American Mineralogist, Volume 103, pages 1228–1252, 2018

Origin of the fluorine- and beryllium-rich rhyolites of the Spor Mountain Formation, Western Utah

Shane R. Dailey[1,*,†], Eric H Christiansen[1], Michael J. Dorais[1], Bart J. Kowallis[1], Diego P. Fernandez[2], and Douglas M. Johnson[1]

[1]Department of Geological Sciences, Brigham Young University, Provo, Utah 84602, U.S.A.
[2]Department of Geology and Geophysics, University of Utah, Salt Lake City, Utah 84112, U.S.A.

Abstract

The Miocene rhyolites of the Spor Mountain Formation host Earth's largest beryllium deposit, which produced 85% of the world's beryllium in 2010. The fresh lava is extremely enriched in Be (up to 75 ppm in matrix glass). We have examined the rhyolite to better understand the Be enrichment. The Spor Mountain rhyolite contains ~40% quartz, ~40% sanidine, ~10% biotite, and ~10% plagioclase, along with accessory fluorite, columbite, euxenite, fergusonite, monazite, thorite, and zircon. Two types of rhyolite are present within the Spor Mountain Formation, a less-evolved magma (1150 ppm Rb, 42 ppm Be, 0.7 wt% F in glass) and a more-evolved magma (1710 ppm Rb, 75 ppm Be, 1.6 wt% F in glass).

Eruption temperatures estimated using two-feldspar (Elkins and Grove 1990; Putirka 2008; Benisek et al. 2010), plagioclase-liquid and alkali feldspar-liquid (Putirka 2008), Ti-in-quartz (Thomas et al. 2010, 2015; Huang and Audétat 2012), biotite (Righter and Carmichael 1996), and zircon saturation (Boehnke et al. 2013) geothermometers converge on 718 °C for the less-evolved magma and 682 °C for the more-evolved magma. Using the Ti-in-Qz equation of Huang and Audétat (2012), the pre-eruptive pressure of the Spor Mountain rhyolite system is estimated to be about 2 kbar at 700 °C. Water content of the rhyolite melt was less than <5 wt%, based on the co-crystallization of all four major mineral phases at 700 °C, and the magma was water undersaturated (Webster et al. 1987). Viscosity of the rhyolite was about $10^{6.2}$ Pa·s for the less-evolved rhyolite and $10^{5.8}$ Pa·s for the more-evolved rhyolite. Fluorine lowered the melt viscosity, though not by a large amount (less than 0.5 log units at 1.6 wt% F).

Partition coefficients for Be and other trace elements were determined for biotite, sanidine, plagioclase, and quartz from laser ablation-inductively coupled plasma-mass spectrometry analyses. Partition coefficients for trace elements in feldspars from the Spor Mountain rhyolite are generally higher than for feldspars from other silicic magmas and lower for biotite. The enrichment of beryllium in the Spor Mountain rhyolite was aided by its high incompatibility in the major mineral phases, with a bulk partition coefficient <0.1.

Trace element models using the measured partition coefficients are inconsistent with accumulation of increments of melt formed by different degrees of partial melting and cannot explain the great depletion of compatible elements. Rather, the trace element abundances and Nd and Sr isotopic compositions are consistent with derivation of rhyolite by ~25% partial melting of crust hybridized with mantle-derived components, followed by extensive fractional crystallization (75%). The combination of these magmatic processes set the stage for the formation of a world-class beryllium deposit.

Keywords: Spor Mountain, partition coefficients, beryllium, fractional crystallization, topaz rhyolite, fluorine; From Magmas to Ore Deposits