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IDENTIFICATION OF ORE MINERALIZATION AND MERCURY ZONES USING GEOELECTRICAL RESISTIVITY METHOD WITH DIPOLE-DIPOLE AND SCHLUMBERGER ARRAY IN MINING FIELD, KULONPROGO, YOGYAKARTA, INDONESIA

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Abstract

The presence of minerals ore especially the presence of mercury is the important thing to be noticed in the mining field. Minerals ore have high economical value in mining industry, but mercury can be a pollution in soil. Geolectrical Resistivity methods with dipole-dipole and schlumberger array was conducted to delineate the presence of minerals in the each layer of soil. The methods concern in the zone of minerals ore and mercury in the research area. These methods inject the current in the subsurface. The two current electrodes and two potential electrodes measure the current and potential difference of each layer of subsurface. Every rocks in subsurface have electrical properties depend on containing of minerals. In this case, the resistivity of mineral ore zone is high (> 100 Ωm) and can be obtained in deeper depth and mercury zone has lower resistivity (50 Ωm – 60 Ωm).

Keywords: *Resistivity, Mineral Ore, Mercury, Dipole-dipole Array, Schlumberger Array*

Introduction

Rocks have electrical properties depended on containing of minerals. The properties can resist the flow of electrical current. One of the method which can be used to identify the properties is Geoelectrical Resistivity Method. The method measures the current and potential difference of each layer of earth in which the rocks will contain many minerals. The two parameters are generated to get the resistivity of the rocks and their minerals by generating into 2D and 3D models.

Generally the minerals of ore are formed in igneous rocks. There are many minerals of ore which are indicated by Pyrite, Quartz, Hematite, Magnetite, Chlorite, Galena, Chalcopyrite, Sphalerite, etc. Each of the minerals has difference resistivity properties.

Delineation of mineral deposit can be modelled by 2D resistivity method with mixed array inversion of Wenner–Schlumberger and dipole–dipole array (Manoutsoglou *et al.*, 2010). From Geoelectrical Resistivity results, The mineralized zone containing manganese ore is associated as of low resistivity (20 Ωm). Not only manganese presence indicated the result of geoelectrical resistivity method, but also oxides and sulphite mineral deposit founded. In some area, high resistivity were generated by these method. These value is due to weathering of the gonditic ore, dissolution, percolation and precipitation (Moreira *et al.*, 2014).

2D resistivity method with dipole–dipole array was conducted to delineate the presence of minerals containing manganese in form of manganese ore. Generally, the presences of manganese in rock have lower resistivity (< 5 Ωm). These low resistivity may have been influenced by the presence of clay or weathered soil (Srigutomo, Trimadona and Pratomo, 2016).

Geoelectrical resistivity method with dipole–dipole array is also suitable method to identify iron ore deposit. Dipole–dipole array will produce good imaging both vertically and laterally. The value of measuring will generate into 2D and 3D model of the cross section of the iron ore deposits. The result of cross section got the iron minerals associated with quartzite at 30 meters depth below the surface with the value of resistivity is about 100–2500000 Ωm (Octova and Yulhendra, 2017).

In additional to the method with dipole–dipole array, the method with Schlumberger array was conducted to delineate the presence of mercury in the mining area. The mercury zone has lower resistivity (53,3 Ωm–55,3 Ωm) at the depth 6 to 7 ft from the surface. From the result, the area contains mercury pollution in its soil (Hendrawati, 2013).

Methodology

Geoelectrical resistivity methods used in this research are dipole–dipole array and Schlumberger array. The Geoelectrical resistivity methods are based on generating electrical field of subsurface by injecting electrical current through two current electrodes and two voltage electrodes (see figure 1). The two parameters are generated to get the resistivity of the rocks and their minerals at the subsurface by applying OHM's Law modified in measuring of resistivity of the rock in laboratory:

$$R = \rho \frac{L}{A} \qquad (1)$$

R is the measurement of the resistivity, Ω . ρ is resistivity material, Ωm . The lenght and the area of the rock is donated in L (m) and A (m^2).

With Ohm's Law applied in equation1:

$$R = \frac{V}{I} \qquad (2)$$

V is the electric potential (Voltage) and the current is donated to I (Ampere).

Equation (1) and (2) can be simplified to

$$\rho_a = k \frac{\Delta V}{I} \qquad (3)$$

k is geometric factor depending on electrodes array and ρ_a is apparent resistivity.

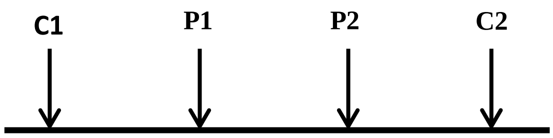


Figure 1: A conventional four electrodes array to measure the subsurface resistivity (Loke, 1999). C1 and C2 are current electrodes, P1 and P2 are electric potential electrodes.

1. **Resistivity Identification**

   There are two types identification of resistivity; Horizontal Profilling (HP) and Vertical Electrical Sounding (VES).

   a. **Horizontal Profiling (HP)**

   Distribution of the various changed resistivity at the subsurface can be determined by mapping the area of subsurface horizontally. Generally, there are two arrays used for this type, they are Wenner Array and Dipole – dipole Array.

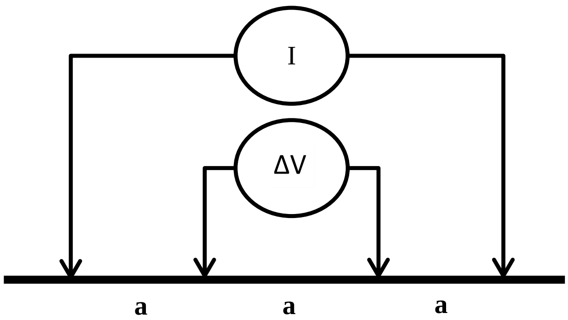


Figure 2: Wenner Array. a - spacing controlling depth of sounding.

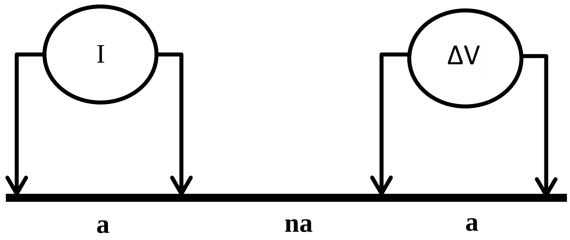


Figure 3: Dipole – dipole Array. n (n = 1,2,3,4,5 etc) is a value of apparent depth level to be made pseudodepth section contours of resistivity variations in lateral direction. Greater "n" will obtain bigger depth (Octova and Yulhendra, 2017).

b. Vertical Electrical Sounding (VES)

Schlumberger array is used to determine the distribution of the various changed resistivity at the subsurface vertically. But generally, the array seems like wenner array (figure 2). In this array, the "a" spacing are moved gradually from the observer. The spacing of current electrodes are wider than potential electrodes.

2. Data Collections

First, this research used Dipole-dipole array in figure 3 with 2 lines with 10 meters distance between lines, and 100 meters long line. Two current electrodes are separated by a constant spacing called "a" and they are used to inject current into the ground. Two potential electrodes are separated by an "a" spacing moving from the current electrodes along the survey line at the distances. The moving of the electrodes are depended on the value of "n". Four electrodes are connected to resistivity meter. The currents and voltage are measured.

After the using of the array, Schlumberger array is used to measured the distribution of resistivity in subsurface vertically with 2 sounding points with 300 meters long line.

The measurements using both arrays depend on the area conditions in topography and the watershed location, the power generator, and electrical pole location.

The currents and voltages obtained from the arrays are generated to get the resistivity, aparrent resistivity, and geometric factor. By obtaining matching curve and inversion methods, the third parameters will be generated to the minerals and rocks true resistivity sections of each layer in subsurface.

a. Matching Curve

Matching curve use the curve of apparent resistivity determined from the calculation and the curve of apparent resistivity determined from the measurements. Both of the curves will be fitted each other to find the real apparent resistivity in each layer of subsurface.

The quantitative interpretation of the matching curve is to obtain fundamental characters, resistivity "ρ" and thickness "h". The characters can investigate a geoelectrical layer (Gardi, 2017).

b. Inversion

The inversion method use a software RES2DINV. Several iterations in this method are used to find a tiny error (RMS error). More tiny the error, more suitable value between the resistivity from theorities and from measurements of the arrays. The result is presented in the form of sections with distance versus depth in terms of pseudo section, calculated section, and inversion model (Moreira *et al.*, 2014). From the two methods above, the presence of minerals in subsurface can be investigated by analyzing the resistivity value of the inversion models every sections. The mineral has no fixed resistivity value. The material subsurface depends on the state of the geology and rocks structure at each location. The range of resistivity value of some minerals and rocks shown in table 1 (Johnson, 2003).

Table 1: Resistivity of rocks and minerals

Rock/mineral	**Resistivity (Ωm)**
Topsoil	50 - 100
Loose sand	500 - 5000
Gravel	100 - 600
Clay	1 - 100
Weathered bedrock	100 - 1000
Sandstone	200 - 8000
Limestone	500 – 10000
Greenstone	500 – 200000
Gabbro	100 – 500000
Granite	200 – 100000
Basalt	200 – 100000

Kuarsite	100 – 2500000
Graphitic schist	10 – 500
Slates	500 – 500000
Pyrite (ores)	0.01 – 100
Phyrotite	0.001 - 0.01
Chalcopyrite	0.005 - 0.1
Galena	0.001 – 100
Sphalerite	1000 – 1000000
Magnetite	0.01 – 1000
Cassiterite	0.001 – 10000
Hematite	0.01 – 1000000

Results And Discussions

A. Dipole-dipole Array

There are two lines applied by dipole-dipole array in the mining area with 10 meters distance between lines. Every field data from the lines were processed by RES2DINV program. Line 1 and line 2 are located close to active mining site with 10 meters distance between the lines, where there are outcrops of exposure pyrite ore. Line 1 in figure 4 shows the presence of various layered structures in the measurement data. The layers are dominated by low resistivity (9 Ωm–50 Ωm). Low resistivity can be divided to two parts, soil and water. The soil part is consisted of minerals and rocks. At the 70 m–80 m long line with 7 m–12.7 m in depth, the low resistivity (< 10 Ωm) is interpretated to clay. Groundwater or alluvium is interpretated at the surface to the subsurface at 12.7 m in depth with the resistivity value between 10 Ωm–100 Ωm. The minerals consisted in this depth are Galena and Pyrite. The presence of these minerals are due to residual waste disposal from mining treatment with resistivity of mercury is between (50 Ωm–60 Ωm).

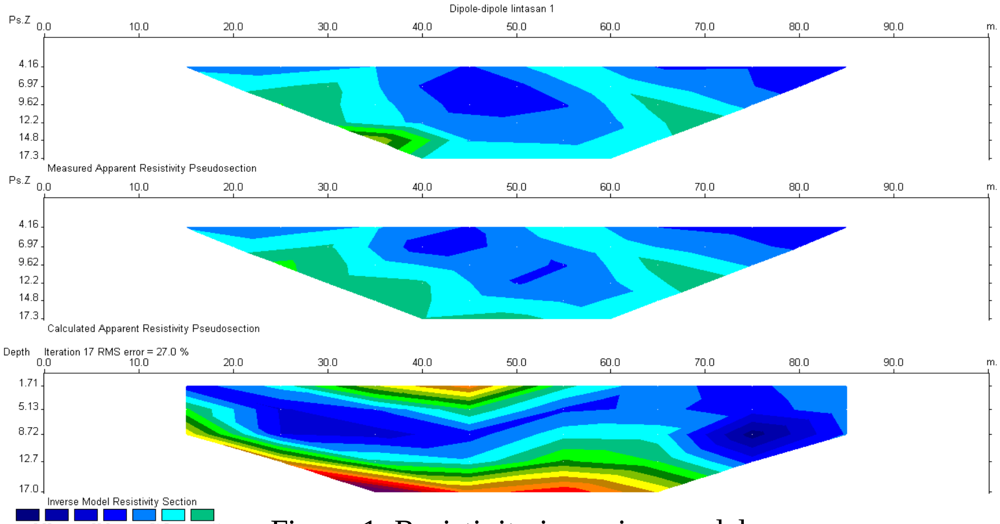


Figure 1: Resistivity inversion models

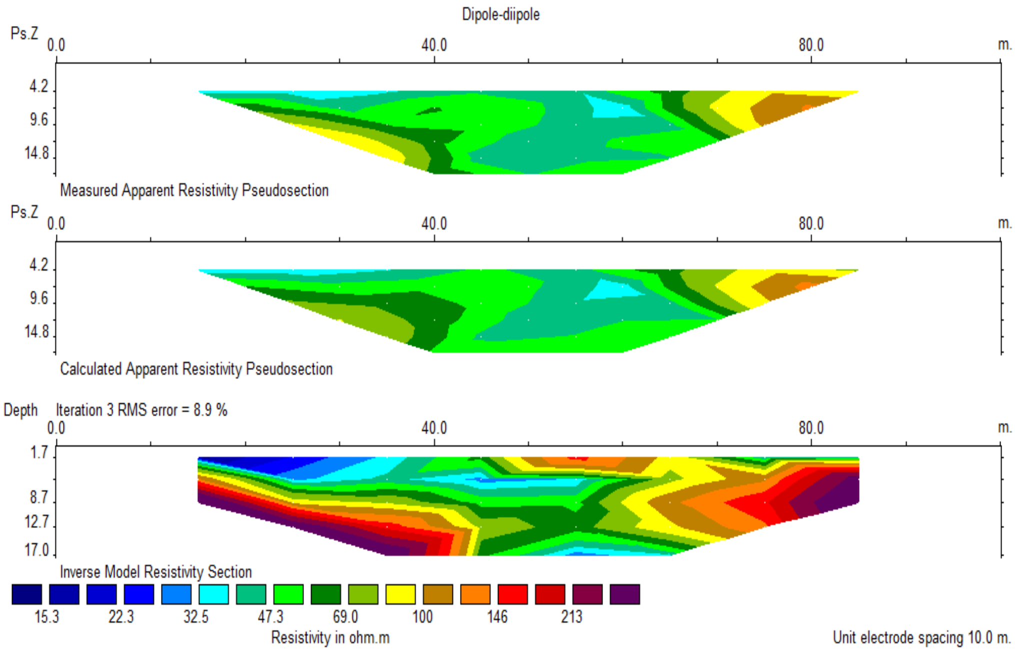
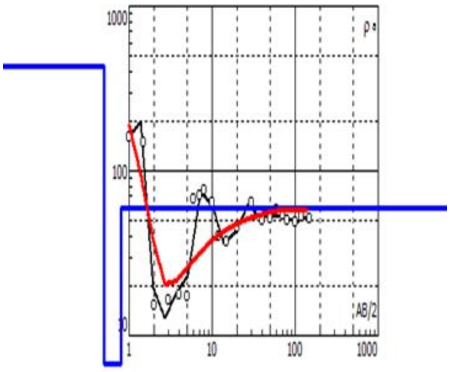


Figure 2: Resistivity inversion models

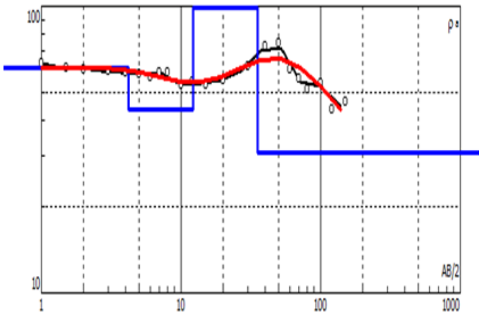
Sedimentary rocks and igneous rocks are obtained at the 3 meters in depth with 30 meters to 50 meters long line. These rocks consist of minerals ore (Sphalerite, Magnetite, Cassiterite, and Hematite) with the resistivity value between 800 Ωm to 2000 Ωm. Line 2 in figure 5 shows the presence of various layered structures in the measurement data. The layers are dominated by sedimentary and igneous rocks (Marble, Slate, and Kuarsite) with resistivity value between 50 Ωm–250 Ωm. In the resistivity inversion model, the mercury resistivity (50 Ωm-60 Ωm) spreads in most of every depth.

B. Schlumberger Array

There are two points were applied to Schlumberger array with 300 meters long line every points. The short long line of this array is due to the escarp with the watershed. The field data from the measurement are processed by matching curve with IP2WIN program. From the processed, every layer of subsurface in the mining area can be known with its composition of rocks and minerals.



(a)



(b)

Figure 3: Matching curve of apparent resistivity field data (the black line) with true apparent resistivity (the red line). The blue line indicate the layer of subsurface. (a) line-1 of Sclumberger array (b) line-2 of Schlumberger array.

Clay is obtained at 0 m to 4.2 m in depth with the resistivity value is 61.1 Ωm. With the resistivity value between 43.8 Ωm to 61.1 Ωm with the depth between 4.2 m to 12.2 m is indicated with minerals ore (pyrite, galena, magnetite, cassiterite, and hematite). Gravel, Gabbro, Graphitic schist, and Kuarsite are indicated at the depth 12.2 m to 35.3 m with the resistivity value is 102 Ωm (figure 6).

Conclusions

1. The two arrays with two methods in this paper show the ore mineralization and mercury zones. The resistivity of mineral ore zone is high (100 Ωm to higher). Eventhough there is any mineral ore indication at surface or at the shallow depth, the mineral ore is only the residual waste disposal from mining treatment.
2. The area is close to mining treatment in separating the minerals ore from the rocks. The mining treatment use mercury liquid for the separations. From the inversion models, the mercury zones are indicated with 50 Ωm–60 Ωm in resistivity.
3. In lower depth, mineral ore deposit in igneous rocks indicated by Sphalerite, Magnetite, Cassiterite, Hematite, Galena, and Pyrite.

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