SEARCHING FOR POTENTIAL BIOSIGNATURES IN JEZERO CRATER WITH MARS 2020 – A SPECTRAL INVESTIGATION OF TERRESTRIAL LACUSTRINE CARBONATE ANALOGS.

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Introduction: The Mars 2020 rover will investigate an ancient lacustrine environment at Jezero Crater to search for signs of ancient life and cache samples for future sample return. Hydrated Mg-carbonate bearing deposits detected from orbit have a high potential for preservation of biosignatures, and will be high priority targets for the rover. Carbonate-bearing deposits in the Jezero delta may reflect detrital sedimentation [1], and some hydromagnesites along the margin of the crater may reflect near-shore precipitation [2]. Developing strategies for where to look for biosignatures in these carbonate deposits is important for maximizing the scientific return of the Mars 2020 mission. In this study, we aim to determine how to use Mars orbital datasets to constrain locations where biosignatures might be detectable in lacustrine carbonate deposits at Jezero. Our objectives are to investigate the morphological, spectral, and mineralogical properties of biosignature-bearing deposits in terrestrial lacustrine carbonate analogs, their large-scale distribution in the lacustrine system, and refine search strategies for Mars 2020 in Jezero. Here we present preliminary results from laboratory and orbital spectral analyses of lacustrine carbonate analogs for Jezero crater.

Terrestrial Lacustrine Carbonates: The presence of carbonate deposits within both modern and ancient lacustrine systems has been well documented on Earth. In modern systems, carbonates are deposited when cations (e.g., Ca^{2+}, Mg^{2+}) derived from the dissolution of silicate minerals react with bicarbonate formed from the deprotonation of carbonic acid. When CO_2 degasses from solution and is released to the atmosphere, the cations and bicarbonate are supersaturated, resulting in the precipitation of carbonate minerals [3]. On Earth, this reaction can be indirectly influenced by microorganisms through the removal of CO_2 from the water via photosynthesis and production of particles for carbonate nucleation. Microorganisms can directly affect carbonate deposition through organomineralization in biofilms and precipitation in shells and casings [4].

The mineralogy of the carbonates can typically range from low-magnesium calcite and aragonite to magnesium-rich magnesite, or more rarely hydromagnesite, and is largely influenced by the source area, salinity, and hydrology of the lake basin [5]. For example, in Lake Salda, Turkey [6] and the playas of the Cariboo Plateau in British Columbia [7], meteoric waters flowing through surrounding ultramafic and mafic rocks bring high concentrations of Mg to the lake, resulting in the precipitation of hydromagnesite. Previous studies using CRISM data have suggested that the marginal carbonates in Jezero may be partially comprised of authigenic lacustrine hydromagnesite [2]. Thus, Lake Salda and the Cariboo Plateau playas are good compositional analogs for a Jezero paleolake [8].

Three key types of near shore lacustrine carbonate deposits in terrestrial lakes include microbialites, tufas and beach sediments. Microbialites are organosedimentary structures formed by microbial communities through binding and trapping and/or in-situ precipitation. Microbialite morphologies can range from stromatolitic (fine lamination), thrombolitic (clotted), oncolitic (irregular, concentric lamination), or leiolitic (no obvious internal structure) [9]. While these deposits are closely associated with microbial activity, previous studies have indicated that these structures can also form as a result of abiogenic processes [10]. Tufas are carbonate precipitates that are generally localized around Ca-rich ground water seeps into alkaline CO_3^{2-}-rich lake waters at ambient temperatures, and may be mediated by microbial activity. Tufas are similar to travertine deposits, but the latter generally forms in hydrothermal settings where high temperature supersaturated groundwater emerges [11]. Carbonate beach deposits include beach rock, oolitic and skeletal sands, and fine-grained sediments [5]. All three deposit types are present in and around the Great Salt Lake (GSL), Utah, and ancient lithified analogs for these deposits are preserved nearby in the Eocene Green River Formation (GRF).

Sample Suite: We collected in-situ VNIR reflectance spectra on a suite of both modern and ancient analog field samples. The sample suite consists of all three types of near shore lacustrine carbonates discussed above. It includes modern hydromagnesite stromatolites and lake sediment from Lake Salda, Turkey; modern stromatolites and oolitic beach rock and sediment collected from GSL; ~14.3 ka tufas [12] from Tabernacle Hill, UT that were deposited on a basaltic lava flow into the Pleistocene-aged Lake Bonneville; and GRF stromatolites collected near Vernal, UT and Boar's Tusk in Wyoming.

Spectral properties: Each of the analyzed samples show hydration bands at 1.4 and 1.9 µm. The GSL stromatolite and Lake Salda samples show an extra narrow absorption in the typically smooth 1.4 µm band. There are observed absorptions around 2.3 µm in all the samples, which in both ancient GRF stromatolites are clearly consistent with carbonates. However, GSL 2.3 µm bands are narrower and sharper than expected for carbonates, and additional smaller ~2.3 µm absorptions present in the Lake Salda samples may be a result of microbes or organics. The GSL stromatolite spectrum displays a slight absorption at 0.68 µm, which is also observed in the Lake Salda stromatolites, and may be consistent with oxygenic photosynthesis [13]. Further mineralogical and organic analyses is needed to identify these complex spectral signatures.

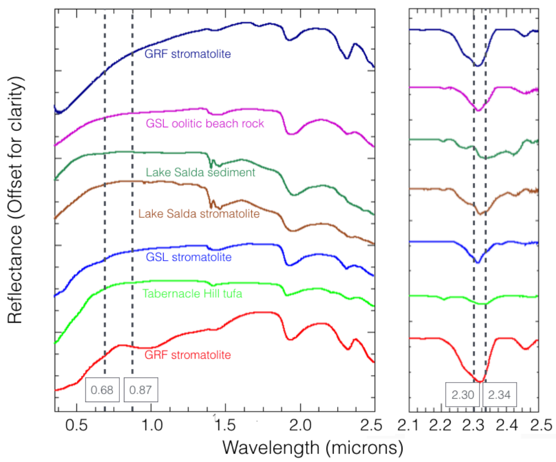

Figure 1: VNIR reflectance spectra of sample suite. Dashed lines at 0.68 µm and 0.87 µm *indicate photosynthetic bands [13]. Right panel shows continuum-removed spectra with dashed lines indicating carbonate bands at 2.30 µm (magnesite) and 2.34 µm (calcite).*

Orbital Remote Sensing: To investigate the composition of Lake Salda from orbit, we atmospherically corrected an EO-1 Hyperion hyperspectral image using FLAASH in ENVI. Initial analysis of the corrected image indicates that the depth of 2.3 µm absorption bands is greatest along the perimeter of the lake. Stronger signatures occur on the eastern margin away from the deltas. Ratioed spectra obtained from locations around the lake show spectral differences between alluvial and shoreline sediments. Shoreline deposits consistently exhibit some absorption feature around 2.35 µm, potentially similar to the complex signatures in Lake Salda lab spectra above.

Discussion: VNIR laboratory spectral analysis of analog samples suggests spectral differences between modern carbonate lacustrine deposits and older lithified deposits. Various bands observed in the Lake Salda stromatolite and sediment samples and in some GSL samples are possibly a result of microbes or organics. These possible organic signatures are not present in the ancient GRF samples, which may be due to diagenesis and alteration that has destroyed the organic signatures and/or recrystallized carbonates; however, these deposits still contain clear morphological biosignatures and microfossils [14]. At Jezero, the marginal deposits exhibit clear carbonate (hydromagnesite) VNIR signatures [2], potentially consistent with lithified lacustrine deposits.

A review of the orbital Hyperion data over Lake Salda indicate that shoreline deposits that occur in regions distinct from fluvial-deltaic deposits exhibit stronger carbonate and/or microbial signatures, presumably reflecting the absence of mixing with other detrital minerals. A strong carbonate signature has been identified within marginal deposits in Jezero crater, and may support the hypothesis that these deposits include authigenic shoreline carbonates. Based on these results, we conclude that the Mars 2020 rover should target possible biosignatures in any carbonate-bearing near-shore deposit at Jezero.

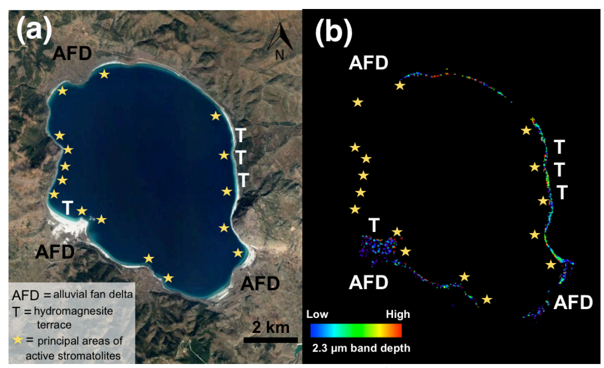

Figure 2: (a) A Google Earth image of Lake Salda with locations of terrace deposits (T), alluvial fan deltas (AFD), and stromatolites (stars) [6]. (b) Sum of band depth maps centered at 2.30 µm, 2.32 µm, and 2.34 µm showing carbonate absorption on Lake Salda shoreline, with locations of features from (a) (water and surrounding terrain is masked).

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