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Morphology of Magnetic Minerals and Magnetic Susceptibility of Volcanic Ash from 2010 Eruption of Merapi Volcano, Indonesia

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Abstract: The composition, morphology and magnetic susceptibility of the volcanic ash samples of Merapi volcano have been tested. The composition of elements in the samples was determined using X-Ray Fluorescence (XRF), magnetic minerals morphology was determined using Scanning Electron Microscopy (SEM) and magnetic susceptibility was determined using Bartington Magnetic Susceptibility meter MS2B. There are about 17 elements found in volcanic ash, with the largest percentage being silica (Si), which is around 45%; iron (Fe) element have a concentration of around 16% and aluminum (Al) around 12%. Meanwhile, other elements are in very low concentration. If it is used to track events related to the dynamics of the earth, that three elements can be used as proxy data. Based on the composition of Merapi volcanic ash, it is possible that the existing of magnetic minerals are dominated by iron titanium oxide. The size and shape of magnetic minerals are very diverse, ranging in size from tens to hundreds of micrometers. Meanwhile, the surface of the magnetic mineral also appears not smooth or porous. This condition is thought to occur due to heat with very high temperatures regarding magnetic minerals before and during the eruptions. Magnetic susceptibility measured at low frequency is in the range of 10×10^{-6} m^3/kg for extract samples and 2200×10^{-6} m^3/kg for non-extracted samples.

Keywords: Composition, morphology, magnetic susceptibility, magnetic minerals, Merapi volcanic ash

1. Introduction

Volcanic ash is one of the volcanic materials whose presence in nature is very important and can be used as an indicator for various volcanic eruptions. Characteristics of volcanic ash can describe the mechanism of the volcano associated with the temperature and strength of volcanic eruptions. Volcanic ash that has settled in the sediment can also be used as a proxy indicator of geological, environmental and paleoclimatological events [1-3]. In paleoclimatology studies, the presence of magnetic minerals in sediments can be referred to as clues to tracking past climate conditions [3]. By carrying out magnetic characterization and physical properties of volcanic ash, we will get data that can be used as a guide to both geological, environmental and paleoclimate events [2,4-6]. As in general magnetic materials, the conditions and presence of magnetic minerals in volcanic ash are closely related to measurable magnetic properties. In this study, the researchers were interested in knowing the composition of the volcanic ash of Merapi explosion in 2010, its magnetic mineral content and the magnetic susceptibility. The results of this study can be used as comparative material or additional data in geological, environmental and paleoclimatological studies to justify the presence of Merapi volcanic ash deposits in sediments. Furthermore, if each volcanic eruption can be characterized by volcanic ash, then the data obtained can be very beneficial for these three study areas. So far, many studies on Merapi have been carried out by applying various Geophysical methods such as seismic, magnetic, resistivity or a combination of these methods to understand the activity and anomalies of magma distribution [7-9]. The study of rock magnetism is still not done. In this study, initial research was conducted on magnetic properties of volcanic product materials which are expected to be able to understand the mechanism of the volcano.

2. Sample Preparation and Measurement

Volcanic ash samples from the Merapi eruption were taken directly in the field area around Kaliurang, on October 27th, 2010. In the laboratory, samples were prepared in the form of non-extracted volcanic ash and volcanic ash extracted by magnetic minerals. Extraction is done in a simple way by inserting a bar magnet to separate magnetic minerals from other elements. This extraction process, of course will not be able to separate pure magnetic minerals. For XRF measurements, two samples were prepared, the non-extracted samples and the extracted ones, likewise for measuring magnetic susceptibility. Meanwhile for SEM measurements, specially prepared samples from extracted magnetic minerals. Before imaging process performed, the samples that have been ultrasonic are placed in the SEM holder and coated (coated with gold) and then SEM is carried out. There are ten non-extracted samples (M1-M10) which are included in a standard cylindrical cup for magnetic measurements and two cup extract samples (Mex1 and Mex2) and were measured for magnetic susceptibility using Bartington MS2B.

3. Results and Discussion

The XRF measurement results showed that the eruption of Merapi volcanic ash contained elements of aluminum (Al), Silicon (Si), Potassium (K), Calcium (Ca), Titanium (Ti) Iron (Fe) and others as indicated in Table 1. The concentration of the largest element is Silicon (Si) with a percentage of about 45%. Meanwhile iron (Fe) contained in the sample with a percentage of about 16%, an element of Titanium (Ti) with a percentage of about 1.2% and an element of Sulfur (S) with a percentage of 1.2%. By looking at the composition, it is possible for the presence of magnetic minerals in volcanic eruption ash to be iron titanium oxide. For extracted samples, the composition is also determined using XRF. From the extracts carried out, it turns out that iron minerals are not pure, but only about 55% while the presence of titanium increases to 4% and conversely silicon decreases to 22%. In general, extraction will increase the concentration of titanium and iron minerals but reduce the silicon. The test results for the content of Merapi elements were compared with the volcanic ash of Agung mount (see Table 1). The range of chemical elements composition still has similarities between volcanic ash of Merapi and volcanic ash of Agung volcano. The similarity of the concentration of the content of this element can be used as an indication of the similarity of the volcanism of the two volcanoes. Tests of the elemental content of volcanic ash in volcanoes throughout Indonesia need to be done to understand the pattern of volcanic mechanisms in Indonesia. Besides the study of the magnetic characteristics of certain volcanic materials, it is also necessary to carry out a characteristic test, each particular volcanic eruption. The study can also be expanded by testing the characteristics of igneous rocks that built the volcano.

Table 1. The concentration of elements contained in Merapi Volcanic Ash.

Element wt. (%)	**M**	**Mex**	**Agung volcano** [10]
Al	12	7.5	10
Si	45	22	34.7
S	1.2	0.6	3.2
K	7.3	3.51	2.41
Ca	14.3	5.26	13.8
Ti	1.16	4.1	1.89
V	0.064	0.28	0.13
Cr	0.039	0.67	0.064
Mn	0.47	0.79	0.31
Fe	15.9	55.3	28.4
Cu	0.077	0.088	0.15
Zn	0.05	0.94	0.02
Sr	0.58	-	0.54
Mo	1	-	3.5
Ba	0.33	-	-
Eu	0.2	0.56	0.4
Re	0.05	0.2	0.2

SEM results for a representative sample of magnetic minerals extracted from Merapi volcanic ash indicate that the size of magnetic minerals varies greatly from tens to hundreds of micrometers. The surface of magnetic minerals does not appear smooth or porous which is possible due to heating by very high temperatures experienced by the magnetic minerals before and during an eruption, then cools quickly to room temperature (Figure 1). As informed by the directorate of volcanology that the eruption temperature can reach thousands of degrees Celsius. The form of magnetic minerals is also very random, there are oval, almost round and irregular shapes. This is very different from natural magnetic minerals in soil or sediments which can be crystalline or rounded. The shape and surface of magnetic minerals from volcanic ash are also very different from the shape, size and surface of magnetic minerals dilated by geothermal for example hot springs which have shown the dominant crystalline magnetic minerals and very smooth and clean surfaces. The irregularities in the form of magnetic minerals in volcanic ash are thought to be caused by fragments of volcanic material due to very high temperatures and energy. Allegedly the more porous surface of the magnetic minerals, the warmer temperature of the ash. The smaller size of the grain the bigger eruption energy. This characteristic can be used as a marker of geological events related to volcanic activity. This needs to be justified for various volcanic ash of various volcanic eruptions.

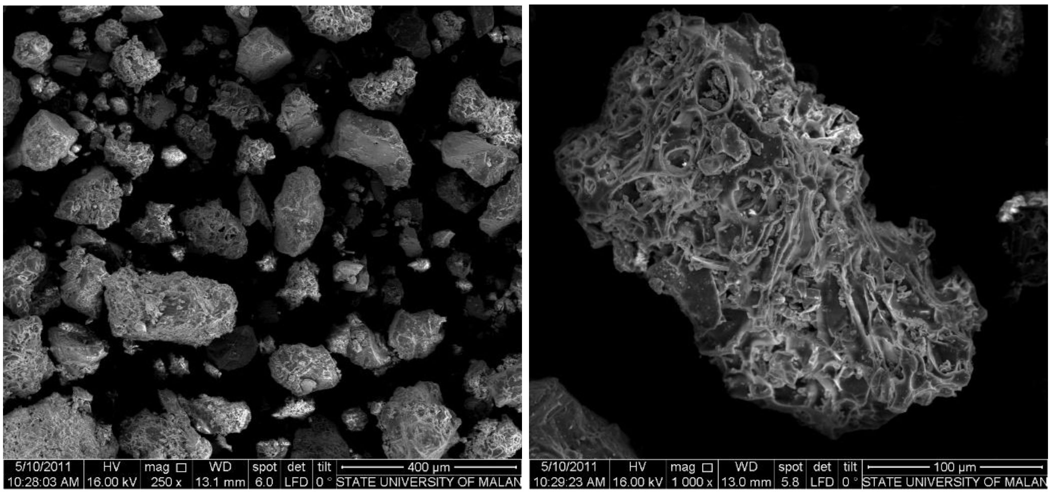

Figure 1. SEM Results representative sample of magnetic minerals in the dust of the Merapi eruption. The size and shape are very diverse (left), and the surface tends to be rough (right).

Measurement of magnetic susceptibility to 10 samples of non-extracted and 2 extract samples showed the range of magnetic susceptibility was relatively constant for each type of sample. For non-extract samples, the magnetic susceptibility is about 10×10^{-6} m^3/kg and for extracted samples of around 2200×10^{-6} m^3/kg. When compared to other volcanic ash, for example Kelud volcanic ash which erupted in 2014 and volcanic ash from Agung volcano the 2017 eruption, showed that the magnetic susceptibility of Merapi volcanic ash in a range 10×10^{-6} m^3/kg that is almost the same as the volcanic ash range of Agung volcano (7.7×10^{-6} m^3/kg) [10]. Meanwhile, the volcanic ash of Kelud eruption in 2014 shows the value of magnetic susceptibility of around 14×10^{-6} m^3/kg. The magnetic susceptibility looks very specific and different from other environments such as geothermal areas [11], and also very specific value comparing some other volcanic ash, mainly from Bromo and Tengger mountain [12]. According to Dearing (1999), for natural magnetic minerals, the smaller of magnetic susceptibility generally the smaller magnetic mineral grain size. This has been proven in several natural samples. If the size of the grain is related to the energy of the eruption, the smaller eruption energy the smaller the grain size, then the magnetic susceptibility can be used as a proxy for energy indicator of volcanic eruptions. However, this still has to be proven further. The range of susceptibility values should also be compared with other volcanic material such as sand or gravel, eruption material derived from igneous rock fragments. In the study of the magnetic susceptibility of Agung volcanic material, it has shown a range of magnetic susceptibility values for certain types of material that have a certain range [10].

4. Conclusion

From the results of measurement and discussion, it can be concluded that by considering the content of Merapi volcanic ash, it is possible that the magnetic minerals contained in the sample are iron titanium oxide (Titanomagnetite). Based on the measured composition, iron (Fe), silica (Si) and aluminum (Al) can be used as proxy data relating to the dynamics of the earth such as the event of a volcanic eruption. From the SEM imaging, it can be concluded that the magnetic minerals in the volcanic ash of Merapi have very diverse sizes and shapes with surfaces that tend to be porous. This is possible due to the very high temperatures and energy experienced by magnetic minerals. The results of measurements of magnetic susceptibility at low frequencies indicate in the same range of other volcanic ash from Agung mount and but has a specific value comparing to the Bromo and Tengger mountain. The study still needs to be continued to understand the magnetic properties of volcanic ash in different eruptions from Merapi volcano. Furthermore, the characteristics obtained can be compared with other volcanoes in Indonesia.

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