2D electrical resistivity imaging to determine depth of andesite spreading at Tanjung Batu, Jambi as eco-friendly exploration of minerals method

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Abstract. Tanjung Batu has potential subsurface minerals in the form of Andesite rocks. Andesite can be used appropriately for infrastructure with excellent physical features, including hardness, compressive strength, density, as well as the water and weather resistance level. In mining, the depth of mineral exploration usually using borehole method. In this study used electrical resistivity method with dipole-dipole configurations. Electrical resistivity is also capable for identifying Andesite rocks in subsurface without drilling the area because each rock has a different rock resistivity value. In this study used 240 meters of track and 20 meters space of electrodes. Based on 2D Imaging, range of Andesite resistivity in this area was 170 - >1095 Ωm. Andesite depth was at 3.42, 10.6, 18.5 and -27.2 m.

1. Introduction
Tanjung Batu, Jambi is one of area that has the potential for natural resources in the form of Andesite rocks. This area was dominated by lava basaltic consisting of basalt and Andesite rock units [1]. Geologically, Tanjung Batu is located at the boundary of the subduction plate or the subduction of the oceanic plate to the continental plate. This subduction was produced Andesite rock [2]. Tanjung batu was formed by Quarter Basalt (Qb) formation, Kasai Formation (QTk) and Muara Enim Formation (Tmpm). Quarter Basalt (Qb) consists of Basalt and Andesit. Kasai Formation (QTk) consist of alternation between tuffaceous sandstone and tuffaceous claystone. Muara Enim Formation (Tmpm) consist of alternation between tuffaceous sandstone and tuffaceous claystone, alternation between quartz sandstone and quartz claystone, inserts coal and iron oxide. In this area is fracture zone of the subduction between the continental plate and the oceanic plate that generated Andesite rock [3].

Andesite is a type of igneous rock formed at temperature 1500 °C – 2500 °C from volcanic activities resulting from cooling magma on the earth's surface [4]. Due to the large temperature difference, Andesite is dense and porous [5]. Andesite has an excellents physical features, including hardness, density, as well as the water and weather resistance level, so that it is not easily damaged [6]. This rock is the one of the types of rocks that can be used appropriately for infrastructure. It is one of the mine 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 (SiO₂) 62.30% [7]. In reality, not all Andesite rocks are exposed on the surface. So, it is necessary to investigate the...
subsurface estimation using geophysical methods to determine the distribution of Andesite rocks below the surface without drilling the area e.g Electrical Resistivity Method. Electrical Resistivity Method is less vulnerable to collapse & contamination when applied. So, it was eco-friendly method for mineral exploration e.g Andesite.

The Electrical Resistivity 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 [8] and for aquifer potential [9], [10]. Besides, it is also capable of identifying the titanomagnetite deposit [11], identifying of Andesite rock sources [12], potential existence of Andesite [13] andesitic-trachytic volcanic geothermal areas [14]. Therefore, in this study, the electrical resistivity method was used to determine the depth of Andesite rocks in Tanjung Batu, Jambi. It is hoped that the information obtained can be used as a reference in the exploration of Andesite rocks in the area.

2. Methods

Electric 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 [15]. This method is completed by injecting electric current to the earth using an electrode, then measuring the different potential from the electrode used [16]. This method presumes that the subsurface layer is isotropic homogeneous [16], meaning that the bottom layer of the rock has a layer with the same resistivity value (Figure 1) [16].

![Figure 1. Generalised form of electrode configuration in resistivity surveys [16].](image)

Based on the equipotential field principle, the measurement of the potential value at the ground surface will produce a value equal to the potential difference in the soil at the same radius between points M (V_M) and N (V_N) from current sources A and B on the surface [17]. The electric potential difference between the electrodes M and N (Figure 1) is given by equation 1 and 2:

\[ V_M = \frac{\rho I}{2\pi} \left( \frac{1}{AM} - \frac{1}{MB} \right) \]  
\[ V_N = \frac{\rho I}{2\pi} \left( \frac{1}{AN} - \frac{1}{NB} \right) \]  

However, it is far easier to measure the potential different, \( \rho V_M \) which can be rewritten as equation (3):

\[ \rho V_{MN} = \frac{\rho I}{2\pi} \left( \frac{1}{AM} - \frac{1}{MB} \right) \left( \frac{1}{AN} - \frac{1}{NB} \right) \]  

Rearranging this so that resistivity (\( \rho \)) is the subject (4 & 5):

\[ \rho = \frac{2\pi \rho V_{MN}}{I} \left( \frac{1}{AM} - \frac{1}{MB} \right)^{-1} \]  
\[ \rho = \frac{2\pi \rho V_{MN}}{I} K \]

K which is known as the geometric factor.

In reality, the subsurface ground does not conform to a homogeneous medium and thus the resistivity obtained is no longer the ‘true’ resistivity but the apparent resistivity (\( \rho_a \)), which can even be negative [16]. It is very important to remember that the apparent resistivity is not a physical property of the subsurface media, unlike the true resistivity. Consequently, all field resistivity data are for apparent resistivity, while those obtained by interpretation techniques are ‘true’ resistivities [17]. Where the
ground is not uniform, the resistivity so calculated is called the apparent resistivity \( \rho_a \) which given by eq. 6.

\[
\rho_a = RK, \text{where } R = \rho V_{MN} \delta V / I
\]  

(6)

I which is known as the current (A).

There are some configurations in the geoelectric method, one of them is Dipole-Dipole (Figure 2). Dipole–dipole arrays have been used extensively in mineral exploration. Dipole–dipole array has a poor vertical resolution but particularly sensitive to deep lateral resistivity variations and suitability to CST [16]. Nevertheless, this sensitivity can be utilised in resistivity profiling [17]. Apparent resistivities for given geometric factors for electrode configurations in Figure 2 given by equation 7:

\[
\rho_a = \pi n (n + 1)(n + 2) aR
\]  

(7)

Figure 2. Electrode Dipole-Dipole configurations used in electrical surveys [16]

The area of this study was taken from the area where Andesite mines and formations Andesite and basalt rock formations about 750 ha that covered in 10 lines survey. Length of line 240 m (20 m point space) and target depth between 20 to 30 m. Resistivity imaging used RES2DINV.

3. Results and Discussion

Figure 3 shows the result of 2-D imaging in Line 1. The range of resistivity value of a subsurface rock in this line is 0 \( \Omega m \) - > 1095 \( \Omega m \) and an average depth of 3.42 - 27.2 meters. Resistivity values was represented in colour blue, light blue, green, yellow, red to purple. There are three layers of rock in this area (alluvial (1.62 – 35 \( \Omega m \)), clay (35 – 170 \( \Omega m \)) and Andesite (170 – >1095 \( \Omega m \))). Based on the resistivity catalog [1], the range of resistivity Andesite rocks is 170 – 45,000 m, which is represented by brown – purple colors in Figure 3.

Figure 3. 2-D Imaging of Electrical Resistivity in Line 1
This layer has a resistivity value ranging from $170 > 1095$ m. Andesite in this line was distributed randomly based on depth and distance. In Figure 3 Andesite is divided into 3 zones. The first zone is at a depth of $3.42 \pm 12$ m which represented at a stretch of $30 - 40$ m along $\pm 10$ m. The second zone is at a stretch of $60 - 140$ m with a depth of $\pm 20 - 27.2$ m which shows a fairly large volume of Andesite rock. The third zone is at a depth of $\pm 15 - 27.2$ m with a stretch of $\pm 170 - 200$ m. The Andesite zone formed was due to a fracture zone in the area, resulting in Andesite rock intrusion at various depths.

Figure 4 shown 2-D imaging in line 5. In this line resistivity ranges are from $0 > 1095$ m with depth of $3.42$ to $27.2$ m. This area is divided into 4 Andesite rock zones. The first zone at a stretch of $30 - 35$ m at a depth of $9 - 11$ m. The second zone in a stretch of $60 - 75$ m (depth of $\pm 18.5 - 27.2$ m). The third zone at stretches $150 - 180$ m (depth of $\pm 15 - 27.2$ m). The fourth zone at a stretch of $\pm 204 - 210$ m (depth of $\pm 3.42 - 13$ m). The distribution of Andesite in this area is influenced by the tectonic setting and is in the fracture zone which is the place for magma intrusion which then freezes and forms Andesite rock.

Figure 4. 2-D Imaging of Electrical Resistivity in Line 5

In Figure 5, Andesite rock seen at surface area because this area has an Andesite outcrop. In this area Andesite is divided into 2 zones. The first zone is a fairly thick andesite zone seen at a stretch of $103 - 140$ m (depth of $3.42 - \pm 10.6$ m). he second zone in the stretch of $83 - 180$ m (depth of $21 - > 27.2$ m). From Figure 5 seen that Andesite volume is quite large and continue to a greater depth from pre-set depth target.

Figure 5. 2-D Imaging of Electrical Resistivity in Line 8

Based on 2-D imaging of electrical resistivity (Figure 3, 4 and 5) above assumed that Andesite in study area was dominated with range electrical resistivity about $170 - >1095 \, \Omega m$ on at the scattered and
out of tune depths. Andesite in this area was dominated by the presence of andesite with shallow depths \( \leq 27.2 \text{ m} \) and can go deeper (Figure 5).

Figure 3, 4 and 5 can be reconstructed into figure 6. Figure 6 represented andesite rock depth distribution in four zone (3.42 m, 10.6 m, 18.6 m, and 27.2 m). Figure 6 shown the complexity of andesite zone in this area. It was influenced by local tectonic setting e.g the present of Sabak Volcanism Back Arc. Sabak Volcanism Back Arc is related to extensional processes of extensional basin continued the Quarternary. The extensional could be triggering continental spreading the initiation graben formed [18]. It has a spatial connection to geothermal system on Geragai. Geothermal system in Geragai that associated with fault activity where the heat caused to be related with increasing thermal gradient at depth [19]. Actually, studied area was located at Kasai Formation which dominated by sedimentary rock (Claystone Kasai Formation, and swamp sediment). The rock units that make up this formation were all composed by fine sediment (natural frequency 1.24 Hz - 4.35 Hz [20]). It was produced an intrusive zone of andesite in different layers.

![Andesite Rock Depth Distribution Based on 2-D Imaging of Electrical Resistivity](image)

**Figure 6.** Andesite Rock Depth Distribution Based on 2-D Imaging of Electrical Resistivity

4. Conclusion
Andesite rock in Tanjung Batu, Jambi dominated by Andesite in shallow depth and scattered irregularly at \( \leq 27.2 \text{ m} \) at subsurface. The depth Andesite distribution in this area influenced by local tectonic setting e.g existence of fracture zone which produced an intrusive zone of andesite in different layers. Electrical resistivity method is also capable for identify the depth of Andesite spreading in subsurface shallow zone. So, this method can be an alternative method for minerals exploration in subsurface shallow zone which eco-friendly.

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