COMPUTER MODELING OF AQUEOUS ALTERATION ON CARBONACEOUS CHONDRITE PARENT BODIES Bourcier W. L., Lawrence Livermore Laboratory, and Zolensky M. E., NASA-JSC.

Carbonaceous chondrites contain hydrous mineral assemblages characteristic of low-temperature (<200°C) aqueous reactions. CM and CI-type carbonaceous chondrites also contain late-stage cross-cutting veins of relatively oxidized minerals including sulfates, carbonates, native sulfur, magnetite, and maghemite (1). In order to constrain the conditions of hydrous alteration on the parent bodies of these meteorites, we have performed computer simulations of water-rock reactions occurring on these parent bodies.

We used the program Gt (C. M. Bethke, U. of Illinois, author) to simulate the reaction of anhydrous mineral assemblages of the Murchison (CM) and Allende (CV) meteorites with water at temperatures from 0-300°C under both open and closed system conditions. The code simulates the reactions between the starting minerals and water and predicts the solution composition (pH, Eh, and species concentrations) and amount and types of secondary mineral phases that form during the reaction. The water-rock ratio is fixed by the amounts of solids and water used in the simulation.

In closed-system simulations, we predict the formation of many of the common alteration minerals found in carbonaceous chondrites including serpentine, saponite, nontronite, brucite, magnetite and tochilinite. Thermodynamic data for tochilinite was estimated by considering tochilinite a solid solution of iron monosulfide and brucite. The set of alteration minerals was relatively unaffected by simulation temperature of 0 to 200°C. However, the formation of saponite was restricted to high water/rock environments (mass ratio >5). In the simulations, the CM starting material gave rise to more tochilinite than the CV starting material. In all simulations, magnetite and other spinels were the most abundant alteration minerals.

Our simulations do not account for heat generated during the hydration reactions. However, other workers (2) have shown that hydration reactions which produce the phyllosilicates and oxides listed above are highly exothermic and will cause significant heating.

In open-system simulations, the system was allowed to lose volatile components such as water and any gases produced during the reaction. We found that the reaction of the mafic anhydrous CV and CM mineralogy with water generates significant pressures of reduced carbon gases (CH₄ and CO). The system becomes more oxidizing as these gases escape. In our simulations, we predict that the oxidation state of the system passes into the sulfate and magnetite stability fields.

Open system behavior can explain the late-stage oxidized veins described above. We envision that near the surfaces of the parent bodies where open-system conditions are most likely, melting of ices in some heating event initiates the reaction.
of water with the solids present and causes the formation of CH$_4$ and CO. The system becomes more oxidizing due to CH$_4$ and CO release. This oxidation causes the reaction of sulfide to form sulfate, which eventually leads to sulfate mineral precipitation. Water loss from the open system concentrates the fluid to salinities needed to precipitate sulfate minerals such as gypsum (about 0.1 molal at 25°C) which are common in the late-stage veins. The oxidation event also causes the precipitation of magnetite and eventually maghemite.

The simulations predict that CH$_4$ pressures as high as 100 bars may be generated under closed systems. These pressures are significant and may be responsible for explosive activity on hydrous asteroids and comets. If asteroidal collisions perturbed the orbit of a carbonaceous chondrite body into the inner solar system, solar heating could melt the meteoritic ice and initiate the water-rock reactions described above. Re-freezing after passage back into the outer solar system would terminate reactions on the surface of the body, but continued reactions at depth would continue to generate gas pressures. Temperatures would remain higher at depth due both to the insulating properties of the outer layers and the exothermic nature of the hydration reactions. It seems likely that the buildup of gas pressures at depth could give rise to explosive activity in most retreating hydrous bodies including comets. The recent observation of an explosion on Comet Halley during its passage away from the sun at a distance of 2 million kilometers may be an example of this behavior.


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