TESTING AIRBORNE-BASED MINERALOGICAL AND GEOLOGICAL MAPPING OF SEDIMENTARY ROCKS: A CASE STUDY IN THE GUADALUPE MOUNTAINS, NEW MEXICO AND IMPLICATIONS FOR MARS. M. J. Meyer1, R. E. Milliken1, and K. M. Robertson1, 1Dept. Earth, Env., and Planetary Sciences, Brown University, Providence, RI 02912. (melissa_meyer@brown.edu).

Introduction: The composition and geological relationships of materials exposed on the surfaces of rocky planetary bodies is often understood in part by analysis of spacecraft-acquired visible-near infrared (VIS-NIR) spectral images [e.g.,1,2]. Imaging spectroscopy can also inform site selection for further in situ analyses, whether that be for rover or lander placement or for sample acquisition and return [3-4]. Despite their prevalence in planetary geoscience, relatively few terrestrial studies exist that are aimed at validating these data types and techniques against robust traditional ground-based geologic mapping efforts [e.g., 5]. As such, there is room for improvement in understanding how geological units and contacts identified in remotely sensed data compare with those identified using traditional, ground-based approaches. In the case of sedimentary rocks observed on Mars, it is also important to understand the degree to which orbital data can be used to accurately interpret changes in lithology, depositional processes, and, by extension, ancient environmental conditions. Here we present initial results for ongoing work that is aimed at addressing this knowledge gap, with an emphasis on sedimentary rocks that contain minerals relevant to the Curiosity and Perseverance Mars rovers.

We explore this concept in the Permian-aged outcrops of the Guadalupe Mountains of West Texas and New Mexico. The Guadalupe Mountains contain arguably the single most well-exposed and well-characterized ancient carbonate platform reef in the world [6,7]. This mixed carbonate-siliciclastic sedimentary system records a variety of rock types that include: shelf, slope, reef margin, and basinal carbonates; shallow shelf and basin fluvial- and eolian-sourced sandstones; basinal mudstones; and shallow and deep-water evaporites [7]. The systematic distribution of these rock types within a sequence stratigraphic framework is well documented and mapped by previous workers [7]. Many minerals (i.e., carbonates, phyllosilicates, and sulfates) inherent to these lithologies have diagnostic features in VIS-NIR reflectance data, and thus major lithologic transitions in this region may be identifiable within airborne data. Recent availability of a wealth of VIS-NIR spectral images that cover ~3600 km² of this region at a resolution of ~4 m/pixel provides an opportunity to test this hypothesis directly.

The primary objective of this work is to compare units and boundaries derived from hyperspectral images to those of more traditional ground-based geologic and stratigraphic maps. Where do results from these two distinct approaches conform and where do they diverge, and why? To what extent can mineral distribution observed in airborne/orbital data be used to accurately infer geologic process(es)? For Earth applications, what new information can spectral image analysis offer to complement traditional ground-based methods?

Image Analysis: We utilize seventeen AVIRIS NG [8] spectral image cubes (0.38-2.51 μm, 5 nm sampling) collected sequentially in October of 2019 at an approximate flight altitude of 17.5 kft for a corresponding spatial resolution of ~4 meters per pixel. All images were radiometrically calibrated, orthocorrected, and atmospherically corrected by JPL [9].

Spectral end members were selected from within the images, guided by principle component analysis. End member spectra were individually inspected and flagged as either irrelevant (i.e., shadowed pixels, manmade materials, water bodies, vegetation) or relevant (i.e., mineral bearing rocks and soils) to the study goals. Two non-negative linear least squares unmixing routines of end members were performed for each pixel. The first unmixing routine incorporated both irrelevant and relevant end members. If irrelevant end members were found to contribute significantly to the modeled spectrum, then that pixel was masked in

Fig. 1: Selected spectral end members mapped in Fig. 2A. Bold line spectra are AVIRIS measurements acquired over the field site via aircraft. Thin line spectra are point measurements acquired in situ at various field locations. Field photos for each end member lithology are shown to the right of each spectrum pair.
the final map products. If irrelevant end members were not significant contributors, a second unmixing routine was run using only relevant end members. Resulting model parameters from the second routine were renormalized to sum to 100% to compare the spectral contribution of endmembers between pixels and images.

**Field Methods:** Samples, lithologic descriptions, photographs, and reflectance spectra (ASD FieldSpec3, 0.35 to 2.50 µm) were acquired *in situ* at each end member pixel location in October 2021. Several transects were also measured at ~1 m intervals in Last Chance Canyon and Rocky Arroyo field areas based on (1) existing detailed ground-based stratigraphic maps [10,11] and (2) significant variability in spectral units from the AVIRIS NG analysis.

**Results & Implications:** Seven spectral end members that correlate with distinct *in situ* lithologies are identified (Fig. 1) and map to distinct regions (Fig. 2A). Spectral end members include: gypsum evaporate, dolomite, limestone, kaolinite-cemented sandstone, dickite-cemented sandstone, kaolinite and dolomite cemented sandstone, and alluvium with Al-bearing clays. Further validation of these end members via thin section analysis, x-ray diffraction, and laboratory-based spectroscopy is ongoing.

In many cases, spectral boundaries coincide strongly with major lithologic types and geologic contacts mapped by km-scale ground-based methods (Fig. 2B). In fewer cases, spectral and geologic unit boundaries are partially or wholly discordant, possibly because (1) geologic feature(s) mapped *in situ* do not correspond to detectable features at VIS-NIR wavelengths or, conversely, (2) units in ground-based maps have been incorrectly extrapolated in some areas. Future *in situ* re-investigation of these areas could determine why this discrepancy exist, but current results demonstrate that an integrated spectral and ground-based mapping approach captures variability at a much higher spatial resolution (<10 m) than can be efficiently mapped at this scale solely by *in situ* methods.

Interestingly, we find that sandstones of the Yates, Queen, and Cherry Canyon Formations (Fig. 2B) are distinctively mappable via spectroscopic methods. Their primary constituent (quartz) is non-absorbing at AVIRIS NG wavelengths, but the minor presence of kaolinite and dickite (Fig. 1), which appear to be the pervasive cementing agent of these sandstones, is spectrally distinct. However, the fact that the clays occur as cement in sandstones (as opposed to clay in mudrocks, for example) is not apparent solely from the airborne data. We demonstrate that spectroscopic methods can be used to identify and map some (but not all) potentially meaningful variability across a region.

Our initial results suggest that plausible, but non-unique, geologic scenarios can be hypothesized to explain the observed spectral variability and airborne-based contacts in the study region. However, *in situ* investigations are ultimately required to provide additional diagnostic geologic context and fine-scale observations necessary to differentiate certain primary and secondary processes, and the same is presumably true when interpreting similar data for sedimentary rocks on Mars.