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SEG Technical Program Expanded Abstracts 2020
Technical Program Chairperson(s):
Olga Nedorub and Bryce Swinford
ISSN (Online): 1949-4645
Copyright year: 2020
Pages: 3887
Publisher: Society of Exploration Geophysicists

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2020 Presentations

Identification of geothermal reservoir based on 3d modeling of data anomaly magnetic residual reduction to pole in the region of geothermal prospect Villamasin East Oku

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Summary :

The study has been done to identify geothermal reservoir in the geothermal prospect area Villamasin, District of Jayapura, East OKU Regency. The existence geothermal reservoir was analyzed based on 3D modeling of residual anomaly from the reduce to the pole process of the subsurface rock. To achieve those objectives, several stages of study are carried out. The first one is uneven surface to level surface transform, the second one is upward continuation, the third one is the separation of residual and regional anomaly, and the fourth one is reduce to the pole. Based on the result of transformation to level surface using the Taylor series approach, we can obtain the magnetic field anomaly contour at the elevation level of 105 meters above the mean sea level. Furthermore, the separation of residual and regional anomalies using second order polynomial fittings and the next stage is transforming the residual magnetic field anomaly to magnetic field anomaly that is generated from the process of reduce to the pole. Than, the final stage is we create 3D residual anomaly model based on the reduce to the pole of the subsurface rock process, which is obtain the information of geothermal reservoir with the range susceptibility of 0.16 cgs (103 SI) to 0.97 cgs (103 SI). The position of the reservoir is relatively located at the NE direction to SW and NW direction to SE and it is located at the depth of 800 meters below the mean sea level.

Introduction

The Villamasin area is located on East Ogan Komering Ulu, South Sumatera Province. The existence of geothermal fluid manifestation in that area is an indication of the potential for geothermal in the subsurface. Based on the geological data, the study area is located on the mountain range of Bukit Barisan that is the result of the tectonic activity which is the collision of the Indo-Australian Plate with the Eurasian Plate. Based on the study conducted by Shell Mijnbow (1978) and Gafoer et.al. (1993) on the geological map of Baturaja Quadrangle (Figure 1), it can be seen that the geological state of Ogan Komering Ulu is included to South Sumatera Basin which is generally arranged by the Tersier sedimentary rock that was deposited on the Pre-tersier rock.

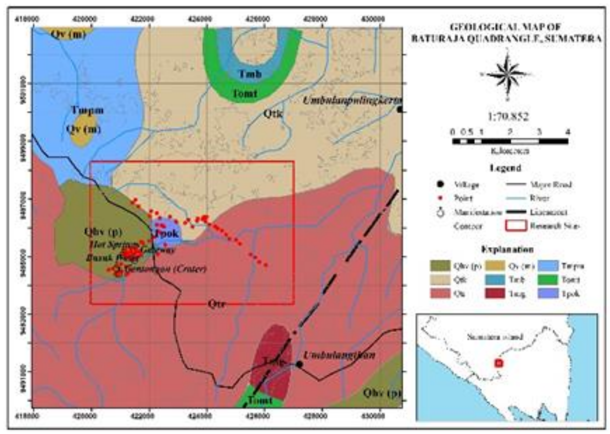

Figure 1: Geological map of Baturaja Quadrangle.

The tectonic framework of South Sumatera basin consists of the Sunda Shelf in the east and the tectonic pathway of Bukit Barisan in the west. This basin is restricted of the highland of Lampung. In some areas, the basement uplift and reverse fault on the pliosen are happen and create anticline that is the main structure of this area. Using the geophysical method, we can determine the physical characters of the rock to estimate the existence of the geothermal system in the subsurface. In the identification of geothermal potential, the geophysical data can be used to determine the existence of the heat source, reservoir zone, and to determine the up flow and permeable zone(Gupta and Ray, 2007).

The geophysical method that is used in this study is magnetic method. In the geothermal exploration, magnetic method is used to find out the variation of the magnetic field in the study area. This variation is caused by the variant magnetic character (nonhomogen) in the crust. In generally, the rocks in the geothermal system have a lower magnetization value than the rocks surround it. It happens because of the demagnetization by the hydrothermal alteration process.

This process can change the minerals in rock become paramagnetic minerals even the diamagnetic. The low magnetization value can indicate the existence of the zones that is has a potential as a reservoir andthe heat source. The existence of the geothermal reservoir is analyzed based on the 3D inversion modelling of the residual geomagnetic anomaly in the subsurface to get the clearer information of the geological model of the subsurface (Grandis and Yudistira, 2001).

Method

The study using the geomagnetic method was carried out in the Villamasin area of Jayapura District, East OKU Regency, South Sumatra Province. In addition to measuring magnetic fields, position measurements are also made using the Garmin e-track GPS (global positioning system). This position measurement data is used to determine the location of acquisition points. Figure 2, is a topographical modeling image of the research area accompanied by measurement points carried out in the area. The measurement point is in the southeast, at an altitude of 110 m.d.p.l that extends to the northwest then extends towards the west and southwest of the research area which is a high geographical area, which ranges from 110 to 150 m.d.p.l

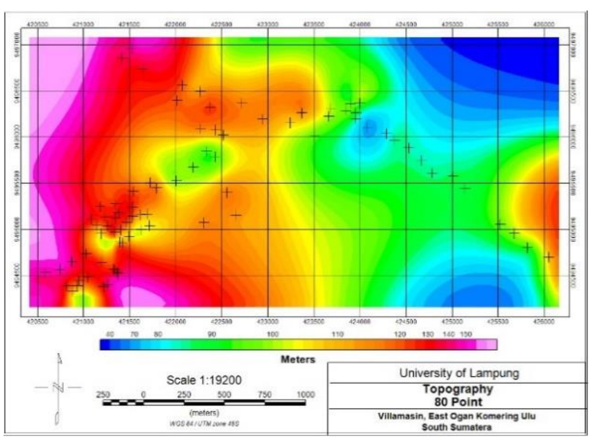

Figure 2: Topography map.

In general, the method used in this study is the measurement of the earth's magnetic field or geomagnet. Magnetic field intensity data is measured data obtained from the data acquisition process and then data processing is performed. Measuring data processing results from the acquisition of magnetic fields begins with daily variation correction and IGRF (International Geomagnetism Reference Field) correction. These corrections are useful to reduce the influence of the earth's main magnetic field and the external magnetic field, so that the total magnetic field anomaly data is generated from magnetic minerals that make up the rocks beneath the earth's surface. Furthermore, the total magnetic field anomaly data is displayed in the form of a contour map. Then reduce the total magnetic field anomaly data that is still scattered in the topography. This process must be carried out because the next data processing requires the input of magnetic field anomalies distributed in the flat plane (Blakely, 1995).

After the reduction process is done, the continuation process is carried out. This process can function to eliminate a local magnetic effect originating from various magnetic objects that are spread over the surface of the topography that is not related to the survey (Bagus et al, 2012). Next is the separation of regional anomalies, residual anomalies, and noise. To separate the magnetic anomaly and noise, a polynomial fitting method is performed. This method assumes that the polynomial surface can describe finer regional field models determined by the Polynomial order. The order used in processing this data is second order (parabola) which has the equation y = a + bx + cx2. In the polynomial fitting stage a quantitative stage is needed, namely by making curve fitting. This process is used to estimate the trend of results needed. The curve fitting process matches the approach curve equation to the observation data. According to the least squares method, the best curve fitting has:

$$\Pi = d_1^2 + \cdots + d_n^2 = \sum_{i=1}^{n} d_i^2 \quad (1)$$

$$= \sum_{i=1}^{n} [\boldsymbol{yi} - \boldsymbol{f}(\boldsymbol{xi})]^2 = \boldsymbol{minimum}$$

After that, reduce to pole is carried out. Reduce to pole is a magnetic data processing filter to eliminate the influence of magnetic inclination angle. The filter is needed because the dipole nature of magnetic anomalies makes it difficult to interpret field data which is generally still asymmetric. When determining magnetic field anomalies, the results from reduce to pole can provide information about the existence of an anomalous position. Next is the equation for reduction to the poles based on Blakely 1995:

$$F[\Delta T_r] = F[\Psi_r] = F[\Delta T] \quad (2)$$

$$F[\Psi_r] = \frac{1}{\theta_m \, \theta_r} \quad (3)$$

F[Ψ_r] is a reduction process to the poles because the anomalies are measured at the north magnetic pole, where magnetization induction and the ambient field will be directed vertically downward. After the reduce to pole stage is completed, 3D inversion modeling of residual rock geomagnetic anomalies below the surface. Model parameters from inversion modeling are obtained directly from the data. 3D inversion modeling provides an overview of susceptibility distribution. If a 3-D subsurface model is built from a set of upright prisms with the intensity of magnetization or homogeneous susceptibility then the vector of magnetic data d (d_i, i = 1,2, ..., N) is a linear transformation between the intensity of magnetization of each prism (m_i, i = 1,2, ..., M) with the kernel matrix (Grandis and Yudistira, 2001) sized (N X M) as follows :

$$d = G\,m \qquad (4)$$

where, G = matrix kernel
m = model parameter
d = data

The kernel matrix is an expression or elaboration of the geometry of an anomalous model built from a collection of prisms. Data (d) is magnetic anomaly data, while the model (m) parameter is the susceptibility of each prism and is the parameter sought. Combined data on the surface (z = 0) and the results of upward continuation (z > 0) produce data with a number greater than the number of model parameters (N> m so that the inversion solution is over-determined (Kusnida et al., 2009)

$$m = [G^T G]^{-1} G^T d \qquad (5)$$

Conclusion

Based on the qualitative analysis of the magnetic field anomaly data from the reduction to pole process in the Villamasin East Ogan Komering Ulu, we can estimate the existence of the geothermal reservoir at the northwest to southeast of the modeling and also at the study area. Based on 3D modeling, the area which has the contrast of high susceptibility at the northeast to the southwest of the modeling, with the susceptibility value is in range of 0.16 cgs (103 SI) to 0.97 cgs (103 SI). The subsurface structure is dominated by basalt-andesite rock with the combination of tuf and breccia which has a function as a reservoir in the geothermal system of Villamasin, East Ogan Komering Ulu.

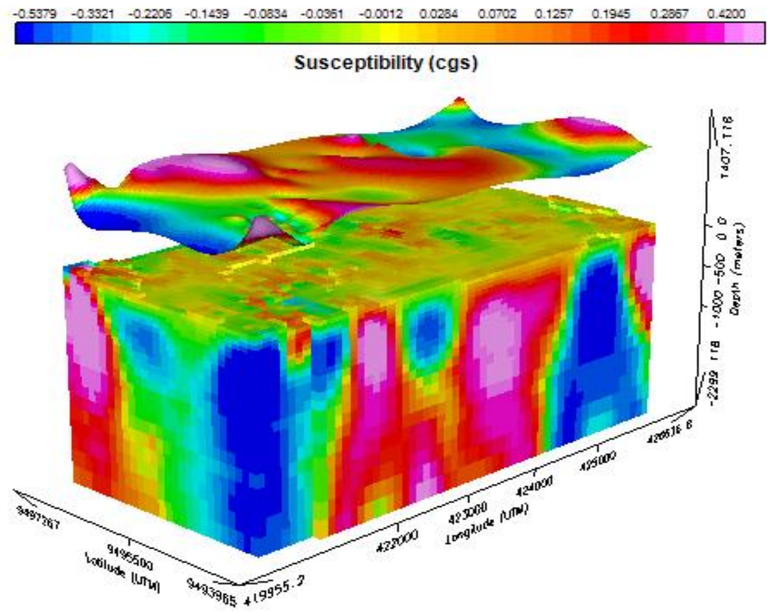

Figure 3: Susceptibility model resulting from inversion of the residual anomaly in the region of the Villamasin East Ogan Komering Ulu..

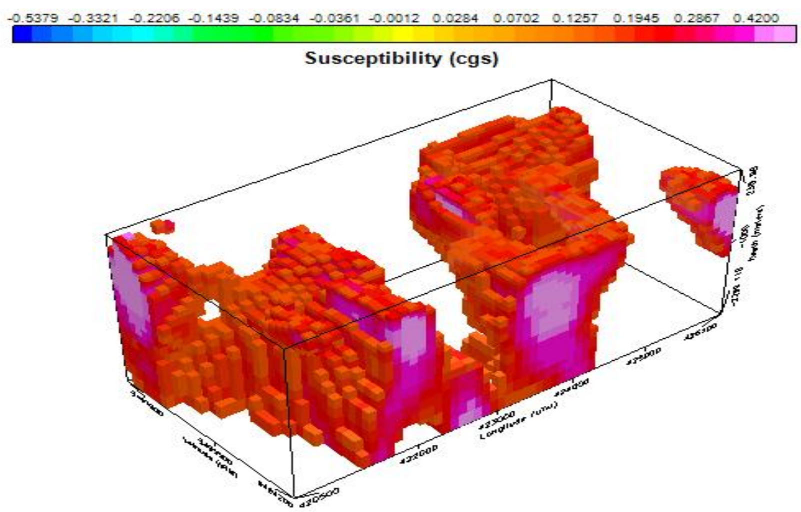

Figure 4: Susceptibility model resulting from inversion of the residual anomaly in the region of The Villamasin East Ogan Komering Ulu. only positive susceptibility contrasts are displayed In the model.

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