Identification of magnetic minerals in peatland at the section of DD REP B 693 lake Diatas using XRD (X-ray Diffraction)

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Abstract. Volcanic ash is dispersed into the air when an eruption occurs, whilst the magma that reaches the surface of the Earth cools to form igneous rocks before eventually breaking down to form sedimentary rocks. One of the places where the sedimentation of volcanic ash occurs following eruptions are peatlands. This study aims to determine the type of magnetic minerals contained in the peat at Lake Diatas. The identity of the magnetic minerals was determined using the X-Ray Diffraction method. The samples used in this study are taken based on depth of the peat core where a value of magnetic susceptibility had been measured previously. The results of the x-ray diffraction analysis for each sample obtained are the diffraction angle (2θ), distance between fields (dhkl), diffraction intensity (I) and relative intensity. Data from this measurement are then compared with magnetic mineral data bases in order to identify the identity of the magnetic minerals within the peat. Analysis of the results obtained using X-Ray Diffraction indicate the identity of the magnetic minerals in the peat samples at Lake Diatas. The dominant type of magnetic mineral is magnetite (Fe₃O₄) along with other magnetic minerals such as hematite. Magnetite diffracts at 18.3773°, 30.9888°, 31.5036°, 53.6169°, 65.7656°, 78.6261°, hematite at 65.9474°, 75.1103°, 78.8619°, while non-magnetic minerals such as quartz diffracts at 28.0575°, 28.2029°, 52.4150°.

1. Introduction

Indonesia is located at the junction of three plates, namely the Eurasian, Indo-Australian and Pacific plates. Interaction between these plates forms the path of a mountain belt that runs from Sumatra to the Banda Sea [1]. Mount Merapi is an area that is traversed by the path of the Great Sumatran Fault. The West Sumatra region is also rich in natural resources. The results of natural wealth possessed can be minerals stored in rocks and sedimentation [2]. Volcanic ash are falling volcanic material that is dispersed into the air during an eruption. Volcanic ash consists of large to fine-sized materials, large grains usually fall within a radius of 5-7 km from the crater, while fine-sized grains can fall at distances reaching hundreds to thousands of kilometres [3].

Volcanic ash generated from volcanic activity can be carried by wind, rain and then deposited around volcanic areas such as lakes, peatlands and other surrounding areas where sedimentation occurs for tens of thousands of years. The sedimentary layers differ in the level of decomposition, types of plants deposited or alternating layers of mineral soil. The history of peat formation in Indonesia began during the ice age where a process of decreasing sea levels (regression) caused strong erosion in the up stream
of the river. As a result, coarse rock deposits such as gravel and gravel called old alluvium, which is deposited in tertiary sediments form the foundation of the peat basin [4]. These mineral layers show evidences of natural flooding and sedimentation over time on peatlands.

Minerals found in nature are generally diamagnetic, paramagnetic and partly ferromagnetic. Ferromagnetic materials have the strongest magnetism. Ferromagnetic is generally classified into the family of Iron Hydroxides, Iron Sulfides and Iron Titanium Oxides. The Iron Sulfide family consists of minerals pyrrhotite (Fe₇S₈) and Greigite (Fe₃S₄), the family of Iron Hydroxide is goethite (α-FeOOH) and the family of Oxides Titanium Iron consists of the mineral magnetite (Fe₃O₄), hematite (α-Fe₂O₃) and maghemite (γ-Fe₂O₃)[5][6]. All minerals have a unique chemical composition and the arrange ment of regular atoms so that each type of mineral has its own physical and chemical properties.

The magnetic method is used to determine how magnetic a peat layer is by measuring the value of the magnetic mineral susceptibility of the peat layer. Measurement of susceptibility values can identify the mineral content of Fe elements, calculate mineral concentrations or volumes, classify mineral types, and identify mineral processes and displacement [7][8].

Identifying magnetic minerals can be done using X-Ray Diffraction. X-Ray Diffraction produces certain diffraction patterns caused by diffracted x-rays with a certain wave length. The results of X-Ray Diffraction measurements are fractured in the form of diffraction angles, diffraction intensity and distance between fields. The data can be used to identify the types of magnetic minerals contained in peat and determine the presence of volcanic ash in the sedimentary layer of peat soil.

2. Method

2.1 Time and Location
The research was conducted, in March 2018 at the peatlands located by Lake Diatas of Solok Regency, West Sumatra, Indonesia at 1°4’19.93”S and 100°46’13.53”E as seen in Figure 1.

![Figure 1. Map of Sampling Location](image-url)
2.2 Sample collection and preparation
A peat core of about ± 7 meters length was collected by means of a Russian Peat Corer that consists of 2 parts namely a container which is 0.5 m long, and a 1 m long container handle. Sampling was carried out by plugging the eye of the container into the peat soil and then the container stalk was rotated 180° in an anti-clockwise direction so that the peat soil was preserved in the container, which is then transferred from the container into the PVC pipe, Figure 2.

![Figure 2](image)

**Figure 2.** (a) Sampling process (b) PVC pipe sample storage area

Before the sample was measured using XRD to determine the type of magnetic mineral sample preparation is required. Sample preparation was carried out at the Geophysical Laboratory of FMIPA UNP using MS2C instruments to identify areas of high magnetic susceptibility, after which samples with high susceptibility values are taken using a spatula and then transferred to the holder, then the sample is extracted using a magnet[9]. The extracted samples were washed using an ultrasonic cleaner to clean samples from the sticky dirt. After cleaning, the samples were dried for ± 1 hour using an oven so that samples could be measured using XRD, can be seen in Figure 3.

![Figure 3](image)

**Figure 3.** (a) Washing process of samples (b) Place for drying samples

2.3 Sample Measurement
In the process of measuring samples of peat soil placed in a diffractometer x-ray specimen. The x-ray diffraction process starts by turning on the diffractometer where the parallel x-ray beam radiates from the x-ray tube. Then the beam is captured by a scintillator detector and converted into an electrical signal. The signal, after being eliminated by the noise component, is calculated as an analysis of high pulses in the form of diffraction lines. The x-ray diffraction line profile is drawn on the graph paper so that the diffractogram results are obtained in the form of a diffractogram which states the relationship between the diffraction angle 2θ and the intensity of the reflected x-ray.
Figure 3. (a) X-ray diffraction (XRD) (b) Schematic diffraction scheme[10]

Figure (3b) shows the presence of x-rays that come on a crystal surface with each layer of atoms as far as d each with the same distance. Diffraction patterns produced by elements or compounds can be used to identify the types of minerals contained in the material. The schematic of the diffraction process can be seen in Figure (3b) which shows the presence of x-rays which come on a crystal surface with each layer of atoms as far apart as each d with the same distance.

Data obtained from these measurements are the value of intensity, diffraction angle and distance between fields. This data is processed using Ms. Excel so that a graph is obtained in the form of a factogram that states the relationship between diffraction angles and diffraction intensity values. While the distance between fields is calculated using the Bragg equation, the measurement data is compared with the magnetic mineral database, so that the magnetic minerals contained in peat soil can be identified from the comparison.

3. Results and Discussion
The measurement results obtained from the diffraction x-ray are in the form of diffraction intensity with a certain diffraction angle. Measurement data show diffraction angle (2θ), diffraction intensity (I), distance between fields (d) and relative intensity (I_r). The diffractogram obtained from the measurement results states the relationship between diffraction intensity (I) and diffraction angle (2θ).

Data from the measurement of peat soil samples from the lake peat soil above using X-Ray Diffraction obtained diffractogram like Figure 4. The resulting diffractogram is in the form of intensity peaks along the values with varying shapes.

Figure 4. Results of X-Ray Diffraction measurement of peat soil

Figure 4 shows a diffractogram which states the relationship between intensity and diffraction angle (2θ) forming intensity peaks with a certain angle of 2θ. Diffractogram shows several peaks of intensity
that are significant at certain angles. Determination of Mineral Types by Comparing Measurement Results with Mineral Database.

Data that are obtained from the measurement results of sample 1 are not only the intensity (I) and diffraction angle ($2\theta$) but the results can also show the distance between fields (d) and relative intensities. The intensity peaks generated from the measurement results can be used to determine the relative intensity by comparing the peaks of significant intensity at a certain angle with the most significant peak intensity.

The diffraction angle can be used to determine the distance between fields based on Bragg's law. Measurement data in the form of diffraction angle, relative intensity and distance between fields. Data can be seen in Table 1.

Table 1. Data on X-ray diffraction measurement DD REP B 693 cm.

| $2\theta$ | d [Å]    | $I_r$ [%] |
|----------|----------|-----------|
| 18.3773  | 4.82785  | 6.13      |
| 28.0575  | 3.18032  | 38.16     |
| 28.2029  | 3.16425  | 40.26     |
| 30.9888  | 2.88584  | 12.03     |
| 31.5036  | 2.83986  | 14.47     |
| 33.0091  | 2.71369  | 3.35      |
| 52.4150  | 1.74569  | 6.81      |
| 53.6169  | 1.70936  | 3.81      |
| 65.7656  | 1.41880  | 100.00    |
| 65.9474  | 1.41885  | 48.32     |
| 75.1103  | 1.26377  | 13.55     |
| 78.6261  | 1.21583  | 72.41     |
| 78.8619  | 1.21580  | 35.10     |

The relative intensity and diffraction angle obtained will be compared with the mineral database to find out the types of minerals obtained from the measurement results. Comparison of measurement results with mineral databases can be seen in Figure 5.

Comparison of the results of measurements of samples with mineral databases (Figure 5) which shows that peat soil has varying mineral content. Where there are magnetic and non-magnetic minerals contained in peat soil samples. The types of minerals contained in peat soil can be identified from the comparison of the measurement results with the mineral database as seen in Figure 5.

Figure 5. Results of X-Ray Diffraction measurement of peat soil
Figure 5 shows the content of the types of magnetic minerals contained in DD REP B 693 cm peat soil is magnetite formed at the diffraction angle 18.3773°, 30.9888°, 31.5036°, 53.6169°, 65.7656°, 78.6261° and Hematite formed at the diffraction angle 65.9474°, 75.1103°, 78.8619° while the non-magnetic minerals contained quartz were formed at the diffraction angle. Diffraction angle 28.0575°, 28.2029°, 52.4150° shows the type of non-magnetic mineral, quartz.

The diffraction angle, distance between fields and the relative intensity obtained from the measurement results can be used to determine the type of minerals contained in the peat soil sample. The type of mineral can be determined by comparing the diffraction angle and the relative intensity obtained from the measurement results with a mineral database as shown in Figure 6. Curve Figure 6 shows the type of minerals found in peat soils DD REP B 693 cm. The mineral database compared to the measurement results shows there are types of magnetic minerals contained in peat soil. The comparison results indicate the content of non-magnetic mineral species contained in peat soil.

![Figure 6](image.png)

**Figure 6.** Comparison of measurement results data DD REP B 693 cm and minerals database.

The mineral content that varies in Table 2 shows that the types of non-magnetic minerals strongly dominate the peat soil samples. The results of identifying the types of minerals contained in guano can be seen in Table 2.

**Table 2.** Comparison of measurement results data DD REP B 693 cm and minerals database.

| Measurement data | Mineral Database |
|------------------|------------------|
| $2\theta(0)$     | $I_r$ [%]        | $2\theta(0)$ | $I_r$ [%] | Mineral type |
| 18.3773          | 6.13             | 18.336       | 7.9       | Magnetite    |
| 28.0575          | 38.16            | 28.109       | 100.0     | Quartz       |
| 28.2029          | 40.26            | 28.323       | 15.9      | Quartz       |
| 30.9888          | 12.03            | 30.161       | 28.5      | Magnetite    |
| 31.5036          | 14.47            | 31.007       | 28.5      | Magnetite    |
| 33.0091          | 3.35             | 33.118       | 100.0     | Hematite     |
| 52.4150          | 6.81             | 52.355       | 3.3       | Quartz       |
### Measurement data

| Mineral Database | Measurement data |
|------------------|------------------|
| 2θ(°) | I_r [%] | 2θ(°) | I_r [%] | Mineral type |
| 53.6169 | 3.81 | 53.570 | 9.1 | Magnetite |
| 65.7656 | 100.00 | 65.940 | 0.8 | Magnetite |
| 65.9474 | 48.32 | 65.971 | 0.2 | Hematite |
| 75.1103 | 13.55 | 75.106 | 0.2 | Hematite |
| 78.6261 | 72.41 | 79.182 | 2.5 | Magnetite |
| 78.8619 | 35.10 | 78.720 | 1.1 | Hematite |

### Conclusion

Based on the diffractogram and the comparison of the results with the mineral database produced using diffraction x-ray, we identify the types of magnetic minerals contained in peat soil from the peatland by Lake Diatas. The types of magnetic minerals contained in the area are magnetite (Fe₃O₄) and hematite (Fe₂O₃). While the non-magnetic minerals identified in the measurement results are caused by the samples used not going through the extraction process so that non-magnetic minerals detected by diffraction x-ray function as impurities.

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