The effect of decompression-induced crystallization on viscosity of basaltic magma: A case study of Fuji 1707 basaltic magma

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INTRODUCTION

Basaltic magma shows wide variety of explosive eruption style from mild strombolian to intense plinian. At Fuji volcano, mild strombolian eruption is the most common style of explosive eruption (e.g., 864-866 Jogan eruption). However, intense basaltic plinian eruption occurred at 1707 Hoei eruption. Mechanism of basaltic plinian eruption is not well understood. Plinian scoria of 1707 Hoei eruption is characterized by high abundance of plagioclase microlite (> 30 vol.%); the abundance is higher than that of strombolian scoria of 864-866 Jogan eruption. The fact cannot be explained by the difference of conduit ascent rate alone and suggests that difference of pre-eruptive temperature and/or melt water content may play an important role. In this study, we performed numerical simulation of decompression-induced crystallization to investigate the effect of pre-eruptive conditions on magma viscosity and eruption style of basaltic magma.

METHODS

We used the rhyolite-MELTS program (Gualda et al., 2012) for decompression-induced crystallization simulation. Composition of initial melt is the same as that of basaltic melt of the 1707 Hoei eruption. Plhase equilibrium calculations are repeated with 0.1 MPa step from 150 to 0.1 MPa. During decompression, we keep the conditions of temperature and oxygen fugacity (Ni-NiO buffer) constant, and crystallized phases and bubbles are immediately fractionated. Initial temperature and melt water content conditions vary in the ranges of 1184-1094 deg. C and 0.5-3 wt. %, respectively. At each pressure, melt viscosity is calculated from temperature and composition of melt by the model of Giordano et al. (2008) and relative viscosity is estimated from crystal content by Einstein-Roscoe equation, and magma viscosity is calculated from melt viscosity and relative viscosity.

RESULTS

Melt fraction at 1 atm (F_{1atm}) decreases and onset pressure of decompression-induced crystallization (P_s) increases as initial temperature decreases. F_{1atm} decreases from ca. 92 wt. % at 1189 deg. C to ca. 40 wt. % at 1094 deg. C. The relations between P_s-normalized pressure and F_{1atm}-normalized melt fraction are almost the same for runs of different initial conditions, indication that pressure-melt fraction path of decompression-induced crystallization is chiefly controlled by initial temperature condition. Increasing rates of magma viscosity during decompression strongly depend on initial temperature; magma viscosity is almost constant at 1184 deg. C whereas it increases by 6 orders of magnitude at 1094 deg. C during decompression.

DISCUSSION

Our results indicate that the effect of decompression-induced crystallization on magma viscosity strongly depends on pre-eruptive temperature condition. As initial temperature decreases, increasing rate of microlite increases, and as a result, both melt viscosity and relative viscosity increase. Therefore, magma viscosity significantly increases for initially H_2O-rich low-T basaltic melt. Increase of magma viscosity facilitates fragmentation. In addition, abundant microlites may suppress bubble coalescence and melt-bubble decupling. Consequently, magma degassing is inhibited and explosivity increases. In conclusion, eruption style of basaltic magma is strongly influenced by pre-eruptive temperature.

Keywords: decompression-induced crystallization, basaltic magma, viscosity, Fuji volcano, MELTS, eruption style