The Island Ventotene: From a Story of Mediterranean Isolation to the Digital Survey and Interpretation of the Baths Area in Villa Giulia

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Villa Giulia is a *villa d'otium* of the Augustan Age on the island of Ventotene. This research concerns the archaeological site of the baths area and their heating systems. The analysis aimed at investigating the site and providing some material that would allow further studies. The first step was a 3D laser scanner survey to ascertain the current situation of the ruins and to obtain a digitalization of the area. The survey resulted in a better understanding of the design and the logic of composition of the baths to determine the technologies used in the heating systems. In addition, the analysis focused on the digital reconstructive hypothesis of the *piscina calida*, a tank of the thermal path in Villa Giulia. The *piscina calida* was chosen because it is a rare example in its kind and size, as well as for the innovative technologies used in its heating system, like the so-called *samovar*. An in-depth study into the type of maritime *villa d'otium* and the functioning of the Roman baths was necessary for the reconstructive hypothesis. This was based on the digital survey and the "retro-progettazione", a solid and progressive, as well as reverse-designing method. The analysis led to a scientific representation of the possible volume of the *piscina calida*. Furthermore, this three-dimensional model contributed to show its value as a historical and archeological heritage.

Key words:
Digital survey, 3D reconstruction, 3D laser scanner, Ventotene, Villa Giulia.

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VILLA GIULIA IN VENTOTENE: AN EXAMPLE OF MARITIME VILLA

Ventotene is a volcanic and beautiful island in the Mediterranean Sea. It is located in front of the coast between Rome and Naples. Tuff characterizes the whole territory and it is an essential element for the development of the island. Villa Giulia was built when Ventotene reached its height in the Augustan Age. The Emperor August brought peace and regained its control over the Mediterranean Sea [Eck 2000], and many luxurious villas began to appear along the coast from Rome to Naples [Marzano 2010]. This stretch of coast was considered particularly strategic in the Roman Age due to its proximity to Rome and the amenities of the Roman baths, a perfect combination of *otium* and *negotium* [Purcell 2001].

Villae d'otium are luxurious houses in which Romans used to go for leisure [Romizzi 2001]. A common feature of the different types of maritime villas is a deep symbiosis with nature obtained through panoramic terraces and pavilions on multiple levels.

Imperial maritime villas are characterized by a series of pavilions and other architectural elements located in different points to highlight the island's unique views [Lafon 2001]. The residential part of the villas was destined for leisure and was designed according to aesthetic rather than functional criteria.

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Fig. 1. Position of Villa Giulia in Punta Eolo, the extreme point of Ventotene

On the contrary, the productive activities were carried out in the *domus*. The maritime quarter was a lively place thank to its fishery [Mielsch 1999]. Maritime villas mirrored the Emperor's lifestyle, a combination of *amenitas* (leisure) and *fructus* (yield) which suggests the importance of business, arts and culture as source of richness, power and prestige in the Roman period [Marzano 2010]. The baths were the symbol of this idea of both business and leisure including four main sectors: *apoditerium*, *frigidarium*, *tepidarium* and *calidarium* and were based on the classical architectural dictates of exposition and orientation in order to enlighten the rooms and the main paths. The baths were in a separate area of the villa and were often in close contact with the sea [Swoboda 1919]. In addition, they had a social role for business meetings and cultural debates [Bellini delle Stelle et al. 1998].

VILLA GIULIA

The Emperor August ordered the construction of a *villa d'otium* which was called Villa Giulia. The villa had also a political function: it served as a place for the exiles of the Julio-Claudian dynasty. August's daughter, Giulia, was the first person to be exiled on the island and the villa was named after her [Braccesi 2014].

Villa Giulia was built in Ventotene because its climate was pleasant and the landscape was flat compared to the nearby islands, and the construction of buildings was quite easy due to the presence of tuff [De Rossi 1986] (Fig. 1).

The urban complex in Roman Ventotene included the Imperial villa, the port, the fishery and water supply tanks (Fig. 2).

Villa Giulia is located on the extreme point of the island. Its surface has been reduced due to the erosion of wind and sea and the extraction of tuff over the centuries. The maritime villa was divided into three sectors: the *domus*, the central garden and the northern area. The *domus* had a productive function, the central area linked the *domus* promontory to the villa through a scenic stairway and the northern area was the nearest to the sea sector, the living quarters and the baths.

Fig. 2. Roman Ventotene

VILLA GIULIA: THE BATHS

The northern area has two different geographic orientations: the garden area is oriented on a north-south axis, while the baths and the living quarters are on a north-eastern and south-western axis to exploit best the sun and to provide shelter for the winds. The baths pavilion included several pools and some service rooms next to each other and ended with a stairway direct to the sea (Figs. 3 and 4). The *apoditerium* (the dressing room) introduced the thermal path. On its right, there were the heated rooms: the rectangular-shaped *tepidarium* whose *suspensurae* were used as a heating system and the *calidarium* (Fig. 6). The Ventotene baths housed a grand *piscina calida*, a circular-section pool with innovative heating system, the *samovar* (Fig. 5). The *piscina calida* had a capacity of 150,000 liters and weighed 200kg/m^2. It was a facility which offered high performance and a large space, a true prototype for the future imperial baths, but especially the greatest and largest example of a *piscina calida* in all of the ancient architecture. Built in more recent times, the c*alidarium* had a rectangular shape with an exedra on its smallest side and it was provided with a proper technical room and a hypogeum oven. The *calidarium* was not aligned with the previous basin, thus suggesting that it was built later as a hot pool. The thermal path ended with the *frigidarium* which was on the left side of the dressing room. The descent to the basin opened to magnificent stairs and its floor included a decorative dolphin which is still visible today. The thermal area is the best preserved section of the villa but it is destined to be destroyed by wind and coastal erosion [Sabbioni et al. 2008]

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Fig. 3. Villa Giulia's baths area

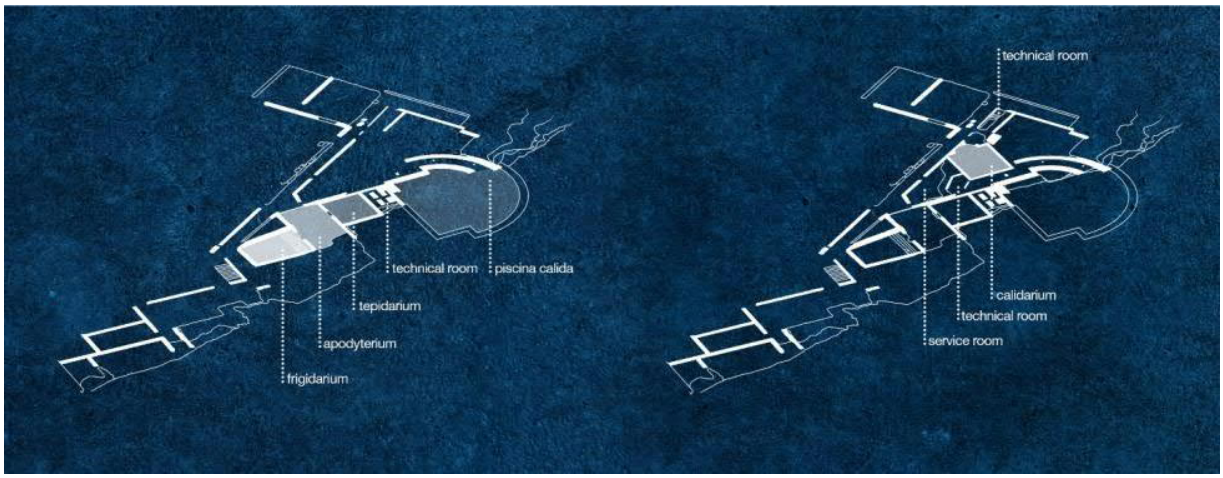
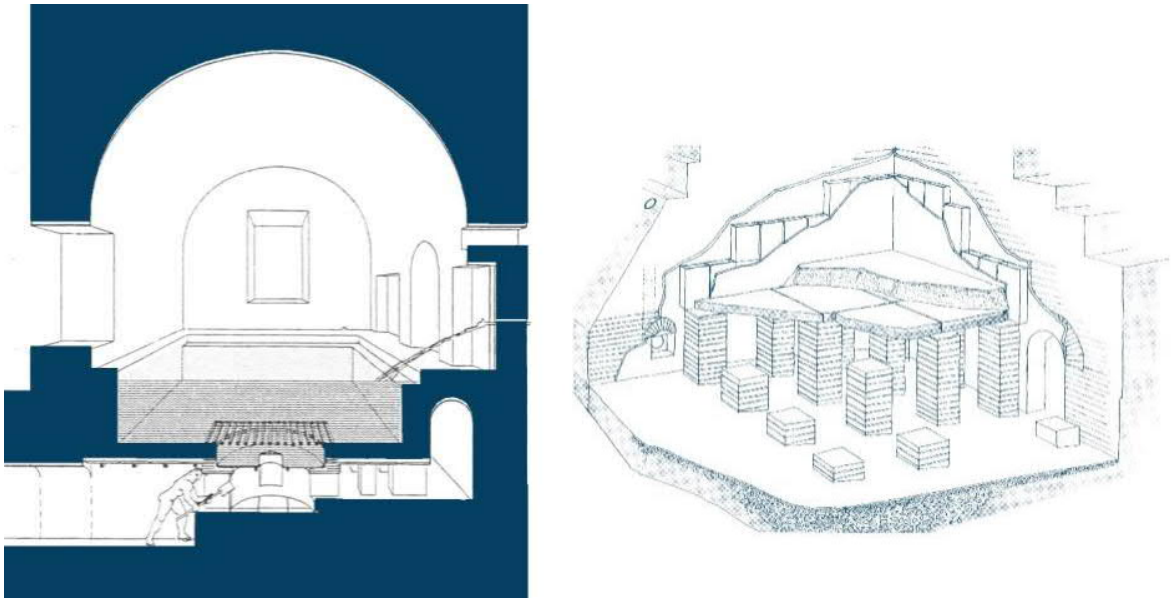


Fig. 4. Rooms of the baths area



FigS. 5-6. Samovar heating systems (piscina calida) (left) and suspensura heating system (tepidarium and calidarium) (right)

NECESSARY DIGITAL SURVEY

The latest surveys of the remains of Villa Giulia in Ventotene date back to the archaeological excavation campaign carried out in the 80s. The aim of the survey is to describe the current state of the archaeological area, to create a digital record of the Roman remains and to provide information, as well as to create a project of conservation and promotion of the site. The survey took place in two days in July 2017. The day before the survey all the technical operations were planned on site. First, the targets were positioned at the end of the *domus rustica* stairway in order to have a reference zero point for the recording. The few targets were positioned on points which were visible from more than one station, so that at least three non-aligned points with neighboring stations could be seen from each one [Bini and Bertocci 2012; Docci and Maestri 1994]. Then the equipment was put along the west coast of Punta Eolo, where the thermal area was, and followed the difference in height up to the other areas. On the first day the survey finished at sunset with many difficulties due to strong wind and on the second the station number was increased compared to the first plan to have a complete coverage of the area (Fig. 7). The survey with laser scanner was aimed at giving a precise representation of the Roman remains thanks to the digital tridimensional and more detailed model. A contactless survey of the remains of *villa d'otium* was required due to the size and characteristics of the complex and it was carried out by using devices able to detect distances and angles through remote analysis. This resulted in the collection of a great deal of data in a short time.

A 3D laser scanner called Faro X 330 (Fig. 8) was used as necessary equipment to briefly detect a very large area also characterized by various differences in soil levels. The result was a detailed description of the archaeological remains and a measurement of elements which were otherwise not easily accessible. However, strong wind in Punta Eolo hindered the contactless survey due to the oscillation of the device which couldn't be lifted much. The movement could have resulted in a graphic disturbance with blurred images which could not be recorded.

The survey required a large amount of high and medium intensity scans. These were carefully selected to avoid the development of areas lacking in data due to the presence of (temporary or permanent) obstacles located between the scanner and the object to be detected. In total, 133 scans were performed, resulting in a point cloud of the whole digital 3D model of 445.120.000 points.

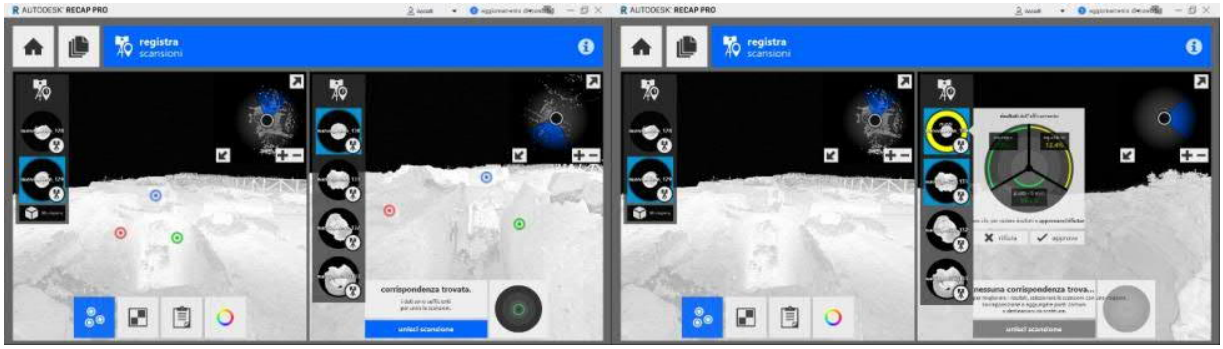
In an architectural survey, the laser scanner plays an essential role as non-invasive and non-destructive diagnostic survey method and it is perfect for sensitive sites such as the remains in Villa Giulia. It was therefore possible to obtain global digital data on which all the stages of subsequent reprocessing and representation could be carried out [Guidi et al. 2010; Guidi 2014].

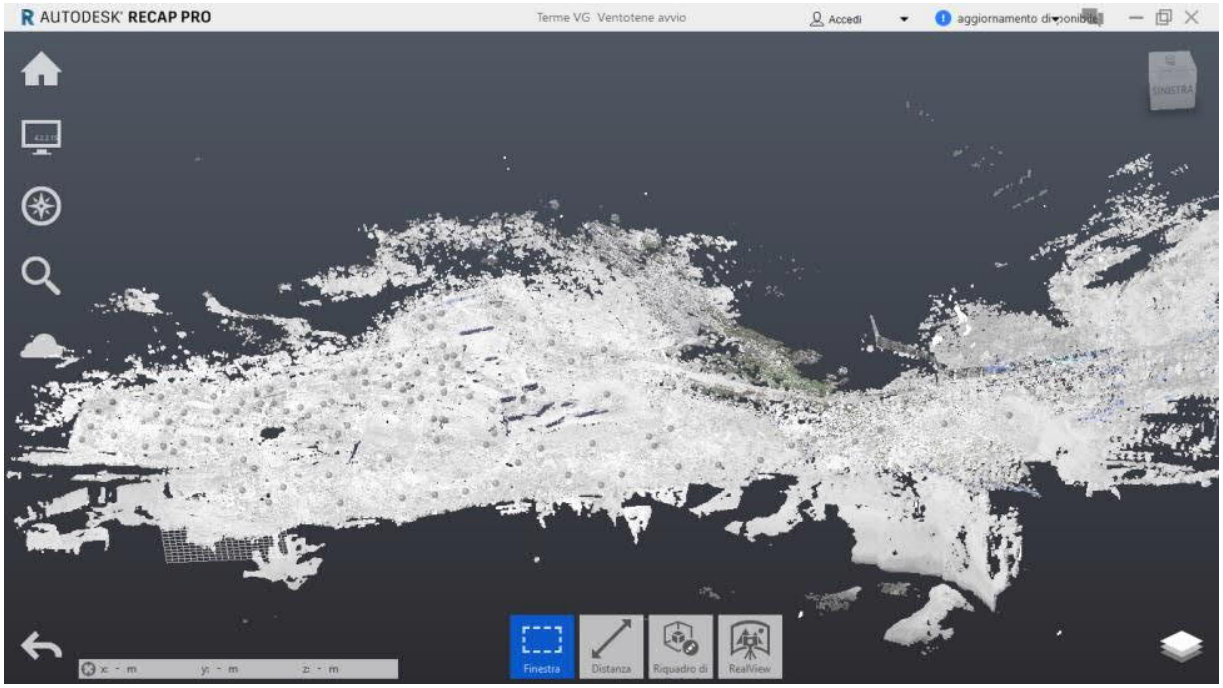
Fig. 7. Laser scanner stations

Fig. 8. 3D laser scanner Faro X 330

THE GRAPHIC REPRESENTATION OF THE SURVEY. CREATING A POINTCLOUD WITH THE RECAP SOFTWARE

The survey was followed by the processing of data on site and the graphic representation. The identification of the most appropriate solution to achieve an adequate result for such a survey was significant [Remondino 2014; Apollonio 2016]. This meant sometimes abandoning the canonical procedures and experimenting with new alternatives. The processing of the digital survey data was carried out with the use of the scanner recorder Autodesk ReCap Ultimate 360. This operation, taking place automatically thanks to systems which use "Iterative Closest Point" (ICP) algorithms, consists in aligning a pair of point clouds based on three known points – identified manually or geometrically – which must be common to the two scans to be recorded and not aligned. The recording is concluded if all the three parameters set by the program (balance, overlap and points > 6 mm) reach an adequate percentage of collimation (Fig. 9). The scans were then aligned to obtain the final cloud: a navigable 3D model which preserves the real scale for each recorded element and enables a subsequent reprocessing through specific software (Fig. 10).





Figs. 9-10. Scanner recorder operations (top) and final 3D cloud (bottom)

FINAL RECORDS. CREATION OF DRAWINGS AND SECTIONS WITH BENTLEY POINTOOLS 8VI SOFTWARE

The final cloud gives a much more real representation of an object than the traditional 2D drawing. However, it is necessary to convert the cloud into plans, elevations and sections. The phases of subsequent work were performed by using both software which reprocesses the general point cloud and the Bentley Pointools 8vi which imports the scans, edits and segments the clouds, as well as making orthophotos. First, the Autodesk Recap file was converted into a compatible file with Bentley Pointools 8vi. The advantage to use this software is to have plans and sections geometrically defined by a system of Cartesian axes (x,y,z) and by an axis rotation around the z. This technology enables a highly accurate geometrical representation of the data. The creation of drawings and sections took place through a Clip Box (Fig. 11), a 3D box which can be rotated and resized in order to isolate the required model parts and hide everything outside it. In this way, the model is reduced in orbit and the program will later calculate fewer points, thus accelerating the procedure. This is the reason why this procedure was chosen. By using the Plane Shader function, it is also possible to establish a repetition range for the chromatic scale, as well as its repetition direction along an axis of the model reference system (Fig. 12). This last option was essential because in the different set views the depth, the distances, and the stratifications of the remains could be immediately detected. The Pointools raster snapshots were imported into Autocad for the 2D drawing to facilitate the measurement and dimensioning of the detected elements and have plans, elevations and sections.

The Digital Canon 1300D reflex camera was used to support the laser scanner survey and to produce high definition photos. These photos were useful to better see the materials and details of the remains for the Autocad 2D drawings. The photos were taken when it was cloudy to avoid the shadows on the objects.

The representation concerns the drawing of the area and 13 sections: two along the axis of the residential part of the villa and 11 in the thermal area. The post-production in AdobePhotoshop CS6 of the images was useful to clear the data from any "noise" generated during the scanning.

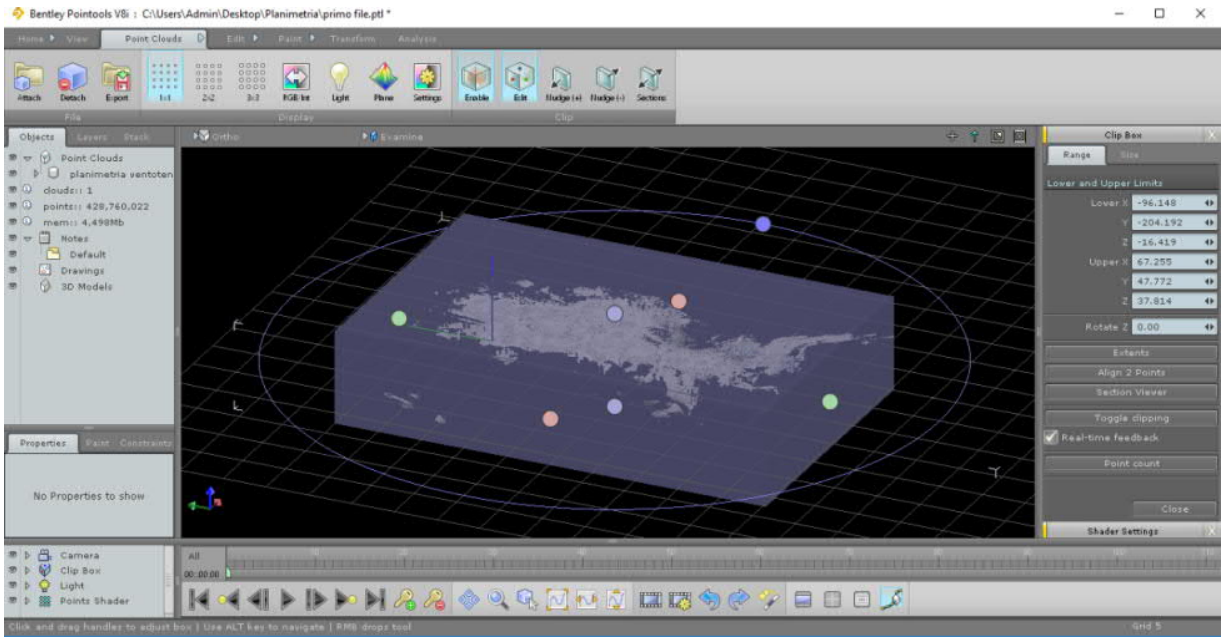


Fig. 11. Clip box

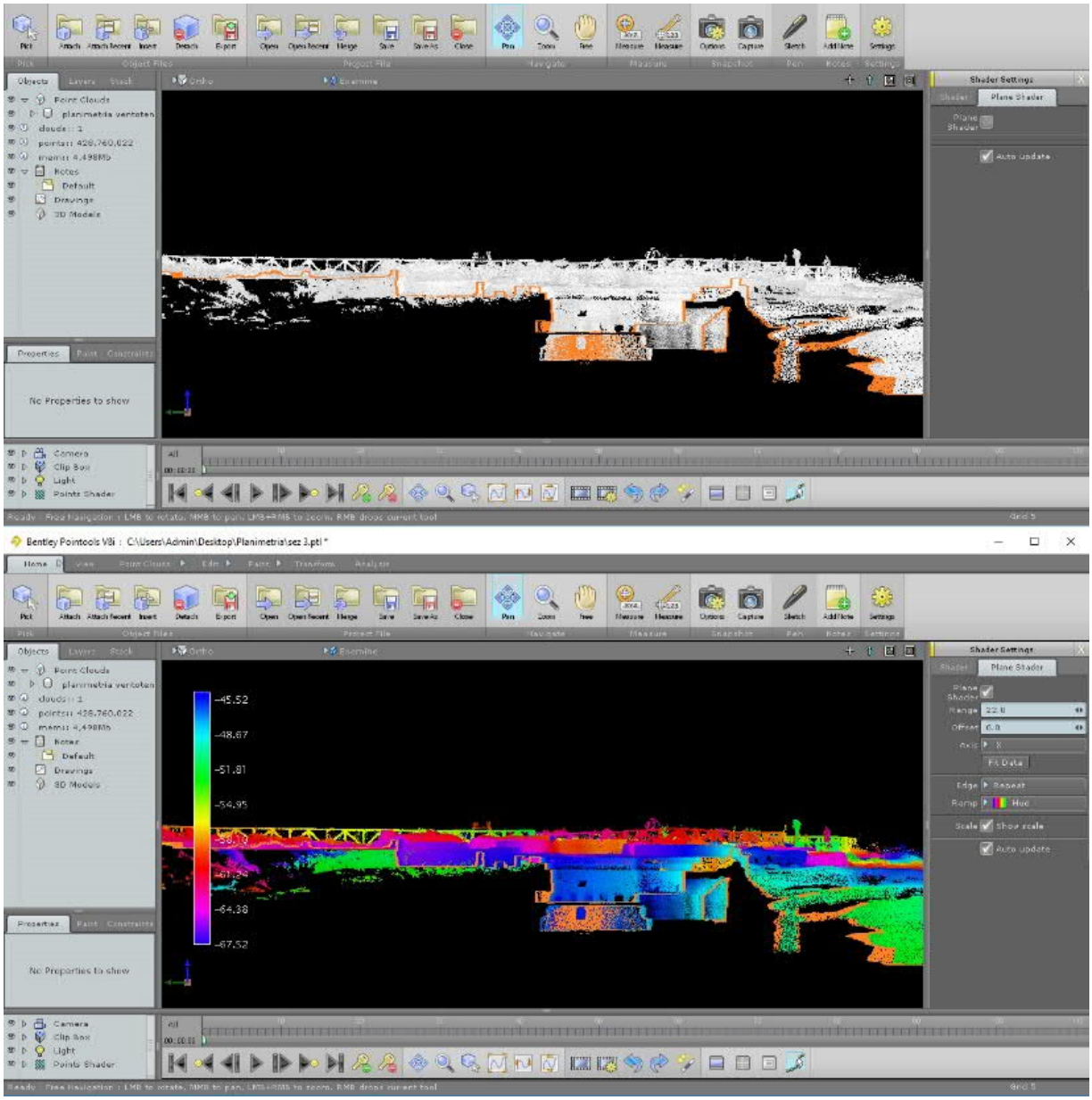


Fig. 12. Plane Shader function

THE RECONSTRUCTIVE THEORIES

The survey describes the current state of the remains of the Roman villa in Ventotene and provides an essential starting point to build a reconstructive plan and the subsequent virtual reproduction of the baths of the *piscina calida* in the thermal area. The reconstruction aimed at representing the volume of the baths as it was in the Roman era and at providing a new interpretation of the place so that the scientific data resulting from the survey is consistent with the reconstruction plan [Blanco et al. 2009].

The *piscina calida* was subject to research for its splendour and impressive volume which exploited the natural difference in level of the tuff rock and for the interesting elements that it still preserves, like part of the heating system. This basin was a rare example for the ancient baths and its use in a private place was a symbol of social prestige.

The approach to the reconstructive analysis was that of researching and understanding the original projects and studying the building techniques of the time, as well as the cultural and technical aspects related to the type of Imperial *villa d'otium*. In order to avoid misinterpretations and to validate the reconstruction plan, it was necessary to be familiar with the relative architectural period and historical time [Blanco and Pucci 2010].

Many variables came into play when interpreting this data. It was necessary to collect all the information available related to the reasons why the villa was built:

Project intentions – Roman structure – Roman construction – Historical information – Roman buildings measuring units – Roman cultural aspect – Geometric schemes – Archeological consultancy – Possible change in time – Comparison with baths area.

The following aspects are those taken into account – and set by the London Charter [2009] and the Sevilla Principles [2011] – when approaching a digital reconstruction: quoting the sources and mentioning the technological devices used, referring to the followed logical process, as well as providing with adequate photographic records and with stylistic observations and typological comparisons.

The reliability of the reconstruction plan varies from case to case. It is more reliable in relation to the plan but less reliable for the facades, given the total lack of vertical walls, and very hypothetical regarding the roofing.

THE RECONSTRUCTION OF THE *PISCINA CALIDA*

Today, only a part of the *piscina calida* is still firmly fastened to the difference in height that occurred after the collapse of a large part of the massive structure. With a visible trace in the ground, at the beginning of the difference in height, it is possible to understand the size of the structure. The *piscina calida* was entirely built of tuff rock, inside which there were the dressing rooms and the multilevel heating system. After the collapse of a part of the structure, the *piscina calida* can be described in sections. From the marks left on the walls and on the ground as well as from the materials found there it is possible to reconstruct the depths of the baths and the heights of the hypogeum. The villa was obviously changed over time, both in its function and in its constructive and technological techniques. This was essential to achieve a suitable construction plan.

After having collected all the information it was important to choose the right software for the 3D reconstruction. Maxon Cinema 3D + VRAY was used to validate the result of the reconstruction. Reconstructing and verifying the plan of the *piscina calida* with the Autocad software was necessary to move from the 2D to 3D representation. The plan was imported into Maxon Cinema 3D + VRAY where the parts were developed gradually. Plans, elevations, and sections were obtained with horizontal and vertical layers in certain points to better understand the volume.

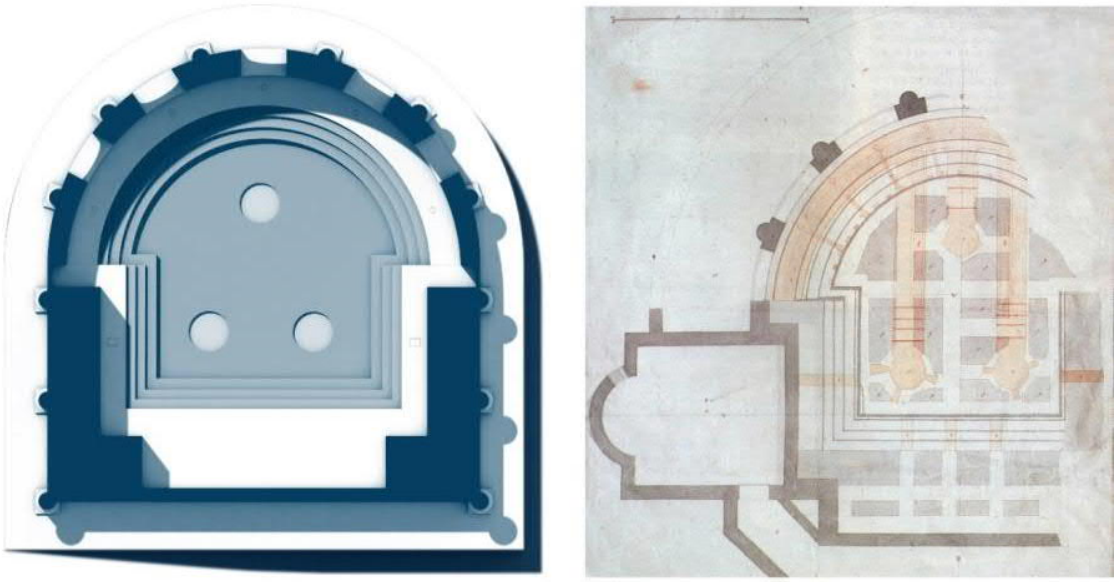
THE PLAN

The elements supporting the “retro-progettazione”, the reverse designing of the original ideas behind the building, were especially the contactless survey, the measurements carried out on site and the drawing of the 18th century *piscina calida* which is currently at the State Archives in Naples.

Thanks to these records it is either possible to verify the state of conservation of the drawing of the baths in 1700, which remains in its entirety, or deduce its proportions and measures. The 2D drawing result was used as a reference and compared with the measurements of the survey campaign, as well as with the historical drawing. As soon as the pooling axes were identified, the curve of the steps was added to the drawing to complete it.

Once the arch and the symmetry axes have been obtained, they were matched with the detected part to understand the missing one. Then it was compared to the 18th century drawing, appropriately reported in scale, and it was then clear that the measurements matched perfectly. This reconstruction is realistic, because the referred sources and the obtained measurements, both direct and contactless survey, led to the same result with minimal differences (Fig. 14).

Fig. 13. Piscina calida in Ventotene



Figs. 14-15. Reconstruction of the plan (left) and drawing of the 18th century (right)

THE HEATING SYSTEM

The survey focused on other aspects too, like the records and the various heating systems in Roman thermal baths, the technology used, as well as the similar models in other villas and thermal baths of the same historical period of Villa Giulia. Also in this case, the reference used to verify the first findings and comparisons was the eighteenth-century drawing. Matching the drawing and the return of the surveyed section, it was possible to reconstruct the height of the rooms under the pool (Fig. 16). The reconstructed heating system of the tuff rock at the lower level was composed of three brick corridors of the hypogeum with a vaulted roof, which was accessible through a small annular corridor.

The roof was understood to be vaulted, not only through comparisons with other structures and material in literature, but also on site. It is in the façade that it is possible to recognize the springer of the vaulted roof. Traces of rust shown in red in the 18th century drawing and suggesting four metal bars were also found on site and were used to match the rooms of the furnace with a flat section. The three tunnels – the central one is shorter in order to heat the entire floor of the baths – ended in circular spaces, the kilns, where the fire was lit and whose heat was then dissipated in the system.

The kilns were placed higher than the tunnel; a step separated the entrance to the combustion room on which was placed a thick wall in tuff so as to prevent the fumes from filtering into the tunnels used by the staff. The mouth was placed at the top and the ducts were small, undoubtedly to disperse as little heat as possible. Considering the remaining section of the wall, the three galleries are about one meter high.

The heat of the kilns spread through three openings into a compartment, the hypocaust, placed a little higher between the suspended floor of the baths, the *suspensura*, and a subfloor.

The hypocaust in Ventotene is a rare example of compresence of the metallic vertical elements and the brick columns, the *pilae*, which supported the suspended ceiling. The presence of the metal grid is proved by its traces behind the curvilinear wall of the baths. The iron grids were connected to the intrados of the baths floor, and fastened to the external wall. The very evident traces measure 7 cm x 7 cm on the base of the air space and had the function of fastening the metal grid to the perimeter walls [Amici 2015]. This technique was used to promote the circulation of hot air inside the hypocaust, freed by brick obstacles, thus improving the heating of the upper baths. Moreover, iron was used in Roman times in projects with significant financial resources or large thermal buildings.

Considering that Villa Giulia is an imperial villa, this material is very likely to have been used. The great financial investment used for this type of advanced technology and the associated cultural prestige created a stimulating environment for new constructive solutions.

Finally, above the three circular kilns was the *samovar*, a metal container supported by *pilae* on the sides of the combustion chambers, whose convex part was in direct contact with the pool water and embedded in the baths floor. The water was heated by induction from the contact with the samovar. Similar examples of a *samovar* system can be found in the baths of Massaciuccoli and suburban baths in Pompeii. These models were analyzed to study their characteristics and technological solutions.

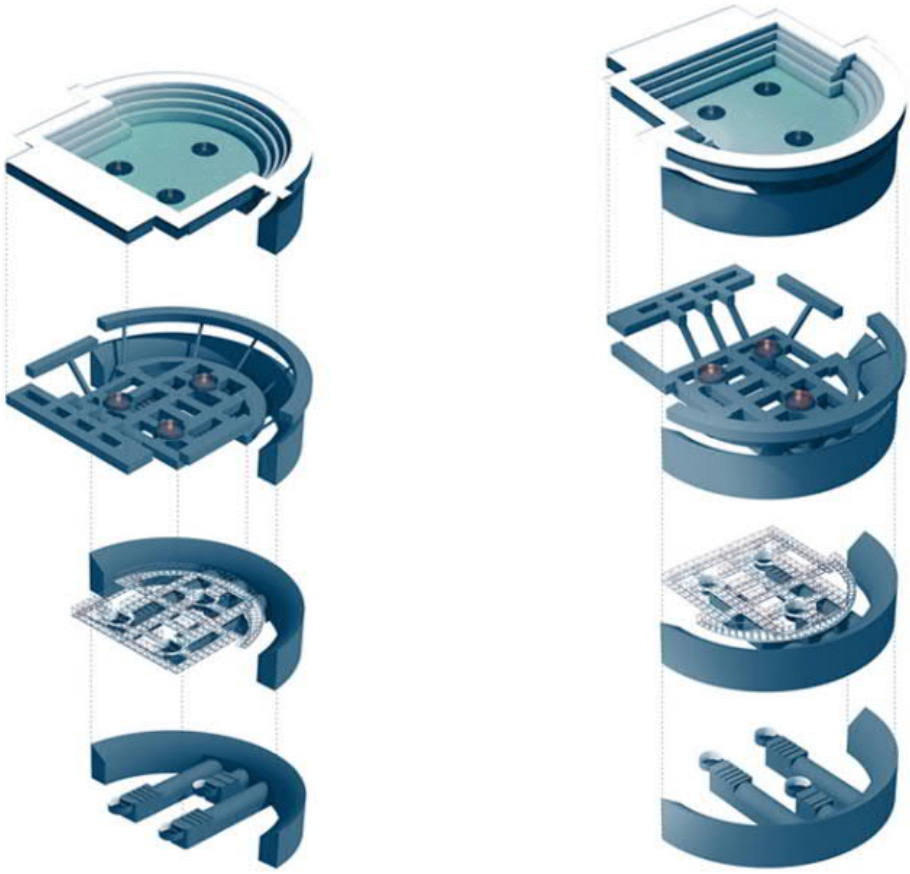


Fig. 16. Heating system of the piscina calida

FACADES

With only the remains of the thermal baths it is difficult to reconstruct the height of the walls. It could be inferred through the proportions between the parts of the structure and by comparing them with the relevant references of the period and the typical measures of the Roman construction methods. Starting from these considerations and taking as a reference the structure of the *piscina calida* in the Suburban baths in Pompeii – whose walls can be easily recognized unlike the one in Ventotene – the perimeter wall must have been 5 meter high.

The traces on the ground of the two columns placed against the base of the outer ring make possible to identify the molding step on the external walls. All the moldings characterizing this architectural element have been reconstructed, relying on the typical measurements and proportions of this ornamental part. The openings must have been on the curvilinear part, given its southern exposure. In this type of structure they were calibrated so as to offer a good lighting with minimum heat dispersion. The section of the windows was proportioned according to the part of the wall which they were going to occupy. In terms of shape, however, the windows look like those in the Pompeii Suburban thermal baths [Cairoli 2006].

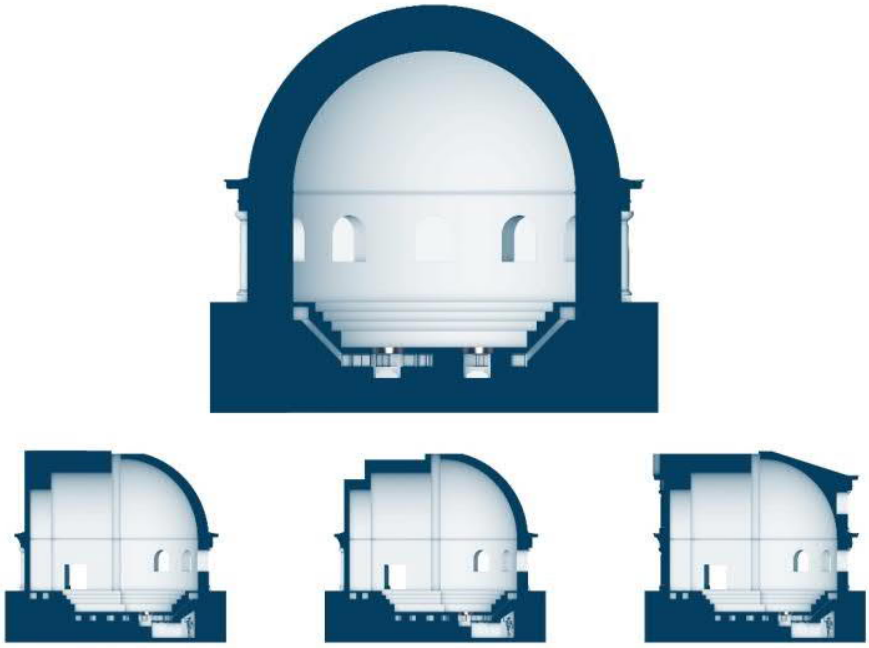


Fig. 17. Sections of the piscina calida

THE ROOF

The “retro-progettazione” [Verdiani 2017] was the most challenging part of the structure due to the total lack of findings (Figs. 17 and 18). This shows that it was built in tuff, so it was lost once it collapsed. Looking at the drawings, the roof must be subdivided into three parts. The two parts above the rectangular-sectioned rooms most likely had a semi-cylindrical vaulted roof, while the other a semi-dome one, given the circular shape of the underlying wall. Also, a joined arch connected the semi-dome with the adjacent roof. The heights of the three parts were retraced by matching the curve of the arch, that of the semi-dome and that of the two adjacent roofs. This is the first theory simply based on geometric rules and proportions [Marta 1990; De Angelis D’Ossat 1993]. An upper dome which joined the roof is thought to have been there so that the heights of the spaces remained unseen. This solution could have balanced the façade, but it could have also resulted in a larger amount of heavy material and a strong pressure on the underlying wall. There is also a third theory – the most convincing one – which states that there must have been a double order of moldings and openings and a tympanum in the north wall at the end of the roof and a buttress in the upper part of the opposite façade. This is a solution that revokes the great buildings of the Imperial era [Adam 1999].

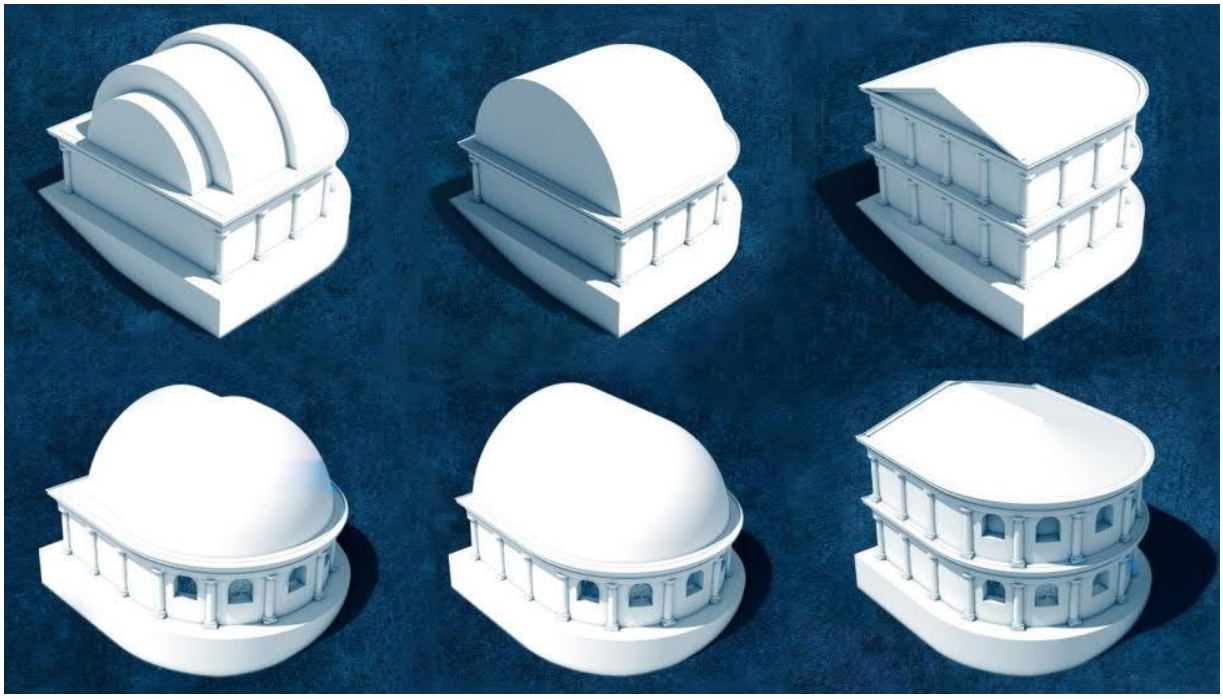


Fig. 18. Three different theories of the roof

Three reconstructive plans have been proposed to respect the methodological principle of the London Charter according to which, in controversial or particularly challenging cases, the right thing to do is to suggest more solutions in order to stimulate critical analyses and constructive discussions [London Charter 2009]. According to all the theories there are neither lateral openings above the vault springers, nor oculi in the semi-dome, as this type of solution was typical in *calidaria*.

Right in front of the thermal pool there is a trace of a buttress which was placed against the slope so as to contain the pressure exerted by the large structure. The buttress is thought to be as high as the villa.

The process of reconstructing the *piscina calida* was based on the principles of London Charter (implementation, aims and methods, research sources, documentation, sustainability, access) and of Seville (general criteria, guidelines, sensible use of technology, research, new methods and digital techniques, virtual archeology awareness) which includes rigorous methodological standards to be strictly observed to provide scientific authoritativeness and promote a technical and intellectual accuracy in the study and interpretation of digital display [London Charter 2009; Sevilla Principles 2011].

The graphic representation was not coincidental. It was aimed at highlighting the volume of the *piscina calida*.

The non-realistic no-texture renders were made using Maxon Cinema 3D + VRAY and by setting the light and the shadows (Fig. 19). Then the most appropriate cameras were chosen to enhance the representation of the objects to obtain a clear and communicative image for all the visitors.

Fig. 19. Exploded diagram and level of reliability of the piscina calida (orange: low; yellow: medium; green: high)

CONCLUSIONS

This research is the result of a collaboration with Dipartimento di Architettura, University of Florence and the municipality of Ventotene. The analysis was aimed at investigating the archaeological site of the baths area and their heating systems and providing some material that would allow further studies. The digital reconstruction ultimately is aimed at creating a connection between history and science: the remains of the past and the scientific research that was necessary to show the value of the architectural objects. The survey and digital reconstruction has transformed forms of communication and understanding into the representation of what was lost. This project was based on a solid approach supported by the use of survey software and tools, as well as the "retro-progettazione" (reverse designing), and was inspired by the unique cultural intelligence, socialization, and history of Villa Giulia and the island. The understanding of the type of maritime villa d'*otium* and the functioning of the Roman baths required an in-depth study of a lot of material found in Ventone's library and in literature, showing that the thermal baths of Villa Giulia were an important cultural heritage and a rare example of the Roman baths in a maritime villa. The 3D laser scanner survey was used to ascertain the current situation of the ruins and to obtain a digitalization of the area. The digital survey was the perfect tool for an archeological site and its high level of detail. Today the digital survey has become essential for any cultural heritage recording and understanding. The cultural and historical context and specific standards of the London Charter and the Sevilla Principles validated the digital reconstructive hypothesis of the *piscina calida*. 3D modeling enabled a deep understanding of the remains, the geometry of the building and the samovar heating system. The digital reconstructive hypothesis of the *piscina calida* was compered to example of reference (suburban baths in Pompeii and the baths in Massaciuccoli) and analyzed by Alessandro Blanco, an expert archeologist of thermal baths. The volume of *piscina calida* was represented for the first time thanks to this research and it will be available for scholars, educational purposes, and visitors, and as a base for further research. In the near future all the information can be found virtually or interactively on a dedicated website or with the help of a QR code, directly on site with a mobile phone. The digital reconstruction tends to have a crucial cultural role in our time with the aim of enhancing the comprehension and safeguarding historical-archaeological heritage.

ACKNOWLEDGEMENTS

The "Dipartimento di Architettura", University of Florence has supported the digital survey campaign of the baths area in Ventotene; the operation was coordinated by Prof. Giorgio Verdiani. All the activities have been developed thanks to collaboration with the Ventotene municipality and in particular with dott. Ph.D Giovanna Patti, the former director of the archeological museum of the island.

The digital reconstructive hypothesis of the *piscine calida* has been done in full collaboration with dott. Ph.D Alessandro Blanco, from the Scuola di Dottorato in Archeologia, Roma La Sapienza, Italy, and arch. Mirco Pucci, Dipartimento di Architetura, University of Florence, Italy.

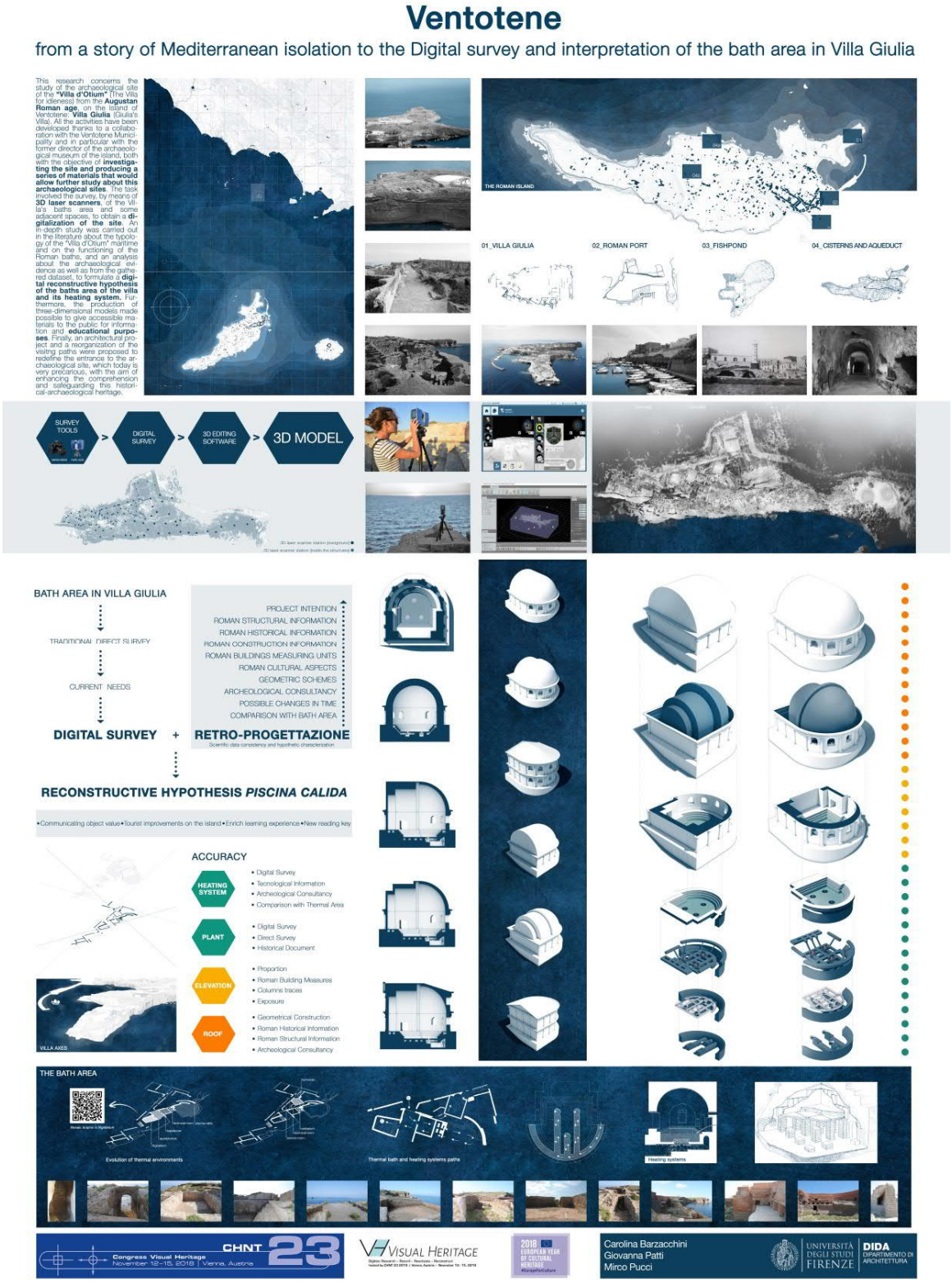


Fig. 20. The poster (original in UNI A0 format) as presented in occasion of the Cultural Heritage and New Technology / Visual Heritage Conference, Vienna, 2018

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