Interpreting Mastcam-Z Spectra of Jezero Crater Using Mastcam-Z Analog Spectral Imager.

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Introduction: The mineralogy of Jezero crater has been mapped based on orbital visible/near-infrared (VNIR) spectral measurements that suggest that the Jezero's crater floor is igneous [1], [2]. This igneous unit has been previously described as the 'volcanic floor' [1], the 'mafic floor' [2], and later Crater Floor Fractured Rough (CFFR) and Crater Floor Fractured 1 (CFF1) [3]. Data from multiple instruments aboard the Perseverance rover have also found support for an igneous origin of the crater floor [4], [5], [6]. Spectral distinctions among the crater broadly reveal an olivine-enriched formation, Seìtah, and an olivine-depleted formation, Màaz. Both units have been physically and chemically weathered by various mechanisms and to varying degrees [2], [5], [7], [8]. These weathering processes affect the observed spectral properties, sometimes masking mineral spectral signatures entirely [9], [10], [11], [12], [13], and confound the goal of interpreting formative processes and depositional conditions.

In order to better interpret the mineralogy of the crater floor at Jezero, it is thus important to characterize the spectral effects of various weathering styles on the types of igneous rocks found in Seìtah and Màaz. Such work has been explored via laboratory analysis of analog rocks in thin section [19], [7], but a study of these effects at the outcrop scale can be explored using a Mastcam-Z emulator. Herein, we utilize the Mastcam-Z Analog Spectral Imager (MASI) to collect multispectral observations of three igneous analog sites and two sets of additional hand samples representing distinct igneous compositions subject to a suite of known weathering styles to characterize possible weathering mechanisms and their spectral effects in Jezero Crater's crater floor.

Methods:

MASI: Mastcam-Z Analog Spectral Imager (MASI) is a multispectral, stereoscopic camera meant to emulate Mastcam-Z's capabilities as closely as possible. MASI is equipped with the same KAI 2020 CCD, as well as the engineering models of Mastcam-Z's 14 spectral filters (12 narrow band geology filters, 2 neutral density filters for imaging the sun, and atmospheric observations) MASI is engineered with the same stereo separation, toe-in angle, and pan/tilt capability as Mastcam-Z [14], [15]. The camera heads are engineered by Finger Lakes Instrumentation, and the zoom lenses are COTS articles from Nikon. MASI is operated using an Arduino interface and is commanded in a Jupyter notebook [14].

MASIMAS: Mastcam-Z Analog Spectral Imager Multispectral Analysis Software (MASIMAS) is used to bias correct, flat-field, align and calibrate images, and convert them to IOF space for spectral analysis using the same algorithms employed by Mastcam-Z's radiometric calibration pipeline [15]. This software is also used to select regions of interest and generate spectra and CSV files for further external analysis.

PANalytical QualitySpec® TREK: The PANalytical QualitySpec® TREK is a handheld spectrometer equipped with an internal light source and produces spectra from 350-2500 nm. The instrument is calibrated before implementation by imaging a magnetic Spectralon target that covers the field of view. Spectra collected by the PANalytical QualitySpec® TREK were used to confirm the accuracy of data collected by MASI.

Field Sites: Three primary field sites were selected in order to offer an olivine enriched endmember (Twin Sisters Dunites), olivine depleted endmember (Mt. Baker Andesites), and intermediate member (Potholes Coulee Basalts) for comparison with igneous materials in Jezero Crater's olivine enriched (Seìtah) and olivine depleted (Màaz) crater floor.

Artist's Point, Mt. Baker, Washington. Mt. Baker is an andesitic stratovolcano located in northern WA. Mt. Baker is composed of >90% andesite [*16*], an extrusive igneous endmember depleted in olivine content. The observed outcrop exhibited light tan, red, red-brown and dark brown weathering rinds and may have spectral similarities to units in the Màaz formation.

Twin Sisters Mountain, Washington. Twin Sisters Mountain is an elliptical-shaped igneous mass, primarily composed of dunites with increasing degrees of serpentinization progressing further from the center and towards the margins of the mass. Dunites, used as our olivine-rich endmember, are composed of >90% olivine, although the Twin Sisters Mountain has been physically and chemically weathered by massive flooding and glaciation [17], [18]. Imaging and samples were collected at Sven Larsen's Dunite Quarry, where tan to dark orange weathering rinds are observed [19]. Past research indicates that the composition of Seìtah is spectrally similar to weathered dunites, making this a valuable target as a Seìtah analog [19].

Potholes Coulee, Washington. The Channeled Scablands of Eastern Washington formed during the retreat of the Cordilleran Ice Sheet, as repeated megafloods stripped the area's topsoil and carved into the underlying bedrock [20]. Located in Eastern Washington, Potholes Coulee is a part of the Channeled Scablands, which are composed of Neogene Period Columbia River Basalts [20], representing an intermediate, more felsic olivine composition.

Additional Hand Samples:

Hand samples were also collected from two sites in Hawai'i, USA. These glassy, porphyritic specimens represent a basaltic composition that is unique from Potholes Coulee and exhibit colorful surface coatings, which appear to be caused by acidic-sulfate leaching from meteoric water interacting with the glass-rich substrate [21], [22]. Understanding the spectral properties of analog coatings may illuminate the nature of purple coatings on rocks observed in Jezero's crater floor [8].

Ka'u Desert, Hawai'i: The Ka'u desert is located southwest of the Kilauea caldera, on the Big Island of Hawai'i, and is composed of a'a and pahoehoe lava flows which exhibit variable degrees and styles of weathering, including the presence of colorful coatings on subaerial surfaces. Coatings range from blue, white, yellow and green to dark orange.

Mauna Iki Trail, Hawai'i: The Mauna Iki Trail is also located southwest of Kilauea's caldera and is composed of a'a and pahoehoe lava flows with similar coatings to those observed in the Ka'u desert. These coatings are primarily yellow to dark orange in color.

Results:

MASI's observations from Twin Sisters Mountain are consistent with the interpretation that Seìtah is composed largely of weathered dunites [7], [19], although initial results suggest that MASI's weathered dunite regions of interest (ROIs) tend to have slightly higher 800 nm/1022 nm ratios than those imaged in laboratory analyses or observed in Jezero Crater [7], [19]. Many ROIs within the Bellegarde abrasion patch (Màaz formation) have similar negative near IR slopes to those observed in Potholes Coulee's basalt outcrop, although their spectral peaks tend to be located at shorter wavelengths. However, two Bellegarde ROIs exhibit spectral peaks at 754 and 801 nm, respectively (Fig. 1, bottom), similar to MASI's ROI 3 and ROI 0 (Fig. 1, top).

Ongoing work is being performed to place spectra collected from field sites and hand samples in the same parameter space used by Rice et al. (In Review) to describe the spectral classes observed in Jezero Crater. This will allow for the further characterization of various weathering profiles and may assist in the further subcategorization within current spectral classes.

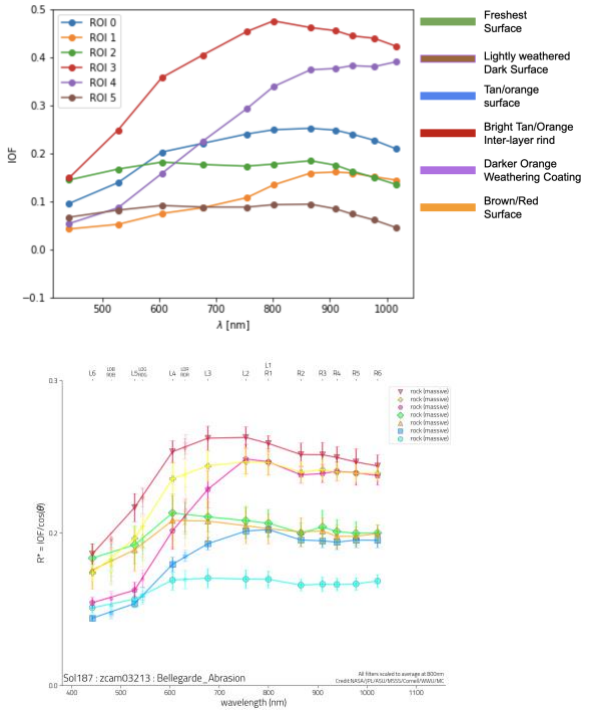

Fig. 1 – Top: MASI Spectra collected at Potholes Coulee. Bottom: Spectra collected from the Bellgarde Abrasion Patch in the Maaz Formation of Jezero Crater.

References:

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