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The generation of hydrogen and ammonia during the hydrothermal alteration of peridotite

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Serpentinization is a low-temperature (≤500 °C) hydrothermal alteration of ultramafic rocks (typically komatiite and peridotite), where olivine and pyroxene are transformed into serpentine, (±)talc, (±)brucite, and (±)magnetite. During serpentinization, ferrous iron (Fe^{2+}) derived from olivine and pyroxene can be oxidized into ferric iron (Fe^{3+}), leading to the generation of hydrogen (H_2). Hydrogen can support communities of microorganisms in hydrothermal vents, suggesting that hydrogen formation may be closely related to the origin of life. This is also indicated by serpentinization on the Earth's surface in the Hadean Eon. After the Magma Ocean period, the Earth's surface consists mainly of ultramafic rocks (peridotite and komatiite). The proto-atmosphere is mainly composed of water vapor, nitrogen (N_2) and carbon dioxide (CO_2), and partial pressures of N_2 and CO_2 are above 2.2 bar and 110 bar, respectively. The interaction of ultramafic rocks with the proto-atmosphere leads to the formation of hydrogen and ammonia (NH_3). The generation of H_2 and NH_3 can be greatly influenced by temperature, chemical compositions of starting fluids, which is closely associated with the rates of serpentinization [1-3]. In experiments at 300 °C and 3.0 kbar, silica impedes hydrogen formation by around 1-2 orders of magnitude [1]. The addition of CO_2 also decreases hydrogen production, whereas NH_3 formation can be greatly enhanced [2]. Ammonia formation is associated with faster rates of pyroxene serpentinization compared to the kinetics of olivine serpentinization. Such process could lead to a great decrease in the amounts of N_2 and CO_2 in the proto-atmosphere. The experiments suggest that hydrogen and ammonia formation during serpentinization may play an important role for the Habitable Earth.

References:

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