V. BALKANMINE OHRID 2013

# 5th JUBILEE BALKAN MINING CONGRESS

# PROCEEDINGS

**18th-21st September 2013** Ohrid, Macedonia

ELEM MACEDONIAN POWER PLANTS

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Photos on the title-page:
Track-type loader excavator at work
- Dmitry Kalinovsky
Miner in a pit
- NTRES Reuters Srdjan Zivulovic

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# GEO-ELECTRICAL MODELS BASED ON DATA GAINED FROM THE COAL MINE "SUVODOL"

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## ABSTRACT

Geophysics as science is significantly used in different industries such as the mining industry, the geotechnics, engineering geology, hydrogeology etc. In the Republic of Macedonia the usage of geophysics researches while determining the geological and structural characteristics of the working environments is not nearly on the level on which it should be. For these reasons this paper is going to elaborate the usage and the practicality of the geophysical examinations in the mining industry.

The example elaborated in this paper is based on data gained from the coal mine "Suvodol". Through examination of the parameters from the boreholes and the geological map of the coal mine we determinate the layered structure of the ore body that provides favorable conditions for applying the method of geo-electrical sounding. For this purpose, we use a measuring composition made of two current and two potential electrodes placed inline in Schlumberger layout.

Synthetic curves for real electrical resistance can be made while using the processed data from the boreholes. If the method is solved indirectly from these curves we can determine the specific electrical resistance of the materials which are present in the examined environment.

The depth of the examined area that is stimulated by the electrical current directly depends on the distance of the current electrodes. After every new measuring the current electrodes are successively drifting away and thereby we gain values for the apparent electrical resistance for different depths in the examined area. By connecting the values of the apparent electrical resistance, we create a curve for apparent electrical resistance of the environment.

A geo-electrical model of the researched environment is created by connecting all obtained curves. By processing the geo-electrical model using the data gained from the curves of the real electrical resistance, a geological image for the examined environment can be made.

When researching a specific environment with applying geophysical methods the number of the boreholes which are necessary for establishing the geological map can be reduced.

The loss of data that occurs by the reduction of the number of the boreholes is compensated with the data gained from the geophysical researches and therefore when researching geologically known or unknown environments with the use of the geophysical methods the costs can significantly reduce.

**Keywords**

Geo-Electrical Examination, Geo-Electrical Sounding, Specific Electrical Resistance, Synthetic Curves

## 1. INTRODUCTION

In order to obtain the most precise and most concrete results of the researched environment when using geophysical methods, it is necessary to determine the most appropriate method depending on field conditions, geological features of the environment and the purpose of the tests. Field conditions in mines and coal deposits allow obtaining the most precise results in trials using geo - electrical methods. Geo - electrical methods are based on conduction of electricity in rocks and recording the electrical resistance that they manifest.

While analyzing and processing of data from the geological map of the research area we can conclude that the ore body in the surrounding is composed of typical rock masses with different specific electrical resistance. Because the differences in the specific electrical resistance of rocks are large enough to be recorded, analyzed and we can separate different geological environments based on them, the use of geo - electrical methods in research is quite reasonable and logical solution. When analyzing the data obtained from mapped boreholes in the research area we conclude that rocks are horizontally stacked. Because of such layering of the ore body the most suitable geo - electrical method to use is the method of geo - electrical sounding.

## 2. METHODS

### Geological modelling

The research area is chosen from the current map situation in the coal mine "Suvodol", in distinctive geological environment with higher levels of groundwater where there is construction of drainage and controlling system of the level of underground water. The drainage system is composed of a series of wells and piazometers serving in two different routes across a semicircular line, both with different number of wells and piazometers. All data which can be obtained for the experimental environment are in favor of detailed design and drafting system. For these reasons this particular environment is selected as a research area to carry out geophysical surveys covered in the paper.

Although the level of underground water is not included in the tests that are elaborated in the paper (due to lack of field testing) it is important to emphasize that in the pursuit of geo - electrical testing underground water has a major impact on the received data and with its appropriate use the research area can be modeled in further detail.

The whole research area is divided into three main parallel sections and two transverse control sections, processes a total of 13 mapped boreholes of varying depth which varies from 75 m to 165 m. The analysis of the mapped boreholes indicates that the investigating area mainly consists of:

- Base plate basin – gneiss
- Sands of varying granularity
- Composition of clay and sand
- Sands with organic matter
- Coal as mineral resource

### Geo – electrical modeling

Geo electrical modeling consists of preparation of geo - electric models. Geo - electric models show the geological environments in the research environment through parameters obtained directly from the geo - electrical testing or indirectly by processing the data obtained in tests. Typically boreholes through which the profile line passes, represent measurement points of the geo - electrical testing. By examining each measurement point a two-dimensional curve is produced, and by the continuation of curves of all measurement points the geo - electrical models are obtained. In this paper the geo - electrical modeling will be processed through the preparation of two different models:

- Geo - electrical model of curves of real electrical resistance
- Geo - electrical model of curves of apparent electrical resistance

## 3. RESULTS

### Geological profiling

Due to the sheer volume of the modeling process in this paper only the modeling of the first Main Profile line will be processed that extends across the five boreholes: 49 / 52-49 / 56-49 / 60-49 / 64-49 / 68. The boreholes have different depth that varies in the range of 107.4 m to 159m. The distance between each borehole is 200m hence, the profiled area has a length of 800m.

The profile line goes directly thorough the drainage system that is already made and starts before the first well and ends after the last made well in the system. All constructed wells in the system have been tested for verifying the level of underground water for each well on day 21.08.2012. Using that data the geological profile for the first profile line is not going to show just the geological features of the examined area. In addition the geological profile presents the wells their position on the surface area, depth as well as the level of underground water. On figure 1 the registered depth of underground water for each well is shown with red lines and unit of measurement that represents the depth of the water. All the depths are connected with blue line that represents the level of underground water through the profile line.

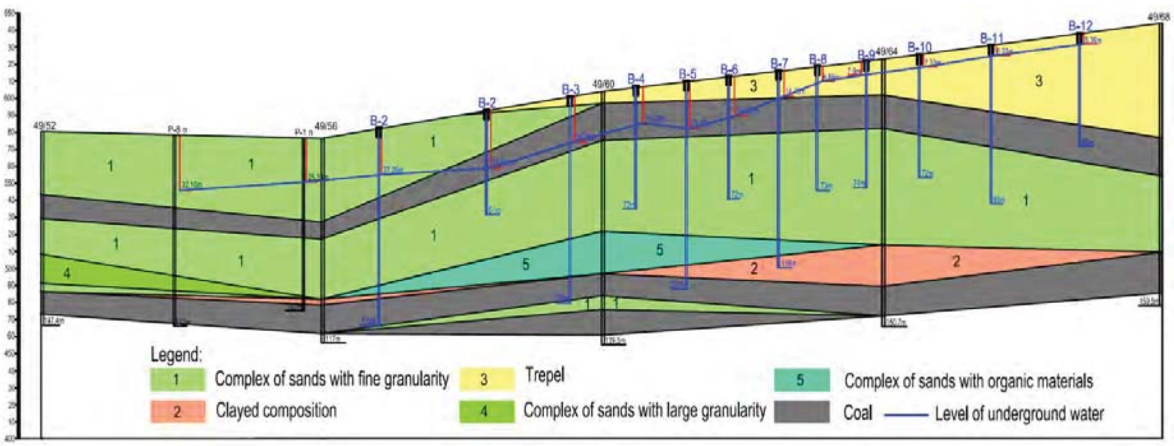


**Figure 1.** Geological profile

The geological profile is based on data from the mapped boreholes and field tests of the drainage system. Figure 1 represents the first geological profile with all field data with a legend explaining all symbols used. From Figure 1 we can determine the presence of six different geological environments in the first profile line.

**Geo - electrical model from curves of real electrical resistance**

The curves of real electrical resistance are two dimensional half logarithmic curves where on the Y axis is marked the depth of excitation expressed in meters (m) and on the X axis is registered the real electrical resistance that is manifested by the rock masses presented in $\Omega$. The curves of real electrical resistance can be produced directly from field trials or synthetically with testing the different geological environments in laboratory conditions [2]. The curves that are used in this paper are synthetic curves that are formed using the data from the mapped boreholes. The geo – electrical profile is a visual presentation of the geological structure presented thorough the real specific electrical resistance that is manifested by the different geological environments. On figure 2 is presented the geo – electrical profile for the first profile line made from curves of real electrical resistance.

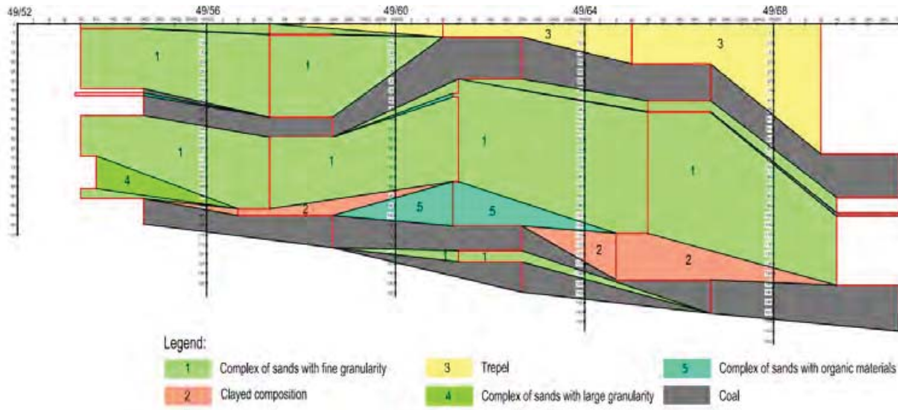


**Figure 2.** Geo-electrical profile from curves of real electrical resistance

Since geo - electrical profiles are made according to parameters directly obtained from mapped boreholes we can conclude that in the process of their creation we do not lose geological data from the examined environment and the represented geological environments are registered and presented as in the geological profiles.

**Geo - electrical model from curves of apparent electrical resistance**

Geo electrical modeling from curves of apparent electrical resistance in this paper is produced through the process of geo - electrical sounding. Geo - electric sounding is usually performed with 4 electrodes (two current and two potential) placed in line in Schlumberger arrangement. Through the two current electrodes, direct current that passes through the rocks in the experimental environment is transmitted. The depth of the excitation directly depends on the distance between the two electrodes and the current is represented by the equation:

$$D = AB/2 \qquad [1]$$

Where:
D is the depth of the excitation
AB is the distance between the current electrodes

With each new repetition the electrodes successively receding and each measurement provides data for different depths. This data is presented in two-dimensional coordinate system where on the X axis the apparent electrical resistance is applied which is registered by the potential electrodes and on the Y axis the depth of excitation is applied that can be obtained via the previous equation from the distance of the current electrodes. With enough repetition (depending on the depth, the layering of the environment and the number of layers) we obtain a sufficient number of data which is applied in the coordinate system and the connection of all acquired points produces a curve of apparent electrical resistance of the environment. By moving the entire measuring disposition and repetition of the procedure throughout the measurement area, we get a growing number of curves depending on how many times the procedure is repeated, which depends on the number of boreholes that are present in the research area, the length of the measuring area, the examined depth etc.

By connecting all obtained curves a geo - electrical model of the research area is produced. The curves of apparent electrical resistance can be obtained synthetically and the data for apparent electrical resistance that is manifested in geological environments is obtained by the mathematical formula [1]:

$$T = h_1\rho_1 + h_2\rho_2 + ....... + h_n\rho_n = \sum_{i=1}^{i=n} h_i\rho_i = \sum_{i=1}^{i=n} T_i \qquad [2]$$

Where:
T is the apparent electrical resistance (Ωm)
n is the number layers in the geological complex
$\rho_i$ is the real electrical resistance for i – layer (Ωm)
$T_i$ is the apparent electrical resistance for i – layer (Ωm)
$H_i$ is the thickness of the i – layer (m)

According to equation 2, the apparent electrical resistance is determined through layering of the geological environments, the thickness of layers (h) and their specific electrical resistance ($\Omega$),values which are known. The curves are presented in two-dimensional semi-logarithm coordinate system where on the Y axis the excitation depth is applied, expressed in m, while on the X axis the apparent electrical resistance is applied registered for the depth expressed in $\Omega$m.

Before going in a stage of modeling, for this type of curves, it is first necessary to interpret the registered values. First, the number of turns of the curve is determined which indicates the number of different geological environments. Any turns are sized according to X and Y and thus data on the thickness of the geological environment is obtained as well as the apparent electrical resistance that is manifested. Using equation 2 and starting from the first geological environment, the specific electrical resistance of each geological environment is calculated inversely and according to that value the rock mass is identified. Once you have completed the process of interpretation of all curves the process of modeling is initiated.

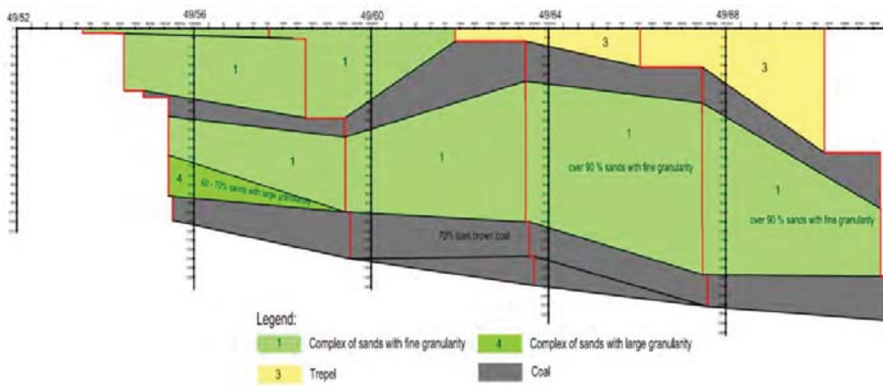


**Figure 3.** Geo-electrical profile from curves of apparent electrical resistance

Figure 3 represents the geo electrical profile made of curves of apparent electrical resistance. The image shows that in this type of modeling certain geological environments are lost or are impossible to identify. Rock masses that are often impossible to determine at this kind of modeling are masses with relatively small thickness and low specific electrical resistance, at greater depth from the surface of the ground. If we compare the resulting geo - electrical profile with the geological profile we are able to conclude which geological environments are lost in the modeling process. However, if there is not enough information to work out the geological profile, we can determine the geological environments that are composed of two or more rock masses by the geo - electrical model itself. Such areas are displayed on the image by a text that according to the received data indicates which geological environment is dominant throughout most of the thickness of the rock composition.

## 4. DISCUSSION

Past researches clearly shows that the geo-electrical sounding and mapping are effective methods for defining subterranean structure of rock masses and especially the level of underground water. This paper presents the development of geo electrical models that can be used as standards for research of similar environments. Although the processed tests are not based on field research and the processed data does not pay enough attention to underground water, still, the procedures discussed in this paper are a good basis which, by further development, can be supplemented to obtaining a complete geophysical elaborate on this type of environments. Geophysical surveys can significantly reduce the cost in defining the geological structure of the rock masses.

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