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MAGNETIC SUSCEPTIBILITY OF PUMICE AT MOUNT SINGGALANG, WEST SUMATERA

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Abstract

Volcanic activity produces eruptions that release pyroclastic material at the time of the explosion. Mount Singgalang is a volcano that has experienced an eruption after 1600. Several types of volcanic rocks around the Mount Singgalang area are Basalt, Andesite, Tuff Breccia, Lava Breccia, and Pumice Tuff. Pumice is formed when saturated liquid magma gas bursts like a carbonated beverage and soon cools, causing the froth that results to solidify into a glass full of gas bubbles. Some minerals contained in pumice are obsidian, cristobalite, feldspar, and tridymite. Pumice contains magnetic minerals, namely ilmenite (FeTiO3), and magnetite (Fe3O4). The purpose of this study is to quantify the magnetic susceptibility and quantity of pumice on Mount Singgalang in West Sumatera. When utilizing the Bartington Magnetic Susceptibility Meter to analyze a sample, magnetic susceptibility parameters are utilized to pinpoint the features of a magnetic rock mineral. The value of the magnetic susceptibility of pumice on Mount Singgalang, in West Sumatera has a value that varies between 2763.3 x 10-8m3/kg - 2192.1 x 10-8m3/kg. The results showed that the tested samples had antiferromagnetic magnetic mineral properties with frequency-dependent susceptibility values (χfd), indicating that all of the measured samples contained almost no superparamagnetic (SP) grains and were generally dominated by multi-domain (MD) grains.

Keywords : *Magnetic Susceptibility, Pumice, Mount Singgalang, Bartington Magnetic Susceptibility Meter*

INTRODUCTION

Volcanic activity produces eruptions that release pyroclastic material at the time of the explosion (Sinaga, Sembiring, & Lubis, 2015). This activity has been going on for a long time, as evidenced by the many findings of pyroclastic materials that are widespread both on land and in the ocean. Large-sized pyroclastic materials typically fall in a 2 to 5 km radius surrounding the crater. In contrast, fine people can fall over hundreds of kilometers due to being carried away by wind gusts (Sinaga, Sembiring, & Lubis, 2015).

Mount Singgalang is a volcano that has experienced an eruption after 1600. Geologically, Mount Singgalang is a volcano with Tandikek Mount but has a different crater. Mount Singgalang is a crater in the north, and Tandikek Mount is in the south (PRIBADI, 2006). Where the Pumice, Tuff, and Andesite (Basal) of Mount Singgalang probably came from the Maninjau eruption. There are also rhyolite rocks and Andesite in the western part of the foot of Mount Singgalang.

Several types of volcanic rocks around the Mount Singgalang area are Basalt, Andesite, Tuff Breccia, Lava Breccia, and Pumice Tuff. The result of the eruption of Mount Singgalang consists of a layer of tephra lapilli composed of Andesite and Key Bed tephra deposits composed of pumice (PRIBADI, 2006). The Singgalang Andesite is older than both the Maninjau Caldera and Marapi Mount Andesite (Fiantis et al., 2017). It is necessary to research the abundance of magnetic minerals of pumice in the Mount Singgalang, West Sumatera.

Pumice is formed when saturated liquid magma gas bursts like a carbonated beverage and soon cools, causing the froth that results to solidify into a glass full of gas bubbles. In general, pumice, or material from volcanic eruptions, contains several essential minerals such as Si (silicon), Al (aluminum), Fe (iron), Ca (potassium), Mg (magnesium), N (sodium), and K (potassium). Based on the XRF characterization, the pumice composition of SiO_2 is 58.3%, Al_2O_3 is 12%, K_2O is 7.73%, CaO is 6.75%, TiO_2 is 1.45%, MnO is 0.42%, and Fe_2O_3 as much as 12.4% (Kurniawidi, Alaa, Mulyani, & Rahayu, 2021). Some minerals contained in pumice are obsidian, cristobalite, feldspar, and tridymite (R.L Bownewitz, 2012). Pumice also contains magnetic minerals, namely ilmenite ($FeTiO_3$), and magnetite (Fe_3O_4) (Lomboan et al., 2016).

Magnetic minerals are materials found in nature that contain magnetic minerals. Magnetite (Fe_3O_4), Hematite (αFe_2O_3), and Maghemite (γFe_2O_3) are classified as iron oxide magnetic minerals. Greigite (Fe_3S_4) and Phyrrhotite (Fe_7S_8) are a group of magnetic minerals from the Iron Sulfide family, while Geothite (αFeOOH) belongs to the Iron Hydroxide mineral (Harrison, Dunin-Borkowski, & Putnis, 2002). The rock magnetism method is one of many methods used to determine the quantity of magnetic materials in rocks.

One geophysical technique that gauges variations in the magnetic field is the rock magnetism technique. This method has relatively high accuracy in measurements, and the measurements made are relatively easy, fast in getting results, and affordable (Rifai, Erni, & M. Irvan, 2010). Many studies of rock magnetism from susceptibility parameters have been carried out, such as analyzing rock types on the ground (Vingiani, Scarciglia, Mileti, Donato, & Terribile, 2014), analysis of the distribution pattern of volcanic material (Putra, Rifai, Fadila, Ningsih, & Putra, 2022), species susceptibility analysis from pre-lava and post-caldera (Putra et al., 2022), and Identifying volcanic ash from volcanic eruptions (Devi, Bijaksana, Fajar, & Santoso, 2019)(Santoso, Bijaksana, Kodama, Santoso, & Dahrin, 2017).

Magnetic susceptibility parameters are used to identify the features of a magnetic rock mineral in the sample to be analyzed using the Bartington Magnetic Susceptibility Meter. Magnetic susceptibility is the amount of material magnetized when exposed to a magnetic field, which provides information on the minerals in a substance. The value of magnetic susceptibility is influenced by the quantity of magnetic materials; the more magnetic minerals, the higher the magnetic value. Depending on the amount of magnetic iron oxide compounds present, different minerals have varied magnetic susceptibility ratings.

METHODS

Pumice from Mount Singgalang rock was used as a sample. The sampling location was Mount Singgalang in the West Sumatra district of Agam. On March 14, 2022, sampling was done at a position with the coordinates 0°23’41.0” North Latitude - 100°20’10.3” East Longitude. Figure 1 shows the location of the sampling in this investigation.

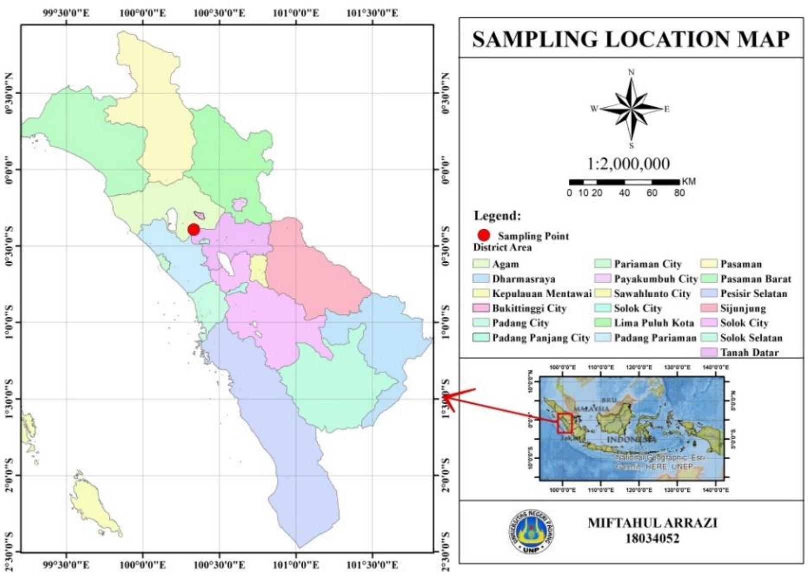

Figure 1. Sampling Location Map

Figure 1 can be seen that the sampling location. Finding the sampling location's coordinates is the first step in the sampling procedure. Using plastic spoons, samples were taken at Cadas (as long as the hiking trail) and put into plastic samples, which were labeled according to the order in which they were gathered. The date and sample number are used to determine the sample's name.

The sample will be prepared by drying, mashing, and then sifting and putting it in a holder. The sample was first cleaned using water to remove impurities. After that, it was dried and crushed using a mortar. Next, calibrate the balance (Ohauss SN EO271119030112) to measure the mass of the empty holder, insert the sample into the holder, label it according to the name of the sample [Figure 2 (a)], and re-measure the mass of the holder containing the sample using a balance (Ohauss SN EO271119030112) [Figure 2(b)].

(a) (b)

Figure 2. (a) The sample that has been prepared and (b) Weigh the mass of the sample to be measured.

The magnetic susceptibility of the prepared sample will be measured using the rock magnetism method at the Geophysics Laboratory, Department of Physics, FMIPA, Universitas Negeri Padang. A geophysical technique called the Rock Magnetism Method examines a rock's magnetic characteristics. The magnetic properties of rocks have a negative and weak sensitivity to diamagnetic fields. Paramagnetic magnetic susceptibility (χ) is small and positive ($\chi \approx 10^{-3}$ until 10^{5}). Paramagnetic magnetic susceptibility (χ) depends on temperature (Butler, 1992) and a low induced field, so at a certain temperature and in a low magnetic field (JILES, 2016). Ferromagnetic materials are well magnetized, so ferromagnetic materials are very strong. Ferromagnetic materials have a magnetic susceptibility value (χ)

positive and large ($\chi \approx 50$ until 10^4). However, despite having parallel and anti-parallel sub-domains, antiferromagnetic materials have a magnetic moment equivalent to that of a magnetization that exists spontaneously at zero (Mather, 1986). Ferrimagnetic materials furthermore have a susceptibility value that is higher than ferromagnetic materials but lower.

The kind of susceptibility is one of the variables that can be employed with the rock magnetism approach. The magnetization of a material's qualities is described by the measurement parameter known as magnetic susceptibility (R. S. Salomo, 2018). The magnetic susceptibility of a mineral is used to determine how susceptible it is to an external magnetic field (H). Magnetization is the conversion of a magnetic moment to the direction of an applied external magnetic field (M) (Ulfa, 2019).

The value of magnetic susceptibility can be shown by the equation:

$$(\vec{M}) = \chi\ (\vec{H}) \qquad (1)$$

Where $(\vec{M})$ is the magnetic intensity in A/m, is the susceptibility value of a material with no dimensions, and $(\vec{H})$ is the magnetic field strength in A/m. Value χ is the basic parameter used in the magnetic method (Telford, Geldart, & Sheriff, 1990). A Bartington Magnetic Susceptibility Meter with a type B sensor (MS2B), depicted in Figure 3, can be used to detect the magnetic susceptibility value of pumice in the Cadas of Mount Singgalang, West Sumatera.

Figure 3. Bartington Magnetic Susceptibility Meter with Sensor Type B (MS2B) in Physics Laboratory, FMIPA, Universitas Negeri Padang.

In Figure 3, researchers can calculate the pumice's magnetic susceptibility in Cadas of Mount Singgalang. A quick, easy, and non-destructive technique called magnetic susceptibility assessment can be used to test nearly anything, including soil for heavy metal contamination. Utilizing a susceptibility meter, one can ascertain magnetic susceptibility.

The Bartington Magnetic Susceptibility Meter sensor type B is one of the most popular susceptibility meters. Magnetic susceptibility measurements can be carried out at two frequencies, namely low frequency (470 Hz) and high frequency (4,7 KHz). The outcomes of magnetic susceptibility investigations at two frequencies can be used as information regarding the presence of superparamagnetic grains due to the characteristics of superparamagnetic grains, which are sensitive to variations in frequency. The difference in magnetic susceptibility at frequency is known as the parameter frequency-dependent susceptibility χ_{fd}%. χ_{fd}% can be represented as magnetic susceptibility per unit mass χ_{fd}%. To find out the value χ_{fd}% can be seen in the following equation:

$$\chi_{fd}(\%) = \frac{\chi_{lf} - \chi_{hf}}{\chi_{lf}} \times 100\% \qquad (2)$$

With χ_{lf} and χ_{hf} are the unit mass susceptibility at low and high frequencies, respectively (Dearing, 1999). χ_{fd} shows the presence or absence of superparamagnetic grains in a material, can be seen in **Table 1**

Table 1. Interpretation of Values χ_{fd}

χ_{fd}	Percentage	Information
Low χ_{fd}%	< 2%	Absent or contains less than 10% superparamgenic grains
Medium χ_{fd}%	2 – 10%	Contains superparamagnetic grains between 10%-75% which is a mixture of fine and coarse SP grains
High χ_{fd}%	10 – 14%	Whole or contain more than 75% superparamagnetic grains
Very high χ_{fd}%	> 14%	Incorrect measurement, anisotropy, weak or contaminated samples

(Dearing, 1999).

Table 1 shows four divisions, each categorized into low, medium, high, and very high levels. The value of frequency-dependent susceptibility with a percentage below two percent where there are no superparamagnetic grains. Superparamagnetic granules are magnetic nanoparticles contained in a ferrimagnetic or ferromagnetic environment. Score χ_{fd} % the highest is with a large percentage of 14%.

RESULTS

Magnetic susceptibility values were measured using a Bartington Magnetic Susceptibility Meter type B (MS2B) at the Geophysics Laboratory, Department of Physics, FMIPA, Universitas Negeri Padang. The sample used is pumice from the rock of Mount Singgalang, which was taken on March 14, 2022.

Measurement results of magnetic susceptibility values in low field susceptibility (χ_{hf}) and high field susceptibility (χ_{hf}) where all samples of χ_{lf} value are always greater than χ_{hf} value. This is due to the superparamagnetic grains contained in the sample. The superparamagnetic grains in the χ_{hf} measurement are less likely to interact with external specific fields because in the χ_{hf} type measurement, the external field change is faster than the relaxation time required for superparamagnetic grains. Therefore, the susceptibility value at higher frequency measurements has a lower value than lower frequency measurements. Furthermore, the susceptibility value of the measure at low-frequency χ_{lf} will always be used because this measurement represents the susceptibility value of the sample more than the high-frequency measurement χ_{hf}. The results of the measurement of the magnetic susceptibility value of pumice in the Cadas of Mount Singgalang of West Sumatera can be seen in Table 2.

Table 2. Magnetic susceptibility values (χ_{lf}, χ_{hf}, and χ_{fd}) of pumice at Cadas of Mount Singgalang, West Sumatera.

No.	**Sample Name**	**Magnetic Susceptibility ($10^{-8}m^3/kg$)**		**χ_{FD} (%)**
		Low Field (χ_{lf})	**High Field (χ_{hf})**	
1	AGAM-20220314-01	2350,9	2307	1,87
2	AGAM-20220314-02	2337,4	2306	1,34
3	AGAM-20220314-03	2485,6	2447,1	1,55
4	AGAM-20220314-04	2376,7	2342,3	1,45
5	AGAM-20220314-05	2526	2485	1,62
6	AGAM-20220314-06	2325,1	2288,5	1,57

No.	Sample Name	Magnetic Susceptibility ($10^{-8}m^3/kg$)		χ_{FD} (%)
		Low Field (χ_{lf})	High Field (χ_{hf})	
7	AGAM-20220314-07	2599,7	2550,5	1,89
8	AGAM-20220314-08	2448,3	2380,5	2,77
9	AGAM-20220314-09	2470,3	2429,1	1,67
10	AGAM-20220314-10	2220,9	2191	1,35
11	AGAM-20220314-11	2192,1	2166,1	1,19
12	AGAM-20220314-12	2250,2	2226,9	1,04
13	AGAM-20220314-13	2337,6	2301,5	1,55
14	AGAM-20220314-14	2451,4	2414,4	1,51
15	AGAM-20220314-15	2763,3	2702,2	2,21

DISCUSSION

Based on Table 1, it can be seen that the magnetic susceptibility values in 15 samples varied, ranging from 2763.3 x $10^{-8}m^3/kg$ to 2192.1 x $10^{-8}m^3/kg$. The data plot is shown in Figure 4.

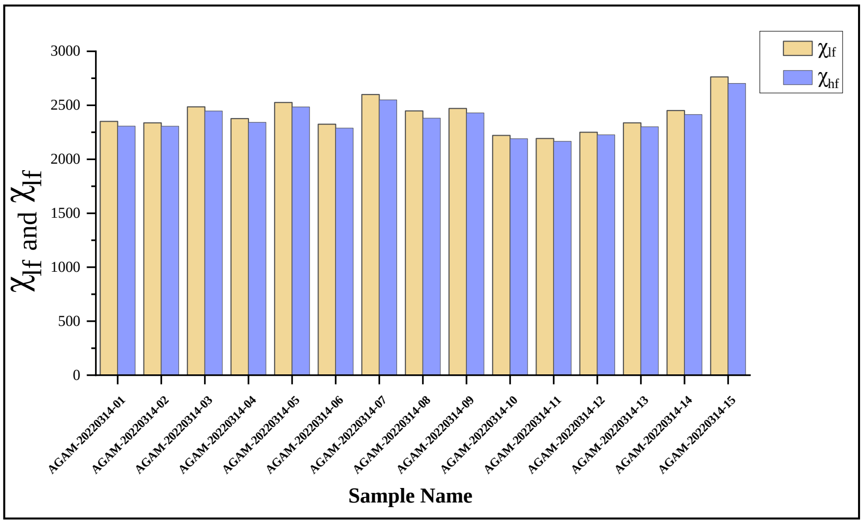

Figure 4. Plot of low field susceptibility (χ_{lf}) and high field susceptibility (χ_{hf}) of pumice in the Cadas of Mount Singgalang, West Sumatera.

Based on Figure 4, it can be seen that the value of magnetic susceptibility in the low field susceptibility (χ_{lf}) of pumice in Mount Singgalang is the largest in the sample AGAM-20220314-15 with a value of 2763.3 x $10^{-8}m^3/kg$, and the smallest is found in the sample

AGAM-20220314-11 with a value of 2192.1 x $10^{-8}m^3/kg$. While the weight of magnetic susceptibility in the high field susceptibility (χ_{hf}) of pumice in the Gunung Singgalang Rock is the largest in the sample AGAM-20220314-15 with a value of 2702.2 x $10^{-8}m^3/kg$, and the smallest is found in the sample AGAM-20220314-11 with a value of 2166.1 x $10^{-8}m^3/kg$. Based on the measurement results of the magnetic susceptibility value, it can be seen the average and standard deviation value of pumice in Mount Singgalang is shown in Table 3.

Table 3. Average and standard deviation value of pumice in Mount Singgalang, West Sumatera.

Sample Name	Subjec	Magnetic Susceptibility (x 10^{-8} m^3/kg)		Frequency Dependent Susceptibility (χ_{fd}) (%)
		Low field (χ_{lf})	High field (χ_{hf})	
AGAM-20220314	Max	2763,3	2702,2	2,77
	Min	2192,1	2166,1	1,04
	Average	2409,0	2369,2	1,64
	Standard deviation	150,7	141,9	0,43

Based on Table 3, it can be seen that the average value of magnetic susceptibility (χ_{lf}, χ_{hf}, and χ_{fd}) on pumice in Mount Singgalang is 2409.0 x $10^{-8}m^3/kg$; 2369.2 x $10^{-8}m^3/kg$; 1.64%. The value of the standard deviation of magnetic susceptibility values (χ_{lf}, χ_{hf}, and χ_{fd}) on pumice in the Mount Singgalang is 150.7 x $10^{-8}m^3/kg$; 141.9 x $10^{-8}m^3/kg$; 0.43%. According to statistics, more samples are used to yield better results. As a result, there is a high probability that the obtained mean and standard deviation will be similar to the population. The standard deviation is a measure of how broad the data is in the sample and how close it is to the mean value.

Magnetic susceptibility measurements revealed variations in the concentration of magnetic mineral material in each sample. A sample with a high magnetic susceptibility value has a high concentration of magnetic minerals, while one with a low value has a low concentration of magnetic minerals. The process of transporting minerals by water and wind is what causes the high value of magnetic susceptibility (Pratiwi et al., 2016)(F. M. Nilam, Sari, 2013). In contrast, the low value of magnetic susceptibility is caused by the presence of diamagnetic materials mixed and precipitated in an organic material (Fajri et al., 2019).

By grouping the magnetic susceptibility values obtained based on the table of magnetic properties of different minerals, it is possible to calculate the magnetic characteristics of pumice using the value of magnetic susceptibility (χ) (Hunt, Moskowitz, & Banerjee, 1995). The results of the magnetic susceptibility value demonstrate that Antiferromagnetic is the predominant magnetic property on pumice in Mount Singgalang. The relationship between low field susceptibility (χ_{lf}) and frequency-dependent susceptibility (χ_{fd} %) on pumice in Mount Singgalang can be seen in Figure 5.

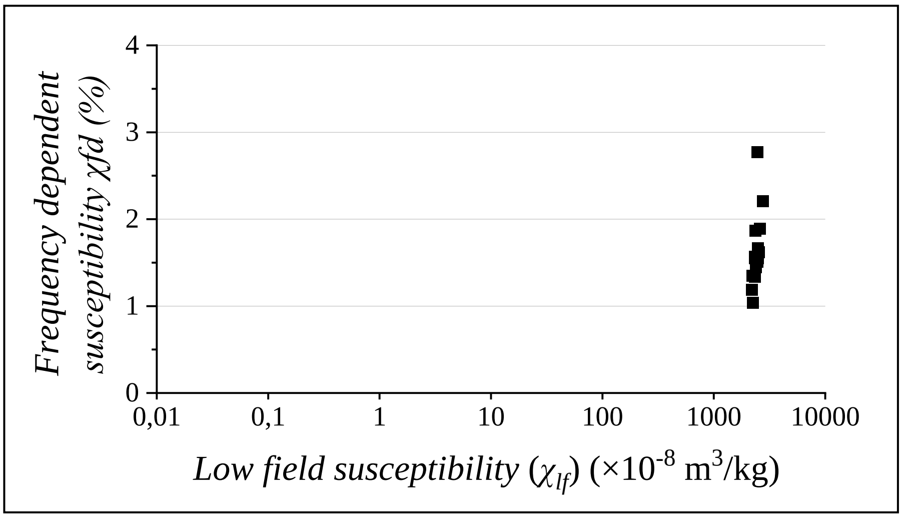

Figure 5. The relationship between Low field susceptibility (χ_{lf}) and Frequency Dependent Susceptibility

Based on Figure 5, the interpretation of superparamagnetic grain content based on frequency-dependent susceptibility (χ_{fd} %) ranges from (1.04 - 2.77) %. The highest value (χ_{fd} %) was found in sample AGAM-20220314-08, and the lowest value (χ_{fd} %) was found in sample AGAM-20220314-12. The properties of magnetic minerals are strongly influenced by the size of their magnetic grains. It can be seen that 13 samples do not contain superparamagnetic grains, and 2 sample has a mixture of superparamagnetic grains. It is known from the value of χ_{fd} (%) on pumice in Mount Singgalang that it is dominant < 2 % of the sample, has almost no superparamagnetic grains, and is included in the multidomain type (Dearing, 1999).

CONCLUSION

The value of the magnetic susceptibility of pumice at Cadas of Mount Singgalang, West Sumatera has a value that varies between 2763.3 x $10^{-8}m^3/kg$ - 2192.1 x $10^{-8}m^3/kg$. The results showed that the tested samples had antiferromagnetic magnetic mineral properties with frequency-dependent susceptibility values χ_{fd} (%), indicating that all of the measured samples contained almost no superparamagnetic (SP) grains and were generally dominated by multi-domain (MD) grains. These results can be used as an initial reference to study volcanic processes at Mount Singgalang, Sumatera Barat.

REFERENCES

Butler, R. F. (1992). Paleomagnetism: magnetic domains to geologic terranes. *Paleomagnetism: Magnetic Domains to Geologic Terranes*, (September). https://doi.org/10.5860/choice.29-5708

Dearing, J. A. (1999). *Enviromental Magnetic Susceptibility Using the Bartington MS2 System*.

Devi, S., Bijaksana, S., Fajar, S. J., & Santoso, N. A. (2019). Characterization of Volcanic Ash from the 2017 Agung Eruption, Bali, Indonesia. *IOP Conference Series: Earth and Environmental Science*, *318*(1). https://doi.org/10.1088/1755-1315/318/1/012014

F. M. Nilam, Sari, H. R. (2013). Penentuan Ukuran dan Jenis Bulir Domain Magnetik Guano dari Gua Rantai dan Gua Solek di Kecamatan Lareh Sago Halaban Kabupaten 50 Kota dengan Metode Anhysteretic Remanent Magnetization (ARM). *Pillar Phys*, *2*.

Fajri, R. N., Putra, R., De Maisonneuve, C. B., Fauzi, A., Yohandri, & Rifai, H. (2019). Analysis of magnetic properties rocks and soils around the Danau Diatas, West Sumatra. *Journal of Physics: Conference Series*, *1185*(1). https://doi.org/10.1088/1742-6596/1185/1/012024

Fiantis, D., Gusnidar, Malone, B., Pallasser, R., Van Ranst, E., & Minasny, B. (2017). Geochemical fingerprinting of volcanic soils used for wetland rice in West Sumatra, Indonesia. *Geoderma Regional*, *10*, 48–63. https://doi.org/10.1016/j.geodrs.2017.04.004

Harrison, R. J., Dunin-Borkowski, R. E., & Putnis, A. (2002). Direct imaging of nanoscale magnetic interactions in minerals. *Proceedings of the National Academy of Sciences of the United States of America*, *99*(26), 16556–16561. https://doi.org/10.1073/pnas.262514499

Hunt, C. P., Moskowitz, B. M., & Banerjee, S. K. (1995). Magnetic Properties of Rocks and Minerals: A Handbook of Physical Constants. *Rock Physics & Phase Relations*, *3*, 189−204.

JILES, D. (2016). Magnetism & Magnetic Materials. In *Nature* (Vol. 328).

Kurniawidi, D. W., Alaa, S., Mulyani, S., & Rahayu, S. (2021). SINTESIS ZEOLIT DARI BATU APUNG (PUMICE) DAERAH IJOBALIT LOMBOK TIMUR SEBAGAI ADSORBEN LOGAM Fe. *ORBITA: Jurnal Kajian, Inovasi Dan Aplikasi Pendidikan Fisika*, *7*(2), 313. https://doi.org/10.31764/orbita.v7i2.6010

Lomboan, F. O., Kumaat, E. J., Windah, R. S., Teknik, F., Sipil, J., Sam, U., … Belakang, L. (2016). *Abu Sekam Padi Universitas Sam Ratulangi*. *4*(4), 271–278.

Mather, P. M. (1986). *Department of Geography, McMaster University, Hamilton, Ontario, Canada*. 94–95.

Pratiwi, R. A., Prakoso, A. G., Darmasetiawan, R., Agustine, E., Kirana, K. H., & Fitriani, D. (2016). *Identifikasi Sifat Magnetik Tanah Di Daerah Tanah Longsor*. *V*, SNF2016-EPA-7-SNF2016-EPA-10. https://doi.org/10.21009/0305020402

PRIBADI, A. (2006). Mekanisme erupsi ignimbrit Kaldera Maninjau, Sumatera Barat. *Indonesian Journal on Geoscience*, *2*(1), 31–41. https://doi.org/10.17014/ijog.vol2no1.20073

Putra, S., Rifai, H., Fadila, R., Ningsih, E. D., & Putra, R. (2022). Distribution of Pyroclastic Deposits around Lake Maninjau Agam District, West Sumatera, Indonesia based on Magnetic Susceptibility. *Trends in Sciences*, *19*(7). https://doi.org/10.48048/TIS.2022.3218

R. S. Salomo, S. A. P. (2018). Studi Sifat Magnetik dan Ukuran Partikel Abu Vulkanik Erupsi Gunung Sinabung Kabupaten Karo Menggunakan Probe Pasco 2162. *Komun. Fis. Indones*, *15*.

Rifai, H., Erni, & M. Irvan. (2010). Ekstraksi Magnetik pada Methanol-Soap Bathed Muds. *Jurnal Penelitian Sains*, *14*, 25–28.

R.L Bownewitz. (2012). *Nature Guide Rocks and Mineral*.

Santoso, N. A., Bijaksana, S., Kodama, K., Santoso, D., & Dahrin, D. (2017). Multimethod approach to the study of recent volcanic ashes from tengger volcanic complex, eastern java, Indonesia. *Geosciences (Switzerland)*, *7*(3). https://doi.org/10.3390/geosciences7030063

Sinaga, B., Sembiring, M., & Lubis, A. (2015). Dampak Ketebalan ABu Vulkanik Erupsi Gunung Sinabung terhadap SSifat Biologi Tanah di Kecamatan Naman Teran Kabupaten Karo. *Jurnal Online Agroekoteknologi*, *3*(3), 1159–1163.

Telford, W. M., Geldart, L. P., & Sheriff, R. E. (1990). *W. M. Telford, L. P. Geldart, R. E. Sheriff Applied Geophysics 1990.pdf* (pp. 535–537). pp. 535–537.

Ulfa, Y. S. dan A. B. (2019). Analisis Suseptibilitas Magnetik Tanah Pada Lahan Perkebunan Kopi Di Kabupaten Solok. *Jurnal Fisika Unand*, *8*.

Vingiani, S., Scarciglia, F., Mileti, F. A., Donato, P., & Terribile, F. (2014). Occurrence and origin of soils with andic properties in Calabria (southern Italy). *Geoderma*, *232–234*, 500–516. https://doi.org/10.1016/j.geoderma.2014.06.001