

Melt impregnation in ophiolitic peridotites: an ion microprobe study of clinopyroxene and plagioclase

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Introduction

Melt impregnation is commonly documented in mantle peridotites which have experienced partial melting, both in present oceans (Dick, 1989) and in ophiolites (i.e. Lanzo, Trinity; Nicolas, 1989). Peridotite-melt interaction is testified by the heterogeneous but widespread occurrence, within the peridotites, of peculiar microstructures: i) plagioclase \pm pyroxene clots confined along grain boundaries or crosscutting mantle minerals, ii) plagioclase + orthopyroxene intergrowth surrounding mantle clinopyroxene.

A major discussion concerns the nature of the trapped melt, whether it is produced *in-situ* by the same partial melting process responsible of the depletion of the host peridotite, or it represents a transient melt migrating through an upwardly convecting mantle. Petrographic criteria able to discriminate between *in-situ* melt segregation and exotic melt impregnation have been proposed by Nicolas (1989).

Recent literature has concerned numerous petrographic and geochemical studies of peridotite-melt interaction processes (Nicolas, 1989; Dick, 1989; Elthon 1992; Kelemen *et al.*, 1992, and quoted bibliography). However, very little is known about the geochemical signature of the trapped melt. With this aim, we have performed *in-situ* trace element analyses (by SIMS technique) on plagioclases and clinopyroxenes in peridotites from various ophiolitic massifs (Lanzo South (S), Western Alps; Internal Ligurides (IL), Northern Apennines; Mt. Maggiore, Corsica), which are interpreted as portions of asthenospheric mantle residual after MORB-type partial melting processes.

The samples studied

The selected samples consist of cpx-poor spherzoliths (5–10% modal cpx) with variable but significant amounts of plagioclase, heterogeneously distributed in the rock. Plagioclase occurs both as, i) veins or blebs with sharp

contacts against mantle minerals, ii) orthopyroxene + plagioclase intergrowth replacing mantle clinopyroxene. We also analysed plagioclase and clinopyroxene in an olivine cumulate from a small pod within the Mt. Maggiore peridotite. Field evidence indicates that this pod is related to the melt impregnation of the surrounding peridotite.

Results

Clinopyroxenes analysed in most peridotite samples show very similar trace element compositions. They have significantly *LREE*-depleted patterns ($Ce_N/Yb_N = 0.02\text{--}0.06$) and very low contents in incompatible elements like Sr (0.4–0.6

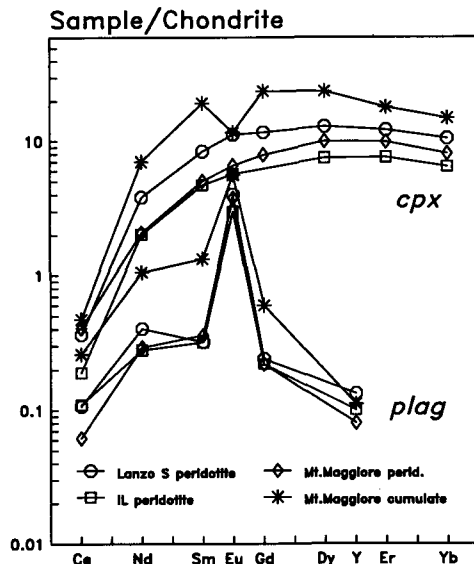


FIG. 1. Cl-normalized REE patterns for clinopyroxenes (cpx) and plagioclases (plag) in (1) ophiolitic peridotites from Lanzo South (Western Alps), Internal Ligurides (Northern Apennine), Mt. Maggiore (Corsica), and (2) olivine cumulate pod from Mt. Maggiore.

ppm) and Zr (2–6 ppm). These chemical features closely resemble those of clinopyroxenes in abyssal peridotites (Johnson *et al.*, 1990), and are consistent with residual compositions after low degrees ($F = 5\text{--}7\%$) of fractional melting. Plagioclases are characterized by strongly *LREE*-depleted spectra ($Ce_N/Sm_N = 0.2\text{--}0.5$) and very low Sr (2–7 ppm) contents.

Clinopyroxenes in one sample from Lanzo S exhibit slightly less depleted *LREE* compositions ($Ce_N/Yb_N = 0.18\text{--}0.21$) compatible with residua after relatively lower degrees ($F = 2\text{--}3\%$) of fractional melting. Accordingly, plagioclases display slightly higher *LREE* ($Ce_N/Sm_N = 1.38$) and Sr (22 ppm) concentrations.

Poikilitic clinopyroxene from the Mt. Maggiore cumulate has very depleted *LREE* composition ($Ce_N/Yb_N = 0.032$) and very low Sr (1.2 ppm) and Zr (16.5 ppm) contents. Plagioclase exhibits *LREE*-depleted pattern ($Ce_N/Sm_N = 0.19$ and low Sr content (20 ppm). These trace element abundances are unexpected for plagioclase in equilibrium with basaltic melts, and are very similar to the composition of plagioclase crystallized in the host peridotites.

Discussion

Our ion probe data reveal the very depleted trace element (i.e. Sr and *LREE*) signature of plagioclases in ophiolitic peridotites. This indicates that the trapped melt from which plagioclase crystallized was strongly depleted in incompatible trace elements. Further support to this interpretation is provided by the depleted compositions of plagioclase and clinopyroxene in the cumulate pod of Mt. Maggiore, which presumably crystallized from the same melt impregnating the host peridotites.

Despite the uncertainty deriving from the choice of mineral/melt partition coefficients, geochemical modeling indicates that plagioclase compositions in peridotites are consistent with crystallization from a depleted melt increment produced by 5–7% fractional melting of a MORB-type sp-facies mantle source (see Johnson *et al.*, 1990 for details concerning the geochemical modelling). Similarly, plagioclase and clinopyroxene from the Mt. Maggiore cumulate can be modeled as segregates from a melt increment formed by 7% fractional melting of the same source, and successively evolved by fractional crystallization (residual liquid = 30%; separating assemblage = 0.8 ol + 0.2 pl).

A less depleted melt (2–3% fractional melting increment) is needed to crystallize plagioclases in the less depleted Lanzo sample.

Interestingly, the fractional melting degrees required for the melts in equilibrium with plagioclase in the different peridotites (5–7% for most samples and 2–3% for one Lanzo sample) are consistent with the degree of depletion of the peridotites. This could be interpreted as the evidence of trapped melts produced *in-situ* and representing the last increment of melt in equilibrium with the peridotite. This hypothesis seems reasonable since the last melt increments have the higher probability to remain incorporated in the residual mantle. It must be observed, however, that the studied samples often display disequilibrium textures between the trapped melt and the peridotite matrix (replacement of mantle clinopyroxene by opx + pl aggregates). This could be explained by changes in P conditions after *in-situ* melting, i.e. progressive upwelling of the mantle section. Alternatively, percolation by exotic melts, originated from deeper mantle levels, must be invoked.

An important result, however, is that the compositions of plagioclase in peridotites more likely reflect a very depleted geochemical signature of the trapped melts. These latter would therefore represent the last increments of melt produced by the ascending mantle. In this light, trapped melts in the studied ophiolitic peridotites are presumably the expression of the very depleted MORB end-member. This 'D' end-member has been often inferred for models of mantle refertilization (Elthon, 1992) and studies of MORB chemistry (Klein and Langmuir, 1987), despite the scarce knowledge on its geochemical signature.

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