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Three-dimensional seismic velocity structure of the upper crust beneath Kirishima Volcanoes

Ryoma Mera[1], Hiroshi Yakiwara[2*], Syuichiro Hirano[2], Shigeru Nakao[2], Kazuhiko Goto[2], Hiroki Miyamachi[2]

[1]Faculty of Science, Kagoshima Univ., [2]GSE, Kagoshima Univ.

Sub-Plinian and successive Vulcanian eruptions of Shinmoe-dake, Kirishima Volcanoes, started at January 2011. Before the eruptions, inflation of the volcano edifice had been observed by GPS monitoring network (GEONET of GJI). Combining the data of GEONET and temporal GPS observations, Nakao et al. (2012, submitted) located a pressure source (Mogi model) at 10km depth beneath northwestern part of the volcanoes (5km northwest of the Shinmoe-dake crater) for the period of magma accumulating process before the eruptions. Several previous studies used artificial explosive sources and natural earthquakes to obtain seismic velocity structures of the volcanoes. Except Yamamoto and Ida (1994), these studies solved velocity distributions limited in the shallow depth ranges from surface to about 3-5km depth (e.g., Tomatsu et al., 2001). Assuming incidence of plane P waves from regional hypocenters and dividing a target volume into blocks of constant velocity, Yamamoto and Ida (1994) calculated P-wave velocity perturbations on each block. The remaining studies did not map the velocity distributions deeper than about 5km depth by limitations of ray paths. The aims of the present research are to show three dimensional P- and S-wave velocity models below 5km to 15km depth derived from data of local earthquakes and to discuss the obtained seismic velocity structure and relation to the pressure source.

Nansei-Toko Observatory for Earthquakes and Volcanoes, Kagoshima University (NOEV) has recorded seismic data observed at seismic stations of Kagoshima Univ., Kyushu Univ., JMA, and NEID in and around southern part of Kyushu, southwest of Japan. 305 earthquakes with 15,221 P phases and 13,649 S phases recorded by 67 seismic stations during the period from 2001 to 2012 were selected to perform this analysis. In the 3-D inversion, we applied methods of grid model (Thurber, 1983), ray tracing with Pseudo-bending (Um and Thurber, 1987), Parameter separation (Pavlis and Booker, 1980), and Damped Least Squares (Aki and Lee, 1976). Damping factor (0.01) was set through the inversions after the performing several quantitative experiments using grid models and observed data. Examining different grid models, the spatial resolution for the velocity model was estimated about 5km horizontally. We also referenced results of checkerboard tests and diagonal elements of resolution matrix (DERMs) to delineate velocity models of only areas where the relative reliable velocity distributions seemed to be obtained. Consequently, we only show the velocities where the interpolated DERMs were larger than or equal to 0.8.

As a result of the 3-D inversions, we obtained reliable P- and S-wave velocities at the depth range of 5-15km beneath the area in and around the volcanoes. Because few seismic stations locate on the volcanoes, seismic ray paths passing through in the shallow part of the volcanoes were limited. Characteristics of the velocity structure at 10km depth are summarized as follows: (1) relative high P-wave velocities (high-Vp, 6.8-7.0km/s) distributed widely beneath the northwest, southwest, and southeast flanks of the volcanoes. The increases of Vp were 10-13%, (2) relative low P-wave velocities (low-Vp, 5.3-5.5km/s) areas, 11-15% decreases, were delineated beneath the whole areas of the volcano edifices, (3) an obvious low S-wave velocity (low-Vs, 2.7-3.2km/s) area, 10-26% decrease, located beneath the northwestern part of the volcanoes. The values of Vp/Vs for the characteristic low P- and S-velocity area were 1.9-2.1 (high-Vp/Vs). The obvious low velocity area contains the pressure source (Nakao et al., 2012, submitted). These features, low-Vp, low-Vs, high-Vp/Vs, and containing the location of the pressure source before the eruptions suggest that a significant volume of magma accumulation existed at the low velocity area and its environs.

Keywords: Kirishima Volcanoes, Seismic velocity structure