HARD LESSONS FROM A MARS ANALOG SITE (MINERAL PARK COPPER MINE): LEARNING TO COMBINE NEAR- AND THERMAL-INFRARED SPECTRAL INTERPRETATIONS FOR MARS. L. E. Kirkland[1,2], K. C. Herr[1], P. M. Adams[1], and B. M. Staab[1], [1]The Aerospace Corporation, kirkland@lpi.usra.edu; [2]Lunar and Planetary Institute, Houston.

Introduction: A common question in Mars remote sensing is why interpretations of data sets that are measured of reflective vs. emissive wavelength regions differ, for example, CRISM or OMEGA vs. TES. Part of the uncertainty is because of the dearth of hyperspectral imagery measured of terrestrial targets that cover both the reflective range (~0.4–2.5 µm) and the emissive range (~7.5–13 µm). Here we present results to bridge that gap via airborne hyperspectral imagery measured of 0.4–2.5 µm (reflective) and 7.5–13 µm (emissive) ranges. This abstract presents data imaged of a site ("Mineral Park") that shows poor agreement between the spectral ranges; conversely, a second LPSC abstract shows a site ("Alunite") that shows good agreement.

Results from Mineral Park are (1) standard laboratory spectra described as jarosite do not match the airborne spectra, even though jarosite is expected at this Arizona copper mine; (2) interpretations of the different wavelength ranges are inconsistent; and (3) information from ground samples will be necessary in order to understand the data. Conversely, results of the Alunite study are (1) the alunite, quartz, and gypsum materials exhibit bands in the airborne data as laboratory data would suggest; (2) interpretations of the different wavelength ranges compare well; and (3) we do not require ground samples to state with reasonable confidence that alunite is present at this site.

Data sets: The overall project goal is to investigate data sets that cover the "full spectrum," that is, the full optical range possible within the Earth's atmospheric windows. The Aerospace Corporation is a Federally Funded Research and Development center (FFRDC) tasked with developing advanced technology, including hyperspectral imaging. Aerospace funded flights of two hyperspectral instruments in May 2006 at a variety of geologic sites in Arizona, California, Nevada, and Utah. The spectral imagers are SpecTIR (~0.4–2.5 µm, 227 bands) and SEBASS (~3–5 µm and ~7.5–13 µm, 256 bands). The imaging spectrometers flew on separate planes. They imaged the Mineral Park copper mine nearly simultaneously on 1 May 2006, at 2 m spatial resolution.

Table 1 lists the different spectral ranges, and illustrates that the physics differ in both the cause of the spectral bands and the signal source. Those differences can cause the spectral behavior to differ at different wavelengths even for the same mineral target. In addition, opacity broadly increases with wavelength, so that for a given material, shorter wavelengths generally sample farther into the material than at longer wavelengths. That penetration depth difference can be especially important when coatings are present. The opacity difference can also impact scattering, and thus the observed spectral signatures, especially for fine, unconsolidated targets.

Mineral Park site: We measured hyperspectral imagery of the Mineral Park copper mine (Fig. 1), which is ~10 miles northwest of Kingman, Arizona (35°21'44.0"N, 114°8'46.5"W). We chose this site because jarosite can exhibit distinct spectral features over multiple spectral ranges. Also, hyperspectral identification of jarosite is of interest for Mars [1]. On Earth, jarosite may form in hydrothermally altered volcanics, acid mine drainages, and acid salt lakes [1,2].

Table 1: The Four Primary Spectral Regimes

Spectral Range	Primary Cause of Bands	Signal Source
1. VIS/NIR ~0.35–1.2 µm	Electronic transfer & ligand field	Solar
2. SWIR ~1.2–2.5 µm	Overtone	Solar
3. Mid-IR ~3–5 µm	Overtone	Solar & Emission
4. TIR ~7–13 µm	Fundamental	Emission

Key: VIS/NIR=visible and near-infrared; SWIR=short-wave infrared; Mid-IR=mid-infrared; TIR=thermal-infrared. The categories are a broad guide, and there is some cross-over.

Results: Fig. 2 and Fig. 3 compare representative SEBASS and SpecTIR signatures with laboratory signatures. In order to replicate mapping approaches for Mars, we used standard laboratory signatures for the SEBASS and SpecTIR mapping (USGS, ASU, and ASTER spectral libraries) Reference [3] shows other example laboratory spectra.

Neither the long nor short-wave airborne spectra match the selected laboratory spectra of jarosite. That result suggests that either (1) the material (airborne or lab or both) is not jarosite or (2) it is a form of jarosite (e.g., a coating) such that the signature differs from the larger crystals measured in the laboratory. For example, if the jarosite is a thin coating, then the jarosite may be transparent at some wavelengths. Alternatively, if the jarosite is present as fine, unconsolidated particles, then the scattering properties will differ, which can alter the spectral band shape. Also, the SpecTIR 2.2 µm band does not show a clear correlation with the

SEBASS 9.5 µm doublet, making it unclear whether jarosite causes the SpecTIR 2.2 µm band. Conversely, the lack of a 2.3 µm jarosite band in SpecTIR data makes it less certain whether jarosite causes the 9.5 µm doublet in corresponding SEBASS spectra.

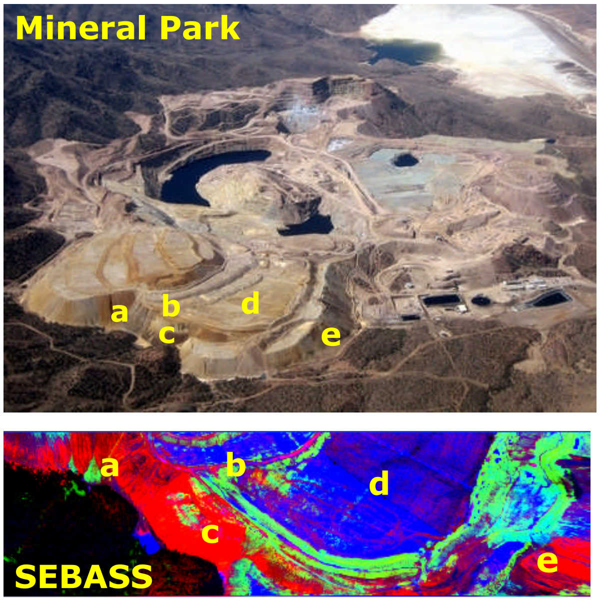

Fig. 1: Mineral Park site, May 2006, visible image (upper) and part of a SEBASS mapping image (lower). The letters reference the same locations in each image. The letter "e" marks the SEBASS and SpecTIR spectrum location shown in Figs. 2 and 3. The SEBASS image is color-coded so that red maps the 9.5 µm doublet (Fig.2); green maps a coarse quartz signature; and blue maps a narrow 9 µm SEBASS band of a currently unidentified material.

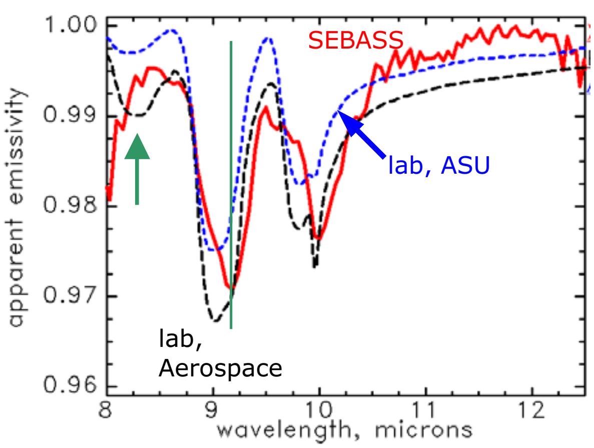

Fig. 2: SEBASS vs. lab spectra. Note that the band centers are offset relative to the laboratory samples (as marked by the green vertical line at 9.2 µm), and that the SEBASS signature does not exhibit a clear band at ~8.2 µm while the laboratory spectra do (green arrow). Sample *lab-Aerospace* is sample "cuprite3 on rhyolite", collected by P. Adams at Cuprite and measured at The Aerospace Corporation laboratory; *lab-ASU* is "jarosite S51" from the ASU on-line spectral library; *SEBASS* is x658/y40, May 2006, shot 060501_133646. The "e" in Fig.1 marks the SEBASS spectrum location.

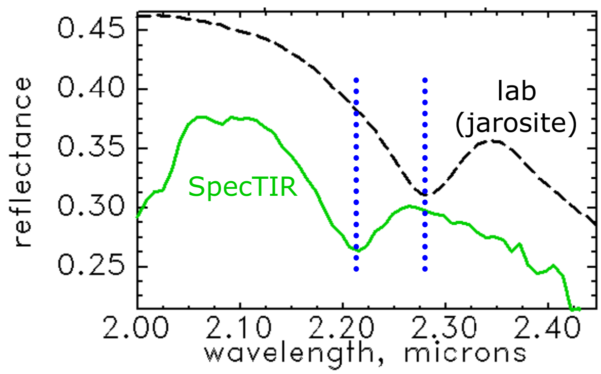

Fig. 3: Example SpecTIR signature from Mineral Park. The band centers differ significantly (blue, vertical dashed lines). SpecTIR sample is from May 2006, shot 009-001, x68/y861. "Lab" is from the ASTER library, "jarosite so-7a", offset -0.15 for clarity.

Conclusions: Sometimes interpretations are hard, even on Earth. Field experience such as at Mineral Park illustrates that we should approach interpretations of similar Mars data sets with due caution. Issues important for Mars that this study highlights include (1) If we had only the SpecTIR (Mars OMEGA/CRISM-analog) data, then we might conclude that a clay is present, but no jarosite; (2) If we had only the SEBASS (Mars TES-analog) data, then we might tentatively conclude that a form of jarosite is identified at this site; (3) We do not know from the remotely sensed data alone what these spectral features actually identify.

We need to build a field foundation in order to interpret combined reflective and emissive data of Mars accurately. The next steps in our Mineral Park study are to (1) Measure XRD of site samples in order to determine what materials are present. We undertake the XRD step after a preliminary examination of the airborne data in order to force our perspective to parallel remote sensing of Mars or any denied sites; (2) Examine airborne data of other regions at the mine; and (3) Further examine what correlations exist between features in the emissive and reflective wavelength regions.

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References: [1] Benison and Bowen (2006) *Icarus 183*, 225-229. [2] Dill (2001) *Earth-Sci. Rev. 53*, 35-93. [3] Cloutis et al. (2006) *Icarus 184*, 121-157.