COMPOSITIONAL AND MINERALOGIC INTERPRETATION OF MSL CURIOSITY ROVER MASTCAM MULTISPECTRAL MEASUREMENTS IN GALE CRATER.

D.F. Wellington[1], J.F. Bell III[1], A. Godber[1], J.R. Johnson[2], M.S. Rice[3], K.M. Kinch[4], and the MSL Science Team. [1]Arizona State Univ., Tempe AZ (dfwellin@asu.edu); [2]Johns Hopkins Univ., Laurel MD; [3]Caltech, Pasadena CA; [4]Univ. of Copenhagen, Denmark.

Introduction: The Mars Science Laboratory Curiosity Rover has been investigating the environment of the interior of Gale Crater since its landing in August 2012. Included in the instrument payload are the Mast Cameras (Mastcams), a pair of 1600x1200 pixel CCD cameras located atop the Remote Sensing Mast [1]. Beyond their color (RGB) imaging capabilities, each of these cameras can produce multispectral images by means of an 8-position filter wheel, of which six positions are narrow-band science filters spanning a wavelength range from 445 – 1013 nm and covering spectral regions of ferrous and ferric iron absorption [2,3] as well as a narrow hydration band observable in certain hydrated minerals [4]. Frequent, near-in-time imaging of an on-board calibration target allows accurate calibration of measurements to values of relative reflectance. Since landing, multispectral Mastcam images have documented a number of different spectral classes of surface materials.

Results: The multispectral observations acquired to date (through sol 611) can be divided into seven spectral classes, described in detail below. Filters are described with a letter for the individual instrument (L is the left, M-34 camera while the right (R) is the M-100) followed by the filter number (cf. [2]). See figure (next page) for examples of regions of interest (ROIs) showing each of the following.

Reddish dust. Reddish dust is present on most surfaces save for those that have been disturbed by the rover or (presumably) cleaned by aeolian activity. Over Mastcam wavelengths, the dust possesses a steep rise in reflectance in the visible wavelengths, flattening out around 751 nm (L3). Dust covering many surfaces is apparently not optically thick, but instead contributes to an intermediate spectrum showing some degree of increased (relative to that of the underlying material) slope at short wavelengths, a generally intermediate reflectance, and a slightly negative near-infrared slope when overlying a darker rock.

Reddish airfall dust has been gradually accumulating on the Mastcam calibration target over the course of the mission [5]. This dust is most concentrated in rings surrounding the locations of six sweep magnets and appears spectrally similar to the surface dust. Away from the magnet rings, a thinner layer of airfall dust has settled unevenly on the calibration target, mixing with lower reflectance dust and sand/silt that was desposited onto the target and the rover deck during the rover's sky crane descent to the surface, and substantially influencing derived calibrated reflectance values of especially the shorter wavelengths. Some data reported here were calibrated relative to the "clean" centers of the target's sweep magnets [3].

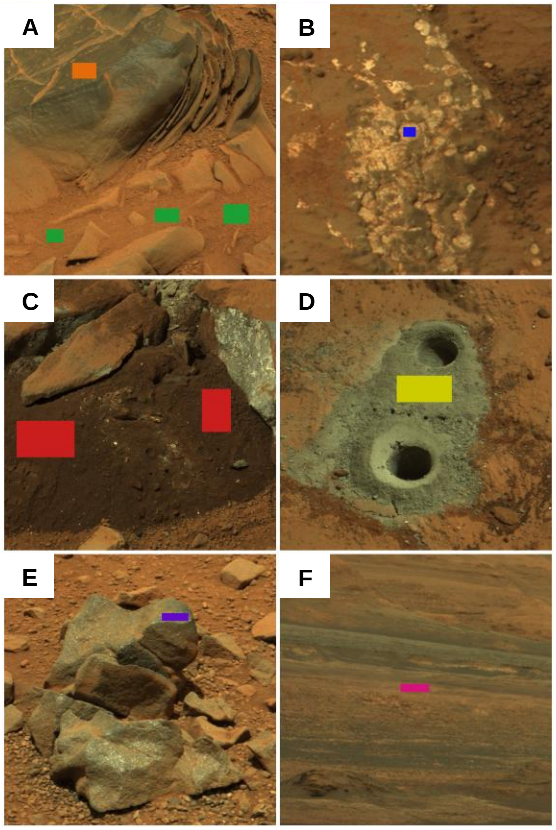
Dark-toned reddish soil. Disturbed soil spectra show a relatively low reflectance with a positive visible wavelength slope and flat to slightly negative near-infrared slope. The average spectrum of this unit is consistent with a mixture of ferric constituents and darker, more ferrous materials perhaps derived from the local population of dark-toned rocks.

Dark-toned rocks/dunes. The majority of clean rock surfaces, as well as the dark-toned dunes located between the rover and the base of Mt. Sharp, possess a relatively featureless, flat Mastcam spectrum of very low reflectance values. These materials possess a weak positive slope in the shorter visible wavelengths (flattening around filters L4 to L3, 676-751 nm) and either flat or very weakly negative near-infrared slopes. Completely clean surfaces are not common, and most rock spectra are influenced to some degree by dust.

Gray rocks. The class of gray rocks has higher overall reflectance values than the dark-toned rocks/dunes, with a flat or weakly sloping visible wavelength slope and a negative near-infrared slope. The negative slope begins between 805 and 867 nm (filters R3 and L5). This class of rocks includes the Ekwir and Wernecke brushed targets, the John Klein and Cumberland drill fines, broken fragments of the Sheepbed raised ridges, as well as several other rocks broken by the rover wheels in the vicinity of Yellowknife Bay. The negative near-infrared slope is consistent with the presence of ferrous silicates like the pyroxenes and olivines identified by Chemin analysis of the John Klein and Cumberland drill material [6].

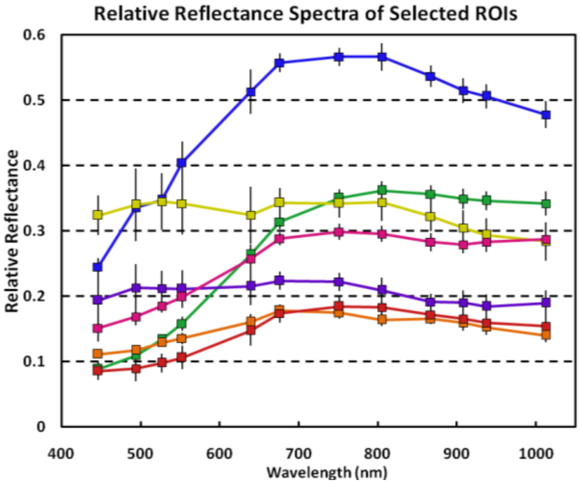
Steep NIR downturn rocks. A third and relatively uncommon class of observed rock spectral class possesses a near-infrared spectral falloff that occurs at shorter wavelengths (between 751 and 805 nm, L3 and R3) than that of the gray rocks. One example of this spectral class is a multispectral observation centered on the Chemcam target known as “La Reine”; both the target rock and a number of surrounding rocks possess this near-infrared feature. This has also been observed in Chemcam passive data for “La Reine” and additional Chemcam targets and has been noted to be consistent with the presence of orthopyroxene [7].

Bright veins/nodules. The highest reflectance materials thus far encountered are bright, light-toned veins



and nodules. Chemcam LIBS detected elevated calcium and sulfur in association with vein material, consistent with the presence of calcium sulfate [8]. Other instrument analyses by AXPS [9] and Chemin [6] support this interpretation, the latter of which detected anhydrite in the Rocknest sample and both anhydrite and bassanite in the John Klein and Cumberland drill fines. The veins have a steep slope in the visible wavelengths likely resulting from dust contamination. The near-infrared slopes are flat to moderately negative beyond R3 (805 nm), and some possess a downturn between R5 and R6 (937 and 1013 nm) interpreted as a hydration band indicative of localized occurences of gypsum [4,10,6] not sampled by Chemin.

Putative Hematite. Mastcam multispectral observations targeted toward a layer at the base of Mt. Sharp that has been mapped as hematite-bearing by CRISM observations [11,12] show a region possessing a unique spectral signature. A positive, concave slope in the visible peaks around 751 nm (L3), followed by an absorption feature centered around 867-908 nm (L5-R4). This latter band is slightly longward of that expected for hematite, but this could be caused by the presence of minor amounts of iron oxyhydroxides such as goethite with features at slightly longer wavelengths [13]. We are also investigating the potential effects of incompletely-corrected Mastcam calibration target dust contamination on the nature of this band.



Left: Selected Mastcam observations [sol-sequence (target_name)]: A) 114-00699 (Jackson_Lake) showing a dark rock with relatively dust-free surfaces surrounded by regions thick with dust cover; B) 133-00805 (Knorr) bright veins/nodules; C) 174-00935 (Sutton_Inlier) disturbed surface showing dark reddish soil; D) 183-00993 (Drill_Tailings) gray material from John Klein drill location; E) 346-01405 (La_Reine) rocks with relatively short-wavelength NIR falloffs; F) 468-01864 (Hematite_Ridge_Ccam) distant observation towards the base of Mt. Sharp targeted at putative hematite-bearing ridge. **Above:** Averaged relative reflectance spectra of colored regions on left; error bars represent the 1σ variance of calibrated reflectance values within each ROI.

Future Work: Mastcam multispectral observations will continue to provide imaging support and context to contact/sampling science and Chemcam observations as well as limited mineralogical assessments such as those discussed here. Improvements to a model correcting for the effects of airfall dust on the reflectances of the calibration target are ongoing [5,14] and should provide more accurate reflectance values especially for later sols. Improved calibration may allow more subtle spectral differences to be reliably discerned, such as minor spectral variation between airfall dust and dust accumulated around the calibration target magnets, more reliable assessment of the hydration feature in bright, calcium sulfate-bearing vein materials, and more accurate estimates of the width and band centers of observed near-infrared absorption features.

References: [1] Malin *et al.* (2010) *41st LPSC,* 1123. [2] Bell *et al.* (2012) *43rd LPSC,* 2541. [3] Bell *et al.* (2013) *44th LPSC,* 1417. [4] Rice *et al.* (2013) *EPSC 8*, 762. [5] Kinch *et al.* (2013) *44th LPSC,* 1061. [6] Vaniman *et al.* (2014) *Science, 343,* 6169. [7] Johnson *et al.* (2014) *Icarus*, in press. [8] Nachon *et al.* (2014) *JGR*, submitted. [9] McLennan *et al.* (2014) *Science, 343,* 6169. [10] Rice *et al.* (2013) *AGU Fall Meeting*, 1795. [11] Milliken *et al.* (2010) *GRL, 37,* (4). [12] Fraeman *et al.* (2013) *Geology, 41,* 1103. [13] Johnson *et al.*, this conference. [14] Kinch *et al.* (2007) *JGR, 112,* E06S03.