Magnetic Susceptibility of Volcanic Soil on the Surface of Mount Singgalang, Sumatra Barat

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Abstract: Volcanic soil is a part of interest for physical, chemical, and morphology studies of soil derived from volcanic ash, which is known to be fertile and is one of the most productive soils in the world. They are also known to have a high environmental carrying capacity, as evidenced by the dense population in the area around the volcano. The soil contains many minerals, one of which is magnetic minerals. However, there is no document so far that records the value of the magnetic susceptibility of volcanic soil on the surface of Mount Singgalang. This study aims to determine the abundance of magnetic minerals based on their magnetic susceptibility values. To achieve this goal, the rock magnetism method is applied with the Bartington magnetic susceptibility meter type MS2B sensor instrument. Magnetic susceptibility values can be used as initial characteristics to understand past volcanic processes and explain environmental changes. This method is very effective, inexpensive, sensitive, fast, and non-destructive. The results showed that the value of the magnetic susceptibility of volcanic soils varied with a value range of 93.3 - 352.5 ($\times 10^{-8}$m^3/kg). Based on this value, it is assumed that the magnetic mineral properties are antiferromagnetic. The average frequency dependent susceptibility (χ_{fd}) (%) ranges from 0.831 - 2.090 %, indicating that the measured volcanic soil contains almost no superparamagnetic grains and is generally dominated by multi-domain grains.

Keywords: Magnetic susceptibility; Volcanic soil; Mount singgalang; Bartington magnetic susceptibility meter MS2B sensor type.

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I. INTRODUCTION

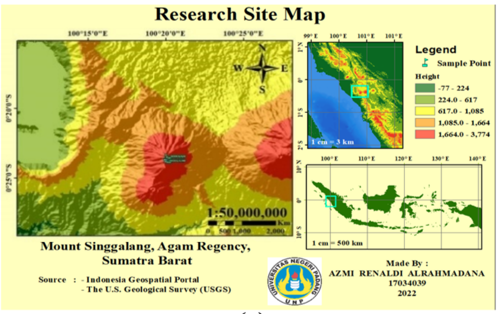
West Sumatra is a province that has quite a lot of volcanoes, including Mount Marapi, Singgalang-Tandikat, Talamau, and many others. The existence of these many volcanoes, indicates that part of the land of West Sumatra was formed from the volcanic ash [1]. Volcanic material such as volcanic ash becomes a source of rock and forms rock structures on the Earth's surface. Volcanic material will be scattered both on land and at sea [2]. The volcanic material consists of coarse and fine grains. Coarse-sized grains (bubbles of gravel) usually fall around the crater up to a radius of 57 km from the crater, and fine-sized grains can fall at a distance of hundreds of km or even thousands of km from the crater caused by wind gusts [3]. Volcanic material that is erupted by this volcano will of course become the parent material that makes up the soil so that volcanic soil is formed [4].

Volcanic soil is soil that comes from volcanic eruptions. Volcanic soil types can be found around the slopes of the volcano. Soils developed from volcanic ash are generally characterized by a high content of allophane [3]. Volcanic soil is young soil formed from weathering of fertile volcanic material and contains high nutrients, characterized by two special properties, namely black and dark brown due to high organic matter content, non-crystalline mineral content, high nutrient content, high groundwater retention, and drainage [5].

The existence of volcanic soil is spread in volcanic areas, one of which is located on Mount Singgalang. Mount Singgalang has a height of 2877 meters above sea level (masl) which is part of the Bukit Barisan mountain range. Several studies on the natural resources of Mount Singgalang that have been carried out are the transformation of halloysite [1], high-level fungal inventories [6], and geochemical fingerprinting of volcanic soils in West Sumatra which are used to determine the origin of volcanic parent material in rice fields [7]. However, studies on the magnetic minerals of the volcanic soil of Mount Singgalang have never been carried out.

Magnetic minerals found in nature actually always exist naturally in rocks, soils or sedimentary deposits, although quantitatively their abundance is quite small, around 0.1% of the total mass of these materials [8]. This magnetic mineral has weak magnetic properties (diamagnetic), medium (paramagnetic), and strong magnetic properties (ferromagnetic) [9]. All of them have different magnetic susceptibility values. The higher the magnetic susceptibility value, the stronger the magnetic properties [10]. These characteristics are needed to know the volcanic processes that occurred in the past.

The magnetic properties of rocks are determined using the rock magnetism method through mineral characteristics such as concentration, type, magnetic domain, grain size, and Curie temperature. This measurement has the advantage of being cheap, fast, does not damage the material, very efficient, and can be carried out in the laboratory or in the field [11]. Measurement of magnetic susceptibility will provide infor-



(a)

(b)

FIG. 1: (a) Research rite map. (b) Sampling point at Mount Singgalang, Agam Regency, West Sumatra Province.

mation about the minerals contained in a material [11]. In this study, magnetic properties were tested by looking at the value of magnetic susceptibility on several volcanic-soil samples on the surface of Mount Singgalang using a Bartington magnetic susceptibility meter MS2B sensor type. From the obtained magnetic-susceptibility value, one can estimate the concentration or abundance of magnetic minerals contained in the soil.

II. METHOD

A. Sampling

The sample used was volcanic soil taken on the surface of Mount Singgalang, Agam Regency, West Sumatra. Sampling was carried out in July 2019. The sample was taken in the form of volcanic soil with coordinates 0^o 23' 28.03" S to 0^o 23' 35.38" S and 100^o 19' 57.22" E to 100^o 21' 10.58" E. The map of research locations and sampling points can be seen in Fig.1.

It can be seen in Fig. 1(a) that the sampling site is very close to the peak of Mount Singgalang. The sampling process begins with determining the location and coordinates of sampling as show in Fig. 1(b), which were taken randomly with 4 sampling points. Samples are taken around the hiking trail using a shovel and put into a plastic sample that is labeled according to the coordinates of the sampling. The naming of the samples was based on the year and numbering of the sampling, namely SG 19-02, SG 19-04, SG 19-06, and SG 19-08. After the sampling process is completed, the samples were stored in a freezer until the preparation was carried out.

(a)

(b)

FIG. 2: (a) Samples that are ready to be measured their susceptibility using Bartington Magnetic Susceptibility Meter MS2B sensor type (in the holder with a diameter of 1 inch). (b) Measurement of the mass of soil samples.

FIG. 3: Bartington Magnetic Susceptibility Meter MS2B sensor type at Geophysics Laboratory, Universitas Negeri Padang.

B. Sample Preparation

At geophysics laboratory of the physics department, faculty of mathematics and natural sciences, Universitas Negeri Padang, the samples were take out of the freezer before the sample preparation process and analysis until the sample reach room temperature to avoid any temperature effect on the measurements. The sample was mashed with a mortar and further put into a holder as well as labeled with the name according to the name of the sample [Fig. 2(a)]. 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 balance (Ohauss SN EO271119030112) that have been firstly calibrated [Fig. 2(b)].

C. Magnetic Susceptibility Measurement

Magnetic susceptibility measurement of volcanic soil on the surface of Mount Singgalang were carried out using Bartington Magnetic Susceptibility Meter MS2B sensor type (Fig. 3).

TABLE I: Magnetic susceptibility value (χ_{lf}, χ_{hf}, and $\%\chi_{fd}$) of volcanic soil on the surface of Mount Singgalang, Sumatra Barat. SG 19 means Singgalang.

Sample name	Subject	Magnetic susceptibility ($\times 10^{-8}$ m^3/kg) Low-field susceptibility (χ_{lf})	Magnetic susceptibility ($\times 10^{-8}$ m^3/kg) High-field susceptibility (χ_{hf})	frequency dependent susceptibility χ_{fd} (%)
SG 19-02	Max	131.9	129.6	2.797
	Min	110.6	107.1	1.326
	Average	120.1	120.1	1.791
	Standard deviation	7.8	8.3	0.677
SG 19-04	Max	458.4	451.7	3.163
	Min	290.1	278.6	1.145
	Average	352.5	345.3	2.090
	Standard deviation	7.0	6.9	0.963
SG 19-06	Max	121.1	120.0	2.014
	Min	79.8	78.3	0.202
	Average	93.3	92.2	1.024
	Standard deviation	17.0	16.2	0.746
SG 19-08	Max	201.7	200.9	2.012
	Min	193.5	190.8	0.252
	Average	199.1	197.4	0.831
	Standard deviation	3.0	3.8	0.805

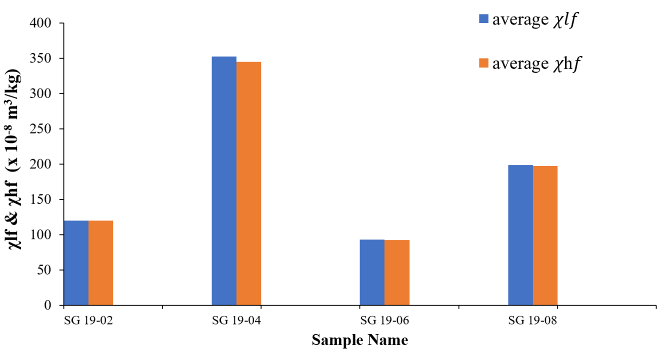


FIG. 4: Plot of low field susceptibility (χ_{lf}) and high field susceptibility (χ_{hf}) of soil samples on the surface Mount Singgalang, Sumatra Barat.

Measurements were made with two frequencies, namely 470 Hz for low field susceptibility (χ_{lf}) and 4.7 KHz for high field susceptibility (χ_{hf}). Measurements were carried out three times in a low field state and three times in a high field state in order to obtain an average magnetic susceptibility value (χ_{average}). The ratio of measurements at both frequencies is recorded as the value of frequency-dependent susceptibility ($\%\chi_{fd}$), which obtained through Eq. 1 [11].

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

III. RESULTS AND DISCUSSION

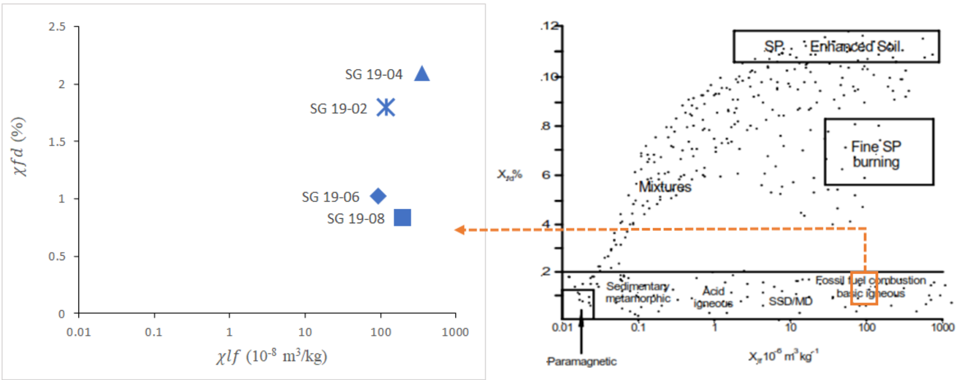
The results of measuring the magnetic susceptibility value of volcanic soil on the surface of Mount Singgalang, West Sumatra, can be seen in Table 1.

Based on Table 1, it can be seen that the magnetic susceptibility values at the 4 sampling points varies, ranging from 79.8×10^{-8} to 458.4×10^{-8} m^3/kg. Plot of the data is shown in Fig. 4.

Based on Fig. 4, the highest mean magnetic susceptibility value of the χ_{lf} was found in the sample SG 19-04 with an average of 352.5×10^{-8} m^3/kg, and the lowest was in the sample SG 19-06 with an average of 93.3×10^{-8} m^3/kg. Meanwhile, the highest average magnetic susceptibility value of the χ_{hf} was found in the sample SG 19-04 with an average of 345.3×10^{-8} m^3/kg, and the lowest was in sample SG 19-06 with an average of 92.2×10^{-8} m^3/kg. The values of χ_{lf} and χ_{hf} obtained are not much different. These results indicate that the sample contains multi-domain (MD) magnetic grains because it shows identical magnetic susceptibility values at low and high frequencies [12].

The magnetic susceptibility of a material is influenced by the type of magnetic mineral and it's concentration contained in material. A high magnetic susceptibility value indicates a low magnetic mineral concentration in the sample. The low magnetic susceptibility value is caused by mixing with organic materials which have diamagnetic features [13, 14]. Meanwhile, a high magnetic susceptibility value indicates the presence of magnetic mineral content in the sample. This is due to the process of mineral transportation by water and wind [15, 16].

Magnetic susceptibility values can determine the magnetic properties and the type of magnetic minerals in the sample. The susceptibility value indicates that the sample SG 19-02 to SG 19-08 are antiferromagnetic according to the concept of Hunt, 1995 [17]. It is suspected that the process of formation of volcanic soil samples on the surface of Mount Singgalang is caused by the temperature difference, so that the initially high magnetic mineral (ferromagnetic) turns into antiferromagnetic which has a small and positive susceptibility value [18].



(a) **(b)**

FIG. 5: (a) Graph of the relationship between χ_{lf} and χ_{fd} (%). (b) Schematic sccategram reported in [11].

Fig. 5 shows the relationship between χ_{lf} and χ_{fd} (%), which is then matched with the Schematic sccategram to show the position of the sample which is dominated by various domains and resources [11].

Based on Fig. 5(a), the interpretation of the superparamagnetic grain content based on the average frequency dependent susceptibility χ_{fd} (%) ranges from 0.831 to 2.090%. The highest χ_{fd} (%) value is found in the SG 19-04 sample and the lowest χ_{fd} (%) value is found in the SG 19-08 sample. The properties of magnetic minerals are strongly influenced by the size of their magnetic grains [19]. By using Sccategram diagram reported by Dearing *et. al*, 1996 [11] shown in Fig.5(b), it can be seen that there are 3 samples that do not contain superparamagnetic grains and 1 sample that has a mixture of sauperparamagnetic grains. It is known from the value of χ_{fd} (%) $< 2\%$ [11] or the sample contains less than 10% superparamagnetic grains and belongs to the type of multi-domain.

IV. CONCLUSION

Volcanic soil on the surface of Mount Singgalang, West Sumatra which was taken as a sample contains magnetic minerals. The results showed that the tested samples have antiferromagnetic magnetic mineral properties with a value of frequency dependent susceptibility χ_{fd} (%) indicating that all the measured samples contained almost no superparamgnetic grains (SP) and were generally dominated by multi-domain (MD) grains. These results can be used as an initial reference to study the volcanic process of Mount Singgalang, West Sumatra.

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