Research Article
Development of Geophysics Conceptual Model of the Diwak-Derekan Geothermal Fields Based on Magnetic Data Interpretation

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Abstract: This study develop geophysics conceptual model for geothermal fields based on magnetic data interpretation. The fields are Diwak and Derekan which located in Indonesia. PPM (Proton Precession Magnetometer) was used to measure 99 moving area points and two points as a base station simultaneously. Measurement data is processed by daily variation and IGRF (International Geomagnetic Reference Field) correction. The data has been used to create a contour of total magnetic field anomalies and subsurface cross sections involving the upward continuation and reduction to the poles. The results show total magnetic field anomaly closure pair of positive and negative closure, indicate a fault zone below the surface. This measurement result is in agreement with prediction results of the model, that is also show two faults in southwest-northeast area. This fault zone is used as an outlet media of fluid to the surface of geothermal systems.

Keywords: Conceptual model, geothermal, total magnetic field

INTRODUCTION

Indonesia has high potential of geothermal energy. The country is located at the volcanic belt along more than 7000 miles and has a large geothermal energy potential (Gaffar *et al*., 2007). One example field that has large geothermal energy potential is Diwak-Derekan, Java Island. The field have a specific low of geothermal enthalpy and unique geothermal characteristic. There are some low temperature of geothermal hot springs were distributed along Jumbleng and Lutung rivers.

Magnetic variations caused by inhomogeneous magnetic properties of the earth's crust. Rocks in the geothermal systems generally have lower magnetization than the surrounding rock. This was caused by the demagnetization process of hydrothermal alteration processes, the process of changing the existing minerals into minerals paramagnetic or diamagnetic. Low magnetic values which can be interpreted as a reservoir zone and heat source (Sumintadireja, 2005). The response of the magnetovariational responses was introduced by Schmucker (1970); and the three dimentional response have been studied (Becken *et al*., 2008; Berdichevsky *et al*., 1984).Integrated geophysical exploration has been applied to explore low enthalpy geothermal field at Lipari Island, Italy. The results

show a good agreement between one to another methods. These studies interpreted the presence of subsurface fluid flow through a fault (Bruno *et al*., 2000).

Research on integrated geophysical studies on the southern slope of Mount Unggaran also stated Diwak is one of the geothermal field. The emergence of manifestations in the form of hot springs in the area Diwak, certainly trigger to do research on the interpretation of the subsurface using geophysical methods,that is a magnetic method. The use of this method to detect subsurface structures as forming a geothermal system and localize low anomalyarea believed to be related to the geothermal manifestations. This study will clarify the subsurface structure by using geophysics particular method of magnetic methods.

The geological overview: According to the stratigraphic setting, Java island can be divided into several parts (Van Bemmelen, 1949): physiographically Java island divided into several sections, including Java Alluvial Plain of North, North and Mountains Anticline Serayu Serayu South, Central Depression and volcanic zones quarter and the South Mountains (Kusumayudha *et al*., 2011).

In general, the research is a strong up bumpy undulating hills weak which is part of the volcanic
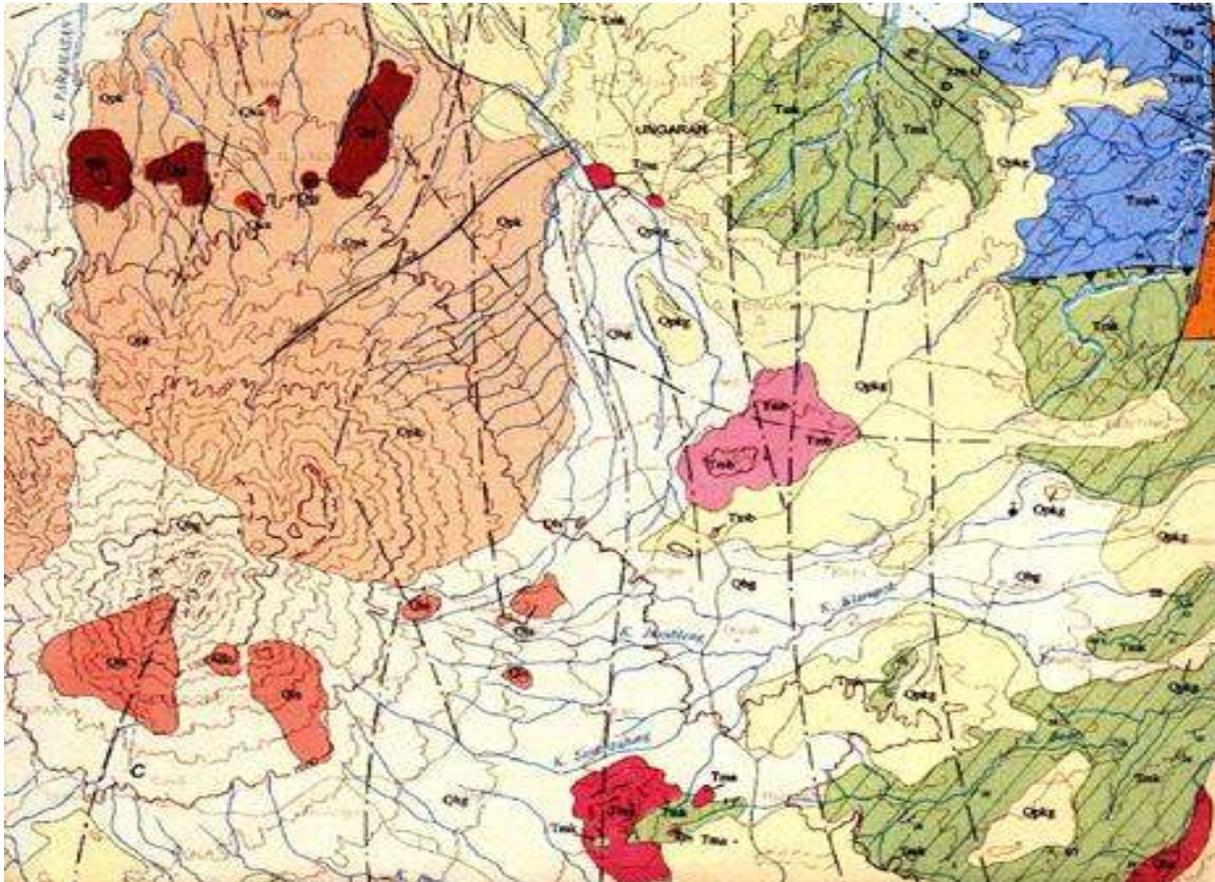
Fig. 1: Geological Map of Ungaran (Thanden *et al*., 1996)

hillsides of Mount Unggaran quarter. In physiographic regional study area includes the volcanic zones Quarter and Central Depression zone that is part of the Central Java Basin Physiographic (Van Bemmelen, 1949).Generally, the research area is one of a strong up bumpy undulating hills weak which is part of the volcanic hill of quaternary Ungaran Volcano. The regional physiography of study area includes the Quarter volcanic zones and Central Depression zone that is part of the Central Java Basin. According to the Geological Map of Magelang and Semarang compiled by Thanden *et al.* (1996) from the Geological Research and development as shown in Fig. 1.Physiographically Java Island divided into several sections, including Java Alluvial Plain and South of Anticlinal Serayu Mount, Central Depression and quarter volcanic zones (Kusumayudha *et al*., 2011; Gupta and Ray, 2007).

Magnetic susceptibility: The ability of an object to be recognized by magnetic susceptibility k is defined by Eq. (1):

$$\overline{M} = k.\overline{H} \tag{1}$$

Magnetic susceptibility can be interpreted as the degree of magnetism of an object. The k value of rocks susceptibility will be increase when finding more minerals rock which are called as a magnetic objects. Source of Earth's magnetic field consist of the earth magnetic field as a main field, the external field and field anomaly. The main magnetic field comes from the earth itself. Then, external field is sourced from outside the earth which is the result of ionization in the atmosphere caused by ultraviolet rays from the sun. While anomaly magnetic field generated by magnetic objects that have been induced by the main magnetic field of the earth, so that the object has its own magnetic field and the great influence the total magnetic field measurement results. Variation of the magnetic field measured at the surface of the target magnetic surveys (magnetic anomalies) (Telford *et al*., 1990).

Field operation: Magnetic method is used to determine the magnetic field variation in the study area. Magnetic variations caused by inhomogeneous magnetic properties of the earth's crust. Magnetic method is very sensitive in verticalchanges, commonly used to the intrusion study ofbedrock, hydrothermal veins rich in ferromagnetic minerals and geologic structures. The geothermal evidence has ferromagnetic minerals. It will be loss of magnetic properties when heated approaching the Curie temperature. The subsurface structure is one
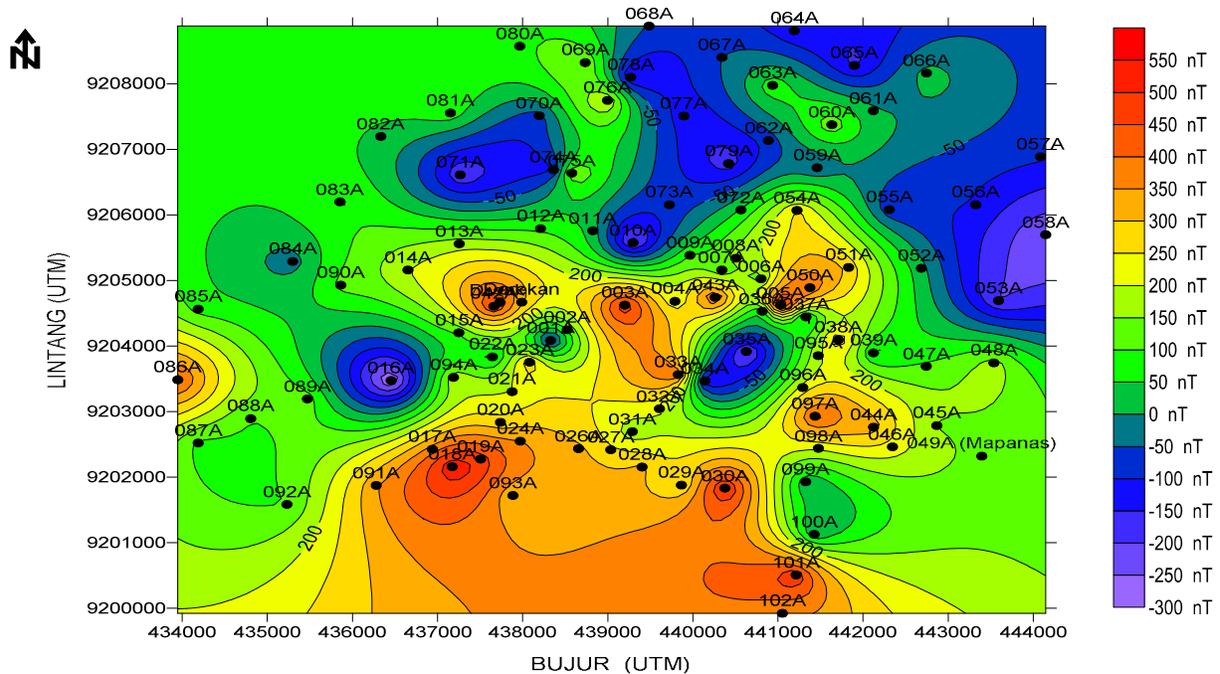
Fig. 2:Total magnetic field anomaly

of the point of view forgeothermal system characterizations. It can be localized the low anomaly area on geothermal manifestations.The survey is the variation of magnetic field which is measured at the surface. Variation of the magnetic field generated by a magnetic object that has been induced by the primary magnetic field of the earth, so that objects has its own magnetic field and the large influence the total magnetic field measurement results. The study area has been investigated by 25 km^2, which is consist of 99 measurement points observed by PPM (Proton Precession Magnetometer) geometrics GSM19T and a second proton magnetometer (G856X models) monitored the diurnal variation at a base station simultaneously.The observed magnetic data were reduced using the global geomagnetic field by IGRF model. Since the regional magnetic anomalies were subtracted from the observed magnetic data (Soengkono, 2001). The processing data will deliver residual magnetic anomalies that are caused only by terrain effects and rocks magnetization (the magnetic structures) within subsurface hydrothermal area.

There is forward 2-D modelling to show the subsurface structure interpretation from magnetic data anomalies. Qualitative interpretation was be done by analyzing upward continuationcontour map.

RESULTS AND DISCUSSION

Total magnetic field anomaly contour map pattern consists of a pair positive and negative closure. A couple of positive and negative closure show the dipole magnetic anomaly. The number of pairs of magnetic dipole which shows many anomalies in the topography of the total magnetic field is still strongly influenced by the local anomaly shows Fig. 2. Furthermore, to facilitate the interpretation of the data carried upward continuation process (upward continuation) and reduction to pole (reduction to the pole) to the total magnetic field anomaly data. The use of continuation to the above may help to separate the regional anomalies with a local anomaly, whereas the reduction to pole filter is used to eliminate the influence of the magnetic inclination angle. The results of the reduction to the pole shows the residual pole anomaly. It is interpreted that the position of the object causing the low of magnetic field. Total magnetic field anomaly data which has been filtered by further qualitative and quantitative interpretation. Qualitative interpretation is done by analyzing contour of the total magnetic field anomaly. Figure 2 shows a map of the total magnetic field anomaly after upward continuation. Based on the map, there are several pairs of positive and negative anomalies. On the negative and positive anomaly maps, contour pattern looks more dense, it indicates that there is a fault structure, because the fault structure is characterized by a high density contours, deflection anomalies and polarized anomalies (negative and positive). Based on the closed contour maps pairs (negative and positive anomalies), we made 2 lineament of model slice, A-A 'and B-B' (the direction indicated by incisions black line). From this incision, will be used
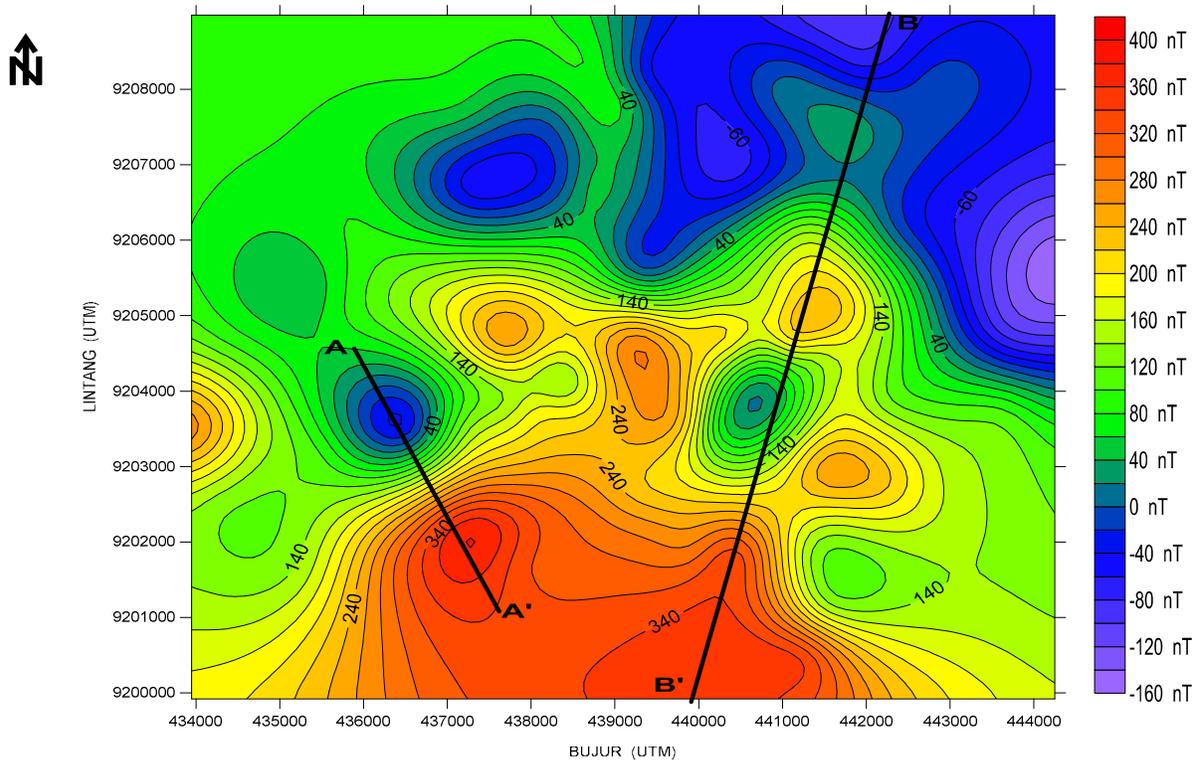
Fig. 3: Total magnetic field anomaly after upward continuation process

for modeling the subsurface structure of the study area.Quantitative interpretation of the incision made to the interpretation of qualitative results, namely sebanhyak two incisions (A-A 'and B-B'). Modeling the incision is expected to explain the structure of a subsurface fault structure and geothermal systems are suspected as the cause of the anomaly. In this model, adapted to the geological information as well as the appearance of the surface in the study area.

The result of incision A-A' as shown in Fig. 3 is drawn from north to south, with the north side on left and the south side of the right image (Fig. 4). Based on the geological information in the area of research, modeling incision A-A'is composed of two layers of rock are generally old quarter. The first layer in this model is a volcanic rock that form Gajah Mungkur breccia and tuff sands on the top layer. This layer is located to a depth of 850 m with a value of 0.0115 susceptibility (SI units). In this rock layer already apparent presence of faults. Then a second layer of rock is breccia with volcanic lava flow from Gajahmungkur with susceptibility value 0.1406 (SI units) which is at Kaligetas formation. The layer is located at a depth of 200 to 1000 m. The presence of the normal fault at the north side of the field. Based on the results of modeling the incision A-A'indicates the presence of faults in the region Diwak-Derekan. It is also reinforced by the appearance on the surface that is the river that stretches from the southwest to the northeast, so it can be

estimated in the region of fault trending southwest-northeast.

Modeling the second is the result of incision B-B' are shown in Fig. 5 as the previous cross section (A-A'), a second incision is also drawn from north to south (Fig. 3), with the north side on the left and south side on the right one of the image (Fig. 5). According to the modeling results, it is appears that there are 3 layers of rock. The first layer is a volcanic rock that form Gajahmungkur breccia and tuff sand the top layer. This layer is located to a depth of 650 m with a value of 0.0001 susceptibility (SI units). In this rock layer already appears the fault is identified by the appearance on the field in the form of rivers (Kali Klampok). A second layer of rock that is composed of breccia with volcanic lava flow from Gajah Mungkur which has a value of 0.6164 susceptibility (SI units). This layer is at a depth of 280 to 1070 m. Then the third layer consists of volcanic breccia unit of Formation Kaligetas the susceptibility of 0.7218 (SI units). The third layer is located at a depth of 780 to 1070 m. In the second and third layers of rock visible presence of two faults. The first fracture (left side in Fig. 5) is the fault down, as indicated by the block hanging wall (north side) down relative to the foot wall (south side). The second fracture (right side in Fig. 5) is a reverse fault in which the hanging wall block relative position up to the foot block wall.

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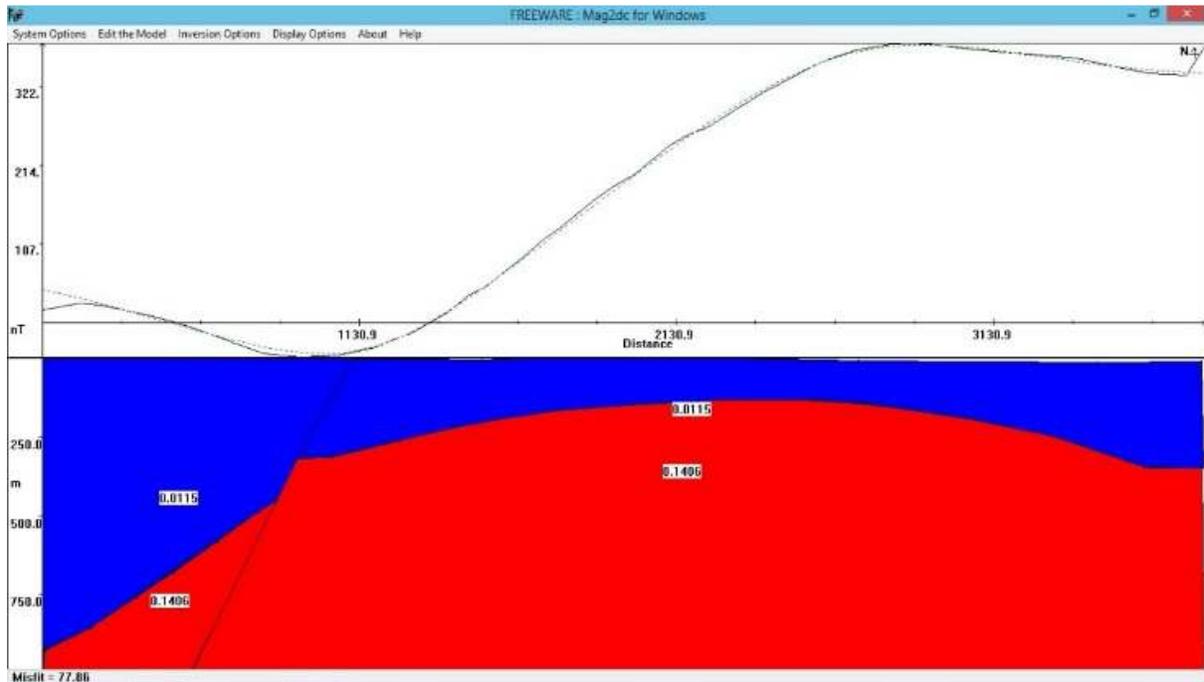
Fig. 4:The magnetic model of cross section A-A'
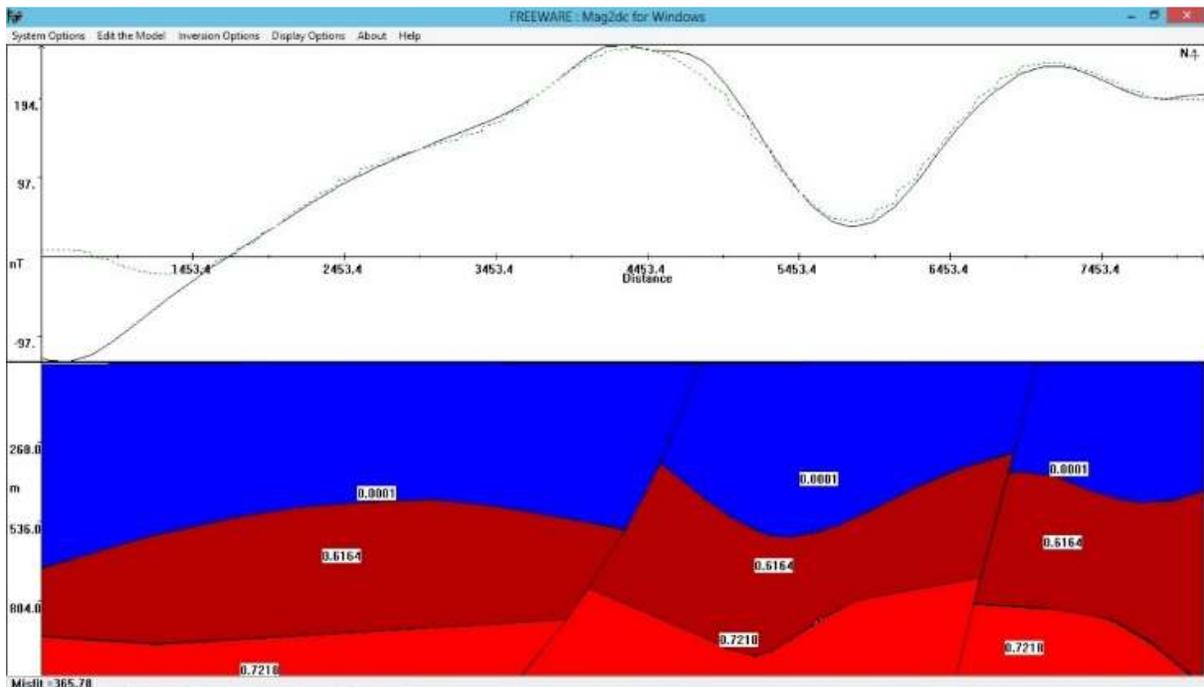
Fig. 5:The magnetic model of cross section B-B'

Based on the magnetic field anomaly data and modeling, the geothermal system and Derekan Diwak can be explained by a geophysical model of the geothermal (Fig. 6). Based on these models, a heat source Diwak-Derekan thought to originate from the intrusion of the body associated with andesitic lava dome. This is an andesite intrusion (Tma) situated in the southwest of the incision A-A '(shown on the geological map sheet Magelang and Semarang). Location of the heat source is coincide with the location of Kendalisodo hot spring. These predictions were also confirmed by the results of previous research in the area Kendalisodo states that there is a separate system with its own geothermal system at Gedongsongo geothermal
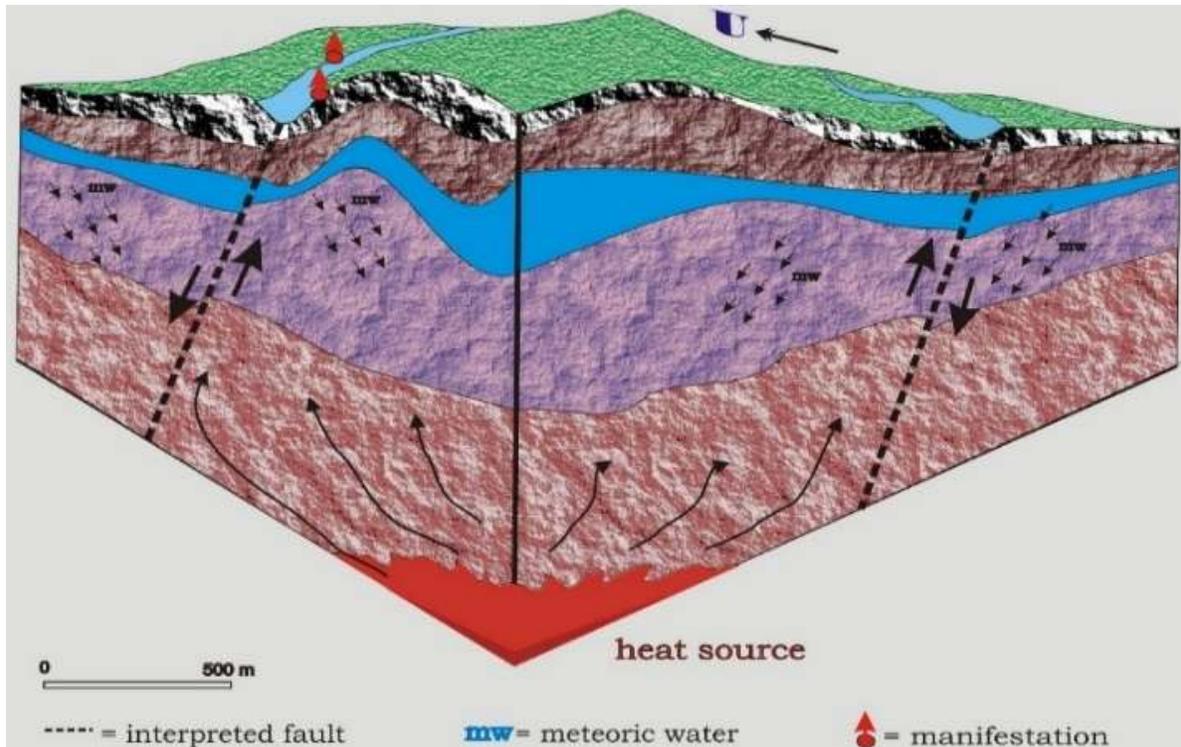
Fig. 6: The simple geophysical conceptual model of Diwak-Derekan geothermal system

field. Heat source is an origin of the intrusion body associated with andesitic lava dome of the mount Kendalisodo.

Figure 6 shows the presence of a heat source in the form of andesite intrusion which acts as a heat source. The heat then dissipates heat source is conductive to the surrounding permeable rock. It also results in a convection flow of hydrothermal fluids (water heated soil) in the rock pores. Furthermore, this hydrothermal fluid move up but not up to the surface because it was blocked by a layer of rock that is impermeable (cap rock). The location where the accumulation of fluids called hydrothermal reservoirs, or rather the geothermal reservoir. From the reservoir, the geothermal fluid will seek permeable zones which the fluid can pass through to the surface. The zone is a fault zone. Through the fault zone, the fluid will flow to the surface in the form of hot springs (hot spring) in Diwak and Derekan geothermal system.

CONCLUSION

The total magnetic field anomaly data show a couple of positive and negative closure indicate an interpretation of the fault. Interpretation is corroborated by the results of the modeling indicate the presence of two faults in the region Derekan-Diwak trending from southwest to the northeast one. The subsurface structure in the Diwak-Derekan geothermal manifestation are

located at the fault zone, which is the way out of the fluid medium to the surface in the geothermal manifestation systems.

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