The effects of silica and water on the viscosity of hydrous quartzofeldspathic melts

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ABSTRACT

The viscosities of hydrous melts (0.65 to 2.8 wt% H₂O) with quartzofeldspathic compositions corresponding to Ab, Ab₇₄Qz₂₆, and Ab₄₈Qz₅₂ (mole proportions calculated on the basis of eight oxygen atoms; Ab = NaAlSi₃O₈, Qz = SiO₂) have been determined between 980 and 1375 °C at pressures between 190 and 360 MPa using the falling sphere technique. The use of large bubble-free hydrous glass cylinders (placed in internally heated pressure vessels) previously prepared and already containing markers and platinum spheres allows falling distances up to several centimeters to be measured with a precision of ±50 to 200 μm. This results in a precision of ±15% relative or less for most viscosity data (±10% relative or less if the temperature is known within ±5 °C).

For a water content of 2.8 wt% H₂O, viscosity increases with increasing Qz content. In the investigated viscosity range, no significant deviation from Arrhenian behavior is observed and the activation energy of viscous flow increases slightly with decreasing water content of the melt (for Ab). Combining the experimental data obtained in this study with data for a haplogranitic composition investigated previously by Schulze et al. (1996) shows that the viscosities, and hence, the activation energies of viscous flow are similar for compositions with the same atom ratio (Si/Al)/(H-Na-K) (SA/HNK). Thus, melt viscosity is constant if Al, charge balanced by Na or K, is exchanged with Si (incorporated as OH or H₂O). The viscosities (in dPa-s) of all investigated hydrous haplogranite compositions with water contents ranging between 0.7 and 8.2 wt% H₂O can be calculated to better than ±0.15 log units using the expression:

\[ \log \eta = -1.8 + [940 + 5598/(SA/HNK)^{0.3774}]^{-1/T} \]

where \( T \) is expressed in Kelvin and varies from 1073 to 1650 K.

INTRODUCTION

The high viscosities (10¹⁰ to 10¹⁴ d-Pa-s or poises) of hydrous aluminosilicate glasses can be measured at 1 atm with different types of viscosimeters (e.g., Lejeune et al. 1994; Dingwell et al. 1996; Richet et al. 1996), if the temperature is low enough to avoid significant diffusion of water out of the sample (water is only dissolved at high pressure in aluminosilicate liquids with compositions close to those of natural melts). At high pressure (P) and temperature (T), determination of the viscosity of hydrous silicate liquids is notoriously difficult because experiments have to be carried out in sealed noble metal capsules, which makes in situ measurements difficult (for possible in situ techniques, see Kanzaki et al. 1987; Persikov et al. 1990). Until now, the most popular technique used for granitic melts is that of the falling sphere (e.g., Bacon 1935; Shaw 1963; Burnham 1964; Baker and Vaillancourt 1995). This precision of the viscosity determinations is mainly a function of the settling distance of the spheres (typically platinum spheres), of uncertainty in the position of platinum spheres before and after the experiments, and of the correction factors applied to account for the effects of viscous drag exerted on the settling spheres by the capsule walls (Faxen correction, see Shaw 1963). Most available data have been obtained from relatively small samples, yielding high uncertainties on the viscosity values, stated as ±15% relative (e.g., Dingwell 1987; White and Montana 1990; Baker and Vaillancourt 1995). This uncertainty, together with possible systematic errors due to the application of different correction factors and with high uncertainties on the determination of the water contents in the melts, result in difficulties combining the available viscosity data sets, which are not always consistent. For example, the data in Figure 1 suggest that almost identical viscosities are obtained for albite melts containing 2.8 and 4.5 wt H₂O and that melts containing 5.6 wt% H₂O are slightly less viscous than melts containing 6.9 wt% H₂O (data from Dingwell 1987 and Persikov et al. 1990, respectively), which is not realistic because melt viscosity is known to decrease with increasing water content. Thus, although the