Grain Shape Analysis of the Volcanic Ash Particle from Soputan Volcano to Investigate Eruption Type

D Tampenawas*, M Bobanto, D Pandara, Ferdy, G Pasau, GAbidjulu and V Kaendung
Department of Physics, Sam Ratulangi University, Manado, Indonesia

*Corresponding author: mariabobanto5@unsrat.ac.id

Abstract. Volcanic ash showcases a diverse spectrum of shapes, each with different physical properties and behaviours. Those properties and behaviours are often linked with fragmentation process of the magma inside the volcano. Analyzing the shape of a volcanic ash can give us valuable information behind the magma formation and the eruption style of a volcano. This research are conducted in hope to find implication between volcanic ash grain size and the eruption style of Mount Soputan. Sample from Soputan volcano eruption are choosed because of the danger the mountain holds to the populated area that surrounds it. Samples from three different eruption date are collected and being examined by ImageJ to determine the shape parameters needed in order to find the eruption type. Manual observation are also conducted to support the result from software analysis.

1. Introduction
Volcanic eruptions are one of the natural disasters with the greatest potential danger in Indonesia. Apart from the high number of casualties, the eruption disaster was also followed by large-scale damage to infrastructure and long-term social and economic impacts [1]-[3]. North Sulawesi is one of the areas in Indonesia that is vulnerable to the threat of volcanic eruptions. One of the most active volcanoes with high potential hazards is Mount Soputan [4]. The danger aspect of Mount Soputan is due to its typical eruption in the form of an explosive eruption with a VEI index of 2-3 which can eject pyroclastic material such as ash, sand, lapilli, and bombs, as well as incandescent lava avalanches [5]. Given the potential dangers, early warning efforts of an eruption must be carried out. One of the important early warning efforts in anticipating the dangers of volcanic eruptions is through understanding the character of volcanic eruptions.

Volcano-inspired ash can provide significant information because the ash comes from magma rising from the depths of the mountain body. This volcanic ash is the result of magma interaction with various processes ranging from magma sacs to oxidation in the atmosphere. Characterization and analysis of the microstructure and geochemical composition of volcanic ash will be able to provide an explanation of the eruption process that occurred in aspects of mineralization, crystallization, vesiculation and fragmentation [6]-[7]. Heiken, 1972 shows that in-depth studies related to the morphology of ash have a relationship with magma composition and type of eruption [8]. Therefore, by analyzing the form of ash, we can get a deeper understanding of the physical mechanisms of volcanic eruptions that can help mitigate disasters due to volcanic eruptions [9]-[10].
Thus, characterization and analysis of the microstructure and geochemistry of the ash from the eruption of Mount Soputan can answer problems related to the mechanism and typical eruptions so as to provide basic information that is important for future mitigation efforts.

2. Methodology

This research uses Scanning Electron Microscopy technique to get the micro structure of the ash particle and then we uses image processing software Image-J to get the shape parameter needed. The research workflows follows the following steps:

a. Preparation
At the preparation stage, the sample will be separated into three fractions, namely fine fraction (<75 µm), medium fraction (70 - 125 µm) and coarse fraction (> 125 µm) with variations in sieve arrangement.

b. Microstructure Analysis
The eruption ash microstructure analysis will be carried out using SEM. The SEM image will be analyzed with Image J software to observe grain size and vesicle size. Morphological parameters of the microstructure of the ash to be studied are grain size and vesicularity.

c. Conclusion
The results of the microstructure analysis of the eruption ash using SEM in the form of parameters of grain size, form factor, roundness, compactness, aspect ratio, will be used to observe the eruption processes and determine the type of eruption.

3. Results and Discussion

Results from the research conducted by using image analysis software ImageJ produces number of shape perimeters essential for determining eruption style such as area of particle, aspect ratio, compactness, roundness.

The area size obtained from ImageJ processing showcases a wide range of size varying from the 15720.23 to 23749.8 µm² as shown in Table 1, Table 2 and Table 3. The area size parameter obtained itself cannot be the sole parameter to determine the type of eruption and thus needs to be compared with other parameters to be able to determine the type of eruption better. The numbers obtained from the shape parameter analysis and result from manual observation shows that most of the ash particle have blocky and blocky vesicular shape as seen in Figure 1 which implicates a phreatomagmatic eruption [9]. Phreatomagmatic are driven from thermal contraction of magma when it comes in contact with water. This temperature difference between the two causes violent water-lava interactions that make up the eruption. The products of phreatomagmatic eruptions are believed to be more regular in shape and finer grained than the products of magmatic eruptions because of the differences in eruptive mechanisms [8].

Variety in both compactness between all three samples doesn’t shows much difference with one another except for sample collected from October 2018 eruption as shown in Figure 2, Figure 3 and Figure 4. This may have caused by difference in eruption style between eruption on October 2018 and the other two eruption. Furthermore, deeper investigation regarding the chemical parts of the ash can shows a lot more details as to the difference in eruption style but overall, it conforms to the theory and previous research that the numbers shown which ranges from 0.56-0.92 to the highest shows the almost complete level of magmatic process inside the volcanic chamber that might helps shape the ash into a more regular shape.
Table 1. Shape parameters obtained from ImageJ on sample collected from Mt. Soputan eruption on October 2018 size 75-125 (μm) under 500x magnification.

| Count | Area     | AR  | Comp | Round | Form Factor |
|-------|----------|-----|------|-------|-------------|
| 55    | 23749.8  | 3.21| 0.56 | 0.31  | 0.27        |
| 39    | 22311.62 | 2.75| 0.6  | 0.36  | 0.4         |
| 40    | 19850.02 | 1.24| 0.9  | 0.81  | 0.56        |
| 1     | 15720.23 | 1.69| 0.77 | 0.59  | 0.35        |

Table 2. Shape parameters obtained from ImageJ on sample collected from Mt. Soputan eruption on February 2016 size 75-125 (μm) under 500x magnification.

| Count | Area     | AR  | Comp | Round | Form Factor |
|-------|----------|-----|------|-------|-------------|
| 1     | 19444.79 | 1.2 | 0.91 | 0.84  | 0.52        |
| 3     | 20167.78 | 1.29| 0.88 | 0.77  | 0.35        |
| 8     | 20661.89 | 1.18| 0.92 | 0.84  | 0.41        |
| 49    | 13981.24 | 1.41| 0.84 | 0.71  | 0.51        |

Table 3. Shape parameters obtained from ImageJ on sample collected from Mt. Soputan eruption on January 2016 size 75-125 (μm) under 500x magnification.

| Count | Area     | AR  | Comp | Round | Form Factor |
|-------|----------|-----|------|-------|-------------|
| 148   | 17319.75 | 1.21| 0.91 | 0.83  | 0.48        |
| 101   | 19985.53 | 1.33| 0.87 | 0.75  | 0.38        |
| 115   | 19735.76 | 1.34| 0.86 | 0.75  | 0.58        |
| 59    | 18990.51 | 1.26| 0.89 | 0.79  | 0.58        |

Figure 1. Comparison between ash collected from Mt. Soputan eruption on January 2016 (Left) and Grain type morphology overview from Liu, 2015 (Right)
Figure 2. A Sample of the ash collected from October 3rd, 2018 eruption after thresholding

Figure 3. A Sample of the ash collected from October 3rd, 2018 eruption after thresholding

Figure 4. A Sample of the ash collected from October 3rd, 2018 eruption after thresholding
4. Conclusion

The shape parameters obtained from ImageJ conforms to previous research that the numbers shown from examining all three samples shows blocky to blocky vesicular figure which usually produced by explosive type eruption. Further investigation on other aspects of the material may provide a more detailed information about the eruption type but as for general information, shape parameters analysis can bring sufficient information.

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