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Identification of Geothermal Potential in Block Ciasmara Sector II, Mount Salak Area, Based on the Correlation of Active Directory Magnetotelluric (ADMT) and Self-Potential Methods

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Abstract. *Indonesia possesses significant geothermal potential, with the largest share located in West Java, accounting for up to 21.7% distributed across 44 locations in 11 regencies. One such location with geothermal potential is in Block Ciasmara Sector II, the Mount Salak area, Bogor Regency, characterized by manifestations such as hot spring bathing pools. This research aims to understand the distribution of geothermal reservoirs in the study area, where these reservoirs contain hot fluids that can be harnessed for renewable energy generation. The methodology used in this research involves a correlation between the Active Directory Magnetotelluric (ADMT) and Self-Potential (SP) methods. A total of 3 ADMT measurements were conducted along tracks ranges from 5-8 meters, while the SP method involved 7 measurement points with coordinates distributed around the geothermal manifestations in the Mount Salak area. The data obtained were then visualized in 2D and 3D to gain insights into the distribution and orientation of the reservoir layers in the study area. The results indicate a correlation between the ADMT and Self-Potential methods. In Line 01 of the ADMT, located in the western part, there is a correlation with high potential difference values on the SP map ranges from 47.6-82.1 mV, suggesting the presence of tuff layers rich in alteration minerals. This is confirmed by the 2D ADMT modeling, which shows that the clay cap is thicker compared to Line 02 and Line 03, associated with the presence of alteration minerals in the clay cap. This correlation also applies to Line 03, which has low potential difference values ranges from 4.9-25.3 mV, indicating a response from lapilli rocks. This is corroborated by the 2D model, which reveals thickening of the lapilli rock layer on Line 03.*

Keywords: ADMT, Geothermal, Mount Salak, Reservoir, Self-Potential.

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Introduction

Indonesia is an archipelagic country located in the pacific ring of fire, which gives it access to geothermal energy sources that make up approximately 40% of the world's potential, totaling 29,554 MW. However, the utilization of geothermal energy in Indonesia is only around 7.2%, indicating that geothermal energy has not been fully tapped in the country [1]. With the ongoing population growth each year, which corresponds to an increase in the standard of living, it's essential to address these needs. According to data from the Central Statistics Agency (BPS) and the National Annual Census, from 2000 to 2010, Indonesia's population growth rate reached 1.43% per year, with an average energy consumption increase of 2.73% per year. Therefore, there is a need for the development of alternative and renewable energy sources, such as geothermal energy [2]. Geothermal energy is relatively environmentally friendly for electricity generation compared to other sources like oil, coal, and others [3-4].

Geothermal power plants play a crucial role in Java-Bali region, as they provide a significant supply of electricity to the local communities. Mount Salak Geothermal Power Plant supplies electricity to its surrounding areas, particularly in the Java-Bali region, with a capacity of no less than 180 Mwe [5]. The largest geothermal potential in Indonesia is in West Java, covering approximately 21.7% of the potential, distributed across 44 locations in 11 districts [6]. Mount Salak Geothermal Power Plant consists of three units, each with a capacity of 60 MW. The electricity generated by these three units is transmitted to Bogor 150 kV transmission network for integration with Java-Madura-Bali power system [7].

The research area, located around Pelangi Waterfall, Mount Salak, Bogor, is one of the regions traversed by volcanic activity, resulting in a diverse landscape of volcanic mountains, hills, and valleys. This landscape is indicative of the presence of geothermal prospects, demonstrated by the manifestation of hot spring pools. Some of the energy generated is also used for local consumption [8]. The objective of this research is to determine the distribution of geothermal reservoirs in the Pelangi Waterfall area of Mount Salak, based on the correlation of the Active Directory Magnetotelluric (ADMT), Self-Potential (SP) methods, and mapping geology.

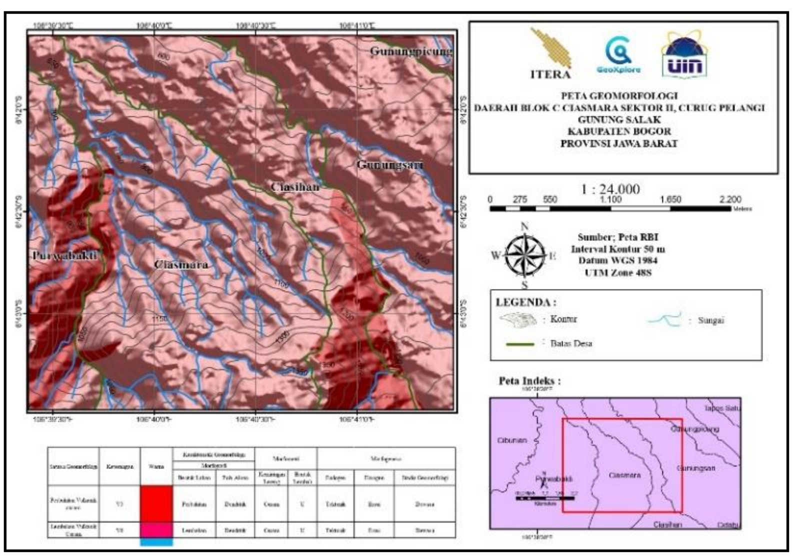

Figure 1. Geomorphological Map of the Research Area

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Theoretical Background

The Geothermal System is a system that stored heat energy called Geothermal the Geothermal energy is a reserve of hot fluids within the Earth's crust and is part of a system known as the geothermal system. This system consists of fluids, reservoir rocks, heat rocks, and overlying rocks [9]. The term "geothermal" is derived from the Latin roots "geo," which means earth, and "thermal", which means heat [10]. Geothermal energy can also be defined as the natural heat generated beneath the Earth's surface [11].

The primary requirements for forming a geothermal system consist of a significant heat source, a heat reservoir, and an overlying rock layer that stores heat. In this hydrothermal system, heat is transferred through conduction and convection [11]. Conduction occurs through rocks, and heat convection happens through the contact between water and the heat source [12]. To find out the subsurface structure of the geothermal area, can use the Self-Potential and ADMT methods.

The Self-Potential (SP) Method

The Self-Potential (SP) method is a geophysical exploration method classified as passive because measurements are taken without injecting electric current into the ground surface. The method involves measuring the natural potential difference of the earth's surface at two points [13]. This method provides data in the form of rock voltage values beneath the Earth's surface. The SP method can detect electrical potentials in flowing fluids [14]. Therefore, SP is useful for geothermal exploration to identify conductive geothermal fluid flow [15].

The results of the self-potential method are closely related to mineral weathering, variations in rock properties, differences in temperature and pressure within subsurface fluids, and other natural phenomena [16]. The application of the Self-Potential (SP) method is suitable for geothermal exploration because geothermal activities beneath the surface create significant SP value contrasts (anomalies) [17].

The Active Directory Magnetotelluric (ADMT) Method

The Active Directory Magnetotelluric (ADMT) method is a passive geophysical exploration method based on electromagnetic values to obtain the impedance variations of each rock layer beneath the surface [18]. Rock impedance values are obtained from the equation:

$$Z_{xy} = \frac{E_x}{H_y} = -\frac{E_y}{H_x} \tag{1}$$

Based on the equation provided, ADMT simultaneously obtains the magnetic field values (H_x, H_y) and electric field values (E_x, E_y) to determine the rock impedance value (Z_{xy}).

The principle of the ADMT method is similar to the magnetotelluric method, where the magnetic field from both MT signal sources (high and low frequency) reaches the Earth's surface and induces currents in the Earth's surface. These currents are known as telluric currents. The image below provides an overview of how the magnetotelluric process works [19].

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Materials and Methods

This geothermal research was conducted in Block Ciasmara Sector II, Mount Salak area, Pamijahan District, Bogor Regency, West Java. Geographically, it is located at 48.683953°E and 9257821°S. Field measurements were carried out from June 2nd to 3rd, 2023, including travel time to and from the research site.

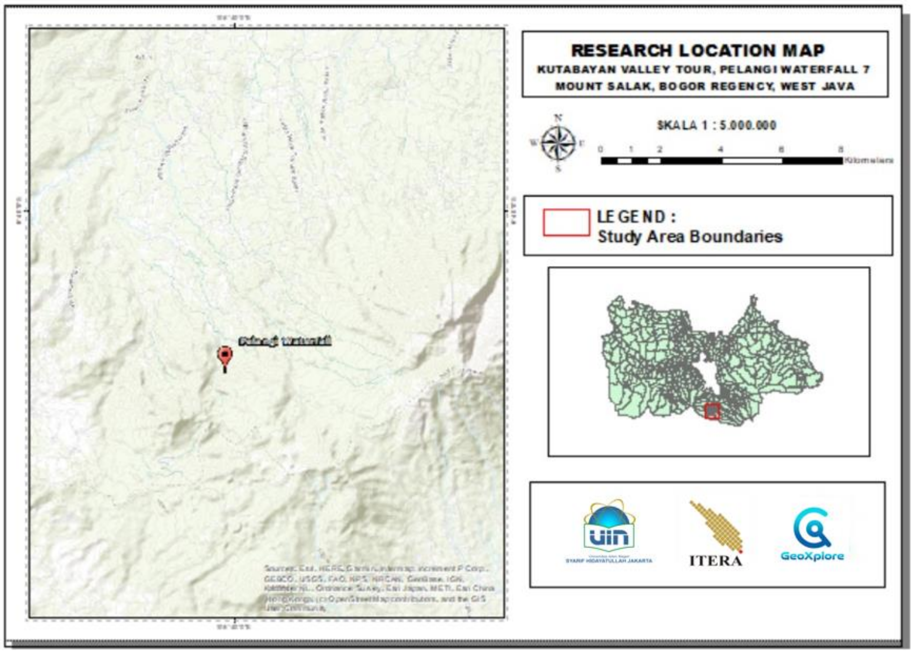

Figure 2. Research Location Map

The research instruments used are hardware devices, including the main tools which is ADMT type 3000HT3, as the field data collection instrument. Next are smartphone, for storing the cross-sectional data from the ADMT method. For the Self-Potential method, the first tools are Digital multimeter, used for measuring voltage. The second is $CuSO_4$ solution, as an intermediary solution that conveys potential difference information from the surface to the copper wire and is then detected by the digital multimeter. And the third and las are Pitcher and Copper Wire us as container for the $CuSO_4$ solution and serving as a catalyst between the $CuSO_4$ solution and the cable.

The number of measurement points carried out in the Ciasmara Block Sector II area, Mount Salak Region, Pamijahan District, Bogor Regency, West Java, is a total of 10 measurement points. These consist of 7 measurement points using the Self-Potential (SP) method and 3 measurement points using the Active Directory Magnetotelluric (ADMT) method.

In the initial phase, the researchers identified the research topic and conducted a literature review on the general conditions of the research area that are relevant to the research topic. Following that, primary data was collected using the ADMT and SP methods, resulting in cross-sectional data. In the final phase, the researchers compiled the data processing results based on

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correlations with ADMT data and geological map data. Then, they drew conclusions to address the research objectives and provided recommendations for future researchers.

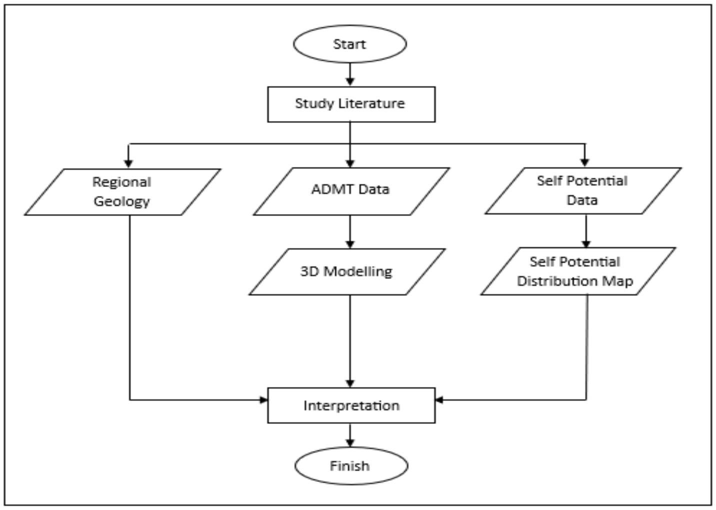

Figure 3. Research Flowchart

Results and Discussion

The Active Directory Magnetotelluric (ADMT) Method

2D ADMT Modeling

In the Line 01 model, it is evident that there are three types of rocks composing the geothermal system of Mount Salak. These include the tuff rock layer exposed at the surface with a depth of 0 to 200 meters, having resistivity values ranging from 105 to 130 Ωm. The clay cap rock layer, which acts as a cap, is found at a depth of 200 to 700 meters, with resistivity values ranging from 5 to 30 Ωm. Finally, the reservoir rock layer accumulates geothermal fluids and is the focus of this study. This reservoir rock is of andesite lithology, located at a depth of 700 to 1000 meters, and it exhibits resistivity values between 65 and 90 Ωm (**Figure 4**).

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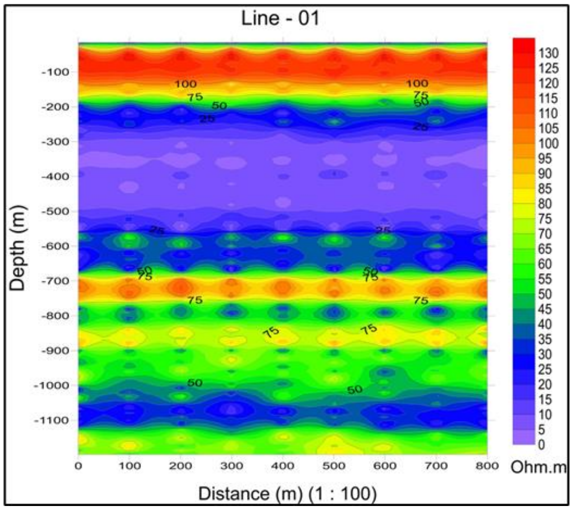

Figure 4. 2D ADMT Model Line 1

In the Line 02 model, it is evident that there are three types of rocks composing the geothermal system of Mount Salak. These include the tuff rock layer exposed at the surface with a depth of 0 to 250 meters, having resistivity values ranging from 105 to 130 Ωm. The clay cap rock layer, which acts as a cap, is found at a depth of 200 to 700 meters, with resistivity values ranging from 5 to 30 Ωm. Finally, the reservoir rock layer accumulates geothermal fluids and is the focus of this study. This reservoir rock is of andesite lithology, located at a depth of 700 to 950 meters, and it exhibits resistivity values between 65 and 90 Ωm (**Figure 5**).

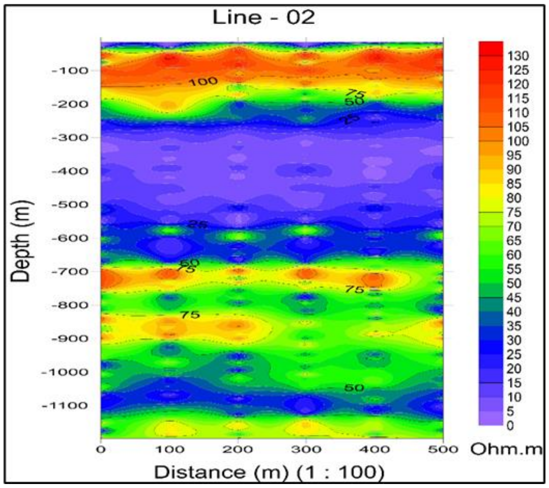

Figure 5. 2D ADMT Model Line 2

In the Line 03 model, it is evident that there are three types of rocks composing the geothermal system of Mount Salak. These include the tuff rock layer exposed at the surface with a depth of 0 to 250 meters, having resistivity values ranging from 105 to 130 Ωm. The clay cap rock layer, which acts as a cap, is found at a depth of 200 to 700 meters, with resistivity values ranging from 5 to 30 Ωm. Finally, the reservoir rock layer accumulates geothermal fluids and is the focus of this

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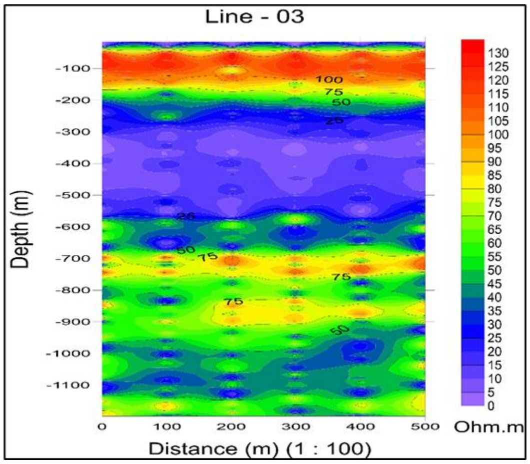

Figure 6. 2D ADMT Model Line 3

3D ADMT Modeling

In the 3D models of Line 01, Line 02, and Line 03, it is evident that the three layers, namely tuff, clay cap, and reservoir, exhibit continuity towards the west (**Figure 7**). In the isosurface layer model with a parameter of reservoir resistivity value at 90 Ωm, it is apparent that the reservoir layer, the main target, continues to the west of the research area (**Figure 8**).

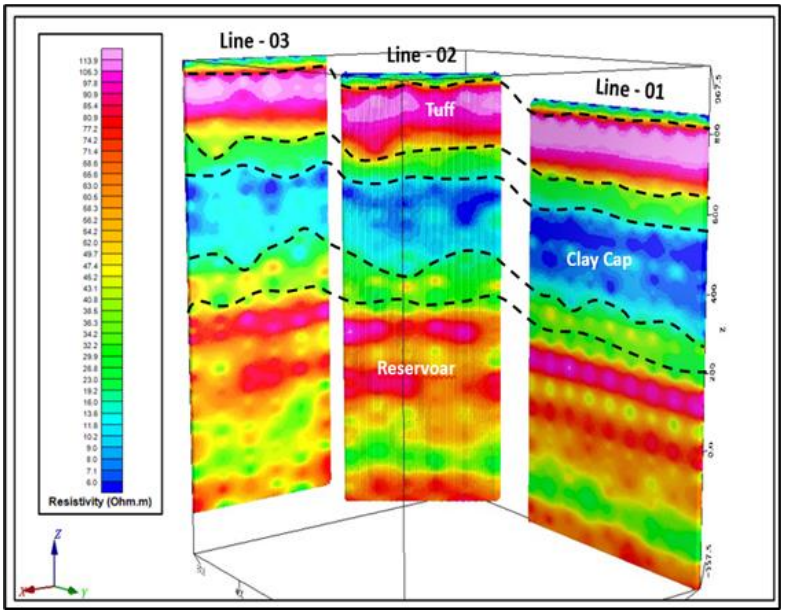

Figure 7. 3D ADMT Model

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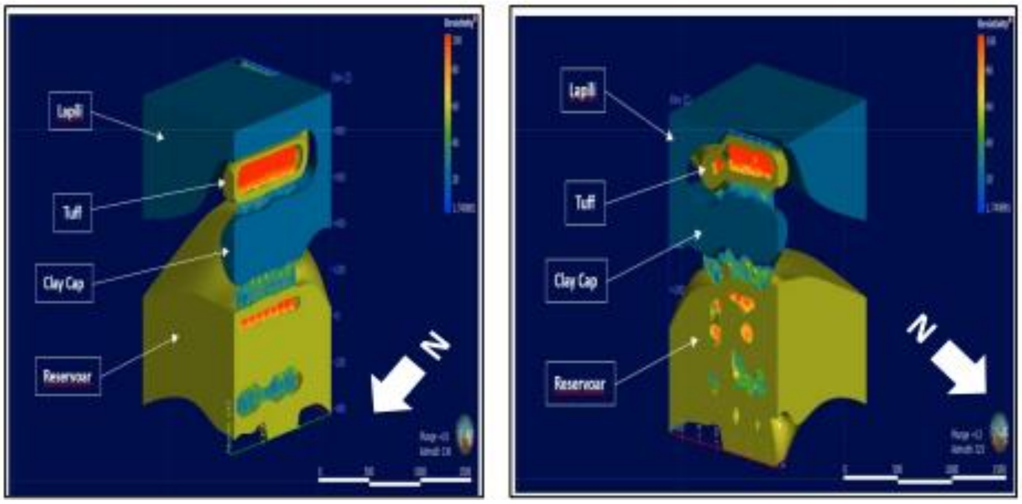

(a) (b)

Figure 8. 3D Isosurface ADMT Model (a) East View (b) West View

3D ADMT Modeling

The measurement points for this method were conducted around the hot spring pool, with a total of 7 measurement points. On the SP map, the distribution of potential difference values in the research area ranges from 4.9 to 82.1 mV. In the southeastern part of the research area, potential difference values range from 4.9 to 25.3 mV, suggesting a response from lapilli rocks. In the central part of the research area, potential difference values range from 25.3 to 47.6 mV, indicating a potential interlayer between tuff and lapilli rocks. In the western part of the research area, potential difference values range from 47.6 to 82.1 mV, suggesting the presence of a tuff layer rich in alteration minerals (**Figure 9**).

Self-Potential Modeling

Measurements for this method were conducted around the hot spring pool at a total of 7 measurement points. On the Self-Potential (SP) map, there is a distribution of potential difference values in the research area ranging from 4.9 to 82.1 mV. In the southeastern part of the research area, potential difference values range from 4.9 to 25.3 mV, suggesting a response from lapilli rocks. In the central part of the research area, potential difference values range from 25.3 to 47.6 mV, indicating a potential interlayer between tuff and lapilli rocks. In the western part of the research area, potential difference values range from 47.6 to 82.1 mV, suggesting the presence of a tuff layer rich in alteration minerals (**Figure 9**).

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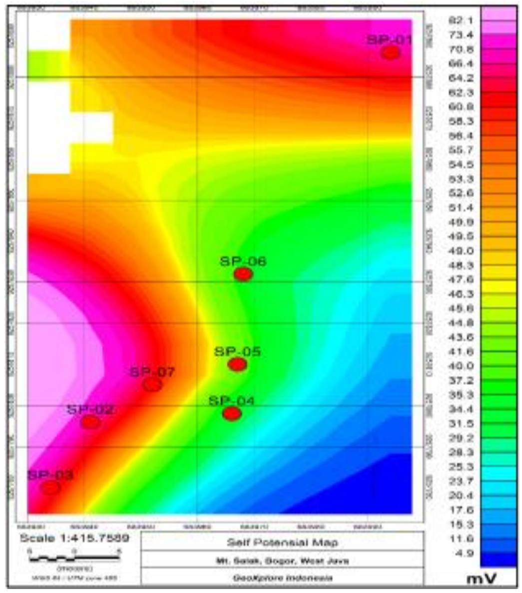

Figure 9. Map of Self-Potential Values Distribution

Correlation of Self-Potential and ADMT Methods

The results below represent the correlation between the distribution of Self-Potential values at the research site and the 2D ADMT cross-sections. It can be observed that in Line 01, which is to the west of the research area, there are very high Self-Potential values ranging from 47.6 to 82.1 mV, suggesting the presence of a tuff layer rich in alteration minerals. This is confirmed by the 2D ADMT model, where it is apparent that the clay cap is thicker compared to Line 02 and Line 03, which is associated with the presence of alteration minerals in the clay cap. The same correlation can be observed in Line 02 and Line 03, which are associated with Self-Potential values in their vicinity. In Line 03, there is a location with low Self-Potential values ranging from 4.9 to 25.3 mV, suggesting a response from lapilli rocks. This is confirmed by the 2D model, which shows the thickening of the lapilli rock layer compared to Line 01 and Line 02 (**Figure 10-12**).

This ADMT and Self – Potential modelling and correlation are located at the center of Ciasmara Hotspring with over 90 °C and based on this modelling implicates there are high potential of geothermal in this area

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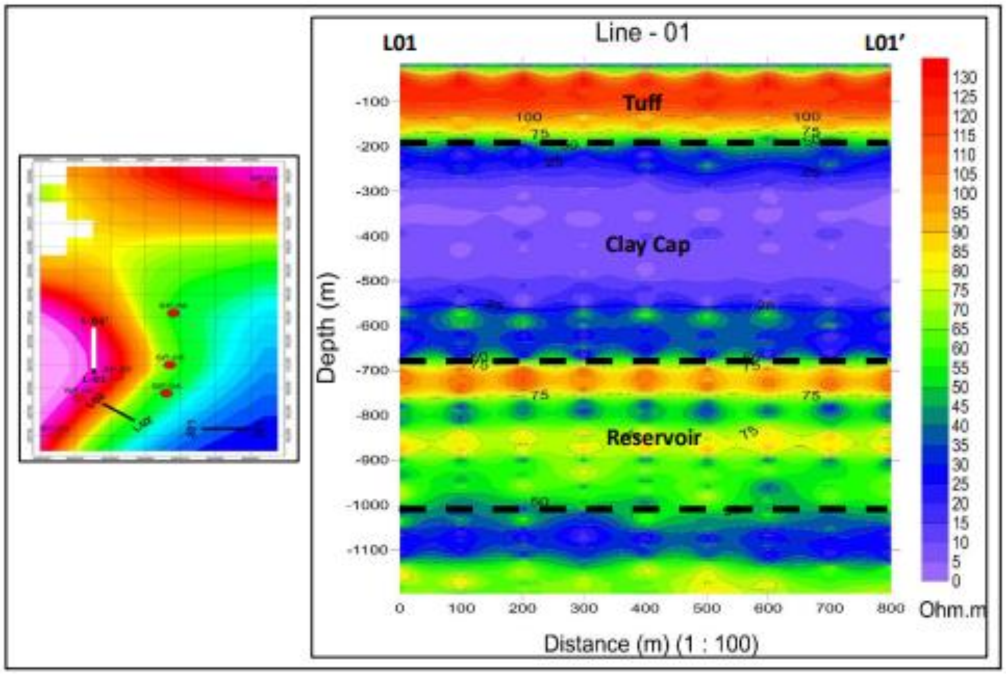

Figure 10. Correlation of Self-Potential Map with 2D ADMT Model Line – 01

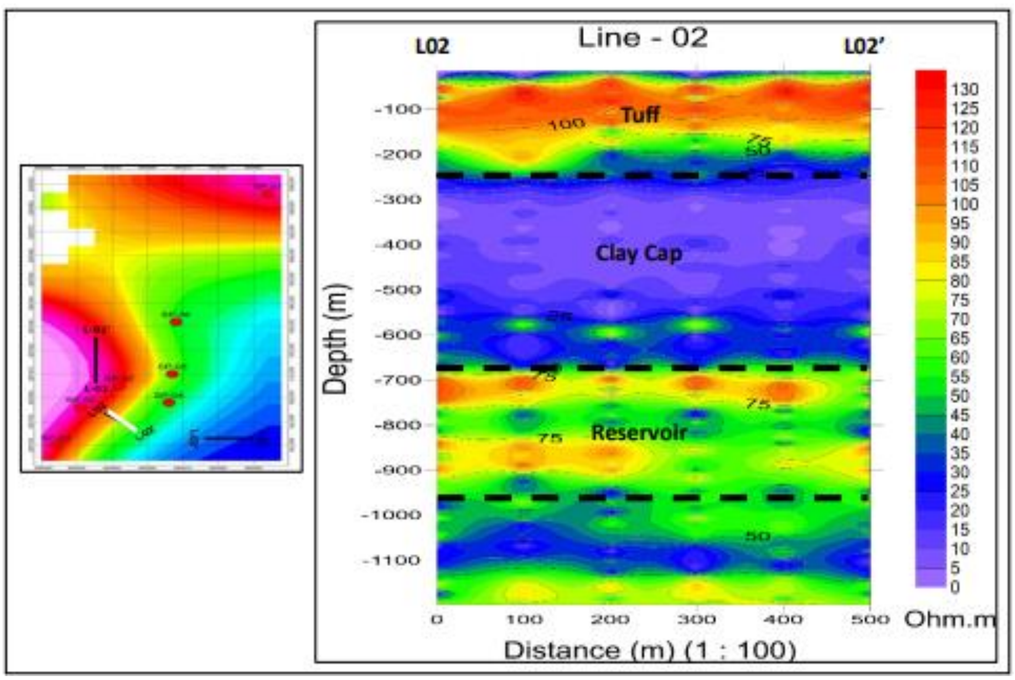

Figure 11. Correlation of Self-Potential Map with 2D ADMT Model Line – 02

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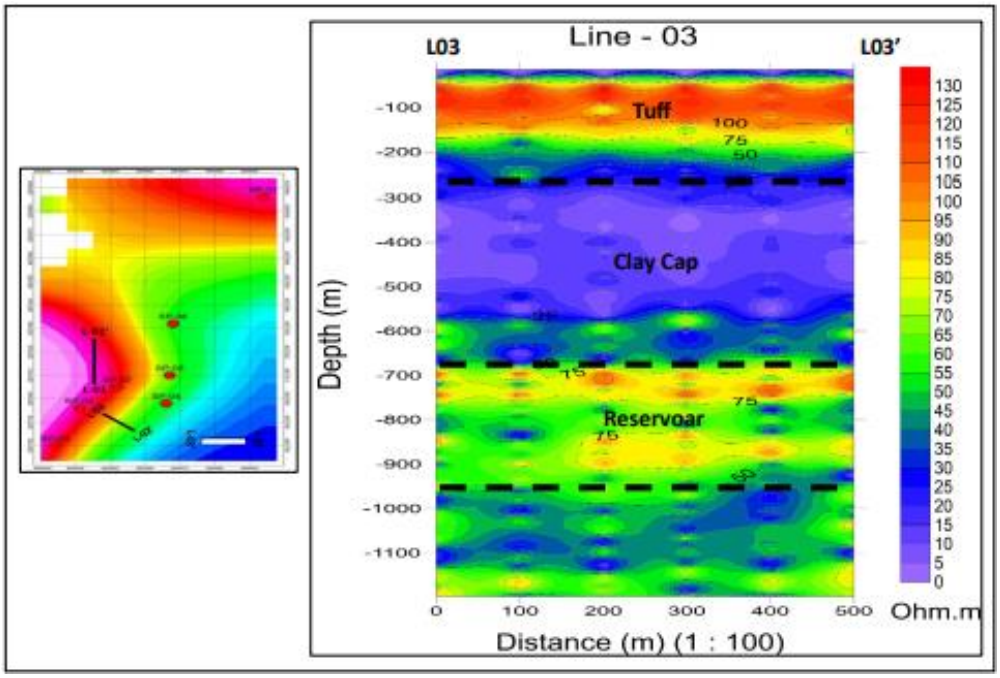

Figure 12. Correlation of Self-Potential Map with 2D ADMT Model Line – 03

Conclusions

The correlation between the ADMT and Self-Potential methods reveals that ADMT Line 01, located in the western part, correlates with high potential difference values on the SP map from 47.6 to 82.1 mV, indicating the presence of tuff layers rich in alteration minerals. This is confirmed by the 2D ADMT modeling, which shows that the clay cap is thicker compared to Lines 02 and 03, associated with the presence of alteration minerals in the clay cap. This correlation also applies to Line 03, which has low potential difference values from 4.9 to 25.3 mV, likely due to a response from lapilli rocks, as confirmed by the 2D modeling showing the thickening of the lapilli layer on Line 03. Based on ADMT and Self-Potential modelling and correlation implicates there are new potential and high temperature geothermal area with an average depth of 700 to 1000 m with the manifestation temperature around 90 °C.

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