MASTCAM VISIBLE/NEAR-INFRARED SPECTROPHOTOMETRIC OBSERVATIONS OF THE RED HILLS REGION OF VERA RUBIN RIDGE. J.R. Johnson[1], J.F. Bell III[2], M. Lemmon[3], P. Pinet[4], [1]Johns Hopkins University Applied Physics Laboratory, Laurel, MD 20723, jeffrey.r.johnson@jhuapl.edu, [2]Arizona State University, [3]Space Science Institute, [4]IRAP, Toulouse, France.

Introduction: The Curiosity rover acquired multispectral Mastcam images of the same terrain at multiple times of day on Sols 2005-2006 while near the Red Hills region on the Vera Rubin Ridge (VRR), which exhibited one of the highest 860 nm band depths from CRISM orbital spectroscopy [1]. This expands on data sets previously acquired along the traverse [2-5] that will be used to investigate the light scattering properties of rocks and soils along the Curiosity traverse using Hapke radiative transfer models [e.g., 6]. The data also allowed examination of the 527 nm and 867 nm band depths as a function of phase angle, an important factor when interpreting spectral variations across the VRR and their relation to potential formation mechanisms of hematite on the ridge. We also examined variations of these parameters using PDS-archived multispectral goniometer measurements of the Mars Exploration Rover Pancam calibration target red color chip [Bell] that was pigmented with submicron powders of hematite.

Data sets. Images were acquired by the Mastcam-34 (M-34) camera using filters at 445, 527, 751, 867, and 1012 nm. Two-frame mosaics pointed in the sunset and anti-sunset directions were taken at 7 times of sol (**Table 1; Fig. 1**). This data set provided phase angle coverage from near 0° to ~130° for different types of bedrock surfaces and surrounding sandy soils. Navigation Camera (Navcam) stereo images were also acquired to provide terrain measurements for computing surface normals and local incidence and emission angles. These will be used to atmospherically-correct radiance data prior to radiative transfer modeling of surface units [e.g., 6-7]. Multispectral observations of the red color chip used on the Pancam calibration target were acquired over many phase angles by the Bloomsburg University Goniometer (BUG) [8]. The red pigment used to color this chip was 5 wt.% of the HMS3 ~140 nm powder from [9] mixed with white GE RTV 655 binder.

Methods. Mastcam image calibration involved conversion to radiance and reflectance via use of flat field images and onboard calibration targets [10]. Regions of interest with strong hematite spectral signatures were examined at different times of day (phase angles) to determine how their 5-band spectra, band depths (at 527 nm and 867 nm), and red/blue ratios varied. BUG multispectral data of the Pancam red color chip were acquired in 11 bands (450-990 nm), allowing examination of similar spectral parameters over a large phase angle range.

Table 1. Mastcam image sequences used in this work.

Sol	Sequences (mcam*)	LTST (avg)	Phase angle (°)
2005	10530	1259	51-54
2005	10532	1303	62-73
2005	10533	1433	30-32
2005	10535	1437	84-96
2005	10543	1550	13-14
2005	10545	1554	102-114
2005	10546	1649	2-11
2005	10548	1653	117-128
2006	10549	0819	114-122
2006	10551	0823	25-27
2006	10552	0938	97-103
2006	10554	0942	25-31
2006	10555	1115	75-80
2006	10557	1119	39-50

LTST=Local True Solar Time

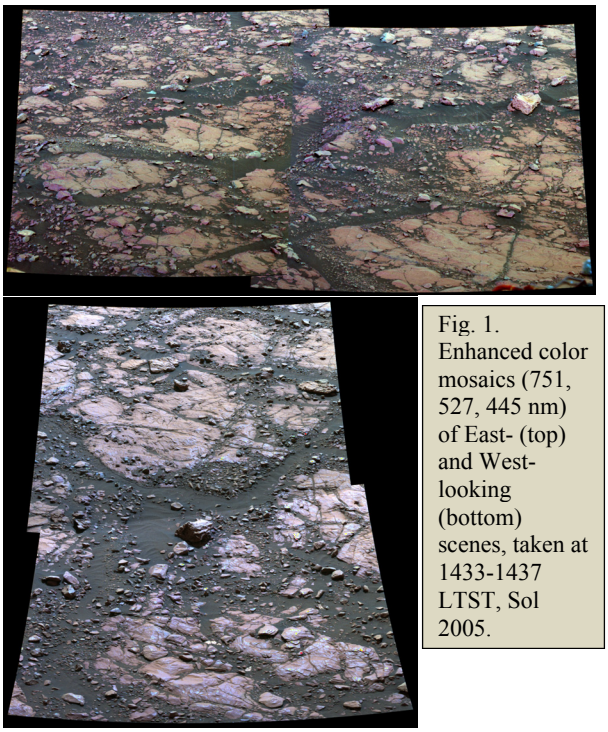

Fig. 1. Enhanced color mosaics (751, 527, 445 nm) of East- (top) and West-looking (bottom) scenes, taken at 1433-1437 LTST, Sol 2005.

Results. Figure 2 shows the 5-band Mastcam spectra extracted at six times of day for a purple-hued rock facet (cyan target in Figure 3). Stronger 527 nm and 867 nm band depths were observed at lower phase angle, as illustrated in Figure 4 where these parameters are shown for four rock facets (identified in Figure 3). The band depths are relatively constant until ~50-60˚,

after which they decrease nearly linearly with phase angle. The BUG data show similar dropoffs in these parameters (Figure 5). Comparisons of red/blue ratios (not shown here) exhibit typical phase reddening with peaks near 30˚ phase.

Conclusions. The hematite-bearing Murray formation rocks in the VRR reveal scattering behaviors that vary at high phase angles, consistent with laboratory observations of hematite-bearing targets. This photometric dependence should be considered (in addition to the effects of grain size and crystallinity [11]) when interpreting spectral parameters.

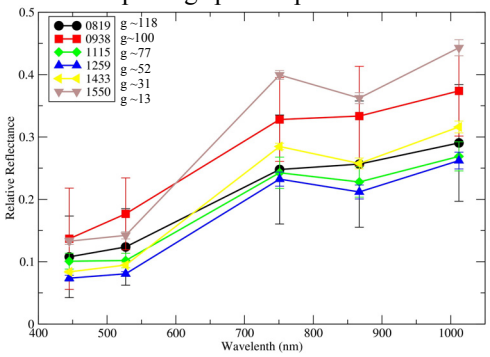

Fig. 2. Spectra extracted at different phase angles (g) for the purple rock facet (cyan target in Fig. 3).

Fig 3. Four regions of interest in one of the East-looking scenes (cf. Fig. 1), whose spectral parameters are shown as a function of phase angle in Figure 4.

References: [1] Fraeman, A. Geology 41.10 (2013): 1103-1106; [2] Johnson, J. et al., LPSC, abs. #1374, 2013; Johnson, J. et al., LPSC, abs. #1371, 2014; Johnson, J. et al., LPSC, abs. #1424, 2015 [3] Johnson, J., et al., AGU, #P43B-2125, 2015; [4] Johnson, J., et al. 8th Inter. Conf. on Mars, abs. #1073, 2014; [5] Johnson, J. et al., LPSC #1354, 2018; Johnson, J.R., et al, AGU, #234925, 2017; [6] Johnson et al., JGR., 2005JE002494, 2006; Johnson et al., JGR, 2006JE002762, 2006; Johnson et al., Icarus, 248, 25-71, 2015 [7] Lemmon, M., et al., Icarus, 2014; 8th Intern. Conf. Mars,#1338;[8]pds-geosciences.wustl.edu/missions/labdata/marsbug.html; [9] Morris, R., et al. JGR, 90.B4 (1985): 3126-3144 [10] Wellington, D., et al., Amer. Mineral., 102(6), 1202-1217, 2017; [11] Johnson, J. et al., this conference.

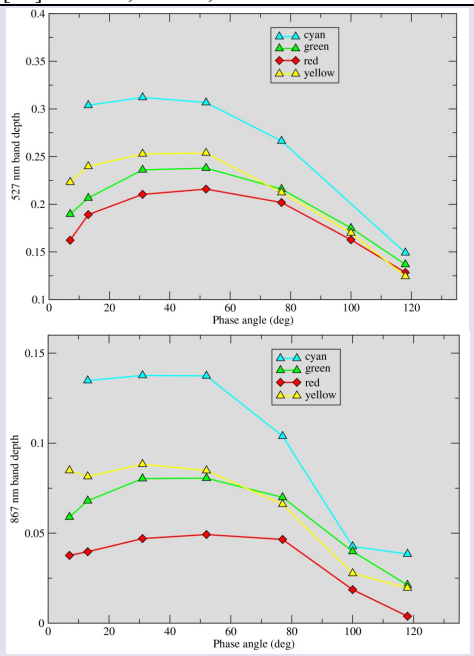

Fig. 4. Variations in 527 nm (top) and 867 nm (bottom) band depths with phase angle for four regions of interest identified in Figure 3.

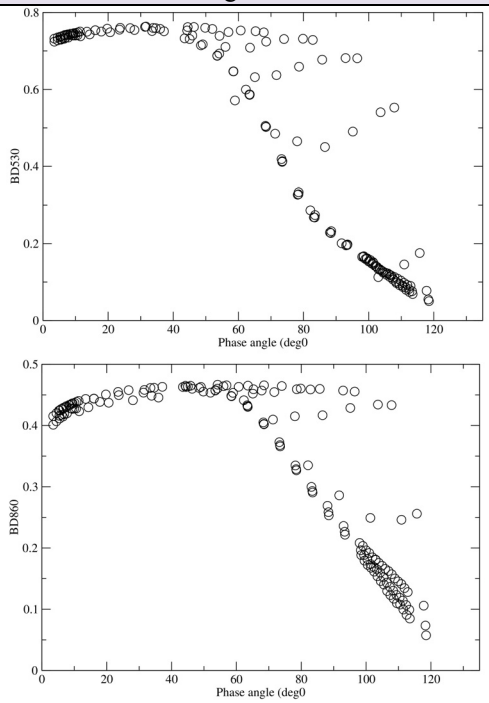

Fig. 5. Band depths at 530 nm (top) and 860 nm (bottom) calculated from BUG data of the Pancam calibration target red (hematite) chip for different phase angles [8].