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ELECTRICAL RESISTIVITY MEASUREMENTS IN SENSITIVE PERIGLACIAL ENVIRONMENT FROM SOUTHERN CARPATHIANS (ROMANIA)

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Abstract: *Electrical Resistivity Tomography (ERT) investigations were carried out on various periglacial landforms in the periglacial belt from Southern Carpathians. Geo-electrical soundings reveal the existence of permafrost in rock glaciers from Retezat Mountains, the depth of active layer, typical internal structure of periglacial deposits and the freezing regime of the sediments inside earth hummocks. The application of ERT investigations proves to be a useful geophysical method to detect the contrast between unfrozen sediments and ground ice from periglacial environments subsurface.*
Key words: *ERT, periglacial, permafrost, internal structure, Southern Carpathians*

1. INTRODUCTION

For the past 15 years, the use of ERT in investigating the periglacial environments has become more and more important. Confident of its success, researchers have applied this method in order to capture the modifications induced by climate change in cold environments. In geomorphology, this geophysical technique has already been successfully employed not only for determining the depth of landslide bodies, sediment thickness and groundwater variation, but also for the detection of permafrost in rock glaciers, moraines and scree slopes and for natural cavities from karstic area exploration. Generally, this technique has been used to find out the internal structure of different types of landforms (Schrott & Sass, 2008).

The method is based on the differences in the electric resistivity of rocks and that is why, one of its advantages is represented by its noninvasive character. In the periglacial alpine environment - rendered quite inaccessible by its large areas with blocky materials mantle - the application of geophysical methods (ERT, ground penetrating surveys and seismic refraction investigation) counts as the only solution for exploring the subsurface materials.

Ever since the 19th century, the existence of periglacial landforms in the Southern Carpathians has been faithfully recorded. Nevertheless, for the whole period of time leading to the last decade of the 20th century, all the (published) studies on periglacial landforms are purely descriptive. Starting with the 1990s, a fresh approach, based on specific methodology, has been developed and new techniques have been applied by Urdea (1993, 2000) in Retezat Mountains. For the past four years, our team has applied ERT in order to investigate the internal structure of periglacial landforms in Southern Carpathians, i.e.: rock glaciers, scree slopes, patterned ground, earth hummocks, debris cones, solifluction lobes and solifluction terraces. These surveys have been carried out for the first time in Romania by the authors of this study.

The general aims of this approach are as follows:

- To map and monitor the permafrost areas;
- To establish the active/fossil character of periglacial landforms;
- To explore the advances and limitations of these methods in different types of landforms;
- To assess global warming-induced modification in alpine environments.

2. STUDY AREA AND METHODOLOGY

The Southern Carpathians, or Transylvanian Alps, are the highest mountains in Romania, having a maximum elevation of 2544 m in Moldoveanu Peak (Făgăraş Mountains). In the alpine area of the Southern Carpathians, the alpine geomorphological landscape is dominated by glacial landforms (glacial cirques, throughs, moraines, erratics and roches moutone) and periglacial features (rockglaciers, talus cones and scree slopes, block fields, rock streams, cryoplanation terraces, patterned ground, solifluction forms etc.). For the aims of this paper, we focused our investigations on Ana rock glacier (Retezat Mts.), Muntele Mic field of earth hummocks (Tarcu Mts.) and Paltina solifluction lobe (Făgăras Mts.) (Fig. 1).

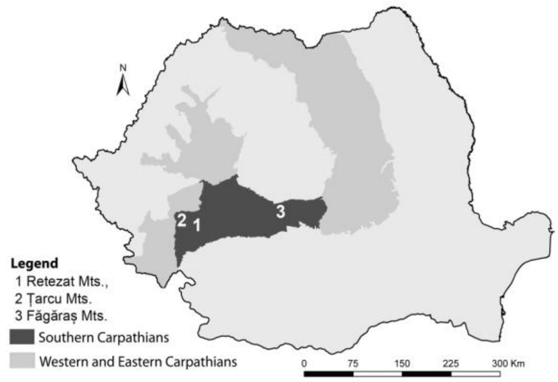

Fig. 1. Study area and test sites location for ERT surveys

The ERT method has been used in order to determine the distribution of subsurface materials resistivities by making measurements at the ground level. ERT is conducted by injecting a direct constant flow of electrical current into the ground by means of two current electrodes placed at the ground level and by measuring the voltage difference of two potential electrodes, also fixed in contact with the substrate. Based on the resulting voltage difference (*ΔV*), the current (I) and a geometric factor (K), which depends on the arrangement of the four electrodes, the apparent resistivity is calculated: $\rho_a = K(\Delta V/I)$. The transformation from apparent resistivity to real resistivity is a complex process, which is done with performance software by making an inversion of the measured apparent resistivity values (Loke, 2004).

All the soundings presented in this study were carried out by the effective means of the complex geophysical system PASI 16GS24N, which consists of 32 electrodes with a standard spacing of 5 m. Depending on the periglacial deposits, Dipole-Dipole, Wenner and Wenner-Schlumberger arrays were employed, with a maximum penetration depth of over 30 m, while the distance between the electrodes would range from 0.1 to 5 m. The 2D subsurface resistivity model was realized with the aid of Res2DINV software.

3. RESULTS AND DISCUSSIONS

As a result of the large differences (recorded) in the electrical resistivity of the distinctive minerals, rock and materials which compose the landforms, geomorphologists are able to recognize the subsurface layers since they already know the specific resistivity values for each type of material.

The permafrost, for example, may vary between $10^3 - 10^6$ Ωm or even more, depending on the ice content, the quantity of impurities and the temperature (Kneisel, Hauck, 2008). In the Southern Carpathians, the presence of permafrost was first reported by Urdea (1993), by applying the BTS method on rock glaciers and by measuring the summer temperature of the springs in Retezat Mts. The specific morphology of rock glaciers is caused by permafrost creep but only in a few rock glaciers in the Southern Carpathians is the presence of frozen materials to be found. Although more than 300 rock glaciers have been mapped in the Southern Carpathians, most of these are inactive nowadays.

In order to have our hypothesis tested, we resorted to ERT for investigating 6 rock glaciers in Retezat and Făgăraş Mts. As regards Ana and Pietrele rock glaciers, large resistivity values (> 10^5 Ωm) were recorded confirming the presence of massive ice. In both cases, we have noticed the specific internal structure, which has an active layer, composed of very large boulders with variable thickness (< 10 m) and low resistivity values. The permanently frozen layer in Ana rock glacier (2000 m a.s.l.) (Fig.2) is discontinuous because of the irregular topography of the rock glacier, which has few trench-depressions filled with fine debris with low resistivity values. The permafrost appears between these depressions and has an ellipsoidal aspect and large values of resistivity. We have also managed to trace the thickness of Ana rock glacier deposits (~ 20 m) and its contact with the bedrock.

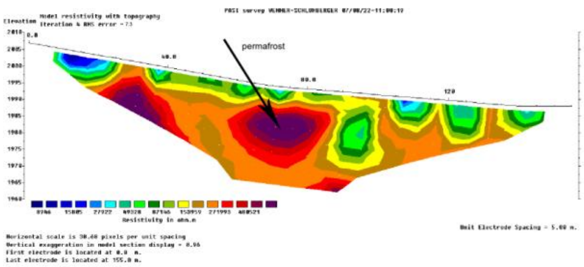

Fig. 2. ERT model of Ana rock glacier (longitudinal section)

The focus of our second application was on discerning - during different times of the year - the resistivity behavior of materials found inside earth hummocks. Periglacial hummocks are small mounds (0,2-1 m height, 0,5-1,5 m diameter) separated by a network of ditches and not restricted to the permafrost area. Not all mounds are periglacial hummocks and they fall in our category only those mounds formed by processes involving periglacial elevation and the presence of ice in the subsurface. In Romania these mounds appear at high altitudes, where the average annual temperature is below 3º C.

In Ţarcu Mts. (1759 m a.s.l.) we have conducted measurements of the periglacial elevation of hummocks and of the flat terrain from the end of the 1990s. Our findings have brought to light that this process is more active in periglacial mounds (3-8 cm/year). Therefore, during different times of the year, we carried out ERT investigations in order to find out the freezing regime of the materials inside. An interesting situation was captured in May 2010 when the core of the periglacial hummock was still frozen, as it is revealed by the large resistivity values (Fig.3), while the surrounding area was completely thawed. We compared resistivity information with temperature data obtained from the thermistors set inside the mounds at different depths and we observed the specific freezing regime of these small landforms.

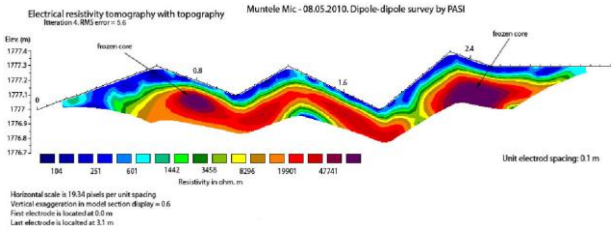

Fig. 3. ERT model of periglacial hummocks

Our latest research was carried out in Făgăras Mts. (2390 m a.s.l.), where we set out to investigate the internal structure of a solifluction lobe. The ERT profile shows that the tongue - shaped lobe has its own particular structure, in which several layers with variable thickness are clearly individualized. It is very easy to differentiate between distinct layers of 40-50 cm and, more importantly, to observe a special design of layers, which is only another type of structure also revealed by diggings. These layers, more or less undulating, were created by solifluctional processes (Fig. 4)

Bad contact between electrodes and rocky deposits represents the major limitation of this method in cold environments. Our experience has shown that adding salt water near the electrodes improve the coupling with the subsurface.

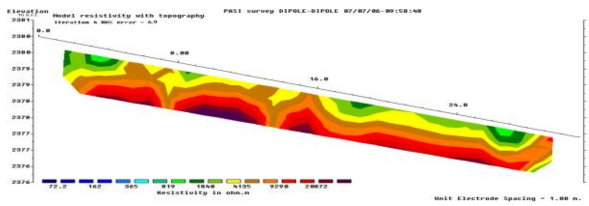

Fig. 4. ERT model of Paltina solifluction lobe

4. CONCLUSION

By applying geophysical techniques on different periglacial deposits, we have the possibility to gain insight into their overall thickness and their inner structures. The ERT investigations reveal that all the periglacial landforms taken into consideration in our study have a specific internal structure, with heterogeneous layers caused by current intense morphodynamic.

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