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Experimental generation of redox water from olivine and molecular hydrogen: implications for Earth's lithosphere and other planetary bodies

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With natural hydrogen (H_2) sources from Earth's continental crust to the deep mantle, there are numerous geologic settings in which H_2-rich fluids could migrate and interact with crustal or mantle rocks. Because the lithosphere is largely oxidized, H_2 must react with oxygen-bearing minerals, potentially leading to the back transformation of H_2 into water. This study uses an experimental approach to investigate this redox water formation at pressures and temperatures most relevant to the mantle lithosphere.

Here we present results from five H_2-olivine experiments, with pressure conditions at 1 GPa and varying temperatures between 400-800 °C. Single-stage piston-cylinder double capsule experiments were conducted reacting olivine (San Carlos, AZ, U.S.A., ~Fo89) and molecular H_2 for approximately seven days at higher temperatures (600°C, 700°C, and 800°C) and about six weeks at lower temperatures (400 and 450°C) to accommodate reaction kinetics. Quadrupole mass spectrometry data of all experiments showed a range of 0.83-3.52 µmol H_2O produced, in large agreement with corresponding thermodynamic model predictions for fluid speciation. Formation of native Fe as a solid product documents both H_2-mediated Fe reduction from olivine and H_2 oxidation to redox water.

Together, these experiments demonstrate that molecular H_2 can reduce Fe in typical mantle olivine (Fo89) to generate redox water at mantle lithosphere conditions. This hypothesis applies to settings such as mantle wedges overlying subducting slabs, where H_2 produced by serpentinization can migrate into dry mantle. Beyond conditions relevant to Earth, this work may provide insight to unconventional water production possible on other celestial bodies with H_2 atmospheres.