Goldschmidt 2026 Abstract
https://doi.org/10.46427/gold2026.35859

Relationship between rock composition and H_2 generation through water-rock reactions in hydrothermal systems

HISAHIRO UEDA[1], MASAHIKO SATO[2] AND TAKAZO SHIBUYA[3]

[1]Gakushuin University
[2]Tokyo Institute of Science
[3]JAMSTEC

H_2-rich hydrothermal fluids generated through water–rock interactions are considered to have provided key environments for sustaining microbial ecosystems on the early Earth and potentially on other planetary bodies such as early Mars. On Earth, hydrothermal systems associated with ultramafic rocks such as komatiite are regarded as among the most plausible candidate settings for such environments [1]. On Mars, the widespread occurrence of hydrous minerals such as serpentine and chlorite in Noachian terrains indicates past hydrothermal activity, suggesting that similar water–rock reactions may have generated H_2-rich fluids. In particular, serpentinization involves coupled oxidation of ferrous iron in olivine and reduction of water, resulting in molecular hydrogen production. Martian basalts commonly contain olivine with higher Fe contents than typical terrestrial mantle olivine, potentially influencing H_2 generation efficiency. Thermodynamic modeling predicts that increasing Fe content suppresses H_2 production at higher temperatures (>150 °C) but may enhance it at lower temperatures [2]. However, the influence of bulk rock composition, including components such as SiO_2 and Al_2O_3, remains insufficiently constrained [3]. To evaluate these effects, we conducted a series of hydrothermal experiments (>3 months) at 300 °C using Fe-rich natural olivine (Fa–Fo80) and Martian basalt containing olivine (Fo70–80). Powdered samples were reacted with NaCl solution under controlled conditions. The results show that H_2 concentrations in fluids reacting with olivine increase with decreasing Fe/Mg ratio, consistent with thermodynamic predictions. Experiments using olivine with higher Fe/Mg ratios yielded greater amounts of unreacted olivine, reflecting enhanced mineral stability. In contrast, fluids generated from Martian basalt exhibited significantly different H_2 concentrations (1–2 mmol/kg) compared to those from Fo80 olivine alone, indicating compositional controls beyond olivine chemistry. Comparative analysis suggests that bulk FeO and Al_2O_3 contents exert important controls on H_2 generation. These findings demonstrate that hydrothermal alteration of Martian crustal rocks could have produced H_2-rich fluids capable of supporting microbial ecosystems. However, assessments of past habitability must account for bulk rock composition and mineralogical context rather than olivine composition alone.

[1] Ueda et al (2021) G-cubed. 22.12.
[2] McCollom et al (2022) Icarus 372, 114754.
[3] Tutolo et al (2020) PNAS. 117.26.