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Along-strike variability of primitive magmas (major and volatile elements) inferred from olivine-hosted melt inclusions, southernmost Andean Southern Volcanic Zone, Chile

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ABSTRACT

Glass compositions of melt inclusions in olivine phenocrysts found in tephras derived from explosive eruptions of the four volcanoes along the volcanic front of the southernmost Andean Southern Volcanic Zone (SSVZ) are used to constrain primitive magma compositions and melt generation parameters. Primitive magmas from Hudson, Macá, and Melimoyu have similar compositions and are formed by low degrees (8–18%) of partial melting. Compared to these other three centers, primitive magmas from Mentolat have higher Al_2O_3 and lower MgO, TiO_2 and other incompatible minor elements, and are generated by somewhat higher degrees (12–20%) of partial melting. The differences in the estimated primitive parental magma compositions between Mentolat and the other three volcanic centers are consistent with difference in the more evolved magmas erupted from these centers, Mentolat magmas having higher Al_2O_3 and lower MgO, TiO_2 and other incompatible minor element contents, suggesting that these differences are controlled by melting processes in the mantle source region above the subducted oceanic plate. Parental magma S = 1430–594 and Cl = 777–125 (μg/g) contents of Hudson, Macá, and Melimoyu are similar to other volcanoes further north in the SVZ. However, Mentolat primitive magmas have notably higher concentrations of S = 2656–1227 and Cl = 1078–704 (μg/g). The observed along-arc changes in parental magma chemistry may be due to the close proximity below Mentolat of the subducted Guamblin Fracture Zone that could efficiently transport hydrous mineral phases, seawater, and sediment into the mantle, driving enhanced volatile fluxed melting beneath this center compared to the others.

1. Introduction

Along-arc variations in the composition of convergent plate boundary magmas may be related to various subduction parameters such as the age, thickness, thermal state, and composition of the subducting oceanic lithosphere, the volume and composition of the sediments entering the trench, and the age and composition of the mantle wedge. Understanding the mechanisms causing variations in the compositions of arc magmas requires constraining details of the processes of melt generation such as primitive magma compositions, volatile contents and melting parameters, details that are often lost during modification of primitive magmas during ascent, differentiation, and eruption. However, melt inclusions hosted in early formed phenocryst minerals such as olivine (Fig. 1) are a potentially valuable source of information on the composition of primitive magmas and the conditions of melt generation. Melt inclusions are small pockets of silicate melts trapped inside of phenocrysts at magmatic temperatures and pressures (Lowenstern, 1995; Wallace, 2005). The phenocrysts isolate the melt inclusions from the ascending and evolving host magma limiting chemical exchange and to a degree, thermal interaction. Additionally, the phenocrysts prevent or at least retard degassing of the melt inclusions (Lowenstern, 1995). This has made melt inclusions a valuable source of information concerning the concentrations in magmas of magmatic volatiles such as H_2O, S, and Cl (Kelley et al., 2010; Portnyagin et al., 2007; Wallace, 2005; Wehrmann et al., 2014).

To better understand the along-strike geochemical variability observed in the eruptive products of the volcanoes Melimoyu, Mentolat, Macá, and Hudson, located along the volcanic front of the southernmost Andean Southern Volcanic Zone (SSVZ; Fig. 2), melt inclusions observed in olivines (Figs. 1 and 3) occurring in tephra deposits taken from lacustrine sediment cores that were derived from explosive eruptions of these volcanoes have been examined. For these arc-front volcanoes of the southernmost SSVZ, we present melt inclusion compositions, including volatile contents (S and Cl), which are fractionation-corrected back to the compositions of primitive magmas in equilibrium with mantle peridotite (olivine Fo90) in order to better understand the influence of subducting Nazca Plate features such as fracture zones on the primitive magma major and volatile element geochemistry during the early phase of magma evolution. Watt et al. (2013) previously

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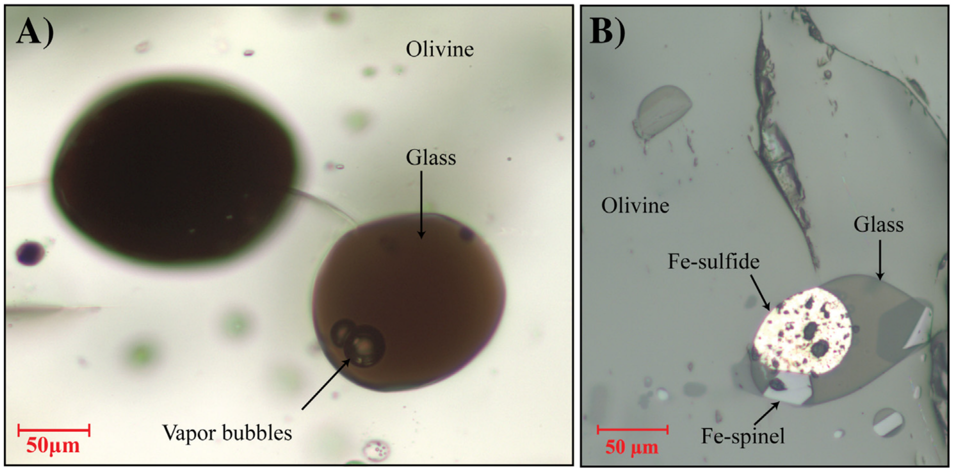

Fig. 1. A. Plane light photomicrograph of a typical Mentolat-derived melt inclusion (MEN4) analyzed in this study. Melt inclusions are generally homogenous with small vapor bubbles. B. Reflected light photomicrograph of a Macá-derived melt inclusion (MAC8) containing a Fe-sulfide and a Fe-rich spinel. Melt inclusion containing crystals were avoided, but provide information on the primary phases during early magmatic evolution. The large size of the minerals within their associated inclusion indicates that they were unlikely to form within the melt inclusion.

analyzed melt inclusions and calculated primitive parental magma compositions for volcanic centers further north in the Andean SSVZ and found a systematic across-arc change in the major, trace, and volatile element geochemistry in primitive magmas which were interpreted as temperature-dependent changes in the type of material (aqueous fluids or sediment melts) entering into the source region with progressive dehydration of the subducting slab. Kratzmann et al. (2010) also presented compositional data for melt inclusions in plagioclase and pyroxene phenocrysts occurring within tephra derived from three large explosive Holocene eruptions of Hudson volcano, the southernmost center in the SSVZ, but the compositions of these inclusions were more evolved than the compositions of the bulk magmas and they were not interpreted to reflect or provide information about primitive parental magmas.

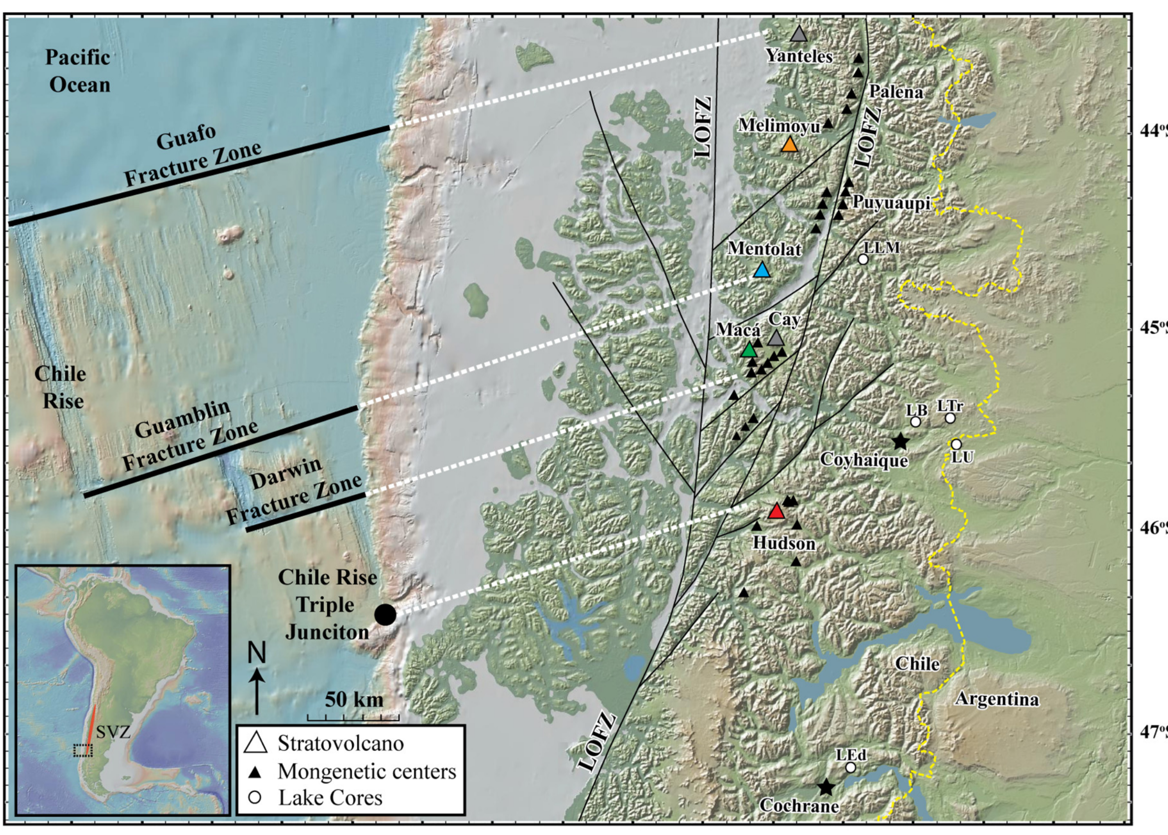

Fig. 2. Map of the southernmost portion of the Andean Southern Volcanic Zone showing the location of Hudson, Macá, Cay, Mentolat, Melimoyu, and Yanteles volcanoes. The volcanoes examined in this study are color coded with the same colors used in the subsequent figures. Also shown are the location of the small monogenetic eruptive centers (MEC) located along the Liquiñe-Ofqui Fault Zone (LOFZ; Vargas et al., 2013) and surrounding Hudson (Gutiérrez et al., 2005), Macá and Cay (D'Orazio et al., 2003), the location of the Chile Rise Triple Junction where the Chile Rise enters the trench, the location of some of the lake cores from which olivines were collected, and the location of Nazca Plate fracture zones with their projected location under the South American continent. Map was constructed using GeoMapApp (http://www.geomapapp.org).