

口頭講演 | S2: 岩石-水相互作用 (スペシャルセッション)

2026年9月25日(金) 14:15 ~ 18:00 | C 会場 (287号室)

S2: 岩石-水相互作用 (スペシャルセッション)

座長: 土屋 範芳、宇野 正起

ハイブリッド形式で開催します。オンラインで参加される場合は「オンライン会議に参加」をクリックしてください。

◆ 研究優秀発表賞エントリー

15:40 ~ 15:55

[S2-06] Influence of the degree of serpentinization on hydrogen production from ultramafic rocks.

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キーワード : Hydrogen generation

Serpentinization of ultramafic rocks at mid-ocean ridges generates significant amounts of hydrogen (H₂), supporting specialized biological communities and highlighting its potential as a green energy resource. Hydrogen is produced abiotically through water reduction coupled with the oxidation of ferrous iron in primary minerals such as olivine and pyroxene. Its generation potential depends on the abundance and oxidation state of iron. Previous experimental and geochemical modeling studies have mainly focused on fresh peridotite and olivine to clarify the mechanisms and reaction pathways of H₂ generation (Klein et al., 2009, 2013; Malvoisin et al., 2013; McCollom et al., 2020). However, despite the widespread occurrence of serpentinized peridotites, the influence of the degree of serpentinization on hydrogen generation remains poorly understood. In this study, we conducted hydrothermal experiments using natural ultramafic rocks with varying degrees of serpentinization. Hydrothermal experiments were performed in a stirring batch-type reactor at 300 deg C and 10 MPa for 72 h using six ultramafic rock samples from Hokkaido. The starting materials range from least serpentinized harzburgites (G1 and G5) and moderate serpentinized harzburgites (G2, G3, and G6), composed predominantly of olivine with minor orthopyroxene (Opx) and clinopyroxene (Cpx), to a fully serpentinized sample (G4). Two types of brucite were identified in G4: Fe-rich brucite (#Mg = 0.81) occurring as large matrix lenses and Fe-poor brucite (#Mg = 0.94) occurring in small veins. Sample G1 produced the highest H₂ yield (15.85 mmol/kg rock H₂), followed by G6 (11.7 mmol/kg rock H₂) and G5 (10.3 mmol/kg rock H₂). Samples G2 and G3 generated similar amounts (8-9 mmol/kg rock H₂), whereas G4 produced the lowest yield (5.5 mmol/kg rock H₂). An additional experiment using pure olivine powder yielded the highest H₂ production (21.9 mmol/kg rock H₂). These results demonstrate a negative linear relationship between H₂ production and the degree of serpentinization, indicating that progressive serpentinization reduces the hydrogen-generation potential of harzburgite. Nevertheless, the fully serpentinized sample G4 still generated measurable H₂, likely through the oxidation of Fe-rich brucite during magnetite formation. Bulk-rock Fe³⁺/ΣFe ratios were determined by Fe K-edge X-ray absorption near-edge structure (XANES) spectroscopy to evaluate changes in iron oxidation during the experiments. All samples exhibited increased Fe³⁺/ΣFe ratios after reaction, indicating progressive oxidation of Fe²⁺. H₂ yields estimated from the XANES-derived Fe³⁺/ΣFe changes agreed well with the measured H₂ production, with the highest yield in G1 (15.86 mmol/kg rock H₂), followed by G2 (14.63), G5 (10.72), G3 (7.32), G6 (7.17), and G4 (5.02 mmol/kg rock H₂). Although bulk XANES cannot resolve mineral-scale Fe redistribution, the results indicate that H₂ generation is primarily controlled by the abundance of remaining olivine and decreases with increasing serpentinization. However, the measurable H₂ production from G4 suggests that Fe-rich brucite provides an additional Fe²⁺ source for magnetite formation, sustaining H₂ generation even after olivine has been consumed.

Influence of the degree of serpentinization on hydrogen production from ultramafic rocks.

Nomin TUMURKHUU, Otgonbayar DANDAR, Jiajie WANG, Kazuki YOSHIDA, Noriaki WATANABE, Masao KIMURA, Atsushi OKAMOTO

Serpentinization of ultramafic rocks at mid-ocean ridges generates significant amounts of hydrogen (H_2), supporting specialized biological communities and highlighting its potential as a green energy resource. Hydrogen is produced abiotically through water reduction coupled with the oxidation of ferrous iron in primary minerals such as olivine and pyroxene. Its generation potential depends on the abundance and oxidation state of iron. Previous experimental and geochemical modeling studies have mainly focused on fresh peridotite and olivine to clarify the mechanisms and reaction pathways of H_2 generation (Klein et al., 2009, 2013; Malvoisin et al., 2013; McCollom et al., 2020). However, despite the widespread occurrence of serpentinized peridotites, the influence of the degree of serpentinization on hydrogen generation remains poorly understood. In this study, we conducted hydrothermal experiments using natural ultramafic rocks with varying degrees of serpentinization.

Hydrothermal experiments were performed in a stirring batch-type reactor at 300 °C and 10 MPa for 72 h using six ultramafic rock samples from Hokkaido. The starting materials range from least serpentinized harzburgites (G1 and G5) and moderate serpentinized harzburgites (G2, G3, and G6), composed predominantly of olivine with minor orthopyroxene (Opx) and clinopyroxene (Cpx), to a fully serpentinized sample (G4). Two types of brucite were identified in G4: Fe-rich brucite ($\#Mg = 0.81$) occurring as large matrix lenses and Fe-poor brucite ($\#Mg = 0.94$) occurring in small veins. Sample G1 produced the highest H_2 yield (15.85 mmol kg⁻¹ rock), followed by G6 (11.7 mmol kg⁻¹ rock) and G5 (10.3 mmol kg⁻¹ rock). Samples G2 and G3 generated similar amounts (8–9 mmol kg⁻¹ rock), whereas G4 produced the lowest yield (5.5 mmol kg⁻¹ rock). An additional experiment using pure olivine powder yielded the highest H_2 production (21.9 mmol kg⁻¹ rock). These results demonstrate a negative linear relationship between H_2 production and the degree of serpentinization, indicating that progressive serpentinization reduces the hydrogen-generation potential of harzburgite. Nevertheless, the fully serpentinized sample G4 still generated measurable H_2 , likely through the oxidation of Fe-rich brucite during magnetite formation. Bulk-rock $Fe^{3+}/\Sigma Fe$ ratios were determined by Fe K-edge X-ray absorption near-edge structure (XANES) spectroscopy to evaluate changes in iron oxidation during the experiments. All samples exhibited increased $Fe^{3+}/\Sigma Fe$ ratios after reaction, indicating progressive oxidation of Fe^{2+} . H_2 yields estimated from the XANES-derived $Fe^{3+}/\Sigma Fe$ changes agreed well with the measured H_2 production, with the highest yield in G1 (15.86 mmol kg⁻¹ rock), followed by G2 (14.63), G5 (10.72), G3 (7.32), G6 (7.17), and G4 (5.02 mmol kg⁻¹ rock). Although bulk XANES cannot resolve mineral-scale Fe redistribution, the results indicate that H_2 generation is primarily controlled by the abundance of remaining olivine and decreases with increasing serpentinization. However, the measurable H_2 production from G4 suggests that Fe-rich brucite provides an additional Fe^{2+} source for magnetite formation, sustaining H_2 generation even after olivine has been consumed.