REFLECTANCE SPECTROSCOPY OF MICROBIALLY-PRECIPITATED MG-CARBONATES FROM ATLIN LAKE, BRITISH COLUMBIA, CANADA.

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Introduction: Mg-carbonates have been spectrally identified in several localities on the martian surface by the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) orbiter [1], Mars Exploration Rover Spirit (MER) [2] Mars Express Orbiter [3], and tentatively by Earth-based spectrometers [4,]. The detection of carbonates in many areas on Mars implies and supports an extensive aqueous history [2] and a more conducive environment for life during the Noachian to early Hesperian than that of the present-day martian surface [5].

The landing site of the Perseverance rover - Jezero crater - contains several units with evidence of Mg-rich carbonates which provides a unique opportunity to investigate carbonates with a possible fluvio-lacustrine origin [6], dated to ~3.9 Ga [7] with potential preservation and detection of microbialites (e.g., stromatolites) [8]. The carbonates within Jezero are hypothesized to have formed from the hydrothermal interaction of fluid with olivine [9] or to have formed from a lacustrine environment [6].

Carbonates are known to have the ability to preserve and entomb microfossils and microbial filaments on Earth [8,10]. Evidence of well-preserved biosignatures have been identified on Earth within laminated and nodular carbonate deposits [13]. Microbially-induced calcification can be traced back to at least 2.6 Ga in the Earth's geological record [11]. Additionally, ancient Archean carbonate deposits are known to have preserved evidence of microorganisms [11,12].

Several types of hydrated Mg-carbonates exist that exhibit distinct spectral properties compared to magnesite [13]. Hydrated magnesite is spectrally similar to magnesite with additional bands around 1400 and 1900 nm due to H_2O/OH and ~2300 nm C-O bands [6]

This study is designed to advance our abilities to detect and characterize Mg-carbonates on Mars and within Jezero crater. Using Atlin Lake as an analogue site will advance our understanding of processes under which Mg-carbonate minerals form and precipitate with microbial interactions in low-temperature mafic lacustrine environments.

Methods:

Study site: Samples were collected around Atlin located in northwestern British Columbia, Canada (59°35′ N, 133°42′ W) at an elevation of 674 m, with a dry sub-arctic climate [14]. Temperatures range between -15.4°C to 13.1°C, with an average of 0.5°C, and average annual precipitation of 348 mm/yr [14]. Near Atlin, hydromagnesite-magnesite playas are located in ultramafic bedrock in topographic lows [14, 15]. The precipitation of Mg-carbonates in this region is microbially-driven with several biological processes operating, including alkalization by cyanobacteria, sulphate reduction by sulphate-reducing bacteria and silica removal by diatoms [15]. The hydromagnesite sediments precipitate and form microbial mats influenced by benthic microbial communities [14].

The Atlin region 16AT-PI-# samples are from the Pictu mine (59°34'11.46"N; 133°39'58.77"W), and the 16AT-Anna sample is from the Anna mine (59°32'48.31"N; 133°37'24.83"W). The collected samples were from relatively high-temperature ($\geq$ 200 °C) listwanites which serves as a local reference for the hydrous Mg-carbonate minerals near Atlin.

Spectroscopy: Reflectance spectra were acquired on whole rock exteriors and as unsorted fine powders using an Analytical Spectral Devices LabSpec 4 Hi-Res® spectrophotometer from 350 to 2500 nm at a viewing geometry of i=30° and e=0°. To understand the general mineralogy of the samples, bulk powder X-ray diffraction data were collected using a Bruker D8 Advance diffractometer.

Results: The unsorted powdered samples from Atlin Lake exhibit characteristic spectral features associated with OH, and H_2O around 1400 and 1900 nm, respectively (Fig. 1). The ATH spectra show additional sharp OH absorption bands at 960 and 1400 nm that are superposed on the OH/H_2O bands at 1440 and 1960 (Fig. 1) associated with hydromagnesite [6]. The reflectance spectra indicates that these samples are hydrous Mg-carbonates.

A C-O associated doublet feature is seen at ~2300 nm in the ATP, ATM and ATA samples, and is associated with carbonates. The absorption feature around 2300 nm is shallow and not well defined, and the band centre varies between 2310-2315. The sample is likely a mixture of magnesite (2300 nm) and aragonite (2331 nm) [16]. The ATH spectrum exhibits differences in its C-O band position compared to other magnesite samples [17, 18], with minima present at 2260, 2320 and 2430 nm [6]. XRD of the Atlin samples with the exception of ATH identified aragonite as the primary

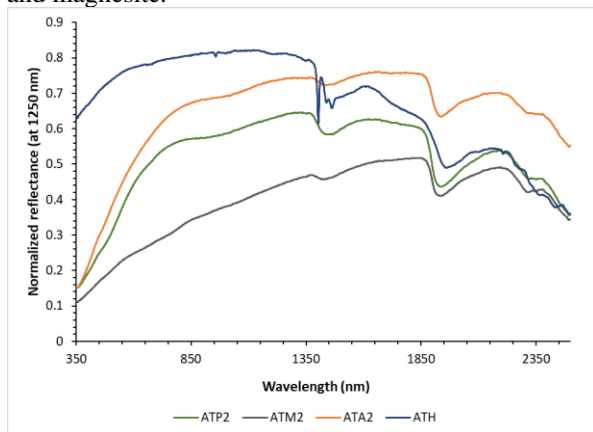mineral while ATH had a mixture of hydromagnesite and magnesite.

Figure 1. The Atlin playas unsorted powder hydrous Mg-carbonate samples reflectance spectra from a pisolith (ATP), a microbialite (ATM), playa sediments found at depths between 15-19" (ATA), and playa sediments (ATH).

The listwanite bedrock samples from the Atlin region exhibit the weak H_2O/OH features near 1400 and 1900 nm along with a distinct C-O feature at ~2310 nm. An additional broad Fe^{2+} feature is exhibited between 1000-1250 nm (Fig. 2) indicating a at least a few wt.% Fe^{2+} likely present in the carbonate, as this feature is seen in siderite spectra [19]. The mine samples from around Atlin are highly enriched in iron which can be related to the breakdown of silicates and oxides in the alteration of serpentine/peridotite to form listwanites. The regional rocks surrounding the Atlin playa indicate the low-temperature carbonation of mafic minerals producing magnesite-rich deposits [20]. XRD of the listwanite samples indicated the presence of magnesite, quartz and dolomite.
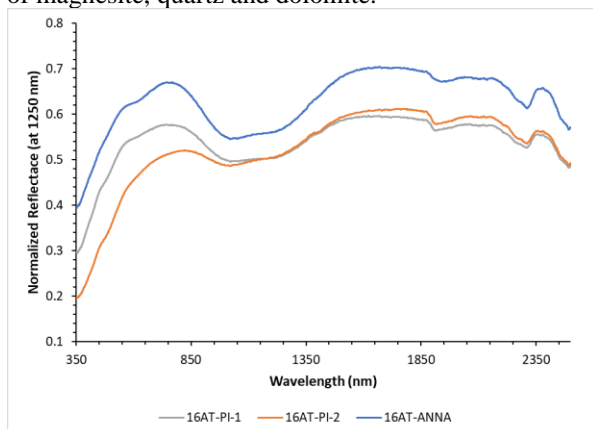

Figure 2. Bedrock fine-grained unsorted listwanite powder samples 16AT-ANNA, 16AT-PI-1 and 16AT-PI-2 from mine sites around the Atlin playas.

Discussion: Carbonates are an important mineral to identify on Mars due to their associations with biosignatures such as microbialites and microbially-influenced carbonate precipitation. Orbital mapping of the Jezero crater basin has identified strong signatures of Mg-rich carbonates [6], making the crater high value for biosignature detection.

MER *in situ* detection of Mg-carbonates indicated the importance of spectrometers onboard rovers [2]. Using reflectance spectroscopy similar to the VISIR instrument on the Perseverance rover can allow for the detection of Mg-carbonates at various distances.

Due to Jezero crater having similar formation conditions to the low-temperature mafic microbially influenced carbonate precipitates of Atlin Lake, similar deposits could have formed on Mars, detectable using spectroscopic instruments on the rover.

Conclusion: The Mg-carbonate playa and surrounding bedrock near Atlin, BC serve as an important analogue site for the formation of Mg-carbonates in a low-temperature mafic environment similar to Jezero crater. Additional >2500 nm wavelength spectral data will be acquired to be able to identify the spectral characteristics associated with carbonates near 3400 and 3900 nm. A larger study of analogue sites showcasing a variety of magnesite/ hydromagnesite samples from mafic terrain environments is also being conducted to better spectrally identify similar outcrops on Mars.

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