



Three-dimensional Magnetotelluric Inversion and Magnetic for The Characterization of The Geothermal Field Reservoir Zone "X"

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Abstract

Geothermal as an alternative energy source that is renewable and environmentally friendly has an important role in providing domestic energy needs. Exploration is one of the most important stages in the development of geothermal energy because it can minimize the risk at the stage of exploitation and development. Geophysical methods such as geomagnet and magnetotelluric are one of the methods used in exploration. Magnetic method can provide information on the description of rock demagnetization due to the presence of heat source. However, the magnetotelluric method will provide information about rock type resistance on geothermal fields. The existence of heat source using the geomagnetic method is represented by a low anomaly value as an indication of demagnetized rocks. The results of 3D inversion processing show a low value of type resistance in the area and form an up dome. The correlation of the two results of processing the data can be seen in the southern part of the "X" geothermal field research area. Based on 3D Inversion modeling it can be seen the depth of the "X" Base of Conductor (BOC) geothermal system ranges from 1000 m to -800 m with resistivity $\leq 10 \Omega\text{m}$ which is suspected as volcanic rocks. Geothermal reservoir is at a depth of 1000 m to -2000 m with a moderate resistivity of 40 - 60 Ωm which is suspected as an andesite volcanic rock, with temperature estimates ranging from 218° C to 255° C.

Keywords: exploration; geothermal; magnetic; magnetotelluric; three-dimensional

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INTRODUCTION

The energy crisis is one of the problems faced by countries around the world today, they are searching for resources other than fossil energy which are environmentally friendly and can meet their energy needs. Geothermal as one source alternative energy that is renewable and environmentally friendly has an important role in supplying domestic energy because geothermal energy cannot be transferred from their origin region. Indonesia has large potential geothermal resources, it could be calculated that there were around 29 GWe (Darma et al., 2010). This number

of geothermal potential makes Indonesia one of the countries with the richest environmental friendly energy potential.

In the process of developing geothermal energy there are several stages which are preliminary survey, exploration, feasibility study, exploitation and utilization. The exploration stage is one of the stages important in the development and utilization of geothermal energy, because at the exploration stage we can minimize the risk of failure at the exploitation stage. The high risk and cost of drilling a well geothermal demands success at the exploration stage. The accurate drilling is when the drilling is carried out in areas which have high temperature and permeability (Darma et al., 2010; Hariyono & Sari, 2018; Hochstein & Sudarman, 1993; Maryanto, 2017), as well as minimal potential damage caused by nature. To determine drilling targets, an accurate geothermal conceptual model is required based on integrated analysis and interpretation. This conceptual model also should describe the conditions, characteristics and geometry of the reservoir geothermal. Various approaches can be used to increase confidence and reduce ambiguity in describing conditions in a subsurface geothermal system. In geothermal development, the conceptual model is created at the exploration stage. Exploration stage includes 3G integrated surveys, which are geological surveys, geochemical surveys and geophysical surveys (Fraser, 1969; McNeill J. D. and Labson V. F, 1991; W.M. Telford, 1991).

A geothermal field survey using geological methods was aimed to systematically and in detail the physical structure rock that forms the uppermost layer of the earth's crust in an area geothermal field (Telford et al., 1990; Telford & W.M. Telford, 2004; Yuhara & Seno, 1969). At this stage the use of technology in the form of images satellites are very effective in acquiring geological data. Satellite image has become one of the exploration tools that play a role in supporting activities exploration. The advantage of satellite imagery is it can determine zones which are estimated before direct observation in the field, can directly map major geological structures and rock alteration areas originating from the reflection of electromagnetic waves originating from sun or from a satellite (Darmawan et al., 2015; Nafian et al., 2022; Sung et al., 2001).

Furthermore, the geophysical method is carried out with the aim of determining the physical properties and conditions of the subsurface (Telford et al., 1990; Yuhara & Seno, 1969). On method in geophysics there are several methods, which are the magnetic method and the magnetic method magnetotelluric. The magnetic method is used to determine the presence demagnetization found in the rocks in the reservoir, and can be used to determine how broad the prospects are geothermal in the area. In addition to the magnetic method there are magnetotelluric methods. The magnetotelluric method is a geophysical method utilizing natural electromagnetic fields in knowing the properties of subsurface rock conductivity (Muthamilselvan et al., 2019). The magnetotelluric method can describe the resistivity distribution to a very deep layer, This is in accordance with the characteristics of geothermal systems found in Indonesia, where the geothermal system reservoir is found at a depth of 1 – 3 km beneath the surface. Several studies have shown a link between resistance types with porosity, fluid content and rock regularity so that the magnetotelluric method is very often used in stages of geothermal exploration (Darma et al., 2010; Giggenbach, 1991).

In this research, a geophysical survey was carried out using magnetic and magnetotellurics to identify surface geological structures based on remote sensing analysis, which was correlated with geological and gravity data. Apart from that, analysis of the position of the demagnetization zone and its correlation was also carried out based on the results of magnetotelluric inversion and created a conceptual model of the geothermal system.

METHOD

This research was carried out by analyzing the surface geological structures based on remote sensing, which was then confirmed with field geological data. For geophysical data processing, we will focus on processing magnetotelluric data, which is processed using the 3D inversion method using MT3DInv-X software, and 3D magnetic inversion processed using Oasis Montaj software.

Geology of Geothermal Area "X"

In this research, the geological map used refers to the Geological Map (**Figure 1**) in the Integrated Geothermal Investigation Report, compiled by Yunus., (2015) and the Regional Geological

Map of the research area at a scale of 1:50,000 by Silitonga and Kastowo, Center for Geological Survey, Geological Agency, ESDM Year 1995, which was then slightly modified, including, among other things, rock unit boundaries and interpretation of geological structures.

In general, the research area is divided into 8 rock units consisting of 1 Pre-Tertiary rock and 7 Quaternary rock units. These rock units, in sequence from old to young, are: Metamorphic (Pre-Tertiary) rocks, Old Volcanic rocks, Bi Volcanic rocks, Mount Br Volcanic product rocks, Lake Tl Volcanic product rocks, Mount Batino Volcanic product rocks, Volcanic product rocks Mount Jn and lava and surface deposits. Metamorphic rock units are thought to be basement/bedrock in this area.

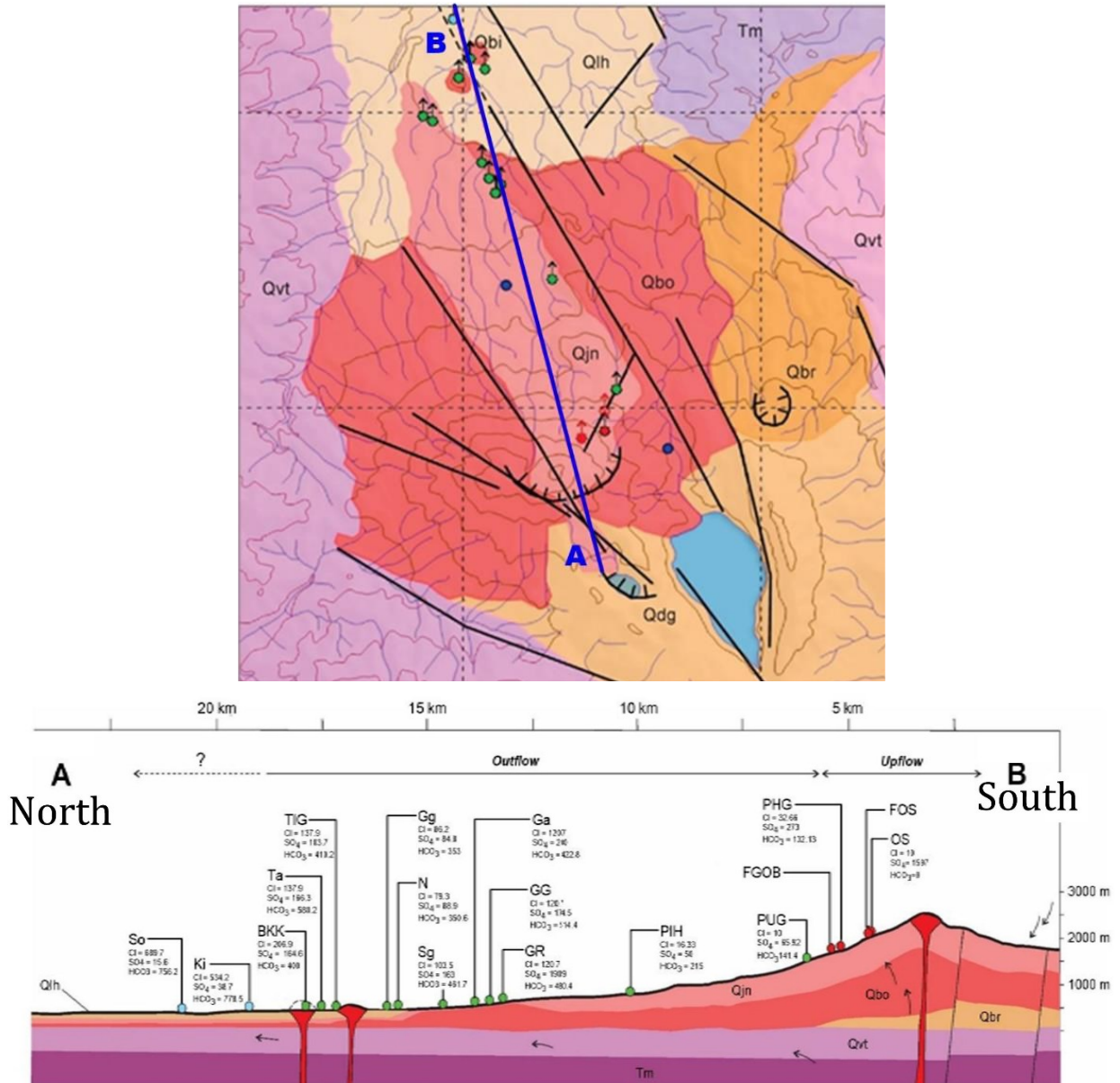


Figure 1. Geological Map of Geothermal Field "X". Metamorphic (Pre-Tertiary) rocks (Tm), Old Volcanic rocks (Qvt), Bi Volcanic rocks (Qbi), Mount Br Volcanic product rocks (Qbr), Lake Tl Volcanic product rocks (Qdg), Mount Batino Volcanic product rocks (Qbo), Volcanic product rocks Mount Jn (Qjn) and lava and surface deposits (Qlh). Metamorphic rock units are thought to be basement/bedrock in this area.

The geological structure that develops in the research area is generally influenced by the main structural patterns resulting from regional tectonics in Sumatra which is part of the Great Sumatran Fault system and the formation of volcanic morphology. This activity shows patterns that can be observed using satellite imagery in the form of lineaments which can describe the presence of

faults/faults as well as circular patterns which generally depict the remains of volcanic activity such as eruption centers.

Magnetotellurics Method

The Magnetotelluric (MT) method is a passive geoelectric method which utilize natural sources, in the form of electromagnetic waves by measuring the fluctuations of the magnetic and electric fields vertically straight on the surface of the earth to determine the conductivity of the rock bottom surface to a depth of thousands of meters (Hardovn et al., 2019; W.M. Telford, 1991). There are three data which will be searched using this method, that are:

a. Skin depth

Electromagnetic waves in the magnetotelluric method are small frequencies, when the frequency is small it will deepen the penetration (W.M. Telford, 1991) Then, to estimate the depth which can be penetrated by the frequency, the following equation (1) is used:

$$\delta = 503 \sqrt{\frac{\rho}{f}} \dots (1)$$

where :

δ = skin depth (m)

ρ = rock resistivity (Ωm)

f = frequency (Hz)

b. Static shift effect

This static shift caused by the electric field arises from the object's charge anomaly in surface heterogeneity. Apart from being caused by heterogeneity near the surface, it can also be affected by uneven topography and vertical rock contact (Pratiwi et al., 2019; Satriani et al., 2012). Therefore it is necessary to make a correction static shift using TDEM, Co-Kriging or Averaging data.

1. Impedance tensors

Impedance is the ratio between the electric field and the magnetic field (Oskooi & Abedi, 2015; Togibasa et al., 2018). The relationship between electric field (E), magnetic field (H) and impedance (Z) is:

$$\vec{E} = Z \cdot \vec{H} \dots (2)$$

2. Magnetotelluric 3D Inversion

To carry out the inversion process required field data and mathematical models to get information about distribution of subsurface physical properties (Pirttijärvi et al., 2015).

Magnetic Method

This method is based on the measurement of magnetic intensity variations on the earth's surface caused by an anomaly of a magnetized object below the earth's surface (Oskooi & Abedi, 2015). Ability to magnetize depending on the magnetic susceptibility of each rock. The price will be greater if the amount of mineral content the magnetic field in the rock increases. If a material which can be magnetized is in the influence of an external magnetic field, which in this case is a magnetic field earth (H), then the intensity of magnetization (I) will be directly proportional to Earth's magnetic field strength (H). On geological material intensity direction magnetization will be parallel to the direction of the earth's working magnetic field as an induction field (Darmawan et al., 2015). The magnitude of the magnetization intensity can be obtained from the following equation (3):

$$\vec{I} = k\vec{H} \dots (3)$$

where :

\vec{I} = magnetization intensity

k = magnetic susceptibility (rock magnetic susceptibility)

\vec{H} = the strength of the earth's magnetic field

The changes that occur in the strength of the earth's magnetic field are very small and it takes a very long time so that in a magnetic survey always considered constant. If the strength of the earth's

magnetic field is considered constant then the magnitude of the magnetization intensity will only depend on variations in rock magnetic susceptibility. It is this assumption that forms the basis of magnetic investigation ([Ismullah et al., 2018](#); [Togibasa et al., 2018](#)).

a. Earth's magnetic field

Earth's magnetic field has physical parameters which also called as elements of the earth's magnetic field, which includes:

- Declination (D), which is the angle between magnetic north with the horizontal component calculated from north heading east.
- Inclination (I), which is the angle between the total magnetic field with the horizontal plane calculated from the plane horizontal to the vertical plane down.
- Horizontal intensity (H), which is the magnitude of the field total magnetic field in the horizontal plane.
- The total magnetic field (F), which is the magnitude of the vector total magnetic field.

b. Geomagnetic data processing

To obtain the value of the magnetic field anomaly desired, corrections are made to the data the total magnetic field measurement results at each point measurement location or station, which includes:

- Daily Correction Daily correction (diurnal correction) is deviation of the value of the earth's magnetic field due to differences in time and the effects of solar radiation in one day.
- Correction of IGRF The main magnetic field value is nothing but a value IGRF. If the value of the external magnetic field is omitted with the daily correction, then the contribution of the magnetic field main is removed by IGRF correction.
- Topographic Correction Topographical corrections in geomagnetic surveys do not have clear rules. One method for determining the value of the correction is to make topography using multiple prism modeling quadrilaterals ([Pirttijärvi et al., 2015](#); [Satria et al., 2021](#)).

c. Magnetic anomaly map filtering

Magnetic anomaly map filtering process on research using two methods, which are upward continuation and reduction to pole (RTP). Appointment to above or upward continuation is done to reduce local magnetic effects originating from various source bodies magnetic dispersal over a topographical surface that is not related to the survey ([Pirttijärvi et al., 2015](#)). Appointment process should not be too high, because this can reduce local magnetic anomaly originating from objects magnetic fields that are the target of magnetic surveys.

Geomagnetic Data Processing

To obtain magnetic field anomaly values, then corrections are made to the data total magnetic field measured at each point measurement locations or stations, which include:

1. Daily Correction

Daily correction is deviation in the value of the earth's magnetic field due to there are differences in time and the effects of solar radiation in a day.

2. IGRF correction

The value of the main magnetic field is also the value of IGRF. If the external magnetic field value is removed with daily correction, then the contribution of the magnetic field primary is eliminated by IGRF correction.

3. Topography Correction

Topographic correction in geomagnetic surveys is not have clear rules. One method for Determining the correction value is by making topography using multiple prism modeling quadrilateral ([Baker & Myers, 1980](#)). When modeling, the magnetic susceptibility value (k) of the rock topography must be known. Therefore, the model of the topography will produces anomalous values magnetic field (ΔH_{top}) corresponds to the facts.

Filtering the Magnetic Anomali Map

This research used two methods of filtering the magnetic anomaly map which are upward continuation and reduction to pole (RTP). Appointment to upward continuation is carried out to reduce local magnetic effects originating from various sources of objects magnetic spread over a topographic surface that is not related to surveys (Khalil & Santos, 2014). Appointment process should not be too high as this can reduce local magnetic anomalies originating from objects magnetic field which is the target of the magnetic survey. Apart from that, the total magnetic anomaly is also processed using reduction to pole (RTP) which aims to rotate direction magnetic inclination and declination in the direction of inclination 90° and 0° declination which provided an ideal magnetic anomaly response. By carrying out upward continuation and reduce processes to pole (RTP), is expected to provide an anomaly pattern magnets are clearer to interpret (Saparun et al., 2022). In the case of these, demagnetization zones are generally associated with Geothermal reservoirs are characterized by low anomalies (Soengkono, 2016). Low magnetic anomaly is related with demagnetization of rocks due to heat from the area geothermal manifestations. The existence of geothermal manifestations and low magnetic anomalies in the study area are suspected caused by ongoing magma intrusion stores heat and becomes a source of heat from the bottom water surface so that hot springs emerge (Nakamura, 1962).

RESULTS AND DISCUSSION

Results of Magnetotelluric's Three Dimensional Inversion

The results of magnetotelluric's three dimensional inversion (Figure 2) obtained eighth iteration, therefore it would be paid attention to which iteration is in accordance with the characteristics of geology. In this case the researcher chooses iteration 7 with RMS 8,542. The results of magnetotelluric's three dimensional inversion describe the distribution of the conductive layer (resistivity 1-10 ohm-m) (Nakamura, 1962). which extends in the direction of the graben pattern ie northwest-southeast direction. Looking from the boundaries of the distribution of resistance layers, this type of low can be estimated that geological structure has a role which is strong in controlling the spread of this layer. Distribution of low resistance type spread to the geothermal manifestations (Saparun et al., 2022) from the upflow in the south to the outflow in the north where this layer thickens to north. The distribution limit of the conductive layer in the east is estimated controlled by the presence of the Batu Bg fault.

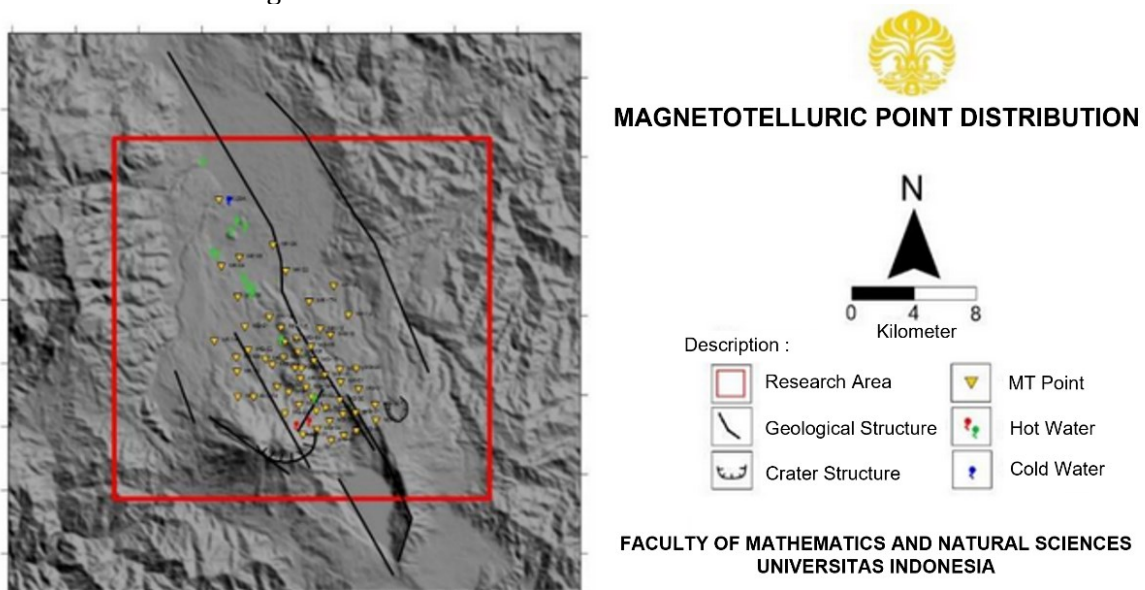


Figure 2. Distribution Map of MT Measurement Points and Tracks of the Vertical Distribution Resistivity.

Results of magnetotelluric's three dimensional of AA' track

Model of resistivity section AA' which is trending southwest - northeast in **Figure 3** shows the presence of resistivity height (> 100 ohm.m) from the surface to a depth of 100 m up to 800 m indicates resistive rock. Under this layer shows a low resistivity distribution (< 10 ohm.m) which extends from a distance of 1000 m to 5500 m which has thickness ranges from 0-800 in the southwest and thickens up to 2500 m to the northeast. This low resistivity distribution is indicated as a clay stamp.

Then the distribution of high resistivity zones (> 100 ohm.m) looks like an updome at depths of -1000 to -4000 m. This high resistivity zone is thought to be a heat source. The zone indicated to be the reservoir zone (40-60 ohm.m) at this track is between points MK-03 to MG-08, this zone forms a dome at a depth of 0 m to -3000 m.

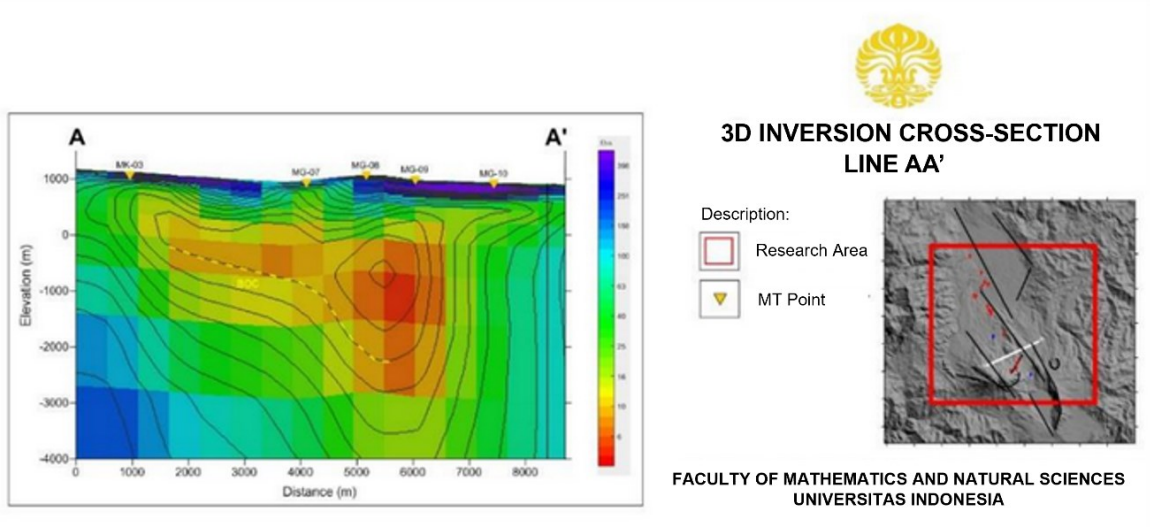


Figure 3. Cross section of magnetotellurics three dimensional's AA' track

Results of magnetotelluric's three dimensional of BB' track

Model of resistivity section B-B' which is trending from north to south in **Figure 4** shows high resistivity (> 100 ohm.m) from the surface to a depth of 50 m indicates resistive rock. Under that layer, there is a long distribution of low resistivity (< 10 ohm.m) which is elongated from a distance of 0 m to 4000 m and has a thickness ranging from 800- 1500 m. This low resistivity distribution is indicated to be a clay stamp (Oskooi & Abedi, 2015).

Then the distribution of high resistivity zones (> 100 ohm.m) could be seen in the form of an updome at depths of -1500 to -4000 m. This high resistivity zone is thought to be a heat source. However, the zone indicated to be a reservoir zone is on trajectory with resistivity ranging from 40-60 ohm.m, this zone forms a dome at a depth of 1000 m to -950 m.

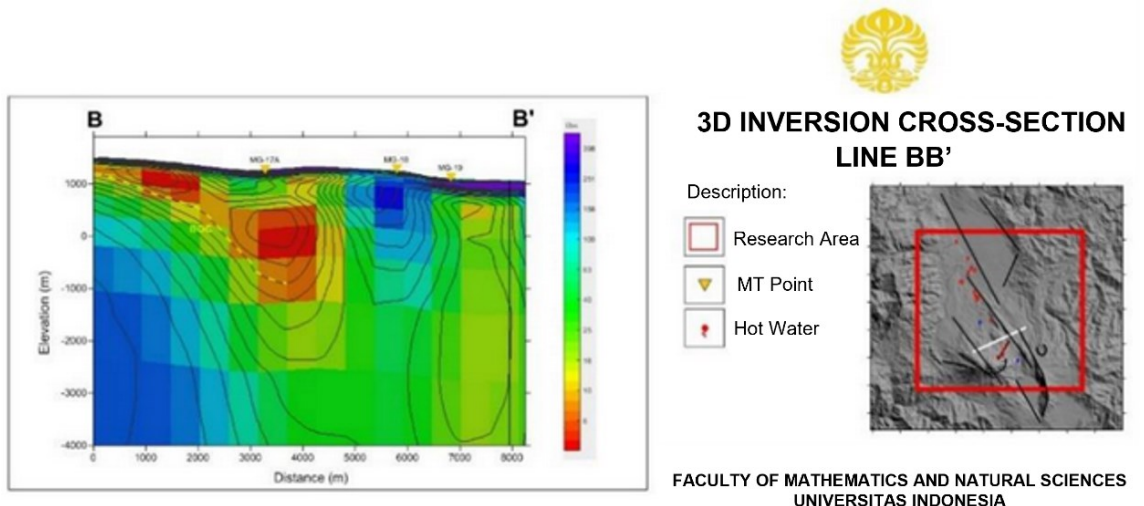


Figure 4. Cross section of magnetotellurics three dimensional's BB' track

Results of magnetotelluric's three dimensional of CC' track

C-C' resistivity cross-section model trending from southwest to northeast which can be seen in **Figure 5**, showed the presence of resistivity high (> 100 ohm-m) from the surface to a depth of 100-350 m which indicated resistive rock. Under the layer, the distribution of low resistivity (< 10 ohm.m) can be seen extends from a distance of 0 m to 3800 m which has a thickness ranging from 850-2200 m. This low resistivity distribution is indicated as a clay stamp.

Then we can also see that the distribution of high resistivity zones (> 100 ohm-m) looks like an updome at a depth of -1000 to - 4000 m. This high resistivity zone is thought to be a heat source. The zone indicated to be the reservoir zone (40-60 ohm-m) is at a track which stands between MG-23 to MG-24 points, and this zone forms a dome at a depth of 800 m to -1500 m.

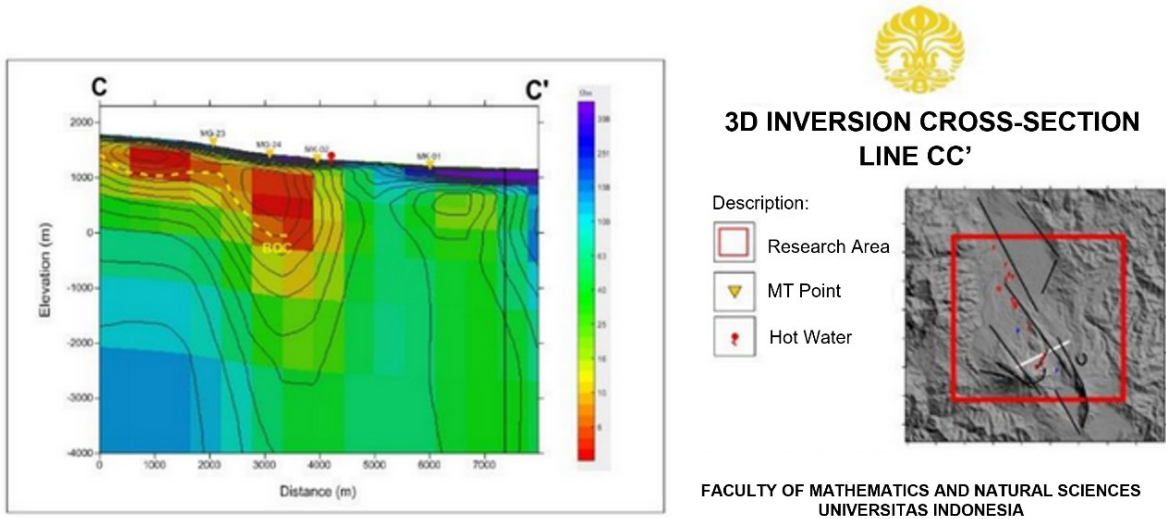


Figure 5. Cross section of magnetotellurics three dimensional's CC' track

Results of magnetotelluric's three dimensional of DD' track

Model of resistivity section D-D' which is trending from southwest to northeast in **Figure 6** shows the presence of resistivity high (> 100 ohm-m) from the surface to a depth of 400 m which indicates resistive rock. Under the layer, the distribution of low resistivity (< 10 ohm.m) can be seen extends from a distance of 0 m to 6000 m in thickness around 1000 m. The low resistivity distribution is indicated to be clay stamp.

Then the distribution of high resistivity zones (> 100 ohm-m) can be seen in the form of an updome at depths of 800 to -4000 m. This high resistivity zone is indicated to be a heat source. The zone indicated to be the reservoir zone (40-60 ohm-m) is a track between MT-21 to MT-43 points, this zone forms a dome at a depth of 900 m to -900 m.

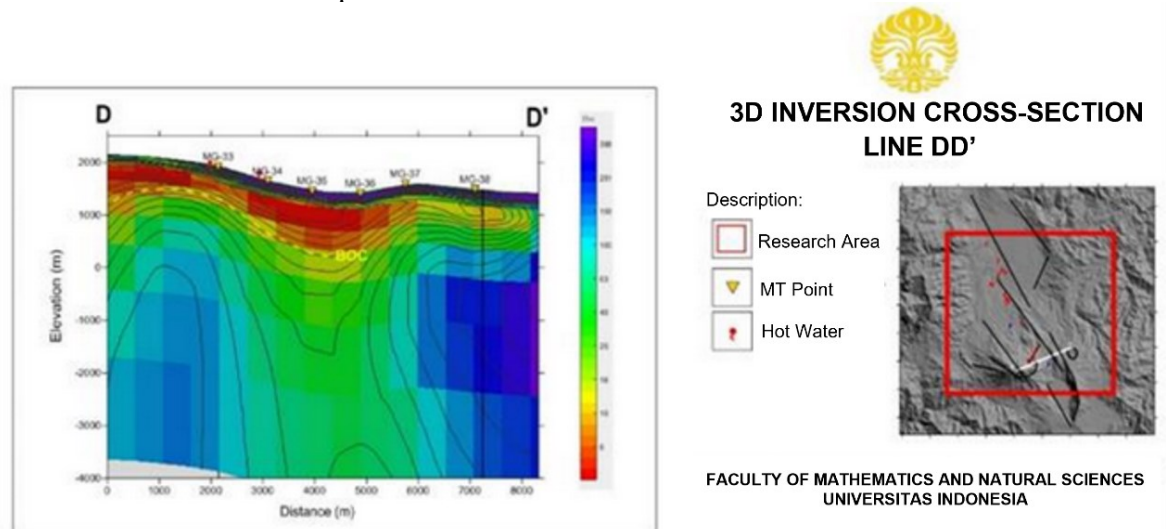


Figure 6. Cross section of magnetotellurics three dimensional's CC' track

Results of magnetotelluric’s three dimensional at each elevation

Similar with the inversion results of each trajectory, the distribution resistivity zones displayed laterally at each depth interval as shown in **Figure 7**. Changes in resistivity at each elevation provide an illustration the depth of the clay cap, reservoir and heat source are different. At a depth of -200 m, low resistivity values (< 10 ohm- m) concentrate on the northwest and southeast, then increasingly fade at a depth of -1500 m. Distribution of resistivity values medium (40 – 60 ohm-m) which is indicated to be the starting reservoir visible at a depth of 0 m to a depth of -500 m. However at a depth of -1000 m, high resistivity values begin to be seen which is indicated to be a heat source.

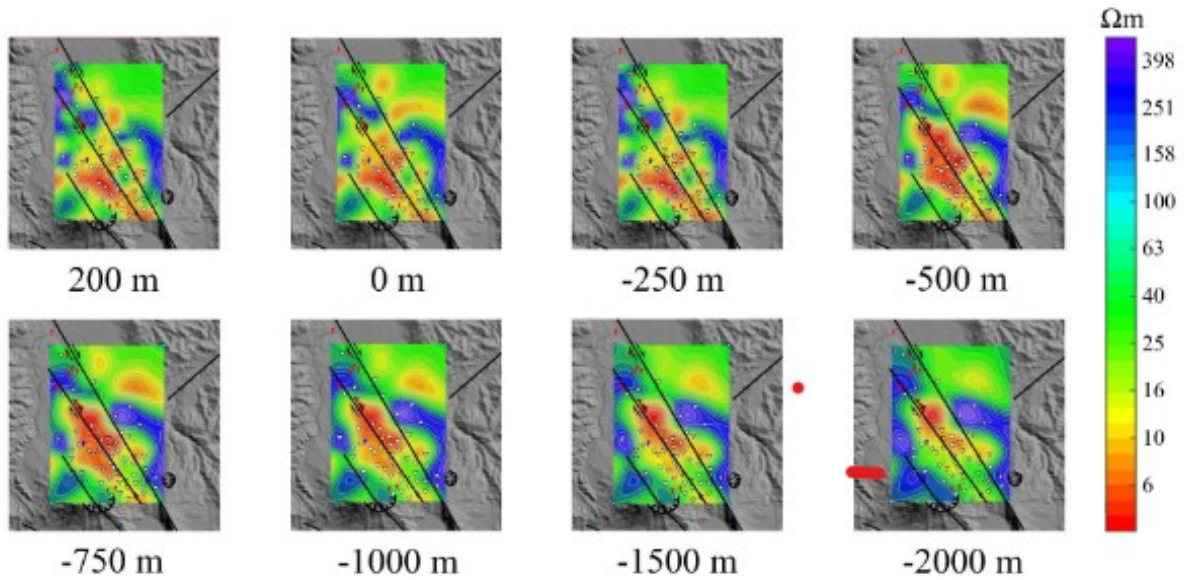


Figure 7. Rock Resistivity Cross Section for Each Elevation

Results of Magnetic Data Processing

Magnetic measurements in the "X" Geothermal Field produce a data field in the form of magnetic anomaly values. The value of this magnetic anomaly then corrected for daily variation values and magnetic values (IGRF) for the "X" Geothermal Field area around 44130 nT. Result of calculating the magnetic anomaly, then creating an anomaly map magnetic (as in **Figure 8**). This magnetic anomaly map still shows magnetic anomaly values based on inclination and declination research area, respectively -14.85° and -0.07.

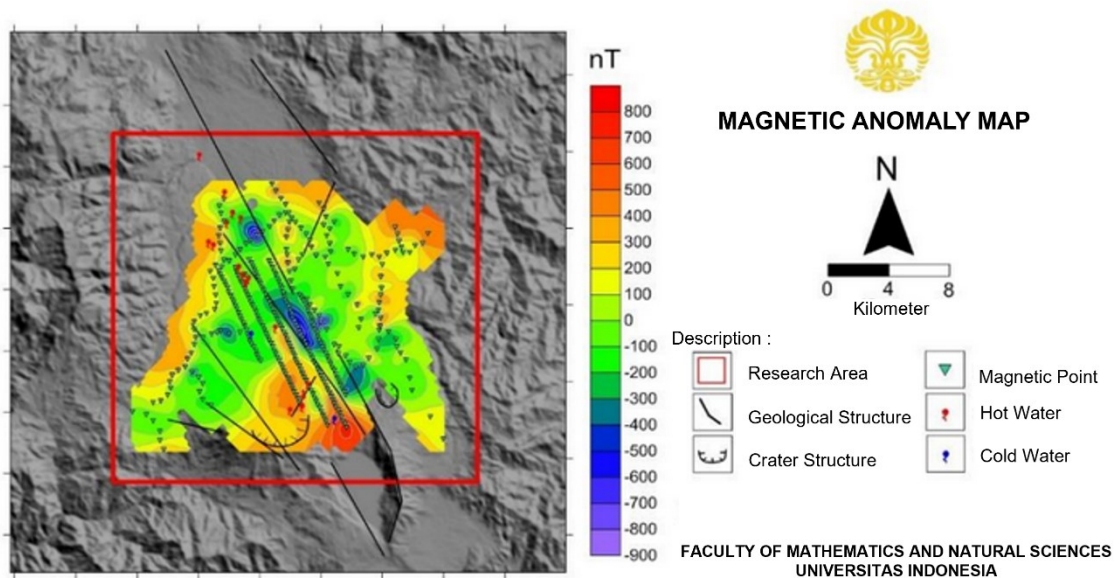


Figure 8. Magnetic Anomaly Map of Geothermal Field X

From the anomaly value obtained, the process is then carried out reduce to pole (RTP) by entering inclination and declination values. This aims to rotate the direction of inclination and declination of the magnet towards inclination 90° and declination 0° which will respond to the magnetic anomaly ideal. The results of this RTP process are shown in **Figure 9**. Based on the RTP results, magnetic anomaly values can provide an appropriate response and can be interpreted geologically.

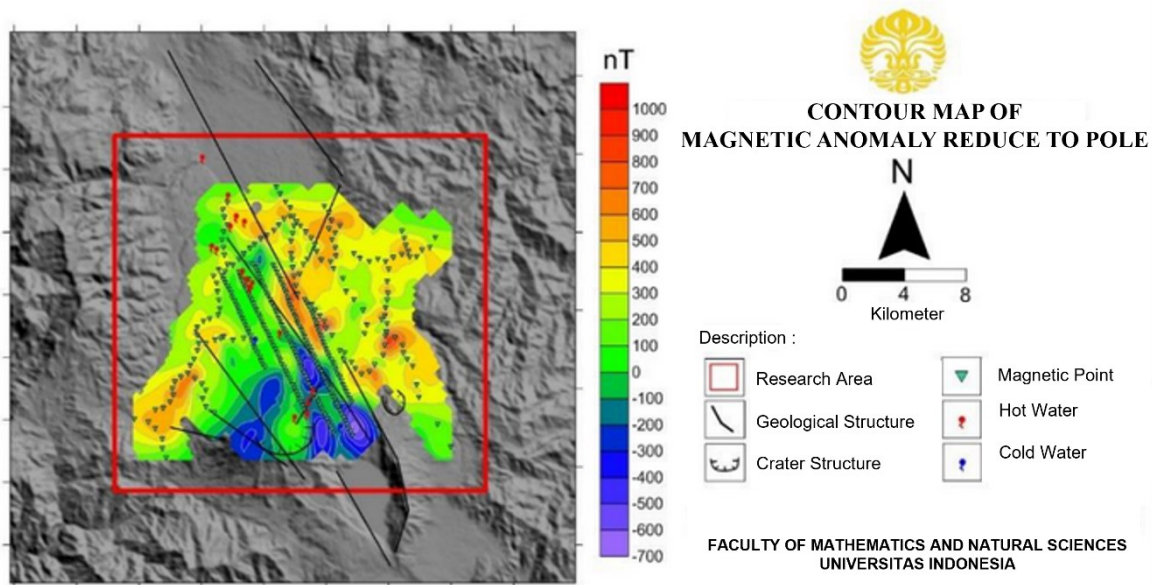
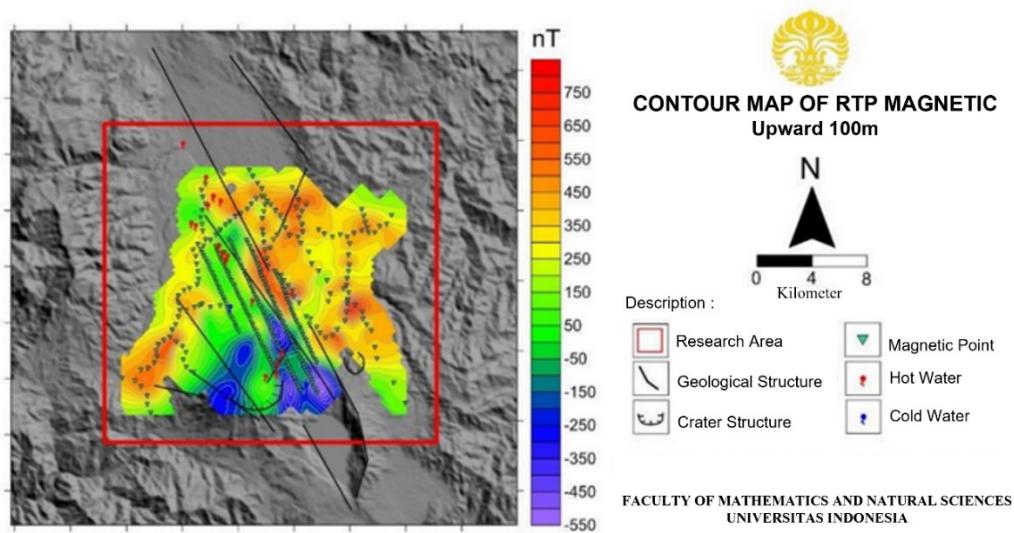
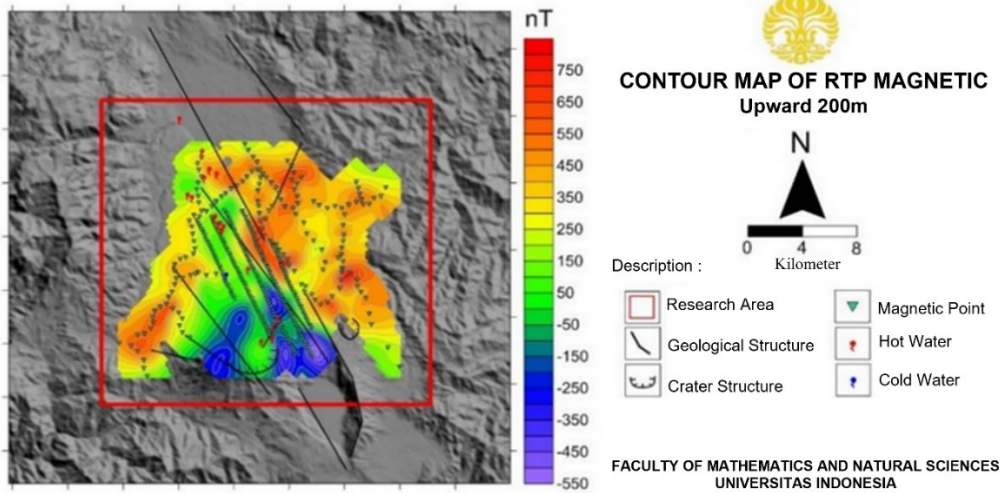


Figure 9. Contour Map of Magnetic Anomaly Reduce to Pole

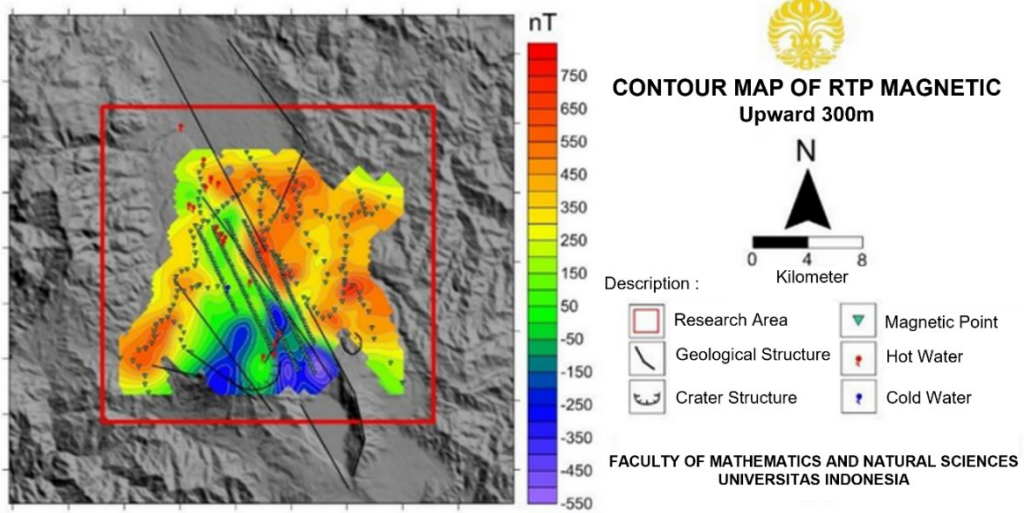
After conducting the RTP, the next step is upward continuation which aims to reduce the influence of source surface magnetic. The upward continuation process is conducting for height 100 m - 500 m (**Figure 9**) in order to know at the height of magnetic anomaly processed upward continuation could provide the optimum anomaly response. Based on magnetic anomaly processing with RTP and upward continuation, the magnetic anomalies height of 500 m are considered quite optimal for describing the condition of the subsurface (**Figure 10a - Figure 10e**). Furthermore, the inversion modeling should be conducted to obtain a magnetic model.



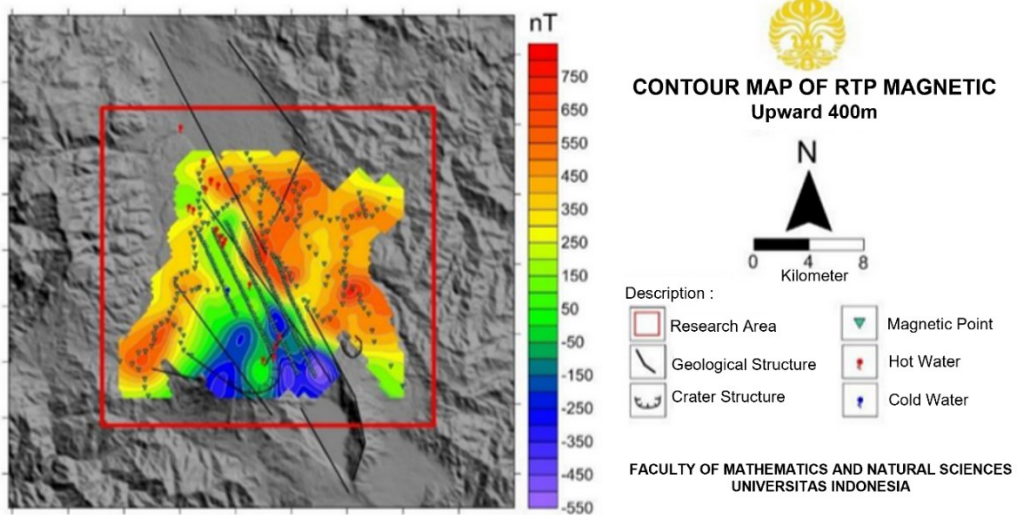
(a)



(b)



(c)



(d)

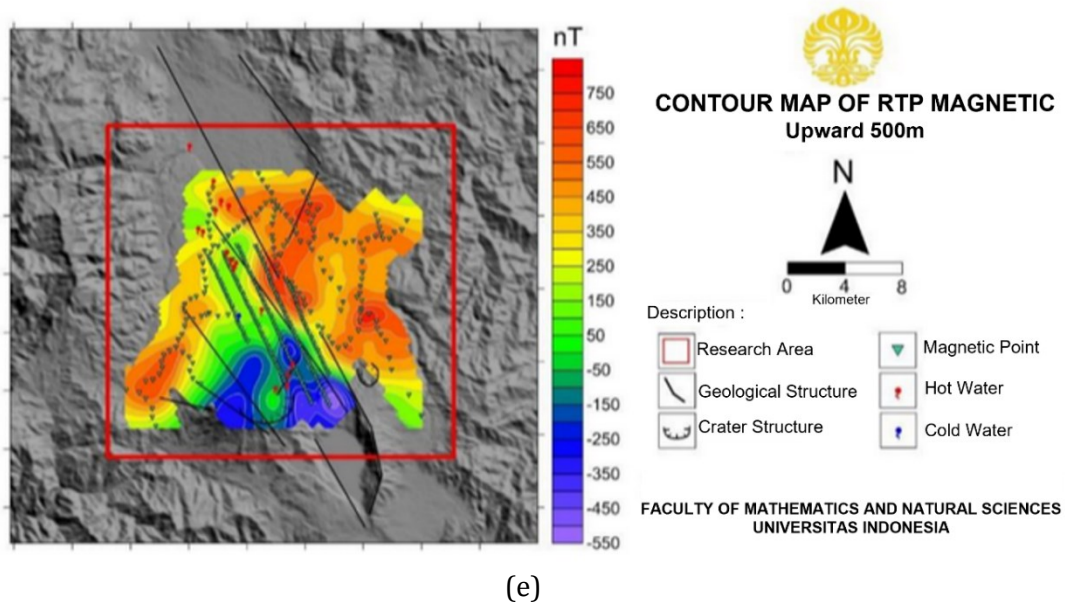


Figure 10. Contour map of magnetic anomaly reduce to pole with upward (a) 100 m (b) 200 m (c) 300 m (d) 400 m (e) 500 m.

Interpretation of Magnetic Data

The magnetic field value in this research area varies between -900 nT to 800 nT. In general, magnetic anomaly values which low and medium are in the southeast to northwest areas. The results of the reduction to pole (RTP) low magnetic anomaly value are in the southern area, at the Tl mountain where there are several G manifestations Bbt, and BB. This can be a clue about the reservoir zone associated with demagnetized zones. However, the result of The RTP is still influenced by local magnetic fields which originate from the surface of the magnetic object so it is necessary to conduct upward continuation.

The upward continuation process is carried out after the RTP process has been done which aims to optimize the information obtained from the magnetic anomaly data. These two processes produce an anomaly map optimum at an altitude of 500 m. Based on upward processing continuation from a height of 100 m to 500 m shows a value of -550 nT up to -300 nT. The anomaly map located in the southern area that is the Tl mountain area. Whereas high magnetic values are in the north, northeast, east and located areas around the western research area. This is thought to be a regional limitation interest (bounded by the Sumatran fault).

Correlation of magnetic data processing results and magnetotelluric's three dimensional Inversion

From the results of magnetic data which has been processed with RTP, upward continuation, and magnetotelluric (MT) three dimensional inversion data; it can be seen that the visible areas with low magnetic anomaly values (-350 nT to -100 nT) are correlate with the 10 ohm-m resistivity distribution seen in the area Mount Tl in the southern part with an elevation of 1800 m to 750 m. In this area, manifestations of G, Bbt, and BB are also spread. From the results of magnetotelluric (MT) three dimensional MT inversion on the DD, it can be seen that the high resistivity (> 100 ohm-m) are in the west and east areas, between these two objects there is a small updome in between. This is reinforced by the results of three dimensional inversion magnetic which has a low value as can be seen in **Figure 11**.

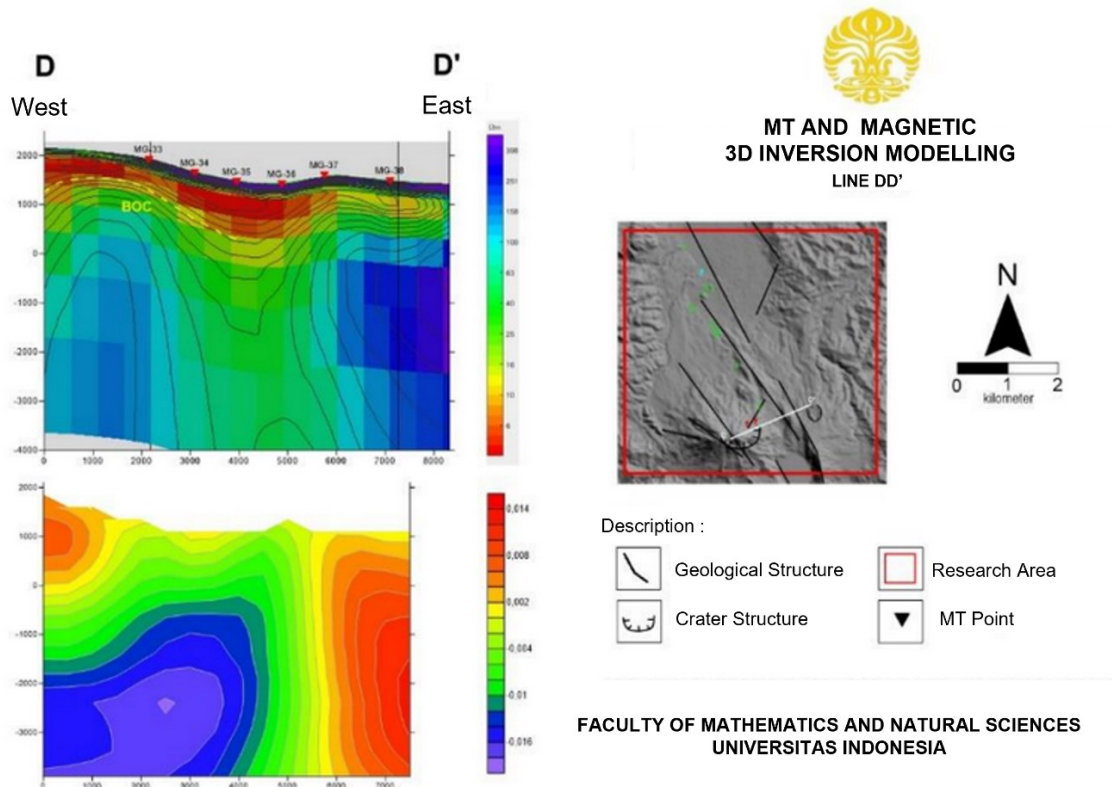


Figure 11. Three Dimensional Magnetotelluric Inversion Model and Magnetic Trajectory DD'

From **Figure 12**, It can be concluded that there is correlation between magnetic inversion data and MT processing results on line AB. The low magnetic anomalies value (-350 nT to -100 nT) occur as far as 4100 m and on this path there is a high resistivity value. This area also has manifestations of G, BBt, and BB in area A (south). In area B (north) there are high magnetic anomaly values and high resistivity. However, there are manifestations with quite high HCO₃ content such as K, BKKII, BKG in this area. Researchers assumed that area B is a zone outflow.

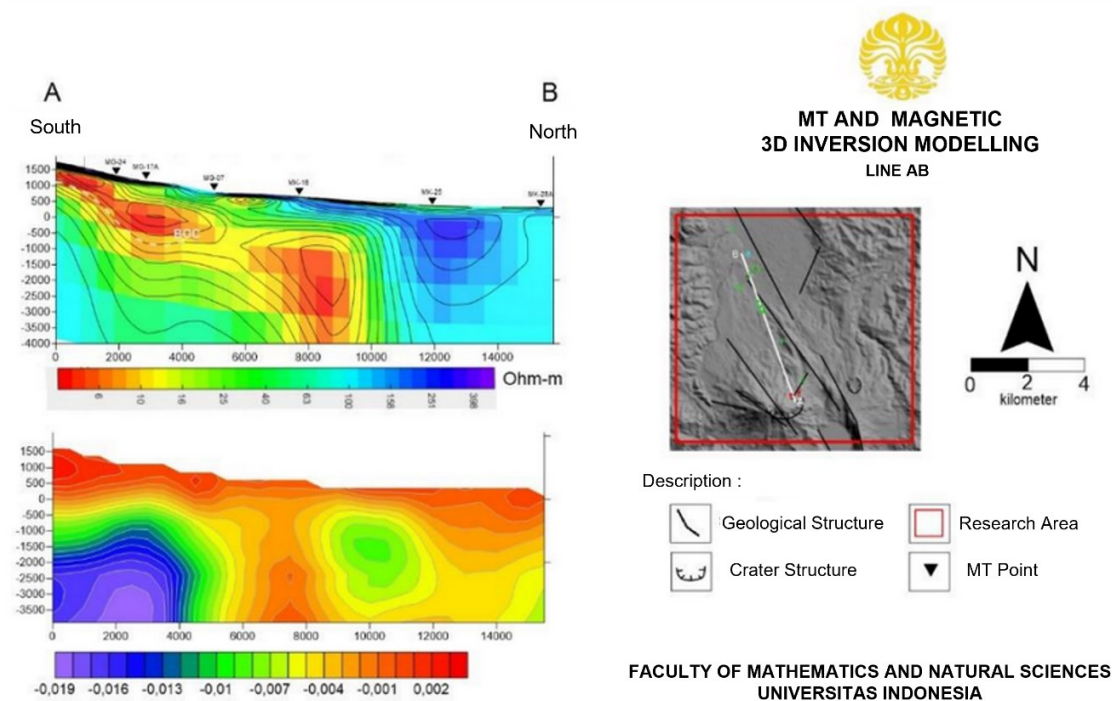


Figure 12. Three Dimensional Magnetotelluric Inversion Model and Magnetic Trajectory AB

conductive layer indicated to be an upflow area, but an area that thickening of the conductive layer (in the northern area) indicated as outflow zone.

Based on data BOC depth in the upflow zone (manifestation complex Gb), there is a reservoir under the cover layer which is estimated to be at a depth of > 1000 m and should be deeper towards edge of the upflow zone (Chae et al., 2006; Hochstein & Sudarman, 1993). Rocks that have the potential to become reservoirs in this geothermal field are a Quaternary volcanic product rock unit, the old volcanic rock unit (Qvt), Lake rock TI unit (Qdg) and a unit of Mount Bo (Qbo) rock. Quaternary volcanic rock which consists of lava and pyroclastic has lithological contact and has undergone tectonic processes (faulting and fracturing), so it can have good secondary permeability. The geothermal conceptual model can be described in Figure 13 and Figure 14.

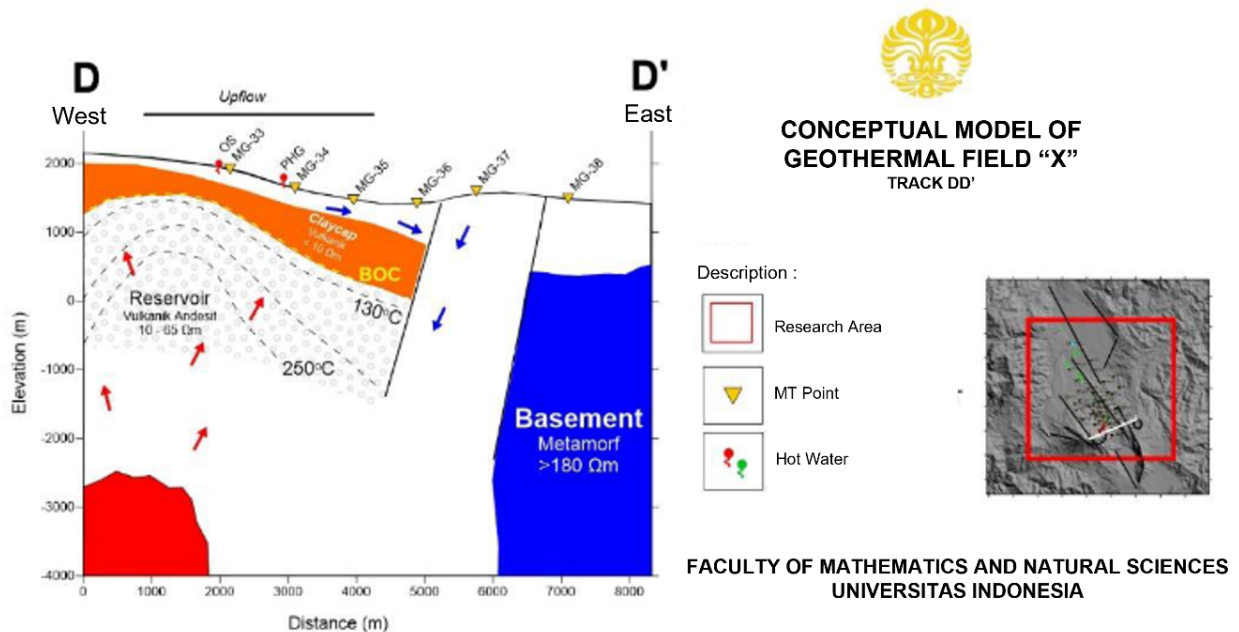


Figure 14. Conceptual Model of Track DD

CONCLUSION

Based on the results of remote sensing processing, the Bouger anomaly and residual anomalies indicate zones that have low density heading from the southeast towards the northwest and also indicated by emergence of manifestations. The demagnetization zone is correlated with the distribution of small value resistivity in the Mount Tl area which indicated as a reservoir zone associated with BOC. Based on liquid geochemical analysis, it showed that the area OS, FOS, PHG and FGOB manifestations are in the upflow zone while the GR, Sg, PGa and TIG manifestation areas are in the outflow zone with estimated temperature in the "X" geothermal field ranges from 218°C to 255°C . Based on three dimensional inversion modeling, the depth of the Base of Conductor (BOC) of the geothermal system "X" ranges from 1000 m to -800 m with resistivity $\leq 10 \Omega\text{m}$ which is indicated to be volcanic rock. Reservoirs geothermal starting at a depth of 1000 m to -2000 m with moderate resistivity $40 - 60 \Omega\text{m}$ which is indicated to be volcanic rock andesite.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest concerning the publication of this article. The authors also confirm that the data and the article are free of plagiarism.

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