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# MASTCAM MULTISPECTRAL AND CHEMCAM PASSIVE REFLECTANCE EXAMINATION OF DARK-TONED ROCKS FROM THE STIMSON TO UPPER GEDIZ VALLIS RIDGE IN GALE CRATER, MARS

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W.H. Farrand, A.R. Trussell, J.R. Johnson, J.F Bell III, A.M. Eng, et al.. MASTCAM MULTISPECTRAL AND CHEMCAM PASSIVE REFLECTANCE EXAMINATION OF DARK-TONED ROCKS FROM THE STIMSON TO UPPER GEDIZ VALLIS RIDGE IN GALE CRATER, MARS. Lunar and Planetary Science Conference, Lunar and Planetary Science Institute, Mar 2024, The Woodlands, United States. pp.2146. hal-04800416

**HAL Id: hal-04800416**

**<https://hal.science/hal-04800416v1>**

Submitted on 24 Nov 2024

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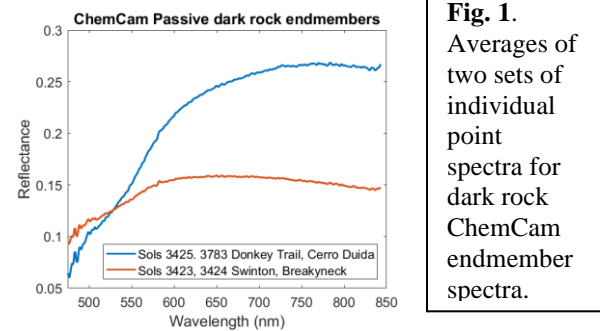
**MASTCAM MULTISPECTRAL AND CHEMCAM PASSIVE REFLECTANCE EXAMINATION OF DARK-TONED ROCKS FROM THE STIMSON TO UPPER GEDIZ VALLIS RIDGE IN GALE CRATER, MARS.** W.H. Farrand<sup>1</sup>, A.R. Trussell<sup>2</sup>, J.R. Johnson<sup>3</sup>, J.F. Bell III<sup>2</sup>, A.M. Eng<sup>4</sup>, E.B. Rampe<sup>5</sup>, R.Y. Sheppard<sup>6</sup>, O. Gasnault<sup>7</sup>. <sup>1</sup>Space Science Institute, Boulder, CO (farrand@spacescience.org), <sup>2</sup>School of Earth and Space Exploration, Arizona State University, <sup>3</sup>JHU Applied Physics Lab., <sup>4</sup>Georgia Inst. Technology, <sup>5</sup>NASA Johnson Space Center, <sup>6</sup>Planetary Science Institute, <sup>7</sup>IRAP-OMP, CNRS-UPS, Toulouse, France.

**Introduction:** The primary objective of the Mars Science Laboratory rover Curiosity is to examine the geologic history of Mars from ancient rocks on the floor of Gale crater to more recent rocks higher on the slopes of Mt. Sharp (formally, Aeolus Mons). The majority of the rocks examined to-date have been relatively light-toned clastic rocks (i.e., mudstones, siltstones, and sandstones) deposited in a variety of subaqueous to subaerial depositional settings. However, Curiosity has also encountered dark-toned float rocks as well as in-place, disconformable exposures of more recently deposited dark-toned rocks. Many of these rocks are also clastic in nature, but have undergone little to no alteration. Thus, these rocks may serve as potential records of past volcanic processes, including pyroclastic materials.

In this presentation, we conducted a survey of the 450 to 1010 nm multispectral character of such dark-toned rocks from Curiosity's Mastcam multispectral instrument with complementary high spectral resolution 475 to 840 nm point spectra from the passive reflectance capability of Curiosity's ChemCam instrument [1,2]. Supporting chemical information from ChemCam or the rover's APXS, as well as mineralogical information from the CheMin instrument provide context.

**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" [3]. Some of the multispectral data examined were from windswept areas on float rocks while some were collected from rock surfaces cleared by the rover's Dust Removal Tool (DRT). Some dark-toned float rocks encountered by Curiosity turned out to be Fe-Ni meteorites [4]. These were nominally excluded from the spectra examined. ChemCam passive reflectance spectra are gathered in association with laser induced breakdown spectroscopy (LIBS) on points on rocks. The Mastcam spectra analyzed were decomposed into a set of 9 spectral parameters and these were clustered using an agglomerative hierarchical clustering approach (AHCA). Given the high spectral dimensionality of the ChemCam passive reflectance spectra, we detected spectrally distinct materials with a set of spectral endmember detection approaches including an Automatic Target Generation Process (ATGP) [5], Vertex Component Analysis (VCA) [6], and N-FINDR [7].

**ChemCam Passive Reflectance Results:** Using 155 spectra from sols 3417 to 3931 (e.g., from the Greenheugh Pediment to an examination of a flank of the upper Gediz Valis Ridge), basically two distinct spectral types were extracted (**Fig. 1**). One was characterized by a relative reflectance maximum near 650 nm with decreasing reflectance to 840 nm, and another with a relative reflectance maximum closer to 760 nm followed by decreasing reflectance thereafter. Mineralogic assessments of these two spectral types will be discussed below in association with the Mastcam multispectral results.

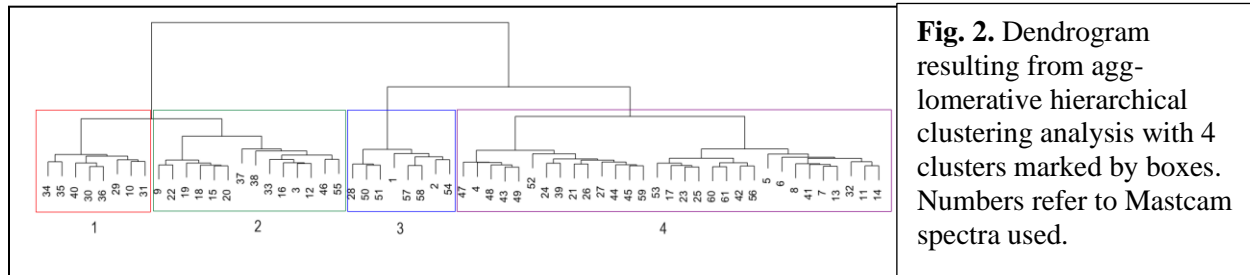


**Mastcam Multispectral Results:** We conducted an initial analysis using 61 spectra from sols 3316 to 3934, corresponding to rocks encountered from the Greenheugh Pediment to upper Gediz Valis Ridge. An expanded set of both ChemCam passive and Mastcam multispectral spectra extending back to at least the rover's first encounter with the Stimson formation will be included in a final presentation.

Application of the AHCA generated a dendrogram for which breaks were made from the second branching of the dendrogram, resulting in 4 groups (**Fig. 2**). Representative spectra of these 4 groups are shown in **Fig. 3**. The first cluster was different from either of the ChemCam passive endmembers in that it exhibited positive spectral slopes that leveled off toward the end of the Mastcam spectral range (1013 nm).

The second cluster approximates the second ChemCam passive spectral type with a relative reflectance maximum closer to 800 nm with a mild drop-off in reflectance at longer wavelengths.

The third cluster approximates the first ChemCam passive spectral type with a shorter wavelength relative reflectance maximum near 640 to 700 nm with a negative slope at longer wavelengths from the max.



**Fig. 2.** Dendrogram resulting from agglomerative hierarchical clustering analysis with 4 clusters marked by boxes. Numbers refer to Mastcam spectra used.

The fourth cluster is generally similar to the second and differs primarily with regards to its members having a stronger 527 nm band depth and steeper blue to red slope. These could indicate greater inherent oxidation or possibly just incomplete dust removal from the measured surfaces.

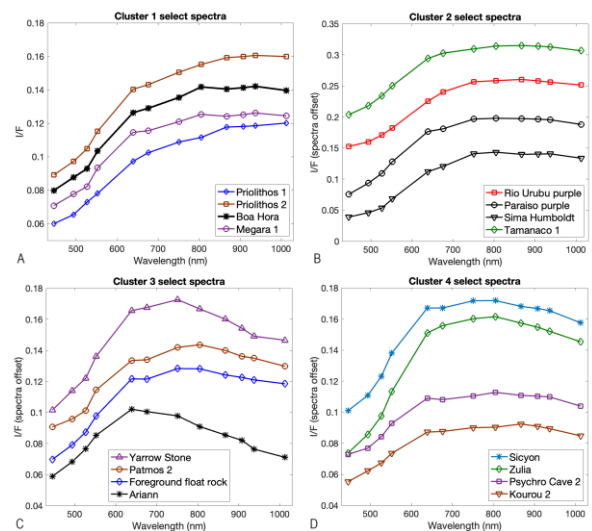
**Discussion:** For the spectra examined to date, there are at least three and potentially four spectrally distinct groups of dark-toned rocks. Both the ChemCam passive and Mastcam multispectral results indicate one group with a shorter wavelength reflectance maximum and a relatively steep drop in reflectance to longer wavelengths. As the comparison in **Fig. 4** makes clear, these spectral characteristics are consistent with the presence of olivine which has a broad crystal field band absorption centered just longwards of 1000 nm. The presence of olivine was confirmed at an abundance of 8% in the dark capping rock drill target Edinburgh (circa sol 2710) [7]. Potentially higher abundances of olivine could be present in the group 3 rocks. If the second and fourth groups are considered as a single group (with the spectral parameters attributable to oxidation considered as dust contamination), that group could be consistent with the presence of high-Ca pyroxene and possibly also ferrous oxides and/or basaltic glass.

ChemCam LIBS chemistry of the Priolithos target included in group 1 indicated that it was a Fe-Ni meteorite. However, the other examples in **Fig. 3A** were not. The lack of a downturn in reflectance at long wavelengths of other spectra in this group suggest that major contributors to the observed reflectance were likely opaque minerals and/or devitrified glasses.

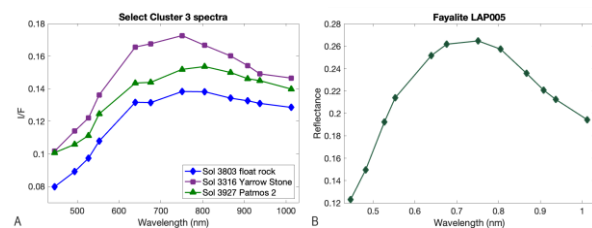
**Future Work:** The set of sols examined here will be expanded back to earlier sols of Curiosity's mission to include its examination of the Stimson formation and other dark-toned float rocks examined along the way. Also, an examination of CRISM data of basaltic materials near Gale crater could reveal potential associations with some of the float rocks observed by Curiosity.

**Acknowledgments:** This work was supported for authors Farrand and Johnson through the Mars Science Laboratory Participating Scientist program.

**References:** [1] Johnson J.R. et al. (2015) *Icarus*, 249, 74-92. [2] Johnson J.R. et al. (2016) *American Mineralogist*, 101, 1501-1514. [3] Bell J.F. III et al. (2017) *Earth & Space Sci.*, 4, 396-452. [4] Meslin P.-Y. et al. (2019) LPSC 50<sup>th</sup>, #3179. [5] Chang C.I. and Li Y. (2016) *IEEE TGARS*, 54, 5081-5094. [6] Nascimento J.M.P. and Dias J.M.B (2006) *IEEE TGARS*, 43, 898-910. [7] Winter M.E. (1999) *Imaging Spectrometry V*, 3753, 266-275, SPIE. [8] Thorpe M.T. et al. (2022) *JGR*, 127, e2021JE007099, [doi.org/10.1029/2021JE007099](https://doi.org/10.1029/2021JE007099). [9] Scholes D. et al. (2021) 5<sup>th</sup> Planet. Data Workshop, #7006.



**Fig. 3.** A. Representative spectra of cluster 1 from the AHCA analysis. B. Cluster 2 spectra. C. Cluster 3 spectra. D. Cluster 4 spectra.



**Fig. 4.** A. Several select spectra from group 3. B. A fayalite library spectrum [9] convolved to Mastcam bandpasses.