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2D Forward Modelling Geothermal Based on Gravity Data in South Solok Region, West Sumatra

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Abstrak. Panas bumi memiliki peranan penting sebagai bahan bakar alternatif karena merupakan sumber energi terbarukan, namun pemanfaatan di Indonesia belum dilakukan secara optimal. Salah satu daerah yang memiliki potensi energi panas bumi adalah Solok Selatan. Oleh karena itu, penelitian ini untuk mengetahui system panas bumi di Solok Selatan, Sumatera Barat dengan menggunakan metode gravitasi. Tahapan pengolahan data dimulau dari mendapatkan nilai CBA (*Complate Bouguer Anomaly*) dilanjutkan memisahkan anomaly menggunakan *Butterworth filter*, setelah itu dilakukan *forward modelling* 2D. Berdasarkan pemodelan pada peta CBA diduga memiliki prospek panas bumi karena terdapat nilai anomali rendah 7,9 mGal – 9,4 mGal. Sedangkan dari ke empat hasil slicing pemodelan yang diperoleh terdiri dari batuan lempung sebagai penutup, batu pasir, sebagai reservoir, granit sebgai batuan sumber panas bumi, dan lapisan berupa magma sebagai sumber panas bumi. Pemodelan anomali selanjutnya diperoleh penampang yang didominasi oleh batuan granit dengan nilai densitas 2500 kg/m^3 pada penampang AB dan nilai densitas 2550 kg/m^3 pada penampang CD.

Kata Kunci : *Forward Modelling*, system panas bumi, metode gravitasi

Abstract. Geothermal has an important role as an alternative fuel because it is a renewable energy source, but in use, it has not been done optimally. One of the areas that have the potential for geothermal energy is South Solok, West Sumatra. Therefore, this study was conducted to determine the geothermal system in the South Solok area, West Sumatra by using the gravity method. The data processing stage starts from calculating the value of the CBA (Complete Bouguer Anomaly), followed by anomalous separation using a Butterworth filter, after which 2D forward modelling is carried out. Based on the modelling on the CBA map, it is expected to have geothermal prospect because there are low anomalies of 7,9 mGal – 9,4 mGal. While the four slicing modelling results obtained consist of clay rock as a cover, sandstone as a reservoir, granite as a geothermal source rock, and a layer of magma as a geothermal source. The next anomaly modelling obtained a cross section dominated by granite with a density value of 2500 kg/m^3 on the AB section and a density value of 2550 kg/m^3 on the CD section.

Keywords: *Forward modelling, geothermal systems, gravity methods.*

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INTRODUCTION

The dwindling reserves of fossil energy coupled with an unstable price that tends to continue to increase, and the evidence that fossil fuels are the cause of global warming and environmental damage, make Indonesia have to think rationally and innovatively to develop new and renewable energy. One of them is developing geothermal energy [1].

In the 2012-2021 PLN Electricity Supply Business Plan (RUPTL), it is stated that there are nearly 4,000 MW of geothermal power plant projects that will increase to around 6,348 MW in 2021. The amount of geothermal energy potential in Indonesia is estimated to be spread across 265 locations [1]. One of the areas that have the greatest potential for geothermal energy is South Solok, West Sumatra. With such a large geothermal energy potential and the government's efforts to prioritize the development of geothermal energy, it is hoped that the geothermal industry can develop in Indonesia, especially the South Solok area, West Sumatra.

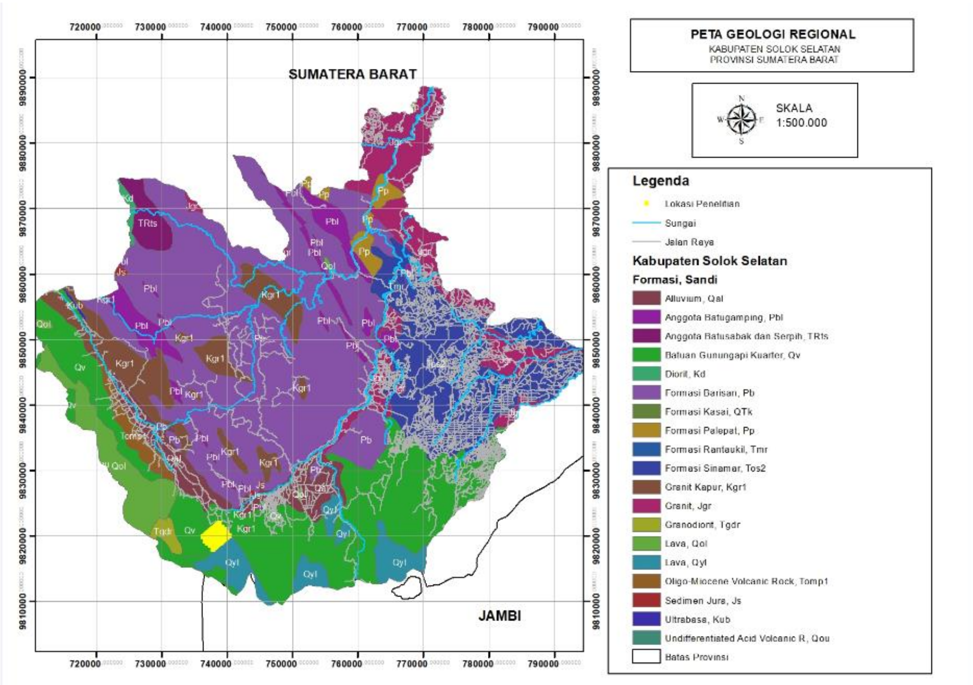

Figure 1. South Solok Regional Geological Map, West Sumatra

Geothermal energy comes from heat energy contained in the bowels of the earth and is generally associated with the existence of volcanoes. Water that comes from, among others, rain, will seep into the underground rock until it reaches the reservoir rock. This water is then heated by magma which is the main heat source so that it turns into hot water or hot steam (thermal fluid) which is then injected back into the reservoir through reinjection wells to maintain fluid and heat balance so that the geothermal system is sustainable [2].

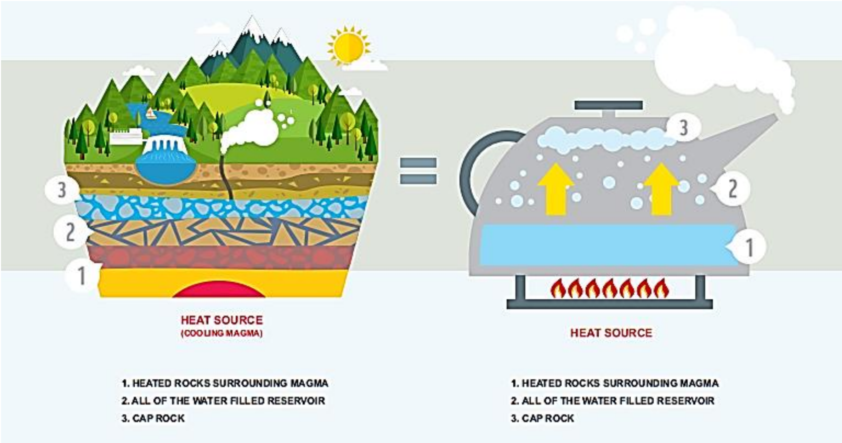

Figure 2. Geothermal Systems Work Like Boiling Water in a Kettle [3].

To see the geothermal system in a certain area requires a precise geophysical method, so that with its advantages it can provide information about subsurface structures and the causes of differences in the density of surrounding rocks. One of the geophysical methods that are suitable and commonly used for geothermal systems is the gravity method, because the gravity method has a pretty good picture for geothermal structures or complex structures through density parameters.

Principle of Gravity Method

The gravity method is included in the geophysical exploration method which is based on variations in mass density below the earth's surface. Gravitational field measurements result in a Complete Bouguer Anomaly, so to obtain gravitational data it is necessary to make corrections. Such as Bouguer correction and terrain correction.

Bouguer's correction is taken into account because there is a pull effect of the mass of rocks located in the stations and datum fields assuming they have infinite radius with a thickness of h (meters) and density of ρ (gr/cc). Bouguer correction value can be searched by the equation: [4]

$$BC = 2\pi g\rho h. \tag{1}$$

Terrain correction is performed because at the point of measurements there are topographic effects and differences elevations, such as hills and valleys around the measurement station, so that it is a correction to a simple Bouguer anomaly, in which the topography affects the reading of the due to its conservative gravity and reduced reading value than the state of Ideal [4].

Forward Modeling

Forward modeling states the process of calculating data that theoretically will be observed on the earth's surface if the price of certain subsurface model parameters is known. The calculation of the theoretical data uses mathematical equations derived from the physics concept that underlies the phenomenon being studied. In geophysical data modeling, a model is sought that produces a response that is suitable or fit with observational data or field data. Thus, the model can be considered to represent

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subsurface conditions where the data is measured. In general, the forward modeling method takes a long time because it is not automatic like inversion modeling [5].

RESEARCH METHODS

This research was conducted from 26 February to 20 March 2021. The research location was in South Solok Regency, West Sumatra. Geographically, Solok Regency is currently located between 01°20'27" and 01°21'39" SL, 100°25'00" and 100°33'43" EL. Solok Regency has a varied topographic state, starting from highlands to relatively low in the northern with altitudes start from 100 meters until1,000 meters above sea level [6].

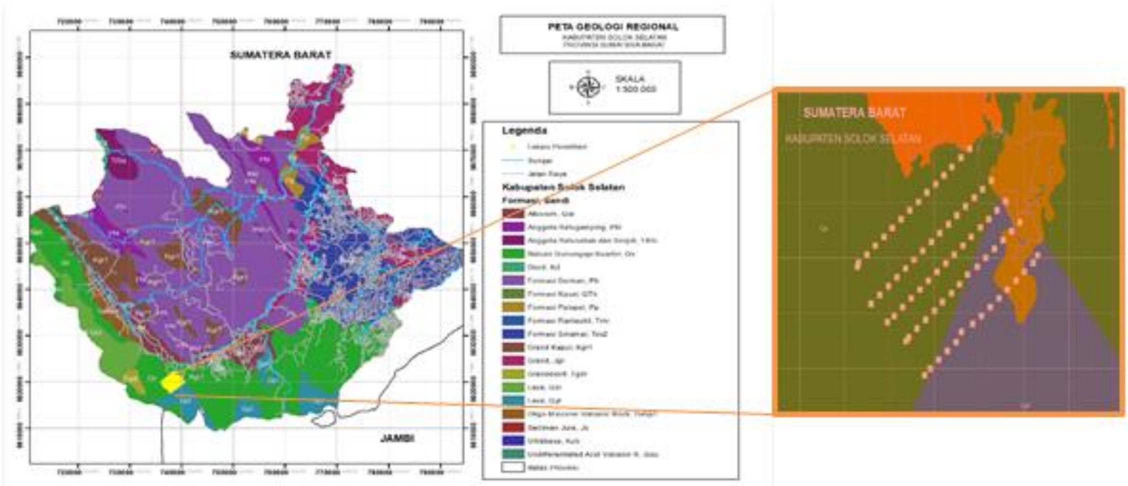

Figure 3. Research Survey Map.

The gravity data for the South Solok region is taken from Topex satellite data with a total of 100 data based on areas that are suspected of having geothermal potential, data from the Topex satellite is in the form of FAA (Free Air Anomaly) data and supporting data in the form of regional geological data made with Arcgis 10.3 software.

The gravity data processing stage requires some software to obtain the CBA (Complete Bouguer Anomaly) value, CBA contour maps, and anomaly separation using the Butterworth filter method. Anomaly separation is done using the Butterworth filter because this filter is very easy to do. In selecting regional and residual cut off zones in Oasis Montaj software, determining the intersection point of residual anomalies, and forward modeling of 2D geothermal systems without using topographic data. For more details see the flow chart below.

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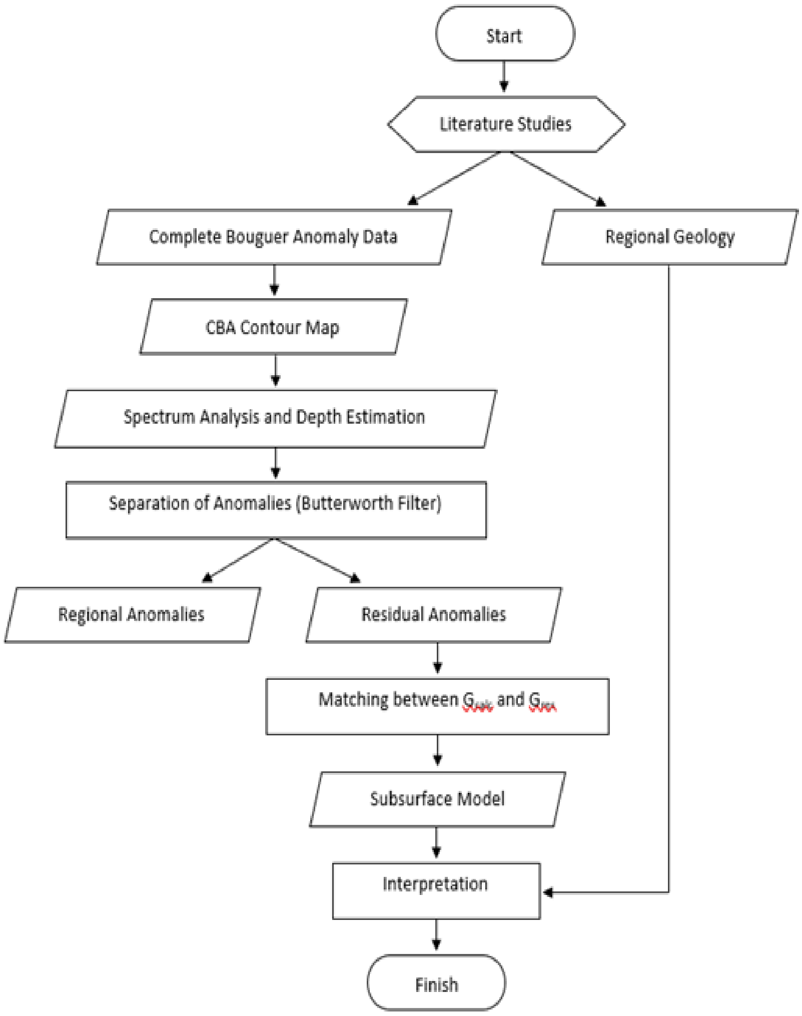


Figure 4. Research Flowchart.

RESULTS AND DISCUSSION

In data processing, after correcting the gravity value, the CBA (Complete Bouguer Anomaly) value is obtained. The CBA map shows that the anomalies generated in the data correlate well with the topography of the study area. Based on Newton's gravitational acceleration equation, shows that the value of gravity is proportional to the density of the rock beneath the surface. Therefore, the high gravity anomaly is proportional to the density of the region. Vice versa, low gravity anomaly shows a lower area density [7].

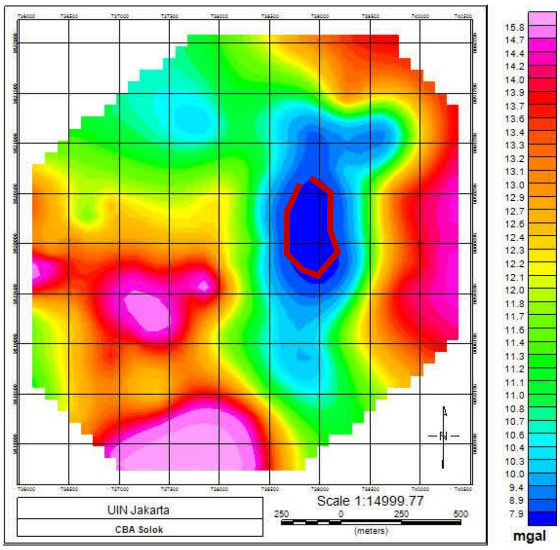


Figure 5. Complete Bouguer Anomaly Map.

Based on the CBA contour map, it can be seen that there are three gravitational anomaly patterns in the South Solok area, West Sumatra. The first anomaly pattern is a low anomaly with a range of values ranging from 7.9 mGal - 10.8 mGal. The second anomaly pattern is a moderate anomaly of 11.0 mGal - 13.3 mGal. The third anomaly pattern is a high anomaly of 13.4 mGal - 15.8 mGal. In this case, the target of the study was a low anomaly start from 7.9 mGal - 9.4 mGal which was marked in dark blue.

Complete Bouguer anomaly consists of residual anomalies and regional anomalies. Therefore, it is necessary to separate the two anomalies. The first step to take is to analyze the spectrum energy to obtain the anomaly depth value.

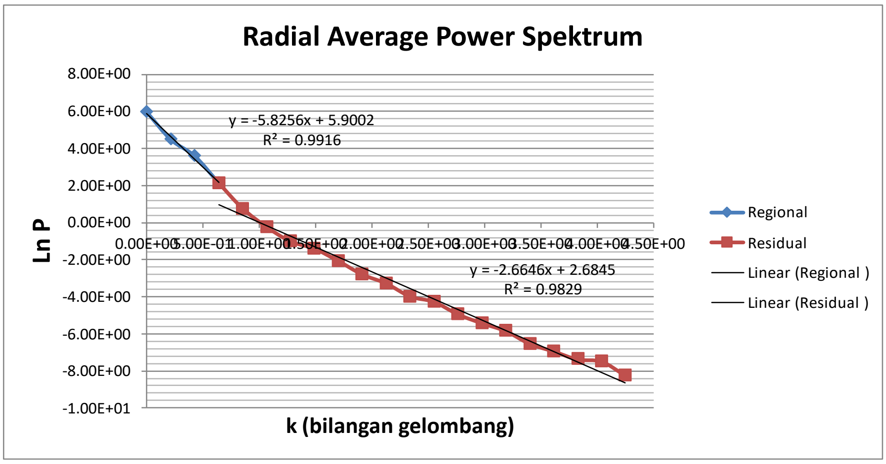
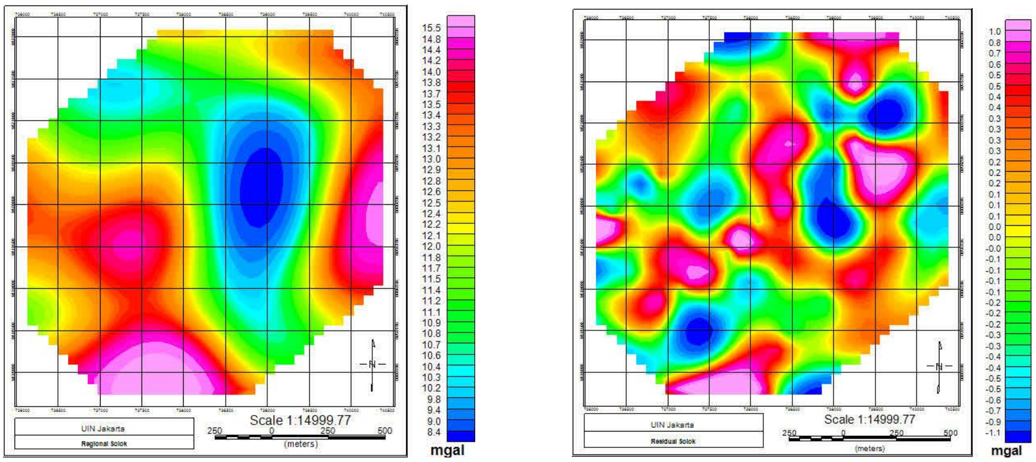


Figure 6. Radially Averaged Power Spectrum.

Based on the RAPS curve, the blue color shows a regional anomaly that can be seen from the presence of 4 observation points with the line equation y = -5.8256x + 5.9002. Because the shape is still in a gradient (in units of km), it must be converted into meters first so that it becomes -5825.6 m, then a calculation of -5825.6 / 4π is used so that the depth of the regional anomaly obtained is -463.8 m. While the red color shows the residual anomaly which can be seen from the existence of 18 observation points with the line equation y = -2.6646x + 2.6845. With the same process as the previous anomaly, the residual anomaly depth obtained was -212.1 m because it appears that the residual depth limit is 212.1 m, a 2D model will be made based on the residual depth of 212.1 m.



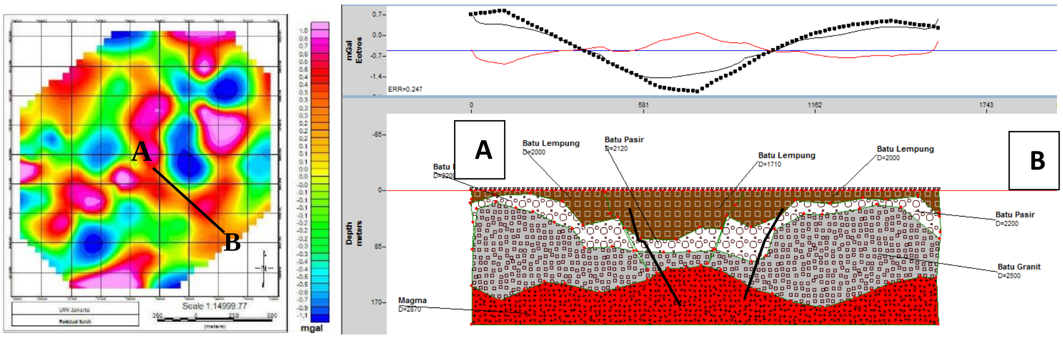
(a) (b)

Figure 7. (a) Regional Anomaly Map, and (b) Residual Anomaly Map.

The anomaly depth value is then depicted on a map through a filtering process using a Butterworth filter, which is one of the most commonly used frequency domain filters. As seen from Figure 7.a and Figure 7.b, it is clear that the difference in the residual anomaly map is rough due to the shallow location of the rocks with a value range of -1.1 - 1.0 mGal, while the regional anomaly map is smooth due to the deep location of the rocks. with a value range of 8.4 - 15.5 mGal. The regional anomaly map is almost the same as the CBA contour map because the regional anomaly value is much higher than the residual anomaly. Also, because the location of the regional anomaly is deeper and the rock density is high or compact, it will have more influence on the value of gravity.

Quantitative interpretation is done by making a model to describe the subsurface structure from the resulting gravitational anomaly profile. Modeling can be said to be correct or appropriate if the observation profile model is the same as the actual profile model which is indicated by the magnitude of the error value. The smaller the error value, the more accurate the model that has been made [8].

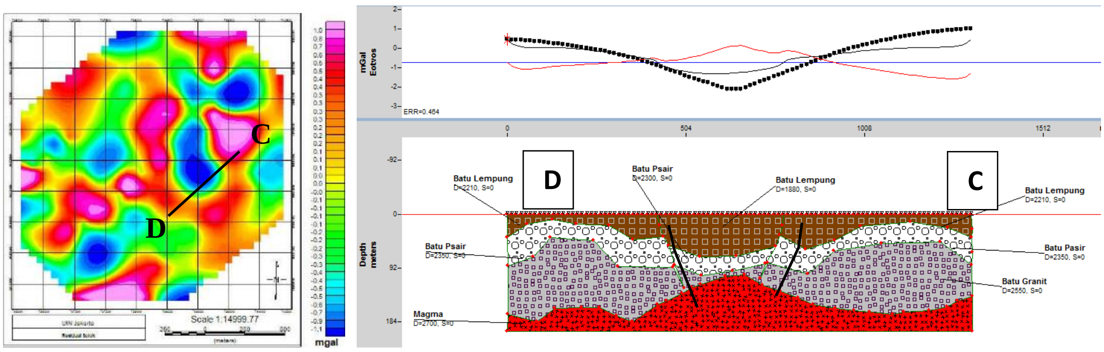
In this study, the residual anomaly map is sliced along a certain path into two parts. This results in two slicing sections of AB in the residual anomaly sliced from northwest to southeast (Figure 8.a) and CD slicing on residual anomaly from southwest to northeast (Figure 9.a). 2D modeling was made from each slicing, so that the geothermal system of Solok Selatan, West Sumatra can be seen.



(a) (b)

Figure 8. (a) Slicing AB Residual Anomalies, and (b) 2D Modeling of AB Sections.

Figure 8.b is a cross-section of AB which consists of four layers. The first layer is marked with a brown color which is thought to have a depth of 0 m - 67 m and a density value of 1710 kg/m^3 and 2000 kg/m^3. This layer contains clay rock which is interpreted as stamp rock because it functions as a reservoir cover to prevent the release of geothermal fluids. Clay rocks also have low porosity and permeability, causing fractures that extend to the second layer due to the compressive force around the rock. The second layer is marked with a white color which is thought to have a depth of 20 m - 90 m. This layer contains sandstone as a subsurface reservoir with density values of 2120 kg/m^3 and 2200 kg/m^3. The third layer is marked in gray color which is thought to have a depth of 35 m - 172 m. This layer contains granite rock that is heated from magma, resulting in hot steam with a density value of 2500 kg/m^3. The fourth layer is marked in red which is thought to have a depth of 100 m - 200 m with a density value of 2870 kg/m^3. This layer is a source of geothermal energy because it contains a very hot liquid magma from the melting of rocks in the asthenosphere.



(a) (b)

Figure 9. (a) Slicing AB Residual Anomalies, and (b) 2D Modeling of CD Sections.

Based on the modeling drawings, the CD section is not much different from the AB cross sectional modeling which consists of four layers. The first layer is marked with a brown color which is thought to contain clay rock, has a depth of 0 m - 68 m with a density value of 1880 kg/m^3 and 2210 kg/m^3. The second layer is marked with a white color which is thought to contain sandstone and has a depth of 23 m - 95 m with a density value of 2350 kg/m^3. The third layer is marked with a gray color which is thought to contain granite and has a depth of 50 m - 182 m with a density value of 2550 kg/m^3. The fourth layer is marked in red, which is thought to have magma as a source of geothermal energy and has a depth of 92 m - 200 m with a density value of 2700 kg/m^3.

Geothermal resources in the subsurface building of the South Solok area, West Sumatra is quite customary, because the area is composed of volcanic rocks and lava flows coming from Mount Kerinci. The water heat source will melt, then the hydrothermal fluid will move above its surface at a temperature that continues to increase and can be utilized in hot air bath attractions or so on.

CONCLUSION

Based on the results of research conducted with the gravity method in the South Solok area, West Sumatra, it can be concluded that:

1. Qualitative interpretation interprets the Complete Bouguer Anomaly map which is divided into three anomaly patterns. A low anomaly pattern with a value range of 7.9 mGal - 10.8 mGal, a moderate anomaly pattern of 11.0 mGal - 13.3 mGal, and a high anomaly pattern of 13.4 mGal - 15.8 mGal. From the map CBA, it appears that anomalies are dominating beneath the earth's surface. However, in this case, the target of the study is a low anomaly with a value range of 7.9 mGal - 9.4 mGal which is marked in dark blue which is thought to be a geothermal prospect area.
2. The quantitative interpretation produces 2D modeling on the anomaly cross sections AB and CD with the same number of layers, namely four. Starting from the first layer consisting of clay rock as a cap rock, sandstone as a reservoir, granite as rock heated by a heat source, and the last layer in the form of magma as a heat source. The anomaly modeling of these two sections is dominated by granite rock with a density value of 2500 kg/m^3 for the AB section and 2550 kg/m^3 for the CD section.

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