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A compilation of magma viscosity at preeruptive chamber conditions

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Magma viscosity is one of the most important physical properties to model magmatic processes, because timescale of magmatic processes is controlled in the balance between viscous resistance of magma and driving forces. Especially, viscosity of preeruptive magmas at crustal chambers beneath active and hazardous volcanoes should be fundamental information to predict future activities and evaluate potential hazards. In this study, petrological data needed to estimate magma viscosity (melt composition, melt water content, temperature and phenocryst content) were compiled, and magma viscosities at preeruptive chamber conditions were petrologically estimated. Similar compilation was previously performed by Scaillet et al. (1998), but their compilation was limited to silicic magmas. Recent experimental studies (e.g. Giordano et al., 2008) have proposed models to precisely calculate viscosity of hydrous melt with various compositions. Moreover, during last decade, many studies have reported precise petrological data of erupted magmas. At the time of writing, this compilation includes viscosity of 81 erupted magmas. Viscosities were calculated by using the model of Giordano et al. (2008) with a simple method to correct effect of phenocryst on magma viscosity (Marsh, 1981).

Estimated magma viscosities range from 10^1 to 10^{10} Pas for basaltic to rhyolitic bulk composition. Bulk SiO_2 content is often used as a qualitative measure of preeruptive magma viscosity. In this compilation, bulk SiO_2 contents, however, are not well correlated with magma viscosities. Especially, andesitic magmas have wide range of magma viscosity from 10^3 to 10^7 Pas due to wide range of phenocryst content from 0 (pure andesitic melt) to ca. 50 vol.% (50 vol.% rhyolitic melt + 50 vol.% phenocryst). Considering this wide range of viscosity, bulk SiO_2 content is not a good measure of preeruptive magma viscosity. In contrast, melt SiO_2 contents (SiO_2 content of total groundmass) show a good linear correlation with melt viscosities.

Magma mixing has often been observed in arc volcanism. In some cases, a mixed magma occurs between a low-temperature, silicic end member magma in a crustal chamber and a high-temperature mafic end member derived from a deeper source. When the silicic end member magma is highly viscous crystal mush (>50 vol.% phenocryst content), magma mixing plays a important role in production of a less viscous mixed magma which has higher temperature, less silicic melt composition and lower phenocyst content than the silicic end member. Such the less viscous mixed magma is also called “remobilized magma”. When the less viscous mixed magma is produced just before eruption, preeruptive viscosity of the mixed magma does not represent viscosity of the silicic end member magma in the shallow crustal chamber.