Petrography characteristics of Quaternary volcanoes in Rawa Danau Caldera, Banten Province

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Abstract. The caldera from volcano eruptions often been found in Indonesia. However, the caldera which has swamp and lake such as Rawa Danau, Serang, Banten is rare in Indonesia. It encompasses with a swamp at the outer part and lake on the central part. The caldera surrounded by five Quaternary volcanoes, which are Mount Karang, Mount Parakasak, Mount Aseupan at the south, and Mount Tukung-Gede along with Mount Marikangen at the north side of the swamp. The Rawa Danau location is about 50 km to the East of Krakatau Volcano, so it might have been some linkage to its rock properties. This similarity can be seen from the textures and mineral compositions of their thin sections. Most of the volcano material resulted from different volcanoes. The challenging work was how to differentiate their sources eruption in the field because the weathering rate is high. Thus, this paper aims to differentiate the products of each young volcanoes in Rawa Danau using petrography analysis. In general, young volcanoes in Rawa Danau have trachytic and porphyritic textures, with plagioclase, pyroxene, and opaque as the phenocryst and microlite plagioclase as the matrix. The plagioclase can be found around 15–30 % as the phenocryst, microlite plagioclase as the matrix. The plagioclase type is around An55 compared with Krakatau which has An58. The magma characteristics of these young volcanoes might have a similarity with the magma of Krakatau Volcano.

Keywords: Rawa danau, Quaternary volcanoes Krakatau, petrography

1. Introduction
Rawa Danau is a caldera which has lake and swamp that located in Serang, Banten, Indonesia. This morphology is caused by two big eruptions from Dano Purba volcano during Pleistocene. This area covered more than 2,500 hectares and surrounded by five Quaternary volcanoes which are Mount Karang, Mount Parakasak and Mount Aseupan at the South side, and Mount Marikangen along with Mount Tukung-Gede at the North side of the swamp. These five volcanoes have been born in syn and post-Dano Purba’s eruption. All their activity regarding eruption in this area stopped in Holocene. Meanwhile, 50 km from the West side of Rawa Danau, Krakatau erupted in Holocene (416 A.D) and stopped its eruption in 1681. From the records of history, Krakatau will erupt again in a particular span of years after 1681 [1-5].

The general composition of Krakatau’s products is composed by pyroxene (augite and hypersthene), small olivine, and 53–66 % plagioclase as phenocryst and microlite with andesine–labradorite (An48–An68) composition [2].
There are difficulties to differentiate the products of Mount Karang, Mount Parakasak, Mount Aseupan, Mount Marikangen, and Mount Tukung Gede on the field (figure 1). The weathering intensity which seemed rather high in this area made the rock was a bit difficult to identify directly. Besides, these five Quaternary volcanoes in Rawa Danau and Krakatau volcano seemed to erupt in a row. Thus, this research is made to characterize those five Quaternary volcanoes of Rawa Danau and to compare their volcanism products to Krakatau’s by using petrography method.

2. Experimental

2.1. Field observation
Field observation was used to develop an understanding of the volcanic products distribution from each volcano. Observations were made in Rawa Danau area that were surrounded by four Quaternary young volcanoes which are Mount Karang, Mount Parakasak, Mount Aseupan, and Mount Tukung-Gede. There are about 200 rock samples of volcanic products such as tuff, breccia and lava.

2.2. Laboratory method
Laboratory method included rock sample descriptions and analysis of their thin sections on direct sample outcrop or the igneous fragment in breccia. The analysis was observed in both crossed Nichols (XPL) or parallel Nichols (PPL). There are 14 thin sections of igneous rock whether from lava or breccia fragment. This observation was made to understand the color, mineral composition, their percentage, and their textures of each young Quaternary volcanoes in Rawa Danau. In general, the composition of the minerals was mainly composed of plagioclase, pyroxene, and opaque.

Figure 1. The location of the five Quaternary volcanoes which are (from right to left): Mount Karang (Gunung Karang), Mount Parakasak, and Mount Aseupan at the South, Mount Marikangen and Mount Tukung Gede at the North. There is also Krakatau Volcano around 50 km from the west side of Rawa Danau.
3. Results and discussion

3.1. Results

3.1.1. Mount Karang. Mount Karang is a young Quaternary volcano located at the Southeast of Rawa Danau. Grey massive lava andesitic and breccia composed by the tuff matrix and andesite fragments are their products that have been found in the research area. They have high weathering intensity. Their products were used in the Late Pleistocene–Middle Holocene [3].

The thin section study indicates that the igneous rock in Mount Karang was composed of plagioclase, pyroxene, and opaque (figure 2). The average quantities compositions were ±60% microlite plagioclase as groundmass, along with other phenocrysts such as 24% plagioclase, 11% pyroxene, and 4.6% opaque. Plagioclase, exist as phenocryst and groundmass (microlite), had greyish white color, no pleochroism, low relief, generally subhedral, show carlsbad, and carlsbad-albite twining, first-order birefringence, mostly found in the size 1–5 mm. Its composition is Andesine–Labradorite (An40–64) with an average An50. The plagioclase had sometimes twin penetration with each other or with pyroxenes. Zoning was also sometimes found in big plagioclase. The second abundant phenocryst was pyroxene which had been found with reddish purple, yellowish brown, pale grey color, and had a variable length from 0.4–4 mm in size. But pyroxene often been found at 1 mm in size. Pyroxene sometimes was found as groundmass along with microlite plagioclase. Opaque often been found as inclusion at 0.5 mm length. It has black color and scattered randomly. Microlite plagioclase as their groundmass covered from 50–70% of its area and mostly has trachytic texture in them.

3.1.2. Mount Parakasak. Mount Parakasak is located at the south of Rawa Danau. Blackish grey massive lava andesitic and brown breccia composed by the tuff matrix and andesite fragments are the products of Mount Parakasak which located at the south of Rawa Danau. The outcrop has high weathering intensity and is used in the Late Holocene–Middle Holocene [5].

The lava or igneous rock fragment in breccia of Mount Parakasak composed by plagioclase, pyroxene, and opaque (figure 3). Most abundant minerals in this area are plagioclase (~18%), which has blackish grey color, no pleochroism, low relief, mostly subhedral, and have carlsbad-albite and albite twinning, with the first-order birefringence. The composition of plagioclase in this area range from Andesine–Labradorite (An40–An68) with the average An55 (Labradorite). Some of the plagioclase have zoning and opaque inclusion in them. Mostly been found with various length range from 0.7–3 mm. The second abundant mineral was pyroxene (~8.6%), which has a yellowish brown color, blue to pinkish purple, no pleochroism, low relief, and mostly sub-anhedral. Sometimes it penetrates with plagioclase and a little of them have been found in plagioclase as an inclusion. They were mostly being found at 0.5–1 mm size. Opaque which covered ~4.4%, had black color and scattered randomly in every thin section of this area. At the length of 0.2–0.5 mm, they are mostly been found as an inclusion of other phenocrysts such as plagioclase, pyroxene, and biotite. Biotite was rarely seen and has been found in just one thin section which covered only ~2% of its area. It has brown color whether in XPL or PPL and has 0.5 mm length. Biotite scattered randomly and sometimes have been found as an inclusion in pyroxene. Often it also has opaque inclusion in them. Most thin sections have a trachytic texture with microlite plagioclase that covered ~68% of its area and sometimes along with microlite pyroxene as groundmass.

3.1.3. Mount Aseupan. Mount Aseupan is located at the southwest of Rawa Danau. Brownish grey basaltic rock and breccia composed by the tuff matrix which has high weathering intensity are their products in Early Holocene–Middle Holocene [5].
Figure 2. Thin sections of andesite in Mount Karang, composed by pyroxene (Px), opaque inclusion (Op), and plagioclase (Pg) as their most abundant phenocrysts. Microlite plagioclase (MPg) existed as their groundmass with trachytic texture. The plagioclase has a big length which ranges 1–5 mm. (a) Thin section of andesite lava, (b) Thin section of basaltic andesite fragment in breccia. Plagioclase zoning often appeared in mediocre to big plagioclase such as in (b).

Figure 3. Thin section of andesite lava at Mount Parakasak. It composed by plagioclase (Pg), pyroxene (Px), opaque (Op), and biotite (Bi) as phenocryst. Microlite plagioclase as their groundmass covered 70% of their area and has trachytic texture in them. The plagioclase composition in this thin section is Labradorite (An55). Opaque scattered randomly and often been found as an inclusion in other phenocrysts. (a) XPL thin section, and (b) PPL thin section.

Basaltic rock in Mount Aseupan is composed by plagioclase, pyroxene, and opaque (figure 4). The plagioclase is the most abundant mineral with 18% as phenocryst and 62% as groundmass (microlite plagioclase). It has whitish grey, no pleochroism, medium relief, first-order birefringence, and mostly subhedral. There is Carlsbad-albite, Carlsbad twinning, and penetration twinning. It has bytownite composition (An75) and mostly been found around 1–4 mm length. Pyroxene as the second abundant mineral in this area (15%) has yellowish brown to blue color. There isn’t any pleochroism and has medium relief. It has mostly been found at 0.5–2 mm length which often been found in a cluster or has glomero-porphyritic texture. Opaque which only covered 5% of this area, has black color and
scattered randomly. Often been found at 0.5 mm length or less as an inclusion in pyroxene. In general, the thin section in this area has a trachytic texture which flows composed by smaller microlite plagioclase than the two volcanoes above.

3.1.4. Mount Marikangen. Mount Marikangen is located at the northeast of Rawa Danau swamp. Brownish grey massive andesite rock and brown breccia with tuff matrix and andesite fragments are their products that have been found. Their products are in the Middle Pleistocene [3]. The weathering intensity in this mountain area is small to moderate.

The thin section study indicates that the compositions of the igneous rock in lava or in breccia fragment are plagioclase, pyroxene, and opaque (figure 5). Plagioclase exists as phenocryst and groundmass (microlite) and is the most abundant mineral that covered ~45–50 % of its area. It has a grey color in the first-order birefringence, no pleochroism, low relief, and mostly sub-anhedral. There are carlsbad and carlsbad–albite twinning, with some plagioclases shown zoning in them. The composition of its plagioclase is Andesine–Labradorite (An40–50), with an average An45 (Andesine). It has been found at 1–5 mm length. Pyroxene is the second abundant mineral in this area which covered ~19 % of its area. With greenish yellow, blue to pinkish purple color, it has been found at 0.5–1 mm length and has second-order birefringence also no pleochroism. Sometimes it penetrates with plagioclase and has opaque inclusion in them. Opaque which covered ~13 % of its area, has black color and scattered randomly. Often been found as an inclusion in other phenocrysts, mostly with 0.5 mm length. Biotite which only covered ~7 % of its area has brown color whether in XPL or PPL. Mostly found at length 0.5 mm or less. In general, the texture in them was trachytic which could be seen by the flow of microlite plagioclase as their groundmass.

3.1.5. Mount Tukung-Gede. Mount Tukung Gede is Rawa Danau’s last young Quaternary volcano in this paper that located at the north of its swamp. Gray andesite rock, greyish white tuff, and breccia with andesite fragment and tuff matrix are in the Middle Pleistocene–Late Pleistocene [5]. The weathering intensity in this mountain area is low.

The andesite rock and andesite fragment in breccia in Mount Tukung Gede were composed by plagioclase, pyroxene, opaque, biotite, and muscovite (figure 6). Once again, plagioclase was the most abundant mineral as phenocryst (~30 %) and groundmass (microlite, ~39 %), which had grey color with first-order birefringence and low relief. Mostly subhedral and shown and carlsbad-albite twinning. Sometimes zoning can be found at big plagioclase which has ~3 mm length. The plagioclase composition ranges from Labradorite – Bytownite (An60–73) with an average An66. Pyroxene which covered (~10 %) of its area has blue, pinkish purple, and greenish yellow color and at 0.5–5 mm at length, but mostly found at 3 mm. The small pyroxene which had a length less than 1 mm, scattered randomly but the bigger one (1–2 mm) mostly found to gather at one point and created glomeroporphyritic texture. Opaque scattered randomly and covered ~6 % of its area. It had black color and mostly found as an inclusion in other phenocrysts. Muscovite exists with blue to pinkish purple color and covered ~10 % of its area. It had bird’s eye extinction. It also had at 1–2 mm length which mostly gathers to one point and created glomeroporphyritic texture. Biotite which only covered ~5 % of its area, had the brown color. It had 1–2 mm length and gather at one point or has glomeroporphyritic texture. Sometimes found to penetrate with pyroxene and has opaque inclusion in them. In general, the texture of the thin section in this area is porphyritic, because of their random size of small microlites as groundmass and small pyroxene phenocryst that seems like mixing with them. But in one area, there is an alignment or flow texture that shown. But the texture still more closely related to porphyritic texture.

3.2. Discussion

Based on the descriptions above, all five Quaternary volcanoes in Rawa Danau mostly had similar characteristics. But there were indeed slight differences in each of their characteristics. Also, the outcrops and rock samples on Quaternary volcanoes at the south side of the swamp have higher weathering intensity rather than at the north side of the swamp.
Figure 4. Thin section of basaltic andesite in Mount Aseupan. (a) XPL, (b) PPL of thin section composed by plagioclase (Pg), pyroxene (Px), and opaque (Op) as their phenocrysts. Microlite plagioclase (MPg) as their groundmass covered 62% of its area. The microlites have a smaller size than two volcanoes before them, but an alignment can be seen and form trachytic texture. Opaque which has 0.5 mm length scattered randomly, often been found as an inclusion.

Figure 5. Thin section of andesite lava in Mount Marikangen. It composed by plagioclase (Pg), pyroxene (Px), opaque (Op), and biotite (Bi) as phenocryst. Microlite plagioclase as their groundmass covered 60% of their area and has a trachytic texture which surrounds their phenocryst. The plagioclase composition in this thin section is Andesine (An45). Opaque scattered randomly and often been found as an inclusion in other phenocrysts. Plagioclase zoning has often been found in big phenocryst such as in picture (a). (a) XPL thin section in andesite rock, and (b) XPL in andesite breccia.

Starting from Mount Parakasak which appeared biotite in their products compared to Mount Karang that did not have any of them. And also, the direction of Mt. Parakasak’s trachytic texture was the most visible and the microlite plagioclase’s size in Mount Aseupan was the smallest than the other four volcanoes. Compared to the other four Quaternary volcanoes in Rawa Danau, Mount Tukung-Gede
Figure 6. Thin section of andesite fragment in breccia, composed plagioclase (Pg), pyroxene (Px), opaque (Op), biotite (Bi), and Muscovite (Mv) as phenocrysts. And microlite plagioclase and small pyroxene as their groundmass. Opaque as always found as an inclusion in other phenocrysts. Pyroxene with moderate size often found to gather at one point and create glomeroporphyritic texture with each other or sometimes with other phenocrysts. Labradorite (An60). (a) Plagioclase zoning and some biotite, and (b) Big glomeroporphyritic texture and some muscovite.

had differences that are most visible, because of its groundmass texture which was porphyritic rather than trachytic. The pyroxene distribution in Mount Tukung-Gede was also varied and could be found at its groundmass like Mount Parakasak’s groundmass compared to Mount Karang, Mount Marikangen, and Mount Aseupan which composed only microlite plagioclase as their groundmass.

In general, all five Quaternary volcanoes of Rawa Danau’s product range from andesite to basaltic andesite rock whether in massive outcrop or in breccia fragment. Mainly composed by plagioclase, pyroxene, and opaque as phenocryst and microlite plagioclase as groundmass. Sometimes biotite and muscovite also appeared as phenocryst. The composition of plagioclase ranges from Andesine–Bytownite (An 40–73) with an average An55 (Labradorite). Zoning in plagioclase often been found in large plagioclase and opaque inclusion found in phenocrysts of every thin sections. This means there is a change in temperature and Ca-Na composition at the rim which reflects the cooling and chemical differentiation of the host magma. From the inclusion appearance, we can conclude that opaque is the first mineral appeared, then pyroxene because it sometimes appeared as inclusion in plagioclase, lastly plagioclase itself. Glomeroporphyritic texture has often been found in pyroxene. Sometimes, biotite can be found in small size and only covered 10 % at maximum. Four volcanoes which are Mount Karang, Mount Parakasak, Mount Aseupan, and Mount Marikangen have trachytic texture except for Mount Tukung Gede which has porphyritic texture, but small alignments of its groundmass can be spotted in some area. Compared to Krakatau, these descriptions have similarity with them. Their plagioclase composition ranges from An48-68 with an average An58 which is not far from Rawa Danau (An55). Plagioclase zoning also often been found in their bigger size and pyroxene inclusion found as the small inclusion in plagioclase. However, small olivine can be found as groundmass along with microlite plagioclase contrasts to Rawa Danau which did not show any olivine in groundmass, but pyroxene was. And opaque which is one of the main compositions in Rawa Danau did not exist as of the main in Krakatau.
4. Conclusion
All these five Quaternary volcanoes mostly composed by plagioclase, pyroxene, and opaque as their main phenocrysts. Their groundmass which is microlite plagioclase sometimes mixing with small pyroxene. Plagioclase zoning indicates there are changes of temperature in magma cooling. The characteristics of Mt. Karang, Mt. Parakasak, Mt. Aseupan, Mt. Marikangen, and Mt. Tukung Gede have some similarity with Krakatau volcano. Whether this similarity is caused by the same magma source cannot be proven yet and needs further studies such as geochemistry and rock dating to know more about their relations.

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