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THE COMPARISON BETWEEN RECENT ERUPTIONS OF KELUD AND SINABUNG VOLCANOES, INDONESIA

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ABSTRACT

The aborted 2007 Kelud volcano eruption marked a character changing from explosive to effusive. The explosive Kelud eruption took place on April 14, 2014 destroying about 70% of the total volume of lava dome leaving a hole about 200 meters in diameter. The eruption took place only 10 hours. The repose period of Kelud volcano in the last hundred years ranged between 15 to 25 years. Contrary to Kelud volcano, the Sinabung volcano eruption took place about six months. Preceding the present Sinabung eruption, a phreatic eruption occurred on August 27, 2010. The last Sinabung eruption dated back to 1.200 years was classified into B type active volcano. According to comparison of both eruptions, the period of activity might range from hours to several months. This comparison shows, that the relatively short repose period of Kelud volcano results in a shorter duration of eruption compared to the eruption of Sinabung as a B type volcano with more than thousand years of quiescence.

Key words: kelud, sinabung, repose period, duration.

ABSTRAK


Kata kunci: kelud, sinabung, masa istirahat, durasi

1. INTRODUCTION

Kelud volcano located in East Java and Sinabung volcano of North Sumatera both recently erupted. Kelud volcano erupted in a relatively short period about 10 hours, in contrast with the eruption of Sinabung volcano that took place about six months. The repose period of those volcanoes differed significantly from 15 to 25 years of Kelud and more than thousand years of Sinabung.

Kelud volcano is located in East Java, Indonesia at the latitude 7°56’ South and longitude 112°18.8’ East. Sinabung volcano lies in North Sumatera about 80 kilometers from Medan, the capital city. Geographically the volcano locates at 3°10’North 98°23.5’ East and (Figure 1).

On February 14, 2014, Kelud volcano erupted, sending materials as far as the area western part of Java. In the last hundred years, the volcano rhythmically erupts at the
repose period of about 15 to 25 years. The aborted eruption took place in 2006 producing lava dome.

Figure 1. Index Map Shows The Locations of Kelud Volcano and Sinabung Volcano. The Hachured Parts (Right Above) Indicate The Position Of The Index Maps of Sumatera and Java

The eruption of 2007 changed the character from explosive to effusive. Instead of ejecting materials, the 2007 eruption built up a lava dome and dried up the crater’s lake. In the eruption of 2007 no information on of lake water available. The prediction based solely on the seismicity.

Sinabung volcano in North Sumatera resumed its activity after a very long period of repose. Based on the C^{14} age determination the last eruption of Sinabung took place about 1,200 thousands years ago. The initial eruption occurred on August 27, 2010 with a short duration. After a quiescent period of about 3 years, the volcano erupted for more than six months.

The present study aims to analyze the different between the two volcanoes concerning their character of the eruption and interpret the behavior of magma and magma supply.

2. METHODOLOGY

This study collected the information from the reports made public by the authorities coping with Sinabung and Kelud crises. The satellite images available from NASA provided the valuable information in the interpretation of the crater. The United States Geological Surveys (USGS) distributed the images through the website. The images taken shortly after the eruption presented the actual information.

A detailed topographic map with the scale of 1:10,000 prepared by the Volcanological Survey of Indonesia in 1968 constituted the basis for the interpretation. The lava dome estimation heavily relied on the topographic map. The photographs made by the Volcanological Surveys and published by the Geological Agency supplied the information on the shape and configuration of the lava dome. Additionally the infrared terrestrial photographs made available by the same Agency showed the information on temperature and the development of the dome. Other photographs of the lava dome (Figure 2) showed the size of its body^{1}. Alzwar^{2} described the geology and hazard mitigation of Kelud volcano. The presented information constituted the basis for the evaluation of the eruption characteristics.

Sutawidjaja^{3} recently published report on the phreatic eruption of Sinabung volcano. The information served an important basis for the interpretation of the eruption. The Geological Agency of Indonesia distributed reports concerning the development of Sinabung eruption through its website.

Figure 2. The Terrestrial Photograph Shows The Shape of Lava Dome (Kushendratno, 2007, used with The Permission of The Geological Agency)^{1}

Other images accessible at the gallery of the Agency of the Volcanological Surveys
and Mitigation of Geological Hazard have contributed significantly to the present study. The Surveys made the photographs and images open for public through its website.

The comparison of Kelud and Sinabung volcanoes took the parameters on (a) duration of eruptions, (b) volume of the materials (Volcano Eruption Index, VEI) and (c) physical characteristics of the ejected materials. That information leads to the interpretation on the configuration of the magma chamber.

3. RESULTS AND DISCUSSION

Various parameters of Sinabung and Kelud volcano demonstrate the significant discrepancies. The characteristics of those two volcanoes might represent many of the Indonesian volcanoes. Table 1 shows the summarized differences between the two volcanoes including the results of discussed interpretation. Based on comparison of several physical parameters, the study came to the following results:

A. Duration of The Eruption

The duration of the eruption differs significantly between Sinabung volcano and Kelud volcano. Sinabung volcano erupted several times within the period of about six months.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Sinabung</th>
<th>Kelud</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ash column height</td>
<td>&lt; 10 km</td>
<td>App. 30 km</td>
</tr>
<tr>
<td>Initial erupt.</td>
<td>Phreatic</td>
<td>Lava dome</td>
</tr>
<tr>
<td>Time lag</td>
<td>3 years</td>
<td>7 years</td>
</tr>
<tr>
<td>Repose period</td>
<td>1,200 years</td>
<td>15-25 years</td>
</tr>
<tr>
<td>Gas pressure</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Porocrastics</td>
<td>Fall, flows</td>
<td>Mainly fall</td>
</tr>
<tr>
<td>Tectonics</td>
<td>Control</td>
<td>No control</td>
</tr>
<tr>
<td>Magma</td>
<td>Shallow</td>
<td>Shallow</td>
</tr>
<tr>
<td>Magma Size</td>
<td>Intermediate</td>
<td>Small</td>
</tr>
<tr>
<td>Magma shape</td>
<td>Elongated</td>
<td>Ball</td>
</tr>
</tbody>
</table>

The initial eruption started with the phreatic eruption and followed by the repose period for 3 years from August 2010 to September 2013. The eruption showed uneven interval repose of each individual eruption. This means that the rate of gas accumulation was not constant. Taking into account that the conduit has already opened through the initial stage of the eruption, the gas must have been flowing smoothly.

In contrast with Sinabung eruption, Kelud volcano erupted within a relatively short period. It showed the characteristics of the eruptions in the last few hundreds years. However due to the formation of the dome in the preceding activities in 2007, it was anticipated that the prolonged eruption would take place. The piecemeal destruction of the lava dome usually occurred similar to that of Galunggung volcano. Piecemeal destruction of Galunggung volcano caused the prolonged eruption of about 11 months². In the case of the present eruption of Kelud, the first reason is that the lava dome has not consolidated and the second reason was that the gas pressure strong enough to destroy the directly destroy the dome. This relates to the rate of gas accumulation during the repose period.

B. Volume of The Materials

The volume of the dome Kelud volcano exceeds 2.7 to 3 million cubic meters based on the interpretation by remote sensing method using the available topographic map prepared by the Volcanological Surveys in 1968. Extended to the root of the volume might increase to about 5 to 6 million cubic meters. Those materials disappeared during the April 14, 2014 eruption, leaving about out 30% intact.

Based on the comparison of the tephra distribution of the present and the 1951 eruptions, the volume of the present ejected materials might exceed 200 millions cubic meters. Taking into account that the volume of lava dome only a small part compared to the total ejected materials, it is favorable to conclude that the present eruption produced tephra of about 200 millions cubic meters.

The 2014 eruption sent volcanic ash as far as Bandung and beyond to the west similar to that of the 1951 eruption. Therefore, it
is quite reasonable to compare those two eruptions. The 1951 eruption produced ejected materials about 200 millions cubic meters\(^4\). This figure agrees with the annual rate of replenishment of magma from the lower chamber located some 20-30 kilometers to the upper chamber of 5 kilometers put forward by Sukhyar and Pardyanto (1992)\(^5\).

Based on the petrochemical study on the bulk products of Kelud eruptions, further it concluded that the annual rate of replenishment amounted to the average of 6.25 millions cubic meters. The calculation of the repose period from 1990 to 2014 gives the figure of 150 millions cubic meters of the ejected materials at the 2014 eruption. It is therefore reasonable to conclude that the ejected materials of the 2014 Kelud eruption range between 150 to 200 millions cubic meters. This figure leads to the classification of Volcanic Explosion Index (VEI) 3 close to 4.

The materials ejected during six-month period of Sinabung eruption, might give the amount to less than 100 millions cubic meters or fell under the category of VEI 2. This figure comes from the calculation of the distribution of ejecta dominantly in the area within the diameter of 20 kilometers. The ash distribution confined to the leeside following the directions of the prevailing wind. Combining the interpretation with the height of the ash column, which was less than 10 kilometers, it might be favorable to conclude that the ejected materials of the present Sinabung volcano might range around 100 millions cubic meters.

C. Physical Characteristics of The Ejected Materials

The materials ejected by Kelud volcano at the present eruption differ significantly from the previous eruptions. The present eruption hurled the rock fragments of coarse lapilli and small size bombs to a distance of about 10 kilometers. These materials apparently came from the destructed lava dome.

The absence of lake water in the crater, resulted in the dry eruption, thus no eruption lahar occurred. The gas might freely blow the ejected materials to the air without the influence of water mantle. This situation might produce the higher ash column.

The ejected materials of Sinabung eruption confine to the area around the volcano. It reflected the low gas pressure, thus magma chamber supposedly shallow. Taking into account that the repose period took place more than 1,200 years, the rate of gas accumulation was very low. The present of the active faulting as part of Great Sumatra Fault provided space for the gas to ascend. The magma heat front came to the contact with underground water resulting in the phreatic eruption. The eruption marked the recurrence of the activity of Sinabung volcano after a quiescent period of 1,200 years\(^6\). The phreatic eruption triggered the magmatic activity which followed by the present eruption. The volcano of long period categorized as B-type can resume the activity and thus fell into A-type category.

The occurrence of the glowing clouds at the latest phase of the eruption confirmed the significant decline of gas pressure. The weak zone at the upper slope broken by the outgoing gas and magmatic materials provided space for the pyroclastics to flow down.

D. The Interpretation of Magma Chambers

The seismic monitoring of the previous activity of Kelud volcano combined with petrographic study lead Sukhyar and Pardyanto\(^5\) to conclude that two magma chambers existed below the crater. The upper magma located about 3 to 5 kilometers, whilst the lower magma chambers about 20 to 30 kilometers. The upper chamber acted as the satellite other terminal of the lower chamber, which was much bigger in size.

The small and shallow magma chamber represented a pocket. The eruption originated from this type of chamber produce a short period of eruption with big energy release. This eruption indicate the very typical eruption of Kelud during the last few hundreds years. As soon as the upper chamber empty, the new magma from the lower chamber ascended with predominantly basaltic composition. The estimation of the rate of the re-
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Sinabung volcano demonstrated the recurrence of the activity after a very long repose period. The intermediate gas pressure resulted in the confined distribution of the pyroclastics fall. Further, the occurrence of glowing cloud at the latest phase of the eruption confirmed the declining gas pressure. This evidence clearly reflected the shallow magma chamber. The fault system provided space from down below for the incoming magma. However, this process consumed a considerable time indicated by long period of repose.

5. REFERENCES


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