GEOELECTRICAL STUDY FOR DELINEATING UNDERGROUND CAVITIES IN KARST AREAS

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Abstract. This study is based on the use of geophysical investigations, in this case of a geoelectrical method, in order to identify underground cavities. The purpose was to identify, delineate and measure underground cavities. We used DC current geoelectrical measurements on profiles, by performing vertical electrical sounding measurements (VES) by the Schlumberger method, such that the lateral effects were attenuated as much as possible. Our studies focused on three areas, located close to the Mangalia town, the Limanu and Movila Caves (where the boundaries of the cavities are relatively known), as well as a new area that proved interesting as a karst zone (Obanu Blebea). Where possible, we performed the correlation between geoelectrical data and geological information including borehole data.

Key words: geoelectric, resistivity, underground cavities, vertical electrical soundings (VES), karst

INTRODUCTION

The geophysical techniques of identifying anomalies related to underground cavities, gaps, underground bodies or aquifers under pressure have been developed recently using miniature geophysical apparatus, data acquisition and complex calculation methods (Mcdowell, 1981; Rigby-Jones *et al*., 1997; Zonge *et al*., 2005).

In this particular case, the underground cavities from karst zones have significant contrasting physical properties when compared to the base rock. This is why they could be detected by geophysical methods (Mccann *et al*., 1987; Militzer *et al*., 1979).

In order to delineate the underground cavities by geophysical methods, in June 2003, we performed a series of geoelectrical measurements in the coastal area of the Black Sea, more specifically close to the Mangalia town. The geophysical research activities took place in three areas. In two of them already (Limanu Cave and Movila Cave) the cavities were previously evidenced, whereas in the third (Obanu Blebea), the presence of the underground cavities was only supposed.

Therefore, our study aimed to find out the possibility of using the geoelectrical method of identification of underground cavities and to gather data on the following: contrasting apparent resistivity, depth of investigation, the minimum size of cavities that could be detected, as well as the detection of the probable communication channels between the karst areas and the Black Sea. From the applicability of the geoelectrical methods, the areas mentioned above were used as test areas, considering that the distribution of the deep underground cavities of the sea is relatively well known. In this particular case, of geoelectrical research of the underground cavities, the interpretation methods using data inversion (in the 1D and 2D version) cannot be used. That is why we considered that the interpretation of data should be performed based on vertical electrical soundings (VES) of the resistivity pseudo-sections and field data.

RESEARCH AND DATA PROCESSING METHODOLOGY

For a geological point of view, the underground cavities in the Mangalia area are located in the coquina limestone successions, a factor that favoured their accumulation and that, in turn, generated the formation of caves of significant surface and depth (see Limanu and Movila).

In the area to be investigated, a few vertical electrical soundings (VES) were performed initially, which revealed the following:

- The limestones have apparent resistivities between 100 and 200 ohmm (Fig. 1);
- The underground cavities have apparent resistivities between 200 and 1000 ohmm;
- The average size of the cavities is about 2 - 3 m^3, and the channels connecting these cavities have heights between 0.30 m and 2 m.

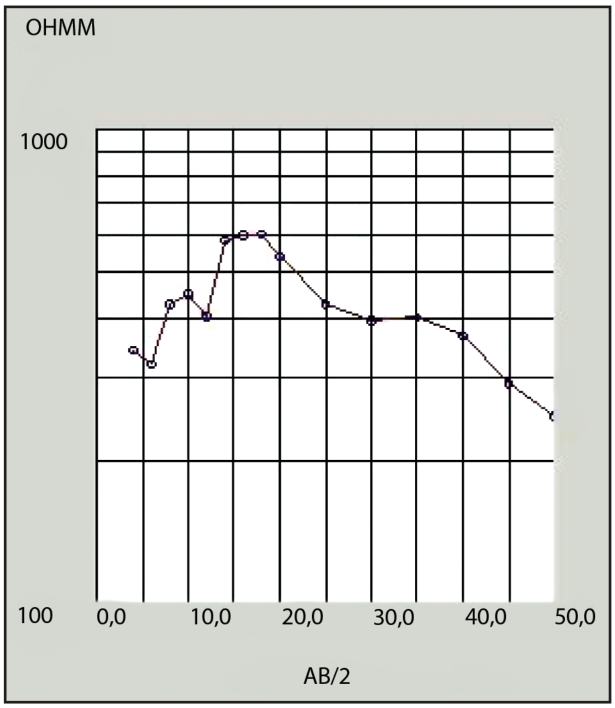

Fig. 1 VES representative for the identification of underground cavities

Based on these first results, in order to obtain concluding results, we adopted a research methodology to best fit the aims of the study and the specific field conditions (Ştefănescu *et al*., 1974):

- 1. The VES were placed on profiles at a 5 m distance from each other;
- 2. We used a Schlumberger device (Mundry, 1980; Millitzer *et al*., 1979) with MN /2 = 1 m , AB/2 variable (4, 6, 8, 10, 12, 14, 16, 18, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70 m);
- 3. The injection current was 20 mA or 50 mA.

The measurements were performed using the INT91V3 Resistivity Meter, which includes a data acquisition system and the on–field visualization of VES. The primary processing of data was performed using the acquisition and processing program, which followed the storage of data in a database.

The data processing generated a series of geoelectrical pseudo-sections, which revealed the depth structure or the presence of the underground cavities. The representation of pseudosections was performed using the Gtmap program.

RESULTS

Limanu Cave Area

In this area, we performed a geoelectrical profile perpendicular to the cave entrance where the difference between the level of the profile and the gallery was estimated at 7 m. The profile was performed at a distance of 15 m from the cave entrance (Fig. 2).

The geoelectrical section in this case reveals the main gallery at the entrance into the cave, as well as the presence of some significant cavities on both sides of the gallery (Fig. 3). In this case, the limestones show apparent resistivities between 150 and 250 ohmm, while the cavities show resistivities between 600 and 700 ohmm .

Movila Cave Area

From a topographical point of view, this area is located on the edge of a significant fault of approximately 10 m distance between the upper part (unaffected by the crack) and the lower part. Moreover, when compared to the Limanu Cave, the maximum depth to the groundwater is 15-20 m in the area. Taking into consideration the presence of groundwater and the fact that the water is mineralized (sulphurous), we expected lower apparent resistivities than in the Limanu Cave area. At the same time, it was assumed as possible that the existing cavities containing sulphurous water might show up on the geoelectrical pseudo-sections as anomalies of the minimum.

In this perimeter, we performed two profiles of 85 m in length each, orientated approximately NE-SW and parallel to the fault limit, and one long transversal profile of 160 m in length (Fig. 4).

Profile 1, located 5 m east of the cave entrance on a smooth topographical surface, reveals a gallery at approximately 20 AB/2 (h=15 m), which connects two underground cavities located at meter 10 and 20 and extending towards the NE. In the upper part of the section, we noticed a „quiet" zone from a geoelectrical point of view with resistivities of 40-60 ohmm, a zone that corresponds to the existing loess layer. On this profile, the limestones show average resitivity values of 100 ohmm, with the underground cavities at 300 ohmm (Fig. 5).

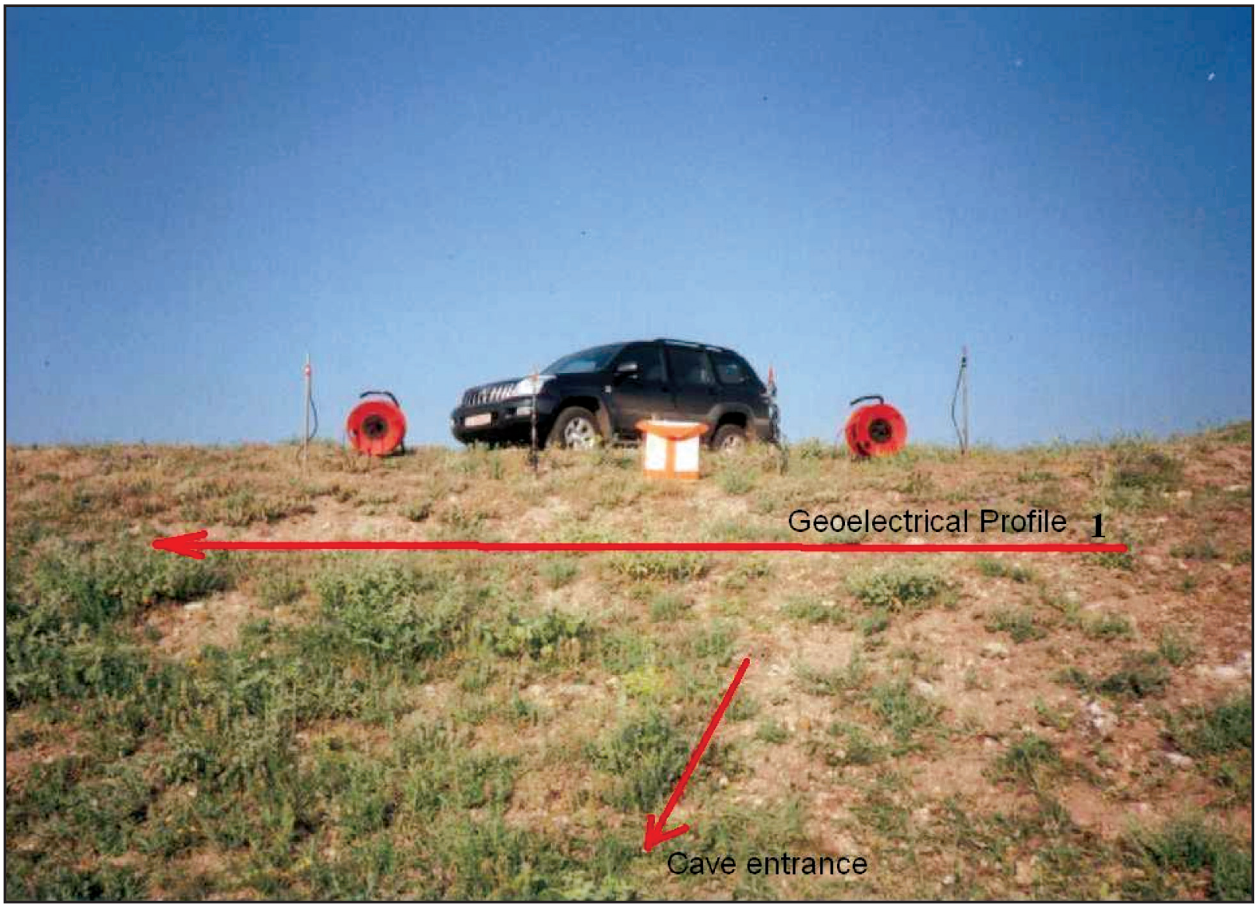

Fig. 2 Location of the Limanu Cave Profile

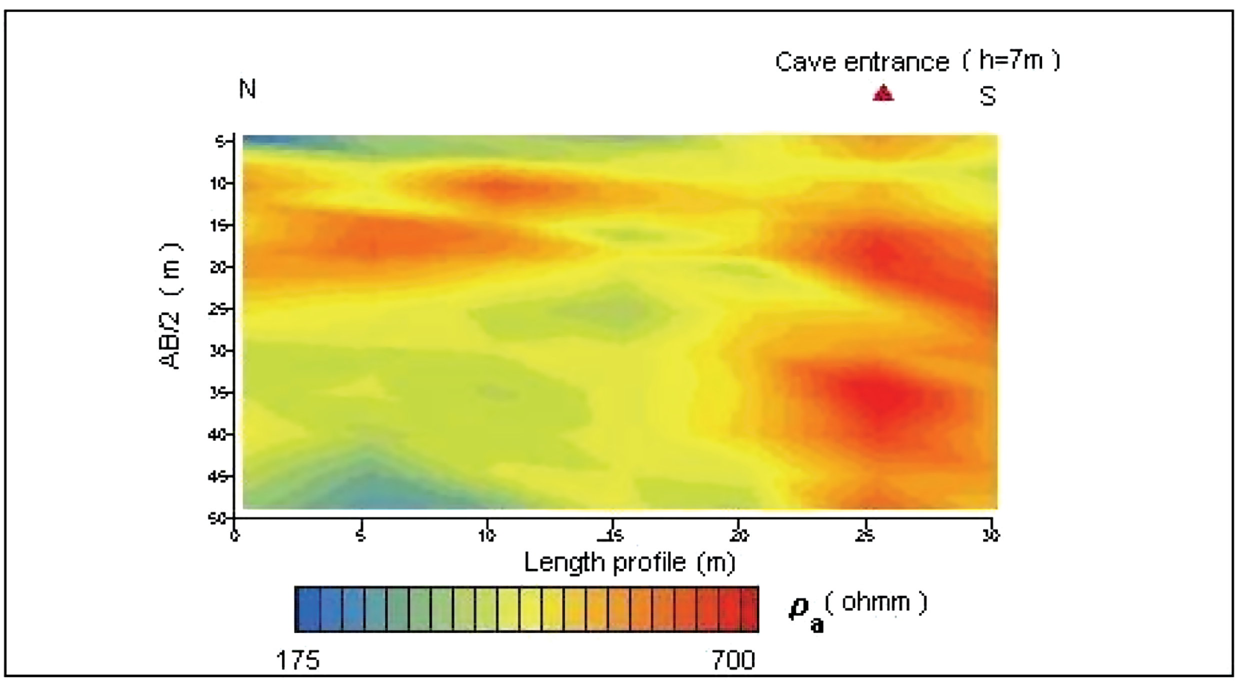

Fig. 3 Geoelectrical pseudo-section at the Limanu Cave

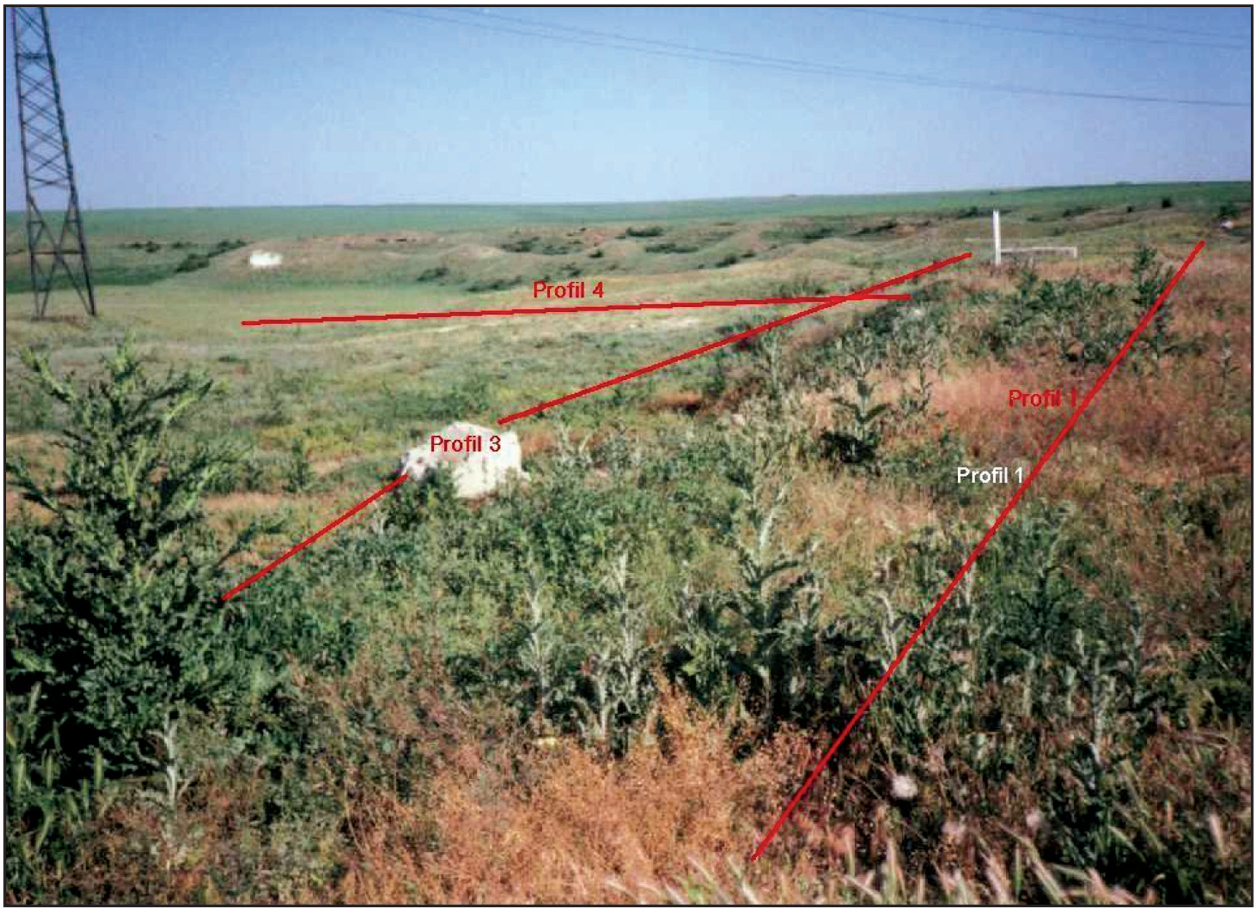

Fig. 4 Location of the geoelectrical profiles in the Movila Cave area

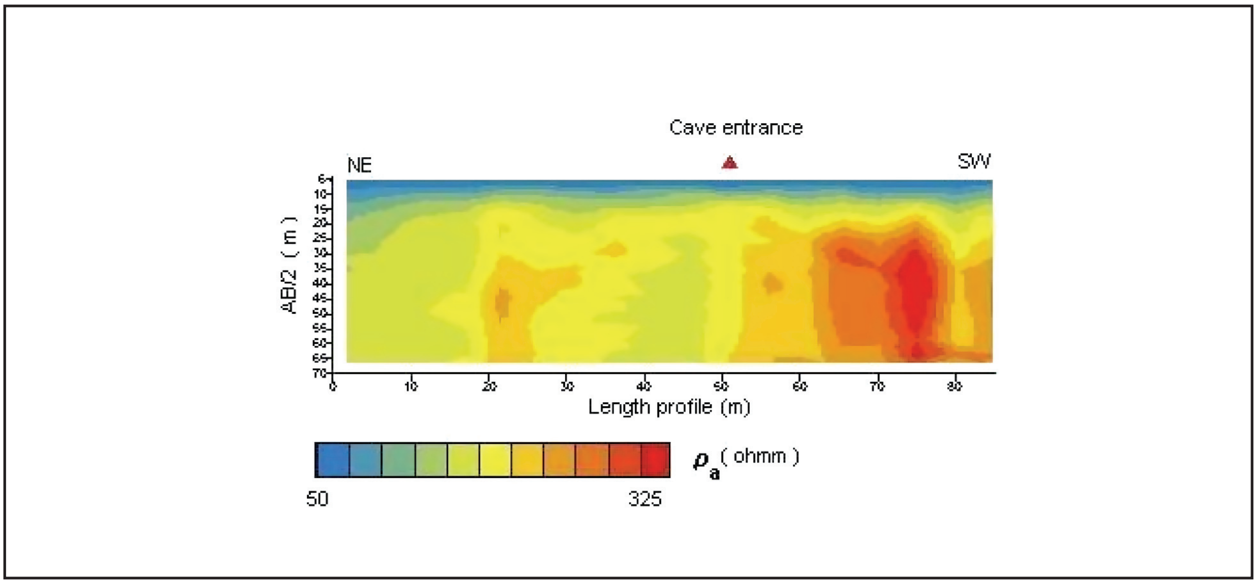

Fig. 5 Geoelectrical cross-section, Profile 1

Profile 3, located at approximately 15 m from and parallel to Profile 1, was placed on morphologically very uneven zone, midway between the limits of the fault (the lowered zone and the unaffected zone). From the absolute elevation point of view, the average elevation of the profile is approximately 3 m lower than the average elevation of Profile 1. Because, for this area, we assumed that the initial sinkhole affected intensely the deep structure of the galleries' system, the alignments that show underground cavities are less obvious. However, on the geoelectrical cross-section, we noticed the presence of one gallery located at AB/2=15 m, and a zone of the minimum, which corresponds in location to the zone of the maximum in Profile 1 (Fig. 6). This leads to the interpretation that this is an underground cavity filled with sulphurous water.

Profile 4, performed transversally on the location zone, reflects accurately the geological situation revealed by the geophysical data. A comparison between the geoelectrical pseudo-section given in Fig. 7 and the geological section (Constantinescu and Constantin, 2001) performed based on borehole data (Fig. 8) is conclusive. In the eastern part of the section, where the limestones are significantly developed, the apparent resistivities are of 200 ohmm, while in the middle of the sinkhole zone, the resistivities have values between 5 and 10 ohmm, due to the clays and the presence of sulphurous water.

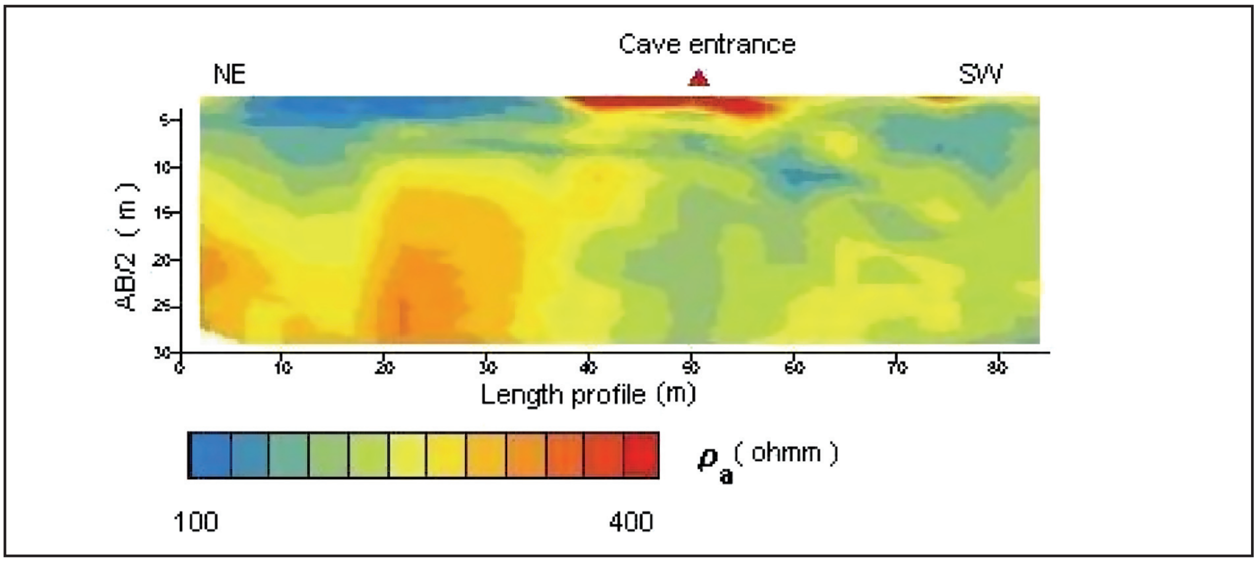

Fig. 6 Geoelectrical cross -section, Profile 3

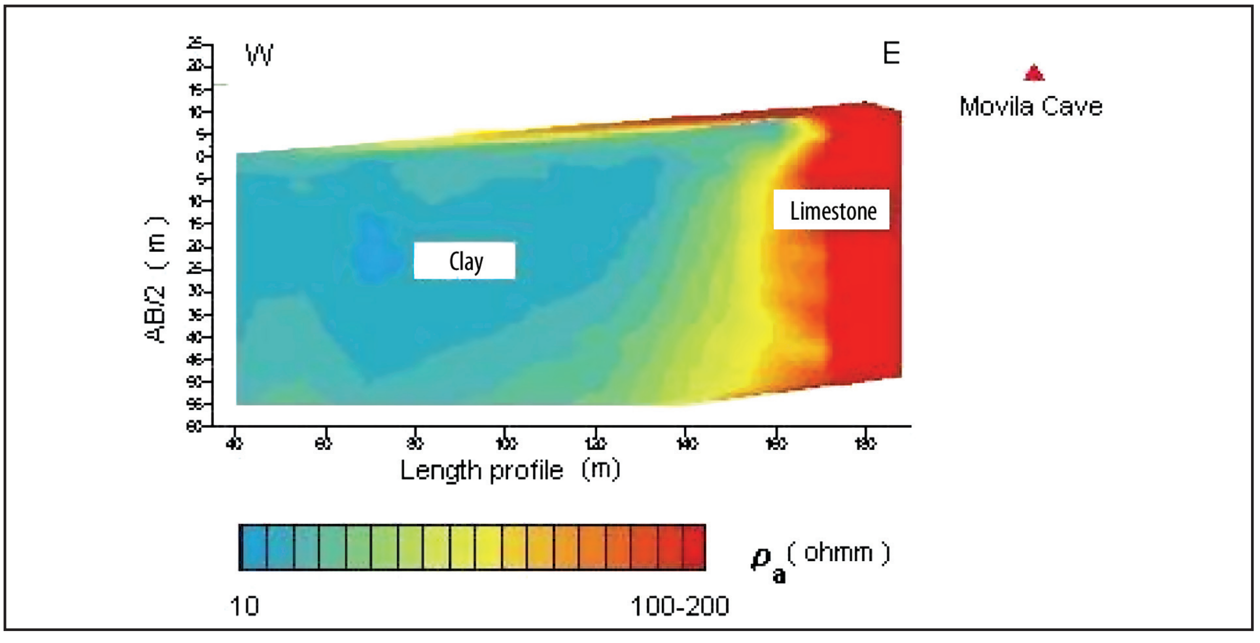

Fig. 7 Geoelectrical cross-section, Profile 4

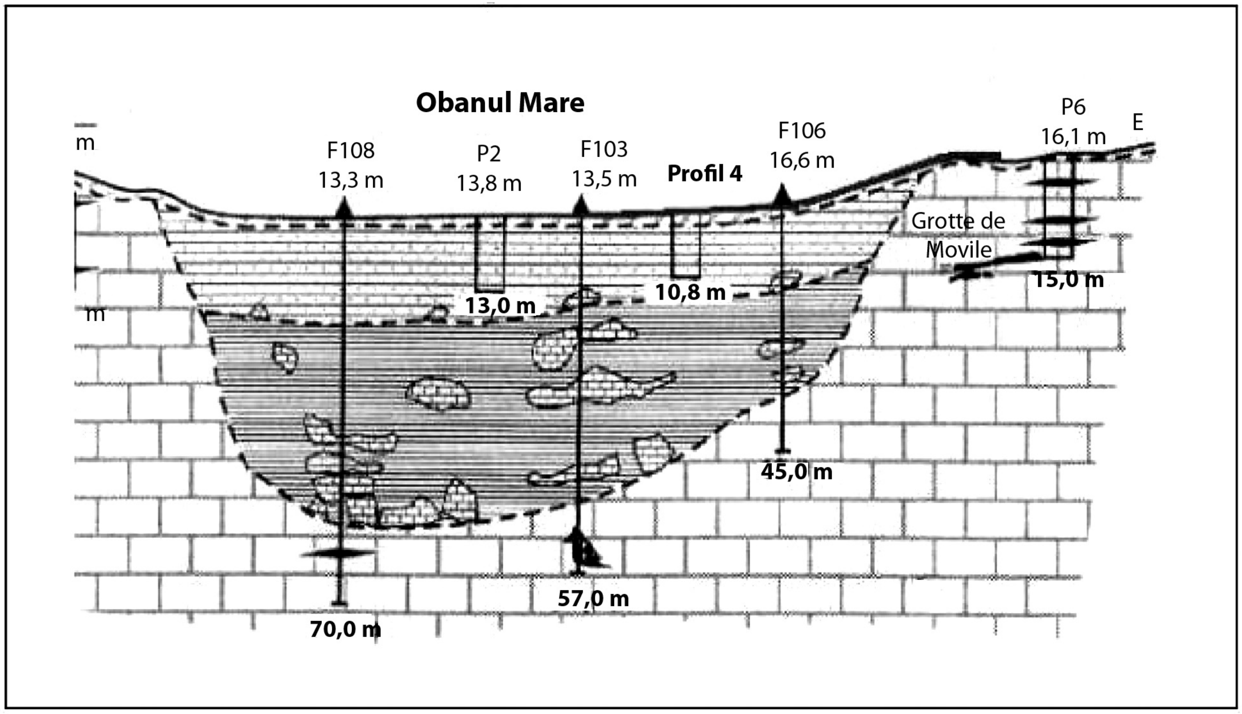

Fig. 8 Geological section - Movila Cave (after Constantinescu and Constantin, 2001)

The Obanu Blebea Area

This area is located approximately 600 m from the Movila Cave. In this area, the sinkhole was more intense and on a larger extent. By our approximation, the depth of the sinkhole is over 20m. Even though there are no known underground cavities, during one of the excavations, one gallery was found. In this area, we performed one geoelectrical profile, which revealed two underground cavities of different dimensions (Fig. 9). In the area of the probable entrance into the cave, we performed one detailed profile, a profile which delineated the entrance gallery.

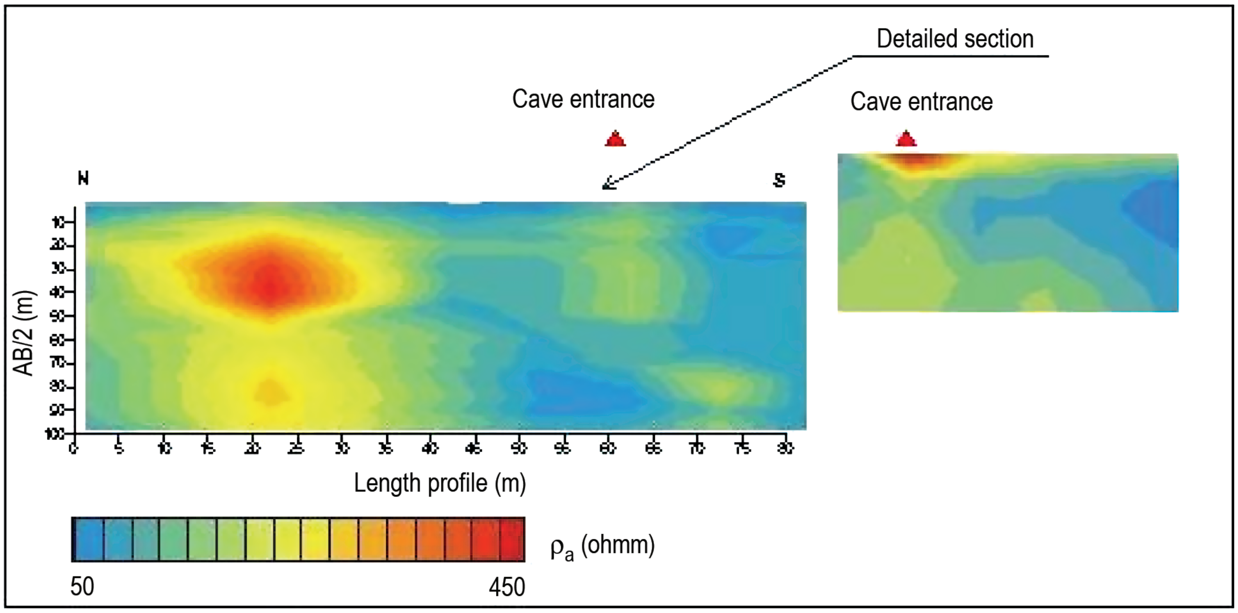

Fig. 9 Geoelectrical cross-section in the Obanu Blebea area

CONCLUSIONS

In the studied area, there are significant apparent resistivity contrasts between the compact limestones and the underground cavities. Moreover, when sulphurous water is present, the geoelectrical method can identify the cavities filled with water.

We consider that this particular research study revealed the extent of the Movila Cave to the north and the presence of a cave in the Obanu Blebea area.

Considering the relatively small size of the underground cavities in the area, an eventual mapping of these cavities using geoelectrical methods must be obtained by performing numerous regular vertical electrical soundings at an optimum distance of 2 m from each other.

The results show the usefulness of the geoelectrical method for the delineation of underground cavities, a method which is easy to use and has all the technical means for measurement, data processing and interpretation.

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