1st International Conference on
Metrology for Archaeology
Benevento, Italy, October 22-23, 2015

Qualitative integration of geological, geophysical and archaeological data for the study of the Latin colony of Aesernia (Molise, Italy)

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***Abstract* – Isernia is a small town located in Central Italy, in the Region of Molise. 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 Liri River Valley.**
In this paper, we present the results of integrated urban and extra-urban geo-archaeology researches realized through a combined use of historical sources, archaeological survey, geological investigations and geophysical prospections. All data were collected in a Geographic Information System that allowed the creation of thematic maps and the realization of spatial analysis.
The research has 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.

I. INTRODUCTION

Isernia is situated at a medium elevation of 442 m a.s.l. on a remnant of river terrace forming an narrow NNE-SSW elongated ridge The study area includes the historical centre of the town and is limited by the incisions of the Carpino Torrent to the east and the Sordo Torrent to the west. Quaternary deposits dominate the area. In particular, travertines crop out on top of the river terrace and are surrounded by anthropic deposits recognized along all the historical centre borders. The slopes bordering the top surface of the river terrace are covered by colluvial deposits, whereas alluvial deposits crop out within the Carpino and Sordo valleys. The pre-Quaternary bedrock consists of carbonates that crop out just in the southernmost portion of the study area.

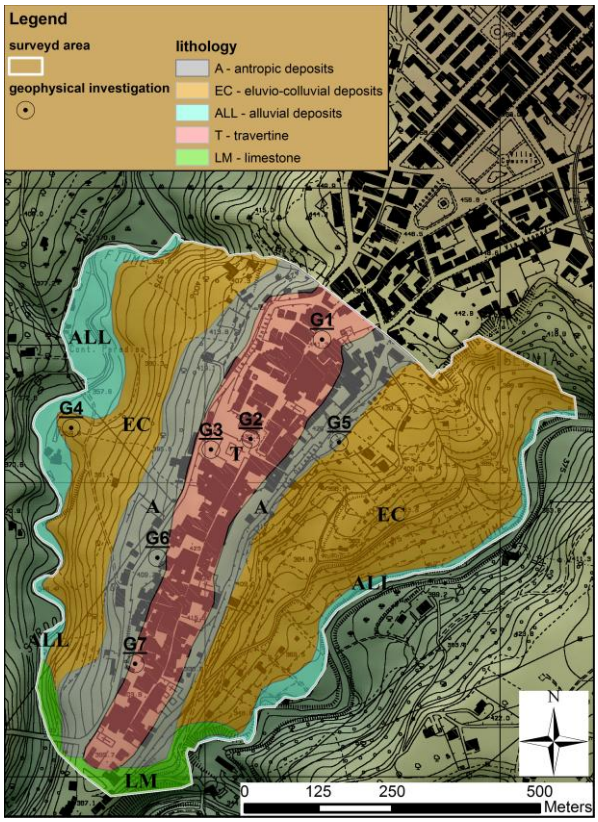

Fig. 1. Lithological map of Isernia.

The shape of the terrace and the presence of the two valleys have prevented the expansion of the city limits to the east and west. The Roman city, founded in 263 BC, 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 [1] 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* [2] [3]. The Latin colony of *Aesernia* had some thermal baths, both public and private, located in the south about 800 m from the south-eastern boundary of the city wall [4].

From the archaeological point of view, there are many gaps in the knowledge of the colony: the position of the *forum* and the theatre of the city is still uncertain; the extra-urban territory has never been studied in a systematic way; the lack of an updated archaeological map that takes into account all the structures found in the last years.

This work focused on integrated techniques of geophysical surveys, geological investigations, topographic and archaeological studies about the urban plan of *Aesernia*. All data have been plotted using the GIS software ArcGis 9.3. Moreover, contour lines and altimetric points of topographic sheets in scale 1:5000 (CTR Regione Molise) have been digitalized and interpolated to derive a 5m DTM of the study area. In the same way, roads and buildings have been digitalized to be plotted in the final maps. Literature data and field surveys were instead used to derive a lithological map [5] (Fig. 1).

II. ARCHAEOLOGICAL PROSPECTIONS

Archaeological data have been collected using the intensive off-site field survey strategy by performing parallel strips spaced approximately one meter apart and registering for each cadastral unit geomorphologic and geological characteristics, type of vegetation, visibility of the surface, type, number and concentration of archaeological finds. Totally an area of about 530000 m² has been covered by prospection. All data have been then plotted in the GIS project in order to derive a Visibility Map and a Concentration Map of the archaeological evidence.

The Visibility Map (Fig. 2) enhances the different degree of visibility of the terrain at the moment of survey: the 65% of the surveyed area is strongly affected by inaccessibility due to dense cover of vegetation or modern alterations or other circumstances; the 8% represents the off limit areas in which have been impossible to enter because of the presence of fences of private homes; the 27% presents medium or good conditions of visibility. However the absence of

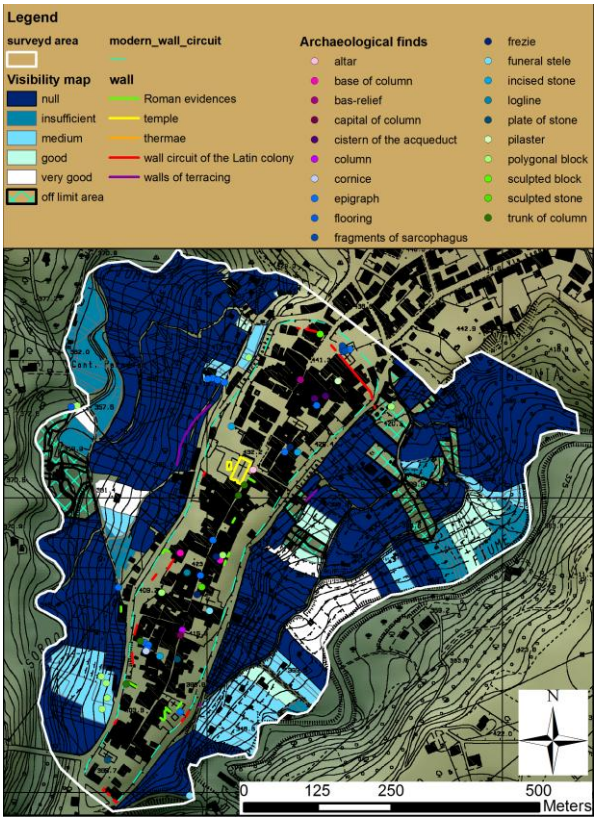

Fig. 2. Visibility Map of the surveyed area.

archaeological documentation in areas with null visibility does not preclude the presence of probable sites. As regards the historical centre, a census of all archaeological evidences has been realized.

The Concentration Map (Fig. 3) shows, for each cadastral unit, the number of finds per square meter. Nine new archaeological sites have been identified (S1-S9). The collected materials define a wider distribution area than previously thought that was occupied from the colonial territory in the third century B.C.

The detailed analysis of archaeological remains outlines an *extra moenia* presence of human activities relatable to places of worship (as site S1 in which terracotta figurines, votive, ointment, balm and also a pedestal miniaturist have been found) and an intensive system of late republican *villae rusticate* (S2), as well as a possible systems of medieval colonial structures (S3, S4, S5 and S8). The sites S6, S7 and present a high concentration of materials without an archaeo-chronological connection, probably washout from upper zones. This type of social organization outside the urban walls is well suited to the functions which acquired *Aesernia* after the end of the Samnite wars and reflects a system of territorial exploitation relating to flat areas surrounding the colony.

In addition, data provide us an interesting picture of what should be extra urban territory in the post Roman

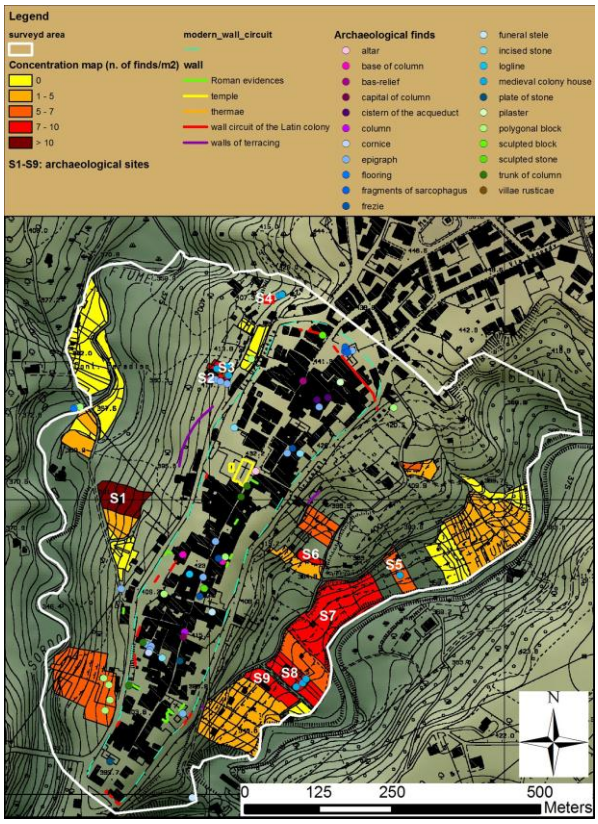

Fig. 3. Concentration Map of the surveyed area.

period until the late Middle Ages: many items indicate a continuity of life in these areas, with a single detachment timeline in the Late Antiquity-Early Medieval (century VI-IX AD). A resumption of activities seems to occur in the X century and, in a more substantial manner, in the thirteenth century during which an intense human activity is assumed in all investigated areas.

III. GEOPHYSICAL PROSPECTIONS

Geophysical surveys, such as the Electrical Resistivity Tomography (ERT) and the Ground Penetrating Radar (GPR), have been an important tool for the understanding and recognition of information in order to support the archaeological research. Thanks to the characteristics of the implemented non-invasive methods, it was possible to obtain a 3D 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 performed in seven sites (G1-G7 in Fig. 1), five located within or immediately outside the walls (G1, G2, G3, G6, G7) and two in the extra-urban territory (G4, G5).

A. *Electrical Resistivity Tomography (ERT)*

A high resolution 3D ERT has been realized in sites G3, G4, G5, G6 and G7. The field procedure has involved the realization of multiple sets of parallel profiles creating a grid pattern. The grid has been set from time to time on the basis of free spaces available in the area object of study.

Each profile has been arranged on the ground, along which a battery of galvanic contacts are placed at regular steps to sense the local nature of the subsoil. The MAE A3000 resistivimeter (www.mae-srl.it) has been used. The dipole-dipole source-receiver coupling, which ensures the greatest lateral resolution in the search for confined bodies, has been implemented as measuring modality with a distance between electrodes equal to 1 m.

For a preliminary evaluation of the ERT information content from a grid of nodal points relative to a single profile, apparent resistivity isolines has been mapped at logarithmic intervals. Such a contoured map is called pseudosection as it looks somewhat like a resistivity cross-section of the ground. Subsequently, combining data of multiple sets, a 3D tomospace of the investigated area has been obtained. The consequent 3D distribution of the apparent resistivity at the datum points has been imaged by drawing sequences of pseudosections and/or horizontal slices at increasing pseudodepths. It must be remarked that any of the apparent resistivity representations has only a rough relationship with the real resistivity pattern, whose modelling is the ultimate purpose of the survey. In fact, shape and amplitude of the anomalies, which strictly represent shifts among different apparent resistivities, depend not only on the unknown true resistivity pattern and data density, but also on contamination due to even small inhomogeneities close to electrodes. In order to remove corrupting effects and model the survey targets as accurately as possible, a numerical inversion is needed to convert apparent into real resistivities. In this work, the probability-based ERT inversion (PERTI) method [6] has been used, which is a fast, reliable inversion tool directly derived from the principles of the probability tomography [7].

G3 site is located inside the garden of the bishopric, in the west side of the church. In the area A, the electrical tomography relative to 1 m depth highlights two interesting high resistive anomalies (Fig. 4). The first, located at the centre, is easily identifiable and has a shape of a rectangle of 2.5 per 4 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 east side, a considerable rectangular anomaly is visible. In the area B, a high resistive anomaly of about 10 m in length is identified. It could be interpreted as a portion of a public building of significant size. A state of high conductivity prevails in the whole area and could be the evidence of an open area, probably paved, in complete synergy with the urban planning of the colony.

The site G4 is placed outside the urban plan, 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. 5b). 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. The site is located about 150 m from the circuit perimeter of the colony and at a lower level than the village. In Fig. 5a the hypothetical road linking the site to the suburban colony is highlighted.

Based on these considerations, an ERT survey was planned in the area in order to understand the morphology of a probably buried structure. 15 intersecting, 31 m long profiles were arranged. 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. 6a). In order to combine the ERT 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 have been blanked (Fig. 6b). 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, probably a 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 larger (approximately 2 m in the radius) than the hypothesis of Isernia.

The G5 is located in an area where, during the construction of the municipal parking, a Roman wall was brought to light and partially excavated. The tomography relative to 0,5 m depth (Fig. 7) shows, in the southwest side of the survey area, a high-resistive anomaly that can certainly be interpreted as the continuation of the wall structure. In the south east part a high resistive anomaly with rectangular size (about 20x5 m) with the same orientation as the previous one emerges. Its exact nature should be verified by a direct archaeological excavation.

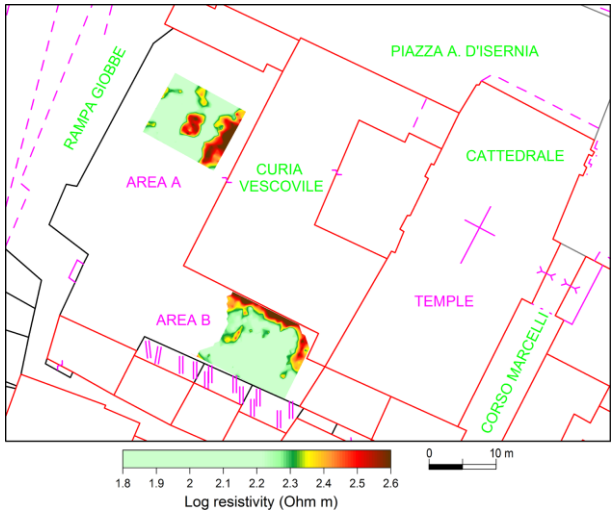

Fig. 4. G2 site: ERT relative to relative to 1 m depth.

Fig. 5. Location of G4 site and hypothetical road linking the site to the suburban colony (a) and view of the semicircle structure (b).

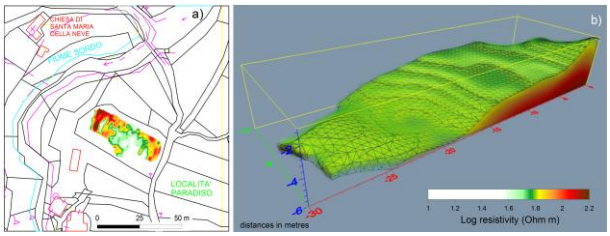

Fig. 6. ERT relative to relative to 1 m depth (a) and 3D representation the portion of the south-east semicircular area (b).

The G6 survey site (Fig. 8) is situated in the east side of Via Occidentale, where, in the 1980s, the Archaeological Superintendence of Molise made some excavation at the back of Palazzo D'Avallos Laurelli. A wall, perpendicular to the road with a length of about 7 m, and a semicircular wall structure in a state of collapse were revealed a few meters from the current ground level. The tomography relative to 0,5 m depth showed a high resistive anomaly that appears to be the exact continuation of the wall emerged from the test excavation. In the southern portion,

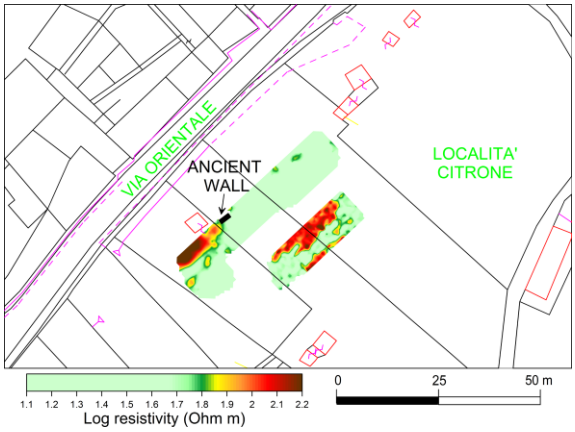

Fig. 7. G5 site: ERT relative to relative to 0,5 m depth.

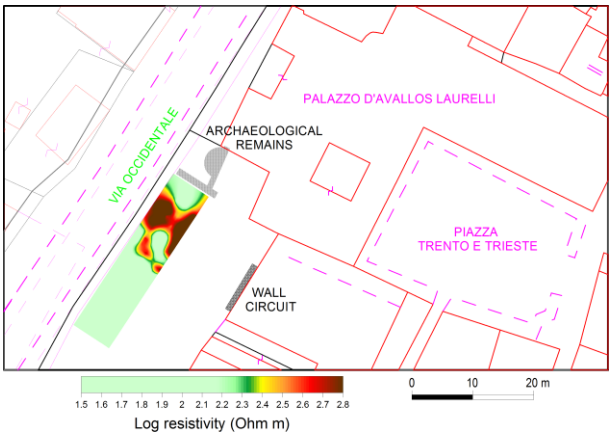

Fig. 8. G6 site: ERT relative to relative to 0,5 m depth.

it is possible to hypothesize a probable environment whose contours appear in synergy with the known archaeological structures.

G7 survey is located in a private property south of the G6 area. Outside the area, along Via Occidentale, a stretch of the wall circuit built with polygonal blocks is visible. In 2009, during the renovation of the house, several aligned limestone blocks of considerable size (about 10 m in length) emerged. This structure has the same physical characteristics as the polygonal blocks of the colony's limestone circuit perimeter, but is perpendicular to the outer wall. Considering the location of the wall, it could be interpreted as a huge urban terrace wall or a fence bounding a major public area. The tomography relative to 1 m depth (Fig. 9) has shown some anomalies in the east area with regular shape and perpendicular to the walls of the circuit. To the west, there is a significant anomaly with similar orientation to the archaeological structures visible in the area.

B. Ground Penetrating Radar (GPR)

High resolution GPR surveys have been realized in sites G3, G4, G5, G6 and G7. For measurements a IDS RIS-K2 georadar, equipped with a multi frequency antenna TRMF (600-200 MHz), was used. All radar reflections were recorded digitally in the field as 16 bit data and 512 samples per radar scan. The spacing between parallel profiles at the site was 0,5 m and they were collected alternatively in opposite directions with angles of 90 degrees in the survey grids. Radar reflections on each line were recorded at 40 scan s^{-1} (1 scan approximately 0,04 m). Standard bidimensional radargrams relative to single transects were processed through the IDSGRED software. Band pass filters and the Gain Control were applied in order to remove high and low frequency anomalies that occurred during the data acquisition, normalize the amplification and remove reflections generated by noise due to the different signal attenuation [8]. Thus, using a sequence of parallel lines, a

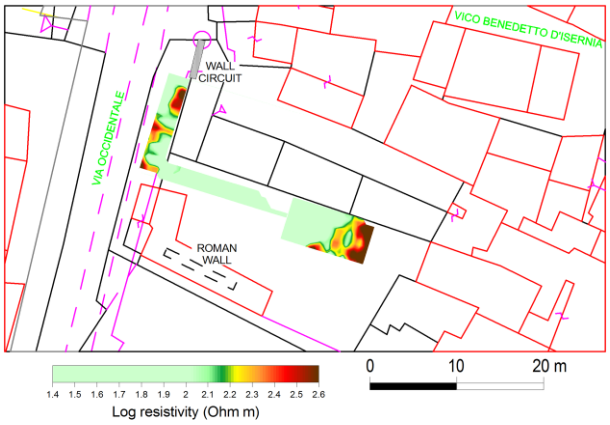

Fig. 9. G7 site: ERT relative to relative to 1 m depth.

three-dimensional matrix of averaged averaged square wave amplitudes of the return reflection was generated and time-slices were realized at various time windows. Data were then gridded using a moving average routine and a radius of interpolation equal to 1 m.

The first GPR surveys were carried out in Piazza Celestino V (G1 site, Fig. 10) where excavations brought to light a section of the walls of the colony [9]. Fig. 10 shows the slice in the time window from 9–24 ns (two way time). 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 circuit into the subsoil. 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 probable 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.

G2 site is located in Piazza Andrea d'Isernia, in the area surrounding the Cathedral (Fig. 11). The time slice has shown two interesting parallel anomalies with high amplitude values. They are in the north side of the

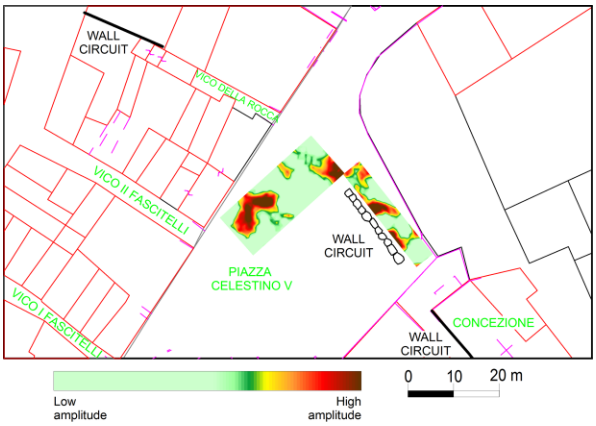

Fig. 10. G1 site: time slice slice in the time window from 9–24 ns.

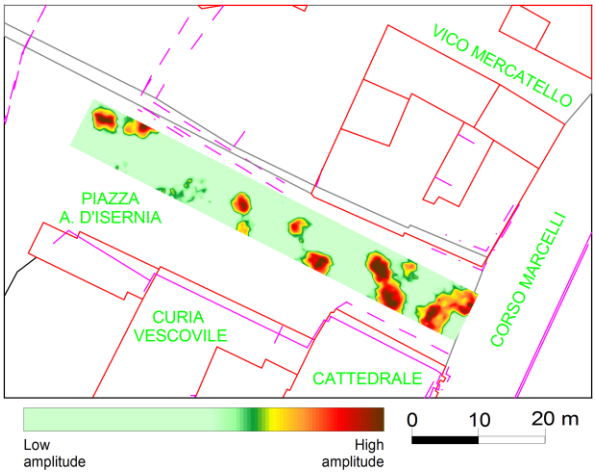

Fig. 11. G2 site: time slice slice in the time window from 9–24 ns.

Republican temple and might indicate the presence of connected buried structures.

CONCLUSIONS

The combination of geological, topographic and archaeological data enhance a strict correlation between the environmental setting and the degree of conservation of the archaeological record. Moreover, reworked archaeological finds include some blocks recognized within the Carpino valley whose actual location is probably due to river bank erosion and transportation, and pottery recognized on the Sordo's valley slope transported by slope processes. On the opposite, archaeological evidence with a good to excellent degree of conservation has been recognized on the top surface of the river terrace where travertine deposits crop out. Concentration and visibility maps highlight the presence of several areas where surveys were not possible due to the abundance of vegetation or because private properties. Anyway, it is interesting to note that both maps show the highest values on the left flank of the Sordo valley, even if the highest value has been recognized on both maps in correspondence of a cadastral unit located on the right flank of the Carpino valley.

Nine new archaeological sites inserted between the third century BC and the Middle Age were found.

The application of non-invasive diagnosis techniques allowed discovering hidden archaeological structures in a predictive way and the location of interesting buildings was determined for each surveyed area. The most important results were obtained in an extra-urban area where the geophysical anomalies emerged from the survey suggest the presence of a semicircular public building on split levels that was a probably theatre. Direct archaeological excavations will be programmed with the purpose to verify the nature of the identified anomalies.

REFERENCES

[1] A. ZEVI, "Isernia. Lo scavo del tempio della colonia latina". Sannio, Pentri e Frentani dal VI al I secolo a.C., Cantilenara R. (a cura di), Napoli, 1981, pp.101-104.

[2] A. LA REGINA, "Il tempio della colonia latina di Aesernia". AA. VV. La cattedrale di Isernia nella storia e nell'arte, Napoli, 1972, pp.27-32.

[3] G. MARASCO, A.S DE ROSE, "Il tempio della colonia latina di Isernia, III secolo a. C.", Le cattedrali di Isernia e Venafro, il santuario dei SS. Cosma e Damiano. Lions club 2000, pp.17-39.

[4] C. TERZANI, "Isernia: complesso monumentale romano di via S. Ippolito", V settimana beni culturali, Tutela, Catalogo della mostra, AA VV, 1989, pp. 99-100.

[5] L. BRANCACCIO, G. DI CRESCENZO, C. ROSSKOPF, N. SANTANGELO, F. SCARCIGLIA, "Carta geologica dei depositi quaternari e carta geomorfologica dell'alta valle del fiume Volturno (Molise, Italia meridionale)". In Note illustrative. Il Quaternario 2000, vol.13 (1/2), pp. 81–94.

[6] P. MAURIELLO, D. PATELLA, "A data-adaptive probability-based fast ERT inversion method". Progress In Electromagnetics Research, 2009, vol.97, pp. 275-90.

[7] P. MAURIELLO, D. PATELLA, "Resistivity anomaly imaging by probability tomography". Geophysical Prospecting, 1999, vol.47, No.3, pp.411–429.

[8] L. B. CONYERS, D. GOODMAN, "Ground penetrating radar. An introduction for archaeologists". AltaMira Press. Division of Sage Publications, Inc., 1997.

[9] C. TERZANI, "Scavo archeologico della cinta muraria di Aesernia", in Fasti on Line Documents & Research, 2005.