Goldschmidt2020 Abstract

Depletion, metasomatism and water distribution in the oceanic lithospheric mantle

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The concentration of hydrogen (H, reported as H_2O ppm by weight) controls key physical properties of mantle peridotite (rheology, melting, electrical conductivity). As H is highly incompatible in bulk peridotite, melting will effectively dehydrate the residual lithospheric mantle. However, existing data on oceanic peridotites show variable and higher H_2O concentrations than predicted for melt residues, implying a role for metasomatism in “rehydrating” the mantle lithosphere. Yet, the competing roles of depletion and metasomatism, and how metasomatism controls the H_2O systematics of the lithospheric mantle remain unclear.

We present H_2O (measured by FTIR), major and trace element concentrations on minerals from oceanic peridotite xenoliths from Hawaii, Samoa, Canaries and the Kerguelen archipelago. Orthopyroxene (opx, the dominant host of H_2O in clinopyroxene (cpx)-poor peridotites) from Samoa and Kerguelen depleted peridotites have the lowest H_2O contents, ~10-70 ppm. The Hawaiian peridotite opx and cpx show two distinct trends of decreasing H_2O with decreasing Al contents, a high H_2O trend for Salt Lake Crater, Aliamanu, and a low H_2O trend for Pali, Kauai. In the Kerguelen and Canaries peridotites cpx H_2O contents increase with increasing intensity of carbonatite metasomatism (e.g., Ti depletions, Ce/Yb), but they have lower H_2O concentrations than Hawaiian cpx affected by silicate metasomatism, approximated by the high H_2O contents of pyroxenites.

While each sample location has distinct H_2O vs. major element trends, these and literature data show decreasing H_2O content in oceanic peridotites with increasing depletion. In turn, carbonatite and silicate metasomatism each result in distinct H_2O vs. trace element systematics, but carbonatite is less effective in rehydrating the lithosphere than silicate metasomatism, likely due to the lower activity of H_2O in CO_2 bearing fluids. The role of diffusion in smoothening out H_2O gradients in the lithosphere appears relevant only on the sampling scale of each location.