Is There any Change from Magma Mixing in Kelud Characteristics?

Achmad Djumarma Wirakusumah[1] and Hanik Humaida[2]
[1] *(Institue of Energy and Mineral Akamigas, Mininstry of Energy and Mineral Resources of Indonesia)*
[2] *(Geological Agency, Mininstry of Energy and Mineral Resources of Indonesia)*
ade.wirakusumah@gmail.com

ABSTRACT *: Kelud volcano is located in East Java Province, Indonesia. According to Geochemical study of Kelud Volcano, it could be divided into 3 periods which are Kelud I (older than 100 ky BP), Kelud II (40 – 100 ky BP), and Kelud III (younger than 40 ky BP). A specific petrogenesis of Kelud are dominatad by magma mixing and fractional crystalization. New petrological data from Kelud volcano was taken through products of the eruption in 1990 (Vulkanian type), 2007 (Lava plug forming) and 2014 (Plinian type). Petrographic study on these rocks showed that reverse and oscilatory zoning on plagioclases, Shieve-like and corroded textures on plagioclases and pyroxenes are common. However, normal zoning textures were also found on plagioclases and pyroxenes. Whole rock study on these rocks showed all rocks were classified into Basalt to Andesite in composition with calc-alkaline group. The study indicated that their magma origin derrived from slab with fractional crystallization during in the magma reservoir, and magma mixing processes are dominant expecially in magma pockets. Concequently, the magma origin and petrogenesis of Kelud magma after the 1966 eruption are still the same as those of old magma of Kelud.*

KEYWORDS : *Fractional crystalization, magma mixing, petrogenesis.*

I. INTRODUCTION

Mt Kelud is an active andesitic volcano in East Java, part of the Sunda arc, lying within a volcanic belt that is about 150 km above the north deeping Benioff Zone, where the Indian Ocean Plate is beeing subducted beneath Java (Fig 1and 2) [1].

Geological map of Kelud volcano have been made based on a convensional field survey during 1985-1986 on the whole body of the volcano such as [2], also [3] based on a field survei on the summit area. On the other hand, some petrographic study on some Kelud volcanic rocks at summit area has been made such as [4].

In 1987 the author remapped geologically Mt. Kelut much more detail than those done by the previous authors. The map was done based on the volcano-stratigraphy method which was compiled by an interpretation of aerial photographs of Kelud volcano. Rock units were divided on the basis of their source (vein origin) and their eruption mechanism and cyclus. According to Geochemical study of Kelud Volcano, it could be divided into 3 periods which are Kelud I (older than 100 ky BP), Kelud II (40 – 100 ky BP), and Kelud III (younger than 40 ky BP) [5]. The Kelud volcanic rock can be classified into 3 kinds of rocks such as basalt, basaltic andesite and andesite [5]. The data was limited up to Kelud volcanic rocks derrived from eruptions products before the 1966 Kelud eruption.

According to last three Kelud eruptions which were in 1990 as a Vulkanian eruption type, in 2007 as a Lava plug production, and in 2014 as a Plinian type eruption, is there any change in petrogenetic characteristics expecially from magma mixing at Kelud? This question is interested to answer as it is closely related to Kelud morphology which is irreguler and many found old craters at the summit area. These eruptions also occurred through the recent crater (Kelud crater).

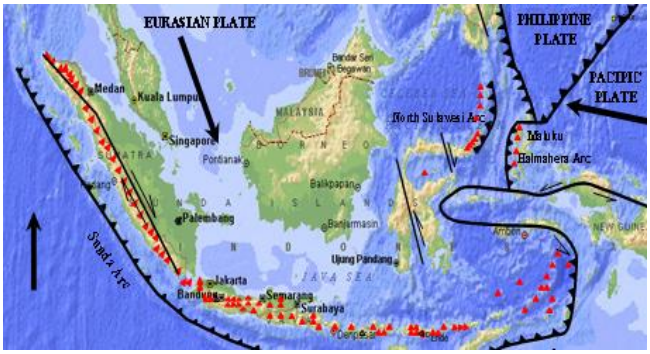


Figure 1. Tectonics in Indonesian Archipelago [5].

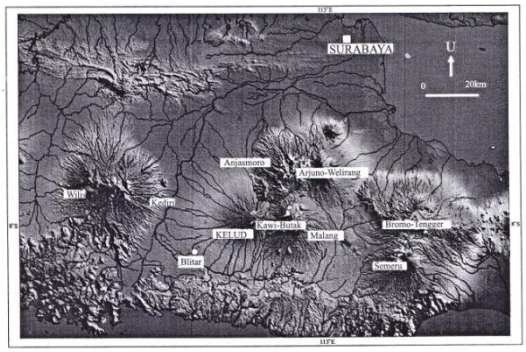


Figure 2. Map of Kelud volcano and its surroundings [5].

II. METHOD.

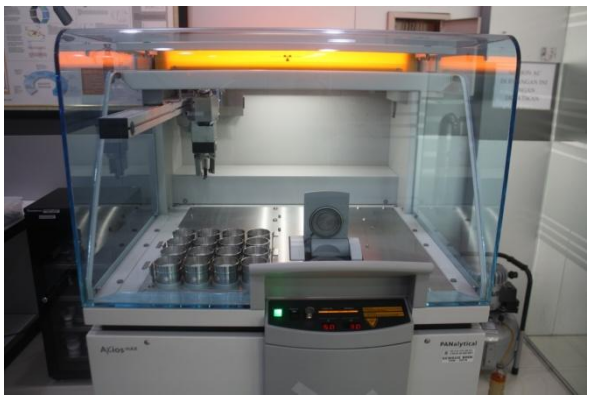
To understand wether there is a change or not in petrogenesis of Kelud magma after the 1966 eruption, a survey and rocks sampling for those of Kelud volcanic rocks which were produced through the 1990, 2007, and 2014 eruptions. Four samples of those of 2007, three samples of 2014, and some from 1990 samples were taken in this study. These activities were condacted in 2016 (fig. 3).

Thin section of the above rock samples of Kelud were made in the Laboratory of Geological Agency at Bandung. Petrographic analysis was done using Polarized Microscopes in the Geological Laboratory of Institute of Energy and Mineral at Cepu, and in the Geological Laboratory of the Geological Agency at Yogyakarta. Zoning analysis to know the magmatism evolution processes below Kelud volcano by using a partly-quantitative method "Scanning Electron Microprobe" (SEM) was done in the Geochemical Laboratory at the Geological Agency in Yogyakarta.

Preparation and Whole Rock Chemical analysis on those rock samples by using the XRF were done in the Geochemical Laboratory at the Geological Agency at Yogyakarta (fig. 4).

Products of petrographic analysis and their whole rock chemiscal analysis for Kelud rocks older than rocks product erupted before the 1966 Kelud eruption had been done [1], [5] and [6]. Finnally the last products (Kelud volcanic rocks of 1990, 2007, and 2014) can be understood.

Figure 3. Situation of Kelud summit area.



Figrure 4. XRF equipment used for whole rock chemical analysis in this study.

III. DATA AND DISCUSSIONS

3.1. Geologi of Kelud Volcano and its surroundings.

Ten craters have been identified on the summit area and the west flank of Mt. Kelut with their volcanic products. Their age relationships imply that the eruption center has moved clockwise (fig. 5) starting from

Lirang crater as the oldest (238 Ky BP) and Kelut crater as the youngest (perhaps 4 Ky BP) which are controlled by the geologic structure at Kelud complex. Pre-Kelut rocks consist of volcanic rocks belonging to

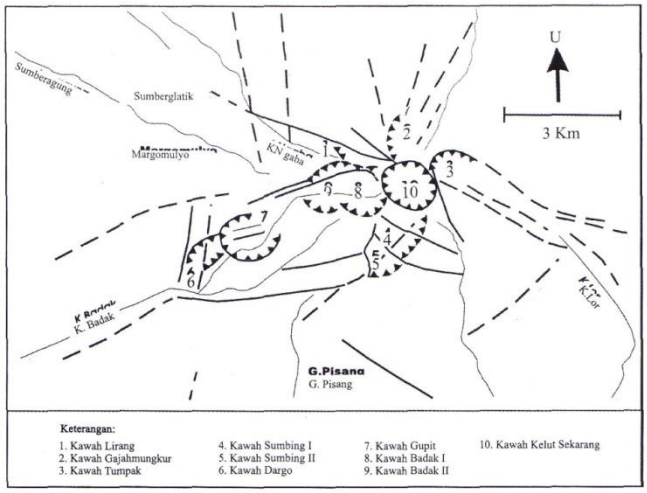


Figure 5. Mecanism of crater forming at Kelud complex [1].

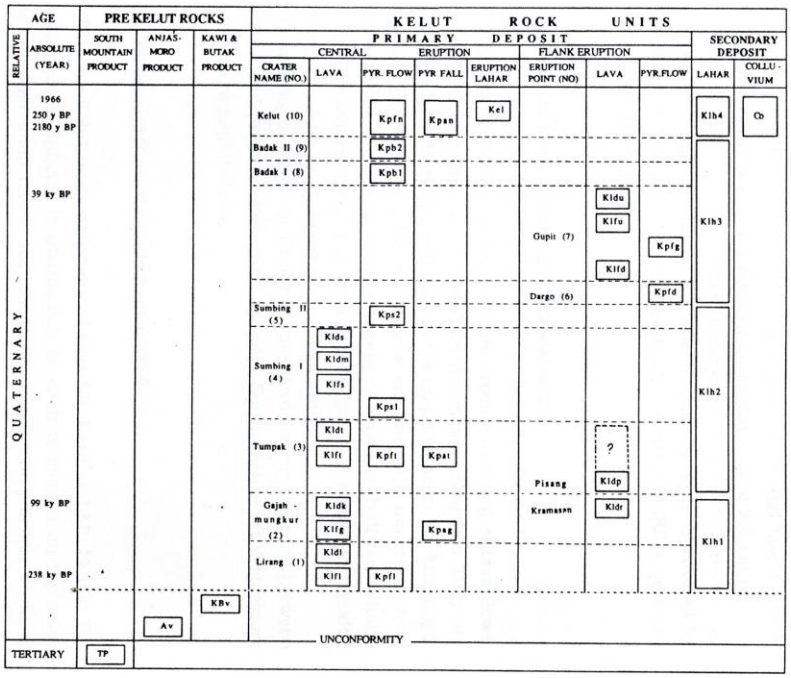


Figure 6. Volcano-stratigraphy of Kelud volcanic rocks [5].

South-mountain (TP), Mt. Anjasmoro (Av) and Mt. Butak and Mt. Kawi. (KBv). Mt. Kelut rock consists of many kinds of lava flows, lava domes, pyroclastic flows and pyroclastic airfall deposits. The geologic map of Kelud volcano was made by using volcano stratigraphy method and has estabished in [5]. The Kelut volcanic rocks were erupted from ten craters on Kelut complex together with some volcanic products from two parasitic. Stratigraphy of Mt. Kelud was shown in fig. 6 [5]. The Kelud volcanic rock can be classified into 3 kinds of rocks such us basalt, basaltic andesite and andesite. The only basalt is formed from the lava flow of Gupit (Klfg), while andesite from lava dome of Kombang (Kldk) and Keramasan (Kldr). The rest of the kelut volcanic rocks are all basaltic andesites

In the last three centuris, Kelud volcano erupted in 1811, 1825, 1835, 1848, 1851, 1864, 1901, 1919, 1951, 1966, 1990, 2007, and 2014. Kelud volcano is an explosive volcano with the quiencing or time interval between eruptions varies from16 to 24 years [7]. The rock samples of Kelud eruption products of 1990, 2007, and 2014 were ejected from Kelud crater as the youngest crater (fig. 5).

3.2. Petrographical study.

Two major time breaks have occurred during eruption story of Mt.Kelut. The first one occurred between the Gajahmungkur and Tumpak craters life. Kramasan dome (about 100 ky BP) was produced as parasitic cone at the late stage of the Gajahmungkur crater. The second break occurred between The Sumbing II and Gupit crater life (fig.6) . Tumpak Lava Dome (about 40 ky BP) is the late stage activity from the Gupit crater . Base upon recognition of the 2 eruption breaks during Mt.Kelud activity, the petrology Mt.Kelud will be divided into 3 periods. These are Kelud I (older than 100 Ka), Kelud II (40-100 Ka), and Kelud III (younger than 40 Ka) [5].

According to the petrographic study on all lavas of Mt Kelud before 1966 indicate the solid phase were in equilibrium with the liquid before the quenching stage reflecting that the magma had experienced of fractional crystalization. However, many basaltic andesite of Kelud I, Kelud II, and Kelud III showed reversal zoning pattern in texture on plagioclase and pyroxene. This features reflect indicate a disequilibrium magma condition. However normal zoning in plagioclases and pyroxenes as indicate normal differentitation sequence.

Rock samples from Kelud eruption products of 1990 [6] as Vulkanian type, those of 2007 producing a lava plug, and those of 2014 as a Plinian type petrographically showed resorbed crystal of plagioclase or pyroxene and sieve-like texture on plagioclase, rounded crystals of plagioclase and pyroxene, and revers and oscilatory zoning textures. These reflect that have solid phases were in equilibrium with the liquid before the quenching stage (fig. 7). However, textures of porphyritic, sometimes glomeroporphyritic, rich in phenocrysts

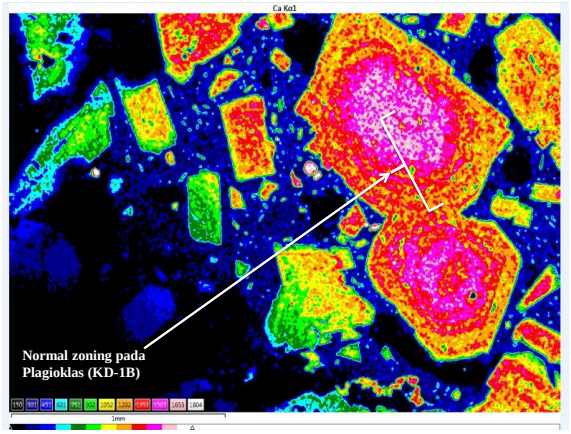


Figure 7. Normal Zoning on plagioclase from lava of 2007 eruption product.

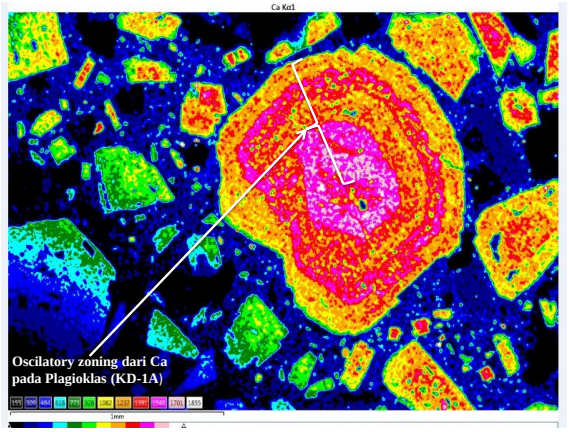


Figure 8. Oscilatory zoning on plagioclase from pumice of pyroclastic flow as the2014 eruption product.

(fine-medium, sometime coarse grained) with a microcrystalline or glassy groundmass were also found. Most of the lavas consist of more than 50% phenocrysts and the most abundan phenocrysts phase is plagioclase followed by pyroxene, opaques and sometimes amphibole, normal zoning on plagioclase (fig. 8). This phenocryst assemblage, reflects that have solid phases were in equilibrium with the liquid before the quenching stage.

3.3. Whole Rock Chemical Study.

Whole rock chemistry from Kelut volcano are classified as medium-K basalt, basaltic andesite and andesite with calc-alkalic suite [5].

Whole rock chemical study on Kelud volcanic of 1990, 2007, and 2014 eruption products mostly classified into basalic andesite with a few of them are basalt and andesite. Composition of SiO2, K2O, Rb, and Sr are still in the range of those belong to the groups of Kelud I, of Kelud II, and of Kelud III.

According to the plot of Kelud rocks into the Harker Diagram, positive corelation between K2O and Na2O to SiO2 and negative coreletion between CaO and Al2O3 to SiO2 are compatible with performance of

huge of plagioclase as phenocrysts in the rock samples of the eruption products of 1990, 2007, and 2014 which are also the same composition as those of rock samples of Kelud I, Kelud II, and Kelud III.

Increasing in Rb, Ba and Sr versus SiO2 in all Kelud rocks (including the last three eruption products) are compatible with process of fractional crystalization as a part of magma differentiation process.

According to the spider diagram plot for trace elemnts of Kelud rocks samples (including the last three eruption products) which are nomalized to MORB, an enrichment to Ba and Sr and depleting to Zr, Y, and Nb. These indicate that the Kelud volcanic rocks were derrived from impurity primitive magma. The enrichment in Sr and Ba indicates that magma of Kelud volcano were derrived from metasomatism process which were released from subduction slab fluids. This condition is compatible that the subduction zone beneath Kelud volcano which is about 150 km depth.

3.4. Discussion

Petrographic data from Kelud rock of the 1990, 2007, and 2014 eruption products show strong evidence of magma mixing. Resorption texture on pyroxene and plagioclase, sieve-like texture, reverse and oscilatory zoning are common in these rocks. The resorbed and rounded pyroxene was formed because of

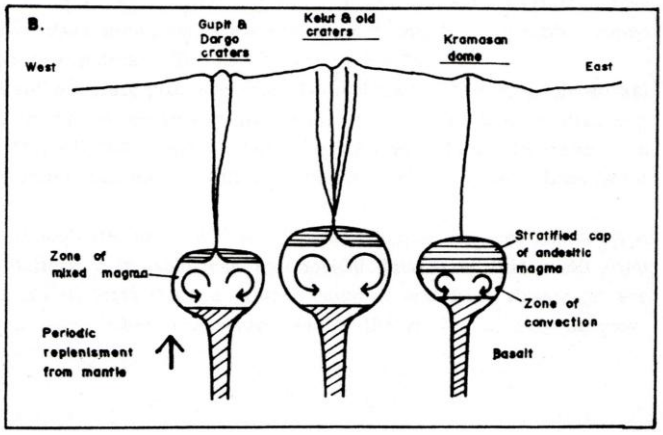


Figure 9. A magma mixing model. The magma reservoir beneath Kelud volcano.

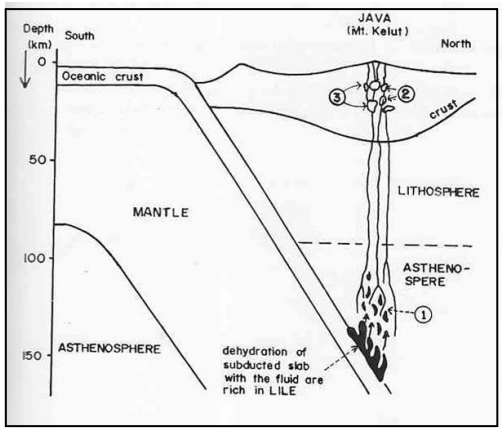


Figure 10. A model of magma origin beneath Kelud volcano.
1 = metasomatim process
2 = fcartional crystalization.
3 = magma mixing.

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melted on inner and outer part of mineral crysta1 when a basaltic magma coming into the previous magma. In addition the inconsistency of the relation between major and trace elements and time reveals a magma mixing as well. This features were also found in the old Kelud vocanic rocks. Thus, up to the last Kelud eruption, magma mixing features process are probably still available for magmatism beneath Kelud volcano.

On the other hand, many features of normal zoning, glomero-porfiritic in the last three Kelut eruption products indicating this liquid had experience of fractional crystalization. These features were also found in many old Kelud rocks.

Consequently, the petrogenesis of Kelud magma which having experience of magma mixing and fractional crystalization as one of the characteristicsof Kelud magmatism processes is still remain up to the last Kelud eruption product (2014). Thus the model of recent magmatism petrogenesis beneath Kelud volcano is still available as shown in fig. 9 [5]. According to the petrographic and whole rock chemical study, a model to show magma origin for magmatism beneath Kelud volcano is shown in fig. 10.

IV. CONCLUSION

Kelud volcano has eruption points consisting of 10 craters and 2 parasitic lava plug. The eruption center has moved clockwise starting from Lirang (the oldest at about 238 ka) to Kelud crater (the youngest at about 4 ka) producing eruption rocks with composition of basalt to andesite but they are dominated by basaltic andesite with

calc-alkaline suite. According to the geologic structure and chemical composition, Kelut volcanic rocks are divided into 3 periods. Kelut I for rocks older than 100 ka which were erupted from Lirang, Gadjahmungkur crater and Kramasan dome ; Kelud II Tumpak erupted from Sumbing 1 and Sumbing 2 craters at 100 ka to 40 ka ; Kelud III rocks erupted from Dargo, Gupit, Badak 1, Badak 2 and Kelut craters since 40 ka. The last three Kelud eruption products of 1990, 2007, and 2014 are included into Kelud III. Many of the last three rock samples are petrographically and chemically show a lot of evidences indicating that the magma have experience of magma mixing, and the rest show evidences indicating that the rocks have experience of fractional crystalization. These features indicate that magma origin and magma genesis during Kelud volcanic complex forming have remain characteristic. Magma mixing characteristic at Kelud is compatible with the condition of craters position which were change from place to other places producing irreguler mountain form at the summit area.

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