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Mastcam multispectral imaging results from the Mars Science Laboratory investigation in Yellowknife Bay

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Abstract

The Mars Science Laboratory (MSL) "Curiosity" rover has been investigating the visible to near-infrared (Vis-NIR) reflectance properties of surface materials at Gale crater using science filter images from the Mastcam instrument. Within the Yellowknife Bay region, Mastcam observations reveal the greatest spectral diversity yet observed during the MSL mission. Mastcam observations of broken or brushed rock surfaces reveal blueish-gray hues, and spectra of some fracture-filling veins are consistent with the presence of hydrated minerals.

1. Introduction

The Mars Science Laboratory (MSL) "Curiosity" rover landed in northwestern Gale crater on August 6, 2012 UTC. After traversing across a rock pavement of loose clasts called "Bradbury Rise" and a sand drift called "Rocknest," the rover entered "Yellowknife Bay," a shallow depression with extensive exposures of fractured outcrop. Rocks of the "Sheepbed" unit within Yellowknife Bay are characterized by dense distributions of concretions and narrow, light-toned veins.

The Mastcam imaging investigation [1,2] provides high-resolution morphological information, RGB color, and visible to near-infrared (Vis-NIR) multispectral data using narrowband "science filters." As of MSL Sol 180 (Feb. 5, 2013), ~105 Mastcam multispectral observations have been acquired of surface targets. Mastcam spectra of materials at Bradbury Rise and Rocknest are consistent with typical nanophase ferric oxide-bearing airfall dust coatings, and some spectra of low albedo rock and soil surfaces are consistent with the presence of weak pyroxene and/or olivine [3] absorptions. The rocks of Yellowknife Bay, however, exhibit greater spectral diversity, as described in the following sections.

2. The Mastcam Instrument

Mastcam is a pair of CCD cameras with fixed focal lengths (34-mm and 100-mm) mounted roughly 2 m above the surface on the rover's mast. Each camera obtains images through a Bayer pattern of RGB filters and telecentric microlenses bonded onto the CCD and an 8-position narrowband filter wheel that provides the ability to obtain spectra in 12 unique wavelengths [2,3]. These multispectral observations have been calibrated to radiance using pre-flight calibration coefficients, and to radiance factor (I/F) using associated observations of the Mastcam calibration target [3].

3. Sensitivity to Hydrated Materials

Mastcam's longest wavelength filters have some sensitivity to hydrated and/or hydroxylated minerals [3]. The 1013 nm near-IR filters (L6 and R6) can detect an absorption due to the $2\nu_1 + \nu_3$ H_2O combination band and/or the 3ν OH overtone when this band minimum occurs between 980-1000 nm (in water ice and some carbonates and hydrated sulfates; Fig. 1). This narrow hydration band leads to a Mastcam spectral profile that is "flat" in the NIR with a sharp downturn in the longest Mastcam wavelength (Fig. 1) and is distinguishable from spectra of iron-bearing minerals with broad absorptions near 1000 nm.

We use this spectral profile to remotely identify and map candidate hydrated surface materials in Mastcam multispectral images, based on the technique developed for Mars Exploration Rover (MER) Pancam instruments [4]. The Mastcam "hydration signature" is based on a nearly flat spectral profile between 805 and 937 nm and a spectral slope from 937 to 1013 nm greater than 4.0 x 10^{-4} nm^{-1}.

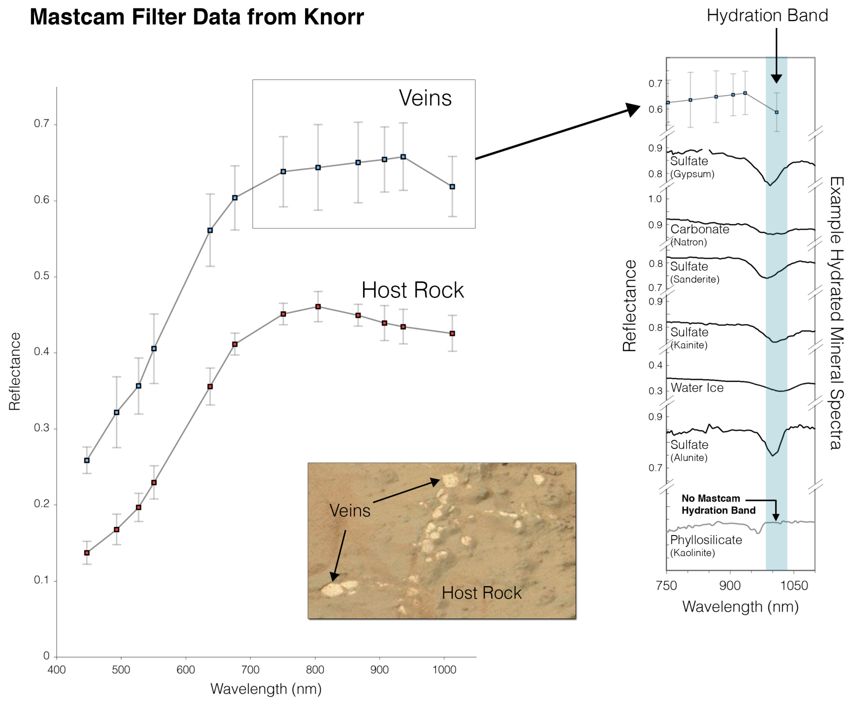

Figure 1: Mastcam spectra of veins and host rock material at Knorr within the Sheepbed unit at Yellowknife Bay. The absorption near 1013 nm in the vein spectrum is consistent with a H_2O and/or OH feature observed in some hydrated minerals. The vein spectrum is consistent with some hydrated Ca-sulfates, such as gypsum, but is not consistent with the presence of phyllosilicate minerals.

It is important to note that the absence of the hydration signature in Mastcam spectra does not necessarily indicate an absence of hydrated minerals; in the spectra of many H_2O and/or OH bearing minerals, including most phyllosilicates, the hydration band we are detecting is centered closer to 950 nm, which falls between the band passes of Mastcam's longest wavelength filters (937 and 1013 nm) and is thus undetectable to the instrument.

5. Results from Yellowknife Bay

Calibrated I/F Mastcam spectra from Yellowknife Bay show some evidence for hydration associated with the light-toned veins of the Sheepbed Unit (e.g., Knorr; Fig. 1). These narrow veins contain enrichments in Ca and S as identified by the ChemCam and APXS instruments [5].

Mastcam spectra of other dust-covered surfaces show overall similarity with spectra of undisturbed materials at Bradbury Rise and Rocknest. Specifically, light-toned, reddish airfall dust surfaces show a steep and smooth reflectance increase from 445 nm to 750 nm that has been interpreted as evidence of nanophase ferric (Fe^{3+}) oxide [e.g., 6].

Disturbed surfaces in Yellownife Bay show a greater spectral diversity in Mastcam multispectral observations. Rocks of the Sheepbed and Gillespie units, when broken by Curiosity's wheels (e.g., Sutton_Inlier) or brushed by the rover's Dust Removal Tool (e.g., Wernecke), have grayish to blueish hues and exhibit higher reflectances in the short wavelength Mastcam filters (447 to 638 nm) than previously observed along the traverse. Some show slightly negative near-IR spectral slopes, consistent with the presence of pyroxene and/or olivine in typical basaltic materials.

Other broken rocks (e.g., Tintina) reveal inner surfaces with whitish hues and high albedo values that also exhibit a strong absorption at 1013 nm, consistent with the presence of a hydrated material.

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