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Identification of Peridotite Bedrock using Resistivity Geoelectric Method in Lapao Pao Estuary Area, Kolaka District

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Abstract

Ultramafic rocks are the main source of nickel laterite deposits. One of the areas that has an ultramafic complex is located in Muara Lapao Pao Village, Kolaka Regency. The research was conducted in the mining area of PT Tri mitra Babarina Putra using the resistivity geoelectric method of the Wenner - Schlumberger configuration, In the area it is not yet known exactly how much peridotite bedrock is present in the subsurface. Therefore, it is necessary to conduct a geophysical survey in identifying the occurrence of peridotite bedrock, and can determine the depth and thickness of peridotite bedrock in the research area. the occurrence of peridotite bedrock in the mining area of PT Tri Mitra Babarina Putra has a resistivity value between 3000 – 17984 Ohm-meters. Peridotite bedrock in the research area on all four tracks has a depth and thickness that is almost uniform. lines 1 and 2 and 4 are at a depth of 34.5 - 39.6 meters with a thickness of up to 5.1 meters. and line 3 peridotite bedrock is at a depth of 40 m to more. There are 3 layers in the study area, namely, soil/overburden layer with a resistivity value of 16.5 – 122 Ohm-meters, serpentinite rock layer with a resistivity value of 200 – 2438 Ohm-meters and peridotite bedrock layer with a resistivity value of 3000 – 17984 Ohm-meters.

Keywords: Geoelectric Method; Peridotite; Resistivity; Kolaka**.**

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Introduction

One of the factors that play an important role in the formation of nickel laterite deposits is the type of bedrock (Jeremiarta et al., 2022). Jeremiarta et al. (2022) explains that ultramafic rocks are rocks that are the main source for laterite nickel deposits. Some examples of ultramafic rocks include dunite, pyroxynite, hornblendite, serpentinite and peridotite. One area that has an ultramafic complex is located in Muara Lapao Pao Village, Kolaka Regency. This area is included in the ofiolite complex in the Southeast Arm of Sulawesi which is part of the East Sulawesi Ofiolite Line. The rocks forming this line are dominated by ultramafic and mafic rocks and pelagic sedimentary rocks and there is melange in several places. (Rachman et al., 2020). The research was conducted in the mining area of PT Tri mitra Babarina Putra, which is engaged in mining that produces peridotite rocks. In the mining area, it is not yet known exactly how much peridotite bedrock is found in the subsurface. Therefore, it is necessary to conduct a geophysical survey in describing the subsurface structure so that later it can be used to identify the presence of peridotite bedrock, and can determine the depth and thickness value of peridotite bedrock in the research area.

Hasria et al. (2022) explains that peridotite rocks are part of ultramafic rocks that contain many mafic minerals, including olivine. Most ultramafic rocks were originally peridotite, formed in the upper mantle and transformed into serpentinite either partially or completely by crustal fluids during its journey to its current tectonic position (Asdar et al. 2022).

To identify the subsurface conditions of the earth in an area generally using geophysical methods. One of the suitable geophysical methods used is the resistivity geoelectric method. The resistivity method is used to study the flow of electricity in rocks under the earth's surface (Pratama et al., 2019a). The use of resistivity geoelectric method to identify bedrock has been done by previous research (Pratama et al., 2019b) in the research area around Lumpue beach, Pare-Pare city, South Sulawesi.

This research identifies peridotite bedrock using the resistivity geoelectric method with the Wenner-Schlumberger configuration. (Sapina et al., 2023) explained that to detect the subsurface structure of the earth horizontally and vertically using the Wenner-Schlumberger configuration. The Wenner-Schlumberger configuration is one of the configurations usually used for 2D resistivity measurements (Amir et al., 2022). The advantage of the Wenner-Schlumberger configuration is that it can describe lateral and vertical variations in resistivity values and its depth penetration is 10% greater than the Wenner configuration (Telford et al., 1990; Hati et al., 2022). The signal strength of the Wenner-Schlumberger configuration is lower than the Wenner configuration, but higher than the Dipole-dipole configuration (Hermawan & Putra, 2016). Wenner-Schlumberger also has slightly better horizontal data coverage compared to the Wenner configuration, although not better than the Dipole-dipole configuration (Hermawan & Putra, 2016). Therefore, the Wenner-Schlumberger configuration masks the weaknesses of each configuration (Pambudi et al., 2022).

Geology of the Research Area

Based on data from BPS Sulawesi Tenggara (2018), Kolaka Regency is geographically located between 02°00' and 05°00' southern latitude and between 120°45' and 124°06' eastern longitude. Administratively, the research area is in Wolo sub-district, Kolaka Regency. According to BPS Kabupaten Kolaka (2023), the area of Wolo Sub-district is 614.58 km².

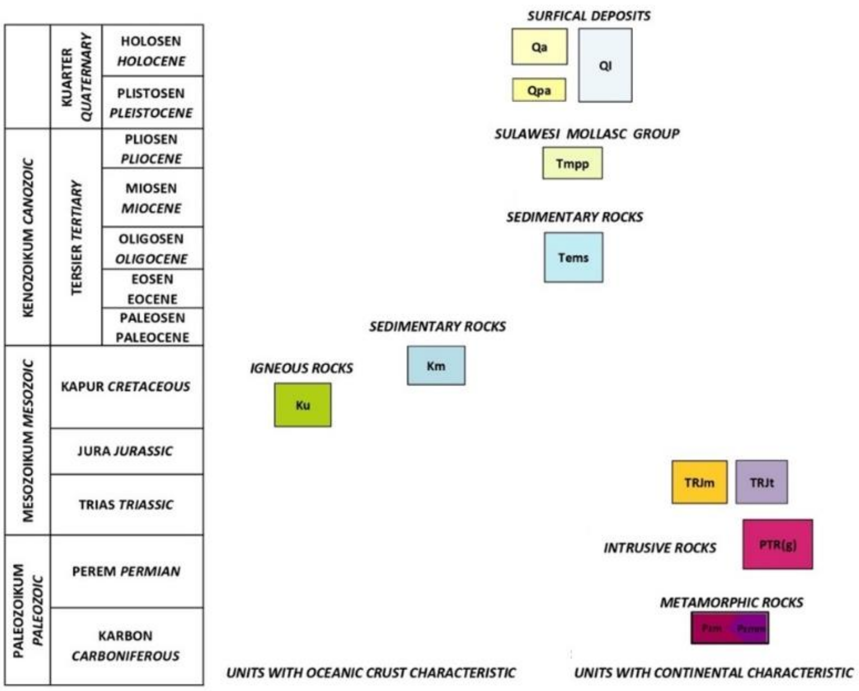

Figure 1. Regional stratigraphy of Lasusua - Kendari sheet (modified from Anggriawan et al., 2021).

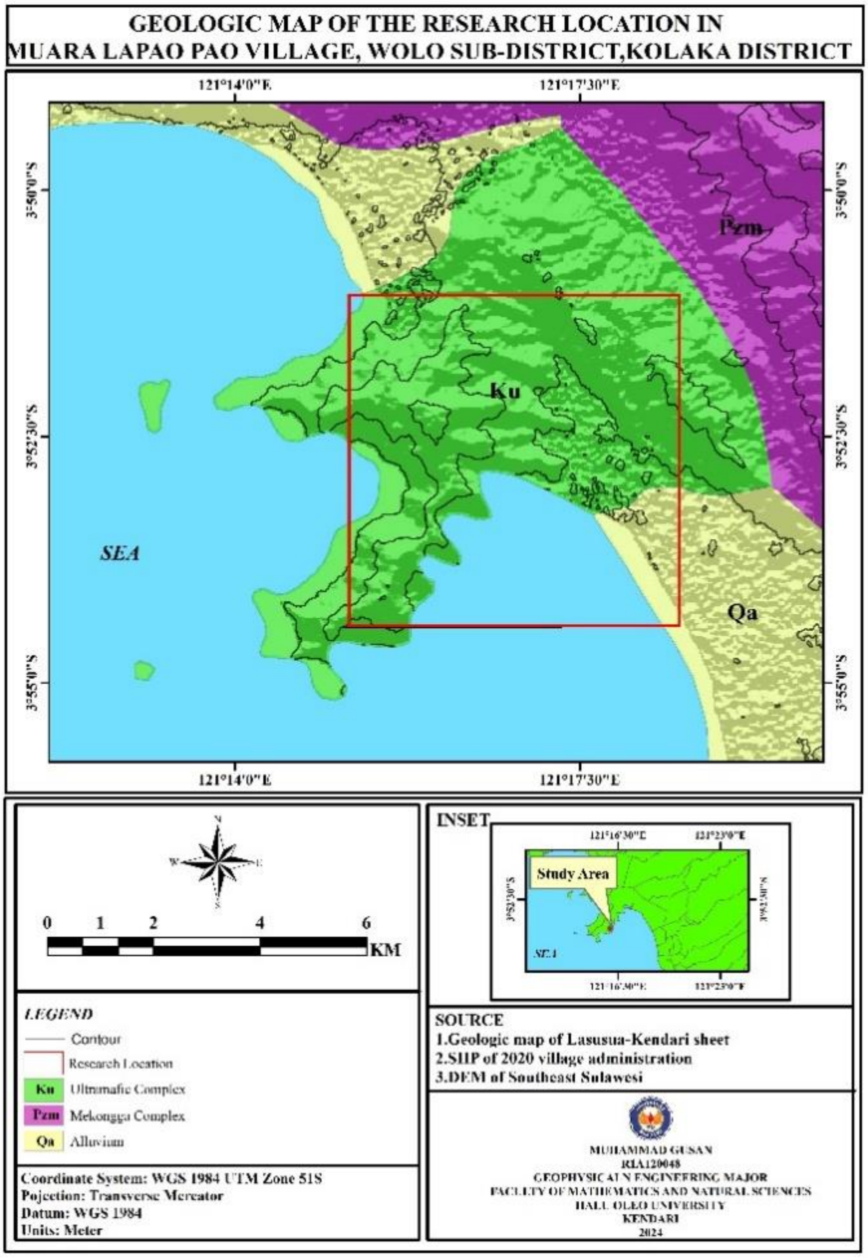

Figure 2. Geologic map of the research area.

Based on the regional stratigraphic map of the Lasusua - Kendari sheet (Anggriawan et al., 2021) in Figure 1. Wolo sub-district is dominated by the carbonaceous to perm aged Mekongga complex (Pzm) which consists of schist, genes, phyllite, quartzite, slate, and a little alabaster has a menjemari relationship with the paleozoic alabaster unit (Pzmm). The complex is overlain by Holocene-aged alluvium (Qa) consisting of gravel, pebbles, sand, clay and silt. The corresponding research area, in Figure 2, is in the ultramafic complex (Ku) which is limestone in age with constituent rocks of peridotite, harzburgite, dunite, gabbro and serpentinite.

Peridotite Rocks

According to Thorffata et al. (2022), bedrock is one aspect that determines the nickel content in nickel laterite deposits because it is the source of nickel content before enrichment occurs. Peridotite rocks consist of holocrystalline minerals with medium - coarse size and anhedral shape. The composition is composed of olivine and pyroxene, the accessory minerals consist of plagioclase, hornblende, biotite, and garnet (Puspita et al., 2022). According to Erwin et al. (2023) explained that Peridotite is one of the nickel-bearing rocks of origin. Peridotite has a high nickel content compared to pyroxynite bedrock because peridotite rocks contain more olivine minerals, while pyroxynite bedrock is generally rich in pyroxene mineral content (Musrifin et al., 2021). The uses of peridotite rock are as building materials, floor or wall ornaments, sculpture making, half gemstones, materials for jewelry, and as emery.

Resistivity Method

Amin et al. (2023) explained that one method to describe the conditions under the earth's surface is the resistivity geoelectric method, which is by injecting electric current into the soil through two current electrodes. then two potential electrodes are used to measure the potential difference that occurs. The resistivity geoelectric method is used to measure a physical quantity such as the resistivity of a subsurface layer. The resistivity value reflects the ability of the layer to inhibit the flow of electric current. This value will be used as a basis for interpreting the condition of the subsurface layer (Ariputra et al., 2021).

Nugroho & Afiatna (2021) explained that pseudo-resistivity is the resistivity of a fictitious medium considered to be the same or homogeneous which is equivalent to the layered medium under review. For example, the layered medium under review may consist of two layers that have different resistivities ($\rho 1$ and $\rho 2$) considered as the same or homogeneous single-layer medium that has one resistivity price of ρa, thus this ρa is a pseudo price. The apparent resistivity value can be expressed in the equation:

$$\rho = 2\pi \left[\left(\frac{1}{r1} - \frac{1}{r2}\right) - \left(\frac{1}{r3} - \frac{1}{r4}\right)\right]^{-1} \frac{\Delta V}{I} \quad (1)$$

$$\rho_a = K\frac{\Delta V}{I} \quad (2)$$

ρ_a is the apparent resistivity value (Ωm), refer to Figure 3, ΔV is the potential difference between P1 and P2 (Volt) and I is the current strength (A) (Sapina et al., 2023) and r is the distance between the two current electrodes (C1C2) and potential electrodes (P1P2) (m) (Sihombing et al., 2023). By measuring ΔV and I, the resistivity value can be determined (Nugroho & Afiatna, 2021).

Table 1. Resistivity values of earth materials (Telford et al., 1990; Pratama et al., 2019b).

Rock Type	Resistivity Range (Ωm)
Granite	$3 x 10^2 - 10^6$
Feldspar Porphyry	$4 x 10^3$
Carbonatized Porphyry	$2.5 x 10^3 - 6 x 10^4$
Porphyry (Various)	$60 - 10^4$
Dacite	$2x10^4$
Diabase Porphyry	$10^3 - 1.7 x 10^5$
Marble	$10^2 - 2.5 x 10^8$
Lavas	$10^2 - 5 x 10^4$
Gabbro	$10^3 - 10^6$
Basalt	$10 - 1.3 x 10^7$
Olivine Norite	$10^3 - 6 x 10^4$
Peridotite	$3 x 10^3 - 6.5 x 10^3$
Serpentinite	$2x10^2 - 3x10^3$
Hornfels	$8 x 10^3 - 6 x 10^7$
Tuffs	$2 x 10^3 - 10^5$
Graphite Schist	$10 - 10^2$
Gneiss (various)	$6.8 x 10^4 - 3 x 10^6$

The configuration used to detect subsurface structures in mapping and sounding is the Wenner-Schlumberger configuration (Sapina et al., 2023). The Wenner-Schlumberger configuration is a configuration that applies a fixed spacing rule system with the factor “n” for this configuration as a comparison of the distance between electrodes C1-P1 (or C2-P2) with the space between P1-P2 as shown in Figure 3. If the distance between potential electrodes (P1 and P2) is a then the distance between current electrodes (C1 and C2) is 2na + a. The process of determining resistivity involves 4 electrodes with placement on a straight line (Yuristina et al., 2015).

The spacing distance between electrodes, the geometry factor of the Wenner-Schlumberger configuration becomes:

$$k = \pi (n+1)a \tag{3}$$

where, k is the geometry factor (m), n is the distance between C1 and P1 (m) and C2 and P2 (m), a is the electrode spacing distance (m), (Saputra et al., 2020). Figure 4 provides a schematic of the Wenner-Schlumberger arrangement.

Materials and Methods

Field data acquisition has been carried out on September 13 - 16, 2023 located in the mining area, in Muara Lapao Pao Village, Wolo District, Kolaka Regency, Southeast Sulawesi Province can be seen in Figure 5. Data processing, data analysis and interpretation were carried out at the Geophysical Engineering Laboratory, Faculty of Mathematics and Natural Sciences, Halu Oleo University, Kendari.

The data used is secondary data in the form of data from field measurements consisting of electric current (I) and potential difference (V). Preparation stage by preparing tools and materials that will be used during measurements in the research area. The preliminary study includes an initial study of the literature and making measurement data tables, to collect information that is relevant or related to bedrock, peridotite rock, resistivity geoelectric method, safety factor and regional geological description of the research area.

The resistivity value obtained from the interpretation results is then interpreted based on the value of the resistivity variation of earth materials (Table 1). So that data analysis is carried out qualitatively on the 2D resistivity cross section, thus it can determine the presence of peridotite bedrock in the research area based on the subsurface resistivity value of the displayed color scale.

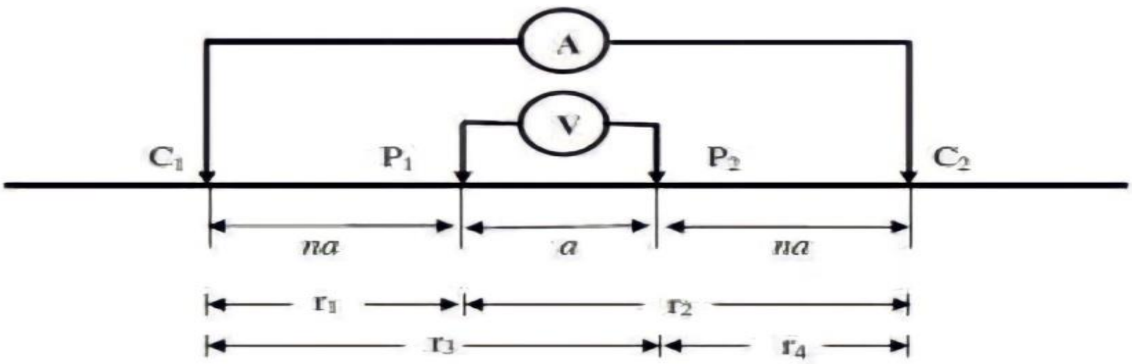

Figure 3. Wenner - Schlumberger configuration (Panjaitan & Jusfarida, 2022).

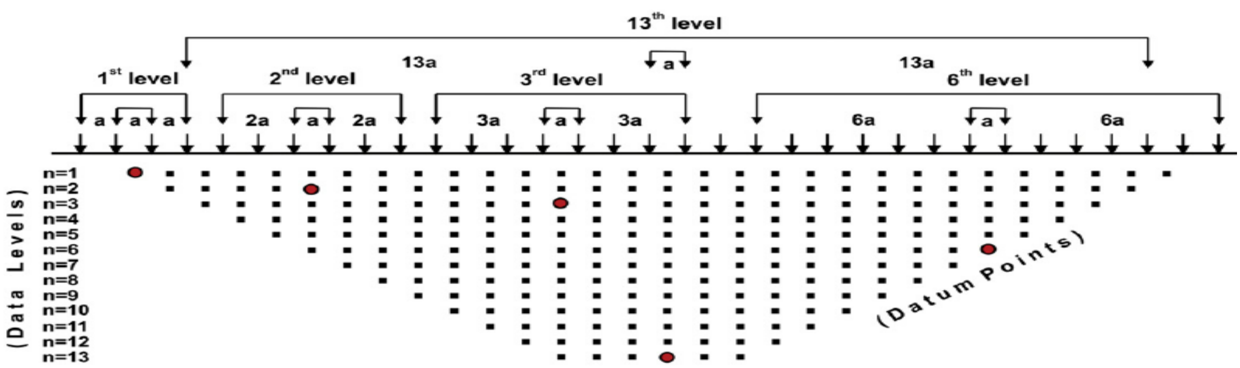

Figure 4. Schematic of the Wenner-Schlumberger array of electrode locations and datum points (Akhasanullatief & Sehah, 2022).

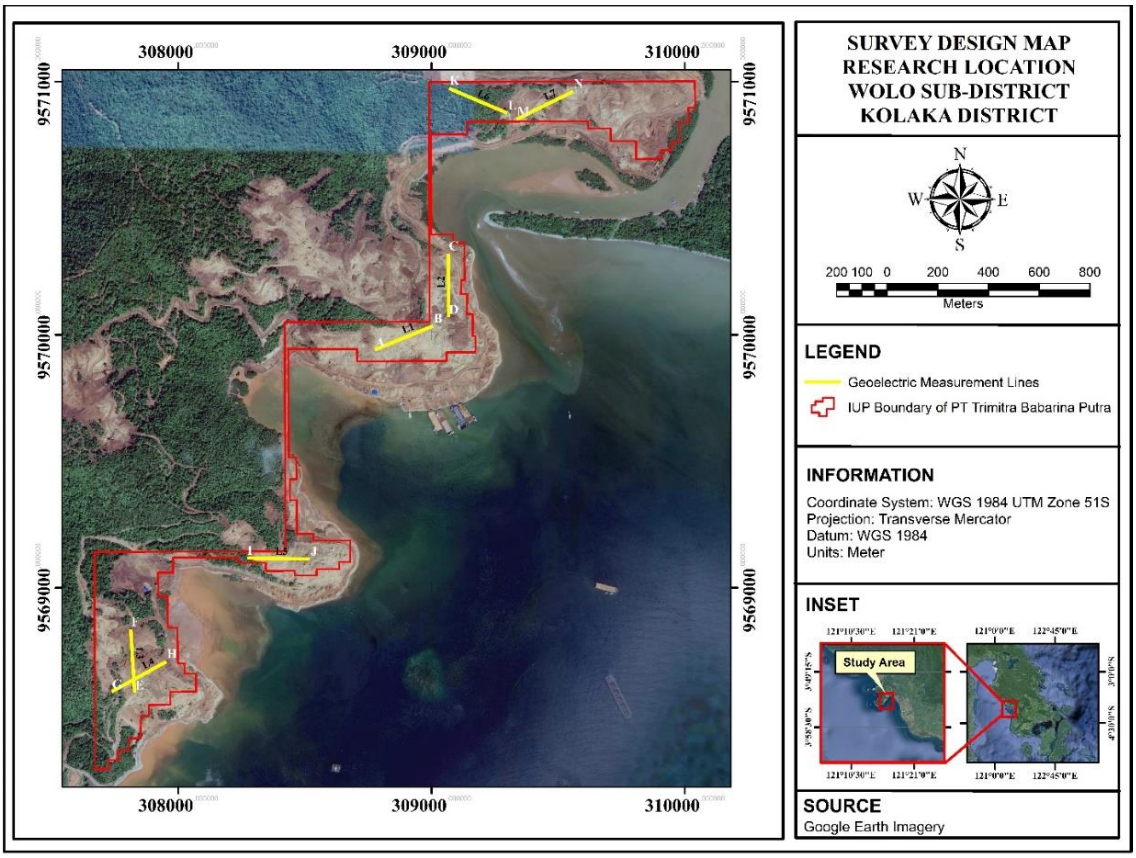

Figure 5. Research Location Map.

Results and Discussion

Line 1

Based on the two-dimensional resistivity cross-section model on line 1 (Figure 6), it can be seen from the span of 0 - 190 meters horizontally while vertically at a depth of 2.50 - 39.6 meters. The distribution of resistivity values on this line ranges from 16.5 to 17984 Ohm-meters with 6 iterations and an RMS error of 9.8%. Iteration is done several times to reduce the error value. The resistivity values vary from low resistivity values to high resistivity values. The lithology layer can be distinguished by looking at the resistivity value that has been obtained from the results of data processing and looking at geological information consisting of regional geological maps, and rock outcrops.

Line 1 with a resistivity value of 16.5 – 122 Ohm-meters is identified as a top soil layer with an average depth from the surface to 13 meters, its physical appearance is yellow-brownish. The resistivity value of 200 – 2438 Ohm-meters is identified as a serpentinite rock layer with a depth from the surface to 18.5 m and at a depth of 32 m. Rock outcrops are seen at 30 m, 60 – 100 m, 130 – 145 m, and 160 – 170 m. This rock layer has undergone a serpentinization process that changes the mineral composition, chemistry, and texture of rocks in ultrabasic rocks when there is interaction between rocks and hydrothermal fluids through them (Permana et al., 2017). The resistivity value of 3000 – 17984 Ohm-meters is identified as a bedrock layer or the lowest layer with constituent rocks dominated by peridotite rocks at a depth of 34.5 to 39.6 meters and the thickness of this layer is 5.1 meters. This rock layer still has the physical properties of its original rock and has not undergone a serpentinization process.

Line 2

Based on the two-dimensional resistivity cross-section model on line 2 (Figure 7), it can be seen from the span of 0 - 190 meters horizontally while vertically at a depth of 2.50 – 39.6 meters. The distribution of resistivity values on this line ranges from 16.5 to 17984 Ohm-meters with 5 iterations and an RMS error of 13.0%. Iteration is done several times to reduce the error value. The resistivity values vary from low resistivity values to high resistivity values. This is because each layer has a different element content. The lithology layer can be distinguished by looking at the resistivity value that has been obtained from the results of data processing and looking at geological information consisting of regional geological maps, and rock outcrops.

Line 2 with a resistivity value of 16.5 – 122 Ohm-meters is identified as a top soil layer with an average depth from the surface of up to 13 meters, its physical appearance is yellow-brownish and has outcrops of peridotite rocks that come to the surface. The resistivity value of 200 – 2438 Ohm-meters is identified as a serpentinite rock layer with a depth from the surface to 18.5 m and at a depth of 32 m. Rock outcrops are seen at 35 – 70 m, 90 – 108 m, 123 – 147 m, and 165 – 175 m. This rock layer has undergone a serpentinization process that changes the mineral composition, chemistry, and texture of rocks in ultrabasic rocks when there is interaction between rocks and hydrothermal fluids through them (Permana et al., 2017). The resistivity value of 3000 – 17984 Ohm-meters is identified as the bedrock layer or the lowest layer with the constituent rocks dominated by peridotite rocks at a depth of 34.5 to 39.6 meters and the thickness of this layer is 5.1 meters. Rock outcrops of peridotite meter 20 – 30 m. This rock layer still has the physical properties of its original rock and has not undergone the serpentinization process.

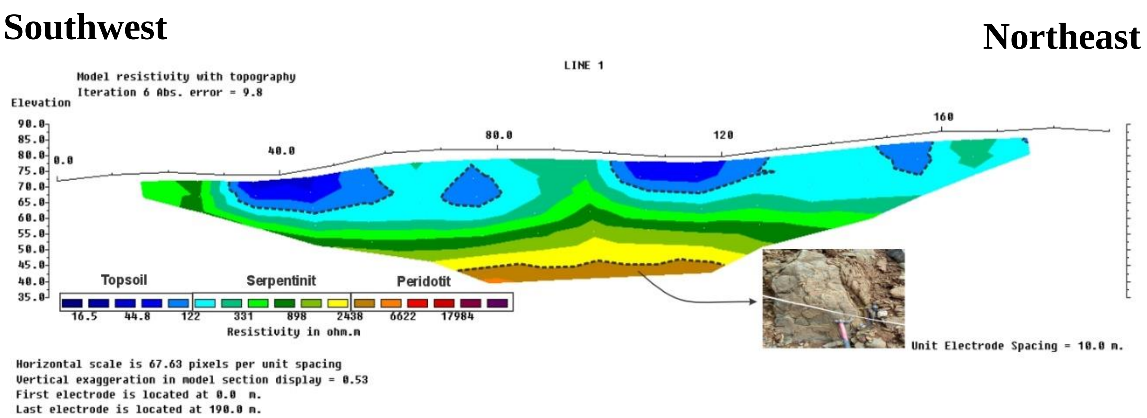

Figure 6. 2D resistivity cross section model of line 1 with topography.

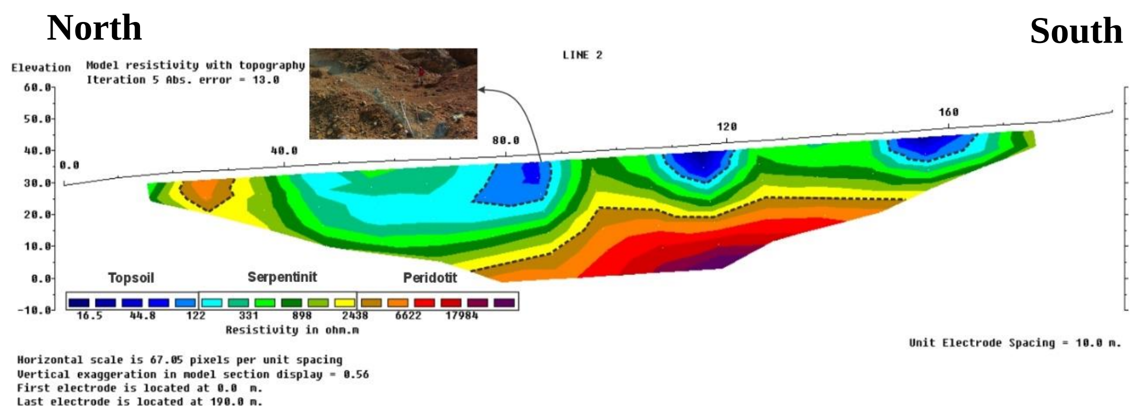

Figure 7. 2D resistivity cross section model of line 2 with topography.

Line 3

Based on the two-dimensional resistivity cross-section model on line 3 (Figure 8), it can be seen from the span of 0 - 200 meters horizontally while vertically at a depth of 2.50 – 39.6 meters. The variation of resistivity values on this line ranges from 16.5 to 17984 Ohm-meters with 5 iterations and the RMS error is 19.6%. Iteration is done several times to reduce the error value. The resistivity values vary from low resistivity values to high resistivity values. This is because each layer contains different elements and materials. The lithology layer can be distinguished by looking at the resistivity value that has been obtained from the data processing results and looking at the geological information of the study area consisting of regional geological maps, and rock outcrops.

Line 3 with an average depth from the surface to 25 meters is identified as a soil layer, the distribution of resistivity values ranges from 16.5 – 122 Ohm-meters, the physical appearance is yellow-brownish and has outcrops of peridotite that is serpentinized to the surface. From the surface to 32 m and at a depth of 39.6 m it is identified as a serpentinite rock layer, the resistivity value distribution is 200 – 2438 Ohm-meters. Rock outcrops are seen at 20 – 30 m, 40 – 50 m, 90 – 105 m, 135 – 155 m and 175 m. This rock layer has undergone a serpentinization process that changes the mineral composition, chemistry, and texture of rocks in ultrabasic rocks when there is interaction between rocks and hydrothermal fluids through them (Permana et al., 2017). At a depth of 40 m to more, it is identified as the bedrock layer or the lowest layer with its constituent rocks dominated by peridotite rocks with a resistivity value of 3000 – 17984 Ohm-meters. This rock layer still has the physical properties of its original rock and has not undergone a serpentinization process.

Line 4

Based on the two-dimensional resistivity cross section model on line 4 (Figure 9), it can be seen from the span of 0 – 190 meters horizontally while vertically at a depth of 2.50 – 39.6 meters. Obtained variations in resistivity values on this line ranged from 16.5 to 17984 Ohm-meters with 5 iterations and an RMS error of 14.8%. Iteration is done several times to reduce the error value. The resistivity values vary from low resistivity values to high resistivity values. This is caused by each layer having different element and material content.

Line 4 with an average depth from the surface to 12.8 meters is identified as a soil layer, the distribution of its resistivity values ranges from 16.5 – 122 Ohm-meters, its physical appearance is yellow-brownish. From the surface to 13 m and at a depth of 32 m is identified as a serpentinite rock layer, the distribution of resistivity values is 200 - 2438 Ohm-meters. The rock outcrops are seen at 20 – 45 m, 65 – 75 m, 90 – 110 m, 125 m and 140 – 145 m. This rock layer has undergone a serpentinization process that changes the mineral composition, chemistry, and rock texture in ultrabasic rocks when there is interaction between the rock and the hydrothermal fluid through it (Permana et al., 2017). At a depth of 34.5 to 39.6 meters and a thickness of 5.1 meters, this layer is identified as a bedrock layer or the lowest layer with constituent rocks dominated by peridotite rocks with a resistivity value of 3000 – 17984 Ohm-meters. This rock layer still has the physical properties of its original rock and has not undergone a serpentinization process.

Interpreting the lithologic layers requires literature studies and field observations. Mentioned in regional geology, Wolo sub-district is included in the Mekongga complex (Pzm), alluvium (Qa) and ultramafic complex (Ku). The research site is included in the ultramafic complex with its constituent rocks identified as serpentinite and peridotite rocks. The soil layer is the opening soil or the topmost layer. The soil is hollow due to land that has been previously stripped. The presence of veins in ultramafic rocks is evidence that the rocks have been serpentinized into serpentinite rocks seen in the rock outcrops. The degree of serpentinization is divided into three categories (low, medium, high) based on the type of serpentine vein (Jaya et al., 2024). An understanding of serpentinization is important in knowing the composition of the bedrock, determining the temperature and pressure conditions under which the hydration process took place, and determining the location of serpentinization in continental crust, oceanic crust, or both (Jaya et al., 2024). Most ultramafic rocks were originally peridotite rocks with pyroxene and olivine mineral compositions that formed in the upper mantle and then transformed into serpentinite, completely or partially. The uses of peridotite rocks are that they can be utilized in the metallurgical, chemical and construction industries and can be used as raw materials in the refractory industry and abrasive industry. The existence of peridotite rocks is reinforced by observations in the field as evidenced by the presence of rock outcrops.

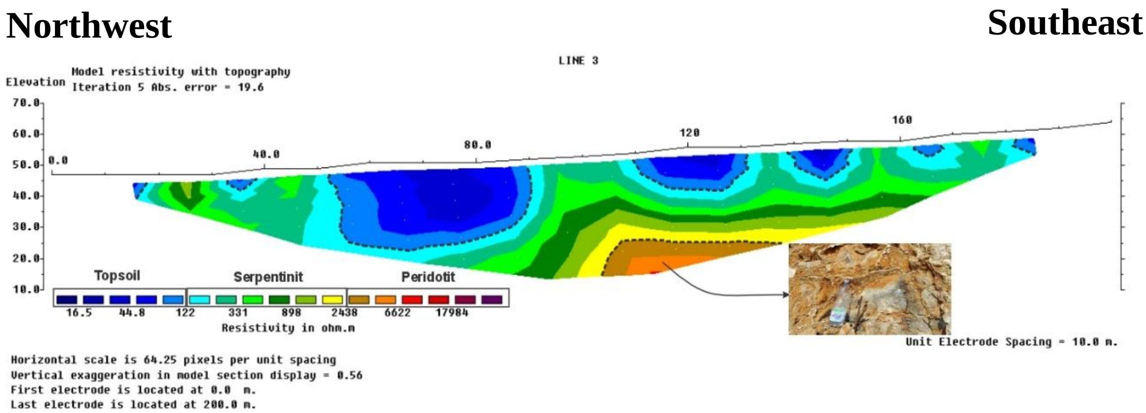

Figure 8. 2D resistivity cross section model of line 3 with topography.

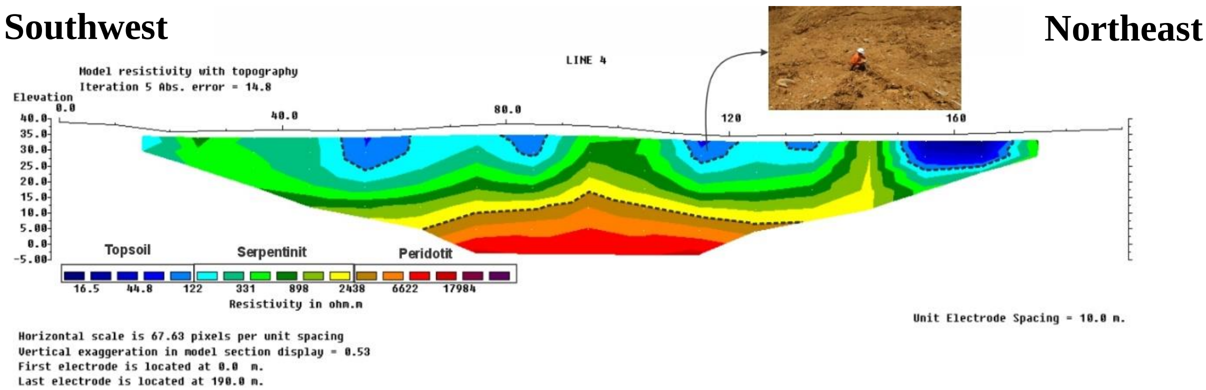

Figure 9. 2D resistivity cross section model of line 4 with topography.

Conclusion

The presence of peridotite bedrock in the mining area of PT Tri Mitra Babarina Putra has a resistivity value between 3000 – 17984 Ohm-meters. Peridotite bedrock in the research area on all four lines has a depth and thickness that is almost uniform. lines 1 and 2 and 4 are at a depth of 34.5 – 39.6 meters with a thickness of up to 5.1 meters. and line 3 peridotite bedrock is at a depth of 40 m to more. There are 3 layers in the study area, which are, soil/ overburden layer with a resistivity value of 16.5 – 122 Ohm-meters, serpentinite rock layer with a resistivity value of 200 – 2438 Ohm-meters and peridotite bedrock layer with a resistivity value of 3000 – 17984 Ohm-meters.

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Author Contribution

The idea of this topic was recommended by Syamsul Razak Haraty and Erzam Salahuddin Hasan as supervisors and helped to review the manuscript. reference collection, field survey, data processing, data analysis and interpretation were done by Muhammad Gusan.

Conflict of Interest

This research has no donation from any party or organization.

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