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Identifying Andesite Rocks Sources Using Geoelectrical Resistivity in Loli, Donggala Regency, Central Sulawesi

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Abstract
Research has been carried out in Loli Village, Donggala Regency, Central Sulawesi using the Wenner-Schlumberger resistivity geoelectric method to determine the resource of andesite rocks. This measurement was done by determining the path points in the field using the Global Positioning System (GPS). The data collection was carried out using the geoelectrical resistivity method based on the area's measurement plan. The data obtained was in the form of position data for each electrode, potential data (V), and current strength data (I) used to calculate the resistivity value (ρ). The results obtained from this research are andesite rock resource content, which was characterized by a high resistivity value ranging from 300–600 Ωm. The resistivity value of the cover layer is low, ranging from 14–45 Ωm. The latent content of andesite rocks was dominated in the southeast region on the trajectory of DRSA_01, DRSA_02, DRSA_03, DRSA_04, and DRSA_06 which had a lower topography than the northwest region.
Keywords: Geoelectrical resistivity, Wenner-Schlumberger, andesite, Donggala.

1. Introduction

Recently, Indonesia is encouraging broad infrastructure development in a rural or urban area. Therefore, natural resources demanded that development is required [1]. One of those natural resources that helps Indonesia's infrastructure development is rocks [2]. Geologically, the Central Sulawesi's tectonic is complicated, so that it possibly has various types of rocks, contains a substantial amount of natural resources, and frequently encounters natural disasters, primarily earthquakes [3]. Thus, some areas in Central Sulawesi acquire types of metallic or nonmetallic minerals that constitute rocks [4], and Donggala has the oldest intrusive rocks in the shape of small andesite and basalt [5].

The types of rocks that can be used appropriately for infrastructure are those with excellent physical features, including hardness, density, as well as the water and weather resistance level, so that it is not easily damaged. One of the rocks that has a robust physical characteristic is andesite [6]. It is one of the mined rocks with a huge potential for society because it can be used as the primary material of buildings, bridges, roads, railroads, and so forth due to its immense chemical content of silica (SiO_2) 62.30% [7].

A study on Central Sulawesi mineral identification was carried out in Toli-Toli, through resistivity and Induced Polarization (IP) method with Wenner-Schlumberger configuration reveals high resistivity granite and andesite rocks [4]. Besides, a geochemical analysis was also conducted in Parigi Moutong to identify minerals in the form of granite, andesite, schist, diorite, gneiss, and molasses indicated to have Cu, Pb, Zn, and Ag particles [8].

There is a limited amount of study that identifies andesite rocks in Central Sulawesi, especially in Donggala. Thus, a further investigation is required to discover the andesite content in the subsurface using the geoelectric resistivity method. This study aims to reveal the composition of andesite rocks in the research location, so that failures during the exploration can be avoided, and the potential source of andesite rocks can be estimated [9].

1.1. Geology of the Research Location

Generally, the research location is challenging to be found since it is situated in highland with dense vegetation. This condition triggers the weathering process causing the surface to get covered by soil. Thus, it was difficult to meet the rocky outcrop. Besides, this area is the track of volcano formation, causing numbers of volcanic products sediment, as illustrated in Figure 1. This sediment is the lava flow, continuously, intermittently, or divaricately formulated, depending on its flow strength, as well as its morphology [10].

The research location is included in the geology map of Palu in the Tinombo formation with intrusive rocks that possibly originated from volcanic rocks canal [5]. This location also contains shale deposits, sandstone, conglomerate, limestone, radiolarian, and volcanic rocks that precipitated in sea area. The western region consists of more flintstone, this area is also incorporated by volcanic flint rocks with middle to high miocene [11].

Figure 1. The research location's condition.

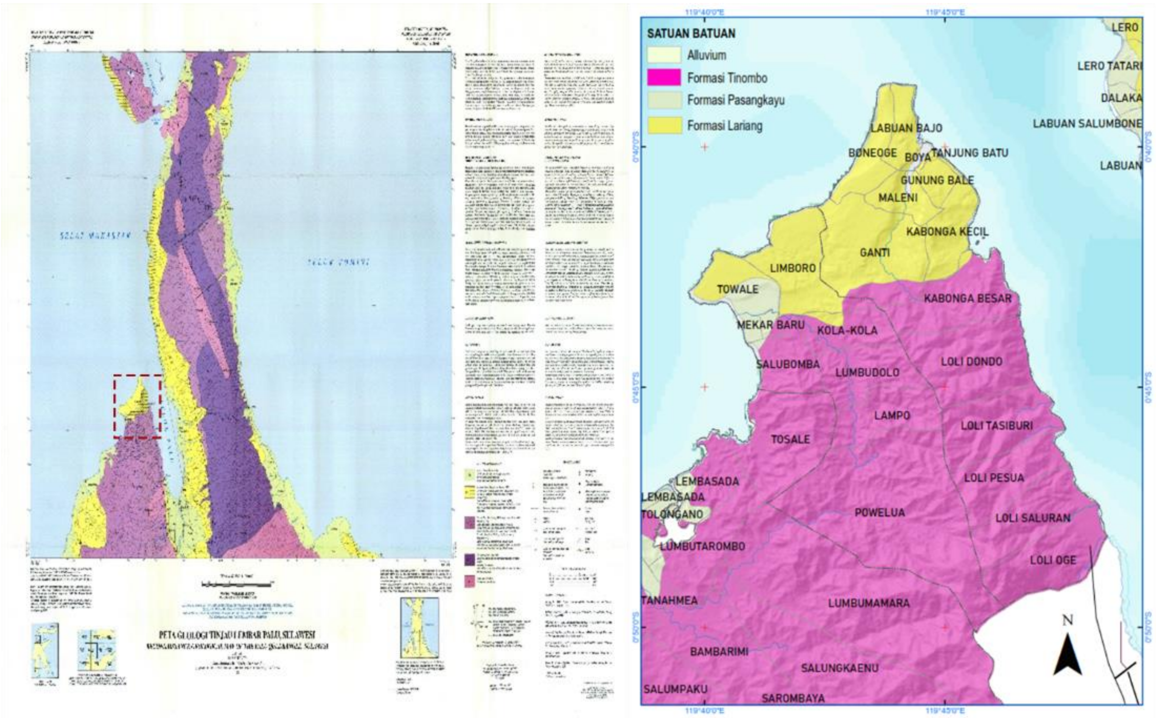

Figure 2. Geological map of the research location in the geology sheet of Palu, Sulawesi.

2. Method

2.1. Geoelectric Resistivity Method

The geoelectric method is relatively easy to be applied and has various benefits of detecting shallow and deep subsurface geology. This method is used to identify rock lithology in an area with different soil electrical conductivity [12] and for aquifer potential [13], [14]. Besides, it is also capable of identifying the distribution and potential of andesite rocks in subsurface [15].

This geoelectric resistivity method is based on the estimation of materials with different resistivity due to electrification. Rock resistivity is defined as rock's physical feature in electrifying [16]. This method is completed by injecting electric current to the earth using an electrode, then measuring the different potential from the electrode used [17]. This method presumes that the subsurface layer is isotropic homogeneous [18], meaning that the bottom layer of the rock has a layer with the same resistivity value [19].

There are some configurations in the geoelectric method, one of them is Wenner-Schlumberger. This configuration obtains more detailed information about the subsurface resistivity in a lateral or vertical way, as well as gaining maximum penetration for a depth of 15% [20]. This configuration combines Wenner and Schlumberger configurations with the electrode configuration model, as illustrated in Figure 3. The geometry factor of Wenner-Schlumberger configuration [18] is presented below

$$K = \pi n (n+1) a \tag{1}$$

In Wenner-Schlumberger configuration, the space among the first current (C1) and second current (C2) electrodes are wider than space between first potential (P1) and second potential (P2) electrode. The two current and potential electrodes have the same space of a, while the inner current and potential (C1 and P1 or P2 and C2) have a space *n.a,* with n = 1, 2, 3, 4 ... (Figure 3).

Wenner-Schlumberger configuration is one of those with a constant system within spacing rules with n note factor. If potential electrodes (P1 and P2) have a space of *a,* then the space between current electrodes (C1 and C2) is $2na + a$ with resistivity determination in a straight line [21], [22]. The excellence of Wenner-Schlumberger configuration is in its continuously changing current and potential electrodes, so it becomes sensitive toward local anomalies, such as lenses and steep walls [23]. This is due to the relatively ample space between potential electrodes, resulting in a relatively significant measured potential [24].

Generally, the measurement of rock resistivity value becomes the benchmark for the interpretation, because of the different geological state of a particular location. Additionally, the resistivity value of andesite rocks is around $\pm$ 1.7 x 10^2 Ωm (dry) to 4.5 x 10^4 Ωm (wet) [18]. The resistivity of a subsurface layer can be estimated using Ohm's law. The obtained results represent an apparent resistivity [25]–[27]. Generally, apparent resistivity (ρ_a) can be written in a formula of

$$\rho_{a=K} \frac{\Delta V}{I} \tag{2}$$

in which K represents the geometry factor of changing electrodes affected by its space, ρ_a is the apparent resistivity (Ωm), ΔV means the potential difference (volt), and I is the strength of the currents (A) [28].

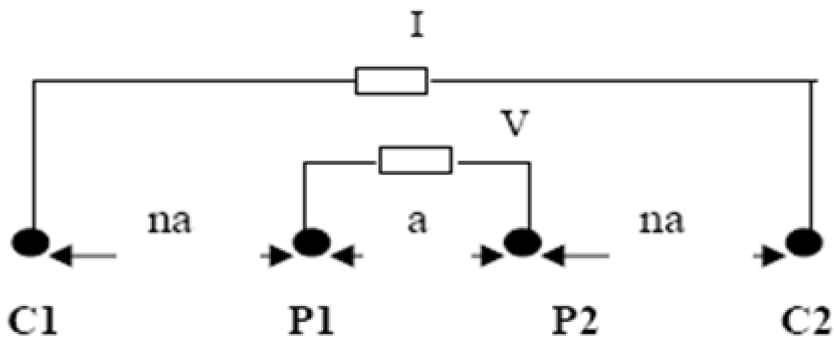

Figure 3. Electrode configuration model on Wenner-Schlumberger.

2.2. *Research Location*

This research was conducted in Loli, Donggala Regency, Central Sulawesi through a morphology area that is dominated by bumpy hills (Figure 4) inclined and steep slope formulated by erosion with a more robust and tender constituent rock or arranged by not perfectly consolidated materials.

In this research, a direct data collection was carried out. It was started by the determination of trajectory points in the field using the Global Positioning System (GPS), corresponding to the location of the geoelectrical measurement track. This research used the geoelectrical method with the Wenner-Schlumberger configuration. The space between electrodes was 6 meters, capable of identifying in the depth of 50–60 meters, with each track length of 282 m. The cable used a multicore cable with 48 electrode bars. There were ten inner tracks within the measurement, adjusted to the subsurface geology and topography state observation data, as illustrated in Figure 5.

The obtained data covers potentials (V) and electric current strength (I). The geometry factor (K) was calculated using equation (1), while the apparent resistivity was estimated using equation (2). Later, the obtained data were analyzed using the subsurface 2D cross sections model. The data processing result in apparent resistivity value and depth. To obtain the actual depth and ρ value, an inversion model should be conducted.

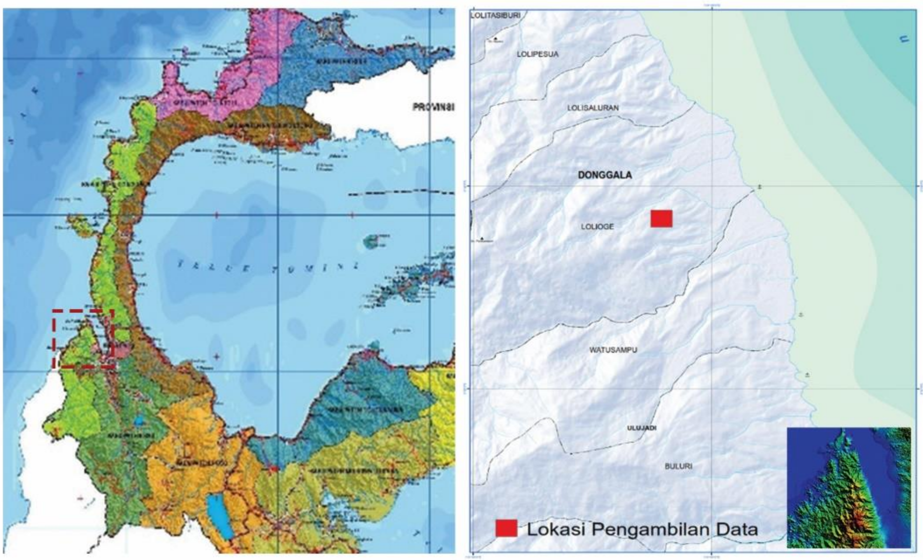

Figure 4. The location of research territory.

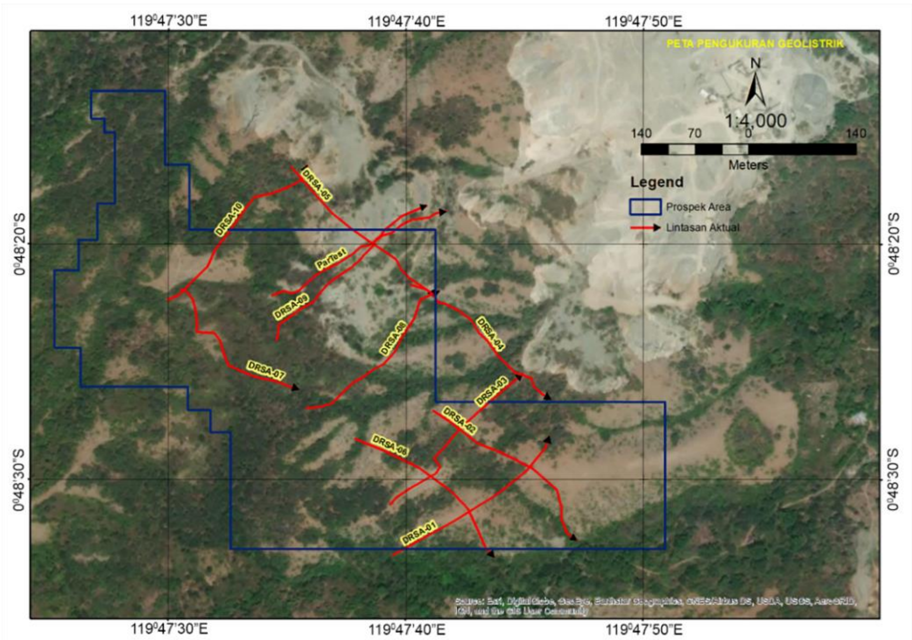

Figure 5. Actual map of geoelectric measurement track.

3. Result and Discussion

The measurement results data were analyzed to discover subsurface 2D profile for each track. A track was measured as a benchmark for the analysis, where the andesite rocks have a relatively high resistivity value around 300–600 Ωm, while the cover layer obtains a low value of 14–45 Ωm, to identify the research interpretation. This happened due to several factors, such as rock density, rock age, amount of minerals content, electrolyte content, porosity, permeability, and so forth.

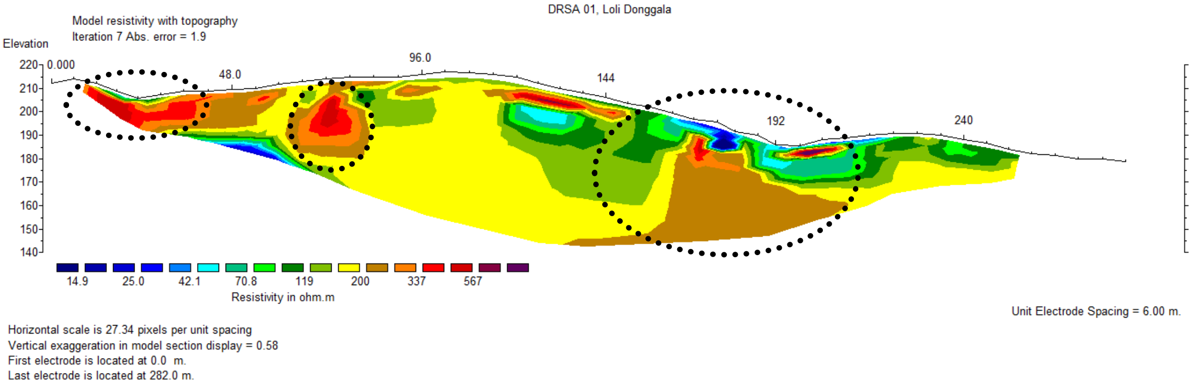

Figure 6. Cross sections of DRSA_01 resistivity track.

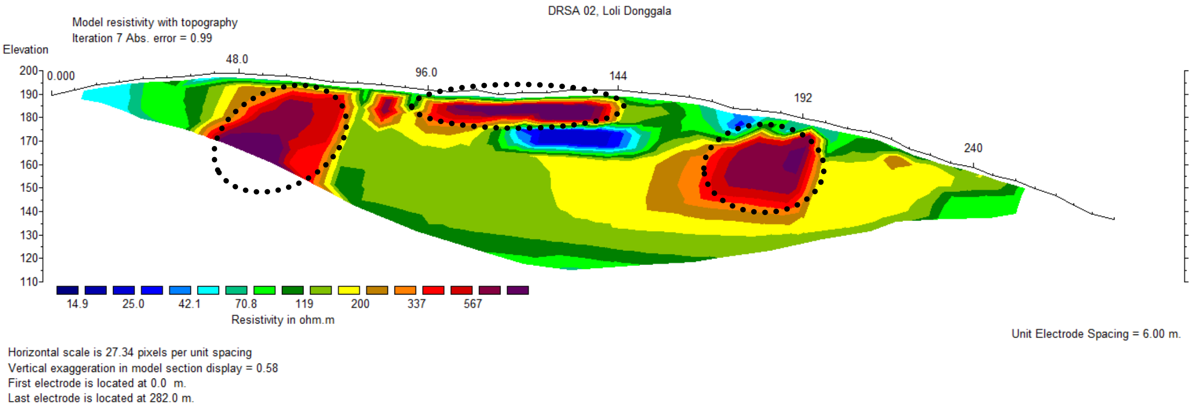

Figure 7. Cross sections of DRSA_02 resistivity track.

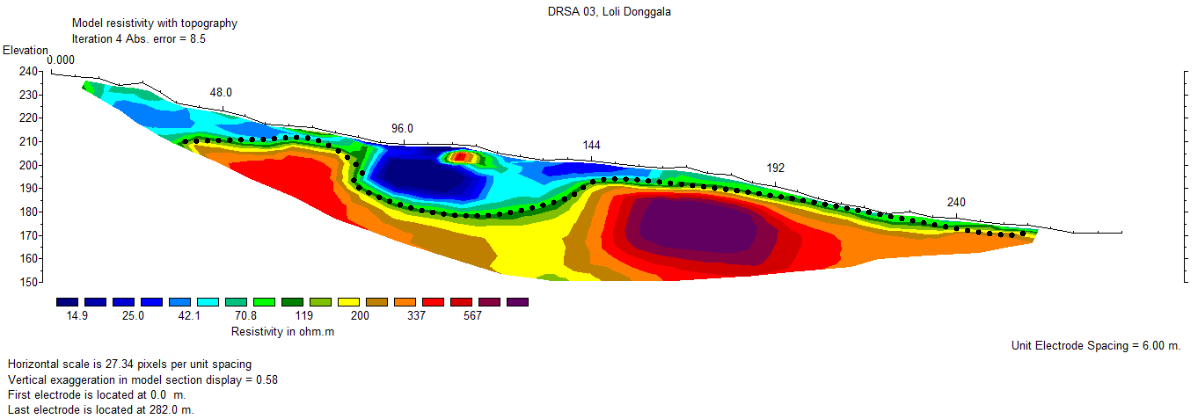

Figure 8. Cross sections of DRSA_03 resistivity track.

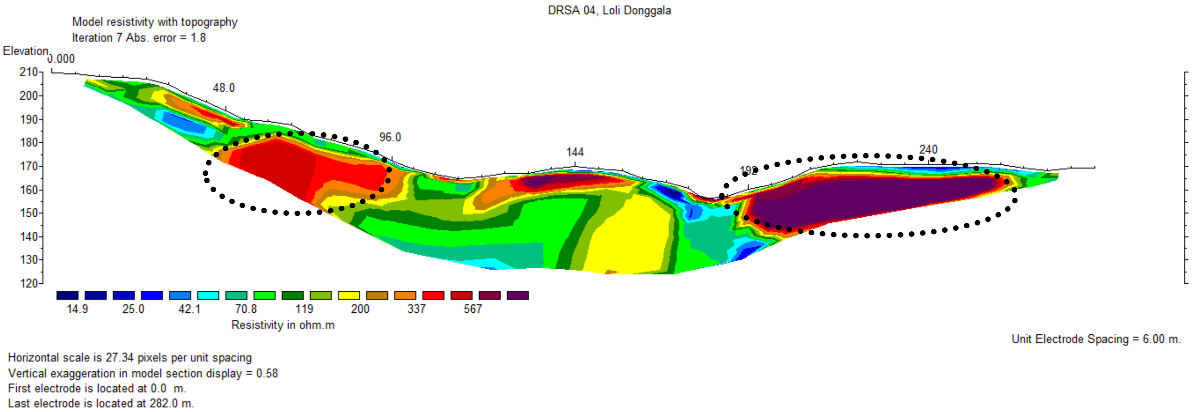

Figure 9. Cross sections of DRSA_04 resistivity track.

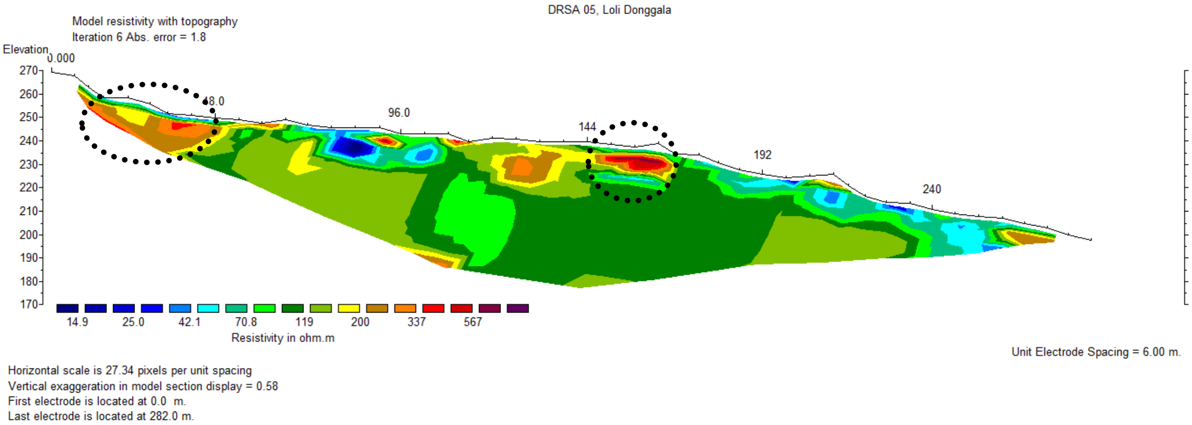

Figure 10. Cross sections of DRSA_05 resistivity track.

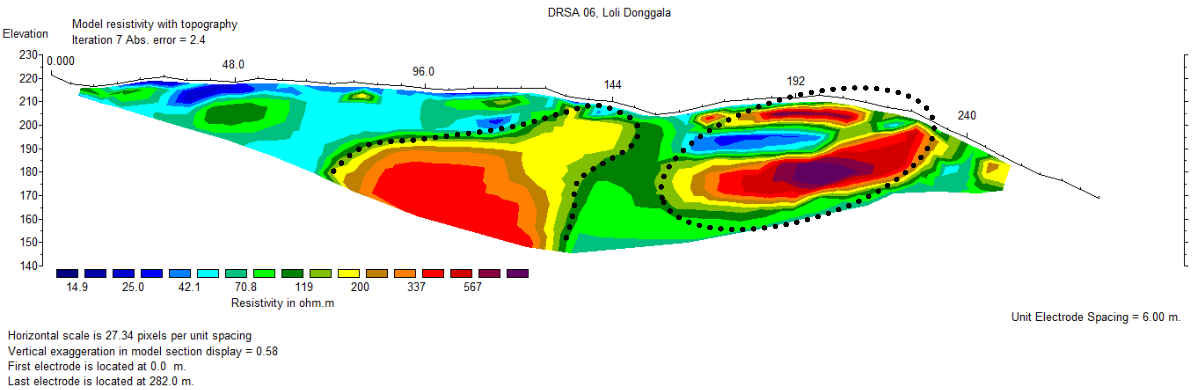

Figure 11. Cross sections of DRSA_06 resistivity track.

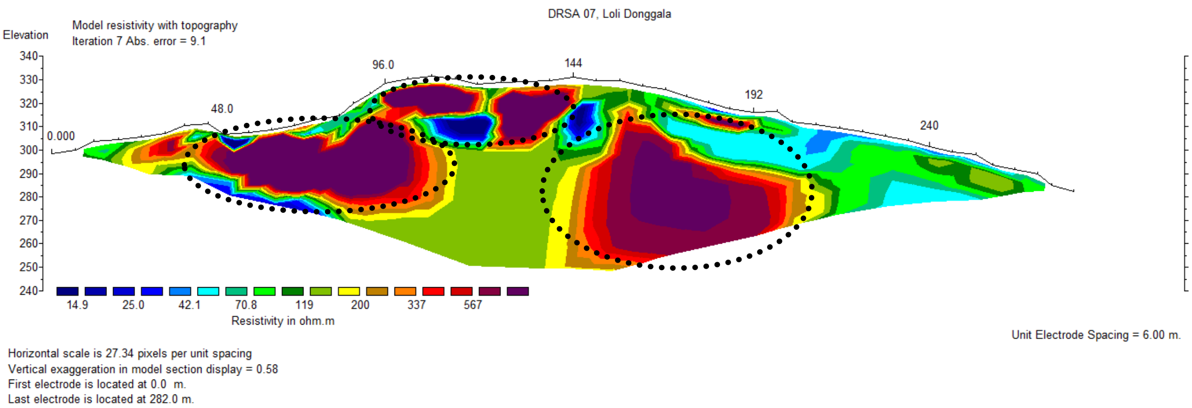

Figure 12. Cross sections of DRSA_07 resistivity track.

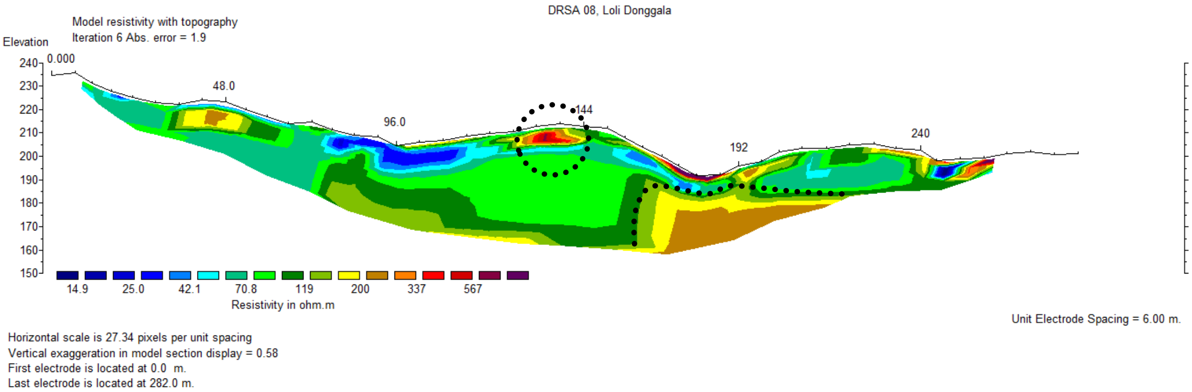

Figure 13. Cross sections of DRSA_08 resistivity track.

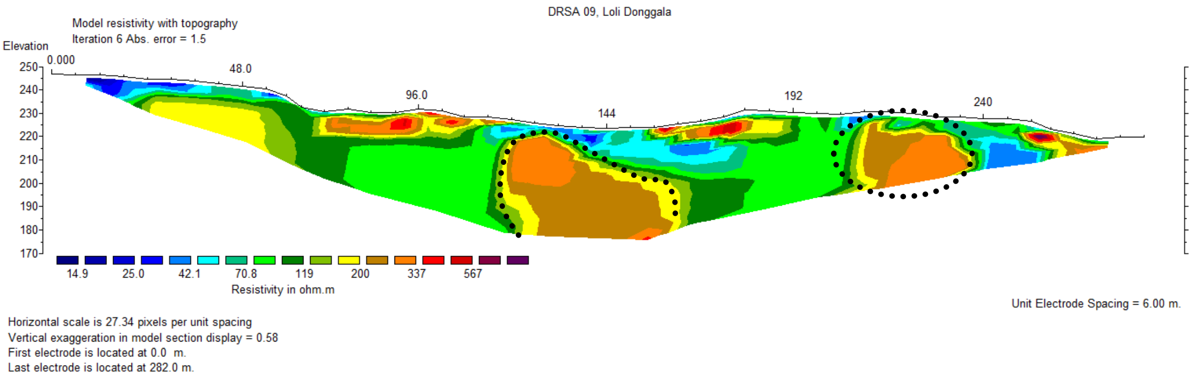

Figure 14. Cross sections of DRSA_09 resistivity track.

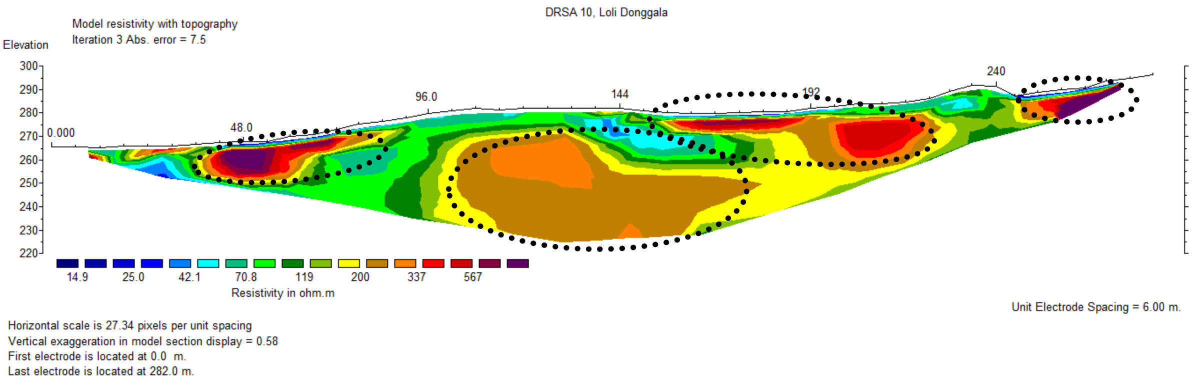

Figure 15. Cross sections of DRSA_10 resistivity track.

According to the cross section of all tracks resistivity, the general resistivity contrast in the research location can be divided into three zones. The first zone is a low resistivity zone with a value of 14–45 Ωm, marked by dark blue to light blue, interpreted as a clay zone and pyrite. The second is a moderate resistivity zone with a value of 45–300 Ωm, marked by light green to dark brown, described as sandstone, granite, and shale zone. Lastly, the high resistivity zone that has a value of 300–600 Ωm, marked by brown to dark purple, interpreted as andesite rocks zone.

Besides, results of cross section resistivity analysis on all tracks reveal that every track has andesite rocks, indicated by high resistivity value below the covering rocks. However, some tracks dominate the andesite rock content, namely DRSA_01 (Figure 6), DRSA_02 (Figure 7), DRSA_03 (Figure 8), DRSA_04 (Figure 9), and DRSA_06 (Figure 11) that are located in the southeast, with lower topographic contours than the northwest area that is only dominated by DRSA_07 track (Figure 12). This is due to the rising magma, along with mafic inclusion that displays relatively long remobilization (~850 ºC), a highly crystalline magma body with a hotter magma mafic [29].

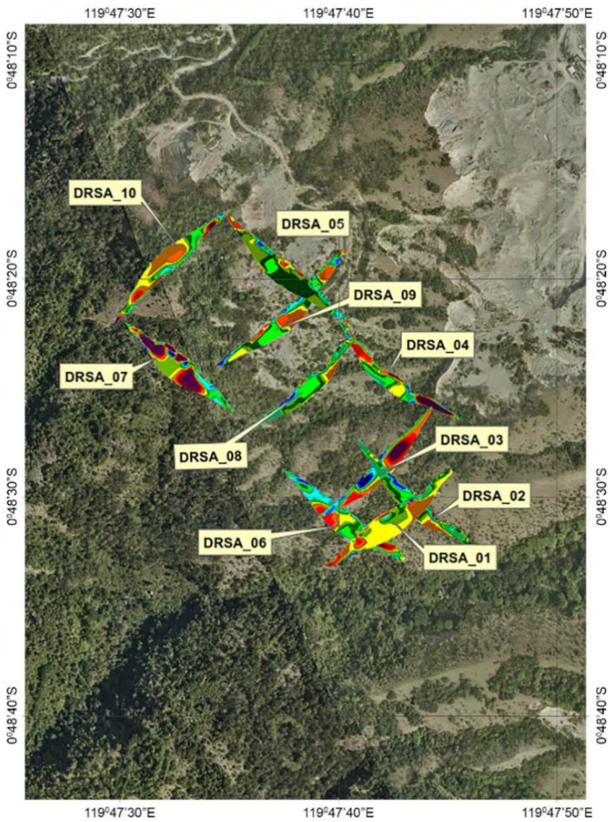

Figure 15. 2D cross sections of all tracks subsurface resistivity combined with topography of research location, covered by forest and mining area.

Geologically, all rock zones in the research location are categorized as Tinombo formation, where there are intrusive of small andesite and basalt along Donggala. The possible intrusion is the volcanic rock tracks with medium to high miocene age in the Tinombo formation, spread across the location [5]. Andesite rocks are the rocks commonly found in the lava flow created by stratovolcano, where the rising lava that reaches the surface experience a quick cooling process [30]. Andesite is a common earth crust rocks, usually located in the subduction zone formulated after the oceanic plates melt due to the subduction process. The subduction process caused by the melting in this zone is the magma source. Once that magma source rises to the surface, it creates andesite [31].

4. Conclusion

Results of 2D cross sections resistivity model show an illustration of andesite rocks, interpreted from the high resistivity value of 300–600 Ωm. The andesite rocks are mostly located at 10–40 meters depth in the DRSA_01, DRSA_02, DRSA_03, DRSA_04, and DRSA_06 tracks with southeast direction, while for the northwest direction the andesite rocks are located in DRSA_07 track with a depth of 35–60 meters. For optimal results, a drilling or trenching process should be conducted based on the analysis and evaluation results toward the research location. That way, verification can be provided, along with the data of rocks types and their hardness level.

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