CHEMCAM PASSIVE REFLECTANCE SPECTROSCOPY OF RECENT DRILL TAILINGS, HEMATITE-BEARING ROCKS, AND DUNE SANDS. J.R. Johnson[1], E. Cloutis[2], A.A. Fraeman[3], B.L. Ehlmann[3,6], R.C. Wiens[4], S. Maurice[5], D. Blaney[6], O. Gasnault[5], S. Le Mouélic[7], P. Pinet[8], S. Bender[4]. [1]Johns Hopkins Univ. Applied Physics Lab, Laurel, MD 20723, jeffrey.r.johnson@jhuapl.edu, [2]Univ. of Winnipeg, [3]California Inst. of Technology, [4]Los Alamos National Lab, [5]Research Inst. in Astrophysics and Planetology, [6]Jet Propulsion Lab, [7]Le Lab. de Planétologie et Géodynamique de Nantes, [8]Centre National d'Études Spatiales, Toulouse.

Introduction: Ongoing acquisition of relative reflectance spectra (400-840 nm) by the Chemistry and Camera (ChemCam) instrument on the Mars Science Laboratory (MSL) rover Curiosity [1,2] has documented recent drill tailings with high and intermediate SiO_2 contents [3], the appearance of hematite-like spectral features in outcrop rocks, and evidence for olivine-bearing materials in initial observations of sands in the Bagnold Dune region.

Methods. We used the onboard ChemCam calibration targets' zinc stearate-painted housing as a reflectance standard, and employed methods to collect, calibrate, and reduce radiance observations to relative reflectance as summarized in [1]. ChemCam laser-induced breakdown spectroscopy (LIBS) observations include 3 msec-exposure "dark" spectra used to remove the background signal from the LIBS measurement. The dark exposures provide useful passive signal in the 400-840 nm region, although better optimization results from longer exposure times (e.g., 30, 400 msec).

Data. In the Marias Pass region drill tailings from the target Buckskin were observed on Sols 1062 (sequences ccam02061, 3061) and 1064 (ccam02064). Within the Stimson sandstone unit, observations were acquired of the drill tailings from the target Big Sky on Sols 1120 (ccam01119) and 1123 (ccam01123, 2123) and on the post-sieve dump pile on Sol 1138 (ccam06136). In the nearby light-toned fractured region, drill tailings from the Greenhorn target were observed on Sols 1139, 1140, and 1141 (ccam01139, 1140, 1141), and the post-sieve dump pile was observed on Sol 1204 (ccam05202).

Ongoing passive spectra observations of the outcrop rocks along the traverse revealed a marked change in reflectance properties beginning on Sol 1157 with the rock target Augusta (ccam01157). This trend has continued along the traverse, with the exception of some targets acquired between Sols 1189-1194. Example targets shown here include Tsumeb (Sol 1162; ccam02162) and Engo (Sol 1199; ccam15041).

Preliminary observations of the low albedo Bagnold Dune materials were acquired on Sol 1167 from a ~140 m distance (ccam01167). Once near the base of High Dune on Sol 1182, the undisturbed and disturbed sands at target Hoanib were analyzed (ccam01182). On Sol 1184 the targets Barby and Kibnas (ccam01184, 2184) were observed near a ripple crest and in a nearby trough region, respectively.

Results. The passive spectra of the recent drill tailings are compared to previous drill tailings in **Figure 1a**. The Buckskin drill tailings exhibited a relatively flat spectrum, likely owing to the presence of spectrally neutral phases such as magnetite and silica. A weak ~550 nm absorption is consistent with the presence of minor hematite, and a weak ~430 nm band is consistent with minor ferric iron-bearing phases. The high SiO_2 content (~65 wt %) in this sample may act as a transparent matrix that enhances the contribution of such minor ferric phases. The Big Sky tailings were spectrally flat (similar to Telegraph Peak) likely from the presence of magnetite, and include a weak downturn > 750 nm, possibly from minor hematite. The presence of a weak ~430 nm band may indicate trace ferric sulfates (below the detection threshold of CheMin). The Greenhorn tailings were spectrally flat but exhibited a weak upturn toward shorter wavelengths (potentially related to small amounts of magnetite or ilmenite) and a weak negative near-infrared slope starting near 750 nm likely from minor, predominantly amorphous, ferric phases. The suggestion of a similarly weak ~430 nm band to that of Big Sky could also be related to trace ferric phases. As was the case with Buckskin, the transparent/amorphous matrix component could enhance bands associated with even small amounts of ferric materials.

Figure 1b shows the spectra from Augusta, Tsumeb , and Engo, examples of rocks in which spectral characteristics similar to crystalline hematite are present, including absorption bands of variable strength near 550 nm, 650 nm, a reflectance peak near 750 nm, followed by a near-infrared downturn. The hematite-bearing drill tailings at Confidence Hills (Figure 1a) provide a useful comparison. These features have been present in nearly all outcrop rocks since Sol 1157. Mastcam multispectral imaging and CRISM orbital spectra are consistent with these findings, indicating a change in oxidation state of the outcrop materials or crystallinity of hematite as the rover drives south toward the Hematite Ridge area [4].

Figure 1c shows representative spectra of sands associated with the Bagnold Dunes. Spectral features consistent with olivine include a weak, broad band near 620 nm, and a peak position near 670-700 nm that is more consistent with olivine than pyroxenes. Differences among disturbed, undisturbed, ripple crest,

and ripple trough sands are marked by changes in the peak reflectance position, its sharpness, and the related steepness of the near-infrared dropoff. These are due to variations in relative olivine abundance (and/or grain size) versus more ferric materials, particularly in the disturbed sands.

Conclusion. The spectral features associated with the recent drill tailings (Buckskin, Big Sky, Greenhorn) are distinct from most previous drill tailings. Buckskin exhibits a stronger ~430 nm band and a near-infrared falloff suggestive of ferric phases such as ferric sulfate. Big Sky shares some strong similarities in overall relative reflectance and spectral shape to Telegraph Peak. Big Sky and Greenhorn also exhibit minor ~430 nm bands, as well as variations in overall spectral slopes. These features may indicate trace amounts of Fe-bearing materials whose relative paucity is nonetheless manifested disproportionately owing to the relatively transparent nature of high-SiO_2, amorphous materials that comprise a substantial fraction of these samples.

The recent encounters with rocks exhibiting hematite-like spectra (e.g., Augusta, Tsumeb, Engo) suggest that the transition to more hematite-bearing materials has occurred slightly northward of the mapped CRISM detections. It is expected that these signatures will continue to be observed, perhaps with greater strength, during the approach to Hematite Ridge and points south.

Preliminary investigations of the Bagnold Dune sands are consistent with olivine-bearing materials. Subtle variations in spectra are related to the variable proportions and grain sizes of olivine, other mafic (or felsic) materials, and ferric crystalline and/or amorphous materials among the surface, subsurface, crests, and troughs of the ripple forms. Future observations of these dune materials as a function of sieved grain sizes will help discern the relative contributions of multiple phases comprising the sands.

References: [1] Johnson, J.R., et al., Icarus, http://dx.doi.org/10.1016/j.icarus.2014.02.028, 2014; Johnson, J.R., et al, in review to Amer. Mineral., 2016; [2] Wiens, R., et al., Space Sci Rev., 170, 167-227, 2012; Maurice, S., et al., Space Sci Rev., 170, 95-106, 2012; [3] Frydenvang, J.., et al., this conference; [4] Fraeman, A. et al., Geology, 41(10), 1103-1106; Fraeman, A. et al., LPSC #2124, 2015 ; Fraeman, A. et al., this conference.

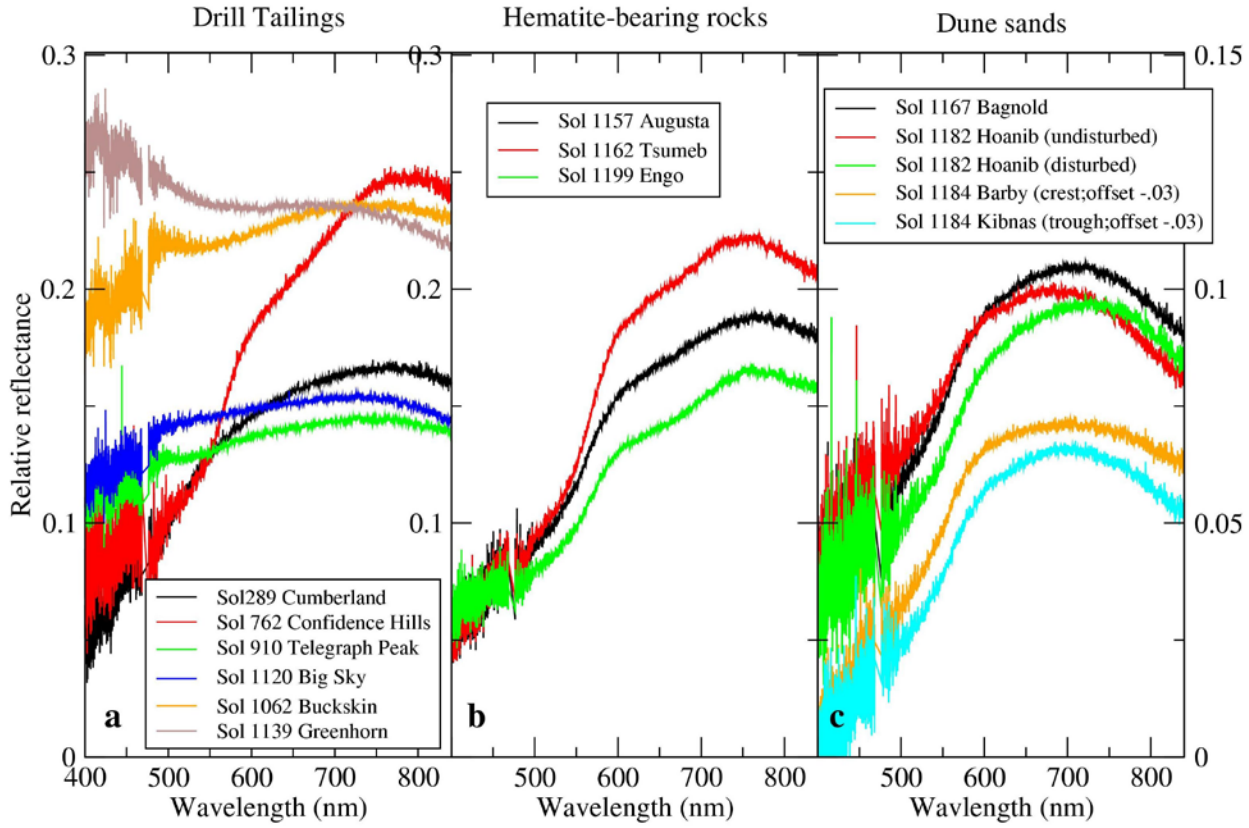

Figure 1. ChemCam reflectance spectra of (***a***) recent drill tailings compared to Cumberland, Confidence Hills and Telegraph Peak; (***b***) examples of hematite-like spectral signatures in outcrop rocks since Sol 1157; (***c***) examples of Bagnold Dune sand spectra from distant (Sol 1167) and near-field observations of undisturbed and disturbed soils, and soils near a ripple crest and within a lower trough region. Note different relative reflectance scale compared to ***a*** and ***b***. The break near 470 nm is a gap between spectrometers.