Analyzing magnetic susceptibility and elemental composition of rocks and soil around Danau Diatas, West Sumatra, Indonesia

Rizki Nurul Fajri¹, Rizaldi Putra¹, Pika Afriyeni¹, Caroline De Maisonneuve², Marcus Phua², Steffen Eisele², Francesca Forni³, Hamdi Rifai¹*

¹Department of Physics, Faculty of Mathematics and Natural Sciences, Universitas Negeri Padang, Jl. Prof Hamka, Padang 25131, Indonesia
²Asian School of the Environment, Nanyang Technological University, Singapore

*rifai.hamdi@gmail.com

Abstract. The rocks on the surface of the earth have different formation process, beginning with the lava of volcanic activity that flow on the surface of the earth and then cool down forming igneous rocks. Rocks derived by volcanic eruptions contain different types of minerals than those formed by sedimentary or metamorphic processes. The aim of study was to evaluate the relation of magnetic susceptibility with the elemental composition of rock and soil around the Danau Diatas. Magnetic susceptibility was measured using Bartington susceptibility meter MS2B and the element composition has been measured by X-Ray Fluorescence. The values of magnetic susceptibility of low frequency ($\chi_{lf}$) obtained for rock are 2332x10⁻⁸ m³/Kg, 2161,7x10⁻⁸ m³/Kg, and 2791,6x10⁻⁸ m³/Kg, while the values of magnetic susceptibility of low frequency ($\chi_{lf}$) obtained for soils are 802,4x10⁻⁸ m³/Kg, 779,8x10⁻⁸ m³/Kg, and 58,4x10⁻⁸ m³/Kg. Rock and soil samples contain several elements such as Fe, Mn and Ti, with Fe having the highest concentration and thus the highest potential influence on their magnetic susceptibility.

1. Introduction
Volcanic eruption activity occurs due to magma in the bowels of the earth which is pushed out because it has high pressure. The magma undergoes solidification compaction and cooling, forming rocks called igneous rocks. Igneous rocks break down exposed to heat, rain, and the activity of living things for thousands of years. Furthermore, the deposition of material occurs by water, wind, and living things at the surface of the earth, the deposition of these materials is called sedimentary rock. After that sedimentary rocks undergo changes due to high pressure and temperature called metamorphic rocks [1].
The magnetic fraction in these rocks is relatively small about 0.1% of the rock mass [2]. Magnetic minerals can be identified by using several methods. One method that was used is the method of rock magnetism. The method of rock magnetism is a method used to determine the nature of magnetic component in rocks, such as mineral concentration, grain size, mineral type, domain type, and Curie point. This method is based on measuring variations in magnetic field intensity on the earth's surface caused by variations in the distribution of magnetized objects under the earth's surface are called susceptibility. The magnetic susceptibility of a material is a quantitative measure of the material to be magnetized when subjected to magnetic fields [3].

The magnetic susceptibility measurement will provide information about the minerals contained in the sample [4]. The number of minerals that are magnetic in the rocks will affect the large amount of magnetic susceptibility value, the greater the number of minerals that are magnetic, the greater the value of magnetic Instead. Susceptibility can determine the nature of the magnetics and the type of magnetic mineral contained in the material. Each rock has different magnetic susceptibility values. Magnetic properties of rock-forming materials-rocks can be divided into: diamagnetic, paramagnetic, ferromagnetic, and ferrimagnetic.

Rock magnetism is used for environmental studies because magnetic minerals can be found in all types of environments, including rock, soil, dust, organic tissues and man-made materials. In recent years, the study of the rocks has increased. In Indonesia, it has been studied and developed since the 19th century [5]. It begins at the Paleomagnetism application used to track plate tectonics [6], then it was applied to biomagnetism, namely the study of magnetism in living things; enviromagnetism; magnetoclimatology [7]; industry [8] the study of rock magnetism that is currently developing is agromagnetism [9] volcanomagnetism [6], and paleoeruption.

The aim of the research was to evaluate the relation of magnetic susceptibility with the composition of rock and soil elements around the Danau Diatas. Review of the magnetic nature of rocks and soil around Danau Diatas is very important to study paleoeruption. Paleoeruption the magnetic nature of rocks is used to examine ancient volcanic eruptions. Based on the explanation above, researchers are interested in conducting research on "the analysis of the linkage magnetic value with the composition of rocks and soil elements around Danau Diatas, West Sumatera"

2. Method

2.1. Research Location

The research was conducted around the Danau Diatas, West Sumatra (Figure 1). The Danau Diatas is located in a geographical position between 1° 01' 51" -1° 07' 39" LS, and between 100° 43’01” – 100° 50’26” BT, about 12 km from the gunung Talang and 2 km Lake Diatas has a maximum depth of 55 m and an average depth of 28 m. It has a relatively flat bottom but a narrow trench-like feature in the northeast, which is the result of tectonic processes - namely the Sumatran strike-slip fault [10]. From The Danau Dibawah, which are located side by side so that they are dubbed the Danau Kembar (Figure 1). Approximately 1 km west of Danau Dibawah, there is a small lake, it’s the Danau Talang. The three lakes are at the foot of gunung Talang. Samples were taken in four locations, namely Jorong Urak, (S01.08059 ° E100.77696 °), Batang Ari Jorong Batu Putiah (S01.10201 ° E100.76115 °), Jorong Taluak Dalam (S01.06361 ° E100.76383 °) Lembah Gumanti Subdistrict and Tanjuang Nan IV in Danau Kembar Subdistrict (S01.05212 ° E100.74757 °). The sample position is determined by using a GPS (Global Positioning System) Garmin GPS Map 60 CSx. Samples taken were in the form of rocks and soil (Figure 2a) which amounted to six samples where three rock samples and three soil samples.
Figure 1. Location map of research area around Danau Diatas

2.2. Sampling process
Measurements of the magnetic properties of samples were carried out at the Geophysical Laboratory of FMIPA UNP by using rock magnetization methods, while the abundance of elements was determined by the XRF (X-ray fluorescence) method in Chemical Laboratory of FMIPA UNP. The rock magnetism method was chosen because the method is easy to implement, sensitive, inexpensive and non-destructive [11] while the XRF method determines the types of minerals contained in the sample which cannot be determined by the rock magnetization method. Before the measurement, sample preparation was first carried out by crushing the rock samples using a crusher, then mashed using mortar, while the soil samples were dried first, the clotted soil was mashed using mortar. Furthermore, rock and ground samples that have been mashed are inserted into a cylindrical holder.
with a height and diameter of 1 inch. After that proceeded to the measurement of sample mass using a digital analytic balance.

Figure 2. a) Sampling process b) Soil and rock samples c) The process of labeling the rock and soil samples
2.3. Sample Measurement

2.3.1. Concentration of magnetic minerals. To determine the concentration of magnetic minerals in rock and soil samples was determined by measuring using the Bartington Magnetic Susceptibility Meter MS2B (Figure 3) dual frequency model that is 470 Hz for low frequency susceptibility (FLF) and 4.7 KHz for high frequency magnetic susceptibility (χHF), from these two measurement methods, the calculated frequency dependent magnetic susceptibility acceptability is DFD (%), where χFD (%) = (χLF - χHF) / χLF x 100% [12].

2.3.2. Types of elements. XRF is used to analyze elements in the material qualitatively and quantitatively [13]. Measurements were taken using the X-Ray Fluorescence (XRF) PANalitical Type Epsilon 3 instrument (Figure 5). The results obtained in the form of a percentage of elements contained in the sediment [14].

Figure 3. Samples in a Holder

Figure 4. Bartington Susceptibility Type MS2B
3. Result and discussion

| Sample Name     | $\chi_{lf}$ (10^-8 m^3/kg) | Fe (%) | Ti (%) | Mn (%)  |
|-----------------|-----------------------------|--------|--------|---------|
| Soil            |                             |        |        |         |
| Diatas 011 2018-07-21 | 802.4                      | 26.2   | 2.8    | 0.02    |
| Diatas 022 2018-07-21 | 779.8                      | 19.2   | 1.6    | 0.31    |
| Diatas 033 2018-07-21 | 58.4                       | 8.0    | 2.6    | 1.08    |
| Average         | 546.8                      | 17.8   | 2.3    | 0.47    |
| Rock            |                             |        |        |         |
| Diatas 1a 2018-07-21 | 2332.0                     | 7.53   | 0.94   | 0.15    |
| Diatas 1b 2018-07-21 | 2161.7                     | 6.72   | 0.84   | 0.14    |
| Diatas 1c 2018-07-21 | 2791.6                     | 9.05   | 1.13   | 0.14    |
| Average         | 2428.4                     | 7.76   | 0.97   | 0.14    |

Table 1 shows the value of low frequency magnetic susceptibility ($\chi_{lf}$) and the elemental composition found in rocks and soil. Where the value of magnetic susceptibility obtained ranged from $58.4 \times 10^{-8}$ m$^3$/kg - $2791.6 \times 10^{-8}$ m$^3$/kg with the average ($\chi_{lf}$) in rocks and soil ranging from $2428.43 \times 10^{-8}$ m$^3$/kg and $546.87 \times 10^{-8}$ m$^3$/kg. The highest elemental composition of Fe found in rock and soil is 9.056% and 26.289% respectively, while the lowest element composition found in rocks and soil is Mn, where the percentage is 1.51% and 1.087%. The average percentage of elements of Fe, Ti, Mn found in samples in the Danau Diatas respectively are 12.82%, 1.66%, and 0.14%.
Figure 6. Graph of magnetic frequency susceptibility relationships with the percentage of Fe, Ti, and Mn elements in a) rock sample b) soil samples.

The graph in Figure 6 shows the relationship of magnetic susceptibility with the elements Fe, Ti and Mn. The three elements has the strongest correlation between elements with susceptibility is the element of Fe both for rocks and soil with the value of $R_R = 0.99$ and $R_S = 0.87$ and Ti content with magnetic susceptibility of the rock also have a strong correlation, where $R_R = 0.99$, while the Ti content with soil magnetic susceptibility has a weak correlation, where the value of $R_S = 0.07$ Mn content elements have a very weak to no correlation with magnetic susceptibility in rock and soil, where the value of $R_R = 0.12$ and $R_S = 0.12$. 


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The high susceptibility values are obtained in rocks and soil around Danau Diatas. It is indicated that the sample contains high concentrations of magnetic minerals and ferrimagnetic minerals [15]. The value of magnetic susceptibility in rocks and soil around Danau Diatas was analyzed by Fajri et al (2019), the magnetic susceptibility values of rocks and soil obtained ranged from 23.77 x 10^-8 m^3 / kg - 2791.6 x 10^-8 m^3 / kg and 17.4 x 10^-8 m^3 / kg - 2804.4 x 10^-8 m^3 / Kg. The magnetic susceptibility values of rocks and soil are included in the group of ferromagnetic minerals and the types of minerals contained therein are ilmenite (FeTiO3) and hematite (Fe2O3) [16]. The magnetic susceptibility value of rock and soils from Danau Diatas are quite similar with magnetic susceptibility value of guano from Solek and Rantai Cave, 50 Kota District, West Sumatra (Rifai et al, 2010). The maximum and minimum magnetic susceptibility values in Solek cave are 862.87 x 10^-8 m^3 / kg and 17.83 x 10^-8 m^3 / kg, while the maximum and minimum magnetic susceptibility values in the Rantai cave are 1004.3 x 10^-8 m^3 / kg and 14.82 x 10^-8 m^3 / kg. The value of magnetic susceptibility obtained is quite large. It is indicated that the high concentration of magnetic minerals in the guano deposit [17].

The minerals which has the highest magnetic susceptibility value is iron (Fe) with the magnetic properties of the material namely ferromagnetic. This is what causes the composition of Fe to affect the magnetic susceptibility value of rocks and soil [12]. Figure 5 can be seen that Fe as the basic constituent of magnetic minerals has the highest percentage compared to other elements. The relationship of the composition of the basic constituents of magnetic minerals to the value of susceptibility is seen in rock and soil samples at Danau Diatas, where the composition of the basic constituents of magnetic minerals is proportional to the value of magnetic susceptibility. The composition of Fe shows a high percentage when the value of magnetic susceptibility is high and shows a low percentage when the magnetic susceptibility value is low, while the elements Ti and Mn have less influence on the magnetic susceptibility of rocks and the land in the Danau Diatas. This is because the composition of Ti and Mn in the sample is very low compared to the abundance of Fe.

The relationships between the abundance of magnetic mineral and the value of guano magnetic susceptibility from Bau-Bau Cave, East Kalimantan have been analyzed by Ganetsya (2014), the results obtained are the composition of proportional Fe to the value of magnetic susceptibility of guano Bau-Bau Cave. When the composition of Fe is high, the value of magnetic susceptibility obtained also shows a high value and vice versa. Whereas the results of the comparison of the value of magnetic susceptibility with the composition of the transition elements of the fourth group other than Fe are not seen in relation to both. This is due to the composition of the fourth class transition elements other than very low Fe [18]. Weak correlation of Ti and Mn elements with magnetic susceptibility likely due to association with authigenics minerals [19]. While the relationship between the value of guano magnetic susceptibility with the composition of heavy metal elements from the Solek Cave, District of Lareh Sago Halaban, 50 Kota District have been analyzed by Rizal et al. (2019). The results obtained are the composition of heavy metal elements to the magnetic susceptibility of each depth has no linear function, the non-linear relationship between the value of magnetic susceptibility to heavy metals is caused by the influence of elements other than metals weight is authigenic.

4. Conclusion
Based on the results of research obtained from rock and soil samples from Danau Diatas (West Sumatra), it can be concluded that there is a clear relationship between the magnetic susceptibility and the chemical composition of the rock and soil samples, which in turn reflects the amount of magnetic minerals. Where the composition of Fe is proportional to the value of its magnetic susceptibility. While the relationship between the elements Ti and Mn to the value of magnetic susceptibility is not very visible. This is because the composition of elements other than Fe is very low. This indicates the presence of authigenic influences.
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