In situ ion-microprobe determination of trace element partition coefficients for hornblende, plagioclase, orthopyroxene, and apatite in equilibrium with natural rhyolitic glass, Little Glass Mountain Rhyolite, California

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ABSTRACT

Partially crystalline hornblende gabbro inclusions from the Little Glass Mountain Rhyolite contain euhedral plagioclase, orthopyroxene, hornblende, and apatite crystals in contact with interstitial rhyolitic (71–76% SiO2) glass. Textural and mineral compositional data indicate that the gabbros crystallized sufficiently slowly that surface equilibrium was closely approached at the interface between crystals and the liquid. This rare occurrence represents a natural dynamic crystallization experiment with a “run time” that is not realistically achievable in the laboratory. SIMS analysis of mineral rim-glass pairs have permitted the determination of high-quality, equilibrium trace-element partition coefficients for all four minerals. These data augment the limited partition coefficient database for minerals in high-SiO2 rhyolitic systems. For all minerals, the D values are consistent with those anticipated from crystal-chemical considerations. These data further support a liquid SiO2 control on the REEs (and presumably other elements) partitioning wherein D values systematically increase with increasing liquid SiO2 content.

Keywords: Ion microprobe, rhyolite glass, trace element, partition coefficient

INTRODUCTION

Trace elements are important tools for deciphering crystallization and melting processes in igneous systems. Unfortunately, for those interested in the generation of silicic magma (i.e., > ∼70% SiO2) the volume of high-quality mineral-liquid trace element partition coefficient data (D) is significantly less than that found in mafic to intermediate systems. This is due in large part to the near ubiquitous presence of accessory mineral inclusions in mineral separates from high-SiO2 natural lavas, thus rendering mineral-matrix based D data potentially unreliable, and to difficulties in achieving equilibrium conditions in experiments with high liquid SiO2 contents. With the advent of in situ trace element analytical techniques (e.g., secondary ion mass spectrometry (SIMS), laser ablation inductively coupled plasma mass spectrometry (LA-ICMPS)) the analysis of coexisting phenocrysts and glassy matrix in natural high-SiO2 lavas has eliminated the problem of accessory mineral inclusions and has led, for the first time, to reliable, high-quality distribution coefficient (D) value information in high-SiO2 liquid systems (e.g., Sisson 1991, 1994; Ewart and Griffin 1994). However, such data are still limited in number. This study takes advantage of a natural occurrence of partially crystalline hornblende gabbros found as cognate inclusions within the Little Glass Mountain Rhyolite lava flow, Medicine Lake Volcano, California (Donnelly-Nolan et al. 1990). The gabbro inclusions contain, among other things, euhedral crystals of hornblende, orthopyroxene, plagioclase, and apatite, that are in direct contact with quenched rhyolitic glass (∼71–76% SiO2). Previous studies (Grove and Donnelly-Nolan 1986; Brophy et al. 1996) have demonstrated that the gabbros are the result of in situ crystallization of a basaltic andesite magma, most likely in an inward-growing solidification front. Brophy et al. (1996) demonstrated that the crystallization was sufficiently slow that the constituent minerals closely approached surface equilibrium with the silicate melt throughout the crystallization process. Thus, this rare occurrence represents a natural dynamic crystallization experiment with a “run time” that is not realistically achievable in the laboratory. In this regard, these inclusions provide an ideal opportunity to acquire high-quality equilibrium D value information for hornblende, plagioclase, orthopyroxene, and apatite in high-SiO2 liquid systems through in situ SIMS analysis of coexisting glass and minerals.

SAMPLE DESCRIPTION

The gabbro inclusions are located within the Little Glass Mountain Rhyolite, a young (∼1065 yr, Donnelly-Nolan et al. 1990) calc-alkaline lava flow erupted along the southwest flanks of Medicine Lake Volcano, California. They have been the subject of multiple investigations (e.g., Mertzmann and Williams 1981; Grove and Donnelly-Nolan 1986; Brophy et al. 1996; Grove et al. 1997). The inclusions consist of an interconnected framework of plagioclase, olivine, orthopyroxene, augite, hornblende, magnetite, and ilmenite set within a matrix of vesicular, clear to dark-brown rhyolitic glass (Fig. 1). Small, euhedral apatite crystals are dispersed throughout the glass. Within a given inclusion the glass is compositionally homogeneous. From one inclusion to the next, the glass composition can