



Combining experimental and simulation studies to constrain the mechanism of metasomatic vein formation

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Metasomatized lithosphere is considered to be a potential source for alkaline lavas observed in oceanic and continental setting [1, 2]. Experiments on natural amphibole-rich veins have recently demonstrated that high degree of melting of amphibole-bearing metasomatic veins with various amount of interaction with surrounding peridotite reproduce key features of the major and trace element compositions of alkaline lavas observed in intraplate volcanoes [3]. However, this model suggests that many geochemical features of alkaline rocks are directly inherited from the metasomatic veins itself. The formation of metasomatic veins is interpreted as the migration, cooling, and fractional crystallization of low degree melts within the lithospheric mantle which would generate a continuum of phase assemblages: from anhydrous to hydrous veins plus a cryptic enrichment in the surrounding peridotite [4]. To constrain this process, two complementary studies have been undertaken.

(1) A series of high-pressure experiments simulating the liquid line of descent of a basanitic magma differentiating within continental or mature oceanic lithosphere (1.5 GPa) has been performed to evaluate whether the evolution of this magma within the lithosphere was able to produce cumulates similar to metasomatic veins. The cumulates produced in this series of experiments are characterized by an anhydrous clinopyroxene + olivine assemblage at high temperature (1250°-1160°C), while at lower temperature (1130°- 980°C), hydrous cumulates with dominantly amphibole + minor clinopyroxene, spinel, ilmenite, titanomagnetite and apatite (1130°C- 980°C) are formed. This data supports the interpretation that anhydrous and hydrous metasomatic veins could be produced during continuous differentiation processes of primary, hydrous alkaline magmas at high pressures [4]. However, the comparison between the cumulates generated from an initial ne-normative liquid (basanite) or from hy-normative initial composition (hawaiite) [5] indicates that for all hydrous liquids, the different phases formed upon differentiation are similar even though the proportions of hydrous versus anhydrous minerals could vary significantly. This suggests that the formation of amphibole-bearing metasomatic veins observed in the lithospheric mantle could be linked to the differentiation of initial hydrous liquids ranging from ne-normative to hy-normative in composition.

(2) To evaluate the trace element composition of amphibole-cumulates, we did Monte Carlo simulations of metasomatic vein formation in the context of mid-ocean ridges based on the model proposed by Niu and O'Hara [2]. This model assumes that some liquid produced at depth at the periphery of a ridge is not collected to form MORB, but generates a modal and cryptic metasomatic enrichment of the lithospheric mantle. For the calculation, we assume that initial metasomatic agents represent low-degree melts from peridotitic sources similar to depleted MORB mantle. The inferred polybaric crystallization sequence of the low-degree melts was constrained by experiments and the mineral compositions and modes observed in metasomatic veins. The main conclusion of these simulations is that the compositions of calculated hydrous cumulates are highly enriched in incompatible trace elements and that their patterns share many similarities with the patterns of alkaline OIBs (positive Nb/La, negative Ce/Pb, same slope of REE).

The combination of fractional crystallisation experiments and Monte Carlo simulations supports the model proposed by Harte et al. [5] for the formation of metasomatic veins; and suggests that low degree melts from "normal" mantle following by fractional crystallisation at high pressure allowed to produce hydrous cumulates suitable to be a source of alkaline magma observed in intraplate setting.

[1] Lloyd and Bailey (1975) *Phys. Chem. of the Earth*, 9: 389-416; [2] Niu and O'Hara (2003) *J. Geophys. Res.* 108, 2209; [3] Pilet et al. (2008) *Science* 320, 916-919; [4] Harte et al. (1993) *Philos. Trans. R. Soc. Lond. Ser. A*, 342, 1-21 ; [5] Nekvasil et al. (2004) *J. Petrol.*, 45: 693-721.