

## **Aqueous Alteration on Mars**

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The formation of extensive valley networks along with layered deposits of phyllosilicates and sulfates during the late Noachian/Hesperian (approx. 3-4 Gyrs) indicates a past martian climate that was capable of maintaining liquid water at the surface. The planet's climate changed substantially after these early "episodes" of water and limited liquid water has occurred on the surface over the past 3.0 Gyrs. The objective of this paper is to describe a few types of aqueous alteration/weathering on Mars based on observations returned by rover and lander missions.

Mars is a basaltic planet. The chemistry of most outcrops, rocks, and soils that have interacted with water has not been extensively changed from average Mars crustal basaltic composition, suggesting open hydrologic systems were not prominent on early Mars and/or the water/rock ratios were low. There are a few occurrences of open hydrologic systems at a local scale, e.g., high-Al boxwork outcrops, possibly containing phyllosilicates, located on the rim of Endeavour crater, high Si rocks and soil deposits around a volcanic feature called Home Plate in Gusev crater, and high Si fracture zones in sandstones in Gale crater.

Geochemical and mineralogical indicators for aqueous alteration have been frequently encountered on the surface by rovers. Discoveries of jarosite and other Fe-sulfates at several locations indicate acid-sulfate alteration conditions. High Si and Ti rocks, sediments, and soil deposits are consistent with basaltic residues altered by extremely acidic fluids. Fe/Mn variations in fracture veins infilled with sulfate-rich materials suggest changes in redox and/or pH conditions of the migrating fluids.

Fluviolacustrine deposits in Gale crater contain phyllosilicates that may have formed under circum-neutral to alkaline pH conditions based on our terrestrial experiences. However, the presence of jarosite in some Gale crater mudstone locations suggest that there was an episode(s) of diagenetic acidic conditions/fluids. Jarosite may have formed over 1 Gyrs after deposition of the sediments suggesting diagenesis occurring well into the Amazonian period (and perhaps a longer history of liquid water interactions with surface sediments than previously thought).