EVALUATION OF LIMESTONES COMPACTNESS USING ELECTRICAL RESISTIVITY METHOD. CASE STUDY: MELOVA

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Abstract. In Albania (and abroad) companies have an increased interest in limestone rocks exploitation in use for construction materials and decorative stones. The aim of this paper is to help the evaluation of limestone compactness at depth using the 2D apparent resistivity method. Compact limestones have high resistivity values compared with cracked limestones. Cracks usually are filled with water or other low resistivity material like clay. Those materials decrease the general resistivity of limestone, sometimes to very low ranges of resistivity values. The contrast between apparent resistivity values of massif and cracked limestone is high, making possible to delineate the massif and compact limestone at depth. The later limestones are mined in big blocks (2 -3 m^3 / block) and are used like decorative stones. The delineation of massif limestones at depth will help concentrate mining work only in those areas, preserving natural conditions of other areas and helping in rehabilitation of the area after mining.

Keywords: Limestones, electrical tomography, Apparent Resistivity "Real Section", mapping.

Rezumat. Evaluarea compactităţii calcarelor prin utilizarea metodei rezistivităţii electrice. Studiu de caz: Melova. În Albania (şi în străinătate), companiile au un interes sporit faţă de exploatarea calcarului, utilizat pentru materiale de construcţie şi roci decorative. Scopul acestei lucrări este de a ajuta la evaluarea compactităţii calcarului la adâncime, utilizând metoda de rezistivitate aparentă 2D. Calcarele compacte au valori de rezistivitate ridicate comparativ cu calcarele fisurate. Fisurile sunt de obicei umplute cu apă sau cu alt material de rezistivitate scăzută, cum ar fi argila. Aceste materiale scad rezistenţa generală a calcarului, uneori la valori foarte mici ale rezistivităţii. Contrastul dintre valorile aparente ale rezistivităţii masivului şi a calcarului fisurat este ridicat, făcând posibilă delimitarea masivului şi a calcarului compact la adâncime. Ulterior, calcarele sunt exploatate în blocuri mari (2 - 3 m^3 / bloc) şi sunt folosite ca roci decorative. Delimitarea masivelor calcaroase la adâncime va contribui la concentrarea muncii miniere numai în acele zone, la conservarea condiţiilor naturale din alte zone şi la ajutarea în reabilitarea zonei după minerit.

Cuvinte cheie: calcare, tomografie electrică, Rezistivitate Aparentă "Secţiunea reală", cartografiere.

INTRODUCTION

Electrical Tomography is known to help in resolving geological problems due to electrical resistivity variations between basement rocks and overlying sediments which form an unconsolidated cover. As a rule, basement rocks are more compact and present higher electrical resistivity values, compared to the loose sediments of the cover, that consist of clays, silts and sands. The first several meters though, in dry season, have higher resistivity values compared to sediments of the cover saturated with water (*below water table*). The use of rock resistivity enables us to delineate several rock layers, their lithology and their structural condition. Limestone resistivity values vary to a high extent, from 50 to 10^7 Ωm (REYNOLDS, 2011).

Figure 1. Surveyed line location (red line) and the mining pit (Google Earth image).

This wide range of resistivity values depends on several factors like limestone compactness, karst development, type of material (water, clay or air) filling the karst, temperature etc. Using those properties, we surveyed the apparent resistivity on a line near a limestone mining pit (Fig. 1).

This survey area is located in central SE part of Albania (Fig. 2), in the Skrapari district near the village of Melova, which is known for the mining of dolomitic limestones used for construction and decorative stones.

Figure 2. Location of the surveyed area (Google Earth image).

The purpose of our survey was the definition of massif limestone at depth. Defining massif limestone will help orienting the limestone mining towards massif parts and, also, will contribute to the preservation (as much as possible) of the nature and environment.

OVERVIEW OF REGIONAL GEOLOGY AND TECTONIC

The study area consist of Upper Cretaceous (Cr_2) carbonatic sediments represented by massif limestones with rudists and dolomitic limestones (Fig, 3). In some parts there are layered limestones, biomicritic and with Globotruncana. Further South we have Eocene (Pg2) carbonates represented by biomicritic and turbiditic limestones overlaying Upper Cretaceous limestones. Near the surface the limestones are affected by the erosion process, creating carst voids filled with red clays material. The limestones have crystaline structure with a light beige color, mostly recrystallized organogenic limestones, are compact and contain micro craks filled with calcite. In massif interlayers we can find oolites that give the rock a considerable solidity. In microscopic analysis this limestone rocks are described like biomicritic limestones where bio mass is represented mostly by foraminiferes non well preserved while micritic mass is the dominant part of the rock composed of limestone micrograins partly recrystallized. In the massif part of limestones it is noticed a dolomitization process developed after litification and connected with the circulation of magnesian waters. Facies of this region are migrated in time and space and today are represented like a compact level containing macro and micro fauna in coral form as: Diabole, Stilophora, Rhizoide, Heliastrea , Isastrea Affinis etc. also big foraminifera and Rudistes accompanied by nummulites and Lepidocyclina.

Lower Oligocen (Pg^1_3) and Middle Oligocen (Pg^2_3) deposits are represented by clay- alevrolitic – sand flysch, containing limestones olistolite horizons.

Paleogene, Neogene and Quaternary deposits are represented by deluvial formations, sometimes mixed with carbonates. They are located generally in all the area in the form of small spots from several cm to 30 cm thickness. They are more widespread in the lower part of the massif, mostly along the road, thus favouring the development of local vegetation, mostly composed of bushes, beech forests and various cultivated trees.

This region is affected by Middle Oligocen tectogenesis. Is limited by two NE – SW main tectonics. Later are developed secondary tectonics deeping SE and extending almost normal to the two main ones. Primary natural fissure system is developed normal to the primary tectonics delineation. Other secondary fissures are caused by erosion of limestones and are not expected to be developed below 3 m of depth.

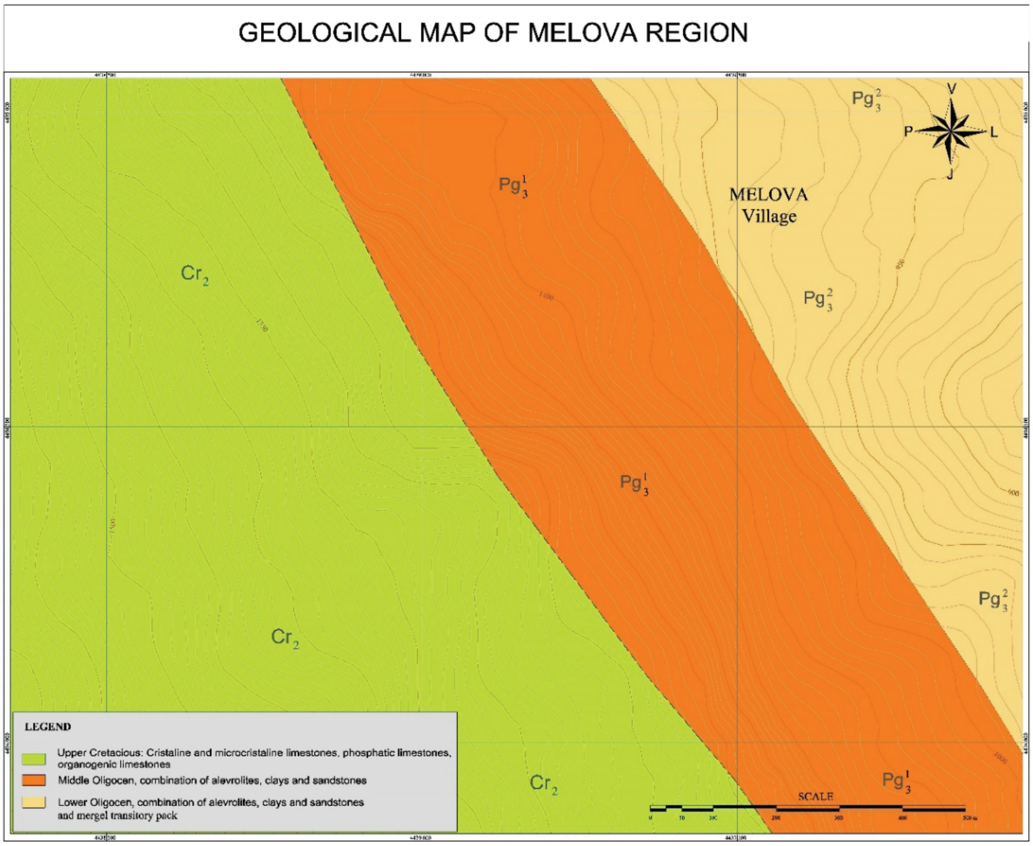

Figure 3. Geological map of the surveyed area.

APPARENT RESISTIVITY METHOD

Apparent Resistivity is a physical parameter of heterogeneous media from an electrical point of view. It is numerically equal with the resistivity of an isotropic homogenous media where, between potential electrodes M and N, for the same current I flowing at current electrodes A and B (Fig. 4) it is created a potential difference ΔU equal with that of the heterogeneous medium.

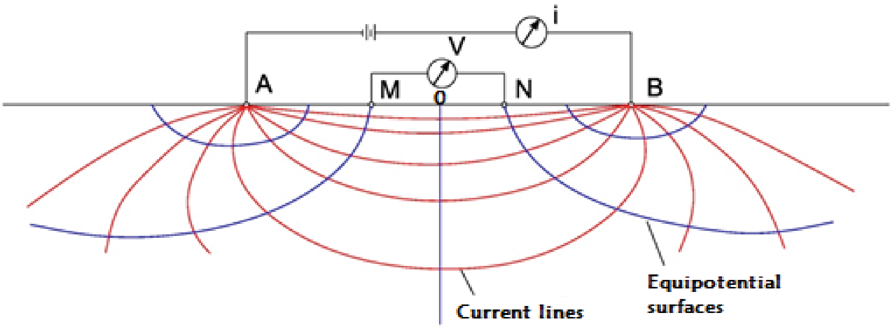

Figure 4. Apparent resistivity survey array.

Through the current electrodes, a current with intensity ***I*** is injected in soil and generates an electrical field. Using potential electrodes, we measure the potential difference ***ΔU*** resulting from the electrical field. This potential difference is proportional with the intensity I and the resistivity ***ρ*** of the rocks underlying the survey line. By measuring ***I*** and ***ΔU***, the apparent resistivity of the rocks may be calculated. This resistivity value corresponds to point O which is the midpoint of M and N distance and is calculated using relation (1)*:*

$$\rho_d = k \cdot \frac{\Delta U}{I} \; [Ohm \cdot m] \qquad (1)$$

where k – geometric constant of the electrical array.

The mathematical expression of this constant and its value depend on the distances between electrodes A, B, M and N.

Some of the most used arrays in apparent resistivity surveys are Schlumberger, Wenner, Dipole – Dipole and Gradient arrays. In our surveys we have used the Multiple Gradient array for 2D apparent resistivity survey.

FIELD PROCEDURE OF RESISTIVITY SURVEYS

The 2D apparent resistivity survey was performed using a technique of survey and interpretation called "Real Section" (*Alikaj P, etc.2012*), which provides a good vertical and horizontal resolution for the maximum required depth of investigation, in our case 30 m, with 5 m interval between stations. The measurements were carried out with five or six multiple gradient arrays, starting from AB = 150 m to AB = 30 m. Line 1 (*see Fig.1*) is located in N - S direction and is surveyed in an interval of 100 m. The measurements were carried out with a Time Domain transmitter IPC- 8. A Syscal (*Iris Instruments, France*) was used as a receiver. A transmitter time (*pulse*) of T = 2 sec and receiving time t = 2 sec was used for these measurements. Data processing of the "Real Section" survey is carried out using a proprietary software (called by authors "*Physical Inversion"*) which, in addition to terrain correction, includes the shape of underground current lines distribution between the current electrodes. Because electrical noise caused by mining activity markedly distorts the signal generated by the underground geological section, the company was asked to switch off power during the surveys. That enabled us to obtain good quality field data.

DATA PROCESSING/INTERPRETATION METHODOLOGY

The Resistivity "Real Section" technique (ALIKAJ & GORDON 1999; KARRIQI & ALIKAJ 2011), employs the data acquisition from multiple gradient arrays or Schlumberger VES to provide a presentation that is close to the true distribution of the electrical resistivity in a geological section.

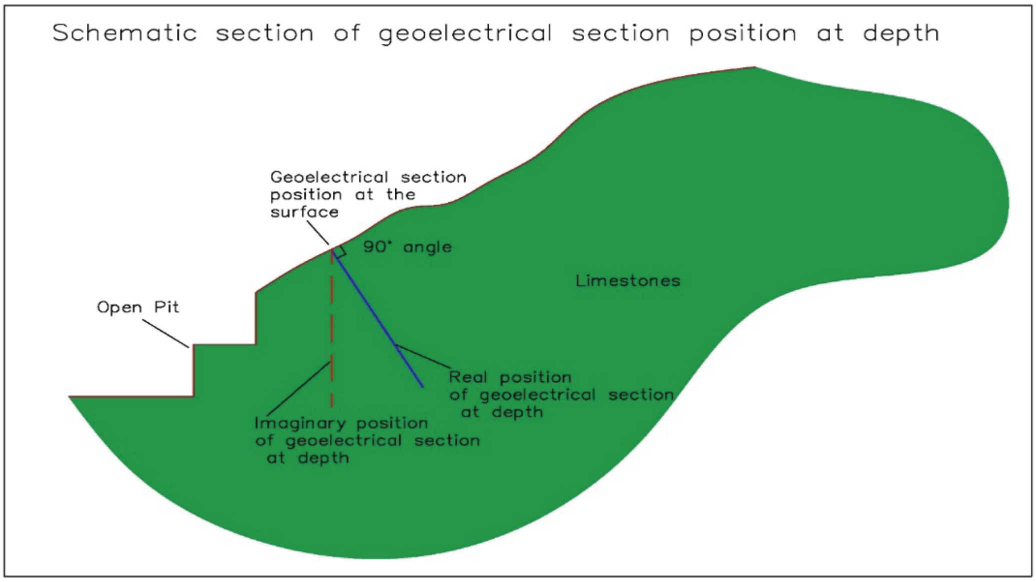

Figure 5. Schematic illustration of geoelectrical section position at depth.

The focus of development of the "Real Section" configuration has been to overcome limitations that have traditionally existed with respect to location, resolution and depth of investigation, inherent in conventional configurations. It is not a mathematical inversion, but rather a presentation of the physical measurements in compliance with the general distribution of the electrical field at depth. Algorithms, developed in conjunction with these configurations, based on scale and mathematical modelling as well as orientation of surveys over known targets allow presentation and interpretation of "Real Section" technique in relation to the true depth and location. The data processing is basically done with Oasis Montaj (Geosoft) software, with some modifications made by our geophysical group regarding the terrain correction. Prior to geoelectrical section interpretation we should give some important information about the position of section at depth defined by the topographic relief of the survey area. Depending of this relief shape, it is also defined the position of surveyed section at depth. In Fig. 5 it is presented a schematic section to better illustrate the idea. It should be noted that the purpose of this section is only illustrative and has nothing to do with the geological reality of the surveyed area.

As we can note in this illustrative section, the geoelectrical section position at depth is not perpendicular to the horizon (at imaginary position of geoelectrical section), but perpendicular to the topographic relief (same as real position of geoelectrical section at depth). This explanation will give a better picture in understanding geological patterns at depth according to the resistivity section position.

RESULTS AND DISCUSSIONS

Fig. 6 presents the apparent resistivity "Real Section" of the surveyed line.

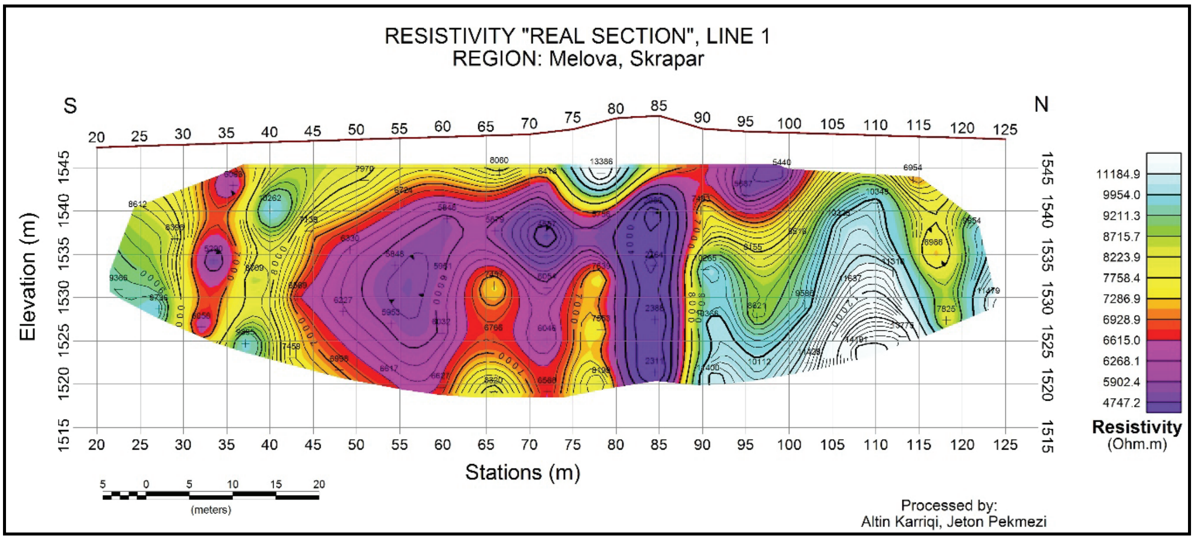

Figure 6. 2D Apparent Resistivity section of surveyed line.

The measured apparent resistivity is characterized by values varying between 2000 ohm.m and 14000 ohm.m. This high range of resistivity indicates limestones in different conditions.

Lower resistivity values are probably connected with the presence of cracks and karst in the limestones. These cracks and karst may be filled with clay or may be caused by high soil humidity. The lowest resistivity values at station 35 and stations 50 – 60, 70 – 75 and 80 – 85 indicate the presence of other materials in limestones that may decrease the resistivity. At the stations 80 – 85 we can observe very low resistivity values from the depth to the surface. This may be probably caused by a cracked zone in the limestones filled with soft material like clay (or presence of humidity or underground water in the cracks). The most probable areas of compact limestones according to the apparent resistivity values in this sections are:

Stations 20 to 30 and 35 to 45, where we can observe an area of high resistivity values coming from the depth toward the surface. This area has an average resistivity of 9000 ohm.m, which is typical for compact limestones.

Stations 75 - 85 define an area of high resistivity from the surface down to the depth of 10 m, which most probably is caused by the presence of compact limestones.

Stations 90 to 115 define the most important area where compact limestones are most probably located. The high values of resistivity (up to 14000 ohm.m) coming from depth and up to 10 m below surface are caused by lithology (most probably compact limestones) and by a factor called lack of mass, caused by a road escarp in the vicinity of the surveyed stations (15 m far from the surveyed stations). Anyway, this factor is not the main cause for the recording of high resistivity values (in this specific case, lack of mass may rise the values by 15% - 20% in the deepest part of the section and by less than 10% in the upper part). The high resistivity values are most probably the result of compact limestones presence in the section.

CONCLUSIONS

The results presented in this paper contribute to defining the massif limestone at depth, helping the mining works to be orientated in this kind of rocks. In the surveyed test line, we can clearly define areas at depth where these massif limestones are located. The apparent resistivity method, and the 2D apparent resistivity section in particular, is very accurate and helpful in resolving the problem of mapping limestone compactness at depth. It easily defines the area at depth where limestones are cracked and subject to karst activity. In the section these areas are represented by relatively average apparent resistivity values (4000 – 6000 ohm.m). Also, we can define areas where this cracks are larger and filled with low resistivity material (mostly clays). In the section these areas are represented by low apparent resistivity values (2000 - 3000 ohm.m). The massif limestone area at depth is indicated by high apparent resistivity values (> 9000 ohm.m). This area represents the zone of interest for the mining company. Authors suggest 2D apparent resistivity surveys in a regular grid, making possible the mapping of massif limestones in the license area and defining in maps the trend direction and the depth of those rocks. Doing this, we can have enough data to present a 3D model of apparent resistivity in the area, which will be very helpful because, taking in consideration that massif limestones are in the interest of the mining company, it is possible to locate mining works only in the area where this kind of rocks are located and make efforts to preserve other areas in natural conditions.

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