Goldschmidt 2026 Abstract
https://doi.org/10.46427/gold2026.36862

Experimental study on hydrogen generation during low temperature serpentinization using various ultramafic rocks in Japan

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Among the various potential mechanisms to generate geologic hydrogen, serpentinization of ultramafic rocks is most plausible in active tectonic settings such as Japan, Philippines, and Indonesia. While serpentinization reactions have been known to occur in high temperature environments (e.g., 200 – 350ºC) such as the mantle wedge during subduction, they may also occur in near surface environments (e.g., <100ºC). In this study, we investigated mineralogical and geochemical factors affecting hydrogen generation during low temperature serpentinization in a series of batch experiments, by comparing various types of ultramafic rocks including those from Japan, as the starting materials [1]. Results of the batch experiments show that fresh harzburgite samples yielded the highest amounts of hydrogen, whereas serpentinized samples tend to generate lower amounts of hydrogen. This suggests that hydrogen was primarily generated by the dissolution of olivine and pyroxene. Chemical compositions of the recovered solution indicate that samples with fresh peridotites resulted in weakly alkaline pH (8.1 – 9.6 at 25ºC) as well as higher dissolved Si and Ca concentrations. Mg- and Fe-bearing silicates were observed by Scanning Transmission Electron Microscopy (STEM) analysis of the precipitates. Thermodynamic modelling suggests that the silicates buffer the solution at this pH. Therefore, we propose that dissolution of pyroxene promotes precipitation of the Mg-bearing silicates and hydrogen generation. Among fresh harzburgite samples from different locations, samples containing chromian spinel with the higher Cr/Al ratios generated higher amounts of hydrogen. The Fe content in the precipitates was higher in the experiment that generated higher amounts of hydrogen. These may suggest that the spinel catalyzes the oxidation of ferrous iron to ferric iron in the solution, which is coupled with the production of hydrogen [2], and that the catalytic ability may vary depending on the chemical compositions of chromian spinel.

[1] Ohtomo, Y., Higashino, S., Kikuchi, R., Otake, T., and Sato, T. (2025) Geochem. J. 59, 207-223.

[2] Mayhew, L. E., Ellison, E. T., McCollom, T. M., Trainor, T. P., and Templeton, A. S. (2013) Nat. Geosci. 6 478–484.