Compositional and Mineralogic Interpretation of MSL Curiosity Rover Mastcam Multispectral Measurements in Gale Crater

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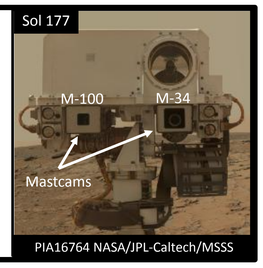
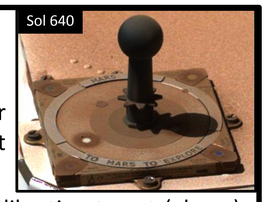
1| Introduction

- The Mastcam instruments aboard the Mars Science Laboratory Curiosity Rover are capable of visible and near-infrared multispectral imaging in up to twelve unique wavelengths.
- To date, over 300 multispectral imaging sequences have been acquired, documenting numerous distinct visible/near-infrared spectral classes predominantly reflecting differences in ferric/ferrous iron mineralogy.



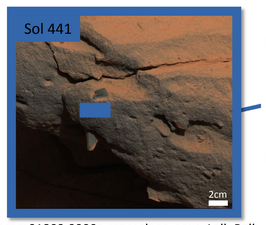
2| Instrument/Calibration

- The Mastcam instrument suite is comprised of two mast-mounted 1600 x 1200 Bayer filter CCD cameras (left M-34 and right M-100), each with a rotating 8-position filter wheel that allows multispectral imaging from 445 – 1013 nm.
- Calibration (cf. [1]) is accomplished with the aid of near-in-time imaging of an on-board calibration target (above). Dust deposition is accounted for by a model derived from caltarget imaging over the first 500+ sols.

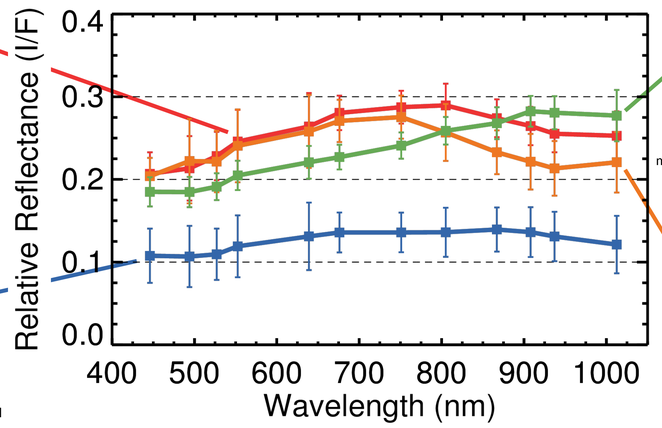


3| Dust-Free Rocks

mcam00935.0000a.sutton_inlier_Lall_Rall



mcam01809.0000a.rensselaer_apxs_Lall_Rall

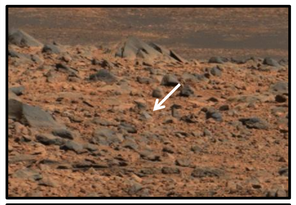


mcam02729.0000a.littleton_lebanon_Lall_2x1_Rall

mcam01405.0000a.la_reine_ccam_Lall_Rall

- Spectra of relatively dust-free rock surfaces generally have a low overall reflectance (lower left, blue), with the exception of certain lighter-toned grayish rocks found in the vicinity of Yellowknife Bay (top left, red). Negative NIR slopes are consistent with a ferrous iron silicate mineralogy (e.g, [2]).
- Several instances of float rocks possessing strong NIR absorptions at relatively shorter wavelengths have been observed by Mastcam (lower right, orange; see also box, right). Also observed by ChemCam passive, this feature in the "La Reine" observation may be indicative of a composition rich in orthopyroxene [3].
- A pair of putative meteorites (shown here is the nearer one, top right, green) imaged on sols 640 and 641 possess positively sloping spectra across most Mastcam filter wavelengths, consistent with a metallic iron composition (e.g. [4]).

Float Rocks With Distinct Near-Infrared Spectra

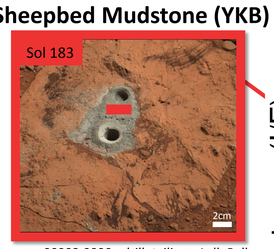


mcam01888.0000a.hematite_ridge_3_ccam_Lall_Rall

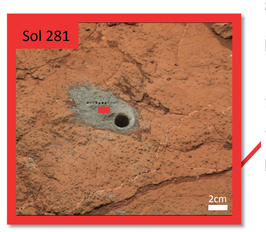
The two images at left show a subset of mcam01888 (sol 475). Hidden within the top RGB image is a rock possessing a near-infrared downturn similar to mcam01405 (see plot, orange) made obvious in the lower view showing the M-100 805-908 nm spectral slope.

4| Drill Fines

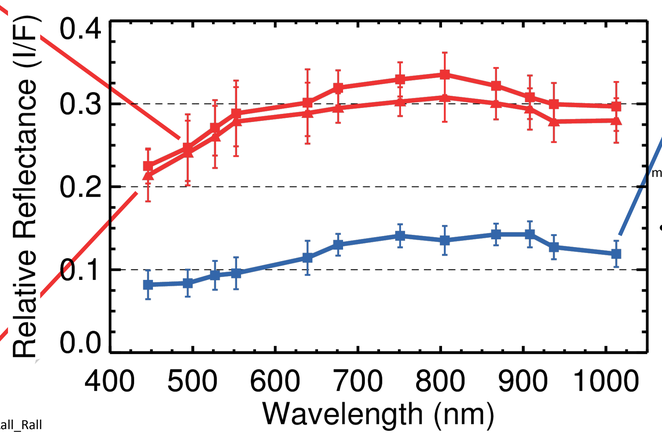
Sheepbed Mudstone (YKB)



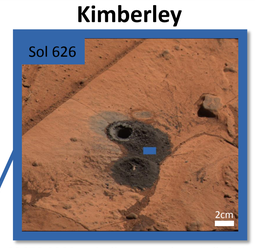
mcam00993.0000a.drill_tailings_Lall_Rall



mcam01202.0000a.cumberland_a_adjusted_Lall_Rall



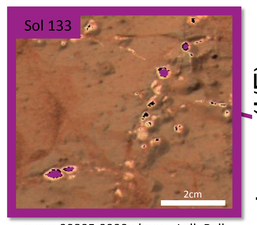
Kimberley



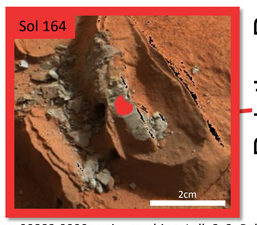
mcam02676.0000a.windjana_stephen_Lall_2x1_Rall

- The overall spectral shape is similar between the three drill targets, although minor variations in the position and strength of the near-infrared drop off may reflect differences in ferrous iron mineralogy (c.f. [5] for the first two) between the Windjana and the two Sheepbed targets.
- Compared to the John Klein and Cumberland drill fines (see plot, red) of the Sheepbed Mudstone unit in Yellowknife Bay (YKB), the Kimberley drill material is darker (plot, blue) in overall reflectance, consistent with a higher abundance of opaque minerals.

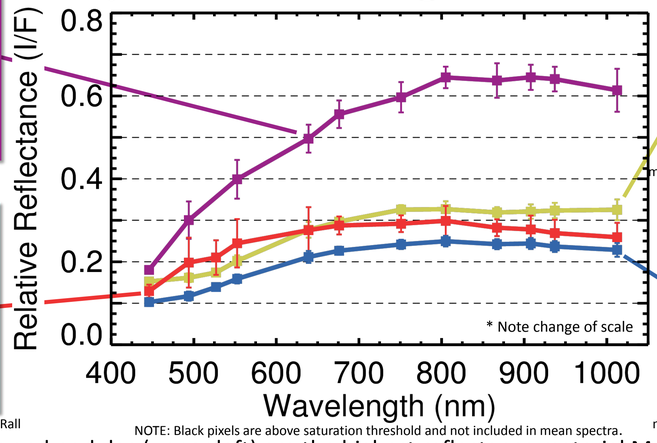
5| Veins/Ridges



mcam00805.0000a.knorr_Lall_Rall

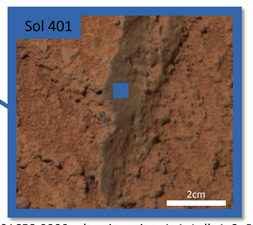


mcam00883.0000a.vein_crushing_Lall_3x3_Rall



NOTE: Black pixels are above saturation threshold and not included in mean spectra.

mcam01888.0000a.hematite_ridge_3_ccam_Lall_Rall

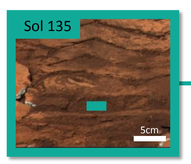


mcam01658.0000a.darwin_veins_1x1_Lall_1x2_Rall

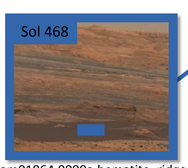
- Dusty light-toned veins and nodules (upper left) are the highest reflectance material Mastcam has observed. Certain localized sections of these calcium sulfate [6] veins may show evidence for gypsum over other Ca-sulfates [7,8].
- Raised ridges in Yellowknife Bay, broken by the rover to reveal fresh surfaces, are comprised of light-toned gray material spectrally similar to John Klein and Cumberland drill fines and other local gray rocks.
- Observations towards the base of Mt. Sharp (upper right) show a region parallel to the mound with a weak absorption feature near 867 nm possibly consistent with hematite detected from orbital observations [9,10].
- Multispectral images of dark ridge-forming material (lower right) at the Darwin Waypoint are spectrally similar to other dark-toned rocks, in this case with moderate amounts of dust contaminating the spectrum.

6| Dust, Soil, and Sand

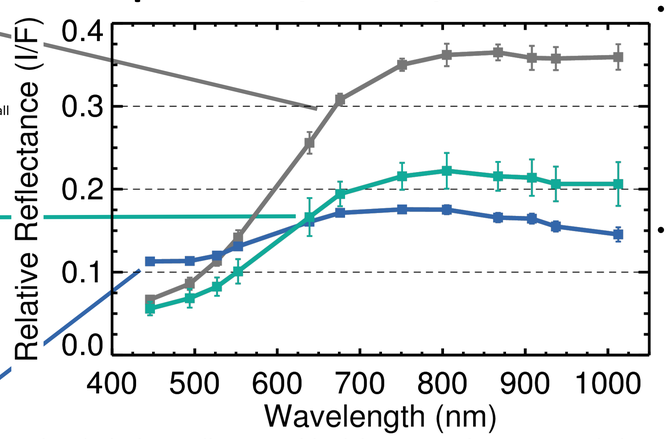
mcam00699.0000a.jackson_lake_Lall_Rall



mcam00823.0000a.pachi_Lall_Rall



mcam01864.0000a.hematite_ridge_ccam_Lall_Rall



- Reddish dust (top, gray) possesses a steep rise in reflectance through the visible wavelengths, consistent with poorly crystalline ferric iron constituents [11].
- Dark reddish soil (middle, turquoise) is exposed where the rover disturbs the ground. The slope from blue to red is shallower than the overlying dust and the reflectance lower.
- The dark dunes (bottom, blue) between the rover and the central mound possess spectra with even less ferric contribution and appear spectrally similar to the local dark-toned rocks.

7| Conclusions

- Mastcam multispectral observations reveal spectral diversity along Curiosity's traverse consistent with variations in iron mineralogy.
- Observations in the near-infrared reveal variability not evident in regular RGB color imaging.

Citations: [1] Bell *et al.* (2006) *JGR 111,* E02S03. [2] Hunt and Salisbury (1970) *Mod. Geology 1*, 283. [3] Johnson *et al.* (2014) *Icarus*, in press. [4] Gaffey (1976) *JGR 81*, 905. [5] Vaniman *et al. (2014) Science, 343, 6169.* [6] Nachon *et al.* (2014) *JGR*, submitted. [7] Rice *et al. (2013) EPSC 8, 762.* [8] Rice *et al. (2013) AGU Fall Meeting, 1795.* [9] Milliken *et al. (2010) GRL, 37, (4).* [10] Fraeman *et al. (2013) Geology, 41, 1103.* [11] Morris *et al.* (1993) *GCA 57*, 4597. | Scale bars based on W. Goetz & B. Madsen rectified Mastcam images.