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Dynamics Eruption of Sinabung Volcano based on Seismic Analysis

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Introduction

Sinabung volcano is located in North Sumatra Province, Sumatra, Indonesia. In August 2010, for the first time since around 1200 years ago (Iguchi et al. 2012), Sinabung experienced a phreatic eruption as a marker of the start of activity which has continued to date. In general, there are 5 phases of Sinabung eruption activity, namely 1) phreatic phase (mostly August 2010 and September 2013); 2) the first phase of dome growth and collapse with pyroclastic density currents (PDC) (18 December 2013–10 January 2014); 3) lava-flow and collapse phase (10 January 2014–mid-September 2014); 4) second phase of dome growth and collapse with PDC (mid-September 2014–July 2015); 5) dominancy of Vulcanian phase with PDC (August 2015–present) (Gunawan et al, 2019).This study will investigate the volcanic earthquakes' parameters to clarify the possibility physical process of dynamics eruption. Moreover, we will analyze the change of parameters over time to identify the main features relating to the dynamics of eruption.

Data and Method

In this study, we analyzed Sinabung's seismic data from August 2010 to December 2015. A total of 6 seismometers (1-component) were installed to monitor Sinabung's activity during those periods.

We classify the seismic events into 5 categories, namely Low Frequency (LF), Hybrid earthquakes, Volcano-tectonic earthquakes (VT), Rockfall events, and PDC events.

We determined hypocenters using 4 seismometers with the Geiger Adaptive Damping method (Nishi, 2005) and relocated using the Joint Hypocentral Determination (Kissling, 1995).

We also perform spectral analysis to obtain corner frequency and spectral flat level to find the source parameter of the earthquake by applying the circular fault model of Brune (1970) to obtain seismic moment, stress drop, and rupture length in VT and Hybrid events.

Results and Discussion

After analyzing various earthquake parameters, we compared the time series of earthquake parameters with changes in slope distances between the GPS stations (Hotta et al, 2019) and changes in total deposit volume (Nakada et al, 2019).

In July 2011, VT's seismicity increased. This activity was accompanied by a slight increase in slope distance along SKNL-LKWR GPS baseline and dominance of shallow VT events. Also, there was an increase in the flat spectral level (Ω) of the VT earthquake. The parameter of Ω is proportional to the seismic moment and stress drop.

This can be interpreted that magma movement has occurred towards a shallower position, build the pressure on the surrounding rocks and resulting in a VT earthquake.

VT activity increased sharply in June 2013, followed by increasing of Ω and the hypocenter became shallower. Also, the increase in slope distance at all baselines and the rise of amplitude RSAM 5-15 Hz. Magma intrusion occurred and resulted in the development of a fracture zone.

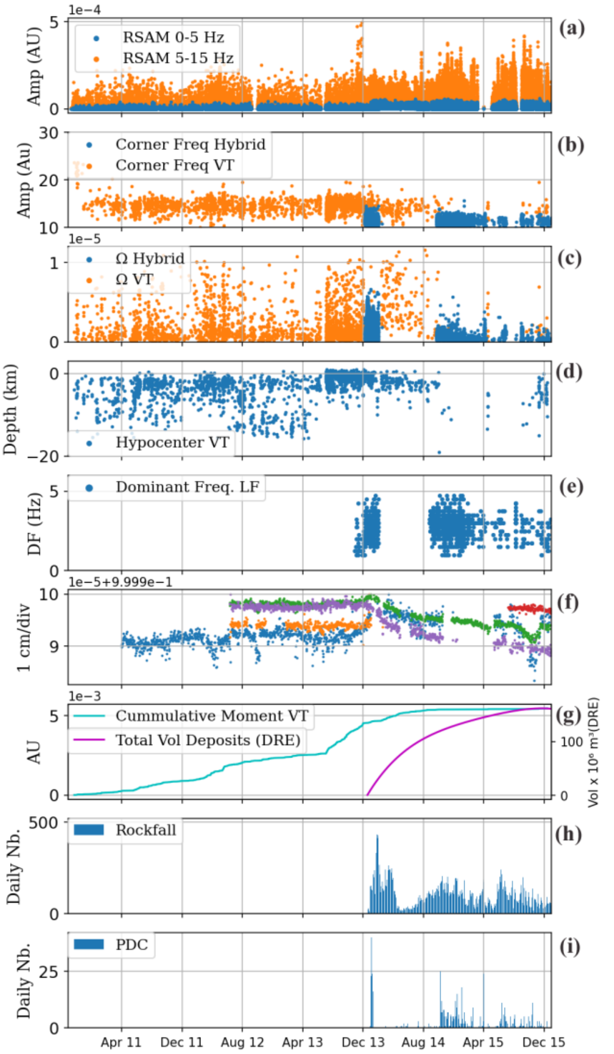

Figure 1. Temporal change of a) realtime seismic amplitude measurement; b) corner frequency of VT and Hybrid; c) Ω of VT and Hybrid; d) hypocenter of VT; e) dominant frequency of LF; f) slope distances between the GPS stations SKNL-LKWR(blue), SNBG-GRKI (orange), SNBG-LKWR (green), SNBG-MRDG (red), SNBG-SKNL (purple); g) cumulative moment of VT and total volume deposit; daily events of h) Rockfall and i) PDC.

In November 2013, the LF earthquake appeared, suggesting that magma that approaches the surface causes the release of gas. This leakage of gas may make the viscosity of the magma increase.

In December 2013, Hybrid earthquakes appeared with high activity. On December 18, the lava dome is visible. This indicates that the lava dome was growing associated with increase in Hybrid earthquake. Appearance of the lava dome was followed by the decreasing of Hybrid activity and LF. The decrease in Ω of Hybrid is interpreted as a caused by a release of pressure due to the extrusion of the lava dome. On December 26, the lava dome collapsed and deflation began (Hotta et al, 2019).

In January and February 2014, magmatic activity became the highest. The high activity of Rockfall and PDC events result in drastic deflation and an increase in the total deposit volume which marks the emptying of the magma chamber (Hotta et al, 2019).

VT activity has decreased drastically as can be seen from the cumulative seismic moment graph. Hybrid and LF were no longer seen from the end of January 2014. The period from February to September 2014 was marked by lava flow activity and collapse accompanied by an increase in RSAM amplitude of 0-5 Hz from the previous period. This means that the increase in amplitude 0-5 Hz is related to the process of magma transport and lava extrusion.

In September 2014, LF reappeared and followed by Hybrid. The emergence of LF and Hybrid is related to the growth of lava domes, but with smaller volumes.

Ω of hybrid in the first lava dome growth was higher than Ω in the second lava dome growth. The contribution of the first lava dome to the total volume of the deposit is higher than that of the second one. This can be interpreted that the magma supply rate in the first lava dome period was higher, resulted in the formation of a plug with higher density and higher rigidity. The formation of plug may allow higher pressure to accumulate below the plug.

The transition of eruption type to Vulcanian are difficult to detect using seismic parameters, as well as deformation and magma chemistry because these parameters did not change significantly with time. Nakada et al (2019) suggests complexity of the degassing process. The degassing pathways along the initially highly fractured zone became coated with the intrusion of new lava flows.