

DETAILED ELEMENTAL, MINERALOGICAL, AND ISOTOPIC EXAMINATION OF JAROSITE IN MARTIAN METEORITE MIL 03346. E. P. Vicenzi¹, M. Fries², A. Fahey³, D. Rost¹, J.P. Greenwood⁴, and A. Steele². ¹Department of Mineral Sciences, National Museum of Natural History, Smithsonian Institution, Washington, DC 20560, USA (vicenzie@si.edu), ²Geophysical Laboratory, Carnegie Institution of Washington, 5251 Broad Branch Rd NW, Washington, D.C. 20013, USA, ³Analytical Microscopy Group, Surface and Microanalysis Science Division, National Institute of Standards and Technology, Gaithersburg, MD, 20899, USA, ⁴Dept. of Earth & Environmental Sciences, Wesleyan University, Middletown, CT 06459, USA.

Introduction: Data obtained from Mars orbital missions over the last years suggest that multiple locations on the planet's surface bear evidence for ancient sulfate mineralization (1). This global view is supplemented by the outcrop-scale observations of sulfate deposits made by the Mars Exploration Rovers, particularly from X-ray and Mössbauer data, that suggest abundant Mg-sulfate and jarosite at the Meridiani Planum site (2, 3).

Until recently, jarosite $K_2Fe^{3+}_6(SO_4)_4(OH)_{12}$ has not been recognized in the SNC meteorite collection. The first reports of jarosite were based upon Raman spectroscopic and EPMA identification of micrometer-sized veinlets in the mesostasis of MIL 03346 (4,5). This follow-up study aims to characterize the microchemical and mineralogical details of the occurrence of Fe-sulfate in the MIL 03346 alteration products. Additionally, we seek to establish whether the observed jarosite was deposited as a result of Antarctic (terrestrial) or Martian secondary mineralization by way of measuring the D/H ratio of the jarosite.

Methods: We have employed several techniques to characterize sulfates in MIL 03346 including: FE-SEM backscattered electron imaging (FEI Nova NanoSEM600), X-ray spectral imaging *via* energy dispersive spectrometry (EDS: ThermoElectron NSS), full-spectrum Raman imaging (Witec α -SNOM using a 532 nm laser source), and magnetic sector secondary ion mass spectrometry (SIMS: Cameca ims 1270).

Results: BSE and X-ray spectral imaging reveals Fe-sulfate filling veinlets that range in width from sub-micrometer up to ~10 micrometers in width (**Figure 1**). We estimate the spatial resolution of our lower voltage (5-7 kV) X-ray datasets to be ~100 nm based upon the degree of sharpness of a phase edge in a sulfur K_{α} image. Although K-bearing Fe-sulfate is present, Na dominates the alkali site in most examples studied to date. This observation is bolstered by contrast noted in the 1110 cm^{-1} Raman image which suggests substitution of Na or hydronium for K in much of the jarosite (**Figure 2**).

Sulfate mineralization appears to represent the last stage of alteration of MIL 03346 and crosscuts an earlier episode of silicate veinlets. This observation is

consistent with previous elemental examinations (5, 6). (**Figure 3**).

Background subtracted/matrix corrected X-ray images reveal that some sulfate veinlets are encased by Fe-oxides/hydroxides (**Figure 4**). This result has been confirmed by Raman spectroscopy by way of spectral match to that of goethite.

We are currently analyzing the bulk D/H value for coarsely crystalline (up to 500 μm) terrestrial jarosite from the Tintic ore deposit. Once characterized, this sample will serve as an ion microprobe standard for hydrogen isotope analysis. We anticipate completion of the ion microprobe D/H spot and imaging measurements for MIL 03346 Fe-sulfate shortly thereafter.

Summary: The microbeam X-ray and Raman results suggest that Fe-sulfate in MIL 03346 is comprised of both K- and Na- (natrojarosite) jarosite. The ratio of K/Na in the alkali site is likely strongly controlled by microenvironment (the "local" igneous phase chemistry in a mesostasis pocket) if the fluid to rock ratio was low.

Veinlets lined by goethite and filled by jarosite suggest alteration of MIL 03346 shifted from pH neutral to acidic fluids during the final phase of secondary mineralization.

References:

- [1]A. Gendrin *et al.*, *Science* **307**, 1587 (2005).[2].G. Klingelhöfer *et al.*, *Science* **306**, 1740 (December 1, 2004, 2004).[3].R. Rieder *et al.*, *Science* **306**, 1746 (December 1, 2004, 2004).[4]. M. Fries, et al., (2006) Workshop on Martian Sulfates as Recorders of Atmospheric-Fluid-Rock Interactions, LPI Contribution No. 1331, 2006, p.38.,[5].C. D. K. Herd, *Meteoritics & Planetary Science*, Vol. 41, **41: A74**.[6].C. D. K. Herd, (2006) Workshop on Martian Sulfates as Recorders of Atmospheric-Fluid-Rock Interactions, LPI Contribution No. 1331, 2006, p.41, October 1, 2006 2006.

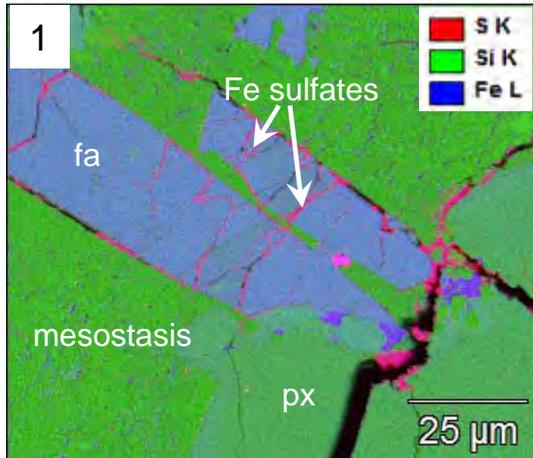


Figure 1. Composite X-ray overlay of sulfur (red), silicon (green), and Fe (blue). Purple regions represent jarosite.

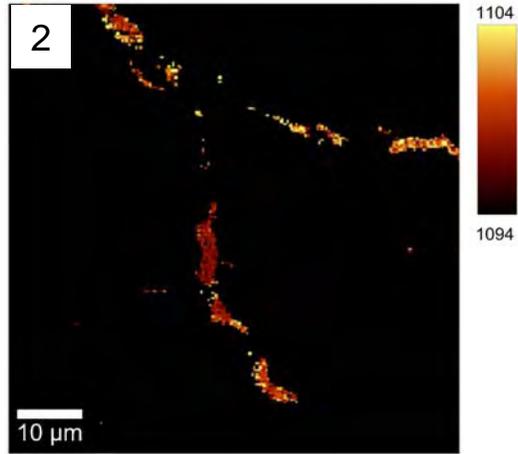


Figure 2. Jarosite ~1110 cm⁻¹Raman peak center image. Higher values represent greater K substitution by Na or H₃O.

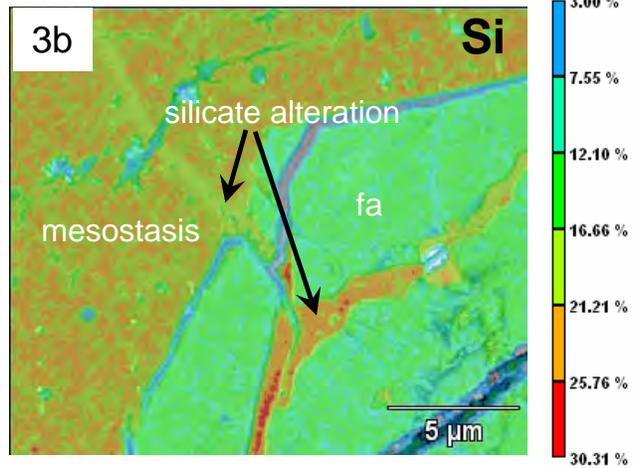
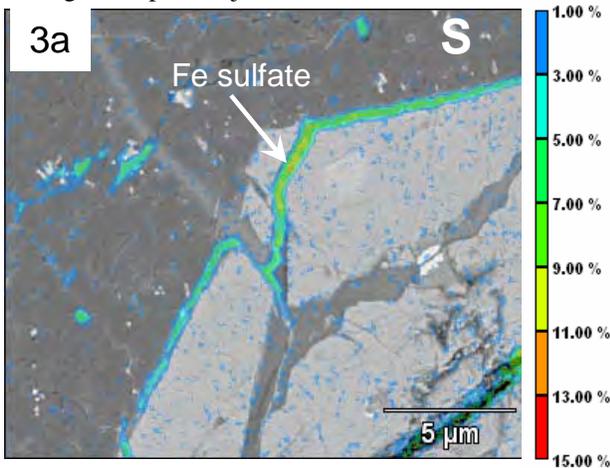


Figure 3. A) Quantified sulfur X-ray image superimposed upon backscattered electron image. B) Quantified silicon X-ray image superimposed upon backscattered electron image.

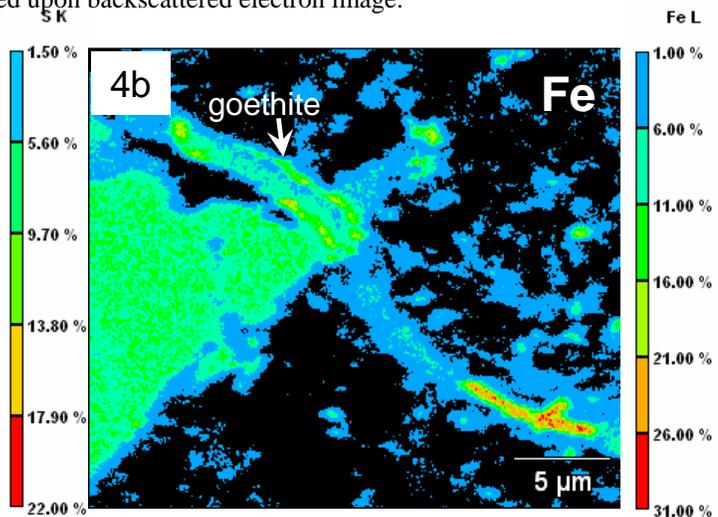
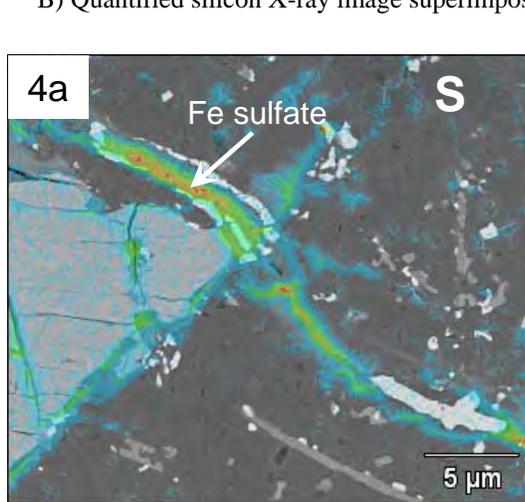


Figure 4. A) Quantified sulfur X-ray image superimposed upon backscattered electron image. B) Quantified iron X-ray image superimposed upon backscattered electron image.