MASTCAM SPECTRAL DIVERSITY OF ROCKS THROUGH CURIOSITY'S EXPLORATION OF GLEN TORRIDON.
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Background: The Mast Camera (Mastcam) on the Mars Science Laboratory Curiosity rover has collected a variety of visible to near-infrared (VNIR) multispectral observations across its traverse in Gale crater, providing context for other instruments and broad mineralogic interpretations. Mastcam is sensitive to iron oxides and some hydrated minerals, both important indicators of alteration [1]. In our previous work, we compiled a database of observations for analysis through Curiosity's exploration of Vera Rubin ridge (sols 0-2302), from which spectral classes were identified [2]. Each class has diagnostic spectral features that reflect a mineralogic interpretation [3]. Now, Curiosity has been on Mars for over 3200 sols and acquired more spectral observations from new terrains within Gale crater. We hypothesize that new classes may appear in accordance with unique stratigraphic members like the clay-bearing Glen Torridon (GT) and the overlying sulfate-bearing unit [4], thus enhancing our understanding of ancient geologic processes and habitability of the surface of Mars.

A transition from clays to sulfates recorded in the stratigraphy of Mt. Sharp indicates an environmental change from a wetter one that accommodated clay formation to a drier, more acidic environment that led to the precipitation of sulfates [4]. A clay-sulfate transition has been observed in several locations on Mars, indicating a global environmental change around the Noachian-Hesperian transition [5]. Orbital data of Mt. Sharp indicate phyllosilicate- and sulfate- bearing strata, while the rover's science cameras reveal complex diagenetic features (e.g. veins, nodules, pitting, etc.) [6]. Here, we present results from a comprehensive analysis of Mastcam multispectral observations through Curiosity's exploration of GT, comparing the spectral diversity within GT to the spectral classes encountered previously in the traverse. These analyses will provide a basis for comparison as Curiosity continues its ascent of Mt. Sharp and characterizes the transition to sulfate-bearing strata.

Methods: Mastcam is a multispectral, stereoscopic imaging instrument that can acquire visible to near-infrared (VNIR) spectra in 12 unique wavelengths from ~400-1020 nm [7,8]. Raw sensor values are radiometrically and photometrically calibrated, using a reduction pipeline that includes near-simultaneous observations of a calibration target. For most of the analyses in this study, photometrically-calibrated *I/F* values are converted to reflectance factor (*R**) by dividing by the cosine of the solar incidence angle. We applied a decorrelation stretch to all calibrated Mastcam images to highlight the color and spectral variability, which we used to identify regions of interest (ROIs) that are representative of the morphologic and color diversity within each scene. We extracted spectra by averaging pixels within each ROI and compiled a database with extensive metadata (including feature type, viewing geometry, sol, local true solar time (LTST), tau, elevation, L_S, etc.) [3]. In order to interpret mineralogic trends across the full dataset, we used principal component analysis with analyses of spectral parameters.

Results: We find that a few key spectral parameters contribute the most to the diversity of the full Mastcam dataset (Fig. 1). The 751/445 nm ratio corresponds to the overall "redness" of spectra. The 1012/751 nm ratio

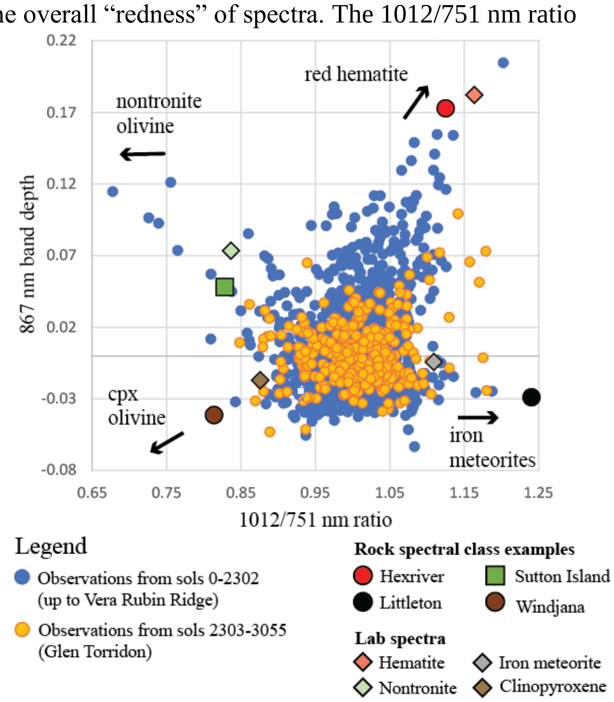

Figure 1: Rock spectra from Curiosity's full traverse plotted against two key spectral parameters [9], with laboratory spectra of pure minerals (Fig. 3) for reference.

is used as a proxy for the NIR profile or slope. 1012/751 nm ratios below 1.0 correspond to olivine, pyroxene, and basaltic glasses while ratios above 1.05 can indicate iron meteorites. The largest 867 nm band depths are correlated to hematite, smaller values are consistent with other Fe-oxides, and negative values (i.e. a peak) are consistent with olivine, pyroxene, and/or nontronite [10]. Based on these and other parameters, we have identified 9 rock spectral classes (Fig. 2) from Curiosity's traverse up until Vera Rubin Ridge (sols 0-2302). Mastcam spectra from within the GT are well characterized by a subset of these previously-encountered spectral classes.

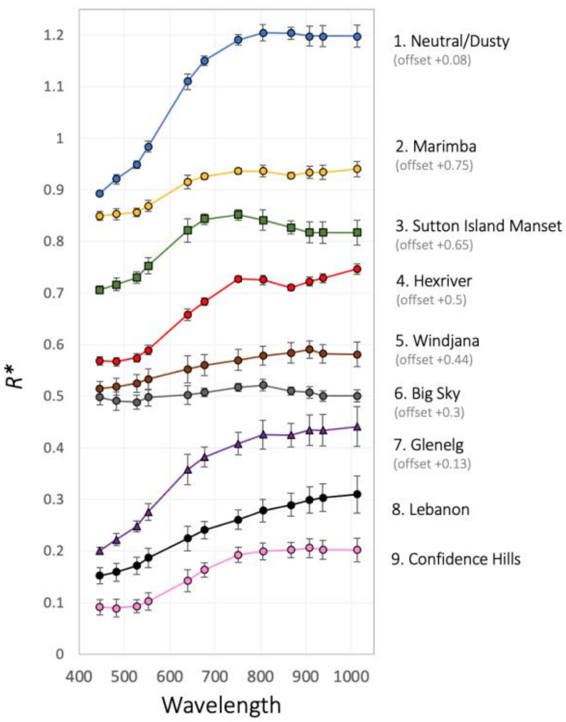

Figure 2: Representative spectra from each rock class.

Discussion: The rock spectral classes are confined to stratigraphic formations or specific to a geologic feature, like meteorites [11]. The soil spectral classes also correspond to specific parts of Curiosity's traverse. Soil spectra exhibit different trends with elevation compared to rock spectra thus locally derived sediments are not significantly contributing to the soil spectra. As of sol 3055, which is part way through GT, spectra continue to remain within the defined classes. Although the diagnostic absorption features for phyllosilicates and sulfates in the near-infrared are beyond Mastcam's wavelength range, their presence can still influence Mastcam spectra. For example, ferric smectites, like nontronite, have been identified in orbital observations via absorptions at 1900, 2240, and 2280 nm [12] but could be correlated to weak absorptions in Mastcam spectra around 900-950 nm [6] (Fig. 3). Variations within Marimba and Sutton Island Manset class rocks (Fig. 2) in GT could be influenced by nontronite and/or other phyllosilicates. In our ongoing analysis, we will extend our Mastcam spectral database through Curiosity's current exploration of the clay-sulfate transition in Mt. Sharp.

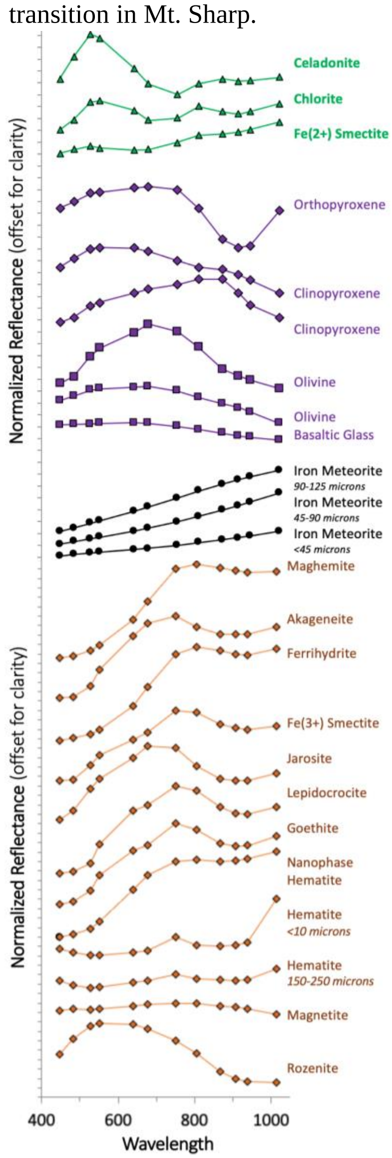

Figure 3: Laboratory spectra of common primary and secondary Fe-bearing minerals and iron oxides, modified from [10]: ferrous alteration phases (green triangles); pyroxenes (purple diamonds); olivines and basaltic glass (purple squares); and ferric alteration phases (orange diamonds). Iron meteorite spectra (of Odessa) shown are from [13] (black circles). Spectra have been convolved to Mastcam spectral bandpasses, normalized to 1.0 at 751 nm, and offset for clarity.

Acknowledgments: Funding was provided by the Mars Science Laboratory Participating Scientist Program. We thank the students at WWU who have contributed to the Mastcam Multispectral database over the years.

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