

3D Models and Interactive Communication for Archaeology: The Nymphaeum Ponari in Cassino

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Abstract

This study is part of a broader research project on Roman *Casinum* archaeological heritage and includes tangible and intangible heritage. In the mid-twentieth century, a *nymphaeum* dating from the second half of the first century B.C. was found not far from the core of *Casinum*, an archaeological site, located in the modern town of Cassino in South Latium, Italy. The *nymphaeum* Ponari is part of a Roman villa still completely buried underground. The excavations had been carried out so far have gradually unearthed a well-preserved environment consisting of a rectangular hall with niches topped by a barrel vault. The metric data acquired in a recent digital survey made it possible to develop a virtual model reconstruction of the *nymphaeum* and to design an interactive communication system, on-site and off-site, linked to the nearby museum complex present at the archaeological site. The present article is focused on the documentation, interpretation, valorization and communication of archaeological heritage of the Roman *Casinum* city site.

Keywords: nymphaeum, Casinum, Cassino, Ponari, 3D models, cultural heritage

Appellantur quidem ita erosa saxa in aedificiis, quae musaea vocant, dependetia ad imaginem specus arte reddendam

Introduction

This work is part of a broader research project on Roman *Casinum* archaeological heritage. Even though this archaeological area contains monuments of considerable interest and importance, it has never been archaeologically documented enough to enable the researcher to analyze the individual findings and the environment of the site through a well-structured survey that would allow one to fully explore it. The main finds of the ancient urban layout are the remains of the Via Latina, the amphitheater, the theater and the mausoleum attributed to the Roman matron Quadratilla, part of *gens* Ummidia. There have been some interesting, very recent discoveries related to parts of a Roman *domus* of the imperial

period, which should stimulate a deeper, organized study of the town planning system. The part of the *domus*, which was discovered some time ago, is the so-called Ponari *nymphaeum*.

The Environmental Context

Today, Cassino is a modern town lying between Rome and Naples. The city was completely rebuilt after its destruction during World War II and is quite famous for the Montecassino Abbey. Cassino is located just below the mountain where the Montecassino Abbey is situated. The history of the city and of the Benedictine monastery of Montecassino are closely linked. The city appears to have been historically consolidat-

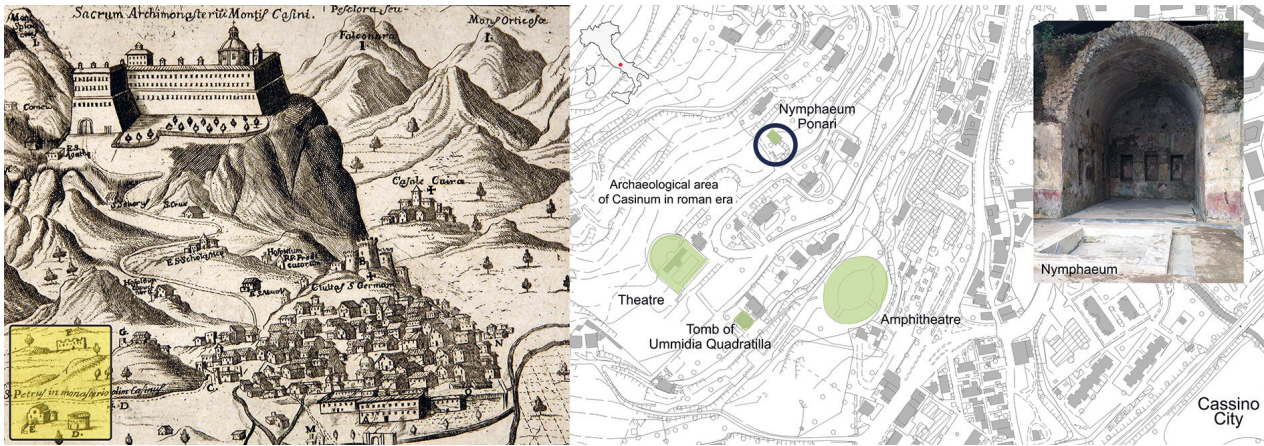


Figure 1. The city of Cassino, the Rocca Janula and the Abbey of Montecassino. On the left, archaeological area with *nymphaeum* Ponari. (Engraving of F. de Grado, in Gattola 1734). On the right: Roman Casinum city, archaeological area today.

ed up to the Second World War when any traces of its past were lost. The earliest settlement of the site dates back to the sixth century BC when first the Volsci and then the Samnites permanently settled in the Liri valley, building the first houses of *Casinum* (the name of the ancient city). From a Roman prefecture, *Casinum* became *municipium* and in the third century it was granted the right of citizenship. It flourished reaching the peak of development towards the end of the republic and during the imperial period, and then it gradually sank into insignificance. In AD 529, with the settlement of St. Benedict (founder of Montecassino Abbey and of the Benedictine monastic order) among the ruins of the pre-Roman and Roman fortified acropolis, the city's history became inextricably linked to that of the Abbey.

Around the first century BC, after the city of *Casinum* had become a Roman town, there began a process of consolidating its urban structure that necessarily took into account the particular topography of the places and the existing conditions, as well as a circuit of pre-Roman walls. The organization of the city was mainly developed on three terraces lying on the hilly topography of the site, of which a large part of the original substructures still exists, expanding the city to the east, outside the city walls, down the steepest area. The settlements already existing during the Augustan period and the late imperial period when the city (at the end of the first century AD) reached an area of about 10 hectares, led scholars to hypothesize an urban network was structured in the shape of a square of two *actus*.

The monumental structures of the present archaeological area are (Ghini and Valenti 1995): the

theater; the core of the Augustan town plan, brought to light in 1935-36; the amphitheater dating back to the second half of the first century AD, which has an elliptical shape of modest dimensions; the so-called tomb of Ummidia (1st century BC - 1st century AD), a building planned on a Greek cross, with the central part covered by a hemispherical dome intersected by four arms; and the *nymphaeum* called Ponari, which was built on a rectangular plan with a barrel-shaped roof, closed at three sides and fully open at the front (Figure 1). The building is connected to a well-structured floorplan of a rich *domus* (Polito 2013) with valuable floor mosaics, as well as fragments of walls of the rooms, preserved at the height of more than 2 m, whose wall decorations are articulated in architectural schemes with small paintings of mythological-symbolic subjects or idyllic-naturalistic themes.

The *Nymphaeum* Ponari

The word *nymphaeum* has a double meaning: the first is of Greek origin and refers to a place (often caves) consecrated to the nymph goddess; the other one is of Latin origin and refers to a place with water and fountains. In the course of centuries, the architectural sense of *nymphaeums* in relation to the position and their typology has changed significantly. By and large, the architectural evolution of the *nymphaeums* in relation to their position can be the following: public *nymphaeums* (monumental intentions - II-IV century AD), located along the main roads or at crossroads; composite *nymphaeums*: interiors for public buildings; private *nymphaeums*, for rich



Figure 2. Similar *Nymphaeums* in Italy: a. *nymphaeum* “Q. Mutius” in Segni (Rm); b. *nymphaeum* “Dorico” in Castelgandolfo near Lake Albano (Rm); c. *nymphaeum* “Egeria” in the park of Caffarella (Rm); d. *nymphaeum triclinium* in a Roman villa in Minori (Sa).

domus decoration. The main typological models of the Roman *nymphaeums* are: environments in natural caves; environments in artificial caves; environments in rooms without niches but with functioning, real monumentalized fountains, sometimes with a bottom apse; environments in rooms with niches in the walls; the basilica plan environments; and other forms.

Another renowned typological classification, proposed by Mingazzini (1955, 1957), distinguishes these buildings according to their location and size. The subdivision is essentially split into three categories: *nymphaeum* for buildings related to monumental public fountains; *musaeum* for structures with natural grottoes, even if artificially modified; *specus estivus* for all artifacts with specially designed fountains. The latter can be divided into three sub-categories: semi-underground, i.e. partially constructed in the ground; completely constructed above ground; or conceived as an integral part of a villa, or a building (Neuerburg 1965: 27-29). A further category for the typology related to villas is found in sub-types linked to the layout and architectural type. Among these, a particular typological category referring to nymphs, is the so-called “chamber”. Chambers appeared at the end of the III century BC and took on more varied and articulated forms over time. The “chamber” es-

entially has a rectangular layout, in most cases enriched by niches in the walls, with a recess or an apse in the bottom wall, while open at the front and generally with a barrel-vaulted roof. Initially, the “chamber” building constituted a direct development of the ‘natural grotto’ model, which is connected to the recurrent use of rustic symbolism. Because of its location, the *nymphaeum* Ponari recalls *Specus estivus* as described by Mingazzini (1955, 1957) and, owing to its geometric and typological characteristics, can be considered to belong to the ‘chamber’ variety.

In Italy, there are some examples of *nymphaeums* similar to that of Cassino in shape and state of conservation (Figure 2): *nymphaeum* “Q. Mutius” in Segni (Rm); *nymphaeum* “Dorico” in Castelgandolfo near Lake Albano (Rm); *nymphaeum* “Egeria” in the park of Caffarella (Rm); *nymphaeum triclinium* in a Roman villa in Minori (Sa).

The “*nymphaeum* Ponari,” identified in the 1940s, thanks to the investigations carried out by the archaeologist Gianfilippo Carettoni (1912-1990) (1940), was the subject of a subsequent intervention by Massimiliano Valenti (1992) in the 1990s, especially in 1998, removing the land fallen meanwhile due to the steep slope of the ground on which it stands. More recently, in 2009 and 2014, the monument was the subject of work that ensured its preservation (Figure



Figure 3. The *nymphaeum* Ponari in the archaeological site of *Casinum*.

3). Thanks to some further discoveries made during this work, architect Silvano Tanzilli (2016), then director of the archaeological site at Casinum, elaborated a reconstruction of an alleged *domus*. To date, however, the elements to support a plausible interpretation of the presence of a *domus* are still insufficient.

With the first regeneration of the *nymphaeum* there also emerged the rich decorative elements that distinguish it: a floor mosaic represented by a three-color tessellated floor with *crustae* in marble, and a “rustic mosaic” on the wall that was subsequently overlaid with a plaster of pictorial decoration imitating marble slabs, defined by a reproducing range of painted, colored shelves in perspective (Betori, Valenti & Tanzilli 2009).

As already mentioned, the decorative wall and flooring system are immensely rich and interesting. In particular, the wall decoration consists of two decorative systems, the second of which was added at a later date. The oldest one, dating to the Late Republican - Early Augustan period is visible only in some areas where the next one collapsed (right wall). It is characterized by a rustic mosaic with Egyptian blue rhomboids, fragments of limestone and polychrome glass as well as various kinds of shells. Even though it is significantly damaged, the decoration allows for the tripartite decorative pattern used to be identified. The pattern consists of a structured top section with parallel strips, a middle part with a vertical scan, featuring three niches on each wall, topped by a triangular crossbar, and the lower part defined by a horizontal strip enclosed between two rows of Egyp-

tian blue mosaic tiles with alternating circular and rhomboidal motifs originally coated with glass tiles. The bottom part encloses a diamond shaped lattice, the result of the alternation of double diagonal rows of “tellins”. As for the later wall decoration, the rustic mosaic from the imperial age overlays a plaster painted with fresco paintings with geometric decoration on false marble slabs (imitation of caristio and numidian marble slabs), retaining the previous horizontal tripartition of the wall. On the bottom wall the strip below the niches consists of a pseudo-perspective representation of red, white and blue protruding shelves (Figure 4). Lastly, the floor decoration has a polychrome checkerboard mosaic of small horizontal textured weave tiles with insertion of irregularly positioned marble chips, with a double strip of black tile frame along the long, white walls on the bottom one. A marble trunking (*bardiglio*) further defines the latter wall, probably used to collect water filtering down from above.

Lastly, the typological and geometric characteristics of the structure and - in particular - the decorative elements, have allowed the *nymphaeum* to be placed in a specific chronological range. Indeed the mosaic floor recalls decorative styles commonly used throughout Lazio and the rest of Italy between the end of second century BC and the end of the first century BC, with Pompeian examples created until the first century AD. The original layout can be dated to the late-republican age, between the end of second century BC and mid-first century AD, on the example of some similar mosaic creations from that era (e.g., villa of Barcola near Trieste). Even the shell-like



Figure 4. The rich decorative apparatus, wall and floor details: below the niches, is a pseudo-perspective representation of the architectural elements, colored red, white and blue; while the flooring mosaic system is formed by a three-colored tessellated floor with *crustae* marble, and a “rustic mosaic”.

mosaic wall became popular around the middle of the first century BC, with numerous references even in central-southern Lazio. The most outstanding is the *nymphaeum* Segni, Frosinone province, the date of which can be established by the architect's signature Q. Mutius, found on the structure and his association with the family of *Mucii Scaevola*. Moreover, the subsequent decoration can be traced back to the imperial era.

The Integrated Digital Survey

An innovative contribution of this research regarded new activities at the archaeological site based on an integrated digital survey. In recent years digital technology has produced a convergence and integration of different instrumental survey methodologies. Some of them are already known, such as topographic mapping (merged into the wider scientific area known as geomatics), while others are more innovative, such as laser scanning and photogrammetry. In the field of 3D shape acquisition, the integrated digital survey configures as the interaction and integration of three distinct methodologies: topographic, laser scanning, and photogrammetric. In the archaeological survey, the combined use of these three techniques is very common today since each has distinct characteristics for costs, mode of data acqui-

sition, processing, and management (Adembri et al. 2016).

The experience in progress at Cassino is significant for the particularities of the site, highly integrated with the existing urban fabric and with a topography that makes the stratigraphic study of the different archaeological phases more difficult. Visible today is only part of the Roman *castrum* and some areas, such as that of the *nymphaeum* Ponari, appear as isolated incidents, while it is generally agreed upon that these should be seen and relocated within a unitary urban configuration. Within this site there are archaeological remains of different type, size, condition and construction features. Therefore, it's important to adopt the best strategies for acquiring and processing data, related to the specificity of individual archaeological features. The starting digital data is a point cloud, whether using a laser scanner or photogrammetry. The point cloud is a set of discrete points, more or less dense, each marked by positional values (coordinates X, Y, Z) and other values that depend on the characteristic of the material (as for example the reflectance value when using the laser or the RGB color value with photogrammetry).

On *nymphaeum* Ponari, the laser scanner survey was integrated with spherical panoramas made with an external camera on a panoramic head. This made it possible to replace the image from the internal camera on the 3D scanner with a higher resolution

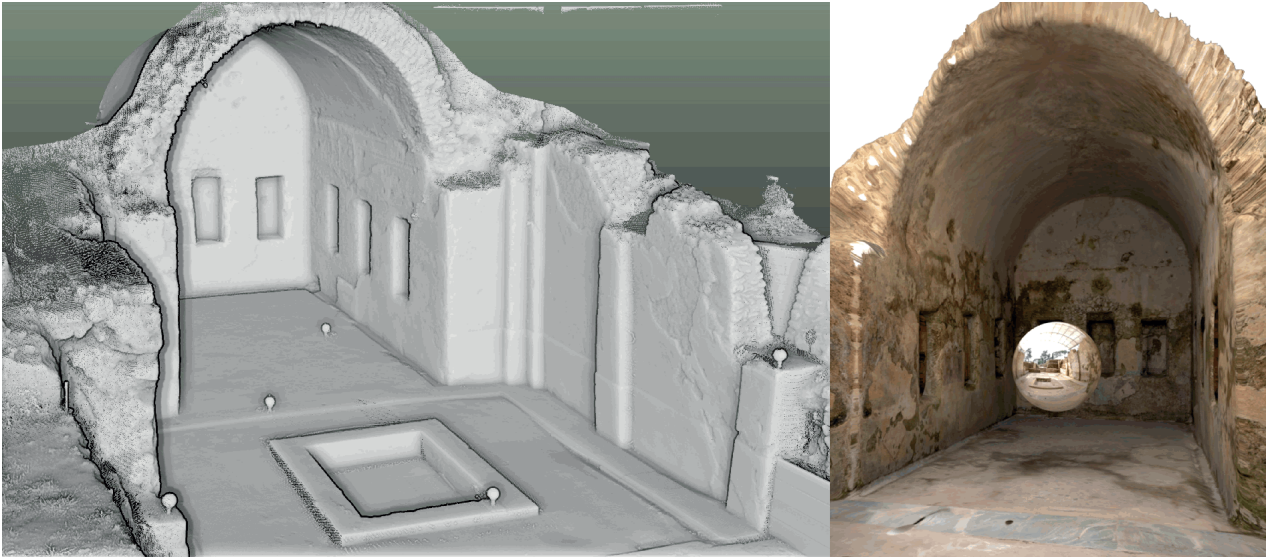


Figure 5. 3D elaborations from point cloud with and without texture. The texture of the 3D model was created and mapped using HDR spherical panoramas.

one in the 3D model. The photos made with the external camera have enabled us to use the High Dynamic Range (HDR) technique to achieve the best exposure compensation. On the walls of the *nymphaeum* there are many traces, also small ones, of the different stratigraphy. These traces can help the archaeologists to understand the several coatings that have been applied over time. A careful study of these traces is possible only through a right integration between the metric data of the point cloud and the high-resolution photos. The survey of the *nymphaeum* Ponari also takes account of the current excavations that brought to light the remains of walls with well-preserved frescoes of a high aesthetic quality.

The first step of the post-processing phase is the elaboration of the point cloud from the laser scanner, obtaining first a 3D model reconstruction as a polygonal mesh surface. The quality of the model depends on two factors: the quality of the point cloud and the Poisson surface reconstruction algorithm (Kazhdan and Hoppe 2013), used for generating the mesh surface from the point sets (Figure 5). In this way, it's possible to switch from a discrete model for points to a discrete model for surfaces. The photos made with the internal camera of the scanner can be replaced with other photos made with an external camera which improves the pixel resolution and the exposure applying the HDR technique or the standard Low Dynamic Range (LDR) mode.

This textured 3D model can be used in the initial investigations on the shape and geometry, extracting

specific information, such as horizontal or vertical slices used for 2D graphic elaborations. Through the plan (Figure 6) and the section (Figure 7) it is possible to see the entire area already excavated and even that small part of the *domus* only partially excavated. The *nymphaeum* is composed of three parts: the rectangular hall with niches, covered by a barrel vault of about 7.50 m long and 4.60 m wide; an open area with a tub at the center which is about 7.50 m long and 6.30 m wide; a filter area linked with the *domus*, perhaps covered, about 3.60 m in width. The measurements are in meters and no metrological analysis has been carried out to obtain the correspondence with the Roman foot because measurements often vary considerably, so it is difficult to identify exactly the measure of reference.

The covered hall contains three niches for each of the three walls. There were certainly some decorative elements (moldings and cornices) that can be partially reconstructed on the basis of the traces still visible in the plaster. There was also a very rich pictorial decorative element that can be largely reconstructed in its original configuration thanks to the many painted parts still in good condition. The layering of plaster allows us to clearly distinguish the different coating techniques corresponding to the different historical phases. Behind the latest layer of plaster, probably dating back to the second century AD, there are traces of a rustic mosaic covering made of stones and shells on the NE wall. Observing the plan (see Figure 6), the overlapping of three different

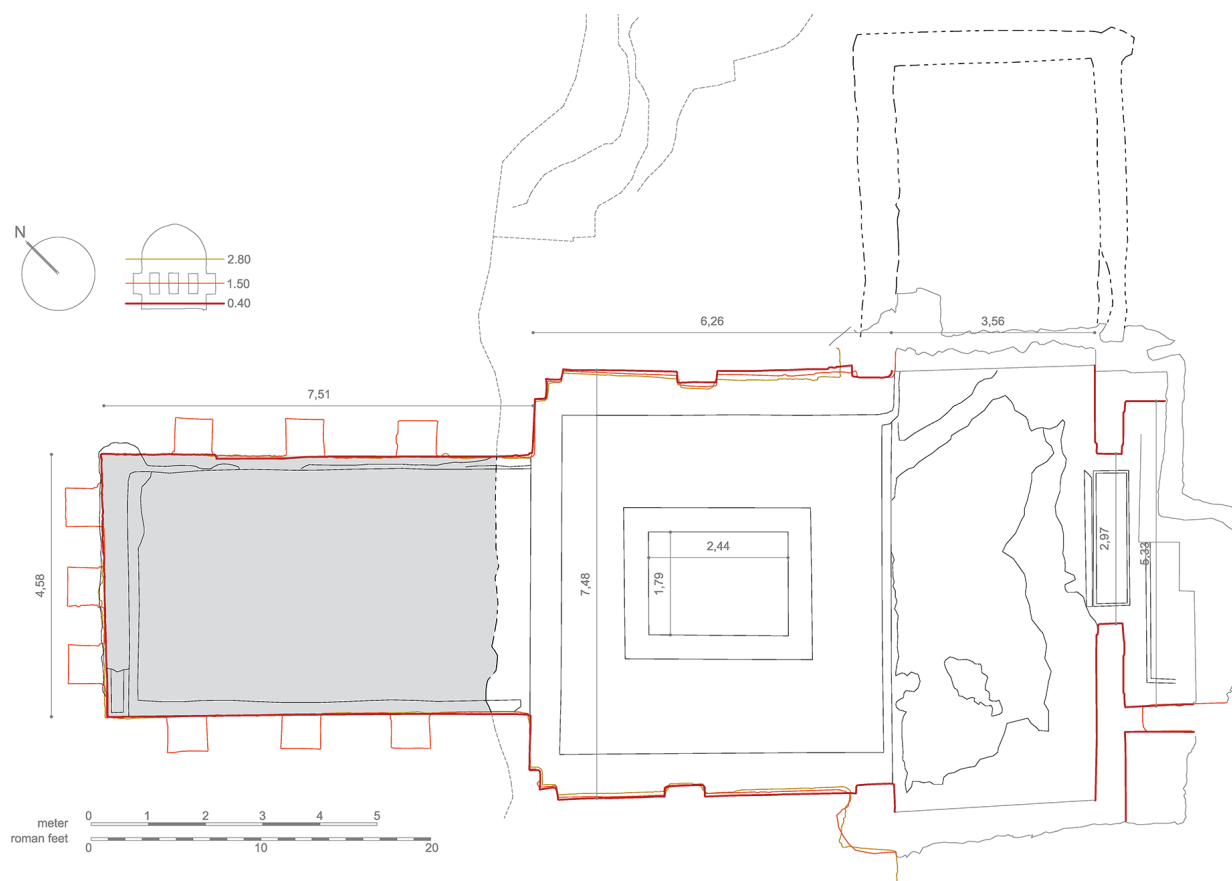


Figure 6. Plan of the *nymphaeum* Ponari. The plan includes three different horizontal sections to highlight the several misalignments, horizontal and vertical.

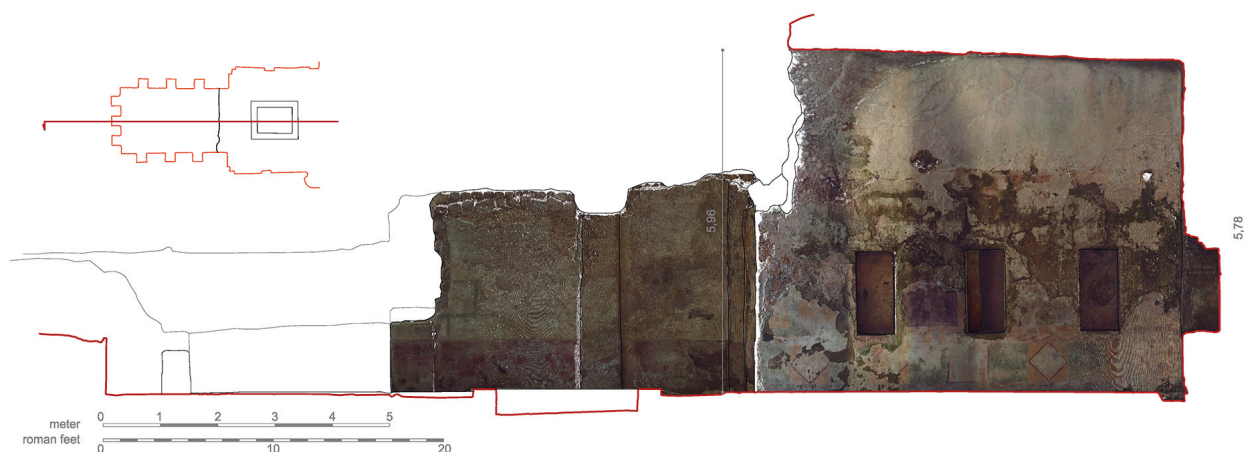


Figure 7. Longitudinal section with the front textured using the spherical panoramas.

horizontal sections made at three different reference points allows us to evaluate the differences from the possible original wall alignments that have undergone noticeable deformations over time.

Some elaborations of the plan and the section allow us to highlight some particular features of the *nymphaeum*. In Figure 8 note, for example, the dif-

ferent axis of symmetry between the *nymphaeum* and the part of the *domus* that is still visible. The niches have the same size in height and width, but there is no symmetry on the two long walls. Even in the open space where there is the water tub there are two unaligned pilasters. These differences can be ascribed to different construction periods. The over-

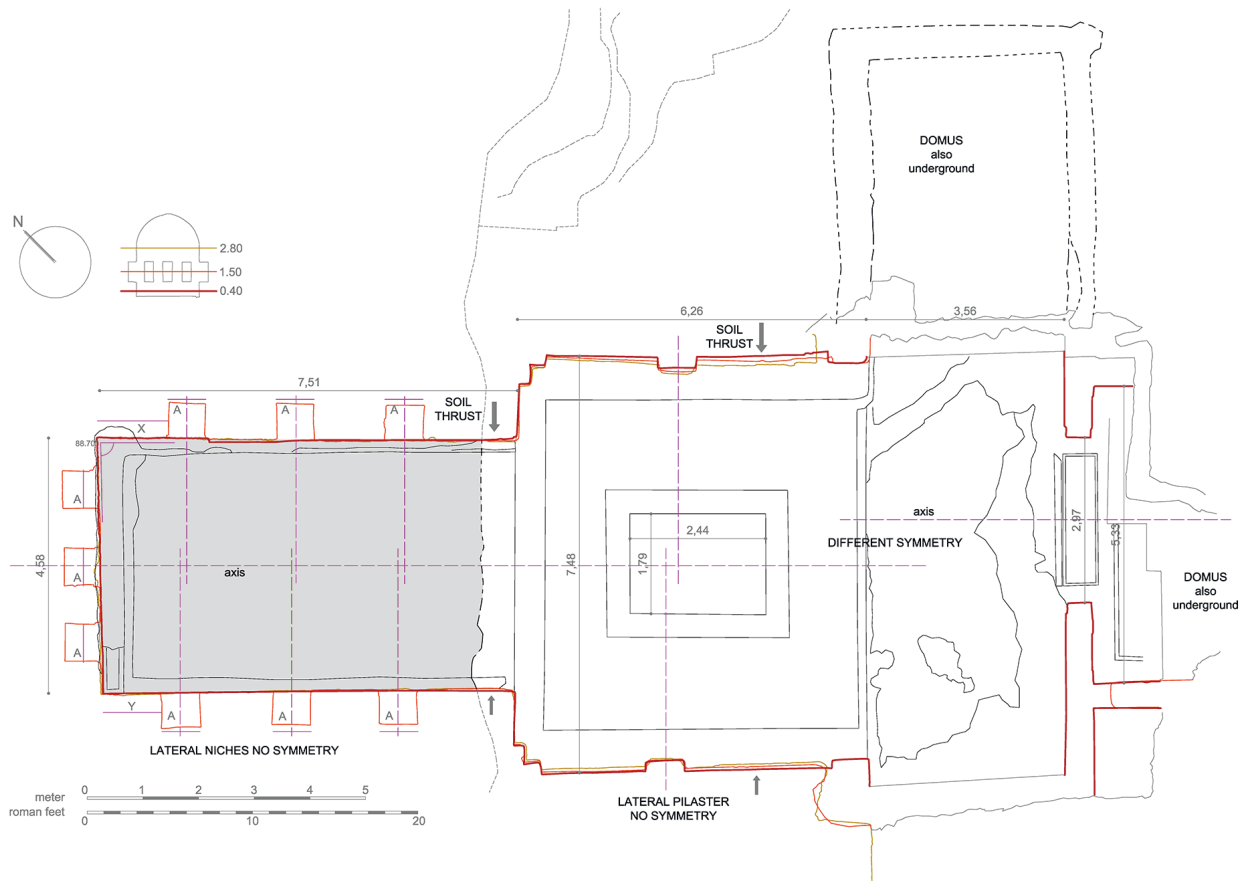


Figure 8. Plan in which some particular features of the *nymphaeum* are highlighted.

lap of the horizontal sections allows us to evaluate the deformation undergone by the whole structure. Deformations are largely attributable to the lateral thrust of the ground.

Other elaborations made directly from the point cloud (such as the elevation maps) allow us to highlight some details not visible to the naked eye. In this way, it's possible to figure out the difference in altitude of the various parts that compose the floor. In the back wall of the *nymphaeum* there is a canal through which the water flows (still partially visible). It is important to note also that the floor of the covered chamber has not undergone particular sagging and is still perfectly level. Figure 9 allows us to verify two things: the correspondence with the round arch geometry of the barrel vault and the deflection upwards of the outermost part of the surface in consequence of the lateral thrust of the two load-bearing walls.

Particularly interesting is the study of the parts of plaster on which it is still possible to observe decorative geometric motifs. As mentioned, the peculiarity of this *nymphaeum* is that an older layer of finish-

ing clearly emerges from under the layer of frescoed plaster (with geometric figures of different colors, a pseudo-perspective frame and panels with drawings depicting different types of marble). The application of different visualization filters on the pattern derived from the point cloud (i.e., "ambient occlusion"), allows us to analyze in detail the imprints on the plaster of the various mosaic tiles. Among these are also some imprints of shells and other natural elements that were used in the decoration according to a well-defined geometric design (which was only partially resumed in the later layer).

Interactive Communication

Another research activity of the project included an on-site application using innovative ways of cultural heritage communication. Recently a museum (named "Museum Caretoni" in honor of the archaeologist who worked on this site for years) has been opened inside the archaeological area. Given that currently the *nymphaeum* is outside the traditional

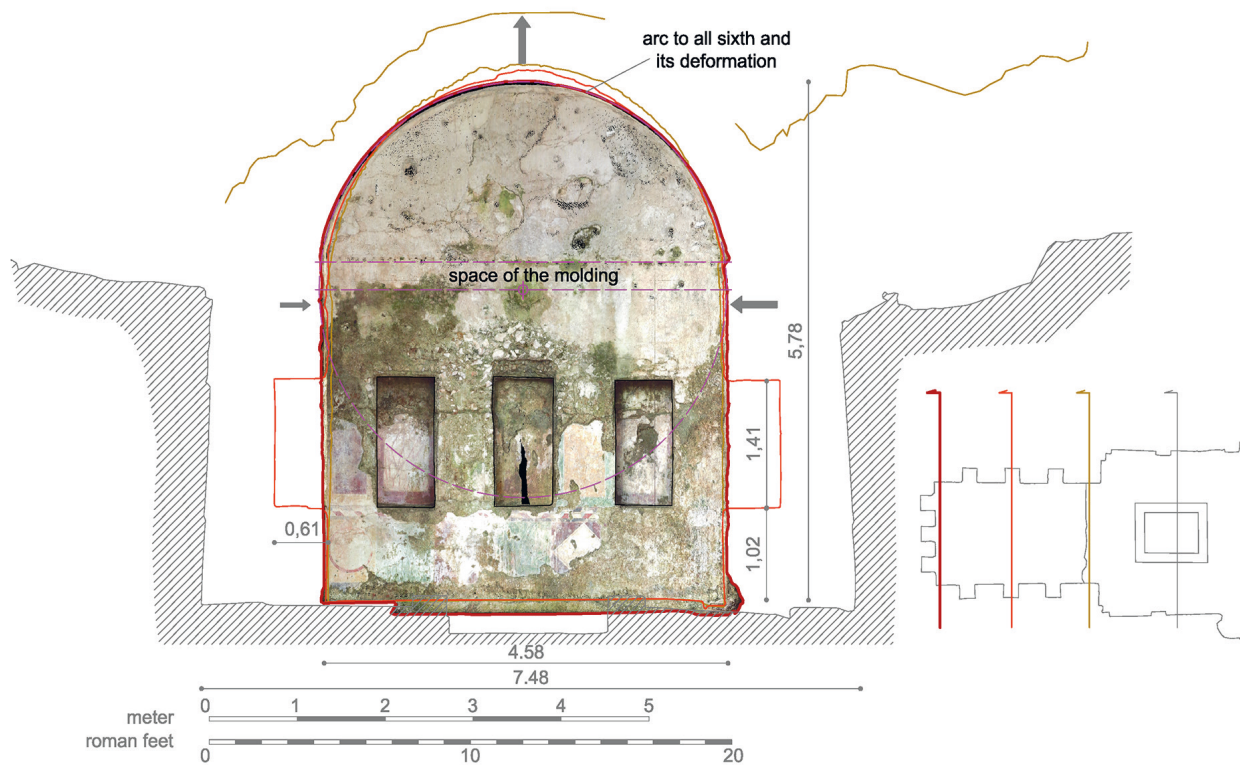


Figure 9. Transversal section in which some particular features of the *nymphaeum* are highlighted.

visitation circuit because it is still a building site, the processing of the models shown here represents a real opportunity to set up in the museum an interactive box for multimedia virtual tours using immersive virtual reality. Today, the ways on cultural heritage communication can be very diverse thanks to the great diffusion and versatility of digital technologies. However, each context evinces its specificities over which some applications may have greater or lesser communicative effectiveness (Frassine et al. 2014).

The virtual tours, for example, can be used on fixed or mobile devices (smartphones or tablets). In the first case, there is almost always an off-site communication mode that is far from the object or site we are visiting; in the second case it is also possible to activate on-site procedures, in direct contact with the cultural heritage. In this case, the effectiveness of communication is certainly greater as it eliminates the loss of visual quality due to technical limitations of mobile devices, which can lead to the loss of the user's attention. In the case of *nymphaeum* Ponari, a very important aspect to consider is the level of freedom of movement within the virtual space. In the virtual tours based on spherical panoramic photos, space exploration is linked to a predefined points-of-

view, while in 3D-based virtual tours, it's possible to interact more freely with the virtual model obtaining a greater communicative impact. However, the quality of the experience depends largely on the level of model accuracy, sensory immersion (obtainable with devices that are still too sophisticated and expensive for mass use), as well as the functionality and simplicity of the navigation tools.

The project that has been developed for *nymphaeum* Ponari involves the installation of a multimedia station within the Caretoni Museum (Figure 10). The communication interface is based on a virtual tour consisting of four spherical views that allow us to navigate within the remains of the *nymphaeum* by rotating the 360° view with simple and intuitive interaction modes. It is also possible to take advantage of greater spatial immersion using virtual reality optical devices. Spherical views have a number of links (hotspots) through which activate more in-depth knowledge pathways (details, historical documentation, comparison with other *nymphaeum*, etc.), thus diversifying communication in relation to the user. Particular care is given to the integration of the visual component with that of the storytelling voice, rather than written texts. This is because in this kind

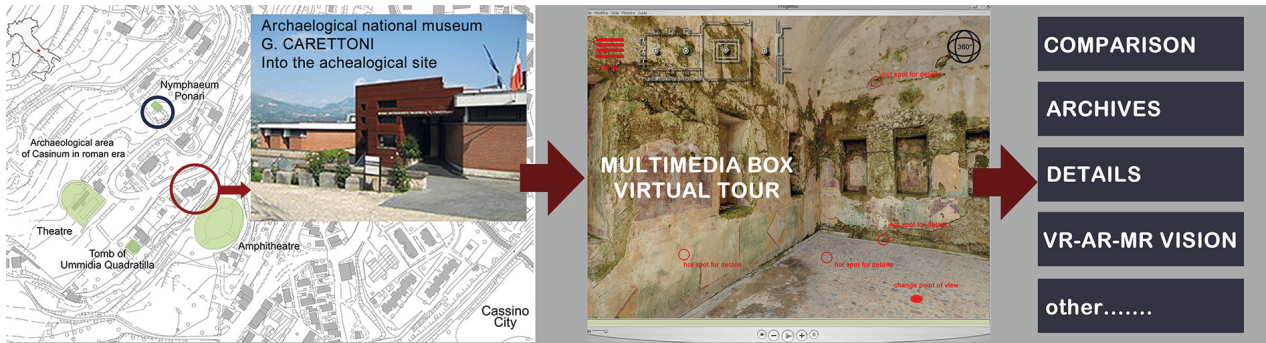


Figure 10. Project of multimedia box to be installed inside the Archaeological National museum “G. Carettoni” built into the archaeological site of *Casinum*.

of communicative experiences the voice message is much more effective than the written message.

This aspect of the project, which is still under development, represents a concrete opportunity for visitors of the archaeological area to know a currently inaccessible place, which is particularly interesting not only for the state of conservation of the spatial context but also for the refinement of some decorative details, largely well preserved in their original features.

Conclusions

This study is part of a broader research on *Roman Casinum* archaeological heritage and includes tangible and intangible aspects of that heritage. Digital technology can be an important means for optimizing resources for the conservation and enhancement

of the cultural heritage so widespread in our territory. After an initial period of experimentation, today a practice that is common among superintendents, surveyors, archaeologists and scholars has established itself. The use of digital survey and 3D modeling for the documentation and study of archaeological sites and historic buildings, has increased significantly in recent years. The survey allowed us to elaborate 2D and 3D representations useful for expanding our knowledge of the nymphaeum Ponari. The study is also an important step to program the future excavations of the Roman domus. Moreover, the 3D models can be used for a new form of communicating cultural heritage both inside the nearby archaeological museum as well as in off-site places.

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