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Identification Lithology of Geothermal Potential Areas Using the Electrical Resistivity Tomography (ERT) Method

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Abstract

The rock lithology of the potential hydrothermal area has been studied using Electrical Resistivity Tomography (ERT) in Pungguk Pedaro Village, Bingin Kuning District, Lebong Regency. Field data acquisition uses a stretch length of 480 meter with the MAE X612-EM Geoelectric tool that forms a straight line. ERT method, using Res2dinvx64 software. The study aims to determine the subsurface conditions of the potential hydrothermal area and the characteristics of the rocks that make up the hydrothermal area. The results of this study can be concluded that Pungguk Pedaro Village is dominated by clay, sandstone, sandy gravel, andesite, basalt, and granite rocks. In this study, measurements were taken with six lines to see variations in resistivity values as a reference for identifying potential geothermal lithologies. There is 1 line that cuts to five lines to validate the resistivity value of each line. Line 1 has no potential for hydrothermal distribution because there has been a mixture of hydrothermal water with mountain water, so this line will only provide groundwater.

Keywords: ERT; Hydrothermal; Lebong Regency; Lithology; Wenner.

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Introduction

Geothermal energy is energy generated by the penetration of high-temperature water confined to the earth's surface at high temperatures for a long time. Geothermal energy is closely related to geothermal systems (Afandi et al., 2013).

Indonesia is one of the countries with great potential for geothermal resources. The government is developing this enormous potential to meet the country's energy needs. Based on the latest survey data from the geology, at the end of 2009, Indonesia had 265 geothermal sites resulting from volcanic and non-volcanic processes.

This situation is closely related to Indonesia's geological position at the meeting zone of three major world plates: the Indo-Australian, Eurasian, and Pacific plates, which are responsible for forming volcanoes in Indonesia (Chaidir et al., 2021).

The potential geothermal energy in Indonesia is abundant. This is inseparable from the geography of Indonesia, which is located on the Pacific Rim. This energy spreads over Sumatra, Java, Bali, Flores, North Sulawesi, and Maluku with 312 potential points. With a resource wealth that reaches 40% of the world's resources, Indonesia has the most extensive geothermal potential in the world, with a potential of more than 23.9 gigawatts

(GW) or 29 Gwe (Nurwahyudin & Harmoko, 2020).

Barrett (2013) define geothermal resources as the earth's stored heat that can be used in the future for power generation or other suitable industrial, agricultural, or domestic uses. Inadequate geological conditions can make geothermal energy expansion uneconomical in many places. The existence of geothermal potential is indicated by manifestations, such as hot springs, fumaroles, and altered rocks, caused by tectonic activity that causes faulting and allows fracture zones to exist (Tarmidzi & Setyawan, 2014).

The geothermal system includes a water system, a heating process, and system conditions under which water is heated (Basid et al., 2014). Geothermal systems include the water system, the heating process, and the conditions under which the heated water is collected. So, the geothermal system has requirements such as the availability of water, heating rock, nest rock, and cover rock (Vargemezis, 2014).

Water generally comes from rainwater or meteoric water. Hot rocks will serve as a source of hot water, which can be granite masses or other forms of batholith (Karaman, 2013). The heat generated by active fault movement is also sometimes used as a heat source, such as hot springs along active fault lines (Hidayat et al., 2021).

The potential geothermal areas are at Bengkulu Province, Bingin Kuning district, Lebong Regency, and Pungguk Pedaro village. The existence of geothermal energy is subject to secondary permeability in the form of annual faults. These faults direct hot fluids from the reservoir to the surface through hot springs, rock formations, and fumaroles (Abdillah & Malik, 2021). The rock geology of the region consists of granite, andesite, and basalt. The hydrothermal zone of Toyokuni Pedaro hot springs is also closely related to magmatic activity in the Barisan Hills (Raihana et al., 2023).

Previous research on geothermal in Lebong regency has been conducted by Fathan (2013) and Gafoer & Amin (2007). The results were obtained in the form of most of the fluid sourced from reservoirs, and some have experienced interaction with sedimentary rocks. This study aims to determine the lithology of potential geothermal areas in Lebong Regency that are thought to originate from Bukit Daun. Therefore, further research needs to be done to look if the lithology of this potential geothermal area has the potential for geothermal exploration so that it can be exploited in Pungguk Pedaro village, Bingin Kuning District, Lebong Regency, Bengkulu Province.

In geothermal reservoirs, lithology is very important to consider as it allows us to identify zones with geothermal potential (Erwin, 2016)).

Electrical Resistivity Tomography (ERT) is one of the most effective geophysical methods to map subsurface conditions and determine the lithology of the study area . This method aims to study the variation of rock resistivity under the earth's surface, both vertically and horizontally (Pitulima & Siregar, 2016). This method produces a two-dimensional profile of the resistivity pattern in the subsurface and describes the vertical and horizontal (2-D) variations in the layered structure of the subsurface resistivity (Railasha et al., 2015).

Regional Geology

The study area is structurally located in the forearc basin of the Bengkulu Basin. Neogene sediments were influenced by the tectonic evolution of the bay (Yulihanto, 1995). Sapiie et al. (2015) argues that Bengkulu Basin sedimentation is also influenced by the activity of right-lateral strike-slip fault systems called the Mentawai Fault Zone (MFZ) and the Sumatra Fault Zone (SFZ). Therefore, fault activity is believed to influence basins' formation and sedimentary processes in basins. In the late Oligocene, the Hulusimpang Formation (Tomh) was deposited by Eocene to early Oligocene volcanic facies.

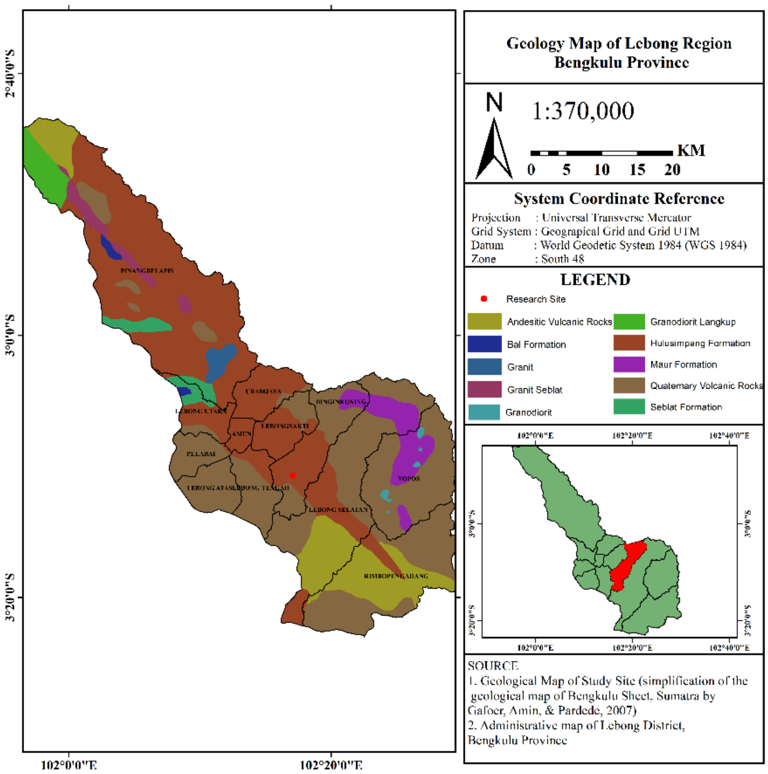

Figure 1. Geology Map of Lebong Region (Gafoer & Amin., 2007).

Materials and Methods

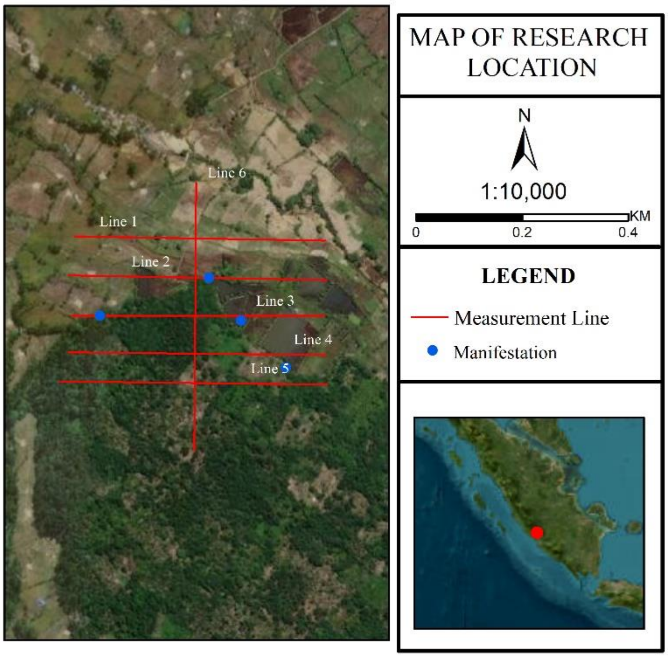

Figure 2. Map of research Location.

The study site is geographically located at the latitude and longitude coordinates (3°10'41.19" LS and 102° 17'4.98" BT). This study uses an MAE X612-EM geoelectric tool in Punguk Pedaro Village, Bingin Kuning District, Lebong Province field data collection Pungguk Pedaro with a line length of 480 meters. The measurement line takes the form of a line or a straight line by adjusting the conditions of the measurement area Pedaro Village, Bingin Kuning District. Therefore, there is 1 line that cuts five lines to validate the value of each line. The results of field measurements are in the form of 2D models, which are processed with Res2DInv.

Results and Discussion

Table 1. Resistivity value of the rock (Telford & Geldart, 1931).

Material	Resistivity (Ωm)
Air	~
Pyrite	0.01–100
Quartz	500–800000
Calcite	$1x10^{-12}$–10^{13}
Rock salt	30 – 10^{13}
Granite	200 – 10000
Andesite	$1.7x10^{2}$ – $45x10^{4}$
Basalt	200 – 1000000
Limestone	500 – 10000
Sandstone	200 – 8000
Shales	20 – 2000
Sand	1 – 1000
Clay	1 – 100
Ground water	0.5 – 300
Sea water	0.2
Magnetite	0.01 – 1000
Dry Gravel	600 – 10000
Alluvium	10 – 800
Gravel	100 – 600

Electric charge cross sections were obtained from processing resistivity geoelectric data (Pratama & Rustadi, 2019) from the field using Res2Dinvx64 software. The Wenner - beta configuration resistivity geoelectric method accepts a subsurface cross-section in 2 dimensions: the resistivity cross-section (Amir et al., 2017). Interpretation of 2D geoelectric data uses the table of resistivity values by Telford & Geldart (1931) (Table 1) and adjusts to the geological conditions of the data collection location.

Table 2. Interpretation in each line site.

Site	Resistivity (Ωm)	Lithology
Line 1	3.71	Groundwater
	7.98	Groundwater
	17.2	Silty Sand
	37.0	Clay
	79.6	Sandstone
	171	Sandy Gravel
	369	Andesite
Line 2	2.14	Hydrothermal
	5.36	Groundwater
	13.4	Tuff
	33.5	Clay
	83.7	Sandstone
	209	Basalt
	523	Andesite
Line 3	1.06	Hydrothermal
	3.01	Hydrothermal
	8.50	Groundwater
	24.0	Clay
	67.9	Sandstone
	192	Sandy Gravel
	542	Andesite
	1532	Volcanic Breccia
Line 4	1.42	Hydrothermal
	3.63	Hydrothermal
	9.25	Groundwater
	23.6	Clay
	60.1	Sandstone
	153	Sandy Gravel
	390	Andesite
	994	Granite
Line 5	1.97	Hydrothermal
	4.86	Hydrothermal
	12.0	Groundwater
	29.6	Clay
	73.0	Sandstone
	180	Sandy Gravel
	444	Andesite
	1097	Granite
Line 6	0.693	Hydrothermal
	1.70	Hydrothermal
	4.53	Groundwater
	12.1	Groundwater
	32.3	Clay
	86.1	Silt-Clay
	230	Andesite
	613	Granite

The source of geothermal energy is magma all over the earth. Magma transfers heat to surrounding rocks (Erwin, 2016). This heat also causes hot water convection within the pores of stones and rocks. This hot water then moves upwards but is blocked by rock formations and does not reach the surface (Putriutami et al., 2014). This is because impermeable rock layers surround the character. Impermeable layers separate the hydrothermal and groundwater within the geothermal reservoir (Widiatmoko, 2019). The reservoir is isolated from shallow groundwater. So far, however, it is still being determined whether that hydrothermal fluid is from bedrock heating (in the form of magma) below the source point or simply hydrothermal flows from other regions (Suciningtyas et al., 2013). A fissure in the rock through which the hot water flows allows hot water from another area to emerge on the surface. The 2-Dimensional resistivity model can also display topographic data (Riputra & Malik, 2021).

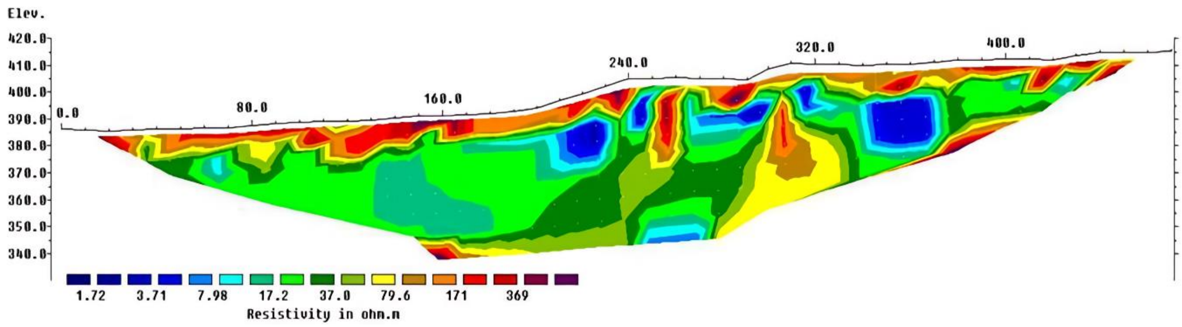

Figure 3. Data processing results of line 1 with topography.

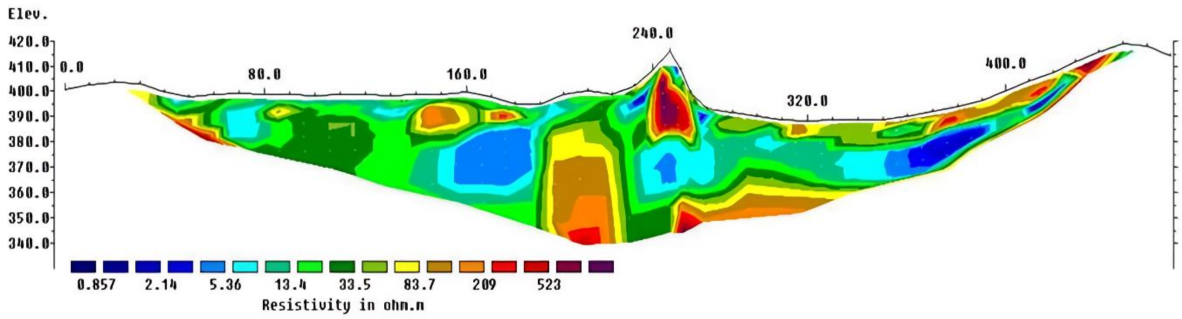

Figure 4. Data processing results of line 2 with topography.

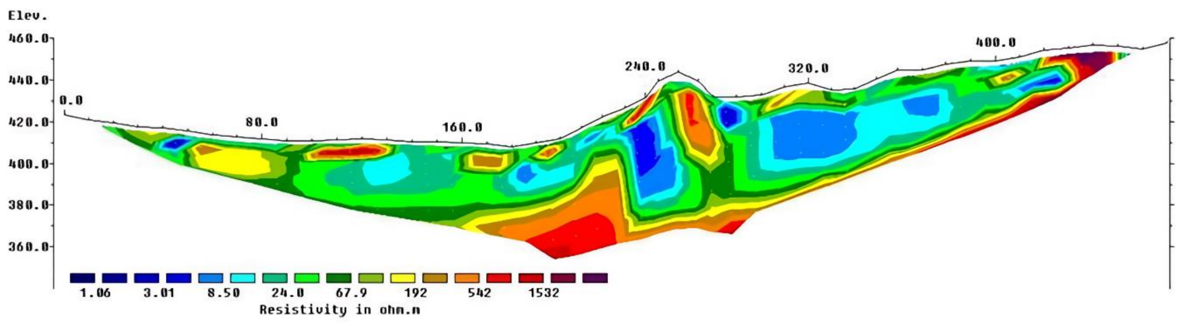

Figure 5. Data processing results of line 3 with topography.

This research was conducted in an area that has hydrothermal potential. This area has a significant perspective for geothermal exploration. This condition requires research to see this area's lithology and geothermal distribution. The results of this research are used as reference material for geothermal exploration, which is then exploited for the benefit of the community and government.

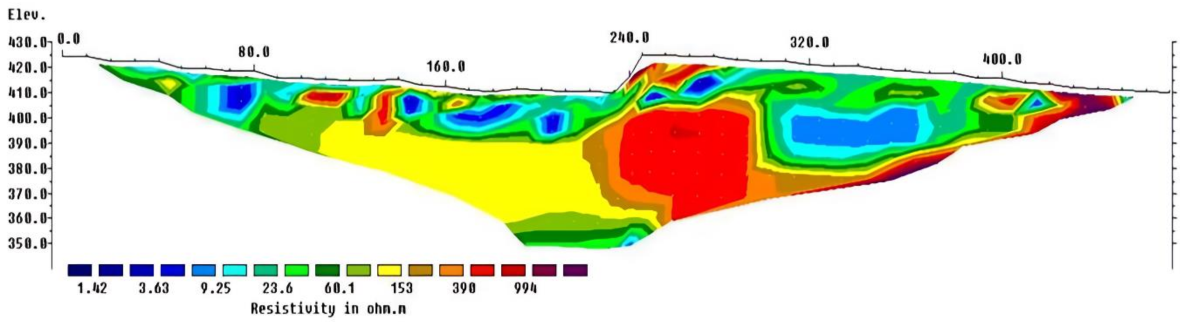

Figure 6. Data processing results of line 4 with topography.

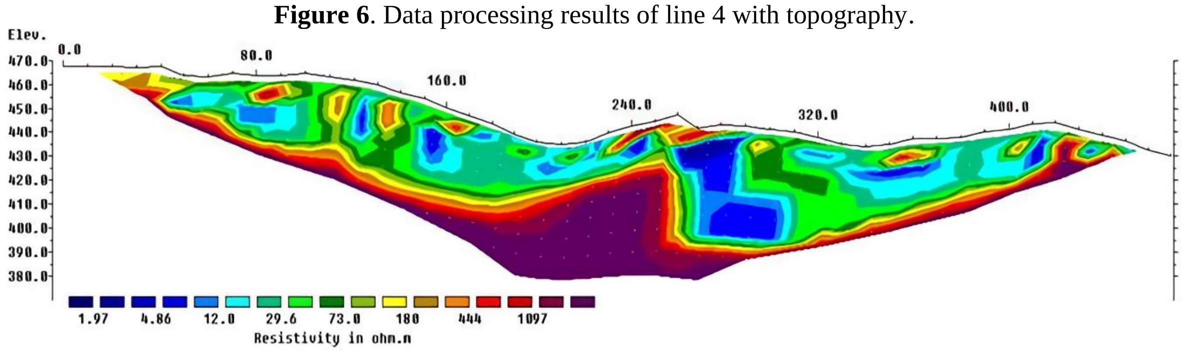

Figure 7. Data processing results of line 5 with topography.

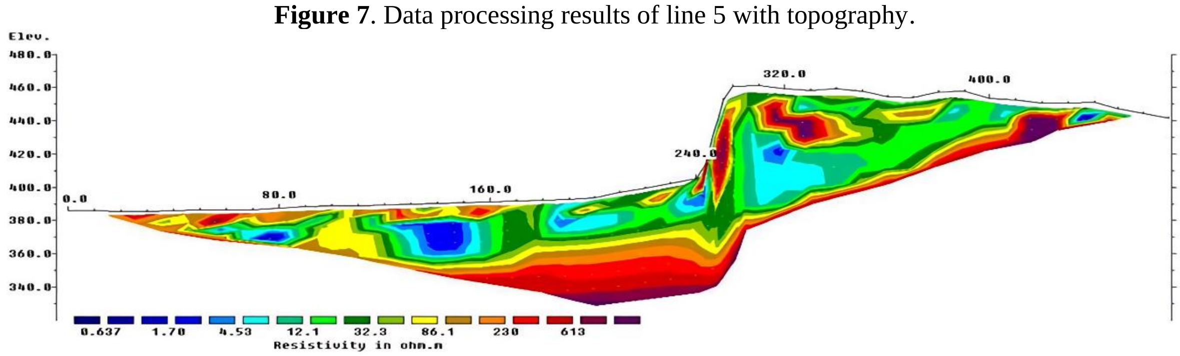

Figure 8. Data processing results of line 6 with topography.

The measurement results in each line with the potential for hydrothermal has a small resistivity value, one of which can be seen in Figure 7. The rock structures dominating this potential hydrothermal area are clay, sandstone, sandy gravel, andesite, basalt, and granite (Telford & Geldart, 1931). This rock type is an andesite-basalt volcanic rock unit, with the formation dominating the Hulusimpang formation. This rock type has low porosity, thermal conductivity, and high permeability (Adli, 2021). After surveying the research site, information was obtained that the hydrothermal potential is in lines 2, line 3, line 4, line 5, and line 6, which have small resistivity values.

In contrast, in line 1 (Figure 3), there is no visible hydrothermal potential because this line is a rice field area. Although it has a small resistivity value, it is groundwater. Line 1 is dominated by silty sand lithology. Although the water in this area is warm, it is water flowing from the hill that has appeared hydrothermal manifestations. The results of each 2D lithology on line 1 (Figure 3), line 2 (Figure 4), line 3 (Figure 5), line 4 (Figure 6), line 5 (Figure 7), and line 6 (Figure 8) are dominated by andesite rocks which are thought to be medium-composition extrusive volcanic rocks with aphanitic to porphyritic textures. Another factor causing hydrothermal is that this area is influenced by the presence of secondary permeability in the form of the Ketahun fault. This Ketahun fault controls the hot fluid in the reservoir to flow to the surface in the form of hot springs, rock alteration, and fumaroles that appear and are also closely related to the magmatic activity in the Bukit Barisan range (Raihana et al., 2023). On line 6 (Figure 8), it made cuts between lines to validate the data of other lines to be more accurate. Line 6 is taken from the bottom of the hill to the top of the slope of the research area to get maximum results. Line 6 has a significant height because line 6 is a cut between hills, between which there are five other lines to validate different resistivity values.

Conclusion

The rock lithology of the hydrothermal area in Pungguk Pedaro Village, Bingin Kuning District, Lebong Regency, using the Electrical Resistivity Tomography (ERT) method, shows that the rock layer structure is an andesite-basalt volcanic rock unit with the Hulusimpang formation. Each line in the study area has an even distribution of hydrothermal potential and similar rock types. Still, those that appear to have considerable potential are seen in several lines. Line 1 has no potential for hydrothermal water with mountain water, so only groundwater is obtained.

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Author Contribution

Compiling this research journal, each writer was divided into several job desks for collecting literature sources and making research survey designs using QGIS by Khairun Nazli, data processing, and journal preparation by Hana Raihana. The observers in the practice of this journal are Suhendra, Refrizon, and Halauddin.

Conflict of Interest

There is no financial or personal relationship between the author and the organization or other parties in this research, so the research results are the author's responsibility.

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