Diffusive characteristics of seismic energy propagation revealed from active seismic experiments at volcanoes

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Volcanoes are one of the most heterogeneous field in the Earth's crust, and the understanding of such inhomogeneities in volcanoes may provide us important information on the various volcanic processes. In the previous studies on the wave propagation at active volcanoes, the diffusion model, which reflects strong multiple scattering of the seismic energy, has been widely used to model the energy transportation in heterogeneous media. Almost all of these studies, however, assume the diffusion of a single mode (usually S-wave), and the contribution of P and S waves and their mode conversion have not been well recognized partly due to lack of dense seismic observations capturing spatio-temporal pattern of energy propagation.

In this study, we present preliminary results of our analysis on the wave propagation in the shallow heterogeneous structure of Asama and Aso volcanoes revealed from active seismic experiments. These experiments were conducted as a part of the national project for the prediction of volcanic eruptions, and the seismic waves exerted from artificial shots were recorded by dense seismic networks. One of the most impressive characteristics of the seismograms observed by the experiment is their envelopes; the seismograms from artificial shots, emitting mainly P-energy around 10Hz, are characterized by spindle-like envelopes having small P-onsets, missing clear S-onsets, and long codas. Furthermore, the spatial distributions of the propagating energy at fixed time shows a clear pattern exhibiting two slopes which are indicative of diffusions of two modes having different diffusivities. From the comparison between the observed energy distributions and the results of Monte Carlo simulation taking into account the mode conversions between P and S energies and the multiple isotropic scattering of these two modes, we found that the energy propagation would be well explained by the multiple scattering of P energy and S energy converted from the P energy radiated from the active source. The total scattering coefficients for P-S and S-S scattering are found to be about three times and one order higher than that of P-P scattering respectively, and the mean free path of S-wave beneath Asama volcano is estimated as about 100-300m in 4-16Hz band.

These results suggest that the mode conversion from P to S and significant multiple scattering of each mode have an indispensable effect in the modeling and analysis of seismic wave propagation in heterogeneous volcanic environments.