International Journal of Advanced Research and Development
www.multidisciplinaryjournal.net
ISSN: 2455-4030
Received: 09-11-2023, Accepted: 24-11-2023, Published: 10-12-2023
Volume 8, Issue 6, 2023, Page No. 18-21

Study of the shape and elemental composition of volcanic Ash from the Eruption of Mount Merapi on March 11, 2023, in Yogyakarta, Indonesia

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Abstract
Research has been carried out to analyse the morphology and composition of volcanic ash oxide compounds resulting from the eruption of Mount Merapi Yogyakarta on March 11 2023. Sampling was carried out around the Mount Merapi National Park Area Yogyakarta. The method used is Scanning Electron Microscopy-Energy Dispersive X-Ray Spectroscopy (SEM-EDX). The results show that the morphology of Mount Merapi's volcanic ash is in the form of glass fragments that have sharp, pointed, sharp and irregular angles. Apart from that, the topography of volcanic ash is flat, rough and textured. The mineral composition of Mount Merapi volcanic ash is dominated by Si, A, Ca, and O. This is followed by Fe and Na. The discovery of Fe indicates that the sample is thought to contain the magnetic mineral Fe3O4, which is ferrimagnetic.

Keywords: Volcanic ash, shape, elemental composition, Mount Merapi

Introduction

Of the approximately 500 volcanoes in the archipelago, 129 are suspected to be active and spread from Sabang to Merauke. One of the most active mountains in the world is Merapi. Mount Merapi is one of the most active mountains in the world. The eruption of Mount Merapi occurs in a cycle every 4–6 years. In the last ten years, two massive eruptions occurred in 2006, and the peak was in 2010, estimated to be the 100-year repeat cycle of Mount Merapi (Surono *et al*., 2012) [8]. 2023, there will be another eruption on Mount Merapi, precisely on March 11, 2023. Mount Merapi's eruption produced volcanic ash found in the Mount Merapi National Park area.

Mount Merapi has unique characteristics for the type of eruption that produces hot clouds or "wedus gembel" in Javanese terms or nuée ardente in scientific terms (Voight *et al*., 2000) [9]. Furthermore, Voight *et al*. (2000) [9] explained that Nuée ardente is a primary hazard caused by Merapi's eruption consisting of gas elements, boulders and volcanic ash, usually preceded by lava flows and lava dome collapse. The eruption of Mount Merapi, which occurred several times with high intensity and strength in October-November 2010, spewed out a massive amount of ash or material ranging from 150 million cubic meters. Of the several materials resulting from the eruption of Mount Merapi, volcanic ash is the most abundant and easy to find.

Volcanic ash is ash that comes from volcanic (volcanic) eruptions, which then flies in all directions according to the direction of the wind. Volcanic ash is often considered waste that disturbs society and can pollute the environment, even though volcanic ash contains materials that are beneficial to society (Murwanto *et al*., 2013) [4]. This volcanic ash can be used as a substitute for sand and as a soil amendment. Even this volcanic ash can also fertilize seawater. Several studies have been conducted to determine the benefits of volcanic ash for human life in agriculture (Natalia & Handayani, 2013) [5], fisheries, health and engineering (Gatot & Sulistia, 2020) [2].

In general, ash or material from volcanic eruptions such as Mount Merapi contains several metal elements such as Si, Al, Fe, Ca, Mg, Na, and K, as well as sulfur and possibly some dangerous heavy metal elements such as lead, cadmium, and arsenic. The elemental composition, especially Si, Al, and Ca contained in the material, gives the material the potential to be used as a base material for cement, ceramics, or adsorbents (Wahyuni *et al*., 2012 [10]; Ramadhanty *et al*., 2021) [7].

Volcanic ash can be used as an indicator of various volcanic eruptions. The characteristics of volcanic ash can describe volcanic mechanisms related to the temperature and strength of volcanic eruptions (Islamiyah *et al*., 2019) [3]. Volcanic ash deposited in sediments can also be a proxy indicator for geological, environmental and paleo-climatological events. By characterizing the magnetic and physical properties of volcanic ash, data that can be used as a guide to geological, environmental, and paleoclimatic events will be obtained. As with materials, the shape, grain size and composition of oxide compounds from volcanic ash can be measured.

Previous research was reported by Zulaikah (2019) [11] regarding the magnetic mineral morphology of volcanic ash from the 2010 eruption of Mount Merapi. The Merapi volcanic ash samples' magnetic mineral content is considered iron titanium oxide (Titanomagnetite). Based on the measured composition, iron (Fe), silica (Si), and aluminium (Al) can be used as proxy data related to earth dynamics such as volcanic eruptions. SEM image results show that the magnetic minerals in Merapi volcanic ash have very diverse sizes and shapes with surfaces that tend to be porous. It is possible due to the extremely high temperatures and energies that magnetic minerals experience.

In this research, researchers are interested in knowing the form and elemental composition of volcanic ash from the eruption of Mount Merapi on March 11 2023. The results of this research can be used as comparative material or additional data in geological, environmental and paleoclimatological studies to confirm the presence of Merapi volcanic ash deposits in sediments.

Materials and methods

The material used is volcanic ash from Mount Merapi due to the eruption on March 11 2023. The tools used are a Global Positioning System (GPS), digital balance, 100 mesh sieve, and SEM Brand JEOL Type JSM-6701F integrated with Energy Dispersive X-ray Spectroscopy (EDX). Volcanic ash sampling was carried out in the Mount Merapi National Park Area at a radius of 4-5 km from the centre of the eruption, totalling three samples (Figure 1). A sample of volcanic ash was taken and weighed 50 g. Retrieval of sampling position coordinate data using GPS.

At the preparation stage, the volcanic ash samples were dried at room temperature until the water content in the samples disappeared. The dried samples were then crushed until smooth and filtered using a 100-mesh sieve. Then, 10 g was weighed again for each sample, and a Scanning Electron Microscopy-Energy Dispersive X-ray spectroscopy (SEM-EDX) test was carried out.

Testing the shape of volcanic ash grains from Mount Merapi using a JEOL Type JSM-6701F SEM tool integrated with EDX. In the SEM test, the grain shape of the sample was observed using the SEM Inspect S50 machine. Equipped with Image software, this software is used to obtain grain shapes from volcanic ash. EDX testing aims to determine the elemental composition of volcanic ash samples. EDX testing was carried out using a Jeol JSM-6701F SEM tool equipped with INCA software to obtain information on the constituent elements of volcanic ash.

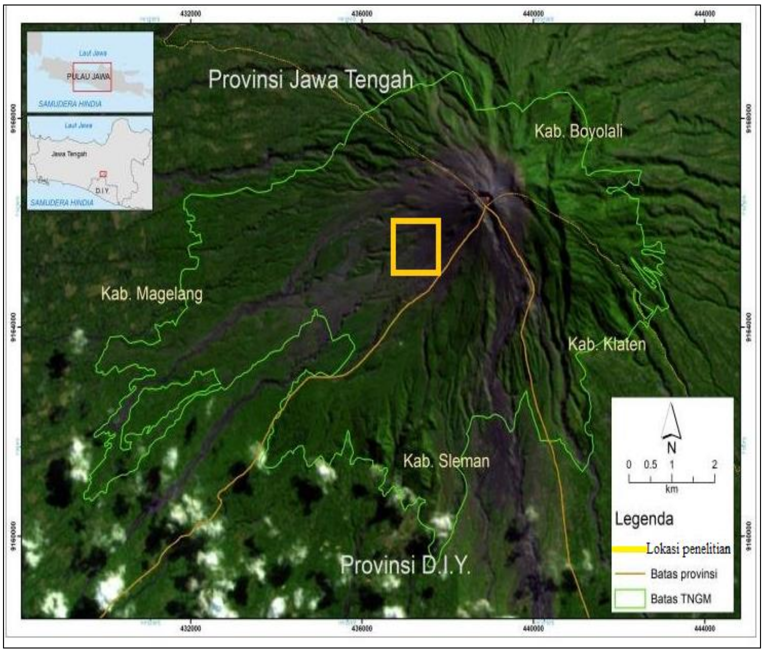

Fig 1: Sampling location

Results and discussion

SEM-EDX characterisation was performed to determine the shape and size of the particles in the volcanic ash samples from Mount Merapi. The samples taken for this test were A, B, and C. SEM images of volcanic ash samples from Mount Merapi are shown in Figures 2, 3, and 4.

Figures 2, 3, and 4 show several similarities in the shape of the volcanic ash grains from these three samples. The shape of the grains is very random; some are shaped like glass shards with sharp corners, pointed, sharp, oval, almost round, and irregular. Apart from that, the topography of volcanic ash has an uneven surface that could be smoother, rough and textured. These results are from research conducted by Cahyandaru *et al*. (2012) [1], which showed that the SEM test results of volcanic ash from Mount Merapi, Yogyakarta, in the 2010 eruption had an irregular shape. It also appears that the volcanic ash particles from Mount Merapi have large grain sizes.

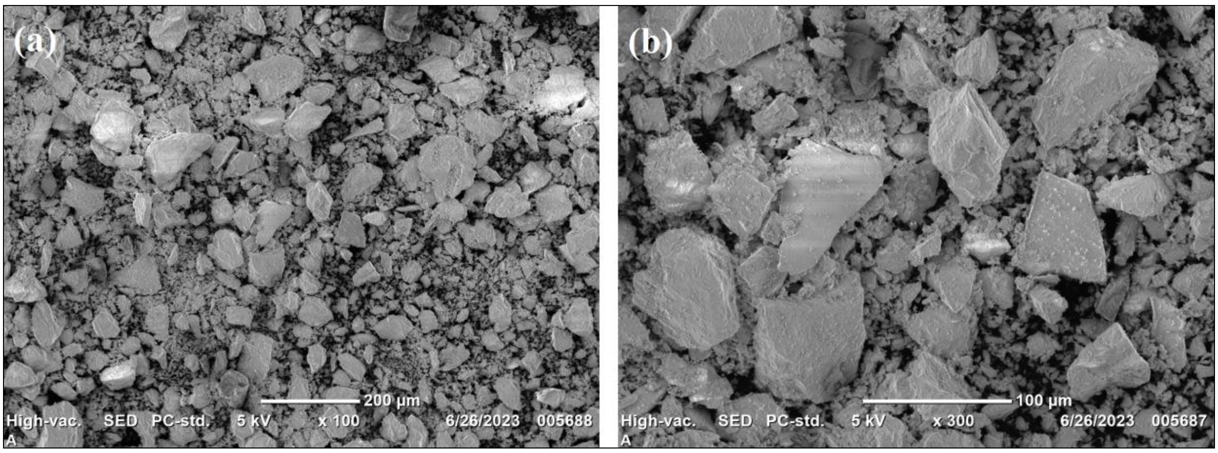

Fig 2: SEM image of sample A of Mount Merapi volcanic ash with a magnification of (a) 100x and (b) 300x

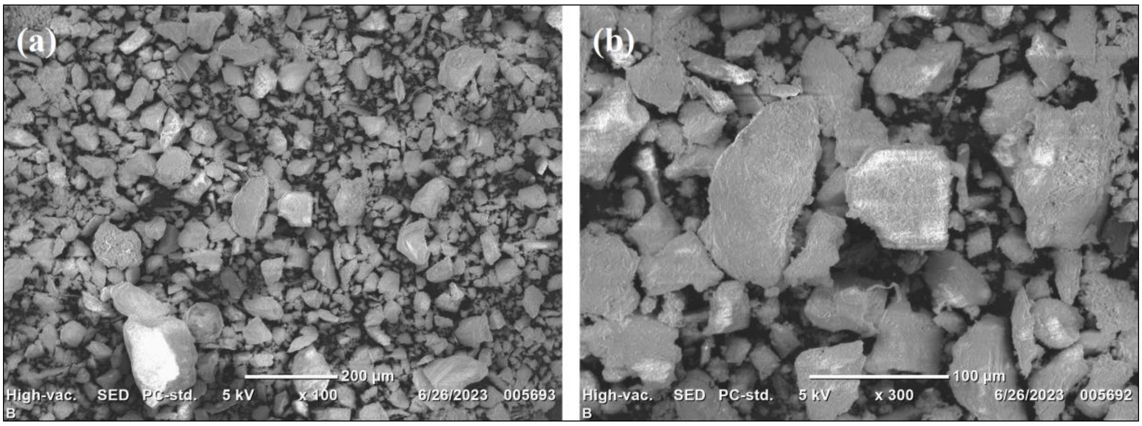

Fig 3: SEM image of sample B of Mount Merapi volcanic ash with a magnification of (a) 100x and (b) 300x

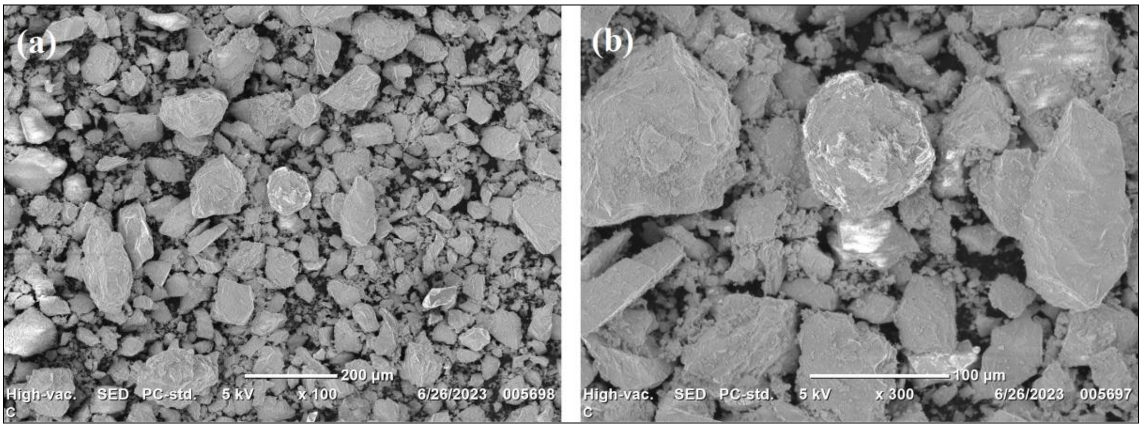

Fig 4: SEM image of sample C of Mount Merapi volcanic ash with a magnification of (a) 100x and (b) 300x

It is possible due to the high-temperature heating experienced by magnetic minerals before and during the eruption, then cooling quickly to room temperature. According to the Directorate of Volcanology information, the eruption temperature could reach thousands of degrees Celsius. The difference in grain shape in volcanic ash is thought to be caused by the fragmentation of volcanic material due to very high temperatures and energy. It is thought that the more porous the surface of the grain, the warmer the temperature of the ash. The smaller the grain size, the greater the eruption energy (Zulaikah, 2019) [11]. These characteristics can be used as markers of geological events related to volcanic activity. It needs to be justified for various volcanic ash from various volcanic eruptions.

Table 1 shows the EDX measurement results of Mount Merapi volcanic ash samples. The elemental composition of Mount Merapi volcanic ash is dominated by Si, Al, Ca, and O. Next, followed by Fe and Na. The presence of Si content suggests that volcanic ash contains SiO_2 compounds. SiO2 content was also found in the volcanic ash of Mount Bromo (Ramadhanty *et al.*, 2021) [7]. The SiO_2 content causes magma to have acidic properties and is associated with dominantly explosive eruptions. The gas and SiO_2 content in magma are determining factors for explosive eruptions, which tend to be acidic (Pandara, 2017) [6]. In the volcanic ash of Mount Merapi, the element Fe, which is ferromagnetic, was also found. Even though its composition is small, Fe controls the magnetic mineral content in volcanic ash. Thus, Mount Merapi's volcanic ash is suspected to contain the mineral Fe_3O_4. This magnetic mineral is included in the category of ferrimagnetic minerals.

Table 1: Elemental composition of Mount Merapi volcanic ash.

Element		Mass (%)		
Name	**Chemical formula**	**A**	**B**	**C**
Oxygen	O	20.01	23.53	20.46
Natrium	Na	1.99	2.02	2.37
Aluminum	Al	23.27	20.49	23.29
Silicone	Si	33.19	34.58	35.80
Calcium	Ca	16.78	16.09	15.21
Iron	Fe	4.77	3.29	2.87

Conclusion

SEM results show that the shape of the grains is very random; some are shaped like glass shards with sharp, pointed, oval, almost round, and irregular corners. The topography of volcanic ash has an uneven surface that does not appear smooth, rough and textured. It is possible due to the high-temperature heating experienced by magnetic minerals before and during the eruption, then cooling quickly to room temperature. EDX results show that Si dominates the elemental composition of Mount Merapi's volcanic ash. In samples of volcanic ash from Mount Merapi, the element Fe was also found, so it is suspected that the samples contain the magnetic mineral Fe_3O_4, which is ferrimagnetic.

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