Earthquake swarms, subsurface structure and deep low frequency earthquakes beneath Hakone volcano, and its relation to magma-hydrothermal system

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Beneath the Hakone volcano, central Japan, remarkable earthquake swarms have been frequently observed in the shallower region than a depth of 6km, sometimes accompanied by crustal expansion whose inflation source was estimated around a depth of 7 km. The deep low-frequency earthquakes (DLFEs) have been also observed at the depth of 20 – 30 km beneath the volcano. A phreatic eruption in 2015 was occurred at the northern slop of central cone (Owakudani geothermal region), following the remarkable earthquake swarms and crustal expansion. Our recent studies reveal the detailed characteristics for the earthquake swarms, subsurface structure and DLFEs, using the dense seismic observation, and found that the elevation of pressure in magmatic fluid plays an essential role to generate the phenomena, including the phreatic eruption.

During the 2009 swarm activity, we found that the hypocenters of earthquake swarms were concentrated on a vertical plane and showed a diffusion-like migration, suggesting that pressurized fluid in the fault damage zone strongly influence the occurrence of swarms (Yukutake et al., 2011). By the seismic tomography method, a low S wave velocity zone with high Vp/Vs ratio was estimated at a depth of 10 km (Yukutake et al., 2015). According to the poroelastic theory for solid-liquid composition (e.g. Takei, 2002 JGR), this high Vp/Vs zone can be explained by a crystallizing magma body. On the other hand, at the depth of 6 km, a low velocity zone with low Vp/Vs ratio was estimated. This zone can be interpreted by the existence of water/gas rich region, suggesting that the dehydrated magmatic fluid/gas developed above the magma body and just beneath the lower limit of earthquake swarms. We also tried to detect the DLFE beneath Hakone volcano during past two decade by using the Matched filter method. The DLFEs were activated before the crustal expansions and the intense swarm activities (Yukutake et al., 2019). In the 2015 activity, the phreatic eruption occurred more than 4 months after the activation of DLFEs. Given these observations, we propose the model to explain the relation between the magma-hydrothermal system and volcanic activity in Hakone (Fig. 1). Magmatic fluid was firstly supplied from a deep area to the source region of the DLFEs, accelerating the occurrence of DLFEs and causing an increase in the fluid pressure at a particular depth. This pressure increase from the magmatic

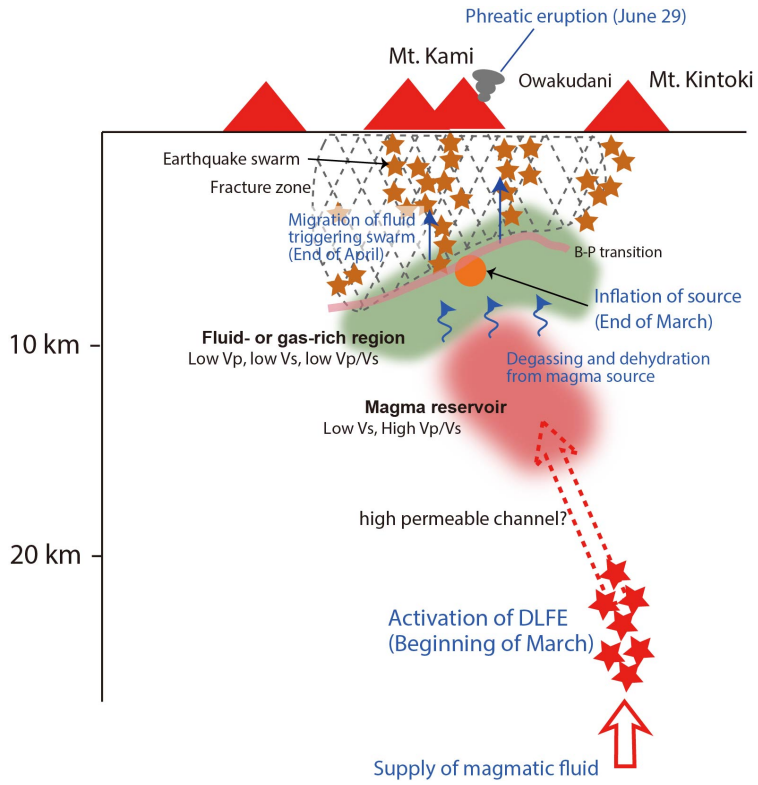

Fig. 1 Schematic of the time sequence of the 2015 activity (Yukutake et al., 2019)

fluid may have migrated to a shallow depth, accelerating the feeding of magmatic fluid into the magma body at the depth of 10 km. The process stimulated dehydration and degassing into the fluid/gas rich region, causing the inflation of pressure source. This inflation may have increased the flux of highly pressurized fluid into the shallow brittle zone. Consequently, the pore - pressures in the fracture system increased within the brittle zone, triggering the earthquake swarms by the fluids migrating through the shallow fracture zone. In the case of 2015, the incremental fluid pressure affected up to the shallow geothermal system, and leaded to the phreatic eruption.

Main References

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