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States of magma chamber of Shinmoe-dake, Kirishima Volcano as inferred from steady flow conduit model

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1. Introduction

Transition from explosive to effusive eruptions is sometimes seen (e.g. Mt. Pinatubo 1991-92, Mt. St. Helens 1980-86). Some recent studies have discussed the mechanism of such transition of eruption regime (e.g. Kozono and Koyaguchi, 2009; Woods and Koyaguchi, 1994). Also in the 2011 event of Shinmoe-dake Volcano, a sequence of sub-Plinian eruptions was followed by lava effusion within the summit crater. In this study, we applied the 1D steady flow model of Kozono and Koyaguchi (2010) to the dome-forming stage to infer the condition of magma chamber to lose explosivity. This eruption event may fit well to physical model approach since discharge rate, and location of the magma chamber are known from observations and some other important parameters regarding the magma property are also being investigated by some geological and petrological studies.The model which we used here assumes two-phase (liquid-vapor) isothermal magma flow in a cylindrical conduit with vertical gas escape. Dependence of magma viscosity on volatile and crystal content is taken into account.

2. Results and Discussion

First, we made systematic numerical tests by using the above-mentioned model to examine how the initial H_2O content, discharge rate, temperature and conduit radius affect the occurrence of magma fragmentation in the conduit. Then we investigated the upper limit of the initial H_2O content to realize a dome-forming eruption, assuming a discharge rate of 40 m^3/s under the temperature range of 950-1050 C (Suzuki et al., 2011; Miyagi et al., 2011), for a conduit radius of 10-50 m. We obtained the upper limit of the initial H_2O content as 1.5-3.8 wt% when the conduit radius is 10 m. Wider conduit gives smaller content of H_2O. This result suggests a release of volatile from the magma chamber during the early stage of the eruption when compared to 3-4 wt%; the initial H_2O content before the sub-Plinian eruptions which is estimated from petrological study(Suzuki et al., 2011).

Even for the non-linear system which has multi-steady states, the pressure of magma chamber is uniquely determined if a discharge rate and a conduit length are given. Herein, we assume 6-8 km for the conduit length as inferred from GPS observation (NIED, 2011; JMA, 2011; GSI, 2011).and the same values of discharge rate and temperature referred above. Applying the upper limit of the initial H_2O content for the dome-forming eruption, we obtain the chamber pressure for the effusive stage which is not so deviated from the pre-eruptive pressure estimation by some petrological studies. This result implies that the degree of pressure decrease due to the sub-Plinian eruptions was not very large, though the deflating ground deformation itself was clearly recognized in GPS records. It may be an implication for the possible size of the magma chamber as discussed below.

It is generally difficult to estimate the volume of a magma chamber by geophysical monitoring. For instance, it is the change in volume, not size of chamber, which is obtained from ground deformation. We here try to estimate the chamber size in two ways. Firstly, the chamber volume is assessed from the relationship between the observed amount of discharged gas during the explosive and the decreased amount of H_2O content in the chamber which is calculate in this study. The other way to estimate the chamber volume uses the the relationship between changes in the chamber pressure and volume at a given rigidity of host rock.

The latter estimation is found to be significantly larger than the former one. This apparent contradiction might be well explained by introducing a conceptual model of a non-uniform magma chamber. For example, a portion of the magma chamber, most plausibly the upper part of it, is efficiently degassed through the sub-Plinian eruptions and loses its explosivity to result in the subsequent dome-forming eruption, while the degree of pressure change is determined by the whole size of the chamber.