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# Subsurface Structure Determination of Geotermal Area in Siogung-ogung Samosir District by Using Magnetic Method

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# Subsurface Structure Determination of Geotermal Area in Siogung-ogung Samosir District by Using Magnetic Method

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**Abstract**. Underwater research often uses geomagnets. It is one of the geophysical methods for measuring magnetic field variations. This research was done to identify how the subsurface rock structure is and determine kinds of rock based on its susceptibility value in Siogung-ogung geothermal area, Pangururan, Samosir District. The tool measurement of total magnetic field called Proton Precission Magnetometer, positioning using Global Position System, and north axis determination using geological compass. Data collection was done randomly with total 51 measuring points obtained. Data analysis started with International geomagnetics Reference Field correction to obtain the total magnetic field anomaly. Then, the data analysis of total magnetic anomaly was done by using surfer program 12. To get a magnetic anomaly cross section used Magdc For Windows program. Magnetic measurement results indicated that the variation of magnetic field strength in each point with the lowest magnetic intensity value of 41785.67 nano tesla. The highest magnetic intensity value is 43140,33. From the results of qualitative interpretation, the magnetic anomaly value is at -200.92 to 1154.45 whereas the quantitative interpretive results of model show the existence of degradation and andesitic rocks, with the value of susceptibility

## 1. Introduction

The Indonesian archipelago locates near with the boundary of the Eurasian and Indo-Australian tectonic plates. The type of boundary between these two plates is convergent. Indo-Australian Plate is a plate that dips under the Eurasian plate (subduction). In addition, to the east, it met 3 tectonic plates at once, namely the Philippines, Pacific, and Indo-Australian plate [1]. Subduction between two plates causes the formation of volcanoes and oceanic troughs. Similarly, the subduction between the Indo-Australian Plate and the Eurasian Plate causes the formation of volcanoes in rows, that is Bukit Barisan on Sumatra Island and volcanoes along Java island, Bali and Lombok, and the ocean trench, that is Java Trough (Sunda) . Tectonic plates continue to move on each other, their movements causing friction with each other to produce big energy that causes magma rise to the surface and volcanic activity increased or the emergence of geothermal sources on the surface. Therefore, Indonesia is in the fire rings area that have enormous geothermal potential.

Population development in Indonesia is accompanied by the increasing of energy demand. So far, energy supplies still utilize energy sources that dominated by fossils such as petroleum, gas and coal. Dependence on fossil energy causes these energy reserves to be depleted, it is necessary to find alternative renewable energy sources. Renewable alternative energy sources that are very potential and it is time to be developed in Indonesia is geothermal. One of the undeveloped geothermal energy sources is geothermal Siogung-ogung, Pangururan District, Samosir District. So far, Geothermal Siogung-ogung is only used as a hot spring water for tourism object [2].

By looking at the potential of this geothermal, it is necessary to conduct comprehensively research so that geothermal energy resources can be utilized better. In this research, the method for identification of subsurface structure is magnetic method. The application of magnetic methods to geothermal exploration is based on the demagnetization of a material due to temperature. The magnetism of a material will decrease as the temperature rises and even disappears when it reaches the Curie temperature. The observation of the magnetic field is based on measuring the magnetic field strength values. Variations in magnetic field strength values are caused by differences of existing rock susceptibility value at the measurement site as an internal factor and the influence of celestial bodies, especially solar activity as an external factor.

## 2. Research Method

### *2.1. Measurement*

The position of each measuring point is determined by Garmin Extrex GPS including latitude, longitude, and elevation. The strength measurement of the total magnetic field was carried out using two tools, they are Proton Precision Magnetometer (PPM) G-856 AX model at base point and PPM elsec 770 type at 51 point stations. Measurements at the base point are periodical at certain intervals, while the measurements at each station point are random and repeatable for three times.

### *2.2. Correction*

The magnitude of the measured magnetic field at each station point is essentially the contribution of the earth's main magnetic field, the outer magnetic field, and the anomalous magnetic field. To obtain the anomalous magnetic field strength that produced by the rock beneath of each measurement point surface, it is necessary to make correction to the main magnetic field and external magnetic field which is also measured through PPM. The corrections which are done include:

1. Daily correction (diurnal correction) is a correction to remove the influence of external magnetic field mainly from solar activity. Daily correction is obtained from a variation in magnetic field strength over a specified time interval at the base point corresponding to the measuring time at each station point. If there is a decrease in magnetic field strength, it must be added for its decrease to the measurement result at the station point, and vice versa.
2. Topographic correction is a correction to remove magnetic field magnetic field influence due to topographic differences. There is no general rule in this correction, but if it is deemed as unemagnetized, the correction made only refers to the elevation difference, that is 0.015 nT / m for the equatorial area.
3) IGRF Correction is a correction to eliminate the influence of the main magnetic field or Internatinal Geomagnetic Reference Field (IGRF). The price of IGRF is certain for each point (Latitude, Arc, and elevation) on the earth's surface [3].

The final result of the magnetic method is the strength of the anomalous magnetic field after correction with the equation:

$$\Delta H = H_{OBS} \pm \Delta H_{vh} \pm H_T - H_{IGRF} \qquad (1)$$

with:

$\Delta H$ = Magnetic Anomaly
$H_{OBS}$ = Measured magnetic field price
$\Delta H_{vh}$ = Daily variation price
$H_T$ = Topography correction price
$H_{IGRF}$ = IGRF correction price

Suceptibility is the degree of the magnetization of an object due to the influence of the magnetic field. To estimate the magnetic susceptibility value at the measurement point, it can be determined from the equation:

$$K = \frac{\Delta H}{H} \quad (2)$$

with: K = Susceptibility of the magnetic field at the point of measurement
ΔH = Magnetic field Anomaly stregth at measurement point (nT)
H = Average magnetic field stregth in the measurement area (nT)

The value of susceptibility is very important for anomalous objects searching, because of its very characteristic for each type of mineral or metal mineral.

### *2.3. Interpretation*
Interpretation of geomagnetic data is done both qualitatively and quantitatively. Qualitative interpretation is done by presenting the magnetic field strength of anomaly in two-dimensional map using Surfer 12. The contour pattern of anomalous magnetic field shows the distribution of geomagnetic objects or geological structures at Earth subsurface. Furthermore, the magnetic field anomaly pattern is interpreted based on local geological information in the form of the distribution of magnetic objects or geological structures, as the basic for estimating the actual geological condition. Quantitative interpretation aims to describe the subsurface structure to determine the lithology of the research area [5]. Interpretation is done to create a geomagnetic sectional model using Mag2dc software. The geomagnetic sectional model is linked to a table of susceptibility values in rock type and geological data of the research area to determine the subsurface rock structure.

## 3. Results

### *3.1. Distribution Patterns of Magnetic Anomalies*
The distribution pattern of anomalous magnetic field strength in the measurement area is shown in Figure 1 below:

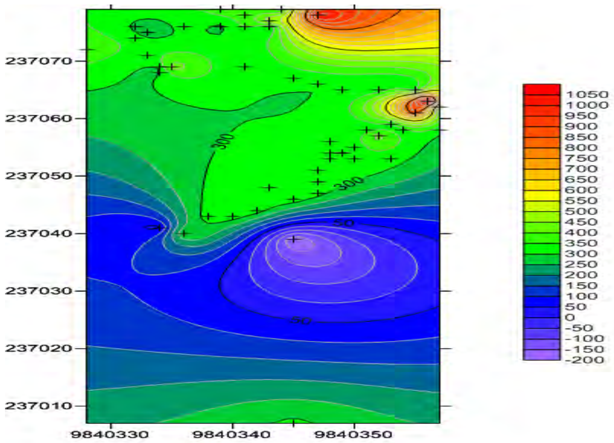


**Figure 1.** Distribution Patterns of Siogung-ogung Magnetic Anomalies

Based on the picture above, it is found that the highest magnetic field strength is 1154.45 (nT) at A27 point and the lowest anomaly is -200,92 (nT) at A1 point. It is accordance with the survey area where the area is a magnetic measurement point that close to the emergence of hot water. The price of low and medium magnetic anomalies is spread over the west which is closely related to the formation of geothermal manifestations in this area. This strong magnetic field states the effect of rocks demineralization due to high temperatures. This area is interpreted as a geothermal prospect area that needs to be examined more thoroughly to ensure its energy potential [6].

### *3.2. Susceptibility of Siogung-ogung Geothermal Rock*

Based on the magnetic field strength of anomaly, then the susceptibility calculation is using equation 2). The pattern of anomalous magnetic field strength distribution in the measurement area is shown in Figure 2 below:

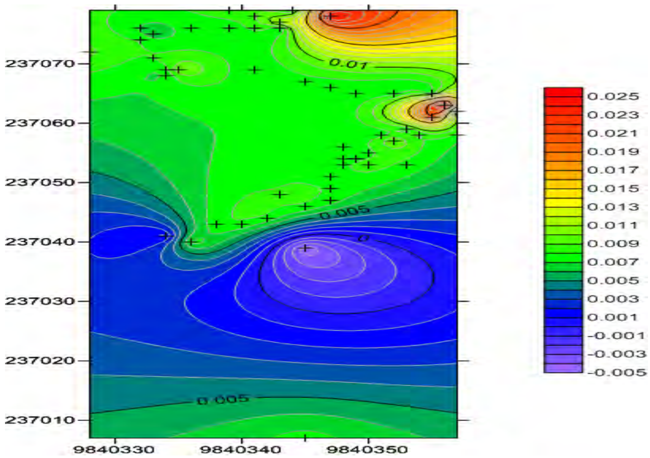


**Figure 2.** Pattern of Susceptibility Distribution at Siogung-ogung

From the calculation of susceptibility value, it is obtained that Siogung-ogung geothermal region has suscetibility value from the lowest to highest that is: - 0,00479 x 103 until 0,0275 x 103. The susceptibility value obtained will be used to determine the type of rock at subsurface of Siogung-ogung geothermal area through quantitative analysis with modeling using Mag2dc software.

### *3.3. Magnetic Anomaly Modeling*

A quantitative interpretation is made to create a geomagnetic sectional model using Mag2dc software for susceptibility data. Modeling is done by making the line section (AA' path) from the lowest anomaly to the highest that suspected as a source of magnetic anomalies. In numerical modeling, some geometric magnetic field parameters are needed in the research area including IGRF value (41987.1 nT), declination angle (-0.1210 °), inclination angle (-0.0164 °) and other parameters. The modeling results are shown in Figure 3 below:

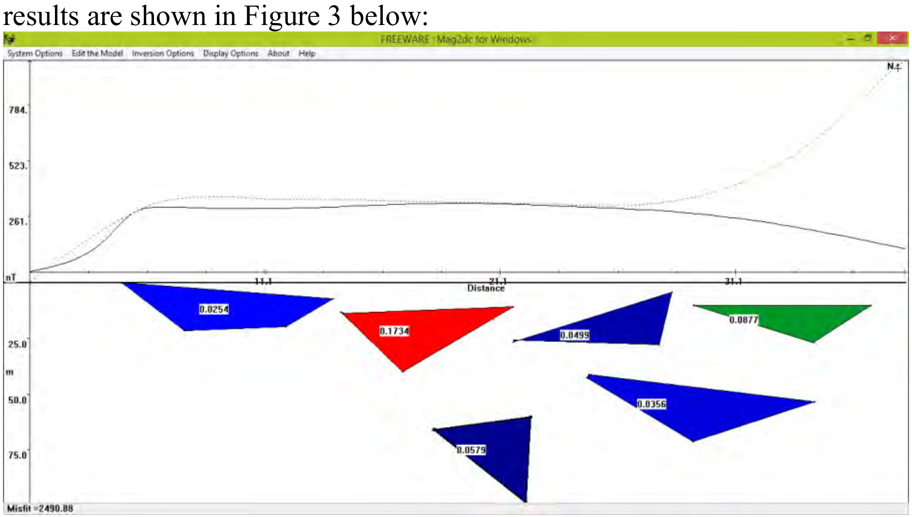


**Figure 3**. Sectional Model of Siogung-ogung Geomagnetic Using Mag2dc

Figure 3 shows the AA' cross-sectional model, where the x-axis denotes the length of the latitude, the positive y-axis represents the strength value of magnetic anomaly, field and the negative y-axis represents depth. From the modeling results, it can be determined rocks lithology based on the susceptibility value. The top layer with a value of k = -0.0254 is interpreted as pyroclastic rock at a depth of 0 to 20 m which serves as cup rock on a geothermal system. Layers with values of k = 0.0499 are interpreted as andesite rocks at depths of 4 to 25 m which serve as a barrier to the loss of geothermal steam. The layer with the value of k = 0.0877 at a depth of 10 to 25 m, k = 0.1734 at a depth of 10 to 35 m, k = 0.0356 at a depth of 41 to 60 m, and k = 0.0579 at a depth of 60 to 100 m, interpreted as a strong alternated rock or have undergone many changes and decreased magnetism properties due to heat. The base of this layer is a reservoir zone and beneath this layer is the geothermal host rock and geothermal vapor.

The contrast of negative and positive susceptibility values to area A is interpreted as a Horst Graben structure, a fracture used as a geothermal vapor exit and in that area there is a fumarole crater which is a geothermal manifestation. If there it is related with the value of the susceptibility table by Telford [8], the rock is andesite that have a susceptibility of 0.0100 to 0.0500 in line with the geological data of the research area. This result is in line with the previously obtained that andesite rocks have a susceptibility between 0.0200 to 0.0400 [9].

## 4. Conclusion

From the research results, it can be concluded, such as (1) The magnetic anomaly value in the survey area ranges from - 200.92 nT at coordinates 237039 N 9840345 E to 1154.45 nT at coordinates 237063 N 9840356 E and (2) Based on the value of susceptibility obtained, the types of rocks found in this research area are desiccation and andesitic rocks with the value of susceptibility (0.0254, 0.0499, 0.0877, 0.1734, 0.0356, 0.00579)

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