Aluminum and iron behavior in glasses from destabilized spinels: A record of fluid/melt-mineral interaction in mantle xenoliths from Massif Central, France†

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ABSTRACT

Infiltrations of melts (and/or fluids) in mantle rocks are witnessed by the presence of glass-bearing pockets in peridotite xenoliths brought to the surface by alkaline volcanism. Several glass-bearing pockets found around spinels corroded at different degrees were investigated for their chemical compositions, including the Fe3+/ΣFe ratios, in two xenolith samples by electron probe microanalysis. The dissolution/recrystallization of spinels enriches the melt in alumina. We show that the spinel-derived Al3+ ions could have been accommodated to the melt network first as network-modifiers. Then Al3+ ions were network-formers using K+ ions, extracted from the aqueous fluid upon melt dehydration, as stabilizers within the tetrahedral site. The transfer of K+ from the aqueous fluid to the melt network is counterbalanced by an inverse transfer of CaO molecules that form crystalline phases exsolved upon eruption. The evolution of the Al content clearly shows that an increasing fraction of the spinel-derived alumina molecules was exsolved as the melt dehydration proceeded. Spinel corrosion could also be at the origin of melt oxidation through dehydrogenation reactions resulting in the formation of Al3+ and Fe3+ anionic complexes within the melt network. This study shows: (1) how the structure of the percolating melt is modified by the accommodation of chemical elements produced by the dissolution of minerals, and (2) how this process could modify the oxidation state of the melt.

Keywords: Silicate melt, mantle xenoliths, electron microprobe, Fe3+/ΣFe measurements, melt/fluid-spinel interactions

INTRODUCTION

Glass-bearing reaction textures are worldwide known in mantle xenoliths. They usually consist of sieve-textured rims on clinopyroxene and spinel, reaction rims on orthopyroxene, and reaction pockets developed around amphibole and spinel. Besides patches of glass, the pocket assemblage contains secondary small crystals of olivine, clinopyroxene, and spinel. The textural and chemical characteristics of the reaction zones have been considered as important clues for elucidating the origin of the associated glass and intensively studied over the past two decades. However, the interpretation of the reaction textures remains controversial as it is difficult to unequivocally determine the processes and timing of their formation. Two main opposite interpretations have been argued considering the reaction textures either as products of mantle processes or resulting from reactions posterior to the xenolith entrainment in its host magma. Partial melting may have occurred in the mantle induced by heating (e.g., Maaloe and Printzlaw 1979) or decompression (e.g., Su et al. 2011). It may also result from the percolation of fluids (e.g., Carpenter et al. 2002; Coltorti et al. 2000), or invading melt (e.g., Perinelli et al. 2008 and papers in Coltorti and Gégoire 2008). In contrast, these textures may have developed in crustal magma chambers or during the xenolith transport to the surface by decompression-induced partial melting, or reactions with the magma host (e.g., Carpenter et al. 2002; Shaw et al. 2006 and references therein; Wang et al. 2012). In hydrous xenoliths, the reaction textures may also have developed after the incongruent breakdown of amphibole in the mantle or during transport (e.g., Shaw and Klügel 2002; Ban et al. 2005; Ismail et al. 2008; Shaw 2009).

We present here a detailed investigation of fresh glass patches preserved in reaction textures (from few tens of μm² to mm²-sized) in two herzolite xenoliths—one anhydrous and one hydrous—from the French Massif Central. The aim of this study is to examine the exchanges, involving Al and Fe particularly, between the melt/fluid and the peridotite minerals by the means of an electron microprobe (EMP) investigation, including the measurements of the Fe3+/ΣFe ratios.

GEOLOGICAL OUTLINES

The French Massif Central is part of the Variscan belt in Western Europe. It shows an intense Cenozoic alkaline volcanism linked to the upwelling of mantle material, possibly related to a hotspot or to channeling of asthenospheric material through lithospheric fractures (e.g., Granet et al. 1995, 2000; Hoernle et al. 1995). Two distinct lithospheric domains situated north and south of the 45°30′N parallel have been recognized: