THE IDENTIFICATION OF SERPENTINIZATION ON MARS WITH MARS2020 SUPERCAM INSTRUMENT.

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Introduction: Serpentinization is a common hydrothermal alteration process involving the hydrolysis and transformation of ultramafic minerals into secondary products such as serpentine [1]. Lizardite, antigorite, and chrysotile are the three main polymorphs of serpentine and often occur in combination with minerals such as talc, magnesite, and brucite. The processes and products of serpentinization on Earth can help us infer the geologic and aqueous history of Mars. The formation of serpentine requires the exposure of ultramafic rocks to circulating aqueous fluids at temperatures between 85°-460°C [2] and implies a highly reducing (near the magnetite-hematite fugacity buffer), high pH (> 9), and low silica content environment in the subsurface [1].

The interest of serpentine on Mars extends further than geologic formation histories and past environmental conditions; it also holds strong astrobiological implications due to the production of H_2 during the serpentinization process. Hydrogen is a key energy source to sustain microbial communities on Earth and can contribute to inorganic formation processes of organic molecules such as CH_4 [1].

The Mars2020 *Perseverance* rover is currently traversing up an ancient river delta near the edge of Jezero Crater [3], which is part of the Nili Fossae region where serpentine minerals have been observed from orbit using the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) data on the Mars Reconnaissance Orbiter [4].

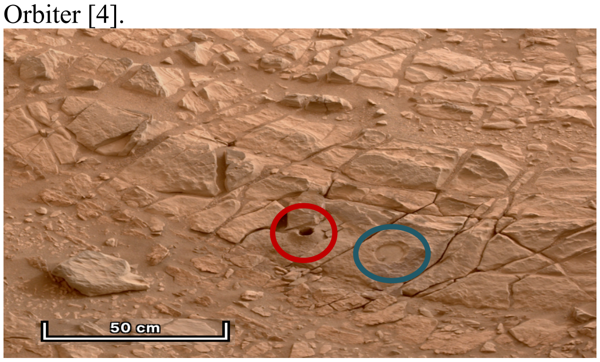

Figure 1. Navcam mosaic of Amalik outcrop. Magiek borehole circled in red. Novarupta abrasion patch circled in blue.

The SuperCam instrument onboard the *Perseverance* rover [5,6] has analyzed targets with potential serpentine, such as the abraded target Novarupta in the Amalik outcrop on Sol 572 (Figure 1). The infrared (IR) reflectance spectra of this target have absorption bands at 1.9 µm (indicative of H_2O), 1.4 µm (indicative of OH), and at 2.33 µm (indicative of serpentine and other phyllosilicates) [7] (Figure 2). Serpentine reflectance spectra are known to contain an Mg-OH stretching overtone at about 1.39 µm and an Mg-OH combination band at 2.33 µm [7], which are both present in Novarupta's reflectance spectra. This in combination with the target's elemental compositional similarity with the SuperCam LIBS serpentine calibration standard (observation points overlap on a SA-CNK-FM ternary diagram) makes targets at the Amalik outcrop, such as Novarupta, some of the best candidates to be the first serpentine-bearing targets that SuperCam has identified. This target's reflectance features are a good match for Mg-rich endmembers of serpentine such as antigorite.

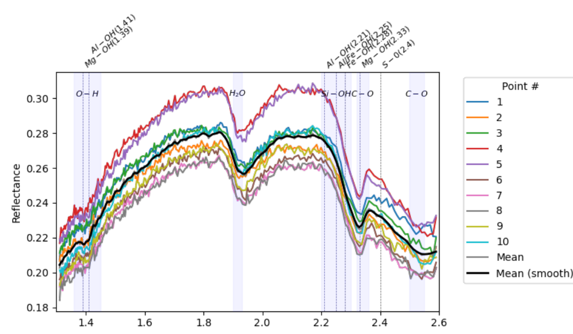

Figure 2. Infrared reflectance spectra of SuperCam target Novarupta_scam_572 from sol 572.

Methods: Using data from SuperCam, an instrument suite with Laser Induced Breakdown Spectroscopy (LIBS), Raman spectroscopy and VISIR reflectance spectroscopy, serpentine and other serpentinization products are identifiable with better spatial resolution and local context than the CRISM orbital data [5,6].

SuperCam's current database of LIBS and Raman calibration standards does not include many serpentine-rich samples, so to improve the instrument-specific spectral understanding of serpentine, a variety of terrestrial analogue samples with varying degrees of serpentinization and mineral assemblages will be analyzed. This will increase SuperCam's potential to create robust calibration models that will aid in the detection serpentinization products.

We prepared 24 rock powder mixtures and samples that will investigate the progression from olivine to serpentine. In addition, mixtures using the following endmembers will be created for this study: Fe-rich olivine, Mg-rich olivine, Fe-rich serpentine, and Mg-rich serpentine. Three mixtures between San Carlos olivine and serpentine standard SARM47 have been created with the ratios: 1:1, 3:1, and 1:3 to fulfill the need for a mixture between Mg-rich serpentine and Mg-rich olivine. Five serpentine samples sourced from the Analytical Database of Martian Minerals (ADaMM) [8] have been collected and characterized with X-ray diffraction (XRD) to confirm their mineralogies. This collection consists of serpentine samples with the varying amounts of the following minerals: lizardite, brucite, antigorite, calcite, magnetite, saponite, and chromite. Eight samples have also been collected from serpentine mud volcanos in the Mariana Trench [9]. Results from XRD analysis show that the samples contain chrysotile, lizardite, magnetite, hornblende, antigorite, montmorillonite, saponite, and feldspar. The Planetary Terrestrial Analogues Library (PTAL) is a multi-instrument spectral database designed to support in-situ planetary missions. Within this collection are samples from Leka, Norway, which consist of ultramafic rocks that have experienced varying degrees of serpentinization. The minerology and morphology of the rocks in this region has similarity to what has been observed in the Nili Fossae. Four samples have been requested from this library. Finally, one sample of ricolite, a banded serpentine from southern Rio Grande Valley, New Mexico, has been collected. XRD results showed a mineral assemblage of lizardite, illite, and calcite.

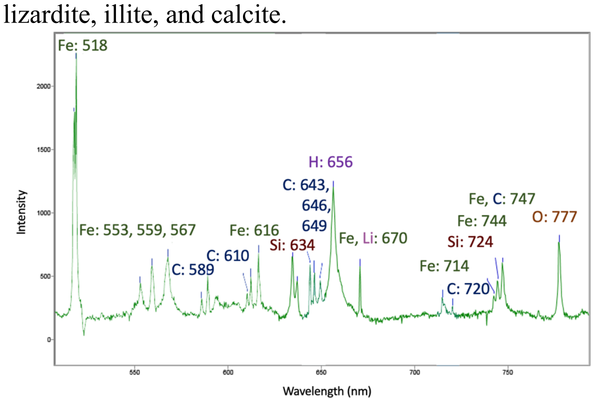

Figure 3. Ricolite chemistry via LIBS from a laboratory setup in ambient conditions. LIBS spot was located on a serpentine band.

Results: Figure 3 shows an example LIBS spectrum of the ricolite ($D_3[Si_2O_5](OH)_4$ D= Mg, Fe, Ni, Mn, Al, Zn) samples labeled with major-element LIBS lines. In laboratory Raman spectra of the ricolite sample we observe 3 major peaks at ~230 cm^{-1}, 384 cm^{-1} and 690 cm^{-1} (Figure 4). These major peaks are consistent with lizardite and antigorite [8, 9].

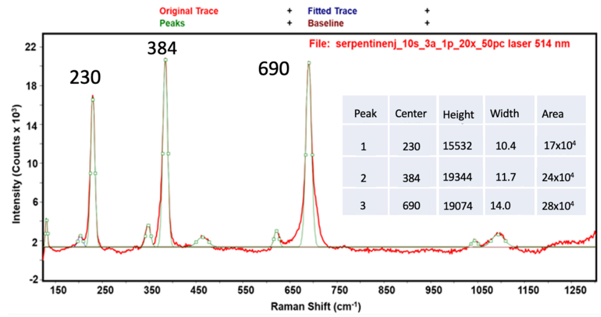

Figure 4. Micro-Raman annotated spectrum of ricolite.

Discussion: There are currently uncertainties in the identification of serpentine when interpreting using our current SuperCam LIBS data and calibration. As an example, there are other phyllosilicates and clays that have similar features and absorption bands in IR reflectance spectra [7]. An improvement in SuperCam's calibration as well as collaboration with other science instruments onboard the *Perseverance* rover and possibly in depth terrestrial analogue studies are needed to confirm the minerology of SuperCam targets like Novarupta.

Conclusion: The identification of serpentine through in situ analysis will broaden our understanding of the geologic history and potential habitability of Jezero Crater. As *Perseverance* continues to traverse up Jezero Crater's river delta and further into the Nili Fossae region, more detections of potential serpentine-bearing targets, such as Novarupta, are likely to be discovered. A more robust and complete calibration database for the SuperCam's Major Oxide Composition models will insure more accurate results of the composition and mineralogy of these targets.

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