Mantle amphiboles and mantle plumes

G. Chazot

Laboratoire de Géologie, Université Blaise Pascal, UMR 6524, 5 rue Kessler, 63038 Clermont-Ferrand, France

Metasomatic minerals such as clinopyroxene, amphibole, phlogopite or apatite found in many mantle xenoliths provide evidence for fluid migration through mantle rocks and reaction with mantle minerals. The chemical composition of these minerals give us insight into the nature and composition of the percolating fluids, the processes of fluid-melt interactions as well as the fractionation of incompatible elements in mantle minerals. This is particularly true above mantle plumes where fluids are thought to be released during ascent of hot material and interact with the lithospheric mantle. The chemical study of mantle xenoliths in such a context should give us valuable information about plume lithosphere interactions with implications for magma generation within mantle plumes.

We report on the chemical composition of mantle minerals from two different localities: amphibole-bearing mantle xenoliths are found in two recent volcanic fields in Yemen, in relation to the uprising of the Afar mantle plume. These xenoliths and the processes they recorded are compared with mantle peridotites sampled in Tertiary and Quaternary volcanoes of the French Massif Central where the presence of a mantle plume is still highly questioned.

Yemen lherzolites

The mantle xenoliths studied from Yemen are spinel lherzolites showing interaction of a fluid with spinel and orthopyroxene leading to the crystallisation of disseminated clinopyroxene, pargasitic amphibole and in some samples apatite (Chazot *et al.*, 1996). The chemical data acquired on new samples confirm that metasomatic clinopyroxenes and amphiboles are Ti-poor (<0.7% TiO_2 in amphibole) and Cr-rich (1.5 to 3.6% Cr_2O_3) and are characterized by extreme enrichment in incompatible elements, especially *LREE*. However, these minerals have very low concentrations in Nb, Zr and Hf. The similarity in the shape of trace element enrichment in the different lherzolites is compatible with the percolation of the same kind of fluid in these samples, with various degrees of interaction with the peridotite minerals. Apatite and amphibole contain large amounts of Cl (>3% for apatite). In several lherzolites, crystals of graphite are associated with amphibole and indicate percolation of CO_2-rich fluid. The graphite has $\delta^{13}C$ values between -13 and -10, slightly lower than the mean value of carbon in diamonds.

The high Cl, CO_2, *LREE* and low Ti, Nb, Zr and Hf contents of the metasomatic minerals probably reflects the carbonatitic nature of the metasomatic fluids in these lherzolites.

Amphibole-bearing peridotites are also found in Plio-Quaternary lavas of Saudi Arabia, beyond the inferred influence of the Afar mantle plume (McGuire, 1988; Blusztajn *et al.*, 1995). The clinopyroxenes are *LREE*-enriched but as for amphiboles are characterized by high Ti and low Cr contents and are clearly not related to the same metasomatic event depicted by the Yemen lherzolites. Furthermore, in the Nd isotopic diagram, minerals from the Saudi Arabia xenoliths define a 600 Ma isochron compatible with a major episode of ### structuration of the Arabian lithospheric mantle related to Pan-African crust formation. Conversely, minerals from the Yemen lherzolites define a horizontal trend consistent with a very young enrichment of the lithospheric mantle compatible with the recent arrival of the Afar plume head.

Massif Central lherzolites

Tertiary-Quaternary volcanic rocks of the French Massif Central contain many occurrences of mantle xenoliths. Amphibole and/or phlogopite are frequent, both disseminated or in vein in these peridotites but have been poorly studied from a chemical point of view. We are undertaking a comprehensive study of the chemical composition of minerals in the metasomatized samples in different localities in order to better understand the fluid percolation processes in the mantle and their possible link with a mantle plume (Granet *et al.*, 1995). As for the Yemen lherzolites, hydrous minerals in the spinel lherzolites from six different localities in the Massif Central are often associated with spinel and are in chemical equilibrium with this mineral.

A striking feature of these minerals is their highly heterogeneous major element composition. In a single locality, the K_2O content of amphibole from

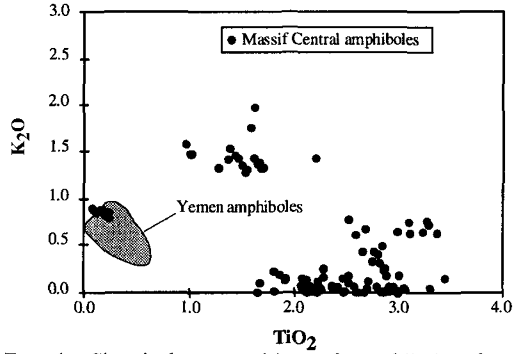

FIG. 1. Chemical composition of amphiboles from Massif Central (10 samples) and Yemen (5 samples) mantle xenoliths.

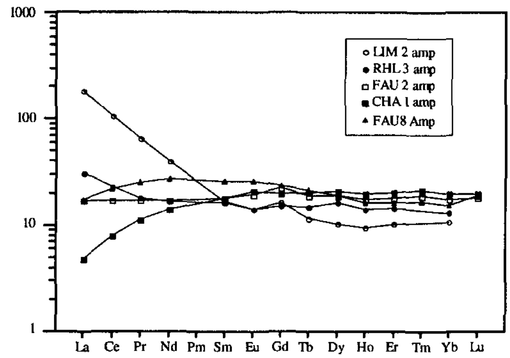

FIG. 2. *REE* composition of amphibole from five Massif Central mantle xenoliths.

different xenoliths can vary from 0.1 to 1.6% while the TiO_2 content ranges from 0.1 to >3% (Fig. 1). The same variations are also observed in phlogopite and clinopyroxene.

Trace element compositions determined with the ICP-MS in Clermont-Ferrand confirm this heterogeneity. Amphibole and clinopyroxene are in chemical equilibrium but in some samples they are *LREE* depleted (sample CHA1) while in others they are *LREE* enriched (samples RHL3 and LIM2). Even in a single locality, amphiboles from different samples have different *REE* pattern shapes (Fig. 2). In some samples they show positive or negative Sr anomalies which are sometimes also displayed by the coexisting clinopyroxenes. In all the samples, clinopyroxenes and amphiboles have low Th and U content but amphiboles are very Nb-rich.

Clearly, mantle peridotites from the French Massif Central have recorded percolation of fluids of different composition and maybe different nature. Even in a single volcano, xenoliths brought up at the surface can display chemical heterogeneities reflecting various percolating fluids and fluid-rock interaction processes. Compared to the Yemen metasomatic minerals, Massif Central amphiboles do not display the characteristic negative anomalies in Nb, Zr, Hf and Ti and, if as seems to be the case in Yemen, do not record percolation of fluid of carbonatitic nature.

Conclusions

In Yemen basalts, mantle xenoliths have recorded the percolation of a single batch of Cl- and CO_2-rich metasomatic fluids, probably of carbonatitic origin. Minerals which have crystallized from these fluids have homogeneous major element compositions and their trace element composition is consistent with various degrees of fluid-rock interactions. The metasomatic fluids are clearly related to the arrival of a mantle plume beneath the lithosphere.

Conversely, mantle xenoliths from French Massif Central basalts contain metasomatic minerals with a large range of major element composition as well as different degrees of *LREE* enrichment or depletion. Even at the scale of a single locality, different samples show different chemical trends reflecting complex percolation processes which are difficult to relate to a single event of plume-lithosphere interaction. More samples from other localities and also from the localities presented here will be analysed soon, to obtain more information about the nature of the percolating fluids in relation to their geographic location in the Massif Central.

References

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