OUTCROP-SCALE STUDIES OF A LACUSTRINE-VOLCANIC MARS ANALOG WITH A MARS 2020-LIKE INSTRUMENT SUITE.
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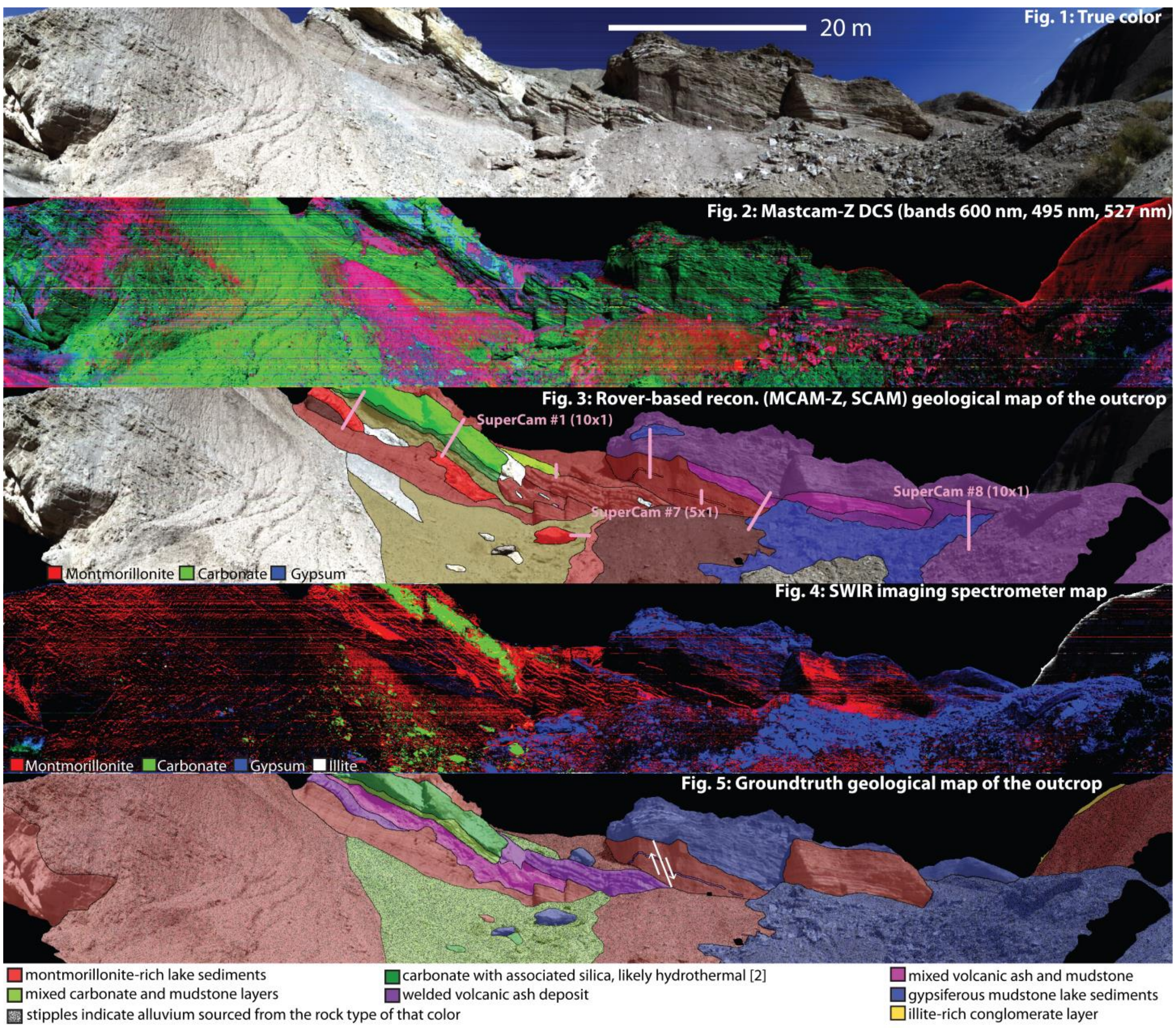
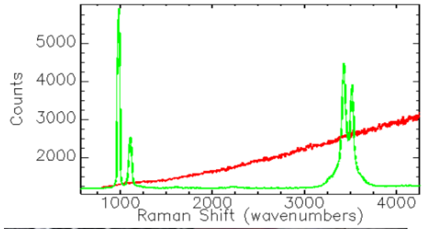
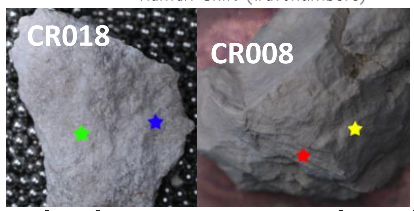
Introduction & Goals: Outcrop analyses with Mars 2020 rover-like datasets have been conducted to evaluate the synergies between instruments and devise suggested protocols for in situ analysis of outcrops and sampling during the future Mars 2020 mission. An outcrop near China Ranch in the Mojave Desert was selected for analysis based on its Mars-relevant mineralogy of sulfates, phyllosilicates, carbonates, and iron oxides within a sequence of interbedded lacustrine sediments, spring deposits, and volcanic ash beds [1-2]. This study aims to determine how scientifically interesting outcrops and samples, relevant to studies of past environments, habitability and biosignature preservation, can be identified and characterized during the Mars 2020 mission. We also examine methods to maximize data collection efficiency with this instrument suite.

Methods: Using the recently developed Ultra Compact Imaging Spectrometer (UCIS) (0.4-2.5 µm) [3] to generate outcrop-scale infrared images and compositional maps, the field site was surveyed and sampled. Hand samples were gathered in the field, guided by the prior infrared compositional mapping. After collection, a limited number of specimens were chosen for more detailed analysis, creating a ground truth dataset consisting of hyperspectral







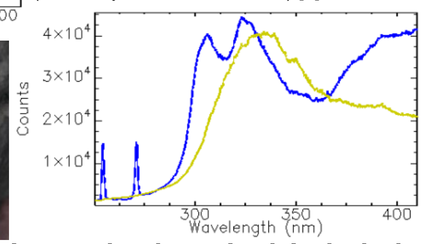


Figure 6: Example SHERLOC spectra, with raman demonstrating high levels of fluorescence (CR008, red) and a diagnostic gypsum spectrum (CR018, green). The fluorescence spectra below suggest aromatic amino acids indicating potential biosignatures (CR008, yellow; CR018, blue) [7].

geocompositional maps, XRD mineralogy, lithochemistry, and background literature [e.g. 1,2].

The infrared image was resampled (spatially and spectrally) to the resolutions of Mastcam-Z [4] and SuperCam [5-6] to simulate data from the Mars 2020 rover. Hand samples were analyzed using a SHERLOC (Scanning Habitable Environments with Raman & Luminescence) [7] prototype, a SuperCam-like LIBS (laser-induced breakdown spectrometer) under Mars conditions [6], and will soon be analyzed using a PIXL [8] (Planetary Instrument for X-ray Lithochemistry) prototype instrument.

Mastcam-Z: By using the Mastcam-Z filter set [4], color images and Fe^{3+} mineralogy can be obtained (Figs. 1 & 2) [9]. We simulated Mastcam-Z at approximately 500 m away (Figure 1). The textures and stratigraphy evident in these data products allow geological units to be discriminated within outcrops. To demonstrate the ability to discern ferric iron, a decorrelation stretch of the 495 nm, 527 nm, and 600 nm bands was performed, which highlights the ~535 nm absorption band center present in iron oxides (green in Figure 2), indicating increased ferric iron in the more clay-rich lake sediments within the outcrop (see 'Ground Truth Comparison'). Due to residual terrestrial atmospheric water bands, this simulation does not yet include bands above 800 nm. Recalibration of the atmospheric correction to allow use of the full data set is currently being completed.

SuperCam: SuperCam is a point spectrometer with reconnaissance capabilities, using LIBS for chemistry and green Raman, UV-VNIR spectroscopy (0.4-0.9 μm), and SWIR (1.3-2.6 μm, 30 cm^{-1} FWHM) spectroscopy for mineralogy [6]. By careful selection of transects across contacts seen in Mastcam-Z images, a geocompositional map can be constructed by tracing the presence of diagnostic vibrational absorptions to describe the mineralogical changes between outcrops. The use of the vibrational wavelength range complements the multispectral imaging provided by Mastcam-Z. An example of such a geocompositional map is shown in Figure 3, where three 5x1 transects and five 10x1 "SuperCam SWIR" transects allow classification of a large portion of the outcrop. This reconnaissance mode can be made more time-efficient by selecting an optimum spectral spacing for SuperCam's acousto-optic tunable filter (AOTF) to increase the spectral spacing, reducing measurement time. Using 40 nm spectral spacing for reconnaissance, general mineralogic class can be obtained, while the highest spectral resolution may be reserved for follow-on work. For example, at 40 nm spacing, carbonates were visible in the scene; at the highest resolution, these carbonates we recognized specifically as calcite. LIBS data has been gathered from hand samples, and is currently being analyzed.

SHERLOC: SHERLOC is a co-boresighted DUV Raman and fluorescence instrument, which allows organics and minerals to be detected and mapped [7]. Most transects contained multiple points that allowed identification of mineralogy. High concentrations of organics caused fluorescence that overwhelmed the mineralogical Raman response in several samples (Figure 6). While a challenge for terrestrial analog studies, this result highlights the sensitivity of SHERLOC to detection of potential Martian organics. The fluorescence detection capability allows identification and mapping of major classes of organics (e.g. conjugated hydrocarbon, aromatics, etc.; Figure 6).

Ground Truth Comparison: The ground truth datasets have been collected into two final maps (Figs. 4 & 5). The Mars 2020-like results presented above compare favorably with those generated in the ground truth dataset. The units described using Mastcam-Z, and shown in the transect map generated with "SuperCam SWIR" (Figure 3) broadly correspond with the true geological map of the outcrop, as does mineral composition. The presence of increased iron oxides in clay-rich lake sediments from Mastcam-Z analyses was borne out by the lithochemical analyses on the hand samples. The major mineralogy described by SHERLOC transects matched XRD results.

References: [1] Hillhouse, J W., and USGS. (1987) "Late Tertiary and Quaternary geology of the Tecopa basin, southeastern California. The Survey." [2] Nelson, S. T., et al. (2001) GSA Bull. 113.5: 659-670. [3] Van Gorp, B., et al. (2104) J. of App. Rem. Sens. 8.1. [4] Bell, J. et al. (2015) IPM abstract #1151 [5] Fouchet, T., et al. (2015) LPSC abstract #1736. [6] Wiens, R.C. et al. (2016) this meeting, abstract #1322 [7] Beegle, L., et al. (2015) IEEE [8] Allwood, A., et al. (2015) IEEE [9] Farrand, W. H., et al. (2008) JGR: Planets 113.E12.