Distribution of Pyroclastic Deposits around Lake Maninjau Agam District, West Sumatera, Indonesia based on Magnetic Susceptibility

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Abstract

Lake Maninjau is an erupting volcano in West Sumatra Province. The results of the eruption have now settled in various places and scattered in all directions due to the transportation process. The process of transporting volcanic material is caused by several factors such as wind and rain. This study aims to analyze the distribution pattern of volcanic material that is scattered around Lake Maninjau, Agam Regency. We have 25 types of samples divided into 3 categories. There are pumice, lava, and ash. This research was conducted at the FMIPA UNP Laboratory using the rock magnetization method. In this study, a Bartington MS2 with MS2B sensor was used by calculating the magnetic susceptibility value based on the mass of the sample. The results of the magnetic susceptibility analysis obtained varied between 74.7×10^{-8} - 3956.7×10^{-8} m^3/kg which is included in the ilmenite (FeTiO$_3$) group. The highest value of vulnerability was 2800×10^{-8} - 4000×10^{-8} m^3/kg found at the core of Lake Maninjau $\pm$ 5.0 km seen from the green contour map. The lowest magnetic susceptibility values 0 - 800×10^{-8} m^3/kg were found in the western part of Lake Maninjau and the material was deposited at a distance of $\pm$ 13 km from the core of the Maninjau caldera. Deposits were also found in the eastern part of Lake Maninjau $\pm$ 22.4 km from the core of Lake Maninjau and to the Middle East $\pm$ 23 miles from the core of the Maninjau caldera. The white color represents 1600 - 2000×10^{-8} m^3/kg which is included in the moderate magnetic susceptibility value, which is $\pm$ 4 km to the southeast of the Maninjau caldera. The benefit that can be taken from this research in the ink industry is the presence of a magnetic mineral distribution map based on suseptibility values and makes it easier to find raw materials for making ink around Lake Maninjau.

Keywords: Lake Maninjau, Magnetic susceptibility, Pyroclastic deposit, Contour maps, Magnetic mineral

Introduction

Lake Maninjau is a volcanic lake created from an ancient volcanic eruption which is estimated to have occurred $\pm$ 50,000 years ago. Volcanic lakes which were formed from the collapse of the caldera and explosive eruptions which caused the formation of a large amount of material transfer in the eruption core. [1]. In a long period of time, the caldera collapse was filled with water from springs, rivers, groundwater and rainwater. The eruption of Mount Maninjau created pyroclastic deposits along 220 - 250 km^3 which spread up to 75 km from the core of the eruption. [2] The material released by the volcano is in the form of volcanic ash, lava, pumice. Over a long period of time, the caldera collapsed filled with water from springs, streams, groundwater and rainwater, thus forming what is today called Lake Maninjau.

Lake Maninjau stores various elements contained in the released material. The elements that make up magnetic minerals are Fe, Si, Ca, Al, K, Ti [3]. The collection of several elements forms the raw magnetic mineral. Raw magnetic minerals are useful in industry and engineering. These minerals include Magnetite•(Fe$_3$O$_4$), Hematite•(α-Fe$_2$O$_3$) and Maghemite•(γ-Fe$_2$O$_3$). Black magnetite is widely used as a copier for dry ink (toner) toner and laser printers [4]   Red hematite is often used as a coloring agent. Maghemite is widely used in the biomedical field [5], magnetic recording medium [6], particle nanotechnology namely in hyperemia [7] eliminating heavy metals in [8] So the raw magnetic minerals se have a very profound impact on life. However, the minerals were not well identified. So that the potential cannot be utilized optimally.

This potential can be maximized by utilizing the Geophysical field of study, namely rock magnets. The Earth's surface magnetic field is a measure of the intensity in the study of magnetism. The magnetic

properties of the rock can be determined using the magnetic method. Magnetic properties are divided into 3 types, weak (Diamagnetic), medium (Paramagnetic), and hard (Ferromagnetic). Ferromagnetics is generally classified into transition metals (ferrite), cobalt, nickel and some earth metals such as Gadolinium (Gd) [9]. Ferromagnetic materials have characteristics capable of recording ancient magnets [10]. The process of measuring magnetic properties uses different instruments. Determination of the type of magnetic minerals using isormal remanent magnetization measurement technique, grain size determination using anhysteretic remanent magnetization measurement technique. The process of determining the value of magnetic susceptibility or the susceptibility of a material is influenced by an external magnetic field using a sensitivity meter [10].

Determination of magnetic susceptibility was carried out [11] The results showed that the magnetic minerals from the site were Maghemite and Ilminite. The value of the susceptibility obtained ranged from 967.8×10^{-8} - 2187.0×10^{-8} m^3/kg. The success of the magnet can be the determination of the igneous rock that is carried out [12] susceptibility is very influential due to wear changes, whereas at low magnets it is difficult to be affected by the wear of the surrounding environment. The magnetic sensibility values obtained ranged from 15×10^{-5} - 2330×10^{-5} m^3/kg. Measurement of magnetic susceptibility in volcano magnetism studies of the igneous arm rock magnetic anisotropy system [13]. The result is 29×10^{-6} - 3506×10^{-6} SI, medieval value is 684×10^{-6} SI indicating that magnetic susceptibility within case study area is influenced by paramagnetic minerals.

Materials and methods

Methods

To see the distribution of pyroclastic deposits using a magnetic susceptibility value, the first step is to find the field to take the sample (**Figure 1**) then determine the magnetic susceptibility value of the sample. The instrument used is a magnetic susceptibility meter that works on the duel frequency sensor (470 - 4700 Hz). This instrument can measure magnetic susceptibility 1×10^{-6} to 9999×10^{-6} in cgs (m^3/g) units or 1.26×10^{-5} to 1.26×10^{-1} in SI units (m^3/kg). Measurements can be made based on the unity of mass (specific mass) and volume. The measurement process is carried out in the geophysical laboratory of the State University of Padang. The next step is to plot these values into a map created using a surfer application so that a contour map is obtained. It is from this contour map that the pyroclastic sediment distribution map can be seen. Map is an image of the Earth projected on a flat plane and is equipped with a scale.
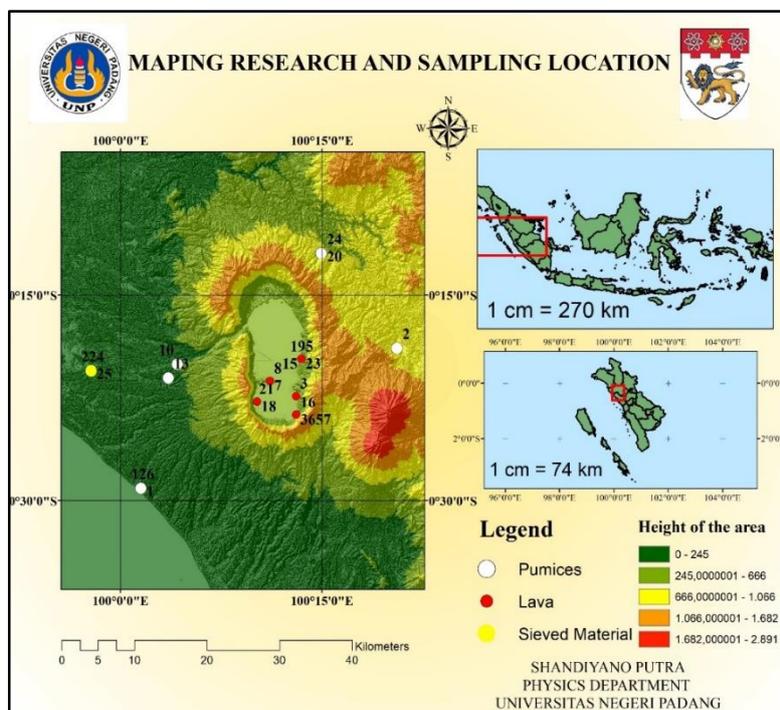

Figure 1 Sampling location is around Lake Maninjau Agam Regency.

Material

The sampling process was carried out by the Sumatepra Team and took 25 samples (**Figure 1**). The green circles represent pumices while the red circles represent lava and the black circles represent ash (**Figure 1**). Sampling for outscaps is available along the road between Lubuk Basung and near the Maninjau caldera. Sampling was carried out by using a hammer to break the hard rock and a hand hoe to take samples of the eruption ash which was stored in the outing. Ash is gray to brown in color and is less than 16 mm in size. Pyroclastic sediment samples were taken around Lake Manlnjau with coordinates −0.34S - 99.959E; −0.177S - 100.299E; −0.308S - 100.361E; −0.495S - 100.472E. The data recorded during the sampling process are elevation angle, coordinates, time and local geological appearance. After sampling, the next step is to refine the samples that have been taken in the field and brought to the laboratory until the table is in fine grains that can be inserted into the holder (**Figure 2**).

Figure 2 A well-purified sample was put in a container. The holder has a mass 2.24 g then the sample is filled with the prepared sample and the sample is ready to be measured.

Results and discussion

The process of measuring the value of magnetic susceptibility at the Geophysical Laboratory of the State University of Padang uses the Bartington instrument with an MS2B sensor. There are 25 points scattered around Lake Maninjau. Research locations around Lake Maninjau ± 36 km to the Middle East, West ± 17 km, North ± 14 km, East ± 37 km (**Table 1**).

Retrieval on 25 pyroclastic sediment samples. Where magnetic sensibility value obtained varies in 74.7×10^{-8} - 3956.7×10^{-8} m^3/kg. Types of minerals contained in the volcanic material produced from pyroclastic deposits is Ilmenite, according to research that has been carried out accordingly [11]. The sample with the greatest susceptibility value lies in the coordinates S 00.37297° E 100.21796° which is a type of lava sample that has frozen due to extremely extreme temperatures. the temperature difference between the crater and the environment outside the Maninjau caldera. The lowest susceptibility value is at the coordinate S 00.33407° E 100.07035° which is a type of pumice stone sample. Pumicess is an igneous rock type. pumice stone comes from volcanic eruptions. This shows that the volcanic material samples vary. This is due to differences in mineral content in volcanic materials. The value of magnetic susceptibility contained in a material depends on the elements ti and fe. The high levels of Fe and Ti contained in a material cause the susceptibility value to be high. The low levels of Fe and Ti in a material cause the magnetic susceptibility value contained to be lower. The low value of magnetic susceptibility is caused by wear and tear processes mixed with diamagnetic organic matter [12,13]. Meanwhile, high susceptibility value leads to absence of magnetic mineral content in sample process of transporting minerals [14-16].

Of all the samples taken measurements, it appears that volcanic material has weak magnetic properties, is positive and changes easily with temperature. Volcanic material contains the mineral ilmenite which in theory can be used as a raw material for making TiO_2 pigments, ferrous metals and chemical compounds containing iron. In the industrial field TiO_2 is widely used as a paint pigment, additives in the paper-making process, ceramic raw materials, pharmaceutical industry raw materials and TiO_2 is also widely used for photoclinic materials, namely as a catalyst that can decompose organic dyes with the help of ultra purple light. The magnetic sesibility is based on the mass range from 46×10^{-8} - $80,000\times10^{-8}$ m^3/kg

[17]. **Table 1** that value of magnetic susceptibility based on mass ranges from 74.7×10^{-8} - 3956.7×10^{-8} m^3/kg. *Ilmenite* is spread out in rocks and sand most ilmenite minerals are produced by volcanic eruptions.

Table 1 Magnetic susceptibility value of volcanic rocks.

| No	Sample name	Sample type	Coordinate	Magnetic susceptibility ($\times 10^{-8}$ m^3/Kg)		Magnetic properties	Type of minerals	Reference
				Low frequency (χ_{lf})	Hight frequency (χ_{hf})			
1.	MT 1	Pumice	S 00.48526^O E 100.02522^O	2205.2	2091.2		Ilmenite	
2.	MT 2	Pumice	S 00.31459^O E 100.34266^O	485.4	477.0		Ilmenite, Hematite	
3.	MT 3	Lava	S 00.37297^O E 100.21796^O	2494.2	2423.0		Ilmenite	
4.	MT 4	Ash	S 00.34213^O E 099.96360^O	2494.2	2423.0		Ilmenite	
5.	MT 5	Lava	S 00.32751^O E 100.22455^O	2187.0	2184.0		Ilmenite	
6.	MT 6	Pumice	S 00.48526^O E 100.02522^O	192.6	191.0		Ilmenite, Hematite, Goethite	
7.	MT 7	Lava	S 00.35429^O E 100.18564^O	1545.7	1545.7		Ilmenite	
8.	MT 8	Lava	S 00.35429^O E 100.18564^O	1730.9	1735.1		Ilmenite	
9.	MT 9	Pumice	S 00.49368^O E 100.47221^O	192.9	190.7		Ilmenite, Hematite, Goethite	
10.	MT 10	Pumice	S 00.33407^O E 100.07035^O	74.7	72.6		Ilmenite, Hematite, Goethite pyrite	
11.	MT 11	Lava	S 00.32751^O E 100.22455^O	2243.0	2234.0		Ilmenite	
12.	MT 12	Pumice	S 00.48526^O E 100.02522^O	2816.8	2788.1		Ilmenite	
13.	MT 13	Pumice	S 00.35102^O E 100.05923^O	134.6	133.6	Antiferromagnetic	Ilmenite, Hematite, Goethite,	[11]
14.	MT 14	Lava	S 00.39510^O E 100.21835^O	3657.2	3572.8		Ilmenite	
15.	MT 15	Lava	S 00.32751^O E 100.22455^O	1875.8	1866.8		Ilmenite	
16.	MT 16	Lava	S 00.39566^O E 100.21791^O	360.2	360.2		Ilmenite, Hematite,	
17.	MT 17	Pumice	S 00.49368^O E 100.47221^O	739.3	729.7		Ilmenite, Hematite,	
18.	MT 18	Ash	S 00.37957^O E 100.16950^O	231.3	229.8		Ilmenite, Hematite, Goethite,	
19.	MT 19	Lava	S 00.32751^O E 100.22455^O	975.4	967.8		Ilmenite	
20.	MT 20	Pumice	S 00.19927^O E 100.24882^O	1390.8	1391.5		Ilmenite	
21.	MT 21	Lava	S 00.37957^O E 100.16950^O	1887.4	1888.4		Ilmenite	
22.	MT 22	Ash	S 00.34213^O E 099.96360^O	1673.4	1629.3		Ilmenite	
23.	MT 23	Lava	S 00.32751^O E 100.22455^O	232.8	236.7		Ilmenite, Hematite, Goethite,	
24.	MT 24	Pumice	S 00.19927^O E 100.24882^O	1834.7	1788.0		Ilmenite	
25.	MT 25	Ash	S 00.34213^O E 099.96360^O	210.4	206.1		Ilmenite, Hematite, Goethite,	

Note: MT = Maninjau Tephra
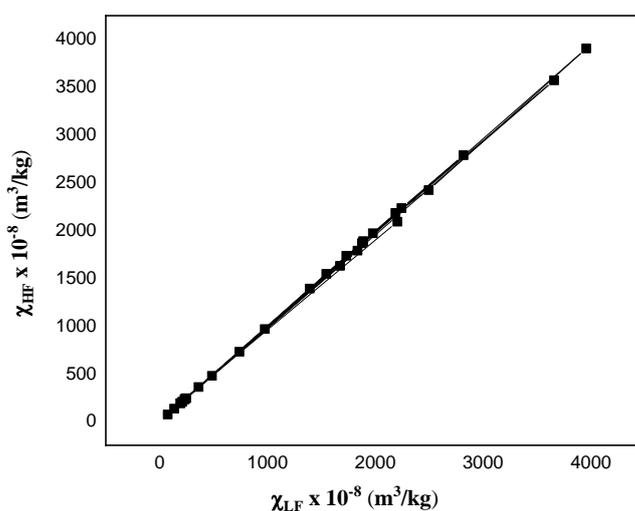
Figure 3 Relationship between low frequency magnetic susceptibility and high frequency susceptibility.

Superparamagnetic grains that use high frequencies are unlikely to react with magnetic fields, because when the relaxation changes occur, a faster change is required for superparamagnetic grains. Consequently, at higher frequencies, lower magnetic sensibility values are found. This difference is used to estimate the superparamagnetic ferrimagnetic particles. When superparamagnetic minerals are present in volcanic rock

samples resulting from an eruption, the magnetic sensibility values at high frequencies are slightly lower than the magnetic susceptibility values at low frequencies. If there are no superparamagnetic minerals (SP), the 2 measurements are identical. The plot results between low frequency and high frequency vulnerability are boldly seen in **Figure 3**.

In **Figure 3**, it can be seen that the magnetic susceptibility value depends on low frequency. It appears that the value of magnetic susceptibility at high and low frequencies is an insignificant difference. Based on the research results, it is known that Multi-Domain magnetic grains (MD) have the same magnetic susceptibility value [18] the value between high and low frequency susceptibility can be said to be identical. That is, volcanic rock resulting from volcanic eruptions is almost non-superparamagnetic [19]. Measurements using high frequency cannot detect the inside of the material due to low translucency [20]. A possible reason for this value is the anisotropy process due to misplacement of the sample when a shift in the measured measurement or the direction of the seat material has shifted from its original state. This shift can cause inconsistent magnetic susceptibility values, causing high frequency values to be higher than low frequencies. Magnetic susceptibility values are plotted and produces a contour map showing the distribution of volcanic material. Can be seen in **Figures 4(a)** and **4(b)**.
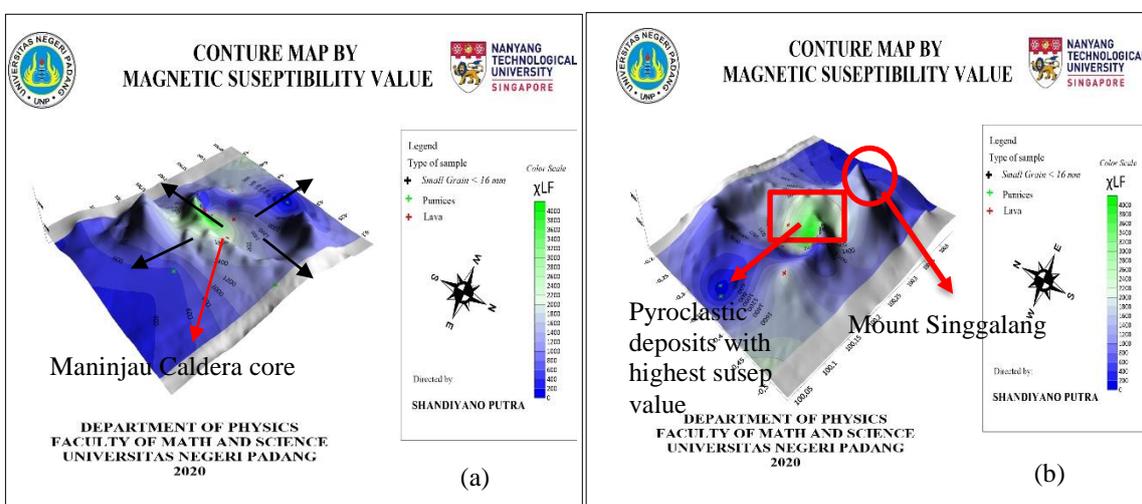

Figure 4 (a) contour map appears from Eastern part, and (b) contour map appears from Western part based on low frequency magnetic sensibility value.

Based on **Figures 4(a)** and **4(b)**, it can be seen that the color difference identifies the different vulnerability values in each sector and then it can be seen that the distribution of magnetic susceptibility values is low. From the contour map, it can be seen that the material from the volcanic eruption is scattered in all directions. Deposits with the lowest vulnerability values are scattered in the West and East with the smallest vulnerability values distributed in the East and West. Light green and dark green are the highest magnetic susceptibility values. Represents color 2800 - 4000×10^{-8} m^3/kg found ± 5 km from core of Maninjau caldera and volcanic material that has highest magnetic sensibility value spread up to ± 7 km to East. Indicators with dark blue represent 0 - 800×10^{-8} m^3/kg spread west wards and material settles at a distance of ± 13km from core of Maninjau caldera. In addition to West direction is also spread to East ± 36 km from core of Maninjau caldera, and to Soueast ± 37 km from core of caldera Maninjau. Indicator with white represents 1600 - 2000×10^{-8} m^3/kg which is located ± 4 km east of core of Maninjau caldera. Based on price of magnetic susceptibility it is seen that dominant result of eruption of Maninjau ancient volcano emits volcanic material with a relatively intermediate susceptibility value 400×10^{-8} m^3/kg is located east divided whichsettles an area ± 17 km.

It can be seen that the dominant colors in **Figures 4(a)** and **4(b)** are light blue and dark blue. Most of the western and eastern parts with deposits based on the theory of volcanic eruptions, previously the Maninjau volcano erupted 3 times. Included in the central eruption where the results of the volcanic eruption are scattered in all directions. After a central eruption, a gap eruption occurs, where the eruption releases an eruption that appears in the form of cracks or faults that can extend for several kilometers. Based on the

results of volcanic eruptions, it can be assumed that the ancient volcanic eruptions of Maninjau belong to the type of plinia eruption which is highly exposed from magma with high viscosity or acid magma, the composition of the magma is andesitic to rhyolitic. The material is likened to a large number of pumice stones.

Conclusions

The result on the explanation above it can be concluded that value of susceptibility in volcanic material from ancient volcano eruptions, with measurements using Bartington Magnetic Susceptibility type MS2B at a range between 74.7×10^{-8} - 3956.7×10^{-8} m^3/kg. Mineral magnetics contained on sample was identified as containing magnetic mineral Ilmenite ($FeTiO_3$) with magnetic properties that included relatively small positive value. From **Figures 4(a)** and **4(b)** it appears that light green to dark green color has highest magnetic susceptibility value representing 2800 - 4000×10^{-8} m^3/kg found ± 5km from core of Caldera Maninjau and volcanic material that has highest magnetic susceptibility value spreads up to ± 7 km to East. While indicators with dark blue color represent 0 - 800×10^{-8} m^3/kg spread westwards and material settles with a distance of ±13 km, to East ± 36 km from core of Maninjau caldera, and to Souteast ± 37 km from core of Maninjau caldera. From this description, engineering and industrial fields can take raw materials of raw minerals that can be used as raw materials to make TiO_2 pigments, iron metals and chemical compounds containing iron. In field of Industry, TiO_2 is widely used as a pigment for Paint, additive material in process of making paper, ceramic raw materials, pharmaceutical industrial raw materials and TiO_2 is also widely used for photoclinly material that is as a catalyst that can decipher organic dye material with help of ultra violet rays.

Acknowledgements

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