Petrology of ultramafic xenoliths from the Massif d'Ambre (Madagascar) combined with volatiles measurements in fluid inclusions: implications for the metasomatizing agent

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The Massif d'Ambre is a Cenozoic stratovolcano that was originated upon intense volcanic activity in northern Madagascar (12.1±0.1 Ma - 0.85 Ma), together with the Bobaomby volcanic field, the Nosy Be Archipelago and the intrusion of the Ampasindava Peninsula (e.g., Cucciniello et al., 2011). This area is characterized by the widespread occurrence of mantle xenoliths, mostly, but not restricted to, spinel lherzolites and subordinately pyroxenites, which are hosted in mafic volcanic rocks.

In this work, we investigated a suite of ultramafic peridotite xenoliths from the Massif d'Ambre by integrating petrography, mineral and glass chemistry and the concentrations of volatiles [CO_2 and noble gases (He, Ne and Ar)] in fluid inclusions (FI) hosted in olivine (Ol), orthopyroxene (Opx) and clinopyroxene (Cpx).

The suite of mantle xenoliths comprises 18 lherzolites, 11 harzburgites, 2 dunites, 3 wehrlites and 1 Ol-clinopyroxenite. Based on their petrographic features, the suite was divided into five distinct groups: group 1A is characterized by protogranular to porphyroclastic textures and includes the largest number of xenoliths; group 1B is characterized by large and porphyroclastic olivines; group 2 xenoliths include infiltrated dunites and wehrlites; group 3 includes cumulate-textured wehrlites, each with a different degree of wehrlitization; and group 4 with the Ol-clinopyroxenite xenolith.

From the mineral chemistry, a clear separation can be observed between Ol in groups 1A and 1B, having highly forsteritic olivine (Fo 88.4 - 93.2) and groups 3 and 4, having a lower and larger forsterite range of olivine (Fo 78.7 - 89.1). The distinction between groups 1A-1B and groups 3-4 is even more evident from the Mg# of orthopyroxenes (89.5 - 93.2 vs. 82.7 - 87.3, respectively) and clinopyroxene (90.9 - 95.2 vs. 81.4 - 89.9, respectively). This provides further confirmation on the distinct origin of the groups, with xenoliths belonging to 1A-1B having the most refractory character, while groups 3-4 xenoliths reflecting metasomatism/refertilization event/s. Based on glass analyses, we propose that a carbonatitic fluid may have interacted with some portion of the source mantle, in agreement with Coltorti et al. (2000). The noble gases in FI hosted in Ol, Opx and Cpx exhibit $^{3}He/^{4}He$ ratio corrected for air contamination (Rc/Ra values) ranging from 5.90 Ra to 7.05 Ra, which is well below the typical MORB-like upper-mantle value (8±1 Ra). Furthermore, the great majority of the xenoliths exhibits $^{4}He/^{40}Ar^{*}$ ratios between ca. 0.2 to ca. 0.8.

The major element distribution in mineral phases together with the systematic variations in FI composition will be used to place constraints on the origin and evolution (in terms of melting and metasomatism) of this portion of the mantle below the Massif d'Ambre.

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