Temperature Effects on Hydrogen Generation During Serpentinization

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The annual production of H_2 is estimated to be ca. 10^7 mol/a per km of ridge axis where mantle rocks occur at slow- and ultraslow-spreading mid-ocean ridges[1]. H_2 faciliates the abiotic synthesis of organic compounds, impacts carbon cycling, and provides chemical energy for microbial life in (sub-)seafloor environments on Earth and possiby elsewhere in the solar system[2–5]. Thermodynamic constraints and laboratory experiments suggest a maximal H_2 yield at temperatures of ca. 300°C, i.e. at conditions that require high heat supply such as at mid-ocean ridges[6,7]. At high temperatures, the formation of magnetite is the main source of H_2. However, serpentinization is not limited to high-temperature ridge-crest environments; it also occurs at magma-poor passive margins, in off-axis environments, and in forearc settings of subduction zones where the supply of heat can be significantly lower than at mid-ocean ridges. With decreasing temperature, more iron is taken up by brucite, which lowers the affinity to form magnetite. Yet, H_2 is still generated via ferric iron in serpentine[8]. While rates of serpentinization and H_2 generation vary with temperature, most laboratory experiments suggest reaction rates that are fast on geological timescales at elevated temperatures[6]. Yet, the decrease in permeability and restricted access of water to primary mineral surfaces during prolonged serpentinization can limit the rate of hydrogen production. Reaction progress becomes diffusion controlled unless tectonic, thermal, and reaction-driven fracturing provide access to unreacted mineral surfaces[9]. Low-temperature weathering under open system conditions can further oxidize serpentinites until their reducing capacity is completely exhausted[10].

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