TEACHING GEOPHYSICS: A "CASE STUDY"

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INTRODUCTION

The University of Milan started the course unit "Laboratory of Earth Physics" for the ("Laurea") Degree's course in Physics on fall 1995. This is a compulsory course unit for the specialisation in Geophysics and Environmental Physics.

The goals of this communication are: (1) the presentation of the results obtained by the students attending the course unit since its start, two years ago; (2) to solicit a discussion about the methodology of teaching geophysical prospecting.

This Laboratory provides the students with basic knowledge of techniques of acquisition, processing and interpretation of geophysical data: particular emphasis is given to the application of exploration geophysics to environmental and engineering problems. The Laboratory is divided into three modules: introductory lectures (instruments and field procedures for magnetic, electric, and seismic prospecting; introduction to geophysical data processing; introduction to interpretation of geophysical data with forward and inverse models); field work (students execute a field survey using different prospecting methods); data processing and interpretation (students apply the methods of processing and interpretation taught during the introductory lectures to the collected field data).

DESCRIPTION OF THE FIELD WORK

The students collected field data during the months of February and March in 1996 and 1997 over a 9-square-kilometres wide area, located 30 km west of Milan. This region is characterised by rice crops and is one of the most important on-shore oil production sites in Europe. The students worked in 4 different sub-areas in 1996; 3 of these sub-areas were investigated again in 1997. The field work included measurements of Earth magnetic field along profiles and the execution of vertical electrical soundings (VES) with Schlumberger and dipole arrays.

The students measured the Earth magnetic field with two EG&G Geometrics proton precession magnetometers (Models G-846 and G-856). They realised several profiles for a total length greater than 5 km; the spacing between next stations varies between 2 and 10 m. They checked the time variation of the Earth magnetic field either by repeating the measurements at the same position at different times, or by performing measurements at a fixed reference station and at a moving station along the profile simultaneously. As an example we show in figure 1 the comparison between the records of Earth magnetic field at a fixed reference station and along a profile. At every station three fast readings were performed; the differences among the readings is usually less than 10 nT, except for areas close to disturbing structures, e.g., AC power line.

The students performed 35 DC VES with a relatively short Schlumberger array ($AB/2 \leq 60$ m); 6 of these were then extended to $AB/2 \approx 300$ m. 8 VES were realised with continuous polar

dipole-dipole arrays, with the centre of the potentiometric dipoles corresponding to the centre of a Schlumberger array. The instrumentation for the current dipole consists of a portable AC power generator connected to an AC/DC converter, to a switch for current commutation and to a digital amperometer; the instrumentation for the potentiometric dipole consists of two copper electrodes, connected to a device for reducing self-potentials and to a portable chart voltage recorder (Yokogawa - YEW 3057). In few cases polarising effects were observed in areas where fertilisers were dispersed in the crops.

Figure 1. Comparison of the Earth magnetic field measured at a fixed station (solid line) and at a moving station (dashed line and circles) along a profile.

Figure 2. Magnetic anomaly of an oil pipe system measured in 1996 (solid line) and 1997 (dashed line).

RESULTS OF THE FIELD SURVEY AND THEIR INTERPRETATION

Measurements of Earth magnetic field allow the determination of some local magnetic anomalies. Most of them are in correspondence of known features, e.g., oil pipes. In other cases magnetic anomalies are not in straight correlation with known sources of magnetic disturbance. A large anomaly is observed in correspondence of the main system of oil pipes that intersects the investigated area; the results for this transept obtained in 1996 and 1997 are represented in figure 2.

Diagrams of apparent resistivity for the VES are generally consistent with a three-layer structure of type K ($\rho_3 < \rho_1 < \rho_2$). A typical example is represented in figure 3, where the results obtained in two successive years at the same location are shown.

Field data have been interpreted by trial-and-error technique with 1-D forward models; several equivalent geoelectrical structures have been proposed for the shortest VES. However it has been possible to imagine the following general geoelectrical stratigraphy for the investigated area. The superficial layer has a resistivity varying between 300 and 1500 ohm m and locally as high as 3000 ohm m, a thickness less than 2 m and corresponds to the vegetated soil often altered by human activities. The intermediate layer has a resistivity which varies between 2000 and 4000 ohm m and locally is greater than 7000 ohm m, and corresponds to the unsaturated zone. The third conductive layer has a resistivity lower than 500 ohm m and represents the saturated region, i.e., the phreatic aquifer. The depth of the water table found from the VES (about 7-15 m) is in agreement with the measurements performed in piezometers sparse in the area.

From the results of the VES with longer arrays we infer the resistivity of the phreatic aquifer. In particular it is suggested the presence of a discontinuity between a shallow level of the aquifer with $\rho \approx 300$ ohm m and the deeper level with $\rho \approx 100$ ohm m. Since the pore water resistivity of the phreatic aquifer is supposed to be constant in the investigated area, this decrease of resistivity is due to a variation of the lithological characteristics, corresponding to an increase of the fine-grained (shale) components into the electrostratigraphic unit.

The results of the VES with $AB/2 \approx 300$ m were compared to those obtained with polar dipole-dipole arrays. In particular from the Schlumberger field results, assuming that the resistivity structure of the subsurface can be approximated as 1-D, we computed the apparent resistivity of the VES performed with a dipole-dipole array where the position of the electrodes are the same as for the Schlumberger array. The results of the comparison are represented in figure 4 and show that the 1-D approximation can be considered valid.

Figure 3. Typical example of diagram of apparent resistivity, obtained at the same position in 1996 (solid line) and 1997 (dashed line).

Figure 4. Diagrams of apparent resistivity for Schlumberger arrays. Solid line: field results. Dashed line: results obtained from dipole-dipole data.

CONCLUSIONS

The main results of the field work have been the following: (1) mapping magnetic anomalies, often corresponding to the known localisation of oil pipes or other metallic structures; (2) determination of the depth of the water table by means of short VES; (3) determination of the electrical resistivity of the phreatic aquifer by means of long VES and separation between the shallow (about 300 ohm m down to a depth of about 35 m) and the deeper part (about 100 ohm m) of the aquifer.

During the course, the students have learnt some techniques of geophysical data acquisition. They interpreted field data as autonomously as possible, so that they could understand some of the problems and the ambiguities that are inherent in the interpretation of geophysical data. The plan for the next years is to move towards Self-Potential measurements, seismic prospecting and monitoring of noise and vibrations.

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