Reservoir Identification Based on Gravity Method at "AUN" Geothermal Field

Annisa Dwi Hafidah[1], *Yunus* Daud[1,*], and *Alfian* Usman[2]

[1] Master Program in Geothermal Exploration, Departement of Physics, Universitas Indonesia, Depok - Indonesia
[2] PT. Pertamina Upstream Technology Center, Jakarta - Indonesia

Abstract. Sumatra Island has the largest geothermal potential in Indonesia spread along the subduction zone between the Indian-Australian plate and the Eurasian plate. "AUN" geothermal field located in Sumatra Island and considered to be one of the largest potential geothermal prospects in Indonesia. This study is focused on identifying the prospect of "AUN" geothermal field using gravity method. First Horizontal Derivative (FHD) and Second Vertical Derivative (SVD) analysis were applied in order to determine a more accurate boundary of the fault. 3D inversions of gravity data were used to reconstruct subsurface model. The result show that analysis of First Horizontal Derivative (FHD) and Second Vertical Derivative (SVD) can confirm southwest-northeast fault and caldera structure as a boundary of geothermal reservoir and 3D gravity inversion can show subsurface layers with density 2.5 gr/cc to 2.8 gr/cc inside the boundary which is determined as a heat source in "AUN" geothermal field.

Keywords: **Gravity, Geothermal; Reservoir**

1 Introduction

Sumatra Island has the largest geothermal potential in Indonesia spread along the subduction zone between the Indian-Australian plate and the Eurasian plate [1]. "AUN" geothermal field located in Sumatra Island and considered to be one of the largest potential geothermal prospects in Indonesia. The dominant rocks of the area are mostly andesites from three dormant volcanoes with the age spans from 1.2 to 0.6 Ma. [2]. Several surface thermal manifestations, such as fumaroles and hot springs, were found. The appearance of these manifestations is probably caused by the permeable pathway due to the intersection of several geological structures. This study is focused on identifying the prospect of "AUN" geothermal field using gravity method. Gravity method can provide information related to density distribution in the subsurface which will be used to identify faults in the geothermal prospect area [3]. First Horizontal Derivative (FHD) and Second Vertical Derivative (SVD) analysis were applied in order to determine a more accurate boundary of the fault [4]. Moreover, the 3D inversion of gravity data was used to reconstruct subsurface model so that the reservoir zone in "AUN" geothermal field can be identified.

2 Data Processing

The gravity measurement was conducted at 399 stations which are distributed in the area to delineate the existence of the geothermal system. Relative gravity data were then processed with several corrections such as drift, latitude, free air, Bouger and terrain corrections. After those correction processes, Complete Bouger anomaly (CBA) was obtained. Furthermore, the spectrum analysis method is required to detect the regional-residual contact boundary. The separation of regional and residual anomalies was done using the moving average method. In this study, the Bouger density based on the Parasnis approach is 2.19 g/cc for the whole area. First Horizontal Derivative (FHD) and Second Vertical Derivative (SVD) analysis were applied in order to determine a boundary of the fault. The zero contour anomaly of SVD correlated with the trend of the estimated fault structures marked by the presence of manifestations on the surface [4]. The 3-D gravity inversion model is carried out to analyze subsurface layers based on differences in density values. The making of the model uses software produced by the University of the British Columbia Geophysical Inversion Facility (UBC-GIF) [5]. When performing

* Corresponding author: ydaud@sci.ui.ac.id

inversion with UBC-GIF software, there are two models to consider: a reference (input) model and a recovered (output) model. The reference model is most commonly a pre-inversion mesh, or volume, of voxels which will be populated by computed physical properties in the recovered model [6].

3 Result And Interpretation

3.1 CBA

Contour patterns on CBA maps show density patterns where the contours are tight then the depth of the bedrock is shallower [7]. On the CBA map, it can be seen that the contour in the Southwest has a higher density than in the Northwest and Southeast (Fig.1). This shows that there is a pattern of the depth of bedrock which is increasingly shallow towards the Southwest. High CBA anomalies in the region also show that there is a density contrast with surrounding area which is indicated as an intrusion.

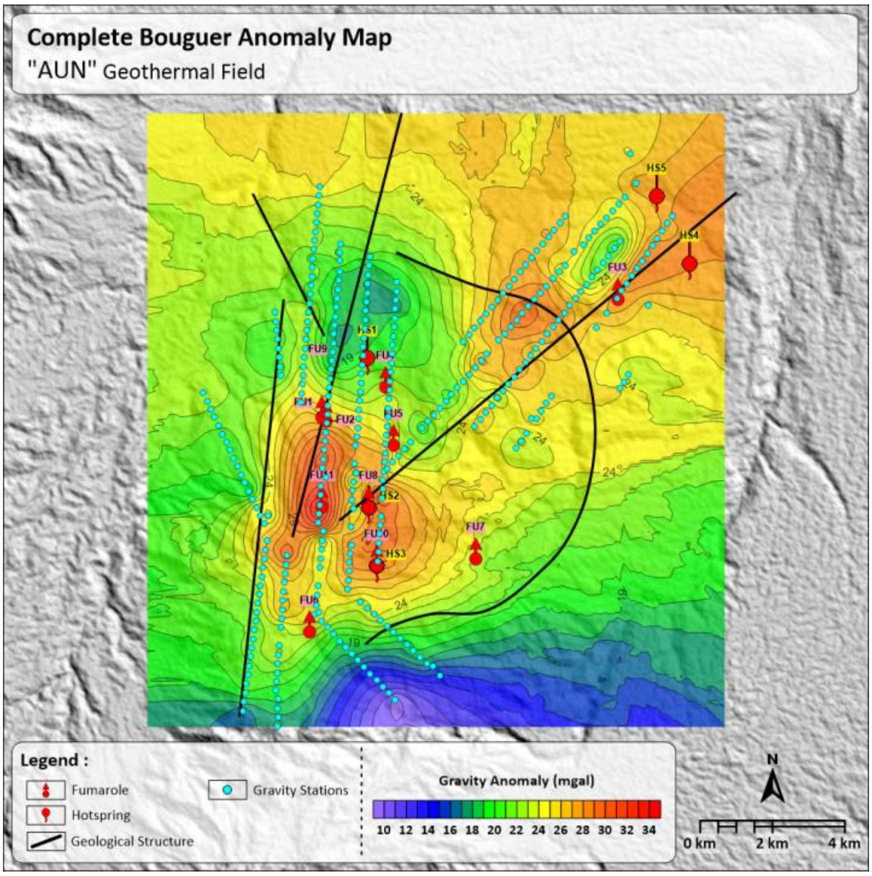

Fig. 1. Complete Bouguer Anomaly Map

3.2 Separation of Regional and Residual Anomaly

The spectral analysis method was applied to investigate the wavenumbers of gravity residual anomalies and to estimate the depths of the bottom and top of the residual anomalies source bodies [8]. Then, moving average method is used to separate complete Bouguer anomalies into regional anomalies and residual anomalies [9]. The results show that the deepest anomaly has a depth of about 3997 m or about 4 km. The anomalous trend shown in the regional anomaly map is similar to CBA map that has high-density contrast in the West to Northeast area and low-density contrast in the South area (Fig.1.a). This reinforcement of the suspicion of high anomaly values on CBA maps which are thought to originate from intrusions of igneous rock. The area of high-density contrast in the residual anomaly map is denser and smaller than CBA map (Fig.2.b). This indicates that there is a suspicion of rock intrusion to a shallow depth. The meeting of high to low anomalous contours also indicates the presence of faults.

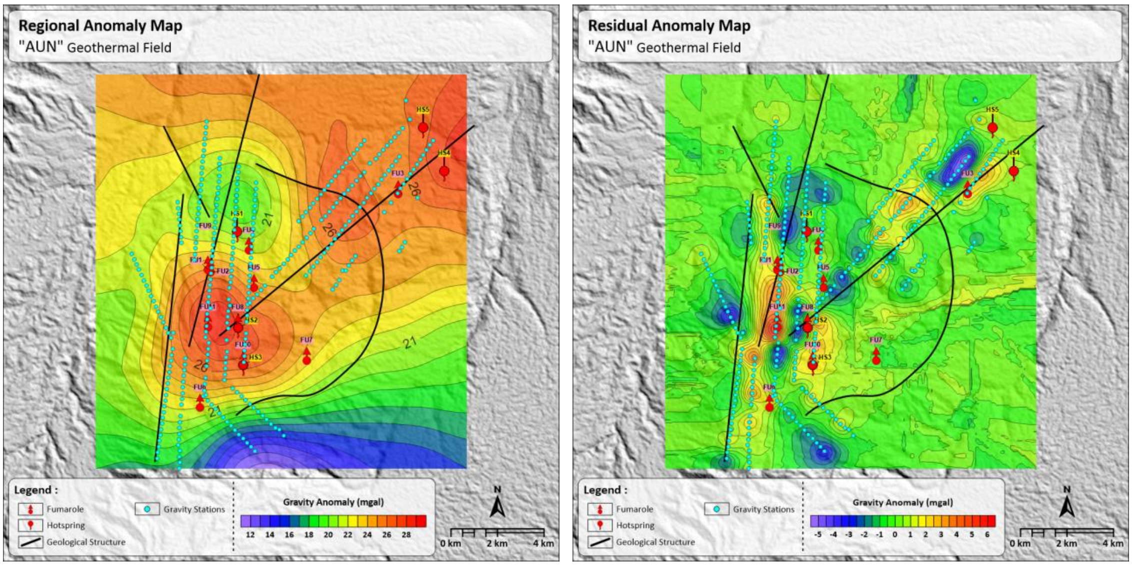

Fig.2. a) Regional Anomaly Map, b) Residual Anomaly Map

3.3 Derivative Analysis

To detect the presence of a fault, then used the FHD method and to determine the type of the fault using SVD method [10]. In the FHD existence of a fault is indicated by a zone of highest anomalous gravity values because on the fault zone there is high contrast rocks density. While SVD method used to indicate a type of faults by looking at the high anomaly and low anomaly adjacent to each other [10]. The zero contour anomaly of SVD correlated with the trend of the estimated fault structures marked by the presence of manifestations on the surface [4]. The type of fault is a normal fault if the value of min g " < max g ". Conversely, the type of fault is a reverse fault if the value of min g " > max g ". On the FHD curve, there are four lines that have the maximum FHD value that matches zero values on the SVD curve (Fig.3). This indicates that FHD can determine the existence of faults confirmed by the SVD.

The curve slicing along line A-A' show when FHD value is maximum, the SVD value is zero. This result can be associated with southwest-northeast fault. Then, the maximum value of SVD curves is bigger than the minimum SVD value. It shows that the type of fault can be identified as a normal fault (Fig.4.a). The curve slicing along line B-B' show when FHD value is maximum, the SVD value is zero. This result can be associated with caldera structure because it has a semicircular shape. Then, the maximum value of SVD curves is bigger than the minimum SVD value. It shows that the type of fault can be identified as a normal fault (Fig.4.b). The curve slicing along line C1-C1' and C2-C2’ show when FHD value is maximum, the SVD value is zero. This result can be associated with rock intrusions (Fig.4.c). The curve slicing along line D-D' show when FHD value is maximum, the SVD value is zero. This result can be associated with caldera structure. Then, the maximum value of SVD curves is bigger than the minimum SVD value. It shows that the type of fault can be identified as a normal fault (Fig.4.d).

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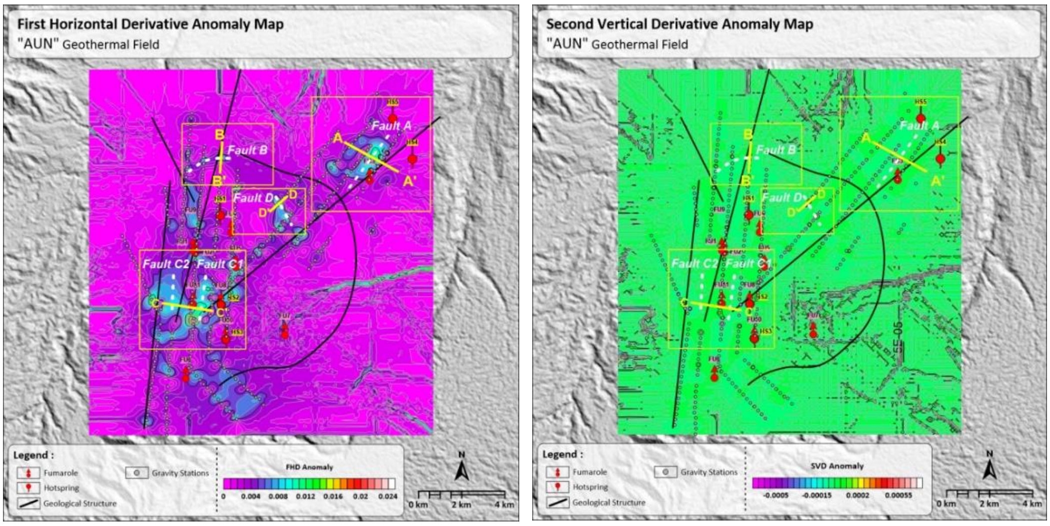

Fig. 3. a) First Horizontal Derivative Anomaly Map, b) Second Vertical Derivative Anomaly Map

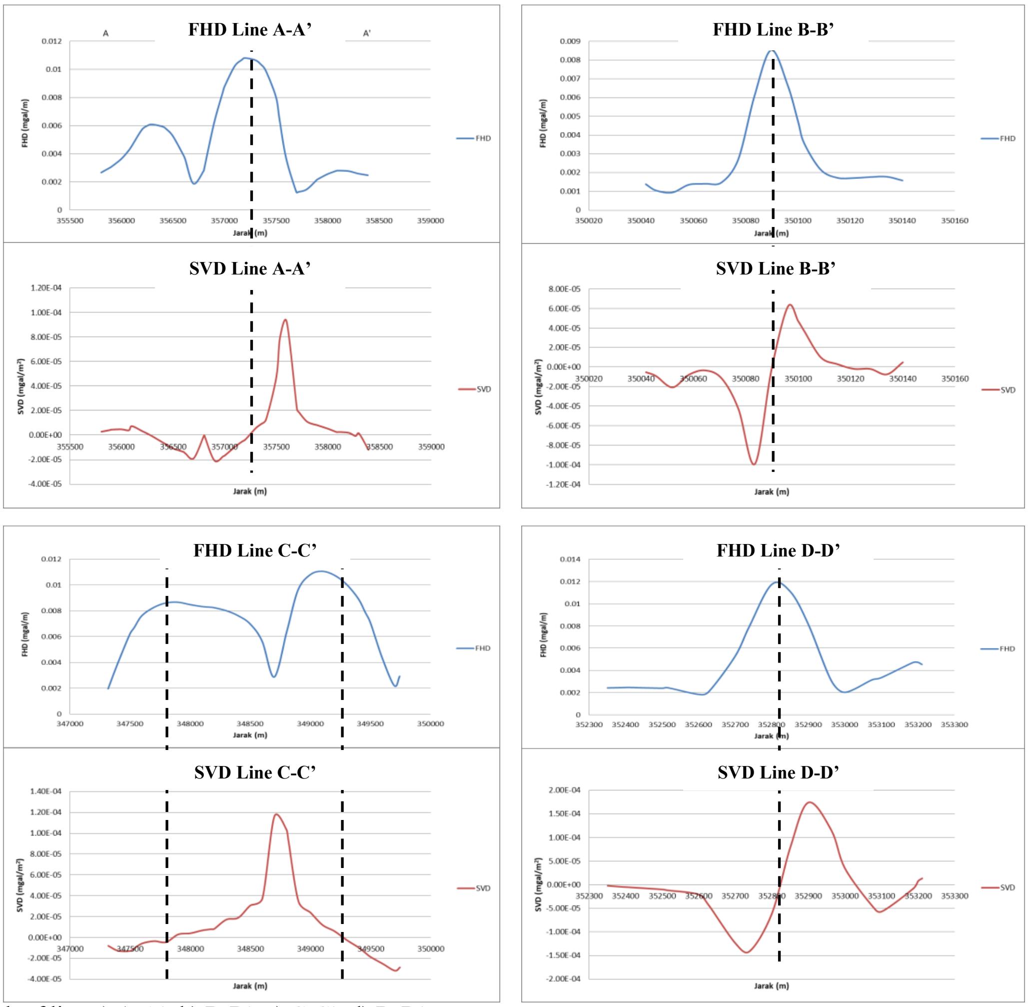

Fig. 4. Slicing result of line a) A-A', b) B-B', c) C-C', d) D-D'

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3.4 3D Gravity

The cross-section along line A and line B based on the 3D gravity inversion model shows the contrast density inside a fault boundary and caldera structure against the surroundings (Fig.5). According to the model, it might possibly be classified into three main layers which determined as caprock, reservoir, and heat source. The caprock has density layer of 2.015 gr/cc to 2.24 gr/cc, the reservoir zone has density layer of 2.3 gr/cc to 2.4 gr/cc and heat source has density of 2.5 gr/cc to 2.8 gr/cc.

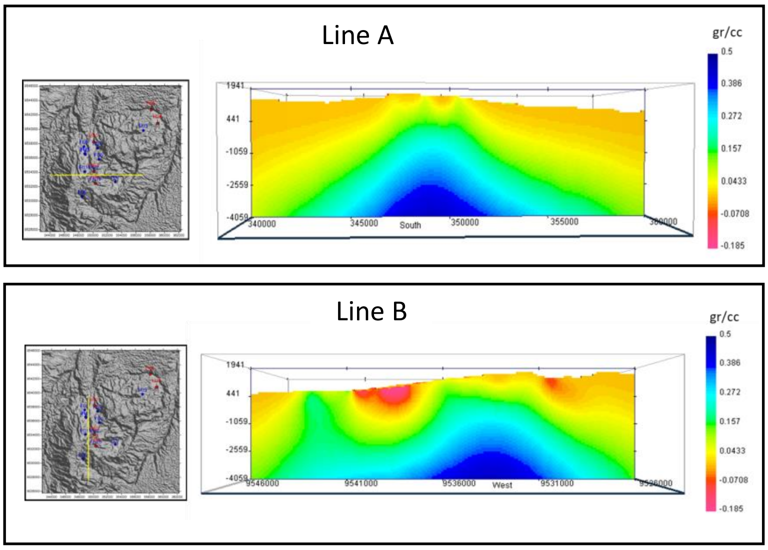

Fig. 5. Cross-section of 3D gravity inversion model in line a) A and b) B

4 Conclusion

The result show that analysis of First Horizontal Derivative (FHD) and Second Vertical Derivative (SVD) data can confirm the southwest-northeast fault and caldera structure as a boundary of geothermal reservoir with the overall structure type are normal fault. 3D gravity inversion model can show three main layers which determined as caprock, reservoir, and heat source. The caprock has density layer of 2.015 gr/cc to 2.24 gr/cc, the reservoir zone has density layer of 2.3 gr/cc to 2.4 gr/cc and heat source has density of 2.5 gr/cc to 2.8 gr/cc.

References

1. M.B.Prijanto, *Resource Characteristics and Development of Sumatera's Geothermal Prospects, Indonesia*, Geothermal Resources Council Transactions, **20** (1996)
2. I.B.Raharjo, *Geophysical Signatures of Volcano-Hosted Geothermal Systems*, The University of Utah (2012)
3. Y.Daud, Y.Arafat, D.A.Kumara, D.A.Fortuna, F.M.Yunus, H.F.Avicienna and Farhan, *An Updated Study of Discovering Blawan-Ijen Geothermal Prospect Area Using Gravity and Magnetic Methods*, E3S Web of Conferences **73**, 0100 (2018)
4. T.Sastranegara, S.S.Nainggolan, and I.B.Raharjo, *The Application of a Triangular Mesh for Gravity Inversion to Reconstruct Subsurface Geological Structures in the Hululais Geothermal Prospect*, Bengkulu, Proceedings World Geothermal Congress (2015)
5. Y.Li and D.W.Oldenburg, *3-D Inversion of Gravity Data*, Geophysics, **63**, 1: 109–119 (1998)
6. B.Spicer, B.Moris, and H.Ugalde, *Structure of the Rambler Rhyolite, Baie Verte Peninsula, Newfoundland: Inversions using UBC-GIF Grav3D and Mag3D*, Journal of Applied Geophysics, **75**, 9–18 (2011)
7. Baharianto, *Interpretation of Gravity Anomaly in Luwuk, Central Sulawesi*, Bandung Institute of Technology (2007)
8. J.J.Nguimbous-Kouoh, S.Ngos, T.N.Mbarga, E.Manguelle-Dicoum, *Use of the Polynomial Separation and the Gravity Spectral Analysis to Estimate the Depth of the Northern Logone Birni Sedimentary Basin (CAMEROON)*, International Journal of Geosciences **8**: 1442-1456 (2017)
9. R.A.S.Darmawan, A.D.Sutomo, and B.Legowo, *Determination of Optimal Window in Spectrum Analysis Process with Moving Average Method Gravity Data Measurement*, 9th International Conference on Physics and Its Applications (2019)

10. M.S.Rosid and H.Siregar, *Determining Fault Structure Using First Horizontal Derivative (FHD) and Horizontal Vertical Diagonal Maxima (HVDM) Method: A Comparative Study*, International Symposium on Current Progress in Mathematics and Sciences (2016)