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Falling sphere viscosity of hydrous rhyolitic melt in centrifuging experiments

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Studies on magma viscosity are necessary to understand magma rheology and behavior. The falling sphere method allows determining the viscosity (Shaw, JGR,1963) of Newtonian fluids, where viscosity is inversely proportional to the velocity of a sinking sphere (Stokes'law). With a sphere size of 100-440 μm (precisely measured by SEM) and an inner capsule diameter of 3.5 mm, the wall effect is small.

The investigated melt has a haplogranite composition. One set of experiments was run with a powder of a standard synthetic haplogranite composition with different amounts of water (2 and 3 wt%). The second set employs synthetic glass cylinders synthesized in a hot isostatic press (T = 1050 °C, p $\simeq 1.8$ kbar) with different water contents (2.7 to 5.25 wt%). The setup includes Pt or Mo spheres and $Au_{80}Pd_{20}$ capsules (inner diameter 3.5 mm) welded in a tin can-like fashion to conserve cylindrical geometry. The starting position of the sphere is marked by a thin (0.05 mm) Pt-ring with an internal diameter of 2.7 mm (ext. 3.5 mm). The post-quench distance between sphere and Pt-ring, determined by x-ray images, and the run time define the sinking velocity of the sphere.

A pressure series (5, 7, 10 and 15 kbar) in a static piston cylinder at high temperatures (1000 and 1100 °C) was performed to determine the pressure dependence of the haplogranite viscosity with 5.25 wt% of water. Magma chambers often have lower pressures but for an accurate control of solid state confining pressures in this apparatus, at least 5 kbar are necessary. Results show a decreasing of viscosity with increase pressure, as predicted by Scarfe et al. (Magm.Proc., 1987) for materials with NBO/T < 1. The 5 kbar experiments are in agreement with the viscosity prediction of

Hess and Dingwell (Am.Min., 1996) (model 4, based on the Vogel-Fulcher-Tamman equation). The difference on viscosity with increasing pressure ($dlog\eta/dP$) is bigger at lower temperature (0.7 log Pa$\times$s) than at 1100 $^\circ$C (less as 0.4 log Pa$\times$s). The dependence of viscosity on the temperature decreases between 5 and 10 kbar and increases again slightly at 15 kbar.

The expected viscosity at magmatic temperatures of 700 to 800 $^\circ$C is between $10^{4.5}$ - $10^{7.5}$ (Pa$\times$s) and the sinking of the sphere would take too long, allowing water loss, crystallization, or desegregation of the melt. Thus a piston-cylinder was mounted onto a centrifuge (maximum acceleration of 1'000 g) strongly reducing the necessary sinking time. Using this technique the viscosity of haplogranite melt was measured between 820 and 1000 $^\circ$C resulting in values between 10^4 and 10^6 Pa$\times$s.

The results yield the expected strong decrease of viscosity with temperature and water contents, but show a smaller dependence on pressure which cannot be neglected. These results broadly agree to the viscosity prediction of Hess and Dingwell (Am.Min., 1996), but result in lower viscosities as predicted by their model at low temperatures or high H_2O contents.