INTRODUCTION

Granitic pegmatites, especially rare-element varieties, attract much attention as a source of gemstones and rare-metal ores (e.g., Ta, Be, and Cs). Such pegmatites are among the most compositionally complex igneous rocks and show extreme enrichment in a broad range of elements including volatiles and fluxes. Classical theories of pegmatite formation (e.g., Jahns and Burnham 1969) emphasize the importance of volatiles (primarily H$_2$O) and state that granitic pegmatites crystallize from coexisting aluminosilicate melt and hydrous fluid. Other models downplay the role of a separate fluid phase and suggest that aluminosilicate melts can produce highly evolved pegmatitic liquids via continuous crystallization under particular kinetic conditions (London 1986, 1992, 1999).

The topology of salt-water systems, such as NaCl-H$_2$O (Sourirajan and Kennedy 1962), shows that over a wide range of P-T-X conditions, fluid separates into a low-salinity vapor and a high-salinity liquid (brine). If such a two-phase field extends to temperatures exceeding the silicate solidus, and if the vapor and the brine do not dissolve completely in silicate melt, a three-fluid equilibrium (melt + brine + vapor) is reached (Bodnar et al. 1985; Shmulovich and Churakov 1998). The expected range of P and T for the three-phase equilibrium is well within that of natural pegmatite magmas (0.1–0.3 GPa, 500–700 °C) and the coexistence of three fluids is most likely for shallow-level, B-, F-, and P-rich pegmatites. Natural hydrosaline melts have previously been found as inclusions trapped in rock-forming minerals. They are not restricted to granites and can be effective agents for enhanced crystal growth, metasomatism, and ore formation. In addition, hydrosaline melts may account for many characteristic features of rare-element and miorolitic pegmatites, such as giant size and perfect shapes of crystals in pegmatite cores, diverse mineralogy, and strong enrichment in rare elements.

EXPERIMENTAL METHODS AND RESULTS

Starting composition

A starting glass with the bulk composition (in wt%): SiO$_2$ = 58.7, Al$_2$O$_3$ = 16.5, B$_2$O$_3$ = 5.0, Na$_2$O = 2.9, K$_2$O = 3.7 Rb$_2$O = 1.1, Cs$_2$O = 1.0, Li$_2$O = 0.5, P$_2$O$_5$ = 4.2, F 4.6, and H$_2$O = 1.5 was synthesized from reagent-grade chemicals in cold-seal pressure vessel at 900 °C and 2 GPa. The glass is strongly peraluminous, with the molar Al$_2$O$_3$/ (Li$_2$O + Na$_2$O + K$_2$O + Rb$_2$O + Cs$_2$O) = 1.46, and models the most-enriched compositions of melt inclusions found in pegmatite quartz (Thomas et al. 2000).

ABSTRACT

We present an experimental study of synthetic peraluminous granite doped with H$_2$O, B, P, and F, which confirms that aluminosilicate melt, hydrous fluid, and hydrosaline melt (high-temperature brine) can stably coexist at 450–900 °C and 0.1–0.2 GPa in bulk compositions similar to those of natural granitic pegmatites. Hydrosaline melt is not quenchable, unstable at room conditions, and requires special techniques for synthesis and preservation. Raman spectroscopy and electron microprobe analyses of hydrosaline melt synthesized in our experiments show that it is composed of H$_3$BO$_3$, Na$_3$AlF$_6$, AlPO$_4$, H$_2$O, and aluminosilicate components. Aluminosilicate melt saturated in both hydrosaline liquid and hydrous fluid at 850 °C and 0.2 GPa contains 3.6 wt% F, 4.2 wt% P$_2$O$_5$, and 4 wt% B$_2$O$_3$. Natural hydrosaline melts have previously been found as inclusions trapped in rock-forming minerals. They are not restricted to granites and can be effective agents for enhanced crystal growth, metasomatism, and ore formation. In addition, hydrosaline melts may account for many characteristic features of rare-element and miorolitic pegmatites, such as giant size and perfect shapes of crystals in pegmatite cores, diverse mineralogy, and strong enrichment in rare elements.