Andesite prospect at West Sungkai of North Lampung: Its distribution based on electrical resistivity tomography

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Abstract. Infrastructure construction made andesite’s demand has increased, particularly in Lampung Province. In this research, its distribution in West Sungkai of North Lampung is mapped based on Electrical Resistivity Tomography (ERT) data from 6 lines, each of them was 186 m in length. Due to its excellent vertical resolution, Wenner configuration is performed. The research area is part of Quarter Holocene Volcanic (Qhv) formation. Lajur Barisan members consist of volcanic breccia, lava, and andesite-basalt tuff; thus, resistivity modeling is built within this aisle. Subsurface resistivity model has been created using the non-linear inversion method with promising low error at the third to fifth iterations, which marks an acceptable value. Using 2D and 3D ERT modeling, it is estimated that there are three mains of rocks based on their resistivity value: sandy tuff with 65 – 212 Ω·m; tuff with 212 – 655 Ω·m; and andesite with resistivity more than 655 Ω·m. Andesite within this area is likely lava andesite which spread from the middle to the West and north. It is located at 5 – 35 m in depths with the reserve estimation of andesite is about 1.65 million tons.

1. Introduction

Infrastructure construction made andesite demand has been increased particularly in Lampung Province either in its urban or rural area. Andesite split stone is usually used as a material for concrete making, but its availability in nature is decreasing [1]. Andesite, which contains 62.3% silica (SiO₂), is commonly used because of its outstanding physical features such as density and hardness. Moreover, it has good resistance to water and weather [2]. It is recorded about 2,791,067.50 m³ reserve at North Lampung alone, making it one of the primary producers of andesite [3].

Possessing these abundances, conducting exhaustive research to support safe and extensive exploitation is compulsory. Even though several studies have been carried out within North Lampung, studies in West Sungkai are still limited. The nearest study was done in West Lampung using the geo-electrical method. Andesite is identified as basement rock that has a resistivity greater than 500 Ω·m [4]. The research conducted by Sarkowi et al. [5] has an aligned result with this.

Electrical Resistivity Tomography (ERT) is well known for mapping subsurface lithology due to the resistivity value difference. It is widely used in groundwater exploration [6–8], landslide investigation [9–11], etc. The exploration using the method itself had been performed several times, such as Purwasatariya successfully estimated near-surface and profound andesite abundance utilizing this method with a Schlumberger configuration [12]. The technique with Dipole-dipole configuration also provided...
a good result [13]. Thus, this study identifies andesite distribution using ERT in West Sungkai, North Lampung.

2. Geological Setting
Due to the geological map of Baturaja, the study area is located within Quarter Holocene Volcanic (Qhv) or breccia igneous rock. The formation consists of volcanic rocks at Barisan Line, volcanic breccia, lava, and tuff from Benatan and Punggur hill; Raya, Kukusan, and Seminung mountains. This formation’s age is Quarter, more specific is Pleistocene up to Holocene. A geological map of this research area is given in figure 1(a).

![Geological regional map of the study area](image1)

**Figure 1.** (a) Geographical regional map of the study area (modified from [14]), and (b) Geological time scale [14].
The formation consists of three rock groups: Quarter volcanic rock, Quarter to tertiary pyroclastic rock, and tertiary volcanic rock. Each group is divided into some rock units:

a. Quarter volcanic (Qhv and Qv). Its period is Pleistocene to Holocene, consisting of basaltic andesite and lava breccia with the sandy tuff influx.

b. The pyroclastic rock, which consists of Ranau Tuff (Qtr) and Liwa Tuff from Plio–Pleistocene

c. Tertiary volcanic rock consist of volcanic breccia

Stratigraphically, Quarter volcanic rock (Qv and Qvs) conformably topped the Ranau Tuff (QTr). It is spreading along the study area. Ranau Tuff (QTr) sits unconformably on the top of Bal formation (Tmba) and Hulusimpang, as shown in figure 1(b).

3. Methodology

Administratively, the study area is located in the Sungkai district, North Lampung. As shown in figure 2(a), six survey lines were used, whereas a topographic map showing altitude variation is given in figure 2(b). ERT commonly identifies the rock lithology based on its difference in electrical conductivity, from meters to tens of meters scales in groundwater investigation, and up to kilometers for deep geological structure.

Figure 2. (a) The geometry of the six lines that are used in this study, and (b) Contour map of the study area.
Data used in this study was secondary data provided by PT Lampung Geosains Survei (LGS) consists of six-line with 186 m length with Wenner array, 6 m fixed spacing of electrodes plugged into the ground is used. Various profiling sections are constructed by combining current electrodes (A, B) and potential electrodes (M, N) pairs. Penetration depth is determined by the geometry of cables (array type, electrode spacing, and numbers of electrodes); and measurement of a signal by the equipment such as signal amplitude, ambient noise, and input power [15].

Inversion modeling by RES2DINV is performed based on the smoothness constrained least-squares technique [15]. The 2D model divides the subsurface into several rectangular blocks and inversion parameters that give a minimum error. These parameters are damping factor, convergence limit, vertical to horizontal flatness ratio, and iteration number. The program calculates the apparent resistivity values of the model blocks using either a finite difference or finite element method and compares these to measured data. The model blocks are adjusted until the calculated values agree with the actual measurements. In this research, iteration for each line is varied from three to five to produce a model with a minimum error of less than 6%. Potential difference and current injected were measured for every datum. The processing flow is written in figure 3.

![Processing flow chart](image-url)

Figure 3. Processing flow chart.
4. Results and Discussion

4.1. 2D Data Processing results
The processing result provides lateral and vertical distribution of resistivity value. It could be utilized to estimate subsurface lithology. Based on a previous study, andesite’s resistivity value is higher than 655 Ω·m, represented by orange to violet color in this article. The first-line 2D section is given in figure 4(a). Thin andesite lithology could be seen near the surface in the top of tuff while a thicker, widely spread one appears deeper at 10 – 30 m depth; this dense andesite is the target of this study due to its economic potential. Line 2 and 3 give the same result with Line 1 about near-surface andesite yet thicker andesite is narrower and more profound. Thickening of Sandy Tuff could be observed from Line 2 to Line 3 (figures 4(b)–4(c)). Thicker andesite was also observed at Line 4 to 6 with slightly different depth, as shown in figures 4(d)–4(f). Detail resistivity value of each lithology from every line is given in table 1.

Figure 4. (a) 2D section of Line 1, (b) 2D section of Line 2, (c) 2D section of Line 3, (d) 2D section of Line 4, (e) 2D section of Line 5, and (f) 2D section of Line 6.
Table 1. Subsurface lithology based on resistivity value of Line 1 – 6.

| Line number | Depth (m) | Resistivity (Ω m) | Lithology   |
|-------------|-----------|-------------------|-------------|
| 1           | 1.05 – 7.65 | 212 – 655         | tuff        |
|             | 7.65 – 20   | 65 – 212          | sandy tuff  |
|             | 11 – 30     | >655              | andesite    |
| 2           | 1.05 – 7    | 212 - 655         | tuff        |
|             | 7 – 23.7    | 65 – 212          | sandy tuff  |
|             | 7.65 - 30   | > 655             | andesite    |
| 3           | 1.05 – 9    | 212 - 655         | tuff        |
|             | 9 – 23.7    | 65 – 212          | sandy tuff  |
|             | 14.9 - 32   | >655              | andesite    |
| 4           | 1.05 – 7.65 | 212 - 655         | tuff        |
|             | 7.65 – 19.1 | 65 – 212          | sandy tuff  |
|             | 5-35        | >655              | andesite    |
| 5           | 1.05 – 7.65 | 212 - 655         | tuff        |
|             | 7.65 – 19.1 | 65 – 212          | sandy tuff  |
|             | 5-35        | >655              | andesite    |
| 6           | 1.05 – 7.65 | 212 - 655         | tuff        |
|             | 6 – 19.1    | 65 – 212          | sandy tuff  |
|             | 10-35       | >655              | andesite    |

4.2. 2D cross-section
The 2D cross-section is built and plotted to show the lithology correlation between each line (figure 5). Correlation between survey lines provides information regarding which direction the andesite spread. Several lines crossed each other; for example, Line 1 crossed Line 2, Line 4, and a little bit of Line 5. The cross-section ties the result to ensure the inversion result model agrees one to another at the same coordinate. Line 6 is the only line that does not cross another line. The cross-section also gives us insight into the thick andesite in the middle of the survey area; it spreads to the North and West. In the East direction, the dense andesite tends to go deeper.

Figure 5. Cross-section of all lines using two different perspectives: (a) front view from West, and (b) front view from South-East.

4.3. 3D Modelling result
The 3D modeling is performed to estimate the volume of andesite within the study area (figure 6). The 3D model of the deeper andesite is given in figure 13. Through these models, it could be observed clearly
that the most considerable andesite potential lies between Line 2, 1, 3, and 4, which spread to the West and North. The volume of the cube is estimated up to 606,900 m$^3$. Thus, multiplying that value with density would give andesite’s reserve volume. Taking the average density of South Lampung andesite, which vary from 2.59 – 2.86 gr/cm$^3$, andesite reserve mas of the study area is estimated around 1.65 × 10$^6$ tons.

Figure 6. 3D section of andesite with three different perspectives: (a) top view, (b) tilted view, and (c) side view.

5. Conclusion
Due to its resistivity value, it is known that the West Sungkai subsurface is mainly divided into three lithologies: sandy tuff with 65 to 212 Ω·m, tuff with 212 Ω·m to 655 Ω·m, and andesite with more than 655 Ω·m. High resistivity andesite chunk could be found at near-surface, while deeper andesite at 5 – 30 m is distributed from middle to the West and North. The estimated andesite reserve of this study area is about 1.65 × 10$^6$ tons (or 1.65 million tons). This estimation is a positive sign that Sungkai has a great potential to fulfill concrete needs. 3D resistivity survey is highly recommended to estimate more accurate reserve.

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