Best Practices for 3D Digital Recording and Global Sharing of Catacombs from Late Roman Sicily

DAVIDE TANASI, University of South Florida, FL, USA
ILENIA GRADANTE, Römisches Institut der Görres-Gesellschaft, Rome, Italy
STEPHAN HASSAM, University of South Florida, FL, USA

During the most recent excavations at the Catacombs of St. Lucy at Siracusa, carried out between 2013 and 2015, an array of 3D technologies were employed to record excavation data and provide new interpretative models for the site. The research focused on some very problematic parts of the Region C of the complex. This area most effectively documents the long life of the Christian hypogeum, which incorporated previous structures and artefacts related to the Greek and Early Roman Imperial periods and continued to be used until the Middle Ages. During the exploration 3D digital techniques were used for the daily recording of the archaeological units, but also to create high-resolution virtual replicas of certain districts of the catacombs. Furthermore, the same techniques were applied to support the study of certain classes of materials, such as frescoes and marble architectural elements that could not otherwise be studied due to the dark environment of the catacombs. The virtual archaeology research undertaken at the Catacombs of St. Lucy represents the first systematic application of 3D digital technologies to the study of such a special archaeological context in Sicily, culminating in a work-plan for digital global dissemination.

Key words:
Roman Archaeology, Sicily, Catacombs, 3D Scanning, Digital Photogrammetry, 3D Models

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1 INTRODUCTION

This paper aims to demonstrate the various benefits and challenges of using digital recording methods in difficult hypogeal contexts, with a focus on their applications in the Catacombs of St. Lucy (Siracusa, Italy). First, we will examine other projects' use of digital technologies, with a focus on two major projects of digitization in the catacombs of Rome. The article will then contextualize the Catacombs of St. Lucy in a wider historical framework in order to highlight the importance of the site and the ability of 3D digital methodologies to complement and sometimes replace traditional recording methods. Many smaller projects have been undertaken to use digital methods to record

Author's address: Davide Tanasi, University of South Florida, 4202 E Fowler Ave, Tampa FL 33620, USA; email: dtanasi@usf.edu.; Ilenia Gradante, Römischen Instituts der Görres-Gesellschaft, Campo Santo Teutonico, Vatican City, 00120 VA; email: ileniag@hotmail.com; Stephan Hassam, University of South Florida, 4202 E. Fowler Ave, Tampa FL 33620, USA; email: shassam@mail.usf.edu

hypogeal contexts, far too many to list here. A brief resume of some similar projects in the central Mediterranean will suffice to show the importance of digital techniques, and how there is still little agreement on what digital techniques are most appropriate. First, we will examine the only two large scale virtualization projects in catacombal contexts. Second, we discuss some of the smaller projects that have been done in Sicily and that have used digital methods to record and analyze the Catacombs of St. John in Siracusa, which are very similar to the catacombs of St. Lucy.

2 3D DIGITAL IMAGING APPLIED TO THE STUDY OF CATACOMBS

There have been two major efforts at using digital methods in recording underground catacombs. These are the Domitilla Project undertaken by the University of Austria, directed by Dr. Norbert Zimmermann, and Project ROVINA that was undertaken by a consortium of universities and research units.

2.1 The Domitilla Catacomb project (START)

The Domitilla Catacomb project was undertaken by the Academy of Sciences of Austria in the Catacombs of Domitilla in Rome from 2006 to 2014 and entitled "The Domitilla Catacomb in Rome: Archaeology, Architecture, and Art History of a Late Roman Cemetery", also known as START [Zimmermann and Eßer 2007] (Fig. 1). The Catacombs of Domitilla consist of some of Rome's oldest and largest network of catacombs, the earliest burials of which date to the 2nd century CE and extend nearly 17 kilometers. The stated goals of the project are to generate a full model of the catacombs and provide access to a "long overdue corpus of the paintings of the Domitilla-catacomb" in order to study the Christian iconography of the paintings more closely and publish those that may have been overlooked by the scholarly community [Zimmermann 2009]. The project resulted in some twenty publications that focused on the virtual exploration of the catacombs and early Christian iconography. The Domitilla project used a Multi-Layer 3D Image algorithm developed by Abdelhafiz [2009] to texture the model developed from the point cloud. Unlike Project ROVINA, however, the use of 3D techniques directly engaged with the contents of the catacomb [Eßer and Mayer 2007] and many publications regarding Christian iconography resulted from the project [e.g., Zimmerman 2012; 2013] including the publication of hitherto unknown frescoes [Zimmermann and Tsamakda 2009, Zimmerman 2010].

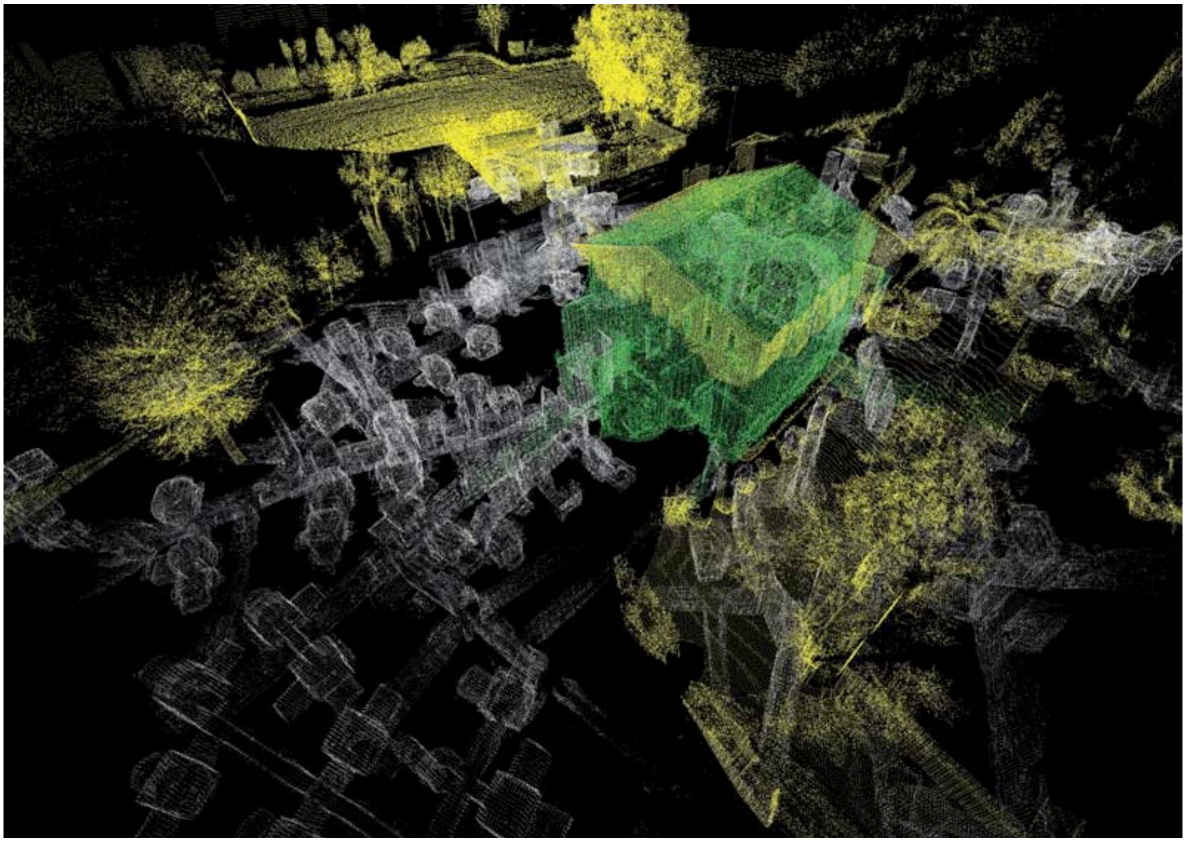


Figure 1. Point-cloud Basilica of Domitilla and the underlying catacomb [Zimmermann 2010].

2.2 Project ROVINA

Project ROVINA – Robots for Exploration, Digital Preservation and Visualization of Archaeological Sites – was a major undertaking that created a consortium of research partners including the ICOMOS IT (the International Council of Monuments and Sites, Italy), the University of Freiburg, the University of Leuven, The University of Rome "Sapienza" and the Rheinisch-Westfälische Technische Hochschule Aachen University, as well as Algorithmica srl [Di Stefano et al. 2016] (Fig. 2). The project used the Catacombs of Priscilla in Rome and the Catacombs of San Gennaro in Naples as case studies. The project's stated goals were to "provide novel technology that supports the preservation of cultural heritage by allowing the acquisition of textured digital 3D models in hard-to-access environments," "to extend the technology of autonomous navigation for robots to explore unknown underground environments such as caves and catacombs," "to develop novel techniques to construct large 3D textured models of these poorly structured environments," and "to offer a cost effective support for performing continuous monitoring of these sites and to enable comparative analysis that will allow to devise better preservation plans" [Stachniss 2015]. The project resulted in nearly three dozen publications on various aspects of digitization, digital recording, robotics, and robot exploration. Unfortunately, though understandably, the case studies of the project themselves are not particularly featured the publications. Most of the point clouds that were collected and the resulting visualizations were only given in figure form [e.g., Serafin at al. 2016]. The major highlights of the project were disseminated in YouTube videos but focused on the performance of the robot more than the collection of data itself. The project was not actually interested in the dissemination of the results of the recording of the catacombs, and despite the advances in robotic solutions to digital recording [Calisi et al. 2017; Ziparo et al. 2013; 2014], exploration [Oßwald et al. 2016; Bogoslavskyi et al. 2016], and conservation to hypogeal contexts [Serrafin et al. 2016], there is no explicit interest in communicating best practices in data collection or its dissemination.

Figure 2. Example of a 3D model in a room of the catacomb of Priscilla produced with Structure from Motion techniques [Ziparo et al. 2015].

2.3 The 3D survey of the catacombs of St. John at Siracusa

Smaller projects have been undertaken in other catacomb complexes in the central Mediterranean. Most pertinent to our case study is the digital recording campaign of the Catacombs of St. John undertaken in Siracusa itself by a team of archaeologists from the University of Catania [Bonacini et al. 2012, 2013] (Fig. 3). A small portion of the catacombs, including the three major rotundas in the central district, were recorded using terrestrial laser scanning in an effort to determine a proper workflow suitable for the catacombs that addresses the issues of a complex built stratigraphy, the difficult, varied terrain, the lack of light, and to address possible uses of the digital models in cultural heritage management [Bonacini et al. 2013]. Although the 3D digitization campaign focused on a small area, the point cloud and 3D models of the three rotundas were used to create a much more accurate plan and section view of the catacombs compared to those done with traditional methods [Santagati 2014].

Figure 3. The 3D model of the cubicles of Eusebius and Paul at the Catacombs of St. John in false RGB visualization [Bonacini et al. 2012].

While the catacombs of St. John engage with similar problems as those in the Catacombs of St. Lucy, the issues of poor lighting and accessibility are however even more prevalent in the Catacombs of St. Lucy.

3 THE CATACOMBS OF ST. LUCY AT SIRACUSA

The Catacombs of St. Lucy represent one of the oldest and most important monuments related to the Christian communities of Siracusa and Sicily in the Late Roman period (Fig. 4). The name of the complex derives from the tradition that Saint Lucy, martyred during the reign of Diocletian in the early 4^{th} century CE, was buried there. Beneath the modern homonymous square, a large underground cemetery slowly developed throughout the 3^{rd}, 4^{th} and 5^{th} centuries CE, incorporating previous structures and hypogea used for funerary, cultural and industrial purposes that were then transformed into monumental burial chambers. The presence of the tomb of St. Lucy guaranteed a certain popularity to the complex even after the end of its use as a cemetery in the 6^{th} century CE In fact, in at least two regions of the catacombs (A and C) oratories were created, probably relating to the activity of nearby monastic groups. These oratories sometimes drastically modified the architecture of those environments in order to create spaces more appropriate to cult practices. Frescoes and devotional graffiti testify to a consistent exploitation of those oratories until the second half of the 13^{th} century CE

The division of the cemetery into four regions (A, B, C, D) proposed at the beginning of the 20th century by J. Führer does not correspond to the original plan of the catacombs but to the layout that resulted from the construction of the Mausoleum of St. Lucy, built by Giovanni Vermexio in 1630. This destroyed a significant part of the cemetery in order to isolate and incorporate the revered tomb of the martyr into the monument. The first archaeological explorations were carried out in 1916-1919 by

Paolo Orsi, who focused in particular on the topography of Region A, where the so-called Byzantine Oratory of the Forty Martyrs of Sebaste was discovered. The plan of the catacombs was further modified in the course of the 40's, when they were used as bomb shelters by local people endangered by Allied air raids during the Second World War. On that occasion, the National Authority for Anti-Aircraft Protection ordered the excavation of wide, connecting tunnels which reached Regions B and C, still unexplored at that time.

The systematic exploration of Region C, the most remarkable of the entire cemetery, was carried out in the early 50's by S.L. Agnello. On behalf of the Pontifical Commission for Sacred Archaeology, he emptied the tunnels of Region C, revealing the backbone of the entire area represented by the double North-South axes of Galleries A and B which, with all the tombs set along the sides, is the largest district of the entire complex. In the southern part of Region C are several earlier structures related to Greek and Roman times that were buried by a catastrophic cave-in that probably occurred at the end of the Early Roman Empire: these include the so-called "Pagan Shrine", a cult place dedicated to Zeus Peloros and dated to the 2nd-1st century BCE, a *columbarium* with cinerary urns dating to the 1st-2nd century CE, and several rooms related to a large pottery workshop. Furthermore, a second Pagan Shrine with features similar to the other one but in much poorer conditions has been identified in Sector F of Region C.

The latter Pagan Shrine – together with the Pagan Shrine of Zeus Peloros, located in the South-West corner of Region C – belongs to the pre-existing structures from the Late Hellenistic and Early Roman periods, that were later incorporated in the cemetery. The religious purpose of the room was determined by the previous scholarship [Agnello 1955] on the basis of the architectural comparison with the Shrine of Zeus Peloros alone, consisting of a trapezoidal plan and pillar with remains of a front niche and because of the burial of terracotta figurines of sailors, found in two dimples, dug in the floor level, interpreted as ex-votos. Unlike the Shrine of Zeus Peloros, which remained intact in its perimeter and was exploited by the Christian cemetery simply by opening burial niches along the walls, this second room presents much more articulated phases of use, which have radically altered its original appearance. In archaeological campaigns 2011-2013 several graves in the floor level were investigated, identifying the pre-cemeterial phases of such space.

Another rather puzzling area of the Region C is represented by the so-called Crypt VI. Located along Gallery B, the Crypt VI comprises a group of cubicula set on different levels, accessible from a single monumental entrance with a sequence of three framed arches. In a later phase, a lower level connected to the rest of the complex by a staircase was excavated. Portions of frescoes related to the last phase of use are still visible on the walls. In one room, there are some massive sarcophagi carved into the bedrock, indicating the high rank of the commissioner of this complex. The excavation of the crypt in the early 1950s produced a large number of architectural pieces and plastering elements in colored marble testifying that this funerary space was designed for an elite group.

After a long break, archaeological excavations resumed in 2011-2012 by the joint effort of the University of Catania and the Pontifical Commission for Sacred Archaeology with a series of investigations in Region C, and the areas of Oratory C and the Second Pagan Shrine in particular. Between 2013 and 2015 further excavations were undertaken by Arcadia University and the Pontifical Commission for Sacred Archaeology again in Region C, under the supervision of the authors, with

Oratory C and the area of the Second Pagan Shrine and Crypt VI as areas of interest [Gradante and Tanasi 2016].

Region C of the catacombs, certainly dated to post-Constantinian times (4th century CE) and used for funerary purposes until the end of the 5th century CE, offers significant evidence for the Medieval phase of use. After the cemetery falls into disuse for burial, the catacombs undergo a series of architectural and monumental transformations that turn it into a true place of martyrial worship: in particular, the so-called "Oratory C". The walls are entirely covered with frescoes which in places overlap to form four layers on top of each other (called palimpsests), ranging in chronology from the Byzantine period (ca. the 8th century CE) to the Norman period (ca. 13th century CE). The fresco-cycle consists of panels painted with figures of saints, two of which are clearly distinguished by the presence of captions in Latin. The most significant palimpsest is on the eastern wall of Room I, traditionally known as the "Fresco of the Little Commissioner", due to the figure of an old man on the left corner of the panel with outstretched hands as if in prayer to the great saints to his right (Fig. 5). The characteristics of the oratory and in particular of the Fresco of the Little Commissioner are the writing and graphic testimonials left by pilgrims who visited the hypogeum, attracted to the venerated resting place of the body of St. Lucy nearby up until the 11th century CE.

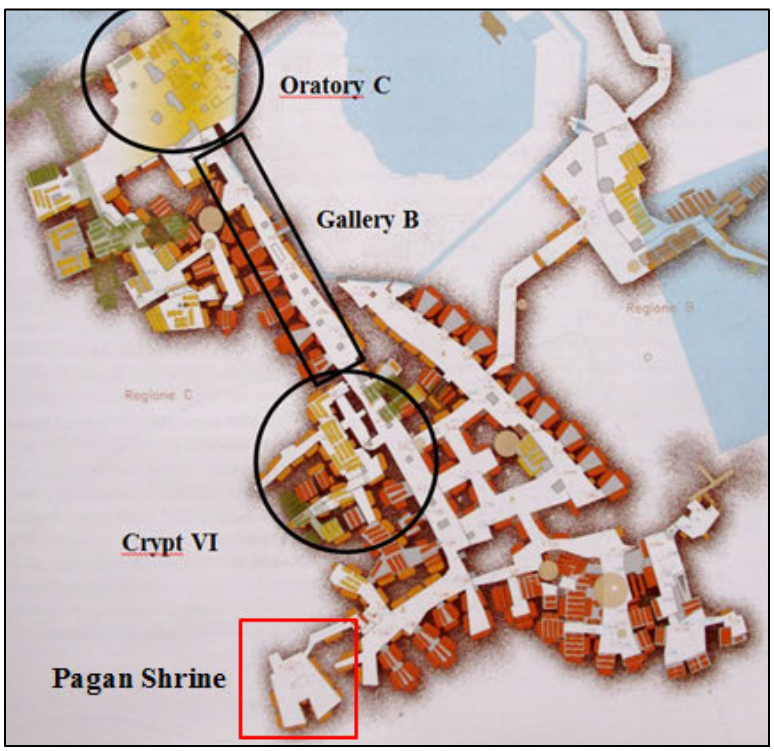


Figure 4. Plan of Region C of the Catacombs of St. Lucy, indicating the areas where 3D digital technologies for data recording were applied [Sgarlata and Salvo 2006].

3.1 The 3D Laser Scanning of the Fresco of the Little Commissioner

Considering the total lack of monitoring of the natural decay of the fresco and the extreme environmental conditions of the catacombs, it was decided to produce a virtual replica of it using 3D laser scanning. The virtual model would provide an unalterable 3D image of the artefact, and properly manipulated, would improve the readability of the graffiti.

a b

Figure 5. Fresco of the Little Commissioner: a) plan of Oratory C with indication of the location of the fresco [Sgarlata and Salvo 2006]; b) the actual artwork on the eastern wall of Room I (Oratory C, Region C)

3D laser scanning (Fig. 6) was carried out with a NextEngine triangulation 3D scanner in macro setting. Due to the high level of detail of the artefacts with different strata of paint and multiple layers of graffiti, it was decided to rely on macro scans, acquiring sections of the surface of 5.1 x 3.8 cm at a time, for a total of 75 scans organized into vertical strips. Coded targets were applied on the fresco in order to create a reference grid to facilitate the alignment of the scanned portions.

During data processing, the open-source software Meshlab was used for alignment and filling gaps, as well as for removing noise and coded targets. Meshlab is an open access cross-platform mesh processor providing tools for editing, cleaning, healing, inspecting, rendering, texturing and converting meshes, largely used since its release in the field of digital archaeology [Cignoni et al. 2008, Cignoni and Renzuglia 2016]. Meshlab turned out to be an ideal choice because students involved in the excavation and post-excavation studies can use it free of charge. The 3D model resulting from the alignment of three main portions showed circa 46 million vertices and 95 million faces and the portions of it bearing graffiti turned out to be significantly more readable than they were on the digital pictures (Fig 7).

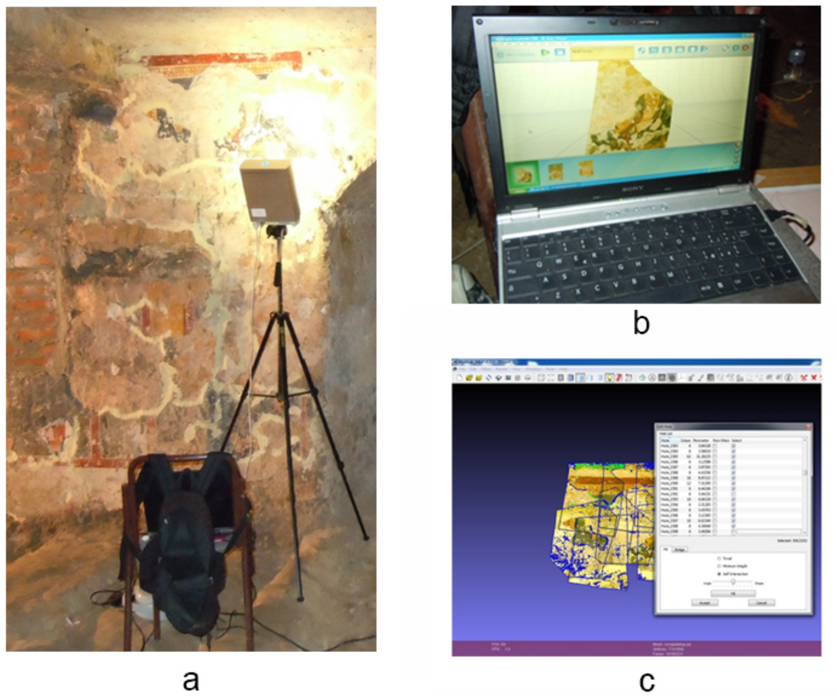


Figure 6. a) Acquisition via triangulation laser scanner of the fresco; b) initial data processing on site; c) advanced data processing via Meshlab.

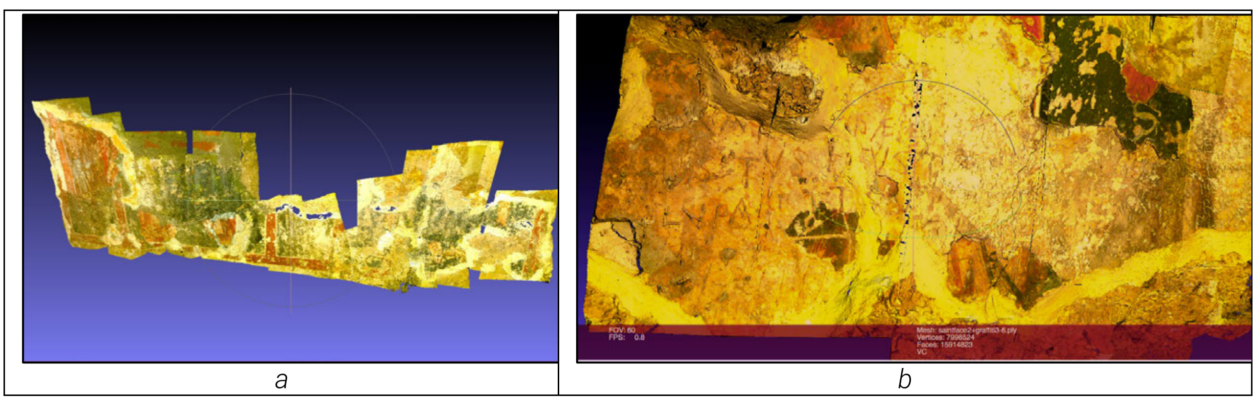


Figure 7. a) High quality 3D model of the lower part of the fresco; b) High quality 3D model of the lower part of the fresco, details of the graffiti.

3.2 The 3D Digital Documentation of the Trench in Room A

The restricted space provided by Room A represented the best environment in which to use 3D scanning to document the progress of the excavation of the *formae* opened on the floor. In particular, in the case of tombs 2043, 2044, 2045, showing a complex stratigraphy characterized by later phases of reuse, this method turned out to be particularly useful.

In order to not slow down the excavation work, the 3D scans were carried out using an infrared light structured portable scanner (Occipital Structure), in order to create highly detailed models in a short time (Fig. 8). Simultaneously the scanner was used to produce the 3D model of the four internal walls of Room A, characterized by several different types of masonry and old restorations.

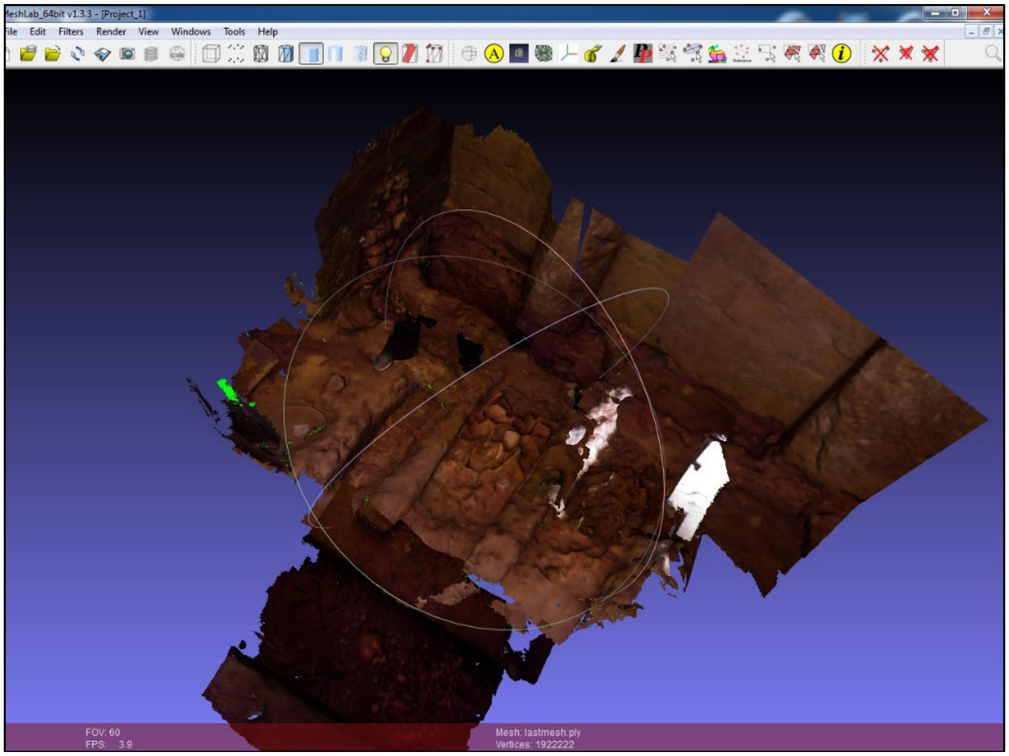


Figure 8. 3D model of Room A of Oratory C acquired after the exploration of tombs 2045, 2046 and 2047.

3.3 The 3D Digital Documentation of Tomb 2174 in Room F

The excavation of Tomb 2174, in the north-eastern corner of Room F, required particular care in data recording. The area contained many burials and important finds, especially bronze coins, but was also possibly ransacked. Therefore, it was decided to use a NextEngine triangulation 3D laser scanner on a macro setting to document the remains (Fig. 9). Five scans for each of the four stratigraphic units identified were carried out for a total of twenty scans organized in vertical strips. During data processing the open-source software Meshlab was used for the alignment and for the filling of gaps and removing noise. The four 3D models resulting from the alignment of the sets of five parts showed approximately 7 million vertices.

Figure 9. Acquisition via triangulation laser scanner of skeletal remains of tomb 2174.

3.4 The 3D Digital Documentation of the Architectural Disiecta Membra from Old Excavations

Due to a decision taken by the Pontifical Commission for Sacred Archaeology, which supervises every scientific enterprise undertaken in the catacombs of St. Lucy, a number of architectural elements discovered during the excavation of the 1950s in Oratory C were left near their places of discovery rather than being moved to the storeroom. Although these objects received preliminary discussion in the scientific literature, they were never properly catalogued and documented. Twenty-two pieces (SL01-SL22), mostly related to the later phase of use of the oratory, including portions of parapets, columns, capitals, inscriptions and stone vessels, were collected and studied and their find-spots recorded (Fig. 10).

The tight working schedule led us to carry out the 3D documentation of the pieces via Image Based 3D Modelling [Olson and Placchetti 2015] in order to speed up the digitization process. The artefacts were set on a wooden turntable and photographed with a Nikon D3300 with 24.2 megapixels, producing a dataset of 40-70 pictures for each object (Fig. 13). The software used to process the images was Agisoft Photoscan, a stand-alone software product that performs photogrammetric processing of digital images and generates 3D spatial data to be used in GIS applications, cultural heritage documentation, and visual effects production as well as for indirect measurements of objects of various scales [Olson 2016]. Comparative studies between various digital photogrammetry software have largely proved the accuracy and reliability of Photoscan over the others, and for this reason it has been employed as main tool for the project [Green et al. 2014; Jaud et al. 2016].

a b

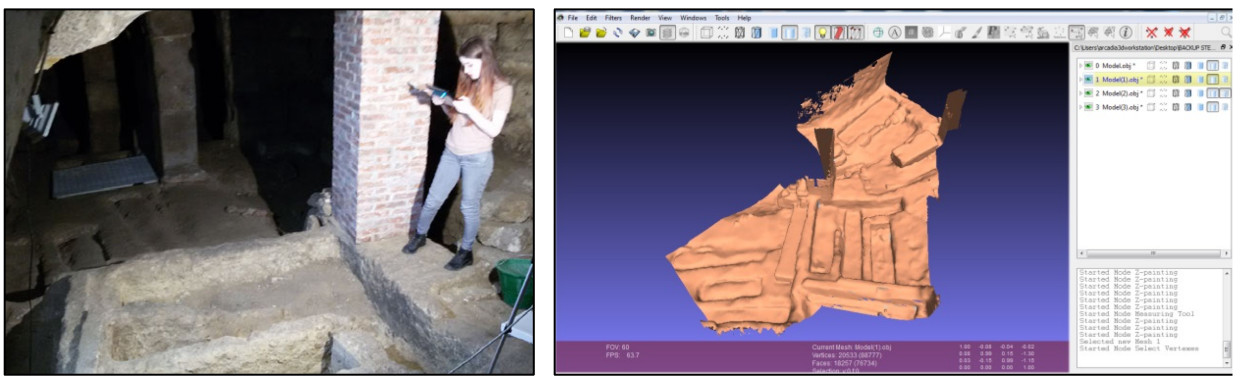
Figure 10. a) Architectural elements from old excavations at Oratory C; b) Students acquiring the data set of pictures on field.

Figure 11. 3D models of architectural elements SL01-SL12 from old excavations at Oratory C, Region C.

The semi-automatic reconstruction process took intermittently three weeks due to the high number of visual sources (slightly less than 1,500 high quality pictures). The final results represented by high-quality 3D models of the *disiecta membra* that surpass every other alternative documentation method (Fig. 11).

3.5 The 3D digital documentation of the trench of tombs 2006-2009 in Room L

The complex stratigraphic deposit represented by the four tombs 2006-2009, set in the south-eastern side of Room L, was a perfect case-study for the application of 3D digital imaging to record excavation data. The four tombs underwent a particular series of architectural transformations during several phases of reuse. It was also important to document as best as possible the relationship between the three tombs and the others nearby. The data was acquired using an infrared light structured portable scanner (Occipital Structure) to create an un-textured high-quality 3D model to represent stratigraphic relations in detail (Fig. 12).



a *b*

Figure 12. a) Room E, Oratory C: data set acquisition via a portable infrared light structured 3D scanner (Occipital Structure) of the area of tombs 2006-2009; b) Room E, Oratory C: 3D models of the tombs 2006-2009 and of the nearby clusters of burials.

3.6 Crypt VI

The hardest but also the most rewarding task regarding the application of 3D digital imaging of the entire excavation campaign was the 3D scanning of the entirety of Crypt VI, a complex about which the available graphic documentation is outdated and incomplete (Fig. 13). The operation was meticulously prepared, taking into consideration the complex plan of the crypt, with three main corridors (B1, B2, B3) and two lower levels (east and west) partly flooded with water coming from an underground spring. The data acquisition project included 16 points of scanning to cover every part of the crypt and a number of markers in strategic spots to be used to link the digital portions.

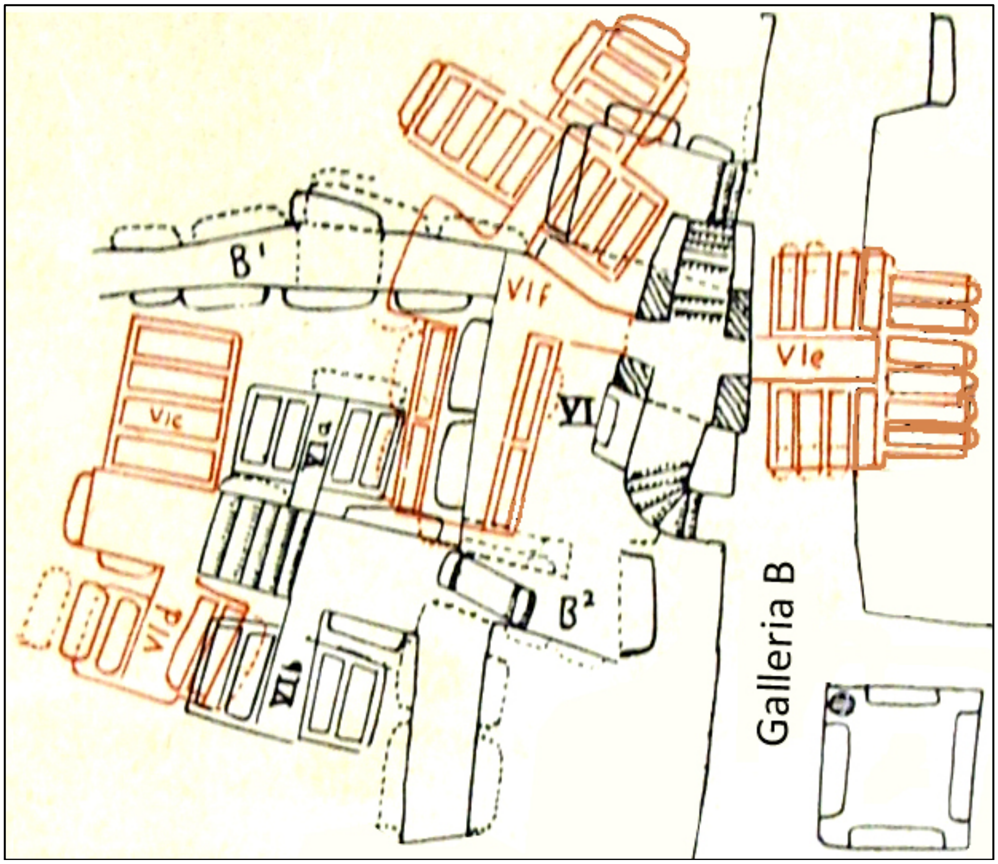


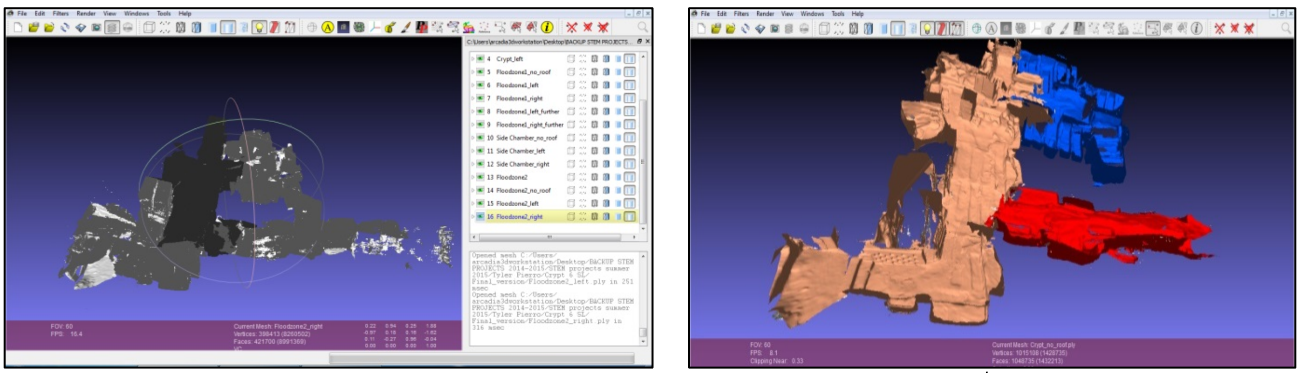
Figure 13. Plan of the Crypt VI.

Considering the unstable power system, the presence of water, the poor lighting conditions and the very real chance for the digital equipment to be damaged, it was decided to use a low-cost infrared light structured portable 3D scanner (Microsoft Kinect). Well aware of the limits that the Kinect has as a 3D scanner, especially considering the structural complexity of Crypt VI, it was decided nonetheless to attempt to scan it. The experimental and educational aspects of the task were considered more important in this case than the accuracy of the outcome.

The four weeks excavation was interspersed with periods of scanning, and 127 coded targets were applied on the wall of Crypt VI in order to facilitate the subsequent alignment of all the pieces.

The huge mass of data acquired in the field took a long time to process but ultimately a point cloud 3D model, counting 9 milion faces, was obtained from the combination of the 16 scans (Fig. 14a).

As the 3D model includes both floors and ceilings, it needs to be further elaborated in order to get section views and plans and this part of the processing work is still ongoing. In addition, the complexity of the 3D model is such that any further elaboration has to be carried out on the un-textured model (Fig. 14b). The scans included Corridor B1, never before documented, and the western flooded area, in which it was possible to capture the floor surface for the first time thanks to a particularly low level of water at the time of the 3D scanning (Fig. 15). Unfortunately, it was not possible to acquire the two chambers of the eastern flooded area, containing the sarcophagi and accessible through a staircase from a monumental landing, as the level of the water was consistently at 0.50-0.60 cm of height and covering them. However, the structure and complex plan of the landing itself was documented in detail and it is currently under processing. With all its limits, coming from the use of the Microsoft Kinect as scanner, the outcome represents the best documentation of Crypt VI available so far and its 3D model can be certainly used to plan the overall 3D scanning of the complex with a time-of-flight 3D scanner which has already been scheduled.



a *b*

Figure 14. a) General point cloud 3D model of the entire complex of Crypt VI (upper and lower levels) obtained by the combination of 16 scans (8.991.369 faces); b) Untextured section view of the 3D model of Crypt VI (in pink corridor B2, in blue corridor B3 and related lower level, in red corridor B1).

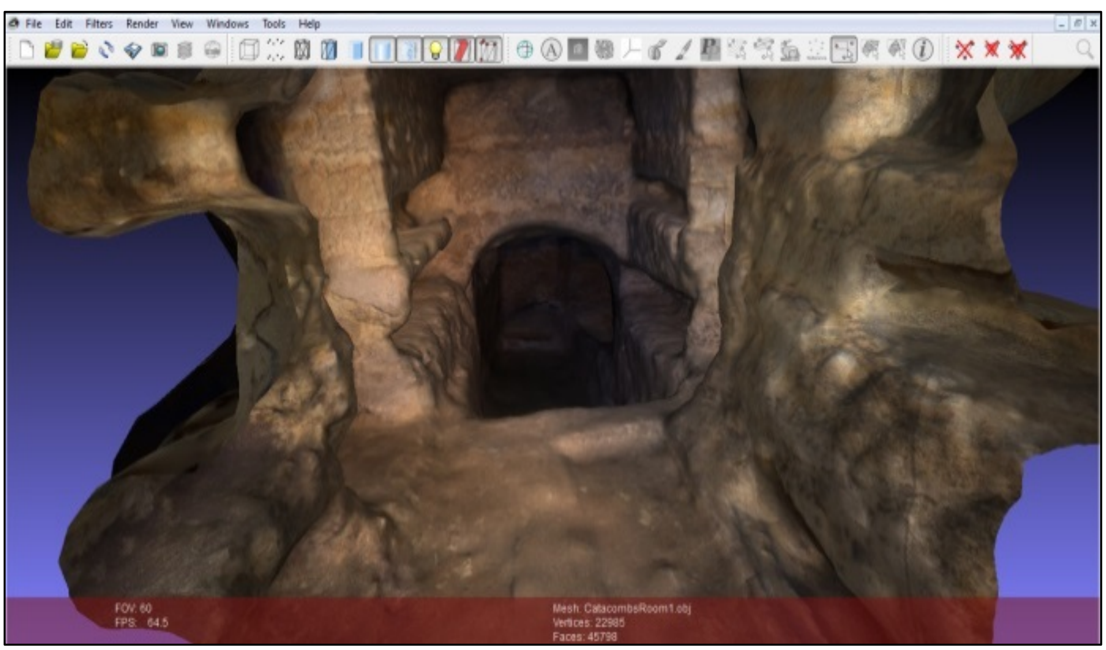


Figure 15. Textured 3D model of the corridor B3 and the staircase to the west lower level.

4 THE CASE STUDY OF THE PAGAN SHRINE

The so-called Pagan Shrine is a trapezoidal room located in the southwest corner of Region C, the largest and most articulated sector of the Catacomb of St. Lucy [Sgarlata and Salvo 2006; Sgarlata 2007]. The chamber displays a NW/SE orientation and still has its original access on the north side, although now it is connected to the rest of the catacomb through a narrow corridor opened at the northeastern corner of the room.

The Pagan Shrine belongs to a complex of pre-existing buildings located along the western limit of the catacomb. These structures were probably orientated and accessible from the front of an ancient stone-quarry [Ricciardi 2015], where over time several rooms with different purposes (funerary, religious and industrial) were excavated or simply enlarged. The structures date between the 3rd century BCE and 1st century CE, and were later included in the catacomb and converted into burial places between the 4th and 5th centuries CE Among these contexts a pottery workshop stands out; the activity of which is closely connected to the history of the Shrine [Lagona 1972-1973].

The Pagan Shrine was discovered in the 1950s during the archaeological campaign of the Region C [Agnello 1954, 53-60; 1963]. The archaeologists reached the room via the north-eastern corridor, which was filled with debris from a landslide that impacted the entire western end of the catacomb [Agnello 1996]. The room was partially occupied by material coming from the original entrance: several strata of ceramic fragments from the hill above the entrance were gradually deposited in the vestibule of the Pagan Shrine, thereby causing its abandonment.

Establishing the chronology and origin of the deposit is crucial to understanding the chronological and functional relationship between the Pagan Shrine and the surrounding structures. Recent studies (Malfitana, Cacciaguerra 2014, 2015) tend to differentiate the stratigraphy of the deposit in two main phases; these two phases are related to the frequentation of a sacred area (4th/3rd - 2nd century BCE), evidenced only by finished pottery (Hellenistic and Republican black and red slipware, cooking ware, amphorae, lamps and terracotta figurines), and to the production activities of the pottery workshop, testified by kiln wasters (2nd century BCE - 1st century CE). However, this first important distinction has been made on the basis of materials collected in the 1950s from the ground of the chamber, whereas a detailed analysis of the preserved stratigraphy is yet to be carried out. Especially obscure is the identification of a sacred area presumably above ground and not otherwise attested. Similarly unclear is the physical and ritual connection between the supposed Sanctuary and the Pagan Shrine [Malfitana and Cacciaguerra 2014, 2015; Germanà Bozza 2016].

The religious purpose of the Pagan Shrine was determined after the discovery of several frescoes depicting mundane themes and pagan deities [Agnello 1954, 1957, 1963; Caruso 2017]. These frescoes cover the three sides of the pillar protruding from the southern wall of the chamber. The most relevant scene is located on the eastern side of the pillar, into a large niche: on the background, a naked male figure stands on a high wall flanked by towers; his right foot rests on the prow of a ship, the right arm is raised and seems to indicate the route, while his left hand holds a long pole.

Over his head – that just like all figures in the frescoes appears damaged, almost certainly by the hands of later Christians – runs a legible caption: ΖΕΥΣ ΠΕΛΟΡΟΣ. A second male figure is seated before the wall, on the left side of the scene, and he is also marked by a caption: ΠΟΡΘΜΟΣ. The two characters are thus clearly identifiable: the first one is a god particularly venerated in Messina and remembered even today by the ancient toponym Cape Peloro – the promontory representing the nearest end of the island to the peninsula [Agnello 1963]. The second character, however, is the only case of a documented personification of the straits of Messina [Caruso 2009].

The subjects of the other scenes are not as easy to interpret, due to the state of conservation of the frescoes and the lack of captions. Nonetheless, comparisons with funerary contexts from the Late Hellenistic and Early Roman period in Western Sicily [Bonacasa 1986; Giglio 1996] – which will be analyzed elsewhere – suggest a reinterpretation of the Pagan Shrine in a funerary context [Germanà Bozza 2016]. In this perspective, the presence of Zeus Peloros – represented in a side scene and therefore subordinate within the hierarchical imagery – would derive from the devotion of the tomb owners, who were probably involved in naval activities.

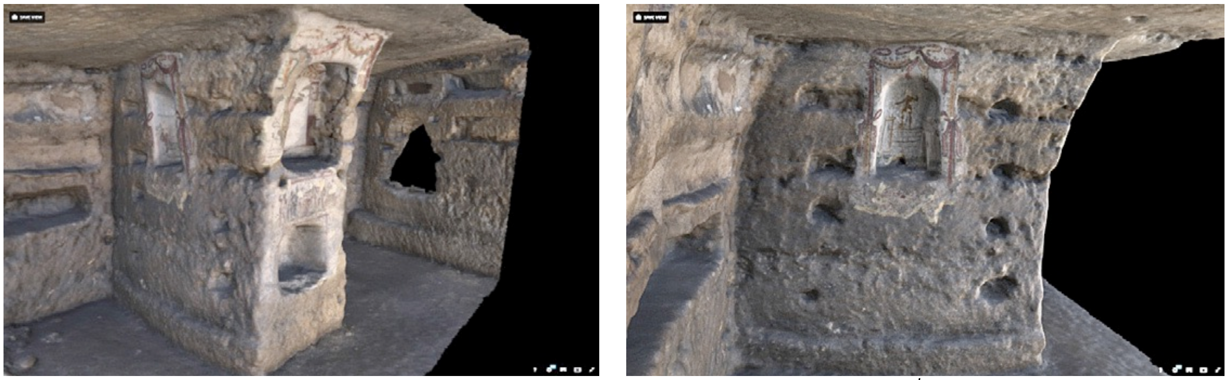
The same suggestion comes from the finding of some terracotta figurines of sailors in two small votive pits, dug in the floor level of another room of Region C. On the grounds of architectural similarities, this room has been identified as a second Shrine [Agnello 1955]. Unlike the Pagan Shrine of Zeus Peloros, examined above, which remained intact when it was exploited in the Christian cemetery phase by simply opening burial niches along the walls, this second Shrine presents many more articulated phases of use that have radically altered its original appearance [Gradante and Tanasi 2016].

The religious purpose of the second Shrine was determined by previous scholarship [Agnello 1955] based solely on architectural comparison with the Pagan Shrine of Zeus Peloros, i.e. the trapezoidal plan of what remains of the pillar and its front niche, and because of the aforementioned sailor figurines, interpreted as ex-votos.

If, as discussed above, it is possible to establish the religious function of the so-called pagan Shrine of Zeus Peloros, such a purpose is harder to recognize in the case of the second Shrine, due to the absence of any iconographic references to pagan cults. Even the presence of the sailors is not indicative, given the numerous occurrences of these characters in funerary contexts [Basile 1991, 1993; Gianfrotta 2014].

Many aspects of the analysis of this monument are yet to be explored and the Pagan Shrine still has a central place in the academic debate. A considerable advancement of the research will certainly come from the possibility that we now have to study a detailed three-dimensional model of it. This means being able to consider the minimum structural details of a context that is currently inaccessible due to its poor state of preservation and low-light conditions

In order to better understand the complex nature of such a puzzling monument, in the summer 2015 a 3D model of the Pagan Shrine of Zeus Peloros was created using Digital Photogrammetry (Fig. 16) within the framework of the rest of the 3D scanning activity of the Region C of the Catacombs [Gradante et al. 2016]. Coded targets were set on the walls in order to create a reference system for the alignment phase. A data-set of 310 pictures was produced using a Nikon D3300 with 24.2 megapixels, covering every spot of the surfaces of the chamber. Subsequently, the data were processed using Agisoft Photoscan Professional.



a b

Figure 16. a) 3D model of the Pagan Shrine, detail of the pillar; b) 3D model of the Pagan Shrine, detail of eastern niche.

For the dissemination of the 3D model, we have relied on the Digital Collections of the University of South Florida Library (http://digital.lib.usf.edu/), a platform for archiving of digital data (audio, media and 3D models) connected with a database where the related metadata are stored (Fig. 17). A DOI has been assigned to the 3D model of the Pagan Shrine (http://dx.doi.org/10.5038/21.00001),which redirects to the page of the Digital Collections, where information about the production of the model itself, a brief descriptive text of the monument and a bibliography are listed. The 3D web viewer embedded in the Digital Collections platform is based on 3DHOP an open-source software package for the creation of interactive Web presentations of high-resolution 3D models, oriented towards the Cultural Heritage field [Potenziani et al. 2015; Scopigno 2017]. 3DHOP allows the creation of interactive visualization of 3D models directly inside a standard web page, just by adding some HTML and JavaScript components in the HTML code. The 3D scene and the user interaction can be easily configured using a simple "declarative programming" approach, and by a series of provided JavaScript functions. By using a multi-resolution 3D model management, supporting an efficient streaming, 3DHOP is able to work with high-resolution 3D models (1-100 millions of triangles) with ease, also on low-bandwidth (http://vcg.isti.cnr.it/3dhop/).

Figure 17. 3D model of the Pagan Shrine on the 3DHOP-based platform of USF Digital Collections.

5 FINAL REMARKS

This contribution has presented the results of the application of an ensemble of 3D digital imaging techniques to record the excavation data of 2013-2015 explorations in the catacombs of St. Lucy at Siracusa. Although the applications of such techniques are quite customary, in this specific case study the production of 3D models of areas of the complex usually not accessible to the public has contributed to its popularization [Ferdani and Bianchi 2016].

The 3D data will certainly be helpful for the post-excavation studies, considering that the catacombs are hardly accessible outside of periods of fieldwork. But the most important result achieved is represented by the full involvement of undergraduate students in a first-hand experience in digital archaeology. Students have, in fact, learned new, innovative and affordable methods to record and process excavation data. This alternative approach to the subject of their study – the catacombs – combined with the immersive experience that the excavation itself grants has provided important learning outcomes [Healey and Jenkins 2009].

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