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# Multimethod Characterization of Volcanic Ashes from The Sunda Island Arc

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**Abstract.** Compared to other countries in the world, Indonesia has the highest number of volcanoes; many of these volcanoes are located in the Sunda Island Arc. Considering their importance's as geological markers, identification of the sources of volcanic ashes is challenging and intriguing task. Standing on that reason, this study was aimed to characterize the magnetic and geochemical properties of several volcanic ashes from Sunda Island Arc to test whether these properties could serve as identifiers for the sources. This study used the ashes from Mount Sirung (in Pantar) and from Mounts Merapi and Slamet (in Java). The data would then be combined and compared with previous studies that used ashes from other volcanoes both inside as well as outside the Sunda Island Arc. The results showed that the magnetic susceptibility of Mounts Merapi and Slamet differed not too much, while that of Mount Sirung differed significantly due to low magnetic content. The plot of hysteresis parameters classified Mount Merapi into PSD domain and Mount Slamet into SP domain, while that of Mount Sirung could not be performed due to the weak signal obtained. Geochemical data also showed that ashes from Mount Sirung contained much lower concentration of  $\text{Na}_2\text{O} + \text{K}_2\text{O}$  compared to that in Mounts Merapi and Slamet. Each volcano had its distinct magnetic properties when these properties were compared to that of other volcanoes previously studied. The geochemical data also could reflect its magma properties regarding to its geological setting. It could be concluded that these multimethod approaches were able to differentiate volcanic ashes based on their sources.

## 1. Introduction

According to LIPI (Lembaga Ilmu Pengetahuan Indonesia-Indonesian Sciences Institution) (2012), Indonesia has the highest number of volcanoes compared to other countries in the world [1]. Many of these volcanoes are located in the Sunda Island Arc [13]. Sunda Island Arc became one of the most active regions since it was formed by subduction between Indo-Australia and Eurasia plates [2, 14]. Considering the existence of volcano-chain in the Sunda Island Arc, the studies on volcanoes in this region became so important. One of the studies regarding to volcanoes is about its products. Volcanic ash is one of the important products since it could serve as geological markers. Considering their importance's as geological markers, identification of the sources of volcanic ashes is challenging and intriguing task.



Previous studies including Zhou et al. [3] and Ruggieri et al. [4] had used geochemical analyses to identify volcanic ashes. While, Sanchez et al. [5] used petrography analyses. Those two analyses could not precisely identify the volcanic ashes due to the wide range of values obtained. Therefore, to complement those two methods, magnetic methods were also conducted in this study. This study was aimed to characterize the magnetic and geochemical properties of several volcanic ashes from Sunda Island Arc to test whether these properties could serve as identifiers for the sources.

## 2. Materials and Methods

This study used the ashes from Mount Sirung (in Pantar) and from Mounts Merapi and Slamet (in Java). The data would then be combined and compared with previous studies that used ashes from other volcanoes both inside as well as outside the Sunda Island Arc. Figure 1 below showed the locations of those three volcanoes relative to other volcanoes, both inside as well as outside the Sunda Island Arc, that were used in this study.

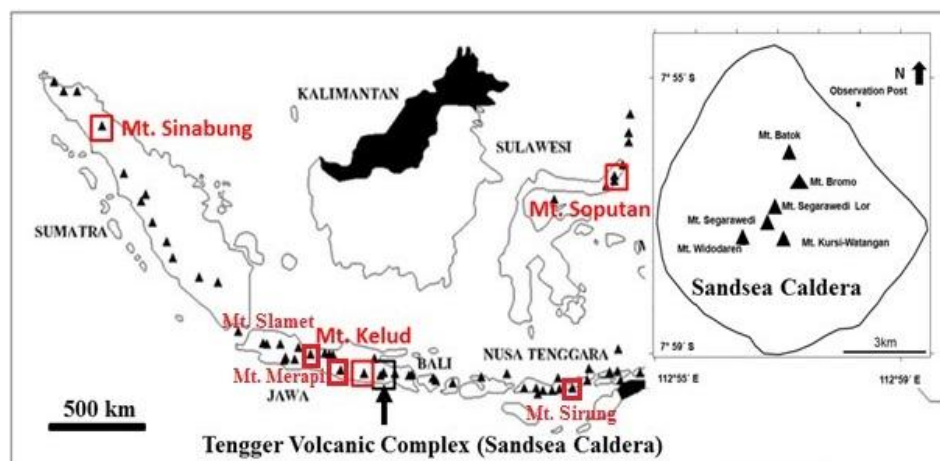


Figure 1. Locations of the volcanoes used in this study (modified from Santoso et al. [6])

Before the measurements and analyses were done, all the samples were prepared first. After the preparation, petrography analyses using polarization microscope were done to quantify the percentage of Opaque minerals and fragments composing each of the samples. Opaque minerals were the magnetic bearing minerals. After that, the geochemical analyses using X-Ray Fluorescence (XRF) method were done to quantify the percentage of major and trace elements composing each sample. It was useful to understand the type of the origin rocks from each sample. Then, the magnetic methods consisting of susceptibility measurement using Susceptibilitymeter and hysteresis parameters determination using Vibrating Sample Magnetometer (VSM) were also done. The susceptibility could indicate the number of magnetic minerals that each sample contained, while the hysteresis parameters represented its magnetic characters.

## 3. Results and Discussion

Table 1 showed the results of the petrography analyses. From the Table 1 below, Slamet ash had the highest crystal composition among the others. It meant that the magma cooling happened relatively slowest than the others [7]. While, Sirung ash was composed by nearly all lithic fragments. It could indicate that the ash was the product of phreatic eruption. Merapi and Slamet ashes both had the same concentration of Opaque minerals. It meant that the concentration of magnetic minerals would be relatively the same too.

Table 1. Volcanic ashes composition based on petrography analyses

Sample	Crystal (%)	Lithic (%)	Glass (%)	Opaque Mineral (%)	Hollow (%)
Merapi	44	10	30	15	1
Slamet	55	0	30	15	0
Sirung	1	98	0	1	0

Table 2 showed the geochemical composition of each ash. The data from Table 2 were then plotted as seen in Figure 2.

Table 2. Geochemical composition of volcanic ashes based on XRF analyses

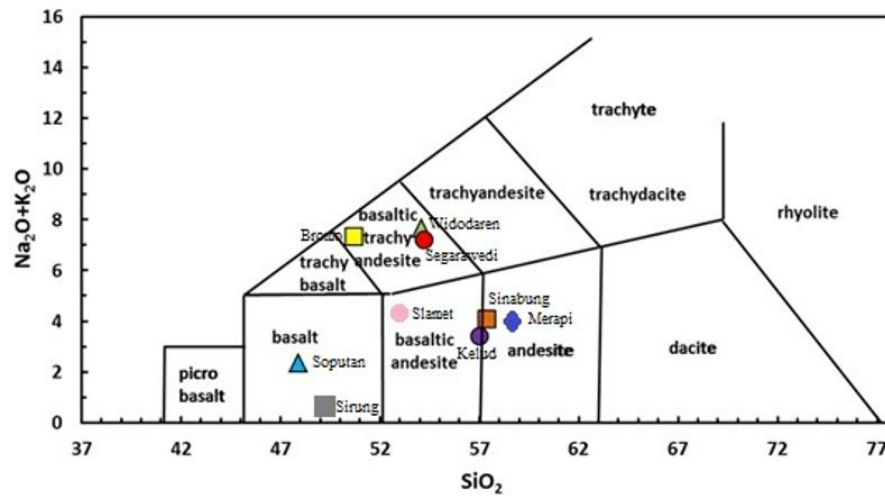
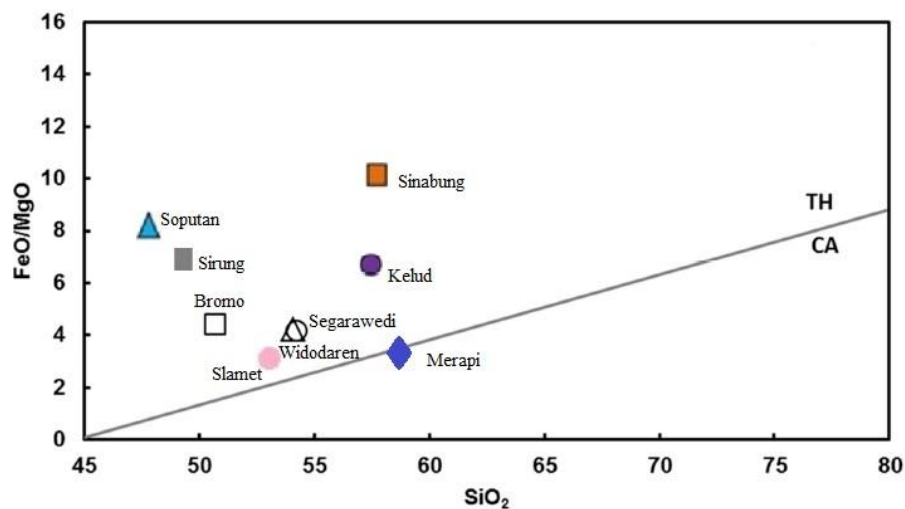
Oxides	Merapi	Slamet	Sirung	BR*	WDD*	SWD*	KD**	SB**	SPT**
SiO <sub>2</sub>	58.67	52.99	49.23	50.70	54.09	54.22	57.00	57.40	47.90
TiO <sub>2</sub>	0.43	0.77	0.49	1.17	1.05	1.02	0.82	0.75	0.98
Al <sub>2</sub> O <sub>3</sub>	15.96	16.36	3.64	17.09	18.23	18.82	18.70	18.80	21.20
Fe <sub>2</sub> O <sub>3</sub>	7.75	11.15	0.78	10.93	9.57	9.29	8.43	7.23	13.00
MnO	0.16	0.17	0.01	0.20	0.19	0.18	0.23	0.14	0.28
MgO	2.31	3.54	0.11	2.22	2.04	2.00	1.30	0.71	1.60
CaO	8.42	9.20	0.41	7.58	6.08	5.90	8.57	6.33	11.50
Na <sub>2</sub> O	3.06	3.32	0.35	4.15	4.40	4.24	2.19	1.64	1.85
K <sub>2</sub> O	1.21	1.16	0.38	3.20	3.27	2.97	1.23	2.43	0.49
Others	1.68	1.11	44.01	1.98	0.60	0.80	1.55	4.58	1.20
Total	99.65	99.77	99.40	99.22	99.52	99.44	100	100	100

\*[6]; \*\*[8]

From the plot Na<sub>2</sub>O+K<sub>2</sub>O versus SiO<sub>2</sub> [9], Merapi ash could be considered as andesite. Slamet ash with lower SiO<sub>2</sub> concentration than Merapi ash was considered as basaltic-andesite. Sirung ash with the lowest Na<sub>2</sub>O+K<sub>2</sub>O and SiO<sub>2</sub> concentration among those three ashes was considered as basalt. The interesting fact could be seen from the plot where all samples from volcanoes within the same caldera (Bromo, Widodaren, and Segarawedi) were considered as basaltic trachy andesite [6].

Data from Table 2 were also plotted in Figure 3. The FeO/MgO versus SiO<sub>2</sub> plot [10] showed that only Merapi ash was classified as calc-alkaline group, while others were classified as tholeiitic group. The calc-alkaline group underwent oxidation, while the tholeiitic related to reduction within the initial magma.

The measurement of susceptibility to each of the sample would give result as seen in Table 3 below. The data from Table 3 were then plotted as seen in Figure 4. From the  $\chi_{FD}$  versus  $\chi_{LF}$  plot [11], it could be seen that each sample gathered based on the similarity of the sources. It could also be seen that the gathering of samples from the same caldera was close each other. Samples from Merapi, Kelud, and Sinabung had the  $\chi_{FD}$  percentage below 2%, while others had percentage between 2-10%. It meant those three samples from Merapi, Kelud, and Sinabung consisted of non-SP (superparamagnetic) grains, while others consisted of the mixing of SP and non-SP grains.

Figure 2.  $\text{Na}_2\text{O}+\text{K}_2\text{O}$  versus  $\text{SiO}_2$  plot [9]Figure 3. The  $\text{FeO}/\text{MgO}$  versus  $\text{SiO}_2$  plot [10]

The measurement of hysteresis parameters by using VSM would result on the Day plot [12] as seen in Figure 5. The plot showed that samples from the same sources would gather each other, while samples from different sources would occupy the different plot also. From that plot, it could be seen that sample from Mount Slamet belong to SP, while samples from Mounts Merapi, Bromo, Segarawedi, Kelud, Sinabung, and Soputan belong to PSD (Pseudo Single Domain). Only samples from Mount Widodaren belong to MD (Multi Domain). The difference on the domain indicated the difference on the magnetic grains size. The SP group had the smallest grain size of about  $0.001\ \mu\text{m}$ , while the PSD had the grain size of  $1\text{--}10\ \mu\text{m}$ . The MD with the grain size bigger than  $10\ \mu\text{m}$  was the biggest magnetic grain size.

Table 3. The susceptibility of each sample

Sample	$\chi_{\text{LF}}$ ( $\times 10^{-8}\text{ m}^3/\text{kg}$ )	Average $\chi_{\text{LF}}$ ( $\times 10^{-8}\text{ m}^3/\text{kg}$ )	$\chi_{\text{HF}}$ ( $\times 10^{-8}\text{ m}^3/\text{kg}$ )	Average $\chi_{\text{HF}}$ ( $\times 10^{-8}\text{ m}^3/\text{kg}$ )	$\chi_{\text{FD}}$ (%)	Average $\chi_{\text{FD}}$ (%)
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M1	1385.6	1421.00	1374.8	1410.87	0.78	0.71
M2	1442.9		1432.8		0.7	
M3	1434.5		1425		0.66	
SL1	989.6	976.37	959.9	955.83	3	2.10
SL2	970		957.4		1.3	
SL3	969.5		950.2		1.99	
SI1	25.4	28.40	23.8	27.00	6.3	5.03
SI2	34.2		32.8		4.09	
SI3	25.6		24.4		4.69	
BR*	-	464.98	-	448.54	-	3.54
WDD*	-	354.64	-	341.04	-	3.83
SWD*	-	530.26	-	511.36	-	3.56
KD**	-	1397.97	-	1390.37	-	0.54
SB**	-	668.9	-	662.07	-	1.03
SPT**	-	971.1	-	943.03	-	2.89

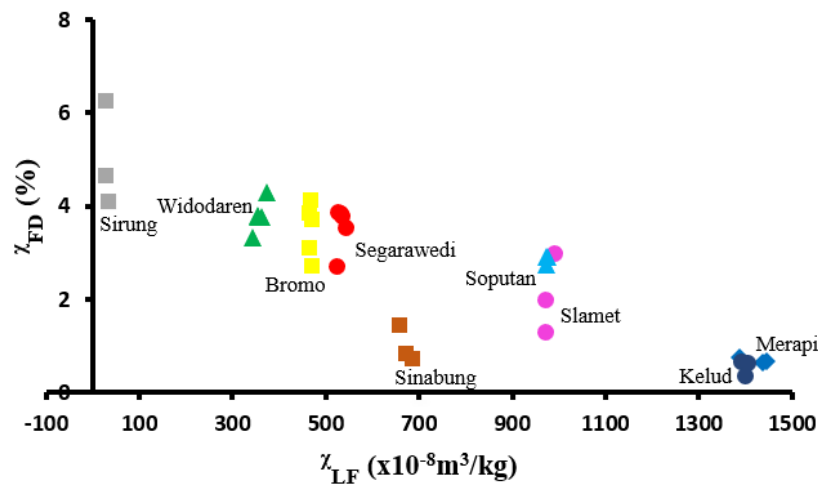
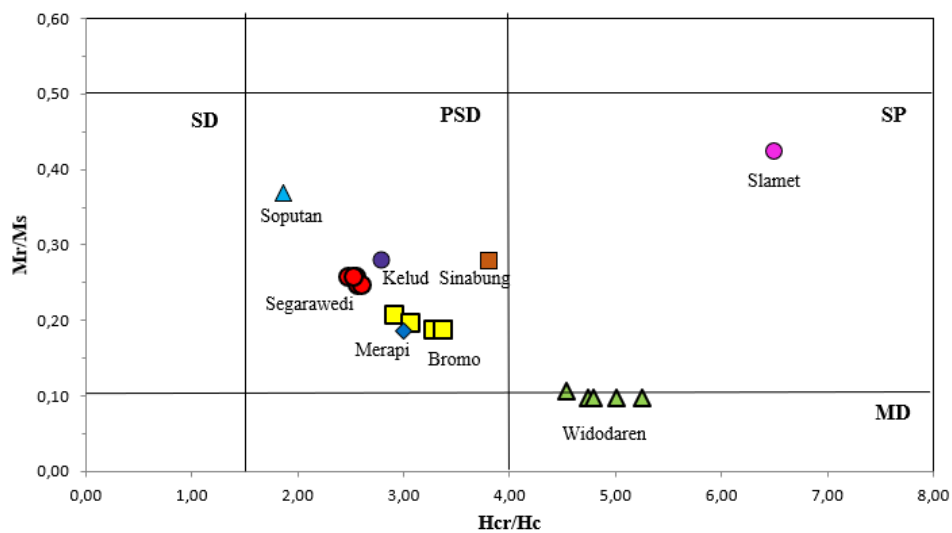
Figure 4. The  $\chi_{FD}$  versus  $\chi_{LF}$  plot [11]

Figure 5. The Day plot [12]

#### 4. Conclusion

Merapi ash had the highest susceptibility value when compared to other samples and belonged to the PSD domain. The sample contained the highest SiO<sub>2</sub> of all samples studied and its magma belonged to the calc-alkaline group. Slamet ash was classified into SP domain and its magma belonged to the tholeiitic group. Sirung ash sample had the lowest susceptibility and Na<sub>2</sub>O + K<sub>2</sub>O concentrations among the samples studied and its magma belonged to the tholeiitic group.

#### References

- [1] LIPI, Data jumlah gunung api aktif di Indonesia, Available online: <http://lipi.go.id/lipimedia/indonesia-miliki-127-gunung-api-aktif/7448>, Accessed on 2 October 2017.
- [2] Verstappen H Th 2010 Indonesian landforms and plate tectonics *Jurnal Geologi Indonesia* **5**(3) 197-207.
- [3] Zhou Y, Bohor B F, and Ren Y 2000 Trace element geochemistry of altered volcanic ash layers (tonsteins) in Late Permian coal-bearing formations of eastern Yunnan and western Guizhou Provinces, China *International Journal of Coal Geology* **44** 305-324.
- [4] Ruggieri F, Fernandez-Turiel J L, Saavedra J, Gimeno D, Valenzuela E P, and Naranjo J A 2011 Environmental geochemistry of recent volcanic ashes from the Southern Andes *Environmental Chemistry* **8** 236-247.
- [5] Sanchez M C, Sarrionandia F, Arostegui J, Martin J E, and Ibarguchi J I G 2016 Petrography and geochemistry of achnelithic tephra from Las Herrerías Volcano (Calatrava volcanic field, Spain): Formation of nephelinitic achneliths and post-depositional glass alteration *Journal of Volcanology and Geothermal Research* **327** 484-502.
- [6] Santoso N A, Bijaksana S, Kodama K, Santoso D, and Dahrin D 2017 Multimethod approach to the study of recent volcanic ashes from Tengger Volcanic Complex, Eastern Java, Indonesia *Geosciences* **7** 63.
- [7] Fischer R V, Heiken G, and Hulen J B 1998 Volcanoes: Crucibles of change *Princeton University Press, United States* 133.
- [8] Santoso N A, Fajri R, and Bijaksana S 2018 Identifying volcanic ash through magnetic parameters: Case studies of Mount Sinabung and other volcanoes *Aip Conference Proceedings* **1987**, 020039 (2018).
- [9] Le Bas M J, Le Maitre R W, Streckeisen A, and Zanettin B 1986 A chemical classification of volcanic rocks based on the total alkali-silica diagram *Journal of Petrology* **27** 745-750.
- [10] Miyashiro A 1974 Volcanic rock series in island arcs and active continental margins *American Journal of Science* **274** 321-355.
- [11] Bijaksana S and Huliselan E K 2010 Magnetic properties and heavy metal content of sanitary leachate sludge in two landfill sites near Bandung, Indonesia *Environmental Earth Sciences* **60** 409-419.
- [12] Day R, Fuller M D, and Schmidt V A 1977 Hysteresis properties of titanomagnetites: Grain size and composition dependence *Physics of The Earth and Planetary Interiors* **13** 260-266.
- [13] Gunawan E, Ghosalba F, Syauqi, Widiastomo Y, Meilano I, Hanifa N R, Daryono and Hidayati S 2017 Field Investigation of the November to December 2015 Earthquake Swarm in West Halmahera, Indonesia *Geotechnical and Geological Engineering* **35**(1) 425-432 DOI: 10.1007/s10706-016-0117-4.
- [14] Simons W J F, Socquet A, Vigny C, Ambrosius B A C, Haji Abu S, Promthong C, Subarya C, Sarsito D A, Matheussen S, Morgan P, and Spakman W 2007 A decade of GPS in Southeast Asia: Resolving Sundaland motion and boundaries *Journal of Geophysical Research: Solid Earth* **112**(B6).