MARSLAB INVESTIGATION OF THE SPECTRAL SIGNATURE OF GYPSUM BEARING ROCKS OF DIFFERING COMPOSITION AND FORMATION ENVIRONMENT.

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Introduction: Infrared spectroscopy has long been used to identify the presence of minerals in laboratory, satellite, and most recently field-based measurements. However, high fidelity compositional identification has largely been limited to laboratory based studies where the numerous mineralogical and textural factors that affect spectral signature can be identified and constrained. In this study, we used field based infrared spectroscopy to compare naturally formed gypsum bearing rocks of differing composition and formation environment to enhance our knowledge of the role of several mineralogical and textural factors in clouding high fidelity compositional identification.

Infrared spectroscopy is a primary method used to explore the mineralogy of Mars remotely. The goals of this project, and ongoing MarsLab efforts, are: (1) define the types of materials that infrared airborne (satellite analog) and ground-based (rover analog) spectrometers identify and miss, and explain why; and (2) define implications for the exploration of Mars [1,2].

Formation Environments: We selected locations at Bristol Lake, a dry lake in the Mojave desert near Amboy, CA, and Alunite, an alunite rich outcrop ~15 miles SE of Las Vegas, NV.

The Bristol Lake location typifies gypsum precipitation from saturated surface water. The gypsum bearing rocks form a compositional "bathtub ring" around the central area of halite bearing rocks that formed as different materials saturated and precipitated as the lake dried and shrank [3,4]. The gypsum deposits sampled at this location are mixed with silt and clay (Figs. 1,3A).

The Alunite location is an example of gypsum precipitation from saturated hydrothermal fluid. Gypsum is found in veins cutting through the host rock. This unit is exposed in a small railroad cut (Figs. 2,3B). There is a curiously high concentration of alunite present surrounding the outcrop, however, this was not seen spectroscopically or visually in the rail-cut itself. *Heavens et al*. further investigates discrepancies between infrared spectroscopic identifications and energy-dispersive X-ray spectroscopy (EDXS) mineralogy at this site [2].

Data: The 2003 rover MiniTES (~6-25 μm) measures thermal infrared, hyperspectral images similar to the MarsLab instruments RamVan and Tonka (~7.5-12.5 μm, 181 bands) [6].

Figure 1: Bristol Lake Site. Gypsum bearing rock exposed as slightly brighter regions, darker regions are silty. Three aluminum targets used for downwelling radiance correction are approximately 1 x 1 meter [5].

Figure 2: Alunite Site. Gypsum bearing rock in a weathered rail-cut. Hydrothermal gypsum veins cut the host rock. Bruce Rockie for scale.

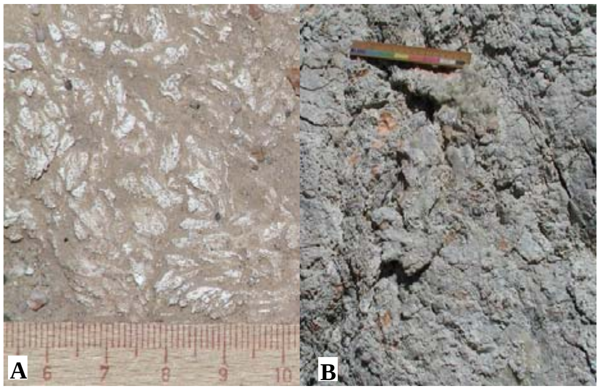

Figure 3: Gypsum Bearing Rocks. (A) Bristol Lake gypsum (weathered, coarse gypsum crystals visible amongst silt and clay). (B) Alunite rail-cut gypsum (large hydrothermal vein cutting the host rock). Rulers for scale in centimeters.

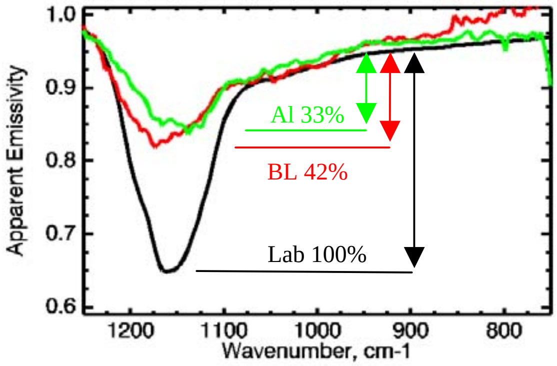

Figure 4: Spectra of gypsum bearing rocks [7]. The green and red spectra are typical gypsum bearing rocks from Alunite (Al) and Bristol Lake (BL), respectively. The black trace is a lab spectrum of crystalline gypsum. Percentages show inferred gypsum concentration based on band depth.

Results: We found that both the Bristol Lake and Alunite gypsum bearing rocks had a remarkably similar spectral signature (Fig. 4). In both cases, the spectra were dominated by gypsum. This shows two major discrepancies between the infrared identification and composition determined by visual inspection: (1) both signatures are dominated by gypsum alone even though other minerals are present; and (2) both signatures exhibit the same spectral contrast despite have different gypsum concentrations.

Bristol Lake Location. At the Bristol Lake location the host rock is dry lake sediment comprised of primarily gypsum mixed with silt and clay. The surface exposures appeared to be ~50-80% gypsum. Silt and clay are very fine grained and usually have a weak spectral signature. Thus, we would expect, based on that mineralogy, gypsum would dominate the spectrum even if it were not the primary constituent. The lack of accessory mineral signatures leads to a higher inferred gypsum concentration.

Another important factor at Bristol Lake is the surface texture of the gypsum. The surface of the gypsum crystals is optically rough, which leads to a relative decrease in spectral band depth and lower inferred gypsum concentration. The crystals may have been rough due to the formation mechanism and certainly have been further roughened by weathering (the outcrop lies horizontal and thus is fully exposed).

Alunite Location. At the Alunite location, the rail-cut is a soup of alteration minerals. Although more work needs to be done to better constrain the mineralogy, we know the outcrop area contains the sulfates gypsum, alunite, and jarosite in addition to some altered remnants of an original rhyolitic host rock. Gypsum does not dominate the composition at this site. Most of the gypsum is present in small (<1 – 2 cm) veins, and coverage was typically <5% of the surface (Figure 3B shows one of a few atypically large gypsum veins although coverage is still <50% of an ~12 inch image pixel). We would expect to see some spectroscopic evidence for minerals beyond gypsum. However, the grain size of the accessory minerals is small which may lead to weakened accessory mineral signatures and a higher inferred gypsum concentration.

Surface texture is a critical factor at Alunite. While most of the outcrop is fine-grained and optically rough, the gypsum forms large crystals. The crystals are optically smooth (have a vitreous luster), which leads to a strong spectral signature and a much higher inferred gypsum concentration.

Conclusions: MarsLab research shows that field infrared spectroscopy is effective at detecting the presence of gypsum and other minerals [1, 2, 3, 5, etc.]. However, it also shows that, when used exclusively, field infrared spectroscopy can result in high ambiguity compositional identifications. Both sites had similar spectral signatures despite differing accessory mineralogies and gypsum concentrations. The Bristol Lake site was inferred to have a somewhat lower gypsum concentration and the Alunite site a much higher gypsum concentration than was observed visually. The surface texture of the gypsum is primarily responsible for disguising the true composition; the role of accessory mineralogy should not be understated. Although for Bristol Lake we can easily explain the weak spectral signature of silt and clay, at Alunite it remains a mystery why accessory minerals (in particular alunite, jarosite, and quartz) were not clearly identified in the rail-cut. Our research shows that on Mars, field infrared spectroscopy alone may not be able to determine the composition or formation environment of gypsum (this likely is also the case for other sulfates). It is important to study the mineralogical and textural factors that affect spectral signature in order to decrease this compositional ambiguity. In addition, many of these limitations can be minimized when used in concert with other remote sensing methods such as NIR spectroscopy and high resolution visible imaging, as evidenced by the MER mission.

References: [1] Kirkland L. E. et al. (2005) *LPSC XXXVI.* [2] Heavens N. G. et al. (2005) *LPSC XXXVI.* [3] Burt D. et al. (2004) *LPSC XXXV*, Abstract #1860. [4] Howard K. A. (2002) Geologic Map - Sheep Hole Mtns, *USGS MF-2344*. [5] Greenhagen B. T. et al. (2003) *LPSC XXXIV*, Abstract #1844. [6] Kirkland L. E. et al. (2002) *Rem. Sens. Env. 80*, 447. [7] Lab spectrum “bristol gyp 15 1 1 bc2” Tonka spectra Bristol Lake 6/30/03 - 6414 (67,65), and Alunite 6/24/04 - 4889 (77,24).

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