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Combined GPR and ERT Survey at the Marathon (Plasi) Archaeological Excavation Site

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Summary

The excavation trenches by the Department of History and Archaeology of the NKUA at the archaeological site of Plasi Marathon (Attica, Greece) have already revealed several architectural remains of the Classical period. A combined GPR and ERT survey was initiated in order to determine the existence and geometry of additional buried structures in the unexcavated parts of the site. The results of this geophysical survey will not only assist the archaeologist's planning for the next excavation steps, but will also provide valuable information for the density of habitation in the area, a significant factor for the understanding of the importance of ancient Marathon. Fifty-two GPR and eighteen ERT profiles were carried out in a selected area. After data processing, the obtained radargrams and resistivity tomograms are presented in the form of fence diagrams. Moreover, volume/depth slices have been extracted for specified depths from GPR and ERT in order to compare their results. Several identified geophysical anomalies can be interpreted as archaeological domestic remains, supporting a rather dense pattern of habitation, hence the archaeological significance of the site.

Introduction

Nowadays, there is a growing interest in novel applications for solving geo-archaeological problems including the use of suitable diagnostic tools for preventive archaeological research (Urbini *et al* 2007). Many researchers support that ground penetrating radar (GPR) is a subsurface survey method indicated to acquire important preliminary information in various geological subsurface investigations, but also in archaeological studies (Conyers, 2016). GPR stands out among the geophysical methods applied in archaeology, given the fact that it is a non-destructive practical field technique. Therefore, it can be used to identify buried targets and their dimensions, allowing the reconstruction of the subsurface in 3D (Porsani *et al*., 2010). On the other hand, Electrical Resistivity Tomography (ERT) is a more accurate but time-consuming technique that is also suited for the investigation of buried archaeological settlements (Alexopoulos *et al.,* 2014). It can provide detailed tomograms that can precisely delineate any buried architectural remains. The combined application of GPR and ERT for archaeological researches is proposed by several authors (Deiana *et al.,* 2018; Fernández-Álvarez *et al.,* 2017; Nuzzo *et al.,* 2009).

Methodology

A combined GPR and ERT survey was performed during the summer of 2018, in the excavation site of the Department of History and Archaeology of the NKUA at Plasi Marathon (Attica, Greece). On the basis of the structural elements of the Classical period already revealed in 2017 and the geoenvironmental conditions of the study area, the main objective of this study is to assess the existence of possible architectural remains in unexcavated parts of the site. This would be of great importance for the archaeologists in order to plan the next steps of the excavation project but also to investigate the density of habitation in the area, which is of high significance in order to understand the importance of ancient Marathon. The uncovered architectural remains in the adjacent excavation trenches were found at a mean depth of 0.3 m and were mainly limestone walls that have a mean width equal to 0.5m (Fig. 1). Due to the high precision required the coordinates acquired of all geophysical measurements were determined with differential GPS (*dGPS*).

Figure 1 *The revealed architectural remains at the excavation site of Plasi Marathon.*

A MALA 250 MHz shielded antenna was used for the field measurements. Single-fold exploratory GPR parallel profiles were initially carried out at the site with 1 m profile spacing along two perpendicular directions. Therefore, fifty-two (52) GPR profiles were carried out (Fig. 2), with a total length of 1250 m, using the following specifications: i) Time sampling rate Δt=512, ii) Time window W_t=196 ns and iii) spatial sampling rate Δx_s=0.02 m.

The GPR data were processed with REFLEXW software. A standard filtering procedure was used during the GPR processing applying a package of filters that included Static Correction, Subtract-mean (Dewow), Background Removal, Bandpass Filter, Deconvolution, Migration and final Hilbert Transformation-Envelope (Goodman and Piro, 2013; Porsani *et al*., 2010). To assist the joint interpretation of the processed GPR sections a series of MATLAB scripts were developed in order to evaluate the depth distribution of reflection intensities, data normalization and the extraction of volume slices at various depths from the existing section geometry.

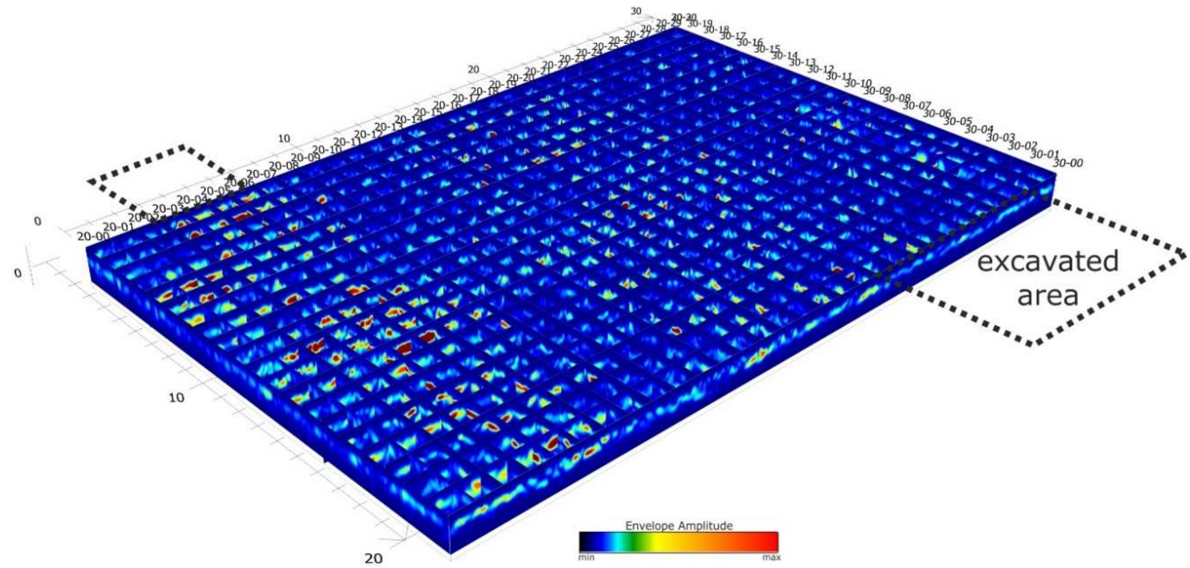

Figure 2 *Fence diagram of the fifty-two (52) GPR profiles.*

The obtained radargrams are presented in the form of fence-diagrams in Figure 2. This simultaneous view of multiple radargrams allows us to identify better the presence of the reflectors and their distribution within each radar section (Imposa *et al*, 2018). In this fence-diagram (Fig. 2), we can observe numerous reflections, sometimes fairly pronounced, located at depths between 0.25 m and 0.85 m. Several detectable reflections appear isolated, observed with a fairly small extent within each single scan, probably generated by objects with rather small dimensions. However, in the context of the fence diagram analysis, it was observed that these isolated reflectors often show a lateral continuity.

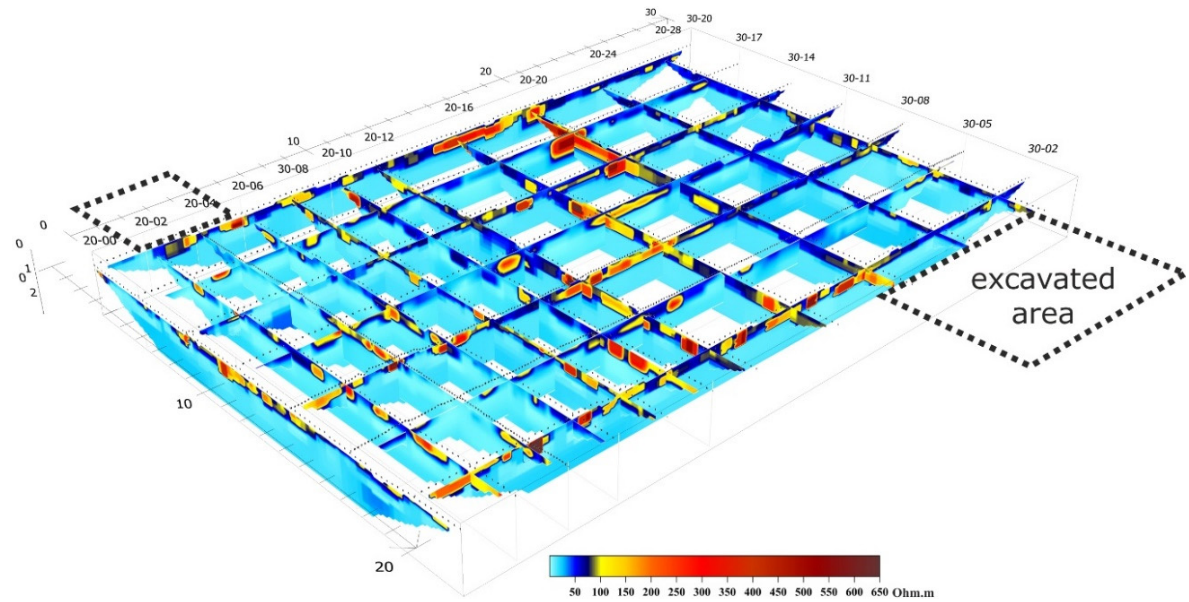

Figure 3 *Fence diagram of the eighteen (18) inversed ERT profiles.*

Additionally, eighteen (18) Electrical Resistivity Tomography (ERT) sections were carried out, with a total length 430 m. The Wenner configuration was used with an electrode spacing of 0.25 m. The initially selected distance between the parallel profiles was 4 meters. Based on the preliminary processing results and the indications for possible targets, grid density was increased over almost half of the area in order to improve the final image. An ABEM Terrameter system was used for the field measurements. The processing of the ERT data was performed with Res2DInv software (Loke and Barker 1996). It iteratively calculates a resistivity model, trying to minimize the difference between the observed apparent resistivity values and those calculated from the model. The robust inversion method was selected for the ERT processing, since it provides results with sharper edges, similar to the shape of architectural and domestic remains (Alexopoulos *et al.*, 2014; Drahor, 2011). In Figure 3 the inverted electrical tomograms are presented in the form of fence-diagrams. We can observe a shallow (0.2–0.8 m) resistant (80.0–400 Ohm.m) zone above a relatively conductive one (50 Ohm.m), which is the local geoelectrical bedrock. These sharp zones of high resistivity (reddish and yellowish) delineate some areas that could be interpreted as archaeological remains buried in the post-alpine deposits of the area.

Four volume/depth slices have been extracted for the specified depths of 20-40cm, 40-60cm, 60-80cm, 80-100cm from GPR and ERT in order to compare their results. The selection of these volume slices was made after careful analysis of the reflection amplitude and resistivity distribution graphs with depth. The volume/depth-slices illustrated in Figure 4 were obtained through the interpolation of the processed radar scans (Zhao *et al.,* 2013; 2015) and ERT sections. A volume/depth slice consists of 2D contour line representations of the signal amplitude and the resistivity over a horizontal plane that is located at a specific range of depths from the surface. Slices provide good quality information from which is possible to gather details on the geometry of the buried object.

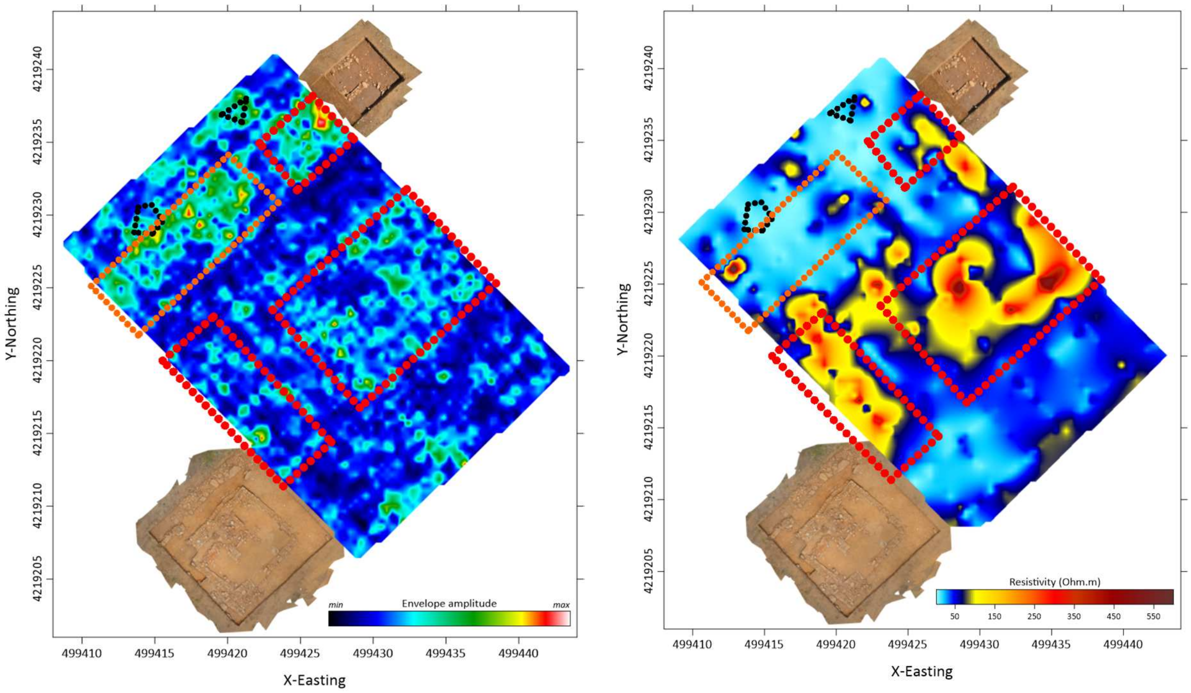

Figure 4 *Volume/depth slices of the GPR and ERT data for the depth range of 0.40–0.60 m.*

In the central part of the illustrated GPR and ERT volume/depth slices between 0.40-0.60 meters (Fig. 4), some areas characterized by high amplitude and high resistivity values (> 80 Ohm.m) in the red-dotted rectangles can be identified. In many cases, these areas do not show a lateral continuity, probably due to the existence of targets with limited extension. In the NW (Fig. 4-orange-dotted box) area, intense reflections but not high values of resistivity can be observed. This could be due to the presence of the adjacent tree root system (black-dotted area). These areas display continuity in depth, suggesting the possible presence of significant targets that may correspond to buried archaeological remains.

Results & Conclusions

This paper presents the results of the combined geophysical survey, including the application of GPR and ERT techniques, performed at the archaeological site of Plasi, close to the famous Marathon Tomb.

The aim of the study was to assess the existence and geometry of possible buried architectural remains in the unexplored area of the excavation of the Department of History and Archaeology of the NKUA. Several geophysical anomalies which have been identified can be interpreted as archaeological domestic remains and reveal a rather dense pattern of habitation, supporting the aspect of the archaeologists that Plasi was a very important ancient area. The validity of the results is expected to be verified during the excavations of 2019-2020.

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