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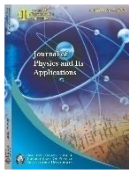

Magnetic Susceptibility of Volcanic Rocks from Pahae Julu Region, North Sumatera Province

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ABSTRACT

Pahae Julu is a sub-district located in North Tapanuli Regency, North Sumatra. This area is often found with volcanic material from the eruption of Mount Toba (Youngest Toba Tuff). The Youngest Toba Tuff eruption occurred ~74,000 years ago with a volume of 2,800 km^3. When there is an eruption, the lava on the earth's surface undergoes a relatively fast freezing process to form volcanic igneous rock. These rocks contain various minerals, one of which is magnetic minerals that can be used as a track record of volcanic processes from Mount Toba. However, no document records the magnetic susceptibility value of the Youngest Toba Tuff volcanic rock in the Pahae Julu area. This research aimsbfor knowing the abundance of magnetic minerals by the low-field magnetic susceptibility. To achieve this goal, the rock magnetism method is used. This way is very effective, cheap, sensitive, and non-destructive. Magnetic susceptibility measurements are done using the Bartington Magnetic Susceptibility Meter MS2B sensor. Rock samples analyzed are pumice which is the result of the Youngest Toba Tuff eruption. The results showed that the magnetic susceptibility value obtained for the sample was between 85.0 x 10^{-8}m^3/kg – 183.1 x 10^{-8}m^3/kg with an average of 119.78 x 10^{-8}m^3/kg. Based on this value, it is assumed that the magnetic mineral properties are Antiferromagnetic. The average value of χ_{fd}% obtained is 0.95%, indicating that the Youngest Toba Tuff volcanic rock in the Pahae Julu area has almost no Superparamagnetic grains.

1. Introduction

North Sumatra is a province located in the northern part of the island of Sumatra with location coordinates 1° - 4° North Latitude and 98° - 100° East Longitude. North Sumatra Province is directly adjacent to the Province of Aceh (North),Malacca Strait (East), Riau Province and West Sumatra Province (South) and Aceh Province and the Indonesian Ocean (West)[1]. Based on its geographical location, North Sumatra is traversed by the Pacific Ring of Fire which causes the area to experience frequent earthquakes and volcanic eruptions. Every volcano has eruptive or eruptive activity.

The eruption is the process of expelling material from the bowels of the earth[2]. Volcanic eruptions are divided into 2, namely effusive eruptions and explosive eruptions. An effusive eruption releases lava slowly in the form of a flow, while an explosive eruption releases lava in the form of an explosion. Explosive eruptions have occurred in several volcanoes in Indonesia. One of them is in the ancient Toba volcano thousands of years ago. The ancient Toba volcano has erupted several times and produced a caldera. Mount Toba caldera is the biggest caldera on earth (100x30 km^2) [3]. A very powerful eruption occurred three times. The first eruption occurred about 840,000 years ago in the Porsea area [4] which formed the Porsea Caldera and produced the Old Toba Tuff[5]. The second eruption about 500,000 years ago occurred in the Haranggaol area which formed the Haranggaol Caldera and produced the Middle Toba Tuff, and the third eruption which was the largest eruption occurred about 74,000 years ago which united the Toba calderas and formed the Youngest Toba Tuff[6], with the volume of volcanic material ejected reaching 2,800 km^3[7]so that the material was spread and found as far as India[8], Arabian Sea[9], and China[10][11][12]. The material is scattered in all directions caused by wind factors and settles in one place. The material deposits form rocks that contain various minerals, one of which is magnetic minerals that can be used as a track record of the volcanic process of Mount Toba.

The eruption of the Youngest Toba Tuff was very influential on regional and global climates in the past[13]. The eruptive material released into the atmosphere covers an area of 2,000 km [14]which causes the so-called “volcanic winter” to last for ~ 6 years [15].Various approaches have been taken to study volcanic processes that occurred in the past. One of them is the measurement of magnetic susceptibility values of rocks from the Youngest Toba Tuff eruption. These characteristics can be used for initial data to know the volcanic processes that occur. Magnetic susceptibility measurements can be carried out on all materials resulting from eruptions, one of which is volcanic rock. In general, the volcanic rocks of Mount Toba contain several minerals including quartz, sanidine, biotite, magnetite, ilmenite, zircon, and apatite [4]. However, the magnetic mineral content in rocks, especially the Pahae Julu area, has not been identified.

In general, minerals that exist in nature have weak (diamagnetic), medium (paramagnetic), and strong (ferromagnetic) [16] magnetic properties with different magnetic susceptibility values. However, ferromagnetic minerals have high susceptibility values [17][18]. These characteristics are very useful for knowing the volcanic processes that occurred in the overpast.

The magnetic properties of rocks are determined using the rock magnetism method through mineral characteristics such as concentration, type, magnetic domain, grain size, and Currie temperature.This measurement has the advantage of being cheap, fast, does not damage the material, and is very efficient [19].

Rock magnetism methods have been widely used in studying the study of recordings of the earth's magnetic field in the past seen through rockssuch as measurements of the magnetic properties of rocks in Lake El'gygytgyn, Russia[20]. Minerals are contained in volcanic rocks in the Lake Maninjau area [21].

Measurement of magnetic susceptibility values was used to determine the abundance of magnetic minerals in the youngest Toba Tuf volcanic rock in the Pahae Julu area, North Tapanuli Regency, North Sumatra Province.

2. Methods

The sampling location in this study was in the Pahae Julu area, North Tapanuli Regency. This area is one of the regencies in the Lake Toba area and in that area a lot of volcanic material in the form of volcanic rocks can be seen based on the geological map Fig.1.

Based on Fig.1, the geology of Pahae Julu Region is composed of granite (pink), alluvium (light green), carbonate (dark blue), and pumice (dark yellow). This type of rock comes from the deposition of material from the eruption of the ancient Toba volcano, one of which is the result of the Youngest Toba Tuff eruption.

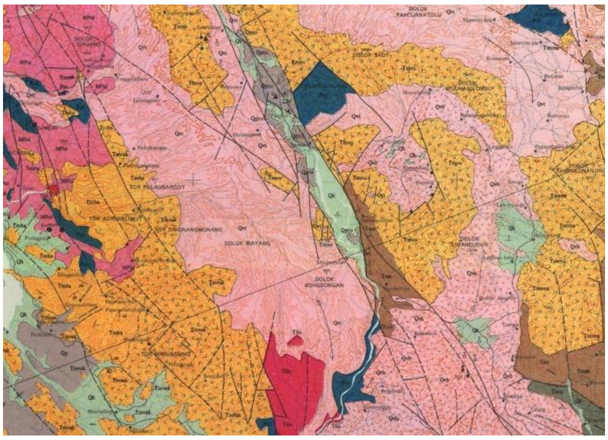

Fig.1: Geological Map of Pahae Julu Region [22].

Sampling was carried out in March 2019. The following map of the research location of volcanic rocks in the Pahae Julu area can be seen in Fig.2.

Fig.2: Sampling map.

2.1 Sampling

Sampling was carried out in the Pahae Julu area, near PT. Sarulla Geothermal Power Plant with coordinates1^{o}49’43.3” LU - 99^{o}05’03” BT. The rock samples used have the characteristics of light gray, hollow, light and brittle. Based on these characteristics the type of sample is pumice. The extraction process is carried out using a hammer. The naming of the sample is based on the year and numbering of the sampling, namely TOB 19-27.

2.2 Sample Preparation

Rock samples that have been taken are taken to the Geophysics Laboratory, Department of Physics, Faculty of Mathematics and Natural Sciences, Padang State University to be continued with the sample preparation process before taking measurements. The sample was mashed with a mortar put into a holder and labeled with the name according to the name of the sample. The initial step of measurement is to measure the mass of the empty holder, then measure the mass of the holder containing the sample using a Digital Neraca (Balance type Ohauss SN EO271119030112) which has been calibrated first.

After the sample preparation, it was found that there were 50 pieces.

2.3 Magnetic susceptibility measurement

Magnetic susceptibility measurements of volcanic rocks in the Pahae Julu area were carried out using Bartington Magnetic Susceptibility MS2B type. Measurements were made with two frequencies, namely 470Hz for low-frequency susceptibility (χ_{lf}) and 4.7kHz high-frequency (χ_{hf}). Measurements were repeated three times in a low field state and three times in a high field state so that the average magnetic susceptibility value (χ average) was obtained. The ratio of measurements at both frequencies is recorded as the value of frequency-dependent susceptibility (χ_{fd}), obtained through equation [23]:

$$\%\,\chi_{fd} = \frac{\chi_{lf}-\chi_{hf}}{\chi_{lf}} \times 100\% \qquad (1)$$

The results of the χ_{lf} and $\%\chi_{fd}$ measurements are plotted so that the type of domain is obtained by matching it to the scategram scheme Dearing, 1999 Data interpretation refers to the Dearing table, 1996.

3. Results and Discussion

The data from the measurement of magnetic susceptibility values were analyzed using Microsoft Excel to see how the magnetic susceptibility values of the Youngest Toba Tuff volcanic rock in the Pahae Julu area, North Tapanuli Regency. Measurement of magnetic susceptibility is seen in Table 1.

Table 1. Measurement of the magnetic susceptibility value of the Youngest Toba Tuff volcanic rock in the Pahae Julu area.

SUBJECT	Magnetic Susceptibility (x 10^{-8} m^3/kg)		Frequency-Dependent Susceptibility (χ_{fd}%)
	Low (χ_{lf})	High (χ_{hf})	
MAX	183.1	181.6	2.27
MIN	85	84.2	0.19
Averages	119.78	118.6	0.95
Standard Deviation	22.34	22.1	0.4

In Table 1, it is known that the magnetic susceptibility value of TOB 19-27 ranges from 85 x $10^{-8}m^3/kg$ to 183.1 x $10^{-8}m^3/kg$. The overall magnetic susceptibility value was 119.7 x $10^{-8}m^3/kg$. This value shows that TOB 19-27 sample is Antiferromagnetic according to the concept of Hunt, 1995. The high value of magnetic susceptibility indicates the high abundance of magnetic minerals, while a low magnetic susceptibility value indicates the low abundance of magnetic minerals in rock samples. The interpretation of Superparamagnetic grain content based on χ_{fd}%in the sample is 0.95%. Based on Dearing 1996 indicates that sample TOB 19-27 has almost no Superparamagnetic grains.

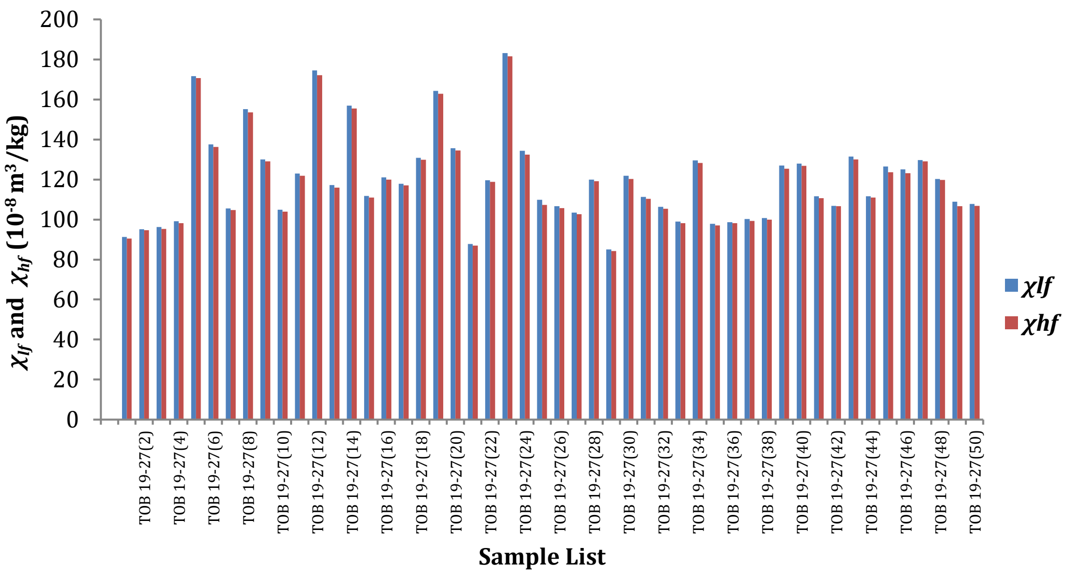

Fig.3: Result of χ_{lf} and χ_{hf} measurements

The results of measurements of magnetic susceptibility to low frequency (χ_{lf}) and high frequency (χ_{hf}) measurements on the Youngest Toba Tuff volcanic rock did not have a significant difference (Fig.3).

The graph of the relationship (χ_{lf}) with χ_{fd} (%) is shown in Fig.4. The figure shows that the value (χ_{lf}) obtained in the sample has almost the same value (Homogeneous).

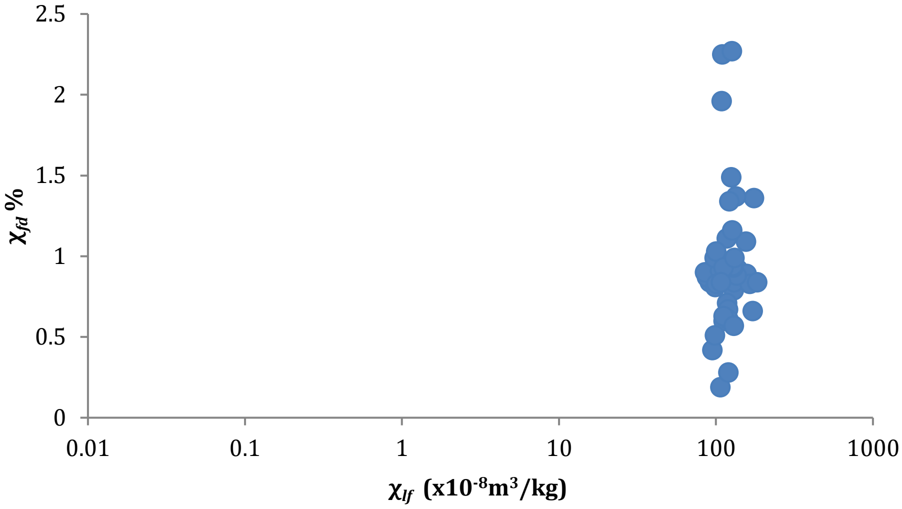

Fig.4: The state of the magnetic grains of volcanic rocks in the Pahae Julu area

Based on Fig.4, a graph of the relationship between χ_{lf} and χ_{fd}% is obtained. For the sample TOB 19-27, it can be seen that the worth of χ_{fd}% ranged between 0.19% - 2.27%. Magnetic grain size greatly affects the magnetic mineral properties [24]. Magnetic grains are the most important in the magnetic domain. This result is in accordance with the theory that declares multidomain magnetic grains (MD). Because it shows the same value of magnetic susceptibility at low frequency and high-frequency measurements. The size of the magnetic granules is often used to determine the origin of magnetic minerals and depositional processes in the past [25].

4. Conclusion

The Youngest Toba Tuff volcanic rock taken as a sample contains magnetic minerals. The results showed that the estimated samples had antiferromagnetic magnetic mineral properties. The frequency-dependent susceptibility value indicates that all the measured sample contains almost no SP grains and has a predominant Multi-domain (MD) grain. These results can be used as characteristics to study the volcanic processes of the Youngest Toba Tuff.

5. Conflict of Interest

The authors declare that they have no conflict of interest.

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