Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

SVC048-10 Room:301B Time:May 22 12:00-12:15

Re-examination of upper limit viscosity of eruptible magmas

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Magma eruptability is an important concept in assessment for eruptive activity of long-dormant volcanoes. The magma eruptability is dominantly controlled by magma viscosity, because timescale of magma movement is controlled in the balance between viscous resistance of magma and driving forces. Using a compilation of magmatic properties such as melt composition, melt water content, temperature, and phenocryst content, the pre-eruptive magma viscosities under chamber condition are calculated for 83 erupted magmas. The studied basaltic to rhyolitic magmas have pre-eruptive viscosities in the range 10^1 to 10^8 Pa s. Although bulk SiO_2 content is commonly used as a qualitative measure of pre-eruptive magma viscosity, the results indicate that bulk SiO_2 content shows a weak correlation with magma viscosity, due to the effect of phenocrysts. By using estimated viscosities, a hypothesis of two-fold upper viscosity limits (dike-propagation and magma-extrusion limits for preeruptive viscosity of eruptible magmas, Takeuchi, 2004, Geology) is examined. Most of the calculated viscosities fall below ca. 10^6 Pa s, which is consistent with the model-based estimate for the dike propagation limit. This study describes 20 examples of highly viscous magma that exceeds the dike propagation limit, and 9 of these magmas erupted following the precursory eruption of less-viscous magma. Two possible mechanisms generating the less-viscous magmas are considered: 1) generation of a remobilized magma through interaction between a high-temperature and a low-temperature highly viscous magma, 2) segregation of interstitial rhyolitic melt from highly viscous magma (crystal mush). Although the hypothesis requires further examination, two-fold viscosity limits operate, to some extent, as a universal control of magma eruptibility.

Keywords: magma viscosity, magma eruptibility, dike propagation, pre-eruptive condition