Jurnal Fisika 14 (1) (2024) 30-36

Jurnal Fisika

https://journal.unnes.ac.id/nju/index.php/jf/index

Identification of Hydrothermal Reservoirs Using the Dipole-Dipole Configuration Geoelectric Method in Air Putih Village, Lebong Regency, Bengkulu

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Article Info

Article History:

Received:
28 August 2024

Accepted:
23 September 2024

Published:
29 September 2024

Keywords:
Hidrotermal, Geolistrik, Dipole-Dipole.

Abstract

This research was conducted in Lebong Regency, Bengkulu Province, where the Ketahun-segmented faults intersect. Using geoelectric data, this study was carried out to identify the distribution of hydrothermal reservoirs, the dipole-dipole method was used because it obtained more data so that it could see the potential distribution of hot water and subsurface constituent rocks in more detail, the results of the analysis were obtained from processing using a resistivity value RES2DINV of 6.66 - 23.5 Ω.m which is suspected to be a source of geothermal heat, rock formations that are considered related to hot springs Air Putih Village is located at (72.4 - 120) meters with a depth of (0.5 -18) meters. The rock layer has a resistivity value (6.6 – 23.5 Ω.m) which is characteristic of hot water because it has low specific resistance and is perpendicular to the hot spring. The existence of this weak zone indicates that the porosity will increase, causing hot water to emerge from the subsurface as a geothermal manifestation, the uneven distribution of hydrothermal in the research area is caused by uneven constituent rocks, based on the geological map in the research area is dominated by the Hulusimpang Formation with the presence of intermediate rocks in the form of andesite, and felsic rocks in the form of tuff. has rocks composed of sedimentary rocks, sand, clastics, and silt which are permeable rocks, then trapped conus water in the sedimentation process. This research is recommended to develop the potential of hot spring tourism in Air Putih Village, Lebong.

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p-ISSN 2088-1509

INTRODUCTION

The earthquake split the land of Sumatra Island into two parts. This strait stretches from the north of the Andaman Sea to the south of the Semangko Bay (Putri and Annisa, 2021). Along 1,900 km, the Sumatra fault is divided into 19 segments, ranging from 60 km to 200 km. The oblique fault activity is caused by the subduction and convergence between the Indo-Australian and Eurasian plates with a collision direction of 10°N–7°S (Mahardhika et al., 2020). The formation of hot springs is one of the movements of tectonic plates (Sumigar et al., 2020). Hot springs occur due to a geothermal system underground that heats water as a result of geological activities such as volcanism and tectonism. This hot water then rises to the surface and becomes a hot spring (Zakina, Haya and Madi, 2023). One of the areas in Lebong Regency Bengkulu Province, that has a fault zone (Mukazairo et al., 2020).

Hot springs that rise to the surface indicate that geothermal heat has developed beneath the surface as a result of geological activities such as volcanism and tectonism. This activity heats the water and causes it to rise to the surface, creating a hot spring. A volcano is a source of geothermal heat (Metcalfe, 2018). The rock formations indicate that hot water flows through permeable rocks. The differences in the characteristics of rocks in hot water channels and heat transfer affect the properties of hot springs (Covington et al, 2011). The temperature in geothermal systems can significantly affect the resistivity value of a rock. The resistivity value of rocks depends on geothermal conductivity, so the resistivity value is minimized as much as possible (Han et al., 2024). The resistivity geoelectric method is useful for geothermal exploration because the resistance to hot water in rocks decreases drastically at high temperatures and thermal activity can alter the minerals in the rocks (Ali et al., 2021).

The characteristics of geothermal energy are determined by the presence of hot water sources, steam flows, hot mud, sulfur sublimation, and rocks that have been eroded due to heating by hydrothermal fluids. Steam and hot water also rise to the surface through the cracks in the rocks (Dickson et al, 2013). Therefore, geothermal energy potential must be considered in heat generation and based on the stratigraphic characteristics beneath the Earth's surface, which depend on the methods used (Farid et al., 2023). The resistivity geoelectric method can be used to determine the characteristics of hot water sources. The subsurface structure is depicted based on its resistivity values (Nurseto et al., 2021). In the resistivity geoelectric method, the arrangement of electrodes is known as the electrode configuration. Some commonly used configurations include the Wenner configuration, Schlumberger, Wenner-Schlumberger, dipole-dipole, and pole-pole. Each configuration has a different way of placing current and potential electrodes, which affects the measurement of subsurface resistivity (Saputra et al., 2020).

Because the resolution in the subsurface area has a low resistivity value, the geoelectric method with a dipole-dipole configuration was chosen (Nyabeze et al., 2018). This is because, when compared to the Wenner Alpha, Wenner-Schlumberger, and dipole-pole configurations, the dipole-dipole configuration provides more data, resulting in a larger cross-section (Puluiyo and Tongkukut, 2018). Rock formations have different resistivity values. The dipole-dipole configuration consists of four electrodes (two current electrodes and two potential electrodes) to enhance the subsurface imaging of vertically penetrating objects (Putra and Malik, 2021). This research was conducted on a single line with a dipole-dipole configuration, measuring 240 meters in length and with an electrode spacing of 3 meters. The obtained data was then processed using Res2Dinv software, which produced a 2D resistivity image. Based on the 2D resistivity image from the profile, areas with depths ranging from 4.08 to 23.5 meters and relatively low resistivity (<6.66 Ωm to 23.5 Ωm) were identified as hydrothermal zones. The dipole-dipole configuration has a penetration of up to about 20% of the total length of the cable used. This configuration is very suitable for detecting vertical structures because it offers the highest resolution, allowing for a deeper identification of details from the subsurface layers (Harman et al., 2017).

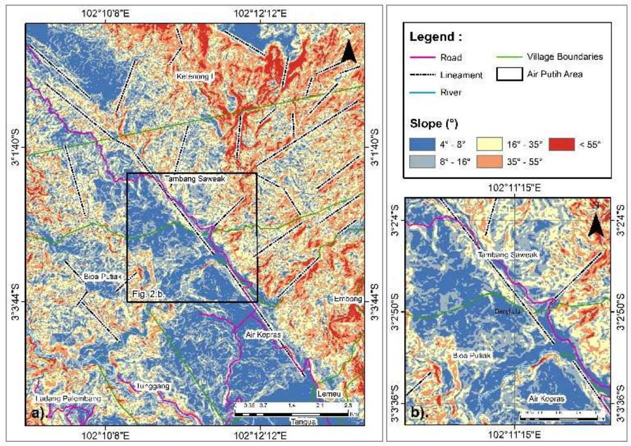

Figure 1. Geological Map of Pinang Belapis District.

The research was conducted in the Pinang Belapis District Lebong Regency, Bengkulu Province. Geographically, the research location is situated at coordinates 20° 59' 59.7" S and 102° 09' 40.3" E as well as 30° 04' 53.4" S and 102° 14' 31.8" E, within the tectonic region of the Fore Arc of Sumatra. Based on the Geological Map, this area includes five rock formations dominated by Tertiary-aged volcanic rocks. The research area is located in the Ketaun Fault Segment, which is oriented northwest-southeast (NW-SE), is a right-lateral strike-slip fault and is part of the Sumatra Fault Zone (Oktariana Mia et al., 2021).

METHOD

This study was conducted in the hot spring tourist area of Air Putih Village, located in the Pinang Belapis District, Lebong Regency, Bengkulu Province. The preliminary survey was conducted to gain a deeper understanding of the area used in the research. Determining the research method, location and elevation of the research area, distance and points between electrodes, and coordinates of the research area. The resistivity geoelectric method used to collect data in the field has a span length of 240 meters and an electrode spacing of 3 meters. During the data collection process, two current electrodes are embedded in the ground to conduct electric current from the battery into the soil, which causes voltage to appear within the ground. To measure the voltage, a multimeter is connected to the resistivity meter. After the data is collected, data processing is carried out using RES2DINV. The distribution can be interpreted based on the color images and the differences in resistivity. hot areas of the Earth beneath the surveyed area.

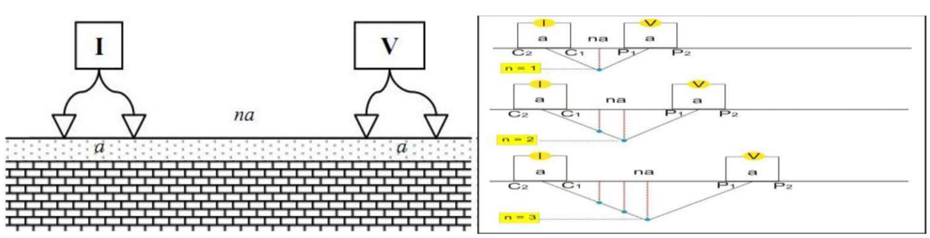

Figure 2. Spacing between electrodes in a dipole-dipole configuration. (Hutagalung and Malik 2021)

The potential at points P1 and P2 can be calculated using the equation.

$$V_{r1=}\frac{\rho I}{2\pi}\left(\frac{1}{r1}-\frac{1}{r2}\right)$$

$$Vr2=\frac{\rho I}{2\pi}\left(\frac{1}{r3}-\frac{1}{r4}\right) \quad (1)$$

The values of the geometric factor configuration of the dipole-dipole are:

$$\pi an\ (n+1)\ (n+2 \quad (2)$$

so that the resistivity of everything becomes

$$\rho a=\frac{\Delta V}{I}\pi an(n+1)\ (n+2) \quad (3)$$

RESULTS AND DISCUSSION

The apparent resistivity value (ρ a) can be calculated by measuring the potential difference (ΔV) and the electric current (I) using a dipole-dipole configuration with a path length of 144 m. This value is then input into the Res2Dinv software to obtain the true resistivity. This software allows you to view the lithology of the subsurface layers as well as the types of rocks present within them.

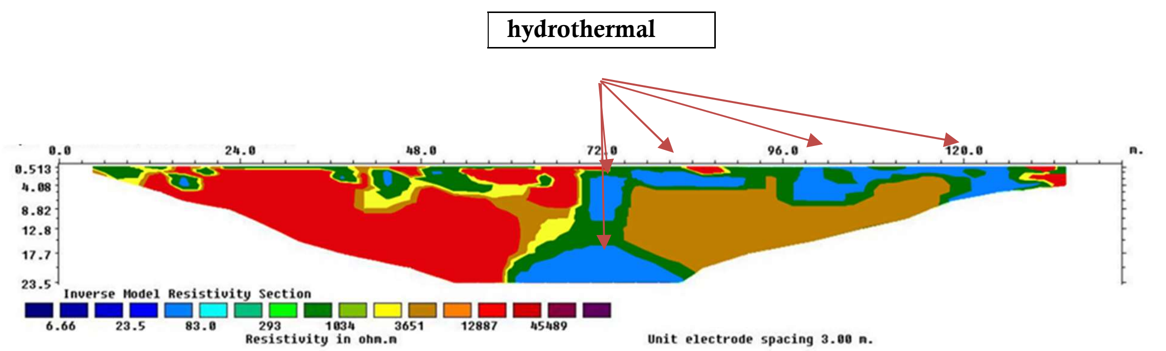

Figure 3. 2D resistivity cross-section.

Table1. Interpretation resistivity value 2D Geoelectric Configuration Dipole-Dipole

Resistivity (Ω.m)	Lithology
6.66 Ωm – 23.5 Ω.m	Hydrothermal
83.0 Ω.m	Mud Sand
293 Ω.m	Tuf
1834 Ω.m	Granite Rock
3,651 Ω.m – 45,489 Ω.m	Volcanic Rocks

Magma inside the Earth is a source of geothermal heat and conductive magma can transfer heat to the surrounding rocks. Then the heat generated causes the pores of the rocks to be filled by the convection flow of hydrothermal fluids. Because the impermeable rock layer holds it back, the hydrothermal fluid will move upward. The impermeable layer separates the hydrothermal fluid in the geothermal reservoir from the groundwater. The groundwater reservoir is shallower. However, it has not yet been confirmed that the heating of the bedrock produces hot water (magma) within it. The hot water flow arises due to fractures in the rocks. According to measurements from geological data and geological maps of the research location, it has a rock formation consisting of sedimentary rocks, sand, clastic rocks and siltstone. This research only covers one aspect as it sufficiently addresses what has been studied. This path shows a striking anomaly with resistivity values that are quite low (<6.66 Ω.m – 23.5 Ω.m), indicated by the dark blue color. This low resistivity value is believed to be associated with a hot water source. The lower the resistivity value, the higher the conductivity of a material. As temperature and pressure increase, the resistivity of the rock decreases (become more flexible). At a depth of 4.08 – 23.5 m, most of it is identified as hydrothermal, but the high resistivity value of 45,489 Ω.m is believed to be the formation rock of Hulusimpang and volcanic rock. The Hulusimpang formation itself consists of mountain breccia lithology, lava, tuff, arranged in basaltic andesitic composition and limestone. According to the interpretation results of Figure 3.1 the rock formation associated with the hot water source in Air Putih Village is located at a depth of (72.4 - 120) meters, with a thickness of (0.5 - 18) meters. The rock layer has a resistivity value (6.6 – 23.5 Ω.m), which is characteristic of hot water due to its low resistance and is perpendicular to the hot water source. It is suspected that the layer believed to carry hot water, which appears yellow and has a wide resistivity range, is a type of rock layer that indicates the presence of hot water in the underground structure. This is because it represents a weak point indicated by a resistivity value (6.66 Ω.m – 23.5 Ω.m). Despite this weak point, its porosity is higher, allowing hot water to flow out from below. This research is recommended to develop the potential and enhance the appeal of the community regarding the geothermal resources that emerge to the surface at the hot spring tourist site in Air Putih village, Lebong.

CONCLUSION

From the analysis, the resistivity value of 6.66 – 23.5 Ω.m shown in dark blue indicates the presence of geothermal sources, with hot water allegedly surfacing due to fractures, so that the hot water comes to the surface. Due to differences in the composition of rock formations, hydrothermal distribution in the study area is uneven. Based on the geological map, the research area is dominated by the Hulusimpang Formation with the presence of intermediate rocks in the form of andesite, and felsic rocks in the form of tuff. which consists of sedimentary rocks, sand, clastic material and siltstone.

ACKNOWLEDGEMENTS

I would like to express my gratitude to the entire survey team of Air Putih Village for their contributions to the data collection, and to the Geophysical Laboratory of Bengkulu University for granting permission to use the field survey facilities and software for data processing. I also thank the community and the Head of Air Putih Village, Lebong Regency, for supporting the administrative process and data collection

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