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Conduit flow dynamics during the 2011 sub-Plinian eruptions of Shinmoe-dake volcano

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The initial phase of the 2011 Kirishima-Shinmoe-dake eruptions is characterized by three sub-Plinian eruptions with forming of eruption columns and tephra dispersion. For these sub-Plinian eruptions, owing to multiple observations such as crustal deformation measurements by tiltmeter, eruption cloud echo measurements by weather radar, and petrological and geological measurements, we have obtained precise information about intensity, duration, magma discharge rate, magma properties and geological conditions. In this study, by incorporating this information into the analysis of conduit flow model, we investigated the conduit flow dynamics during the sub-Plinian eruptions of Shinmoe-dake volcano.

During the sub-Plinian eruptions, there was a good correlation between eruption cloud echo and tilt change. The eruption cloud echo measurements by C-band weather radar (Shimbori and Fukui, 2012) show that 6.5-8.5 km (asl) high eruption columns were continuously formed during the three sub-Plinian events, at about 16:00-18:30 on January 26, and at 1:50-4:40 and 16:20-17:40 on January 27. The borehole-type tiltmeter data by NIED also show clear tilt changes in response to the sub-Plinian events, and the timings of these changes coincide well with those of the formation of the eruption columns detected by the radar echo. Here the source of the tilt change is a spherical deflation source at a depth of about 10 km bsl, implying deflation of a magma chamber caused by migration of magma to the surface. These observations suggest that there was a magma plumbing system connecting a magma chamber at depth and the surface during the sub-Plinian eruptions.

We modeled the magma plumbing system during the sub-Plinian eruptions using a 1-dimensional steady conduit flow model in which bubble flow transits to gas-pyroclast flow at fragmentation surface. In the case of the sub-Plinian eruptions of Shinmoe-dake volcano, magma discharge rate, which is an essential parameter controlling the conduit flow dynamics, has been precisely estimated using geodetic method as about 1.5 x 10^6 kg s^{-1} (Kozono et al., 2013). Under given this discharge rate, we can obtain the relationship between chamber pressure (p_{ch}) and conduit length (L) ("p_{ch}-L relationship") using the conduit flow model, in which conduit flow satisfies the boundary conditions at the chamber and the vent. When this relationship is close to lithostatic pressure-depth relationship, conduit flow is considered to be realistic. We systematically investigated the features of the p_{ch}-L relationship for wide ranges of conduit radius, critical gas volume fraction for fragmentation, permeability for gas escape, and crystal growth rate, under given magma properties at the chamber that are constrained from petrological data. We found that the p_{ch}-L relationship strongly depends on conduit radius, and it is close to the lithostatic pressure-depth relationship in the case that the radius is about 5 m. This indicates that the chamber-surface magma plumbing system during the Shinmoe-dake eruptions was formed by a relatively narrow magma path.

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Keywords: conduit flow, Shinmoe-dake, sub-Plinian eruption, numerical model