Goldschmidt 2025 Abstract
https://doi.org/10.7185/gold2025.32231

Aqueous alteration of chondrite-like material under asteroidal conditions: experimental approach and modeling

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Most solid bodies in the solar system have accreted metal, rock and organic dust, as well as ices. During their subsequent thermal evolution, ice melted and fluid-rock interactions were inevitable. Recently, the Hayabusa-2 and OSIRIS-REx space missions sampled the Ryugu and Bennu asteroids, respectively, to bring back to Earth samples taken directly in situ from carbonaceous, primitive but weathered asteroids. In this context, the study of aqueous alteration of primitive carbonaceous chondrites (CI or CM type) takes on its full meaning.

Carbonaceous chondrites contain up to 3–5 wt.% organic matter, distributed within the matrix and finely associated with secondary minerals such as phyllosilicates, as revealed by TEM or STXM [e.g. 1]. This raises the question of the interactions between organics and silicates, and the inter-influence of both phases during alteration on the parent bodies. If several studies have highlighted significant evolution of organic compounds during aqueous alteration and the role of certain minerals such as clays in various organic reactions [1], the role and influence of organic matter on secondary mineral formation and on the involved reaction pathways remain poorly known.

Here we performed a first series of kinetic laboratory hydrothermal experiments in anoxic conditions with and without organics to (1) investigate the exact reaction pathways towards secondary minerals found in carbonaceous chondrites as a function of the physico-chemical experimental conditions, and (2) study the effect of the presence of organics in the system. The starting material consisted of a mixture of olivine, iron powder, pyrite and an amorphous silicate phase (glass). The experimental products were then characterized using XRD, SEM-EDS (for the solid phase) and chromatography, ICPMS (for the solution). The analyses underline the different dissolution kinetics of the four phases and, more importantly, confirm the influence of organics on the nature and structure of secondary minerals formed. All these results are discussed in the light of geochemical and thermodynamic modeling performed using the PHREEQC software.

[1] Pearson V.K. et al. (2002) Clay mineral-organic matter relationships in the early solar system. MAPS 37, 1829-1833.