WHAT DO CARBONATE STROMATOLITES LOOK LIKE USING MARS ROVER-LIKE INSTRUMENTS? SAMPLES FROM GRAND RAPIDS, MANITOBA, CANADA.

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Introduction: A stromatolite is a distinctive laminated category of organosedimentary deposits that results from a benthic microbial community that traps and binds sediments or mineral precipitates termed microbialites [1, 2]. Many different definitions of stromatolites have been proposed to date, with attempts to classify the different varieties of microbiolites from their dominant internal macrofabrics [2].

Stromatolites are predominantly found in carbonate materials forming columnar mounds in aquatic habitats [1,2]. These microbial communities are comprised of dominantly photosynthetic organisms such as cyanobacteria or blue-green algae [2]. Stromatolites can offer a unique insight into how life developed on Earth and are highly significant for planetary exploration due to their presence on early Earth [3]. Previous studies from C-TAPE have indicated that carbonate minerals retain their diagnostic spectra features and are stable on the Martian surface [4, 5]. Therefore there is a potential to detect ancient carbonates and identify stromatolites on the surface of Mars. The goal of this study is to demonstrate the ability of instruments on the upcoming NASA Mars 2020 and ESA ExoMars rovers to detect carbonate-bearing stromatolites. The identification of stromatolites on Mars would be significant, as it would provide compelling evidence for past or present life [3].

Carbonates have been detected on Mars in a wide variety of localities [3, 6, 7, 8]; a large number of terrestrial stromatolites are volumetrically dominated by carbonates, including those from the area near Grand Rapids, Manitoba, Canada. These are of particular interest due to the possibility of finding similar structures on Mars in similar geological environments [3]. Analyzing terrestrial carbon-bearing stromatolites using instruments that yield data similar to those produced by the instruments on Mars 2020 provides an important endpoint for future comparison with Martian carbonates.

The targeted stromatolites from Grand Rapids are between 419.2 and 443.8 million years old [9]. The small bun-shaped structures were created during deposition of the Moose Lake Formation, and are characterised by their thin laminations that reflect their growth in very shallow water conditions. The lamination formation localities were most likely associated with reduced sediment flow due to low water energy [9]. Johnson and Lescinsky [9] posited they were formed in sheltered regions associated with mud flats.

Lab-based analyses have been conducted within these well-preserved Silurian-age stromatolites. Instrumental ability and detection capabilities are being assessed in the context of the detection of potential hydrated carbonates and biosignatures associated with past life within the stromatolites. The understanding of the mineralogy, chemistry, and biology of the sampled material was conducted through spectral analysis due to their specific characteristics [3,10].

Methods: Stromatolites were collected from the Interlake region between Lake Winnipeg, Lake Manitoba and Lake Winnipegosis where there is exposed Silurian strata along a 500km belt [9]. Within the lower Silurian sequence stromatolites are present within multiple formations. The Moose Lake Formation was of particular interest with exposed well preserved fossilized stromatolites at the surface as outcrops in the Grand Rapids region [9].

Each sample was cut and polished. Whole rocks with weathered surfaces and the cut and polished surfaces were analyzed using a LabSpec 4 Hi-Res spectrometer (ASD) to acquire reflectance spectra between 350 and 2500 nm (Fig. 1). The ASD was used to simulate the visible and near-infrared (VNIR) instrument from the SuperCam remote sensing instrument suite on the NASA Mars 2020 rover [11] and other instruments using similar wavelengths [12]. A BWTek i-Raman-532-S instrument was used to simulate SuperCam on the Mars 2020 rover and the ExoMars RLS instrument.

Figure 1: Stromatolite sampled off Highway 6 at Little Limestone Lake ~40 km north of Grand Rapids, MB (GRM006). Visible macroscale laminations are identidied on the weathered rock (left) and throughout the top cut and polished slab and the bottom broken unpolished slab (right).

To understand the general mineralogy of all the samples, bulk powder X-ray diffraction was collected on GRM006 using a Bruker D8 Advance diffractometer. The diffraction patterns can be used to simulate XRD patterns from the Curiosity CheMin instrument.

Results:

VNIR reflectance: Both the cut (Fig. 2) and weathered surface data indicate that the samples contain H_2O, appearing as absorption bands near 1400 and 1900 nm [13]. The bands are likely associated with inclusions in carbonates and were observed in both data sets. An absorption feature at ~2323 nm can be attributed to the second overtone of the asymmetric stretching mode of the carbonate ion [14]. This particular band minimum is characteristic of dolomite [14].

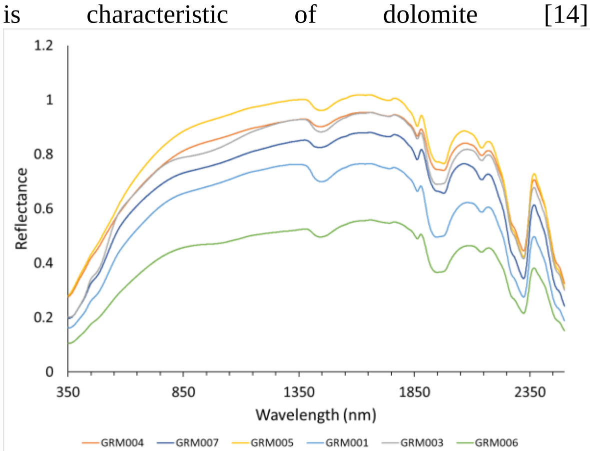

Figure 2: Cut and polished surfaces of the Grand Rapids, MB, laminated stromatolite samples, including GRM001, GRM003-007.

X-ray diffraction: XRD shows nearly pure dolomite with possible traces of fairchildite.

Raman: Raman spectra showed no organic signatures, likely due in part to the strong fluorescence masking the Raman signal (Fig. 3). This highlights the importance of fluorescence mitigation techniques, such as time-gating, serial-shifting, and alternative wavelength Raman. SuperCam will have some level of time-gating (40 ns exposures).

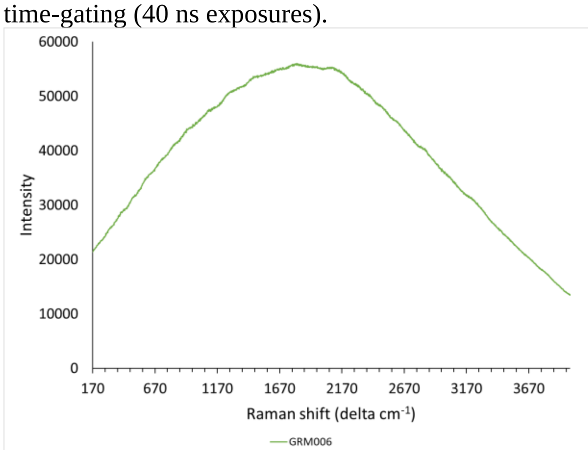

Figure 3: Cut and polished surfaces of one of the Grand Rapids, MB, laminated stromatolite samples, GRM006

Optical imaging: Due to their macroscale structure, we can visually detect laminations (Fig. 1) therefore the high-resolution color imager would be able to detect structures associated with stromatolites. Further imaging of the samples is being done with the resolution of the Mars 2020 rover cameras.

X-ray fluorescence: Further examination of the samples is being done using SEM-EDS to simulate data collected by PIXL, at its spatial resolution.

Discussion: Due to stromatolites being predominantly carbonate-rich materials, these minerals are important targets for astrobiology.

Geomorphic mapping and VNIR spectral analyses of the Jezero crater basin, the Mars2020 landing site, show strong evidence for concentrations of carbonates [15]. The northern fan of Jezero crater has been spectrally characterized as having Mg-rich carbonates mixed with olivine [15]. These details therefore suggests this landing site is a high-value target for stromatolite preservation and detection.

This analysis suggests that the most effective way to detect these putative stromatolite formations is by VNIR spectroscopy and optical imaging. VNIR reflectance was capable of detecting the dolomite that comprised the laminations. Visual identification can be done by imaging the potential stromatolites with reference to the materials composition signals from the SuperCam instruments (VNIR) on the Mars rover. Detection of laminations and of carbonate spectral signatures would then be followed by Raman spectroscopy, which can better detect organic compounds.

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