

**FORMATION OF JAROSITE IN THE MAWRTH VALLIS REGION OF MARS BY WEATHERING WITHIN PALEO-ICE DEPOSITS.** J. R. Michalski<sup>1,2</sup> and Paul B. Niles<sup>3</sup>. <sup>1</sup>Planetary Science Institute, Tucson, Arizona. [michalski@psi.edu](mailto:michalski@psi.edu) <sup>2</sup>Institut d'Astrophysique Spatiale, Université Paris Sud, Orsay, France, <sup>3</sup>Astromaterials Research and Exploration Science, NASA Johnson Space Center, Houston, TX 77058

**Introduction:** Here we report new detections of jarosite in the Mawrth Vallis region of Mars. These newly recognized deposits expand the known occurrences of sulfates [1-2] in the region and further expand the already considerable geologic-mineralogic diversity of the Mawrth Vallis area [3-6]. The occurrence of sulfates such as jarosite in geologic contact with thick deposits of phyllosilicates in the Mawrth Vallis area is a relatively rare case on Mars where the enigmatic transition from an early phyllosilicate-forming era to a younger sulfate-forming era [7] can be explored. We propose an ice-weathering model which can potentially explain the formation of jarosite-silica-kaolinite within acidic ice deposits.

**Detection of jarosite:** Near infrared data from the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) were processed using standard techniques to correct for instrument effects, calibrate to I/F, and remote effects of atmospheric transmission from a scaled volcano scan [8-9]. Hyperspectral images in the Mawrth Vallis region were investigated using principle component stretches and by searching through false color infrared images for unique infrared units. Spectra extracted from unique spectral units were ratioed against spectrally unremarkable terrains of comparable albedo to in order to accentuate uniqueness of spectral features corresponding to the unit of interest.

New evidence for jarosite was found within CRISM data in the northern part of the Mawrth Vallis region, to the east of the previously known deposit reported by [1]. Evidence for jarosite rests in the rare observation of co-occurring bands at 1.9, 2.26, 2.4, 2.46, 2.52, and 2.6  $\mu\text{m}$  within CRISM image HRL285A. However, pure jarosite measured in the laboratory has a narrow spectral band at 2.26  $\mu\text{m}$  with well-defined spectral shoulders and the CRISM observation shows a wider band 2.15-2.27  $\mu\text{m}$ . We attribute this observation to the presence of admixed materials that occur with the jarosite at the scale of CRISM pixels ( $\sim 18\text{m}^2$ ). Hydrated silica is a likely candidate material that could potentially explain the observation.

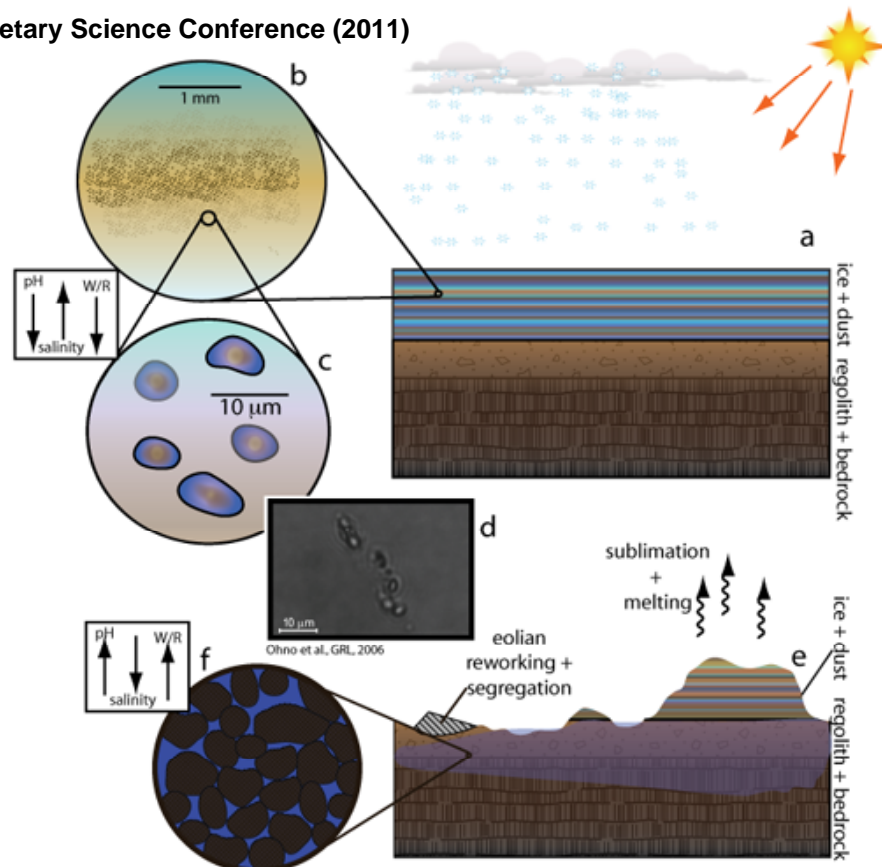
Images from the High-Resolution Imaging Science Experiment (HiRISE), Mars Context Imager (CTX), and High-Resolution Stereo Camera (HRSC) show the geologic context of the jarosite-bearing units. As is the case with the previously identified deposits of jarosite described by [1], the newly reported deposits occur within a local depression. Also similar to the previously reported results, this jarosite appears to overlie the lower Fe/Mg-smectite bearing unit and be strati-

graphically equivalent with the aluminous phyllosilicate-silica-bearing materials.

**Origin of jarosite at Mawrth Vallis:** The presence of jarosite at Mawrth Vallis implies different aqueous geochemical conditions at the time when it formed, compared to the conditions under which the vast deposit of underlying Fe/Mg smectites formed [10-13]. The younger jarosite deposits may broadly be the result of a global climate change, which may have evolved from an a phyllosilicate-forming era to a sulfate-forming era [7]. But, specific interpretations of the context of the aqueous environment in which it formed must consider the context. The geologic context of the jarosite at Mawrth Vallis, in perched topographic depressions, may present a challenge to existing ideas for sulfate formation that require upwelling of acidic groundwater [13-15]. We propose an alternative view, which is a top-down, atmospherically driven, ice weathering model for sulfate and possibly also phyllosilicate formation [16].

The ice weathering model [16] involves several key elements (Figure 1): 1) Thick deposits (10s to 1000s of meters) of ice (snow), dust, and volcanic aerosols were deposited onto a substrate consisting of either altered or unaltered Martian crust. 2) Due to freezing point depression and fed by insolation, small pockets of briny sulfuric acid form around dark dust grains; the fluids evolve to higher acidity and salinity. 3) The dust grains are aqueously altered from (mafic silicate grains + sulfuric acid) to  $\rightarrow$  (poorly crystalline silica, secondary aluminosilicates, goethite, and sulfates); while the mineralogy is completely changed, the bulk chemistry is essentially unchanged in the closed system within the ice. 4) Climate change occurs resulting net sublimation and melting; sublimation produces large piles of fine-grained, hydrated, altered sediment that is reworked by wind and meltwater. 5) Upon redeposition, the sediments partially dehydrate and undergo diagenesis which results in the formation of hematite and textural changes to the sulfate-bearing siliciclastic rock.

Jarosite in the Mawrth Vallis region could be explained by the ice weathering model if thick deposits of snow and ice were ever present in the area. A number of observations suggest that the surface was indeed resurfaced near the Noachian-Hesperian boundary [17]. In fact, the origin of the observed mineralogical stratigraphy of aluminous phyllosilicates overlying Fe/Mg-phyllosilicates [5, 18-19] seems to be linked to or postdate the resurfacing event. For example, remobilized sediments in the floor of Oyama Crater also



**Figure 1:** Schematic representation of the ice weathering model showing a) deposition of dust, ice, and volcanic aerosols on the Martian surface, which contains small pockets of acidic brine around dust grains (b-c). Such a process occurs on Earth [21], resulting in the formation of sulfates and secondary silicates within Antarctic ice (d). Basal melting of the ice could result in fundamentally different aqueous environments with neutral pH and high water/rock conditions (e-f)

contain the same mineralogical stratigraphy as in situ bedrock at higher topographic settings. More interesting is the recent results suggesting that the “aluminous phyllosilicates” may actually be a mixture of kaolinite and silica [20], both weathering products expected in acidic settings [12]. In addition to the occurrence of remobilized sediments, the presence of channels, inverted channels, and a reset cratering record all point to a major episode of resurfacing [17]. It is possible that the Mawrth Vallis region was physically resurfaced by processes associated with the past present of ice, and meltwater derived from it.

Weathering within massive ice deposits may provide a way to explain the formation of sulfates and silicates under highly acidic-saline conditions at low water/rock ratios, consistent with the conditions anticipated from sulfate chemistry and mineralogy [12-13,16]. However, if massive ice deposits existed at Mawrth Vallis or elsewhere, they may have also been linked to phyllosilicate formation. Given a sufficient thermal gradient, ice deposits would be expected to experience basal melting, which would result in the generation of dilute, neutral pH fluids that could potentially have altered the Martian crust to phyllosilicates either in the surface or subsurface environment [16]. Such a scenario should be strongly considered in contemplating the emerging picture of global Mars min-

eralogical stratigraphy, which commonly shows amorphous phyllosilicates overlying Fe/Mg-bearing smectite clays.

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