

MARS EVAPORITE ANALOG SITE CONTAINING JAROSITE AND GYPSUM AT SULFATE HILL, PAINTED DESERT, AZ. S. L. Perrin^{1,2}, J. L. Bishop^{2,3}, W. G. Parker⁴, S. J. King², and B. Lafuente³, ¹Stanford University (Stanford, CA;), ²SETI Institute, (Mountain View, CA; jbishop@seti.org), ³NASA Ames Research Center (Moffett Field, CA), ⁴National Park Service (Painted Desert, AZ).

Introduction: The Painted Desert region has long been considered an analog for Mars due to wide expanses of clay-rich layers [1,2]. Here we present results on samples collected at Sulfate Hill in the Petrified Forest National Park. Gypsum is present as a component of the surface crust material, both in large tabular crystals, and in thin sheets of crystals 3-4 cm below the surface. One site also contains orange-colored jarosite-rich soil. This unique evaporate setting presents a terrestrial example of jarosite and gypsum found together. Co-occurrence of jarosite and gypsum on Mars could have formed in a similar environment.

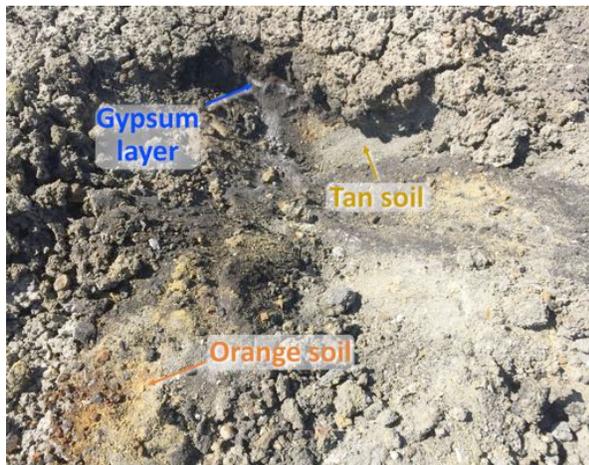


Fig. 1. Jarosite outcrop at Sulfate Hill. Gypsum crystals are found here in a thin white layer ~3 cm below the surface (image ~40 cm wide).

Methods: Visible/near-infrared (VNIR) spectra were measured in the lab using an ASD FieldSpecPro from 0.35-2.5 μm . The “Orange” and “Tan” samples were gently crushed and dry sieved to <125 μm and 125-1000 μm for this study. The white gypsum flakes of thin crystals were measured without grinding or sieving. Multiple spectra were acquired for each sample in a black Teflon dish and averaged to generate the spectra presented here. Particulate 45-125 μm fractions of each sample were measured by XRD showing that the gypsum flakes are nearly pure, the orange soil contains about half natrojarosite (+gypsum, quartz, montmorillonite), and the tan soil contains quartz, gypsum and montmorillonite.

VNIR Spectra of Sulfate Hill Samples: VNIR spectra of these samples are shown in Fig. 2. The spectrum of the “Orange soil” sample is characteristic of

jarosite/natrojarosite with bands at 0.44, 1.47, 1.85, 2.22, and 2.26 μm [3]. Additional bands near 1.41 and 1.91 μm are likely due to montmorillonite. The Fe band is observed at 0.88 μm , which is a shorter wavelength than jarosite, indicating the presence of another Fe^{3+} -bearing phase. The spectra of both grain sizes are similar, but the <125 μm sample spectrum is brighter and has stronger bands due to jarosite. This indicates that jarosite is not just a fine-grained alteration rind on coarser grains, but is present throughout the sample, although more dominant in the fines.

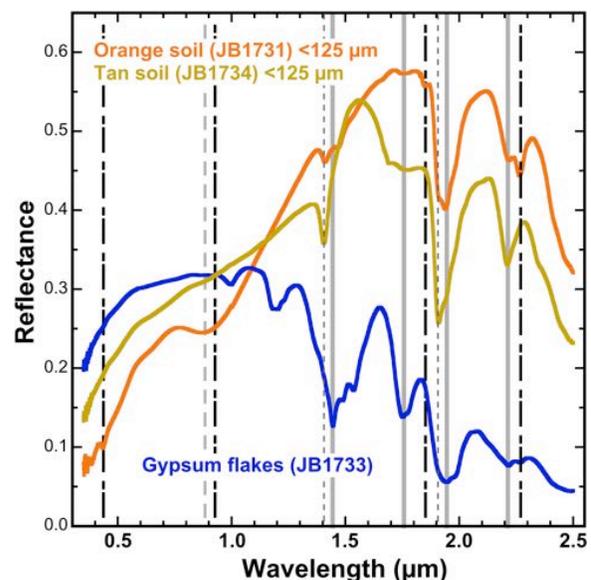


Fig. 2. VNIR spectra of Sulfate Hill samples. Spectral features due to gypsum are marked by grey solid lines, due to jarosite by broken black lines, due to montmorillonite by dotted grey lines, and due to another Fe^{3+} phase by broken grey lines.

VNIR spectra of the “Tan soil” sample contain features at 1.41, 1.91, and 2.21 μm that are characteristic of the phyllosilicate mineral montmorillonite [4]. An additional band near 1.76 μm is consistent with some gypsum in this sample. Spectra of both grain sizes are similar, although the montmorillonite bands are stronger in the <125 μm sample. XRD on the 45-125 μm fraction indicates less montmorillonite than quartz and gypsum, likely because the phyllosilicate is concentrated in the fines.

The spectrum of the “Gypsum flakes” sample contains multiple features consistent with gypsum including a strong triplet at 1.45, 1.49, and 1.52 μm , a band

at 1.76 μm and a doublet at 2.22 and 2.26 μm [5]; however, the spectrum is not as bright as expected for pure gypsum (Fig. 3). As XRD shows this sample to be 99% gypsum, the flakes may have been too thin to fully absorb the light from the spectrometer.

VNIR Spectra of Mineral Mixtures: In order to better understand natural samples containing both gypsum and jarosite, a mixture of these two minerals was prepared in the lab. Spectra of the jarosite and gypsum endmembers and their mixture illustrate how the overlapping bands are affected (Fig. 3). The jarosite spectrum has bands at 0.44 and 0.93 μm due to Fe^{3+} electronic transitions. The 0.92 μm band broadens only slightly for the jarosite/gypsum mixture at the long wavelength edge because of a contribution from the H_2O overtone in the gypsum spectrum at 1.00 μm .

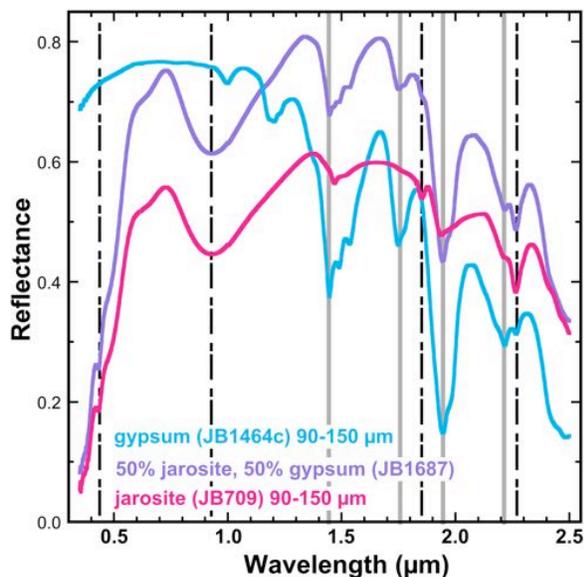


Fig. 3. VNIR spectra of jarosite, gypsum and a mixture containing 50 wt.% of each sulfate mineral. Spectral features due to gypsum are marked by grey solid lines and due to jarosite by broken black lines.

The mixture spectrum contains 4 overlapping bands near 1.5 μm due to a combination of the gypsum H_2O stretching overtone triplet and the jarosite OH stretching overtone at 1.47 μm . The gypsum band at 1.75 μm is weaker in the mixture spectrum, but the shape is the same, while the jarosite band at 1.85 μm is only present as a shoulder in the 50/50 wt.% mixture spectrum. Comparing this observation with the “Orange soil” spectrum (Fig. 2), where the band at 1.85 μm is weak but clearly defined, is consistent with greater jarosite than gypsum in that sample. The gypsum H_2O combination band at 1.94 μm is similar, but weaker in the mixture spectrum (Fig. 3). Pure anhy-

drous jarosite does not have a band here, but frequently water is partially bound in jarosite as H_3O^+ , giving a band at a similar wavelength.

OH combination bands are present at 2.22 and 2.26 μm in spectra of both gypsum and jarosite, but these bands have different relative intensities in spectra of each mineral. The spectrum of gypsum has a stronger band at 2.22 μm and a weaker band at 2.26 μm , while jarosite has a stronger band at 2.26 μm with a shoulder at 2.22 μm (Fig. 3). The mixture spectrum exhibits a doublet here with a stronger band at 2.26 μm but a clearly distinguishable band at 2.22 μm . This is very similar to bands observed in the “Orange soil” spectrum (Fig. 2) for ~52% natrojarosite, ~26% gypsum and ~21% quartz by XRD.

Implications for Mars: This study provides insights for identification of jarosite- and gypsum-bearing samples on Mars using VNIR spectra, and provides a terrestrial example of a salty, evaporate environment containing both of these sulfate minerals. Traditionally, gypsum forms in neutral environments [6] and jarosite/natrojarosite in low pH environments [7]; however, these minerals have been found together where high S and Cl levels are present [8-9]. The Painted Desert Sulfate Hill site in the Petrified Forest National Park provides another example of co-existing jarosite/natrojarosite and gypsum.

This study shows that VNIR spectra of jarosite-bearing samples can be identified through the presence of bands at 1.85 and 2.26 μm . The 1.85 μm band is difficult to detect for 1/1 jarosite/gypsum mixtures, but clearly evident for 2/1 jarosite/gypsum mixtures. The doublet at 2.22 and 2.26 μm could be due to gypsum or combinations of other minerals and is a less certain indicator of jarosite without the 1.85 μm band. Thus, remote detection of jarosite/natrojarosite on the Earth or Mars is more accurate using a combination of the 1.85 and 2.26 μm bands.

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