## MORPHOLOGY AND OCCURRENCE OF DARK TONED DIAGENETIC FEATURES IN THE VERA RUBIN RIDGE, GALE CRATER, MARS FROM MAHLI COLOR IMAGES.

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Introduction: The Vera Rubin Ridge (VRR) is a linear topographic feature located on the northwest side of Mt. Sharp in Gale Crater, Mars [1,2]. The VRR is characterized by lithologic units with diverse colors and a variety of diagenetic features, most likely indicating both early and late diagenetic processes [3]. These color variations are primarily concentrated in the Jura member of the VRR, and at least three distinct color and spectral units of Jura have been identified by [5]. In between clear red, and smooth gray units, spectral variability on the mm to cm scale is accompanied by these dark toned features. Mastcam studies of these dark toned features revealed possible diagenetic origins [5], citing evidence of bulk spectral variability compared to surrounding Jura terrain. The Mars Hand Lens Imager (MAHLI), on Mars Science Laboratory (MSL), has provided high resolution images of Martian sediments, minerals, textures, and structures [6]. In this study we use MAHLI images to investigate these features, by applying various image stretches that potentially reveal further morphological characteristics for each occurrence, in addition to helping recognize less obvious occurrences of the material among Jura terrain. Variability in this features morphology, and spectral characteristics as MSL travels up the Vera Rubin Ridge (VRR) will help constrain the features origin, and alteration history.

Methods: MAHLI, a 2 megapixel CCD camera, offers Bayer pattern filtered RGB imaging with a macro lens. Images taken as closely as 22.5 mm will exhibit pixel scale resolution of 14.5µm/pixel, and a depth of field of 0.9 mm. At a 66 mm working distance, resolution is about 31 µm/pixel. A vertically mounted Flight Calibration Target is used to calibrate color, white balance, resolution, and UV LED functionality. Raw data is placed through an automated calibration pipeline; Decompression, Color Correction, Radiometric Calibration, Linearized (Geometric Calibration). Nighttime observations look for fluorescent materials, shining a 365 nm UV LED on specified targets. In this study, a decorrelation stretch (DCS) is used to enhance color separation, exposing high variability in terrain with targets of interest. The DCS stretches along principle components of the image, converting the 3 band MAHLI image into separate stretched Principle Components, then transforming these back into the original RGB space. The intensity of each pixel is transformed to the color eigenspace of the 3 by 3 band covariance matrix, stretched to match the band variance, and then transformed back into the original RGB bands. The original color values of the

image map to a new, broader range. This process primarily removes cross-wavelength brightness variations due to effects like dutargst cover and overall albedo, and emphasizes variability in spectral shape across the image. The DCS used on MAHLI helps to bring out the mm to cm scale diagenetic features found in the VRR.
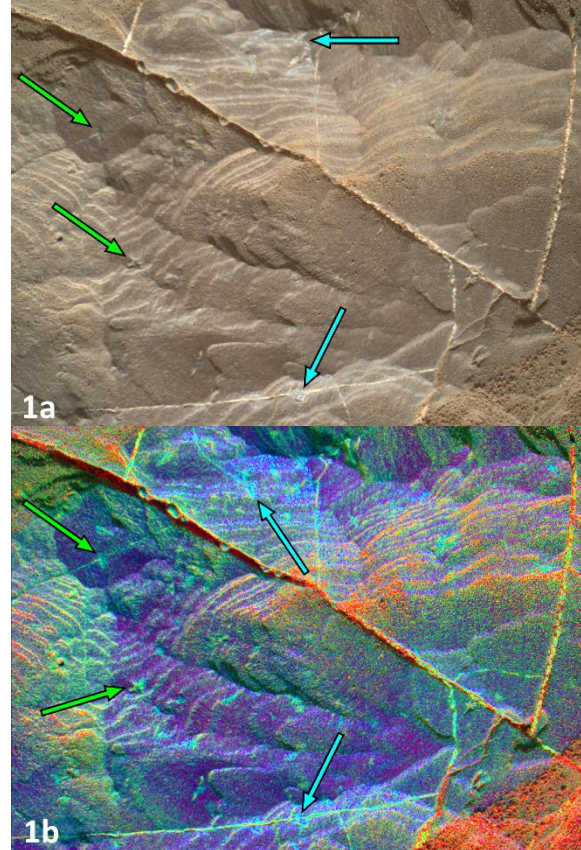
Figure 1: MAHLI Sequence 00297, sol 1892, target "Drakensberg", red bedrock in the Jura member of the VRR. (a) DCRL Calibrated unstretched image and (b) Decorrelation Stretch (DCS) image. Examples of the dark toned diagenetic features indicated by the green arrow. Secondly, indicated by the Cyan arrows, regions of mottling of Drakensberg exhibits color and spectral variability in mm to cm scales, and shows as cyan in the DCS. Scene is 5.5 cm across.

Results: Figure 1a shows the target "Drakensberg", corresponding to typical red Jura. Although the scene appears uniform in color and texture in the standard RGB image, the DCS shown in Figure 1b exaggerates multiple kinds of variabilities in the bedrock. The dark toned diagenetic features, as sub-circular nodules, are more clearly visible in the DCS, and show up as green (indicated by the green arrows in both figures). In some

areas, indicated by the cyan arrows, clusters of light-toned "mottles" exhibit color variability in mm to cm scales in MAHLI, and show up as cyan in the DCS. These areas also exhibit spectral variability in MASTCAM data sets [2]. Within the DCS, veins appear as cyan to green, sometimes covered by red dust, and the dark toned features in the veins appear as green.

Figure 2a shows MAHLI sequence 00153 from sol 2169 target "Inverness", corresponding to typical gray Jura. Figure 2b shows the dark toned features on a 0.5 cm scale, which are much more visible in RGB when compared to previous target examples. Figure 2c shows a DCS of this scene, bringing out the dark toned features as cyan to green, when compared to the veins that show as yellow to orange. In this target, dark features appear more often in the veins than in the primary bedrock. Figure 2 also shows raised possibly darker regions in the bedrock. Ridges on these features sometimes align linearly, and have a similar dark toned color that the diagenetic features have. In the DCS of this target, these features show as topographic expressions but do not appear to have much color variability, so they may just be slightly cleaner protrusions of bulk bedrock..

Figure 3a shows MAHLI Sequence 00172 sol 1922 target "Haroldswick" in raw RGB, corresponding to potential "bleached" zones in the gray Jura [5]. Figure 3b shows a zoomed image of this target overlaid by a DCS. The dark toned branched features in this target are highlighted in blue by the DCS, and they sit over the target which is also highlighted blue. This suggests that the bedrock and diagenetic feature have different albedos but similar spectral properties, which is confirmed by Mastcam spectra [5].

Discussion: These features are significant due to their variation in occurrence along the Vera Rubin Ridge. By understanding how these features change along the VRR, we can help constrain the diagetic history of each unit within the ridge. Our preliminary survey suggests that dark toned diagenetic features are found in red Jura material at somewhat lower frequencies than in the gray Jura; however, the DCS is very helpful in estimating the true density of the features. In Figure 1, these occur as sub-circular nodules that are difficult to see in raw data. In the Grey Jura these dark toned features have higher frequency of occurrence, and occur inside of the veins (Figure 2) as well as in the lithified rock (Figure 3). However, the major difference between the red and gray Jura diagenetic features is that the color of the features in the gray Jura is much more similar to the surrounding bedrock (Figure 3; although their albedo is usually lower). All of Haroldswick, where dust is brushed off, has similar color, in both the raw and DCS images.

These dark-toned features are likely diagenetic in

origin, and are potentially the result of reducing fluids dissolving fine-grained iron oxides disseminated throughout the rock and precipitating the iron in concentrated locations as more reduced oxides like magnetite or goethite [5]. Changes in their morphology within each unit of the Jura may reflect different fluid or chemical conditions during diagenesis.

References: [1] Milliken *et al.* (2010) *GRL 37*, L04201. [2] Fraeman *et al.* (2013) *Geology, 40*, 1103. [3] Sun et al. (2018) *GRL 45*, 10,221–10,228. [4] Heydari et al. (2018) LPSC 49, #1817. [5] Horgan, B. et al (2019) this volume. [6] Edgett *et al.* (2009) LPSC 40, #1197.
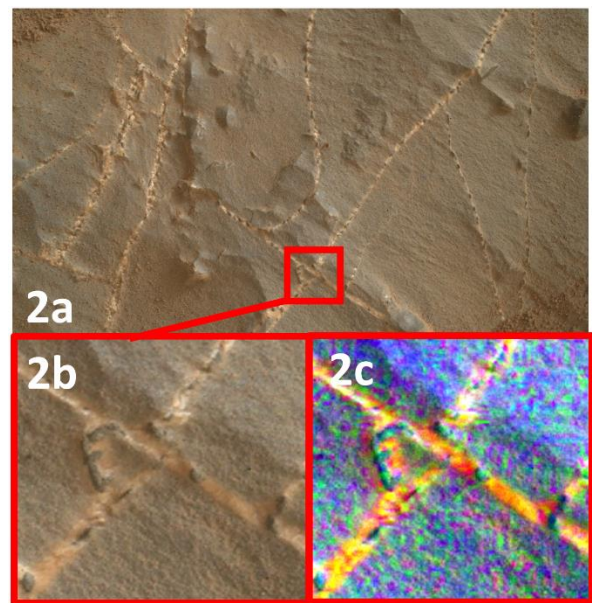
Figure 2: MAHLI Sequence 00153, sol 2169. (a) DCRL Calibrated unstretched image with red view box, (b) shows this view area unstretched. (c) Decorrelation Stretched (DCS) image of zoomed view area. Dark toned diagetic features are found inside of white vein features. These dark toned nodules appear in the DCS as cyan to green. Zoom is 0.5 cm across.
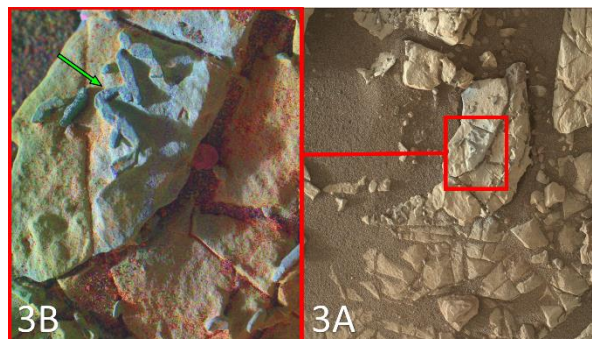
Figure 3: MAHLI Sequence 00172 sol 1922 target "Haroldswick" (A) in raw RGB. (B) is a zoomed image of the target, overlain with a DCS. The Branching Features are highlighted in blue, but the entire target with dust removed also appears to be lightly highlighted blue.