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Transition in eruption style during the 2011 eruption of Shinmoe-dake: implications from a steady conduit flow model

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Mount Shinmoe-dake, in the Kirishima volcanic group, (located in southern Kyushu, Japan), erupted in January 2011. The eruption was initially magmatophreatic, and then the eruption style underwent a series of transition, from sub-plinian explosions to an extrusion of lava in the summit crater. The purpose of the present study is to investigate the cause of such changes in eruptive styles. We focused primarily on the transition between the sub-plinian and lava extrusion phases, as well as on the termination of lava effusion. To examine the conditions in the conduit and magma chamber, we devised a numerical code based on the one-dimensional steady flow model of Kozono and Koyaguchi (2010), in which a dome-forming eruption is modeled. The model assume that magma ascent as two phases isothermal flow in a cylindrical conduit with vertical and lateral gas escape. The magma viscosity depends on the volatile and crystal content.

Firstly, we systematically searched for a condition in which the magma would not be fragmented, but in which the volatile content would remain constant and unchanged. The magma permeability was estimated to suit that the gas fraction did not exceed the critical value. In this study, we introduced the criterion of Proussevitch *et al*. (1993), in which the critical gas fraction is representatively 0.75. However, calculations using a critical gas fraction ranging from 0.7 to 0.8 showed that the estimated permeability was not sensitive for the critical value. Besides, we tested another fragmentation criterion suggested by Papale (1999), in which occurrence of magma fragmentation depends on the strain rate.

Then we investigated the relationship between the magma chamber pressure and mass-flow-rate under a given magma chamber depth (i.e. conduit length). As the result, we found that reduction of the chamber pressure in the course of the eruption and a subsequent jump in the mass-flow-rate between multiple steady solutions played essential roles for the transition.

Further, we estimated the pressure decrement at the cessation of lava extrusion, and then discussed the total volume of the magma chamber by applying the pressure reduction to the Mogi model. Then we inferred the total volume of the magma chamber as an order of 10^{10} m^3. However, considering that the following processes are probably relevant, our estimation of the chamber volume might be regarded as the upper limit. In other words, volume of the erupted material might be larger than the change in chamber volume which is deduced from the simple deformation model: (a) The rigidity of the host rock just around the magma chamber being lower than that of the ordinary crust; (b) the effect of the compressive property of the chamber magma; and (c) the existence of a co-eruptive supply of magma into the chamber from a depth. At present, no preceding geophysical studies such as the seismic tomography have reported a remarkable anomaly of a comparable size to our estimation at the pressure source of Shinmoe-dake. It suggests that contributions of the above processes may not be negligible. Subsurface exploration with a higher spatial resolution would contribute to a detailed verification of the total chamber volume, as well as the further modeling of the processes listed above.