AQUEOUS ALTERATION OF CM2 CHONDRITES EVALUATED WITH KINETIC MODELS

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Introduction: CM2 carbonaceous chondrites reveal early stages of low-temperature aqueous alteration in a parent asteroid [e.g. 1-3]. Secondary phyllosilicates (cronstedtite, serpentine), some magnetite, and tochilinite in fine-grained matrices and chondrule rims imply hydration and oxidation of primary olivine, enstatite, and kamacite. Secondary mineralogy also indicates special and temporal variations in solution pH [4]. Here we model sequences of mineral dissolution and precipitation, chemical evolution of solution, and time scales of early alteration in a parent body of CM chondrites.

Model: We perform kinetic-equilibrium modeling in closed Fe-Mg-Si-O-H solution-solids-gas systems. At each time step, the numerical model considers pH-dependent rates of mineral dissolution and calculates chemical equilibrium in solution, which affects secondary precipitation [cf. 5]. A procedure is developed to calculate pH- and PH_2-dependent rate of metal oxidation via reaction $3Fe^o + 4H_2O(l) \rightarrow Fe_3O_4 + 4H_2$(gas and solute) (1). In addition to kinetic and thermodynamic data, input parameters include initial mineralogy (forsterite, enstatite, Fe^o metal) and solution composition, surface area (e.g. grain sizes), water/rock ratio (*W/R*, 0.1-10), temperature (*T*, 0-25 ^oC), and pressure ($P \approx PH_2$). Escape vs. accumulation scenarios are considered for H_2. The output includes amounts and compositions of gas, solution, and primary and secondary solids.

Results: Modeling shows faster alteration of the metal compared to silicates (Fe^o > enstatite > forsterite). Correspondingly, a low Mg/Fe ratio in early solutions leads to formation of Fe-serpentine in association with magnetite. Although cronstedtite is expected to form from H_2-, Mg-less, low-*T* solutions, it does not form in the models. At later stages, increasing supply of Mg and SiO_2 from dissolving silicates leads to deposition of increasingly Mg-rich serpentine. Once metal is oxidized, serpentine with Mg/Fe+Mg ratio > 70 becomes dominant. Magnetite dissolves partially and Fe (including Fe^{2+} reduced from Fe^{3+}) goes to serpentine. Higher PH_2 values slow Fe^o oxidation. Lower volume of free space leads to faster increase in *P*. However, at typical asteroidal $P < \sim 10^2$ bar, accumulation of H_2 cannot suppress Fe^o oxidation via eq. (1) unless $H_2O(l)$ is consumed earlier, as observed in runs with low *W*/*R* ratios. At 0 ^oC, major alteration of 1 μm grains occurs by 10^2-10^4 yr, but it is faster for smaller sizes and higher *T*. Solution pH increases rapidly (in 1-10 yrs) and is about 10 to 11 thereafter.

Conclusions: The results allow estimates of sequence and timing of aqueous alteration and are roughly consistent with observations. The lack of cronstedtite in modeled assemblages may reflect a tentative nature of used thermodynamic data [6].

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