Elemental fractionation in composite spinel lherzolites from Massif Central (France). Constraints on possible link between cryptic and modal metasomatism

C. Wagner — Lab. Pétrologie, Université Paris 6, CNRS-ESA 7058, 75252 Paris cedex 05, France

E. Deloule — CRPG-CNRS, UPR A9046, 54501 Vandoeuvre-lès-Nancy cedex, France

G. Chazot — Dép. Sciences de la Terre, Université Blaise Pascal, UMR 6524, 63038 Clermont-Ferrand cedex, France

J-C. Vilminot — Lab. Pétrologie, Université Paris 6, Paris, 75252 cedex 05, France

Recent studies of peridotite massifs and xenoliths pointed out the complexity of magmatic and metasomatic processes within the subcontinental lithosphere. Three types of metasomatic signatures have been recognised (Harte, 1983; Dawson, 1984): formation of hydrous phases (patent or modal metasomatism), Fe-Ti addition, and enrichment in incompatible elements (cryptic metasomatism). However the interpretation of the scales and processes of mantle metasomatism remain controversial both in the melt transport mechanisms and in the melt mantle interactions. Mantle metasomatism modelling requires well-constrained observations that may be provided by composite xenoliths, which are fresh material with various rock types and contact relations like those of peridotite massifs but without complex 'post -metasomatic' history. For this work, the area of St Didier d'Allier (Massif Central, France) has been selected for the large variety of mantle inclusions which have been found in a diatreme volcanic breccia. We focus on three protogranular spinel lherzolite nodules: two composite amphibole-bearing nodules (SD13, SD27) showing cross-cutting hydrous selvages and one anhydrous non-composite xenolith (SDi). Major element results are presented for all phases, and trace element data (ion microprobe analyses) for pyroxenes and amphiboles.

Mineralogy of the xenoliths

SDi is composed of olivine (Fo90), orthopyroxene (En90) with high cr* (100Cr/(Cr+Al) = 7), Cr-rich (0.9 wt.% Cr_2O_3) diopside with 5 wt.% Al_2O_3, and Al-spinel (cr* = 16–18); orthopyroxene and spinel may form layers. The mineral composition is typical of dry peridotites from Massif Central (Brown *et al.*, 1980). As only two small (<50 µm) grains of interstitial amphibole have been found in one layer among three thin sections, this sample is further considered as representative of the most anhydrous peridotite. Amphibole is a low Ti (0.5 wt.% TiO_2), Cr- and Mg-rich pargasite (1.2 wt.% Cr_2O_3, mg* (100Mg/(Mg+Fe) = 88).

The two samples SD13/SD27 are pargasite-bearing lherzolites cross-cutted by or included in micaceous hornblendite selvages, remnants (1–7 mm thick) of dyke margins. The lherzolites show layers of pyroxene, spinel and amphibole in which amphibole rims irregularly-shaped spinel or forms coarse grains.

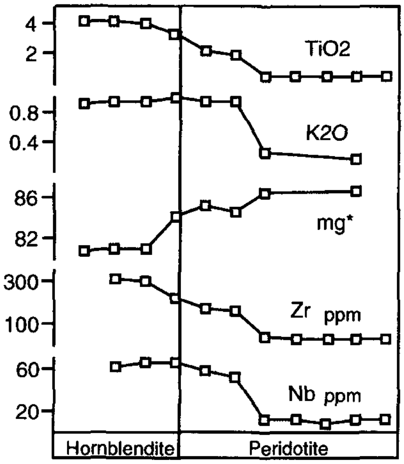

FIG. 1.

In SD27 amphibole occurs also as disseminated crystals always associated with relict spinels. The lherzolites contain magnesian olivine (Fo85/88) and orthopyroxene (En85/89), Cr-diopside (cr* = 10–12/15), Cr-rich spinels with a large range in composition and Cr-bearing (1.2–1.8 oxide wt.%) pargasite with variable mg* (81–86) and TiO_2 (0.5–2.2 wt.%) values. The hornblendite consists of coarse-grained Fe- and Ti-rich pargasite (mg* = 81, 4 wt.% TiO_2) with less Cr (<0.1 wt.% Cr_2O_3) than the lherzolite amphibole, and subordinate Cr-poor, Ti-rich phlogopite. Amphiboles from the hornblendite have an overall higher *REE* abundance than amphiboles from the peridotites, but both amphiboles are *LREE*-enriched (Cen = 76–112, Cen/Ybn = 7–10).

Amphibole compositional variations

Amphiboles have a general tendency to lower TiO_2 (4 to 0.5 wt.%), Fe (mg* = 81 to 86) and K_2O (1 to 0.2 wt.%) and higher Cr_2O_3 (0.05 to 1.2–1.8 wt.%) and Na_2O (3 to 3.8 wt.%) as function of increasing distance from the selvage. Detailed investigations in sample SD27 show progressive variations for Ti, Fe and Mg and more abrupt ones for Cr and K (Fig. 1): amphiboles rimming Al-spinels have high and rather constant Cr contents independently of the distance from the selvage, while high K values, typical of the hornblendite amphiboles, are still observed at 2.5 mm from the selvage and then decrease abruptly. Similarly, the decrease in Zr and Hf is continuous, while it is more brutal for V, Sr and Nb. *REE* vary systematically and also form more or less regular decreasing gradients away from the contact.

Chondrite-normalised *REE* profiles (Fig. 2) show the similarity in shape and abundances for hornblendite amphiboles and amphiboles close to the selvage from composite nodules SD13 and SD27 (b1), while farthest amphiboles (SD27, b2) have lower L- and *MREE* enrichment. Amphiboles from the non-composite SDi nodule have a *REE* pattern similar in shape to that of the SD27 (b2) amphiboles but at lower L-and *MREE* levels.

These progressive chemical variations demonstrate that the peridotite has been modified adjacent to hydrous selvages by reactions with a metasomatic melt emanating from the dyke. In the peridotite the reaction fronts of the various elements have reached slightly different distances from the hornblendite selvage. Comparison between the two composite samples shows that the width of the modified zone appears to be dependent on the size of the selvage. The composition of the farthest amphiboles matches that of the rare amphiboles from the non-composite peridotite SDi, with the exception of lower Sr (200–300/550 ppm) and *LREE* (Cen = 25–30) in SDi. The *REE* signature of amphiboles from SDi could thus record the imprints of a metasomatic melt as in the composite nodules.

Chemistry of anhydrous phases

Anhydrous silicates show compositional trends analogous to those of amphiboles. Fe- and Ti-richer near the contact zone, they become progressively Mg-, Al- and Cr-richer with distance from the selvage: olivine, Fo=82-84; orthopyroxene, En = 87–89, TiO_2 = 0.2– <0.09 wt.%, Al_2O_3 = 1.8–3 wt.%, Cr_2O_3 = 0.09–0.5 wt.%. Spinels show similar variations but for a decrease in Cr (cr* = 54–21) reflecting their breakdown to amphibole.

Chondrite-normalised *REE* patterns in clinopyroxene (Fig. 2) show varying degrees of *LREE* enrichment (Cen/Ybn = 3 in SDi and 6–10 in composite nodules) and a rather flat *HREE* part with low values (5–6 × chondrite). Clinopyroxenes from the non-composite SDi and composite SD27 nodules have similar rather angular patterns, but at a lower L- and *MREE* level in SDi. In SD13 enrichment is not restricted to *LREE* but appears to have affected all *REE* to different extents. Clinopyroxenes and amphiboles show thus quite similar *REE* patterns, slightly richer in amphiboles, which confirm the chemical equilibrium between these phases in a given nodule.

Conclusion

The presented data suggest that the metasomatizing melt responsible for the formation of amphibole in the composite nodules is also responsible for the enrichment in *LREE* of the clinopyroxenes. In this case 'modal' and 'cryptic' signatures are linked to a same metasomatic process. Variations in metasomatic signatures may arise from variable compositional contrasts between the metasomatic agent and the peridotite and their relative abundances, and thus may not be indicators of contrasting metasomatic processes. As was shown by the comparison with the sample SDi, detailed investigations of composite nodules may constrain the interpretation of metasomatic imprints in the most abundant non-composite nodules. Further works on composite and non-composite xenoliths from different localities from Massif Central are currently undertaken, as well as their isotopic characterisations.