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A geophysical approach to the archaeological excavation of Plasi Marathon (Attika, Greece)

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Introduction

Many researchers have presented 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 and cultural heritage 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. GPR results can be presented as bi-dimensional profiles (2D) and three-dimension images (3D), in the form of block diagrams, fence-diagrams and volume/depth-slices. Especially the amplitude maps (e.g., depth-slices maps) allow the identification of areas with high or low amplitude of specific deep reflectors. Therefore, they can be used to identify buried targets and their dimensions, allowing the reconstruction of the subsurface in 3D (Porsani *et al.*, 2010).

Geophysical survey

A combined GPR and ERT survey was performed during the summer of 2018, in the excavation of the Department of History and Archaeology of the NKUA at Plasi Marathon (Attica). On the basis of the walls 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, particularly in an indicated area of 655 m^2. The existence of architectural remains would be of particular importance for the archaeologists in order to plan the next steps of the project but also to understand the density of habitation in the area. The revealed architectural remains in the adjacent excavation trenches were found in a mean depth of 0.5 m and the walls have a mean width of 0.5m.

A MALA 250 MHz shielded antenna was used for the field measurements. Single-fold exploratory GPR profiles were initially carried out at the site with a horizontal spacing between the parallel profiles equal to 2 m, in order to create a 2x2 m grid. Therefore, thirty-four (34) GPR profiles were carried out (Fig.1), with a total length of 610 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, using the following package of filters: Subtract-mean (Dewow), Time-Zero Correction, Background Removal, Bandpass Filter, Deconvolution, Migration and final Hilbert Transformation-Envelope (Goodman and Piro, 2013; Porsani *et al.*, 2010). The obtained radargrams are presented in the form of fence-diagrams in Fig. 1. This simultaneous view of multiple radargrams allows us to identify the presence of the reflectors and their distribution within each radar section (Imposa *et al*, 2018). At this fence-diagram (Fig. 1), we can observe numerous reflections, sometimes fairly pronounced, located at depths between 0.25 m and 0.85 m. Many detectable reflections appear isolated, observed with a fairly small extension 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.

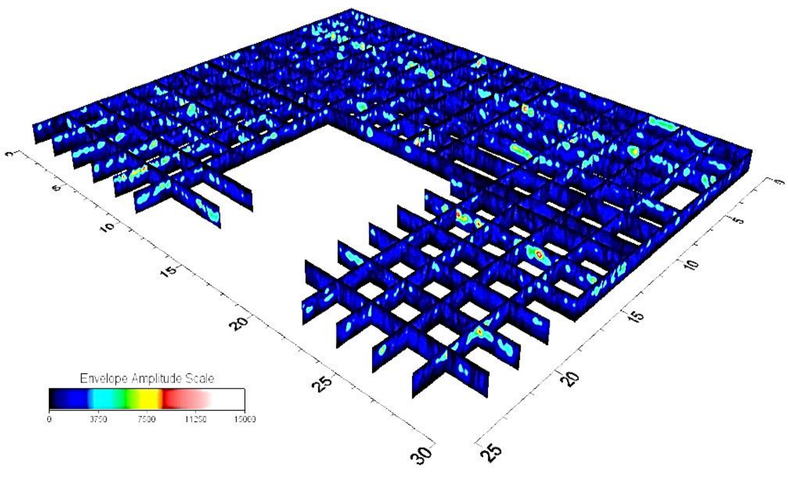

Figure 1. Fence diagram of the thirty-four (34) GPR profiles in the survey grid.

Beyond this, twenty (20) electrical resistivity tomography (ERT) sections were carried out, with a total length 413 m, in a 3x3 m grid and electrode spacing 0.25 m. An ABEM Terrameter system was used for the field measurements. The processing of the ERT data was performed with Res2DInv software. The robust inversion method is indicated for the

ERT processing (Alexopoulos *et al.*, 2014), since it provides results with sharper edges, similar to the shape of ancient domestic structures. For all the acquired ERT and GPR profiles, the coordinates were determined with dGPS (TOPCON Hiper-Pro).

Discussion and Results

The volume/depth-slices illustrated in Fig. 2 were obtained through the interpolation of the radar scans, derived from the processed data. These slices show the variation of the reflected signal amplitude distribution at different depths/volumes (Zhao *et al.*, 2013; 2015). The most reflective zones are illustrated in green and red colors.

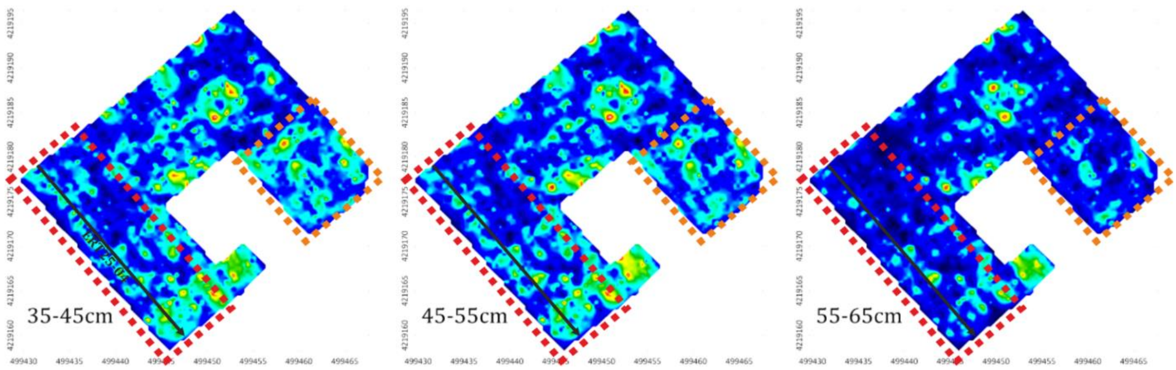

Figure 2. Volume/depth slices of the GPR data, with a depth range of 0.35–0.65 m.

After a careful analysis of each radargram, we obtained three slices for depths between 0.35 and 0.65 meters (Fig. 2), where the areas characterized by high amplitude values (reflection strength) are illustrated. In many cases, these areas do not show a lateral continuity probably due to the existence of targets with limited extension. These outcomes seem to enhance the results obtained from the previous analysis (Fig.1). In the SW area of these slices (Fig.2-red dotted zone) and in a smaller part at the SE area (Fig.2-orange dotted zone), additional areas that are characterized by high amplitude values but are not identified by the previous analysis, are now observed. These areas display continuity in depth, suggesting the possible presence of significant targets that may correspond to buried archaeological remains. The validity of the results will be tested during the excavations of 2019-2020, but they suggest a rather dense pattern of habitation, implying that Plasi could have been the location of the ancient demos of Marathon.

The inversion results (Fig.3) of the acquired ERT profiles, have also adumbrated areas of higher resistivity (Fig.3-reddish and purplish colors, ERT 25-04 positioned in Fig.2) that probably correspond to buried architectural remains.

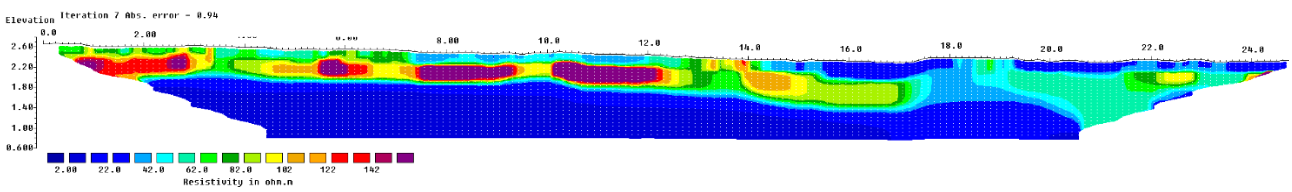

Figure 3. Inversion model of ERT 25-04 cross-section (RMS=0.94%), with electrode spacing 0.25m.

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