Hydrothermal Identification Based on Rock Resistivity Value using Dipole-dipole Configuration Geoelectric Method in Lemeu Village, Lebong Regency, Bengkulu Province

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Abstract: Geothermal potential is identical to the presence of volcanoes as reservoir sources, but hydrothermal sources are rarely found in places that are not associated with volcanoes and faults. One of the areas where there is a hydrothermal system located in Lemeu Village has not yet been studied. This research was conducted in November 2023 and data collection was carried out around the hot springs of Lemeu Village, Lebong Regency, Bengkulu Province. This study used the X612-EM VHR MAE multichannel Geoelectric resistivimeter tool. using a dipole-dipole configuration with a low resistivity value (20.5 m). This low resistivity value is likely due to a hydrothermal source. At a depth of 13.4 m, the surface is usually dominated by a hydrothermal layer, while the relatively high resistivity value of 8525 m is likely to be hard rock. Based on the results of the interpretation of the 2D resistivity pseudo section, there is a hydrothermal distribution on the survey line in Lemeu village. The hydrothermal is believed to come out to the surface through rock cracks in the subsurface. so that hot water flows through faults near the area. The temperature of the water in the area is around 35-55 C. Because the faults around there are quite far away, the water in the area propagates to the surface from the nearest fault.

Keywords: Hydrothermal; Lemeu; Geoelectric; Dipole-dipole

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I. INTRODUCTION

Geographically, Indonesia is an archipelago located at the confluence of three plates, namely the Indo-Australian, Eurasian and Pacific plates, so it is called the ring of fire [1, 2]. The meeting of these plates has made Indonesia one of the disaster-prone countries. Indonesia has 130 active volcanoes, or 16% of the total number of volcanoes in the world. The number of active volcanoes in Indonesia causes many hydrothermal manifestations to be found, where the geothermal potential produced in Indonesia reaches 40% of the total in the world [3].

Indonesia's geothermal potential is mostly spread along the distribution of volcanoes stretching from the tip of Sumatra Island to the Maluku Islands. Geothermal potential is identical to the presence of volcanoes as reservoir sources, but geothermal sources are rarely found in places that are not associated with volcanoes and faults [4].

Geothermal energy is a source of heat energy found and formed within the earth's surface, which is related to geothermal energy in a region. Hydrothermal is caused by the spread of heat in the subsurface or cracks that allow hot fluids (steam and hot water) to flow to the surface so that a geothermal system is formed [5].

The conditions for the formation of a geothermal system are the presence of heat sources, reservoirs and cap rock layers, heating and conditions of the system where the hot water is (hydrothermal aquifers), so that the main requirement for the formation of a geothermal system is the availability of water, this water usually comes from rainwater or meteorites, heating stones (hot springs), reservoir rocks and cap rock [6].

One of the areas where there is a geothermal system in Bengkulu Province is in Lemeu Village, Lebong Regency, Bengkulu Province. Geothermal heat is found in this area, generally because it is located close to the bukit barisan mountain system, hydrothermal in Lemeu Village in the form of hot water vapour means that there are geothermal sources in the area and there has been no study of how the 2D subsurface structure and how hydrothermal distribution in the area.

With the hydrothermal manifestations that appear in this research area, it is necessary to conduct research to determine the condition of the subsurface structure using one of the geophysical methods, namely the 2D type resistance geoelectric method with dipole-dipole configuration which aims to determine the condition of the subsurface structure and hydrothermal distribution in Lemeu Village. The type resistance geoelectric method is a geophysical method that is often used to determine subsurface conditions [7].

The dipole-dipole configuration geoelectric method is accurate in detecting changes in rock layers vertically and horizontally [8]. The dipole-dipole configuration is most effective and efficient for geothermal hydrothermal source detec-

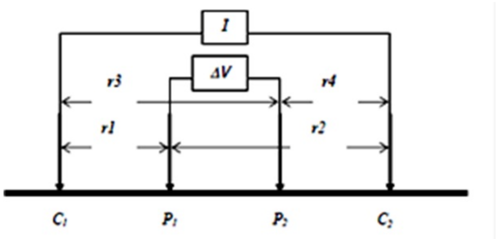


FIG. 1: Electrode arrangement for measuring resistance current and potential [7].

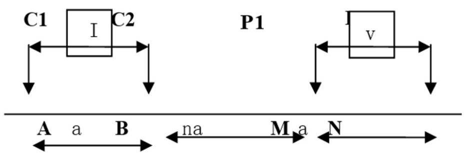


FIG. 2: Dipole-dipole configuration.

tion compared to the Wenner Alpha, Wenner-Schlumberger and Pole-dipole configurations because the dipole-dipole configuration obtains more information so that it has a more detailed 2D cross-sectional picture. The dipole-dipole configuration provides more effective resolution for subsurface areas with lower resistivity values than the Schlumberger and Wenner configurations [9]. The dipole-dipole configuration is commonly used because this setup can capture images of targets at the surface with relatively deeper penetration compared to other configurations [10].

The difference between the Dipole-dipole configuration and other configurations lies in the arrangement of electrodes that are adjusted to the conditions of data collection in the field and the depth of the material whose resistivity value is to be known below the earth's surface [11]. It has high sensitivity in both horizontal and vertical directions and is very effective for depth penetration. The dipole-dipole configuration is a configuration in which the current electrodes are placed separately from each other depending on the depth of interpretation. The resisitivity value obtained is the apparent resistivity value (a), which is the resistivity obtained from the earth which is considered to have a homogeneous layer [12]. By using electric current to detect the potential of an electrified surface as shown in Fig. 1.

An electrode array for measuring resistance current and potential, this figure shows the electrode array, labelled C_1, P_1, P_2, and C_2, that would most likely be used to measure current and resistance using resistivity geophysical methods. Two current electrodes (C_1 and C_2) are used to inject current into the medium, while two potential electrodes (P1 and P2) are used to measure the potential difference created by the current. The dipole-dipole configuration is often used in geophysical surveys to measure resistivity or induced polarisation. In this configuration, there are two pairs of dipoles located at points A-B and M-N. The distance between the current dipole (AB) and the potential dipole (MN) is usually set based on survey needs to adjust the depth of investigation, as can be seen in Fig. 2.

The magnitude of the potential value at points P1 and P2 is calculated by the equation.

$$Vr1 = \frac{\rho I}{2\pi}\left(\frac{1}{r1} - \frac{1}{r2}\right) \tag{1}$$

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

The apparent resistivity of the measured medium can be calculated by the equation.

$$\rho = \kappa \frac{\Delta V}{I} \tag{3}$$

κ, is with the following geometry factor.

$$\kappa = \frac{2\pi}{\left(\frac{1}{r1} = \frac{1}{r2}\right) - \left(\frac{1}{r3} = \frac{1}{r4}\right)} \tag{4}$$

The apparent resistivity of the Dipole-dipole configuration can be written with the equation.

$$\rho = \kappa R \tag{5}$$

with K being the geometry factor.

$$\kappa = n(n+1)(n+2)\pi a \tag{6}$$

A. Regional Geology

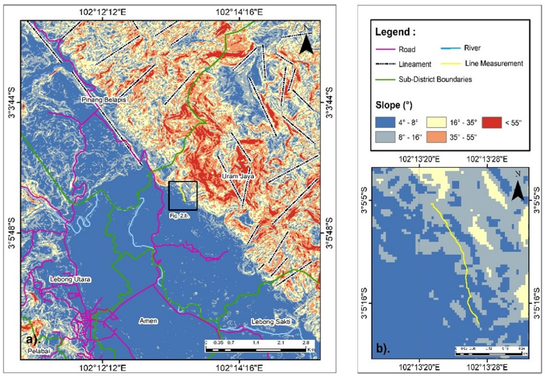
This study area is included in the bukit barisan [13]. The study area is located on the Ketaun fault segment. The Paleogene system of the Bengkulu Basin and the South Sumatra Basin are in one basin [14].

The rocks in this study area also contain five formations consisting of Kgd, Tomh, Toms, Kgr and Qv. The granodiorite formation (Kgd) is Late Jurassic. Hulusimpang Formation (Tomh), this formation is Oligocene to Miocene in age and consists of volcanic breccia rocks. volcanic, andesite-basalt lava, basalt, andesite, tuff and sandstone-grewak and the thickness of the rock is about 700 M. Seblat Formation (Toms) This formation is of Middle to Early Miocene age, consists of wood shale sandstone, mudstone, conglomerate sandstone, limestone, shale, shale rock, shale, clayey sandstone with sandstone inclusions, sedimentary rocks and there are also igneous rocks and the thickness is up to 700 M.

Granite Formation (Tmgr), this formation is Middle Miocene in age. and Andesite-Basalt Volcanic Rocks (Qhv), these rocks are Quaternary in age consisting of volcanic breccias, lavas, tuffs and lahars and the thickness of these rocks is around 400 M [15]. Can be seen in Fig. 3.

II. METHODOLOGY

This research was conducted in November 2023 and data collection was carried out around the hot springs of Lemeu



(a) (b)

FIG. 3: (a) Geological map of Lebong District. (b) Geoelectric trajectory drawing [16].

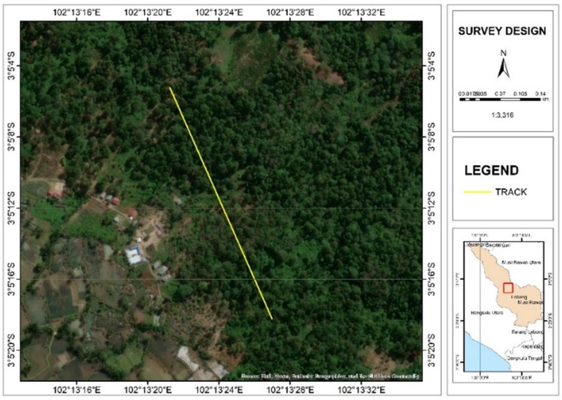


FIG. 4: Research map of Lemau village, Lebong district.

Village, Lebong Regency, Bengkulu Province. The location is at the coordinate position 3°5'14.82"LS 102°13'19.59"E, the coordinate point can be seen in Fig. 4.

This research uses the X612-EM VHR MAE Geoelectric Multichannel Resistivimeter tool. Measurements were made directly using a one-pass dipole-dipole configuration with a stretch length of 480 metres used to see the distribution of deeper hydrothermal potential depths due to deeper current penetration. then prepare the tool, determine the location of the measurement point using a geological compass and electrode coordinates, extend the cable and attach it to the electrode. with a spacing of 10 metres the electrodes used were 48 pieces, then take measurements.

After data collection, data processing is carried out. For processing 2D resistivity geoelectric data, RES2DINV software is required. To find out the subsurface of the results of resistivity geoelectric data collection. The steps for processing this data are as follows:

- Open the RES2DINV software.
- Select file on the toolbar, then select read data file. Select the data to be processed, namely data in DAT format (which contains datum points, electrode spacing and apparent resistivity values). Then click open. Then appear reading of data file completed, OK.
- Next, select the inversion menu, then click least square inversion, wait until the process is complete. Then a 2D resistivity cross section will appear.

TABLE I: Resistivity value of rock or mineral type.

Rock/mineral type	Resistivity (Ω.m)
Hydrothermal	20.5
Andesite	271
Granite	643

III. RESULTS AND DISCUSSION

The data used in this study are data from field measurements using the geoelectric method with Dipole-dipole configuration. Based on the results of data processing using RES2DINV software to determine the value of rock resistivity. The cross section of the specific gravity that explains the relationship between depth and the value of rock specific gravity in this research area can be seen in Fig. 5.

This study used one track. Fig. 5 shows the subsurface resistivity cross section generated from the geoelectric survey using the dipole-dipole configuration. the colours in the cross section represent the variation in resistivity values in the subsurface, with the range marked by the colour scale at the top of the figure. resistivity is measured in Ohm metres (Ω.m), with certain coloured areas representing certain types of materials or geological properties in the subsurface. the spacing between electrodes in this modelling is 10 metres. at a depth of 13.4 metres it is usually dominated by hydrothermal layers and the width obtained by this method is $\pm$ 5 metres.

This table lists (Table I) the resistivity values of several types of rocks or minerals, which include: hydrothermal 20.5 Ω.m, Andesite 271 Ω.m, Granite 643 Ω.m. This resistivity value is important for identifying the type of rock that exists below the surface. For example, hydrothermal has a low resistivity (20.5 Ω.m), indicating that it is more conductive than andesite and granite. while the relatively high resistivity value of 8525 Ω.m is likely to be hard rock or hulusimpang formation and volcanic rock.

Geothermal energy comes from magma kitchens, conductive magma conducts heat to the surrounding rocks [17]. The heat generated causes convection currents of hydrothermal fluids in the rock pores. However, it is not certain whether hydrothermal can be ascertained from the heating of the underlying bedrock (magma) [18]. The hot water flow appears because of the fractures in the rock that cause the hydrothermal flow to appear.

The temperature at the research point is around 35° - 55°C because it is warmer and we can see from the geological map that the fault around the research point is quite far from the research area which is about 5 KM away. hydrothermal arises

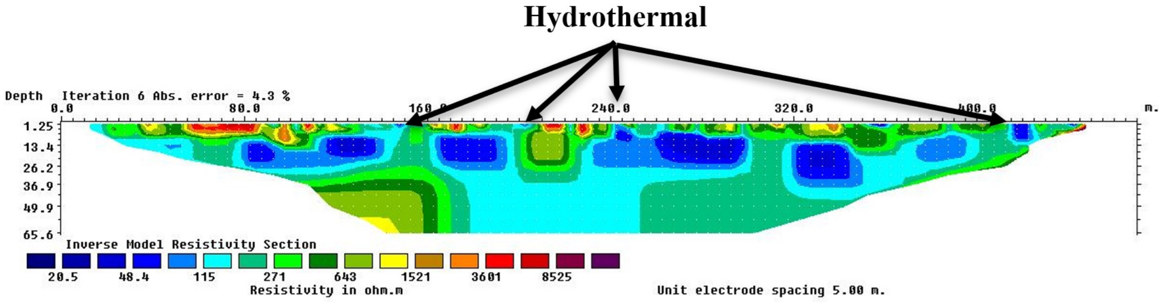


FIG. 5: Cross-section of 2D modelled dipole-dipole configuration.

because it propagates from the nearest fault from the location under study so that the water in the area tends to be less hot. According to [19], the village of Lemau is directly adjacent to bukit barisan, as it is at the epicentre of an active fault.

IV. CONCLUSION

The 2D resistivity cross-section interpretation revealed the distribution of hydrothermal systems along the survey route in Lemeu Village. This hydrothermal system is strongly suspected to occur due to the presence of fractures in the rock below the surface, which acts as a migration path for hot water to the surface. The hot water flows through faults around the survey area, showing a close relationship between geothermal symptoms and tectonic activity in this region. The temperature of the hot water in this area ranges from 35°C to 55°C, confirming the presence of active hydrothermal activity. Interestingly, although the hot water is located relatively far away from the main fault, its heat distribution is still felt at the surface. This indicates that the hydrothermal system in this area has significant potential for further research, both in terms of geothermal resource development and understanding the interaction between faults, fractures and hydrothermal fluids.

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