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# Rock types characteristics of Prambanan and Sambisari Temples, Yogyakarta Province, Indonesia

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**Abstract.** Many Hindu and Buddhist temples built in the 8<sup>th</sup> to 10<sup>th</sup> centuries are found in the Yogyakarta Province, Indonesia, including Prambanan and Sambisari temples. Based on petrographic and geochemical observations, both temples are built using basaltic to andesitic lavas and pumice breccias. The rock types are relatively similar to those the basaltic to andesitic lavas around the Quaternary age Merapi volcano, and the pumice breccia of the Tertiary age Semilir Formation in the Piyungan area situated at the south of the Prambanan temple. Selected rocks samples were analyzed using petrographic and X-ray fluorescence methods to identify minerals, textures and geochemical characteristics. Petrographic observations show that the rocks used to build Prambanan temple are hornblende-pyroxene andesite and pyroxene basalts, while the rocks of Sambisari temple consist of hornblende-pyroxene andesites and pumice breccias. Hornblende-pyroxene andesite is generally gray, showing porphyritic texture, 1-3 mm crystal size; phenocrysts are composed by plagioclase, hornblende, pyroxene, and opaque minerals set in groundmass of plagioclase microcrysts and volcanic glass. Pumice breccia, showing a light gray colour, moderate sorting, fragments, consist of andesite and pumice clasts in size range 2-6 cm, embedded in sandy to clay matrix. Most of the rocks are generally weathered or oxidized, which is reflected by the presence of secondary iron oxide. This is probably most of the basaltic to andesitic lavas used had a high vesicular texture, and that Yogyakarta has a tropical climate.

**Keywords:** rock types, Prambanan Temple, Sambisari Temple

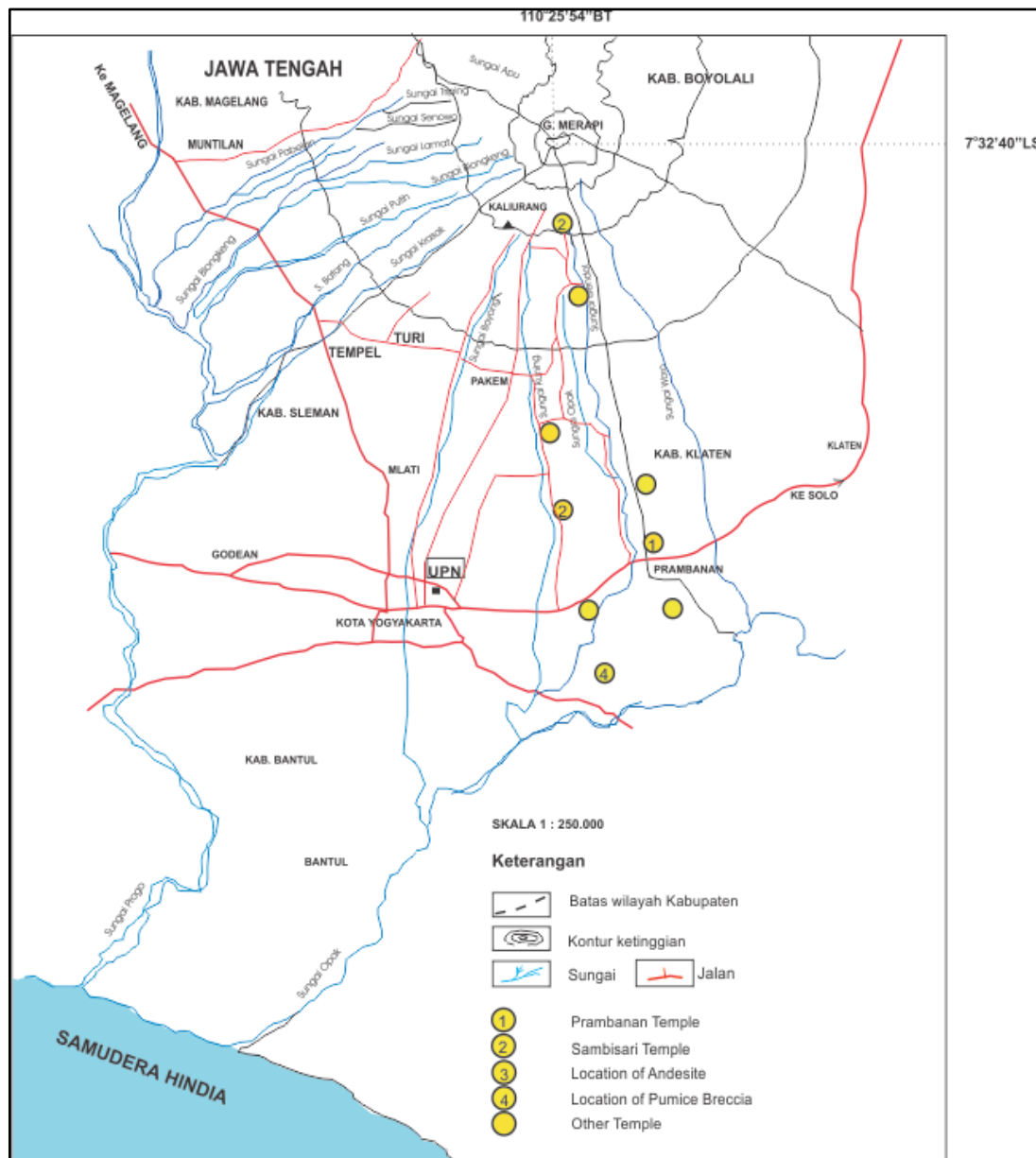
## 1. Introduction

Many Hindu and Buddhist temples were built between 8<sup>th</sup> to 10<sup>th</sup> centuries in the south of Merapi volcano, Yogyakarta, Indonesia [6]. Mundardjito [7] reported that there are 218 temples distributed at the flank and plain of the Merapi volcano, including the Prambanan and Sambisari temples. Prambanan and Sambisari temples are situated at about 25 km south of the Merapi volcano peak and approximately 3-7 km north west of the small hill of the Tertiary age volcanoclastic rocks of Semilir Formation. The temples are composed by mostly basaltic to andesitic lavas but some of their ornament are made of volcanoclastic rocks of the Semilir Formation.

Prambanan Temple is the biggest Hindu temple within Prambanan Temple compounds, other temples are Sewu Temple, Buraah Temple and Lumbung Temple. These compounds are located on the border between Yogyakarta and Central Java provinces on the central part of Java Island (Figure



1). All the temples mentioned above were built in the 8th- 9th century AD. Prambanan Temple Compounds were built in the 9th century AD, and collapsed due to the earthquake and eruption of Merapi volcano were rediscovered in the 17th century. Restoration have been conducted since 1918, using both original traditional as well as modern method.



**Figure 1.** The location map of the Prambanan and Sambisari temples.

The Sambisari temple stands 6,5 meters below the surrounding land in Sambisari Village, Purwomartani Sub-District, Kalasan District, Sleman Regency. The temple is situated at about 2 kilometers west of Prambanan temple and 10 kilometers away from Yogyakarta city center. Sambisari temple believed to be constructed between 812 - 838 AD, consists of 1 main temple and 3 supporting temples. There are 2 fences surrounding the temple complex mostly composed by volcaniclastic rock.

## 2. Materials and Methods

This research uses secondary and primary data, based on a megascopic observation, geochemical and petrographic analysis both of rock materials type of the temples as well as lithologies outcropping in the surroundings. Petrographic analyses using thin section preparation are used to identify minerals composition as well as rock textures under polarisation microscope. Geochemical whole rock major elements are analyzed by X-ray fluorescence (XFR).

## 3. Aim of The Research

Aim of the research is comparing the geochemical and petrographic data between the Prambanan and Sambisari temples rock materials to the Merapi volcano lavas and volcanoclastic rocks of the Semilir Formation surrounding the temples.

## 4. Result and Discussion

### 4.1 Geology of the Prambanan Area

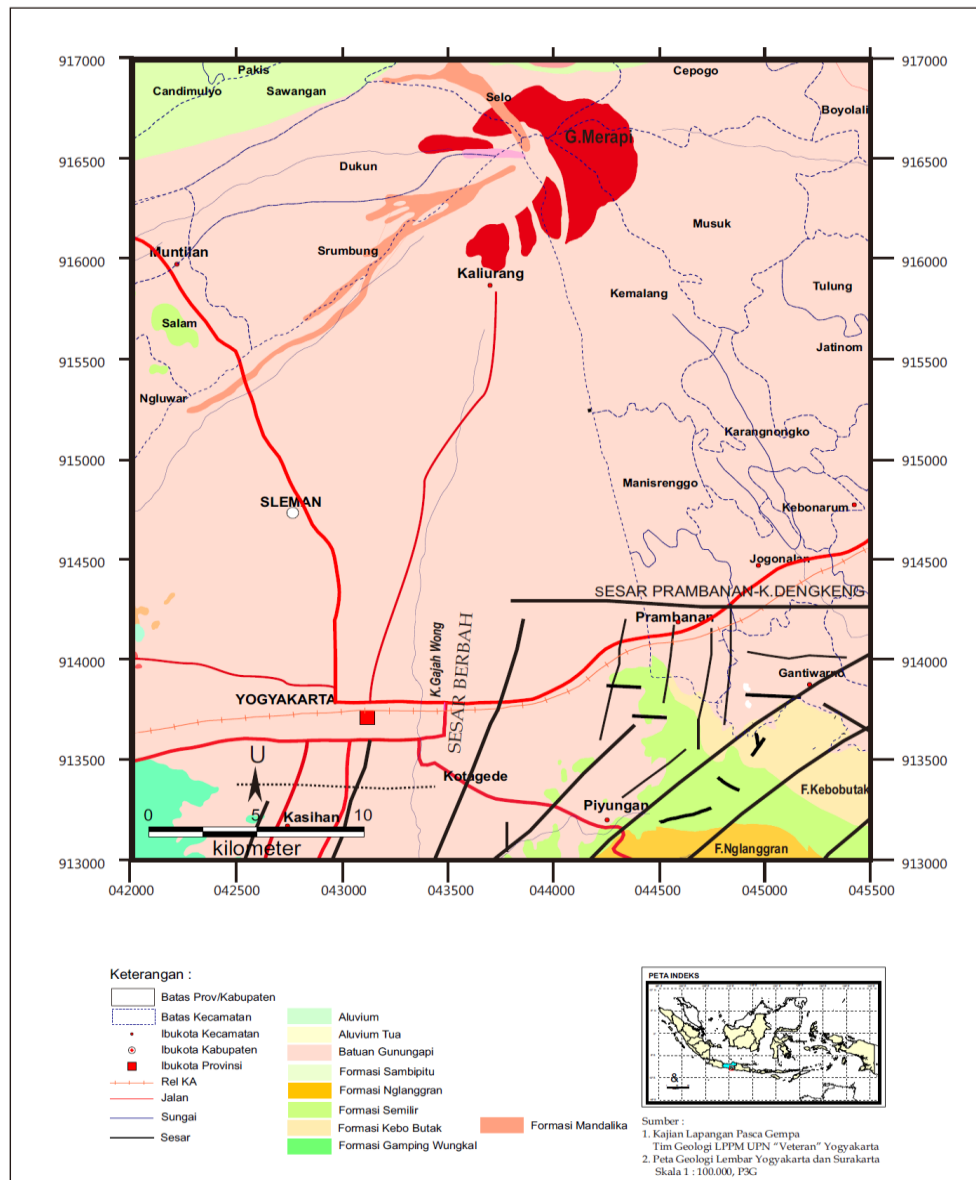
Indonesia archipelagos are controlled by magmatic arcs, which vary in age from Late Mesozoic through the Cenozoic, including the Sunda-Banda, Central Kalimantan, Sulawesi-East Mindanau, Halmahera and Medial Irian Jaya [2].

Java is part of Sunda-Banda arc extending from Sumatra through Java to east of Damar island, known for the presence of many ore deposits ([2]; [5]). The arc is the longest arc in Indonesia, developed by northwards subduction of the Indian-Australian oceanic plate beneath the southeastern margin of Eurasian continental plate, named the Sundaland ([3]; [4]). Java island includes at least three generations of Tertiary to Quaternary age magmatic rocks, ([9]). The Prambanan Temple and its surroundings area are occupied by igneous volcanic and volcanoclastic rocks of Quaternary age of Merapi volcano and Tertiary age volcanoclastic rocks of the Semilir Formation (Figure 2).

The Semilir Formation is composed by pumice breccias, lapilli-tuffs, tuffs, tuffaceous sandstones and intercalation sandstones and siltstones. This rock unit is about Early-Middle Miocene in age, deposited and formed by gravity flow within shallow to deep sea water environment [11]. The Semilir Formation dominated by pumice breccia is representing the huge eruption of volcano. Smyth *et al.* [8] suggested that Cenozoic volcanic activity which build the Late Eocene-Early Miocene of Soeria-atmadja *et al.* [10] began in the Middle Eocene (*ca.* 45 Ma) and ended with major explosive event, which is represented by Semilir eruption in Early Miocene (*ca.* 20 Ma). The Semilir eruption formed the Semilir Formation consists of pyroclastic rocks (dominated by pumice breccia) and the Nglanggran Formation (intercalation andesite breccias and lavas) with thickness about 1200 m (Toba eruption only formed about 600 m of ignimbrite deposit).

At the surface, the volcanic rocks of the Late Eocene-Early Miocene and Late Miocene-Pliocene magmatic arcs are mostly covered by volcanic rocks of Quaternary age eruption volcano materials, including Merapi volcano at the Central Java.

The Merapi volcano is one of hundreds of volcanoes located in the Island arch belt in Indonesia, known as one of the most active volcanoes of the world. The Merapi volcano (2968 m above sea level) is located on the border of the Central Java and the Yogyakarta province, as an active volcano that has eruption period of 5-10 years. Every eruption period of Merapi volcano always ends with lava flow having basaltic-andesitic composition.



**Figure 2.** Geological map of the Prambanan area and vicinity.

## 4.2 Rock Types

**4.2.1 Rock Types of The Merapi Volcano.** The Merapi volcano is a classical stratovolcano, composed with alternating phases of effusive lava flows and vertical vulcanian explosions of pyroclastic deposits. Based on the morphology and stratigraphy, Merapi volcano can be divided to four stages, they are a) Ancient Merapi, b). Middle Merapi, c). Recent Merapi, and d). Modern Merapi [1]. Using total alkalis versus silica diagram classification of Lebas *et al.* (1986), the ancient Merapi lavas have a composition range from basalt, trachy basalt, basaltic andesite, basaltic trachy andesite, trachy andesite and andesite. The other hand, middle and recent Merapi lavas are dominated by basaltic andesite to basaltic trachy-andesite.

In general, the major elements of the Merapi volcano lavas are representing a magmatic arc setting (Table 1), as pointed by wide variation of SiO<sub>2</sub> contents (49.7-60.6 wt.%), low TiO<sub>2</sub> (0.6-1.1 wt.%), MgO (1.7-4.0 wt.%), relatively high of Al<sub>2</sub>O<sub>3</sub> (17.5-19.6 wt.%) and Na<sub>2</sub>O (2.4-3.7 wt.%) when compared with most of the Oceanic Island Basalt (OIB) and Mid Oceanic Ridge Basalt (MORB) setting.

**Table 1.** Geochemical major elements of basalt-andesite lavas of the Merapi volcano, the Prambanan and Sambisari temples (Sources: this study<sup>1)</sup>; Camus *et al.* [1]; Warmada and Hapsari, [13]).

Sample	Loc.	SiO <sub>2</sub>	TiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	MnO	MgO	CaO	Na <sub>2</sub> O	K <sub>2</sub> O	LOI	TOTAL
PR 1 <sup>1)</sup>	ST	53.61	0.82	16.6	8.01	0.17	3.13	7.83	3.35	1.62	0.33	95.73
SS 2 <sup>1)</sup>	PT	53.85	0.76	16.5	8.18	0.20	3.12	8.63	3.67	2.11	0.5	97.82
RB01 <sup>2)</sup>	PT	51.1	0.85	18.5	9.73	0.2	3.72	9.54	3.19	1.93	0.75	99.92
RB02 <sup>2)</sup>	PT	52	0.85	18.7	9.27	0.19	3.2	8.71	3.16	2.07	0.72	99.23
RB03 <sup>2)</sup>	PT	54.2	0.75	18.7	9.97	0.18	2.72	8.32	3.53	1.19	1.11	99.78
RB04 <sup>2)</sup>	PT	53.4	0.76	18.6	8.21	0.18	2.63	8.25	3.4	2.09	0.48	98.4
RB06 <sup>2)</sup>	PT	55.6	0.7	18.5	7.78	0.18	2.41	0	3.29	1.74	1.61	100.1
RB07 <sup>2)</sup>	PT	52.4	0.88	18.7	9.34	0.19	3.38	9.04	3.21	2.05	0.48	100.0
MP33 <sup>3)</sup>	MM	56.5	0.8	18.4	7.7	0.2	2.9	8.1	3.5	2.1	0	100.2
MIB4 <sup>3)</sup>	MM	57.5	1	18.2	7	0.2	2.9	7.9	3.5	2.3	0	100.4
MP32 <sup>3)</sup>	MM	56.2	0.8	17.5	7.7	0.2	2.9	7.6	3.5	2.1	0.8	99.3
84-1A <sup>3)</sup>	RM	56.5	0.8	18.2	8	0.2	2.6	8.4	3.6	2.6	0	100.8
P297 <sup>3)</sup>	RM	51.5	0.9	18.1	9.9	0.2	4	9.9	3.2	1.9	0	99.6
P285 <sup>3)</sup>	RM	56.3	0.7	18.7	7.9	0.2	2.6	8.5	3.7	1.7	0.6	100.8
P85 <sup>3)</sup>	RM	52.1	0.8	19.4	7.4	0.2	2.1	7.2	3.1	1.3	2.9	100
P266 <sup>3)</sup>	RM	57.6	0.7	19.3	7	0.2	2.1	7.9	3.7	2	0.1	100.5
MP41 <sup>3)</sup>	MV	55.5	1.1	18.3	8.9	0.2	2.8	7.3	3.7	2.1	1	100.6
MP283 <sup>3)</sup>	MV	54.1	0.8	19.3	8.5	0.2	2.8	9.1	3.5	1.9	0.2	100.3
222-2 <sup>3)</sup>	MV	51	0.8	17.8	10.5	0.2	3.6	9	2.4	1.2	2.1	99.5
P226 <sup>3)</sup>	AM	60.6	0.6	17.8	5.7	0.2	1.7	6.6	3.5	2	1.9	100.2
P231 <sup>3)</sup>	AM	49.7	0.7	18.9	9.8	0.2	3.7	11.5	3	1.3	1.5	100.3
P65P <sup>3)</sup>	AM	50.3	1.1	19.6	10.1	0.2	3.6	9.9	3.3	1.9	0.4	100.2
P235 <sup>3)</sup>	AM	55.9	0.8	18.6	8.2	0.2	2.7	8.5	3.7	1.8	0.5	100
P312 <sup>3)</sup>	AM	55.3	0.8	19.1	8.1	0.2	2.6	8.8	3.4	1.5	0	99.8

ST : Sambisari temple lava

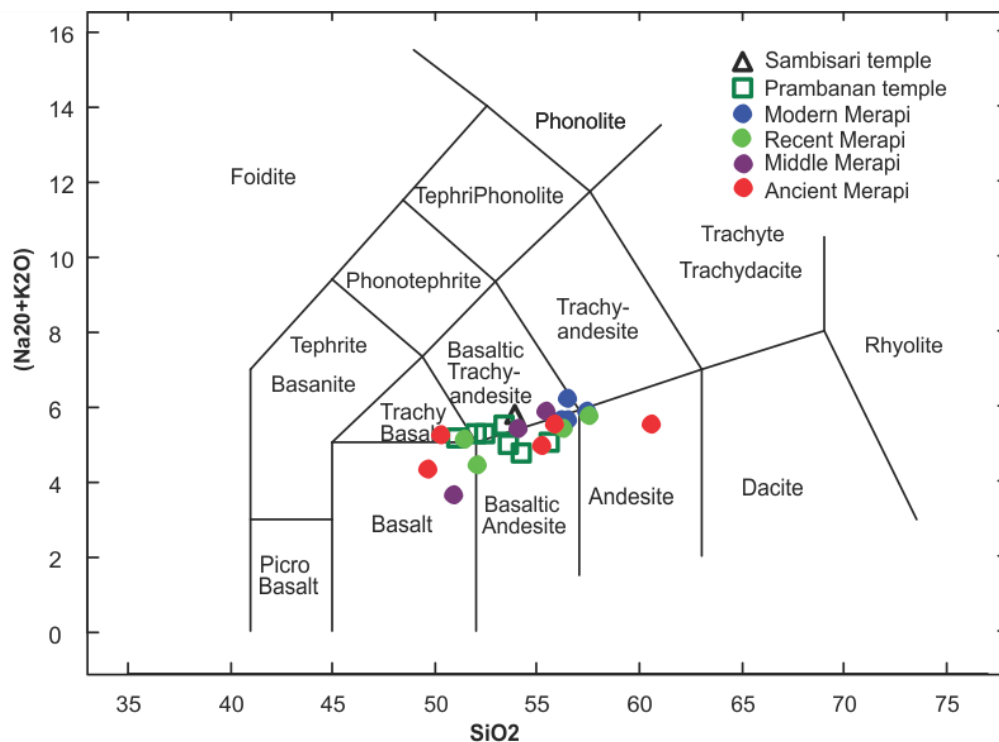
PT : Prambanan temple lavas

MM: Modern Merapi lavas

RM : Recent Merapi lavas

MV : Middle Merapi lavas

AM : Ancient Merapi lavas



**Figure 3.** The  $\text{SiO}_2$ - $(\text{Na}_2\text{O}+\text{K}_2\text{O})$  rock classification diagram (Midlemost, 1975) of the Merapi volcano, Prambanan and Sambisari temples lavas. The diagrams show that the samples are plotted within basalt, trachy basalt, basaltic andesite, basaltic trachy andesite, trachy andesite and andesite field.

Field observation show that the Merapi volcano lavas consist of the olivine basalt, pyroxene basalt, hiperstene-augite-hornblende andesite lavas intercalated by andesite-basaltic breccia and tuff.

The pyroxene andesite is generally dark gray in colour; showing porphyritic texture, phenocrysts (0.1-3.5 mm crystal size) are composed by plagioclases, pyroxenes, and lesser of hornblendes and opaque minerals set in groundmass of plagioclase and pyroxene microcrysts as well as volcanic glass. Field outcrops of the lavas are mostly weak to strong weathered or oxidized, reflected by the brown to reddish ranges of colour. Petrographic observation under microscopic, pyroxene andesite show massive to vesicular texture; porphyritic with phenocrysts have range from 0,14 to 2,8 mm in crystal size, consist of plagioclases, pyroxenes, hornblendes, opaque minerals, and volcanic glass and lack of apatite and sphene. Camus *et al.* [1] described that Merapi lavas generally show porphyritic texture with phenocrysts consist plagioclase (20-53%), clinopyroxene (1-17%), orthopyroxene  $\pm 1\%$ , amphibole (<1-5%), olivine (0-3%), oxides (0-3%) set in the groundmass (glass volcanic and microcrystal) range from 38-78%.

**4.2.2 Rock Types of The Semilir Formation.** The Prambanan and Sambisari temples are located at about 3-7 km north of the Tertiary age volcanoclastic rocks of the Semilir Formation, including intercalation pumice breccias, lapilli-tuffs, tuff and tuffaceous sandstones.

The pumice breccias show white-light grey colour, medium-poor sorted, matrix-grains supported, fragment grain size range about 2-12 cm, angular-subangular, mostly consist of pumices and andesites components. The lapilli-tuffs usually have a similar textures and composition to those of pumice breccia above, but have smaller grain size (0.3-3.5 mm). Some field outcrops reveal that lapilli-tuffs have a parallel to cross lamination, ripple mark and loadcast structures.

**4.2.3 Rock Types of the Prambanan and Sambisari Temples.** The rock geochemical composition ranges and classification suggest that the rock materials used for the Prambanan and Sambisari temples may come from the Merapi volcano, particularly the Middle and Recent Merapi.

Similar geochemically trends are also demonstrated by the Prambanan and Sambisari temples samples, they show  $\text{SiO}_2$  content from 51.1 to 55.6, low  $\text{TiO}_2$  (0.7-0.88 wt.%),  $\text{MgO}$  (2.41-3.38 wt.%), relatively high  $\text{Al}_2\text{O}_3$  (16.5-18.7 wt.%) and  $\text{Na}_2\text{O}$  (3.21-3.67 wt.%). The trends are relatively resemble to those Merapi volcano lavas (Table 1).



**Figure 4.** The Prambanan temple complex (left) and the Merapi volcano view as a background the stones of the Plaosan temple which is stand about 1 km north of the Prambanan temple (right).

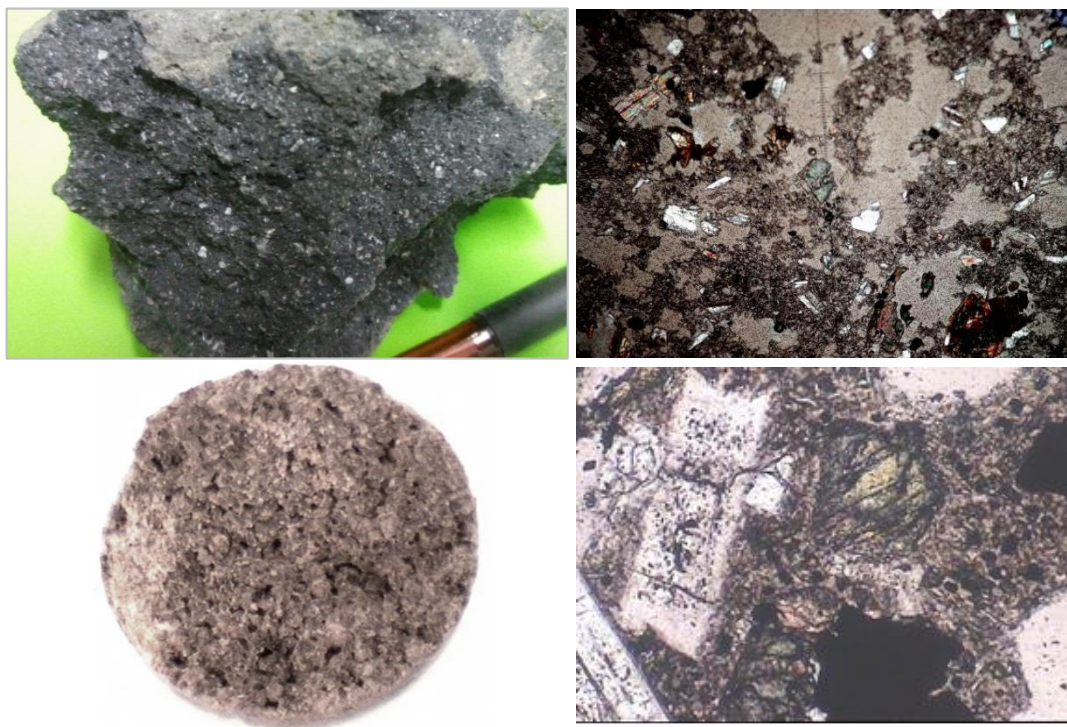


**Figure 5.** The Sambisari temple stands about 6,5 meters below the surrounding land in the Sambisari Village (top). The Sambisari temple fences are mostly composed by pumice breccias (bottom left) and closeup of pumice breccia of the Semilir Formation (bottom right).



Petrographically, most of the Prambanan and Sambisari lavas are also dominated by basaltic andesite to basaltic trachy-andesite composition. Field observation show that rocks used to build the Prambanan temple are hornblende-pyroxene andesite, pyroxene basalt (Figure 4) and small quantity of volcanoclastic rocks, while the Sambisari temple is made of hornblende-pyroxene andesite and pumice breccia (Figure 5). Hornblende-pyroxene andesite is generally gray, showing porphyritic texture, 1-3 mm crystal size, phenocrysts are composed by plagioclases, hornblendes, pyroxenes, and opaque minerals set in groundmass of plagioclase microcrysts and volcanic glass (Figure 4). Most of the rocks are generally weathered or oxidized, reflected by the present of secondary iron oxide and clay minerals. Under microscopic observation, andesites mostly show vesicular texture; brownish gray colour; porphyritic texture with crystal size of phenocrysts have range from 0,15 to 2,6 mm, consist of plagioclases, pyroxenes, opaque minerals, volcanic glass, and lack of apatite.

Plagioclase (40-56%), as a phenocryst (0,15-2,6) mm and microcryst (< 0,12 mm), anhedral-euhedral, some show albit and carlsbad twins. Phenocrysts commonly contain opaque minerals inclusions. Pyroxene (8-15%), mostly present as a phenocryst (0,3-1,3 mm) also contain opaque minerals inclusions, and within the cleavage some of the are altered to iron oxide. Olivin (1-3%), transparent, as a phenocryst ( $\pm$  0,2 mm), anhedral, showing intense fractures. Opaque mineral (3-5%), anhedral-subhedral, have range in size from 0,04 to 0,18 mm, disseminated. Apatite (1%), very fine in size (< 0,005 mm), euhedral. Glass volcanic (7-11%), brownish grey, mostly are oxidized to clay minerals and iron oxide. Iron oxide (8-12%), brown to maroon color, as secondary mineral replacing within volcanic glass and pyroxene cleavage. Vesicular (16-22%) with diameter range between 0,3-1,5mm, irregular to opal in shape (Figure 6).



**Figure 6.** The hand specimen and photomicroscopic of the vesicular andesitic lava of the Merapi volcano (top: sample from M. Yedi) and the Prambanan temple rock sample (bottom: sample from Agus).



**Figure 7.** The field outcrop of andesitic lava at Adem river, southeastern slope of the Merapi volcano (left) and contact between andesitic lava and volcanic breccias in the Sileng river, southwest of the Merapi volcano slope (right).

Pumice breccia reveals a light gray white colour is composed by pebbles contains andesite and pumice lithic clasts, pyroxenes, plagioclases; poor to moderate sorting with fragments size range from 1.2 to 15 cm embeded in sandy to clay matrix in size. A thin section of the matrix reveals a high porcion of volcanic glass shard (20-50%), pumice grains (30-40%), andesite lithic fragments (4-7%), opaque minerals (3 -6%), pyroxene (2-3%), plagioclase (4-10%) and quartz (5-8%). Some parts of the volcanic glass shard have been devitrified to clay minerals, and sericites (Figure 5). This is mean that petrographically, the basalt-andesite lavas and pumice breccia rocks of the Prambanan and Sambisari temples are relatively similar with those of basalt-andesite lavas of the Merapi volcano and pumice breccia of the Semilir Formation.

## 5. Conclusion

1. Geochemically and or petrographically, the basalt-andesite lavas and pumice breccia rocks of the Prambanan and Sambisari temples are relatively similar with those of basalt-andesite lavas of the Merapi volcano and pumice breccia of the Semilir Formation.
2. Most the basalt to andesite lavas which were used to build the Prambanan and Sambisari temples are mostly showing high vesiculer, although there are massive or low content vesicular lavas in the flank of Merapi volcano may stronger in physical properties. These lavas were chosen may be caused :
  - a. It is relatively not hard, therefore easy to be form
  - b. It is lighter rather than massive lavas, therefor easy to be lift to the top of the temple

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