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Identification of Hydrothermal Distributions Using the Wenner-Schlumberger Configuration Geoelectric Method in Lemeu Village, Lebong Regency, Bengkulu

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Abstract

The hot spring pool, Lemeu Village, Lebong Regency, is one of the geothermal fields. This research aims to identify the study area's geothermal potential and lithology. This is illustrated by the correlation method of resistivity and electrical conductivity values of rocks based on geoelectric measurements. This research uses the Wenner-Schlumberger configuration geoelectric method, as many as four tracks spread around the hot spring hill with a length of 480 meters, which are used to see variations in resistivity values that can indicate the presence of hydrothermal potential. The result is a 2D Resistivity model processed with Res2DinvX32 software. Based on the interpretation results, the subsurface rock lithology in each track is relatively similar in color, texture, grain size, and composition because it is around the hill. The Hulusimpang formation consists of clay, silty sand, tuff, andesite, basalt, and granite. Hydrothermal is found on lines 2 and 4 with resistivity values of 7.3 and 10.1 Ωm at a depth of 26 meters. Geothermal potential in the research area is divided into several temperature categories; some have low, medium, and high temperatures. In the research area, tracks 1 and 3 have low temperatures.

Introduction

Indonesia is located on significant world plates, the Indo-Australian, Eurasian, and Pacific plates, which play a role in volcanoes in Indonesia [1]. Geothermal heat can be generated by magmatic activity resulting in subsurface [2]. Parameters for determining geothermal are limited by volcanism, rock, and geothermal structure [3]. Bengkulu Province has highly tectonic activities, volcanoes, hydrothermal systems, geothermal activity, and earthquakes [4]. The formation of volcanoes, intrusions, and faults allows groundwater to be heated instead of sinking downward and meeting magma. There is a gap between groundwater downward, and hot water rises above the surface. This process heats the surrounding rocks, including reservoir rocks that store fluids or water [5]. The heated water moves to the surface through fractures or faults in the structure due to high pressure. The high pressure comes from magma, which has a high temperature, causing hydrothermal emergence on the surface [6].

One of the areas of geothermal potential is Lebong Regency in Bengkulu Province. The geographical location of Lebong Regency is the intersection with the Ketahun Fault, an active volcano called Bukit Daun. The Geothermal heat in Lebong Regency is widely spread in several areas. Lemeu Village in Lebong District is one of the areas with hydrothermal potential in the form of hot springs that gush out of rock, so it becomes hot spring tourism. Previous research has been conducted by Rihana et al. on the study of hydrothermal alteration in the Putih Water Tourism area, Lebong Regency, using the Time Domain Induced Polarization (TDIP) to identify rock alteration in geothermal areas, subsurface structures obtained from resistivity and charge-ability cross sections in 2 dimensions [7]. The characteristics of hydrothermal alteration in the research area are visible: potassic alteration zone, silicate alteration zone, and profiteering alteration zone [8]. In addition, another study by [9] Using the seismic refraction method of geothermal potential to characterize geothermal reservoirs in the Air Putih Tourism area, Lebong Regency shows that hot water comes to the surface due to rock fractures in the subsurface.

An effective geophysical method for detecting geothermal heat is the geoelectric method [10]. The geoelectric method is a measurement method that aims to estimate the resistivity of each type of rock along the measurement trace. The geoelectric method is designed to obtain information from rocks that have anomalous electrical conductivity (resistivity) [11]. The purpose of geoelectric (resistivity) surveys is usually to determine the conditions or structure of subsurface geology based on changes in the resistivity of rocks [12]. Usually, hydrothermal manifestation shows high or low resistivity due to the conductivity of water. Hence, the Wenner-Schlumberger configuration geoelectric method is very effective for imaging hydrothermal potential distribution. It can provide information about variations in resistivity values based on the depth function to describe subsurface conditions. After we measure in the field, we process the data using Res2dinvx32 software. This research proposes to make a model of the subsurface structure in hydrothermal manifestation areas and then identify the lithological composition of rocks in the research area. Knowing the hydrothermal distribution is a crucial step before drilling for geothermal exploitation.

Regional Geology

The geology of the Lemeu Village Baths Tourist Area, Lebong Regency, is generally part of the Sunda-Banda magmatic arc of the Miocene-Pliocene age and is a Bengkulu Basin (arc front) of the Tertiary age. Figure 1 shows the geologic map of the Lemeu Village Basin in Lebong Regency. Figure 1 also indicates rock types ranging in age from Lower Miocene to Holocene. We observe that the Ketahun main fault runs along the Lebong Regency to Jambi [13].

Typically, the rocks in hydrothermal systems are naturally fractured rocks. Hot water flows through the fractures or permeable rocks and undergoes phase changes on its way to the surface. The phase change occurs because the temperature of the water reaches its boiling point, resulting in the formation of various manifestations. These manifestations are in the form of hot springs, fumaroles, underground warm pools, and mud pools, which are located close to each other, but each has different characteristics [14]. The distinct characteristic of the hydrothermal is that manifestations result in different conductivity of the rock. The study area is tectonically located in the Bengkulu forearc basin. There are several types of rock formations in this study area. Tomh Formation (Hulusimpang Formation) is a formation in geological time between the Oligocene and Miocene and consists of volcanic rocks. This volcanic rock contains volcanic breccia, lava, and tuff with inserts of conglomerate, sandstone and tuff, limestone, and clay inserts whose age has been mineralized [15].

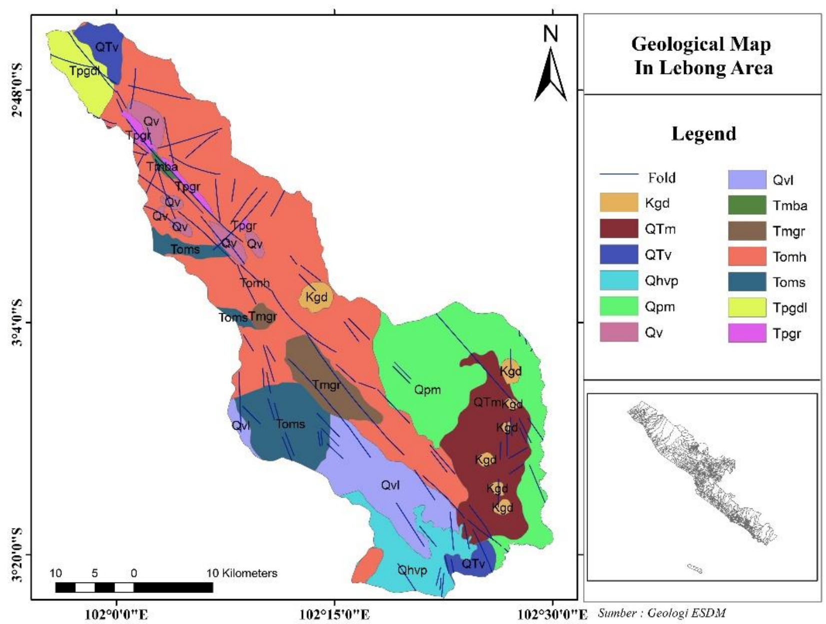

Figure 1. Geology Map of Lebong Region [15]

Method

This research was conducted in the hot spring tourism area of Lemeu village, Lebong Regency. Geographically, the research site is located at 3º5'14.82''LS and 102°13'19.59''E, as shown in Figure 2. This study uses the geoelectric instrument MAE X612-EM with the battery as a power source in data acquisition. The current source from the battery is injected into the earth through 48 electrodes that have been plugged in. Electrodes connected to the MAE X612-EM geoelectric cable and inserted into the ground. The investigation was carried out with up to 4 measuring lines crossing the area of the hot springs of the village of Lemeu. consists of 48 electrodes, each with a distance of 10 meters and a length of 1 track line. The size of 1 line is 480 meters. An illustration of the field measurements can be seen in Figure 3. The results of field measurements are a 2-dimensional resistivity model processed with Res2dinvX32 software.

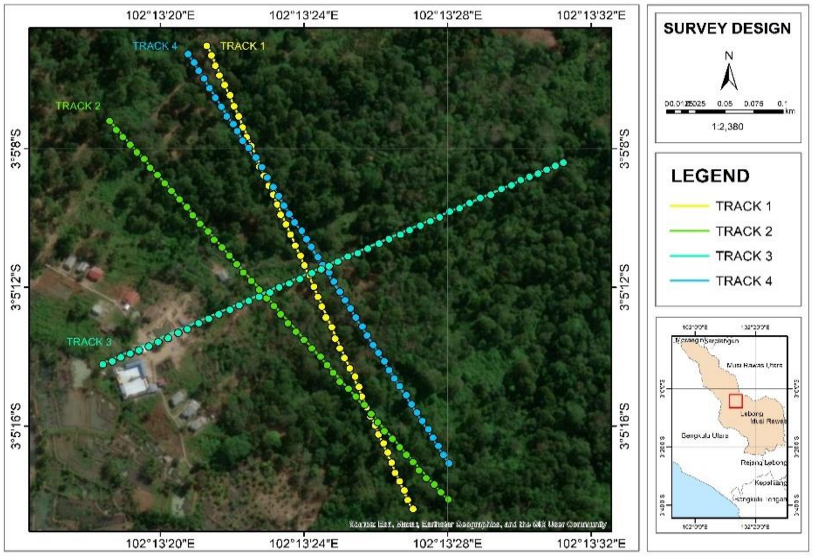

Figure 2. Design of Resistivity 2D Survey

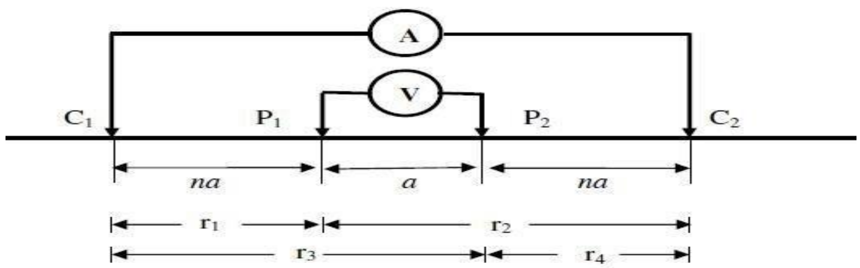

Figure 3. Illustration of field measurement [18]

In this configuration, each measurement's distance between electrodes must be uniform. If the distance between electrode C1 and C2 is 12 m, then the distance between electrode P1 and P2 is 4 m, and so on. From the figure, the geometry factor for the Wenner configuration can be obtained:

$$K_w = 2\pi a \tag{1}$$

So, in the Wenner configuration, the relationship applies

$$\rho_o = 2\pi a \frac{\Delta V}{I} \tag{2}$$

According to Chaidir et al. l [1]The Wenner-Sclumberger configuration has a maximum penetration depth of 90 meters, while the Wenner configuration only reaches 80m. The variable n is a multiple to indicate the observed layer level. The geometry factor of the Wenner-Schlumberger electrode configuration is:

$$K_{W\text{-}s} = \pi(n+1)\, a \tag{3}$$

Where a is the distance between electrodes P1 and P2, and n is the ratio between electrode distances C1-P1 and P1-P2 (for example, 3a, then n = 3). Thus, the apparent resistivity value is formulated:

$$\rho_0 = \pi(n+1)\, a \frac{\Delta V}{I} \tag{4}$$

Result and Discussion

In this study, current (I) and potential difference (V) data for each measurement point are analyzed [16]. The electric charge was obtained from the processing of resistivity geoelectric data [11] using Res2Dinvx64 software. The resistivity geoelectric method with the Wenner - Schlumberger configuration provides a 2D resistivity model [17]. To interpret the result, we use the Telford resistivity value table [18], which is adjusted to the geological conditions of the data collection location.

The source of geothermal energy is magma inside the Earth [19]. The magma transfers heat to the surrounding rocks [20]. The heat also causes hydrothermal convection in the rock pores. The impermeable layer of the hot water in the geothermal reservoir [21]. However, it is still unclear whether the hydrothermal fluid originates from the heating of rocks (as magma) beneath the source point or simply from hydrothermal flow from other areas [22].

The subsurface lithology in the study area is relatively similar in terms of color, texture, grain size, and composition because the four measurement traces are located close to each other, namely around a hill with volcanic rocks [23]. The pores cause the rock layer in the conductive zone to be filled with liquid or water at a sufficiently high temperature [24]. This is evidenced by the manifestation of hot water that comes to the surface between the rocks and forms the semblance of a hot pool. [25]. The data processing results show several different colors, for low resistivity values (1.30 Ωm) indicate hydrothermal, while high resistivity values (6718 Ωm) indicate volcanic rock formations in the study area.

The 2D resistivity model in line 1 shows volcanic rock information consistent with the area's geologic information. This study was conducted in an area with geothermal potential. The results of this study are used as a reference for geothermal exploration, which is then utilized for the benefit of the community and government. Measurements on each trace with hydrothermal potential have a small resistivity value. Figure 4 shows the 2D resistivity model in line 1 in the subsurface. The rock structure dominant in trace 1 includes silty sand, clay, tuff, andesite, and granite. This rock type is an andesite-basalt volcanic rock unit with the Hulusimpang Formation as the dominant formation [7].

The results of each 2D lithologic analysis along line 1 (Figure 4), line 2 (Figure 5), line 3 (Figure 6), and line 4 (Figure 7) are dominated by andesitic rocks, which are considered to be extrusive volcanic rocks of medium composition with aphanitic and porphyritic textures. The presence of secondary permeability, the lowest layer on the Ketahun surface also identifies hydrothermal occurrence. The Ketahun fault controls the release of hot water in the reservoir to the surface through hot springs, rock alteration, and fumaroles that occur and are also closely associated with magmatic activity in the Bukit Barisan Mountains [7]. Figure 4 shows the transverse traverse along the hill. Line 3 was drawn from the foot of the mountain to the top of the slope in the study area to maximize the resistivity measurement results.

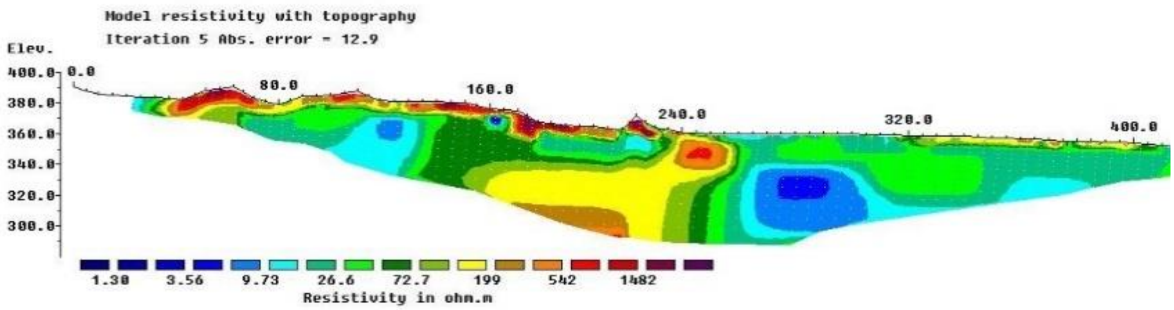

Figure 4 Geoelectric data processing results in line 1

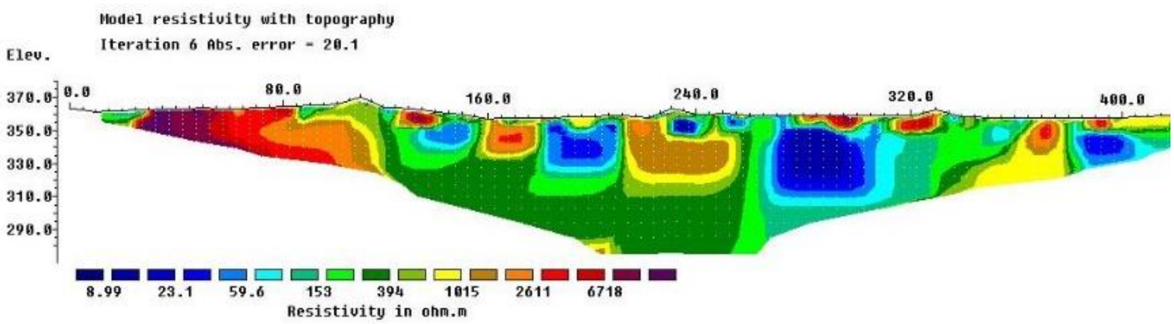

Figure 5. Geoelectric data processing results in line 2

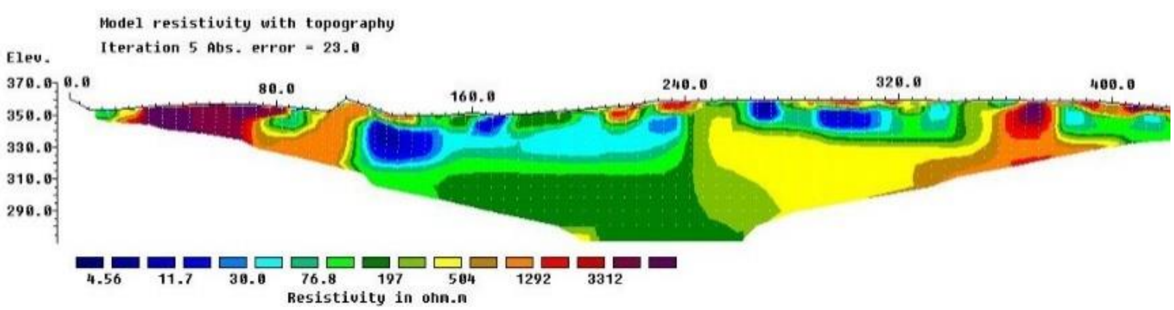

Figure 6. Geoelectric data processing results in line 3

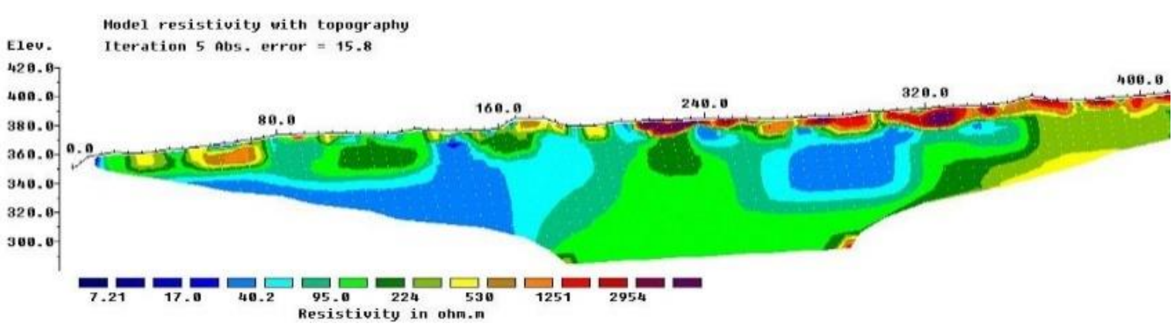

Figure 7. Geoelectric data processing results in line 4

The sensitivity model data generated from the most minor square inversion process is based on the electrical properties of rocks below the surface shown in the figure above.Figure 4 to Figure 7 show the resistivity values on each of the surveyed lines; the variations in resistivity indicate different lithologies. Table 1 shows the correlation between resistivity and lithology based on Telford interpretation from data collection [18].

Table 1 shows the resistivity value on each line, and lines 1 and 4 show the resistivity value. The resistivity value in the range 1.3 Ωm – 7.21 Ωm represents hydrothermal. Clay has a resistivity value in the range 19.73 Ωm – 76.8 Ωm. Silty has a resistivity value in the range 95.0 Ωm - 197 Ωm, Resistivity in the range 143 Ωm - 287 Ωm refers to tuff, and 248 Ωm - 354 Ωm represents andesite. Basalt has a resistivity value of 504 Ωm - 980 Ωm, and granite has higher resistivity compared to the others; it is in the range of 1015 Ωm - 6718 Ωm Each track has a hydrothermal potential due to its low resistivity value in a depth of (1 meter - 30 meters), make it more specific, below the earth's surface and has geothermal potential even though it is included in the low-temperature reservoir system according to the geothermal grouping.

This study area is located on a hill near a tourist spot with hot springs. Hot water appears at two locations: the first one is on the mountain, and the other one is in the pool. Based on the measurements, we obtain a meager resistivity value assumed to be hydrothermal. There is a hydrothermal manifestation in line 1. Appears on the surface forming a pool, and it is classified as low-category geothermal because the water that occurs is quite warm. Geothermal resources have been classified into low, intermediate, and high by their reservoir temperatures. The temperature ranges used are arbitrary, and there is no general agreement.

Lines 2 and 4 show hydrothermal because line 2 is a track through the survey area that is approximately mid-hill next to the manifestation coming to the surface (try to connect the resistivity value, too), and line 4 is a line at the bottom of the hill (try to connect the resistivity value too). On lines 2 and 4, the hydrothermal manifestation is 26 meters below the ground surface in which part (where), describe with color in the figure and the resistivity value, or you can mention 30 meters from the starting point, but further identification is needed to understand how promising this study area is for geothermal exploration.

Conclusion

The results of identifying a hydrothermal distribution using the Wenner-Schlumberger configuration geoelectric method in Lemeu Village, Lebong Regency, have subsurface hydrothermal potential, so geothermal manifestations were found on the surface. The survey tracks that have more excellent geothermal potential based on resistivity value are on lines 2 and 4 at a depth of 26 meters, while lines 1 and 3 also have geothermal potential but are thought to have smaller potential. Geothermal potential in the research area is divided into several parts, some of which have low, medium, and high temperatures. In the research area, lines 1 and 3 have low temperatures; line 4 has medium temperatures, and line 2 has high temperatures.

Table 1. Resistivity value and interpretation in each line site

No	Site	Resistivity (Ωm)	Lithology
1	Line 1	1.30	Hydrothermal
		3.56	Hydrothermal
		9.73	Clay
		26.6	Clay
		64.5	Clay
		72.7	Clay
		120	Silty Sand
		199	Tuff
		248	Andesite
		542	Basalt
		1482	Granite
2	Line 2	8.99	Hydrothermal
		23.1	Clay
		43.4	Clay
		59.6	Clay
		126	Silty Sand
		153	Silty Sand
		276	Tuff
		394	Andesite
		876	Basalt
		1015	Granite
		1988	Granite
		2611	Granite
		6718	Granite
3	Line 3	4.56	Hydrothermal
		11.7	Clay
		24.7	Clay
		30.0	Clay
		76.8	Clay
		134	Silty Sand
		197	Silty Sand
		287	Tuff
		504	Basalt
		968	Granite
		1292	Granite
		3312	Granite
4	Line 4	7.21	Hydrothermal
		17.0	Clay
		32.0	Clay
		40.2	Clay
		64.6	Clay
		95.0	Silty Sand
		143	Tuff
		224	Tuff
		354	Andesit
		530	Basalt
		980	Basalt
		1251	Granite
		2954	Granite

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