PETROGRAPHIC AND MINERALOGIC GROUND-TRUTH FOR AIRBORNE-BASED HYPERSPECTRAL MAPS OF SEDIMENTARY ROCKS: A CASE STUDY IN THE GUADALUPE MOUNTAINS, NEW MEXICO AND IMPLICATIONS FOR MARS.

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Introduction: High spatial and spectral resolution visible-near infrared (VIS-NIR) reflectance imaging is an essential tool for mapping the surface composition of planetary bodies [e.g.,1,2] and whose data can inform site selection for further *in situ* analyses (i.e., rover traverse or lander placement, sample acquisition and return) [3-4]. Despite the growing availability of these data in the geosciences, detailed studies on validating geological units and contacts identified in such data remain limited. For sedimentary systems, it is also important to assess how VIS-NIR reflectance spectra can be used to correctly interpret lithology, depositional processes, and, by extension, environmental conditions. Here we present updated results for ongoing work that is focused on these issues, with an emphasis on sedimentary rocks whose mineralogy is relevant to Mars.

The Permian Capitan reef system exposed in the Guadalupe Mountains of West Texas and New Mexico represents a mixed carbonate-siliciclastic sedimentary system [5,6]. Carbonate, phyllosilicate, and sulfate minerals in the lithologies of this system have diagnostic features in VIS-NIR reflectance data, and this study focuses on generating and validating mineral/geologic maps from AVIRIS NG spectral images (0.38-2.51 µm, 5 nm sampling) [7] over ~3600 km^2 of this region at a resolution of ~4 m/pixel.

Previous work (i.e., [8]) toward this goal included the construction of a map of eight distinct spectral end members identified within the images (Fig. 1). Here we present detailed petrographic and mineralogic analyses of 52 rock and soil samples acquired *in situ* across the field site to validate the spectrally-based map and determine the factors that influence the observed spectral variability. We discuss the degree to which mapped spectral changes reflect fundamental differences in lithology and minerology and how this affects interpretations of geological processes.

Methods: Thin sections were prepared from rock billets and epoxied soil pucks by TPS enterprises. All samples were impregnated with bright blue dye Petropoxy 154 prior to thin section preparation. Half of each thin section was stained with Alizarin red and K-Ferricyanide stain. For all powdered analyses, samples were ground using a mortar and pestle and hand sieved to a particle size of <45 µm. Powder x-ray diffraction (XRD) patterns were collected on all samples using a benchtop Bruker D2 Phaser with a Cu-Kα x-ray source. Rietveld refinement on diffraction patterns was conducted in Topaz. The minor presence of swelling clays
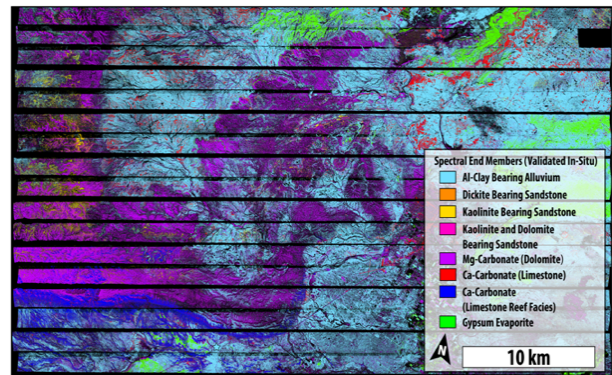

Fig. 1: Composite spectral image-based map showing key spectral end members that have been validated by in situ spectral measurements and sample collection. See [8] for spectral analysis and mapping methods.

observed in some samples was not quantified in this preliminary work, though future work will include full-pattern fitting. Spectral measurements of all powdered samples were made in the NASA Reflectance Experiment Laboratory (RELAB) [9] using the custom bi-directional reflectance spectrometer (BDR) for visible to near-infrared wavelengths (0.3 to 2.6 µm) and a Nicolet 870 Nexus FTIR for near-infrared to mid-infrared wavelengths (2 to 25 µm). BDR and FTIR measurements are connected at ~1.3 µm.

Results and Discussion: There is good agreement between airborne, ground-based, and laboratory based spectral measurements across all end members (Fig. 2). Subtle differences in spectral slope between field and laboratory measurements are likely attributed to variations in particle size between intact and powdered samples. We also demonstrate that mineralogy is fundamentally linked to lithologic and petrographic characteristics of samples (Fig. 2). A good correlation exists between the strength of absorptions for minerals with active VIS-NIR features (e.g., carbonates, phyllosilicates, sulfates) and their total XRD-derived abundance. Though volumetrically important phases such as quartz are not apparent in the VIS-NIR, this correlation appears sufficient to link variations in airborne spectral data to first-order variations in lithology.

Seemingly subtle differences in spectral characteristics can be identified, mapped from airborne data, and are shown to correspond to meaningful variations in lithology. For example, we identify two Ca-carbonate spectral endmembers that are largely mineralogically identical (bottom two end members in Fig. 2), but spectrally distinct such that they can be respectively mapped (Fig. 1). These spectral end members correspond to the

fossiliferous reef margin facies of the Goat Seep Formation [7] and limestone facies of the Queens Formation [10]. We also observe that quartz has a muting effect on other mineral absorptions that can be identified and mapped in airborne data (not shown here). This may allow for spectral proxies to be constructed to infer relative variations in quartz.

We also note several limitations of spectral-based mapping. First, nearly all samples contain clay minerals in at least trace amounts, even where there are no indications of their presence in laboratory, field, or airborne spectral data. This demonstrates a clear spectral detection threshold for this mineral group. Additionally, although mineralogically similar facies may be distinguishable in spectral imaging data, this is not always the case (e.g., a dolomite dominated by micrite mud can look spectrally similar to one that is dominated by dolomitized skeletal fragments).

Overall our results continue to show that airborne spectral imaging—particularly when validated with limited ground truthing—can be used to rapidly identify and map important geologic variability and relationships in sedimentary successions over large spatial scales.
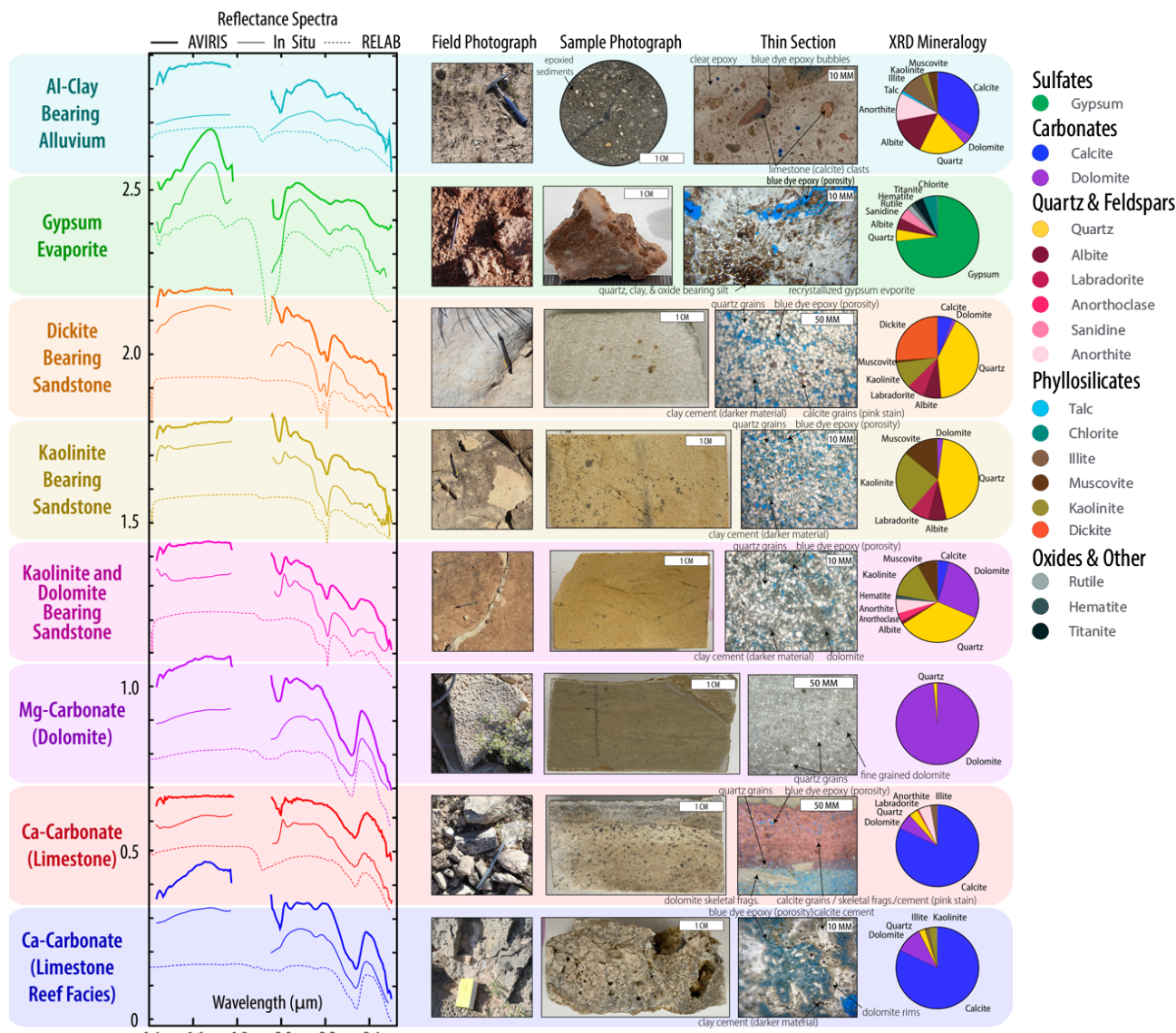
Fig. 2. Integrated spectroscopic, lithologic, petrographic, and mineralogic characteristics for each spectral end member. Reflectance spectra include airborne AVIRIS measurement collected over sample site, an in-situ measurement using a field spectrometer (see [8]), and RELAB acquired measurements of reflectance on powdered samples.