Deep volatile-induced melting, crustal melt-peridotite interactions, and the origin of primary ocean island basalts in the Earth's ambient mantle

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Intraplate magmas are known to display large variability in terms of long-lived radiogenic isotopes, trace, major, and volatile element abundances and ratios. These differences and variability have been interpreted to reflect heterogeneities in the mantle compositions and temperature. However, the origin of intraplate magmas in general and that of alkalic ocean island basalts (OIBs) in particular remain matters of active debate. In particular, the relative contributions of excess mantle potential temperature (T_P) and mantle heterogeneity in terms of lithology and volatiles remain incompletely constrained for alkalic OIBs.

Here we present key constraints on OIB petrogenesis based on recent advancement on laboratory experiments on carbon-induced silicate melting of peridotite (1) and subducted crust-derived partial melt and mantle interactions (2,3). We show that either via redox melting or by carbonate-fluxed decompression melting, carbonated silicate melts akin to silica-poor, primary basanite, nephelinite, melilitite can form at depths spanning 70 to 150 km at a T_P of 1350 °C. Moreover, strongly carbonated, kimberlitic to melilititic primary melt is generated and may be present as deep as 150-250 km in the ambient mantle, influencing the seismic structure and electrical conductivity of the deep ocean island source.

Although most major element chemistry of near-primary, silica-poor OIB can be derived from a fertile peridotite with minor $CO_2 \pm H_2O$, a number of minor, trace (Ti, Ni, Mn, Zn, Mn/Fe), and isotopic compositions call for eclogitic lithologies in the source regions. Previous experimental studies, however, argued against MORB-like ocean crust in the source regions of alkalic magma production because the partial melts derived from the crust is silica-rich and Mg-poor. To evaluate how eclogite-derived melt evolves in reaction with peridotite, we conducted basaltic andesite and peridotite reaction experiments with and without CO_2. Our results show that reactive infiltration of eclogite-melt into peridotite leads to formation of orthopyroxene and garnet and dissolution of olivine, leading to silica and alumina depletion and MgO-enrichment in the reacted melt. Dissolved carbonates enhance these changes further and high-MgO (>14-16 wt.%) alkalic basalts can be generated at T_P of 1350 °C. The compositions of reacted eclogite-derived melt produce a reasonable match to near-primary alkalic OIBs. Our data, therefore suggest that production of OIBs can occur in an ambient mantle through fluxing of CO_2 and mantle hybridization via MORB-eclogite-melt-peridotite reaction.

(1) Dasgupta, R. et al. (2013). Nature 493, 211-215.

(2) Mallik, A. and Dasgupta, R. (2012). EPSL 329-330, 97-108.

(3) Mallik, A. and Dasgupta, R. (submitted). JPetrol.