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Hydrogen, Ammonia, and Formate Formation During Serpentinization: Key Drivers of Prebiotic Chemistry and Earth's Habitability

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Serpentinization, a low-temperature (≤500 °C) hydrothermal alteration of ultramafic rocks, may have been widespread on the Earth's surface in the Hadean Eon after the Magma Ocean period. At this time, the Earth's surface consists mainly of peridotite, komatiite and basalt, while the proto-atmosphere is mainly composed of H_2O, N_2 and CO_2. The interaction of these atmospheric gases with ultramafic rocks through serpentinization would have generated substantial fluxes of molecular hydrogen (H_2) and methane (CH_4), potentially driving significant depletion of atmospheric N_2 and CO_2. Previous experimental simulations of serpentinization processes have focused on simplified systems using olivine and pure H_2O, neglecting the geochemical complexity of natural peridotite assemblages and their implications for planetary habitability. Here we show that peridotite undergoes serpentinization at rates markedly faster than olivine, accompanied by much higher H_2 yields [1]. In N_2-bearing systems, serpentinization drives the synthesis of ammonia (NH_3) at concentrations sufficient to initiate prebiotic amino acid formation [2]. With the addition of carbon dioxide, CO_2 hydrogenation generates formate ($HCOO^-$) and CH_4 [3], effectively sequestering atmospheric CO_2. All these suggest that serpentinization in the Hadean Eon may influence compositional evolution of the proto-atmosphere and possibly the origin of life.

References:

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