Falling sphere viscosity of hydrous rhyolitic melt considering H_2O-T-P variations

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The rheological properties of silicate melts control transport dynamics, eruption style and rates of physicochemical processes in magmas. Magma viscosity varies up to 15 orders of magnitude due to the effect of composition, temperature, pressure, and volatile content (mainly H_2O). The effect of water is dramatic, 1 wt% added to a rhyolitic melt at eruptive temperatures decreases viscosity by 6 orders of magnitude. Rhyolitic melts may contain up to 10 wt% of water at magma chamber pressures. We employ a falling sphere technique (in static and centrifuging piston-cylinders) to investigate the Newtonian viscosity of a dry and hydrous haplogranitic melt (GG1) as a function of water content, temperature and pressure. Model based predictions [1] indicate viscosities of 10^4-10^7 Pa s (at 650–850 ˚C).

The homogeneous starting material was synthesized in a hot isostatic press at 1050˚C, 1.8 kbar, with water contents of 2.68, 3.73 and 5.25 wt% (confirmed by Raman, KFT and FTIR analysis). The experimental setup employs Pt spheres (diameter: 100–440 μm) and $Au_{80}Pd_{20}$, $Pd_{75}Ag_{25}$, or Pt capsules (o.d.: 4.0 mm) welded in a tin can-like fashion. The starting position of the sphere is marked by a thin (50 μm) Pt-ring and the post-quench distance is determined by x-ray imaging. The wall effect has only a minor effect on the derived viscosity as the ratio between the sphere's radius and that of the capsule is < 0.1.

The viscosity of haplogranite was determined between 580 and 1200˚C (at 5 kbar), at accelerations of 1-1000 g. The resulting viscosities, between $10^{2.4}$ and 10^7 Pa s, show Arrhenian behaviour for each H_2O content. To constrain the effect of pressure on viscosity we performed experiments at 5 to 25 kbar. These experiments indicate a similar viscosity trend indicating an increase of the activation energies (E_A). Extrap-

olation of anhydrous viscosity data measured by the concentric cylinder technique at high T (1500-1650˚C) indicates a higher E_A, more than twice the one determined in H_2O bearing melts.

The results yield the expected strong decrease of viscosity with temperature and water content, but show variable pressure dependence. The E_A increases with pressure and decreases with increasing water content in the melt. The values broadly agree with the viscosity prediction of [1], but at low temperatures, measured viscosities are lower. The results are used to build a more general composition, T and P dependent viscosity model for silica-rich melt.

[1] Giordano et al., Geochimica Cosmochimica Acta, 2004