Deep low-frequency earthquakes, tomography and magmatic system beneath active volcanoes

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We made a systematic study of deep low-frequency earthquakes, high-resolution tomography and magmatic system beneath active volcanoes on the Japan Islands. Low-frequency earthquakes (LFEs) in the lower crust and uppermost mantle are widely observed, and they occur not only along the subducting Philippine Sea (PHS) slab interface but also beneath active arc volcanoes. The volcanic LFEs are still not well understood because of their limited quantities and less reliable hypocenter locations. We used seismic tomography to determine detailed three-dimensional (3-D) P and S-wave velocity (Vp and Vs) models of the crust and upper mantle beneath the Japan Islands, and used the obtained 3-D Vp and Vs models to relocate the volcanic LFEs precisely (Niu et al., 2008; Yu et al., 2018). Our results show that the volcanic LFEs can be classified into two types: pipe-like and swarm-like LFEs, and both of them are located in or around zones of low-velocity (low-V) and high-Poisson's ratio (high-σ) in the crust and uppermost mantle beneath the active volcanoes. The pipe-like LFEs may be related to fluid migration from the lower crust or the uppermost mantle, whereas the swarm-like LFEs may be related to local magmatic activities or small magma chambers. The number of LFEs sometimes increases sharply before or after a nearby large crustal earthquake that may cause cracks and fluid migration. The spatiotemporal distribution of the LFEs may indicate the track of migrating fluids. As compared with the tectonic LFEs along the PHS slab interface, the volcanic LFEs are more sensitive to fluid migration and local magmatic activities. High pore pressures play an important role in triggering both types of LFEs.

We also investigated the 3-D seismic structure of source areas of the 6 October 2000 Western Tottori earthquake (M 7.3) and the 21 October 2016 Central Tottori earthquake (M 6.6) that occurred near the Daisen volcano in SW Japan (Zhao et al., 2018a). The two large events took place in a high-velocity (high-V) zone in the upper crust, whereas low-V and high-σ anomalies are revealed in the lower crust and upper mantle. LFEs (M 0.0–2.1) occurred in or around the low-V and high-σ zones, which reflect upward migration of magmatic fluids from the upper mantle to the crust under the Daisen volcano. The nucleation of the Tottori earthquakes may be affected by the ascending fluids. The flat subducting PHS slab has a younger lithosphere age and so a higher temperature beneath the Daisen and Tottori area, facilitating the PHS slab melting. It is also possible that a PHS slab window has formed along the extinct Shikoku Basin spreading ridge beneath SW Japan, and mantle materials below the PHS slab may ascend to the shallow area through the slab window. These results suggest that the Daisen adakite magma was affected by the PHS slab melting and upwelling flow in the upper mantle above the subducting Pacific slab.

Detailed 3-D Vp, Vs and σ images of the crust and upper mantle beneath Kyushu are determined, with a focus on the source area of the 2016 Kumamoto earthquake (M 7.3) that occurred in the Beppu-Shimabara graben (BSG) where four active volcanoes and many active faults exist (Zhao et al., 2018b). The 2016 Kumamoto earthquake took place in a high-V and low-σ zone in the upper crust, which is surrounded and underlain by low-V and high-σ anomalies in the upper mantle. This result suggests that, in and around the source zone of the 2016 Kumamoto earthquake, strong structural heterogeneities relating to active volcanoes and magmatic fluids exist, which may affect the seismogenesis. Along the BSG, low-V and high-σ anomalies do not exist everywhere in the upper mantle but mainly beneath the active volcanoes, suggesting that hot mantle upwelling is not the only cause of the graben. The BSG was most likely formed by joint effects of northward extension of the Okinawa Trough, westward extension of the Median Tectonic Line, and hot upwelling flow in the mantle wedge beneath the active volcanoes.

References

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