SYNERGISTIC ORBITAL AND *IN SITU* OBSERVATIONS AT VERA RUBIN RIDGE: COMPARING CRISM AND CURIOSITY OBSERVATIONS. A.A. Fraeman[1], R.E. Arvidson[2], B.H. Horgan[3], S.R. Jacob[4], J.R. Johnson[5], R.V. Morris[6], M.S. Rice[7], M.R. Salvatore[8], V.Z. Sun[1], D.F. Wellington[4], J.F. Bell III[4], P. Pinet[9], R.C. Wiens[10] [1]Jet Propulsion Laboratory, California Institute of Technology (afraeman@jpl.caltech.edu), [2]Washington University in St. Louis, [3]Purdue University, [4]Arizona State University, [5]Johns Hopkins Applied Physics Laboratory, [6]Johnson Space Center, [7]Western Washington University, [8]Northern Arizona University, [9]CNRS, [10]Los Alamos National Laboratory

Introduction: Vera Rubin Ridge (VRR) is the first geomorphic unit on Mt. Sharp Curiosity has explored that is defined partially by its mineralogy seen from orbit [1, 2]. Specifically, a strong hematite spectral signature, with diagnostic absorptions centered at 535 nm and 867 nm, and a peak at 750 nm, is associated with VRR in Compact Reconnaissance Spectrometer for Mars (CRISM) orbital data.

Curiosity documented hematite and other oxidized phases throughout much of Mt. Sharp, even in locations that did not correspond with strong orbital spectral signatures of hematite or ferric phases [3-6]. What special geologic environments are preserved in VRR that makes hematite within it so easily observed in CRISM data, and what are the implications for the geologic history of VRR? We compare Curiosity spectral data from the rover's traverse through the Murray formation with orbital observations to address these questions.

Spectral datasets: CRISM is an orbital hyperspectral imaging spectrometer that has a highest spatial resolution of 18 m/pixel, or ~12 m/pixel when operated in an along track oversampled mode [7, 8]. CRISM covers 0.4 – 4 µm in 544 wavelengths.

Mastcam is a multispectral imager on Curiosity that has spatial resolutions of millimeters to meters depending on distance [9]. Mastcam provides spectral information from ~0.45 – 1.2 µm at 12 unique wavelengths.

ChemCam can be operated as a hyperspectral point spectrometer that collects spectra from individual spots ~1-2 mm in size when used in "passive mode" [6]. Passive spectra are acquired after active LIBS shots, and have the added advantage that LIBS often clears away surface dust. ChemCam covers the surface from 0.4 – 0.84 µm at thousands of wavelengths.

Controls on Orbital Signature: Curiosity data reveal three factors influence CRISM observations:

(1) Dust. The role of dust was evident when Curiosity first climbed onto VRR and observed large fractures crossing the surface (Fig. 1a). From a distance, Mastcam multispectral data showed a strong 867 nm absorption feature (hematite indicator) associated with small, broken, tilted rocks near the fractures and a weaker or absent feature in the smooth areas between fractures (Fig. 1b). Up-close investigation of locations near a fracture vs. an area between fractures showed no differences in the chemistry or spectral properties of the two areas. Instead, Curiosity observed a thicker optical layer of dust had settled on the smooth surface between fractures. The rough, upturned rocks near fractures were less dusty. The association of an apparently stronger 867 nm absorptions with fractures is also seen in orbital data; areas of the lower VRR with visible fractures in HiRISE sometimes have stronger 860 nm absorptions in CRISM data than nearby non-fractured, and presumably dustier, areas.

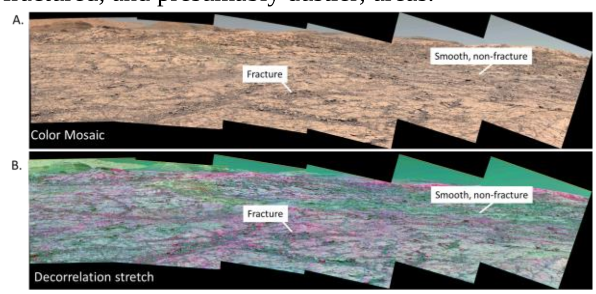

Fig. 1. (A) Mastcam L0 mosaic from sol 1814 of fractures on VRR. (B) Decorrelation stretch of L653 data (1012, 867, 751nm). Purple areas have stronger 867 nm absorptions. Curiosity investigated "Fracture" and "Smooth, non-fracture" areas.

(2) Sub-pixel mixing of sand and bedrock. Portions of Curiosity's traverse leading to VRR were dominated by bedrock (Fig. 2a), and portions were dominated by mixtures of broken bedrock and sand (Fig. 2b). Examination of CRISM data shows a subtle 860 nm absorptions is visible along areas of Curiosity's traverse in the Murray that are bedrock-rich. Checkerboard mixing models using bedrock and sand endmembers in proportions consistent with ground observations are similar to spectra from sandy portions of the traverse (Fig. 2c).

(3) Bedrock spectral variability. Both ChemCam and Mastcam spectral data from dust-free bedrock targets show actual variability in the position of the ~750 nm peak and depth of 535 nm absorption along Curiosity's traverse. ChemCam data also show variability in the magnitude of the turndown between 750 and 840 nm, and Mastcam data show variability in the depth of the 867 nm absorption feature. Notably, *in situ* spectra from the areas corresponding to the deepest 867 nm absorption in CRISM also correspond with areas that had the deepest 535 nm and 750-840 nm slope in Mastcam and ChemCam passive (Fig. 3) data.

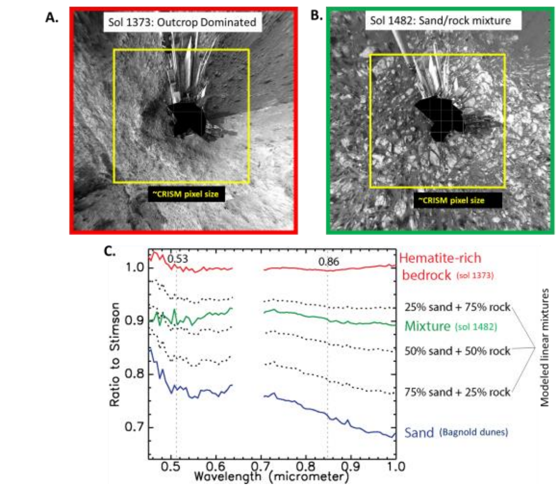

Fig. 2. (A) Sol 1373 Navcam overhead projection. Yellow box = approx. CRISM pixel size. (B) Sol 1482 Navcam overhead projection. (C) CRISM ratio spectra from sol 1373 (red) and 1482 (green) location compared to linear mixture models (black) and sand endmember spectra (blue). CRISM data from ATO0002EC79.

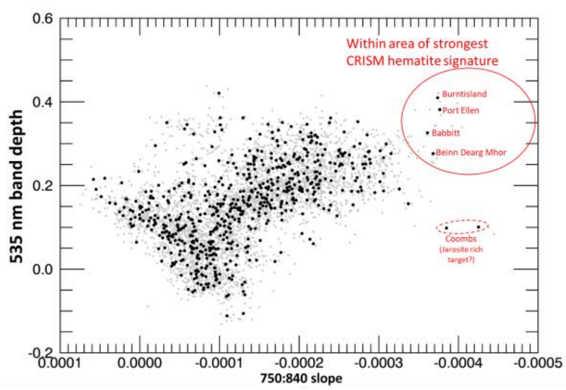

Fig. 3. 750:840 nm slope vs. 535 nm band depth for ChemCam data from all bedrock targets in Murray formation, including VRR. End members correspond to areas in VRR with deepest 867 nm signature in CRISM.

CRISM and ChemCam Direct Comparison: 535 nm band depth and 750 - 840 nm slopes calculated from CRISM data along Curiosity's traverse and from ChemCam bedrock targets largely show similar trends. The spectral contrast of CRISM data is greatly reduced compared with ChemCam and there are some discrepancies in particularly sand-dominated areas of the traverse (Fig. 4). Overall, this demonstrates CRISM data can be sensitive to actual spectral variability in bedrock targets, although sand and dust reduce spectral contrast and can complicate interpretations.

Conclusions and Implications for Geologic History: Hematite is most visible from orbit on Vera Rubin Ridge due to a combination of actual deeper spectral absorptions in that area, as well as lower amounts of sand and dust. The observed spectral variability primarily reflects changes in grain size/crystallinity and other phases present, but only minor changes in the total abundances of crystalline hematite [10, 11]. By eliminating confounding effects of sand and dust, *in situ* data reveal that the ferric-related spectral variability in VRR and underlying strata does not correlate with stratigraphy. While oxidized phases in the Murray formation and VRR could be primary [12] or secondary [3], the spectral variability and strong hematite signature observed at Vera Rubin Ridge likely reflects overprinting and recrystallization during interactions with secondary diagenetic fluids.

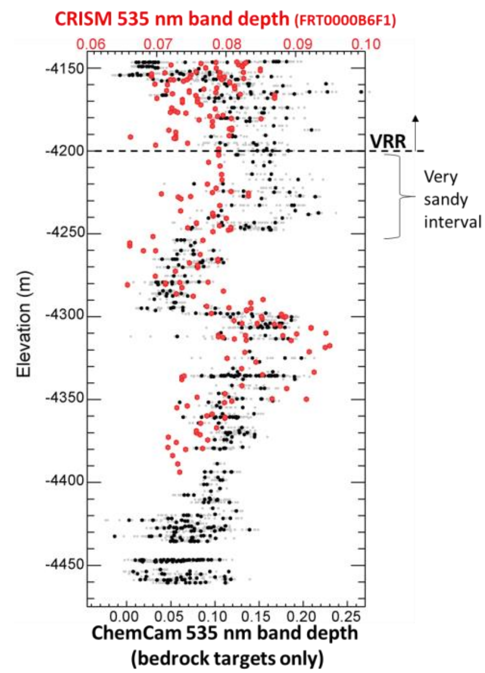

Fig. 4. Comparison of CRISM (red) and ChemCam passive (black) 535 nm band depth calculated using same formula vs. elevation. CRISM x-axis scale labeled on top, ChemCam x-axis on bottom. Light gray dots represent all ChemCam passive spectra, dark black dots show average values for each individual target.

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AAF was funded through the MSL Participating Scientist Program. Government sponsorship acknowledged.