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Viscosities of hydrous andesite and the effect of crystals on the rheology and relative viscosity of magmas: An experimental study

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The effects of chemical composition and pressure on the viscosity of pure melts were investigated at super-liquidus and sub-liquidus temperatures by the falling sphere technique in a conventional and a centrifuging piston cylinder, and at high viscosities (10^{10}-10^{12} Pa*s) by creep experiments in a high-pressure, high-temperature Paterson-type deformation apparatus.

Synthetic mixtures of oxides and silicates, equivalent to Montserrat andesite and to a haplogranite containing different water contents (between 2.5 and 5.5 wt. %, analyzed by SIMS and Raman spectroscopy), were hot isostatically pressed to obtain glasses that were used as starting materials in the viscosity experiments. The Fe^{+3}/Fe^{+2} ratio of the andesite glass was fixed at a value corresponding to the Ni-NiO equilibrium. Mössbauer spectroscopy was carried out on the glasses before and after the experiments and confirmed that during the experiments no significant variations of the ferric/ferrous ratio occurred. Analyses of the water content after the runs showed that no detectable water loss occurred during the experiments.

Viscosities of the hydrous andesite obtained at super-liquidus conditions are in general agreement with the literature data, whereas at sub-solidus temperature the data tend to lower values. This could be related to the fact that in previously published data, Fe was substituted by Ca and Mg.

Additional experiments were conducted to constrain the effect of variable, but high crystal contents (60-80 vol. %) on the viscosity and rheology of the haplogranitic composition. Quartz crystals of fixed size (56-125 μm) were employed as solid particles. The quartz-saturated composition of the haplogranite ensured a minimum interaction rate between quartz and melt, thereby providing the possibility to control all relevant parameters during the experiments (viscosity of the melt and degree of crystallinity). The viscosity of the pure melt phase was measured beforehand in a conventional and centrifuging piston cylinder apparatus using the falling sphere method.

The transitions from Newtonian to non-Newtonian and Binghamian behavior were identified and the experimental results were used to formulate a comprehensive description of a partially crystallized system as a function of degree of crystallinity and strain rate.