# Volume Estimation Using Resistivity Tomography Method In Bakauheni, South Lampung

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***Abstract***

*Lampung is an area that has various natural resources, one of which is andesite rock. National economic growth and incessant infrastructure development have resulted in an increased need for building materials, including Andesite. Andesite rocks are widely used for the formation of building foundations, making bridges, and paving roads. In this study, the volume of andesite rocks was calculated using the resistivity tomography method in the Bakauheni area of South Lampung in Pegantungan, Bakauheni District, South Lampung Regency, Lampung Province. which consists of 5 lines with a spacing between electrodes of 5 meters, with a span length of about 315 meters. The apparent resistivity data obtained are processed into a two-dimensional model through linear inversion using RES2DINV software. The two-dimensional model was then interpolated using the Rockworks 15 tool to become a three-dimensional model. Based on the 2D cross-section model, the high resistivity values varied. identified as andesite rock, which is imaged in red to purple colour, and volumetric andesite rock based on 3D interpolation for an area of ± 15.20 Ha is 3,411,066.876 m$^3$.*

***Keywords:*** *Volume, resistivity, tomography, bakauheni.*

## I. INTRODUCTION

Andesite rock is an intermediate rock that occurs as a result of magma cooling on the earth's surface or volcanic activity [1]. As a result of temperature differences during cooling, andesite rocks generally consist of solid, porous rocks. A geophysical survey is an initial survey that aims to map subsurface geology and is the first step to determine the rock layers below the ground surface. One of the methods in geophysical surveys is geoelectric. The geoelectric method is also a method for determining the nature of the earth's electric current by detecting it on the earth's surface. The measurement procedure for each configuration depends on the variation of resistivity with depth, namely in the vertical direction (sounding) and horizontal direction (mapping). The presence of andesite rock in Bakauheni District is found in several locations in hilly areas, outcrops formed due to erosion by water flows and rock patterns resulting from melted lava [2].

This research was conducted in the Bakauheni District, South Lampung Regency, Lampung Province. The geophysical method used in this research is the resistivity method with the Wenner-Schlumberger configuration, this method was chosen because it has accurate voltage readings at the electrodes, the distance between current and potential electrodes still provides ideal calculated values. This is because the position between the current electrode and the potential electrode are close together, apart from that the resistivity method was chosen because the costs are cheaper, the measurement process is faster and the data processing process is easier compared to other geophysical methods [3].

This research was carried out with the aim of identifying andesite rocks in the field in prospect areas for their resistivity values, analyzing the depth and distribution of andesite rocks through 2D resistivity cross-sections, and looking for volumetric andesite rocks in the research area based on 3D interpolation.

The research area is administratively located in Bakahueni Village, District. Bakahueni District. South Lampung, Lampung Province. The coastal area of Bakauheni Village is the coastline of the high seas of the Sunda Strait, Bakauheni Village. Geographically, it is located at 5°52'58.13" South Latitude and 105°44'36.75" East Longitude with the northern border of Hatta Village, Kec. Bakauheni and Sidoluhur Village, District. Ketapang, east of Sumur Village, Kec. Ketapang is south of the Sunda Strait and west of Kelawi Village, Kec. Bakauheni.

Geologically, the Pegantian area is in the Andesite Formation (Tpv) with andesite lava as its constituent material. This formation is interbedded with the Lampung Formation (QTi), with the constituent materials: tuff, rhyolite tuff, tuff mudstone and tufface sandstone [4]. The Andesite Formation (Tpv) is interpreted as a series of processes related to the formation of Mount Raja Basa. During the Tertiary period, magmatic rise produced melt to the south and east of Mount Raja Basa. During the Quaternary period, the Tpv Formation, in some parts, is covered by the Lampung Formation and the Young Volcano Formation (Qhv) from the activity of Mount Rajabasa [5].

## II. MATERIALS AND METHODS

This research was carried out in Bakauheni District, Lampung Regency. The geophysical method used in this research is the resistivity method with the Wenner-Schlumberger configuration. This method was chosen because it has accurate voltage readings at the electrodes, and the distance between current and potential electrodes still provides ideal calculated values. Rocks with varying compositions will produce varying resistivity value ranges due to different types of soil and rock (Table 1) [6].

Table 1. Range of resistivity values for rock types [6]

| Material | Resistivity (Ωm) |
|---|---|
| *Sea water* | 0.2 |
| *Groundwater* | 0.5 – 300 |
| *Alluvium* | 10 – 800 |
| *Andesite* | $1.7x10^2 – 45x10^4$ |
| *Basalt* | 200 – 100000 |
| *Sandstone* | 10 – 8000 |
| *Breccia* | 75 – 200 |
| *Limestone* | 50 – 1000 |
| *Granite* | 200 – 100000 |
| *Calcite* | $1x10^{12} – 1x10^3$ |
| *Gravel* | 100 – 600 |
| *Conglomerate* | $2x10^3$ - $10^4$ |
| *Quartz* | 500 – 800000 |
| Lava | 100 – $5x10^4$ |
| *Clay* | 1 – 100 |
| *Marl* | 3 – 70 |
| *Sand* | 1 – 1000 |
| *Pyrite* | 0.01 – 100 |
| *Shale* | 20 – 2000 |
| *Tuff* | 20 – 100 |

In detail, the stages of this research consist of two stages, namely:

### A. *2D & 3D resistivity data processing*

Based on the resistivity data, which has been converted into ".dat" or ".txt" format, the next step is to QC the data using Ms. Excel, was then adjust it to the data input format for the Res2Dinv software [7]. After that, inversion modeling was carried out using the least-squares inversion feature, and 2D data appeared, then a topography display was carried out to project surface heights in the research area. After that, the 2D resistivity data that have been inverted are then selected for 3D modeling. In this research, the author selects the data for each measurement line, which will then be processed using 3D geophysics software.

### B. *Interpretation of the potential distribution of andesite in the research area*

After successful data processing, the next stage is to interpret the potential distribution of andesite in the measurement area where data acquisition was carried out. This interpretation is based on regional geological data depicted from 2D projections. The rocks that make up the subsurface layer can be obtained from the results of 2D geoelectrical resistivity processing supported by regional geology, morphology, and rock resistivity tables. Each material has its electrical conductivity characteristics, and rock is a material that also has a certain electrical conductivity and resistance value. Different rocks can have the same resistivity value; this happens because the resistivity values of the rocks have a range of values that can overlap.

## III. RESULTS AND DISCUSSIONS

### A. *Resistivity Tomography*

The measurement data is in the form of a .dat file, which has been transferred from the tool and then processed using the Excel program to see the track name, apparent resistivity, number of datum points, and so on. After that, topographic data and measurement coordinates were obtained with GPS (Global Positioning System). The first stage in geoelectrical resistivity processing is entering resistivity data and also topographic data, which has been compiled into the software in .dat format. After entering the data, the first stage of the modeling process is carried out to see how small the error is obtained from the data. The results obtained from the input data are a pseudo-section model as in Figure 1.

After determining the size of the error, we carry out several stages of correction to reduce it. The first stage is to remove data that are considered inappropriate (bad data points). This occurs when there is a measurement error that causes the data obtained to be less than good.

After these stages, 2D modeling is carried out by clicking display sections, then selecting include topography in model display, and selecting choose iteration number. Select the defined logarithmic contour interval to determine the range of resistivity values on the contour. If the error obtained is not satisfactory, data interpolation can be carried out. The 2D cross-section and topography can be seen in Figure 2.

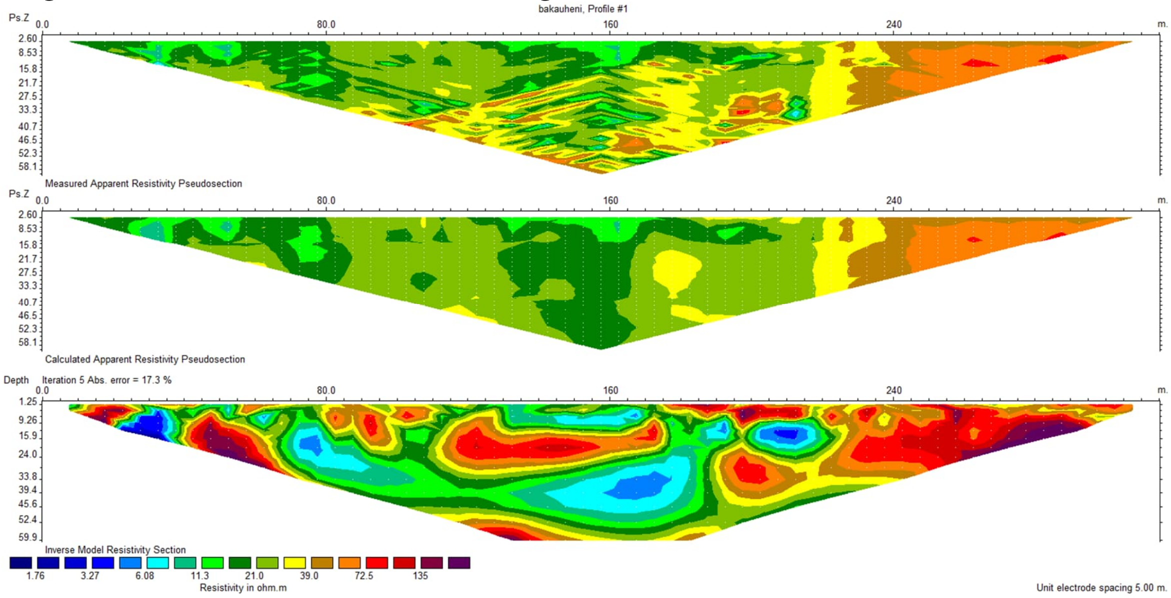


Figure 1. Pseudo-section

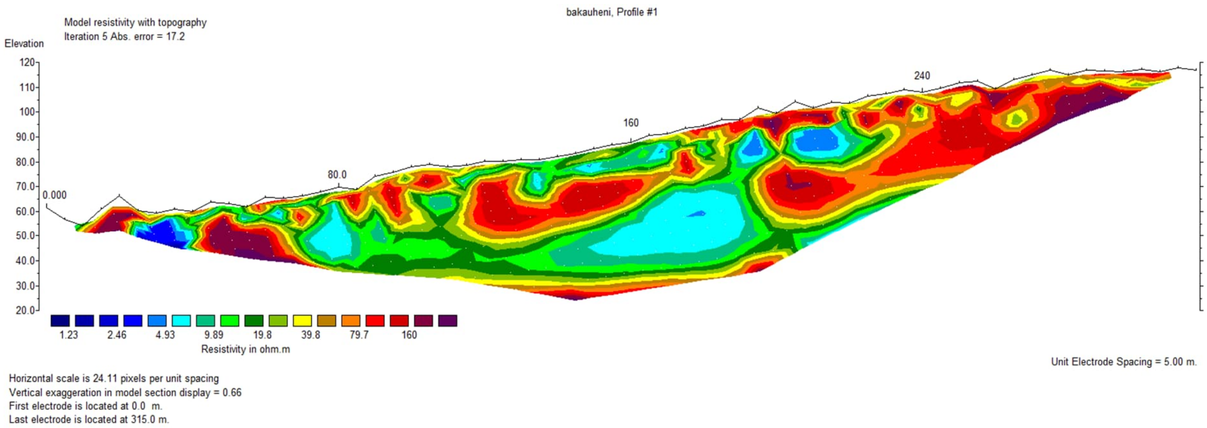


Figure 2. 2D cross-section and topography.

### *B. 3D Data Processing*

The results of 2D inversion data in .inv format obtained in the 2D processing process produce the location of the datum point (x, y), layer depth (depth), and resistivity.

Then the data is combined into 5 trajectories and arranged in .dat (x, y, z, resistivity) format for 3D interpolation processing in the software. 3D interpolation is carried out to interpolate or extrapolate resistivity values over a certain distance range between measurement paths. This process is carried out to estimate the resistivity value at a measurement location in 3D, so that it can estimate the volume of certain rocks that are the measurement target.

The next stage is to import data that has been arranged with parameters x, y, z, and resistivity into geophysical software. Then, the 3D data that has been interpolated using 3D Gridding data will be modelled, as can be seen in Figure 3. This process is carried out to model the resistivity data according to the coordinates and depth of the data points that have been obtained. What can be seen in the picture is the result of 3D resistivity modeling.

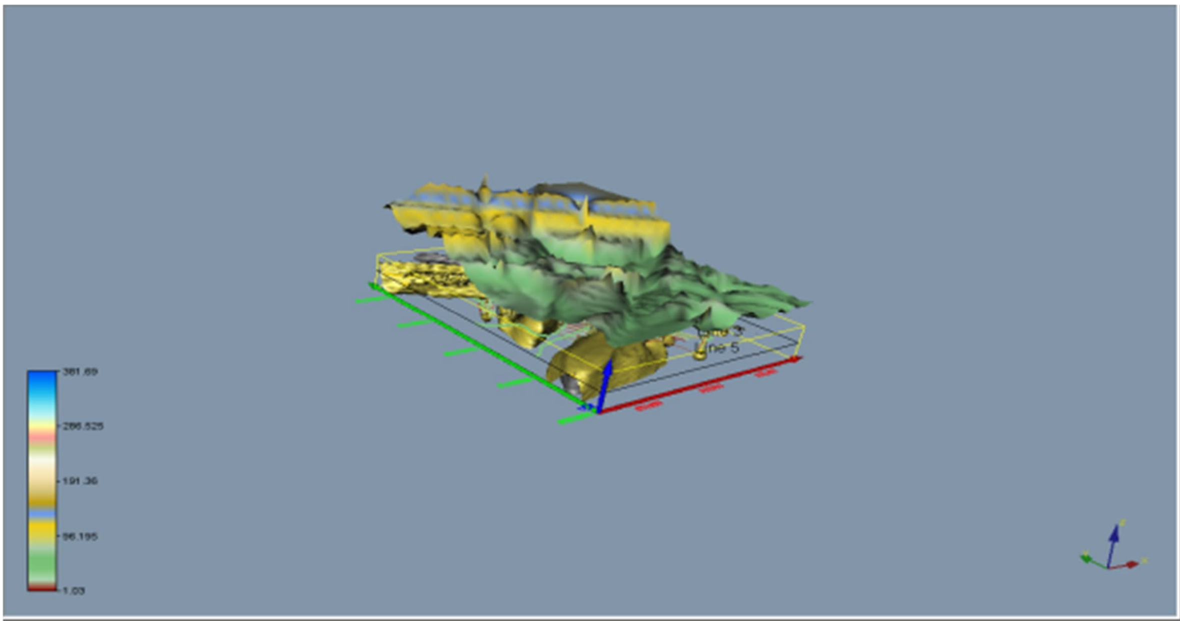


Figure 3. 3D database gridding process.

### C. *Discussion*

Geoelectric resistivity is the geophysical method used to identify the distribution of subsurface rocks. By using this type of resistivity geoelectricity, 2D cross-sections, and 3D reconstruction, models will be obtained, which show the distribution of rock resistivity. So the results can describe the research area based on the electrical properties of the rocks below the surface. The data obtained will be linked to geological information and direct observations in the research area for the interpretation stage. Because rock resistivity values only provide physical information from geoelectric methods.

Data from field measurements is in the form of a data file, and the data is then inverted using Res2Dinv software to obtain a 2D cross-section. The 2D cross-section resulting from the inversion provides information regarding the distribution of resistivity values of the rock below the surface at each measurement path. The results of the interpretation of the Wenner-Schlumberger configuration were obtained by changing the iteration several times until an interpretation was obtained that was close to the actual field conditions, and the data resulting from the inversion of the resistivity value data had an error value. The error value produced from the processed data can be caused by natural conditions or the existence of extreme values in the data, caused by reading errors.

Line 1 shows that low resistivity values have resistivity values ranging from 1.2 Ωm to 4.9 Ωm, interpreted in dark blue to light blue. Medium resistivity values have resistivity values between 9.9 Ωm to 39.8 Ωm, interpreted as light green to brown. Meanwhile, the resistivity value is high, with a resistivity value between 79.7 Ωm to >160 Ωm, interpreted as a reddish brown to purple color, which can be seen in Figure 4.

Based on the results of 2D modeling, the subsurface layer was obtained with a stretch of around 315 m (electrode spacing 5 m) with a depth of approximately 50 m. The results of the 2D resistivity cross-section on path 1 using 5 iterations obtained an RSM error of 17.2%.

Trajectory 1 looks for a target in the form of andesite rock which at a distance of 230 m to 315 m on the measurement track (on the left of the model) at a depth of around 5 m to >30 m forms large boulders (boulders) and several small boulders along the trajectory and layers. thinly spread over the surface. High resistivity values (reddish brown to purple) are predicted to be andesite rock lithology. From an economic perspective, route 1 is a fairly suitable area (medium recommended) for the andesite rock exploitation process.

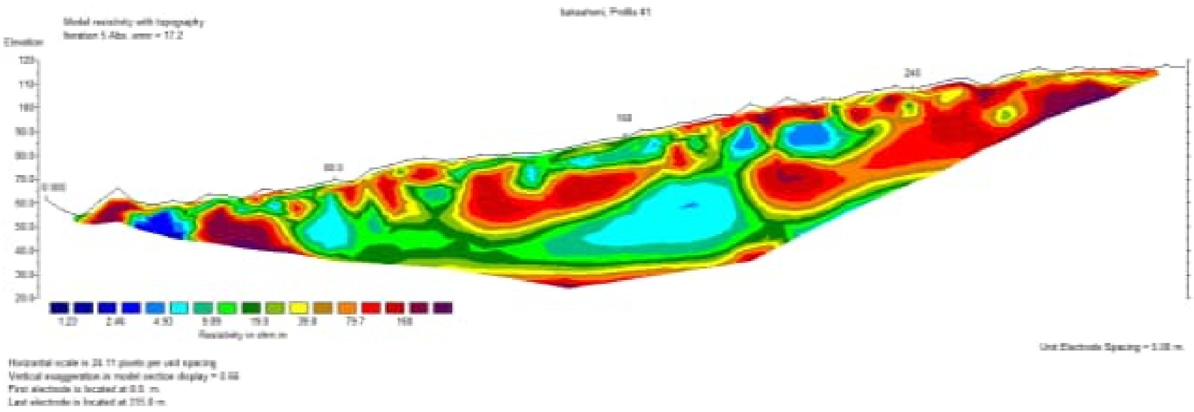

Figure 4. Subsurface imaging on line 1.

Line 2 shows that low resistivity values have resistivity values ranging from 1.8 Ωm to 6.6 Ωm, interpreted in dark blue to light blue. Medium resistivity values have resistivity values between 12.5 Ωm to 46 Ωm, interpreted as light green to brown. Meanwhile, the resistivity value is high, with a resistivity value between 88.1 Ωm to >169 Ωm, interpreted as a reddish brown to purple color, which can be seen in Figure 5.

Based on the results of 2D modeling, it was obtained that the subsurface layer had a stretch of around 315 m (electrode spacing 5 m) with a depth of approximately 50 m. The results of the 2D resistivity section on path 2, using 5 iterations, obtained an RSM error of 19.9%.

Trajectory 2 looks for targets in the form of andesite rock, which at a distance of 160 m to 230 m and 240 m to 315 m on the measurement track (on the left of the model), at varying depths of around 5 m to 30 m, takes the form of boulders and cones. (suspected to be the result of intrusion or rock breakthrough) and several small boulders along the track and thin layers on the surface were scattered. High resistivity values (reddish brown to purple) are predicted to be andesite rock lithology. The andesite rocks in route 2 are in the form of chunks, which are spread quite widely along the route. If seen from an economic perspective for the exploitation process, route 1 is a good and feasible area (highly recommended) for the andesite rock exploitation process.

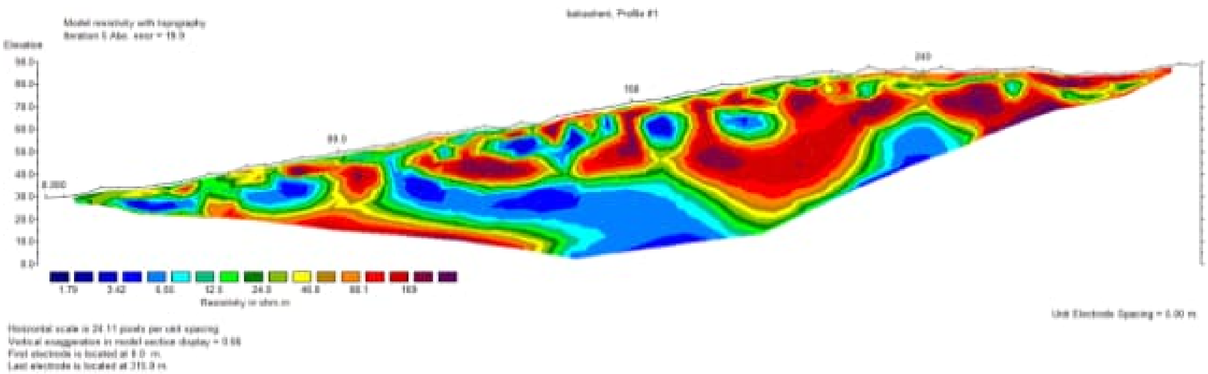

Figure 5. Subsurface imaging on line 2.

Line 3 shows that low resistivity values have resistivity values ranging from 2.4 Ωm to 11.3 Ωm, interpreted in dark blue to light blue. Medium resistivity values have resistivity values between 17.1 Ωm to 63.4 Ωm, interpreted as light green to brown. Meanwhile, the resistivity value is high, with a resistivity value between 63.4 Ωm to >235 Ωm, interpreted as a reddish brown to purple color, which can be seen in Figure 6.

Based on the results of 2D modeling, the subsurface layer was obtained with a stretch of around 315 m (electrode spacing 5 m) with a depth of approximately 50 m. The results of the 2D resistivity cross section on path 3, using 5 iterations, obtained an RSM error of 25.0%.

Trajectory 3 is looking for targets in the form of andesite rocks which at a distance of 70 m to 150 m and 250 m to 280 m in the measurement track (on the left of the model) at varying depths of around 10 m to 30 m are in the form of large boulders (boulders) and some are shaped cones (suspected to be the result of intrusion or rock breakthrough) and several small boulders along the scattered track. High resistivity values (reddish brown to purple) are predicted to be andesite rock lithology. The andesite rocks in route 3 are in the form of chunks, which are spread quite widely along the route. If viewed from an economic perspective for the exploitation process, route 1 is a fairly suitable area (medium recommended) for the andesite rock exploitation process.

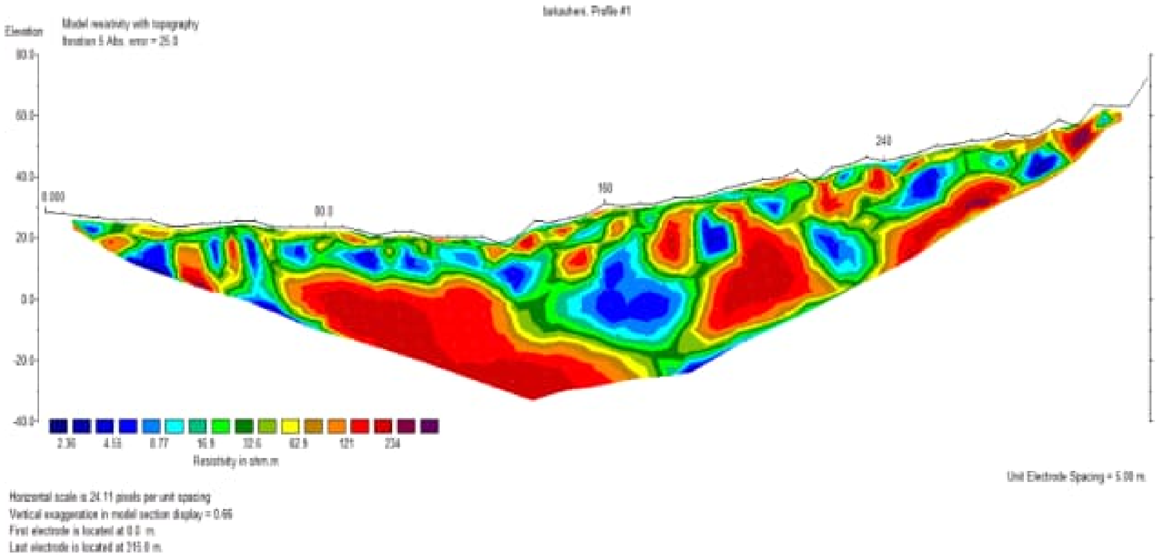


Figure 6. Subsurface imaging on line 3.

Line 4 shows that low resistivity values have resistivity values ranging from 1.6 Ωm to 5.6 Ωm, interpreted in dark blue to light blue. Medium resistivity values have resistivity values between 10.6 Ωm to 38.2 Ωm, interpreted as light green to brown. Meanwhile, the resistivity value is high, with a resistivity value between 72.4 Ωm to >137 Ωm, interpreted as a reddish brown to purple color, which can be seen in Figure 7.

Based on the results of 2D modeling, the subsurface layer had a stretch of around 315 m (electrode spacing 5 m) and a depth of approximately 50 m. The results of the 2D resistivity cross-section on path 4 using 5 iterations obtained an RSM error of 18.3%.

Line 4 looks for targets in the form of andesite rock at a distance of 95 m to 150 m and 225 m to 295 m in the measurement track (in the middle and left of the model) at varying depths of around 10 m to >50 m takes the form of large boulders (boulders). and some are cone-shaped (thought to be the result of intrusion or breakthrough of extrusive rock), and some are small boulders along scattered tracks. High resistivity values (reddish brown to purple) are predicted to be andesite rock lithology. The andesite rock on track 4 is in the form of chunks, which are spread quite widely along the track. If seen from an economic perspective for the exploitation process, track 1 is a good and feasible area (highly recommended) for the andesite rock exploitation process.

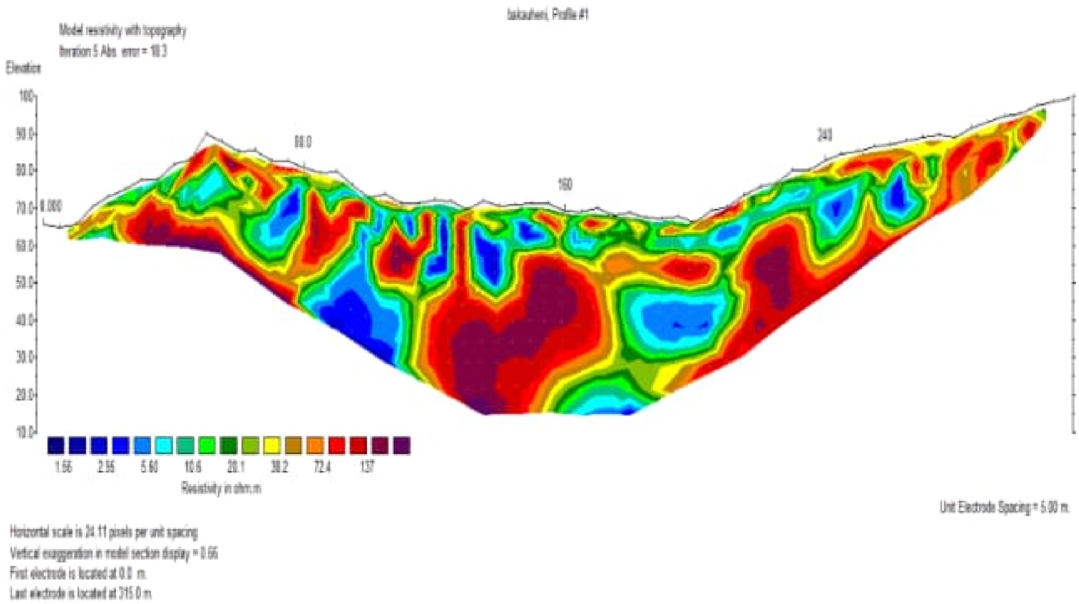


Figure 7. Subsurface imaging on line 4.

Line 5 shows that low resistivity values have resistivity values ranging from 1.8 Ωm to 6.1 Ωm, interpreted in dark blue to light blue. Medium resistivity values have resistivity values between 11.4 Ωm to 39.3 Ωm, interpreted as light green to brown. Meanwhile, high resistivity values with resistivity values between 73 Ωm to >136 Ωm, interpreted as reddish brown to purple, can be seen in Figure 13.

Based on the results of 2D modeling, it was obtained that the subsurface layer had a stretch of around 275 m (electrode spacing 5 m) with a depth of approximately 50 m. The results of the 2D resistivity cross-section on path 4 using 5 iterations obtained an RSM error of 8.7%.

Trajectory 5 looks for targets in the form of andesite rock at a distance of 5 m to 130 m and 245 m to 295 m on the measurement track (in the right and middle parts of the model) at varying depths of around 0 m to >50 m takes the form of large boulders (boulders). and some are cone-shaped (thought to be the result of intrusion or breakthrough of extrusive rock), and some are small boulders along scattered tracks. High resistivity values (reddish brown to purple) are predicted to be andesite rock lithology. The andesite rock on route 5 is in the form of chunks which are widely spread along the route. If viewed from an economic perspective for the exploitation process, route 1 is a good and feasible area (highly recommended) for the andesite rock exploitation process.

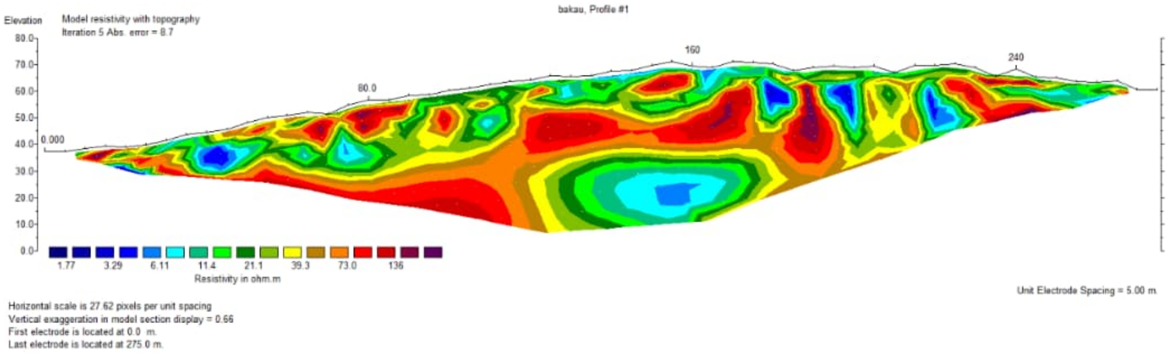


Figure 8. Subsurface imaging on line 5

Based on the interpretation results of the 2D resistivity cross-section, 3D geoelectric reconstruction modeling of the andesite rock resistivity was carried out. This 3D reconstruction modeling aims to determine the distribution pattern of andesite and volumetric rocks in m3 units by inputting the x, y, and z values and the actual resistivity value in the 2D cross-section.

3D resistivity data is reconstructed by combining all 2D resistivity data. Volumetric calculations from 3D Resistivity Imagin data with an area of ± 15.20 Ha from 5 2D geoelectric trajectories. Based on 3D geoelectric reconstruction, the resistivity explains the distribution of andesite rock (an indication of reddish brown to purple-colored rock) that was collected. If volumetric reserves are calculated from 3D geoelectric resistivity data, we get an estimate of the volumetric reserves of andesite minerals, as in Table 2.

Table 2. Estimated volumetric reserves of andesite minerals.

| No. | Category | Resistivity Value | Volume |
|---|---|---|---|
| 1 | Pessimistic | 74 – 200 Ωm | 3.465.292 $m^3$ |
| 2 | Semi Pessimistic | 74 – 125 Ωm | 3.103.045 $m^3$ |
| 3 | Optimistic | 125 – 200 Ωm | 362.247 $m^3$ |
| | | Total Volume | 3.827.239 $m^3$ |
| | | Tonage | 10.716.269 Ton |

Based on the overall calculation in the pessimistic category which has a volume of 3,465,292 m3 and to calculate the economic value we multiply it by the current price which is approximately IDR 300,000 to get a price of IDR 930,913,500,000 and for the optimistic category which has a volume of 362,247 m3 and To calculate the economic value, we multiply it by the current price which is approximately IDR 300,000 to get a price of IDR 108,674,100,000, a depth of around 40m which is known from geoelectrical data and an area of 15.20 Ha.

Figure 9 shows that large volumetric reserves of andesite rock have several colors, where the color describes the resistivity, where the yellow color is >74 to 100 Ωm, which has an estimate of 1,372,125 m3. For blue rocks, the resistivity value is >100 Ωm to 125 Ωm, which is estimated at 1,676,693 m3 and for grey rocks, the resistivity value is >125 Ωm to 160 Ωm, which is estimated at 362,247 m3, and the resistivity > 160 to 200 Ωm, amounting to 416,173 m3. So the overall volumetric reserves of andesite rock from all measurement routes are 3,827,239 m3.

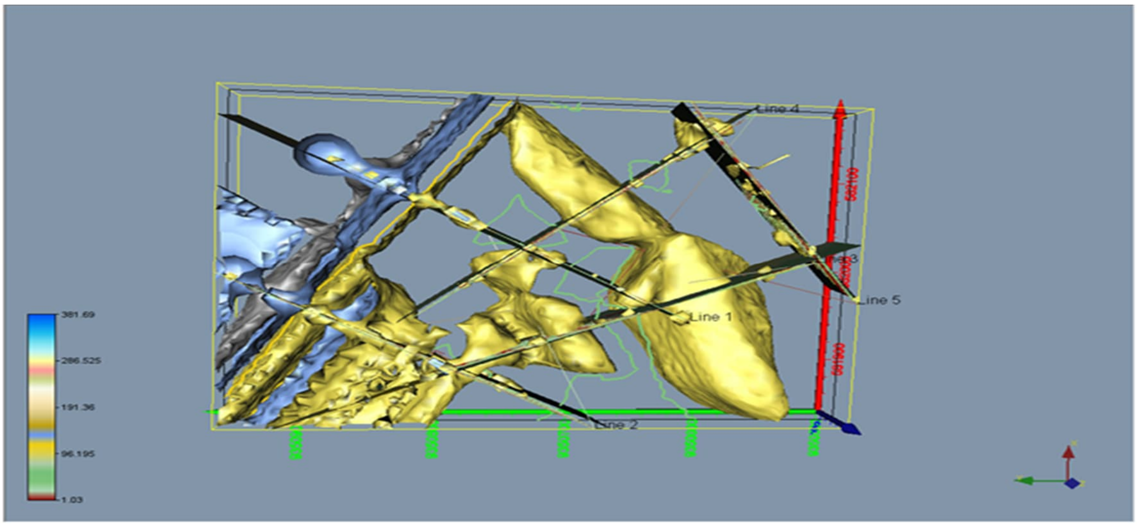


Figure 9. 3D reconstruction of geoelectric resistivity.

## IV. CONCLUSIONS

The rock layer based on 2D Geoelectric cross-sectional modeling of resistivity is thought to be an andesite rock layer, which has a resistivity value of 155-315 Ωm, which is imaged in red to purple. Based on the 2D geoelectrical resistivity model, path A of andesite rock is found at a depth of 0-25 meters with an average thickness of 8 meters, path B of andesite rock is found at a depth of 0-25 with an average thickness of 7 meters, path C of andesite rock is found at a depth of 0-28 meters with an average thickness of 7 meters, track D of andesite rock was found at a depth of 0-25 meters with an average thickness of 8 meters, track E of andesite rock was found at a depth of 0-25 meters with an average thickness of 6 meters. The estimated volumetric reserves of subsurface andesite rock obtained based on interpolation of the 3D geoelectric resistivity model for an area of ± 15.20 Ha is 3,411,066.876 m3.

## V. ACKNOWLEDGMENT

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