The Latin Colony of *Aesernia*:

integrated urban geo-archaeology researches realized through a combined use of historical sources, archaeological survey, 3D photogrammetric reconstructions and non-invasive geophysical prospections.

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Abstract: In this paper we present the results of integrated urban geo-archaeology researches realized through a combined use of historical sources, archaeological survey, 3D photogrammetric laser scanner and non-invasive geophysical methods such as ground high resolution penetrating radar and geoelectrical tomography. We propose the analysis of the Latin Colony of *Aesernia*.

The city, founded in 263 BC, was developed on a river terrace bordered by steep escarpments and was surrounded by walls built using the technique of *polygonal opus*, *opus quadratum*, *opus reticulatum* and *opus incertum*. The temple of the Latin colony of *Aesernia* was built in that place within the walls considered by the colonists the most dominant of the city and was situated at the junction of the particular road system of the city consisting of a north-south oriented *cardo major* and different east-west oriented parallel *decumani*. The Latin colony of *Aesernia* had some thermal baths, both public and private, located in the south about 800 m from the southern-east boundary of the city wall. The position of the *forum* and the theatre of the city is still uncertain.

Geophysical surveys and 3D photogrammetric reconstructions carried out within and outside the city walls have provided interesting data and filled many gaps in the knowledge of the colony. In a global analysis the use of multiple source systems was very useful for planning the archaeological research and a sustainable management of the cultural heritage.

Keywords: the Latin colony of *Aesernia,* archaeological survey, 3D photogrammetric reconstructions, non-invasive geophysical prospections.

Introduction

Isernia (N 41°35’49” E 14°14’07”) is a small town of 68.74 square kilometres located in Central Italy, in the Region of Molise (Fig. 1). The city, situated at 442 m above sea level, lies on a river terrace which is formed in travertine in the upper part, alluvial materials in the central part and limestone in the terminal one. The hill is surrounded by two deep and steep valleys formed by the slow erosion of the rivers Carpino in the east and Sordo in the west and it is surrounded by the Matese Mountain in the east and by the chain of Mainarde in the west. This spur of rock is characterized by a marked slope; in fact it shifts from 442 m to 397 m with 45-metre-drop above sea level. The shape of the hill and the presence of the two valleys have prevented the

expansion of the city limits to the east and west favouring, in recent years, the development of the northern limit of the ancient settlement thanks to the special topography of the city which is narrow, elongated, almost sinuous and decreasing in the southern section. In Roman times it became an important road junction for communications, especially in the south with *Bovianum* and *Beneventum*, in the north with *Aufidena* and the Sangro Valley, in the west with Venafrum and the Valley of the Liri.

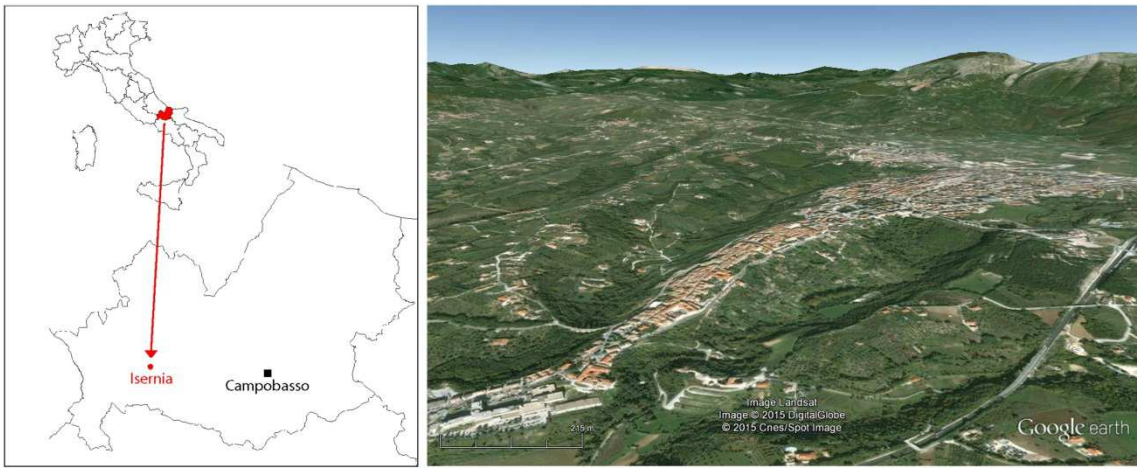

Fig. 1 – Isernia (Molise Region, Italy): location (left) and tridimensional view of the city (Google Earth image).

The foundation of the Latin colony of Aesernia is to be included in the control operation of strategic centres and population realized by Romans between the end of the IV and the first half of the II century BC, at the beginning of the Punic Wars, in order to strengthen the internal control over mountain passes and the connection with the Apulia. At the end of the war against Pirro (280-275 BC), Rome materialized this policy in the strip of territory at the border with the Samnites, through the deduction of colonies in Aesernia (263 BC) and Beneventum and the attribution of the status of prefecture to Venafrum, Atina and Casinum (TERZANI 2001).

Inside the historical centre of the city of Isernia, ruins attributed to ancient walls of the circuit of colony are visible (Fig. 2). Depending on the cutting block, the installation and positioning of them, different masonry techniques are classifiable. They correspond to the different life stages of the perimeter wall itself, i.e., opus polygonal, opus quadratum, opus incertum and opus reticulatum. Within the Latin colony of Aesernia, the settlers built a temple in the most dominant place within the walls of the city (ZEVI 1981). It was placed to the intersection of the particular road system of the city, consisting of a north-south oriented cardo maior, and many east- west oriented parallel decumani (LA REGINA 1968, MARASCO & DE ROSE 2000). Also this colony, like all Roman cities, possessed same thermae, probably both public and private, located in Via S. Ippolito, about 800 m from the south-east limit of the city walls (TERZANI 1989). Moreover, the city was supported by an aqueduct that, from the slopes of the mountains of Miranda to the outskirts of the modern town, was developed along a fairly linear north-south oriented course and bended south-west towards the town of Isernia. A first section (about 1950 m) was open air while the next one (about 1431 m) was set in gallery. The castle of water distribution is located outside the city walls that are at the end of Corso Garibaldi in the former washhouse. From that place the branches within the town are not fully known although the presence of several tanks and cisterns is confirmed (CIARLANTI 1644, TERZANI 2001, RAMUNNO 2001).

This work focused on integrated techniques of geophysical surveys, topographic and three-dimensional photogrammetric reconstructions and archaeological studies about the urban plan of Aesernia. In the first phase the occupation during the pre-Roman period of the study area was analyzed putting into evidence the differences among the settlements chosen by the Samnites respect to the Romans. Then all archaeological pieces of the Roman period, both urban and suburban, were treated in a systematic way, trying to provide the richest general framework as possible. Subsequently, from time to time, geophysical prospections were realized using the proper method with the aim to detect any invisible heritage. Moreover, three-dimensional techniques of photogrammetry were applied in order to obtain 3D models of the Visible Heritage for a better definition of the urban structure of the ancient colony of Aesernia.

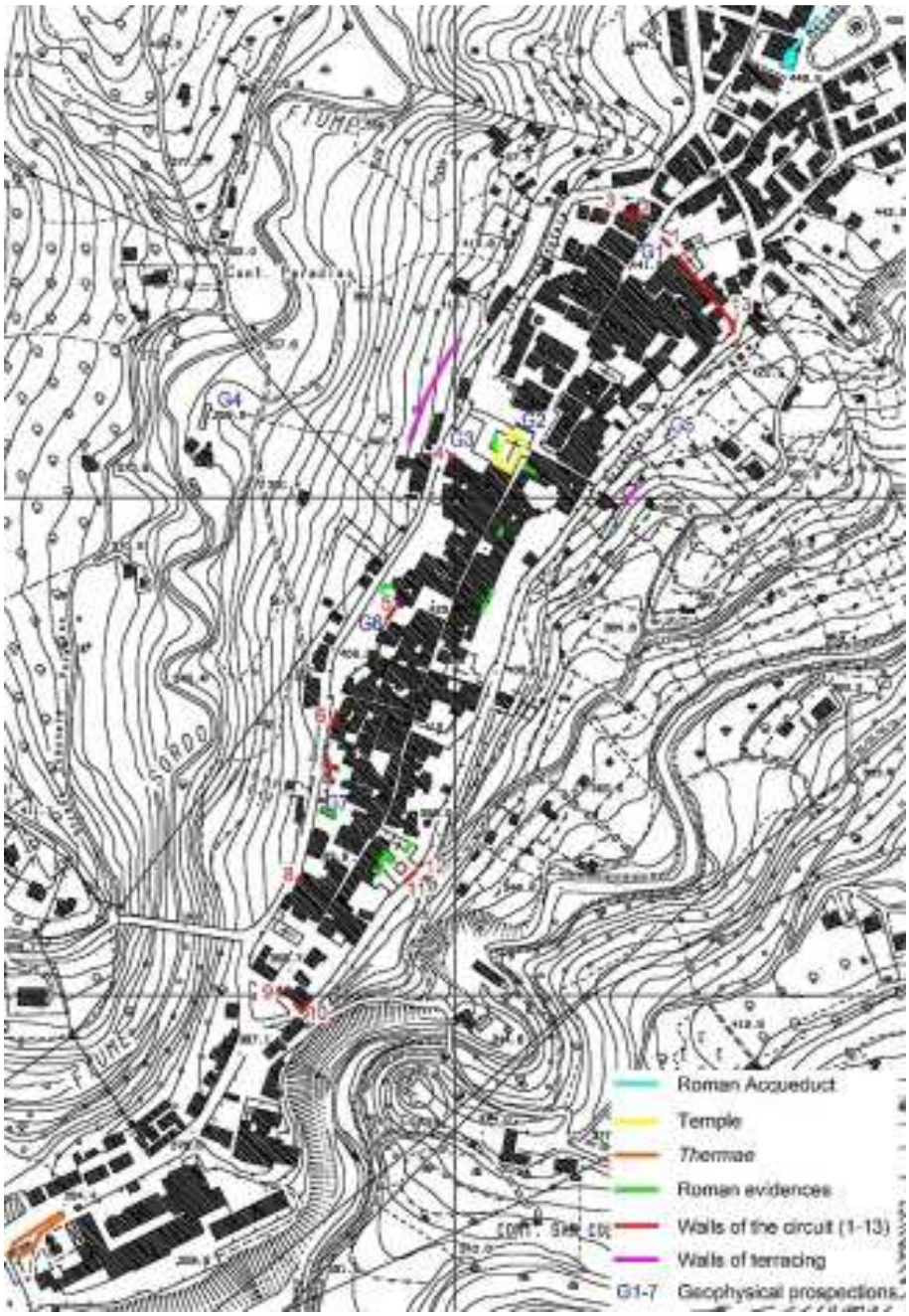

Fig. 2 – Isernia (Molise Region, Italy): Roman evidences and location of geophysical survey areas.

Three-dimensional models of visible traits of ancient walls of the circuit

Inside the historical centre of Isernia, thirteen ruins belonging to ancient walls of the city are visible (Fig. 2). In this work each segment was analyzed according to a few characteristics such as positioning (location, source, reuse and shares), building technology (absolute and relative size of the individual blocks, construction material, type of work, the presence or absence of ligands), stratigraphic reports (any structures they are supported or covered by) and history.

The polygonal technique was applied to the first group of construction, i.e. the phase of foundation of the colony (263 BC). The limestone blocks (travertine) are arranged in parallel rows with an average size of about 1 m per 2 m. The most imposing evidence built with this technique is visible in the north of the historic centre, in Piazza Celestino V (walls No. 1 in Fig. 2). They are reunited, on the north-west side, with the walls situated in the restaurant Osteria Antiche Mura (walls No. 2 in Fig. 2). They continue also outside the building, towards the road that leads to Piazza Fascitelli, but they were heavily damaged during the modern era (walls No. 3 in Fig. 2).

Another building technique used in the Latin colony of *Aesernia* is the *opus quadratum*: it probably corresponds to a phase of reconstruction that took place following the social *bellum*. The limestone blocks are characterized by single segments that have an average height of 0.5 - 0.7 m and a maximum width of 1.20 m. The blocks are square and linear in the horizontal and vertical planes, thus creating a provision in horizontal rows. The face view of the individual blocks is almost smooth and in general, the first row protrudes a few centimetres with respect to the veneer in order to form a bedding for subsequent rows. Near Rampa Giobbe, outside the wall of Palazzo Vescovile, it is possible to notice two sections of masonry, in particular three rows of blocks in *opus quadratum* which probably continue below the current street level (walls No. 4 in Fig. 2). A few metres in the southern direction from the latter part of the circuit, a segment is visible inside the walls of Palazzo D'Avallos Laurelli (walls No. 5 in Fig. 2). Continuing along Via Occidentale, it is possible to see a stretch of blocks in *opus quadratum* and molded stones for reuse (walls No. 6 in Fig. 2). In this context a stone with denticulate decoration, a semi column, a drainage channel in limestone and a molded stone in floral characters can be seen. These blocks probably refer to a Roman public building dismembered at a short distance from the place of reuse. A few metres in south direction, inside the perimeter wall of a private house, another mixed *opus quadratum* and *opus polygonal* stretch of blocks is visible (walls No. 7 in Fig. 2). In 2009, during the renovation of the house, several limestone blocks of considerable size (about 10 m in length) emerged. This structure has the same physical characteristics of the polygonal blocks of the colony circuit, but it resulted orthogonally oriented towards the outer walls. Considering its location, it could be interpreted as a huge urban terrace wall or a fence boundary of an important public area of the colony (FASANO 2011).Going on to south, inside a medieval tower, there is a section formed by seven rows of square blocks (walls No. 8 in Fig. 2). In the southern part of the historic centre, where Corso Marcelli ends, there are two lined up blocks that border the roadway (walls No. 9 in Fig. 2). Considering their arrangement, they could be associated to the city walls (TERZANI 2001). The south eastern corner of the city wall is still visible at the beginning of Via Roma (walls No. 10 in Fig. 2). This part of the walls is characterized by limestone blocks in travertine built using the polygonal technique. Proceeding along Via Roma, in correspondence of the Monastery of Santa Maria delle Monache, three sections of walls of different manufacture can be detected (walls n ° 11-12 in Fig. 2). The first section shows reworked blocks,

the second and the third one are interpreted as two spurs of parallelepiped blocks, well-squared, partly uneven, which could have the function of buttress. At the end of Via Roma, in a private home, there is the northeast corner of the perimeter walls consisting in two segments built in *opus polygonal* (walls No. 13 in Fig. 2). Then they continue in the ground floor of a building placed in Vico Concezione.

Along the municipal road of Ponte Marana, downstream of Via Occidentale, three rows of blocks in polygonal technique can be seen. As much as we know it is not possible to understand whether they correspond to terraces or a hypothetical second wall circuit (DRAGO 1983).

Within the walls, in Via Mazzini, a well-preserved stretch of wall in *opus quadratum* is visible. This segment may indicate the presence of a possibly public building considering the close connection with the temple of the Latin colony.

The unique example built in *opus reticolatum* is attested by a photographic documentation. The wall segment is currently covered by plaster and located in a medieval tower in Piazza Annunziata.

For each section three-dimensional models were realized using the ZScan Software (Menci Software). Fig. 3 shows some three-dimensional reconstructions obtained using this technique.

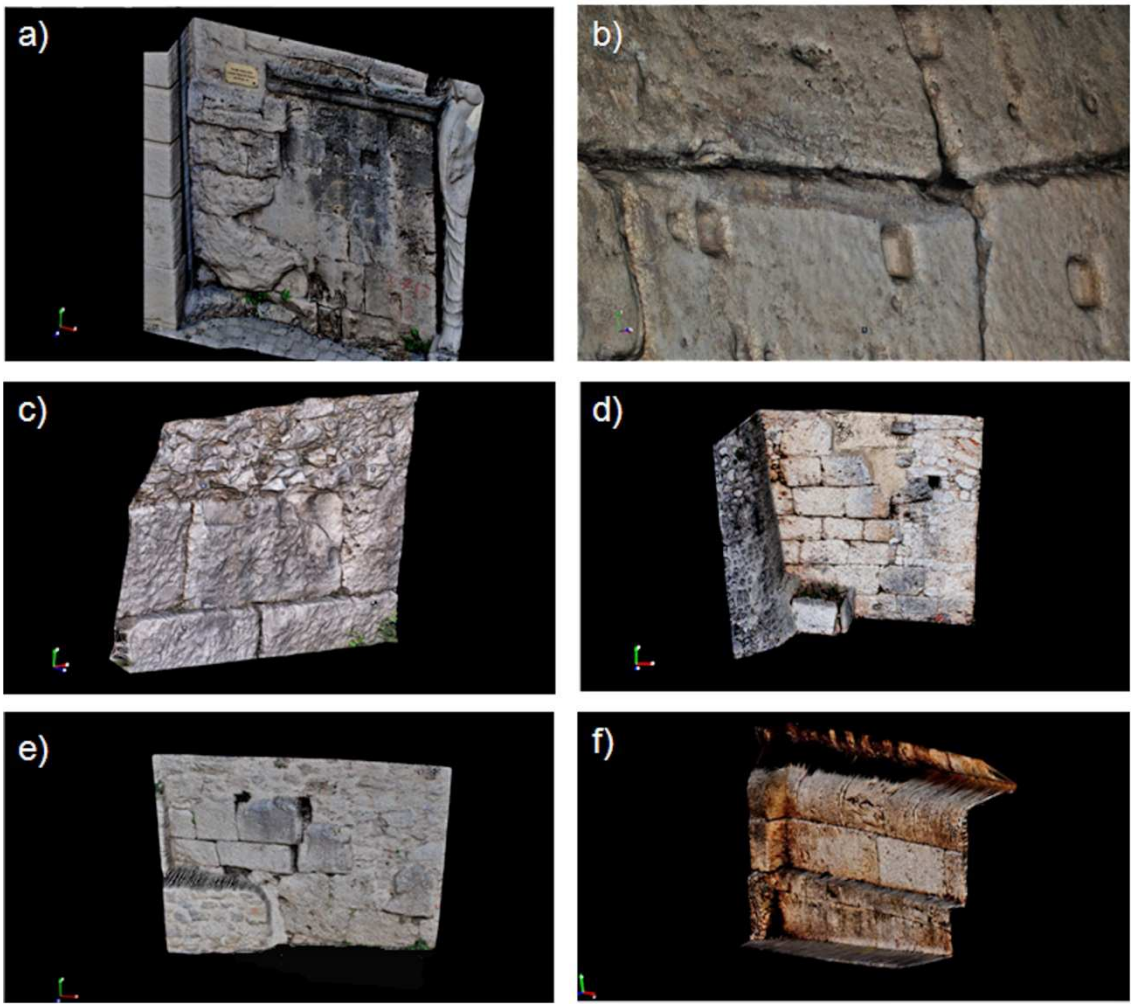

Fig. 3 – Isernia (Molise Region, Italy): three-dimensional models: a) detail the temple ara, b) detail of wall No. 2, c) detail of wall No. 5, d) walls No. 8, e) walls No. 4, f)) detail of the podium of the temple.

This technology is based on digital photography and the principles of stereo-photogrammetry that can effectively supplement or replace the laser scanning survey (MENCI et al 2007). Indeed, acquiring more frames and in accordance with certain rules of recovery for the total covering of the object, it is possible to provide geometries at different levels of complexity and in the form of point clouds with associated contextual metric information. In order to make the set of photographic data measurable, shots are realized under known conditions. The digital camera can slide on a special trolley placed on a calibrated steel bar, in which some holes have been prepared, at known distances. They represent the possible positions of the shutter. The shots are taken in sequence (left to right) from different positions, with the foresight of adjusting the interval between them in relation to the distance of the object that must be captured. It will then be entrusted to a sophisticated algorithm of image analysis the processing of the individual pixels of the digital images in a cloud of points with known coordinates in space with the colour information in RGB format. 3D models are virtual reconstructions of great visual impact and a valuable teaching aid because they exactly reproduce the original appearance of the depicted item. The models may be useful to researchers to perform any type of study but they are especially helpful for the creation of a 3D virtual store that could be used to build multimedia platforms for a museum and promote restoring interventions useful to preserve the analyzed Heritage.

The work has immediately proven to be useful for the conservation of the historic and archaeological identity: on 14 March 2013 a section of circuit suddenly collapsed (walls No. 6 in Fig. 2, Fig. 4). The main cause of the landslide was a heavy rainfall that gave rise to the movement of a part of the outer walls of a private house located in the terrace above the ancient segment. At present we cannot determine whether the wall has been affected or not by the collapse because the debris has not removed yet and the wall is not visible. If we should consider the worst case, i.e. the wall is completely collapsed, it would meant that we lost an important evidence of the past and the 3D model could be useful to promote restoration activities or perform any type of study.

Fig. 4 – Isernia (Molise Region, Italy): a) data acquisition, b) three-dimensional model of wall No. 6, c) the place after the collapse.

Application of Geophysical Prospections

The application of geophysical surveys, such as the Electrical ResistivityTomography (ERT) and the Ground Penetrating Radar (GPR), has been an important tool for the understanding and recognition of information in order to detect the presence of anomalies and highlight the geometry of buried sources (COMPARE et al 2009, 2010, GOODMAN 1994, MALAGODI et al. 1996, MAURIELLO & PATELLA 1999, 2009).

In the ERT method a four-electrode array is applied in order to estimate the intrinsic resistivities of the media composing the subsoil under investigation. Two electrodes are used to inject a pre-selected current into the ground and two other electrodes are used to measure the resulting potential differences on the ground surface. An apparent resistivity parameter is determined at each position of the array by multiplying the measured resistance opposed by the ground to the current flow. However, due to the spreading of the exciting current from the current electrodes all over inside the solid half-space, the apparent resistivity generally differs from each of the intrinsic resistivities because, in inhomogeneous subsoil, the global influence of different volumes with different intrinsic resistivities is detected. The result is that the apparent resistivity is a volumetric average of all of the intrinsic resistivities underground, calculated through a complex weighting function dependent on the four electrode device and how it is used (COZZOLINO 2012).

In this work the MAE A3000TM resistivity meter (www.mae-srl.it) was used adopting a dipole-dipole array. Resistivity profiling involved the lateral movement on a single line of the array of fixed size, with a constant electrode separation of 1m. The dipole-dipole (DD) array has the characteristic of having the receiving electrodes aligned with the energizing electrodes and has the ability to let better delineate lateral resistivity changes (PARASNIS 1997). Resistivity mapping was used as a logical extension of resistivity profiling to a sequence of parallel lines: when one traverse was finished, the array was moved to the next parallel line (in

our case the distance between profiles was fixed at 1 m) and so forth until the area of investigation was covered. The apparent resistivity values were then plotted on a map typically displayed in the form of grilled contours (KURAS 2002). A numerical inversion procedure was needed to convert the measured apparent values into real resistivities. We have used the probability-based ERT inversion (PERTI) method (MAURIELLO & PATELLA 2009), which is a fast, reliable inversion tool directly derived from the principles of the probability tomography (PATELLA 1997, MAURIELLO & PATELLA 1999).

In GPR prospections an electromagnetic signal is emitted into the ground by an antenna; the electromagnetic wave propagates through the medium and, when it impinges on a non-homogeneity in the electromagnetic properties (a buried target), a backscattered electromagnetic field arises. If the time for the pulse to go to the reflector in the ground and return to the receiving antenna (the two way time) is measured, the position of the reflector can be determined when the velocity of the pulse in known (PARASNIS 1997). By moving the antenna system along a selected profile above the ground surface a two-dimensional reflection profile (radargram) is obtained in which, for each location of the antenna system, a trace is achieved where the amplitude and the delay time of the recorded echoes (that can be related to the depth of the underground reflectors) is drawn (DANIELS 1996). During data processing, complex algorithms, such as band pass filters and Automatic Gain Control, were applied in order to remove high and low frequency anomalies that occurred during the data acquisition, normalize the amplification and also remove reflections generated by noise due to the different signal attenuation. Thus, using a sequence of parallel lines, a three-dimensional matrix was generated and time-slices were realized at chosen intervals. Within the slices, low amplitude variations express small reflections from the subsurface and, therefore, indicate the presence of fairly homogeneous material. High amplitudes denote significant discontinuity and often show the presence of buried objects in the subsoil or cracks and ruptures in the stonework. A definite change between high and low amplitudes may indicate the presence of a buried interface between two media.

Thanks to the characteristic of the implemented non-invasive methods, it was possible to obtain a three-dimensional reconstruction of hidden structures in a particular environment, such as the historic centre of Isernia, where the logistical problems represent a major obstacle. The analysis of the subsurface was applied to different sites located within or immediately outside the walls. Here, for example, the results of surveys in sites G1-G4 (located in Fig. 2) are reported.

The first geophysical surveys (G1 in Fig. 2) were carried out in Piazza Celestino V where excavations brought to light a section of the walls of the colony (walls No. 1 in Fig. 2). Ground Penetrating Radar was performed and the data processing allowed obtaining a map relative to 1 m depth in which very interesting geophysical anomalies are highlighted. In particular in the northern part of the wall a strong concentration of high amplitude spots was measured and it could be interpreted as the presence of the continuation of the wall into the subsoil (Fig. 5a). In the west side of the survey area an anomaly with an inverted V shape is visible and could correspond to the angle of a buried structure. On the east side of the trench excavation, small straight anomalies were identified and they seem to be the continuation of some medieval walls leaning on the wall in polygonal technique.

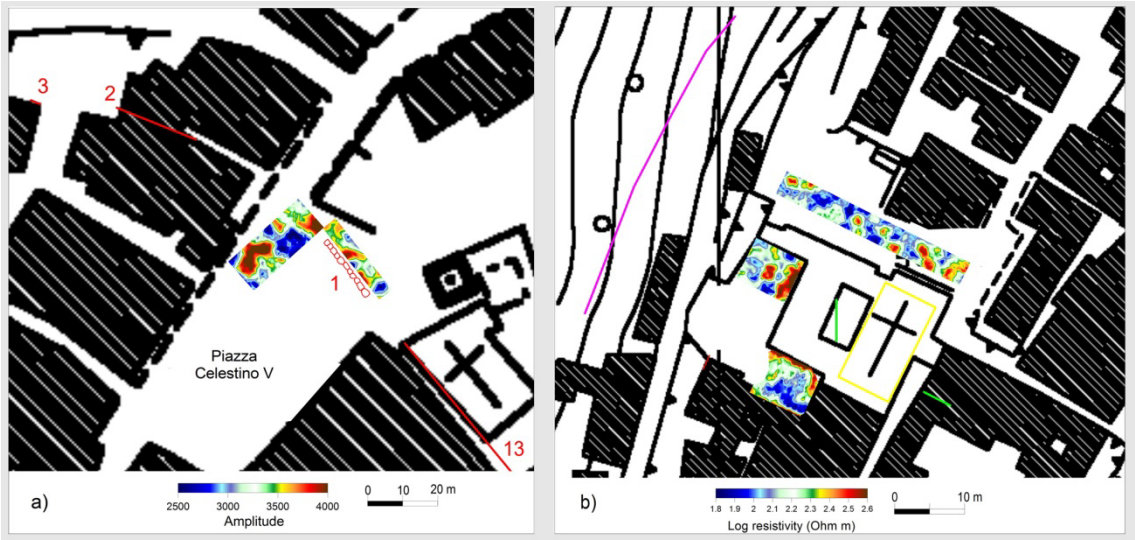

Fig. 5 – Isernia (Molise Region, Italy): a) georadar tomography relative to 1 m depth realized in Piazza Celestino V (G1), b) Electrical Resistivity Tomography relative to G2 and G3 survey areas.

ERT surveys were realized in the area surrounding the Cathedral located in Piazza Andrea d'Isernia (G2 and G3 in Fig. 2). In G2 site, the map surface relative to 1 m depth showed two interesting parallel anomalies with high resistive values. They are in the north side of the Republican temple and might indicate the presence of connected buried structures (Fig. 5b). G3 site is located inside the garden of the bishopric, in the west side of the church. The electrical tomography highlights two interesting high resistive anomalies. The first, located at the centre of the investigated area, is easily identifiable and has a shape of a rectangle of 2.5 per 4.0 m. Considering the small size of the anomaly, it could be interpreted as the image of a probable altar or base of a statue. In the south-west area, another high resistive anomaly of about 10 m in length can be identified. It could be interpreted as a portion of a public building of considerable size. In the south portion, at the front entrance of the Republican temple, a state of high conductivity prevails and it could be the evidence of an open area, probably paved, in complete synergy with the urban planning of the colony.

The last site is located outside the urban plan (G4 in Fig. 2), in Località Paradiso, where a particular soil anomaly was identified. This element, hardly attributable to a natural geomorphologic formation, is clearly visible as it is located on a mezzanine floor over the surrounding land (Fig. 6, right image). The area occupies a semicircle area with a radius of 25 m and is completely covered by vegetation. An analysis of the surface brought to light few fragments of Roman pottery, probably leached from above areas, and a few metres from the site stones in molded limestone were identified in a complete state of abandonment. After a first analysis of such irregularities, it is possible to think that this site is associated with the presence of a submerged structure of the same semicircular shape. The site is located about 150 m from the circuit perimeter of the colony and at a lower level than the village. In Fig. 6 (left image) the hypothetical road linking the site to the suburban colony is highlighted.

Fig. 6 – Isernia (Molise Region, Italy): location of G4 site and hypothetical road linking the site to the suburban colony (left) and view of the semicircle structure (right).

Based on these considerations an ERT survey was planned in the area in order to understand the morphology of the structure. 15 intersecting profiles were arranged, with profile lengths equal to 31 m. The ERT dipole-dipole mode was used with a 1 m dipole spread. Along each profile, the dipoles were displaced and spaced at steps of 1 m, up to the maximum pseudodepth. About 5500 datum points were collected. In the shallowest horizontal real resistivity slices at 1 m depth, a high resistive anomaly appears near the edges of the semicircular area and a low resistivity situation is visible in the central portion (Fig. 7a). In order to combine the Probability Electrical Resistivity Tomography Inversion (PERTI) results in a unique 3D representation and give some more insight into the observed anomalies, a three-dimensional tomospace of the real resistivity space was realized. For better disclosing nature and shape of the resistive structures, a smaller space (the portion of the south-east semicircular area) has been contoured using as the cut-off resistivity the mean resistivity value. All of the isosurfaces corresponding with resistivities below the cut-off resistivity has been blanked (Fig. 7b). This presentation presumes the probably presence of an articulated structure on split levels. The geophysical anomalies emerged from the survey suggest the presence of a semicircular public building that was a probably theatre. Despite the plausible and obvious correspondence between the geometry of the geophysical results and the architectural design of a theatre, the geomorphology of the area does not seem to correspond to an exploitation of the natural slope of the area as usually happened in the Roman period. From a stylistic comparison with Latin colonies that present geo-structural conditions similar to the Latin colony of Aesernia, an analogy with the Colony of Sessa Aurunca (CE) was identified. In that case, the theatre was built by exploiting the natural slope in the west of the city and the dimensions are slightly higher (approximately 2 m in the radius) than the hypothesis of Isernia.

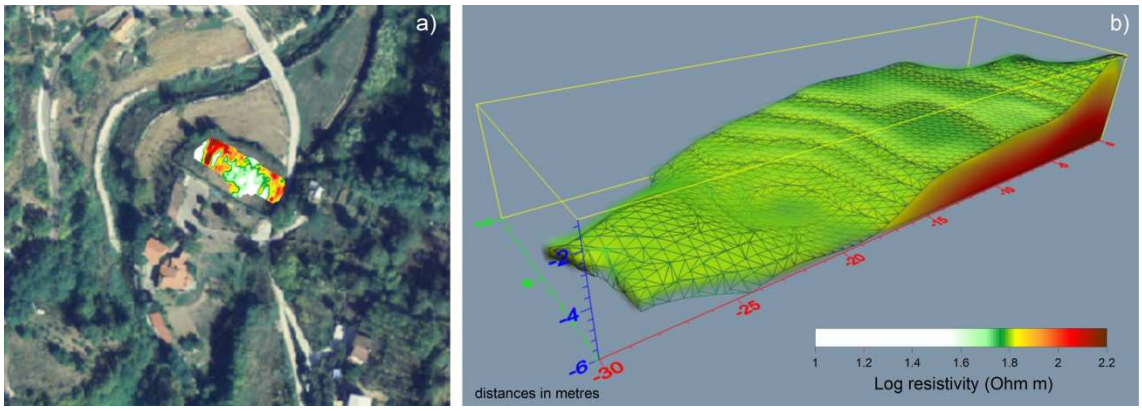

Fig. 7 – Isernia (Molise Region, Italy): location of G4 site and hypothetical road linking the site to the suburban colony (left) and view of the semicircle structure (right).

Conclusions

In a global analysis the use of multiple source systems was very useful for planning the archaeological research and a sustainable management of the Cultural Heritage.

Geophysical surveys and 3D photogrammetric reconstructions carried out within and outside the city walls have provided interesting data and filled many gaps in the knowledge and comprehension of the urban structure of the Colony of Aesernia. Both analysis were related and integrated with the study of historical sources and archaeological surveys. Even if there was not a direct connection between geophysical surveys and 3D photogrammetric analysis, because of the absence of perfect superimposing of data, in a global point of view, the work was helpful for a large-scale reconnaissanceof the considered territory.

From the archaeological point of view an important updating of archaeological evidences was realized and a new map of archaeological structure was produced.

The creation of 3D models had supported the archaeological researches creating a virtual store that was demonstrated to be fundamental in projects that promote interventions of restoring in cases of damaging of analyzed Cultural Heritage.

The application of non-invasive diagnosis techniques allowed to discover hidden archaeological structures in a predictive way and the location of interesting buildings was determined. Direct archaeological excavations will be programmed with the purpose to verify the nature of the identified anomalies.

Works are still ongoing with the aim to enhance the comprehension of the complex planning of the Latin colony of Aesernia and to resolve uncertain archaeological theses.

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