

MARS ANALOG FIELD INFRARED SPECTROSCOPY AT ALUNITE, CLARK COUNTY, NV: COMPARISON WITH EDXS. N.G. Heavens¹, L. E. Kirkland^{2,3}, P. M. Adams³. ¹Department of the Geophysical Sciences, University of Chicago, 5734 S. Ellis Ave., Chicago, IL, 60637 (heavens@uchicago.edu); ²Lunar and Planetary Institute, kirkland@lpi.usra.edu; ³The Aerospace Corporation.

Introduction: There is an active and robust literature that compares the results of laboratory infrared spectroscopic measurements with results from other analytical methods, e.g., [1] [2] [3]. However, there have been very few studies that compare the results of measurements by ground-based field instruments such as the MER flight instrument, Mini-TES, with ground truth [4]. There is consensus in the planetary spectroscopy community [5] that studies are vitally needed to “test remote sensing interpretations against results from field research” [4].

Here we interpret the results of spectroscopic measurements of a single outcrop using a Mini-TES-like instrument, compare it with energy dispersive X-ray spectroscopy (EDXS), X-ray diffraction (XRD), and backscattered electron (BSE) images of samples collected from the measured site (“ground truth”), analyze the discrepancies between the methods, and propose a measurement protocol that could eliminate some of those discrepancies.

Site Measured and Instrumentation: The Alunite Mining District is located in Clark County, Nevada, 10 km. SE of Henderson (approx. 35.98234° N, 114.90600° W). A basic summary of the local geology and mining history of the area is given in [6]. The site measured is about 200 m. east of the parking lot of the Railroad Pass Hotel and Casino. Photographs taken of the site suggest that it consists of a hill made up of: (1) talus at the bottom of the hill adjoining active railroad tracks; some of the talus is man-made or transported from other sites, (2) a thick layer of white material in the middle of the hill exposed during the construction of the railroad (“the white railroad cut”), and (3) colluvium at the top of the hill. The talus and colluvium consist of boulder to sand-sized or finer material. The white railroad cut appears to consist of sand-sized or finer material.

In July of 2004, we made field measurements using Tonka, which has a Model 100 (M100) Block Engineering Fourier transform interferometer spectrometer. Mini-TES raster scans images, and the M100 is the only similar thermal infrared hyperspectral raster scanner used for Mars analog studies. It measures with the highest fidelity to Mini-TES of any field instrumentation available [7].

In August of 2004, the colluvium and the white railroad cut were sampled. These samples were imaged by BSE in the SEM and the elemental abundances and mineral content of “sites of interest” were measured using EDXS and XRD.

Procedure for Spectroscopic Analysis: The field measurements were processed and corrected for atmospheric downwelling radiance and then output as separate bands at 4 cm⁻¹ intervals.

We identified two kinds of spectra, “type spectra” that are representative of most of the spectra measured and “key spectra” that are rare and exhibit especially deep and well-defined reststrahlen bands. (An unstated assumption of many spectroscopy studies is that these strong bands indicate high abundances of a particular geologic material, though it is sometimes admitted that the physical properties of a material more than its abundance control the band strength and contrast of its spectral signature [8] [9].) Then using both published [10] and our own libraries of laboratory spectra, preliminary identifications were made.

To map the presence of minerals in the scene, we used the minerals preliminarily identified in the cut and the colluvium to construct a linear mixture model. We obtained a fairly stable model using 45-125 μm. gypsum from the ASTER Library, Quartz 1.f (0-74 μm.) from the JHU Library, and “purple platy alunite” [KAl₃(SO₄)₂(OH)₆] from Paul M. Adams’ Cuprite library, fitting to the measured spectra on the interval from 748 to 1253 cm⁻¹ to avoid strong atmospheric bands and disregarding model values smaller and larger than +/- 10% to allow for non-linear mixing and scattering effects.

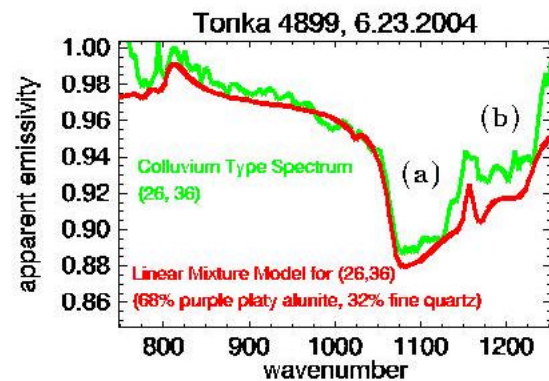


Figure 1: Colluvium Type Spectrum Compared with the Linear Mixture Model: Green trace is a typical measured spectrum from the colluvium. Red trace is our linear mixture model result for this spectrum.

Spectroscopic Identifications of Minerals: Based on spectra that exhibited clear spectral bands, the talus contains the minerals quartz and dolomite. Comparison of photography with the measured spectra indicates that these minerals are most clearly present in boulder and cobble-sized material.

The white railroad cut has a type spectrum that has an absorption band centered near 1150 cm⁻¹. This spectrum

can be modeled as a mixture of 10-30% of the selected gypsum laboratory spectrum band depth and 70-90% of the selected quartz laboratory spectrum band depth.

The colluvium has a type spectrum with a primary absorption band centered near 1100 cm^{-1} with shoulders at 1053 and 1150 cm^{-1} (marked (a) in Figure 1) and a secondary band centered near 1195 cm^{-1} and shoulders at 1150 and 1230 cm^{-1} (marked (b) in Figure 1). The two major absorption bands of the type spectrum match a mixture of 30-80% of the selected alunite laboratory spectrum band depth and 20-70% of the selected quartz laboratory spectrum band depth.

It is difficult to determine with remote infrared spectroscopy whether alunite, quartz, or gypsum are present in bulk or as coatings. The available library spectra for sulfates do not have spectral features that are known to distinguish coatings from bulk materials.

It is important to recognize that a mineral could be present in the scene that is not identifiable in the measured spectra for four reasons. First, a mineral with a similar spectrum to gypsum or alunite, for example, could be present in the scene but not in the libraries used. Second, a mineral could be present that does not have absorption bands in the portion of the spectrum measured (e.g., halite). Third, scattering effects can reduce the spectral band contrast to the point that the bands are undetectable. Fourth, scattering effects alter band shape.

EDXS and BSE Analysis:

Colluvium: EDXS indicates that samples of weathered surfaces from the colluvium contain jarosite, alunite, and potassium feldspar with accessory quartz. In our samples, jarosite and alunite are generally present together (either as a mixture of pure minerals or as a mineral of intermediate composition due to Fe-Al simple substitution) within ubiquitous bulbous material of a few μm . in diameter or trigonal bipyramidal grains and hexagonal platelets of about $10\text{ }\mu\text{m}$. in diameter. Potassium feldspar is less abundant and is present in more or less "rotten" tabular laths of $100\text{-}200\text{ }\mu\text{m}$. in length.

White railroad cut: XRD of the white railroad cut samples indicates they contain gypsum, quartz, and probably clays. EDXS measurements of samples from the colluvium just above the cut indicate they contain quartz, jarosite, alunite, and probably clays.

Discrepancies Between Spectroscopic Identifications and Ground Truth: The infrared spectral identifications of gypsum and quartz in the white railroad cut and alunite and quartz in the colluvium were confirmed by XRD or EDXS. However, XRD and EDXS indicate a significant presence of other minerals, even though we see no clear indication of them in the Mini-TES analog spectra. Most surprising is the strong gypsum infrared signature in the cut, when visual inspec-

tion indicates that the cut probably has no more than ~5-10% gypsum present.

The failure to identify the accessory minerals in the Mini-TES analog data is either due to the lack of identifiable spectral features in many of their thermal infrared spectra or their low concentrations.

One logical measurement protocol to detect the "spectrally missing" materials would be to measure at a smaller pixel size to increase the probability of an optically smooth grain in a pixel and decrease the probability that an optically rough grain would dominate a pixel. However, the difficulty with that line of reasoning is that rough materials may lack spectral features even for full pixel coverage. For example, neither field measurements with a handheld spectrometer nor laboratory measurements of samples from the site detected bands associated with the other minerals present.

While higher spatial resolution with the spectrometer would apparently not have been helpful, microscopic imaging of the site (e.g. BSE, though this cannot be done remotely, or the Microscopic Imager on the MERs) can provide information about the form and size of mineral grains. Such information, for example, would have suggested that gypsum was in an optically smooth form and provided constraints on its abundance by implying that other minerals were present in abundance. Microscopic imaging also might have suggested the particular presence of other minerals. Hence, microscopic imaging of portions of a site measured in the thermal infrared can be a useful adjunct to interpreting the spectral data.

Conclusions: We have shown that Mini-TES-like measurements of geologic targets in the field can (1) identify some minerals in a particular outcrop but (2) will overemphasize the presence of optically smooth minerals in low abundance and (3) fail to detect optically rough minerals in high abundance. We propose that regions that are spectrally homogenous at low resolution should be sampled with a microscopic imager to constrain the abundance of optically smooth minerals and suggest the presence of abundant, but optically rough minerals and accessory minerals.

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