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Application of Geoelectrical Resisivity Method for Iron Sand Exploration in Ulakan Tapakis Padang Pariaman

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Abstract. There is no doubt about the presence of iron sand around the west coast of West Sumatra. Several studies have been carried out, but in Ulakan Tapakis area is still under observation, and no investigation of its potential and distribution. One of the methods that can provide models and subsurface descriptions is using goelectrical resistivity method. The geoelectrical application in Ulakan Tapakis was used Wenner-Schlumberger array into 4 section. The section was designed perpendicular to the beach with a length of 47 meters for short lines and 470 meters for long line, the distance between sections was about 65 meters. The results obtained in the form of pseudosection types. Each section describes the distribution and lithology of rocks below the surface. The combination of all sections gives an overview of the iron sand model at Ulakan Tapakis. From the model obtained the results of geoelectrical measurements with the Wenner-Schlumberger array, the distribution of iron sand can be found along the coast of the study area at a depth of 0.7 m - 3 m in short line and 40 m in long line with resistivity values ranging from 52 - 289 Ωm

1. Introduction

Iron sand in the coastal area of Ulakan Tapakis in Padang Pariaman Regency, West Sumatra is very promising for mining. Besides being useful as a raw material for the steel industry, iron sand is also useful as a raw material for the cement industry. The presence of iron sand should be able to awaken industries in West Sumatra to use local raw materials. In mining activities, the most decisive activity is exploration.

Geoelectrical method is one of the geophysical exploration methods that can be used to determine the subsurface structure of the earth based on the electrical properties of a medium. Each rock that makes up the surface layer has different electrical properties. This electrical property is the resistivity value that describes the ability of a medium to conduct electric current. The higher the resistivity value of a material, the more difficult it is for the material to conduct electric current, and vice versa.

Exploration of earth materials using the geoelectrical resistivity method can be carried out in several electrode arrays, such as the Wenner, Sclumberger, Dipole-dipole arrays and so on. The choice of electrode array depends on the purpose of the exploration being carried out. The anomaly that appears is expected to detect subsurface heterogeneity. This anomaly will depend on the conductivity contrast that causes the response or changes the potential field. Media that has a contrast, for example between air and soil, sand and clay, etc. can generate or change a potential field that is in homogeneous isotropic conditions such as a sphere into a distorted shape.

In the earth resistivity method, an electric current, direct current or low frequency alternating current, is flowed into the earth through two electrodes, namely the current electrode and the resulting potential distribution is measured by two other electrodes called the measuring electrode (potential). The arrangement of the location of the electrodes can vary depending on the purpose of the exploration carried out. In this study, the Wenner-Schlumberger array was applied to provide an overview of the subsurface area of the iron sands in Ulakan Tapakis, Padang Pariaman.

2. Geoelectrical Resistivity Method

Geoelectrical resistivity method is one of the geophysical methods that can provide an overview of the composition and depth of rock layers, by measuring the electrical properties of rocks [1]. Measurement of the earth's material properties with the geoelectrical resistivity method will produce a resistivity value. Specific resistance can be related to various geological parameters such as mineral and fluid content, porosity and degree of water saturation in rocks [2]. The survey using the resistivity method produces information on changes in the variation of resistivity values in both lateral and vertical directions.

The basic principle of this method is to inject an electric current into the earth using two current electrodes, then measure the potential difference through two other electrodes on the earth's surface. The injected electric current will flow through the rock layers below the surface, and produce potential difference data whose value depends on the resistivity of the rock in its path [3]. Based on the value of the resistivity, the subsurface structure of the earth can be known the characteristics of the layer. The measurement of specific resistance is generally related to the size of the saturation and the pore space of the water. Water has a low specific resistance, as a result the electric current will follow the path of the smallest resistance [2]. Increasing saturation, increasing salinity of underground water, increasing rock porosity tend to reduce the measured resistivity value. Increasing the compactness of the soil or rock unit will repel water and effectively increase the resistivity value. Air, having a high value for resistivity, causes an inverse response to water when filling a void. As a result, the presence of water will reduce the value of the resistivity, while the presence of air in the void increases the value of the resistivity below the earth's surface. Rock electricity is the response given by rocks when current is applied to them. The response given is proportional to the value of the resistivity of the rock.Rock electricity depends on the nature of the rock's electrical flow which is classified into three parts, namely: electronic conduction, electrolytic conduction and dielectric conduction. Electronic conduction occurs if a rock has a lot of free electrons and a current is passed to it, then the free electrons will continue the current. Electrolytic conduction occurs when the rock is porous or pores and the pores are filled with electrolytic fluids. In this conduction electric current is carried by electrolyte ions. Dielectric conduction in rocks occurs if the rock is dielectric to the flow of electric current, the electric current flowing to it will be polarized. Based on the value of resistivity, rocks/minerals can be classified into: good conductors with resistivity values from $10^{-6}\Omega$m to 1 Ωm, bad conductors with resistivity values from 1 Ωm to 10^7 Ωm, and insulators with specific resistivity values. greater than 10^7 Ωm. It means that the more conductive a material, the smaller its resistivity value, and the more insulating a material, the greater the value of its resistivity.

3. Basic Theory

Generally, a simple approach to discussing the electrical phenomena of the earth is to consider the earth as an isotropic homogeneous medium. With this assumption, the electric field from a point source in the earth is spherical symmetry [1]. Figure 1 shows the distribution of currents on the earth as a homogeneous medium.

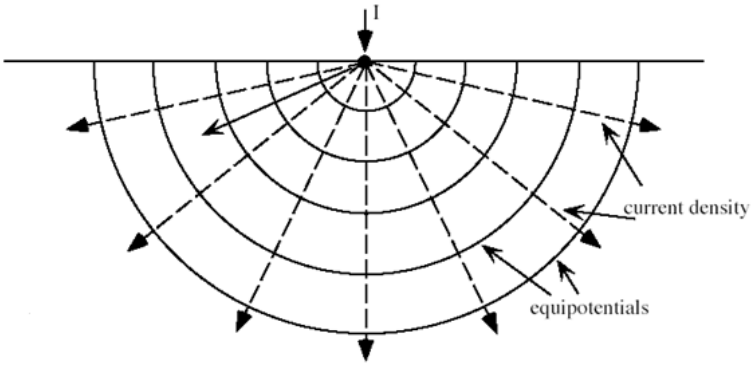

Figure 1 Current Distribution on Earth as a Homogeneous Medium

If the earth is energized by direct current I (given an electric field E), then the current element I through the element area A, with the current density $\boldsymbol{J}$ is

$$dI = \boldsymbol{J} \cdot d\boldsymbol{A} \quad (1)$$

The relationship between current density and electric field intensity is expressed by Ohm's law as follows:

$$\boldsymbol{J} = \sigma \boldsymbol{E} \quad (2)$$

$$\boldsymbol{J} = \frac{I}{A} \quad (3)$$

$$\boldsymbol{E} = \frac{V}{L} \quad (4)$$

Where :
$\boldsymbol{J}$ is the current density
σ is conductivity
E is the electric field intensity

The value of the resistivity of a homogeneous medium can be obtained from the substitution of equations (1) to (4), because the resistivity value is inversely proportional to the conductivity value so that it is obtained:

$$\rho = \frac{1}{\sigma} = R\frac{A}{L} \quad (5)$$

where :
ρ is the resistivity of the material (ohm-meter)
L is the length (meters)
R is the measured resistance (ohms)
A is the cross-sectional area (meter2)

because R = $\frac{V}{I}$, then the equation is obtained:

$$\rho = \frac{V}{I} \cdot \frac{A}{L} \quad (6)$$

where :
V is the electric potential (volts)
I is the current flowing in the material (amperes)

Currents on the earth's surface flow in all directions and make the surface like a sphere with an area of 4πr2. Air that has a very large resistivity (~) causes current to not flow in the air. When viewed from the surface of the earth, the distribution of current flowing in the earth is in the form of a hemisphere with a radius of r, thus equation (6) can be:

$$\rho = \frac{V}{I} \cdot \frac{\frac{1}{2}4\pi r^2}{r}$$
$$\rho = \frac{V}{I} 2\pi r \quad \text{or} \quad V = \frac{I\rho}{2\pi r} \qquad (7)$$

The measurement of the resistivity value of the earth material using the geoelectrical method in practice uses four electrodes, namely two current electrodes and two potential electrodes, as shown in Figure 2.

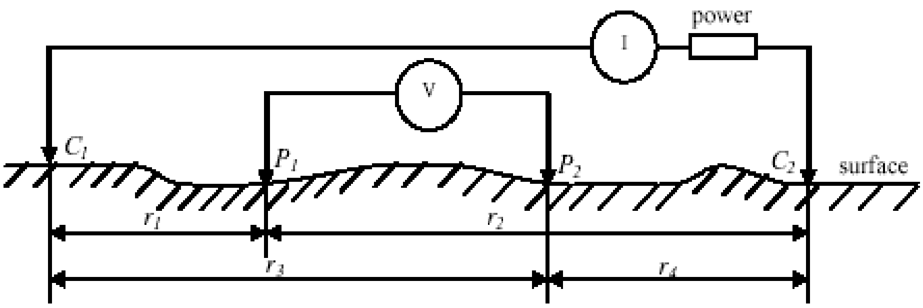

Figure 2. Electrode Arrangement in Geoelectrical Practice with Spesific Resistance [1]

Based on Figure 2, the distances between the electrodes can be explained as follows:

r1 is the distance between the current electrode C1 to the potential electrode P1
r2 is the distance between the current electrode C2 to the potential electrode P1
r3 is the distance between the current electrode C1 to the potential electrode P2
r4 is the distance between the current electrode C2 to the potential electrode P2

The electric potential generated by both current sources C1 and C2 is the potential difference measured at two potential measurement points (P1 and P2). The measured potential difference between the two potential electrodes P1 and P2 is:

$$V(P_1) = \left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$
$$V(P_2) = \left(\frac{1}{r_3} - \frac{1}{r_4}\right),$$
$$\Delta V = V(P_1) - V(P_2) = \frac{I\rho}{2\pi}\left[\left(\frac{1}{r_1} - \frac{1}{r_2}\right) - \left(\frac{1}{r_3} - \frac{1}{r_4}\right)\right] \qquad (8)$$

with $$K = 2\pi\left[\left(\frac{1}{r_1} - \frac{1}{r_2}\right) - \left(\frac{1}{r_3} - \frac{1}{r_4}\right)\right]^{-1} \qquad (9)$$

K is geometric factor of electrode arrangement used.

$$\Delta V = \frac{\rho I}{K} \qquad (10)$$

So that the equation (7) can be changed to:

$$\rho = K\,\frac{\Delta V}{I} \qquad (11)$$

The geometry factor K, is an important element in geoelectrical estimation, both vertical and horizontal estimates, because the geometry factor will remain for fixed positions of AB and MN.

The measurement of specific resistance is related to various depths depending on the distance between the current and potential electrodes in the investigation of earth materials. The greater the electrode distance, the deeper the earth material that can be detected [2].

4. Apparent Resistivity of Rocks

The basic assumption of the geoelectrical resistivity method is that the earth is an isotropic homogeneous medium that provides the same resistance value for the same electrode arrangement [3]. But in reality, the earth consists of layers with different resistivity values. The measured stress is the influence of these layers. The resistivity measured in the experiment is the apparent value (apparent) of various rocks, this resistivity is called apparent resistivity. The apparent resistivity is the resistivity of a homogeneous fictitious medium which is equivalent to the layered medium which is considered for one layer only, so that the measured resistivity value is as if it were the resistivity value for one layer only.

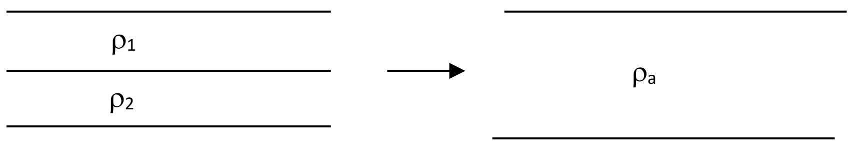

Figure 3 Concept of Apparent Resistivity in Coated Medium [3]

Figure 3 shows the concept of apparent resistivity by assuming the layered medium consists of 2 layers having different resistivities (ρ1 and ρ2). This medium is considered as a homogeneous one-layer medium which has one resistivity value, namely apparent resistivityρa in the measurement. Based on the above understanding, equation (11) can be written as:

$$\rho_a = K\frac{\Delta V}{I} \quad (12)$$

where a is the apparent resistivity. Analysis of the apparent resistivity data will produce the actual resistivity value of the earth material.

5. Method

5.1. Data Acquisition

The geoelectrical resistivity method has several measurement techniques related to the purpose of the measurement. These techniques include sounding, profiling, and offset sounding in previous research [4][5][6]. The measurement using the sounding method aims to obtain information on the conductivity of the medium in the vertical direction (layered earth model). Measurement with this model assumes that the medium has laterally homogeneous properties, thus the modeling at the time of interpretation is adjusted to these assumptions [7][8]. The array that gives the best results for this measurement method is the Wenner-Schlumberger array.

The measurement line consists of 4 lines. Lines 1, 2, and 3 are parallel lines, while line 4 is line 1, 2, and 3. The design of the trajectory as shown in Figure 4.

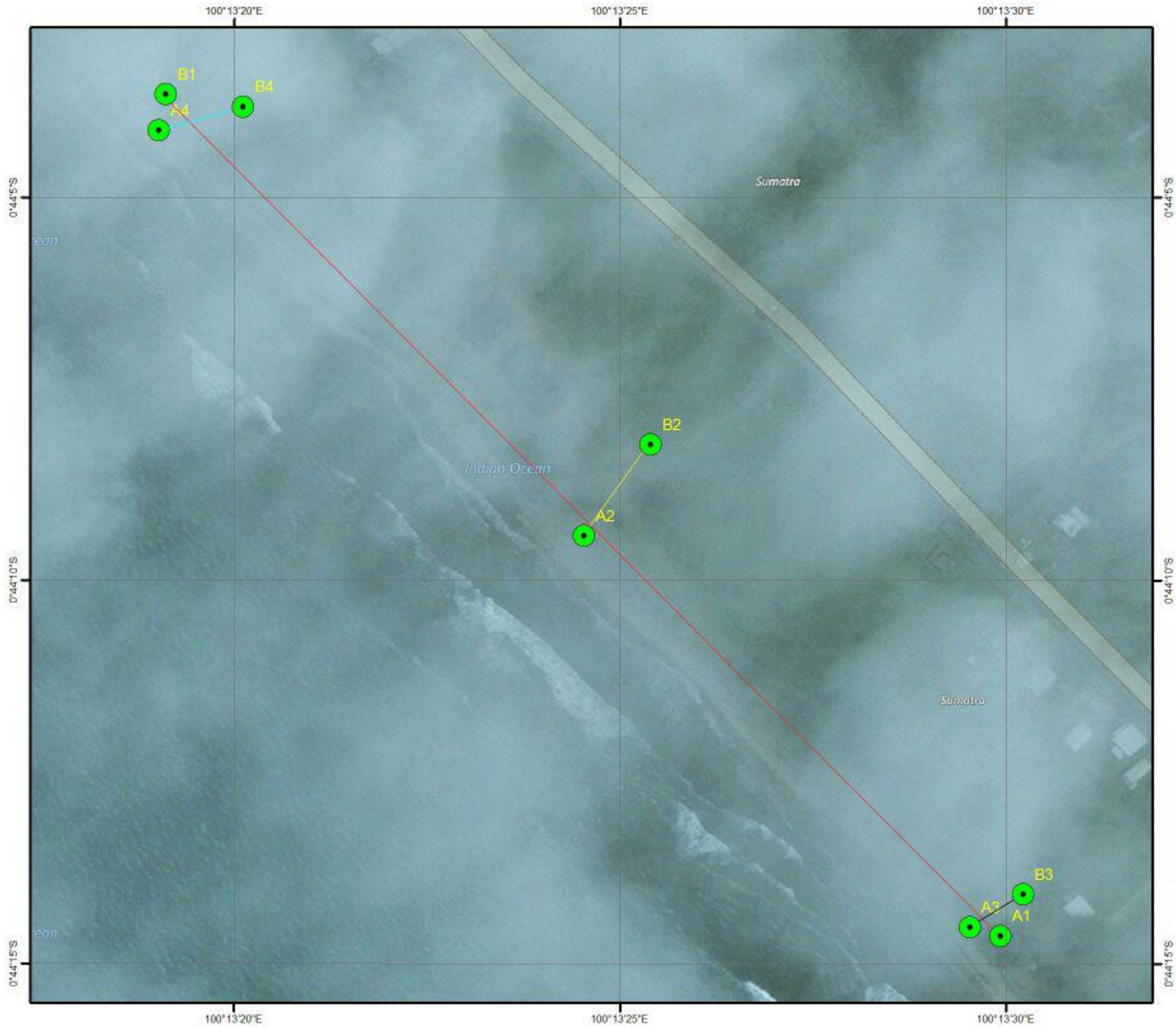

Figure 4. Lines design

Before taking measurements, the following are prepared:

- Designing a Wenner array electrode spacing is possible. This is done by looking at the geographical conditions of the research area.
- Prepare the electrodes with the same distance.
- Check the current source (battery)
- Connect all cables, be it from the resistivity device to the current source or from the resistivity device to the electrodes.
- Activate the resistivity meter
- Calibrating the resistivity meter

5.2. Data processing

The acquisition activity produces several parameters which are then processed using the Res2Dinv software. The parameters obtained are: electrode spacing, distance between pairs of electrodes, voltage (V), and current (I). After the data is obtained, the next step is to:

- Determine the value of the geometric factor (K) of the relationship between the spacing and distance between pairs of electrodes.

- Determining the value ρa (rho apparent) based on the existing formula.
- Then scatter ρa (rho apparent) is plotted to form a pseudosection using the Res2Dinv software.
- Perform the inversion of the value of ρa (rho apparent) to determine the distribution of resistivity values below the surface using the Res2Dinv software.

6. Results and Discussion

6.1 Line 1

The cross-section of the 2D resistivity model of line 1, the length of the path is 47 m with the smallest spacing of 1 m, the amount of data is 450, using the Smoothness-Constraint Least Squares inversion can be seen in Figure 5 below:

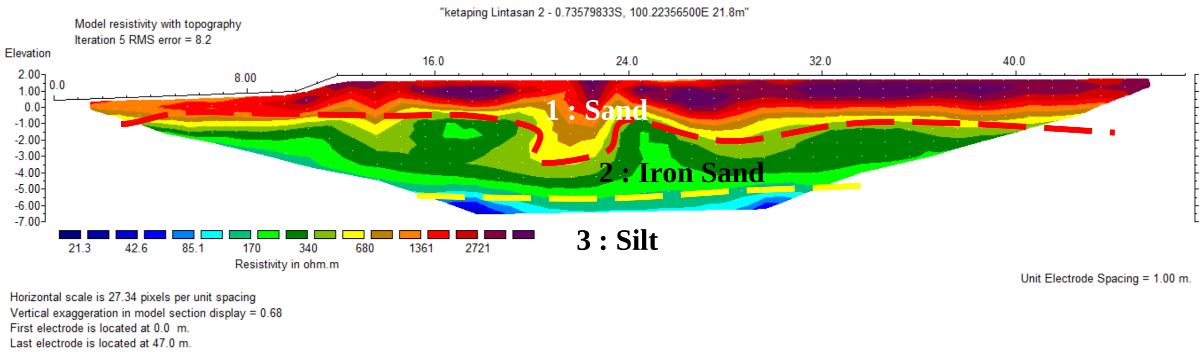

Figure 5. Cross-section of 2D Resistivity Line 1

Figure 3 shows a cross-section of the 2D resistivity line 1. The maximum depth that can be detected is 7 m. The distribution of resistivity values ranged from 21,3 to 2721 Ωm. Layers of light green to dark green are interpreted as layers of iron sand with a resistivity range of 170 Ωm – 580 Ωm. Iron sand layer is found at depth of 2 m below surface with average thickness is 2-4 m. The first layer of this line assumed dominantly as sand where its thickness is about 2-3 m. As shown in the picture, this area contains sand as the most visible material. Also there is no outcrop of iron sand seen in the location. As for the third layer assumed as fine grain sand mixed with water, so it defined as silt because it has lower resistivity than the 2 layers above.

6.2. Line 2

The cross-section of the 2D resistivity model of line 2, the line length is 47 m with the smallest spacing of 1 m, the amount of data is 450, using the Smoothness-Constraint Least Squares inversion can be seen in Figure 6 below:

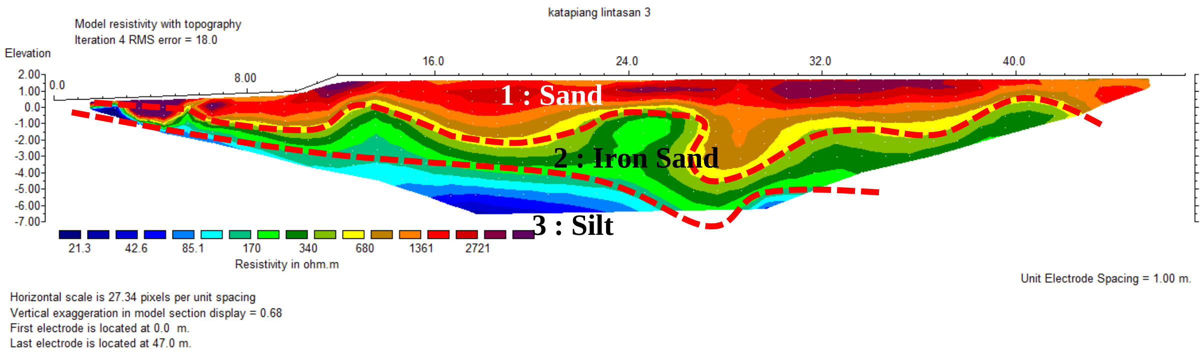

Figure 6. Cross-section of 2D Resistivity Line 2

Figure 6 shows the maximum depth that can be detected is 7 m. The distribution of resistivity values ranged from 21,3 to 2721 Ωm. Layers of light green to dark green are interpreted as layers of iron sand with a resistivity range of 170 Ωm – 580 Ωm. Sand layer with resistivity range is 580 to 2721 that shown in the picture with yellow to purple has thickness more than 2 layers below it. The thickness is ±3-3,5 m. The iron sand layer found here is a bit wavey , acoording to the formation process in the picture. The depth of iron sand is found 1,5-4 m with thickness is about 1-2 m. While for the third layer, has outcrops that can be seen in around the 1st to 2nd electrode with diagonal formation that is thicker to the right. This layer ranges from 21,3 to 170 Ωm for the resistivity value.

6.3. Line 3

The cross-section of the 2D resistivity model of line 3, the line length is 47 m with the smallest spacing of 1 m, the number of data is 450, using the Smoothness-Constraint Least Squares inversion as shown in Figure 7 below:

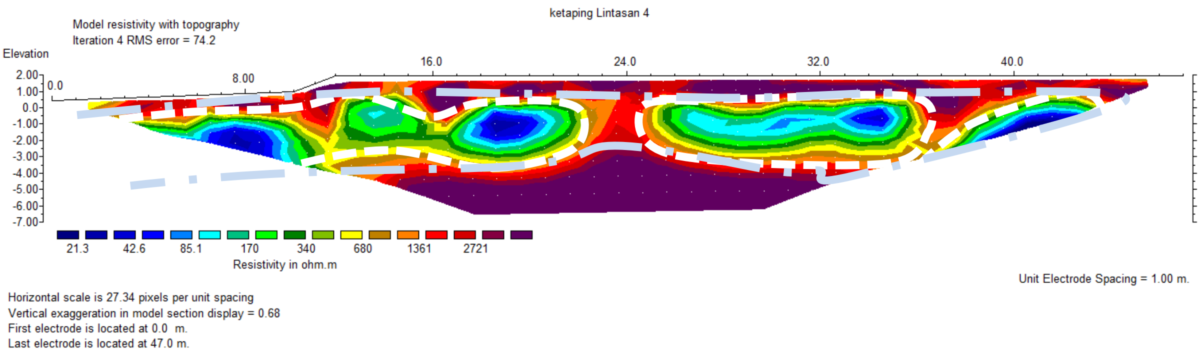

Figure 7. Cross-section of 2D Resistivity Line 3

Figure 7 shows a cross-section of the 2D resistivity model with the maximum depth that can be detected is 7 m. The distribution of resistivity values ranges from 21,3 to 2721 Ωm. Layers of light green to dark green are interpreted as layers of iron sand with a resistivity range of 170 Ωm – 580 Ωm. In this line, the shape of iron sand deposits do not seem as layers, but it has circular form. But if we combine this blue layer with green layer, this deposit could create layers. And it seems that this layer is cutted maybe as the impact of fault or joint (shown by blue line). There is also found that the first layer is the base material, with high amount of this material found in this area.

6.4. Line 4

The length of the line is 470 m with the smallest spacing of 10 m, the amount of data is 576, using the Smoothness-Constraint Least Squares inversion can be seen in Figure 8 below:

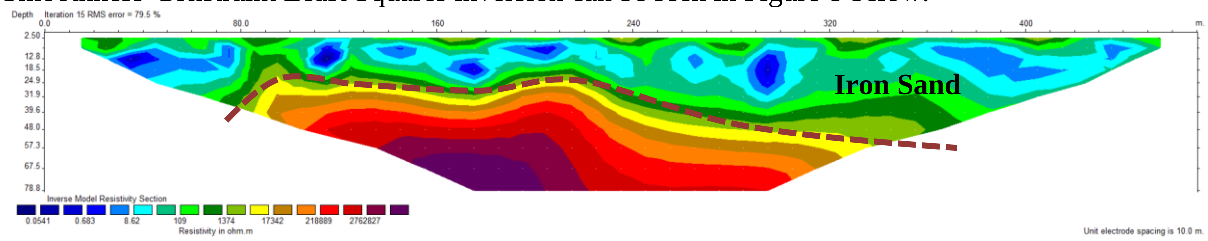

Figure 8. Cross-section of 2D Resistivity Line 4

Figure 8 shows a cross-section of the 2D resistivity with maximum depth that can be detected is 78.6 m. The distribution of resistivity values ranged from 0.0541 to 2762827 Ωm. Layers of light green to dark green are interpreted as layers of iron sand with a resistivity range of 52 – 1400 Ωm. In line 4, iron sand layer lays in the first layer above sand. With thickness is almost 40 m below surface. This layer also associates with silt material that the shape is mostly circular. Sand layer is at 40 – 78.6 m below surface with resistivity value ranges from 1400 - 2762827 Ωm, so the thickness is almost 40 m below surface. This very high resistivity range happens because that area contains mostly gravels while sand as the filling material.

7. Conclusions

Based on the results of geoelectrical measurements with the Wenner-Schlumberger array in the research area, it can be concluded that the distribution of iron sand in Ketaping Nagari, Batang Anai District, Padang Pariaman Regency can be found along the coast of the study area at a depth of 0.7 m - 3 m in short line and 40 m in long line with resistivity values ranging from 52 - 289 Ωm.

Acknowledgments

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