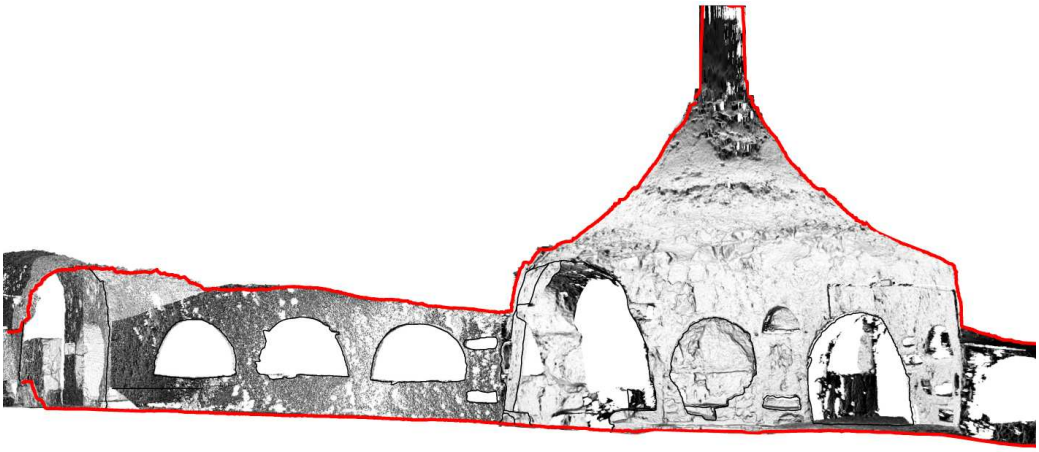

Fig. 7. Vertical section of the rotunda of Adelfia extracted from the mesh model

5 Conclusions and Future Works

Work is still underway for the full 3D surveying of the San Giovanni archaeological complex. To this day only a small portion has been surveyed and analysed by means of laser scanning. To complete the project large amounts of data will have to be acquired, modelled and processed, using specific procedures and advanced data processing technology.

The first results are promising. Based on the considerable amount of data registered thus far, we can elaborate hypotheses and give definite answers based on the metrics available. Moreover, being able to appreciate the volumes and the real physical aspect of the rooms is a unique experience for archaeologists, who can now see the object of their studies from a new perspective.

The next step in this research would be to implement new and optimised techniques in order to create 3D textured models with a simpler geometry [24,25]. These models could in turn be used on the multimedia digital platform designed to revitalise and improve the archaeological site.

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