Magma transport system beneath Hakone volcano inferred from deep low frequency earthquakes

*Yohei Yukutake[1], Yuki Abe[1]

1. Hot Springs Research Institute of Kanagawa Prefecture

It has been recognized that the occurrence of deep low-frequency earthquakes (DLFEs) beneath a volcano is related to a behavior of magmatic fluid (e.g. Nakamichi et al., 2003). On the other hand, the linkage between the DLFE and shallow volcanic activities such as a swarm activity and crustal deformation has not been well understood. In the present study, we compared the temporal sequence of the DLFEs occurred around the depth of 25 km beneath Hakone volcano, central Japan, with the swarm activity and the inflation of pressure source occurred in the area shallower than the depth of 10 km.

During recent two decades, we observed the remarkable swarm activities at Hakone volcano in 2001, 2006, 2009, 2013 and 2015. In each swarm activity, crustal deformation associated with an inflation of pressure source was estimated at the depth of 7km beneath the central cone of caldera, by using the GNSS data (Harada et al., 2018). Tthe tomography analysis (Yukutake et al., 2015; Yukutake et al., 2018) reveals that the crystalizing magma body locates around the depth of 10km and the hydrothermal fluid dehydrated from the magma exists above it.

The DLFEs were detected by using the Matched Filter method. We used continuous seismic waveforms at 12 permanent stations around Hakone volcano in the period from January, 2000 to January, 2017. The template waveforms of 94 DLFs were prepared on the basis of the JMA catalog. We also estimated the temporal sequence of b-value by using the DLFE catalog. The temporal change was calculated by using the method in Wiemer and Wyss (2000), using the moving time-windows containing a constant event number of 300 events.

As a result, we could detect the numerous DLFEs corresponding to 46 times in comparison with the number detected by JMA. It is clearly evident that the DLFEs activated prior the swarm activity in 2006, 2009, 2013 and 2015, and synchronized with the onset time of crustal expansion caused by the inflation of pressure source. We estimated the increment of b-values by accompanied with the activation of DLFEs. An increase of b-values during the swarm activity in several volcanic regions can be explained by assuming the increment of pore pressure or the change of thermal gradient associated with the intrusion of magma/hydrothermal fluid (Jacobs and McNutt, 2010; Nanjo et al., 2018). It is likely that the activation of DLFEs accompanied by the increase of b-values reflects the inclusion of magma at the depth. The inflation of pressure source at the depth of 7 km may suggest the increase of a volatile component at the shallow magma/hydrothermal fluid from the deep intruded magma at the source region of DLFEs or the increment of temperature due to the migration of hot material. The increase of strain rate due to the inflation can promote the migration of highly pressurized to the shallow brittle zone (Fournier, 1999), triggering the earthquake swarms. On the other hand, the remarkable activation of DLFE was observed in the later stage of swarm activity in 2001, rather than precursory activity for the earthquake swarms. This result may imply that the activation of volcanic phenomena such as the shallow swarm activity and crustal deformation is not necessary initiated by the deep magma intrusion.

Acknowledgments
We used the waveform record obtained by the permanent stations of National Research Institute for Earth

Science and Disaster Resilience and GNSS data of Geospatial Information Authority of Japan. We used zmap program code (Wiemer, 2001) to estimate b-value.

Keywords: Deep low frequency earthquake, earthquake swarm, Hakone volcano

