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IDENTIFICATION OF SUBSURFACE STRUCTURE USING GEOMAGNETIC METHOD AND ROCK MINERAL ANALYSIS WITH XRD TEST IN GEOTHERMAL AREA OF PAYUNG VILLAGE KARO REGENCY

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ABSTRACT

This research was carried out to know the distribution of subsurface magnetic anomalies and determine the type and content of rocks based on susceptibility values in the geothermal area of Payung village, Karo district. Field measurements use PPM (Proto Precision Magnetometer), GPS (Global Position System) and compass. The data was processed using Mag2dc and surfer 13 software, to obtain susceptibility results. Determination of rock content was tested using XRD (X-Ray Diffraction). Geomagnetic data collection in the field at 40 measurement points. The research results show that there are variations in magnetic field strength at each point with values ranging from 20 nT to 380 nT. This shows that the geothermal area in Payung village has a susceptibility value ranging from 0.0013 x to 0.0088 x and is igneous rock in the form of andesite lava rock and pyroclastic rock. Igneous rocks and pyroclastic rocks are the building blocks of geothermal energy in the research area. The minerals that make up the rocks of the geothermal area in Payung village are the minerals, Asbecasite () and the mineral Quartz (). The mineral has an orthorhombic crystal system with crystal size a= 12.2842Å b= 7.6537Å c= 7.5151Å. The crystal system of the Asbecasite mineral is trigonal (hexagonal axes) with crystal size a= 8.3180Å c= 15.2640Å. Quartz with a triclinic (anorthic) system with crystal size a= 9.9320Å b= 17.2160Å c= 81.8640Å.

Keywords: Geomagnetic Method, Anomaly Value, Susceptibility, XRD

INTRODUCTION

Indonesia is located in a cluster of volcanoes and at the confluence of three active tectonic plates in the world called the Ring of Fire. Therefore, there is great potential for the existence of geothermal energy in the territory of Indonesia. Indonesia's geothermal potential is estimated to reach 40% of the world's geothermal reserves, with a total energy potential of 28,100 Mwe. Only 4% (1,189 MWe) of the 40 geothermal reserves are utilised (Kadri et al., 2016).

Geothermal is one of the renewable energies that aims to reduce the use and dependence on fossil fuels. The depletion of oil and gas reserves due to continuous exploitation, it is necessary to find alternative energy sources that have great potential for national energy sustainability, namely geothermal energy (Kadri et al., 2018).

Indonesia has 256 geothermal potential locations, 16 of which are located in North Sumatra Province (Simanullang & Kadri, 2020). Several volcanoes are still active and no longer active in Sumatra, including Mount Sinabung (altitude 2.475 mdpl) which is still active located in Karo Regency, precisely in Payung District (Febrianty, 2015). One of the geothermal manifestations found on Mount Sinabung is located in Payung Village, Payung District, Karo Regency, on the slopes of Mount Sinabung approximately 2 to 6 kilometres from the summit, which is geographically located between 3°LU and 98°BT.

Geomagnetic method is one of the geophysical methods often used for preliminary investigation in geothermal exploration. This is because geomagnetic method has several advantages compared to other geophysical methods. The method is very sensitive to vertical changes in rock layers and the operation of the geomagnetic method is relatively simple, easy and fast compared to other geophysical methods. This is due to the fact that ferromagnetic minerals will lose their magnetic properties when heated to near curie temperature (Wijaya et al., 2016). The XRD test can be an accurate way to identify rock minerals, because this method is able to provide information about the type of mineral and crystal structure formed in rock samples by comparing the value of the distance d (crystal plane) with the intensity of the diffraction peak (Sari, 2016).

RESEARCH METHOD

The research was conducted around Payung village, Payung sub-district, Karo district, North Sumatra province, at the coordinates of 3° North latitude and 98° East longitude. The village has an area of about 8.80 km^2 with an altitude of 980 m above sea level (Badan Pusat Statistika, 2021).

Measurement of data in the field with geomagnetic methods using PPM (Proto Precision Magnetometer), GPS (Global Position System and) and compass. Then the data will be processed using Microsoft Excel, Oasis montaj, Surfer 13 and Mag2dc software, so as to obtain susceptibility results that are interpreted with colour codes. Magnetic data collection in the field as many as 40 measurement points. The rock content determination uses XRD test to identify the minerals contained in the rocks of the geothermal area.

RESULT AND DISCUSSION

Research Result

The results of the earth magnetic survey research in Payung village, Payung sub-district, Karo Regency are topographic data using GPS and earth magnetic field observation data in the field obtained from reading the Proton Precession Magnotometer (PPM) Type Standard GSM 19. The magnetic field data obtained in this study are 40 observation points in the form of earth magnetic field values, latitude, longitude, time, and altitude. The investigated area has an altitude of about 890 mdpl to 900 mdpl.

Field measurement data is in the form of a total earth magnetic field that is still mixed with the main earth magnetic International Geomagnetic Reference Field (IGRF) and daily magnetic. To obtain the total magnetic anomaly value, the following corrections were made: daily correction, IGRF correction, and topography correction.

Based on the measurement results of observation data obtained magnetic field anomalies displayed in the form of anomaly contour maps using surfer 13 software shown in Figure 1.

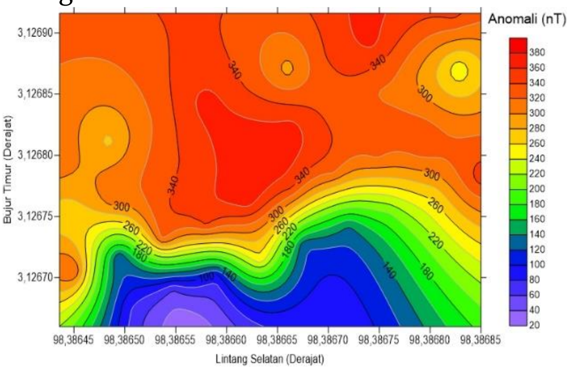

Figure 1. Earth magnetic anomaly distribution map

Figure 1. shows that the magnetic value at the research location ranges from 20 nT to 380 nT. For the magnetic anomaly with low intensity has a value of about 20 nT to 120 nT seen in the section marked with thick blue, medium magnetic anomaly has a value of

about 140 nT to 220 nT seen in the section marked with green and high magnetic anomaly has a value of about 240 nT to 380 nT seen in the section marked with yellow to reddish colour.

To get a clear picture of the magnetic properties found in the research area, magnetic susceptibility measurements were made at each measurement point. The following is a picture of the susceptibility contour map shown in Figure 2.

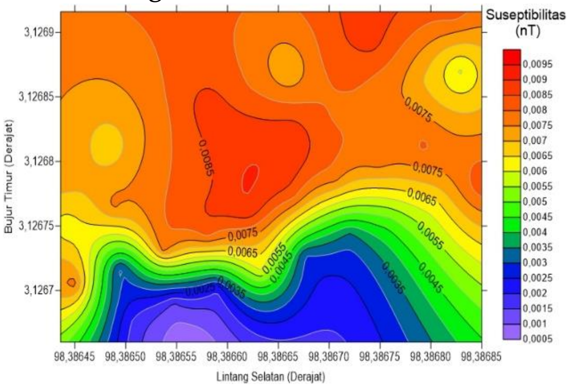

Figure 2. Susceptibility contour map

From the calculation of susceptibility values, it is obtained that the geothermal area of Payung Village has a susceptibility value from the lowest to the highest susceptibility, namely $0.5 \times 10^{-3} nT$ until $9.5 \times 10^{-3} nT$. The susceptibility price obtained is used to determine the type of rock under the surface of the geothermal area in Payung Village. In the geothermal survey, the anomaly sought is a low anomaly, due to the demagnetisation process by hydrothermal alteration so that minerals from a rock become paramagnetic or even diamagnetic minerals.

Discussion

Based on the results of magnetic anomalies and rock susceptibility obtained, magnetic anomaly modelling is made to interpret the subsurface rock structure. The first steps in modelling are line section in the form of AA' trajectory from low anomaly to high anomaly which is suspected as the source of magnetic anomaly on top of the anomaly contour map shown in Figure 3.

Interpretation is done to describe the subsurface structure of the measurement data. This interpretation aims to determine the lithology of the research area. Interpretation is carried out by modelling a 2-dimensional geomagnetic cross section using Mag2dc software by entering anomalous data so that modelling will be obtained as in Figure 4. which is explained in the form of images by showing susceptibility values and colours based on rock layers. In carrying out numerical modelling, several parameters of the earth's magnetic field in the research area are needed, including the IGRF value (43703.4 nT), declination angle (-0.4927 nT), inclination angle (-24.0782 nT), and several modelling parameters.

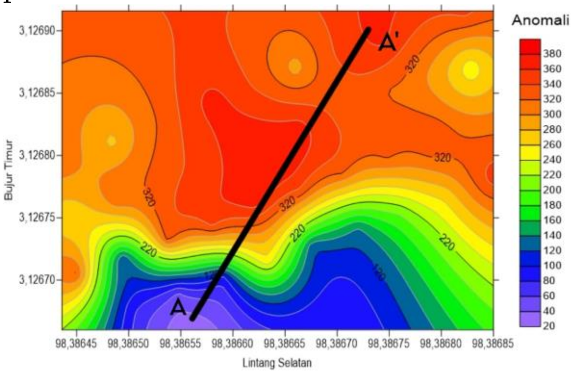

Figure 3. Magnetic anomaly contour map with incision A-A'

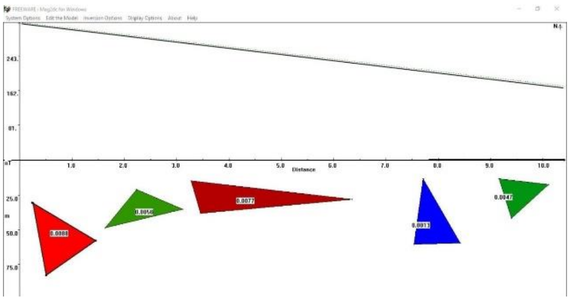

Figure 4. Geomagnetic cross-section model using Mag2dc

Figure 4 is obtained based on the rock susceptibility value seen in Figure 4.2 which produces magnetic modelling using Mag2dc software, so that the anomalous body and magnetic susceptibility value are clearly illustrated where the magnetic susceptibility (k) is quite varied in each body. The shape of the body in the cross section model has no effect, while the susceptibility value contained in the body will affect the magnetic anomaly value, where the greater the susceptibility value, the greater the magnetic anomaly value. The anomaly cross-section model on the positive Y-axis shows the magnetic anomaly value, the negative Y-axis shows the depth, the X-axis shows the length of the incision, the dotted line on the curve is the observed anomaly value, while the line that intersects the dotted line is the modelling anomaly and the colour seen on the body / shape of the cross-section model shows the susceptibility value obtained. Based on the modelling in incision A-A', it is found that the subsurface lithological structure of the study area has susceptibility values ranging from $0.0013 \times 10^3 - 0.0088 \times 10^3$(in SI) and is igneous rock in the form of andesite lava rock and pyroclastic rock. These igneous rocks and pyroclastic rocks are the constituent rocks of geothermal heat in the research area.

Testing Samples with XRD

The types of samples that will be tested using XRD are rock samples. Samples were taken from 2 different places around the research area in Payung village, Karo district. Sample 1 is located at coordinates 03°07'36.280 'LS and 98°23'11.690' BT with a temperature of 53.5 °C. From the results of testing using X-ray diffraction and data processing using Match software, images in the form of graphs and output data are obtained as shown in Figure 5 below.

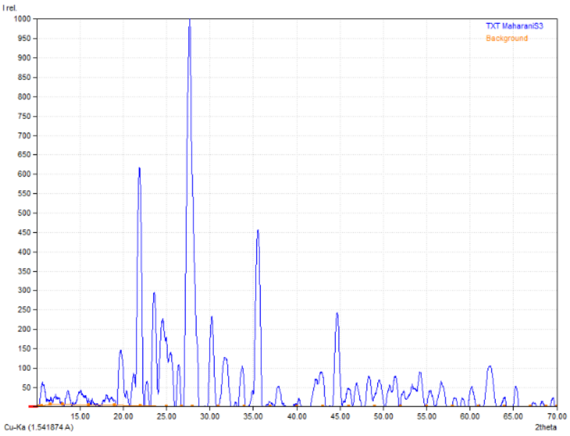

Figure 5. XRD graph of sample 1

Tampilan dua dimensi dari hasil Res2Dinv terdiri dari 3 kontur resistivitas pada bagian pseudodepth atau penampang kedalaman semu. Bagian pertama menggambarkan kontur resistivitas semu terukur (Measured Apparent Resistivity), bagian kedua menggambarkan kontur resistivitas semu yang dihitung (Calculated Apparent Resistivity), dan bagian ketiga menggambarkan kontur resistivitas semu aktual yang diperoleh setelah melalui pemodelan proses inversi (Inversi Model Resistivity Section). Data resistivitas 2D yang telah diolah menggunakan software Res2Dinv kemudian diubah menjadi gambar penampang 2D di bawah permukaan sepanjang jalur dimana nilai resistivitas atau tahanan jenis diberi kode warna untuk menunjukkan kontras resistivitas pada setiap lapisan, berdasarkan Tabel 2.1. (Variasi Resistivitas Batuan dan Mineral), didapatkan informasi mengenai nilai tahanan jenis yang sebenarnya secara lateral (sepanjang rekahan permukaan bumi) dan vertikal. Analisis data dilakukan pada setiap lintasan geolistrik dua dimensi untuk memperkirakan kondisi bawah permukaan yang lebih detail. (Hakim, 2016).

Nilai resistivitas material dan batuan dapat dilihat pada tabel 1 berikut.

Tabel 1. Resistivitas material dan batuan

Material	**Resistivitas (Ωm)**
Air tanah	0,5-150
Lempung	1-100
Pasir	1-1000
Andesit	100-200
Aluvium	10-800
Kerikil	100-600
Batu Pasir	200-8000
Gamping	50-($1x10^7$)
Granite	$5x10^3$-10^6
Basalt	10^3-10^6
Sandstone	8-$4x10^3$
Limestone	5-$4x10^3$
Tufa Vulkanik	20-100
Lava	100-$5x10^4$
Konglomerat	$2x10^3$-$2x10^4$

Sumber (Telford et all, 1990)

Figure 5 shows that there are 7 peaks located at angles 2θ = 21.86º; 23.54º; 24.48º; 27.64º; 30.20º; 35.46º; 44.60º, while the highest peak is at the 4th peak with an intensity of 1000 at an angle of 27.64. Analysis of the mineral phase content obtained from the rock sample at point 1 shows that the deposit is a crystalline material with the main content of Asbecasite ($As_6Be_2Ca_3O_{20}Si_2Ti$) and

C_2N_2Zn. The crystal system in the mineral Asbecasite is trigonal (hexagonal axes) with crystal size a = 8.3180Å c = 15.2640Å. The C_2N_2Zn mineral has an orthorhombic crystal system with crystal size a = 12.2842Å b = 7.6537Å c = 7.5151Å.

Sample 2 is located at coordinates 03°07'36.5" N and 98°23'25.9" East with a temperature of 53°C. From the test results using X-ray diffraction and data processing using Match software, an image in the form of a graph and output data is obtained as shown in Figure 6 below.

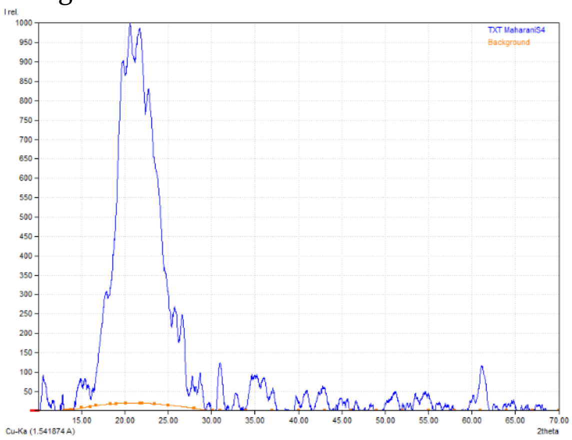

Figure 6. XRD graph of sample 2

Figure 6 shows that there are 5 peaks located at angles 2θ = 20.54º; 21.64º; 22.66º; 30.92º; 61.14º, while the highest peak is at the 1st peak with an intensity of 1000 at an angle of 20.54º.

Analysis of the mineral phase content obtained from the rock sample at point 2 shows that the deposit is a crystalline material with the main content of Quartz (O_2Si). The crystal system of the Quartz mineral is triclinic (anorthic) with crystal size a = 9.9320Å b = 17.2160Å c = 81.8640Å.

CONCLUSION AND SUGGESTION

Based on the susceptibility values obtained, the distribution of subsurface magnetic anomalies is around 20 nT to 380 nT. The magnetic field anomalies obtained occur due to contact between several types of rocks in the form of igneous rocks and pyroclastic rocks with susceptibility values around 0.0005 nT - 0.0095 nT.

The main minerals that make up the rocks of the geothermal area in Pyung Village are C_2N_2Zn, Asbecasite($As_6Be_2Ca_3O_{20}Si_2Ti$) and Quartz (SiO_2) minerals. The mineral C_2N_2Zn has an orthorhombic crystal system with crystal size a = 12.2842Å b = 7.6537Å c = 7.5151Å. The crystal system in the mineral Asbecasite is trigonal (hexagonal axes) with crystal size a = 8.3180Å c = 15.2640Å. Quartz with a triclinic (anorthic) system with crystal size a = 9.9320Å b = 17.2160Å c = 81.8640Å.

Based on the research results obtained, further research is needed with wider data collection so that rock types can be seen properly. Further research can also use other geophysical methods such as resistivity methods, gravity methods, electromagnetic methods and others as methods that can obtain better results with the actual state of subsurface structures.

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