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MAGNETIC AND GRAVITY MODELING TO DETERMINE RESERVOIR DEPTH AND PROSPECT AREA AT RAJABASA LAMPUNG

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ABSTRACT

A Model in three dimension will provide the clearer image. It made the interpretation aesier. This study has been carried out to make the 3D modeling for determining area and depth of Rajabasa geothermal reservoir using Mag3D and Grav3D software. The combination of the two geophysical methods that is magnetic and gravity method constructed to reduce the ambiguity and increase the accuracy of interpretation. The both modeling results indicate that the top reservoir is about at 1000 m and the bottom is about at 3500 m depth by mean sea level (MSL) reference. Reservoir area covers around Rajabasa Peak, Peak Balerang, Cugung Fumaroles and Pangkul Fumaroles. Results of the both methods are good agrrement with the calculated temperature gradient.

Keywords: the total magnetic anomalies, Bouguer anomalies, Mag3D modeling, Grav3D modeling, reservoir depth

INTRODUCTION

Rajabasa geothermal area is an interesting geothermal area to be investigated. There are several manifestations that spread into 2 groups. The manifestations on the northern part of Mount Rajabasa are Kalianda, Sukamandi, Maja (hot spring water) and Fumarole Simpur, while in the southern part located manifestation of Mount Gunung Botak hot spring water, Pangkul fumarole, Cugung fumarole and Kunjir hot mud pool.

Rajabasa geothermal prospect area is located in in the southeastern part of Sumatera island, which is included in the South Lampung regency territory of Lampung province (Figure 1).

Preliminary studies in this area have been carried out since 1989 by rersearcher from Indonesian Geologycal Agency. However, no researchers who examined Rajabasa geochemical manifestations has studied the overall manifestation in it's studies. Sometimes there are inconsistencies in naming the manifestation. This is due to the initial assumption that claimed Rajabasa geothermal system have two heat sources.

Soeparman and Soetoyo (1989) investigated the geochemistry in the northern part of Rajabasa manifestation i.e. Sukamandi, Maja, Kalianda and Simpur. Fauzi and Aswin (1989) calculated geothermometer manifestations of water in Southern that are Cugung, Kunjir and Gunung Botak. Budiardjo (1995) calculate geothermometer of vapor in the Pangkul fumarole. Haerudin (2008) measured Geothermometer of hot spring water in the Sukamandi, Simpur and Gunung Botak manifestation. Dimwani et al. (2011) measured chemical isotopes in all manifestations. Kusumasari (2011) studied geochemistry in Sukamandi, Maja, Kalianda, Simpur, Kunjir and Gunung Botak manifestation.

The results of geochemical investigations of several researchers who have been mentioned in the previous paragraph claimed that Simpur, Cugung, Pangkul and Kunjir tend sulfate water type; Kalianda and Maja are bicarbonate type and Gunung Botak is chloride type (Table 1).

The geophysical research in Rajabasa geothermal that cover around Rajabasa areas begun by the Geological Agency of Indonesia in order to preliminary geothermal prospects Survey. However, this study only perform qualitative interpretation and unpublished. Rasimeng, et al., (2008) conducted a study with magnetic method to investigate major fault that occurred at Mount Rajabasa. Furthermore Suharno et al., (2008 and 2010) which examined the permeability reservoir geothermal system with the same data. This study data dominated in the northern part of Mount Rajabasa and not cover the entire area of geothermal prospects Rajabasa especially in middle and southern parts . Then Haerudin et. al., (2011) conducted research with the magnetic method and measuring data to complete the previously Geological Agency data. Combined these data cover the entire region of Mount Rajabasa. A Qualitative analysis results obtained fault picture that confirm with the geological interpretation from geological research have done before. The study by Dimwani, et. al. (2011) with the MT method is proved that Rajabasa geothermal system has just only one heat source. Finally, the 3D magnetic modeling Rajabasa that described the geometry of the reservoir showed it located at around manifestation Pangkul and Cugung about 1000 m depth.

Figure 1. Lampung Province Map (inset Sumatra Island)

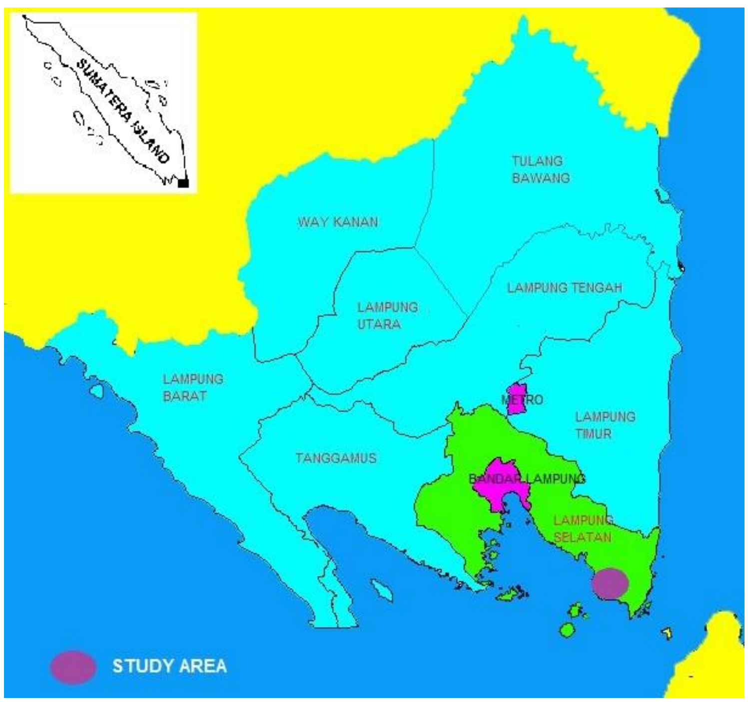


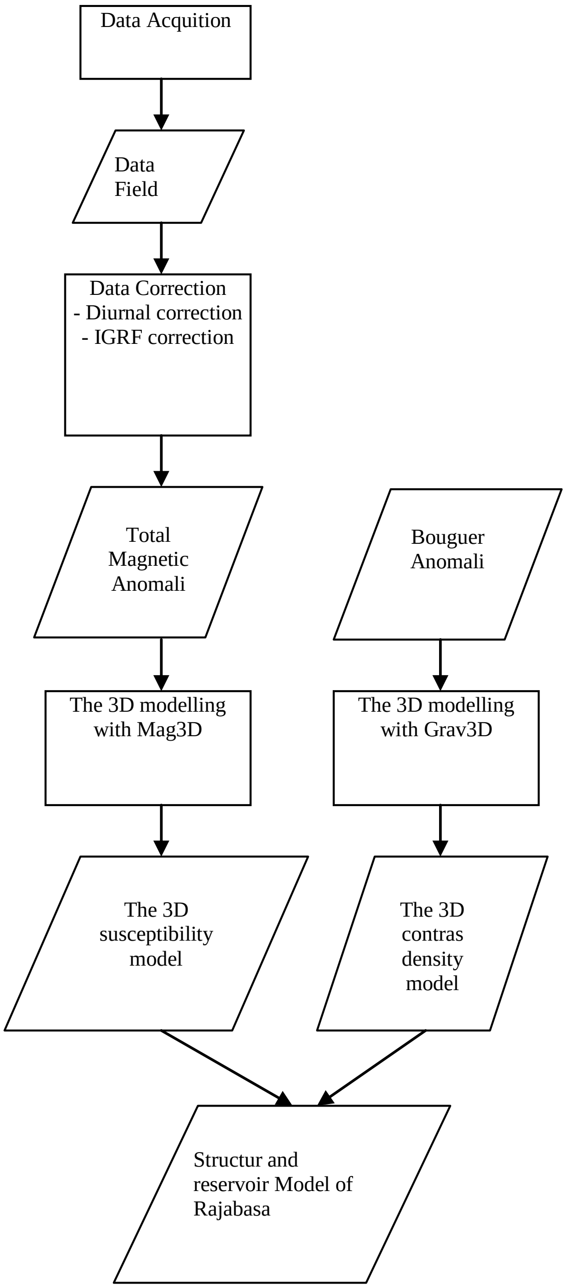
Table 1: Compilation of result study in Rajabasa manifestation

Manifestation	Type of water	Reservoir's temperature (^oC)
Simpur	Sulfat	260
Sukamandi	Bikarbonat	212
Kalianda	Bikarbonat	207
Maja	Bikarbonat	172
G. Botak	Klorida	250
Cugung	Sulfat	241
Kunjir	Sulfat	247
Pangkul	Sulfat	247

Magnetic method is a method that has ambiguity. To corroborate these results, it is necessary to be compared with the interpretation result by the gravity method. That comparation expect to be able to determine geothermal structure and reservoir accurately . Therefore, this study carried out interpretation of magnetic and gravity method to determine the structure and reservoir.of Rajabasa geothermal filed.

METHODS

Figure 2. Flowchart Data Processing



Magnetic data are combination of primary data were taken in 2011 to complement the magnetic data that has been taken Indonesian Geological Agency in 1995. Gravity data is secondary data taken in 1995.

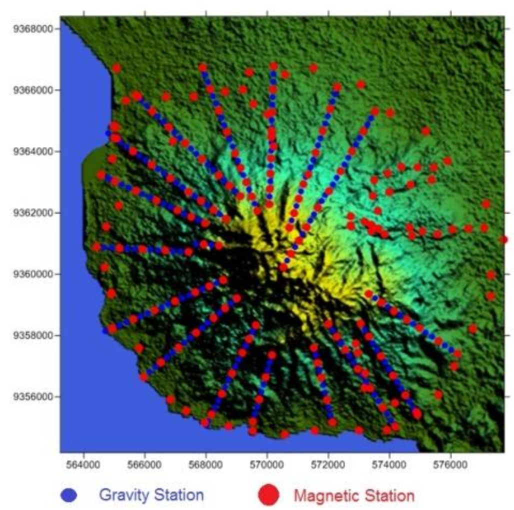
Magnetic and gravity data processed as described in the flowchart of data processing (Figure 2) The results of 3D modeling of gravity and magnetic compared the data to get the disjoint area which is suspected as the geothermal reservoir. Reservoir depth of 3D modeling as compared with the depth matched by geochemical calculations. The result overlayed on detail geological map to be analyzed.

RESULTS AND DISCUSSION

Graviyty and magnetic measurement data covers the entire area Rajabasa volcano. Distribution of the measurement station showed and overlayed on DEM map (Figure 3. Then the combining data is presented in the contour map. Figure 4 showed contours of the total magnetic anomaly with a maximum value is 900 nT and a minimum value is -900 nT. At the center of the map, there are seen the contour pairs of positive and negative anomalies extending from the northwest - southeast. This indicated the presence of subsurface structure that extends from the northwest - southeast.

The pattern of the main structure at Rajabasa volcano influenced by regional structures such as Lampung fault that had close relation to Semangko fault. This fault is shear fault trending northwest-southeast. The dashed black line represented the direction of the main structures that control the minor structures occured in the Rajabasa volcano (figure 4.).

Figure 3. Garvity and Magnetic Station



Based on Figure 4, the susceptibility values could be classified into 3 groups., fistly, high magnetic anomalies anomalous, it had susceptibility value more than 300 nT . High magnetic anomaly was interpreted as igneous rocks that have not gotten the weathering so its magnetism value is high. Secondly Intermediate magnetic anomaly, it's susceptibility values had range between -300 nT up and 300 nT. This magnetic anomalies were interpreted as a lossing partly of magnetic properties rocks due to weathering. Finally, the low magnetic anomaly, it's susceptibility value is less than -300 nT. In the total magnetic anomaly map. it is shown in blue color scale. A low magnetic anomaly interpreted as hydrothermal rocks that undergo deep weathering, thus causing the susceptibility value is reduced and becomes a low magnetism rock. Low anomaly is estimated as the geothermal reservoir because the rock is in continuous heating by a heat rock. Heating in a long period of time will cause a decreasing to rock magnetism value. The main magnetic minerals (magnetite and titomagnetit) is replaced by a non-magnetic alteration minerals such as pyrite or hematite . So the reservoir zone is associated with low susceptibility zones (Soengkono, 2011).

Figure 4. Contour map of total magnetic anomali of Rajabasa Geothermal field

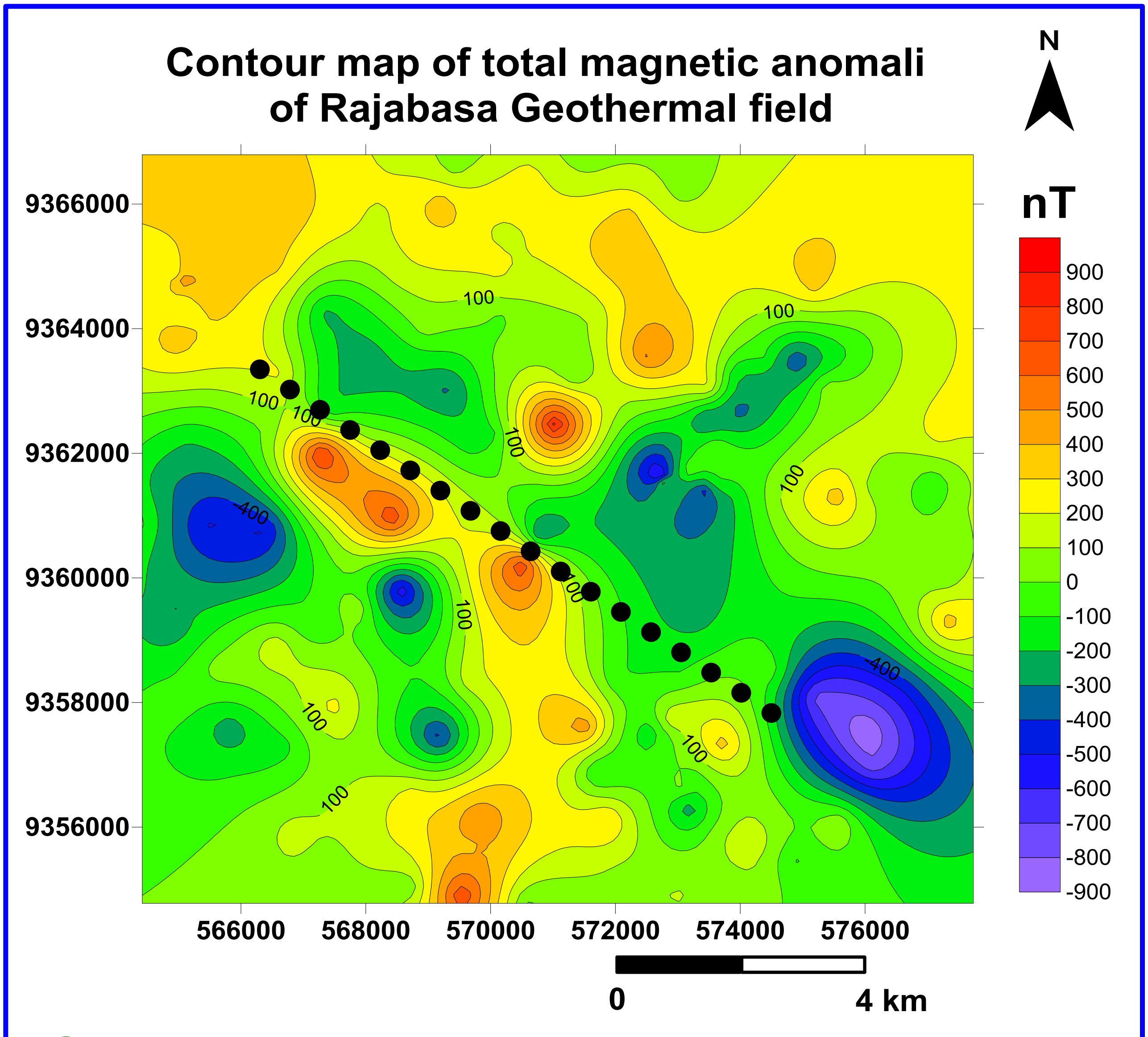


Figure 5. showed two diagonal slices in the study area. In the center model below the Balerang peak, it seen low susceptibility zone that suspected to be the Rajabasa geothermal reservoir. That had susceptibility values ranged from -0.06 to 0.114 which is estimated andesite rosk that has been damaged due to hydrothermal processes. The estimated depth of the top reservoir is about 1000 m depth and the bottom is about 3500 m in mean sea level references (Figure 6).

Figure 5. The 3D magnetic modelling of Rajabasa geothermal field. (Left: southwest–northeast crosssection; rigth: northwest–southeast crosssection).

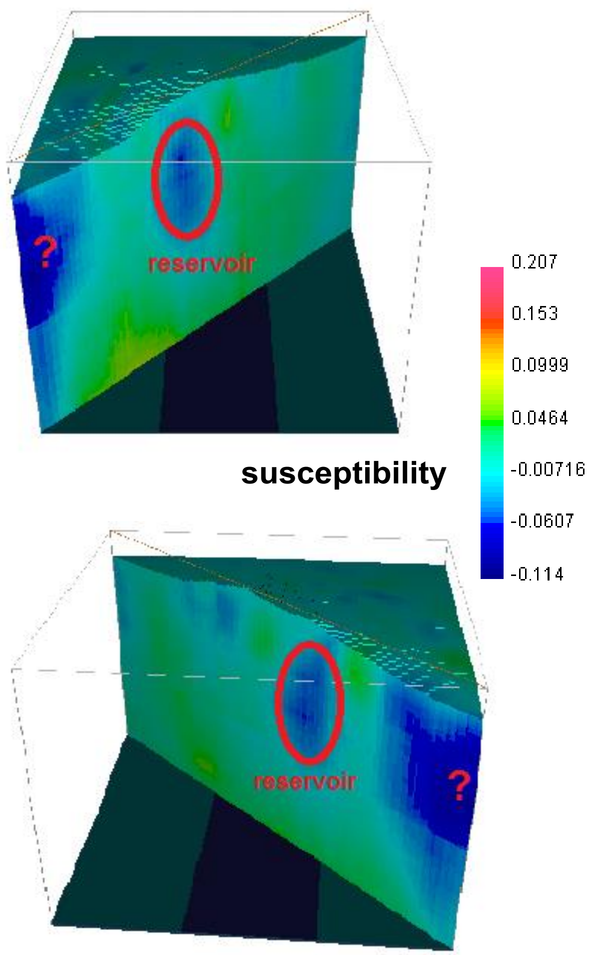
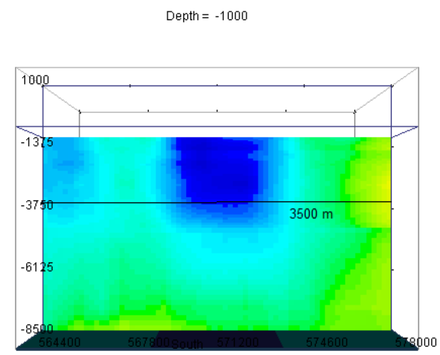


Figure 6. Reservoir depth based on the 3D magnetic modeling.



The complete Bouguer anomaly contour map of Rajabasa volcano showed in figure 7. It have a variation of the density contrast from 28 mGal to 80 mGal. These values are classify into 3 groups. The hight anomalies had values more than 64 mGal are shown in red colour. High anomaly is interpreted as igneous rocks that have not undergone a process of alteration, so the conditions still fresh, massive and hard. The anomaly is spread across the Northwest, Northeast and Southeast in the corner of the study area . The anomalous value about 45 mGal up to 64 mGal is shown in green and yellow. This anomaly was interpreted as igneous rocks that have undergone a process of intermediate alteration. The group is spread across north and south. Low anomaly groups had less than 44 mGal are shown in blue. Low anomaly is interpreted as a rock that has undergone a thorough high alteration process that caused rock density values decreasing. This anomaly groups spread across the central part from west to east.

Figure 7. Contour map of Bouguer anomali of Rajabasa Geothermal field

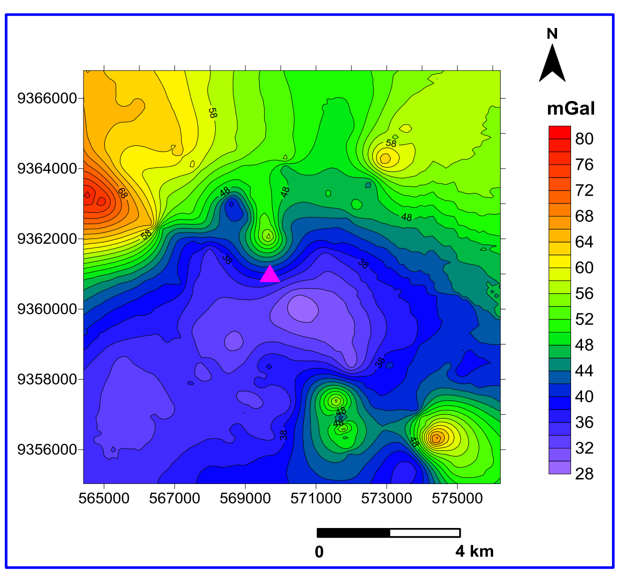
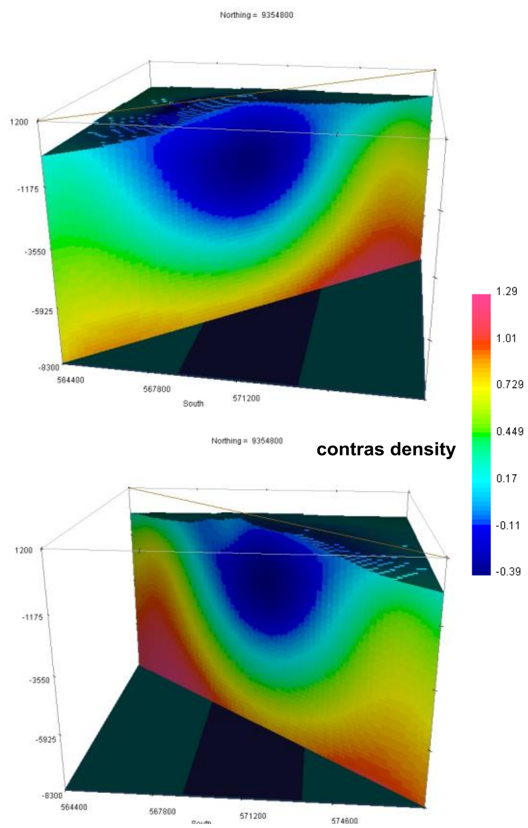


Figure 8. showed two diagonal slices in the study area. In the middle under the Rajabasa peak and Balerang peak, low density zone is visible. that zone supposedly cracks immassive rock due to the influenced of hydrothermal fluid. Density contrast values range from 0 to -0.39. based on observations in the field, an overview Geological map and previous research results as Budiardjo et al. (1995), Suswati et al. (2001) and Bronto et al (2012) suggest that the rocks that dominate the entire Rajabasa volcano area is andesite-basaltic.

So Rajabasa geothermal reservoir rock is estimated andesite crushed zone due to hydrothermal processes. Zone of low density contrast is starting from 0 m to 3500 m depth.

Figure 8. The 3D gravity modeling of Rajabasa geothermal field . (Up: the southwest-northeast crosssection; Bottom: the northwest-southeast crosssection).



If we take the value of the reservoir depth is about 1000 m to 3500 m, it is still a good agreement for both magnetic and gravity modeling (Fig. 6 and 9).

Figure 9. Reservoir depth based on the 3D gravity modeling.

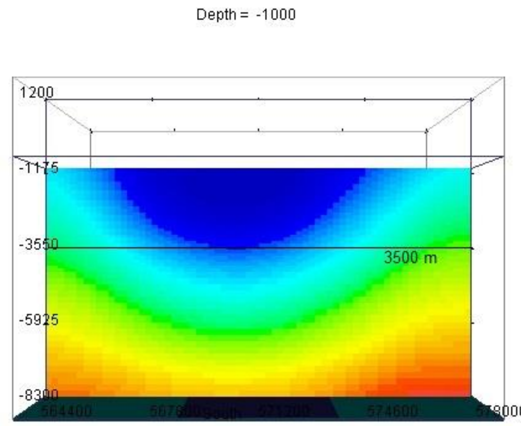


Table 2. showed results of the estimated reservoir depth by heat gradient. Here we take a gradien value that is 17.3 ^{o}C/100 m based on reference from Indonesian Geological Agency. We simply calculate it into upflow manifestations, not counted to out flow like Kalianda, Sukamandi and Maja. Assuming that the reservoir is under the upflow zone and all manifestations of the southern part supplied by only one reservoir, the reservoir is estimated to be under Cugung or Pangkul area. Simpur suplied by other reservoir in the northern part, but the both model could not decribe clearly.

Table 2: Reservoir's depth with temperature gradien 17.3/100 m

Manifestation	elevation (m)	Reservoir's Depth	
		Surface (m)	MSL (m)
Simpur	342	1503	1161
Gunung Botak	26	1445	1419
Cugung	418	1393	975
Kunjir	74	1428	1354
Pangkul	470	1428	958

Once we determine the depth of the reservoir of the two methods above, then we will be comparing the suspected reservoir area in the horizontal plane. We take slice of both models at 1250 m depth. Figure 10 showed a comparison of the reservoir area resulting the magnetic and gravity modeling. To clarify the position of the surface, we overlayed it with position of the Rajabasa peak and geothermal manifestations.

Reservoir area covers the area around Rajabasa Peak, Balerang Peak, Cugung fumaroles and Pangkul fumaroles The results of both methods are good agrrement with the temperature gradient calculation results that list in Table 2 .

To clarify the picture on the surface, we overlayed suspected reservoir area with detailed geological map (Figure 11).

Figure 10. Comparation between magnetic and gravity models to Determine the reservoir area. (a) magnetic method. (b) gravity method

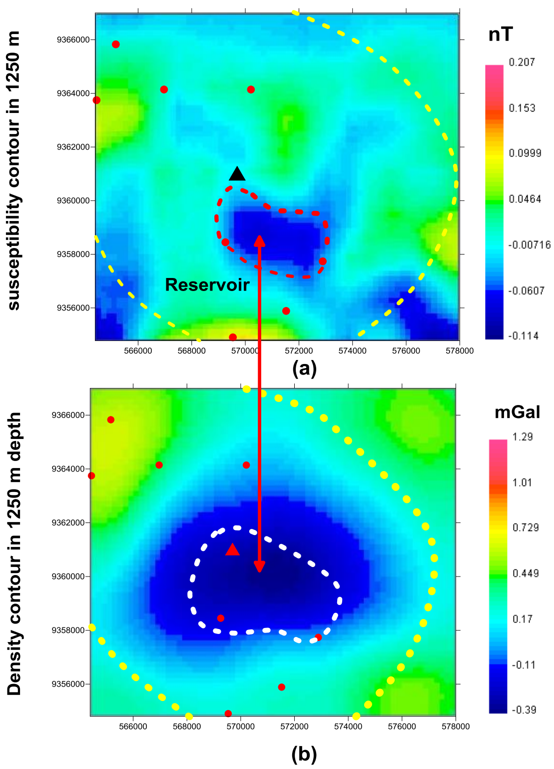
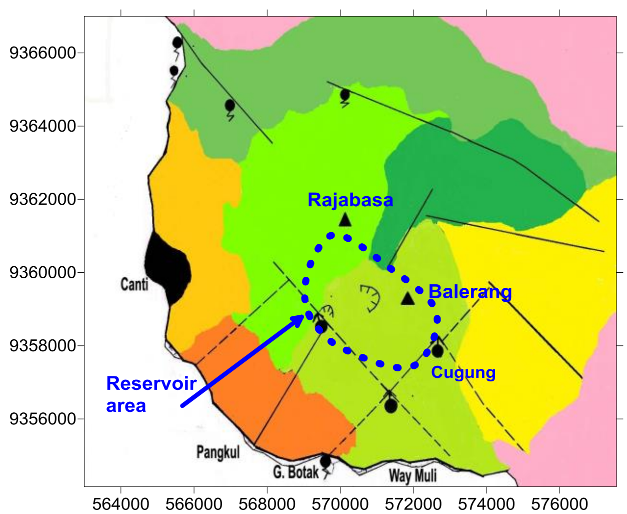


Figure 11. The main prospect (reservoir area) of Rajabasa geothermal system overlayed on geological maps.



CONCLUSION

Based on the 3D modeling by Mag3D and Grav3D, geothermal reservoir covers Rajabasa peak, Balerang peak, Cugung fumarole and Pangkul fumarole.

The depth of the reservoir obtained from the heat gradient calculations and the both 3D modeling is about 1000 m - 3500 m at the mean sea level (MSL).

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