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Identification of Andesite Rocks Using Dipole-Dipole Geoelectric Method in Batursari Subdistrict, Pekalongan Regency, Central Java

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ABSTRACT

A study has been conducted to identify andesite rocks using the dipole-dipole geoelectric resistivity method in the Batursari Subdistrict, Pekalongan Regency, Central Java Province. Measurements were taken along 12 Lines stretching from northwest to southeast, with a Line length of 280 m and electrode spacing of 10 m. The aim of this research was to model the 2D resistivity value Line of the path, determine the type of andesite rock, and assess the depth of the rock in the study area. Based on data processing results, four lithology units were identified: resistivity values ranging from 0 to 150 Ωm were interpreted as soil, 150 to 250 Ωm as weathered andesite, 250 to 400 Ωm as moderate andesite, and resistivity values from 400 Ωm to 3000 Ωm were interpreted as fresh andesite.

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INTRODUCTION

Andesite rock is classified as an igneous rock that forms due to the solidification and crystallization of magma with an andesitic magma type (Isa, 2020). This rock is formed from magma with temperatures ranging from 900 to 1200 degrees Celsius (Blatter et al, 2022). In its applications, andesite rock finds use in the construction and industrial sectors, playing a vital role in development (Timur et al, 2020). Due to its hard and compact characteristics, this rock is widely utilized for foundations, crushed stone aggregate, cladding, and more (Widagdo et al, 2022).

Given the usefulness of andesite rock, there is a need for exploration and identification of its distribution to support development. Therefore, a geophysical method that utilizes electric currents to measure potential differences and resistivity values of rocks is employed (Syukri M, 2020).

The geoelectric method is utilized to identify the presence of rocks or minerals beneath the Earth's surface. This method is based on the electrical properties of the rock, which are inferred through electrode injections to determine subsurface rock distribution (Rahmat, 2023). To achieve greater depths, the distance between each current electrode and potential electrode is incrementally increased (Muallifah, 2009). A larger spacing between current electrodes allows for deeper current penetration, enabling the determination of the physical properties of deeper rocks (Nadliro, 2013). In this study, the geoelectric method with a dipole-dipole configuration will be employed to identify the distribution of andesite rock in the Batursari Subdistrict, Pekalongan Regency, Central Java.

LITERATURE REVIEW

Andesite is a common type of volcanic rock, composed primarily of plagioclase feldspar and amphibole minerals. Its identification and characterization are essential for geological and environmental studies, as well as resource exploration. The dipole-dipole geoelectric method, a non-invasive geophysical technique, can be employed to identify and characterize subsurface andesite formations.

The dipole-dipole geoelectric method is a widely used geophysical technique for mapping subsurface resistivity variations. This method involves the injection of a controlled electrical current into the ground through two electrodes, with a potential difference measured between two other electrodes. By analyzing the distribution of electrical potential and current flow in the subsurface, it is possible to determine the resistivity structure of the earth, which, in turn, can help identify and characterize geological formations.

Identification of Andesite Rocks:

a. Resistivity Contrast: Andesite rocks typically have distinct resistivity values compared to the surrounding geological materials. When a dipole-dipole survey is conducted, the resistivity of andesite will usually result in anomalies in the data, given its characteristic electrical properties. These anomalies can be detected and analyzed to identify and delineate andesite rock formations.

b. Depth Estimation: The dipole-dipole method provides information about the depth of subsurface structures. By analyzing the depth at which anomalies in resistivity occur, geologists can estimate the depth of andesite rock formations. Andesite bodies at different depths can be distinguished, contributing to a more detailed understanding of the subsurface geology.
c. Inversion Modeling: To improve the accuracy of andesite identification, inversion modeling techniques can be applied to the dipole-dipole geoelectric data. Inversion modeling algorithms can reconstruct the subsurface resistivity distribution and produce a visual representation of the andesite bodies' geometry. This aids in the precise identification and characterization of andesite formations.
d. Integration with Other Data: Geophysical methods are often most effective when used in conjunction with other geological data, such as borehole information, seismic data, or remote sensing data. The integration of dipole-dipole geoelectric data with other sources can further enhance the identification and characterization of andesite rocks.

METHODOLOGY

This research was conducted in the Batursari Subdistrict, Pekalongan Regency, Central Java Province, with data acquisition taking place from August 29th to September 5th, 2017. The study utilized a Resistivitymeter instrument of the Oyo McOhm brand for measurements along 12 Lines. In each Line, a cable (AB/2) was laid out over a distance of 280 meters, with electrode spacing set at 10 meters, adjusted according to field conditions or requirements. The configuration used in this study was dipole-dipole, chosen for its sensitivity to vertical as well as horizontal changes (Suntoko, 2017).

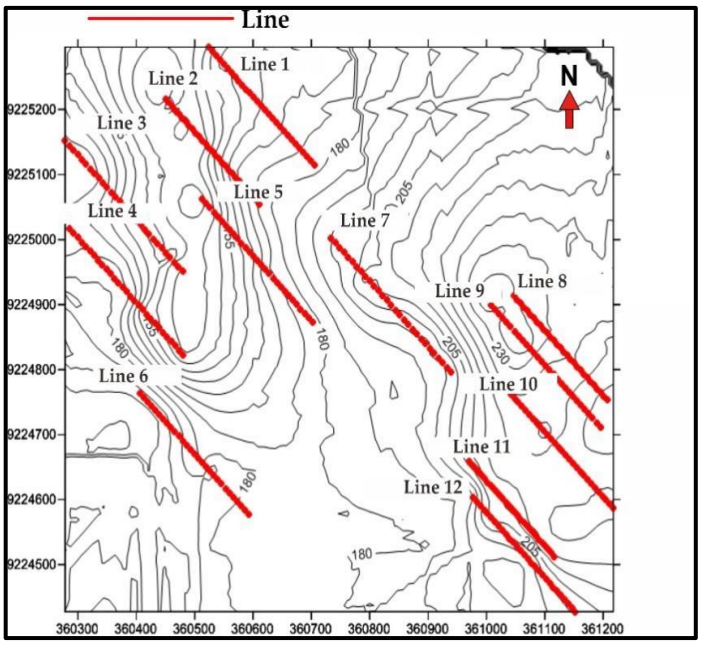

Figure 1. Research Area Trajectory

RESULTS AND DISCUSSION

The following is the result of lithology interpretation using the resistivity table from Telford et al, 1990.

Table 1. Rock Resistivity Values (Telford et al, 1990)

Rocks Type	Resistivity Range (Ωm)	
	Wet	Dry
Granite porphyry	4.5×10^3	1.3×10^6
Diorite porphyry	1.9×10^3	2.8×10^4
Porphyrite	$10 - 5 \times 10^4$	3.3×10^3
Carbonatized porphyry	2.5×10^3	6×10^4
Quartz diorite	$2 \times 10^4 - 2 \times 10^6$	1.8×10^5
Andesite	4.5×10^4	1.7×10^2
Basalt		$10 - 1.3 \times 10^7$
Olivine norite	$10^3 - 6 \times 10^4$	
Peridotite	3×10^3	6.5×10^3
Hornfels	8×10^3	6×10^7
Schists	$20 - 10^4$	
Tuffs	2×10^3	10^5
Slates (various)	6×10^2	4×10^7
Gneiss (various)	6.8×10^4	3×10^6
Skarn	2.5×10^2	2.5×10^8
Limestones	$50 - 10^7$	
Dolomite	3.5×10^2	5×10^3

In Line 1, various variations of andesite rocks were identified, ranging from weathered to moderate, and there were also andesite rocks that had solidified on the Earth's surface (boulder andesite). Line 1 exhibited a depth of 25 meters, a slope of 6 degrees, and a range of resistivity values between 9.46 and 375 Ωm. Within the depth range of 0–10 meters, andesite rocks that had solidified on the Earth's surface were identified, along with moderate andesite rocks in small fragments. Both of these rock types exhibited resistivity values ranging from 240 to 400 Ωm. In the depth range of 10-20 meters, there were moderate to weathered andesite rocks, with resistivity values between 150 and 400 Ωm. Rocks at a depth of 20-25 meters were primarily weathered andesite with resistivity values of 150-250 Ωm, occasionally accompanied by a few moderate andesite rocks with resistivity values of 250-375 Ωm.

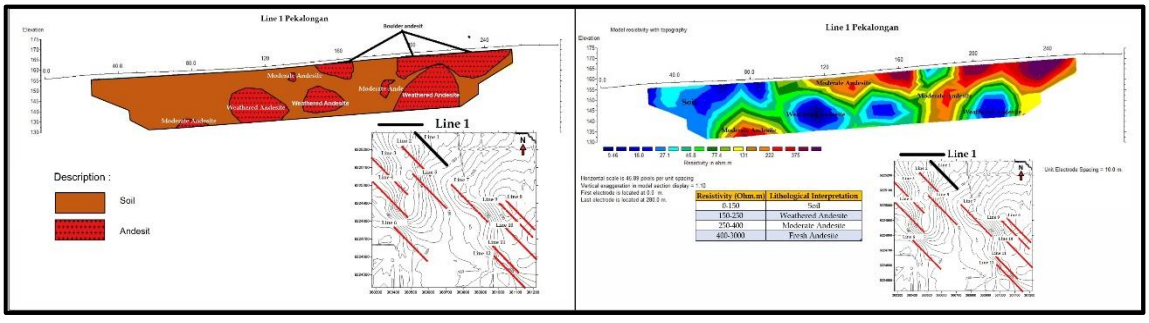

Figure 2. Interpretation and 2D Cross-section of Line 1

In Line 2, a higher concentration of andesite rock content was identified compared to Line 1, and it was dominated by moderate to fresh andesite rocks. In Line 2, a depth of 15 meters was identified along a 280-meter length with a slope of 48 degrees, and the resistivity values along this Line ranged from 4.33 to 1190 Ωm. Within the depth range of 0–10 meters, moderate to weathered andesite rocks were identified, with a prevalence of weathered andesite. moderate andesite in this depth range exhibited resistivity values between 250 and 400 Ωm, whereas weathered andesite had resistivity values ranging from 150 to 250 Ωm. However, at depths of 10-15 meters, the andesite rock displayed a higher quality, as indicated by elevated resistivity values of 400-1190 Ωm.

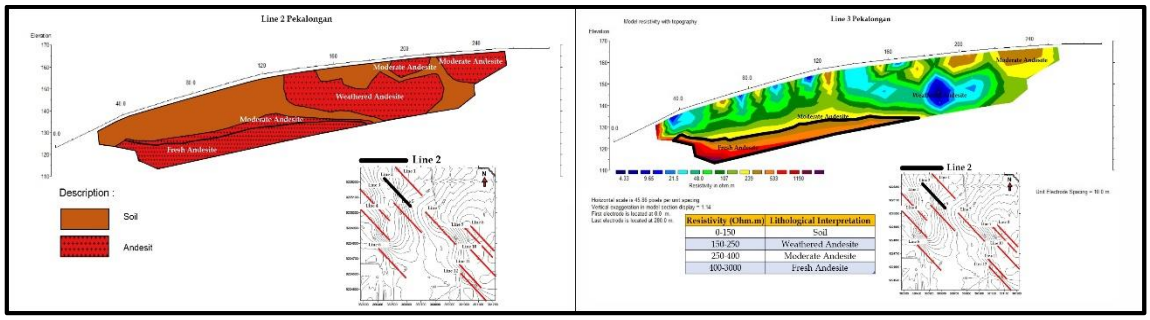

Figure 3. Interpretation and 2D Cross-Section of Line 2

In Line 3, a greater proportion of andesite rock content was identified compared to the soil, with the constituting rocks being weathered to fresh andesite. Line 3 exhibited a depth of 35 meters along a 280-meter length with a slope of 10 degrees, and it displayed resistivity values ranging from 9.20 to 600 Ωm. Within the depth range of 0-35 meters, there were intermixed fresh and weathered andesite rocks. Fresh andesite exhibited resistivity values of 400-600 Ωm, moderate andesite ranged from 250 to 400 Ωm, and weathered andesite had resistivity values ranging from 150 to 250 Ωm.

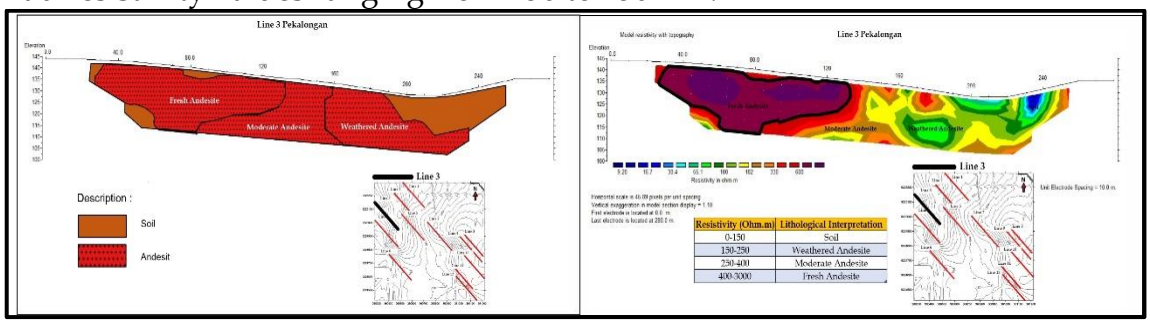

Figure 4. Interpretation and 2D Cross-Section of Line 3

In Line 4, weathered to fresh andesite rock was identified, predominantly dominated by fresh andesite. Line 4 exhibited a depth of 40 meters, a length of 280 meters, and a slope of 8 degrees. The resistivity values within this Line ranged from 16.8 to 3378 Ωm. These resistivity values are classified into three categories for andesite rock: weathered andesite with resistivity values ranging from 150 to 250 Ωm, moderate andesite with values from 250 to 400 Ωm, and fresh andesite with values from 400 to 3373 Ωm. Within the depth range of 0-10

meters, weathered to moderate andesite rock was identified, while within the depth range of 10-40 meters, the rock was identified as moderate to fresh andesite with varying qualities.

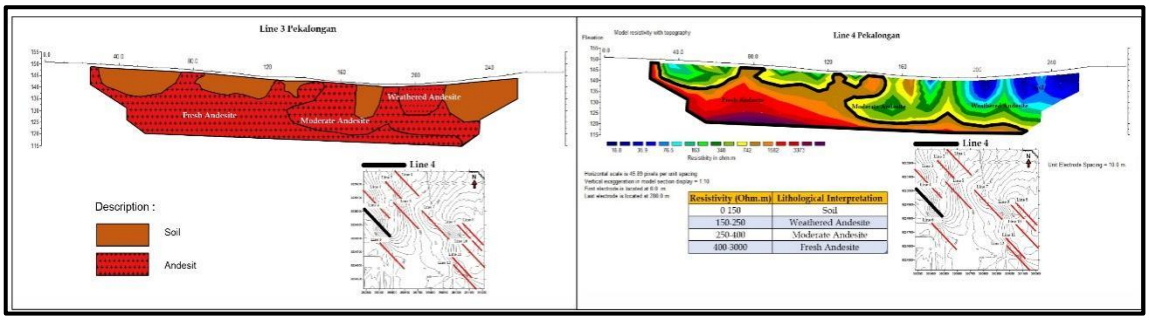

Figure 5. Interpretation and 2D Cross-Section of Line 4

In Line 5, andesite rock was identified, divided into three categories: weathered to fresh andesite, with fresh andesite rock dominating, followed by weathered andesite, and lastly moderate andesite. Line 5 is estimated to have a depth of 25 meters, a length of 280 meters, and a slope of 8 degrees, with resistivity values ranging from 9.76 to 581 Ωm. These resistivity values are categorized into three groups for andesite rock: weathered andesite with resistivity values ranging from 150 to 250 Ωm, moderate andesite with values from 250 to 400 Ωm, and fresh andesite with values from 400 to 581 Ωm. Line 5 is dominated by soil, but in the northwest direction, andesite rock is identified from a depth of 0-25 meters, while in the southeast direction, weathered to moderate andesite rock is identified at a depth of 0-20 meters.

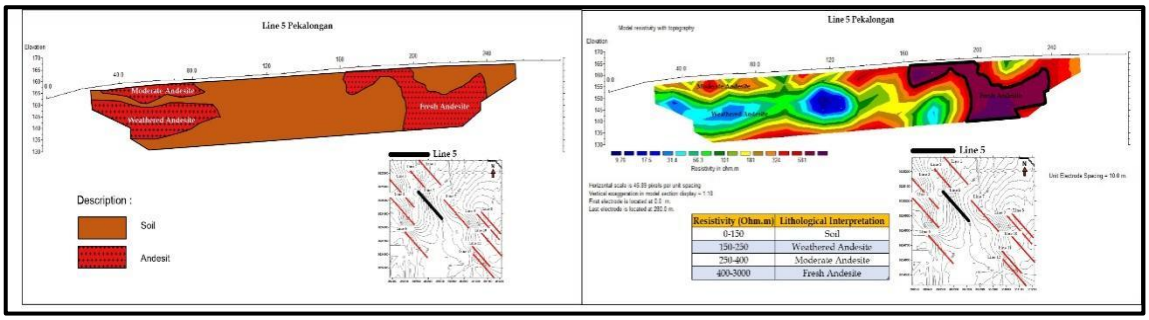

Figure 6. Interpretation and 2D Cross-Section of Line 5

In Line 6, andesite rock was identified and classified based on its weathering state, where fresh andesite rock dominated in Line 6, followed by moderate andesite, and weathered andesite. Line 6 has a depth of 35 meters, a measurement length of 280 meters, and a slope of 12 degrees, with a rock resistivity value ranging from 51.3 to 4427 Ωm. These resistivity values are divided into three categories: weathered andesite having values of 150-250 Ωm, moderate andesite ranging from 250 to 400 Ωm, and fresh andesite ranging from 400 to 4427 Ωm. Fresh andesite rock dominates the depth range of 15-35 meters along Line 6, extending from the northwest to the southeast. Meanwhile, moderate and weathered andesite are found in the shallow depth range of 0-10 meters.

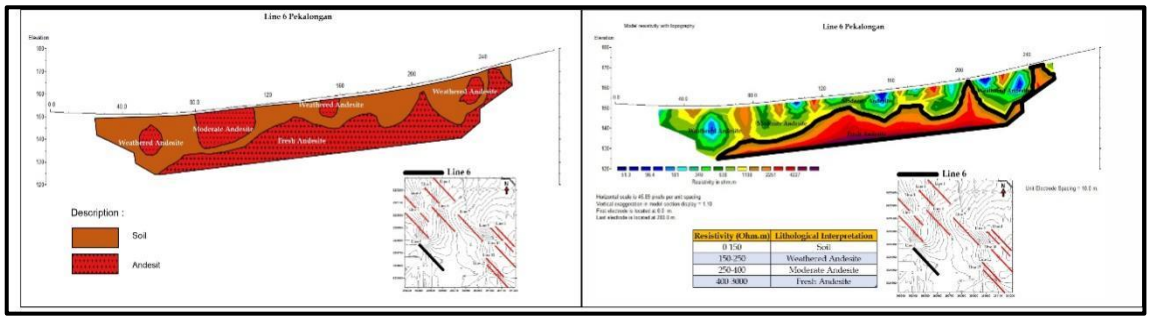

Figure 7. Interpretation and 2D Cross-Section of Line 6

Line 7 was identified to contain diverse andesite rocks, classified as weathered to fresh, and there are exposed boulder-sized andesite rocks on the surface. Line 7 is dominated by fresh andesite rock, followed by weathered andesite, and then moderate andesite. Line 7 has a depth of 30 meters, a measurement length of 280 meters, and a slope of 8 degrees, with a resistivity value ranging from 23.8 to 1099 Ωm. These resistivity values are divided into three categories: weathered andesite with values of 150-250 Ωm, moderate andesite ranging from 250 to 400 Ωm, and fresh andesite ranging from 400 to 1099 Ωm. Fresh andesite rock is present at depths of 0-10 meters and 20-30 meters. Other andesite rocks are distributed within the depth range of 0-30 meters, with uneven depth distribution. Boulder-sized andesite rocks are categorized as fresh andesite due to their resistivity values falling within the range of 400-1099 Ωm.

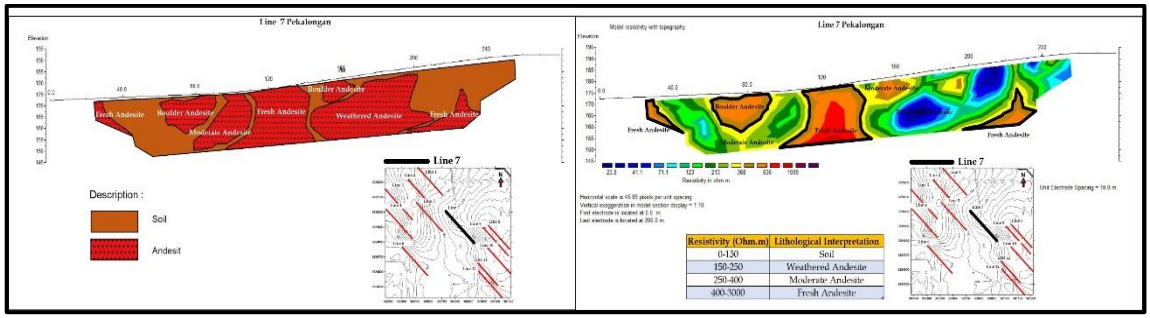

Figure 8. Interpretation and 2D Cross-Section of Line 7

In Line 8, andesite rock was identified with an moderate to fresh classification, but without indicating weathered andesite rock. Line 8 is dominated by fresh andesite rock, followed by moderate andesite, and there are also boulder-sized andesite rocks visible on the surface. Line 8 has a depth of 25 meters, a measurement length of 280 meters, and a slope of 9 degrees, with resistivity values ranging from 56.5 to 1116 Ωm. These resistivity values are divided into two categories: resistivity values for moderate andesite rock ranging from 250 to 400 Ωm, and resistivity values for fresh andesite rock ranging from 400 to 1118 Ωm; the remaining values are interpreted as soil, with resistivity values ranging from 150 to 250 Ωm. Fresh andesite rock dominates the depth range of 0-25 meters, and moderate andesite rock is present at a depth of 0-20 meters.

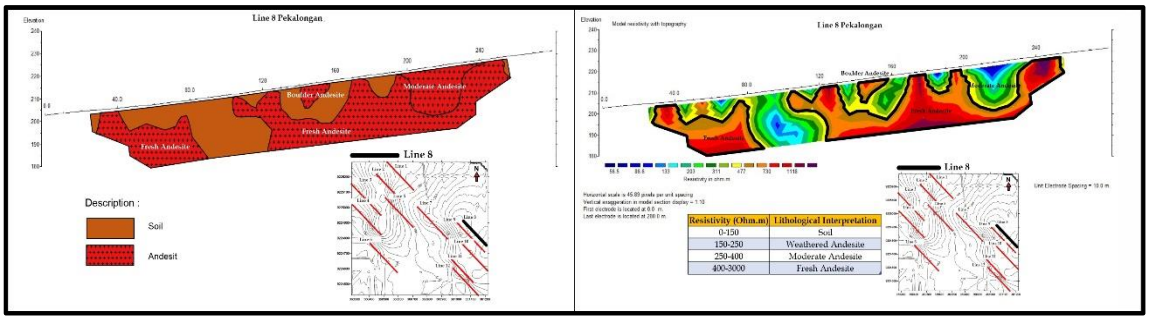

Figure 9. Interpretation and 2D Cross-Section of Line 8

Line 9 was identified to contain weathered to fresh andesite rock, and there are also exposed boulder-sized andesite rocks on the surface. Line 9 is dominated by fresh andesite rock, followed by weathered andesite, and then moderate andesite. Line 9 has a depth of 30 meters, a measurement length of 280 meters, and a slope of 6 degrees, with resistivity values ranging from 75.5 to 1099 Ωm. These resistivity values are divided into three categories for andesite rock: weathered andesite with values of 150-250 Ωm, moderate andesite ranging from 250 to 400 Ωm, and fresh andesite ranging from 400 to 1099 Ωm. Andesite rock occupies the deepest position within Line 9, situated at a depth of 30 meters, and it is anticipated that there may be additional boulder-sized andesite formations at even greater depths.

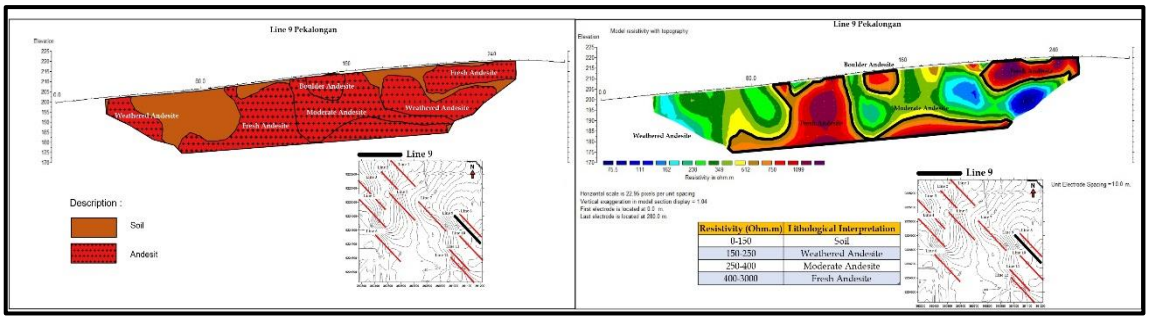

Figure 10. Interpretation and 2D Cross-Section of Line 9

Line 10 has been identified to contain weathered to fresh andesite rock. Additionally, Line 10 is predominantly composed of fresh andesite, followed by moderate andesite, and weathered andesite. Line 10 has a depth of approximately 30 meters, a length of 280 meters, and a slope of 6 degrees. The resistivity values of the rock in this Line range between 88.4 and 1999 Ωm. These resistivity values can be categorized into three groups for andesite rock: weathered andesite with values of 150-250 Ωm, moderate andesite with values of 250-400 Ωm, and fresh andesite with values of 400-1999 Ωm. Andesite rock forms the deepest layer in Line 10, situated around 30 meters below the surface, and it is anticipated that there may be further andesite rock formations at even greater depths. However, several fresh andesite boulders are exposed on the surface.

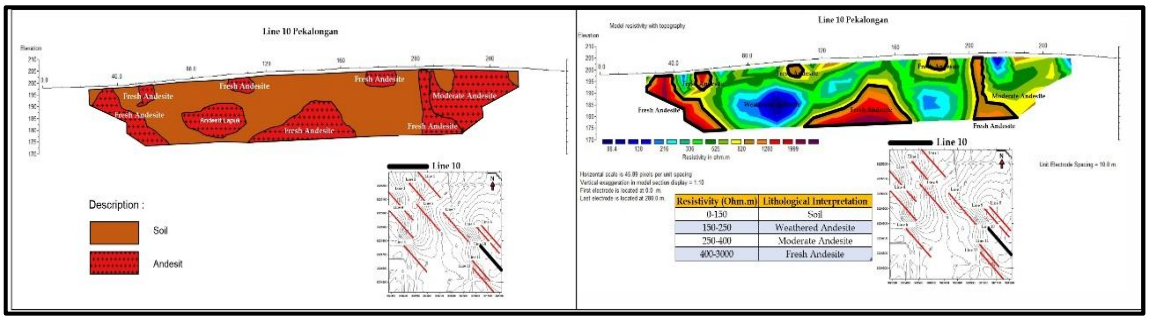

Figure 11. Interpretation and 2D Cross-Section of Line 10

Line 11 was identified as containing weathered to fresh andesite rock. The dominant rock type in Line 11 was moderate andesite, followed by fresh andesite, and then weathered andesite. This Line had a depth of approximately 30 meters, a length of 280 meters, and a slope of 6 degrees. The range of resistivity values for the rock in this Line was between 31.9 and 615 Ωm. These resistivity values can be classified into three categories for andesite rock: weathered andesite with values of 150–250 Ωm, moderate andesite with values of 250–400 Ωm, and fresh andesite with values of 400–615 Ωm. Additionally, there were exposed boulder-sized andesite rocks on the surface, classified as fresh andesite, with resistivity values ranging from 400 to 615 Ωm.

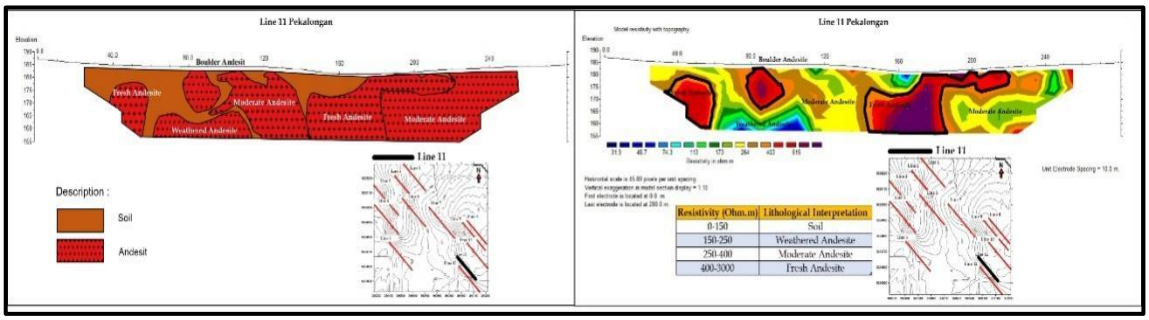

Figure 12. Interpretation and 2D Cross-Section of Line 11

In the last Line, which is Line 12, weathered to fresh andesite rock was identified. The andesite rock in Line 12 was predominantly weathered andesite, followed by fresh andesite, with the least presence of moderate andesite. Line 12 had a depth of approximately 35 meters, a length of 280 meters, and a slope of 7 degrees. The range of resistivity values for the rock in this Line was 11.1–1660 Ωm, classified into several categories: 150–250 Ωm for weathered andesite rock, 250–400 Ωm for moderate andesite, and 400–1660 Ωm for fresh andesite. Additionally, exposed boulder-sized andesite rocks were present on the surface, classified as fresh andesite with a resistivity value range of 400–1160 Ωm.

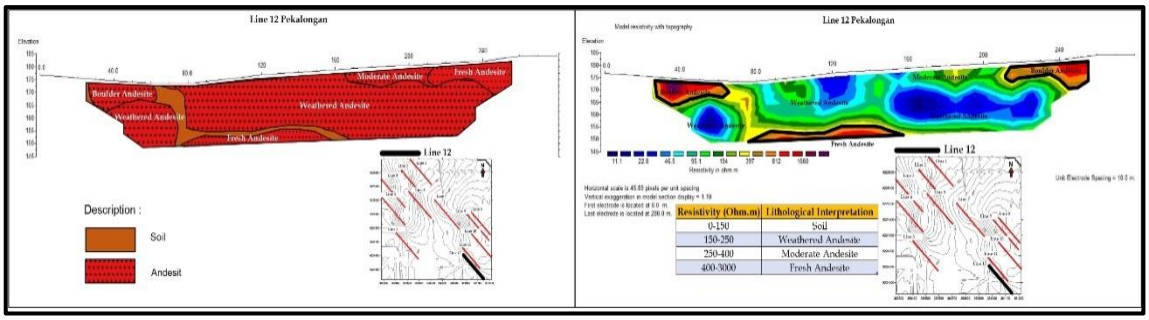

Figure 13. Interpretation and 2D Cross-section of Line 12

CONCLUSIONS AND RECOMMENDATION

Based on the interpretation of data from Lines 1 through 12, the geological composition of the Pekalongan region in Central Java consists of four lithological units: resistivity values ranging from 0 to 150 Ωm are interpreted as soil, 150 to 250 Ωm as weathered andesite, 250 to 400 Ωm as moderate andesite, and resistivity values from 400 Ωm to 3000 Ωm are interpreted as fresh andesite. In some Lines, there are indications of andesite rock intrusions and well-defined boulder-sized andesite..

ADVANCED RESEARCH

This research still has limitations, so it is necessary to carry out further research related to the topic "Andesite Rocks Using Dipole-Dipole Geoelectric Method" to increase insight for readers.

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