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Heterogeneous sub-oceanic mantle: Evidence from contrasting water contents in Mid-Atlantic Ridge peridotite

Esther Schmädicke (1), Jürgen Gose (1), and Thomas Will (2)

(1) University of Erlangen-Nürnberg, GeoZentrum Nordbayern, Schlossgarten 5a, D-91054 Erlangen, Germany, (2) University of Würzburg, Department of Geography and Geology, Geodynamics and Geomaterials Research Division, Am Hubland, D-97074 Würzburg, Germany

Orthopyroxene (opx) in oceanic spinel peridotite is a useful proxy for water contents in the sub-oceanic mantle. Because of its large grain size (compared to olivine), opx is less affected by secondary diffusional water loss due to decompression. Contrasting water contents were found in opx of oceanic spinel peridotite, comparing samples from the Mid-Atlantic Ridge near 15°N (ODP-Leg 209) and those near 23°N (ODP-Leg 153). Orthopyroxene from ODP-Leg 209 contains 15 wt.-ppm H_2O, incorporated as OH groups in the mineral structure. In contrast, H_2O contents in opx from ODP-Leg 153 are one order of magnitude higher, with typical values of 270 wt.-ppm. These latter values agree well with both the H_2O contents known from sub-continental spinel peridotite xenoliths and the water storage capacity of opx at pressures typical of the spinel peridotite facies. The water contents in opx from the sub-oceanic mantle at the Mid-Atlantic Ridge, ranging from 15 (= highly depleted) to 270 wt.-ppm (= water saturation in opx), compare well with the highly variable water contents of Atlantic MORB glass that also scatter over one order of magnitude.

Mineral trace element data indicate different degrees of partial melting: 18% for Leg 209 peridotite and 12% for Leg 153 samples. The mantle equilibrium temperature differs by 200 °C: Leg 209 = 1150-1200 °C, Leg 153 = 950-1000 °C). The opx water contents of Leg 209 are compatible with residual values after c. 18% partial melting of a peridotitic source with original bulk rock water contents of 120-130 wt.-ppm and original opx water contents of 300 wt.-ppm, respectively. In contrast, the water content of 270 wt.-ppm in opx of Leg 153 peridotite cannot be reconciled with residual amounts to be expected after 12% partial melting. This is because an unrealistically high initial water content of 3500 wt.-ppm would be required for the original opx – exceeding the water storage capacity of opx at an ambient pressure of c. 20 kbar by one order of magnitude. The data imply that – following melt depletion – the water contents of Leg 153 peridotite re-equilibrated in the spinel-peridotite facies. This may have been facilitated by a longer mantle residence time of Leg 153 peridotite (compared to Leg 209) after partial melting and prior to tectonic exhumation from c. 60 km depth. An extended mantle residence time is compatible with isobaric cooling from >1200 °C to 950-1000 °C (at c. 20 kbar) as documented by Leg 153 peridotite, and it facilitates re-introduction of water from less or non-depleted mantle regions due to the high diffusivity of H.