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Volcanic Deep Low-Frequency Earthquakes and Cooling Magma

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Deep low-frequency earthquakes (LFEs) are deep earthquakes that radiate low-frequency seismic waves. While tectonic LFEs on plate boundaries are thought to be slip events, the physical mechanism of volcanic LFEs around the Moho beneath volcanoes is not well understood. For initial brittle failure to be produced at these temperature-pressure conditions, high strain rates should exist there.

Since an ascending magma diapir tends to stagnate near the Moho, where there is a density discontinuity, we suspect its thermal contraction acts as a driving force of volcanic LFEs. In the present study, we estimated thermal strain rates caused by a cooling magma near the Moho beneath volcanoes.

We calculated thermal evolution after an initial perturbation of 400K uniformly within planar and cylindrical magma intrusions. Then, we estimated thermal strain rates within the region of δT $<$200K, where the medium can be treated as a Poissonian elastic body. We assume a thermal diffusivity of 6×10^{-7}m^2/s and a thermal expansion coefficient of 2×10^{-5}/K, taking into account latent heat release and the density change caused by a phase change of partially molten material.

As a result, strain rates larger than the effect of tectonic loading ($>5\times10^{-14}$/s) is observed for planar magmas of width of $<$200m and cylindrical magmas of radius of $<$160m. Even if the initial crack were not observed because of small amplitude and high attenuation, an exited larger-scale deformation such as a resonance would be observed as an LFE.

The orientation of produced strain rates differs between planar intrusions and cylindrical intrusions. Assuming that magma shape and strain rate correspond to source distribution and source mechanism, respectively, we expect a correlation between source distribution and source mechanism for volcanic LFEs. Although a part of this relationship has been recognized for the LFEs in eastern Shimane in western Japan [Aso and Ide, 2014], more mechanism analyses are needed to verify our model.

Keywords: volcanic low-frequency earthquakes, cooling magma, CLVD