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Experimental constraints on the serpentinization rate under the antigorite-stable P-T condition

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Water transport into the Earth's interior can be limited by the rate of serpentinization reaction proceeding at slow spreading ridges and along bending related faults (Iyer et al., 2012). Moreover, the distribution of H_2O in the mantle wedge may be controlled by the extent of progression of the reaction between the slab-derived fluid and the hanging wall mantle, as suggested by theoretical models (Iwamori, 1998). Previous hydration experiments for kinetic studies have been vigorously conducted at relatively low P-T condition (up to ca. 400 ℃ and 0.3 GPa) where the low T serpentine variety lizardite or chrysotile is stable. In contrast, antigorite is expected to be the dominant serpentine variety under the higher P-T condition corresponding to the deep oceanic lithosphere and the mantle wedge.

In order to constrain the serpentinization rates of peridotite under the antigorite- stbale conditions, we conducted piston-cylinder experiments at 580 ℃ and 1.3 GPa. Four types of starting materials were prepared from the crushed powder of a San Carlos lherzolite xenolith: 1) olivine (Ol), 2) orthopyroxene (Opx) + clinopyroxene (Cpx), 3) Ol + Opx, and 4) Ol+ Opx + Cpx + spinel. These systems were abbreviated as OL, OPX+CPX, OL+OPX, and LHZ, respectively. The starting materials were reacted with 15 wt% distilled water for 4-15 days. The formation of serpentine + talc + magnetite was observed in all the systems except for OL. Based on Raman spectroscopy results and crystal shapes, the synthesized serpentine mineral was identified as lizardite with 6?9 wt% Al_2O_3, rather than antigorite. The high Al_2O_3 content in the system possibly stabilized the aluminous lizardite at the experimental temperatures. Low silica activity precluded olivine reaction in the OL system, whereas olivine reacted with the SiO2 com-ponent in orthopyroxene to form lizardite and talc in the other systems. The reaction progress followed an interface-controlled rate law. The growth rate, G, was estimated to be 2.31 ± 0.37, 1.23 ± 0.20, and 2.78 ± 0.64 μm/day in the OPX+CPX, OL+OPX, and LHZ systems, respectively. As an example, we applied the hydration rates of peridotites, which were obtained experimentally, to a reactive-transport model for the convecting mantle wedge hydartion. In the case of grain-scale pervasive flow, the mass flux ratio of water fixable in the hanging wall peridotites to that supplied from the dehydrating oceanic lithosphere was calculated to be 2.7×105 - 1.5×108. This indicates that the water is completely fixable in the convecting mantle wedge and carried down to the stability limit of serpentine as soon as it is supplied from the slab. Aqueous fluid may penetrate all the way through the serpentine stable layer and reach the hot center of the mantle wedge only when the fluid migrates via crack-like pathways with a spacing $>$270-15000 m, which is not consistent with observations of natural serpentinites.

Keywords: hydration, serpentine, fluid, subduction zone, mantle wedge