THE COMPOSITION OF NASA'S MARS 2020 ROVER LANDING SITE AT JEZERO CRATER: A SUMMARY OF REMOTE SPECTRAL ANALYSES.

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Introduction: Jezero crater, Mars, was recently selected as the landing site for NASA's next Mars rover to launch in 2020. The crater hosts a variety of geologic units of interest for *in situ* planetary exploration, including deltaic and lacustrine deposits and mafic and carbonate-bearing floor units [1-4]. In addition, the composition of this exploration region has been previously studied using both visible/near-infrared (VNIR) reflectance [1] and thermal infrared (TIR) emission spectroscopy [5]. In this study, we summarize these important compositional and spectral analyses and provide the most up-to-date interpretations of the available spectral data. We also discuss ongoing and future work dedicated to improving and validating methods used to remotely model mineral signatures.

Background: Jezero crater was selected as the landing site for the Mars 2020 rover in late-2018, concluding a four-year landing site selection process [6]. Its selection was partly based on the mineralogical diversity observed from orbit, which shows a range of primary and secondary mineral phases indicative of a complex geologic record. Numerous investigations have studied the local and regional geology and mineralogy of this area using orbital data, and most agree that the broad geologic controls on this region include Noachian- and pre-Noachian-aged crustal alteration, the formation of the Isidis impact basin, and subsequent erosive processes that exposed, altered, eroded, and deposited materials across the landscape [7,8]. Both VNIR and TIR spectral techniques have shown that the mineralogy observed throughout the region can be accurately modeled using a mixture of typical basaltic compositions with the addition of variable amounts of primary mafic and secondary alteration phases [1,5].

The geologic history and resultant compositional units found in Jezero crater are consistent with this regional story [1] (**Fig. 1**). The floor of Jezero crater consists of a mafic-rich floor unit, hypothesized to be a volcanic flow or ash unit, underlain by a light-toned olivine- and carbonate-bearing unit of high thermal inertia. On the floor of Jezero crater are sedimentary materials associated with two deltaic deposits, one entering the crater from the northwest and the other more prominent delta entering from the west. The western delta contains a range of alteration mineral phases that include smectite clays and carbonates, with the spectrally strongest carbonate signatures occurring near the contact between the deltaic deposit and the crater rim [1,3].

Summary of Methods: VNIR spectral analyses have primarily used data from the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) [9], which are the highest spatial resolution spectral data obtained from orbit to date. VNIR wavelengths are sensitive to electronic processes and transitions as well as the vibrational overtones and combination tones generated by many molecules common in rock-forming minerals. These capabilities allow for VNIR spectroscopy to identify and characterize both primary and secondary mineral phases associated with igneous and alteration processes.

TIR spectroscopy using both the Thermal Emission Spectrometer (TES) [10] and Thermal Emission Imaging System (THEMIS) [11] have also provided valuable information about the composition and thermophysical properties of Jezero crater and its surrounding watershed. The TIR is sensitive to both the vibrational modes of many common rock-forming minerals, including silicates, carbonates, sulfates, and oxides. The optical properties of most coarse-grained geologic materials at TIR wavelengths are dominated by high absorption coefficients, which results in the TIR spectra of geological landscapes being linearly related to the areal abundance of its spectral endmembers at the surface. This principle has resulted in the most widely accepted estimates of surface abundances being derived from the linear unmixing of TIR spectral data. In addition to its compositional capabilities, thermally emitted radiation measured at different times of day can be used to understand fundamental surface properties, including apparent grain size and the presence of near-surface layering or ice deposits.

Summary of Results: This work summarizes the spectral results from several previous studies [1,3,5,7,8] (**Fig. 2**). Below, we highlight several regions of interest to Jezero crater and the Mars 2020 mission:

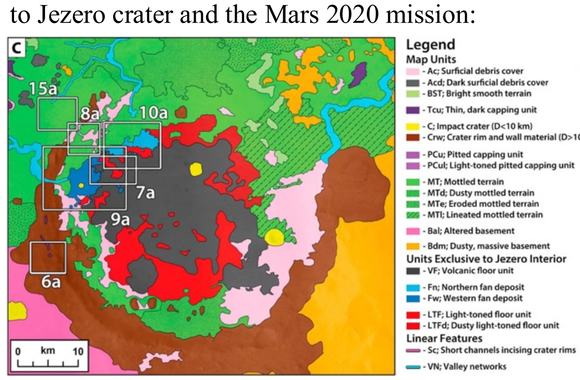

Figure 1. A geomorphic map of Jezero crater from [1], Figure 4c. Units were also characterized using CRISM data. Inset box references refer to figures in [1].

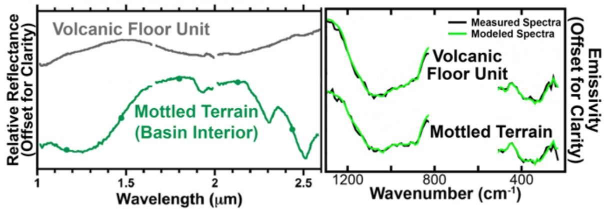

Figure 2. VNIR (left) and TIR (right) spectra of two prominent geologic units in Jezero crater: the mafic Floor Unit and the carbonate-bearing Mottled Terrain. Figures adapted from [1] and [5], respectively.

Jezero crater watershed. The Jezero crater watershed is more than 30,000 km^2 in area and extends through many different geologic and compositional terrains. Of note are a basaltic capping unit that is present throughout much of the Nili Fossae region, the carbonate- and olivine-bearing Mottled Terrain that underlies the capping unit (whose carbonate abundances were quantified using TIR spectroscopy [3]), and the lowermost Massive and Altered Basement units that contain evidence of Fe/Mg-smectites. These and the other geologic units within the Jezero watershed are potential targets of interest for the Mars 2020 extended mission.

Jezero crater delta. Jezero's western delta exhibits vibrational absorptions primarily dominated by Fe/Mg-smectites with minor contributions from Mg-carbonates, although specific regions of the delta show strong carbonate absorptions [12]. This observation is consistent with the relative proportions and areal extents of observed mineral phases throughout the delta's watershed, suggesting that the alteration phases observed in the delta are primarily detrital and not authigenic in origin [1].

Jezero floor units. The uppermost geologic unit on the floor of Jezero crater is composed of unaltered mafic compositions that are dominated by pyroxene and plagioclase [3]. This unit's lack of alteration minerals suggests an origin likely related to primary emplacement processes including volcanic flows and/or ash units. Underlying this uppermost mafic unit is a light-toned and high thermal inertia unit that is spectrally dominated by olivine and carbonate at VNIR wavelengths. However, like most units within Jezero crater and its watershed, the light-toned floor materials are predominantly basaltic in composition with variable types and abundances of alteration mineral phases.

Future & Ongoing Work: Additional orbital investigations of Jezero crater and its watershed are both planned and ongoing. For example, non-linear mixing and radiative transfer modeling necessary to characterize mineral assemblages using high-resolution VNIR datasets are ongoing and are utilizing Hapke modeling, Discrete Ordinate Radiative Transfer (DISORT) modeling, and factor analysis and target transformation (FATT) techniques (**Fig. 3**). This work will provide the most accurate estimates of mineral assemblages in Jezero crater, and will be pivotal in assisting with traverse planning for the Mars 2020 rover. Accompanying such modeling efforts are refined effective particle size estimates derived using THEMIS infrared data. These new estimates can be used to further model the abundances of different mineral phases as a function of particle size both in the TIR and VNIR.

Lastly, the Mars 2020 rover's SuperCam [13] and Mastcam-Z [14] instruments will have the ability to validate and "ground truth" orbital VNIR data using their hyperspectral point and multispectral imaging capabilities, respectively. These instruments, in addition to the suite of correlative compositional measurements to be made by the Mars 2020 rover, will enable us to identify the geologic context of the mineral signatures observed from orbit. The ability to do so is pivotal towards understanding the geologic history of this region and the role of liquid water within and throughout this system.

References: [1] Goudge et al. (2015), *JGR* **120**, 775-801. [2] Fassett & Head (2005), *GRL* **32**, 10.1029/2005GL023456. [3] Ehlmann et al. (2008), *Nat. Geosci.* **1**, 355-358. [4] Schon et al. (2012), *PSS* **67**, 28-45. [5] Salvatore et al. (2018), *Icarus* **301**, 76-96. [6] Grant et al. (2018), *PSS* **164**, 106-126. [7] Mustard et al. (2007), *JGR* **112**, 10.1029/2006JE002834. [8] Mustard et al. (2009), *JGR* **114**, 10.1029/2009JE003349. [9] Murchie et al. (2007), *JGR* **112**, 10.1029/2006JE002682. [10] Christensen et al. (2001), *JGR* **106**, 23823-23871. [11] Christensen et al. (2004), *SSR* **110**, 85-130. [12] Goudge et al. (2017), *EPSL* **458**, 357-365. [13] Wiens et al. (2017), *Spectroscopy* **32**, 50-55. [14] Bell et al. (2014), *IPM-2014*, #1151.

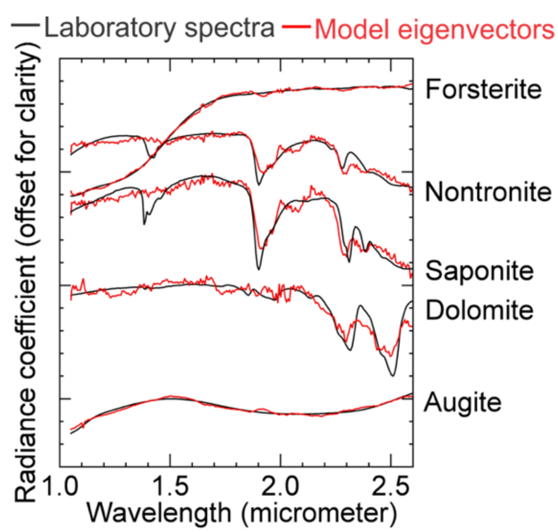

Figure 3. FATT modeling results of spectra from CRISM image HRL000040FF of the western Jezero delta. Laboratory spectra are fit well by the eigenvectors, indicating their likely presence in the scene.