

Acid alteration of clay minerals with implication for Mars' surface processes

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The co-occurrence of phyllosilicates (clays) and sulfate stratigraphies at many locations on Mars are associated with a sharp change in surface conditions from neutral/alkaline pH during the Noachian (4.1-3.7 Ga) which favored the formation of clays to acidic conditions during the Hesperian (3.7-2.9 Ga) which favored the formation of sulfates. Yet, if these two contrasting geosystems were temporarily sequential, it is unknown how the Hesperian acidic conditions altered the previously formed clay units.

We performed laboratory batch experiments to fingerprint the diagnostic features produced during interactions of Mars-analog clays and acidic solutions. Two clays, and silicon (IV) oxide, were reacted with solution of either sulfuric acid or filtered natural acid rock drainage (ARD) in plastic bottles. The solutions were adjusted at four pH values (1, 3, 5, and 7) and reacted at 4, 30, and 80°C for 3, 7, and 14 days. At the end of the experiments, the filtered supernatants were analyzed by ICP-MS while the solids were characterized by X-Ray Diffraction; Energy-Dispersive X-Ray Fluorescence analyses; Raman and Short-Wave Infrared spectroscopies and Scanning Electron Microscopy.

Results show that the solution chemistry played a key role in the evolution of the clay-solution systems. In H₂SO₄ systems, the solution pH steadily increased due to partial clay dissolution with no secondary phase formation detected. Contrary, in the ARD systems, the pH decreased due to the ample presence of Fe which controlled both the reactivity of clays by the growth of protecting surface coatings and the solution pH by the precipitation of Fe nanophases; secondary phase detected included goethite, jarosite, gypsum, and siderite.

These results indicate that, on Mars, the chemical interaction between clays and acidic solutions was complex and dependent on the solution chemistry. Acidic, sulfate-rich solutions have a high dissolution capacity and could have induced widespread clay disintegration. Notably, if Fe-rich ARD was involved, the clays on Mars could have remained stable during acidic Hesperian period due to formation of protective coatings. Comparison of our results with martian observations will be performed to determine how acidic conditions could potentially affect clays in sedimentary settings, including the Gale crater.