INTRODUCTION

Fluids play important and varied roles in many geologic processes such as metamorphism, magma generation, and ore formation. Fluids may act as agents to catalyze reactions, and reduce, oxidize, or transport elements. The mobility of fluids, which makes them effective catalysts and metasomatic agents, also limits their direct study. Boron is an element that has potential as a tracer for such processes because it can be quite soluble in fluids. Noting the large range of B isotopic ratios in naturally occurring samples (~9% range in terrestrial rocks and waters; Palmer and Swihart 1996), we have been curious to discover if this isotopic system might shed light on fluid-solid interactions. Understanding the significance of this isotopic variation first requires quantitative measurements of B fractionation. This work presents results of experimental studies that measured B isotopic fractionation between silicate melts and H2O fluid and analyses of natural samples that shed light on B isotopic fractionation and the partitioning of B into CO2-rich fluids.

SAMPLES STUDIED

Experimental run products

Experiments to measure B partitioning (fluid/melt) and isotopic fractionation were conducted using basaltic and rhyolitic melt and aqueous fluid. The basalt was a mid-ocean ridge sample from the Juan de Fuca ridge (TT-152; Table 1). An aliquot of this glassy sample was combined with NIST SRM 951 and boric acid to a level of ~2000 ppm B, melted, reground, and remelted. The rhyolite (Table 1) was a natural peraluminous sample from Macusani, Peru, containing ~2000 ppm B (Pichavant et al. 1987). Conditions for the experiments are given in Table 2. The basalt was studied at 950–1100 °C and between 110 and 170 MPa in a rapid-quench, internally heated apparatus (Holloway et al. 1992). Experiments on the rhyolite used a non-end-loaded piston cylinder at 500 MPa and 750–850 °C (http://depthsoftheearth.com/catalog.html). Both sets of experiments followed a similar protocol. A chip of “dry” glass was sealed in a capsule (either Au-Pd or Au, see Table 2) with a 1:1 ratio of H2O. The run was taken up to pressure and temperature for a period of 24–52 hours and quenched. The capsules were weighed, punctured, and re-weighed after drying at 110 °C to ensure that a fluid phase had been present. Fragments of the glassy run products were mounted in epoxy with fragments of the starting material and polished.

Natural samples

One pelite from the Bradshaw Mountains (central Arizona) was studied. The metamorphic rocks in the area contain andalusite, sillimanite, staurolite, garnet, biotite, and muscovite; this assemblage constrains the peak metamorphic temperature at ~550 °C (O’Hara 1980). Boron isotopic analyses of coexisting tourmaline and muscovite were made under the assumption that the analyses would represent the isotopic fractionation between these two phases at the peak metamorphic temperature, thus providing a “natural experiment.”

Several melt inclusions from olivine crystals found in the Cerro Negro (Nicaragua) volcano were analyzed for their H2O and CO2 contents (Roggensack et al. 1997) by infrared spec-