Identification of magnetic minerals in the peatlands cores from Lake Diatas West Sumatra, Indonesia

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Abstract. Peatlands in Lake Diatas can store various types of minerals. One of the mineral phases that can be found in peatlands are magnetic minerals derived from volcanic eruptions. This study was used to determine concentration of magnetic minerals found in peatlands. We applied the rock magnetism method, measuring the magnetic susceptibility of peat sediments to estimate the concentration of magnetic minerals within a peat core. Bartington Magnetic Susceptibility Meter type MS2C and dual frequency MS2B types, namely 470 Hz and 4.7 k Hz. In this study we analysed the magnetic susceptibility of core Diatas REP B at depths of 0-170 m and 240-720 m. From MS2B the values of low frequency magnetic susceptibility ($\chi_{lf}$) and high frequency magnetic susceptibility ($\chi_{hf}$) are obtained. The magnetic susceptibility values ranged from $365.2 \times 10^{-8}$ m$^3$/kg to $386.8 \times 10^{-8}$ m$^3$/kg and the value of magnetic susceptibility depends on frequency ($\chi_{fds}$) range between 0.6 % - 1.3%. These low values indicate that almost no superparamagnetic grains are present. We identified a positive peak in magnetic susceptibility $386.8 \times 10^{-8}$ m$^3$/kg at 386 cm, whereas the lowest values were measured $365.2 \times 10^{-8}$ m$^3$/kg at 675 cm. Based on the value of magnetic susceptibility, the dominant magnetic mineral phases are Hematite (Fe$_2$O$_3$) and ilmenite (FeTiO$_3$).

1. Introduction

Peatland environments can provide an archive for various mineral phases, including magnetic minerals. Along the volcanic front of Sumatra one possible source for these magnetic minerals are volcanic eruptions. Explosive volcanic eruptions produce pyroclast ranging from bomb size to fine ash. Pyroclastic fall deposits are characterized by well sorting, mantel bedding and decreasing grain sizes and thickness with increasing distance from the vent. Pyroclastic bombs and lapilli/pumices are in general restricted to the proximal to medial areas of a volcano[1], while volcanic ash can be transported over distances of 10s to 100s of km by wind[2][3][4]. Volcanic magnetic minerals can be used to identify cryptic tephra layers in distal archives like peats[5][6][7].

To identify these minerals we take advantage of their magnetic properties that can be measured by various methods. In this study we used a Bartington susceptibility meter type MS2C and MS2B to measure the magnetic susceptibility. One of them determination concentration of magnetic minerals in something ingredients determined with use for measure value susceptibility magnetic [8][9].
Susceptibility magnetic will give away information about minerals contained in something ingredients [10][11]. Based on the value of magnetic susceptibility, the material is distinguished above diamagnetic, paramagnetic or ferromagnetic[9].

The magnetic properties of rocks have been studied in Indonesia since the 19th century [12]. Paleomagnetism was first used to reconstruct plate tectonics [13], after wards the method was applied to all different kinds of research fields such as biomagnetism[14]; enviromanetism[15]; magnetoclimatology [16]; industry[17] and study magnetism rocks were developing when now is agromagnetism [18]; volcanomagnetism [13], Paleoclimatology, Paleogeography [19][20] and Paleoeruptions [21].

This study aims to identify horizons with increased magnetic susceptibility in the peat sediments from Danau Diatas as a potential indicator for cryptotephra deposits. As these tephra layers can not be visually identified.

2. Methods
2.1. Sample location

![Figure 1. Map location taking sample peatland on Lake Diatas](image)

Lake Diatas is located, in a geographical position between 1° 01'51"-1° 07'39" S and 100° 43'01"-100° 50'26" E. The peat soil is located on the eastern side of Lake Diatas, Lembah Gumanti District,
Solok Regency, West Sumatra Indonesia. The peat core was taken at the Lake Diatas peat soil 1°49.93'S and 100°46'13.53"E using a Russian Peat Corer (Figure 2).

Figure 2. Sampling process at Lake Diatas peat land. a) The peat core was retrieved using a Russian Peat corer. b) The sediments were described immediately after they were retrieved. c) Samples after transfer to PVC half-tubes for sample transport.

The peat core was retrieved from two holes (A and B) approximately 1-2m apart from each other. To avoid any disturbance by the corer a 50cm sample was retrieved alternately from both cores with a 10cm overlap (hole A: 0-50cm, hole B: 40-90cm, hole A: 80-130cm, hole B: 120-170cm, hole A: 240-290cm, hole B: 280-330cm, hole A: 320-370cm, hole B: 360-410cm, hole A: 400-450cm, hole B: 440-490cm, hole A: 480-530cm, hole B: 520-570cm, hole A: 560-610cm, hole B: 600-650cm, hole A: 640-690cm, hole B: 680-720cm). Each retrieved segment was described immediately after it was retrieved and before it was transferred to PVC half-tubes. The samples were then wrapped with cling wrap and stored in a fishing box, filled with ice for transportation. At the UNP Physics Laboratory the samples were stored in a freezer. The samples were taken out of the freezer before the analyses to reach room temperature and avoid any temperature effect on the measurements.

Figure 3. Lake Diatas peat sediment samples that are ready to measure their susceptibility using the Bartington Magnetic Susceptibility Meter. a) MS2C type (in the form of a half core with a diameter of 2.5 inches) b) type MS2B (in the form of a cylinder with a diameter of 1 inch).

The peat sediments were analysed for magnetic susceptibility and to identify the magnetic domain of the magnetic minerals. The magnetic susceptibility is determined using a Bartington The Magnetic Susceptibility Meter type MS2C (Figure 4a). Peaks in magnetic susceptibility indicate horizons with
increases abundance of magnetic minerals. To determine the domain of the magnetic minerals the *Bartington Magnetic Susceptibility Meter type MS2B* dual frequency was used with 470 Hz for the low frequency susceptibility ($\chi_{lf}$) and 4.7 KHz for high frequency susceptibility ($\chi_{hf}$) (Figure 4b). For magnetic susceptibility each 50 cm segment was scanned and the results were combined in a composite core (Figure 5). Horizons with peaks in magnetic susceptibility were then subsampled and transferred into plastic cylinders with 1 inch diameter (Figure 3b) using a plastic spoon. These samples were weighed and then analysed 3 times each for frequency dependent magnetic susceptibility $\chi_{fd}$ (%). Which is defined as $\chi_{fd}$ (%) = ($\chi_{nf}$-$\chi_{hf}$)/$\chi_{nf}$ x 100%. The domain of the magnetic minerals can be determined based on their $\chi_{fd}$ (%) values. $\chi_{fd}$ (%) <2.0% is interpreted as non magnetic minerals or less than 10% superparamagnetic magnetic minerals are present, $\chi_{fd}$ (%) of 2.0% - 10.0% is interpreted as presents of superparamagnetic and non-superparamagnetic grains, or superparamagnetic grains with grain sizes <0.005µm and $\chi_{fd}$ (%) values of 10.0% -14.0 % is interpreted as more than 75 % of the magnetic minerals are superparamagnetic[22]. The results are shown in Figure 6a. The domain type is determined using the scacategram classification scheme (Figure 6b). This diagram can also be used to distinguish between grain size and domain status[23].

Figure 4. a) Magnetic Susceptibility Meter type MS2C in the Lab.Geophysics b) Magnetic Susceptibility Meter type MS2B in the Lab.Geophysics.

3. Results and discussion

![Figure 5. Graph of peat susceptibility values based on depth.](image-url)
16 core segments in the depth range of 0-170 cm and 240-720 cm were analysed and the data was then combined to a composite core (Figure 5). The magnetic susceptibility values vary between -1.9 x 10^-3 m^3/kg - 21.6 x 10^-3 m^3/kg. Positive peaks were identified in the lower part of the peat core below 650 cm (Figure 5) with the highest peak at 693 cm, while the lowest magnetic susceptibility values are found at a depth of 161-167 cm. The low values of magnetic susceptibility can be caused by weathering, precipitation or mixing with diamagnetic organic materials [24][26]. While high values indicate increased magnetic mineral contents in the sample. Therefore, samples at a depth of 669-717 cm appear to have magnetic mineral content. Three sub-samples from the peak area were taken at 675 cm, 689 cm and 693 cm to measure the frequent dependent magnetic susceptibility using the Bartington Magnetic Susceptibility MS2B (Table 1). This is due to the process of transporting minerals by water and wind [25][26]. Where peat is formed from swamp vegetation that is entirely dependent on nutrient input from rainwater and no longer from mineral soils below or from groundwater seepage [27].

### Table 1. Results of the Frequentz depending Magnetic Susceptibility Using Bartington Susceptibility MS2B

| Number | Sample name       | χₘ (x10^-3 m³/kg) | χₘ (x10^-3 m³/kg) | χₘ (%) |
|--------|-------------------|-------------------|-------------------|--------|
| 1      | DD REP B 675      | 365.2             | 362.1             | 0.7    |
| 2      | DD REP B 689      | 371.3             | 366.5             | 1.3    |
| 3      | DD REP B 693      | 386.8             | 384.4             | 0.6    |

### Table 2. Magnetic properties of a number of rocks and magnetic minerals (John A. Dearing, 1999).

| Mineral          | Chemical Formula | Density (10³ kg m⁻³) | Volume k (10⁶ SI) | Mass χ (10⁸ m³ kg⁻¹) |
|------------------|------------------|----------------------|------------------|----------------------|
| Hematite         | Fe₂O₃            | 5.26                 | 500-400.000      | 10-760               |
| Maghemite        | α-Fe₂O₃          | 4.9                  | 2.000.000-2.500.000 | 40.000-50.000        |
| Ilmenite         | FeTiO₃           | 4.72                 | 2.200-3.800.00   | 46-80.000            |
| Magnetite        | Fe₃O₄            | 5.18                 | 1.000.0005.700.000 | 20.000-110.000        |
| Titanomagnetite  | Fe₃Ti₄O₄        | 4.98                 | 130.000-620.000  | 2.500-12.000         |
| Titanomaghemite  | Fe₃-xMgTi₄O₄    | 4.99                 | 2.800.000        | 57.000               |
| Ulvospinel       | Fe₄TiO₄          | 4.78                 | 4.800            | 100                  |

Based on these measurements the dominant magnetic material phase of each sample can be identified. The magnetic susceptibility values vary between 362.1 x 10^-3 m³/kg - 386.8 x 10^-3 m³/kg for low frequency and 362.1 x 10^-3 m³/kg - 384.4 x 10^-3 m³/kg for high frequency measurements. It can be said that there are differences in the magnetic mineral content of these peatlands [28]. Using the classification of mineral magnetic ad reference for Table 2 here Table 2, our data indicates that ilmenite (FeTiO₃) and hematite (Fe₂O₃) are the most dominant magnetic mineral phases in these peat sediments. In addition, weathering can lead to reduced magnetic susceptibility values as Hematite can be oxidized [29]. Magnetic susceptibility analyses of volcanic ash from Mount Sinabung is 2000x10^-3 m³/Kg - 8732x10^-3 m³/Kg. Based on this value, the ash from the eruption of Mount Sinabung is in the interval (46-80000 x 10^-8 m³/Kg). Which means the sample contains ilmenite (FeTiO₃) [26]. This result implies that ilmenite will also be the dominant magnetic minerals in volcanic soils formed after this eruption [26].

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**Figure 5:** Schematic representation of the peat core with identified magnetic peaks.
The frequency dependent magnetic susceptibility $\chi_{fd} (%)$ values range between 0.6\% - 1.3\%, with the highest $\chi_{fd} (%)$ value at 693 cm and the lowest $\chi_{fd} (%)$ values at 675 cm. Using the scagatgram diagram of Dearing et al., 1996 [23] shown in Figure 6b it can be seen that the sample contain less than 10\% superparamagnetic grain and is a type of multi domain domain. The nature of magnetic minerals is strongly influenced by the size of the magnetic grain[30]. Magnetic grains are the most important thing in magnetic fields. There are 3 types of magnetic domains, namely logical domain (SD) which has a grain size of <$0.1 \mu$m the magnetic moment is in the same direction, multi domain (MD) with a large size of 10 $\mu$m, and pseudo single domain (PSD) having only 2-3 domains, but the behavior is more like a single domain than multi domain. The PSD grain size interval for magnetite is 1-10 $\mu$m [23].

The size of magnetic grains is often used to track the origin of magnetic minerals and deposition processes in the past. The higher the wind speed, the more dust in the form of fine magnetic minerals are carried away and conversely the lower the wind speed, the less fine magnetic minerals are transported. According to Hamdi (2011) eolian transportation of magnetic minerals leads to characteristic finer grain sizes of magnetic minerals in the sediments compared to transportation by water flow. Assuming the same analogy works for the Diatas peatland, this would imply that two parallel transport mechanisms happen at the Diatas Peatland. The larger magnetic mineral grains wouldbe carried by water, while the smaller magnetic minerals would have been carried by wind.

4. Conclusion
We identified peaks in magnetic susceptibility below 650 cm in the Diatas Peat core, potentially indicating cryptotephra deposits related to volcanic eruptions in the area. High and low frequency Magnetic Susceptibility measurements indicate that the dominant magnetic mineral phases are ilmenite and/or hematite. Further the low frequency dependent magnetic susceptibility is interpreted as a multi domain type.

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