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Analysis of Geothermal Potential Using Gravity Method in Way Ratai Area, Pesawaran Regency, Lampung

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Abstract. Way Ratai, Pesawaran is one of the areas in Lampung that has a surface manifestation, in the form of geothermal potential. Based on data from the Directorate of Geothermal in 2017, Way Ratai has a potential of more than 330 MW with the manifestation of hot springs and hot steam. This study aimed to determine the distribution of subsurface density of Mount Way Ratai, Pesawaran, Lampung region by using GGMplus satellite gravity data. Based on fault analysis method and 2D forward modeling in Oasis Montaj software. The results showed that the geothermal area of Way Ratai identified 2 types of faults, namely reverse faults and normal fault. Based on the results of forward modeling, subsurface density of Way Ratai area, Lampung offering can be identified at a density of 1.2 gr/cc suspected alteration rocks in the form of clay minerals, density of 1.55 gr/cc suspected sand gravel, density of 1.6 gr/cc suspected Tuff rocks, density of 2.3 gr/cc suspected breccia rocks and conglomerates, density 2.6 gr/cc suspected schist and chert, and density 2.99 gr/cc suspected basalt rocks.

***Keywords**: Gravity Data, GGMplus, Oasis Montaj, Geothermal, Way Ratai.*

INTRODUCTION

Background

The potential of geothermal energy sources in Indonesia is quite potential to be developed. Indonesia is included in a country that is rich in geothermal energy sources. This is because Indonesia is located between the confluence of three tectonic plates, namely the Indo-Australian Plate, Eurasian Plate and Pacific Plate [1]. The combination of these tectonic plates causes the formation of distinctive mountains and different types such as active mountains produce geothermal energy sources that make Indonesia have considerable geothermal potential. The potential of geothermal energy in Indonesia ranges from 28,617 MW, which is 40% of the world's geothermal reserves [15 = 2].

This study is one of the areas that have geothermal potential, namely Way Ratai located in Padang Cermin District, Pesawaran Regency, which is one of the areas in Lampung that has a surface manifestation, in the form of geothermal potential [16 = 3]. Based on data from the Directorate of Geothermal in 2017, the Way Ratai geothermal source has a potential of more than 330 MW with the manifestation of hot springs and hot steam [2=4].

The gravity method serves as an alternative approach to other geophysical methods in assessing the potential of geothermal systems. Gravity method is one of Geophysical methods to determine density distribution of subsurface structure [17=5]. Gravitational methods can provide enough detailed information about subsurface structures through rock density contrast to identify the presence of heat sources below the

Earth's Surface [3=6]. Based on the discussion above, in this study will be conducted two-dimensional modeling of subsurface structure Way Ratai Lampung with forward modeling method based on gravity data analysis

METHODS

The research site is located in Way Ratai, Pesawaran Regency, Lampung with the coordinates of the boundary 5°30'59.76" - 5°38'33.54" S and 105° 7'41.52" - 105°15'25.93" E and area 29.86 x 31.04 km. Data processing is done by obtaining secondary data from the site GGMplus. This data processing is done to get the value of Complete Bouguer Anomaly that has been corrected - correction using gravity correction includes free-air correction, bouguer correction, and terrain correction [18=7]. Separation of anomalies in the Complete Bouguer Anomaly (CBA) which produces regional anomalies and residual anomalies. Furthermore, perform fault analysis in the Second Vertical Derivative (SVD) which will display the structure of the fault and fault.

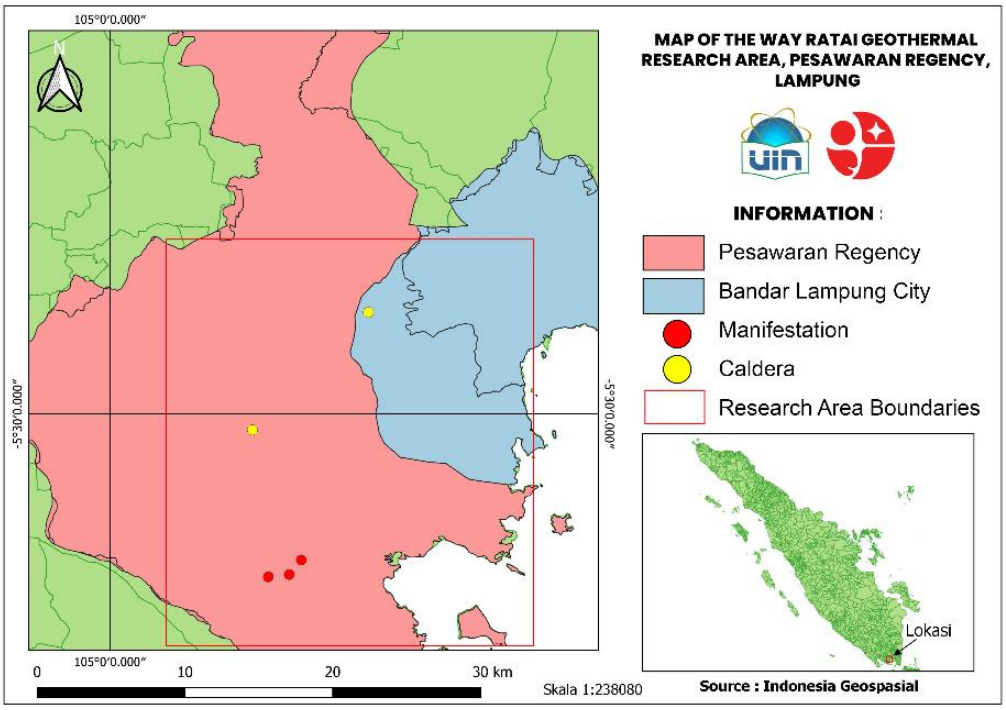


Figure. 4 Research Area Map.

Way Ratai Geological Setting

Regional geology in the Way Ratai area, Pesawaran is composed of rocks from four groups of rock types, namely tertiary, pre-eruptive volcanic, eruptive volcanic, quarter, and surface deposits. Tertiary rocks around the Way Ratai area are composed of sedimentary rocks from the ratai formation, composed of conglomerates, sandstones, lava breccias and clay rocks that are sometimes associated with andesite tuff. Pre-eruption volcanic rocks are Gebang Volcanic Rock, Gebang Ignimbrite, Gebang Lava, Debris Deposits, and Volcanic Banjarmerger. Rocks are located above tertiary sedimentary rocks. Quaternary volcanic rocks are separated into two eruption sources, namely the eruption of Mount Betung and Ratai at the bottom of the Gebang Caldera. Surface deposits include lava deposits and alluvial deposits [4=8], as **Figure 1.**

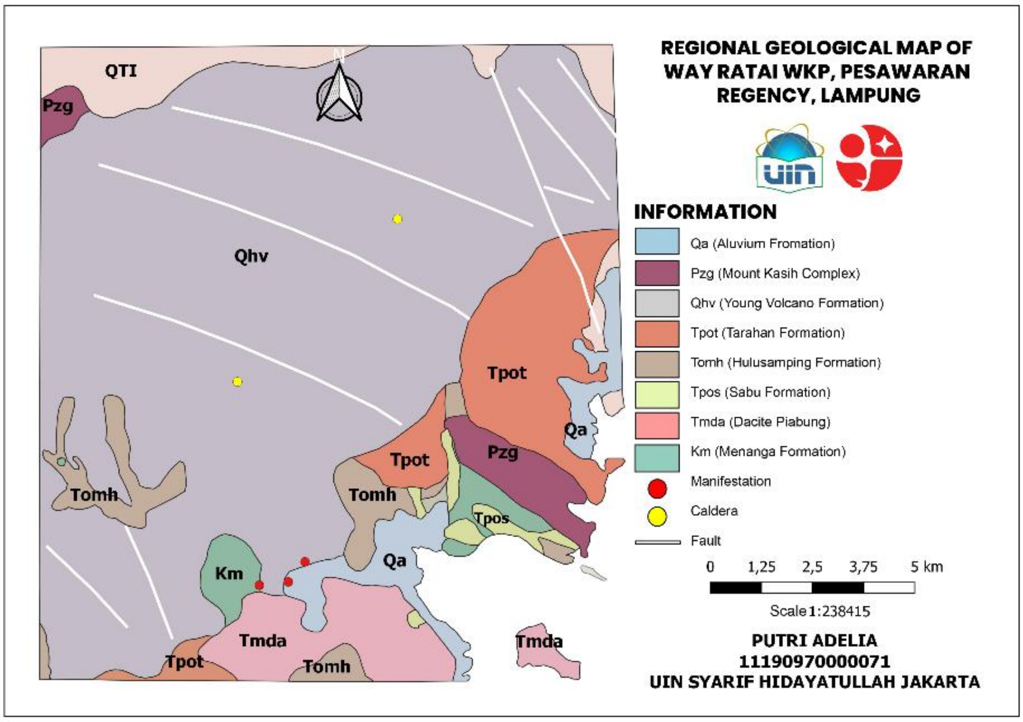


Figure. 1 Geological Map of Research Area [5=9].

Based on the geological map of Way Ratai area is dominated by the first formation, namely, QTI Formation (Lampung formation), Qhv Formation (r, b, p), Km Formation (Menanga Formation), Pgz Formation (Mount Kasih Complex Formation), Tmda Formation (Dacite Piabung), Tpos Formation (Sabu formation), Tpot Formation (Tarahan Formation), Tpos Formation (Sabu formation), Tomh Formation (Hulusamping Formation). Here are the rock formations of this research area on **Figure 2**.

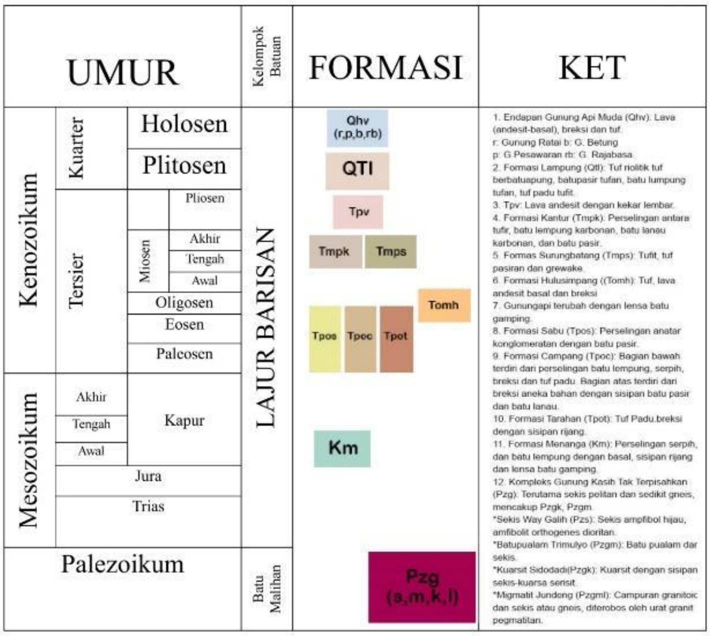


Figure. 2 Regional Stratigraphy on the Tanjung Karang Geological Map Sheet [5=9].

Geothermal System

Geothermal systems are systems that allow fluid from meteoric recharge to fill a reservoir above a heat source [6=10].

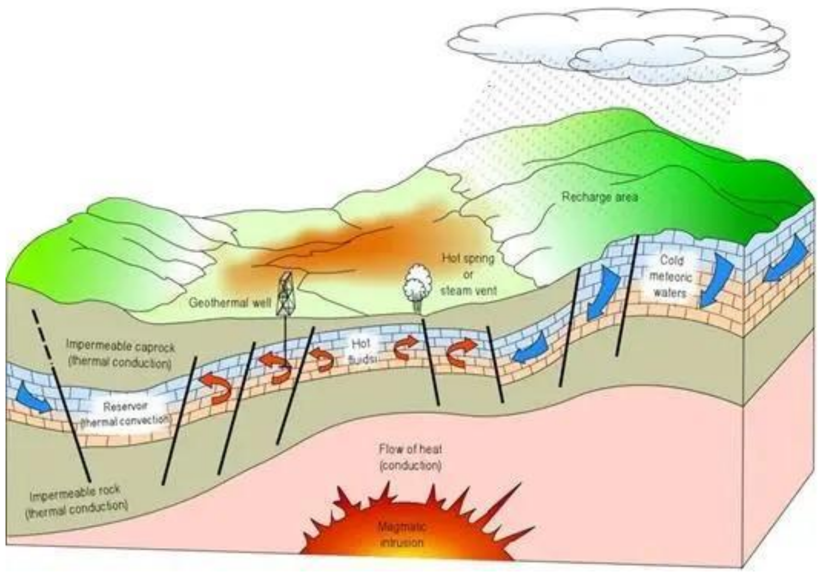


Figure. 3 Geothermal System Schematic [7=11].

The main components of a geothermal system [8=12] are as follows:

1. Heat source, in the bowels of the Earth and usually associated with the presence of volcanoes. Technically, for example, rainwater seeps into the underground rock until it reaches the storage rock.
2. Reservoir rocks are underground rock formations that can store and drain geothermal fluids. Reservoirs tend to be rocks with good porosity and permeability. Porosity serves to store hot liquids while permeability allows hot liquids to flow.
3. A layer of rock at the top of the tank called overburden, which is impermeable to water or difficult for liquids to penetrate. This layer is mostly mudstone because this mudstone can bind water but it is difficult to get out.
4. Recharge area or daerah resapan is an area where water seeps into the subsurface of the Earth. This area usually has a higher elevation. This area has a high water absorption potential than the surrounding area.
5. Discharge areas in geothermal fields are characterized by the appearance of surface manifestations in the form of Wells, hot springs, fumaroles (smoke), and hot pools.
6. Geological structures in the form of faults, fractures, and inconsistencies.

Gravity Correction

Free air correction or free air correction is a correction that occurs due to the effect of differences in altitude (h) to Earth's gravity. Which is where the measurement of gravity on the ground must be adjusted to the height above or below sea level [9=13]. Free air correction is expressed in the equation (1).

$$C_F = 0.3086 \times h \quad (1)$$

Bouguer correction is used to reduce the value of gravity because there is a mass of rock h meters above sea level between the measurement points. So that the measured gravity value is greater than the gravity value that should lie on the equipotential surface [10=14]. Bouguer correction is expressed in the equation (2).

$$C_B = 0.04193 \times \rho \times h \quad (2)$$

Terrain correction or terrain correction is a correction that accommodates the difference in topographic elevation around the measurement area usually within the inner and outer radius, measured elevation. Terrain correction is expressed in the equation (3).

$$C_T = 0.04191 \frac{\rho}{n} \left(r_2 - r_1 + \sqrt{{r_1}^2 + z^2} - \sqrt{{r_2}^2 + z^2}\right) \quad (3)$$

First Horizontal Derivative (FHD)

The First Horizontal Derivative (FHD) or the first horizontal derivative has another name, the Horizontal gradient. Horizontal gradients are caused by gravitational anomalies by bodies that tend to show the edges of the body [12=15]. The FHD equation is expressed as follows (5).

$$FHD = \frac{g_{(i+1)} - 2g_{(i)}}{\Delta x} \quad (5)$$

Second Vertical Derivative (SVD)

Second Vertical Derivative (SVD) is a screening technique for gravitational anomalies to obtain the second derivative and which shows little influence from regional effects [13=16]. SVD acts as a high-pass filter, which can describe residual anomalies associated with shallow structures that can be used to identify the type of descending or ascending fault formation [14=17]. The SVD equation is expressed as follows (6).

$$SVD = \frac{g_{(i-1)} + g_{(i+1)} - 2g_{(i)}}{\Delta x^2} \quad (6)$$

2D modeling in this study using a forward modeling method. Forward modeling is done in Geosoft Oasis Montaj software using GM-SYS tools by inputting residual grid data that has been obtained and then draw slicing or lines on the indicated trajectory of geothermal passing through faults and manifestations [19=18]. Modeling is done by making a variety of possible rock formations in each layer and the density of each in the rock. So as to analyze the structure of the subsurface research well.

RESULTS AND DISCUSSION

Complete Bouguer Anomaly or Anomaly Bouguer Lengkap is the result of the observed gravity value g_{obs} obtained by free air correction, bouguer correction, and field correction have been obtained from the value obtained is the result of the value of the acceleration of Earth's gravity [11=19].

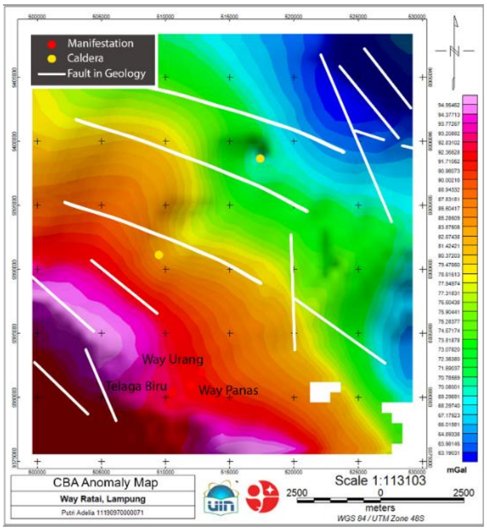
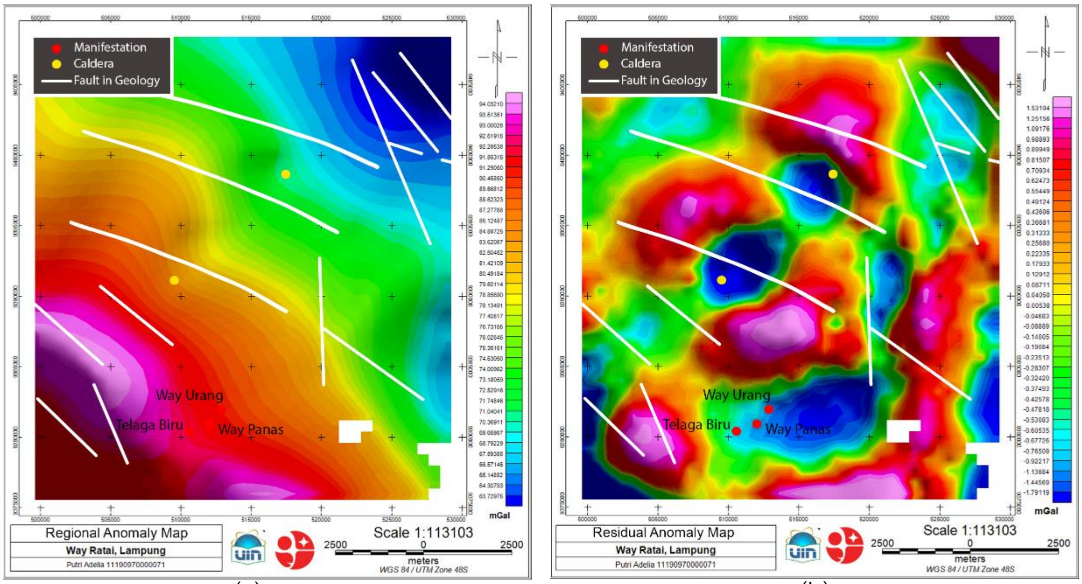


Figure. 6 Complete Bouguer Anomaly Map of Way Ratai, Lampung.

On the map Complete Bouguer Anomaly (CBA) **Figure 6** research area showed results ranging from 63.19 to 94.95 mGal of which there are three types of anomalies, namely low anomalies ranging from 63.19 to 70.78 mgal. This low anomaly dominates in the north to east areas of Pematang Wailimus, Segalamidar and Lebak Budi. A moderate anomaly that ranges from 71.59 to 82.67 mGal. This moderate anomaly dominates in the northwest to southeast, namely the area of Mount Betung and Mount Pesawaran. And the anomaly height ranges from 87.83 mGal to 94.95 mGal which dominates in the south to Southwest, namely the area of Pematang Kamtur and Pematang Kubuato.

Separation of regional and residual anomalies resulting from the filtration process on the map Complete Bouguer Anomaly (CBA) using butterworth filter [20]. Viewed from both maps in regional anomaly Figure 7 (a), the resulting contour looks smoother due to the density of the study area deeper so that the resulting rock is deeper (homogeneous). While on the residual anomaly map Figure 7 (b), the resulting contour looks rougher due to the density of the study area is more shallow so that the resulting rock is shallow (heterogeneous).



(a) (b)

Figure. 7. (a) Regional Map of Way Ratai, Lampung, (b) Residual Map of Way Ratai, Lampung.

On the regional map **Figure 7(a)** the research area showed results ranging from 63.72 to 94.03 mGal. The low anomaly pattern in the study area is seen to dominate in the north to east, moderate anomaly dominates in the northwest to southeast, and high anomaly pattern dominates in the south to southwest. On the residual map of **Figure 7(b)** the research area showed results ranging from -1.79 to 1.53 mGal. Based on the depth, residual anomalies are shallow anomalies from the surface compared to regional anomalies, residual anomalies have a rougher and closed contour pattern. Positive and negative values indicate the difference in density, position, and body in the rock.

Fault analysis is done by digitizing the grid on the SVD map to determine the type and location of the fault structure. The digitization process is carried out as many as 3 tracks, namely Line a–a' heading southwest to northeast, Line B–B' heading northwest to southeast, and Line C–C' southwest to northeast in Figure 8.

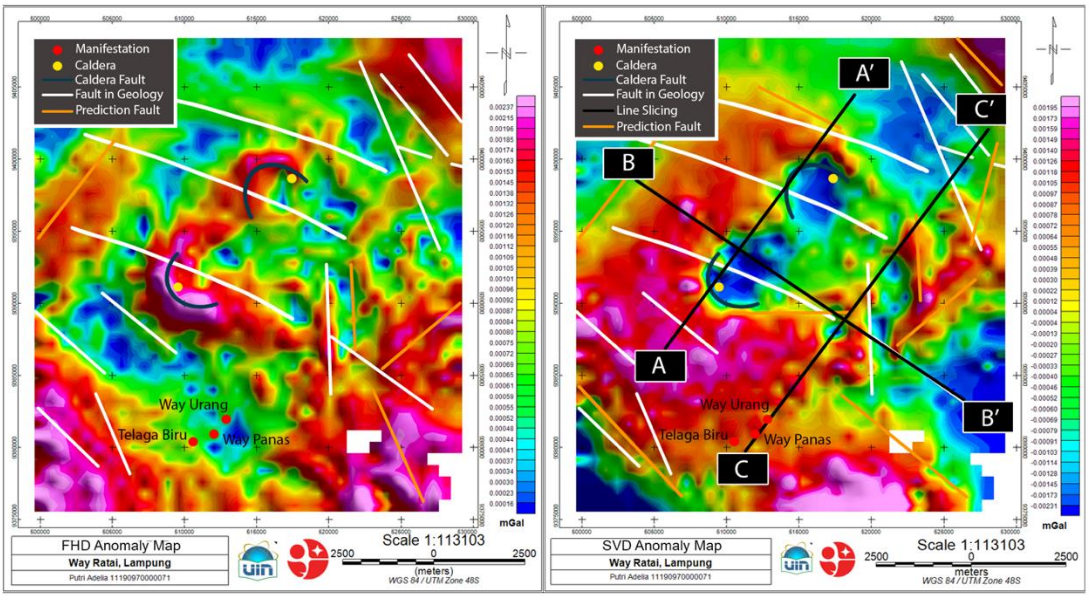


Figure. 8. Track Map FHD and SVD in the Way Ratai, Lampung.

Fault analysis is done by digitizing the grid on the SVD map to determine the type and location of the fault structure. The digitization process is carried out as many as 3 tracks, namely Line A-A' heading southwest to Northeast, Line B-B' heading northwest to Southeast, and Line C-C' Northwest to Southeast. Figure 5. From the results of this analysis obtained values in the form of coordinates UTM X, UTM Y, and SVD values. Fault indication results are shown with SVD values that are worth or close to zero (0).

In the results of the SVD graph, the X axis shows the value of the location of the coordinates on the UTM X and Y axis shows the value of SVD that has been normalized to SVD(n). The result of the graph is visible there will be a comparison between the two values, where the values confirm each other the type of location, as well as the direction of the fault.

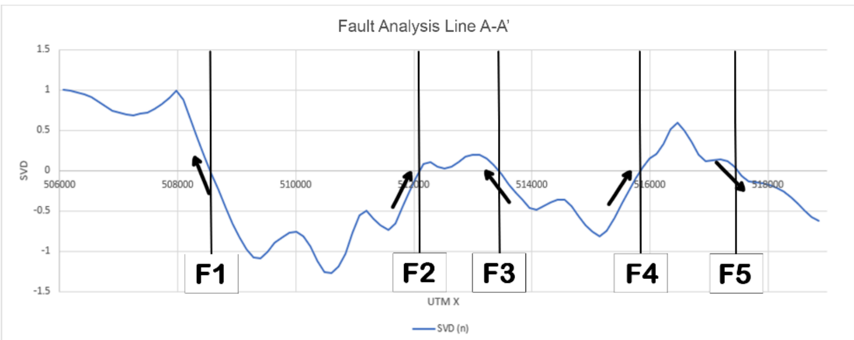


Figure. 10. Fault Point Chart in Line A-A'.

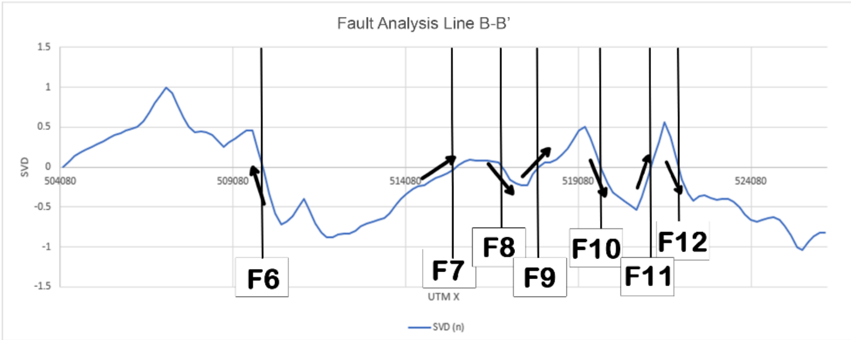


Figure. 11. Fault Point Chart in Line B-B'.

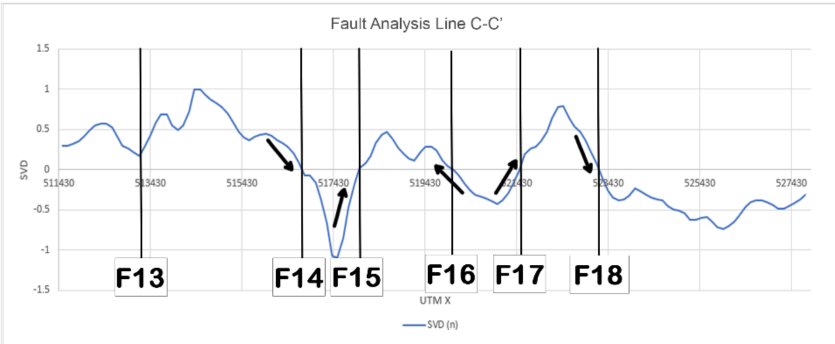


Figure. 12. Fault Point Chart in Line C-C'.

Sourced from the analysis of the three graphs, it was found that the existence of a fault structure at the incision Line A-A ' there are 5 faults, Line B-B' there are 7 faults, and Line C-C' there are 5 faults identified so that a total of three tracks there are as many as 10 faults marked by a black straight line. Then determine the type of fault, from the value $|SVD|min$ and $|SVD|max$. When:

$$|SVD|max > |SVD| = normal\ fault$$
$$|SVD|max < |SVD| = reverse\ fault$$
$$|SVD|max = |SVD| = strike - slip\ fault$$

The results of the calculation and analysis of the fault states that there are 13 types of reverse faults, and 4 normal faults. On Line A-A' shows 5 types of reverse faults and 1 type of normal faults. Then on Line B-B' shows 6 types of reverse faults and 1 normal faults. And Line C-C' shows 3 types of reverse faults and 2 normal faults. Obtained information 17 point fault marked in Black is a reverse fault and white is a normal fault. While the white line is the fault structure based on geological maps, and the black line is the same conjecture on the residual anomaly map.

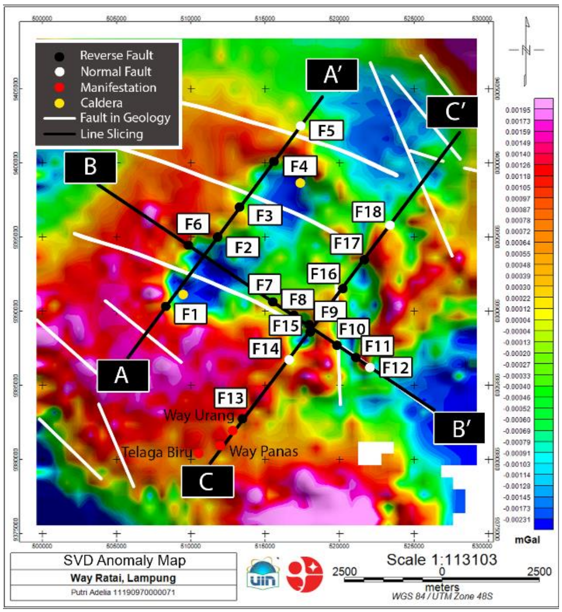


Figure. 9. Fault Point Plotting on SVD Map.

Forward modeling is the process of calculating data from theoretical results that will be observed on the Earth's surface if the model parameters are known. Often the term forward modeling is used for the process of Trial and Error. Forward modeling involves calculating the effect produced by a mathematical model of the expected subsurface conditions by changing the parameters of the model made so as to produce an effect that has an “acceptable” correlation with residual anomalies. 2D modeling in this study there are 3 modeling trajectories using residual anomaly map.

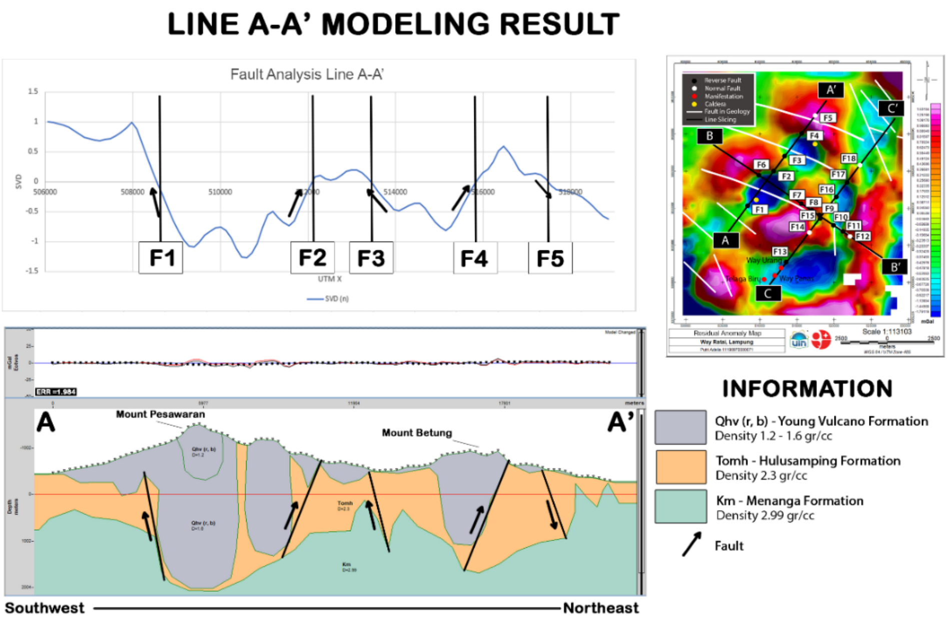


Figure. 13. Results Forward Modelling 2D Line A-A’.

Based on the modeling results of Line A - A ' in **Figure 13**, which is directed from Southwest to Northeast there are 3 layers of rock formation, with rock density values used respectively 1.2 gr/cc to 1.6 gr / cc is suspected as caprock rock rock alteration in the form of clay and tuff minerals from the Formation of Young Volcano (Qhv (r, b)). Then the rock density of 2.3 gr / cc is thought to be a reservoir rock, which is a sedimentary rock in the form of breccia from the Hulusamping Formation (Tomh). And the lowest layer with a rock density of 2.99 gr / cc is thought to be an igneous rock in the form of basalt from the Menanga Formation (Km). The fault in the Model Line A-A' is produced in the form of F1, F2, F3, F4, as the reverse fault because the value of SVD_{min} is greater than SVD_{max}. While F5 as a normal fault because the value of SVD_{min} is smaller than its SVD_{max}.

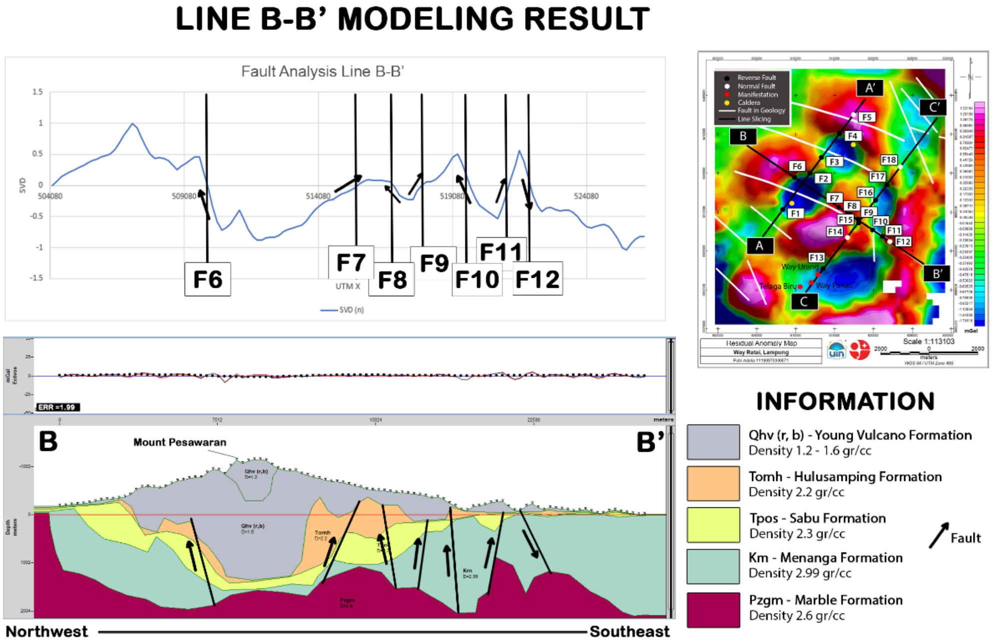


Figure. 14. Results Forward Modelling 2D Line B-B'.

Based on the modeling results of Line B - B ' in **Figure 14**, which is directed from Northwest to Southeast there are 5 layers of rock formations, with rock density values used each 1.2 gr/cc to 1.6 gr/cc is suspected as caprock rocks as well as alteration rocks in the form of clay and tuff minerals from the same formation, namely the Formation of Young Volcano (Qhv (r, b)). Then the second layer with a rock density of 2.2 gr/cc is thought to be a reservoir rock, which is a sedimentary rock in the form of breccia from the Hulusamping Formation (Tomh). The third layer with a rock density of 2.3 gr/cc is thought to be a reservoir rock in the form of a conglomerate from the Sabu Formation (Tpos). Furthermore, the fourth layer with a rock density of 2.99 gr/cc is thought to be an igneous rock in the form of basalt from the Menanga Formation (Km). And in the lowest layer with a rock density of 2.6 gr/cc is thought to be a metamorphic rock in the form of schist from Trimulyo Marble Rock Formation (Pzgm). The fault in the Model Line B-B' is produced in the form of F6, F7, F8, F9, F10, and F11 as the reverse fault because the value of SVD_{min} is greater than SVD_{max}. While F12 as a normal fault because the value of SVD_{min} is smaller than its SVD_{max}.

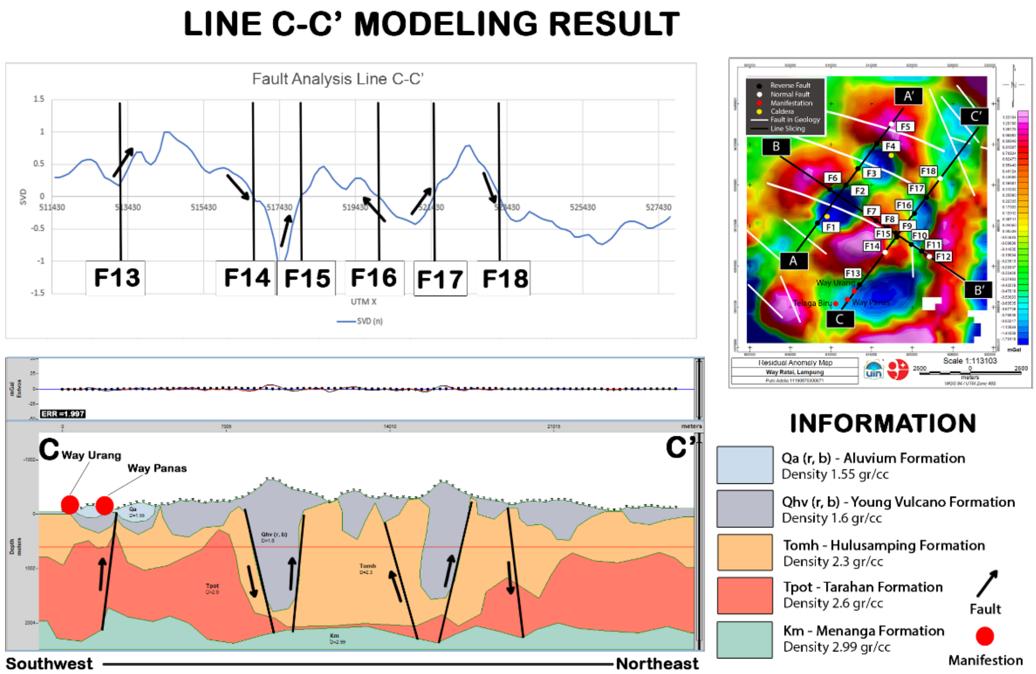


Figure. 15. Results Forward Modelling 2D Line C-C'.

Based on the results of modeling Line C - C ' in **Figure 15**, which is directed from Southwest to Northeast there are 5 layers of rock formation, with the value of rock density used each 1.55 gr/cc is suspected as a caprock rock that is sand gravel from Alluvial Formation (Qa). Then the second layer of rock density of 1.6 gr / cc is thought to be caprock rock as well as tuff rock from the Formation of Young Volcano (Qhv (r, b)). The third layer with a rock density of 2.3 gr/cc is thought to be a reservoir rock in the form of breccia from the Hulusamping Formation (Tomh). The fourth layer with a rock density of 2.6 gr/cc is thought to be a reservoir rock in the form of chert from Tarahan Formation (Tpot). And in the lowest layer with a rock density of 2.99 gr / cc is thought to be an igneous rock in the form of basalt from the Menanga Formation (Km). The fault on the Model Line C-C' is produced in the form of faults F13, F15, F16 and F17 as a reverse fault because the value ofSVD_{min} is greater than SVD_{max}. While F14 and F18 as a normal fault because the value of SVD_{min} is smaller than its SVD_{max}. Line C - C ' there are also 2 geothermal manifestations in the form of hot springs, namely Way Panas and Way Urang, indicating that there is indeed the potential of geothermal systems below the surface of the area due to reverse faults and the presence of reservoir rocks, namely breccia and chert.

CONCLUSIONS

Based on the results of research conducted to the authors draw the conclusion that:

1. Based on the results of forward modeling, subsurface density of Way Ratai area, Lampung offering can be identified at a density of 1.2 gr/cc suspected of alteration rocks in the form of clay minerals, density of 1.55 gr/cc suspected of sand gravel, density of 1.6 gr/cc suspected of tuff rocks, density of 2.3 gr/cc suspected of breccia and conglomerate rocks, density of 2.6 gr/cc suspected of schist and chert rocks, and density of 2.99 gr/cc suspected of basalt rocks.
2. Based on the results of fault analysis on the Model Line A-A' there are 4 faults. On Line B-B' there are 3 faults. And on Line C-C' there are 3 faults.
3. Potential distribution of geothermal system in Way Ratai area located in Padang Cermin sub-district identified as Way Panas and Way Urang Hot Springs is thought to be caused by reverse faults.

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