



Alkaline magma- oceanic lithosphere interaction: a key to understand the nephelinite-alkali basalt transition observed in oceanic islands

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An important question in the petrogenesis of oceanic island basalts is related to the location of the different mantle components which interact during their formation. Most models suggest that all components are located within the convecting mantle and therefore neglect the potential role of the oceanic lithosphere [e.g. 1]. Here we show that lithospheric mantle plays a fundamental role in the process responsible for the range of parental melt (i.e. from nephelinite to tholeiite) observed in intraplate volcanoes.

Alkaline lavas from continental volcanoes or oceanic islands characterized by thick lithosphere (>50 km) define a compositional continuum from nephelinites to alkali olivine basalts and often to tholeiites. The decrease in incompatible trace-element concentrations from nephelinitic to tholeiitic magmas in single volcanoes is consistent with this continuum reflecting an increase in the degree of partial melting of a common source [2]; however, no experiments on mantle lithologies (peridotite, pyroxenite) have reproduced the observed compositional continuum (nor even the observed range of silica contents: ~40 to 48 wt. % SiO₂). Alternatively, this continuum could be explained by reaction between nephelinitic/basanitic liquid and surrounding peridotite [3, 4, 5]. To test this latter hypothesis, “sandwich” experiments were performed in which a layer of hornblende (producing nephelinitic magmas [5]) was packed between layers of moderately depleted peridotite. Experiments were done at 1.5 and 2.5 GPa, with temperature ranging from 1225 to 1425°C. At the same temperature (1250-1300°C), the SiO₂ contents of partial melts produced in the sandwich runs are up to 4-5 wt. % higher than liquids from the hornblende-only experiments. This difference reflects the dissolution of orthopyroxene in the peridotite layers in the sandwich runs. For both major and trace elements, the compositional trends defined by glasses from the hornblende-only melting experiments and from the sandwich experiments are similar to trends observed in natural basanite → alkali basalt suites. These results suggest that compositional trends from nephelinite/basanite to alkali basalt observed in intraplate setting are related to reaction between nephelinitic/basanitic liquids and peridotite rather than, for example, a pressure effect and/or an increase in the degree of partial melting of peridotitic sources.

Although we do not exclude that the alkaline magma-peridotite interaction is an important process in the convecting mantle (i.e. at pressure higher than 2.5-3 GPa), we suggest that the main interaction which produces the nephelinite/basanite to alkali basalt/tholeiite composition ranges observed in oceanic islands happens in the lithospheric mantle. These experiments indicate also that the temperature at which alkali melts interact with peridotites could be significantly lower than the solidus temperature of these peridotites. This provides an explanation for the implication of lithospheric components during the generation of alkaline lavas without requiring that these components reach their melting temperature. We conclude that lithospheric mantle needs to be considered as an important component in the petrogenesis of alkaline lavas.

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