Imaging of the magma pathway beneath Kirishima volcanoes by seismic interferometry

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Shinmoe-dake, one of Kirishima volcanoes, experienced magmatic eruptions in 2011. The analysis of ground deformation shows that the pressure source locates 5 km to the northwest of the Shinmoe-dake summit at a depth of 8 km, which implies the existence of a magma reservoir. We are trying to resolve a better image by a seismological technique toward ensuring its existence and deriving precise crustal structure and reveal a magma pathway.

The technique we employed is seismic wave interferometry, which extracts the seismic wave propagation between two seismic stations by taking cross correlations of random wavefields, such as the ambient seismic noise or the seismic coda wave. The cross correlations of random wavefields recorded at two stations can be represented as if the source is at one station and the recorder is at the other. This technique is suitable for exploring local structure since the extracted wave is sensitive to the internal structure between the two stations.

We inferred the crustal phase velocity anomaly using three-component records of the ambient seismic noise recorded by a seismic array between April 2011 and December 2013. Rayleigh and Love waves are extracted by taking cross correlations (Rayleigh waves from cross correlation functions of pairs of vertical components, and Love waves from transverse components). We derived reference dispersion curves of Rayleigh and Love waves, respectively, using all possible pairs of stations, then measured phase velocity anomalies of all possible pairs with respect to the reference in multiple frequency bands (0.1-0.2 Hz, 0.2-0.4 Hz, 0.3-0.6 Hz, and 0.4-0.8 Hz). Finally, three-dimensional V_{SV} and V_{SH} structures were obtained from a collection of local one-dimensional velocity profiles derived by inverting phase velocities of Rayleigh and Love waves, respectively, at each grid point.

Kirishima volcanoes exhibit a low V_{SV} body that is embedded beneath the deformation source and extends horizontally by about 15 km at around 10 km below sea level beneath the volcanoes. We interpret it as a crustal magma reservoir. V_{SH} did not detect low velocity bodies, implying the radial anisotropy generated by a sill complex in the magma reservoir. The ground deformation source of the eruptions in 2011 locates at uppermost and northwesternmost of the low velocity body, indicating that the low velocity body is a magma reservoir of the volcanoes. Moreover, low frequency earthquakes occur beneath the southeasternmost of the low velocity body. We can, therefore, present a model of a magma pathway that magma rising up from the deeper region right beneath the volcanoes is once stored at a magma reservoir and further ascend toward the surface from the uppermost and northwesternmost of the magma reservoir.

Our study presents the effectiveness of the estimation of S wave velocity structure using phase velocities of Rayleigh and Love waves in deciphering the magma pathway beneath the active volcanoes and the importance of further investigation of magma plumbing systems beneath various types of volcanoes.

Keywords: Kirishima, seismic interferometry, ambient seismic noise, radial anisotropy

