McMURDO DRY VALLEY SEDIMENTS AS ANALOGS FOR NEAR-SURFACE PROCESSES IN THE COLD DESERT-LIKE ENVIRONMENT ON MARS.

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Introduction: The McMurdo Dry Valleys (MDV) have long been valued as analogs for the cold desert environment on Mars [e.g. 1], and processes for past and present water action and salt formation in cold and arid deserts [2]. Since that time numerous studies have investigated the chemical, physical and biologic properties of sediments, both from the bottom of ice-covered lakes and from surface regions [e.g. 3-8]. These studies observed microbial life nearly everywhere as well as some evidence for clays, carbonates, sulfates and other minerals associated with microbes in the sediments.

Lakebottom sediments: Studies of the mineralogy, geochemistry, spectroscopy, and isotope patterns have been performed on igneous sediments from Lake Hoare, Taylor Valley, [e.g. 6], a nearly isolated lake covered year-round by a layer of ice several meters thick (Fig. 1). The mineralogy and chemistry of these sediments were studied in order to gain insights into the biogeochemical processes occurring in a permanently ice-covered lake and to assist in characterizing potential habitats for life in paleolakes on Mars. Obtaining VNIR, mid-IR, and Raman spectra of such sediments provides the ground truth needed for remote exploration of geology, and perhaps biology, on Mars.

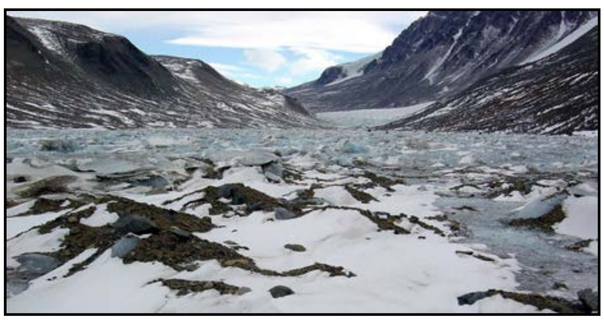

Figure 1. Surface of Lake Hoare, Taylor Valley, Antarctica. Snow, sediments and small rocks (few cm width) are shown covering the thick ice layer.

These sediments are dominated by quartz, pyroxene, plagioclase, and K-feldspar, but also contain calcite, organics, phyllosilicates, sulfates, sulfides, and iron oxides/hydroxides that resulted from chemical and biological alteration processes [6]. Chlorophyll-like bands are observed in the spectra of the sediment-mat layers on the surface of the lake bottom, especially in the deep anoxic region (Fig. 2). Layers of high calcite concentration in the oxic sediments and layers of high pyrite concentration in the anoxic sediments are indicators of periods of active biogeochemical processing in the lake. Micro-Raman spectra revealed the presence of ~5 µm-sized pyrite deposits on the surface of quartz grains in the anoxic sediments. C, N, and S isotope trends were compared with the chemistry and spectral properties. The $\delta^{13}C$ and $\delta^{15}N$ highlight differences in the balance of microbial processes in the anoxic sediments versus the oxic sediments. Biogenic pyrite found in the anoxic zone sediments is associated with depleted $\delta^{34}S$ values, high organic C levels, and chlorophyll spectral bands, and could be used as a potential biomarker mineral for paleolakes on Mars.

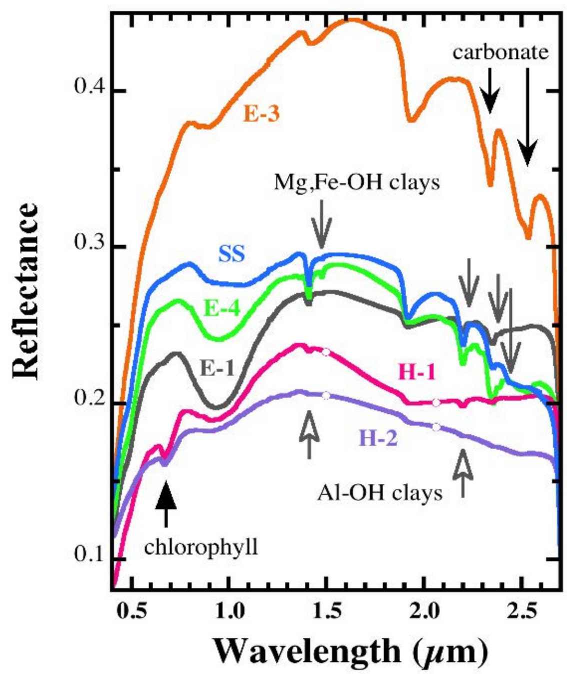

Figure 2. VNIR reflectance spectra from 0.4 to 2.7 µm, Lake Hoare sediments. Spectra illustrate chlorophyll, carbonate, and phyllosilicate bands. Broad bands near 1 and 2 µm are characteristic of pyroxene.

Surface Sediments: ADV surface sediments at Lake Fryxell, Taylor Valley, and Lakes Vanda and Brownworth, Wright Valley, were investigated as analogs for the cold, dry environment on Mars [8]. Sediments were sampled from regions surrounding the lakes and from the ice cover on top of the lakes (Fig. 3). The ADV sediments were studied using Raman spectra of individual grains (Fig. 4) and reflectance spectra of bulk samples. Elemental abundances were coordinated with the spectral data in order to assess trends in sediment alteration (Fig. 5). Surface sediments in this study were compared with lake bottom sediments [6] and samples from soil pits [7].

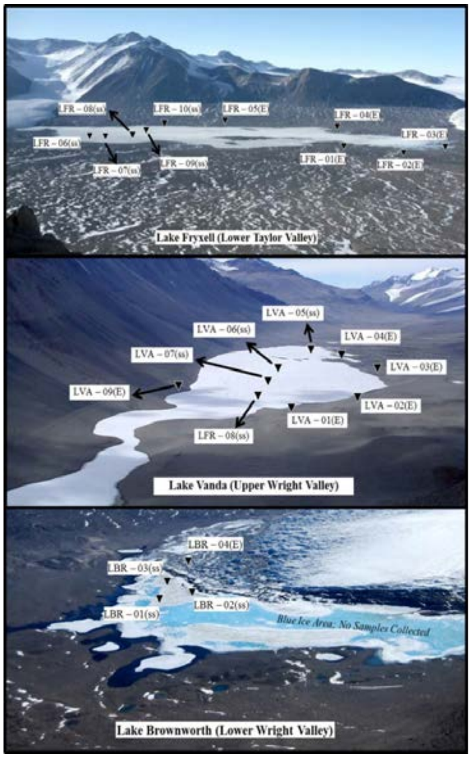

Figure 3. *Sampling sites from [8]: Top) Lake Fryxell, Center) Lake Vanda, Bottom) Lake Brownworth.*

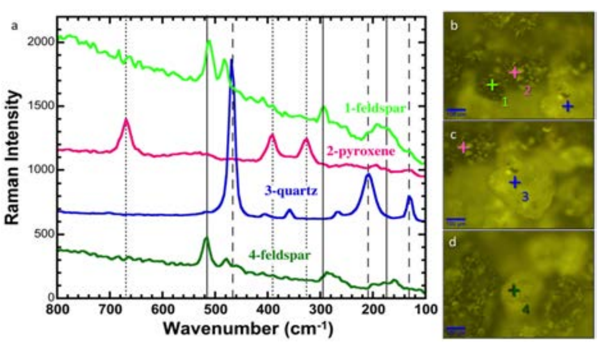

Figure 4. *a) Raman spectra of mineral grains in a surface sample JB651 from Lake Fryxell, b) image of grains 1-3, c) image of grains 2-3, and d) image of grain 4. Spectra are offset for clarity and lines mark key features in Raman spectra (data from [8]).*

Feldspar, quartz and pyroxene are commonly observed by XRD in most sediments (Fig. 6). Minor abundances of carbonate, chlorite, actinolite and allophane are also found in the surface sediments, and these are similar to minerals found in greater abundance in the lake-bottom sediments. Surface sediment formation is dominated by physical processes in contrast to bio-mineralization taking place in lake-bottom sediments. Characterizing the mineralogic variations in these samples provides insights into the alteration processes occurring in the MDV and supports understanding alteration in the cold and dry environment on Mars.

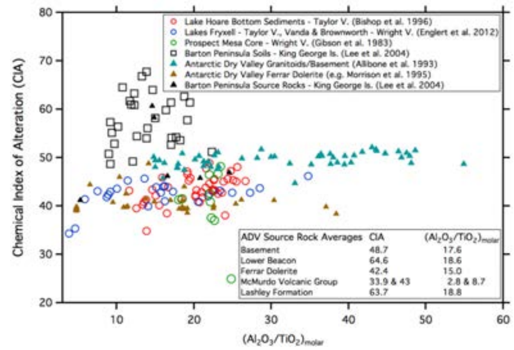

Figure 5. *Chemical Index of Alteration for sediments throughout the MDV compared with source rocks.*

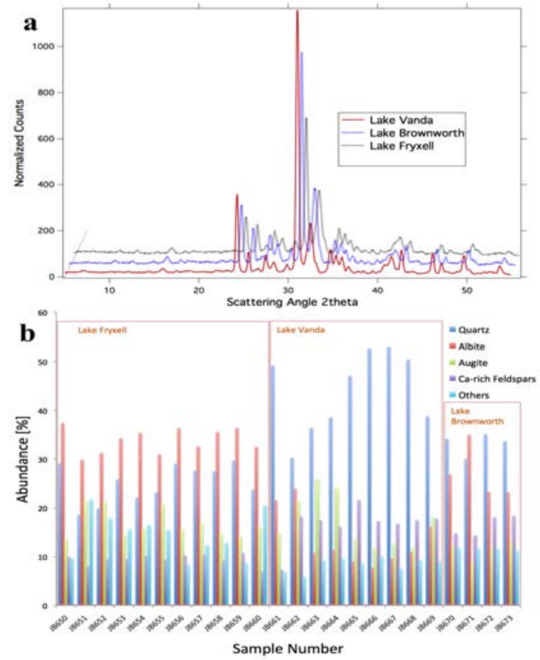

Figure 6. *XRD data show quartz, feldspar and pyroxene in all samples, but the relative abundances vary. a) Representative XRD scans from the lake samples, and b) Relative abundance of major mineral components from each sample (data from [8]).*

Summary: Physical processes dominate alteration of MDV surface sediments, while lake-bottom sediments have revealed differences in mineralogy and geochemistry due to biogeochemistry in the lakes. Ongoing studies of sediment cores illustrate changing chemistry and mineralogy with depth [e.g. 9].

References: [1] Cameron R.E. et al. (1971) *Antarct. J. US*, **6**, 211-213. [2] Gibson E.K. et al. (1983) JGR, 88, A912-A928. [3] Wharton R.A. et al. (1989) Adv.SpaceRes., 9, 147-153. [4] McKay C.P. et al. (1992) Adv.SpaceRes., 12, 231-238. [5] Doran et al. (1998) JGR, 103, 28-48. [6] Bishop et al. (2003) IJA, 2, 273-287. [7] Englert et al. (2014) 77th Met.Soc., abstract #1800. [8] Bishop et al. (2014) *Phil. Trans. R. Soc. A*, **372**, 20140198. [9] Englert et al. (2019) LPSC abstract #2252.

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