Preferential orthopyroxene serpentinization in the fore-arc mantle and implications for seismic velocity interpretation

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The hydration state of the stagnant fore-arc mantle has been estimated from seismic velocity observations based on the petrologically estimated hydrous mineral phase and modal compositions. When interpreting seismic tomography data, antigorite serpentine is often assumed as the only hydrous mineral in the hydrated fore-arc mantle (e.g., Reynard 2007). However, our recent experimental study showed that the preferential orthopyroxene (Opx) reaction results in the formation of talc along with serpentine at most in the same amount as for serpentine (Nakatani and Nakamura, 2016). In this study, we further examined the P-T conditions for preferential Opx reaction in the olivine (Ol) + aluminum-bearing Opx system in the range of 400–580˚C and 1.3–1.8 GPa. We found that the preferential Opx reaction is expected to produce talc in more than one-third of the serpentine in the shallow fore-arc mantle at hot subduction zones, such as Cascadia and Nankai (i.e., P < 1.3 GPa and T > ~500˚C). We then calculated the isotropic seismic velocity for hydrated harzburgite using a volumetric proportion of Ol:Opx = 7:3 and the Voigt-Reuss-Hill average. Using these calculations, we can evaluate the influence of talc formation on seismic velocity.

Seismic velocity calculations indicate that V_p and V_s of hydrated harzburgite decrease monotonically with increasing reacted H_2O content; the rate of decrease does not depend on the extent of the preferential Opx reaction. However, the harzburgite hydration reaction reaches completion at a relatively low H_2O concentration (as low as 2.6 wt%) in the preferential Opx reaction because the talc H_2O concentration (4.8 wt%) is lower than that of serpentine (13 wt%). For example, V_p decreases from 8.3 to 7.7 km/s when all the Opx reacts (i.e., 100% reaction progress) at 580˚C and 1.3 GPa. However, it corresponds to a reaction progress of only 33% when the hydration reaction proceeds stoichiometrically to produce serpentine alone. Another important effect of talc formation is that, due to its lower V_p/V_s (~1.60) compared with that of serpentine (~1.78), the bulk rock V_p/V_s does not change significantly with talc formation along with serpentine. Regions with low V_p and V_s but no conspicuous V_p/V_s perturbation might be explained by the presence of talc, which may contribute to weakening of the mantle (Hirauchi et al., 2016). We also found a case of preferential Opx reaction and resultant talc formation in natural samples; peridotite from the Lower Zone of the Horoman complex, which is assumed as hydrated at pressures below 0.5 GPa. This observation supports the possibility of preferential Opx reactions occurring in the fore-arc mantle.

Keywords: fore-arc mantle, serpentinization, orthopyroxene, talc, seismic velocity

