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3D GEOMETRY MODELING OF GEOTHERMAL SYSTEM, BASED ON GEOPHYSICAL DATA FOR DELINEATING THE PROSPECT AREA

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ABSTRACT

A conceptual model is became an essential tool in the process of determining the prospect area of geothermal field, and the two dimensional conceptual model is the commonly used. Sometimes the use of two dimensional models showing the ambiguity of interpretation, so that the development of the geothermal field such as drilling exploration failed to achieve the goal to get the boundaries of the area's prospects. Therefore, three dimensional models should be used in the determination of prospect area to minimize the uncertainty, and optimize the accuracy of interpretation existing data. To construct the model, three dimensional geometry of the conceptual model of geothermal system became an important key to produce an accurate and optimal interpretation. Model that made are based on the geometry of the geophysical methods, magnetic and gravity. The gravity and magnetic models are used to predict location of heat source and permeable zone, beside that the geological structure information can confirm the model result. The results of the three dimensional model created, give a better and accurate representation of actual geothermal system and make optimum prospect area delineation.

INTRODUCTION

Delineation of the geothermal prospect areas became one of the important points in the development stages of the geothermal field. Area calculation will determine the prospects of the potential value of geothermal electricity selling price, and in the end later. Therefore, the precision of the determination can affect costs incurred in the development and profit. To support this need created three dimensional models so that the determination of prospect area becomes more detailed and precise. Three dimensional models would be more informative because the model show the magnitude of volume, construct from mathematical approach. The three dimensional model was created based on the integrated geophysics (gravity and magnetic). These studies contributed to the drafting component of the geothermal system.

Beside geophysical information, geological information was taken into account, although not used in three dimensional integration. Geological information are become consideration in prospect delineation.

From the result of topographic map and remote sensing analysis in the study area for structure delineation, the major structural features in the area are in NW-SE direction, found around the mountain in the quaternary formation and on the southeast of study area. Most of NW-SE structural features are found buried by eruption product of the mountain. The volcanic product divided into three units: lava-breccia-pyroclastic, breccia pyroclastic, and debris avalanche.

From NDVI interpretation, low anomaly NDVI that cause by vegetation stress found on the mountain peak and the caldera related to geothermal manifestation. Some manifestations are found around the shoe horse shape caldera (crater and hot springs). Active crater found in the center of the caldera and the hot springs are found in the southeast side of the caldera.

METHODS

Three dimensional models are constructed using gravity and magnetic data. Gravity and magnetic data on three dimensional models combine to make geothermal component like heat source. Geological information became a consideration in making delineation prospect area based on lithology.

Geophysical Methods

Geophysical studies have been carried out in this geothermal field. The aim of the studies is to investigate the deep structures and delineate prospect area. The methods are includes Magnetics and Gravity survey.

Gravity survey was conducted in 400 km^2 area with total 118 stations, interval 1 km between each station. Data reduction and terrain correction were applied on the observed data, in order to get complete Bouguer values. Bouguer anomaly calculated using average crustal density 2.67 g/cc. Bouguer anomaly reflect regional and residual anomaly. Regional anomaly values calculated using second order polynomial curve fitting.

The residual anomaly result showed in **Figure 3**. From the residual anomaly map a contrast anomaly gradient are related to the structural features based on SRTM analysis and remote sensing data. High residual anomaly values found around the mountain peak, and on the south west study area.

Magnetic surveys are conducted in this area with total 118 stations. Data reduction using diurnal correction and normal geomagnetic field correction using IGRF was applied, in order to get total magnetic anomaly that can describes the study area. Total magnetic anomaly presented in **Figure 4**. Reduce to pole technique applied into the data to get a better result and interpretation. Magnetic anomalies are associated with the total magnetization of rocks, which is the vector sum of remanent and induced magnetizations. The induced magnetization is always parallel to the present day earth magnetic field. The strength is determined by magnetic susceptibility, which entirely depends on the abundance and identities of magnetic mineral in the rock. In most quaternary volcanic rocks the strength of TRM (Termoremanent Magnetization) is much greater than that of the induced magnetization (Soengkono, 1990). From the magnetic RTP result on **Figure 5**, low anomaly located around the caldera, related to demagnetization body. Another low anomaly was located in the east side of study area.

Three Dimensional Modeling

Three dimensional models made using inversion algorithm. Gravity and magnetic model showed in one model to give better result comparison between the two methods about heat source location. Heat source location constrained by geological and geophysical observations.

DISCUSSION

Analysis of Gravity and Magnetic Anomalies

Figure 3 showed residual high gravity anomaly lies around the mountain, and in the south of study areas. High gravity anomaly around the mountain describes high density anomaly lies below the mountain, located in quaternary rock formation can be related with the presence of heat source. High gravity anomaly in the south area related to dense old volcanic product, from geological information, tertiary formation with lower density located below the dense volcanic product, that cause the high gravity anomaly on the lateral map. Low gravity anomaly caused by debris avalanche from volcanic mountain product filled in the graben structure in south-east area.

Magnetic anomaly in the **Figure 5**, are result from reduce to pole filtering. Low magnetic anomaly located below the caldera, can be related with demagnetization body effect of high temperature system or heat source presence.

Gravity and magnetic contrast gradient give a clear boundary that can be interpreted as a geological structure from surface. To confirm the structure permeability and depth, three dimensional models showed most of the contrast gradient that interpreted as a structure in the surface from remote sensing still can be seen in gravity and magnetic model until 3000 m depth (**Figure 6, Figure7**). Gravity model showed the contrast gradient clearly than magnetic model. Low magnetic anomaly and high gravity anomaly below the caldera looked like an intrusion body from the three dimensional model. The presence of intrusion was found around 0 msl depth until the lower boundary of the model. Low magnetic value also found near the caldera in the northeast side of study area, but with little bit higher magnitude than the magnetic anomaly below the calderas, it can be related to demagnetization reservoir presence.

CONCLUSIONS

Three dimensional models in this study are used to show a clear description about geothermal system and the component that related to the gravity and magnetic methods. Based on the geophysical model result, geological information, and presence of manifestation, the upflow zone was located around the caldera, and prospect area showed in **Figure 8** with total area 100 km^2. Presented in **Figure 9** heat source location is one of geothermal component that can be interpreted this model. From three dimensional model the anomaly boundary can easily see in every direction.

To get a better and optimum delineation, resistivity method or EM method need to be conducted in this area, to give an information about another geothermal important features, such as caprock and reservoir. The resistivity model should be combined with gravity and magnetic model to make easier interpretation.

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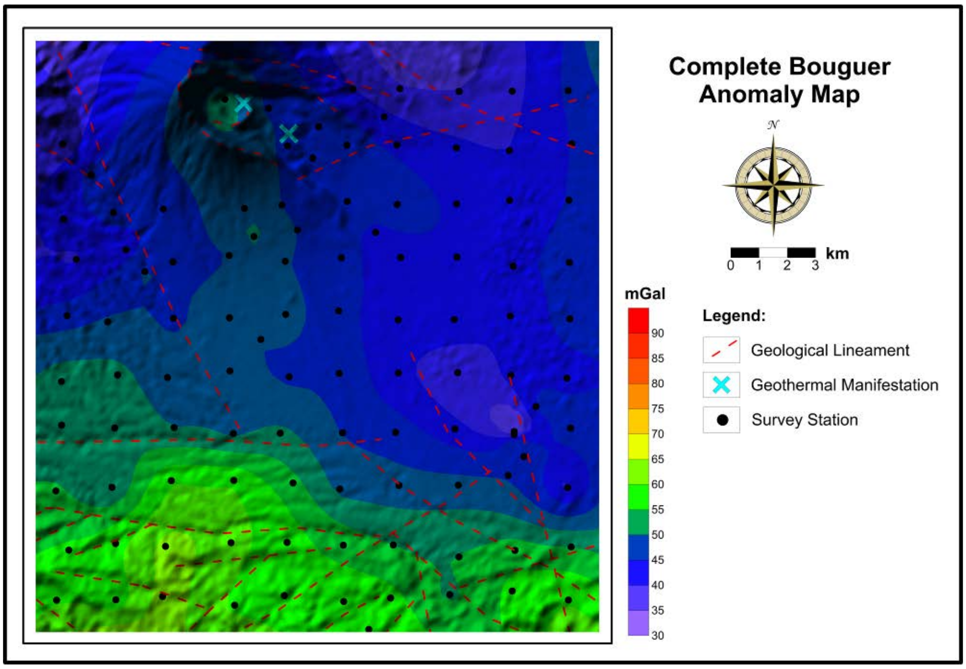

Figure 1. Complete Bouguer anomaly map.

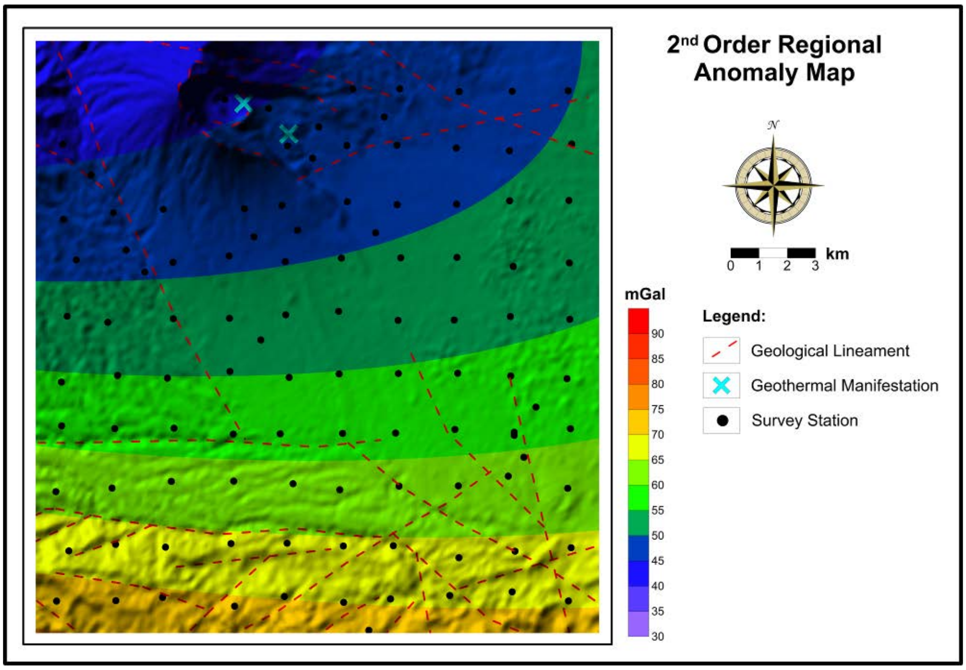

Figure 2. 2nd order regional anomaly map

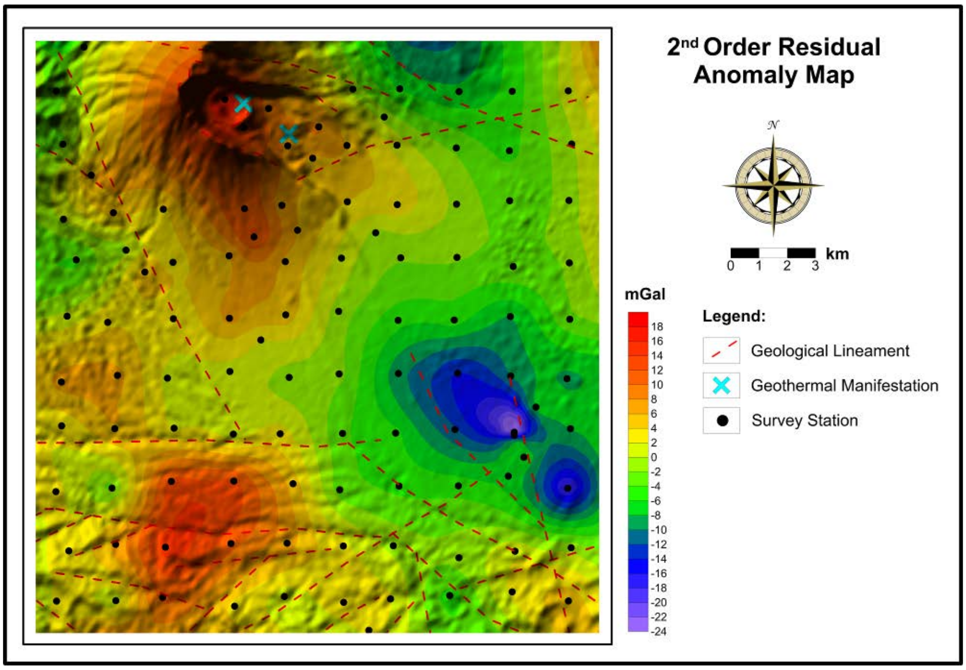

Figure 3. 2^{nd} order residual anomaly map

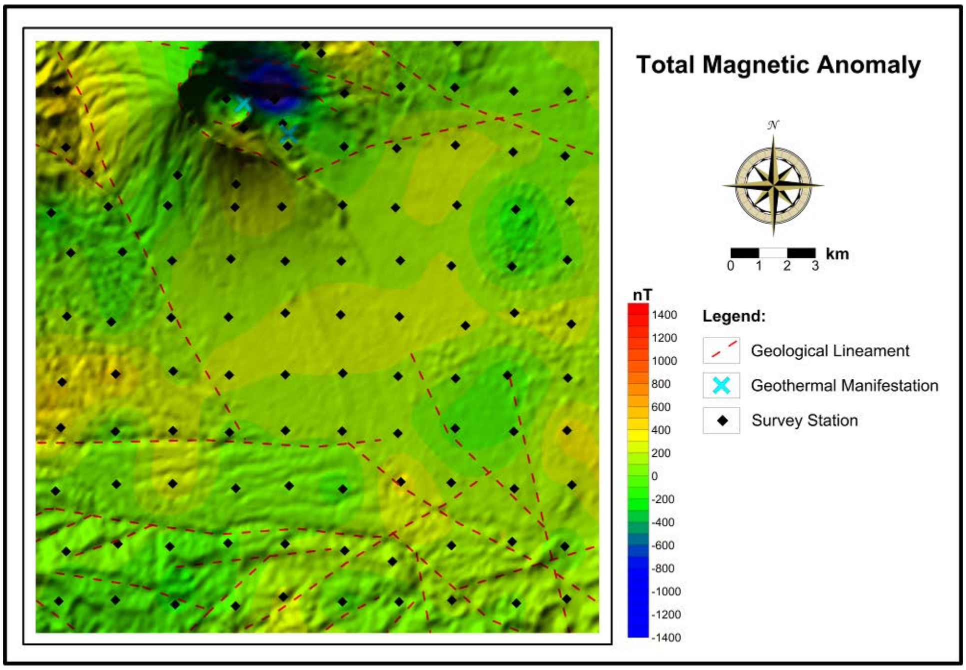

Figure 4. Total magnetic anomaly map

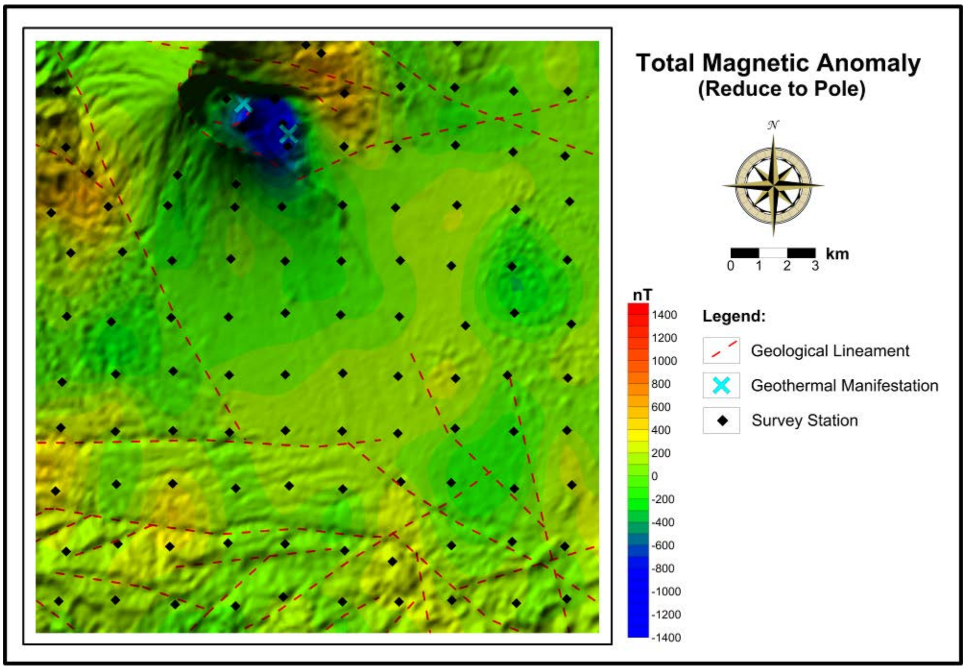

Figure 5. Total magnetic anomaly map result of reduce to pole filtering

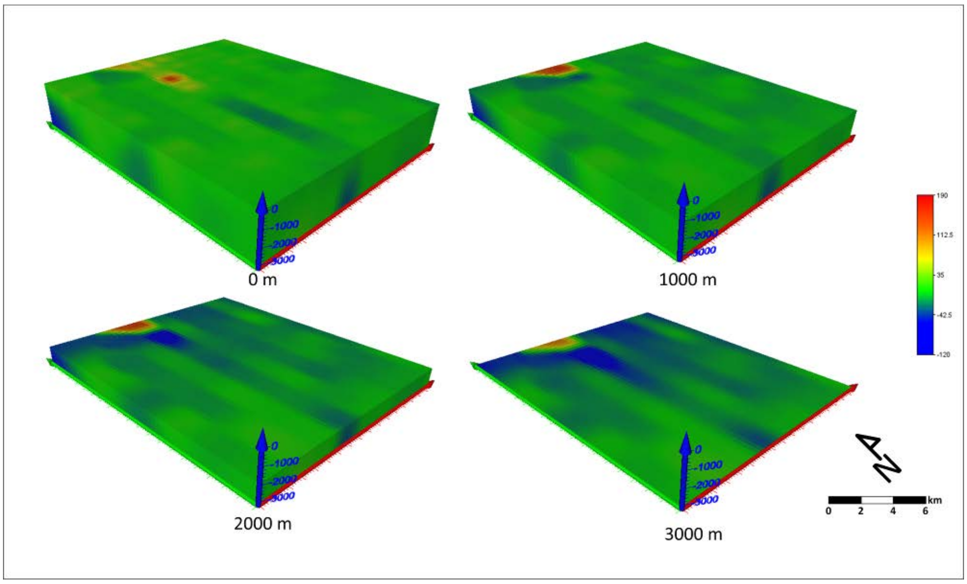

Figure 6. Three dimensional magnetic model

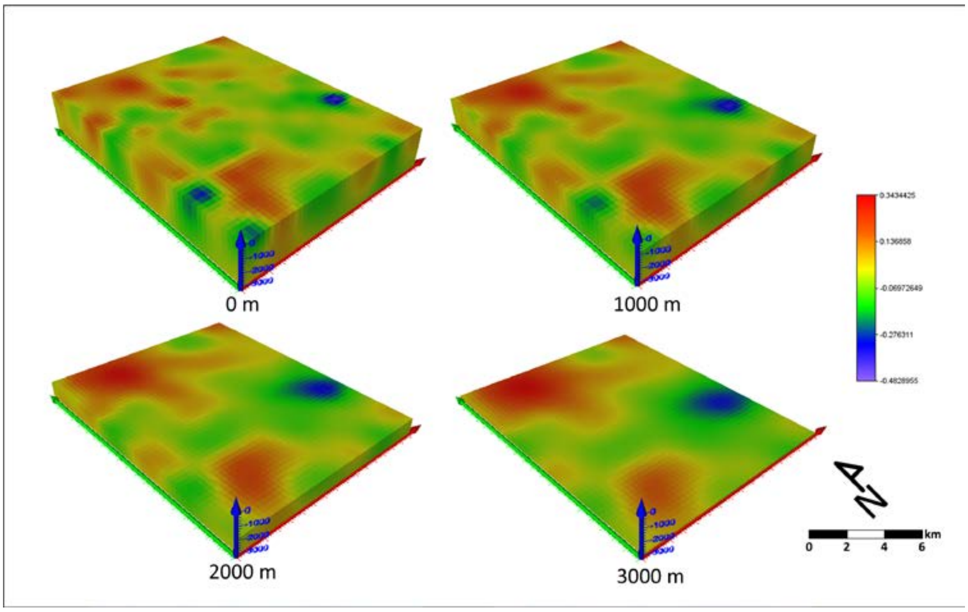

Figure 7. Three dimensional gravity model

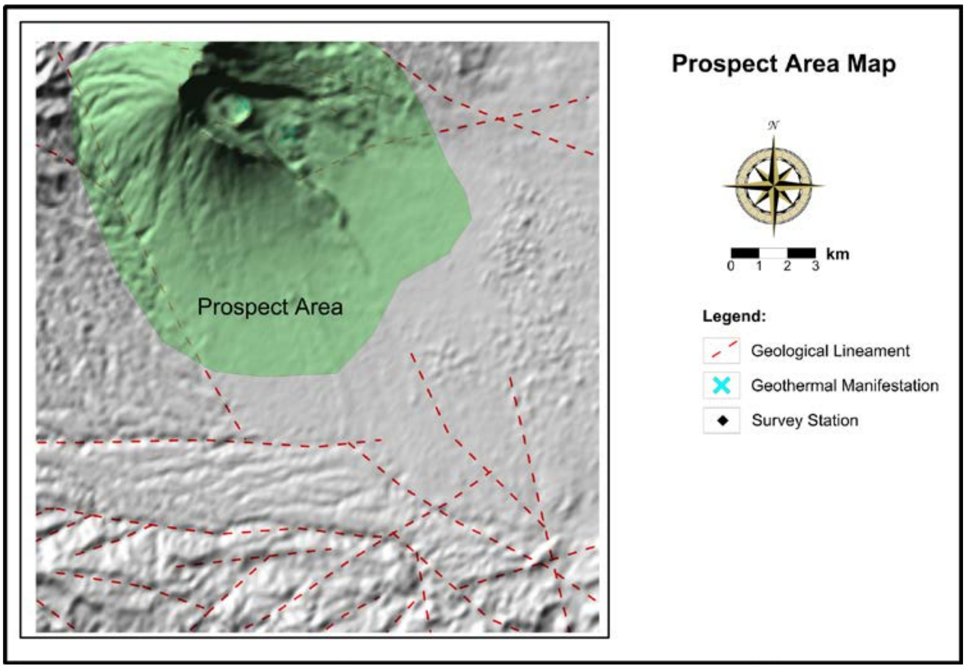

Figure 8. Prospect area map in based on model an geological data

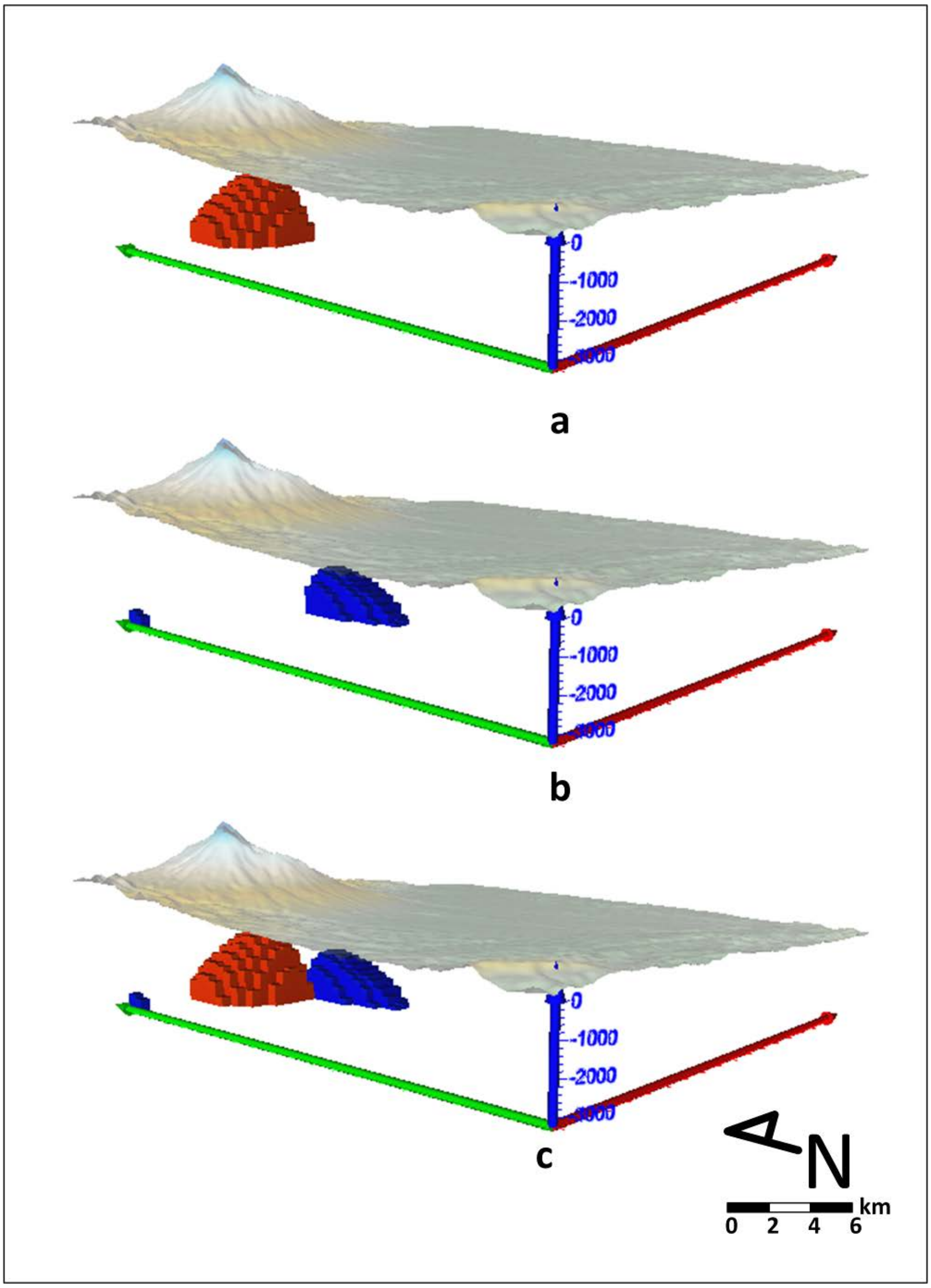

Figure 9. (a) High density gravity anomaly; (b) low magnetic anomaly; (c) Gravity and magnetic anomaly that interpretated as a heat source.