INTEGRATED GEOPHYSICAL METHODS APPLIED TO SOME ARCHAEOLOGICAL SITES OF NORTH SARDINIA

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INTRODUCTION

Fast and effective methods for studying the physical characteristics of subsoil are particularly helpful in detecting buried structures, to assess the lithological variation in horizontal and vertical directions and to monitor the variations, as a function of time, of the subsoil parameters.

In the archaeological research a preliminary knowledge of the sites, according to the information of the archaeologists, is essential for a correct planning of further investigations. The geophysical techniques, by offering a non-invasive high-resolution survey, provide great benefits in terms of reduction of costs, time and the risk associated with direct and destructive investigations such as excavation and masonry coring.

This study deals with the application of two geophysical methods, electrical (Electrical Resistivity Tomography; Fig. 1a) and electromagnetic (Ground Penetrating Radar; Fig. 1b), to characterize two archaeological sites near the shore in Northern Sardinia: the Sant'Imbenia Roman villa (Alghero, SS) and the settlement of Santa Filitica (Sorso, SS), a roman villa reoccupied until the IX century A.D.

The aim of this study is to demonstrate the advantages of combining geophysical methods and their effectiveness to detect, map and characterize different type of buried man-made structures in coastal archaeological contests, where the intrusion of the marine water in shallow aquifer could reduce the efficacy of some geophysical methods such as GPR.

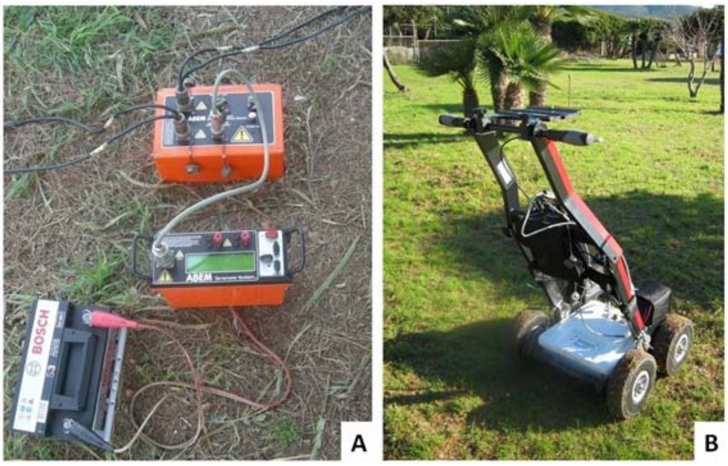

Fig. 1 - A) Abem Terrameter SAS1000 device and Lund System for electrical data acquisition. B) Ground Penetrating Radar (GPR) IDS model "RIS_MF_HiMod".

ANALYTICAL METHODS

The electromagnetic surveys were conducted using a Ground Penetrating Radar (GPR) IDS model "RIS_MF_HiMod", composed of a control channel (K2-FastWare) working simultaneously with two transmitters (Tx), at 200 and 600 MHz, and two receivers (Rx) (Fig. 1A). The radar data were processed with the software "Gred" distributed by "IDS-Ingegneria Dei Sistemi". These were further processed in order to obtain 2D sections and 3D representations of the subsurface. Electrical prospecting was performed by using a Terrameter SAS 1000, a single-channel georesistivimeter developed by ABEM Instruments (Sweden), based on the use of metal electrodes for galvanic coupling (Fig. 1B). The Electrical Resistivity Tomography (ERT) were conducted using the dipole-dipole array, sensitive to horizontal changes in resistivity and thus suitable for detecting vertical structures like walls and cavities. Geoelectrical data acquired were processed to obtain both 2D and 3D models of the subsurface. For this purpose, the softwares "Res2dinv ver.3.53g" and "Res3dinv ver.2, 13v" (Geotomo software) were used. 2D models derived from real field data, whereas the 3D models resulted from their interpolation. Finally, an high resolution 3D models were obtained through the resistivity values exported and interpolated by the software "RockWorks 2009 (Rockware software)".

CASE STUDIES

Integrated geophysical methods on a coastal archaeological site: the Sant'Imbenia Roman villa (Northern Sardinia)

The Sant'Imbenia Roman villa is located in the most sheltered point of Porto Conte Bay (northwestern Sardinia) in an area where the carbonate Mesozoic succession outcrops locally buried by coastal alluvions.

The original structure of the villa dates back to the 1st century A.D., anyway modifications and additions lasted until the Late Middle Ages. The recent archaeological campaigns have brought to light 49 different spaces, which stretch 133 meter along the coast.

Fig. 2 - Survey location. The red lines show the electrical surveys, the blue lines show the GPR surveys.

Based on these archaeological evidences, and according with archaeologists an area of approximately 700 m^2 adjacent to the excavations has been investigated with electrical resistivity and electromagnetic methods (Testone *et al.*, 2011).

The complete coverage of the area was performed, by GPR, with a regular grid of 34 m × 22 m, with 68 transverse (T) and 44 longitudinal (L) lines, running acquisition every 50 cm (Fig. 2). Geoelectrical profiles were located where GPR data seemed to show the presence of interesting targets. Overall eight geoelectrical profiles, with an inter-electrode spacing of 50 cm and a unit length of 31.5 m were performed (Fig. 2).

The resulting geophysical models helped in defining the depth, vertical extension, location, thickness of buried walls. The good performance of these techniques was facilitated by physical property contrasts generated by the buried targets, with respect to the surrounding medium.

The comparison of the results evidenced a good correlation between the electrical and electromagnetic models on the same targets, providing useful information to the archaeologists (Fig. 3).

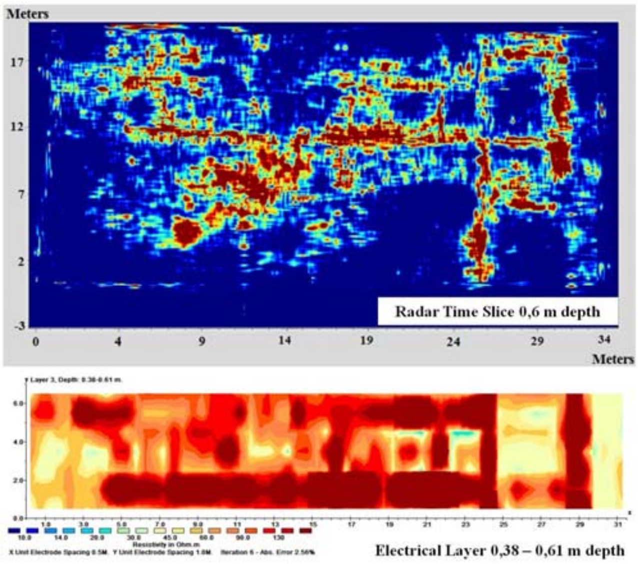

Fig. 3 - Visual comparison between the different methodologies used for buried structures reconstruction.

Ground Penetrating Radar and Geoelectrical Surveys to investigate the Santa Filitica Archaeological Complex (Northern Sardinia)

The archaeological area of Santa Filitica is located a few meters from the shore, on the coast between Porto Torres and Castelsardo along the SS 200 (northern Sardinia), at the eastern edge of a wide fertile plain characterized by Miocene-aged carbonate and siliciclastic sediments and bounded by a mainly andesitic volcanic relief. Santa Filitica is a multilayered archaeological complex, consisting on the remains of an imperial Roman villa, a settlement of V-VI century A.D., and a village of Byzantine period, reflecting a prolonged a use of the site from at least the 3rd until the 9th century A.D. (Rovina, 2003).

The electromagnetic data were acquired by 84 transverse (T) and 150 longitudinal (L) lines with 0.5 m spacing in order to build 4 different irregular grids (Fig. 4A) located in function of the obstacles on the ground, with a total area of about 900 m^2 (Testone *et al.*, 2012).

Electrical surveys have covered two rectangular areas at the east and the south of the current limits of excavation (Fig. 4B). These areas were investigated by a set of parallel 2D electrical lines, with an inter-line spacing of 1 m. For each 2D electrical line 64 stainless steel electrodes were deployed in the ground with constant spacing of 50 cm and a unit length of 31.5 m.

Fig. 4 - A) Site plan including GPR surveys location. B) Site plan including electrical resistivity surveys position.

The geophysical models show electromagnetic and electrical anomalies related to buried man-made structures in the shallow level of the investigated area.

The layer containing the archaeological targets was distinguished with the 2D sections of both methods.

The Roman structures, later reworked in the Byzantine period, resulted in a thickening of buried structures in some areas of the site, causing a low electromagnetic contrast between targets and host alluvial sediments, thus producing weak and confused signals in some electromagnetical horizontal slices. Moreover, the seawater infiltrations into the deeper level have caused a high moistening, resulting in a strong attenuation of the radar waves. Conversely, the electrical surveys have detected the alignments of structures, whereas the many collapses yielded chaotic forms that do not allow a clear distinction of the buildings.

Even if the applied methodologies can be considered suitable to detect buried archaeological remains, only in some cases the complexity of the site allows a good fitting between the models obtained with both geophysical techniques.

Nevertheless, the integration of the two methods resulted in a comprehensive overview of the study area, otherwise not achievable with a single methodology. Overall, the surveys provide a simple and useful tool for localize future excavations.

CONCLUSION

The comparison among the models shows a good correlation between the different signals, reducing the uncertain typical of indirect methods.

In this study was demonstrated as a more reliable and accurate interpretation of the data is obtained by integrating the results of these two geophysical methods, even if the ERT method has proved more performant.

In fact, the GPR signals exhibit a loss of definition both in sites located in the proximity to the coast, where the deepest ground levels are saturated, and in sites where the buried structures are surrounded by a similar physical context as Santa Filitica archaeological complex.

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