The effect of P$_2$O$_5$ on the viscosity of haplogranitic liquid.

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Abstract: The effect of P$_2$O$_5$ on the viscosity of a haplogranitic (K$_2$O-Na$_2$O-Al$_2$O$_3$-SiO$_2$) liquid has been determined at 1 atm pressure in the temperature interval of 700 - 1650°C. Viscosity measurements of a haplogranite, haplogranite + 5.1 wt.% P$_2$O$_5$ and haplogranite + 9.5 wt.% P$_2$O$_5$ have been performed using the concentric cylinder and micropenetration methods.

The viscosity of haplogranite liquid decreases with the addition of P$_2$O$_5$ at all temperatures investigated. The viscosity decrease is nonlinear, with the strongest decrease exhibited at low P$_2$O$_5$ concentration. The temperature-dependence of the viscosity of all the investigated liquids is Arrhenian, as is the case for P$_2$O$_5$ liquid. The Arrhenian activation energy is slightly lower in the P$_2$O$_5$-bearing liquids than in the P$_2$O$_5$-free haplogranite with the result that the effect of P$_2$O$_5$ on viscosity is a (weak) function of temperature. At temperatures corresponding to the crystallization of phosphorus-rich granitic and pegmatitic systems the addition of 1 wt.% of P$_2$O$_5$ decreases the viscosity 0.2 log$_{10}$ units.

The effect of P$_2$O$_5$ on haplogranitic melt viscosity is much less than that for B$_2$O$_3$, F$_2$O-1 on the same melt composition (Dingwell et al., 1992 and this study). This implies that P$_2$O$_5$ concentration gradients in high-silica melts during, for example, phosphate mineral growth or dissolution in granitic magmas, will not significantly influence melt viscosity.

Keywords: silicate melt, viscosity, micropenetration, concentric cylinder, granite, phosphorus.

1. Introduction

The remarkable phosphate mineralogy of pegmatite fields (Moore, 1982) and the significant phosphorus contents of nominally phosphorus-free minerals (London et al., 1990a) may result in part from extreme enrichment of phosphorus at the magmatohydrothermal stage of pegmatite evolution. Certain rare-element granitic pegmatites are estimated to contain up to 1 wt.% of P$_2$O$_5$ (London et al., 1990a; Černý, 1991) and the glassy eruptive macusianites of SE Peru contain 0.5 to 1.0 wt.% P$_2$O$_5$ (Pichavant et al., 1987). There is no reason to doubt that even higher concentrations may be attained in certain extreme pegmatic differentiates (Černý et al., 1985). Such enrichments may well occur at the magmatohydrothermal stage and thus the properties of P$_2$O$_5$-rich magmas, both chemical and physical, are of geological relevance.

Several experimental hydrothermal investigations of phosphate - melt equilibria exist. Wyllie & Tuttle (1964) demonstrated that the addition of P$_2$O$_5$ to granitic and albitic melts strongly reduces the melting temperature under 2.75 kbar pH$_2$O. Studies of apatite and monazite solubility in peralkaline and metaluminous compositions indicate moderate melt P$_2$O$_5$ contents (0.1-0.4 wt.%, Watson, 1979, 1980; Rapp & Watson, 1987). Peraluminosities, however, has been demonstrated to enhance P$_2$O$_5$ solubility up to several weight percent (Montel, 1986).

In a different but equally important context, the rich diversity of phosphate mineralogy is matched by a large glassforming range of composition in silicophosphate and phosphate glasses (Scholze, 1988), and indeed P$_2$O$_5$ itself is glassforming. As a result the properties of phosphate glasses and liquids have been investigated (Banuls & Doremus, 1986).