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Fe behavior on the surface of early Mars: Insights from weathering Fe-rich olivine

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Iron-rich olivine (Fe contents ≥ 20%) is widely distributed on Mars. However, the dissolution rates, weathering products, and particularly Fe behavior of Fe-rich olivine under Mars-relevant conditions are largely unconstrained.

We experimentally investigated the aqueous alterations of synthetic olivine with gradient Fe contents (Fa_{100}, Fa_{71}, Fa_{50}, and Fa_{29}). Synthetic forsterite (Fo) or natural terrestrial olivine (Fa_{10}) were also examined for comparison. Three Mars-related weathering scenarios were examined: (1) serpentinization (W/R = 5; 200°C, 15 MPa, 20 days); (2) aqueous alteration under a CO_2 atmosphere (W/R = 10, 45°C, 1 bar CO_2, 180 days); and (3) cryogenic sulfuric dissolution (233 K, H_2SO_4, 100 days). The products (solid, liquid and gas) were collected and analyzed for compositional, isotopic, spectral and magnetic characteristics.

The preliminary findings are: (1) during serpentinization, brucite was absent in all Fe-rich olivine experiments (from Fa_{29} to Fa_{100}). Magnetite, talc (or minnesotaite) were present at early stages during serpentinization, as the majority of olivine samples remain unaltered. The initial Fa# values of olivine have a great influence on the fluid compositions and the D/H fractionations in the fluids and olivine rims. (2) Under CO_2 atmosphere, (hydro)magnesite was found only in the Fo experiments and carbonates were absent in all the Fe-rich olivine experiments. The mobility of Fe was relatively hindered compared to Mg and was primarily present as solid phases. Minor hematite and goethite were also found along with phyllosilicates in the Fa_{100} and Fa_{71} experiments, indicating anoxic Fe oxidation controlled by Fa# values and W/R ratios. (3) Under cryogenic sulfuric conditions, the primary alteration products of Fe-rich olivine are Fe(II)-Mg sulfates and amorphous silica with minor ferric sulfates and gypsum. The lifetime of Fe-rich olivine is two to three orders of magnitude shorter than that of Mg-rich San Carlos olivine. The freezing and acidic conditions greatly enhance Fe mobility and subsequent Fe cycling.

Fe-rich olivine weathering under relative water-limited conditions on the Martian surface suggest that primary controls on Fe behavior and weathering products are the physical and chemical conditions of water. Fe oxidation on Mars may decouple from the atmospheric redox conditions.