

Identification Geothermal Reservoir of Telomoyo Mount from Anomaly Magnetic Data using 3D Magnetic Inversion

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Abstract. The geophysical investigation research of Telomoyo Mount has been done. We aim to get a description about reservoir of the geothermal system by geomagnetic survey. Magnetic data acquisition has been carried out in 83 points with approximately 44 km² of around. The total magnetic anomaly directly modeled by *Mag3D* software. Using inversion of magnetic 3D, the alteration rock that to be a manifestation of geothermal field has been corrected in 3 areas, they are Keningar, Kendal Duwur, and Sepakung. They have low susceptibility value that approximately -0.173 to -0.498 (SI) and indicated as *upflow* zone of Telomoyo mount geothermal system. Kendal Duwur area becomes a main reservoir in the 1400 to 3000 meters of depth.

Keywords: 3D Magnetic inversion, geothermal, Telomoyo mount

Introduction

Telomoyo mount is located at the 3 cities, those are Magelang, Temanggung, and Semarang, Central Java province. Telomoyo mount border on Ungaran mount in the northern, Merbabu mount and Merapi mount in the southern.

Subduction zone of the Java Island between Eurasia plate and Indo-Australia plate causing the geological structure of the survey area. Fracture structures and suspect faults are in the north-south arrow relatively caused by the tectonic activity and the suspect fault in the west-east arrow relatively caused by volcanic activity of survey area. The tectonic activity came from beginning of Tertiary age that founded intrusion of basaltic and andesitic dominantly and followed by appointment and erosion [1]. After that, in the Plio-Plistosen era shear fault at the northeast-southwest and southwest-southeast, and normal fault has been appeared. Those fault cause the emergence of hot spring in the Candi Umbul, Pakis Dadu and Candi Dukuh [1].

In the survey area has founded, Rim caldera and hot-spring. Rim caldera that consist of alteration rock has found in three places, those are Keningar, Sepakung, and Kendal

Duwur (Fig. 1). The alteration rock, has been processed by hydrothermal activity that changed to be alunite-kaolinit, montmorillonit, and halloysit minerals. Tectonic structure that consist of shear fault north-south relatively and southwest-southeast were re-activated and causing Candi Dukuh manifestation appeared. Candi Dukuh-hot spring has a bikarbonat-cloride, that showing us hot water came from inner layer and interact with meteoric water and dilution of them happened, so that we interpret that Candi Dukuh-hot spring is an *outflow* zone of Telomoyo geothermal system. The estimation of reservoir temperature based on drilling research is 230 °C and has 160 MW of geothermal potential for electrical resources [1].

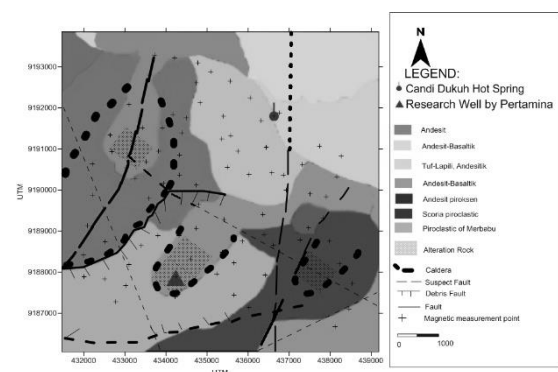


Figure 1. Geology map of the survey area (modified from [1])

There are many Geophysical methods has been studied in this area. Magnetotelluric method has conclusion that the bottom of *caprock* is located at 1500 meters depth and continue with reservoir zone [2]. Magnetic data processing methods of this survey by applying a forward modeling has been applied too in research of Telomoyo mount. The result of depth is distributed from 800 meters to 1400 meters and interpreted the low susceptibility value of -0.313×10^{-3} (SI unit) as a *caprock* [3].

The limitedness of magnetic forward is needed the intuition of geophysical sense for make model of interpretation, although have the geological of survey but intuition of geophysical is important thing [4]. Using 3D inversion of magnetic data has a full solution to Maxwell's equations for source-free magnetostatics that was developed using a finite volume discretization. The Earth region of interest is discretized into many prismatic cells, each with constant susceptibility, which allows for models of arbitrary geometric complexity [5].

The method is to determine the depth and reservoir boundaries (the prospect area) as a source of geothermal energy to be exploited. Accurate determining of subsurface reservoir location is required to achieve that goal. And the purpose of this study is to determine the position of geothermal reservoir as a three-dimensional model using *Mag3D* software.

Methods

In this research, magnetic data measurement has been taken in 2013 by Geophysics Laboratory of Diponegoro University. Total of magnetic data is 83 points with approximately 44 km² around the survey areas. There are some steps for magnetic data processing, The preliminary magnetic processing is starting from IGRF correction, and then the daily magnetic correction and get value of the total field magnetic anomalies. Position of research area is 1.108° in declination and -32.223° in inclination. Data presented in a contour map. Then it is being input data for *Mag3D* program to model the Telomoyo geothermal system. Then the modeling results were matched

with detailed geological maps for the reservoir analysis.

Result and Discussion

The observation data are presented as a total magnetic anomaly contour map. Fig. 2 shows the contour map of point data distribution overlaid with the total magnetic anomalies. Values of positive and negative anomalies appeared is balanced at 1800 nT and -1800 nT.

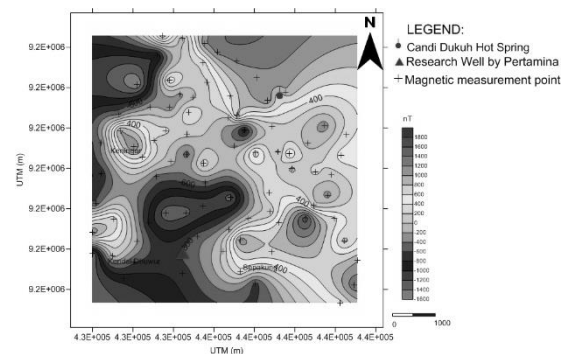


Figure 2. Measurement Points Overlaid by Contour Map of Magnetic Total Anomalies.

Structural pattern of area's survey influenced by volcanic activity of Telomoyo ancient mount and make a shear fault at north-south relatively and southwest-southeast that has been reactivated and causing Candi Dukuh-hot spring manifestation appeared. From figure 2, the dipole of positive and negative value indicating magnetic anomalies under the surface. The geological data mentioned that there are some alteration rocks are found at 3 places of Telomoyo mount, those are Keningar, Sepakung, and Kendal Duwur hill. By using conventional magnetic processing, the contour of magnetic total anomalies (Fig. 2), is not correlated well. We just have a middle of the dipole magnetic indicates the anomalies.

We did 3D magnetic inversion of the same data by *Mag3D* software, than we can determine the alteration rock correlate with the low permeability zone (as shown on Fig. 3). The susceptibility values are negative values. The magnetization of volcanic rocks can be significantly reduced by hydrothermal fluids. Main magnetic minerals (magnetite and titanomagnetite) replaced by alteration minerals such as pyrite or non magnetic hematite. So reservoir zones

associated with low and negative susceptibility zones [6].

supported the geological data of the area survey.

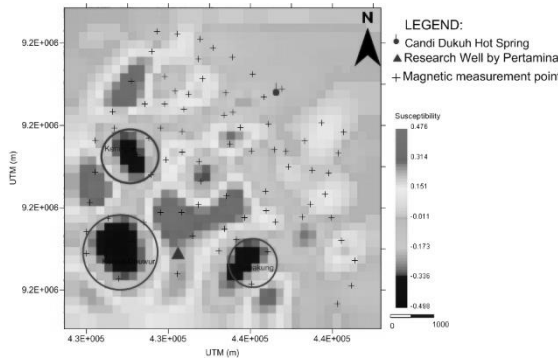


Figure 3. Horizontal Viewed on Surface Susceptibility of Survey Area by 3D Magnetic Inversion.

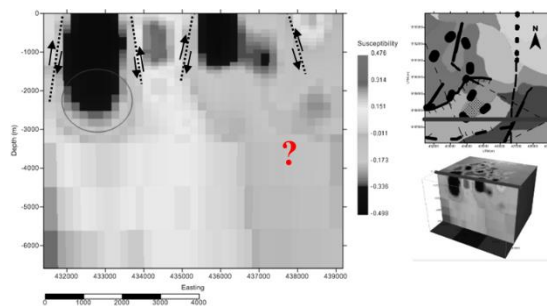


Figure 4. The result of 3D modelling using Mag3D software in the west-east crosssection.

Fig. 4 displayed results of general susceptibility zones. Fig. 4 displayed results of general 3D modeling. The *caprock* of Telomoyo geothermal system is in the alteration rock of Telomoyo's *caldera* that indicating of the interaction between hydrothermal fluids and the rock, and then go to surface by fractures. The reservoir of the Telomoyo geothermal systems are volcanic and sediments rocks and has high permeability that can save geothermal's fluids [1]. We sliced the model from west to east (red line at the geology map in Fig. 4) that across Pertamina's research well. We interpreted that there're normal faults in this section and have the *graben* shaped, that are in the Sepakung zone and Kendal Dhuwur zone. If we correlating with topography of the survey area, the Kelir mountain range is in the western and Gajah mount is in the eastern. That structure can we interpret that Sepakung and Kendal Dhuwur zone have the lower structure because normal fault of the area. So, the magnetic inversion has been

In that area, from surface until 1400 meters of depth determine as *caprock*. From [1], the *caprock* come from surface until 1400 meters of depth and from [2] the *caprock* come from surface to 1500 meters of depth. There was contrast susceptibility at this point (red circle on Fig.4) and from 1400 meters to 3000 meters of depth interpreted as reservoir of the Telomoyo geothermal system. The thickness of the reservoir is about 1600 meters, which is from 1400 meters to 3000 meters of depth. From the Fig.4, the lowest susceptibilities are in two places, those are Kendal Duwur and Sepakung. That value is approximately from -0.173 to -0.498 (SI units). The lower susceptibility we can interpret that they are alteration rock which lost of magnetism due to hydrothermal fluid interaction. The alteration rock has content clay minerals (montmorilonit, halloysit, and kaolinit), and classified to argilic-advance alteration [1]. The coordinate of estimating reservoir is 431868 to 433486 and 9187220 to 9188771. Kendal Duwur has bigger potential low susceptibility than Sepakung.

On either side of the Sepakung, there is a low susceptibility value. That's probably the Merbabu volcanic rocks.

Conclusion

The research shows that 3D magnetic inversion can raise significantly the appearance of the magnetic total anomaly significantly. According to the inversion by *Mag3D* result, we interpreted that there're normal faults in the potential reservoir and made the *graben*. The reservoir of Telomoyo geothermal system is located at the coordinate of 431868 to 433486 and 9187220 to 9188771, the susceptibility value is approximately from -0.173 to -0.498 (SI units), and has the thickness about 1600 meters from 1400 to 3000 meters of depth.

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