Introduction: The Vera Rubin Ridge (VRR) is a narrow ridge that runs along the northwest side of Mt. Sharp in Gale Crater, and from orbit exhibits strong hematite spectral signatures [1]. In situ images from the Curiosity rover have shown that the topmost member of the VRR, the Jura, exhibits spectacular color gradients. Decameter-scale gray patches are interspersed among the otherwise red bedrock, suggesting a possible redox relationship between these color units. However, the nature (reducing vs. oxidizing) and timing (early vs. late diagenesis) of the fluids that caused these color differences are poorly constrained. Here we use color and multispectral data from the Mastcam cameras to constrain the mineralogy of the red and gray Jura, their relationship, and the diagenetic history of the VRR.

Methods: Mastcam is two cameras (34/100 nm) with filter wheels that acquire multispectral images in 13 channels between 445-1013 nm [2]. This wavelength range can be used to differentiate between iron-bearing materials [3,4]. We use false color images as well as decorrelation stretches to identify Jura color units and characterize their spectral diversity. Spectra are extracted from representative color units in images from both cameras, and then merged by scaling at 1013 nm and averaging channels at overlapping wavelengths [5].

VRR Color Units: VRR bedrock typically varies from bright to pale red or purple in color, and these color differences may correspond to hematite abundance [6] or grain size [7-8]. Light to dark gray patches are present throughout the ridge, but are concentrated in the Jura member at the top of the VRR. In the Jura, the gray patches are bright gray and smooth bedrock in shallow topographic depressions below surrounding red Jura bedrock. The red and gray Jura are sometimes overlain by a dark purple unit that may have a distinct origin (Fig. 1). The boundary between the red and gray Jura is often broken up, but in some locations appears to grade from red to gray through a transitional “mottled” area that exhibits red and gray patches intermixed at the cm-scale (Fig. 2). Both red and gray Jura exhibit diagenetic features and Ca-sulfate veins [9], but the gray Jura also exhibits distinct dark gray round or branching features.

Mastcam spectral properties: The red Jura exhibits weak 860 nm and strong 530 nm absorptions, similar to other pale red areas on the VRR (Fig. 3). Weak bands near 860 nm suggest that crystalline red hematite is present in the red Jura, and strong 530 nm absorptions suggest the presence of crystalline ferric oxides.

In contrast, the gray Jura exhibits much higher reflectivity at short wavelengths, and a flatter spectrum throughout. Weak bands are often present near 700 nm and 860 nm, but the former not been confirmed with ChemCam passive spectra. The lack of strong
absorption in the gray Jura below 700 nm generally suggests that very little poorly crystalline or fine grained hematite is present [10,11]. This could be due to a lack of oxidized iron, but could also be consistent with some varieties of coarse grained gray hematite [12]. The high reflectance of the gray Jura is not consistent with typical gray hematite, but the presence of other bright materials (e.g., silica, alumina, sulfates) could help to increase the albedo and contribute to the overall flat spectral shape [10,11]. Dark diagenetic features in the gray Jura also exhibit flat spectra but overall lower albedo, potentially more consistent with magnetite or gray hematite [13]. In some light-toned areas in the vicinity of the largest diagenetic features, the gray Jura exhibits bands near 700 nm. These bands are common in mixed valence Fe-phyllosilicates (e.g., chlorite). The mottled areas in the red to gray transition are spectrally variable, and include strong 860 nm hematite bands, bands centered near 900 nm that are potentially consistent with some Fe^{3+}-clays, akageneite, or goethite, and bands near 680 nm consistent with goethite, lepidocrocite, or some Fe^{3+}-clays.

**Composition of the gray Jura:** Preliminary ChemCam XRD analyses of the mineralogy of the red Jura target Rock Hall show hematite and the Fe-oxide akageneite [14], potentially supporting akageneite spectral detections in the transitional zones. The gray Jura target Highfield contains significant hematite and abundant amorphous phases [14]. The hematite in the gray Jura must be present in the form of gray (coarse-grained) hematite to account for the spectral and color properties, and the high amorphous content could be responsible for the high albedo. APXS chemistry indicates that the gray Jura contains higher abundances of Al+Si than the rest of the VRR [15], and bedrock “haloes” around large diagnostic features in the gray Jura are further depleted in Fe and enriched in Al+Si in ChemCam chemistry, consistent with removal of Fe-oxides during the diagenetic process that formed the features [17].

**Implications:** The presence of gray hematite in the gray Jura requires that it experienced a different diagenetic history than the red. This could be due to a different late diagenetic history – for example, the slightly larger grain size predicted for gray Jura [17] could allow more fluid flow than red Jura. The gray Jura may have started out red but underwent late bleaching by reducing fluids, to remove [18] or recrystallize [19] red hematite in favor of gray hematite. Haloes around the dark diagnostic features could be produced through further bleaching and removal of all hematite. Thus, one way to interpret the color and spectral transition from red into gray Jura is the gradual removal of spectrally dominant Fe-oxides to reveal other Fe-bearing minerals. We hypothesize that removal of red hematite in the gray Jura may have revealed the gray hematite, and removal of all oxides in the bleached haloes revealed mixed valence Fe-bearing clays or spectrally similar amorphous phases. Alternatively, the difference between red and gray Jura could be related to starting mineralogy – for example, gray hematite is a common late diagenetic replacement of less oxidized iron oxhydroxides like goethite, magnetite, and green rust [20]. Magnetite is present within the lower Murray [21], and may have precipitated in a reducing lacustrine environment [22]. In this scenario, the gray Jura could have started out as locally reduced, magnetite or goethite-bearing sediments, but underwent late diagenesis after lithification to convert magnetite or goethite to gray hematite.

**Figure 3:** (a-b) Mastcam spectra from Jura targets Assynth (red/transition), Newnacher (gray), and Haroldswick (bleached/ nodules), compared to (c) lab spectra of Fe-bearing minerals convolved with Mastcam filters.