QUALITATIVE AND QUANTITATIVE RESISTIVITY (VES) STUDY IN BEDROCK MAPPING. CASE STUDY MOGLICA

KARRIQI Altin, PEKMEZI Jeton

Abstract. A resistivity survey has been carried out in order to determine the subsurface structure of a site near Moglica village in Korça district. The survey line is located on the Devolli river valley, oriented perpendicular to the river bed. The scope of the survey was the delineation and mapping of bedrock, in help of geotechnical study of the site. Four Vertical Electrical Soundings (VES) have been conducted with maximum current electrodes separations of 130 m. In performing resistivity surveys, Schlumberger array has been used. Using those array parameters make possible a maximum survey of 26 m in depth. VES centers (stations) have been located 15 m apart, making possible a survey line length of 45 m. Both qualitative and quantitative interpretation of electrical resistivity data were carried out, giving information in terms of depth to bedrock, nature of superficial materials and geological features characterizing the subsurface basement rocks in the area.

Keywords: Vertical Electrical Soundings, bedrock, qualitative resistivity section, quantitative section.

Abstract. Studiul calitativ și cantitativ al rezistivității (VES) în cartarea rocilor. Studiu de caz Moglica. A fost efectuat un sondaj de rezistivitate pentru a determina structura de cartografiere stratigrafică subterană a unui sit în apropierea satului Moglica din cartierul Korça, în sprijinul studiilor geotehnice. Linia de sondaj este situată pe valea râului Devolli, orientată perpendicular pe versantul albiei. Scopul sondajului a fost delimitarea și cartografierea rocii de bază, în sprijinul studiului geotehnic al sitului. Au fost realizate patru sonde electrice verticale (VES) cu separări maxime de electrozi de 130 m. În efectuarea anchetelor de rezistivitate, a fost utilizată matricea Schlumberger. Utilizarea acestor parametri de matrice face posibilă o analiză maximă de 26 m în profunzime. Centrele VES (stații) au fost amplasate la o distanță de 15 m, ceea ce face posibilă o lungime a liniei de anchetă de 45 m. Au fost realizate atât interpretarea calitativă, cât și cantitativă a datelor de rezistivitate electrică, oferind informații în termeni de adâncime la roca de bază, natura materialelor superficiale și caracteristicile geologice care caracterizează rocile subterane de subsol din zonă.

Cuvinte cheie: Sunete electrice verticale, rocă de bază, secțiunea rezistivitate calitativă, secțiune cantitativă.

INTRODUCTION

Resistivity Survey method using Vertical Electrical Soundings (VES) is one of most used method in bedrock mapping and determining the subsurface structure. This method is easily applied in field, with no need of a large crew and depending of the depth of investigation needed, one can use easily transportable portable equipment. The accuracy of the method is very good when soil layers are horizontal or dipping with a smooth angle. These facts make this survey method a low cost one. VES data interpretation provides 1D results of rocks apparent resistivity at depth. Combining several VES surveys along a line, we can use the data to have a 2D image of rocks resistivity at depth (qualitative 2D section). On the other hand, using appropriate inversion software, we can interpret every VES in terms of number of layers, their true resistivity values and their thickness. After doing that we can interpolate several VES data, obtaining a 2D geophysical section. By knowing average resistivity values of different type of rocks, we can transform this in a geological – geophysical 2D section (quantitative section).

This is the case in our study, where 4 VES surveys are done along a line. VES centers are 15 m apart, resulting in a 45 m surveyed line length. The vertical electric soundings (VES) were conducted by using the symmetrical Schlumberger array with a maximum current electrode spacing (C1C2) of 130 m. This arrays parameters give us a maximal depth study of 26 m.

SITE DESCRIPTION AND GEOLOGICAL SETTINGS

The study site is located in SE part of Albania, near Moglica village, part of Korça district (Fig. 1). This area is under development because of HydroPower plants that are in construction in Devolli river cascade. The rural roads network is reconstructed and several bridges also. The surveyed line is located near Devolli river, on the side of a concrete bridge. The line is oriented perpendicular to the river bed and is surveyed in help of geotechnical studies for a new bridge and road construction.

The region is characterized by a complex geology combined with a very developed tectonic setting. In our site of study are represented these type of rocks:

Middle Eocene and Upper Eocene Flysch deposits (Pg_2^2 - Pg_2^3). The section is represented in lower part by combined clay – alevrolitic packs flysch deposits with sandstones and sporadic limestones. This pack underlays a sandstone – alevrolitic – clay pack with limestones and marl. In the upper part the section is represented by a clay – sandstone alevrolitic pack.

In Moglica village region this flysch is represented by alternation of clay – alevrolitic – sandstones packs with sandstone – clay packs. In between are encountered layers of micritic limestones, gray to beige in color, 10 – 15 cm thick, rich of planktonic foraminifers. Also conglomeratic turbidites with variable thickness are found.

In younger levels is noted flysch with layered conglomerates and turbidites with limestone olistolites of different sizes. This is covered by thin clay – marl flysch with sandstone (several cm thick) dated Upper Eocene (Pg_2^3). Those deposits have a high presence of folds and micro folds.

Alluvial deposits are represented in the site by sand and gravel sediments of actual river bed and old terraces of Devolli river.

Figure 1. Survey site and VES centers location (schematic presentation from Google Earth).

MATERIALS AND METHOD OF STUDY

Electrical resistivity techniques measure earth resistivity by passing an electrical current into the ground and measuring the resulting potentials created at the surface. This method involves the supply of direct current or low-frequency alternating current into the ground through a pair of current electrodes and the measurement of the resulting potential through another pair of electrodes called potential electrodes. As the distance between the current electrodes is increased, so the depth to which the current penetrates is increased. In the case of the Schlumberger array (Fig. 2), the potential electrodes (P1, P2) are placed at a fixed spacing (b) which is no more than a fifth of the current-electrode half-spacing (a) (REYNOLDS, 2011).

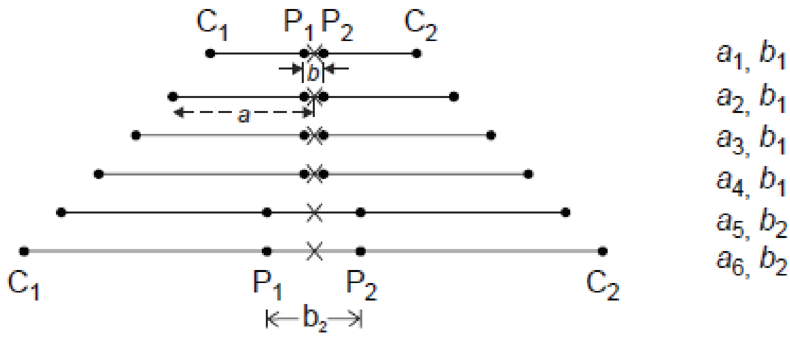

Figure 2. Expanded arrays with successive positions displaced at VES survey using Schlumberger array (REYNOLDS, 2011).

The current electrodes are placed at progressively larger distances. When the measured voltage between P1 and P2 falls to very low values (owing to the progressively decreasing potential gradient with increasing current electrode separation), the potential electrodes are spaced more widely apart (spacing b2). The measurements are continued and the potential electrode separation increased again as necessary until the VES is completed. The position of measurement is taken as the midpoint of the electrode array. For a depth sounding, measurements of the resistance ($\Delta V/I$) are made at the shortest electrode separation and then at progressively larger spacing (REYNOLDS, 2011).

At each electrode separation a value of apparent resistivity (ρa) is calculated using the measured resistance in conjunction with the appropriate geometric factor for the electrode configuration and separation being used.

The values of apparent resistivity are plotted on a graph ("field curve"), the *x*- and *y*-axes of which represent the logarithmic values of the current electrode half-separation (AB/2) and the apparent resistivity (ρa), respectively.

A total number of four VES surveys were conducted. The VES centers were projected in a line perpendicular to the river bed, starting from 2 m far from the riverbed with a step of 15 m along the line, making possible about 45 m of total length surveyed line. All the arrays are spread parallel with the riverbed. VES 4 center is displaced from the line to avoid the concrete bridge effects upon the current lines spread. The measurements were carried out with a Time Domain transmitter IPC- 8. As receiver it was used a Syscal (*Iris Instruments, France*). A transmitter time (*pulse*) of T = 2 sec and receiving time t = 2 sec were used for these measurements. The field data are interpreted using Geosoft Oasis Montaj for a qualitative section and IX1D software for VES data interpretation in terms of a quantitative section.

Potential electrodes (P1, P2) are placed in the center of survey array and served to measure the potential difference between them. The P1P2 electrodes distance was changed progressively from (P1P2)/2 = 1.5 m up to over 65 m. Tmaaking into consideration that survey depth is approximately 0.2 · P1P2, we have obtained 26 m maximum investigation depth. All resistivity surveys are high quality surveys. Several repeated surveys were done to assure the surveyed data quality. The standard deviation between repeated surveys was less than 5%. This accuracy is helpful in the processing and interpreting phase of field data.

The apparent resistivity (ρa) was calculated using the expression:

$$\rho_a = k \cdot \frac{\Delta V}{I}$$

where:

k – Geometrical factor of the array (in meter units), calculated as:

$$k = 2\pi/(1/C1P1 - 1/C1P2 - 1/C2P1 + 1/C2P2)$$

ΔV – Difference of potential between P1 and P2 electrodes (in Volts)

I – Current injected using the C1 and C2 electrodes (in Amps).

RESULTS AND DISCUSSION

After field data quality control and processing, the results are presented as both qualitative and quantitative interpretations. In the qualitative interpretation it is observed the shape of the VES curve and qualitative information about the number of layers and the resistivity of layers is obtained. The results of this method of interpretation involved geoelectrical sections using resistivity "Real Section" methodology of data presentation (KARRIQI & ALIKAJ, 2011; ALIKAJ et al., 2012*)*. All the apparent resistivity surveyed data are plotted for each VES and a 2D section is obtained.

In the quantitative method, true resistivity and layer thicknesses are obtained. The main objective of the quantitative interpretation of VES curves is to obtain the geoelectrical parameters and geoelectric section. A geoelectric layer is called by its fundamental characters, resistivity "ρ" and thickness "h". After obtaining geoelectrical parameters for each VES surveyed, we can correlate all VES data, obtaining a 2D quantitative section. By knowing the average resistivity of different lithologies, we may obtain a geoelectrical – geological 2D section.

Fig. 3 presents a 2D apparent resistivity section. In this 2D section we can notice the presence of high apparent resistivity values at VES 1, VES 2 and VES 3 in the upper part. This is an indicator of the gravel presence at the section. In the upper part (first 4 – 6 meters of the section) gravels are not mixed with clay material and this causes high values of apparent resistivity. At the upper part of VES 2 (about 1 m) we can note relatively lower apparent resistivity values, indicating the presence of mixed clay material in gravels in this part of the section. From 6 m to about 13 m of depth, the apparent resistivity values are lower, indicating a higher presence of clay material mixed with gravels. VES 4 is projected on the section for interpretation purposes. Normally this VES center is located about 30 m perpendicular to the line where other VES surveys are performed.

At the upper part of VES 4 (first 4 meters) can be noted low apparent resistivity values (in the range of clay and silt values). This is explained by deposition of clay and silt material eroded by flysch which is outcropping near the road. Also, river meanders may have deposited in this part clay and silt material.

Deeper, the apparent resistivity values are higher at VES 4 (at the level of gravel mixed with clay values). In all four VES surveys, at depth (below 12 – 13 meters), can be noted an immediate decrease of the apparent resistivity values, at the range of 40 – 100 ohm·m, indicating the presence of flysch deposits. The upper part of the flysch deposits is undulated and can be surveyed at different depths on VES surveys, but the average depth is on the range of 10 – 13 meters.

In quantitative interpretation, the geoelectrical parameters (true resistivity and thickness) are obtained for each geoelectrical layer through data inversion. In Fig. 4 are represented the quantitative interpretations of VES curves and true resistivity values and thicknesses for each interpreted layer.

From the quantitative sections it can be noticed that the flysch basement at the bottom part of the section is characterized by true resistivity values on the range of 40 -50 ohm·m. The depth of the flysch basement varies from 8 m to around 13 m.

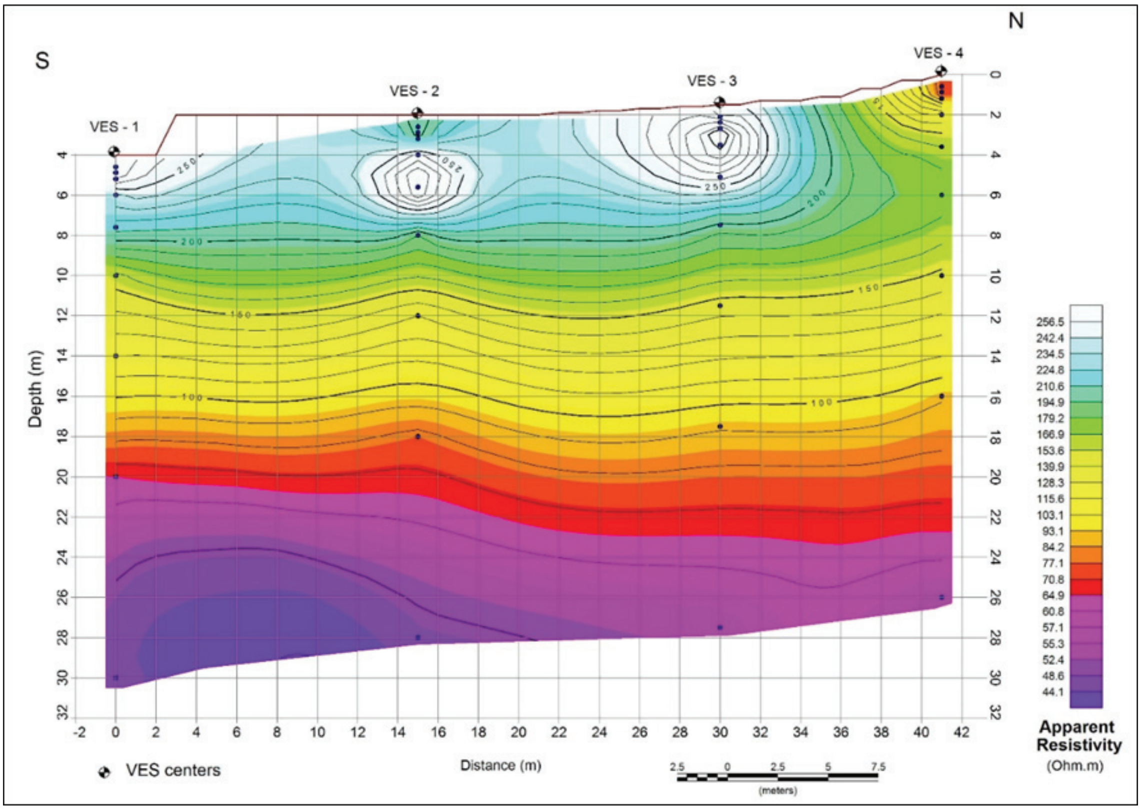

Figure 3. Qualitative 2D interpretation of apparent resistivity resulted from the VES surveys.

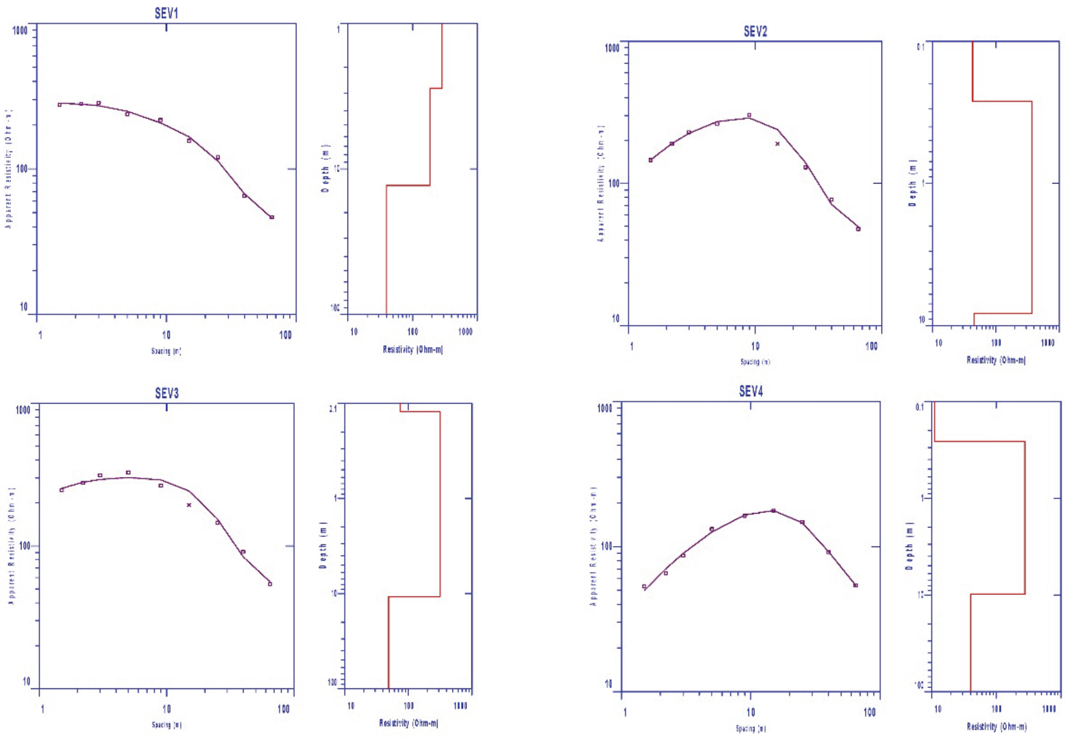

Figure 4. Interpretation curves of VES data defining true resistivity and thickness for each layer.

Above the flysch basement it is interpreted a gravel layer mostly heterogeneous, with some parts where clay and silt material is mixed with gravel. Because the upper part of the gravel is dry or with moderate moisture, the resistivity values are slightly higher (VES 1 first 2 meters). The gravel layer thickness is interpreted as 8 to 13.5 m. The level of underground water in gravel layers is below 3 m of depth, in the river bed quote. In the upper part of the sections is present a thin layer where predominant are silts and clays mixed with sand and gravel. The thickness of this layer varies from 0.2 to 0.4 m. At VES 1, which is about 3 m from the river bed, this thin layer is not present because of river erosion effect.

Qualitative 2D section served as a basis for an accurate quantitative interpretation, based on the correlation of geoelectrical section with the lithology, by plotting a 2D geoelectrical – geological section (Fig. 5).

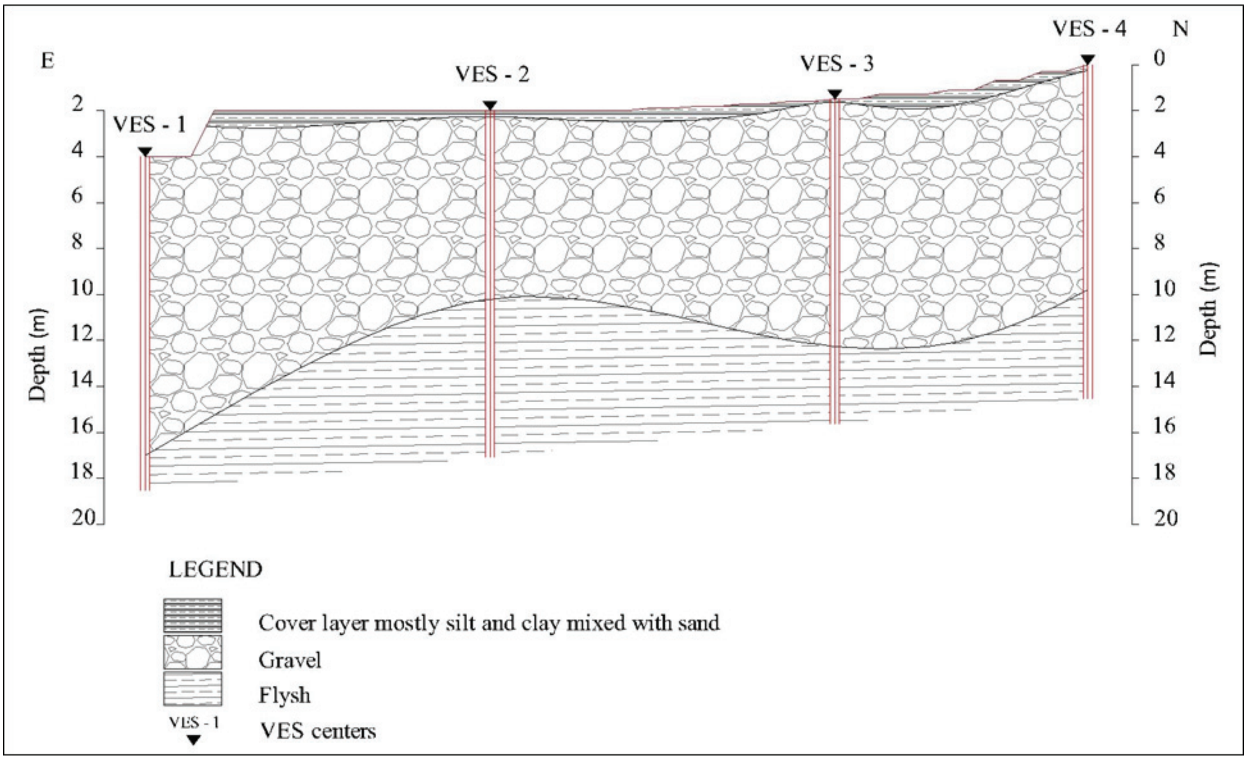

Figure 5. Quantitative geoelectrical - geological section derived from VES data interpretation.

CONCLUSIONS

Geoelectrical surveys can be very helpful in mapping bedrock. This surveys are easy to apply, they don't need a large crew, for shallow depth studies can be used portable, light weight equipments and VES surveys provide accurate results. VES surveys are giving information about depth from a point in surface which is the center of the survey array. In a certain way, a VES survey we may be called "electrical drilling". By surveying several VES along a line, it is possible to correlate all VES surveys and plot a 2D section.

Qualitative sections give information on how the apparent resistivity parameter varies in the section, where are the high and low resistivity areas located. In our study we have plotted a qualitative section using VES field data and apparent resistivity "Real Section" technique in data presentation. Qualitative 2D section served like a basis for an accurate quantitative interpretation, based on the correlation of geoelectrical section with the lithology

Quantitative sections give information about true resistivity and layer thickness (geoelectrical parameters). The flysch basement at the bottom part of the section is characterized by true resistivity values on the range of 40 -50 ohm·m. Depth of the flysch basement varies from 8 m to around 13 m. The flysch surface is undulated, so the gravel layer thickness varies along the line. Finding the flysch boundary pattern, helps geotechnical works in future.

A gravel layer mostly heterogeneous with some parts where clay and silt material is mixed with gravel is interpreted above the flysch basement. The gravel layer thickness is interpreted from 8 to 13.5 m. In the upper part of the sections is present a thin layer (0.2 – 0.4 m thickness), where the predominant lithology consists of silts and clays mixed with sand and gravel. At VES 1, this thin layer is not present because of the river erosion effect.

REFERENCES

ALIKAJ P., LIKAJ N., KARRIQI A., COLLAKU E. 2012. Advancement in IP/Resistivity "Real Section" presentation. *Bulletin of Geological Sciences*. Albanian Geological Survey. Tirana. **1**: 292-297.

KARRIQI A. & ALIKAJ P. 2011. Combination of Resistivity "Real Section" with quantitative interpretation of Vertical Electrical Soundings. *Procedeengs of the International Geo-Science Conference GeoAlb 2011, 27 - 30 September.* Mitrovicë: 466-469.

REYNOLDS J. M. 2011. *An introduction to applied and environmental geophysics*. Wiley-Blackwell. Hoboken. 696 pp.

Karriqi Altin
Polytechnic University of Albania
Faculty of Geology and Mining, Department of Earth Sciences
Rruga e Elbasanit, Tiranë, Republic of Albania.
E-mail: altin.karriqi@fgjm.edu.al

Pekmezi Jeton
Polytechnic University of Albania
Faculty of Geology and Mining, Department of Mineral Resources
Rruga e Elbasanit, Tiranë, Republic of Albania.
E-mail: jpekmezi@gmail.com

Received: March 15, 2018
Accepted: August, 19, 2018