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Facies and Stages of Volcanic Eruption Case Study of the Kendil Volcano and its Surroundings Dieng Caldera, Central Java, Indonesia

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Abstract.
The Dieng volcano area is geologically a caldera formation due to a collapsing structure that has many craters and volcanic stratocones in it. So with the presence of many stratocones, it is necessary to research the stages of eruption and volcanic facies. This study uses a field mapping methodology, observation of rock outcrops, identifying rocks, and measuring the position of rock layers. The Dieng Volcanic Complex consists of three episodes: the pre-caldera episode, the post-caldera episode, and the present episode. However, in the study area, it only occurred in pre-caldera and caldera episodes. In the pre-caldera stage, there is a constructive phase of Prau Volcano. The post-caldera II stage begins with the constructive phase and Jojogan's destructive phase of Jojogan, then the constructive phase of Pangonan and the destructive phase of Pangonan. Next are Kendil's constructive phase and Kendil's destructive phase. The last phase is the constructive phase of Pakuwaja. Based on the characteristics of rock types, the types of volcanic facies in the study area include central and proximal facies. Central facies are owned by Prau Volcano, Jojogan Volcano, Pangonan Volcano and Pakuwaja Volcano. While Volcano Kendil owns the central facies and proximal facies. Research on facies and stages of eruption is expected to be used as a reference for further research regarding volcanoes and geothermal development, especially in the Dieng area.

Keywords*: *dieng, facies, pyroclastic, volcano

INTRODUCTION

Indonesia is a subduction area of the Eurasian plate, the Pacific plate, and the India-Australia plate. The interaction of these plates forms a volcanic arc, one of which forms the Dieng Volcano Complex. The Dieng Volcano Complex has 20 volcanic cones, including Sikunang Volcano, Seroja Volcano, Pakuwaja Volcano, Kendil Volcano, Watusumbu Volcano, Sikunir Volcano, Prambanan Volcano, Igirbinem Volcano, Pangonan Volcano, Merdada Volcano, Sipandu Volcano, Pagerkandang Volcano, Sembungan Volcano, Sidede Volcano, Bisma Volcano, Nagasari Volcano, Jimat Volcano, Reban Volcano, Sigemplong 1 Volcano, and Sigemplong 2 Volcano.

In connection with a large number of volcanoes in the Dieng Complex, a study of the facies and stages of the eruption of each volcano in the Dieng Complex is required would be fascinating to learn. For this reason, this study aims to conduct geological mapping and identification of volcanic facies that can be interpreted as the stages of the eruption. The research area selected is the Kendil Volcano and its surroundings (**Figure 1**), which has a volcanic distribution: Prau Volcano, Merangkul Volcano, Benda Volcano, Jojogan Volcano, Pangonan Volcano, Kendil Volcano, and Pakuwaja Volcano.

The aspect of the volcanic facies used in this study follows the Indonesian Stratigraphy Code (1996), which explains that facies are simultaneously the physical, chemical, or biological aspects of a deposit. Two bodies of rock deposited simultaneously are called different facies if the two rocks have different physical, chemical, or biological characteristics. In addition, Bogie and Mackenzie (1998) also explain the division of the volcanic facies of a composite volcano. The volcanic facies can be divided into four groups (**Figure 2**), namely central/vent facies (center), proximal facies (near the center), medial facies (middle), and distal facies (away from the center). The division of volcanic facies is based on some lithological characteristics of volcanic rocks simultaneously at a specific location. Lithological characteristics can involve aspects of physics, chemistry, and biology. Since volcanic rocks are not always found in fossils, the biological aspect is not used as the main parameter (Bronto, 2006).

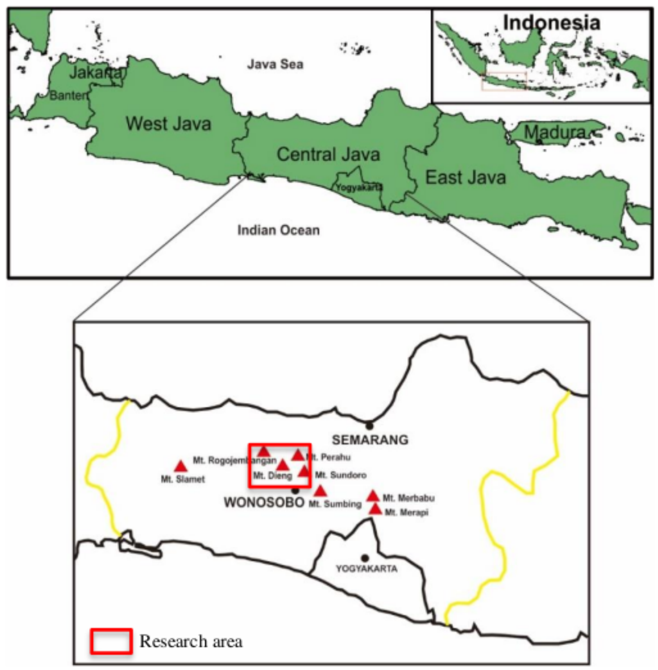

FIGURE 1. Research area map of Complex Dieng Volcano.

Meanwhile, Bogie and Mackenzie (1998) divide volcanic facies into four groups, namely central/vent facies, proximal facies, medial facies, and distal facies (**Figure 2**)

The central facies is the opening for magma from the earth to the surface. Therefore, this area is characterized by associations of igneous rocks in the form of lava domes and various kinds of semi-volcanic intrusions. These igneous rocks are volcanic necks, sills, cracks, and subsurface domes (crypto domes). Shallow breakthrough rock can be found on the walls of present-day volcanic craters, calderas, or ancient volcanoes that have been eroded further because the opening area from the diatreme to the crater is the location for the formation of hydrothermal fluids. The proximal facies is the volcanic area closest to the source location or the central facies. The proximal facies are interspersed with pyroclastic flows of lava and breccias, and agglomerates dominate rock associations. The alternation of lava strongly dominates the rock associations in this facies flows with pyroclastic breccias and agglomerates.

According to Bronto (2013), they were explaining that for the volcanic caldera model of eruption, in the near facies, co-ignimbrite breccias are found, which move towards the middle and far facies gradually into pumice breccias and acid tuffs. At the time of the eruption and hot clouds formed or large pyroclastic flows (block and ash flows, pumice flows, or ignimbrites). Also, chunk-sized old rock fragments (diameter > 64 mm) are left near the crater. While some pumice, lapilli, and volcanic ash flow away from the source of the eruption. Wright and Walker (1977), Wright (1981), and Walker (1985) called this pyroclastic flow tail deposit rich in old rock fragments a co-ignimbrite lag-fall deposit, while Cas and Wright (1987) gave the name co-ignimbrite breccias (co-ignimbrite breccia).

The medial facies is the facies that is farther away from the source location. Lava flows and agglomerates have decreased. So they are more dominated by pyroclastic breccias, and tuff is dominant. Lava breccias have also started to develop in these facies. Meanwhile, the distal facies is dominated by volcanic debris. This volcanic debris includes lava breccias, fluviatile breccias, conglomerates, sandstones, and siltstones.

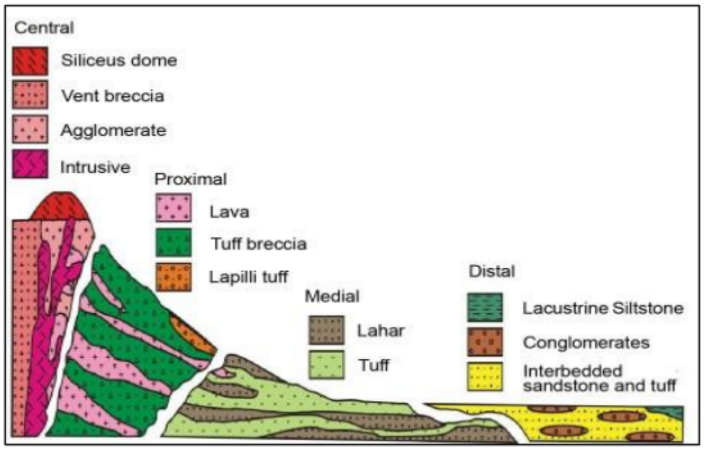

FIGURE 2. The division of volcanic facies into central facies, proximal facies, medial facies, and distal facies, along with their rock compositions (Bogie and Mackenzie, 1998).

LITERATURE.REVIEW

Geological setting

Based on previous research, the Dieng volcanic complex consists of several volcanic periods formed in a caldera structure with dimensions of approximately (14 x 6 km2). The structure of the caldera is most clearly visible on the western side of the Prau volcano. Dieng stratigraphy comprises Tertiary marl, limestone, tuff, and volcanic sandstone (Sukhyar et al., 1986). The volcanic period of the Dieng volcanic complex can be grouped as pre-caldera (~3 Ma), post-caldera I (~2 - 1 Ma), and post-caldera II, or the last stage (<1 Ma), based on their relationship to the caldera structure and distribution and radiometric age (**Figure 3**). Radiometric age data were determined using the K-Ar dating method (Harijoko et al., 2010).

1. The pre-caldera consists of Prau, Rogojembangan and Telerejo. The peak of magma evolution is the explosive eruption of the caldera structure that formed Prau.
2. The second period, post-caldera stage I, consists of Nagasari (2.99 Ma), Bhishma (2.53 Ma),

Sidede, Bucu, and Jimat.

3. The last or post-caldera II includes Pagerkandang (0.46 Ma), Pangonan Merdada (0.37 Ma), Butak, Kendil (0.19 Ma), Pakuwaja (0.09 Ma), Prambanan, Seroja (0.07 Ma), and Sikunir.

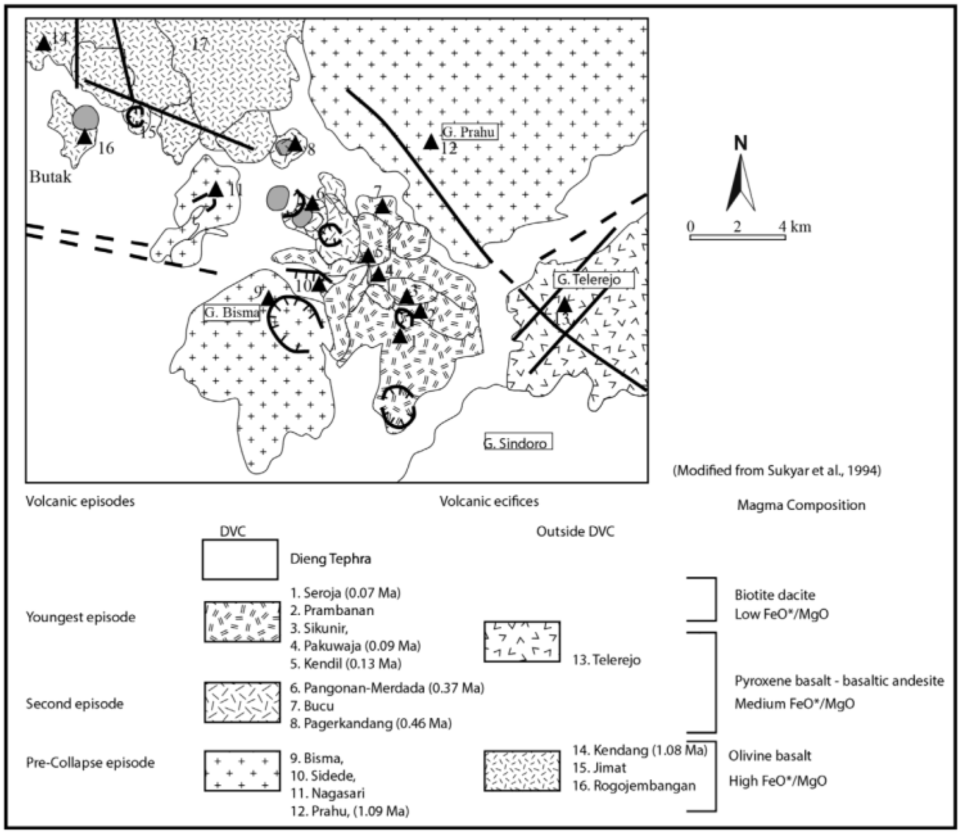

FIGURE 3. The geological map of the Dieng Volcanic Complex, modified from Sukhyar et al. (1986) and Boedihardi et al. (1991) in Harijoko et al. (2016).

RESEARCH METHODOLOGY

This research was conducted to study the stages of volcanic eruptions and facies, especially in the Kendil Volcano and surrounding areas. The analytical method used is geological mapping and petrographic description of lava in the study area. Geological mapping is mainly carried out by observing rock outcrops in the form of lava and pyroclastic deposits, identifying or describing rocks, measuring the position of rock layers, measuring the profile of rock outcrops and determining the position and stratigraphic relationship of the rock types encountered. Apart from that, it also measures the position of geological structures and takes rock samples. The data obtained from the mapping is then plotted on a base map based on the point of observation using a GPS (Global Positioning System) device, resulting in a geological map.

RESULTS AND.DISCUSSION

Geology of Kendil Volcano

The study area is dominated by pyroclastic falls, pyroclastic flows, and lava from Prau Volcano, Merangkul Volcano, Benda Volcano, Jojogan Volcano, Pangonan Volcano, Kendil Volcano, and Pakuwaja Volcano. It is divided into rock units based on the characteristics of each dominant lithology, as presented on the geological map in **Figure 14**. Thus, the stratigraphic sequence of the study area from old to young can be arranged, which includes:

Prau Volcano

The naming of the unofficial stratigraphic Prau Volcano unit is based on field observations. The field observations by looking at the lithological physical characteristics in the field. While the name Prau is based on the administrative name of Prau Volcano. The lithology of Prau Volcano consists of basalt lava Prau, and pyroclastic flow Prau 1, pyroclastic flow Prau 2, pyroclastic flow Prau 3, and pyroclastic fall Prau.

Hornblende andesite lava Prau is at the peak of Prau Volcano, which is interpreted as the center of volcanic activity on Prau Volcano. Lithology is basalt (**Figure 4**) with fresh grey and weathered brown with a massive structure. The hypocrystalline intersertal porphyritic texture and euhedral-subhedral crystal form. They are composed of the minerals plagioclase (45%), pyroxene/hypersthene (10%) and olivine (5%). The mineral is embedded in the bottom of volcanic glass (40%). The pyroclastic flows Prau 1 is composed of tuff lapilli pyroclastic flows, and pyroclastics fall. This deposit is brownish-yellow with poor sorting. Blocky andesite and little pumice are specific fragments in these pyroclastic deposits. According to McPhie et al. (1993), pumice is a volcanic glass with many vesicular (with or without crystal).

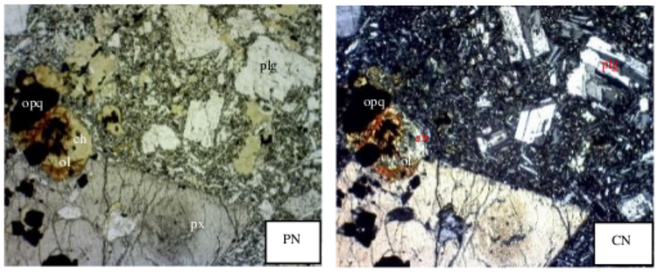

FIGURE 4. Basalt petrography shows an intersertal texture and the presence of plagioclase, pyroxene and opaque minerals. plg: plagioclase; px: pyroxene; olv: olivine; opq: opaque mineral; PN: parallel nicol; CN: cross nicol

Pyroclastic flows Prau 2 consists of tuff lapilli pyroclastic flow and pyroclastic fall deposits. The composition of the fragments consists of oxidized blocky andesite and a small amount of pumice. While the tuff lapilli pyroclastic fall showed poor sorting and had the same fragments. It's just that it has a graded bedding sediment structure that can be seen in fallen pyroclastic deposits. The pyroclastic flows Prau 3 deposits consist of interlude breccia pyroclastic flow, breccia pyroclastic fall, lapilli tuff pyroclastic flow, and agglomerates. The breccia pyroclastic flow has a massive structure and is poorly disaggregated.

Meanwhile, breccia pyroclastic fall has a well-sorted graded bedding structure. The tuff lapilli pyroclastic flow has a brownish-yellow color and has a fragment size of 2-64 mm with oxidized fragments and a massive structure. The tuff lapilli pyroclastic fall has angular fragments, is poorly sorted, and is layered. In contrast, agglomerates have a massive structure and are poorly sorted. The fragments are in the form of bombs and a little blocky andesite.

Merangkul Volcano

This volcano produces pyroclastic fall deposits. Pyroclastic fall Merangkul consists of lapilli tuff pyroclastic fall, breccia pyroclastic falls, and agglomerates. The pyroclastic fall Merangkul consists of an alternation of tuff lapilli pyroclastic fall, breccias pyroclastic fall, and agglomerates.

The tuff lapilli pyroclastic fall (**Figure 5**) is a brownish-yellow color and has a grain size of 2-64 mm (Fisher, 1966). The shape of the fragments is angular and poorly sorted. The fragments consist of blocky andesite and some show oxidation. Breccia pyroclastic falls have graded bedding structures. Fragments blocky andesite is a pebble to gravel in size. Agglomerates have a massive structure and are poorly disaggregated. Fragment in the form of blocky andesite is shallow to gravel in size with a bit of pumice and a rock matrix of coarse tuff.

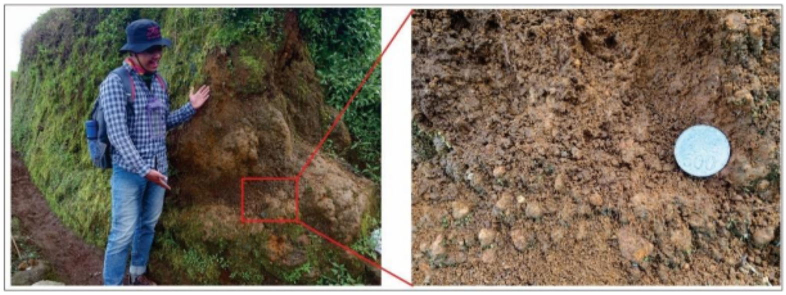

FIGURE 5. Outcrop appearance of the pyroclastic fall Merangkul deposit unit.

Benda Volcano

The volcano produces pyroclastic deposits consisting of pyroclastic flow and pyroclastic fall (**Figure 6**). The pyroclastic flow deposits (**Figure 7**) are alternating lapilli tuff pyroclastic flows deposits, pyroclastics fall, and pyroxene andesite lava. The fragments are in the form of oxidized andesite and a little pumice. Pyroxene andesite lava is an insert between pyroclastic deposits. The mineral composition consists of plagioclase (33%), pyroxene (15%), quartz (5%), and groundmass (47%). The pyroclastic fall deposits comprise breccia pyroclastic fall, tuff lapilli pyroclastic fall, and tuff lapilli pyroclastic flow.

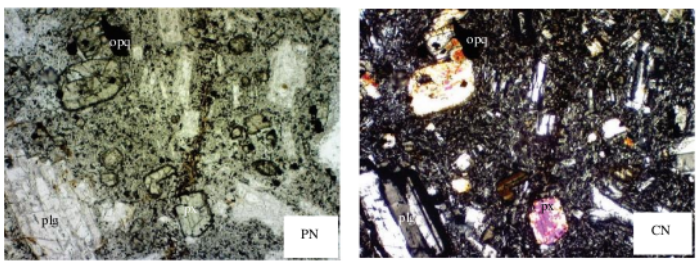

FIGURE 6. Pyroxene andesite petrography shows the presence of plagioclase, pyroxene, and opaque minerals. plg: plagioclase; px: pyroxene; opq: opaque mineral; PN: parallel nicol; CN: cross nicol.

FIGURE 7. Outcrop of the pyroclastic fall Benda Volcano (A) and (B) of each pyroclastic fall lithology unit.

Jojogan Volcano

The product of the Jojogan volcanic eruption produced pyroclastic falls. The pyroclastic falls alternate with flow pyroclastic tuff lapilli, flow pyroclastic breccia, and agglomerates. Pyroclastic deposits from Jojogan's fall have brownish-yellow color. The presence of graded bedding sedimentary structures characterizes these pyroclastic deposits. The andesitic fragment is oxidized in a coarse tuff matrix. Agglomerates have a massive structure and are poorly disaggregated. Also, found blocky andesite ranging in size from gravel to gravel. Pumice is present in small quantities.

Pangonan Volcano

Pangonan Volcano comprises pyroclastic rock units consisting of pyroclastic flow deposits and pyroclastic fall deposits (**Figure 8**) and oxidized blocky andesite fragments in a coarse tuff matrix. The graded bedding sediment structures are common in fall pyroclastic deposits. While massive structures are often found in flow pyroclastic deposits.

FIGURE 8. (A) Outcrop of the pyroclastic fall Pangonan. (B) Close observation of each outcrop.

Kendil Volcano

The results of the Kendil Volcano eruption include several rock units. The rock units consist of biotite hornblende andesite lava 1 Kendil, biotite hornblende andesite lava 2 Kendil, pyroclastic flow Kendil and pyroclastic fall Kendil.

Biotite hornblende andesite lava 1 Kendil occupies the top of Kendil Volcano. As an outcrop of biotite hornblende andesite lava with fresh grey and weathered brown color (**Figure 9**). The hypocrystalline porphyritic intergranular texture is composed of minerals such as plagioclase (36%), biotite (15%), hornblende (10%), quartz (5%) and groundmass (34%) in the form of volcanic glass (**Figure 10**).

Biotite hornblende andesite lava 2 Kendil is massive in structure with a hypocrystalline porphyritic intergranular texture. The mineralogy composition of the rock composition is plagioclase (45%), biotite (12%), hornblende (8%), quartz (5%), and groundmass (30%) as volcanic glass.

The results of the Kendil volcanic eruption were not only dominated by lava. But also pyroclastic flows Kendil deposits and pyroclastic fall Kendil (**Figure 11**). The pyroclastic flow Kendil deposits were composed of tuff lapilli. And the tuff lapilli showed poor sorted with blocky andesite fragment composition. Also, the pyroclastic fall deposits Kendil show a graded bedding sediment structure.

FIGURE 9. (A). Outcrop biotite hornblende andesite lava 1 Kendil. (B). Close up shot of biotite hornblende andesite lava.

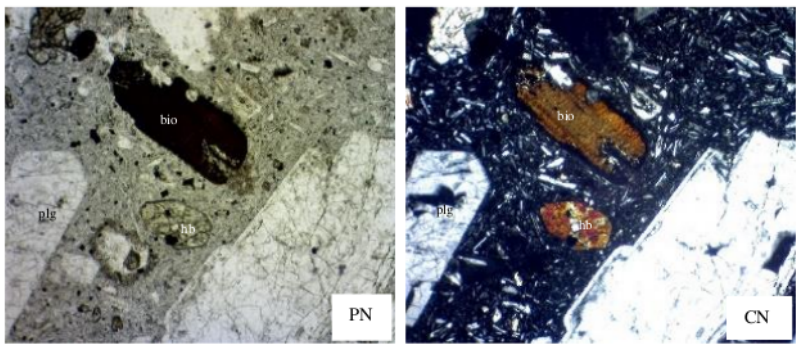

FIGURE 10. Biotite hornblende andesite lava 1 Kendil petrography shows the presence of plagioclase, pyroxene, and opaque minerals. plg: plagioclase; bio: biotite; hb: hornblende; opq: opaque mineral; PN: parallel nicol; CN: cross nicol.

FIGURE 11. (A). The outcrop features of pyroclastic fall Kendil deposits show a graded bedding sediment structure. (B) Close observation of each outcrop.

Pakuwaja Volcano

The volcano is composed of hornblende andesite lava (**Figure 12**). Pakuwaja lava is well exposed at Pakuwaja Volcano. Lithology is grey in color. The mineralogical composition (**Figure 13**) is the presence of plagioclase (47%), hornblende (13%), pyroxene (10%), quartz (5%) and volcanic glass as the groundmass (25%). These rocks exhibit an intergranular hypocrystalline porphyritic texture. Scoria and vesicular structures are common on the exterior of this lava.

FIGURE 12. (A). Outcrop appearance of hornblende andesite lava Pakuwaja unit. (B). Close up shot of hornblende andesite lava.

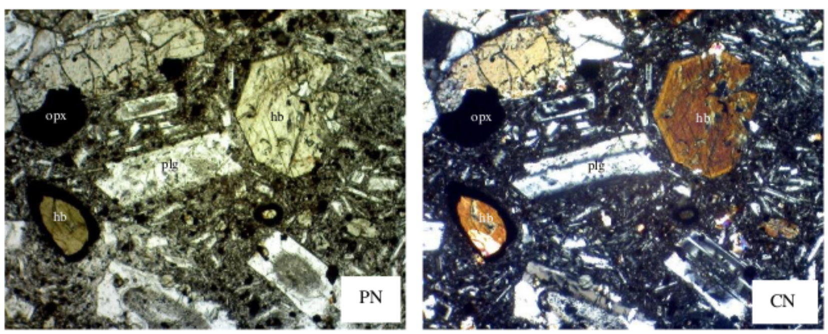

FIGURE 13. Hornblende andesite lava Pakuwojo petrography shows the presence of plagioclase, hornblende, and opaque minerals. plg: plagioclase; hb: hornblende; opq: opaque mineral; PN: parallel nicol; CN: cross nicol.

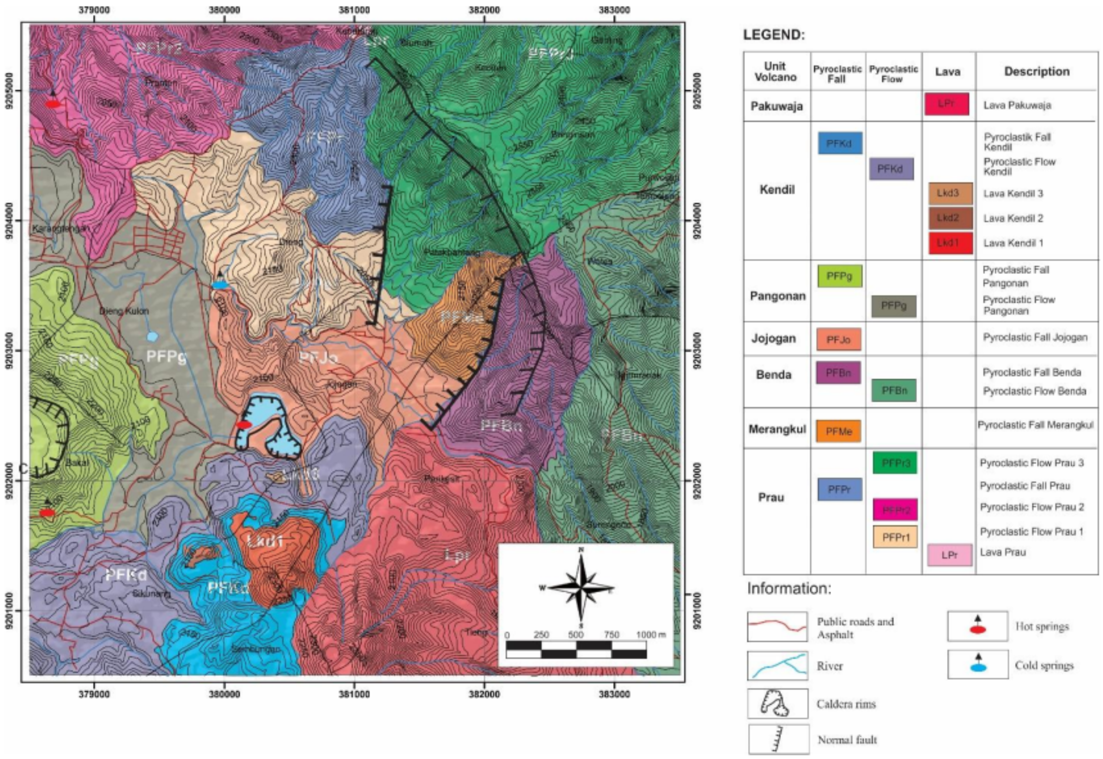

FIGURE 14. Geological map of the study area.

Volcano Facies Model

From observations and data collection carried out in the study area and referring to the volcanic facies model according to Bogie and Mackenzie (1998), the volcanic facies in the study area include central facies, proximal facies, and distal facies. These facies were applied to each volcanic unit in the study area (**Figure 15**).

Prau Volcano

Based on field observations and the classification of the Bogie and Mackenzie volcanic facies (1998), Prau Volcano has central facies and proximal facies. The explanation of each facies is as follows:

The central facies of Prau Volcano was composed of hornblende andesite lava, blocky andesite and lapilli tuff that form hills that extend to resemble the caldera rim, which is the center of the eruption. At the research location, a lava hill was found at the peak of Volcano Prau in the form of andesite lava and showed a solid structure caused by cooling magma. While the proximal facies consists of fallen pyroclastic lapilli tuff deposits and pyroclastic flows that form volcanic slopes.

Jojogan Volcano

Jojogan Volcano only has a central facies composed of fallen pyroclastic tuff lapilli deposits and pyroclastic flows. This volcanic deposit is a product of volcanic eruptions from Jojogan Volcano.

Pangonan Volcano

Pangonan Volcano, based on field observations and the classification of volcanic facies, Bogie and Mackenzie (1998) have central and proximal facies. The explanation of each facies is as follows:

The central facies consists of sediment fallen pyroclastic tuff lapilli. In this research area, there is also a crater that has become a savanna. So this indicates the morphological formation of the eruption center of the Pangonan Volcano. Meanwhile, the proximal facies consist of tuff lapilli pyroclastic fall and pyroclastic flows deposited on the volcano's slopes or around the volcano's foot.

Kendil Volcano

Kendil Volcano has central facies and proximal facies. The explanation of each facies is as follows:

The central facies is characterized by the presence of hornblende lava 1 Kendil, biotite lava Kendil, hornblende lava 2 Kendil, and lapilli tuff. In the study area, a lava dome was found at the peak of Volcano Kendil, indicating that the rock reflects the morphology of the eruption center of Volcano Kendil. The proximal facies is a lapilli tuff deposit that forms volcanic slopes with a massive structure.

Pakuwaja Volcano

Volcano This Pakuwaja Volcano only has a central facies. This facies is in the form of hornblende andesite, and many blocky andesites are found on the slopes of the Pakuwaja Volcano. A lava dome is at the top of the Pakuwaja Volcano, which is interpreted as the center of the eruption of Pakuwaja Volcano.

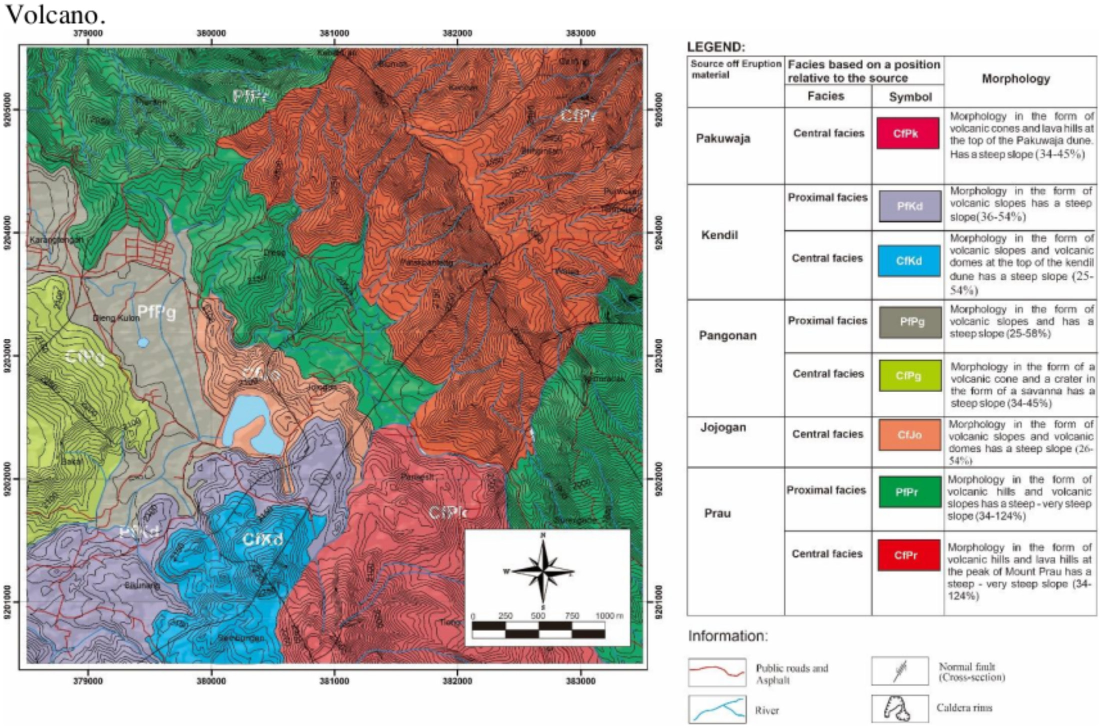

FIGURE 15. Map of the volcanic facies of the study area.

Eruption Stages

The volcanic period of the Dieng Volcano Complex can be grouped into the pre-caldera stage, post-caldera stage I, post-caldera II, or the last stage. So this is based on its relationship with the structure of the caldera and its distribution and radiometric age. Radiometric age data was determined by the K-Ar dating method (Harijoko et al., 2010). However, the volcanic period includes pre-caldera and post-caldera II in the research area. An explanation of this can be followed as follows:

Pre-caldera stage

In the research area, the pre-caldera stage is represented by Prau Volcano. This volcano is a large explosive eruption to form a caldera structure. At this time, it only shows the morphology of the rim of some of the morphology of the caldera. The pre-caldera stage started with the constructive phase of Prau Volcano at 3.6 Ma during the Pliocene (Boedihardi et al., 1991). The destructive phase of Prau occurred in the form of an explosive eruption which left the current morphology of Prau Volcano (**Figure 16**).

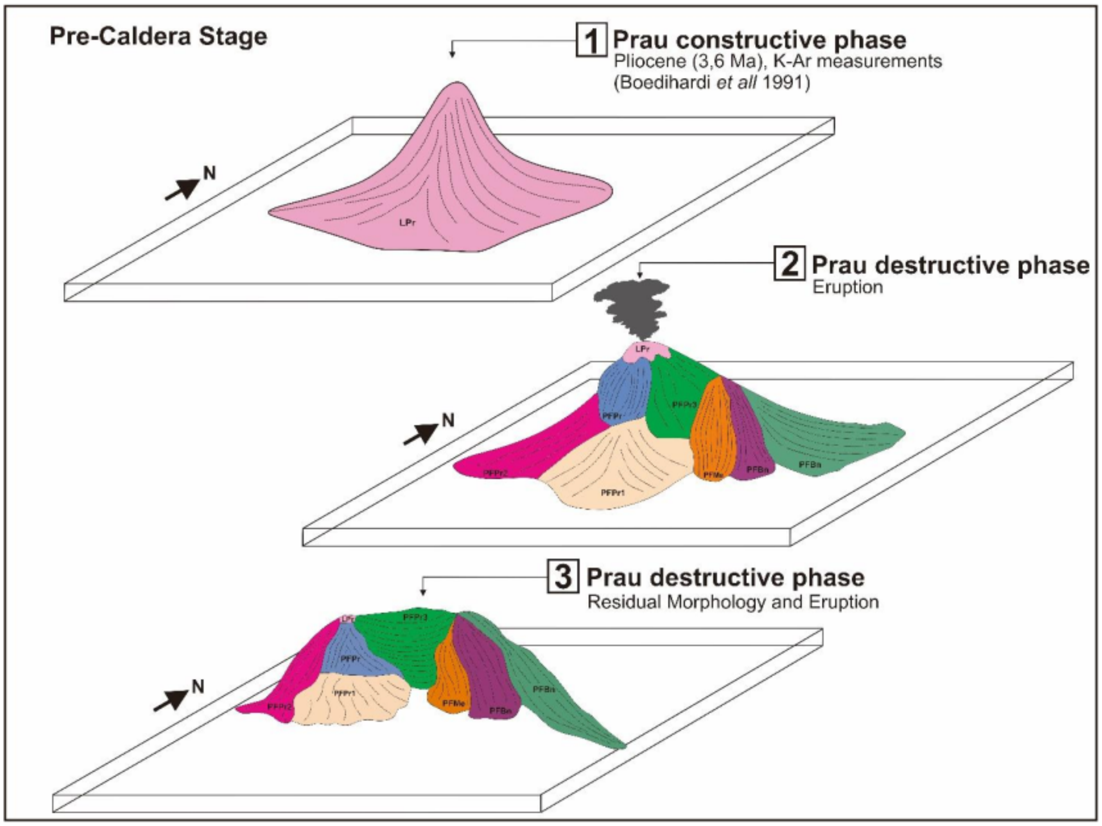

FIGURE 16. Illustration of the pre-caldera stage block diagram

Post-Caldera II

Stage The post-caldera II stage in the research area begins with the constructive phase of the

Jojogan Volcano, which is marked by the presence of a crater that is the center of the eruption of the Jojogan Volcano (**Figure 17**). This crater forms a lake morphology called Telaga Warna and is then followed by the destructive phase of Jojogan, characterized by the presence of pyroclastic deposits from the Jojogan fall. At 0.37 Ma, or the Pleistocene's time, the eruption stage was followed by a constructive phase of the Pangonan Volcano. The morphology of the Pangonan crater characterizes this phase. Then followed the destructive phase of the Pangonan Volcano, which was marked by the presence of the pyroclastic flows and pyroclastic falls Pangonan.

At 0.19 Ma, the Pleistocene epoch continued with the constructive phase of the Kendil Volcano. This eruption phase was marked by the presence of hornblende andesite lava Kendil, biotite andesite lava Kendil and hornblende andesite lava 2 Kendil. So the followed by a destructive phase marked by the pyroclastic flows of Kendil and pyroclastic falls of Kendil. Finally, at 0.13 Ma during the Pleistocene, a constructive phase of Pakuwaja Volcano was marked by the presence of hornblende andesite lava Pakuwaja in the study area (**Figure 18**).

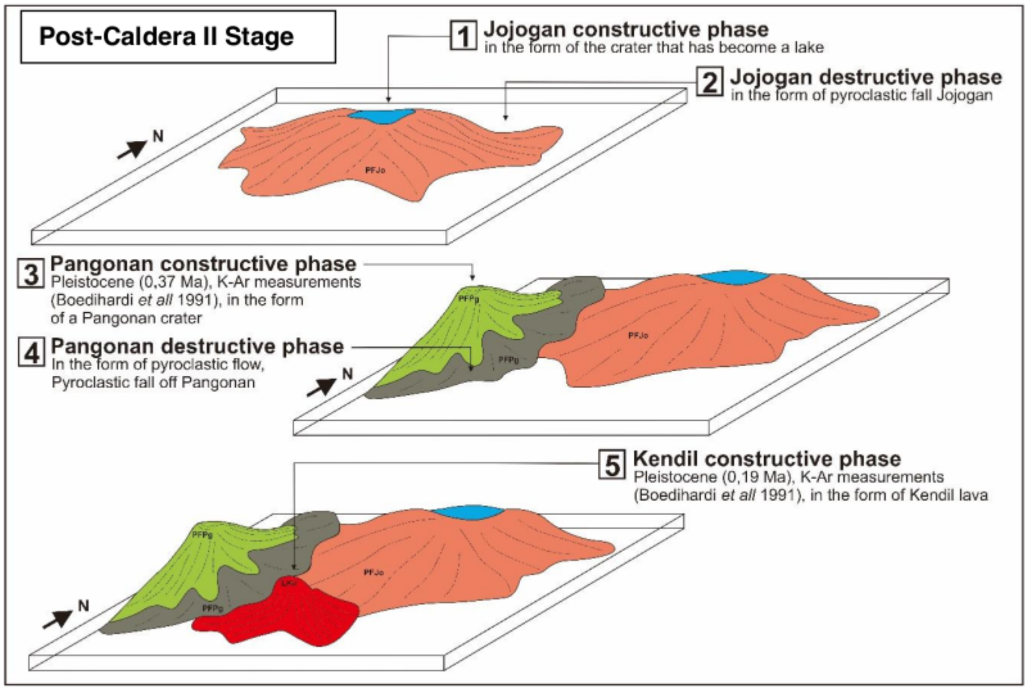

FIGURE 17. Illustration of a block diagram of the post-caldera II stage of Pangonan Volcano.

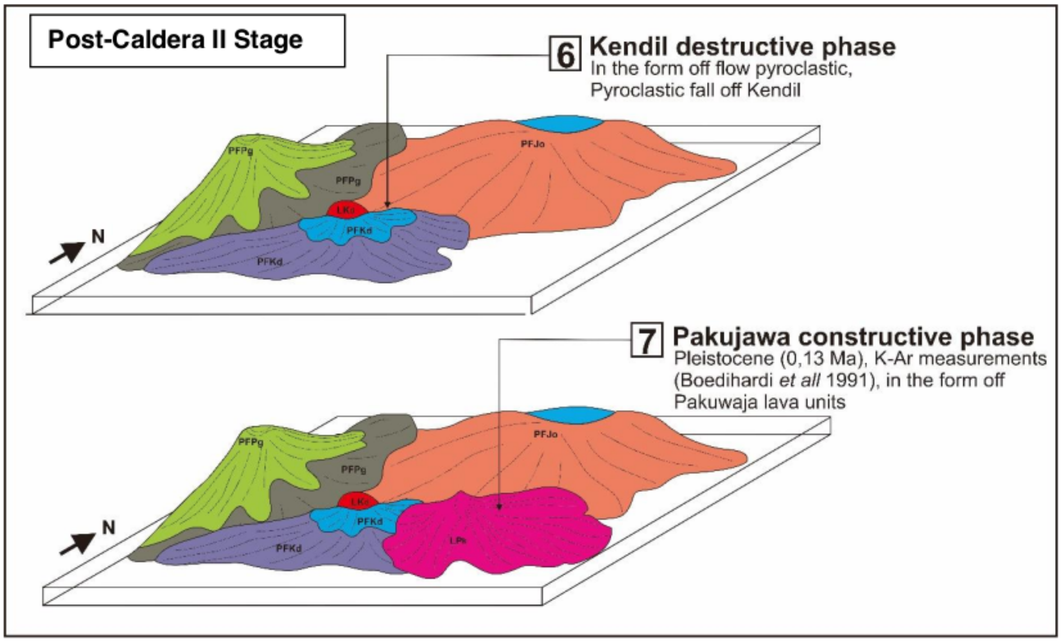

FIGURE 18. Block diagram illustration of the post-caldera II phase of Kendil Volcano.

CONCLUSION AND FURTHER RESEARCH

The geology of the study area consists of several volcanic cones such as Prau Volcano, Merangkul Volcano, Benda Volcano, Jojogan Volcano, Pangonan Volcano, Kendil Volcano, and Pakuwaja Volcano. These volcanoes produce pyroclastic fallout and flow pyroclastic deposits. In addition, some lava is an insert or interlude of pyroclastic deposits and lava domes. The lavas are hornblende andesite and biotite andesite lava.

Various types of volcanic facies can be arranged based on the characteristics of pyroclastic deposits and lava from volcanic eruption deposits in the research area. The volcanic facies in the study area include central and proximal facies. Central facies are owned by Prau Volcano, Jojogan Volcano, Pangonan Volcano and Pakuwaja Volcano. While Volcano Kendil owns the central facies and proximal facies.

In general, the eruption period of the Dieng Volcano Complex is grouped into the pre-caldera stage, post-caldera stage I, and post-caldera II, or the last stage. However, the stages of the eruption period of the Kendil Volcano and its surroundings include the pre-caldera and post-caldera stage II. In the pre-caldera stage, there was a constructive phase of Prau Volcano and a large eruption that left Mount Prau's morphology as it is today. Then the post-caldera II stage began to appear with younger volcanoes after Prau Volcano. So it begins with the constructive phase of Jojogan and the destructive phase of Jojogan, then the constructive phase and the destructive phase of Pangonan. Next are Kendil's constructive phase and Kendil's destructive phase. The last phase is the constructive phase of Pakuwaja.

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REFERENCES

Boedihardi, M., Suranto, and Sudarman, S., 1991. Evaluation of the Dieng geothermal field; review of development strategy: in Proceedings of the 20th Annual Convention, v. 1, Indonesian Petroleum Association, p. 347-361.

Bogie, I., and Mackenzie, IC M., 1998. The Application of a Volcanic Facies Model to an Andesitic stratovolcano Hosted Geothermal System at Wayang Windu, Java, Indonesia, Proceedings of Netu Zealand Geothermal Workshop, Auckland, New Zealand.

Bronto, Sutikno. 2006. Volcanic Facies and Its Applications. *Indonesian Journal of Geology: Vol. 1, No. 2* 59-71.

Bronto, S., 2013. *Ancient Volcano Geology*. Bandung: Geological Agency of the Ministry of Energy and Mineral Resources

Cas, RAF, and Wright, JV, 1987. Volcanic successions: modern and ancient. Allen and Unwin, London, 528 p.

Fisher, R V., and Schmincke, HU, 1984. *Pyroclastic Rocks*, Springer-Verlag Berlin.

Harijoko, Agung, et al 2010. Long-Term Volcanic Evolution Surrounding Dieng Geothermal Area, Indonesia. Proceedings of the 2010 World Geothermal Congress, Bali, Indonesia, 25-29 April 2010. Harijoko, Agung, et al. 2016. Geochronology and magmatic evolution of the Dieng Volcanic Complex, Central Java, Indonesia and their relationships to geothermal resources. Journal of Volcanology and Geothermal Research 310 (2016) 209– 224.

Harijoko, A., Uruma, R., Wibowo, HE, Setijadji, LD, Imai, A., Yonezu, K., Watanabe, K., 2016. Geochronology and magmatic evolution of the Dieng Volcanic Complex, Central Java, Indonesia and their relationships to geothermal resources. Journal of Volcanology and Geothermal Research 310 (2016) 209–224

Indonesian Stratigraphic Code Commission. 1996. *Indonesian Stratigraphic Code*. Jakarta: IAGI.

McPhie, J., Doyle, M., Allen, R, 1993. *Volcanic Textures (A Guide to Interpretation of Textures in Vulcanic Rocks),* Tasmanian Government Printing Office, Tasmania.

Sukhyar, R., Sumartadipura, NS, Effendi, W., 1986. Geological Map of Dieng Volcano Complex, Director at Volcanology.

Walker, GPL, 1985. Origin of coarse lithic breccias near ignimbrite source vents. Journal of Geothermal and Volcanology Research, 25, pp.157-171

Wright, JV, and Walker, GPL, 1977. The ignimbrite source problem: significance of a co-ignimbrite lag-fall deposit. Geology, 5, p. 729-732.

Wright, JV, 1981. The Rio Caliente ignimbrite: analysis of a compound intraplinian ignimbrite from a major late Quaternary Mexican eruption. Bulletin of Volcanology, 44, p. 189-212

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