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Evidence for Equilibrium Crystallization of Amphiboles and Clinopyroxenes in Mantle-Modally-Metasomatized Peridotite Xenoliths from French Massif Central

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Peridotite xenoliths brought up by alkali basalts in the French Massif Central are mostly anhydrous but sometimes can contain hydrous phases such as amphiboles and micas. The formation of these hydrous phases can be attributed to modal metasomatism due to the presence of various fluids in the mantle. In the French Massif Central, only cryptic metasomatism has been deeply investigated. The aim of this work is thus to study a suite of hydrous peridotites in order to characterize modal metasomatism, and to compare it with cryptic metasomatism. For this purpose, we have realized two investigations: firstly an REE and Sr ion microprobe analyses of amphiboles and clinopyroxenes which permits observation of chemical variations at a grain scale, and secondly, a determination of Sr-Nd isotopic compositions of clinopyroxenes and amphiboles to assess whether or not they are in equilibrium.

The investigated samples have been collected in diatreme volcanic breccia near Lapeyre and St Didier in the Deves magmatic province. The nodules measure from 5 to 15 cm in diameter and show no evidence of alteration or interaction with the basalt host. Among the numerous samples collected, ten hydrous samples were selected, as well as two anhydrous samples for comparison. Anhydrous samples are common spinel lherzolites and hydrous ones are amphibole-bearing lherzolites and harzburgites (53-69% olivine, 7-28% orthopyroxene, 2-8% clinopyroxene, 2-20% amphibole and 0-2% spinel in volume). In hydrous samples, amphiboles are disseminated in the rock and generally develop at the expense of clinopyroxenes and spinels, the latter remaining as relics within the amphiboles. In some samples, amphiboles also occur as complete or partial selvage and/or as veins within the peridotite. Xenoliths show variable textures which appear to be related with amphibole abundance, ranging from slightly deformed (protogranular type) to very deformed (equigranular type) with intermediate porphyroclastic textures. Equilibrium temperatures of the nodules have been estimated at 900-1000ºC. Olivines and pyroxenes have high Mg# in every sample (from 0.89 to 0.91) and clinopyroxenes show variable Cr# (from 0.06 to 0.13).

Clinopyroxenes and amphiboles of the hydrous samples show a strong enrichment in REE, in particular in LREE (La from 12 to 100 times the chondrite concentration and $(La/Yb)_N$ varying from 10 to 25). The enrichment is generally the same for amphiboles and clinopyroxenes suggesting that they both crystallized in equilibrium with strongly enriched fluids. In contrast, clinopyroxenes from anhydrous samples have differently shaped REE patterns with lower contents in LREE. In one hydrous sample the two kinds of patterns have been observed. Isotopic Sr and Nd ratios measured by TIMS on these clinopyroxenes and amphiboles plot in the depleted mantle field. They are all very similar (from 0.703116 to 0.703686 for $^{87}Sr/^{86}Sr$ and from 0.512846 to 0.512918 for $^{143}Nd/^{144}Nd$) except for the two anhydrous samples (0.702824 and 0.702151 for $^{87}Sr/^{86}Sr$ and 0.513018 and 0.512854 for $^{143}Nd/^{144}Nd$). In each sample, amphiboles and clinopyroxenes have almost the same ratios, indicating that they crystallized at equilibrium. Sr concentrations were also measured by ion microprobe on adjacent amphiboles and clinopyroxenes. The resulting data show that amphiboles are always more Sr-enriched than clinopyroxenes and that in certain samples clinopyroxenes have rims richer in Sr than the cores. A possible explanation for this zoning could be a partial re-equilibration of the pyroxene during amphibole growth. Other samples display similar values of Sr in clinopyroxenes and amphiboles which could be interpreted as a complete homogenization between minerals during crystal growth.

Consequently, we can conclude that metasomatism in these xenoliths has led to a strong enrichment in LREE and Sr in clinopyroxenes and amphiboles. The similarity of REE patterns for amphiboles and clinopyroxenes provides evidence for equilibration between these minerals during crystallization as do the similar Sr and Nd ratios for amphiboles and clinopyroxenes. Lastly, similar Sr-Nd isotopic ratios in all of the hydrous samples suggest that metasomatism has been so intense that it resulted in a complete rehomogenization of Sr and Nd isotopic ratios.