

Crystal-chemical variations in amphiboles close to a hornblendite vein: implications for models of mantle metasomatism

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Introduction

Systematic investigations of compositional variations in peridotite infiltrated by a small volume of metasomatic agent allow a better understanding of both the scales and processes of mantle metasomatism (Nielson *et al.*, 1993; Nielson and Wilshire, 1993). Insights into liquid-rock mantle reactions have been provided by recent whole-rock (Bodinier *et al.*, 1990) and clinopyroxene (Takazawa *et al.*, 1992) investigations, from which the composition of most altered and unmetasomatized end-members as well as reaction gradients can be evaluated. This study focuses on amphibole directly deposited by the reacted melt, as it is the most sensitive phase to changes in liquid composition. Variations in amphibole crystal-chemistry can be, therefore, applied in monitoring P-T-X gradients.

We used a combination of microanalytical techniques (EPMA and SIMS) and single-crystal structure refinements (SREF) to investigate compositional variations in amphiboles in proximity (cm-scale) of an alkaline vein infiltrated in the ambient peridotite.

The sample studied

Sample LH10 is a spinel lherzolite cut by a thin hornblendite vein from the Lherz orogenic peridotite (Bodinier *et al.*, 1990). It shows no evidence of recrystallization to plagioclase-facies assemblage and may represent a simple case of single injection.

The hornblendite vein (1.3 cm thick) consists of Ti-pargasite to kaersutite (up to 90% by volume), interstitial Ti-phlogopite (8%) and accessory clinopyroxene and Fe-Ni sulphide. The host peridotite (up to 5 cm from the vein) is a porphyroclastic spinel lherzolite containing up to 15% clinopyroxene. Close to the vein, the peridotite is impoverished in clinopyroxene and contains abundant kaersutitic amphibole, which

progressively decreases in its mode with the distance from the vein. Near the contact, amphibole overgrows the primary assemblage (mainly clinopyroxene), while further into the wall-rock it occurs in textural equilibrium, with sharp boundaries against the spinel-bearing assemblage. Major- and trace-element variations were monitored on all the mineral phases.

Results

Amphiboles from the vein are characterized by LREE-enriched convex-upward patterns (La_n/Yb_n

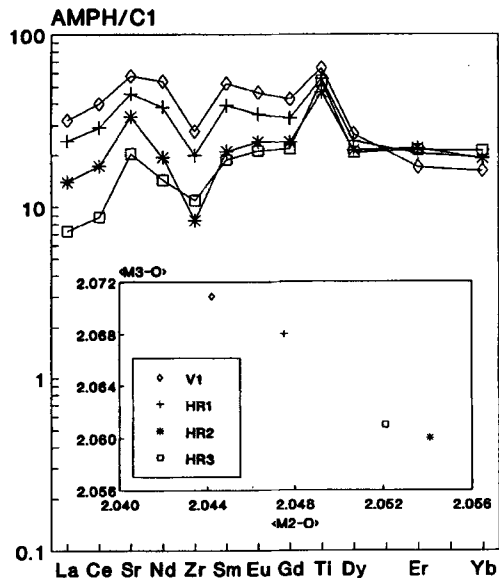


FIG. 1. Incompatibility diagram for the X-ray refined amphiboles: V1 (vein), HR1 (within 1 cm from the vein), HR2 (3-4 cm from the vein), HR3 (interstitial amphibole in the host peridotite far from the vein). Inset: variations in $\langle M2-O \rangle$ and $\langle M3-O \rangle$ mean bond lengths.

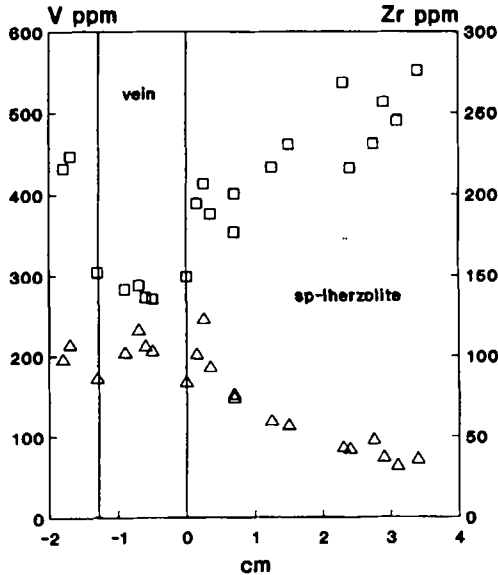


FIG. 2. Geochemical gradients for V (squares) and Zr (triangles) in proximity to the vein. The abscissa is the distance from the right contact between the vein and host peridotite.

from 1.79 to 2.32), typical of phases segregated by alkali-basaltic melts. They also show positive Sr, Ti and negative Zr anomalies. In the wall rock, *REE* patterns vary systematically with distance and become almost flat from *H-* to *MREE-* (about 20 times C_1) and slightly *LREE*-depleted (La_n/Yb_n down to 0.69, see Fig. 1).

The concentrations of the most incompatible elements (K, Ba, Sr, Rb, Zr, Nb, *LREE*) in amphibole progressively decrease away from the contact, whereas those of Na, Y, V, Cr, *HREE* increase (Fig. 2); Ti is laterally constant. Relative to the adjacent *REE*, Sr and Zr show an opposite behaviour: Sr/Sr^* is higher than 1 and progressively increases, Zr/Zr^* is always negative and decreases moving away from the vein.

Clinopyroxenes show *REE* patterns that closely resemble those of the associated amphiboles. Gradients for Cr, Zr, Sr, *LREE* and V are congruent with the variations observed in amphibole, whereas Na, Y and *HREE* contents do not show clear correlations with distance. A regular Ti enrichment is observed moving towards the vein. The *REE* variations are very similar to those found by Nielson *et al.* (1993) in a composite hornblende-peridotite xenolith from Dish Hill, California. Interestingly, clinopyroxenes within 2 cm from the vein display significant core-rim variations: *REE*, Sr and Cr decrease, while Ti, Zr, Sc and V increase towards the rim.

Compositional gradients for orthopyroxene show a decrease of *HREE*, Y and V and an increase of Ti, Zr and Sr moving towards the contact. In proximity to the vein, Ti, Zr and Sr progressively decrease from core to rim.

The structures of selected amphibole crystals at increasing distances from the centre of the vein (see inset in Fig. 1) were refined and compared to those of amphiboles from host rocks with no evidence of intrusion. Variations in $\langle M2-O \rangle$ and $\langle M3-O \rangle$ mean bond lengths indicate increasing disorder of the octahedral trivalent cations up to the level observed in the host rock.

Discussion

The variations observed at Lherz can be explained by models of mantle metasomatism that use Hofmann's (1972) and Nielson and Wilshire's (1993) chromatographic fractionation concept. During melt infiltration, the depleted ambient peridotite reacts with the liquid enriched in incompatible elements, which becomes progressively depleted until the equilibrium between liquid and host-rock composition is attained. Major-element variations in the investigated amphiboles show that the infiltrating liquid reaches equilibrium at a few centimeter distance from the vein, in good agreement with the conclusion of Nielson *et al.* (1993) that the scale of single-stage metasomatic events is small. Moreover, core-rim variations suggest that intercrystalline diffusion processes at P-T sub-solidus conditions postdating metasomatism played a significant role in modifying trace elements composition of major phases in proximity to the vein.

^{60}Al disorder in pargasite has been related to compositional constraints (Oberti *et al.*, 1994); in the absence of relevant compositional variations and of evidences of kinetic constraints, we are forced to assume that the increasing disorder of octahedral trivalent cations at Lherz is related to different T of crystallization. Two alternative explanations are envisaged: 1) at the time of the hornblende intrusion, host peridotite contained disseminated amphibole produced by a previous (higher-T) metasomatic event; 2) amphibole crystallization, if related to a single melt intrusion, started at higher T in the most distal zone.

References

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