Determine Geothermal Fluid spreading pattern under subsurface using 2d Resistivity Imaging and geomagnetic method at Silaou Kahean.

Muhammad Kadri\textsuperscript{1}, Nazaruddin Nasution\textsuperscript{2}, Mulkan Iskandar\textsuperscript{2}, Masthura\textsuperscript{2}, and Ety Jumiati\textsuperscript{2}

\textsuperscript{1}Department Of Physics, Universitas Negeri Medan  
\textsuperscript{2} Department Of Physics, Universitas Islam Negeri Sumatera Utara

Abstract. The Research has been carried out at geothermal Regional using 2d resistivity imaging and Gemagnetic method in Dusun Silou Kahean Subdistrict, Kabupaten Simalungun. The purpose of this study is to determine the distribution of earth magnetic anomalies, rock structures, and fluid distribution patterns. The measurement of geomagnetic method uses PPM (Proton Precession Magnetometer) type Elsec 770. Data retrieval have been done randomly with the number of points obtained by 40 measuring points, the data is processing by using surfer 10 to determine the contours and Mag2DC to obtain a magnetic anomaly cross section. The 2D resistivity imaging is used to determine the rock resistivity value. The results showed that the anomaly value with the geomagnetic method had the lowest value of 20.51 nT and the highest value of 67.18 nT. The susceptibility value of 0.00051 to 0.00098 cgs is indicated by sandstone and susceptibility value of 0.0013 to 0.0016 cgs is indicated by limestone. The 2D Resistivity imaging method has a resistivity value of 12.5 to 37.3 $\Omega$m is indicated by Silts layer with a depth of 1.25-3.75 meters, and a resistivity value of 1.26 to 8.72 $\Omega$m is indicated by clay layer with a depth of 6.38-12.4 meters . from the results it can be concluded that the fluid dispersion contour using geomagnetic and geoelectric methods is spread across from the southwest to the northeast.

Keywords: Geomagnetic, resistivity imaging, Geothermal

1. Introduction

Energy is an absolute necessity that is needed in human life. The availability of the energy gives a large influences on the progress of development in this world. The more Increasing of human activity and also the demand of energy the more energy consumption. The most energy consumption in the world especially in Indonesia is from fossil fuels. It makes the fossil is dwindling. makes the government saves fuel and energy continue to look for alternative energy sources to re-fulfill the growing need. One-air sum expected energy as an alternative energy is geothermal energy.

Geothermal energy is the energy that is located in the fluid and stones beneath of the earth surface. The thinned and fractured crust allows the magma to rise to the surface as lava. The greatest part of the magma does not reach the surface but heats large regions of underground rocks. Rainwater can seep down the faults and fractured rocks for miles. After being heated, it can return to the surface as steam or hot water. When hot water and steam reach the surface, they can form fumaroles, hot springs, mud pots and other interesting phenomena. Otherwise, when the rising hot water and steam is
trapped in permeable and porous rocks under a layer of impermeable rock, it can form a geothermal reservoir, which could be a powerful source of energy. Geothermal is very clean renewable energy.

The potential of geothermal energy in Indonesia is reach almost 40% from the geothermal energy in the world or it is reach 28,000 MWe. But the use of geothermal energy for electricity energy only 3% from the total geothermal energy in Indonesia. It is caused the location of the geothermal energy is very relatively difficult to reach.

One of the potential location of geothermal in Indonesia at North Sumatera Province is in Simalungun district at Silaou Kahean village. Silaou Kahean is located at 3.1997063 98.8583309.

Based on geological map, Simalungun has potential geothermal energy area at especially at Silou Kahean district. In order to determine the potential geothermal area in Silaou Kahean geomagnetic method is utilized. The purpose of this survey is also to identify the geothermal fluida flowin this area.

The data will be proceed by using software Mag2DC. For finding the geothermal energy can be used by geophysical surveys, and one of the geophysical survey is Magnetic survey.

2. Tools
   a. GPS (Global Position System)
   b. Compass
   c. Hammer
   d. HT (Handy Talky)
   e. PPM (Proton Procession Magnetometers)
   f. Stopwatch.

3. Data Analysis And Data Interpretation

   Daily correction
   Daily correction is done to eliminate the influence of the external magnetic field on the measurement results. This correction is done if there is a difference in the measurement of the earth's magnetic field at the base with the survey area. The value of the deviation is obtained by the following interpolation equation:
   
   \[ I_f = \left( \frac{t_2 - t_1}{t_2 - t_1} \right) x (I_2 - I_1) \]
   
   The equation above is the measurement between \( t_1 \) and \( t_2 \) to \( I_1 \) and \( I_2 \). While the daily correction is:
   
   \[ T_{vh} = I_1 \pm I_f \]

   Topography correction
   Topographic correction is a correction applied to observed geophysical values to remove the effects of topography. In gravity studies, it is the correction applied to each individual determination of gravity to allow for the attraction of rocks occurring as hills above the height of the recording station and as valleys below this level. The topographic correction equation is shown as follows:
   
   \[ T_f = T_{vh} - (\Delta h \times 0.015 \gamma) \]

   IGRF
   The International Geomagnetic Reference Field (IGRF) is a standard mathematical description of the large-scale structure of the Earth's main magnetic field and its secular variation. It was created by fitting parameters of a mathematical model of the magnetic field to measured magnetic field data from surveys, observatories and satellites across the globe.

   IGRF correction can be done by decreasing the IGRF value to the total magnetic field value whoch has been corrected daily each point according the geograpical position. The IGRF equation is shows as follows:
   
   \[ \Delta H = H_{obs} \pm \Delta H_{daily} - H_0 \]
Magnetic Susceptibility
Magnetic susceptibility is a dimensionless proportionality constant that indicates the degree of magnetization of a material in response to an applied magnetic field. A related term is magnetizability, the proportion between magnetic moment and magnetic flux density.

The susceptibility in the stones can be shown as follows
\[
\vec{M} = \alpha \vec{H} \quad \text{atau} \quad \alpha = \frac{\vec{M}}{\vec{H}}
\]

Geomagnetic data Interpretation
Generally, Geomagnetic data Interpretation divided into two, which are qualitative interpretation dan quantitative interpretation. Qualitative interpretation based on the magnetic field contour pattern which is from the distribution of objects magnetized by subsurface geological structures. While qualitative interpretation aims to determine the shape and depth of anomalous objects in geological structure mathematically.

4. Result And Discussion

Stones Susceptibility

![Figure 1: Susceptibility contour](image)

Figure 1 is shown the survey area with low susceptibility value to the highest susceptibility value which are from \(0.0004900 \times 10^3\) to \(0.0016054 \times 10^3\). It is indicated that the area survey contains sand stones and limestones.

Earth's Magnetic Spreading Pattern

![Figure 2: Earth's Magnetic Spreading Pattern](image)
Figure 2 is shown that the survey area has a low magnetic value (M1) which is from 21,51 nT and the highest magnetic value (M21) is 67,18 nT.

**Geomagnetic data interpretation**

![Image of magnetic contour map]

**Figure 3** Earth’s magnetic contour map A-A Incision

Figure 3. shows the A-A incision on the earth's magnetic values which are slashed based on the geology of the research area and qualitative interpretation. A-A incision across from the southwest to the northeast.

This lithology can be determined by the susceptibility value of the modeling results. This interpretation is done by making a model using Mag2DC software, so that it will be obtained in Figure 4.

![Image of cross-sectional model]

**Figure 4.** Geomagnetic Cross Section Model Using Mag2DC

Figure 4. shows the cross-sectional model of A-A where there are x-axis and y-axis. The x axis is the value of the path distance, the negative y axis is the depth value, the dashed line on the curve is the earth's magnetic observation value, while the line that squeezes the dashed line is the magnetic value of the earth modeling. The modeling results of the obtained susceptibility values indicate the type of
limestone with a susceptibility value of 0.0013 cgs; 0.0015 cgs; 0.0016 cgs; and sandstone with a susceptibility value of 0.00051 cgs; 0.00058 cgs; 0.00079 cgs; 0.00089 cgs.

**Resistivity discussion**

**Horizontal cross section**

The results of the horizontal cross section of each layer have different resistivity values as shown in Figure 5.

![Figure 5. Horizontal 3D Resistivity Cross section](image)

Based on Figure 5, inversion of data processing results with Res3Dinv software shows horizontal cross-sectional resistivity section.

| Layer | Depth (m) | Resistivity (Ωm) |
|-------|-----------|------------------|
| 1     | 0.00 – 2.50 | 5.1 – 14.3       |
| 2     | 2.50 – 5.38 | 5.1 – 14.3       |
| 3     | 5.38 – 8.68 | 3.9 – 18.6       |
| 4     | 8.68 – 12.5 | 3.9 – 24.1       |
| 5     | 12.5 – 16.9 | 5.1 – 24.1       |
| 6     | 16.9 – 21.9 | 5.1 – 24.1       |

From Table 1, the result of resistivity cross section shows the difference in resistivity values in each layer. In a horizontal cross section at a depth of 5.38-8.68 meters with a resistivity value of 3.9 Ωm as a layer that has the potential to contain geothermal fluid and as conductive clay.

Geothermal distribution in the study area is based on rock resistivity values spread vertically, where the clay layer is a conductive zone and the Silts layer is the cover layer.

**Vertical cross section**

Results from vertical cross sections of XZ and YZ. XZ vertical cross section is a cross section intersection on the X and Z axis vertically, as in Figure 6.

![Figure 6. 3D Resistivity Cross section Vertically XZ](image)
Table 2. Rock Layer Resistivity Value on XZ Vertical layer

| Depth         | Resistivity | Rocks type |
|---------------|-------------|------------|
| 1,25 meter    | 11.1 Ωm     | Silts      |
| 7.03 meter    | 18.6 Ωm     | Silts      |
| 10.6 meter    | 3.9 Ωm      | Lempung    |
| 14.7-24.8 meter | 6.6 Ωm   | Lempung    |

Based on Figure 6. and Table 2, XZ vertical path is dominated by green with a resistivity value of 11.1 Ωm which is interpreted as silt (Silts). At a depth of 10.6 meters with a resistivity value of 3.9 Ωm as a layer that has the potential to contain geothermal fluid and as conductive clay. Based on the geological map of the District of Silou Kahean shows the similarity of the third layer, namely the silt (silts) and clay layers. Geothermal distribution in the study area is based on rock resistivity values spread vertically, where the clay layer is a conductive zone and the Silts layer is the cover layer.

YZ vertical cross section is a cross section intersection on the Y and Z axis vertically, as in Figure 7.

Table 3. Rock Layer Resistivity Value on YZ Vertical layer

| Layer | distance (m) | Resistivity (Ωm) | Rocks type |
|-------|--------------|------------------|------------|
| 1     | 0.00 – 5.00  | 14.3 – 24.1      | Silts      |
| 2     | 5.00 – 10.00 | 14.3 – 18.6      | Silts      |
| 3     | 10.00 – 15.00| 11.1 – 14.3      | Silts      |
| 4     | 15.00 – 20.00| 8.5 – 11.1       | Silts      |
| 5     | 20.00 – 25.00| 5.1 – 8.5        | Lempung    |
| 6     | 25.00 – 30.00| 6.6 – 8.5        | Lempung    |
| 7     | 30.00 – 35.00| 6.6 – 8.5        | Lempung    |
| 8     | 35.00 – 40.00| 5.1 – 8.5        | Lempung    |
| 9     | 40.00 – 45.00| 3.9 – 8.5        | Lempung    |
From Table 3, the result of resistivity cross section shows the difference in resistivity values in each layer. In the vertical section at a distance of 40.00-45.00 meters with a resistivity value of 3.9 \( \Omega \text{m} \) as a layer that has the potential to contain geothermal fluid and as conductive clay. Geothermal distribution in the study area is based on rock resistivity values spread vertically, where the clay layer is a conductive zone and the Silts layer is the cover layer.

5. Conclusion

From the results of the research carried out, it can be concluded, among others:

1. The magnetic value of the earth in the study area ranged from 20.51 nT at coordinates 476433 N and 348413 E to 67.18 nT at coordinates 476455 N and 348465 E.

2. The subsurface rock structure in the geothermal area in Bahoan Hamlet, Silou Kahean Subdistrict, Simalungun Regency based on susceptibility value consists of sandstone with susceptibility value of 0.00051-0.00098 cgs and limestone with a susceptibility value of 0.0013-0.0016 cgs. Fluid distribution pattern and based on the resistivity value consists of Silts with resistivity value 12.5-37.3 \( \Omega \text{m} \), clay with resistivity value 1.26-8.72 \( \Omega \text{m} \).

References

[1] Byerly, P. E., and Stolt, R. H., 1977, Attempt to define the Curie point isotherm in Northern and Central Arizona: Geophysics, 42, 1394-1400.
[2] Campos-Enriquez, J. O., Arroyo-Esquivel, M. A., and Urrutia-Fucugauchi, J., 1990,
[3] Basement, Curie isotherm and shallow-crustal structure of the Trans-Mexican Volcanic Belt, from aeromagnetic data: Tectonophysics, 172, 77-90.
[4] Conard, G., Couch, R., and Gemperie, M., 1983, Analysis of aeromagnetic measurements from the Cascade Range in central Oregon: Geophysics, 48, 376-390.
[5] Kadri, M., et al, 2016. Geothermal fluid determination and geothermal stones mineral identification at geothermal area tinggi raja simalungun, north sumatera, indonesia using 2d resistivity imaging. Journal of sciences and environment. ISSN (Paper)2224-3216 ISSN (Online)2225-0948.
[6] Nemzer, M. L., Carter, A. K., Nemzer, K. P., 2004, Geothermal energy facts: Geothermal Education Office, on-line at: http://geothermal.marin.org/pwrheat.html.
[7] Okubo, Y., Graff, R. G., Hansen, R. O., Ogawa, K., Tsu, H., 1985, Curie point depths of the Island of Kyushu and surrounding areas: Geophysics, 53, 481-494.
[8] Okubo, Y., Matsushima, J., Correia, A., 2003, Magnetic spectral analysis in Portugal and its adjacent seas: Physics and Chemistry of the Earth, 28, 511-519.
[9] Salem, A., Ushijima, K., Elsirafi, A., and Mizunaga, H., 2000, Spectral analysis of aeromagnetic data for geothermal reconnaissance of Quseir area, Northern Red Sea, Egypt: Proceedings World Geothermal Congress, 1669-1673, on-line at : http://www.geotermie.de/egec-geothernet/ci-prof/africa/egypt/0221.pdf
[10] Spector, A. and Grant, F. S., 1970, Statistical models for interpreting aeromagnetic data: Geophysics, 35, 293-302.
[11] Stampolidis, A. and Tsokas, G., 2002, Curie point depths of Macedonia and Thrace, N. Greece: Pure and Applied Geophysics, 159, 1-13.