

**MASTCAM MULTISPECTRAL EXAMINATION OF ROCKS IN THE SULFATE-BEARING TERRAIN OF MARKER BAND VALLEY, GALE CRATER, MARS.** W.H. Farrand<sup>1</sup>, A.Eng<sup>2</sup>, J.R. Johnson<sup>3</sup>, S.R. Jacob<sup>4</sup>, J.F. Bell III<sup>4</sup>, E.B. Rampe<sup>5</sup>, R.E. Arvidson<sup>6</sup>.<sup>1</sup>Space Science Institute, Boulder, CO, [farrand@spacescience.org](mailto:farrand@spacescience.org); <sup>2</sup>Western Washington University, <sup>3</sup>Johns Hopkins Applied Physics Lab, <sup>4</sup>Arizona State University, <sup>5</sup>NASA Johnson Space Center, <sup>6</sup>Washington University in St. Louis.

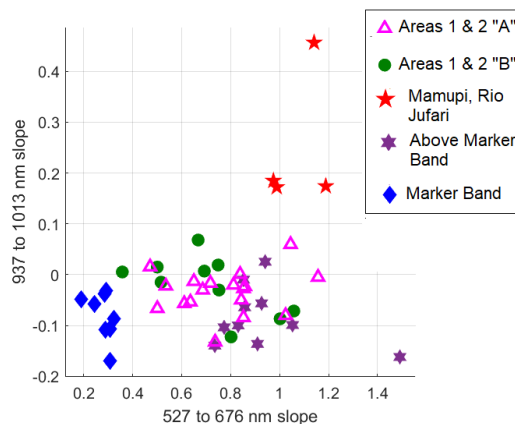
**Introduction:** A primary objective of the 4<sup>th</sup> extended mission of the Mars Science Laboratory rover Curiosity is to characterize the sulfate-bearing beds exposed on the slopes of Mt. Sharp (Aeolis Mons) above the clay-bearing beds of the Glen Torridon region characterized in the 3<sup>rd</sup> extended mission [1]. Orbital reflectance spectroscopy from CRISM [2] has indicated the presence of polyhydrated Mg sulfates in the portion of Mt. Sharp dubbed “Marker Band Valley” (MBV). The Marker Band is a darker toned, high-Ca pyroxene bearing [3] unit that extends around much of Mt. Sharp above the first exposures of sulfate-bearing beds. Stand-off imaging of the Marker Band indicates that it is not monolithic, but contains at least two subunits [4,5]. Curiosity measures multispectral reflectance in the 430 to 1012 nm range with its Mastcam. While diagnostic spectral features of Mg-sulfates are not present in the Mastcam spectral range, a water overtone feature of some polyhydrated sulfates can be observed as a drop in reflectance in the longest wavelength one to three bands of Mastcam multispectral data [6,7]. Other minerals associated with sulfate-generating alteration processes, most notably Fe-bearing minerals, are more readily detectable in Mastcam multispectral data.

**Data and Analysis Approach:** Mastcam is a stereo camera and collects 12 narrow spectral bands (and three broad Bayer Pattern filter bands) between the two Mastcam “eyes” [8]. Multispectral data gathered on rock surfaces cleared by the rover’s Dust Removal Tool (DRT) and windswept areas were analyzed. Using a set of 55 spectra, a hierarchical clustering approach yielded 4 broad spectral groups with each having two finer branches.

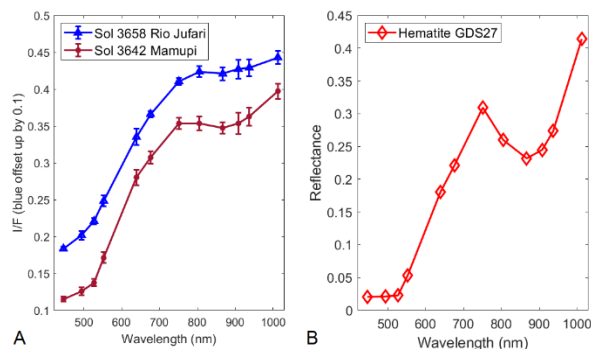
**Assessment of Multispectral Data:** Out of the 8 fine and 4 broad spectral groups, the Marker Band rocks have positive 527 to 676 nm slopes (Fig. 1) and 676/445 nm ratios lower than other MBV rocks. Also distinct are more highly altered rocks from the Mamupi DRT spot directly below the Marker Band and the Rio Jufari DRT above the Marker Band. Mamupi and Rio Jufari spectra have relatively large 867 nm band depths and high 937 to 1013 nm positive slopes and their spectra (Fig. 2A) are consistent with the presence of crystalline red hematite (Fig. 2B).

Spectra of rock surfaces from the first portion of MBV traversed by the rover (dubbed “areas 1 and 2”) (Fig. 3A) stand out from other spectra in a plot of 751 to 1012 nm slope vs. 867 nm band depth (Fig. 4) with

negative 751 to 1012 nm slopes and relatively elevated 867 nm band depths. The spectra of these rock surfaces are similar to rock surfaces observed in the clay-sulfate transition region prior to the arrival at the sulfate-bearing terrain. They are also similar to the “Sutton Island Manset” class of [7] discussed also by [9 and 10], but generally lack the longer wavelength upturn of the Sutton Island Manset observations.

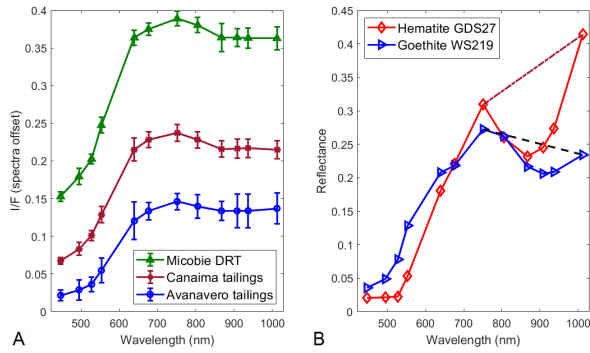


**Fig. 1.** 937 to 1013 nm slope vs. 527 to 676 nm slope of measured MBV rock surfaces.

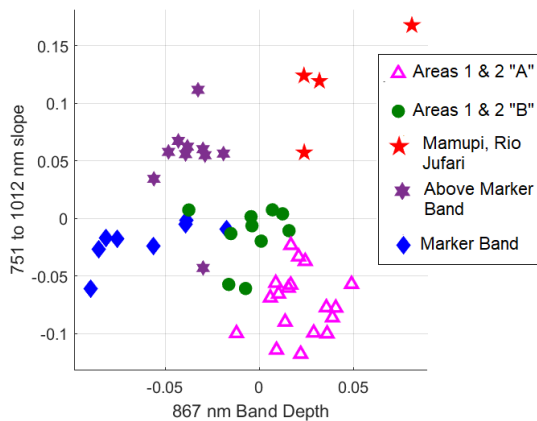


**Fig. 2. A.** Reflectance spectra of DRT spots on targets Mamupi and Rio Jufari showing influence of hematite. **B.** Library spectrum of hematite at Mastcam band-passes.

**Discussion:** Several outstanding features from these spectral results have implications for the interpretation of the geologic history of the rocks making up MBV. With regards to the Marker Band itself, the low level of values of parameters such as 527 to 676 nm slope (Fig. 1) superficially suggest incompletely oxidized materials; however ChemCam [11] and APXS [12] derived chemistry suggests elevated levels of Mn, and likely



**Fig. 3.** A. Clay-sulfate transition to sulfate area 1 and 2 type spectra. B. Library spectra of hematite and goethite at Mastcam bandpasses showing high 751 to 1012 nm slope of hematite and negative slope for goethite.

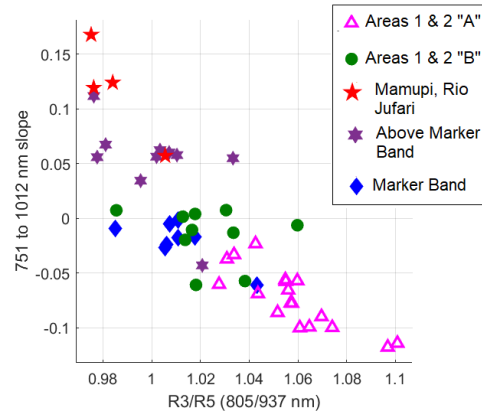


**Fig. 4.** 751 to 1012 nm slope vs. 867 nm band depth of measured MBV rock surfaces.

Mn oxides, in the Marker Band. Mn oxides could potentially be masking Fe oxide spectral features. Also, morphologic features (such as ripples) in part of the Marker Band suggest movement of the constituent granular materials in water [5]. The “area 1 and 2” rock surface spectra can be assessed with reference to mineralogy determined from the Canaima drill hole as measured by CheMin [13] as well as with reference to previous, but spectrally similar observations such as the Avanavero drill hole. Both Canaima and Avanavero had 2 to 7 wt.% hematite and goethite. The drop in reflectance of these spectra (Fig. 3) from 805 to 867 nm is consistent with the influence of both hematite and goethite, but the flat to only mildly positive or mildly negative slope to longer wavelengths is more consistent with the influence of goethite (Fig. 3B).

The hematite-like spectra of the Mamupi and Rio Jufari DRT targets (Fig. 2) suggest higher fractions of red hematite and greater levels of oxidative alteration for those targets.

The “Above Marker Band” rocks are also elevated in the 751 to 1012 nm positive slope parameter (along with the hematitic Mamupi and Rio Jufari DRT spots). This is illustrated in the 751 to 1012 nm slope vs. R3/R5 plot of Fig. 5.



**Fig. 5.** 751 to 1012 nm slope vs. R3/R5 of measured MBV rock surfaces.

**Conclusions:** Marker Band rocks have low values of spectral parameters associated with ferric oxides, but this could be due to masking by Mn oxides [11, 12]. Rocks above and below the Marker Band are spectrally distinct. Those below have spectra similar to rock surfaces from the clay-sulfate transition region and are nominally consistent with the subequal amounts of hematite and goethite determined by CheMin. Rocks above the Marker Band have, to date, not been examined by CheMin, but higher 751 to 1012 nm slopes suggest less influence from goethite.

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**References:** [1] Fedo C.M. et al. (2022) *JGR*, 127, e2022JE007408. doi:10.1029/2022JE007408. [2] Milliken R.E. et al. (2010) *GRL*, 37, L04201, doi:10.1029/2009GL041870. [3] Weitz C.M. et al. (2022) *JGR*, 127, doi:10.1029/2022JE007211. [4] Weitz C.M. et al. (2023) this conference. [5] Gupta S. et al., this conference. [6] Rice M.S. et al. (2013) *Icarus*, 243, 499-533. [7] Rice M.S. et al. (2022) *JGR*, 127, doi:10.1029/2021JE007134. [8] Bell J.F. III et al. (2017) *ESS*, 4, 396-452. [9] Haber J.T. et al. (2022) *JGR*, 127, e2022JE007357, doi:10.1029/2022JE007357. [10] Rudolph A. et al. (2022) *JGR*, 127, doi:10.1029/2021JE007098. [11] Gasda P. et al. (2023) this conference. [12] Thompson L.M. (2023) this conference. [13] Rampe E.B. et al. (2023) this conference. [14] Jacob S.R. et al. (2023) this conference.