COMPLEX GEOPHYSICAL PROSPECTING FOR DISCOVERING AND NVESTIGATION OF ARCHAEOLOGICAL TES

Abstract
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The opportunities offered by a complex of methods for discovering and investigation of archaeological sites are presented. The studies start with aerial observations and photography of large areas of land. The prospecting is repeated many times from a two-seat powered handglider, under different conditions. The sites for which there is a probability to be of high archaeological value are set aside after a careful analysis. Geodetic methods are used to localize these sites on the Earth's surface, after which various geophysical investigations are carried out. The preliminary results of these investigations allow the precise localization of the site and provide guidelines for the subsequent detailed geophysical prospecting.

The paper presents the results of geophysical prospecting (electrical and magnetic) of sites in the archaeological reservation of Debelt, discovered from the air. A description is also given of the methods used for complex profiling and sounding measurements for obtaining three-dimensional images of the sites.

In the past six years the research team of the Archaeometry Laboratory of the Institute of Thracology of the Bulgarian Academy of Sciences has worked actively on the application of complex geophysical prospecting for investigating archaeological sites.Most of these investigations are carried out on the territory of the Debeltum-Deultum archaeological reservation localized near Debelt village, Bourgas district, where more than 20 sites of different types and ages have been discovered so far. Active uninterrupted human presence has been documented in these lands for nearly three millennia, from the Early Bronze Age to the Middle Ages.

The in situ research complex which we are trying to achieve includes the application of: air prospecting and documentation of vast areas with the aim of detecting promising sections; geodetic measurements for fixing and localization of interesting areas,laying of measurement grids and documentation of the sites;geophysical prospecting using electrical, magnetic, electromagnetic and other methods; computer processing and analysis of the information obtained; partial archaeological excavations with the aim of verification of the prospecting. A number of specialized equipment and software have been designed for the successful utilization of this complex, as well as programmes for processing the results of the measurements.

The high archaeological value of air prospecting needs no proof. Much to our regret, Bulgarian aeroarchaeology is still an aggregate of isolated activities, rather than regular practice. It is necessary to organize permanent aeroarchaeological activities with a high scientific and economic effectiveness. Archaeological tasks usually involve prospecting of relatively small areas from a small height 50 - 500 m. They require light, manoeuvrable and economical aircraft, therefore we decided to used multi-seat and one-seat powered hand gliders.

Air prospecting was carried out in the Debelt archaeological reservation in the summer of 1989, using two-seat powered hand gliders. The flights were made at different hours of the day,

predominantly early in the morning, from a height of 50 to 300 m. Many unknown sites were discovered and the archaeological information about the reservation was subsrantially increased.

In the summer of the same year, a considerable part of the newly discovered sites were localized and marked on the terrain by means of precise geodetic measurements. Terrain geophysical prospecting was performed in five of them, including:

- electrical profiling with symmetrical four electrode configurations A1M1N1B and A2M1N2B, applied along a system of mutually perpendicular profiles with N-S and E-W orientations, and a 1 x 1 m grid. The measurements were made using a resistivity meter and commutation equipment designed at the laboratory.
- magnetic measurements along N-S profiles and a 1 x 1 m grid, using a 0.5 x 0.5 m grid in the strongly anomalous areas. The vector of the magnetic field and its vertical gradient were measured using MP-3 proton magnetometer of the Canadian company Scintrex. The diurnal variations of the magnetic field were measured using another proton magnetometer.
- electrical sounding performed in points on a 25 x 25 m grid. On the basis of the results obtained the archaeological-geophysical sections along profiles are made,suggesting considerable thickness (1.5 to 9 m) of the surface layer consisting of clays and small rock fragments with resistivity of 25 to 55Ohm.m. Below it there is a thick layer of clayey sands with 15 - 30 Ohm.m resistivity, overlying the andesite bedrocks. In isolated sections in the surface layer it is possible to distinguish groups of intercalations with a small thickness and a resistivity of 65 - 200 Ohm.m, probably marking the different building horizons.
- metal detectors,used to clean the terrain from contemporary metal scrap before the magnetic measurements are under taken and for seeking metal objects of archaeological value.

It is interesting to compare and generalize the results of the air observations and terrain prospecting, i.e. a comparison between the image and the details of the site seen and photographed from the air and its configuration obtained as a result of geophysical prospecting using various methods.

Our comparison is based on two sites. The first site, provisionally referred to as the "Roman villa", is at a distance of about 800 m to the northwest of the Roman city of Deultum. Figures 1a and 2a show pixel maps accordingly of the apparent resistivity, measured by the A2M1N2B configuration along profiles with N-S orientation and of the gradient of the magnetic field along the same profiles. Figures 1b and 2b present only values exceeding 30 Ohm.m and 10 nT, respectively. This allows to filter the background values and to obtain a higher contrast image of the site in the ground, which is totally invisible on the surface.The dimensions and the shape of the site obtained using the two methods reveal very good coincidence.

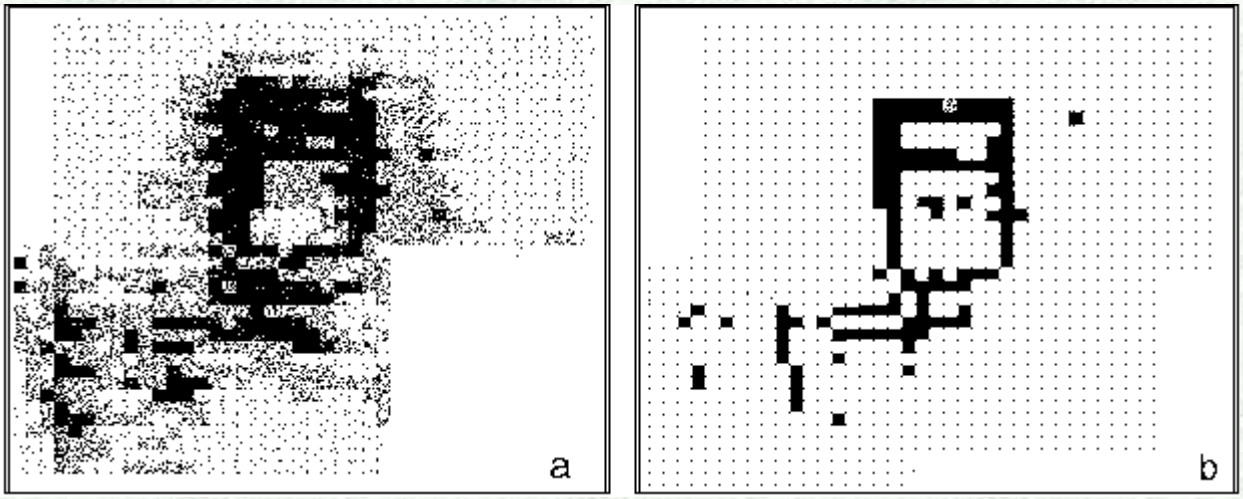

Fig. 1. *Pixel map of the apparent resistivity of the Roman villa. Configuration A2M1N2B. N-S profiles. a - image comprising all measured values; b - image comprising values exceeding 30 Ohm.m.*

The localization of the site, its architecture and the results of the investigations gave grounds to specialists to define it as a Roman villa in the vicinity of the city. The western part of the villa is built of stones and is well outlined. The eastern part is probably a brick addition which does not differ in apparent resistivity substantially from the environment, but has very different magnetic properties, therefore it is not detected bythe electrical prospecting.

The second site, provisionally called The Spot, is localized at about 100 m north of the Roman city of Deultum.

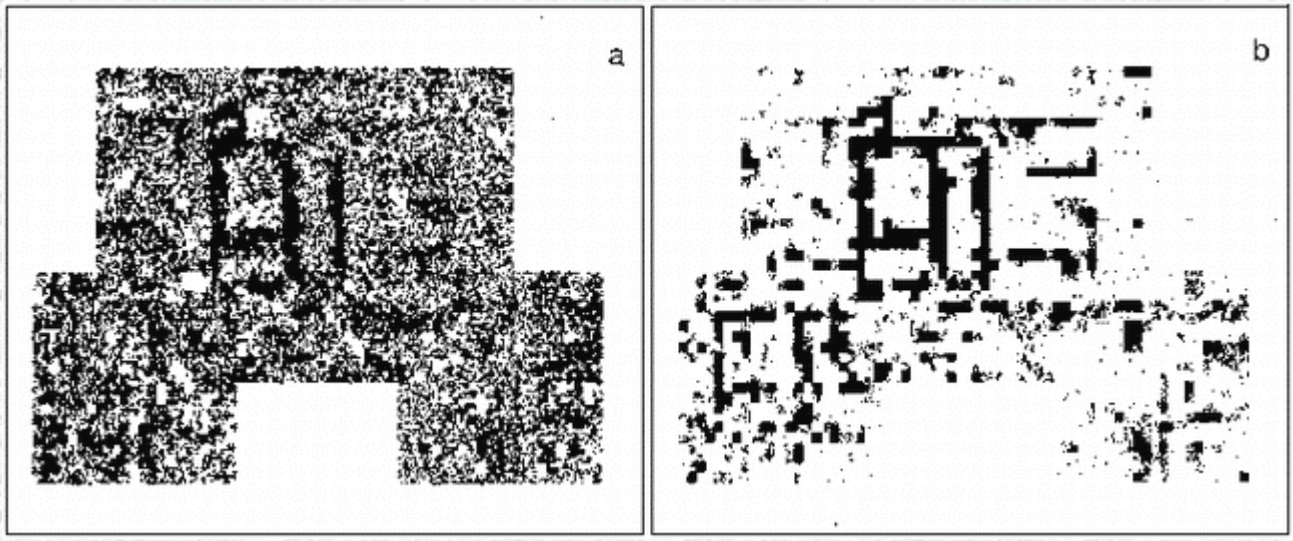

Fig. 2. *Pixel map of the vertical gradient of the magnetic field of the Roman villa. a - image comprising all measured values; b - image comprising all values ex-ceeding 10 nT.*

Similar prospecting was performed there as well. Figure 3 presents a contour map of the apparent resistivity along N-S profiles and using configuration A2M1N2B. The position ofthe site,its architecture andthe results of the prospecting gave grounds to specialists to define it as a separate building

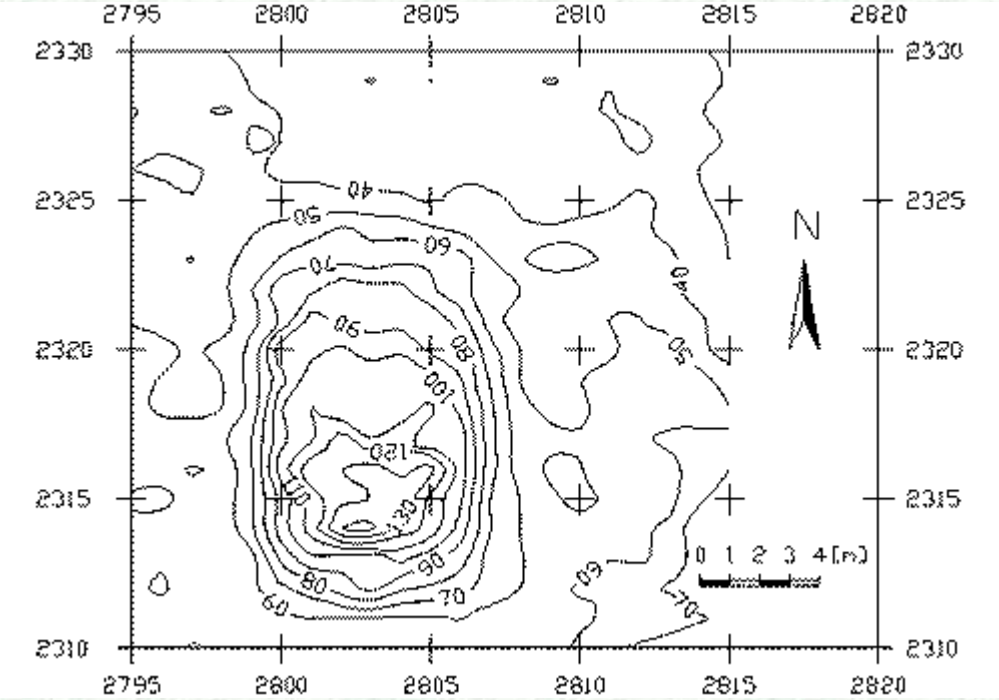

Fig. 3. *Contour resistivity map of the site referred to as "The Spot". N-S profiles. Configuration A2M1N2B.*

which probably performedsome religious function, probably a chapel or a church.

Combined electrical measurements were also performed in this site profiling, using souding methods at each point. This method of measurement and the subsequent processing of the results allow the site to be studied in depth and to form a three-dimensional image of the disturbing body with a high degree of precision. The prospecting was made using a three-electrode configuration and along profiles with N-S orientation. The results obtained served as a basis for maps of the vertical geoelectrical sections along profiles, maps of the changes of the apparent resistivity at different levels and maps of the differences in the apparent resistivities between the different levels.

Figure 4 presents maps of the vertical geoelectrical sections for six profiles.With the exception of the anomalous zone,the six sections presented are characterized by a reduction of the apparent resistivity from 40 - 60 Ohm.m on the surface to 20 - 30 Ohm.m in depth, which is connected with the homogenization and higher density of the environment, and with the clearing of disturbing bodies. A similar character of the change in the apparent resistivity in depth is observed also on the maps of the horizontal levels whose pixel images are shown on Figure 5.

From the sections shown on Figure 4 it can be seen that the main part of the anomaly is concentrated

between profiles 1 and 5, profiles 2, 3 and 4 passing through it, whereas in profiles 1 and 5 only reflections of the disturbing body are detected.The anomalous zone reaches about 3.5 m in depth. The maximum values reach 140 Ohm.m at a depth of 1.5 - 2 m. The anomaly is with a marked rectangular shape for levels 1 to 3, with subsequent gradual appearance of a second crosslike zone in the interior of the contour outlined for levels 4 and 5, decreasing in size in N-S direction. Less intensive anomalous zones are marked transversely to the site at levels 2 and 3,probably generated by weaker linear sites with the same orientation.

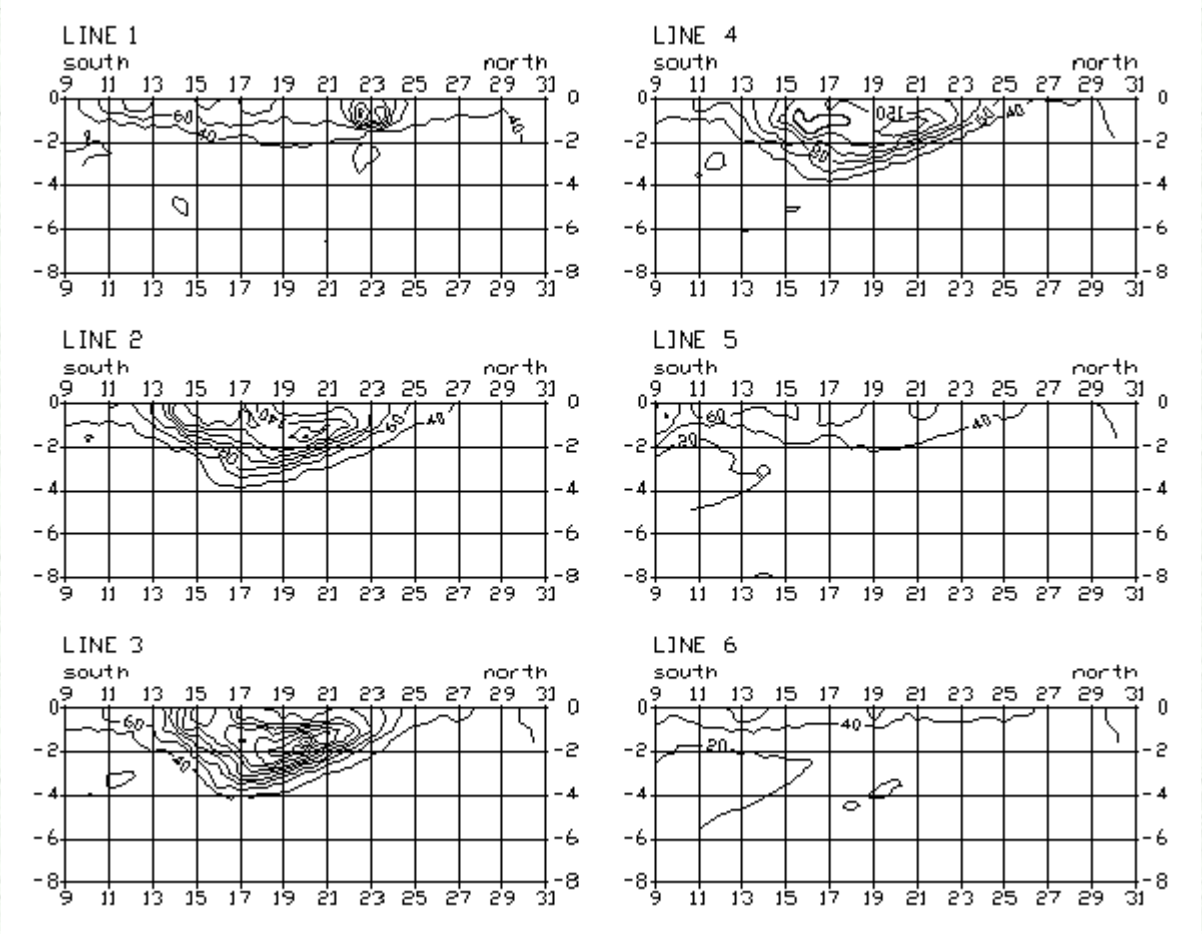

Fig. 4. *Maps of the vertical geoelectrical sections along profiles. "The Spot".*

Analysing the specificities of the maps in question from an archaeological point of view, the anomaly may be assumed to have been caused by a buried rectangular construction with N-S orientation, with well preserved walls longitudinally, overlying a foundation of much smaller dimensions longitudinally and with an elaborate configuration.The site is probably strongly destroyed in its southeastern part. In its interior there appears to be an anomalous zone, probably generated by a transverse inner wall in the southern part. The site is probably likewise connected to a wall which goes beyond the limits of the investigated area, in the northwestern corner.The foundation of the site resembles a cross,with lighter additional constructions on both sides and with N-S orientation.

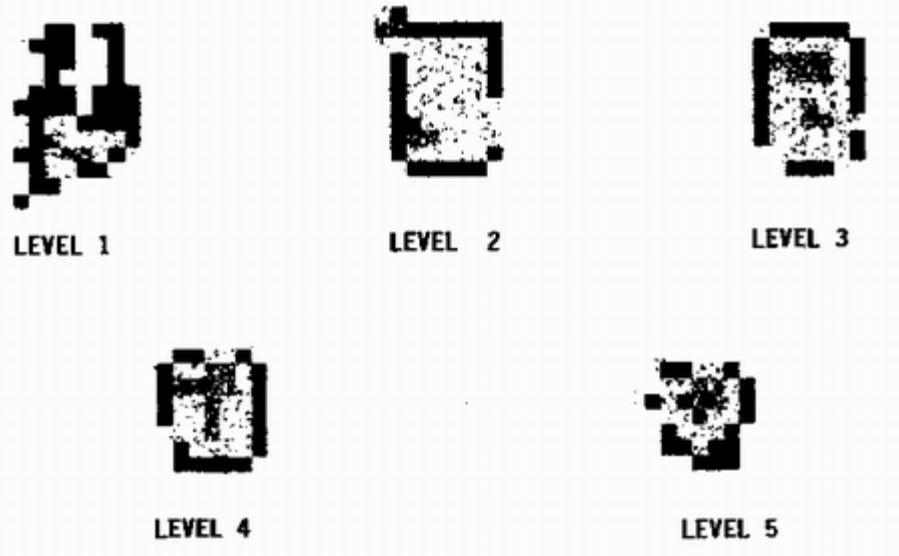

Fig. 5. *Pixel images of the apparent resistivity at different levels. "The Spot".*

The differences in the development of the studied site in depth may also be interpreted as the presence of two superimposed and mutually independent constructions.

Finally,the application of complex geophysical prospecting in the region of the Debelt archaeological reservation has led to the following conclusions:

- from the air photographs it is possible to define very precisely the areas on which geophysical prospecting should be undertaken. This sharply reduces the number of sites to be studied, with their area, hence bringing down costs and raising the efficiency of the studies;
- geophysical prospecting gives very detailed information about the site and its environment. Sometimes it can detect new sites which are invisible from the air;
- air and terrain geophysical prospecting are mutually complementary and useful, hence there is no doubt about the utility of combining the two methods in a complex.

ACKNOWLEDGEMENTS

We would like to thank Ordanizing Committee of the 2nd Southern European Conference on Archaeomerty, especially Dr. Y. Liritzis and Dr. G. Tsokas for a denerous grant which allowed our participation at the conference.

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