Ferric and Mixed Ferric/Ferrous Sulfates in the Northern Mawrth Vallis Region of Mars

W.H. Farrand[1], T.D. Glotch[2], and B. Horgan[3]
1. Space Science Institute, Boulder, CO; farrand@spacescience.org
2. Stony Brook University, Stony Brook, NY
3. Purdue University, W. Lafayette, IN

1) Introduction.

The Mawrth Vallis region hosts extensive exposures of phyllosilicate-bearing outcrops [1 – 4] and has been proposed as a site for rover exploration. The ferric sulfate jarosite has been observed in isolated exposures in northern Mawrth Vallis (**Fig. 1**) near the top of the stratigraphic section [5, 6] and in association with scattered exposures of an “acid-leaching product” phase [7]. The CRISM “SINDX” parameter is a measure of the convexity of spectra at 2.29 μm and can be an indication of the presence of sulfate minerals. Across the northern Mawrth Vallis region there are scattered areas with high values of the SINDX parameter in a number of scenes (**Fig. 2**). Some of these high SINDX areas also exhibit an absorption near 2.4 μm. The sulfate library spectra in **Fig. 3** also have an absorption near 2.4 μm. We have examined [8] a number of CRISM scenes over northern Mawrth Vallis in order to determine what mineralogic phase or phases might be responsible for the high SINDX values.

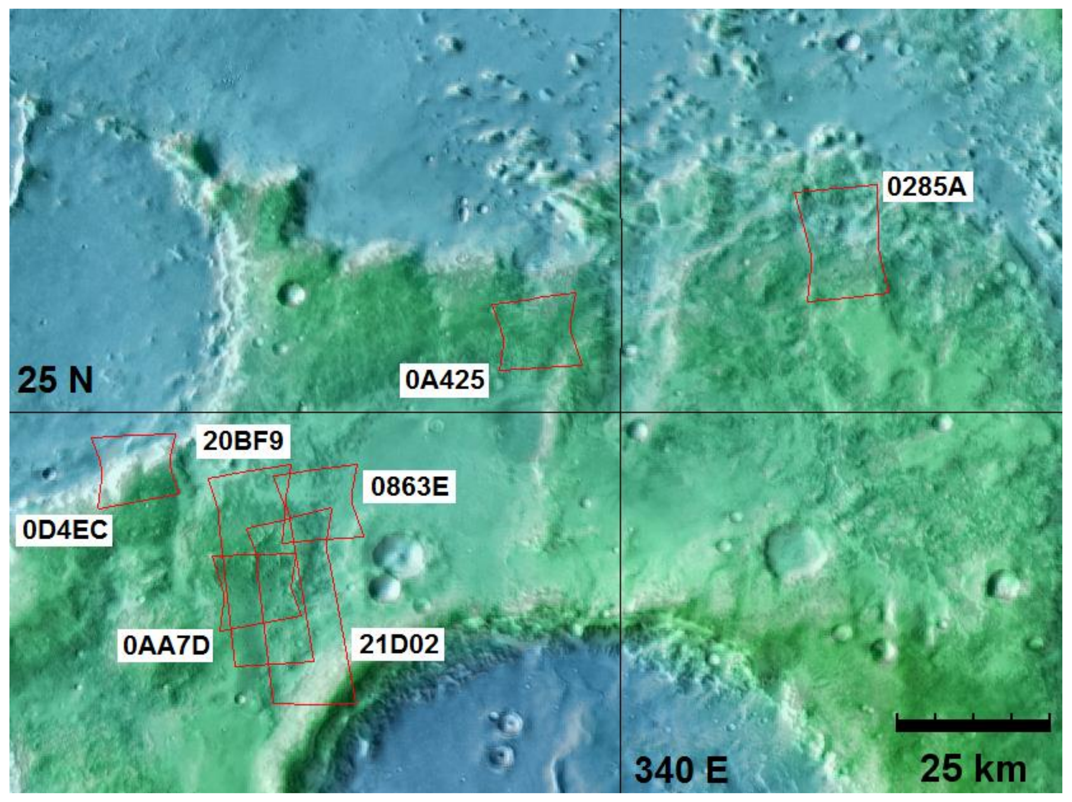

Fig. 1. Northern Mawrth Vallis region considered in this study with outlines of primary CRISM scenes.

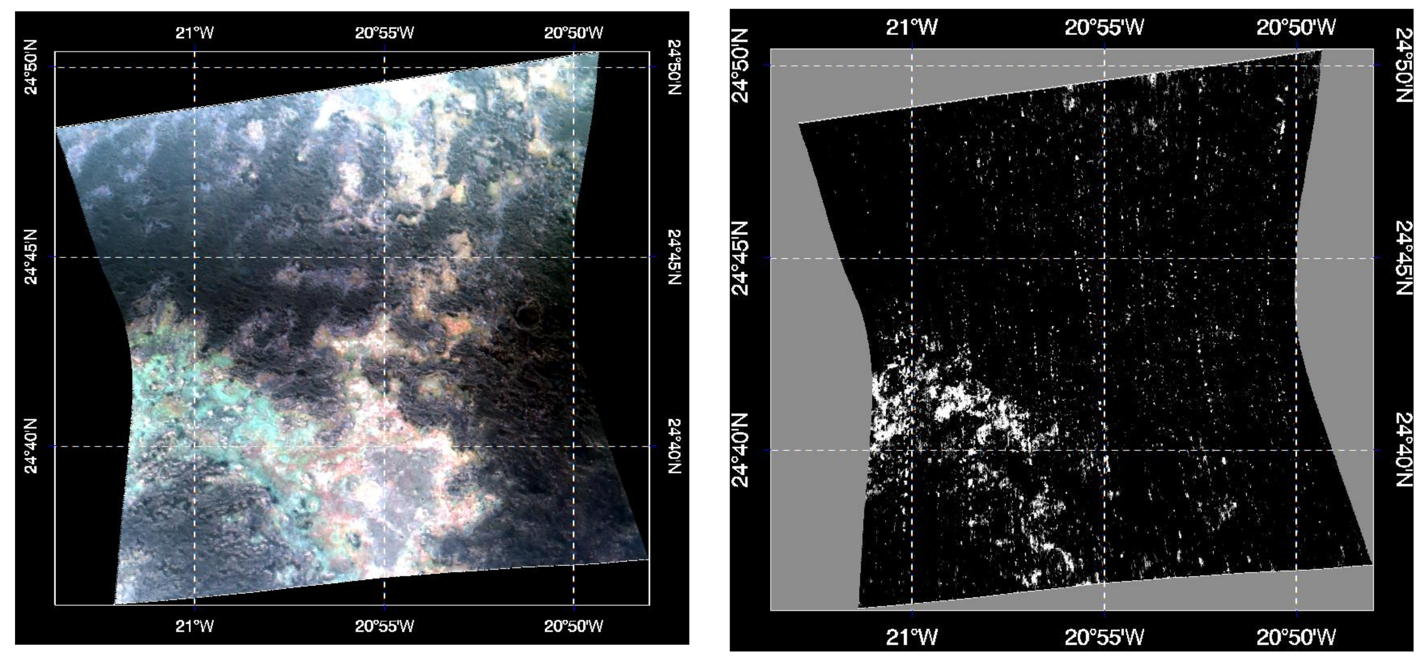

Fig. 2. (**A**) Composite of CRISM scene FRT 863E with bands centered at 2.5, 2.5, and 1.08 μm. (**B**) SINDX parameter image of FRT 863E showing high SINDX material occurring in association with parts of Al phyllosilicate unit (cyan in **Fig.2A**).

2) CRISM Data.

Atmospheric correction of CRISM near IR “L” spectrometer scenes was performed using the “volcano scan” approach resident in the CRISM Analysis Tools (CAT) software package. Spectra of specific regions of interest were divided through by spectra of spectrally neutral areas in the same column. Visible to near IR “S” spectrometer data were also divided through by spectrally neutral areas in the same detector columns.

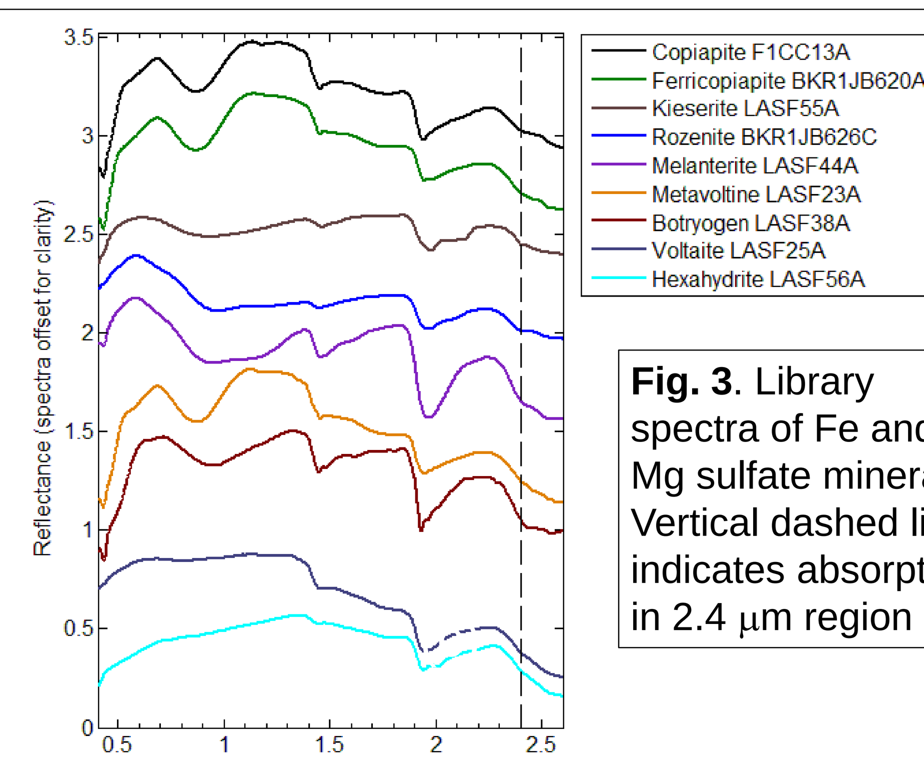

Fig. 3. Library spectra of Fe and Mg sulfate minerals. Vertical dashed line indicates absorption in 2.4 μm region

3) More Jarosite Exposures.

Examination of the scenes in **Fig. 1** indicated a pair of regions with jarosite spectra in the scene FRT 20BF9 (**Fig. 4A**). A region of interest (ROI) spectrum from one of these exposures is compared against a library jarosite spectrum in **Fig. 4B** and **C**.

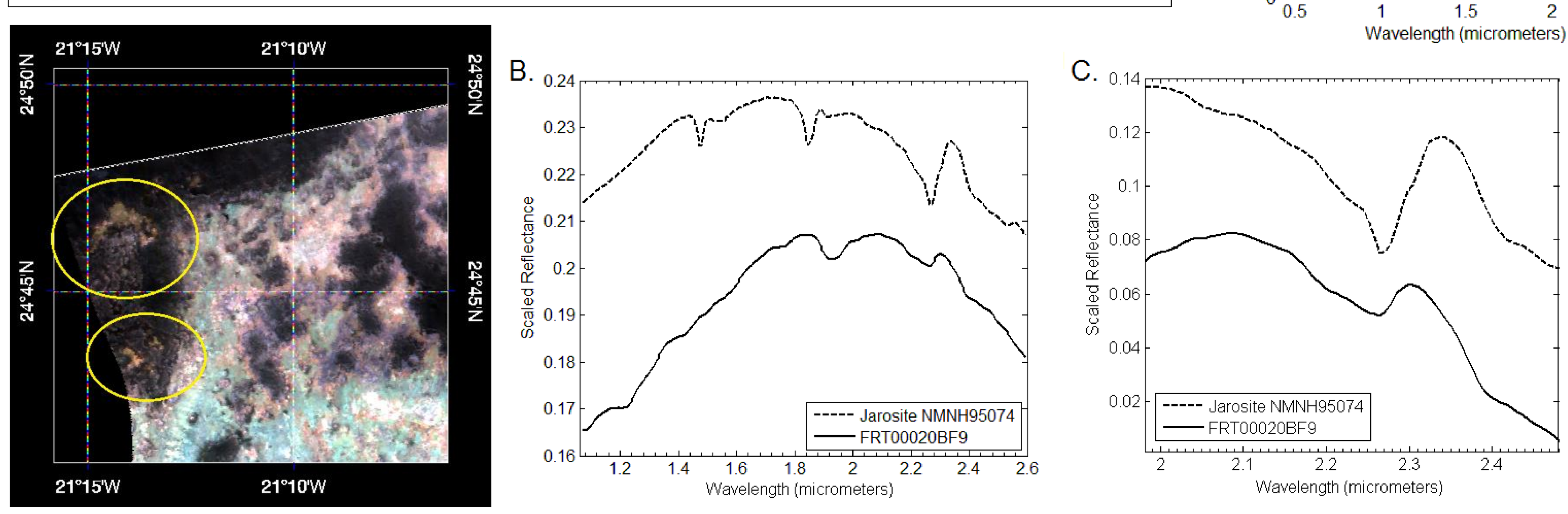

Fig. 4. (**A**) Subset of CRISM scene FRT 20BF9 with jarosite-bearing areas circled. (**B**) CRISM spectrum of jarosite-bearing area from FRT 20BF9 over the 1 to 2.6 μm range with a library jarosite and in (**C**) the 2.26 μm region is enlarged with the diagnostic jarosite 2.265 μm band. Spectra have been smoothed with a Lowess filter.

4) High SINDX Areas: NIR spectral features.

CRISM spectra of high SINDX areas from the scenes HRL 43EC and FRT AA7D are shown in **Fig. 5**. There are weak spectral features in the 2.3 to 2.6 μm range which are accentuated by removing the continuum in this region. These are highlighted by the vertical lines in **Fig. 5C**.

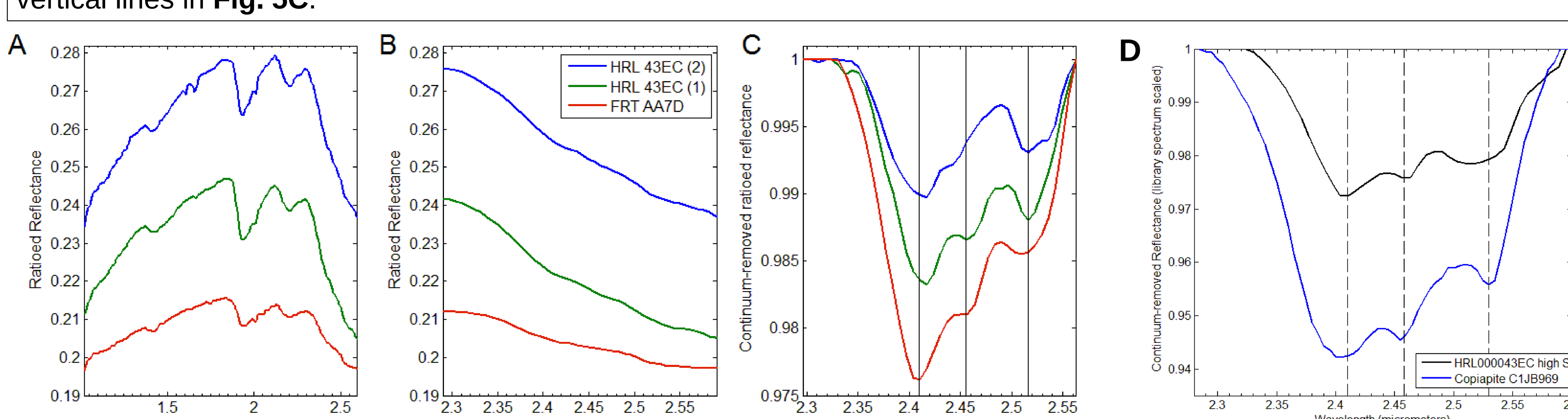

Fig. 5. (**A**) CRISM spectra of high SINDX areas from the HRL 43EC and FRT AA7D scenes over the 1 to 2.55 μm range. (**B**) Subsection over the 2.3 to 2.59 μm range. (**C**) Continuum-removed version of the spectra with vertical lines highlighting absorption features. (**D**) Comparison of HRL 43EC spectrum with library copiapite.

5) High SINDX Areas: VNIR spectral features.

VNIR spectra of high SINDX areas from several CRISM scenes are shown in **Fig. 6A** and for jarosite-bearing areas from FRT A425 [5] and from FRT 20BF9 are in **Fig. 6B**. Although the SNR of the data is reduced at shorter wavelengths, the high SINDX spectra appear to have a short absorption near 0.43 μm and a wider band centered from 0.86 to 0.9 μm (vertical dashed line) in **6A**). Using merged data from the CRISM “S” and “L” detectors, a high SINDX area from HRL 43EC and the jarosite-bearing area in FRT 20BF9 are shown over the full range (**Fig. 6A**), the 0.4 to 1.25 μm range in (**Fig. 7B**), and the 0.65 to 1.2 μm range in **Fig. 7C** and **D**. Clearly, the high SINDX areas examined here represent a mineral phase distinct from the jarosite-bearing areas.

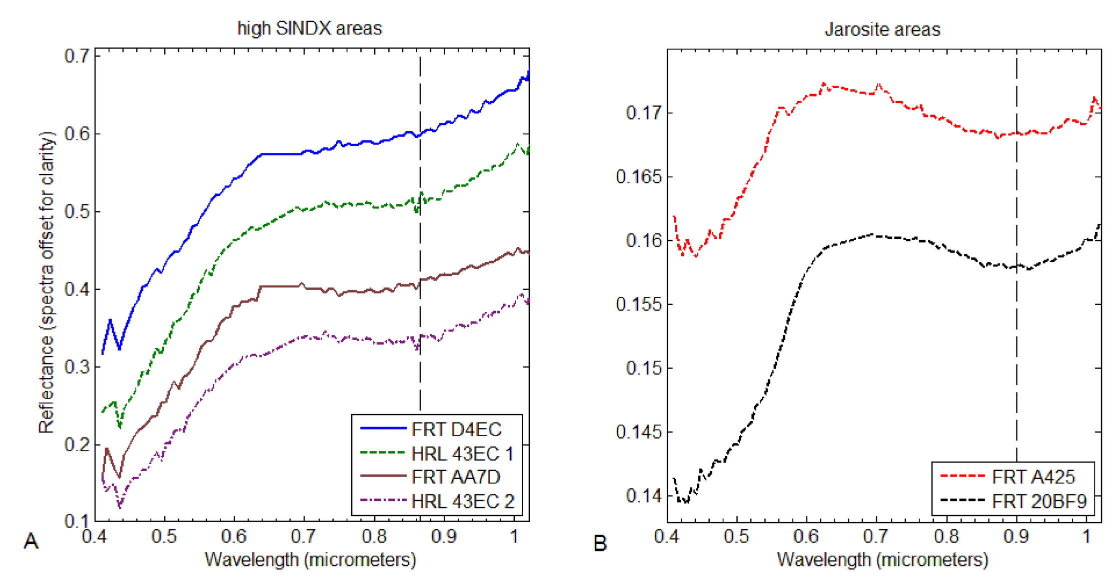

Fig. 6. (**A**) CRISM “S” detector spectra of high SINDX areas from several CRISM scenes. (**B**) CRISM “S” detector spectra of jarosite-bearing areas from FRT A424 and 20BF9.

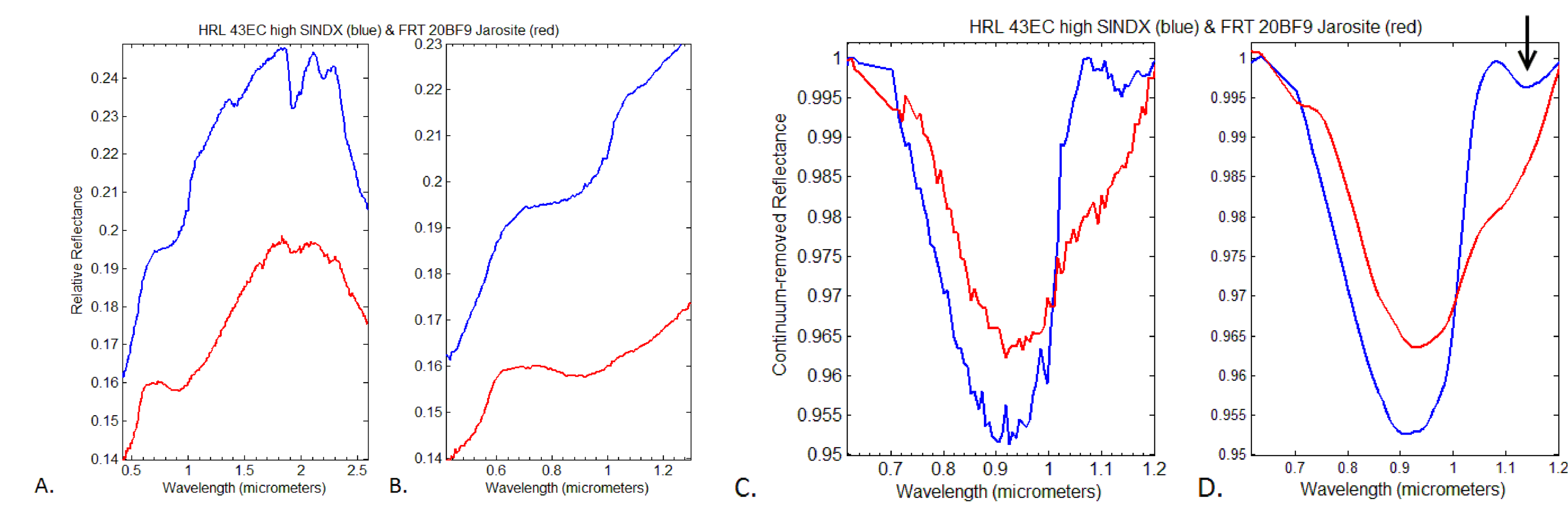

Fig. 7. (**A**) Full range spectra of high SINDX ROI from HRL 43EC and jarosite area from FRT 20BF9. (**B**) Focus on the 0.4 to 1.25 μm range. (**C**) Unsmoothed, continuum-removed spectra over the 0.65 to 1.2 μm range. (**D**) Lowess smoothed version of the **Fig. 7C** spectra. Arrow marks 1.15 μm ferrous iron band.

6) Discussion.

As shown in **Fig. 5D**, the triplet absorption in the 2.3 to 2.6 μm region is a good match to copiapite ($Fe^{2+}Fe^{3+}{}_4(SO_4)_6(OH)_2) \cdot 20(H_2O)$). Likewise, the presence at 1.15 μm of a minor absorption is a near match to a Fe^{2+} band in copiapite observed near 1.17 μm [9]. Thus our interpretation is that the phase observed in the examined high SINDX areas is copiapite. The copiapite has patchy occurrences on top of the Al phyllosilicate unit and we interpret its presence as evidence of acid sulfate alteration at the top of the Mawrth Vallis stratigraphic sequence; potentially caused by weathering of Fe sulfide minerals by a fluctuating ground water table [10].

7) Conclusions.

- There are a number of occurrences of high values of the SINDX parameter in CRISM scenes covering the northern Mawrth Vallis region
- These high SINDX areas can be associated with absorptions in the 2.4 μm region
- In the FRT 20BF9 scene, additional exposures were found of jarosite-bearing materials, like that described in the FRT A425 scene by [5].
- In the VNIR, these high SINDX areas have absorption features with centers near 0.43, 0.86 to 0.9 μm, and near 1.15 μm
- The VNIR absorption features and the triplet absorption in the 2.4 μm region are a match for the mixed ferrous/ferric sulfate mineral copiapite
- Copiapite forms in acidic conditions and its presence here is evidence of acid sulfate weathering at the top of the Mawrth Vallis stratigraphic sequence, consistent with the scenario described by Horgan et al. [10].

References: [1] Bibring J.-P. et al. (2005) *Science*, **312**, 400–404. [2] Michalski J.R. and E.Z. Noe Dobrea (2007) *Geology*, **35**, 951–954. [3] Bishop J.L. et al. (2008) *Science*, **321**, 830–833. [4] Loizeau D. N. et al. (2010) *Icarus*, **205**, 396-418. [5] Farrand, W.H. et al. (2009) *Icarus*, **204**, 478-488. [6] Michalski, J.R. et al. (2013) *Icarus*, **226**, 816-840. [7] Noe Dobrea, E.Z., et al. (2011) *Mars*, **6**, 32-46. [8] Farrand, W.H. et al. (2014) *Icarus*, in press, doi:10.1016/j.icarus.2014.07.003. [9] Cloutis, E. A. et al. (2006) *Icarus*, **184**, 121-157. [10] Horgan, B. et al. (2014) This meeting, abstract #1276.

Acknowledgements: The initial portions of this work were funded through the NASA Mars Data Analysis Program.