Joint Use of Geomatic and Geophysical Methods for the Survey and Documentation of the Vespasian's Thermal Baths (Cittaducale, Rieti, Italy)

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Abstract. The paper is related to the in-depth study of the route and characterization of a stretch of the ancient Via Salaria, an ancient Roman consular road, which connected Rome with Porto d'Ascoli on the Adriatic Sea. Researches were focused in the archaeological area of the Baths of Vespasian, also called Baths of Cotilia, in Cittaducale near Rieti in central Italy. The study of the sources, the analysis of the wall palimpsests and the interpretation of the results carried out return a much more articulated overall picture than what is currently visible, entirely resembling a territorial compartment characterized by a scattered settlement. A 3D laser scanner and digital photogrammetric survey of the structures was carried out, supplemented with a campaign of geophysical surveys (GPR). The results show interesting anomalies related to the roadway and adjacent structures, taking into account the transformations that the whole system must have undergone in subsequent epochs.

Keywords: Laser scanning · photomodeling · historical maps · GPR · Vespasian's Thermal Baths · Ancient Salaria road

1 Introduction

The research activity at the Baths of Vespasian in Cittaducale (RI) originated as a case study of the Project "Stone road paving. History, conservation, valorization and project", funded in 2017 by the Italian Ministry of University and Research in the frame of the action "Projects of Relevant National Interest (PRIN)". The research was developed with the analysis of the construction and execution techniques of stone roads through the comparative study of the works, based on what their function was supposed to be and the historical-geographical and political-cultural contexts of reference.

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In cases where the road infrastructure are no longer present, the study continued with the collection of information derived from toponymy or through iconographic sources.

The present work was aimed at carrying out survey operations, bibliographic research and direct analysis in order to evaluate different types of road pavements made through the centuries, also intended as covering architectural artifacts related to road routes such as: archaeological substructure works and ancient bridges. In order to compare the identity elements of different contexts, case studies were chosen on national territory, in urban and suburban areas, taking into account the function and historical-geographical and environmental characteristics of the sites.

The contribution summarizes the results related to in-depth studies on the route and characterization of the ancient Via Salaria near Rieti, through an interdisciplinary methodological approach based on integrated survey systems and the documentation and analysis of visible archaeological evidence.

The subject of the investigation was the archaeological area of the so-called Baths of Vespasian in Cittaducale (RI) where, following recent excavation campaigns carried out by the then Soprintendenza Archeologica del Lazio, a glare section of the ancient Via Salaria, about 30 m long, was found (Fig. 1a).

The architectural complex, placed in close relation to the road, was part of the infrastructure of one of the most important stopover stations in central Italy, witnessed, among other sources, by the representation on the *Tabula Peutingeriana* (*Aquae Cutiliae*); it was articulated, not surprisingly, around a monumental basin.

The study of the sources, the analysis of the wall palimpsests, and the interpretation of the first survey and diagnostic results carried out return a much more articulated and complex overall picture of what is currently visible, entirely resembling a territorial compartment characterized by a scattered settlement. The structures show not only a large number of construction phases, but also a high variety of functions. Given the geomorphological characteristics of the site and the distance of the other coeval sites along the ancient route, it is believed that the bath complex must have played a landmark role in the surrounding area.

This project had three main objectives: the first was to develop a study model based on a multidisciplinary, multi-scale approach to archaeological investigations and to map the invisible. This is a model that many scholars in the field of archaeology have been using and refining for some time now with some excellent results, and which makes use of instrumentation capable of representing in different forms and with common visualization systems the results of an approach at different levels of knowledge. The second was to test different diagnostic techniques whose results are useful precisely to calibrate the methods of investigation on a particularly interesting and probably still under-investigated case study. The last one was to link under homogeneous reference systems the results of the investigations done, integrating them within a GIS platform to define different geomorphological analyses and the definition of thematic cartographies specific to the research results.

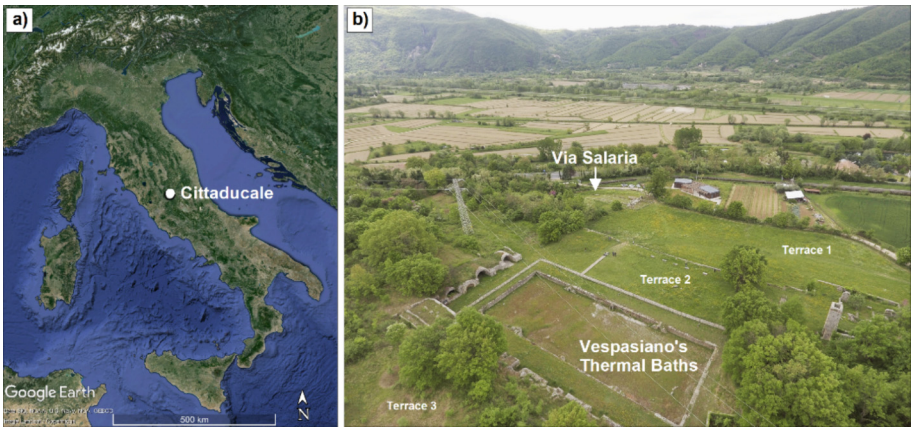

Fig. 1. Location of Cittaducale in central Italy (a) and aerial view of the thermal baths of Vespasian and Via Salaria (b).

2 Archaeological Background

The architectural complex of the Baths of Vespasian is structured around a first structure dating back to the second half of the 2nd century BC and the first half of the 1st century BC, which was followed by multiple construction phases both in the imperial age and in the late ancient and medieval eras [1]. In the *Tabula Peutingeriana*, a 12th-13th century copy of an ancient Roman map showing the routes of the Roman Empire, the site of Cotilia is localized with the symbol used for thermal structures in the variant with a *quadriporticus* and two-tower façade, indicating the presence of the complex which probably also constituted a resting place for travelers [2]. The site also seems to correspond with the toponym *Aquae Cutiliae* of the *Itinerarium Antonini*, a register of stations and distances between localities located on the various roads of the Roman Empire, which was located along the Via Salaria nine miles from *Reate* (Rieti) and seven from *Interocrium* (Antrodoco). This location currently corresponds to the district of Paterno in the municipality of Castel Sant'Angelo, near which there are some modest-sized lakes, one of which could correspond to the *lacus Curiliae* [3]. In this area, numerous terraces and substructures of the Via Salaria and infrastructures connected to it are documented and, in the past, notable discoveries have occurred during agricultural and road works reported mainly in the Italian periodical dedicated to archaeology *Notizie degli Scavi dell'Antichità* (News of the Excavations of Antiquity) as early as 1878.

From a geomorphological point of view, it is a territory in which, due to the solubility of the rocks, karst phenomena occur (F.I.G.M. n. 1939 IIISO; Geological Map of Italy, f. 139 [4]). In some underground cavities originating in ancient and recent times, there are springs of sulphurous or highly mineralized water, accompanied by manifestations attributable to secondary volcanism to be related to the existence of the very ancient Coppaeli volcano north-east of Rieti. The sulphurous water springs were also known to the ancients who took their healing properties into consideration [5–7]; the emperor Vespasian, native of *Falacrinae*, used to go to *Aquae Cutiliae* during the summer period.

The first excavations at the site date back to the years 1890–1891 [8]. The works began south-east of the *natatio*, where numerous walls, traces of marble and mosaic floors and a room identified with the *laconicum* of the baths were found. The investigations then restarted during the 1970s with tests in the central and northwestern areas, during which the thermal use of the buildings was confirmed [9, 10]. From 1982 to 1984, the excavation of the *natatio* continued and the north façade and the rooms behind it were highlighted and restored [11]. Only during the excavations directed by the Superintendency from 2010 to 2012, the remains of the stretch of road believed to belong to the ancient Via Salaria were found (Fig. 2).

The structures belonging to the thermal complex are mainly positioned on three terraces approximately 100 m long (Fig. 1b). At the second terrace, there is a *natatio* with a rectangular plan, which can most likely be identified with the *natatio*, accessible by stairs positioned symmetrically on the long sides. On the north and east sides of the pool there are various rooms characterized by a composite front with structures that reach approximately 5 m in maximum height. On the northern façade, there are alternate niches with rectangular and semicircular sections arranged on the sides of a rectangular room with an apse on the rear side. The eastern façade preserves large rectangular rooms alternating with small apses and in the northeastern corner a staircase is still visible which must have served as access to the upper floor, which branches off from a pillared portico where remains of mosaic flooring have been recovered. Furthermore, to the west of the basin and the architectural structure that surrounds it, there is the church of S. Maria di Cesoni, dating back to the 12th century due to its typology and construction techniques, but probably founded in an older era. The structure was entirely built with materials recovered from the Roman baths in continuity with the pre-existing walls. In the first terrace, the remains of what has been interpreted as a stretch of the ancient Via Salaria are currently visible.

Today the road has been excavated for a length of only 30 m and it seems clear that new excavation campaigns could bring to light even larger portions. In this stretch, the roadway of the ancient Via Salaria is made of crushed stone and gravel, delimited by stones arranged in cuts, and has a wall structure in blocks along the north side (Fig. 2). The path of the road and the wall end abruptly to the east, probably due to the cut made in the fascist era for the construction of the canal of the nearby hydroelectric power station. The presence of a structure made of large blocks of very compact limestone with a northeastern trend perpendicular to the road is a peculiarity of the site and is unique considering its typology. This structure, already partially identified in 2010, was interpreted as a sewer pipe, a hypothesis also confirmed by the latest excavation campaign [12]. Numerous questions remain open regarding the relationship between the road and the possible sewer and the dating of the conduit itself. Considering what emerged from the excavation documentation and the materials found in the abandoned layers of the structure it's not possible to advance a precise dating of the structure.



Fig. 2. A view of Via Salaria from west to east showing the hypothesis of sewer pipe, perpendicular to the road in the middle of the image.

3 Methods

The objective of this work was to represent at the appropriate scale the set of visible structures and the environmental context in consideration of the strong vegetation that characterizes the area and for a timely and accurate description of the territory on which archaeological structures stand.

Operating in a heterogeneous context and with different levels of detail has led to the integration of various relevant instruments. It was therefore decided to operate on three different levels: one relating to aerial vision using historical images and new acquired images by drone, another relating to the architectural scale with the use of laser and photogrammetric instrumentation, the last relating to the visualization of what is below the ground through geophysical diagnostics.

As part of the documentary analysis activities, various online digital archives were examined to verify the aerial coverage of the area from the years of the Second World War up to the most recent images downloadable from Google Earth. The objective was to analyze historical images that could provide further information on the area and identify possible anomalies in the territory based on sharpness, the camera model used and the acquisition altitude. The investigation area is very small compared to the extension of the images available and the resolution has not allowed accurate detailed analyses so far. Various digital archives were viewed, including for example that of the IGM, the National Aerophoto Library, the National Collection of Aerial Photography (NCAP) and The Library of Congress [13].

In particular, several shots taken in 1943 in the Rieti area were examined from the IGM website. The images had not a high resolution; however, among those available, there were some with higher definition. Taken from 9000 m above sea level, the area of the baths of Vespasiano was very small compared to the viewable territory. The methodology involved the use of available high definition images and their georeferencing on a Google database through the QGIS GDAL georeferencer. This operation allowed to project historical images onto the digital terrain model (DEM) of the available area taken from TIN Italy [14, 15]. The main difficulty consisted in identifying the homologous points between what is visible today and what was visible at the time of the shot. Furthermore, the difference in resolution between the images affected the accuracy of the process. Anyway, with six homologous points, it was possible to resolve projection ambiguities.

Regarding on-site surveys, part of the work was carried out using SfM-based digital aerial photogrammetry systems. The surveying was aimed to reach a large scale knowledge of the site and was carried out using a remotely piloted aircraft. Data processing of images was performed with Agisoft Metashape software (LLC. St. Petersburg, Russia) [16] using the structure from motion (SfM) technique [17, 18].

The area of the pool and the surrounding structures was surveyed with a laser scanner (Faro Scan S350 +, Faro Company, Lake Mary, FL, USA); in this case, it was necessary to use a long-range instrument to record both the elevated structures and the context relating to the terrain, to precisely describe the geomorphological trend with high resolutions. About 40 high-resolution scans were performed on the area. Particular attention was given to the enormous *natatio*, which occupies almost the entire upper terrace. The part of structures relating to the medieval church was also surveyed with laser scanner to have an accurate geometric description of the western part of the site.

The ancient route of the Via Salaria was the subject of more in-depth analysis concerning the general objectives of the project and it was surveyed both with laser scanners and with a photogrammetric system hooked to a carbon pole. In this case, the use of a reflex camera (Canon 5D Mark II with a focal length of 28 mm) mounted on a carbon telescopic pole of 6 m allowed several high resolution shots to be taken which were subsequently oriented using and integrating the laser scanner data.

The amount of data produced was processed according to widely standardized protocols in different application sectors for the management and restitution of point clouds [19, 20]; the latter were also georeferenced within a topographic network built *ad hoc* to organize the data in a single reference system aimed at an overall vision of the area within GIS platforms or data viewers. Since the area is characterized by a strong presence of vegetation at the limits of the archaeological structures with particular concentration in the northeastern area and in consideration of the morphological complexity of the site, it was also decided to use the LiDAR information of the integrated online services of the Lazio Geoportal to those obtained directly with a flight performed in April 2022 [21]. From the WMS services of the geoportal it was possible to visualize on Google mapping both the DSM and DTM of the Reatino area from LiDAR, excluding the predominate vegetation. As visible in the figure (Fig. 3), although the scale of representation is high and the resolution of the data is 1 m, it is possible to observe some very interesting anomalies of archaeological nature. The most obvious one is the continuation of the

substructure wall of the second terrace in an easterly direction for at least another 50–60 m, where it is also possible to see the corner that turns to the north. This discovery makes it possible to reestablish the correct extent of the terrace by decentralizing the reading of the infrastructure just to the east. A little further north it is possible to identify other small anomalies of an archaeological nature probably related to the structure of the baths. Only a field analysis will clarify the real nature of these anomalies referring them to ancient structures.

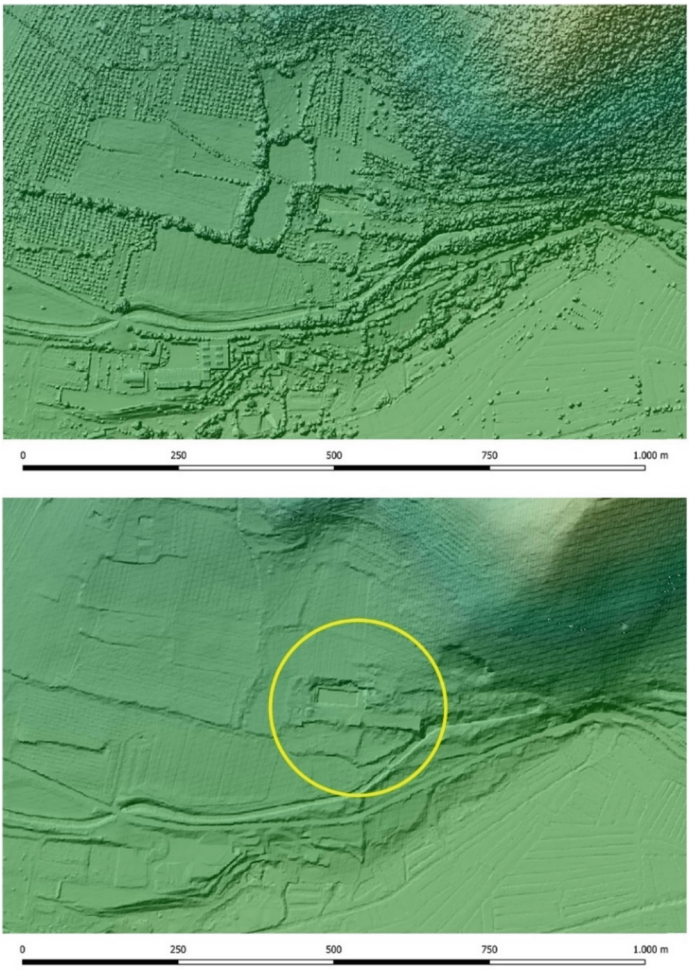

Fig. 3. DSM First and DTM Last LIDAR with 1 m of resolution (Ministero dell'Ambiente e della Sicurezza Energetica, WMS service http://wms.pcn.minambiente.it/ogc?map=/ms_ogc/WMS_v1.3/servizi-LiDAR/LIDAR_LAZIO.map&version=1.3.0)

Lastly, preventive non-invasive geophysical surveys were carried out on the first terrace with the aim of outlining in detail the route of the Via Salaria, partially identified southeast of the area. The investigations were partly overlapped with the areas investigated in 2020 by the British School at Rome, in collaboration with the Saint Mary's University of Halifax and McMaster University, using magnetometry and Ground Penetrating Radar (GPR), equipped with an antenna with a frequency of 400 MHz. These data show a complex range of structures between the road and the northern medium terrace. The continuation of the Via Salaria is clearly visible in the dataset towards west, while on the same east-west alignment a significant dividing wall is detected, behind which there are traces of some buildings [22]. In 2021, GPR surveys were repeated, as part of this project, with the aim of increasing the depth of investigation and qualitatively correlating the data with the distribution of the elevations of the entire surface. During data acquisition, the RIS K2 Georadar (IDS GeoRadar s.r.l., Pisa, Italia) was used, equipped with a 200 MHz antenna. The choice of the antenna frequency was dictated by the need to reach an investigation depth of approximately 3 m given that the road route was identified at an altitude of approximately −2.40 m from the plateau to be investigated. This, however, discriminated against the high-resolution identification of any more superficial structures. The survey covered an area of approximately 4400 m^2 through a regular grid of profiles spaced 1 m apart considering the overall size of the investigation area and the investigative purposes. In this way, the most useful detail resolution for data processing and their interpretation was obtained.

Radar reflections on each line were recorded as 16-bit data in a time window of 90 ns, acquiring 512 samples per radar scan at 25 scans per mark (unit/marker, 1). Raw data were processed using the IdsGred [23] and GPR − SLICE 7.0 software [24] using standard methodological approaches: data and trace editing, subtraction of the dc-drift (wobble) in the data, time-zero correction, bandpass filter, background removal and automatic gain. The entire data set was used to extract horizontal sections relating to different time windows equal to 4 ns with an overlap of 1–2 ns. By combining an average speed of 100 m/mm with some diffraction hyperbolas identified near specific objects, the estimate of the depth of the expected buried elements was found to be confined to the volume of soil included in the 0–3 m interval. This assessment is in agreement with the archaeological data considering that the structures excavated in the area appeared in the ground a few decimeters from the surface up to 3 m deep.

4 Results

From a preliminary analysis of historical aerial images, no elements suggesting important evidence have been identified in the excavation area. However, in the surrounding area, the presence of rather regular geometries could reflect ancient structures facing the ancient road route or simply be related to the growth of local vegetation. In particular, on the continuation of what may correspond to the route of the ancient section of the Via Salaria in the directions of Rieti (west), a rectangular-shaped anomaly of about 25 m × 35 m, overlooking the ancient route, has been identified. It is not possible to determine whether this anomaly constitutes the presence of an ancient structure or simply traces the growth of local vegetation (olive trees), but it is interesting from a topographical point of

view the correspondence of one side of this figure with what could represent the ancient route, a few hundred of meters from the area of the Baths. In Fig. 4, a high-resolution orthophoto of the currently visible thermal complex characterized by three terraces is reported. The image is georeferenced and represents the most accurate documentation of the whole structures reached until today. Both the structures pertaining to the baths and the medieval ones in the western area are recognizable. Figures 5, 6 and 7 show, respectively, the high-resolution point cloud of the thermal complex, the Via Salaria and the medieval structures coming from laser scans. Data processing is still ongoing and it is regarding the productions of horizontal plans relative to different heights and the drawing of vertical sections and side elevations.

The integration of laser scanning and photogrammetry at the via Salaria site was obtained through the projection of the images of the photogrammetric survey onto the laser model. This allowed the representation of this stretch of road through the restitution of plans, elevations and sections in different areas to have a complete documentation of a road stretch that continues below the current first terracing (it is located at a lower level than approximately 2.40 m) (Figs. 8 and 9).



Fig. 4. North-oriented high-resolution orthophoto of the archaeological complex.



Fig. 5. High-resolution point cloud of the thermal complex. The *natatio* measures a total of 60 m long, 22 m wide and 2 m high.



Fig. 6. High-resolution point cloud of the Via Salaria. The surveyed section of road measures about 30 m long by 5 m wide



Fig. 7. High-resolution point cloud of the medieval structures. The tower has a height of 10 m.

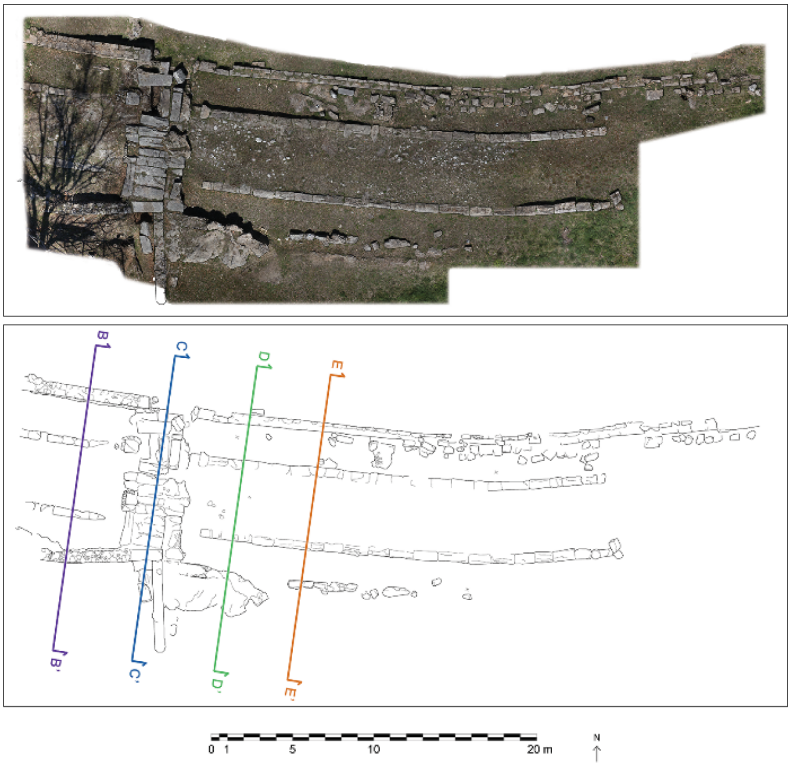

Fig. 8. Model obtained with the integration of laser scanner and photogrammetrc acquisition (top) with relative representation of the plan (bottom) of the ancient stretch of the Via Salaria. The location of the sections shown in Fig. 9 is indicated with colored lines.

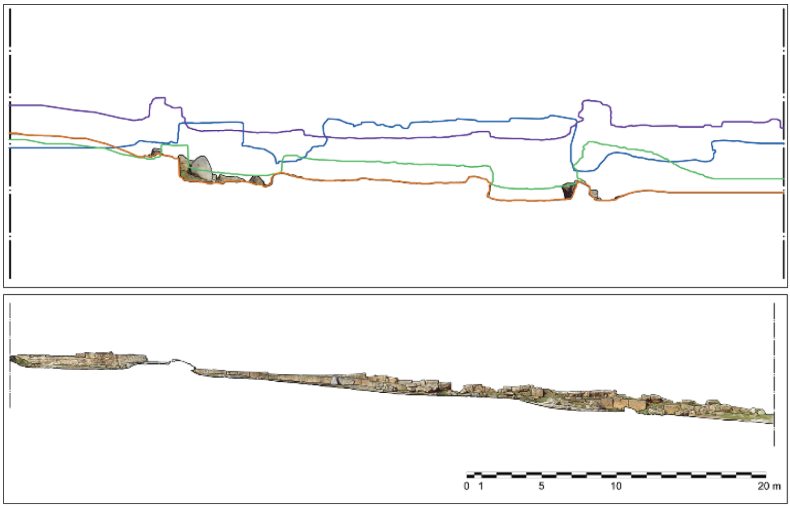

Fig. 9. Cross sections extracted by the numerical model and a longitudinal section (bottom) of the Via Salaria. The location of the sections is indicated with colored lines in Fig. 8.

Figure 10 shows some more significant horizontal sections. Image analysis allows the recognition of a complex regular system of maximum amplitudes of electromagnetic signals. Starting from the most superficial horizontal section, some anomalies with NNE/SSW orientation are noteworthy, which are most likely attributable to recent agricultural channels (two of them are partially visible in the field). From a depth close to 1 m onwards, alignments begin to be noticed which, with variable intensity, persist up to a depth of 2 m. Segment AA' appears to be the continuation of the curb of Via Salaria. However, there is an interruption about 25 m from the excavation trench, which shows the road. To the north, some probable walls can be identified that enclose large rooms. Focusing attention on the Via Salaria, the analysis of radargrams provided the approximate section along each transect. Five meters from the edge of the archaeological excavation, the profile of the road is very clear (Fig. 11, n. 1). The localization depth of the road pavement at this point is approximately 2 m. The anomaly is also visible at 11 m and 15 m (Fig. 11, n. 2 and n. 3) from the edge of the trench. Here, in the initial part of the profile, the anomaly corresponding to what could be a structure to the north of the road is also evident. At 31 m from the edge, while the hyperbola representing the wall parallel to the road appears clear, there is no clearer evidence of the Via Salaria (Fig. 11, n. 4). This interruption is approximately 30 m and it could indicate the absence of paving stones and curbs in that strip of land. Continuing towards the west, the road is detected again although at a lower altitude (Fig. 11, n. 5).

The numerical data resulting from the LIDAR and Laser Scanner detection were used for a methodological comparison with the results derived from the geophysical acquisitions. The overall and unstructured LIDAR point cloud was compared through the DSM inspection filter of the JRC 3D Reconstructor 4.4.2 software with the laser scanner data, acquired some time before at a time when no vegetation was present (Fig. 12) [25, 26].

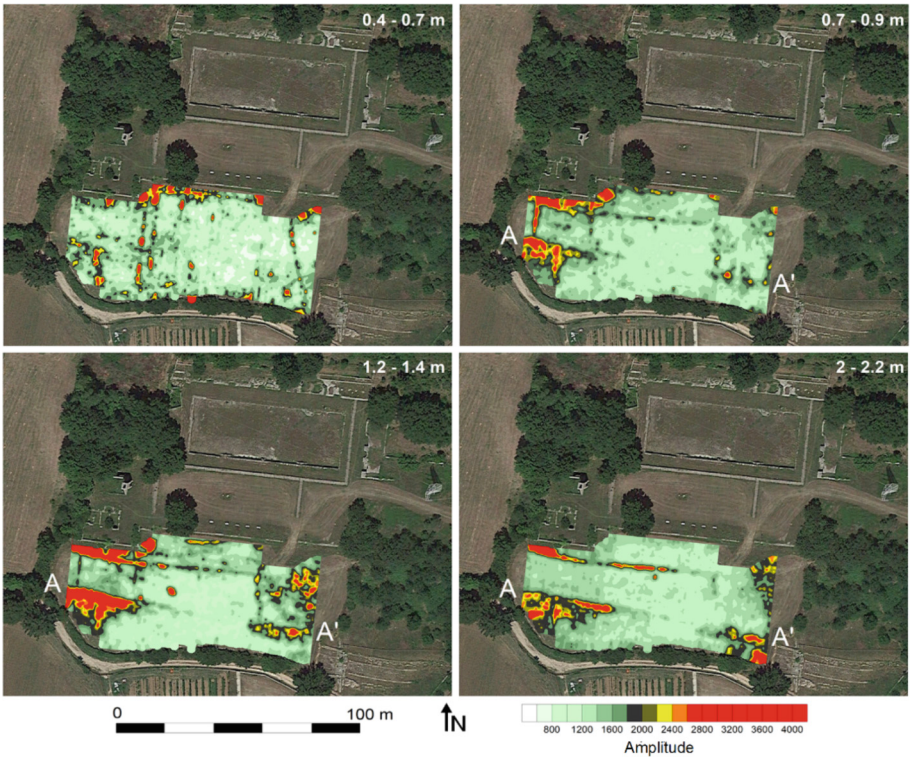

Fig. 10. Horizontal sections relating to various depths overlapped on Google EarthTM satellite image.

This filter was used on some specific areas, in particular the lower terrace and the large basin in order to better define the anomalies present in the area. The filter is based on the analysis of the differences in the relative altitudes of the part examined and is therefore able to clearly highlight what is on the ground from what is vegetation.

Once an auxiliary plane placed at a predetermined distance has been created, the relative elevation values with respect to the plane are associated and the differences are calculated. Usually the inspection filter is based on the definition of a plane positioned at a predefined distance; the reference numerical model is subtracted from this plane. From this subtraction, a false color map is obtained with respect to the elevations. The choice of the position of the plane strongly influences the result of the final map.

In this case, however, it was decided to use the inspection filter by subtracting from the LIDAR numerical model the one acquired from the ground with the laser scanner in the same area. In this way, the displayed map corresponds to the difference in height of the vegetation present in the area.

The available data made it possible to use this filter in an experimental configuration for which it was possible to identify the different relative heights of the surrounding vegetation in false colors.

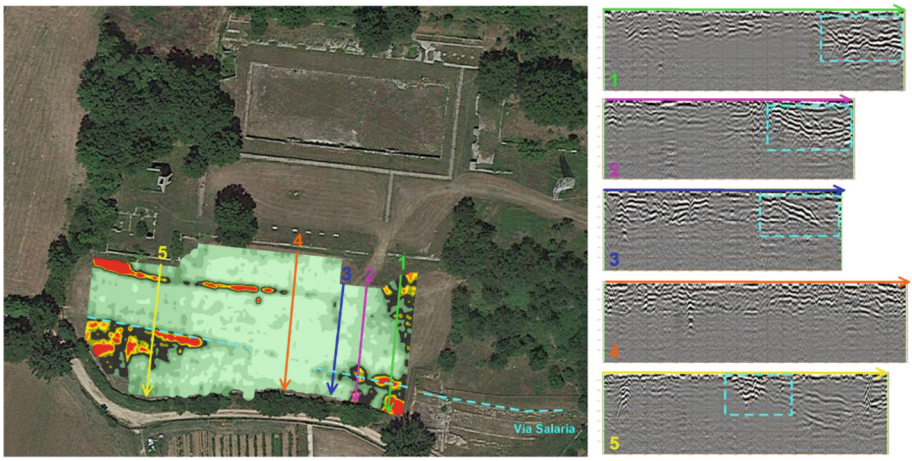

Fig. 11. Examples of radargrams, the location of which is shown on the section relating to the depth of 2–2.2 m, with indication of the anomalies attributable to the presence of the Via Salaria (in blue).

The growth of vegetation on the lower terrace is particularly interesting when compared to the anomalies found in the geophysical results (Fig. 12). The comparison between the two images of the figure suggests an affinity between what is visible on the surface and what is below the walking surface up to a height of −0.9 m. The direction and some forms of the vegetation give us indications on how the road axis must have developed in this part of the terrace.

This experimentation certainly allows us to analyze the methodologies used in greater detail and see for example, based on vegetative growth, how much anthropic material we should expect below and possibly at what altitude.

The same experiment was also conducted inside the large *natatio*. In this case, the area was not investigated with geophysical surveys, but the result of the anomaly is clearly visible (Fig. 13). In the figure, inside the basin, it is possible to find an off-centre rectangular shape of more than 25 m on a side in the south direction, located at a lower level than the surface of the basin, which suggests older phases or buried structures.

Other areas have also been further mapped with this processing to give greater prominence to possible anthropic anomalies invisible on the raw data. The analysis performed in this way was particularly effective not so much on wooded areas but on those where the grass grew in a differentiated manner. In other cases, it will be necessary to have further confirmation with the results of the geophysical activities.

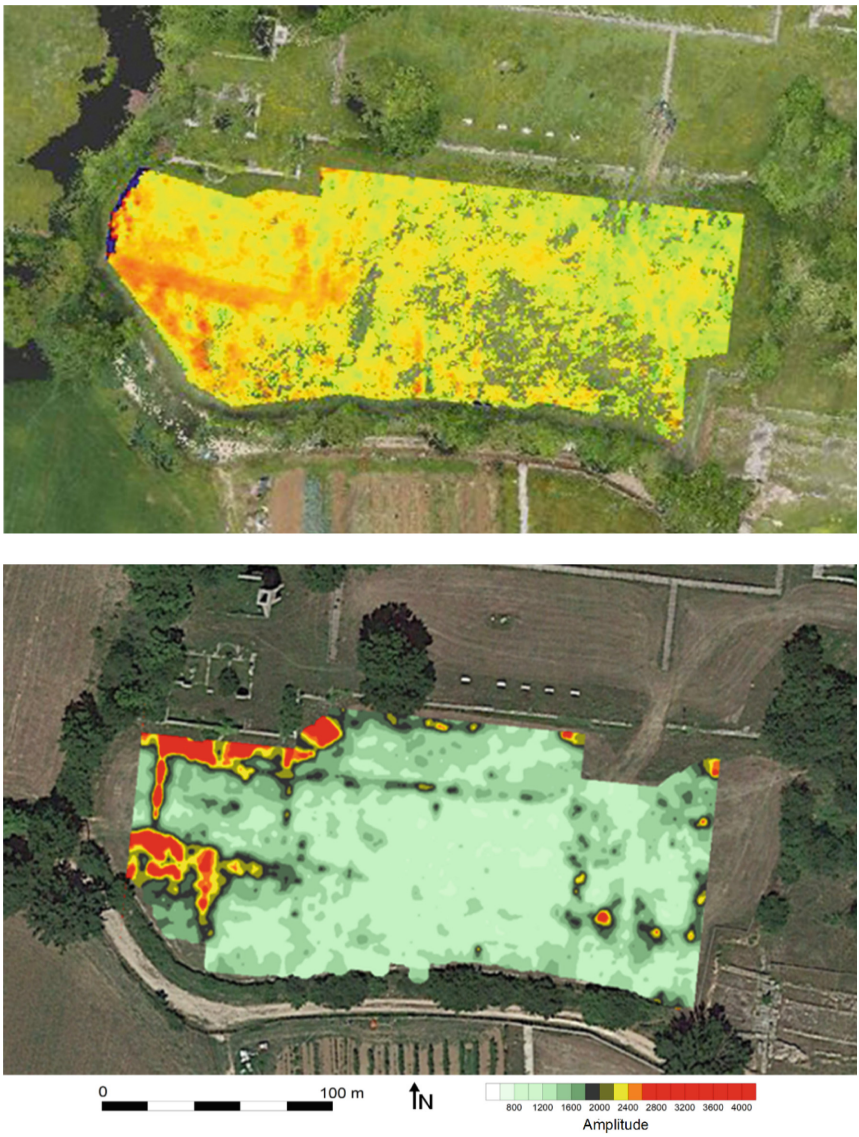

Fig. 12. Comparison of the geophysics results (bottom) and those deriving from the inspection filter (top) which shows an affinity in the representation of the anomalies.

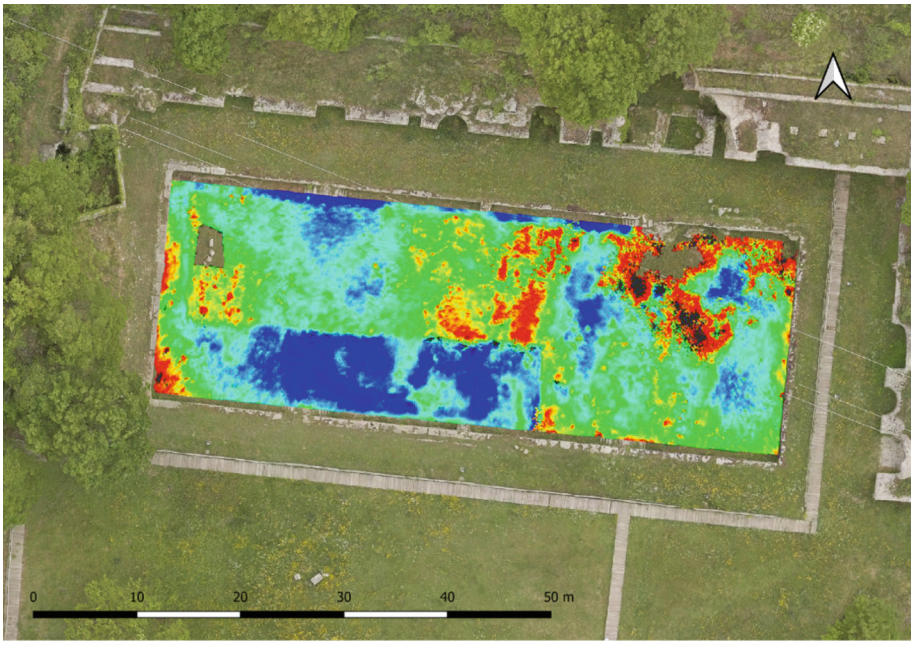

Fig. 13. Application of the inspection filter on the area of the *natatio*, which highlighted a possible rectangular anomaly inside the *natatio* itself.

5 Conclusions

The integrated reading of the territory on a large scale is now necessary for any archaeological study through the use of aerial, drone or LIDAR images, but above all numerical data present in different databases or acquired at the moment. The numerical data available, combined with zenithal and oblique shots, allow an interpretation of anomalies that has never been achieved, and to identify archaeological structures or real inhabited centers that are in fact not visible.

The contribution of new technologies has actually paved the way for the use of instruments capable of mapping a large area and the surrounding territory directly from below, which was unthinkable until a few years ago. The same applies to photogrammetric processes, which moreover now also benefit from drone acquisitions at very low altitude, as well as geophysical systems that have been mapping the territory below ground level for many years.

The acquisition of millions of pieces of information during survey campaigns allow us to position ourselves at an advantageous point for the final interpretation of the data, and from which we can associate different levels of detail and heterogeneous data as long as they are in the same reference system.

This is what was pioneered at the Baths of Vespasian and is often applied in the survey of ancient centers. The reading of a territory can now make use not only of images from above but also from diversified multiscale territorial analysis systems that concur toward the same result.

The research work highlighted the importance of cross-skills and diverse approaches in calibrating study methodologies and obtaining more information about the territory under investigation.

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References

1. Betori, A., Licordari, F., Piermattei, P.: Lungo il corso del Velino. Officina Edizioni, Roma (2021)
2. Levi, A.L.M.: Itineraria picta, L'Erma di Bretschneider, Roma (1967)
3. Guattani, G.A.: Monumenti sabini II. Tipografia Puccinelli, Roma (1828)
4. Istituto Superiore per la Protezione e la Ricerca Ambientale website, https://www.isprambiente.gov.it/en/databases/data-base-collection/soil-and-territory/geological-and-geotematics-map. Accessed 21 Mar 2024
5. Varrone: De lingua latina. 1th edn., 711 (47–44 BC)
6. Seneca: Naturales Questiones. 1th edn., III, 23 (62–64 BC)
7. Plinio il vecchio: Naturalis historia. 1th edn, libro II, 951 – 3 (77–78 BC)
8. Persichetti, N.: Viaggio archeologico sulla Salaria nel circondario di Cittaducale. Editrice E.R.A., Roma (1893)
9. Santangelo, M: Aquae Cutiliae. FA XXX-XXXI, 2, n. 11661 (1975–76)
10. Reggiani, A.M.: Le Terme di Cotilia. Archeologia Laziale, Quaderni del Centro di Studio per l'archeologia etrusco-italica **III**, 91–98 (1979)
11. De Palma, G.: Terme di Cotilia. Archeologia Laziale. Quaderni del Centro di Studio per l'archeologia etrusco-italica. **VII**, 185–192 (1985)
12. Alvino, G.: Sabina e Cicolano: archeologia, storia e territorio, in Lazio e Sabina. In: Atti del Convegno Nono Incontro di Studi sul Lazio e la Sabina (Roma 27–29 marzo 2012), pp. 97–104, Edizioni Quasar, Roma (2012)
13. Ceraudo, G., Shepherd, E.: Italian aerial photographic archives: holdings and case studies. In: Cowley, D.C., Standring, R.A., Abicht, M.J. (eds.) Landscapes Through the Lens: Aerial Photographs and the Historic Environment (Occasional Publication of the Aerial Archaeology Research Gr), pp. 237–246. Oxford Books, Oxford (2010)

14. Tarquini, S., Isola, I., Favalli, M., Battistini, A., Dotta, G.: TINITALY, a digital elevation model of Italy with a 10 meters cell size (Version 1.1). Istituto Nazionale di Geofisica e Vulcanologia (INGV) (2023)
15. Tarquini, S., Isola, I., Favalli, M., Mazzarini, F., Bisson, M., Pareschi, M.T., Boschi, E.: TINITALY/01: a new triangular irregular network of Italy. Annals of Geophysics (2007)
16. Verhoeven, G.: Taking computer vision aloft—Archaeological three-dimensional reconstructions from aerial photographs with photoscan. Archaeol. Prospect. **18**, 67–73 (2011)
17. Cutugno, M., Robustelli, U., Pugliano, G.: Structure-from-Motion 3D Reconstruction of the Historical Overpass Ponte della Cerra: a Comparison between MicMac® Open Source Software and Metashape®. Drones **6**, 242 (2022)
18. Angelini, A., Portarena, D.: Advice for archaeological survey with recent technologies. Acta IMEKO **7**, 42–51 (2018)
19. Angelini, A., Cozzolino, M., Gabrielli, R., Galatà, P., Gentile, V., Mauriello, P.: Integrated methodologies for the survey and the documentation of two byzantine churches at the UNESCO archaeological site of Umm ar-Rasas (Jordan). In: Gervasi, O., Murgante, B., Misra, S., Rocha, A.M.A.C., Garau, C. (eds.) Computational Science and Its Applications – ICCSA 2022 Workshops. ICCSA 2022. LNCS, vol. 13382. Springer, Cham (2022). https://doi.org/10.1007/978-3-031-10592-0_39
20. Angelini, A.: Tecniche di rilevamento e metodi di rappresentazione per l'Architettura Rupestre. Il Monastero Benedettino di Subiaco. BAR International Series, Oxford, S2889 (2018)
21. Ministero dell'Ambiente, Geoportale Nazionale website. http://wms.pcn.minambiente.it/ogc?map=/ms_ogc/WMS_v1.3/servizi-LiDAR/LIDAR_LAZIO.map. Accessed 21 Mar 2024
22. Kay, S., Pomar, E., McCallum, M., Beckmann, V.: Geophysical survey projects 2020–2021: investigations in the Sabina. Papers Br. Sch. Rome **89**, 350–352 (2021)
23. Ground Penetrating Radar, Products. www.idsgeoradar.com. Accessed 21 Mar 2024
24. Goodman, D.: GPR-SLICE. Ground Penetrating Radar Imaging Software. User's Manual. Geophysical Archaeometry Laboratory, Los Angeles, CA, USA (2004)
25. Cozzolino, M., Gabrielli, R., Galata, P., Gentile, V., Greco, G., Scopinaro, E.: Combined use of 3D metric surveys and non-invasive geophysical surveys at the stylite tower (UMM AR-RASAS, JORDAN). Ann. Geophys. **62**(3), 1–9 (2019)
26. Angelini, A., Cozzolino, M., Gabrielli, R., Gentile, V., Mauriello, P.: Three-dimensional modeling and non-invasive diagnosis of a huge and complex heritage building: the patriarchal basilica of Santa Maria Assunta in Aquileia (Udine, Italy). Remote Sens. **15**, 2386 (2023)