Viscosity data for hydrous peraluminous granitic melts: Comparison with a metaluminous model

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ABSTRACT

We performed 27 viscosity determinations on dry and water-bearing peraluminous haplogranitic melts. The dry melt compositions cover the range of normative corundum to be expected in peraluminous granitic melts in nature. The compositions are based on addition of Al$_2$O$_3$ to a haplogranitic melt (HPG8) whose composition is near that of the projection of the 2 kbar H$_2$O-saturated minimum melt composition into the system NaAlSi$_3$O$_8$-KAlSi$_3$O$_8$-SiO$_2$. The H$_2$O contents of the hydrous melts were analyzed using Karl Fischer titration ranging from 1 to 3 wt%. The viscosity determinations were performed using a modified micropenetration method in the viscosity range of $10^{10}$ to $10^{11}$ Pa·s, at 1 atm pressure, and in the temperature ranges of 880–940 °C and 470–640 °C for the dry and wet melts, respectively. For the dry peraluminous melts in this high viscosity range, addition of the first few percent of normative corundum to a metaluminous granitic melt increases the viscosity, which remains nearly constant despite further addition of Al$_2$O$_3$. Thus a viscosity maximum is inferred for dry slightly peraluminous granitic melts. The hydrous melt viscosity data were compared with the recent calculational model of Hess and Dingwell (1996), which was based on and designed for metaluminous melt viscosities. That model is capable of describing the viscosities of hydrous peraluminous granitic melts within the uncertainties stated for its application in metaluminous melts.

INTRODUCTION

The Newtonian shear viscosity of hydrous granitic melts is the most important material coefficient relating the stresses to which largely molten granitic magmas are subjected to the resulting deformation. Reliable modeling of the mass transfer involved in the physical evolution of granitic magmas and its consequences for chemical evolution of the residual melts of highly fractionated magmas requires a model that can accurately predict melt viscosity. Considerable attention has been focussed on experimental measurement of granitic and analog melt viscosities (e.g., Burnham 1963; Shaw 1963; Friedman et al. 1963; Persikov 1991; Dingwell et al. 1996; Schulze et al. 1996). Because metaluminous compositions dominate granitic terrains, experimental studies (listed above) have largely focussed on a restricted range of melt compositions. Multicomponent models based on the Arrhenian temperature dependence of viscosity well describe the high-temperature viscosities of both dry (Bottinga and Weill 1972) and wet (Shaw 1972; Persikov et al. 1990) silicate melts. However, such models have been recently shown to be inadequate in dealing with the high viscosity region for hydrous melts (Baker and Vaillancourt 1995; Baker 1996). This became quite apparent when new viscosity data were obtained by dilatometric means (Dingwell et al. 1996; Richet et al. 1996). Hess and Dingwell (1996) produced a non-Arrhenian model for calculation of hydrous granitic melt viscosities and demonstrated that the minor variations in the silica content or alkali/aluminum ratio of hydrous melts produced no noticeable influence on the viscosity at significant H$_2$O contents. Greater variations in the chemical composition of the dry melt might, however, be expected to produce significant variations in melt viscosity at moderate H$_2$O contents. In this context, perhaps the most important compositional variable influencing the viscosity of dry granitic melts is the alkali/aluminum ratio. The present study investigates the influence of H$_2$O on the viscosity of peraluminous granitic melts.

METHODS

The dry melt compositions are based on the addition of Al$_2$O$_3$ to a haplogranitic melt (HPG8) whose composition lies near the 2 kbar pH$_2$O ternary minimum melt composition projected into the system NaAlSi$_3$O$_8$-KAlSi$_3$O$_8$-SiO$_2$. The synthesis of the dry base glasses by means of 1 atm direct fusions of oxide-carbonate powder mixes was described by Holtz et al. (1992) and chemical analyses of the glasses by ICP-AES (Table 1) were presented by Knoche et al. (1995).

Hydrothermal syntheses of the H$_2$O-bearing samples were performed in rapid-quench TZM vessels using methods described in Dingwell et al. (1996). The hydrous samples were analyzed for H$_2$O content using Karl-Fischer titration (KFT) and methods described in Dingwell