Metasomatism in the lithospheric mantle beneath the Calatrava volcanic field: constraints from peridotite xenoliths of the Cerro Gordo volcano

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INTRODUCTION

The Calatrava volcanic field (CVF) comprises about 250 volcanic centers in an area of ~5000 km². Detailed studies on mantle xenolith suites have been focused on the Cerro Pelado (Villaseca et al., 2010, and references therein) and the El Aprisco (González-Jiménez et al., 2014) volcanoes, and on other CVF edifices (e.g., Andía et al., 2018; García Serrano et al., 2019). The Cerro Gordo (CG) volcano is a composite edifice made by a scoria cone with short lava flows, which was partially destroyed during an explosive stage generating a maar. Moreover, they show higher Na, Al and Cr contents than in lherzolites-1. Secondary neoblasts show a divergent chemical evolution depending of the chemistry of the associated intergranular glass: Al-Cr-Ti-rich if the glass is basaltic trachyandesite, and Mg-Ca-rich (and Ti-Al-Cr-poor) when it is andesitic.

PETROGRAPHY OF THE XENOLITHS

Most of the studied xenoliths are medium- to coarse grained porphyroclastic lherzolite. The most common porphyroclasts are olivine (44-63 modal %) and the two pyroxenes (in similar amounts), commonly rimmed by fine-grained secondary clinopyroxene, olivine, spinel and glass (reaction zones). Primary amphibole is preserved in some xenoliths, but we interpret the clusters of fine-grained secondary clinopyroxene, olivine, spinel and glass (reaction zones). Primary amphibole is preserved in orthopyroxene either in reaction zones, symplectitic to reaction zones. Some lherzolite groups have secondary pyroxenes (in similar amounts), commonly rimmed by porphyroclasts are olivine (44-63 modal %) and the two group-1 lherzolites have lower Al, Cr, Ti (and slightly higher Mg) contents than primary crystals. Clinopyroxene has also higher Mg# in group-2 lherzolites. Moreover, they show higher Na, Al and Cr contents than in lherzolites-1. Secondary neoblasts show a divergent chemical evolution depending of the chemistry of the associated intergranular glass: Al-Cr-Ti-rich if the glass is basaltic trachyandesite, and Mg-Ca-rich (and Ti-Al-Cr-poor) when it is andesitic.

MINERAL MAJOR ELEMENT CHEMISTRY

Olivine in depleted lherzolites has a higher Mg# [MgO/ (MgO+FeO) on a molecular basis] (91.9-92.4) than in group-1 lherzolites (89.7-90.6). Orthopyroxene also shows the above slight difference, with Mg# values similar to those of olivine: 91.8-92.3 (group-2) and 89.1-90.9 (group-1). Secondary orthopyroxene in group-1 lherzolites have lower Al, Cr, Ti and slightly higher Mg contents than primary crystals. Clinopyroxene has also higher Mg# in group-2 lherzolites. Moreover, they show higher Na, Al and Cr contents than in lherzolites-1. Secondary neoblasts show a divergent chemical evolution depending of the chemistry of the associated intergranular glass: Al-Cr-Ti-rich if the glass is basaltic trachyandesite, and Mg-Ca-rich (and Ti-Al-Cr-poor) when it is andesitic.

WHOLE-ROCK CHEMISTRY

The chemical composition of four samples with suitable size has been obtained. They define a low FeO and TiO₂ suite when compared to other CVF xenoliths. There are two groups of lherzolites: enriched (group-1) and depleted (group-2) in LREE-Th-U, but with similar HREE-Y-Zr-Hf contents.
MINERAL TRACE ELEMENT CHEMISTRY

Chondrite-normalized clinopyroxene REE patterns of group-1 lherzolites depict an almost continuous variation from the N-MORB-like pattern of the depleted lherzolite 117150 (group-2) towards the LREE-enriched pattern shown by lherzolite 110858 (Fig. 1). A similar compositional trend is also evident in primitive mantle-normalized multi-element diagrams, where patterns depart from a base profile represented by the depleted 117150 sample (not shown).

Amphibole has similar REE and multi-element patterns than the associated primary clinopyroxene, suggesting a chemical equilibrium between them. In fact, amphibole/cpx trace element ratios are close to 1 except for Nb-Ta and Rb-Ba, strongly fractionated to amphibole, as typical of other peridotite suites (Raffone et al., 2009).

DISCUSSION

Partial melting of the mantle sources

Valuable information about the characteristics of the lithospheric mantle beneath the Cerro Gordo volcano before metasomatism can be gained through the mineralogical and geochemical features of the group-2 xenoliths, in which amphibole is absent and enrichment in the most incompatible elements (LREE, LILE, Th, U) is not observed. Partial melting modelling using HREE-Y in clinopyroxene indicates low melting degrees (mostly < 5%).

Origin of the glasses

Glass related to amphibole breakdown (110858 lherzolite) has the same REE and multi-element patterns than the associated corroded amphibole. The thermal impact, combined with the sudden decompression underwent by the xenolith after entainment in the host volcanic magma, could have triggered the breakdown reaction. The presence of Ti-Al-rich and Mg-poor clinopyroxene-2 is typical of amphibole breakdown reaction in experimental studies (e.g., Shaw, 2009).

Metasomatism of the xenoliths

Clinopyroxene exhibiting a variable degree of enrichment in LREE, LIL, and Th-U-Pb contents is likely of metasomatic origin. The high Ti/Eu ratios of this mineral in all lherzolites suggest reaction with silicate melts rather than carbonate-rich ones. The composition of metasomatic melt in equilibrium with clinopyroxene, calculated using partition coefficients of basaltic systems, is characterized by a flat REE pattern (from Sm to Lu), that is unlikely to be related to alkaline melts (e.g., Calatrava magmatism). The marked negative Nb-Ta anomaly of these melts and the high Ti/Nb ratios of the associated amphibole are also indicative of a subduction-related metasomatic agent.

The variable LREE enrichment of single clinopyroxene grains in some samples, along with the absence of MREE and HREE fractionation, suggest that all the REE patterns shown by the CG lherzolites can be explained by a single metasomatic event during a reactive porous flow process. This process leads to changes in trace element concentrations as a function of distance from the melt flow channel (e.g., Ionov et al., 2002). The higher modal amount of amphibole in the more LREE-enriched lherzolites and its significant equilibrium with primary clinopyroxene suggest a vicinity of those samples with the metasomatic conduit produced by the percolation of subduction-related liquids.

REFERENCES


