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Simulating serpentinization on the early Earth: Effects of temperature and atmospheric composition on H_2 and NH_3 production

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Serpentinization is associated with oxidation of Fe^{2+} in minerals of ultramafic rocks and production of H_2 and NH_3 in a N_2-bearing fluid, providing a key nitrogen source for prebiotic chemistry (Liu and Deng, 2024; Shang et al., 2023). However, the combined effects of temperature and atmospheric composition on serpentinization rates and volatile production remain poorly understood under early Earth conditions. Here, we conducted hydrothermal experiments in the "peridotite–H_2O–N_2/CO_2/(N_2+CO_2)" system at 200–400 °C. Aqueous and gaseous products after reaction were analyzed for pH and contents of H_2 (by gas chromatography), dissolved metals (ICP-OES), and total NH_3 (by UV spectrophotometry); solid products were characterized by XRD, TGA, Raman, and FTIR. Our results reveal a clear temperature optimum at ~250–300 °C for both serpentinization extent and H_2 production, whereas NH_3 yields display more complex patterns that point to additional controls on nitrogen reduction. Dissolved metal concentrations (Mg, Fe, Si) also vary systematically with temperature, consistent with coupled mineral dissolution and secondary phase precipitation. Importantly, the initial gas composition strongly controls fluid pH, with N_2-only systems developing strongly alkaline conditions, whereas an additional CO_2 component significantly lowers pH. The generation of NH_3 and formate during reaction further shifts the acid–base balance. These results suggest that the alkaline conditions, which have been widely considered to be essential for the origin of life, could have developed only after substantial CO_2 drawdown from the early atmosphere — a process to which serpentinization-driven carbonate formation may have been a major contributor.

References:

Liu & Deng (2024) *Solid Earth Sciences* 9(4): 100202.
Shang et al. (2023) *Science Bulletin* 68: 1109-1112.