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GEOPHYSICAL INVESTIGATIONS OF TUMULI IN THRACE, N. GREECE

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Abstract

Four of the largest funeral tumuli located in the region of SW Thrace, Greece, were investigated through the use of geophysical techniques. These monumental mounds are found scattered all over Thrace and belong to a period spanning from the Late Bronze Age to the Roman period. Rescue excavations that have been carried out in a few of these tombs revealed a significant number of burials and finds, including funeral pyres, tomb architectural remnants and grave pits. Still, most of the tumuli do not contain any significant relics.

Ground penetrating radar was systematically employed, among other techniques for the study of the tumuli in the region of Orestiada and Trigono. The goal of the geophysical campaign was to pinpoint the most prominent targets to be explored by future excavations. Controlled GPR experiments were carried out on the top of a tumulus at Elaphochori-Daphni, where excavations had revealed a medium sized stone built tomb. In Spilaion, shallow depth time slicing maps of the tumuli were combined together with the soil resistance maps of the neighboring hill, which showed evidence of a large circular feature. In the tumulus of Mikri Doxipara, time slicing techniques identified a recent war trench together with other candidate targets. All data were corrected taking into account the topography of the tumuli. Comparison of time slices produced by transects of different orientations showed a low degree of correlation, suggesting that the alignment of the antenas may play a critical factor in the GPR survey. Finally, time slices were also used for the production of 3-dimensional solid modeling of the tombs. In the case of the tumuli of Chelidonas-Ladi, the high resolution magnetic survey conducted after the removal of the bulk of the mound mapped the details of a neolithic settlement, located at the base level of the tomb.

Keywords: tumuli, GPR, geophysical prospection, Thrace, Greece.

1. Introduction

Tumuli have been always one of the most attractive targets of geophysical prospection techniques, although they are characterized by a number of limiting parameters such as their sloping surface, as well as the height and depth of the underlying features that may be concealed within them. Various methods have been applied in the prospection of tumuli including seismic techniques (Vafidis *et al.* 1995; Tsokas *et al.* 1995) and resistivity methods (Tonkov, 1996). Each of these methods has exhibited a different degree of success, depending on the nature and depth of the subsurface targets.

A large number of Late Bronze Age – Roman funeral tumuli are spread all over the region of Thrace. Only a few of them have been studied by archaeological excavations and even fewer have been the subject of geophysical survey in the past. In the fall of 1998, the Laboratory of Geophysical – Satellite Remote Sensing and Archaeo-environment of the Institute for Mediterranean Studies/Foundation of Research and Technology, Hellas (F.O.R.T.H.) undertook a geophysical exploration campaign of some of the most significant tumuli of the southwest Thrace, northern Greece (Sarris, 1999). The tumuli at the sites of Elaphochoriou-Dafnis, Spilaiou, Mikris Doxiparas and Chelidonas-Ladi were investigated through the use of ground penetrating radar, magnetic and soil resistance techniques. A number of controlled experiments was carried out in the tumulus of Elafochoriou/Dafnis to test the signal response and registration, as preliminary excavations by the Ephoreia of Prehistoric & Classical Antiquities of Komotini revealed a shallow depth (<1m) and well-preserved Roman tomb (Triantaphyllos & Terzopoulou, 1996).

2. Methodology

The goal of the geophysical survey was to investigate a number of tumuli and map the potential targets in relation to the underlying structural remains, burial features or tombs. Specific emphasis was given to the use of the ground penetrating radar for the deeper investigation of the tumuli, although other techniques were also used depending on the specific needs of the site. The tumulus of Elaphochoriou-Daphnis was surveyed by GPR and geomagnetic techniques. In Spilaion, the large tumulus was surveyed by the GPR, while the smaller hill in the surrounding area was covered by soil resistance and magnetic techniques. GPR was exclusively used in the prospection of the Tumulus of Mikri Doxipara, while magnetic techniques were used in Chelidona-Ladi, as excavation works had already removed the bulk of the soil of the tumulus. The total area of coverage was 12,000 sq. m. Geophysical investigations included an EKKO 1000 GPR system with 25 and 110 MHz antennas, a Geoscan Research RM15 soil resistance meter and a Geoscan Research FM36 fluxgate gradiometer. All methods were carried out within a rectangular grid, which was based on the topographic layout of the region, with a constant sampling interval along the two horizontal axes.

GPR data were processed transect by transect through the application of high pass filtering (removal of wow) and spatial filtering techniques (trace-to-trace averaging for emphasizing horizontal reflectors, down-the-trace averaging for smoothing out the high frequency noise and trace differencing for emphasizing verticallly changing reflectors (SSI, 1993). Other filtering techniques were also used for the better representation of the reflection anomalies. Time slices were calculated for various time (depth) ranges for each transect. Upon combination of the corresponding time slices of each transect, interpolation techniques were employed for constructing the total layer representing the average at a particular depth range (Goodman, 1998; Nishimura & Goodman, 1995). The topographical maps constructed by the Ephoreia of Prehistoric & Classical Antiquities of Komotini were used for the elevation correction of GPR measurements and the construction of the digital elevation model (DEM) of the tumuli, upon which all the geophysical measurements and horizontal GPR slices were overalaid. Finally, the corresponding depth slices were used for the generation of 3-D models of the subsurface stratigraphy of the tombs.

Processing of the magnetic gradient and soil resistance measurements included despiking techniques, removal of trend, application of high pass filtering techniques and calculation of the first and second horizontal derivatives. Together with the compression of the dynamic range of the original values, the above techniques were successful in outlining the most prominent anomalies.

3. Magnetic Survey at the Tumulus of Chelidona-Ladi.

In the area of Chelidona-Ladi there were two tumuli, lying at opposite sides of the road. After the removal of the bulk of soil, a burial was revealed in one of the tumuli. High resolution controlled experiments with the fluxgate gradiometer were carried out in the area surrounding the burial in order to examine the magnetic signature of it. Due to the enhancement of the magnetic susceptibility by the burning mechanism of fire and the metal fragments placed as offerings to the dead, a strong magnetic signal was produced (Fig. 1).

Similar excavations in the other tomb were unable to locate any remains of burial. Instead, they brought to light portions of ceramic pits, lying at the bottom of the tumulus, probably dated to the Neolithic Period.

Based on the assumption that it would be possible to discriminate ceramic pits by cremation burials on the basis of the signal produced, magnetic survey was carried out at the bottom of the second tumulus covering an area of 60m x 40m, with a sampling interval of 0.5m. The results of the magnetic survey, enhanced by range compression techniques and the application of directional derivatives and high pass filtering, were able to map the wealth of the subsurface features lying at the bottom of the tumulus (Fig. 1). A semi-circular feature lying in the SE part of the magnetic maps might be related either to the boundaries of the tumulus or the limits of a neolithic settlement that seems to have been located at a shallow depth below the surface (Fig. 2). A number of smaller (~1-2m) isolated anomalies might be corellated to ceramic pits, similar to the one discovered by excavations and which was registered as a strong magnetic anomaly in the SW part of the map (x=10-14E, y=14-19Ñ). The central part of the region (x=17-26E, y=13-29N) is also characterized by a number of strong magnetic anomalies. Although this area exhibits the strongest magnetic signals, and was considered as the most probable candidate for being related to a cremation burial, excavations that followed the geophysical survey revealed a large ceramic neolithic pit. Finally, a linear anomaly crossing the site in a SW to NE direction is possible to be caused by the presence of a wide corridor or trench. In this way, magnetic measurements, verified by excavation results, were able to identify and map a neolithic settlement, one of the very few existing in the particular region.

4. GPR & Magnetic Survey at the Tumulus of Elaphochori-Daphni

Previous excavations at the Tumulus of Elaphochori-Daphnis have revealed a Roman structural tomb lying less than a meter below the upper surface of the tumulus (Fig. 3). The purpose of the geophysical investigations was twofold: first, to study the GPR and magnetic response resulting by the tomb structure and second to investigate the possibility of the existence of additional targets within the tumulus.

Geophysical investigations were carried out within a 18m x 27m grid, along south to north traverses. Sampling interval was set to 1m for the magnetic measurements. GPR measurements were taken along S to N traverses 2 meters apart, using an EKKO 1000 ground penetrating radar and a 225MHz antenna, with a 10cm sampling interval. One more transect in the W to E direction, right above the tomb, was also measured.

The measurements of the magnetic gradient indicated a semi-circular feature of low intesity, together with a number of high intensity isolated anomalies (Fig. 3). The feature runs along the perimeter of an older metal fence that was removed relatively recently.

A quadrapole dipole, in the SW section of the map is located exactly above the tomb, which is extended about 4m within the tumulus. The high magnetic gradient anomaly is caused by a metal fence-like grid placed just above the entrance of the tomb during conservation works. Most of the GPR transects crossing the tomb show evidence of the precence of a construction or some kind of soil stratigraphy disturbance. A few GPR anomalies are indicated at the position of the older fence, and specifically at the position where the cemented posts used to be. The most significant reflections have been projected on the map of the magnetic results. Generally, there was no indication of any additional subsurface feature other than the excavated tomb.

5. GPR, Magnetic and Resistivity Survey at the Tumulus of Spilaion.

Geophysical techniques in the Tumulus of Spilaion included GPR measurements above the tumulus and magnetic and soil resistance measurements in the region of the small hill, located east of the tumulus. Sampling interval was set 1m for both directions for the magnetic and resistivity techniques and 0.25m along transects 2m apart for the GPR techniques. The GPR measured 23 traverses with direction from south to north and 6 traverses with direction from east to west. A total area of 4200 sq. m was covered by the rest of the techniques.

Soil resistance techniques applied in the region of the small hill indicated a circular anomaly, enhanced through the computation of directional derivatives and the application of high pass filtering techniques (Fig. 4). A 30m in diameter circular anomaly and a few more linear features are present in the map of the soil resistance measurements. In contrast, the magnetic measurements did not show any significant anomalies other than some isolated anomalies, probably related to the presence of small ceramic pits. It is most probable that the subsurface features are related to the relics of a neolithic settlement.

Above the tomb, GPR techniques employed an antenna of 110MHz in order to achieve a larger penetration. GPR reflection data exhibited a high depth candidate anomaly at x=7-13 and y=25-30. Other shallow depth anomalies might be caused by trenches opened through illegal excavation or disturbances of the upper soil layers of the tumulus. Time slicing techniques were applied for each transect, by calculating the average value of the reflection signals for different depth ranges (Fig. 5). Kriging interpolation techniques were used for constructing the different depth reflection layers, which were later superimposed on the digital elevation model of the tumulus. Finally, the surface layer of the GPR data from the tumulus and the soil resistance map from the nearby area were superimposed on the topographic layout of the site. The rectangular anomaly at the centre of the tumulus (time slice t=0-60nsec) is probably related to a recent trench opened by treasure hunters reaching a depth of more than 9 meters towards the bottom of the tumulus.

6. GPR Survey at the Tumulus of Mikri Doxipara

The 110MHz EKKO 1000 was used for the detailed mapping of the Tumulus of Mikri Doxipara. Measurements were taken along S to N transects, 2m apart with a 0.25m sampling interval. The rough surface of the tumulus produced a few anomalies caused by the imperfect contact of the antennas with the surface of the soil. A significant anomaly was produced at x=23-27E, y=28-36N, caused by an old cement structure of an underground military post. Time slicing techniques were applied for various time (depth) ranges (Fig. 6). The most detailed time slices (Δt=2 & 5nsec) were characterized by increased noise levels. The definition of the time zero drift and the application of high pass filting techniques were found to be useful in the computation of the time slices. The most significant anomalies are present in the northern (x=12-16E & y=33-43N) and the northeastern (x=30-38E & y=30-45N) part of the tumulus, indicating that they may continue for at least 4m below the surface of the tumulus.

A region confined by coordinates x=15-40E and y=36-50N was also investigated with the GPR along transects in the west to east direction. Comparison of the time slices produced for the same region along transects of perpendicular direction exhibit a small degree of correlation, suggesting that the orientation of the antennas plays a critical role in the GPR survey. Finally, solid models were constructed based on the reflection signals of the GPR survey. Emphasis was given to the shallow depth anomalies. Further refinement of the solid models is under progress, in order to take into account parameters such as the elevation variation of the tumulus and the time zero drift of the GPR signals.

7. Conclusions

Although tumuli are characterized by inherent boundary conditions, ground based prospection techniques can contribute significantly to the study of the subsurface features within them. In this way, it becomes possible not only to map the subsurface targets, but also to preserve the monuments as they stand.

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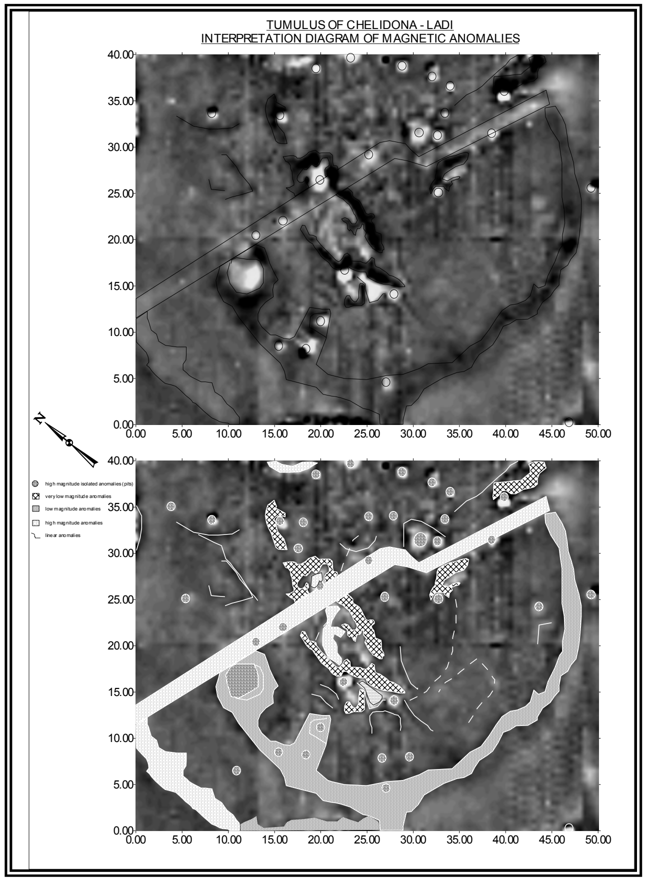
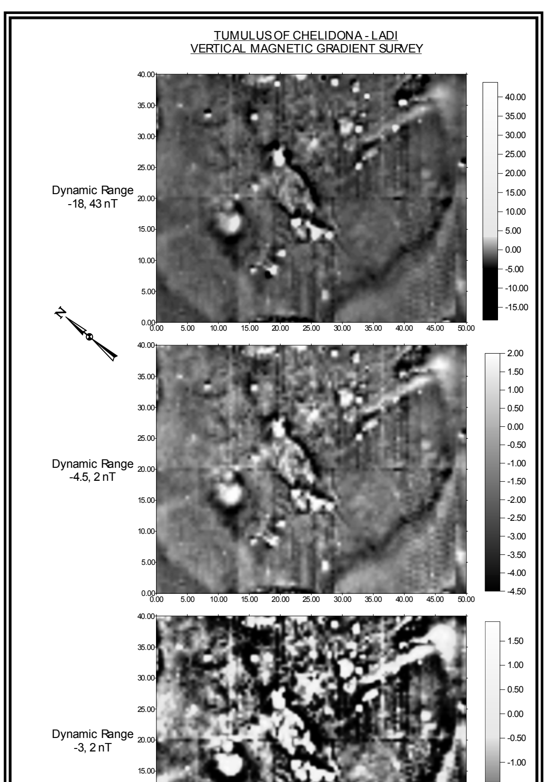




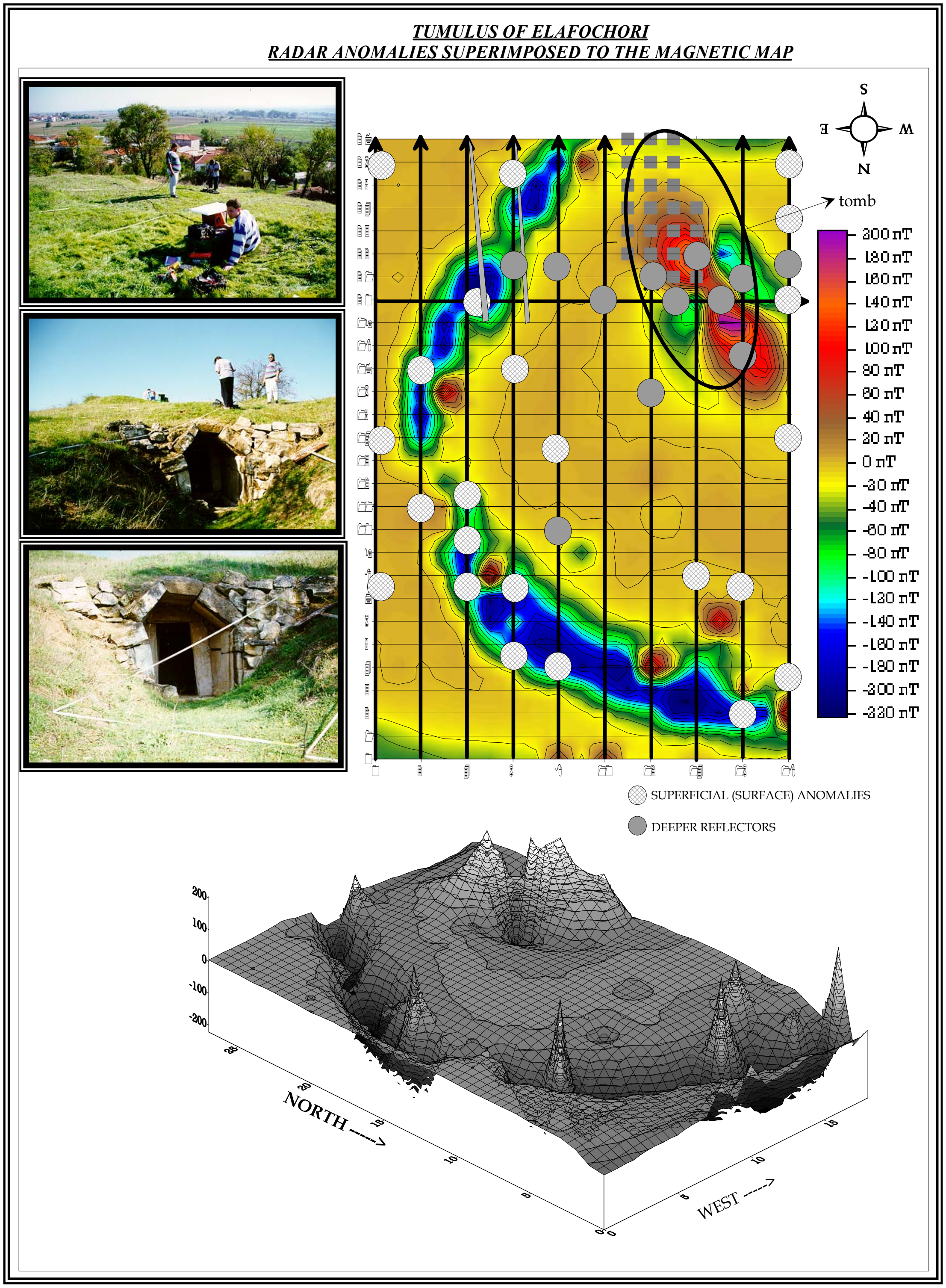


Figure 3. Details from the GPR and magnetic survey at the tumulus of Elaphochori-Daphni.

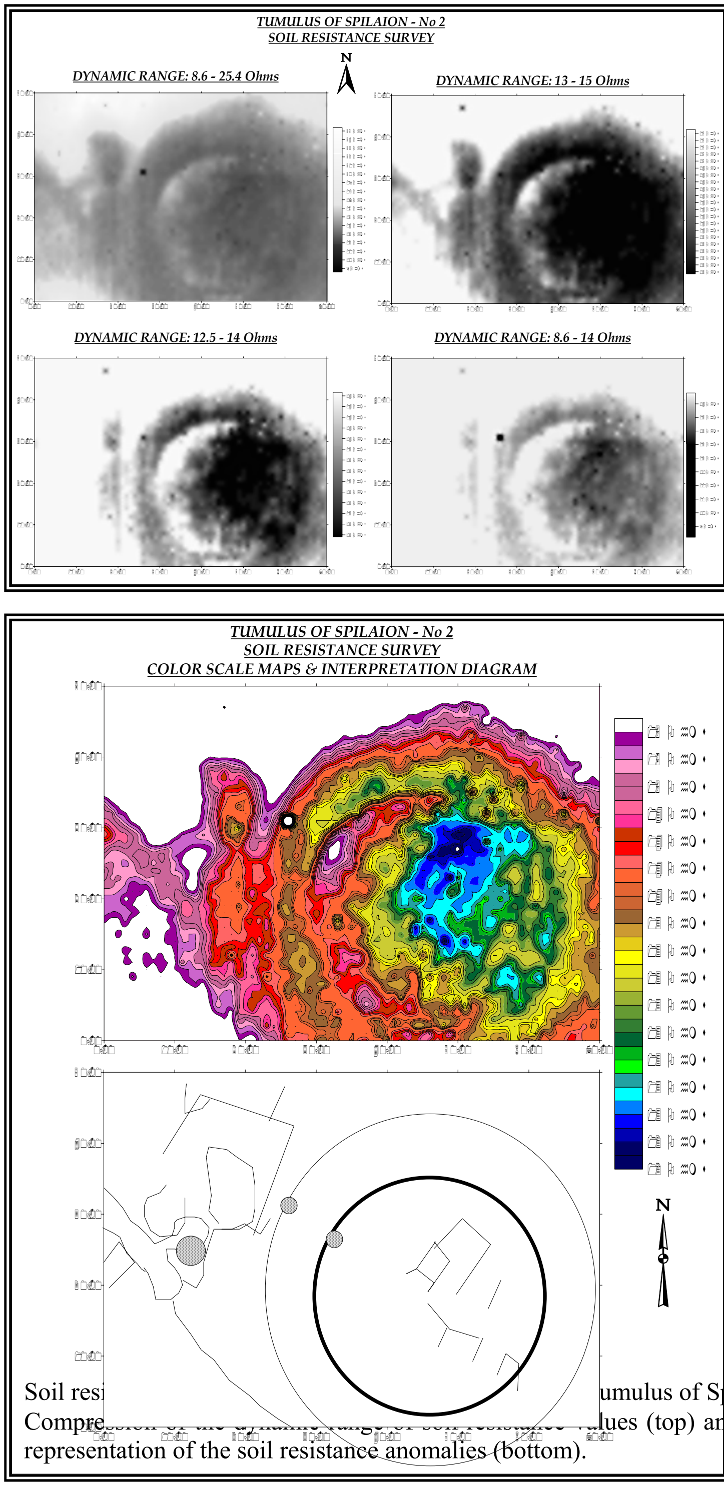
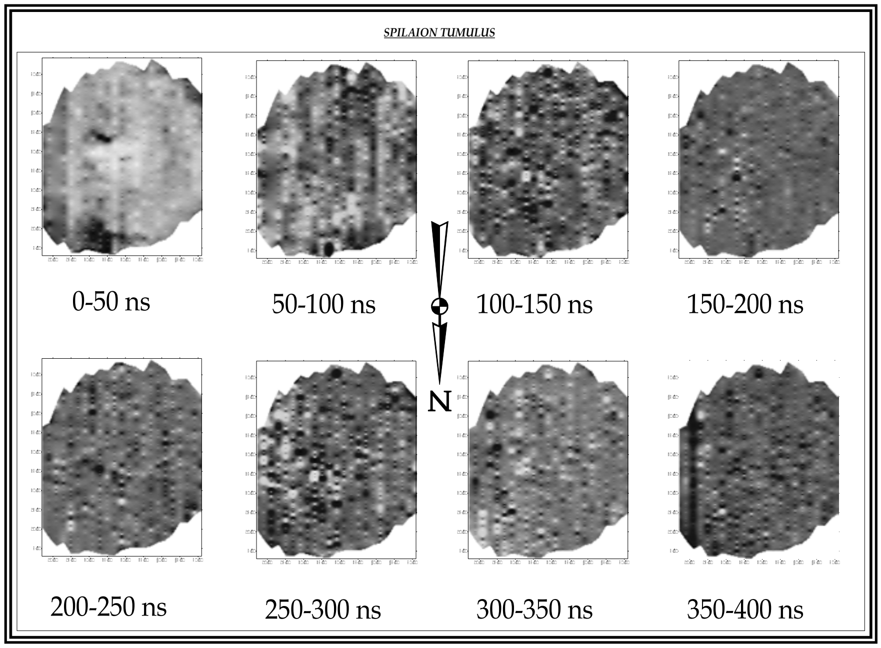


Figure 4. Soil resi[illegible]umulus of Spilaion. Compression of the dynamic range of soil resistance values (top) and diagrammatic representation of the soil resistance anomalies (bottom).



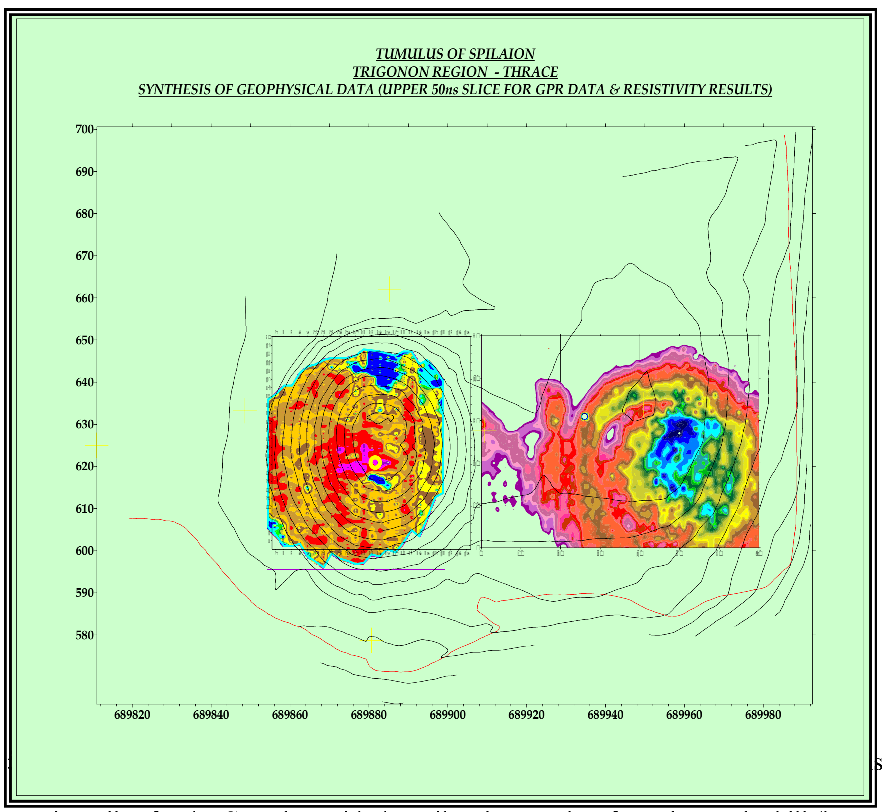
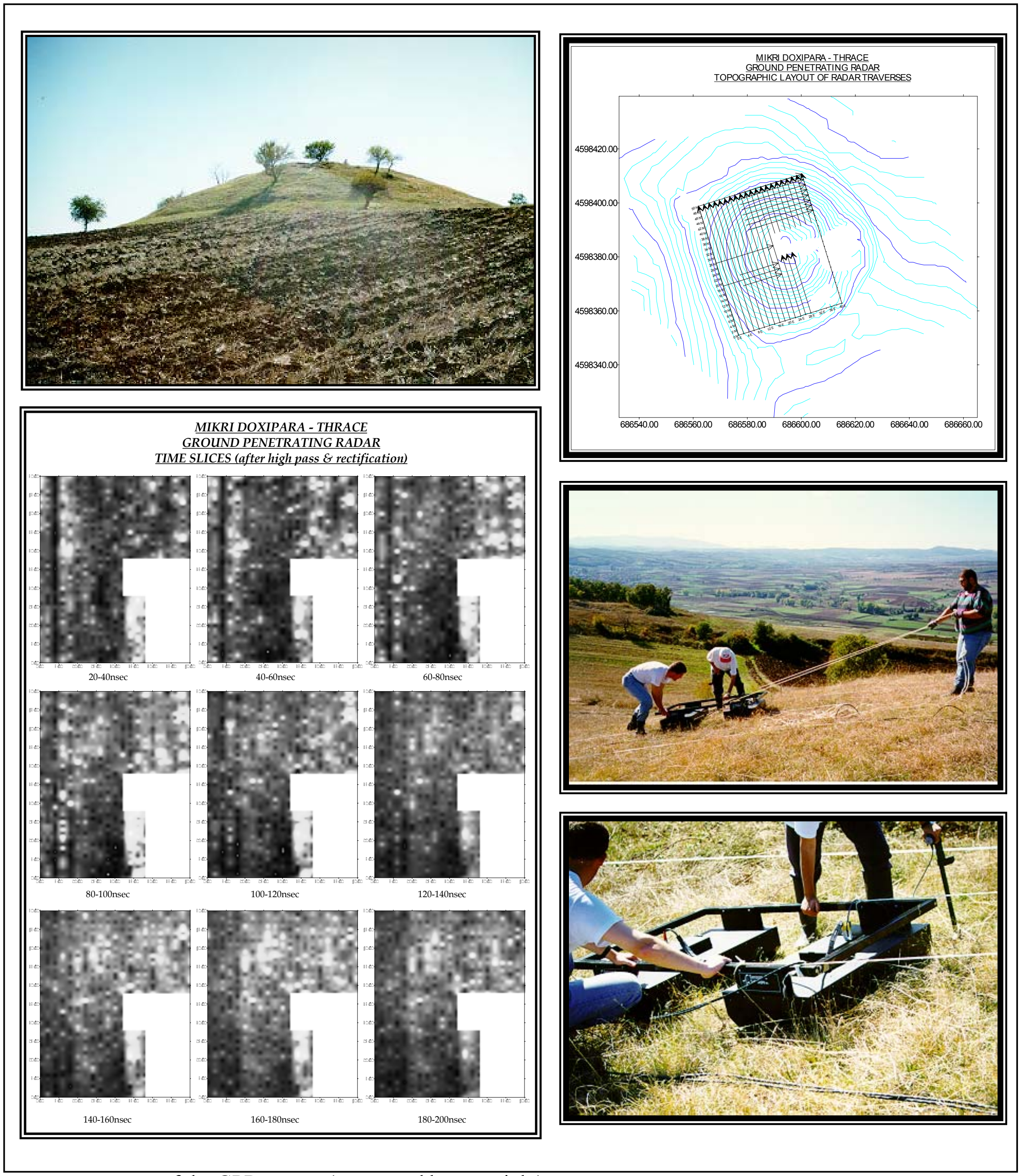


Figure s of the upper

time slice for the GPR data with the soil resistance data from the nearby hill (bottom).



of the GPR survey (centre and bottom right).