ANALYSIS OF SUBSURFACE STRUCTURE OF IRON SAND POTENTIAL WITH 3D MODELLING RESISTIVITY GEOELECTRIC METHOD IN PANDANWANGI VILLAGE KUNIR LUMAJANG

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ABSTRACT

This research was conducted to analyze the sub-surface structure of the potential iron sand area and the distribution of iron sand depth in terms of its specific resistivity in Pandanwangi Village, Kunir District, Lumajang Regency. This research uses the Wenner configuration resistivity geoelectric method to identify subsurface structures. Measurements were made using 4 lines that have a length of 200 meters per line and then processed using Res2Dinv software to see the results of the 2D cross-section and using Voxler software to see the results of the 3D cross-section. Based on the results of the study, there are several types of rocks and constituent minerals that are below the ground surface, including iron sand, sand, sandstone, and basalt which are found at certain depths. Line 1 tends to contain sand, and line 2 is often passed by residents' vehicles so that it has a different density than other lines because, on line 3, activities are often carried out by local residents. Line 3 has the least iron sand potential compared to other lines, and line 4 has the greatest iron sand potential than other lines. The potential of iron sand is assessed based on its lower resistivity value compared to other rocks and minerals, which is around 0.13-37.11 Ωm.

Keywords: Iron sand; Subsurface structure; Geoelectric resistivity; Wenner configuration

Introduction

Resistivity geoelectricity is one of the methods to determine the subsurface structure and recognize the formation of rock or mineral layers. This method can be used for the exploration of groundwater,[1–3] determine the rock structure in the landslide zone.[4–6] Geoelectric methods can also be used to identify the thickness of soil layers, such as estimating the thickness of peat layers.[7] Another implementation of this method can also be used to detect vital minerals, including iron sand.[8,9]

Iron sand is sand that contains a high concentration of iron. Iron sand is usually dark grey or blackish in colour. Iron sand is one of the natural resources in Indonesia that has industrial applications.[10] More specifically, it is used as a raw material for the production of iron and steel. Iron sand consists of sand grains mixed with opaque minerals.[11] Minerals contained in iron sand include *limonite*, *siderite*, *magnetite*, *silica*, *manganese*, *hematite*, *titanium*, *vanadium*, and *calcium*. Minerals such as *ilmenite* found in iron sand deposits can be associated with titanium oxide (*titaniferous iron ore*).[10]

One of the areas in Indonesia that produces iron sand with the best iron content is Lumajang district. This is because Lumajang lies in a volcanic zone with Mount Semeru and Bromo nearby, both of which are active volcanoes that, when erupted, deposit material such as iron sands along the coast and river.[12] One of the places in Lumajang district that is used as a sand mining site is Pandanwangi village, located in the Tempeh sub-district.

Iron sand exploration can be done directly and indirectly. Direct exploration can employ two methods: drilling and test wells. In contrast, geophysical methods represent an indirect exploration approach. One such method is geoelectric resistivity. The geoelectric method is one of the geophysical research methods used to

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study subsurface structures by utilizing the electrical characteristics of rocks.[13–15] The procedure employed in the geoelectric method entails the channelling of an electric current into the subterranean environment or the injection of said current through the use of current electrodes, followed by the measurement of the potential difference on the surface in question. Data from geoelectric measurements can be in the form of resistivity maps, either in the form of horizontal sounding or depth mapping.[16]

With this background, the author is interested in conducting research on iron sand in Tempeh District, Lumajang Regency, using the resistivity geoelectric method with the *Wenner* configuration *with 3D modelling*. The *wenner* configuration was chosen because the distribution of iron sand is at a shallow depth, so the wenner configuration is suitable for use. The *Wenner* configuration is good at mapping the ground horizontally so that it can be used to analyze the type of subsurface material and has good resolution for the identification of lithological layers.

Methods

The method used to collect data is the *Wenner* configuration geoelectric method. The data obtained from this research is the value of the potential difference (V) and current strength (I) obtained from measurements in Pandanwangi Village, Kunir District, Lumajang Regency. The number of lines used is 4 lines which have a length of 200 meters each that intersect each other and can be seen in Figure 1.

Figure 1. The location of the research

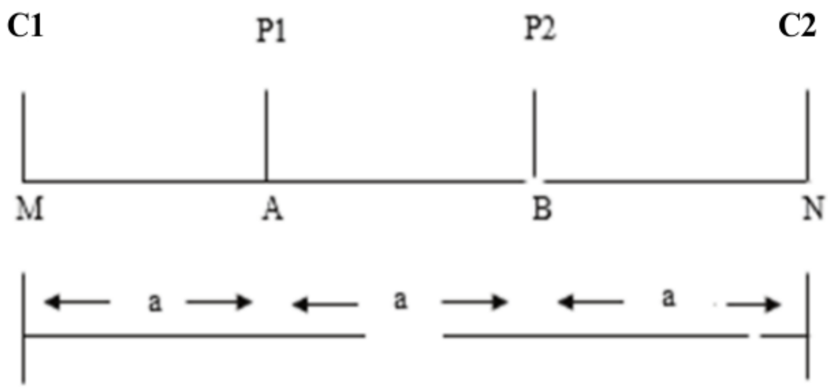

Figure 2. Current and Potential Electrode Arrangement in Wenner Configuration.

The electrode configuration used in this study is the Wenner configuration. The *Wenner* configuration involves placing four electrodes in a straight line with similar spacing.[13,17] *The Wenner* configuration comprises two current electrodes (C1-C2) and two potential electrodes (P1-P2). The multiplier factor for the *Wenner* configuration is 0.173.[18]

Based on the figure, the equation is obtained:

$$K_w = 2\pi \left[\frac{1}{\left(\frac{1}{MA}-\frac{1}{MB}\right)-\left(\frac{1}{NA}-\frac{1}{NB}\right)}\right] \quad (1)$$

$$K_w = 2\pi \left[\frac{1}{\left(\frac{1}{a}-\frac{1}{2a}\right)-\left(\frac{1}{2a}-\frac{1}{a}\right)}\right] \quad (2)$$

$$K_w = 2\pi a \quad (3)$$

Therefore, the geometry factor for the Wenner configuration is:

$$K_w = 2\pi a \quad (4)$$

$$\rho = K_w R \quad (5)$$

The result is the apparent density resistance in Wenner configuration:

$$\rho s = 2\pi a \, \Delta v / I \quad (6)$$

Because the length of the line is 200 meters and the number n or repetition is 5 times, the estimate for depth interpretation is approximately 17 meters. After the calculation in *Microsoft Excel software is* carried out, the same *software* can be used to find the apparent resistivity value (ρa), which is obtained by the equation $\rho a = 2\pi a \, \Delta v / I$.

The Res2Dinv application is a computer program that automatically generates resistivity (2-D) models for subsurface layers from geoelectric survey data. The 2-D model consists of square boxes using the inversion program. The distribution of datum points in the *pseudo-section* binds the square grid arrangement.

Voxler application presents three-dimensional (3D) scientific visualization focusing on *Volumetric Rendering* and data display in 3D. Besides focusing on 3D volumes, *Voxler* can also use two-dimensional (2D) grids such as *Digital Elevation Models* (DEM) files and others[19].

Result and Discussion

Based on the results of field research, data on the value of potential difference (*V*) and current (*I*) were obtained. Furthermore, the data obtained is processed using Microsoft Excel to calculate the resistance value (R), datum, and geometry factor (Kw) to obtain the apparent resistivity value (ρs). Then, the data is inputted into notepad in the form of .dat in the form of datum values, the value of the distance between electrodes (a), and resistivity values (ρs) according to the format and configuration used so that it can be programmed into the Res2Dinv software. The results obtained from Res2Dinv software are in the form of 2D cross-sectional images displayed with colour and resistivity values of underground layers.

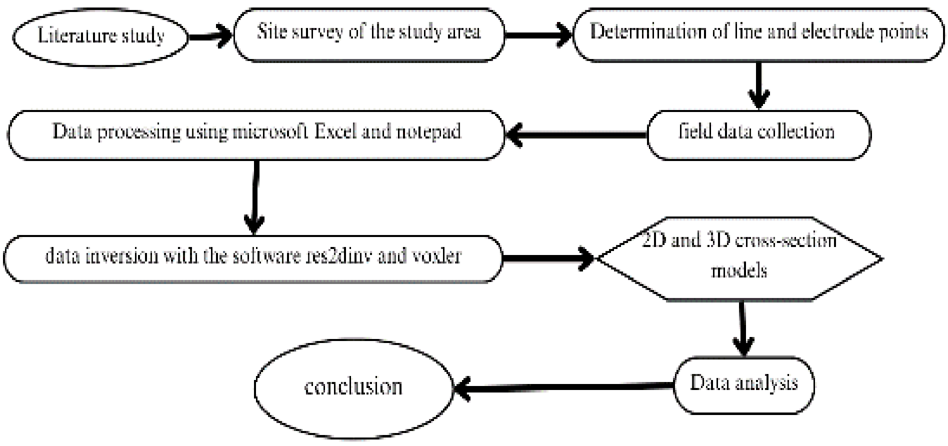

Figure 3. Research procedure

- 2D Cross-section Results

The iron sand found from the research results contains iron oxide, so the resistivity value tends to be lower and can be found in coastal and river alluvium. The following is the 2D cross-section modelling generated by *Res2Dinv Software* from the 4 lines.

The cross-section results on line 1 obtained resistivity values of 19.8 - 77.5 Ωm, and there are differences in the colour of each resistivity value. At a resistivity value of 19.8 - 35.6 Ωm with dark blue to green colours, it is thought to be iron sand minerals spread across the surface of the line at a depth of 0 to 3.75 meters. Furthermore, the resistivity value of 19.8 - 35.6 Ωm with yellowish green to purple colour is thought to be sand minerals scattered across the line's surface at a depth of 3.75 meters to 3.75 meters.

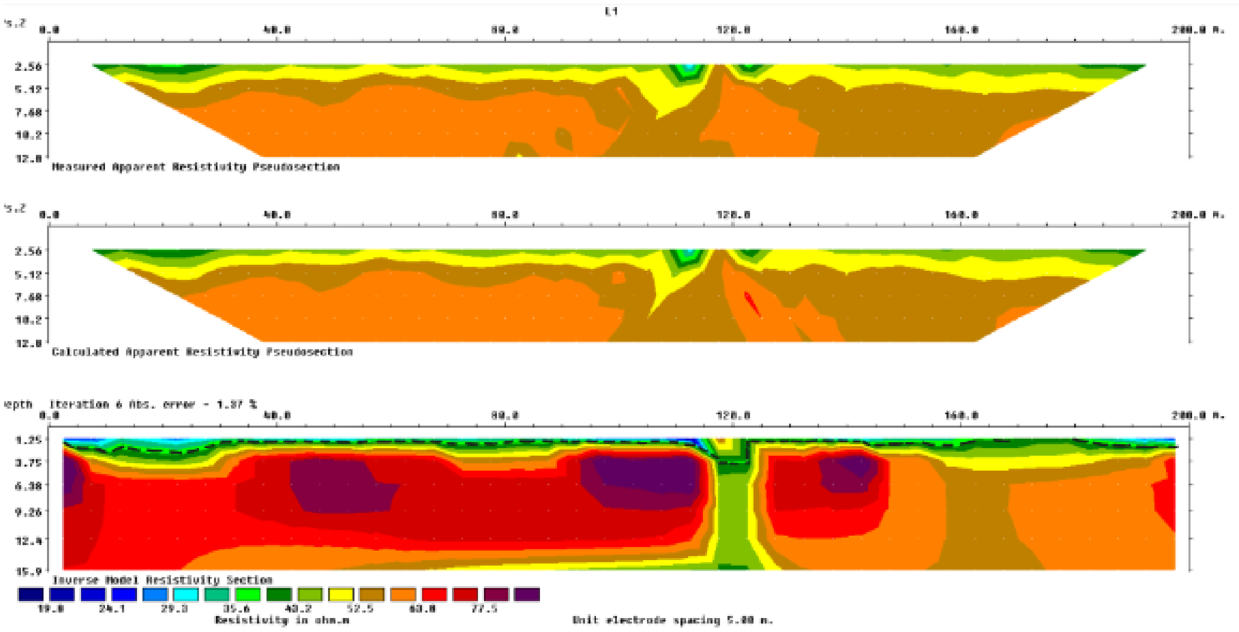

Figure 4. 2D cross-section data processing result of line 1

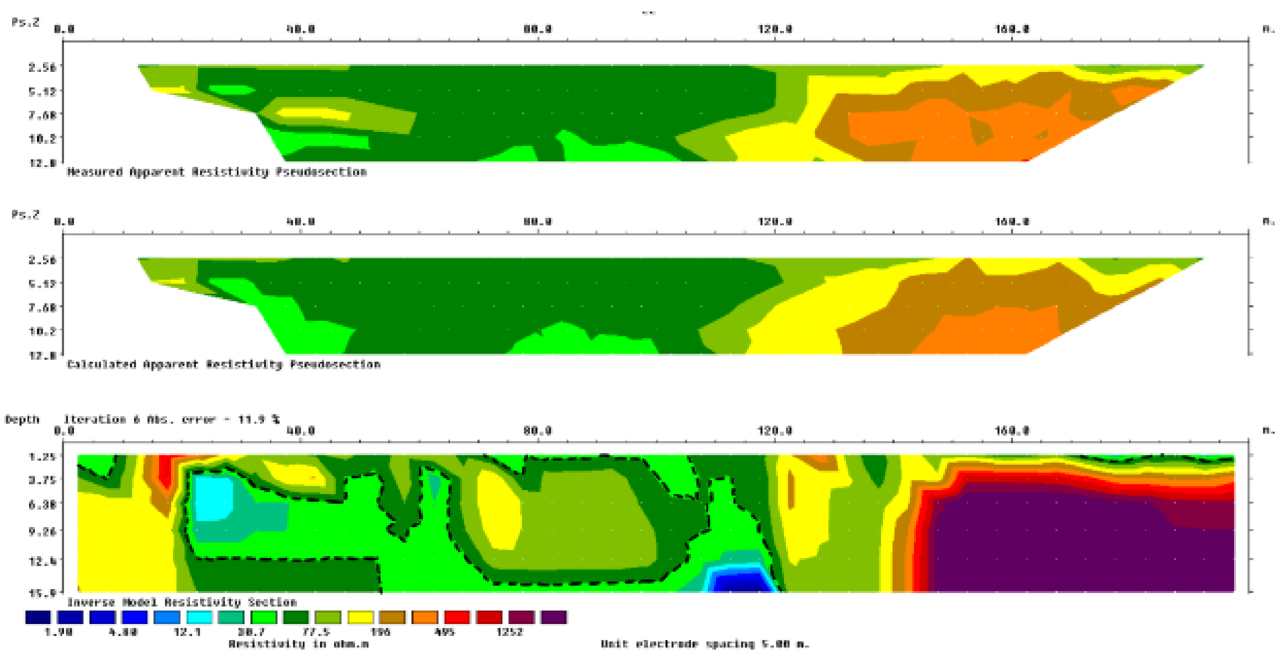

Figure 5. 2D cross-section data processing results of line 2

The cross-section results on line 2 obtained resistivity values of 1.90 - 1252 Ωm, and there are differences in the colour of each resistivity value. At a resistivity value of 1.90 - 30.7 Ωm with dark blue to green colour is thought to be iron sand minerals scattered at a depth of 0 - 3.75 meters at electrode points 0 - 10 meters, at a depth of 3.75 - 15.9 meters at electrode points 20 - 120 meters, at a depth of 0 - 6.38 meters at electrode points 70 - 105 meters, and at a depth of 0 - 1.25 meters at electrode points 170 - 200 meters. At a resistivity value of 77.5 - 495 Ωm with dark green to red colour, it is thought to be sand minerals scattered at a depth of 0 - 15.9 meters at electrode points 0 - 145 meters and at a depth of 0 - 6.38 meters at electrode points 145 - 200 meters. Furthermore, the resistivity value of 1252 Ωm with red to purple colour is thought to be sandstone rocks and minerals scattered across the surface of the line at a depth of 6.38 - 15.9 meters at the 145 - 200 meter electrode point.

The cross-section results on line 3 obtained resistivity values of 7.09 - 10172 Ωm, and there are differences in the colour of each resistivity value. At a resistivity value of 7.09 - 20 Ωm with dark blue to blue is thought to be rock and iron sand minerals scattered at a depth of 0 - 1.25 meters at electrode points 0 - 5 meters, at a depth of 12.4 - 15.9 meters at electrode points 35 - 65 meters, and at a depth of 0 - 1.25 meters at electrode points 120 - 125 meters. At a resistivity value of 56.6 - 451 Ωm with a light blue to yellowish green colour, it is thought to be rocks and sand minerals scattered at a depth of 0 - 15.9 meters at electrode points 0 - 190 meters. At a resistivity value of 1275 - 3601 Ωm with yellow to red colour is thought to be sandstone rocks and minerals scattered at a depth of 1.25 - 15.9 meters at electrode points 85 - 110 meters, at a depth of 0 - 1.25 meters at electrode points 135 - 145 meters and electrode points 155 - 175 meters, and at a depth of 0 - 15.9 meters at electrode points 125 - 200 meters. Furthermore, the resistivity value of 10172 Ωm with red to purple colour is thought to be basalt rocks and minerals scattered at a depth of 6.38 - 15.9 meters at electrode points 95 - 110 meters and at a depth of 0 - 6.38 meters at electrode points 190 - 200 meters.

The cross-section results on line 4 obtained resistivity values of 0.869 - 11025 Ωm, and there are differences in the colour of each resistivity value. At a resistivity value of 0.869 - 12.9 Ωm with dark blue to blue is thought to be rock and iron sand minerals spread at a depth of 0 - 12.4 meters at electrode points 5 - 75 meters, at a depth of 0 - 3.75 meters at electrode points 85 - 90 meters, at a depth of 1.25 - 15.9 meters at electrode points 100 - 150 meters, at a depth of 0 - 3.75 meters at electrode points 155 - 165 meters, and at a depth of 0 - 9.26 meters at electrode points 170 - 195 meters. At a resistivity value of 49.9 - 741 Ωm with a colour of green tosca to light brown, it is thought to be rocks and sand minerals scattered at a depth of 0 - 15.9 meters spread throughout line 4. At a resistivity value of 2859 Ωm with an orange to red colour, it is thought to be rocks and sandstone minerals scattered at a depth of 0 - 3.75 meters at electrode points 0 - 5 meters, at a depth of 12.4 - 15.9 meters at electrode points 20 - 55 meters, and at a depth of 0 - 3.75 meters at electrode points 195 - 200 meters. Furthermore, the resistivity value of 11025 Ωm with red to purple colour is thought to be basalt rocks and minerals spread at a depth of 0 - 3.75 meters at electrode points 0 - 5 meters.

- 3D Cross-section Result

Data processing to obtain 3D results using *Voxler Software* first by inputting the results obtained from the *Res2Dinv Software* inversion results, which are stored in the .xyz file and then opened using *Microsoft Excel*. Then proceed with processing the data to get the UTM X and UTM Y values. Furthermore, the data that has been obtained for each line is input into *Voxler Software. The* data that has been processed in *Voxler Software can* be seen in the following figure:

In the research that has been done, line 1 is in the north and intersects with line 2 on the left and line 3 on the right. Line 4 is in the south and intersects with line 2 on the left and line 3 on the right.

3D cross-section modelling is a combination of each trajectory that will produce colour and shape images that match the colour and shape of 2D modelling. So that the results obtained from the interpretation of each line are shown in Figure 8 and Figure 9. Figure 8 is a display of each intersecting trajectory, and Figure 9 shows the combined results of each 2D trajectory. The potential for iron sand can be seen in blue and green images because iron sand has a smaller resistivity value than other rocks and minerals.

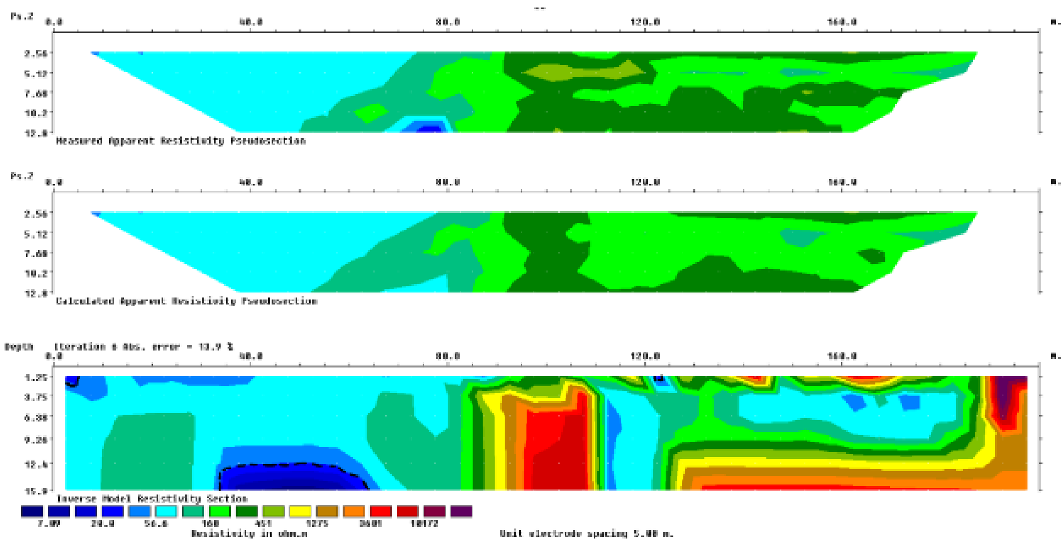

Figure 6. 2D cross-section data processing results of line 3

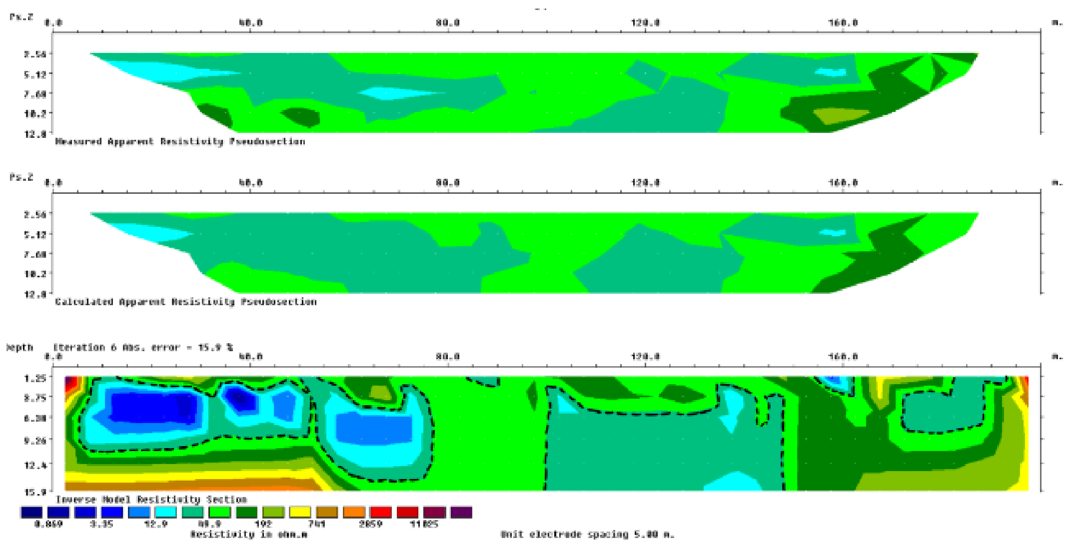

Figure 7. 2D cross-section data processing results of line 4

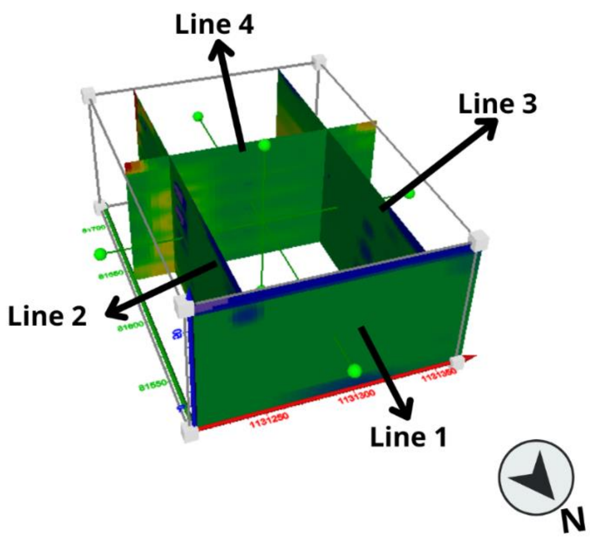

Figure 8. Result of Cross-Section with *ObliqueImage* feature

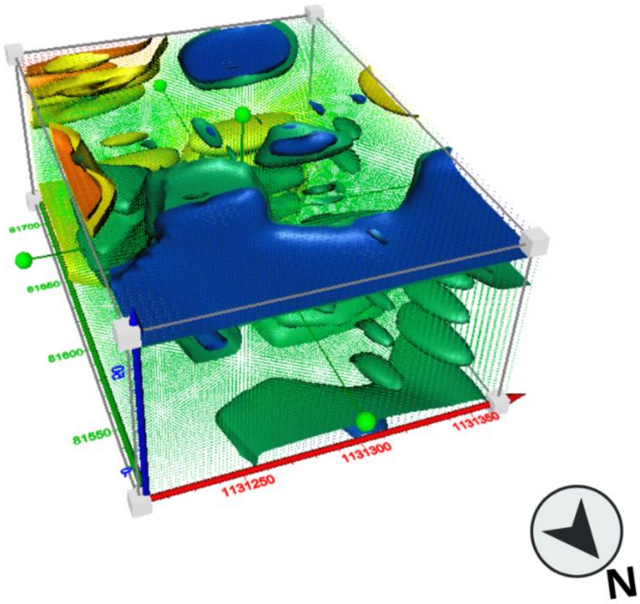

Figure 9. Cross-section result with Isosurface feature

Table 1. Results of interpretation of iron sand distribution in each line

Line	Resistivity Value (Ωm)	Depth (m)	Colour
1	19.8 – 35.6	3.75	Blue - Green
2	1.98 – 30.7	15.9	Blue - Light Green
3	7.09 - 20	15.5	Blue
4	0.869 – 12.9	15.9	Blue - Light Green

- Distribution of iron sand in terms of its specific resistivity

Through the analysis of the results of rock resistivity data processing in the form of cross-sections of subsurface conditions, there are several types of rocks found and then associated with hydrothermal conditions in the study area after being equalized with geological data.

In this study, iron sand has a lower resistivity value compared to the resistivity value of other rocks and minerals because iron sand, especially in Lumajang Regency, has a magnetic mineral content of 39.4% consisting of *magnetite*, *titania magnetite*, *iron albite*, *and anthophyllite* so that the resistivity value of iron sand is Ωm. 0.13 – 37.11 Ωm. The following table shows the results of the interpretation of the distribution of iron sand in each line:

Based on the results of the four intersecting or related lines will show the distribution of iron sand depth. The distribution of iron sand in line 1 is on the entire surface of the line with a resistivity value of 19.8 - 35.6 Ωm and is marked with dark blue, blue, light blue, Tosca green, and green where line 1 is located to the north. Line 3 has the least potential iron sand than the other lines, where the distribution of iron sand is only in the north of the line precisely at electrode points 35 - 65 meters and is at a depth of 12 - 15 meters with a resistivity value of 7.09 - 20 Ωm and marked with dark blue and blue. On line 2, the distribution of iron sand is in the north of the line, which intersects with line 1 to the middle of the line, which intersects with line 4 with a resistivity value of 1.98 - 30.7 Ωm and is marked with dark blue, blue, light blue, Tosca green, and green. Line 4 has the most iron sand distribution among other lines spread in the west, which intersects with line 3 and in the middle of the line, which intersects with line 2 with a resistivity value of 0.869 - 12.9 Ωm and is marked with dark blue, blue, and light blue colours.

Conclusion

The results of the analysis of the subsurface structure of the potential iron sand at the location of data collection show that the constituent of the subsurface structure consists of iron sand, sand, sandstone, and basalt found at a certain depth. In line 1, the potential for iron sand is found on the surface of the line and spread throughout the line with a resistivity value of 19.8 - 35.6 Ωm marked with dark blue to green colour. On line 2, the potential for iron sand is widely spread at points 20-120 meters with a resistivity value of 1.98-30.7 Ωm marked in dark blue to green. On line 3 has little iron sand potential, which is only scattered at points 35 - 65 meters at a depth of 12.4 - 15.9 meters with a resistivity value of 7.09 - 20 Ωm marked in dark blue and blue. Line 4 has more potential distribution of iron sand compared to other lines, namely at points 5 - 75 meters and 100 - 150 meters, with a resistivity value of 0.869 - 12.9 Ωm marked with dark blue to light blue.

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