Origin and petrogenetic implications of anomalous olivine from a Cascade forearc basalt

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ABSTRACT

Erupted absarokitic-shoshonitic volcanics in subduction zones make up a relatively small proportion of the total erupted volcanic material. However, they are a critical component for quantifying subduction metasomatism and mantle source heterogeneity. This study examines the geochemistry of anomalous olivine within a forearc absarokite lava and associated tephra, a compositional end-member of the Cascadia subduction zone magmatism, to infer mantle heterogeneity and magma petrogenesis. Ni concentrations from the young (42 ka) Quartzville absarokitic basalt lava flow and tephra in the Cascade forearc are up to ~6400 ppm Ni with correspondingly low Ca, averaging ~850 ppm Ca in Fo91 olivine cores. Decreasing Ni and Ca toward olivine rims cannot be accounted for by simple fractional crystallization and instead necessitates magma mixing ± diffusive re-equilibration between the high-Ni, low-Ca olivine cores and low-Ni, high-Ca rims. δ18O of olivine phenocrysts (5.64‰) are elevated compared to other Cascade compositional components and outside of the range typically associated with peridotitic olivine or olivine crystallizing from peridotite-derived basaltic magmas. Trace element contents of whole rock, melt inclusions, and scoria glass have high Sr, high Dy/Yb, and low Y, characteristic of adakitic slab melts; however, major element compositions are of an alkali-rich basalt. In addition, similar trace element compositions between all analyzed glasses indicate a related petrogenesis between all components. We propose that a slab partial melt has reacted with depleted harzburgite in the mantle wedge, underlying the older Western Cascades (~40–10 Ma). Reaction of the siliceous slab-derived melt with depleted harzburgite could produce a metasomatized, zoned pyroxenite-harzburgite mantle source. High-Ni, low-Ca olivine crystallizes from melts of the subarc mantle reaction-pyroxenite. Later melting of the metasomatized harzburgite produces the absarokitic bulk composition, with olivine compositions recording diffusive re-equilibration following incorporation of pyroxenite-derived olivine in a peridotitic magma. Importantly, then, the observed olivine chemistry reflects mineralogical variations in the subarc mantle while melt trace element variations record melts/fluids derived from the subducting plate. High-Fo olivine rims (up to ~Fo94) appear to be the result of late-stage oxidation in the lava flow resulting from SO2 degassing and are unrelated to the otherwise complex magma petrogenesis.

Keywords: Reaction pyroxenite, shoshonite, subduction, trace element, diffusion, mixing

INTRODUCTION

Shoshonitic magmas, including the more primitive absarokites, are found in volcanic arcs around the world, typically associated with low-degree partial melts of highly fluid-metasomatized mantle (e.g., Kamenetsky et al. 1995; Luhr 1997; Hesse and Grove 2003; Rowe et al. 2009). Given their normally small erupted volumes, and formation as low-degree partial melts, shoshonites may preserve evidence of small-scale heterogeneity lost during homogenization of larger melt fractions. In the Cascade volcanic arc, a global end-member for “hot” subduction (Syracuse et al. 2010), absarokites and shoshonites are rare. However, shoshonitic magmas comprise one of several distinct magmatic compositions, each providing insight into subduction zone magma genesis in the Cascadia system (Borg et al. 1997; Conrey et al. 1997; Reiners et al. 2000; Leeman et al. 2005; Schmidt et al. 2008, 2013; Rowe et al. 2009). This study focuses on the petrogenesis of the most primitive absarokite identified to date in the Cascade arc. In particular, prior research has identified the presence of anomalous olivine compositions, characterized by high-Ni (>6000 ppm Ni) and low-Ca (<900 ppm Ca) contents in olivine ranging from ~Fo88–94 (Conrey et al. 1997; Rowe et al. 2006, 2009). Prior petrogenic models have not taken into account the significance of these anomalous olivine grains. Here we utilize the unique mineral chemistry to create a holistic petrogenic model related to subduction zone processes in this global end-member of “hot” subduction.

SAMPLES AND ANALYTICAL METHODS

Samples

The herein named Quartzville basalt is located in the Quartzville mining district in the western forearc margin of the Oregon Cascades (Lat. 44° 36.047′ N, Long. 122° 20.146′ W) (Fig. 1; Rowe et al. 2006, 2009). Field relations of the scoria cone and lava flow indicate the Quartzville volcanism is much younger than the