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Hydrogen Solubility of Garnet: Insights into Water Transportation and Distribution in the Upper Mantle

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Water (hydrogen) strongly influence the physical and chemical properties of the Earth's interior (Peslier et al., 2017). Nominally anhydrous minerals (NAMs), such as garnet, can accommodate small amounts of water in the form of hydroxyl defects, thus potentially acting as important hosts and transporters of water in the mantle (Mookherjee & Karato, 2010). Given the stability and abundance of garnet in the upper mantle and subducting slabs, this study investigates the effects of pressure, temperature and composition on water solubility of garnet through high-pressure experiments (3-7 GPa, 1100-1300°C) on pyrope-rich and almandine-rich garnets. Results show that water solubility in garnet increases systematically with pressure and temperature, with a relatively minor compositional influence. The dominant hydrogen incorporation mechanism is identified as the coupled substitution of $Al^{3+} + H^{+}$ for Si^{4+}. A new thermodynamic model for garnet water solubility is developed, allowing quantitative predictions of water storage capacity under various mantle conditions. Water partitioning between garnet and olivine is found to be pressure and water fugacity dependent, with implications for mantle rheology and geophysical properties. Combined with phase equilibrium modeling, this study suggests that subducting slabs can transport 140-230 ppm H_2O to depths of 410-660 km, primarily stored in garnet and clinopyroxene. The water storage capacity of the upper mantle generally increases with depth in both continental and oceanic settings, potentially contributing to observed seismic velocity variations. These findings provide new insights into the Earth's deep water cycle and the influence of water on upper mantle properties.

References:

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