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MAGNETIC AND GEOELECTRIC PROSPECTING IN THE ARCHAEOLOGICAL AREA OF SELINUNTE (SICILY, ITALY)

Abstract. In this paper we describe the results of magnetic and geoelectric prospecting at a site in the archaeological district of Selinunte (Trapani, Italy), where traces of precolonial habitation are believed to exist inside a calcarenitic block underlying a cover of silty sediments. The maps of the total magnetic field intensity did not evidence any significant anomaly. The vertical electric soundings showed that the calcarenitic slab rapidly looses solidity from S to N. Finally, the geoelectric pseudosections outlined the fragmentary character of the calcarenitic block. From these results it seems reasonable to state that in the selected site the archaeological hypothesis is not supported by the magnetic and geoelectric evidence.

INTRODUCTION

This paper reports the results of magnetic and geoelectric prospecting in the archaeological district of Selinunte (Sicily, Italy), over a square of side of 90 m denominated the "Greek area", located very close to temple G dedicated to the god Apollo (Fig. 1).

The purpose of the study was to single out geophysical anomalies due to buried archaeological targets. The possible presence in the survey area of a precolonial settlement, characterized by residential rooms dug into a solid calcarenitic slab and surrounded by stone walls, at a maximum depth of 2-3 m below ground level is hypothesised.

The magnetic survey was performed in co-operation with researchers from the Istituto di Tecnologie Applicate ai Beni Culturali, CNR, Rome.

In the following sections, we give first a short description of the methods and instruments used in the field, then we describe the criteria used for data acquisition and representation. Finally, the data processing and the qualitative/quantitative interpretations of the relevant geophysical anomalies are outlined.

METHODS AND INSTRUMENTS

Magnetic surveying

The magnetic measurements were done with two Geometrics G856 proton precession magnetometers, fixed at a vertical distance of 60 cm, one above the other. The height of the bottom sensor above ground level was 60 cm. The instrument specifications assure a sensitivity of 0.17 nT/m for the gradiometric acquisition mode.

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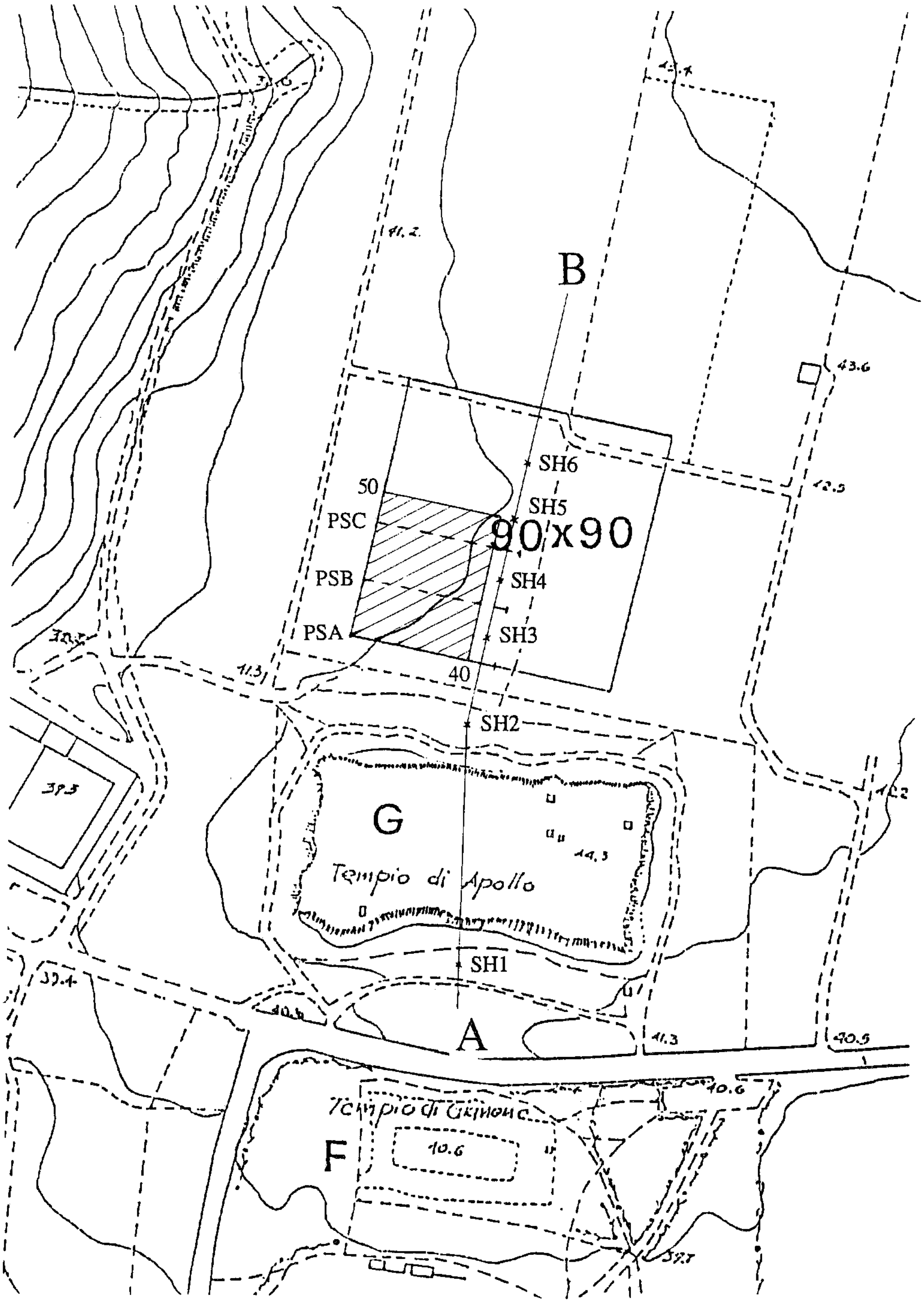

Fig. 1 — The 90×90 m^2 survey site in the archaeological district of Selinunte (Sicily, Italy). The hatched sector is the area mapped by the magnetic measurements and crossed by the three dipole-dipole pseudosections PS-A, PS-B and PS-C. AB is the profile line covered by the six Schlumberger geoelectric soundings SH-1 through SH-6. The Apollo temple is marked by the letter G.

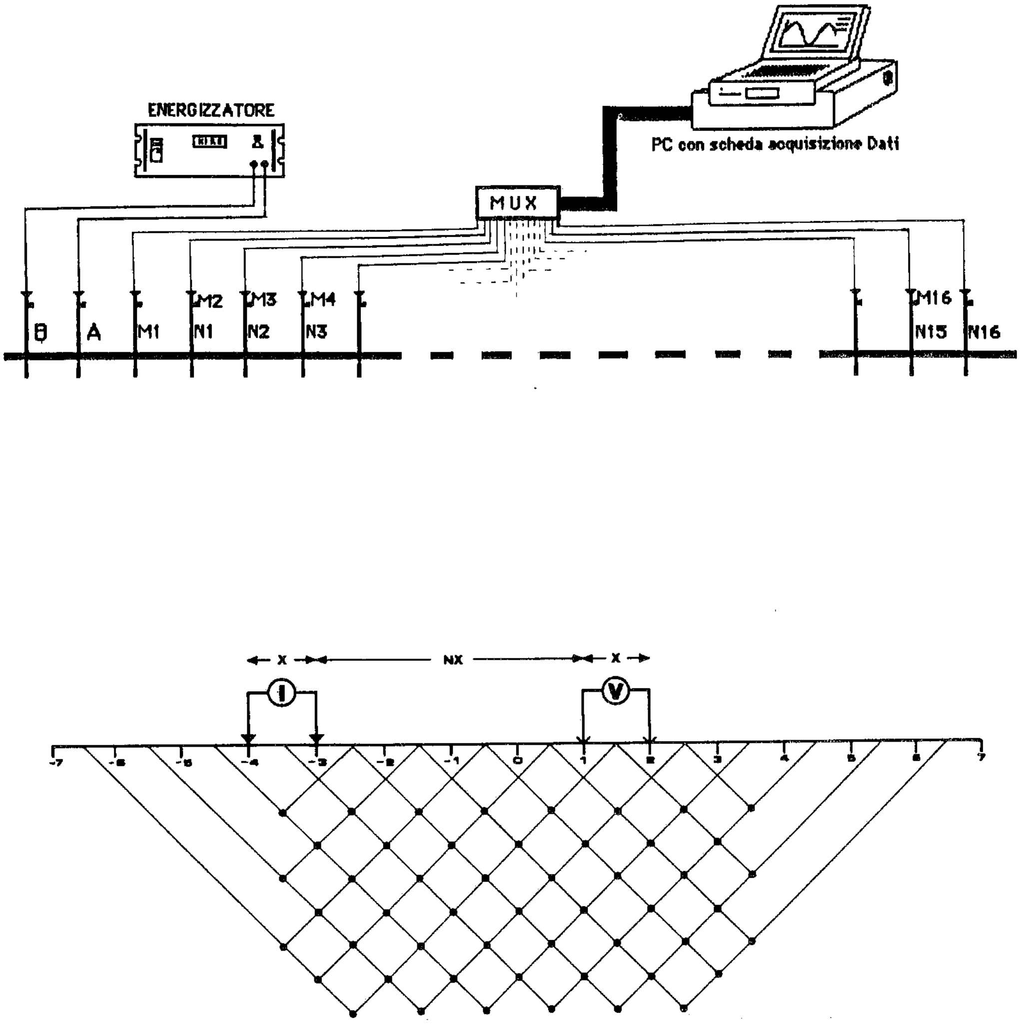

Fig. 2 — Diagram of the dipole-dipole profiling technique and method used to plot the results in a pseudosection.

The use of two sensors allows both a traditional magnetic survey at two different heights and a gradiometric survey, i.e. immediate readings of the vertical gradient of the Earth's magnetic field. The gradiometric technique is particularly suitable for the identification of short wavelength anomalies associated with shallow targets of small dimensions, as is the case in archaeological research. In fact, the gradiometric profiling or mapping technique corresponds to an experimental anomaly residuation process, equivalent to the mathematical high-pass filtering which is usually performed on field magnetic data recorded with only one sensor. Of course, in the gradiometric mode, the regional gradient and the time variation of the Earth's magnetic field are uninfluential.

The gradiometric mode is not suitable when a random stationary noise is present in the survey site, which cannot be removed and which generates anomalies having wavelengths and amplitudes of the same order as those of specific interest. In this case, the signal-to-noise ratio is so strongly reduced that it is preferable to use the standard representation of the magnetic field measured at a predefined height above ground level in order to have at least some complementary information about the deeper geological features.

Geoelectric surveying

The geoelectric survey consisted of a dc vertical electric sounding with a Schlumberger array (VES) and dipole-dipole pseudosection profiling (DPP).

With regard to the VES method, we give here only a few details about the instrumentation used in the field, all the other aspects being very well known. For measuring the potential drop between the M and N electrodes, we used an HP3421A data logger on line with an HP41CV microcomputer for data checking and storing.

For the DPP method, however, we made some technical improvements in order to reduce both the execution time and the survey cost, without reducing the measurement accuracy. Fig. 2 depicts in a schematic way the field cable layout and the pseudosection data representation in the DPP method. The electric current is sent into the ground via two contiguous electrodes x metres apart, and the potential drop is measured between two other electrodes x metres apart in line with the current electrodes. The spacing between the nearest current and potential probes is an integer n times the basic distance x. In surveying, several traverses are made with various values of n (1, 2, ...). The values of the apparent resistivity for each traverse are assigned, along a horizontal axis, at the intersections of two converging lines at 45 degrees from the center of the current dipole and the center of the measuring dipole.

The DPP acquisition system, specifically designed for the survey in Selinunte, consisted of a 16 MHz portable PC 286 provided with an A/D card connected to a multielectrode cable layout. The card consists of a 12 bit A/D converter endowed with 16 analogical inputs in order to take 16 contemporary potential drop measurements (see again Fig. 2). This instrument allowed an average of 500 measurements/hour of apparent resistivity, which is a very good result in terms of reduction of execution time and cost.

In both the VES and DPP methods, the electrical power source consisted of an alternating voltage generator linked to a rectifier with a digital amperometer for reading the intensity of the injected current. The rectifier also has an automatic current inverter at preselected intervals.

DATA ACQUISITION

The data acquisition campaign was carried out in two stages, July 1990 for the magnetic survey and October 1990 for the geoelectric survey, and involved an area of about 50×50 m^2 corresponding to the SW square of the ancient Greek area designated for the geophysical intervention (Fig. 1).

Magnetic survey

The measurements of the intensity of the magnetic field, at the two heights of 60 and 120 cm above ground level, were acquired at the intersections of vertical and horizontal grid lines spaced every 1 m, and proceding along traverses from S to N.

In order to check the time variation of the Earth's magnetic field, we considered data recorded at a reference station 50 m to the south of the area. The reference station consisted of a G856 proton precession magnetometer located 2 m above ground level.

In total, 4182 magnetic measurements were collected in 2 days.

Geoelectric survey

Resistivity measurements were made over 5 consecutive days after a rainy period that caused a uniform moistening of the shallowest layer.

At first, we tried to ascertain the structural conditions of the area by carrying out 6 Schlumberger VES. The main purpose of the geoelectric soundings was to delineate the lateral continuity of a calcarenitic slab underlying a cover of silty sediments from the Greek temple G, which was founded over the solid calcarenitic block, until the whole selected Greek area.

After having verified the existence of outcrops of the calcarenitic rock all around temple G, which is about 40 m from the survey area, and having ascertained the presence of the same rock under a cover of silty sediments at a point inside the study area from the hole drilled by the research team of the University of Padua, we tried to evaluate its boundaries and lateral

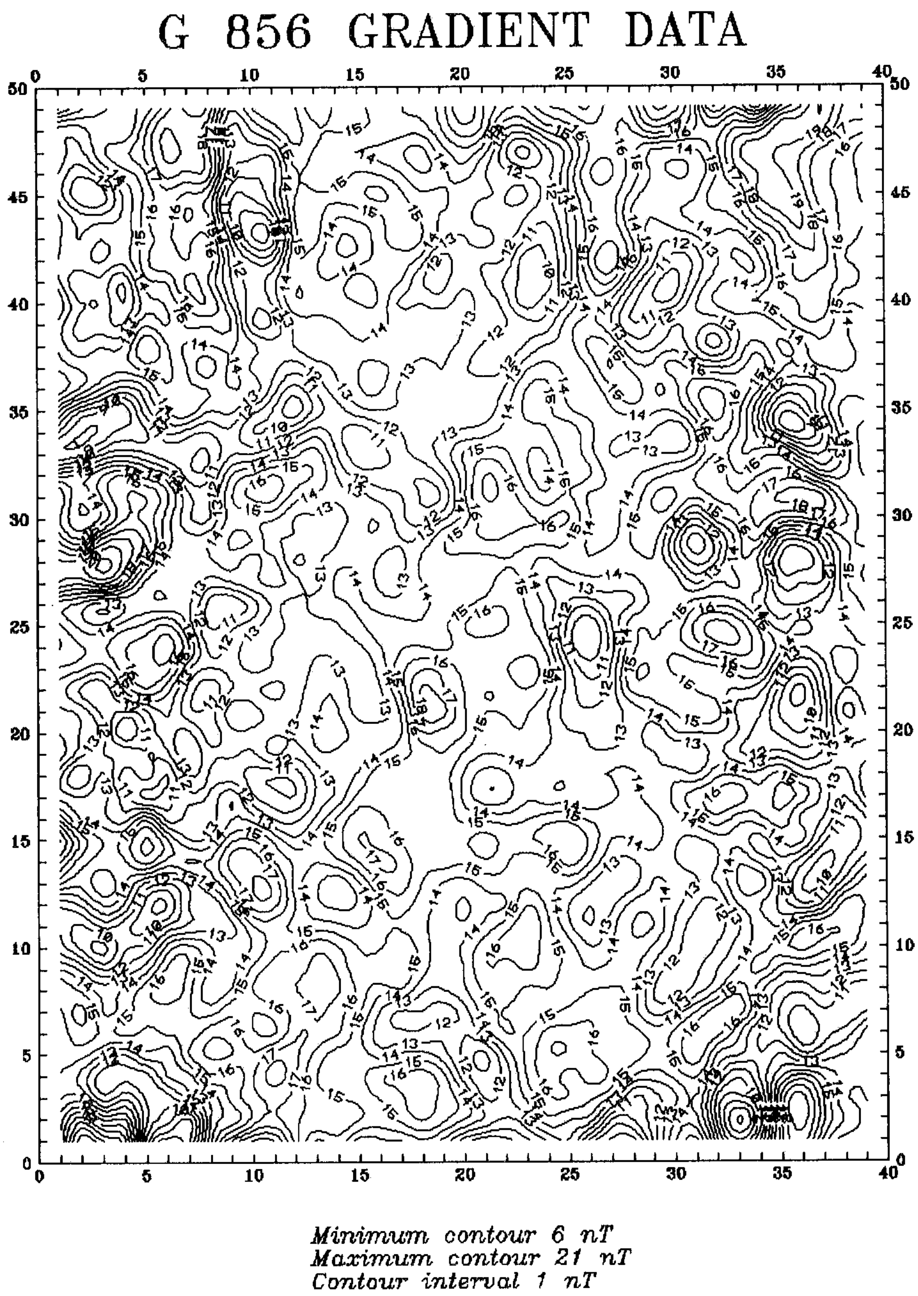

Fig. 3 — Vertical gradiometric map of the total magnetic field at 90 cm above ground level, measured in the hatched area of Fig. 1.

extent within the Greek area.

Dipole-dipole pseudosection profiling was employed along three E-W traverses, each of 50 m length. The three parallel profiles were spaced 20 m from each other and the first profile was made coincident with the southern border of the Greek area.

As previously stated, the sampling of the apparent resistivity was done in blocks of 16 simultaneous recordings. Since the fixed dipolar length was 0.5 m, the maximum spacing between the centres of the two collinear dipoles was thus 8.5 m, which corresponds in the pseudosection

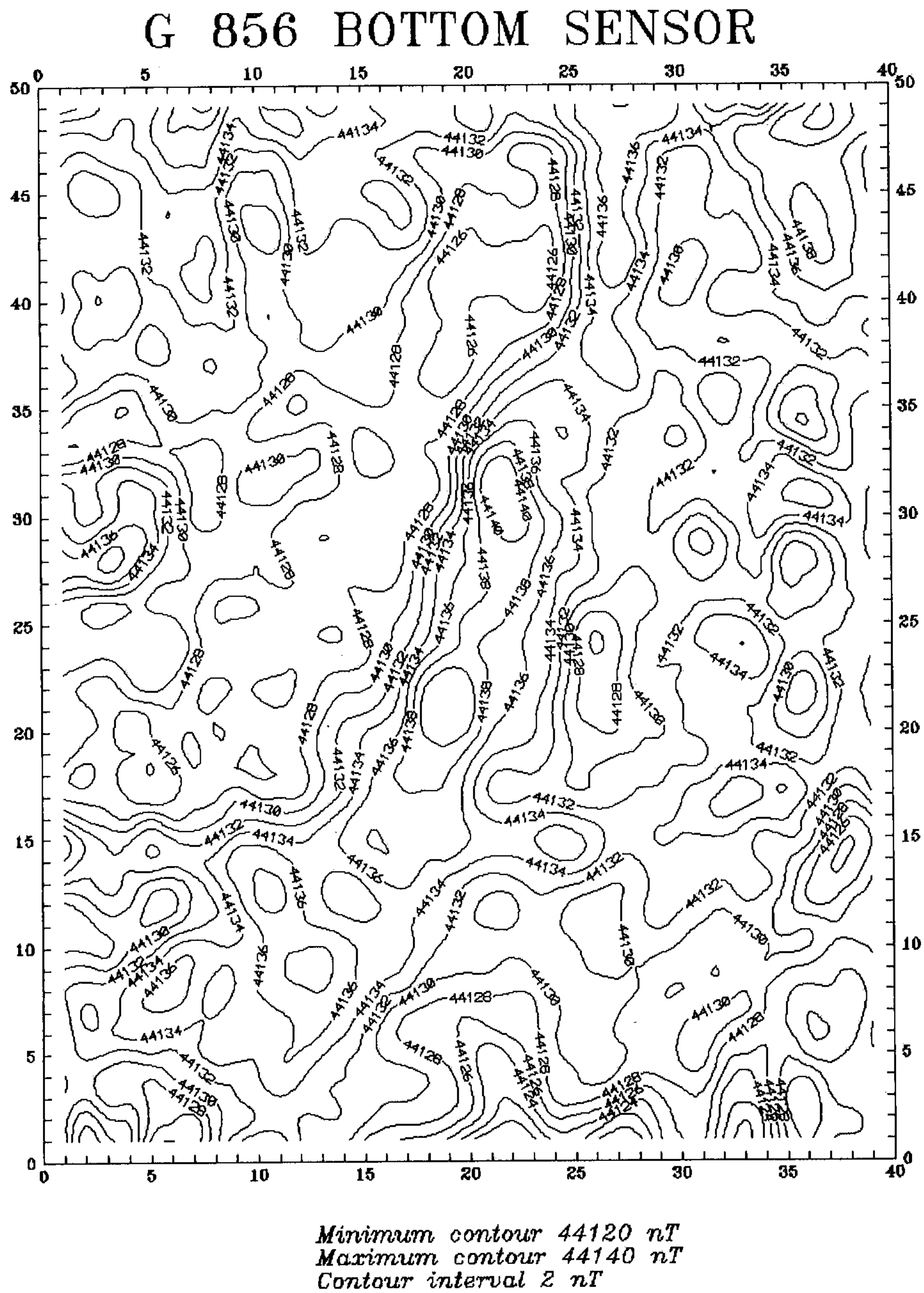

Fig. 4 — Map of the intensity of the total magnetic field at 60 cm above ground level, measured in the hatched area of Fig. 1.

to a maximum depth of 4.25 m of the last horizontal plotting line. Every successive recording block was done with a constant shift by 0.5 m of the whole 16-channels electrode layout along the profile. The pseudosections, which will be described in the next section, were thus processed using a mesh with nodal attribution points 0.5 m apart along 16 horizontal lines gradually deepening every 0.25 m, starting from 0.5 m below the surface line until the maximum depth of 4.25 m. The plotting density corresponds to 7 data per square metre of pseudosection, which is unusually high.

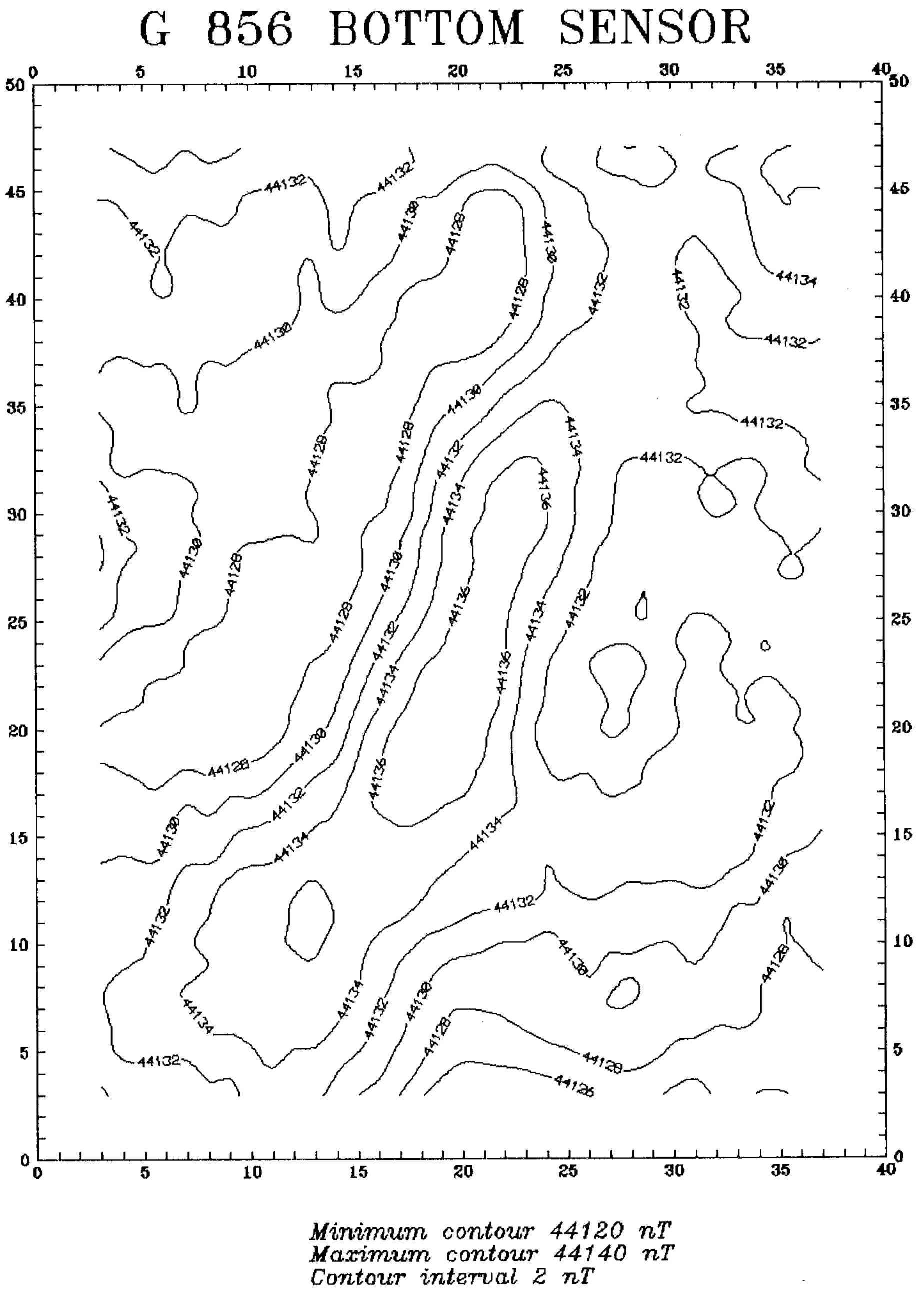

Fig. 5 — Smoothed map of the intensity of the total magnetic field at 60 cm above ground level, measured in the hatched area of Fig. 1.

DATA PROCESSING AND INTERPRETATION

Magnetic survey

The magnetic data, acquired in the gradiometric mode, did not allow certain identification of anomalies of archaeological interest due to strong high wavenumber noise caused by many spurious sources randomly distributed over the exploration area (Fig. 3). Therefore, we utilized

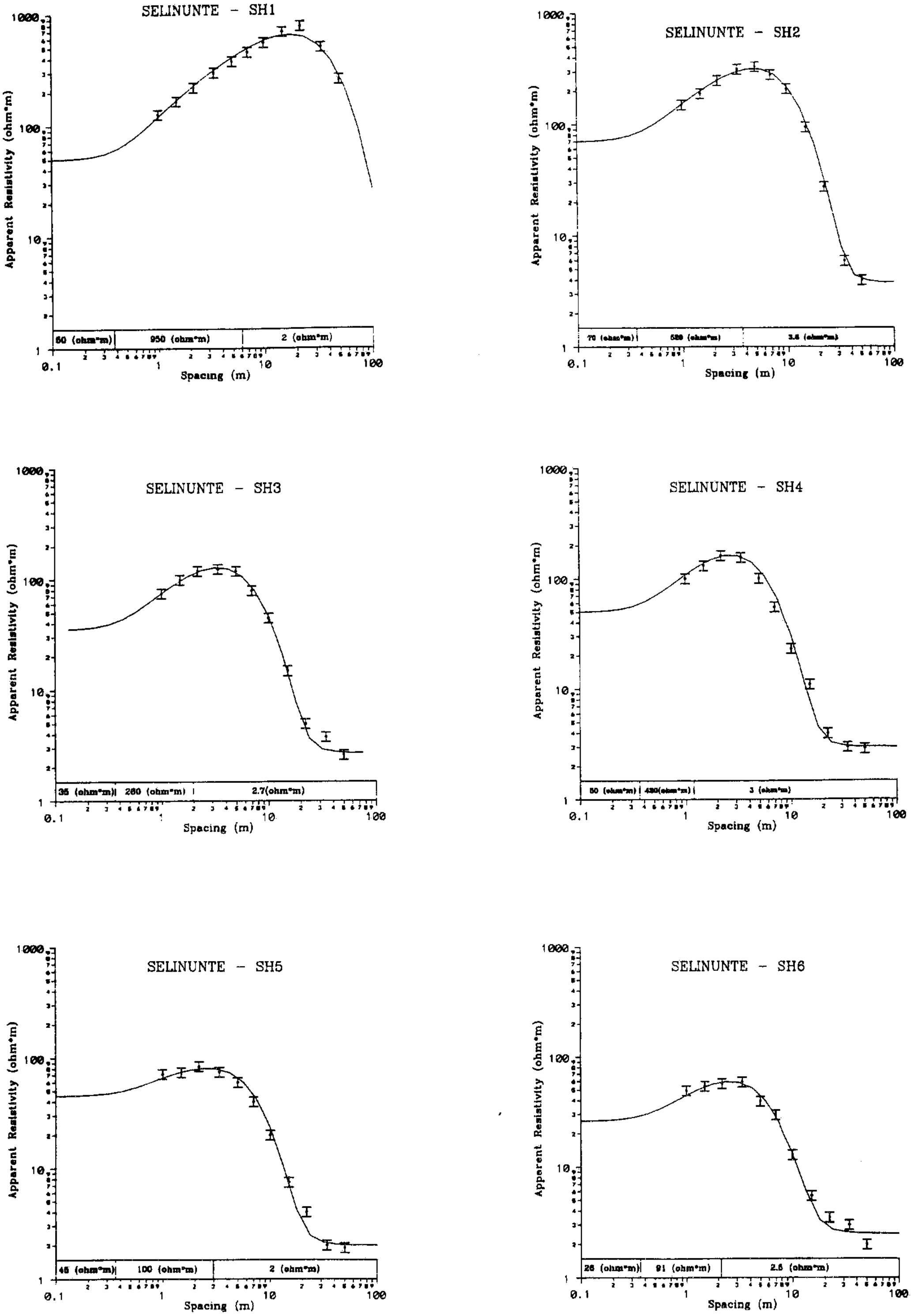

Fig. 6 — Apparent resistivity diagrams of the Schlumberger geoelectrical soundings performed along the AB profile of Fig. 1 and corresponding electrostratigraphies.

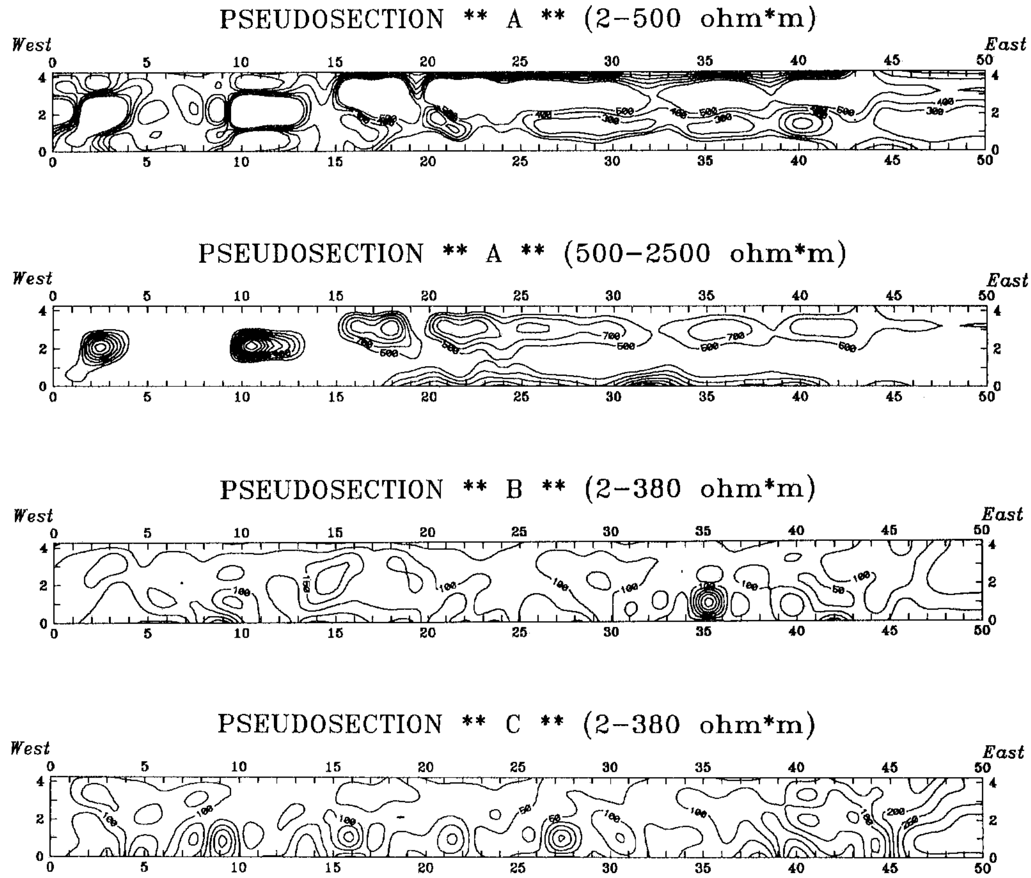

Fig. 7 — Dipole-dipole pseudosections along the profiles PS-A, PS-B and PS-C of Fig. 1. The pseudosection PS-A is split in two parts for a better visualization of the anomaly pattern.

the two distinct magnetic field records at the two different heights, since we had also recorded the diurnal variation of the Earth's magnetic field. We refer here to the magnetic map obtained with the bottom sensor. Fig. 4 shows this map. The recognition of anomalies is now easier than in the previous gradiometric mode, notwithstanding the presence of the high wavenumber noise, which can be easily filtered out.

Fig. 5 shows the low-pass filtered map of the total magnetic field intensity map relative to the bottom sensor. The smoothing consisted of substituting the value at each point by the weighted average of the 8 conterminous stations.

It is now possible to distinguish in both maps a weak positive anomaly of about 10 nT maximum intensity, elongated in the SW-NE direction and extending over nearly the whole investigated area.

Due to its small amplitude, this anomaly does not allow any obvious correlation with archaeological targets. It could very likely be attributed to some geological and/or morphological feature in the calcarenitic block or in the sedimentary cover, along the anomaly longitudinal axis.

Geoelectric survey

The six VES were interpreted using the curve matching procedure with 1D master curves, computed on the basis of Ghosh's linear filter theory.

The field apparent resistivity diagrams and the relative interpretative theoretical curves with corresponding electrostratigraphies are reported in Fig. 6.

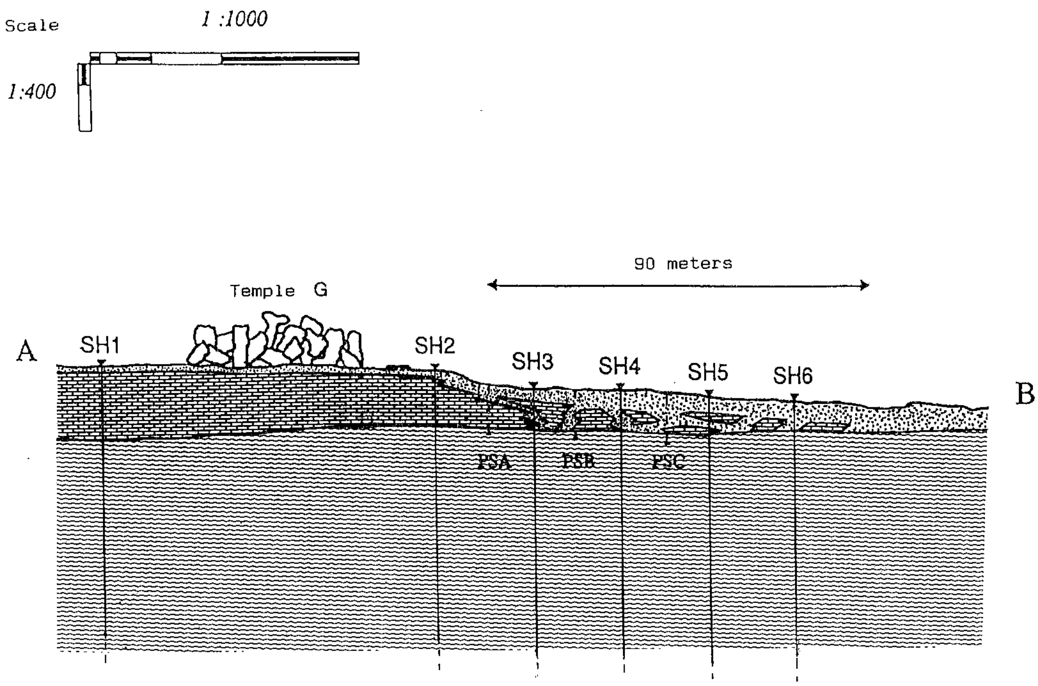

Fig. 8 — Geologic section along the AB profile of Fig. 1, reconstructed on the basis of the geophysical interpretation.

The VES interpretation assumes the presence of three-layer sequences along the whole profile connecting the centres of the VES. The first layer is ascribed to the thin cover of silty-sandy sediments, with resistivity in the range 25-70 Ω·m and thickness a little less than 40 cm. The second layer is associated with the calcarenitic slab, whose resistivity varies over a very large interval, from about 90 Ω·m to about 900 Ω·m, and thickness from about 1 m to about 6 m. Finally, the geoelectric substratum, with resistivity as low as about 3 Ω·m, represents the clayey basement throughout the area. From a comparative analysis of all the VES, it seems clear that the calcarenitic rock looses its compactness, thickness and perhaps also continuity just inside the Greek area. This suggests that the calcarenitic slab ends lenticularly towards the north, probably with vague boundaries.

The DPP data have been plotted by an automatic interpolation procedure based on the inverse squared distance weighting method. The three contoured pseudosections A, B and C are shown in Fig. 7. Because of the wide range of apparent resistivity values found in pseudosection A, we preferred to represent it by two separate plots, with apparent resistivity values in the range 0—500 Ω·m (100 Ω·m contour interval) and in the range 500—2500 Ω·m (200 Ω·m contour interval), respectively, in order to emphasise the contrast between the calcarenitic slab and the surrounding soil in the first plot, and to show the larger solid blocks in the second plot.

The DPP results confirm the structural inhomogeneity of the calcarenitic slab inside the Greek area, as already observed by the VES. In fact, pseudosection A shows in the central part, along nearly its entire length, apparent resistivity values remarkably higher than those observed in the other two pseudosections in the same depth range.

Moreover, the DPP results clearly evidence the fragmentary character of the calcarenitic block inside the surveyed Greek area. This fragmentary character could probably explain the background noise observed in the magnetic maps.

Fig. 8 gives an overall picture of the geoelectrical interpretation.

CONCLUSIONS

In the previous sections, we described the results of magnetic and geoelectrical prospecting carried out in the so-called Greek area within the archaeological district of Selinunte (Trapani, Italy). The archaeologists had hypothesised that there could be traces of precolonial habitation inside a calcarenitic block underlying a cover of silty sediments.

The maps of the total magnetic field intensity did not evidence any significant anomaly. The vertical electric soundings showed that the calcarenitic slab rapidly looses solidity from S to N. Finally, the geoelectric pseudosections clarified the fragmentary character of the calcarenitic block.

From these results it seems reasonable to conclude that in the selected site the archaeological hypothesis is not supported by the magnetic and geoelectric evidence.