MAPPING SULFATES IN NEVADA USING REFLECTED, EMITTED, MULTI-SPECTRAL AND HYPERSONAL SYSTEMS. W. M. Calvin¹, R.G. Vaughan², C. Kratt³, and J. D. Shofnner¹, ¹Geological Sciences, MS172, University of Nevada – Reno, NV 89557, wcalvin@unr.edu; ²Jet Propulsion Lab, greg.vaughan@jpl.nasa.gov; ³Desert Research Institute, christopher.kratt@dri.edu.

Overview: The remote sensing group of the Arthur Brant Laboratory for Exploration Geophysics at UNR has used a wide variety of airborne and spaceborne sensors to map the occurrence of sulfates using both reflected solar wavelengths (0.4 to 2.5 µm) and emitted thermal wavelengths (7 to 14 µm). Data sets range in spatial resolution from 2m/pixel to 30m/pixel and spectral fidelity varies from hyperspectral systems (hundreds of channels) to multi-channel systems. Data sets have been acquired over geothermal systems and old mine districts. New work on an acid producing system in an historic California mining district is just beginning. Here we summarize the results of these efforts [1-5] and make recommendations for the exploration of Mars, based on our terrestrial experience.

Geologic terrains: We have mapped sulfates in Nevada in association with current geothermal systems at Steamboat Springs [1,2], Brady’s Hot Springs [3], in regions of geothermal development potential on Pyramid Lake Paiute Tribal Lands [4], over the historic mining district of Virginia City [5], and are beginning to examine Leviathan Mine, CA.

Geothermal Systems. Geothermal systems in Nevada are concentrated in regions of extensional tectonics, rather than active volcanism as seen in the Pacific “ring of fire”. These systems are typified by active fumaroles and mud pots, large expanses of steaming ground, recent and ancient siliceous sinter and structurally controlled tufa (carbonate), and of course, sulfates. Sulfates tend to concentrate near old vent structures or around current fumaroles (Fig 1). Yellow and white crusts are common, and iron alteration is also sometimes seen. At Pyramid Lake sulfates are seen in playa evaporites and in seeps where geothermal ground water reaches the surface.

Mining Districts. Historic mining districts in the state tend to occur in areas of intrusive volcanics with substantial hydrothermal alteration with varying levels of sulfur. Virginia City economic mineralization appeared during a low-sulfidation hydrothermal phase, but many sub-economic minerals contain sulfides that weather in mine tailing piles to form hydrated sulfate minerals. At Leviathan, the region is hosted by intrusive volcanics with former open pit mining of elemental sulfur – presumably a capped vent.

Sensors and Data Sets: We have used a variety of airborne hyperspectral systems: AVIRIS, HyMAP, HyperSpecTIR, all measuring the optical and shortwave infrared, and SEBASS, measuring the thermal infrared. Multi-channel spaceborne data from ASTER and airborne data from MASTER have also been used to map mineralogy at varying spatial scales. We perform extensive field validation of remotely mapped mineralogy using portable field spectrometers (ASD, D&P) and collect samples for laboratory measurements and XRD corroboration of mineral species.

Mapping Results: We have mapped common sulfate species at these locations, including alunite, gypsum, and jarosite. In many regions hydrated sulfates were mapped remotely and later XRD characterized them as hexahydrite, alunogen, tamarugite, or kieserite. In all cases the most diagnostic spectral features were identified using hyperspectral airborne data at high spatial resolution corroborated with field measurements. Coarse spatial resolution and low spectral fidelity can broadly identify alteration zones, but are not capable of uniquely identifying specific sulfate minerals. In many instances, mixed sulfates were identified in remote data sets, but field and laboratory measurements were needed to confirm individual species. Sulfates are identified in both shortwave and thermal infrared data and using measurements from both spectral regions allows greater mineral identification ability.

Recommendations: Laboratory measurements of more exotic sulfate species are needed. Our experience shows that both high spatial and spectral resolution are needed to map these minerals remotely. Spectral identifications benefit from complementary XRD.

Figure 1: Vent structure at Brady’s with sulfur/sulfate crusts and iron alteration.


Acknowledgements: This work has been supported by PGG, GSRP, EPSCOR, DOE, and MER.