MASTCAM SPECTRAL CHARACTERIZATION OF STRATIGRAPHIC UNITS ALONG CURIOSITY'S TRAVERSE IN GALE CRATER, MARS.

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Introduction: The Mars Science Laboratory Curiosity Rover has traversed through nearly 400 meters of stratigraphy over the course of its mission to date. From the landing site near Yellowknife Bay, the rover traversed through the fluvio-deltaic deposits of the Bradbury Group, which prograde into the lacustrine deposits of the Murray Formation; distinct stratigraphic units have been determined based on depositional environment, morphology, and chemical composition [*e.g.,* 1]. These observations define a traverse-wide stratigraphic column, using elevation to demark lithologies [2]. There have also been several efforts to define chemical classes for rocks encountered using the APXS and ChemCam instruments [*e.g.,* 3, 4].

The Mastcam instrument has periodically acquired multispectral, visible to near-infrared (VNIR) observations of these various lithologies along the traverse. Identifying spectral trends within and between stratigraphic units using Mastcam can help to constrain mineralogy and extend the mapping of compositional units beyond where *in-situ* measurements have been acquired. No previous efforts have analyzed the full multispectral dataset on a broad scale to investigate traverse-wide trends. Here, we utilize a newly-compiled database of representative spectra from all Mastcam multispectral images [5] to study traverse-scale spectral relationships. Specifically, we explore spectral variations and their correlations to known stratigraphic units in order to identify trends in iron oxidation across the different units observed.

Methods: The Mastcam instrument can acquire images in 12 unique wavelength positions from 440-1010 nm using its narrowband filter set [6]. The spectra are calibrated based on pre-flight calibration coefficents and calibration target observations, and the resulting I/F-calibrated images are converted to relative radiance with a cosine of solar incidence angle correction [7].

We utilize a multispectral database [5] that includes representative Mastcam spectra from every multispectral image collected along the rover's traverse. To create this database, regions of interest (ROIs) were drawn for all spectral end members identified in each image, and spectra were extracted as the average of all pixels within each ROI. Error bars indicate the variance within each ROI, which is typically larger than the estimated error in the instrument calibration [7].

In this work, we defined spectral parameters and plotted spectra as described by [8]. To help connect spectral observations to stratigraphy, we evaluated all ROIs to determine if the outcrop blocks are in-place bedrock or float material. We based our characterizations on rock shape, shadowing, relationship to broader workspace context, and morphological congruity with surrounding bedrock. We integrated these characterizations into the database for analysis of spectral variations between float material and surrounding bedrock.

We assigned each outcrop ROI a lithology based initially on elevation and correlations with the stratigraphic column. Next, unit assignments were refined based on an inspection of each image to assess context, color, texture, and similarities to known types of each rock (as corroborated by APXS and ChemCam data). Results presented here focus on observations made along the traverse from the start of the Murray Formation to the base of the Vera Rubin Ridge. Classifications of the members composing the Vera Rubin Ridge, which have subtle spectral distinctions, will be added to the database in our ongoing work, as will characterization of the Bradbury Rise units.

Results: We observe several trends in Mastcam spectral variability with stratigraphy along Curiosity's traverse. Figure 1 illustrates correlations between key spectral parameters and elevation for all Mastcam multispectral observations of outcrop. The 867 nm and 527 nm band depths can indicate the extent of iron oxidation. They generally increase through the traverse until the middle of the Sutton Island member (Murray Formation), where the highest values occur around elevation -4325m in the vicinity of the Old Soaker outcrop. A decrease in band depths within the Blunts Point member indicates lesser oxidation, while the Pettegrove Point and Jura members exhibit the largest variation of these parameters of any units encountered to date. We also show the 937 nm band depth, which can be indicative of the presence of iron based on the presence of a broad absorption near 900 nm.

We highlight the spectral variations corresponding to Ivanhoe, a typical example of eolian Stimson Formation, and Old Soaker, a distinct block within the Murray Formation potentially indicative of chemical changes observed in the traverse after sol ~1550 [9] (Figure 1b). Color images (from the RGB Bayer filters) of these representative outcrops provide context for the distinct morphological differences between these two outcrops, which aid in their lithologic classifications. These two units also have very different spectral signatures, as reflected in their individual reflectance spectra (Figure 1c). These spectral variations couple with the stratigraphic differences between these two outcrops to demonstrate the value of augmenting the traverse-wide multispectral dataset with stratigraphic designations.

Summary and Future Work: Mastcam Multispectral observations can provide valuable information on traverse-scale trends in outcrop composition. By incorporating stratigraphic designations for each image collected into a database of all Mastcam multispectral observations, we can identify spectral variations between and among stratigraphic units, and investigate spectral relationships on a much finer scale. Our ongoing work includes direct comparisons of the Mastcam spectral variability with ChemCam passive spectral trends with elevation, in addition to the trends in chemistry observed by ChemCam and APXS.

References: [1] Grotzinger et al. (2015) *Science* 350(6257). [2] Siebach et al. (this meeting). [3] Schmidt et al. (2014) *LPSC* XXXXV, Abs# 1504. [4] Mangold et al. (2017) *Icarus*, 284, 1-17. [5] Rice et al. (this meeting). [6] Malin, M.C. *et al.* (2017) *Earth & Space Sci., 4,* 506. [7] Bell, J.F., III *et al.* (2017) *Earth & Space Sci., 4,* 396. [8] Starr et al. (this meeting). [9] L'Haridon *et al.* (2017), *4th Conf. Early Mars.*

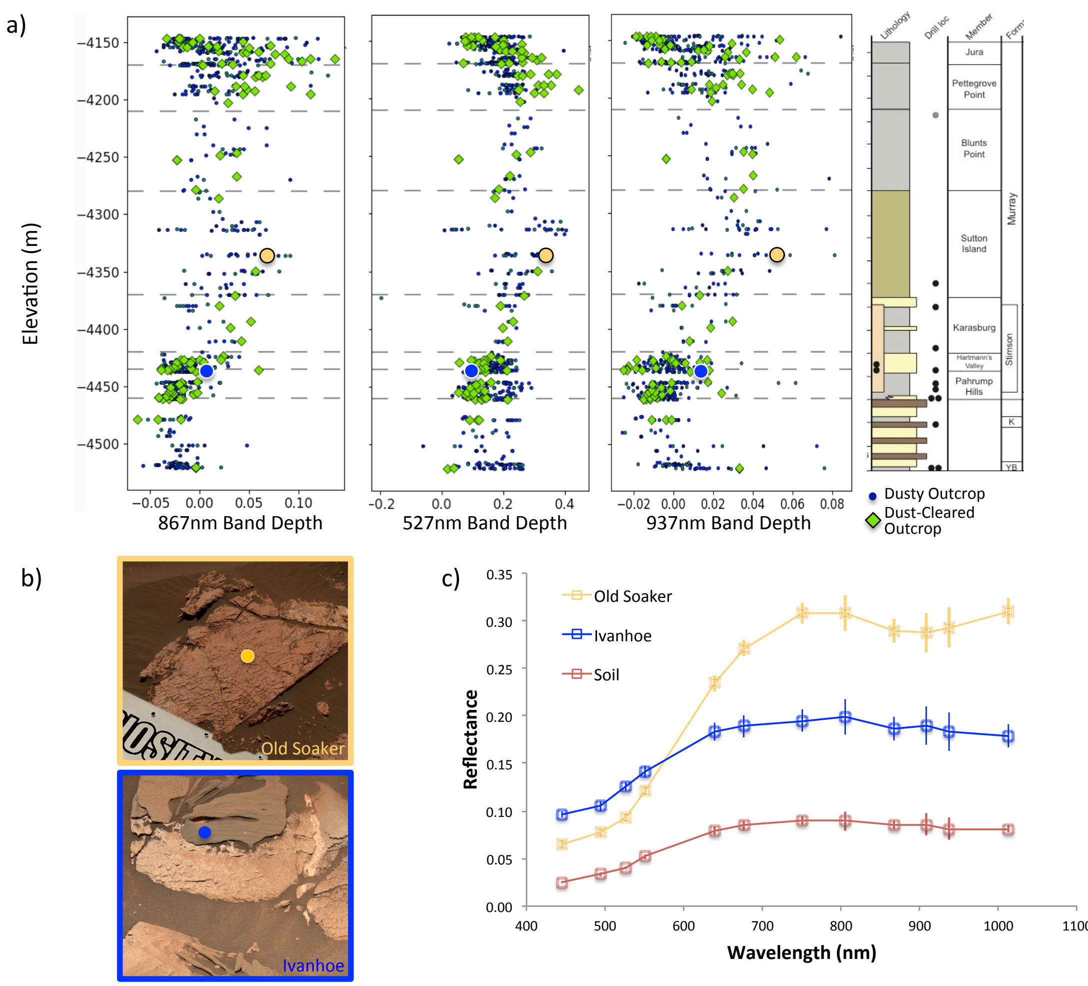

Figure 1. a) Spectral parameters vs. elevation for all Mastcam spectra of outcrops (both dusty and dust-cleared) across Curiosity's traverse: band depths centered at 867 nm and 527 nm (indicative of iron oxides) and 937 nm (broadly indicative of iron). Dashed lines delineate stratigraphic units by elevation, as contextualized in the stratigraphic column on the right. Band depths for ROIs identified in Old Soaker and Ivanhoe outcrops indicated in yellow and blue, respectively. b) RGB images of example lithologies, with highlighted outcrop ROIs. The Old Soaker image is mcam07987 taken on sol 1566; the Ivanhoe image is mcam04788 taken on sol 1092. c) Reflectance spectra extracted from select dusty outcrop ROIs in Old Soaker and Ivanhoe outcrops, accompanied by a representative soil spectrum from the Old Soaker observation. Left- and right-eye spectra have been scaled to their average value at 1013 nm, and reflectance values for overlapping bands have been averaged.