

Pyroxenites everywhere. Comment on “High-pressure melting experiments on garnet clinopyroxenite and the alkalic to tholeiitic transition in ocean-island basalts” by Keshav et al. [Earth Planet. Sci. Lett. 223 (2004) 365-379]

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Abstract/Summary

Keshav et al. [1] focus on the role of pyroxenitic lithologies in the Ocean Island Basalt (OIB) genesis. Under the acronym OIB are grouped oceanic island basalts (s.l.) generated away from active or fossil subduction zones in intra-plate tectonic settings. Keshav et al. [1] deny any important role for pyroxenitic material in the chemical budget of OIB. Their conclusions are based on the transverse trends of their experimental partial melts of garnet clinopyroxenite compared to the global OIB trend in Harker-type diagrams. Here we put criticism on their conclusions.

During the last ten years, the role of garnet clinopyroxenites (and, more generally, basaltic compositions metamorphosed to high-density assemblages in the mantle) in OIB petrogenesis has been the subject of a number of detailed investigations. Experimental studies and geochemical/petrological modeling have suggested that pyroxenitic s.l. material is a potential source component for basaltic magmatism in general (e.g., [2,3]). For example, recycling of former basaltic material (in the form of garnet-clinopyroxenites, granulites, eclogites, websterites, olivine websterites) has been proposed to explain variability in MORB geochemistry (e.g., [4,5]), as well as in HIMU-OIB lavas (e.g., [6,7]), both continental and oceanic EMI-like basalts (e.g., [8-10]), subduction-related magmas (e.g., [11]), intra-plate igneous rocks (e.g., [12,13]) and Continental Flood Basalts [14,15].

The hypothesis of recycling of pyroxenitic material in the mantle is gaining more and more consensus within the geochemical community to explain some distinctive features of a wide range of basaltic s.l. magmas emplaced in different tectonic settings. The main differences among the various models regard the starting composition, the different metamorphic histories, the restitic or cumulitic nature of the protolith, the time of geochemical isolation in the mantle, the degree of partial melting of such material and the styles of interaction of the resultant melts with the surrounding peridotite.

Based on partial melting experiments of a high Mg garnet pyroxenite at 20 and 25 kbar, Keshav et al. [1] conclude that “although the partial melts of this garnet-clinopyroxenite resemble ocean-island basalt lava compositions in some of their traits, garnet clinopyroxenite of similar bulk composition plays (if any) a minor role in dictating the major-element budget of OIB”.

Our criticism of Keshav et al. [1] is that these authors conclude that garnet pyroxenite is not a significant source component of OIB chiefly because the trends of their experimental partial melts are transverse to trends displayed by OIB. Figs. 7b and 7c of Keshav et al. [1] show a general negative correlation of Samoan, Hawaiian and Polynesian volcanic rocks in terms of CaO vs. SiO₂ and MgO vs. Al₂O₃ that strongly contrast with the positive correlation of their experimental melts obtained at different temperatures.

In Fig. 1, Al₂O₃, CaO, TiO₂ and Fe₂O_{3t} vs. MgO diagrams are reported for Samoan, Hawaiian and Polynesian (Pitcairn-Gambier Chain) taken from the GEOROC database (<http://georoc.mpch-mainz.gwdg.de/georoc/>; accessed February 2005). In the same figure are also shown: a) the garnet-clinopyroxenite starting composition used by Keshav et al. [1]; b) their garnet-clinopyroxenite experimental partial melts at 20 and 25 kbar [1]; c) experimental partial melts from SiO₂-deficient and SiO₂-excess pyroxenites from the literature (references in [16]); d) fractional crystallization vectors involving removal of olivine, clinopyroxene and Fe-Ti oxides (magnetite s.s.) and accumulation of olivine.

As seen in Fig. 1, OIB compositional variation is mostly controlled by olivine ± clinopyroxene fractionation at MgO contents of ~15 to ~5 wt%; only with decreasing MgO (<5 wt%), Fe-Ti oxides segregation becomes important. Moreover, some of the MgO variation in OIB compositions (in particular, extension to very MgO-rich >15 wt%) requires olivine accumulation. There is no doubt that a transverse trend between Keshav et al.'s [1] experimental melts and naturally occurring OIB samples can be observed in Fig. 1; however, we believe this is not sufficient to exclude an important role for pyroxenitic material in OIB genesis. Indeed, Keshav et al. [1] ignore the effects of shallow fractionation processes in reaching their conclusions.

Implicit and never stated in Keshav et al. [1] is that the principal cause of major element variation in OIB is varying degrees of partial melting of the source(s). As seen in Fig. 1, however, the OIB trends are mostly controlled by mafic phases fractionation. If the principal explanation for the major element variation of OIB is near-surface fractional crystallization, then any model for the mantle origin of a suite of basaltic lavas needs only to demonstrate that the mantle can generate an appropriate parental liquid, and Keshav et al.'s experiments [1] are entirely consistent with this requirement.

Low degrees experimental partial melts of garnet clinopyroxenite used by Keshav et al. [1] have major element contents (e.g., SiO₂ ~43-45 wt%; Al₂O₃ ~13-14 wt%; MgO ~13-14 wt%;

CaO ~9.5-10 wt%) coherent with near-primitive OIB compositions (Fig. 1). This reinforces the idea that basaltic compositions s.l. (i.e., pyroxenites, granulites, eclogites) can be considered a potential source component in OIB (and MORB) genesis.

Contrary to the conclusion of Keshav et al. [1], we argue that garnet clinopyroxenite recycled into the upper mantle (either along subduction zones or as a consequence of delamination and detachment processes) can contribute effectively to the chemical budget of OIB magmas and basaltic volcanism in general. Several experimental investigations and detailed geochemical/petrological studies have evidenced the importance of pyroxenitic material to explain the chemical and isotopic heterogeneities of many oceanic and continental basalts. We agree with Keshav et al. [1] that OIB major element trends are not formed by variable degrees of melting of pyroxenitic material, but this observation is not sufficient to preclude a role for the involvement of such a material in the upper mantle. Keshav et al. [1] only consider chemical variations produced by variable degrees of partial melting, without any consideration of the effects of fractional crystallization of the primary melts.

In conclusion, the role of pyroxenitic material is certainly important to explain the geochemical heterogeneities of primitive basalts emplaced both in oceanic and continental settings, even though we still have not completely understood how the chromatographic metasomatic processes work.

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Figure caption

Al_2O_3 , CaO, TiO_2 and Fe_2O_{3t} vs. MgO diagrams for Hawaiian (open circles), Samoan (grey circles) and Polynesian (Pitcairn-Gambier Chain; black circles) OIB (references from GEOROC database <http://georoc.mpch-mainz.gwdg.de/georoc/>, accessed on February 2005). Green rhomb = garnet-clinopyroxenite starting composition of Keshav et al. [1] experimental work. Blue crosses = experimental melts of garnet-clinopyroxenite at different T (temperatures increasing moving towards the starting composition) at 20 kbar [1]. Red crosses = experimental melts of garnet-clinopyroxenite at different T (with increase of temperature, compositions move towards the starting composition) at 25 kbar [1]. Dotted line = experimental partial melts of SiO_2 -excess partial melts (references in [16]). Dashed line = experimental partial melts of SiO_2 -deficient partial melts (references in [16]). Arrow 1 = fractionation vector of olivine-dominated assemblage. Arrow 2 = fractionation vector of clinopyroxene-dominated assemblage. Arrow 3 = fractionation vector of Fe-Ti oxides-dominated assemblage. Arrow 4 = olivine accumulation vector. The patterns of OIB lavas in Harker-type diagrams are clearly related to fractional crystallization (segregation or accumulation of mineral phases) processes, whereas the patterns of experimental partial melts of Keshav et al. [1] are related to increasing degrees of partial melting. This means that the transverse patterns between naturally occurring OIB samples and Keshav et al.'s [1] experimental partial melts cannot be considered evidence against active involvement of pyroxenitic (s.l.) assemblages in the source region of basalt. Major and trace elements as well as Sr-Nd-Pb-Os-O isotopic compositions of different OIB magmas have shown the need of pyroxenite/eclogite (with basaltic composition s.l.) involvement in their sources (e.g., [17]).