# Geochemical and Mineralogical Indicators for Aqueous Processes in Gusev Crater and on Meridiani Planum.

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The Athena Science Instrument Payload is providing geochemical and mineralogical information for determining the properties of rocks, soils, and outcrops at the Mars Exploration Rovers landing sites. These measurements indicate that a variety of aqueous processes as well as various degrees of alteration occurred at the two landing sites.

Light-toned rocks around the Spirit landing site appear to have coatings or alteration rinds that may have resulted from limited aqueous alteration on the surfaces of basaltic rocks. Hematite and high Fe(III)/Fe(total) occur at the surfaces of these rocks. High concentrations of elements highly mobile in water (i.e., S, Cl, and Br) occur in rock veins, vugs, and coatings and at the bottom of soil trenches in the "intercrater plains." One scenario for the formation of rock coatings or rinds and translocation of mobile elements is that water might have occurred briefly at the Martian surface during periods of high obliquity and thin films of water may have mobilized elements and altered the surfaces of rocks. Outcrops on the slopes of the Columbia Hills appear to be extensively altered as suggested by their relative "softness" (measured as resistance to abrasion) as compared to basalts on the adjacent plains, high Fe(III)/Fe(total), iron mineralogy dominated by nanophase Fe(III) oxides and hematite, and high Br and Cl concentrations beneath outcrop surfaces. These outcrops may have formed by the alteration of basaltic rocks and/or volcaniclastic materials by solutions that were rich in volatile elements (e.g., Br, Cl, S). However, it is not clear whether aqueous alteration occurred at depth (e.g., metasomatism), by hydrothermal solutions (e.g., associated with volcanic or impact processes), by vapors rich in volcanic gases, or by low-temperature solutions.

The occurrence of jarosite, hematite, and other sulfates (e.g., Mg sulfates) in Eagle and Endurance crater outcrops are strong indicators of aqueous processes at Meridiani Planum. These phases occur with siliciclastic materials in outcrops. Jarosite can only form by aqueous processes under very acidic conditions; e.g., acid sulfate weathering conditions resulting from the oxidation of Fe sulfides or by sulfuric acid alteration of basalts by solutions associated with $SO_2$-rich volcanic gases. It is plausible that acidic solutions rich in sulfur (and Fe(II)) reacted with basaltic sediments (which provided a host of soluble cations) under oxidizing conditions and then, through evaporation, formed sediments rich in jarosite and other sulfates along with siliciclastic materials. Hematite-rich spherules in outcrops may have formed by aqueous processes within the sedimentary layers, which promoted transport of Fe (II) solutions to nucleation sites where oxidation and precipitation occurred to form hematite-rich spherules.