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RESEARCH ARTICLE

PETROLOGY OF VESICULAR BASALT OF YOUNG SLAMET VOLCANO, BANYUMAS REGENCY, CENTRAL JAVA

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Abstract
Vesicular basaltic rocks are exposed on the southern slope of Slamet Volcano, forming part of the Young Slamet Volcano system. Due to the lack of detailed studies on these vesicular basalts, this research aims to describe their petrology and mineral composition. Field observation methods and direct descriptions of outcrops and rock samples were conducted, along with petrographic analysis to determine the mineral composition. Petrologically, the basalt outcrops are dark gray, ranging in dimensions from 30 cm to 3 meters, and extend along the river. The rocks exhibit an aphanitic texture with a vesicular structure, composed of plagioclase, olivine, and pyroxene as phenocrysts with a porphyritic texture and vesicular structure. Specific textures such as zoning and sieve textures provide evidence of magma mixing, while the presence of glomerocrysts indicates fractional crystallization processes.

Keywords: Slamet Volcano, Basalt, Petrography, Petrology.

1. Introduction

Basalt is a volcanic igneous rock formed by the solidification of basaltic lava on the Earth's surface, typically characterized by a mineral composition dominated by plagioclase, pyroxene, and minor amounts of olivine (Winter, 2010). This rock is classified as mafic, with a relatively low silica content (45–52%) but enriched in iron (Fe) and magnesium (Mg), making it one of the most common volcanic rocks in oceanic crust and continental volcanic regions (Wilson, 1989). Basalt formation is commonly associated with specific tectonic settings, such as divergent plate boundaries along mid-ocean ridges and subduction zones that form continental volcanoes (Winter, 2010).

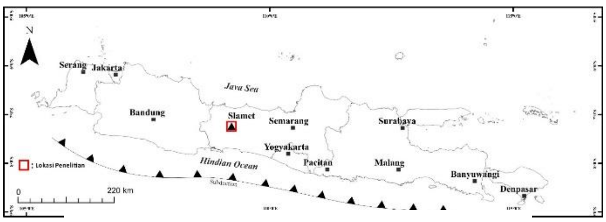

Fig. 1: Distribution of active volcano in Indonesia.

Vesicular basalt forms when gas-rich magma reaches the surface and undergoes rapid decompression, allowing gas bubbles to escape and create vesicles or cavities in the rock as the lava cools. This phenomenon makes vesicular basalt important in volcanological studies, as it provides insights into pressure and decompression conditions during eruptions and helps in identifying lava flow histories and cooling processes (Zou & Guo, 2024). Studying the petrology of volcanic rocks thus contributes significantly to understanding the behavior of magma in volcanoes.

Slamet Volcano is a type-A active stratovolcano located in Central Java Province (Figure 1), with strombolian-type eruptions characterized by basaltic magma producing scoria, volcanic bombs, and basaltic lava flows. The volcano remains active, with its most recent recorded activity occurring from September 1 to October 18, 2023 (Global Volcanism Program, 2013). Slamet Volcano is part of the Sunda Arc. According to Hamilton (1979), it formed regionally due to partial melting in the subduction zone between the Indo-Australian and Eurasian plates, which subduct at a rate of approximately 6

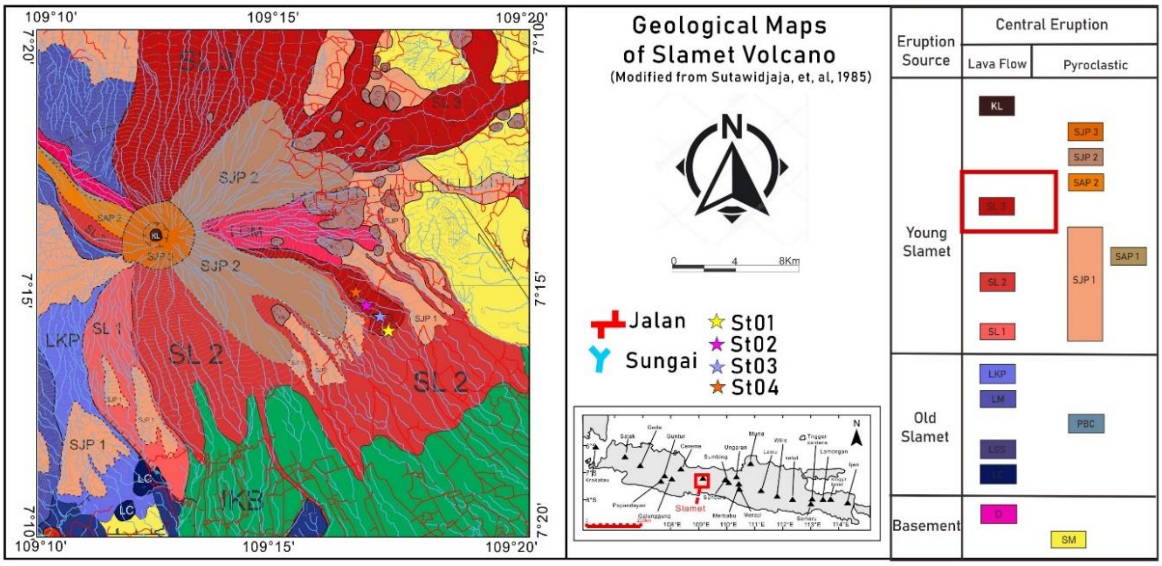

Fig. 2: The geological map of Slamet Volcano modified from Sutawidjaja, et, al, 1985, it shows the sampling location of SL 3.

cm/year beneath southern Java. Slamet Volcano is located about 310 km north of the subduction trench and about 160 km above the subduction zone (Handley et al., 2014).

Based on the Purwokerto–Tegal geological map by Djuri et al. (1996), the rock units on Slamet Volcano are divided into three groups: the Undivided Slamet Volcanic Rocks (Qvs), consisting of volcanic breccia, lava, and tuff; the Slamet Lava (Qvls), consisting of vesicular andesitic lava mainly on the eastern slope; and the Slamet Lahar Deposits (Qls), composed of laharic material with andesitic-basaltic volcanic clasts ranging from 10 to 50 cm. According to the geological map by Sutawidjaja et al. (1985) (Figure 2), Slamet Volcano is divided into the Old Slamet and Young Slamet volcanoes, consisting of both central and flank eruptions, producing lava, pyroclastic, and lahar deposits. The Old Slamet rocks are mainly andesitic to dacitic in composition, while the Young Slamet rocks are more basaltic, indicating a magma evolution from intermediate to mafic (Prasetya & Gibran, 2024).

Several studies have been conducted on Slamet Volcano. Vukadinovic and Sutawidjaja (1995) classified the lavas as high-abundance magma (HAM) and low-abundance magma (LAM) based on incompatible elements such as Zr/K and Zr/Rb. Reubi (2002) reported the presence of magma mixing in the magma chamber of Young Slamet. Sutawidjaja and Sukhyar (2009) studied the cinder cones on the eastern side of the volcano.

Harijoko et al. (2018a; 2018b; 2020; 2021) documented pumice deposits on the western flank, scoria cones on the eastern flank, geochemistry of lava flows, and pyroclastic deposits in the Guci area of Tegal Regency.

Prasetya and Toramaru (2022) analyzed the geochemical and petrological comparison of pumice and scoria fall deposits from Slamet Volcano. The most recent study was conducted by Barber et al. (2023)[18], focusing on olivine mineral types from monogenetic volcanoes on the eastern side of Slamet Volcano.

The vesicular basalt in Young Slamet, which is the focus of this study, is part of the Slamet Lava 3 unit, according to the geological map of Slamet Volcano by Sutawidjaja et al. (1985). This unit has never been studied in detail and is only mentioned in the 1985 map. Therefore, the aim of this research is to report and describe the petrology and mineral composition of the vesicular basalt rocks in this area.

2. Methods

The research method employed in this study was field observation, which involved describing outcrops and collecting rock samples. The observed outcrops belong to the Slamet Lava 3 (SL3 unit as identified in the 1985 geological map of Slamet Volcano. These vesicular basalt lava outcrops are located on the southern slope of Slamet Volcano, accessible via the Baturraden–Serang road, a forest road managed by the forestry agency of Banyumas Regency. The outcrops are situated in a forested area along a river channel.

The collecting data were conducted at four locations along a single river flow, from upstream to downstream (Figure 2). A total of four rock samples were collected from these sites. Thin section analysis was performed by slicing the rock samples into 0.03 mm sections, which were then analyzed using an optical microscope to identify the mineral composition and assemblage. The rock types were classified based on their mineralogical composition following the standard classification of igneous rocks.

3. Result and Discussion

Field Observation

Based on field observations, the rock outcrops at the study site are located on the southern slope of Slamet Volcano. These outcrops are found along the banks of an intermittent river, extending from the upstream to downstream sections and are exposed in the riverbed with vertical dimensions ranging from 30 cm to 3 meters (Figure 3).

Observations were conducted at four specific points (Figure 3):

a) ST01: The first site is located at the upstream section of the river, where the basalt outcrop lies on the riverbed. The outcrop is fresh, dark gray in color, approximately 30 cm in height, and extends along the river. The rock exhibits an aphanitic texture and vesicular structure.

b) ST02: The second site is approximately 10 meters downstream from ST01. The basalt outcrop is situated on the riverbank, is fresh, with dimensions ranging from 2 to 3 meters. It has a dark gray color, aphanitic texture with no visible mineral grains, and a vesicular structure.

c) ST03: The third site lies about 50 meters downstream of ST02. The outcrop is located on the riverbed, extends approximately 10 meters along the river with a width of about 1–2 meters. It is in a fresh condition, dark gray in color, with an aphanitic texture and vesicular structure.

d) ST04: The fourth site is the furthest downstream, approximately 15 meters from ST03. The basalt outcrop is found on both the riverbed and bank, with an exposure extending 5–8 meters in length and 1–2 meters in width. The basalt rock is dark gray, with an aphanitic texture and vesicular structure.

According to Sutawidjaja et al. (1985), the study location belongs to the Slamet Lava 3 unit, which is part of the Young Slamet volcano. Compared to previous studies on basaltic lava from Slamet Volcano (Prasetya & Gibran, 2024), the rocks in this study area appear darker in color and exhibit more prominent and larger vesicles.

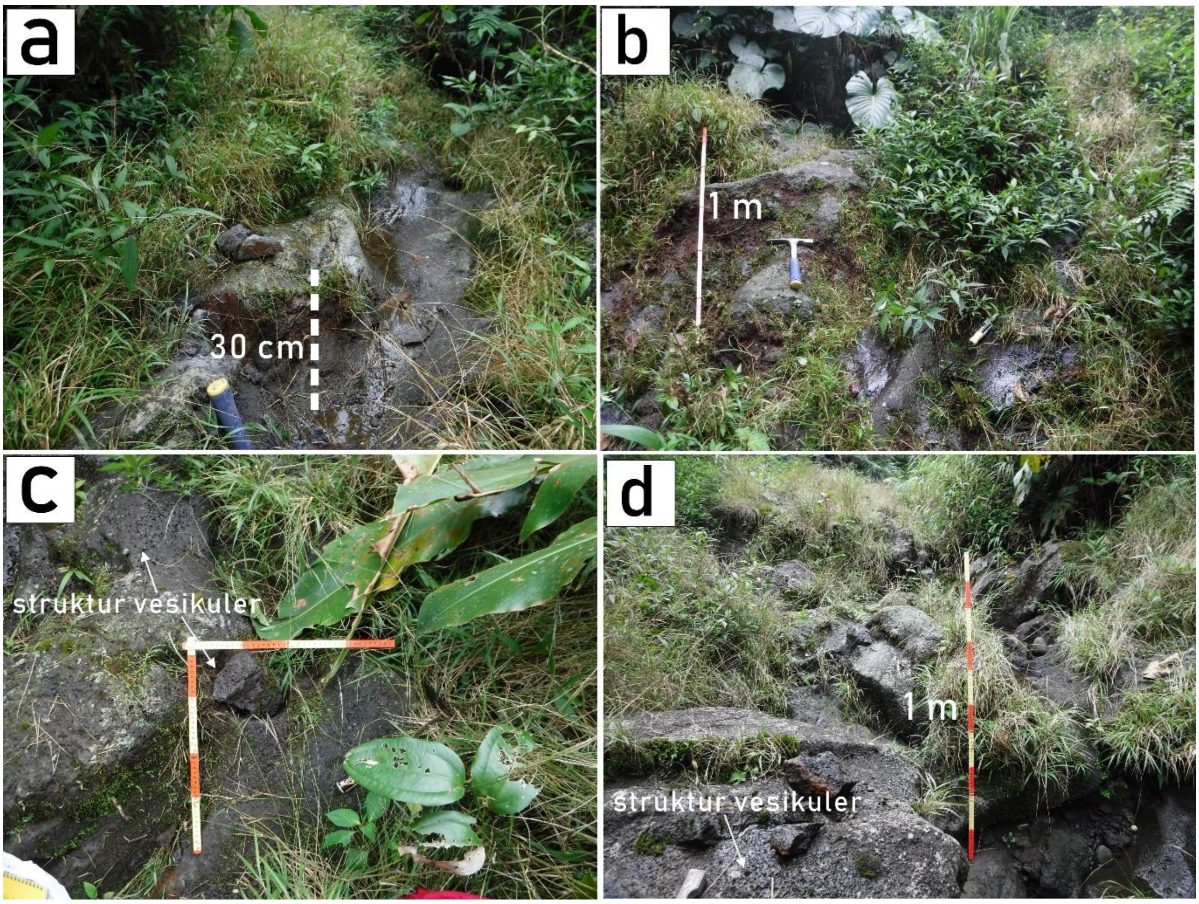

Fig. 3: The photograph of basaltic lava outcrop of Slamet Lava 3 (a) outcrop at ST01, (b) basalt outcrop at ST02, (c) basalt outcrop at ST03, (d) outcrop at ST04.

Petrography

Four rock samples were selected for thin section analysis to determine the mineral composition of the basalt. All samples exhibit a porphyritic texture, with plagioclase as the dominant phenocryst, followed by pyroxene and olivine. The groundmass comprises plagioclase, pyroxene, olivine, and Fe-Ti oxides (Figure 6).

The samples are characterized by an abundance of plagioclase and large vesicles. Crystal sizes vary, and the minerals generally exhibit anhedral to subhedral forms. The primary mineral constituents are plagioclase, olivine, and minor pyroxene.

also found within the olivine. The maximum observed crystal size is 1.51 mm.

Pyroxene, identified as clinopyroxene, is rare and varies in size up to 4.3 mm. It is found in aggregates with plagioclase and olivine, forming glomerocrysts. The crystals are anhedral to subhedral with irregular sizes and include inclusions of plagioclase, olivine, and Fe-Ti oxides.

Fe-Ti oxide minerals (opaque minerals) appear black under both plane-polarized and cross-polarized light. These are anhedral in shape, small in size, and occur as inclusions within olivine and pyroxene (Table 1).

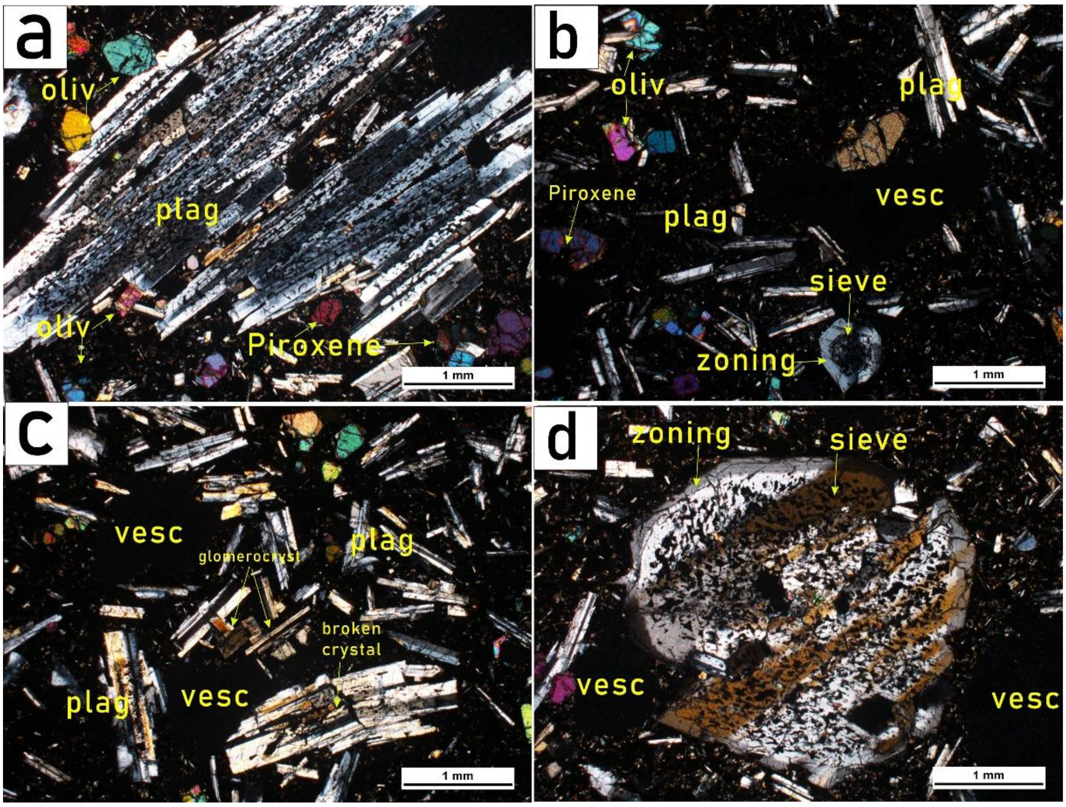

Fig. 4: Photomicrographs of thin sections from rock samples collected at the study site, showing mineral compositions of plagioclase (plag), olivine (oliv), pyroxene, and vesicular structures (vesc): a) sample from location ST01 with phenocrysts of plagioclase, olivine, and pyroxene; b) thin section from ST02 showing vesicular structure (vesc), phenocrysts of plagioclase, olivine, and pyroxene, along with zoning and sieve textures in plagioclase; c) thin section from ST03 with plagioclase and olivine minerals, and the presence of broken crystals in plagioclase; d) zoning and sieve textures in plagioclase crystals larger than 1 mm.

In thin section, plagioclase occurs both as phenocrysts and in the groundmass, typically exhibiting anhedral to subhedral shapes. Observed mineral textures include sieve texture, glomerocryst, zoning, syneusis, and broken crystals. Plagioclase crystals contain inclusions of olivine and Fe-Ti oxides and can reach sizes up to 6.5 mm.

Olivine is smaller and less abundant than plagioclase, with variable crystal sizes and anhedral to subhedral shapes. It occasionally forms crystal aggregates, contains broken crystals, and exhibits sieve texture and symplectite structures. Fe-Ti oxide inclusions are

The presence of sieve textures and zoning in plagioclase indicates that the basalt-forming magma at the study site underwent magma mixing. According to Winter (2010)[1], sieve texture forms due to resorption, where a mineral partially dissolves as a result of mixing between two different magmas. Zoning is also indicative of magma mixing, where variations in composition, temperature, or pressure create unstable growth environments for crystals, leading to compositional layering within a single crystal.

Table 1: Abundance of minerals in the rock samples at the research location.

NO	Mineral Composition	Sampling Location			
		ST01	ST02	ST03	ST04
1	Plagioclase	50	45	51	53
2	Olivine	11	10	14	12
3	Pyroxene	12	14	16	14
4	Opaque Mineral	8	9	9	7
5	Groundmass	19	22	10	14
	Structure and Texture				
1	Vesicular	√	√	√	√
2	Porphiritic	√	√	√	√

Renjith M.L. (2014) also suggests that sieve textures result from decompression processes, especially when H_2O-undersaturated magma ascends rapidly, increasing water pressure ($P(H_2O)$) and causing plagioclase to become unstable and start dissolving. Zoning occurs due to disequilibrium conditions such as magma mixing, where the changing environment leads to zoning in the crystals (Figure 4).

In addition to magma mixing, the magma at the study site also experienced fractional crystallization, as evidenced by the presence of glomerocrysts—aggregates of early-formed minerals. According to Winter (2010), these mineral aggregates form when early-crystallized minerals cluster or adhere to each other as they settle to the base of the magma chamber. As a result, clusters of crystals, either of the same or different mineral types, form what is known as a glomeroporphyritic texture. This process represents the physical separation of crystals from melt, leading to crystal accumulation

4. Conclusion

Based on the results and discussion, the following conclusions can be drawn:

The rock samples collected from the study area are basaltic in nature, distributed along the river from upstream to downstream. They are dark gray in color, exhibit an aphanitic texture, and display a vesicular structure.

Petrographic analysis reveals that the rock samples have a porphyritic texture, with abundant plagioclase phenocrysts and minor amounts of pyroxene and olivine. The groundmass is composed of plagioclase, pyroxene, olivine, and volcanic glass. Evidence of magma mixing and fractional crystallization processes was also observed in the samples..

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