

SALTS AND CLAYS BENEATH SURFACE SEDIMENTS IN ANTARCTICA PROVIDE CLUES TO WEATHERING AND GEOCHEMISTRY ON MARS. Z. F. M. Burton^{1,2}, J. L. Bishop², P. Englert³, C. Koeberl⁴, and E. K. Gibson⁵, ¹Stanford University (Stanford, CA; zburton@stanford.edu), ²SETI Institute (Mountain View, CA), ³University of Hawaii (Mānoa, HI), ⁴University of Vienna and Natural History Museum (Vienna, Austria), and ⁵Johnson Space Center (Houston, TX).

The McMurdo Dry Valleys (MDV) in Antarctica have long served as a process analog for Mars due to their cold and xeric conditions [1]. Liquid water is unstable on the surface most of the year [2], yet life is abundant [3]. This study focuses on the sediments and minerals that formed due to liquid water activity at a transient pond site. Understanding aqueous alteration in the cold and xeric MDV environment provides guidelines for the geochemical history of Mars that led to formation of the currently observed phyllosilicates and sulfates [e.g. 4].

Introduction: A multitude of climatic and geological factors make the MDV an excellent analog for Martian environments. The climate is extremely cold and dry with mean annual temperatures of -18°C [1,2] and minimal snowfall (<10 cm per year with sublimation >50 cm per year) [1,3]. Despite this, liquid water does occur, due to glacial meltwater and deep groundwater [3,4]. Most of the lakes, ponds and streams are highly saline, providing a direct analogue for runoff- and groundwater-fed saline bodies of water inferred to have existed on Mars to produce the observed surface minerals [e.g. 4-6]. Ferrar dolerite rich in pyroxene, feldspars and phyllosilicates is pervasive in the sandstone mountains of the MDV [7,8] and serves as an analog for igneous lithologies on Mars. Weathered dolerite and sediments thus provide an analog for the martian regolith.

Study Site: We studied the geochemistry, mineralogy, and spectral properties of sediments collected in 1980 at multiple depths from an intermittent pond site (VXE-6 pond) in the South Fork of Wright Valley (Fig. 1). VXE-6 pond is proximal to the chemically unique Don Juan Pond (Fig. 1) and is fed by shallow groundwater. We analyzed sediments from six depth intervals (0-1, 1-4, 4-7, 8-10, 12-15, 20-24 cm) in a pit dug at the site that was dry during sampling [9]. Previous analyses observed elevated gypsum at a depth of 8-10 cm [10].

Methods: Samples were available as coarse sediment grains in their original form as collected (C) and finely-crushed particles prepared in 1983 [9] (F). We ground and dry sieved $<150\ \mu\text{m}$ aliquots (G) of the bulk grains in 2018 for comparison with the previously ground material. Visible/near-infrared (VNIR) reflectance spectra of samples were collected at ambient conditions with an ASD spectrometer at the SETI Institute, while bidirectional reflectance spectra from 0.3-

2.55 μm and FTIR reflectance spectra from 1-50 μm were collected under controlled dry conditions at the RELAB facility at Brown University, following procedures as in [11]. Major element geochemical analysis was conducted by X-ray Fluorescence (XRF) at the Bureau Veritas in Vancouver and by Instrumental Neutron Activation Analysis (INAA) at the University of Vienna.

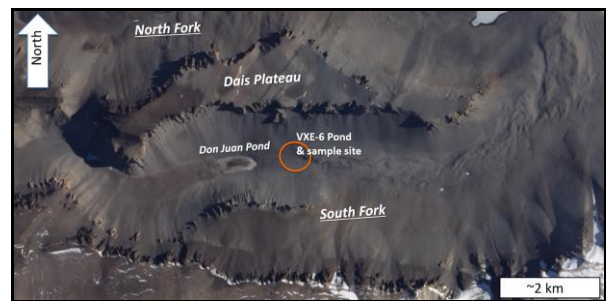


Figure 1. Pond site (orange) in ADV's Wright Valley.

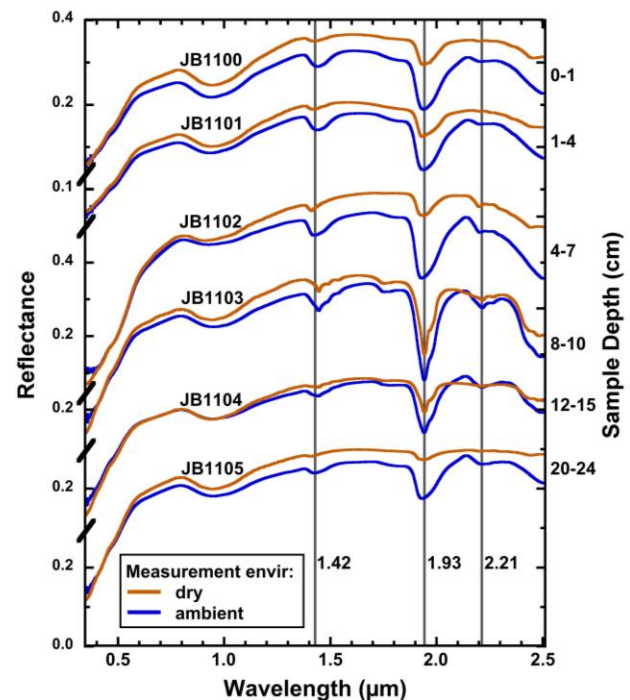


Figure 2. VNIR spectra measured under controlled, dry (tan lines) and ambient (blue lines) conditions of ground samples from the VXE-6 pond soil pit.

Results: VNIR spectral properties were compared as a function of depth in the soil pit, measurement con-

ditions, and grain size. Water bands near 1.4 and 1.9 μm in spectra of the previously ground samples ($\sim <125 \mu\text{m}$) vary greatly depending on the moisture environment for most samples (Fig. 1). This is likely due to the presence of salts and poorly crystalline materials that readily adsorb H_2O molecules from moist air. The gypsum-bearing sediments at 8-10 cm depth vary the least with changing environment. A band near 1 μm is attributed to pyroxene in all samples, while a band at 1.75 μm and doublet at 2.22 and 2.26 μm (plus 4.4-4.8 μm [10]) are characteristic of gypsum at 8-10 and 12-15 cm depths. Broad bands near 1.4, 1.9 and 2.2 μm (0-1, 1-4, and 20-24 cm depths) suggest poorly crystalline aluminosilicates such as allophane or hydrated salts. A narrower band at 2.2 μm and brighter reflectance for the 4-7 cm depth is consistent with a phyllosilicate such as montmorillonite.

	0-1 cm	1-4 cm	4-7 cm	8-10 cm	12-15 cm	20-24 cm
SiO ₂	70.8	68.3	48.5	59.1	64.3	65.7
Al ₂ O ₃	8.07	8.94	16.2	8.29	9.15	9.75
Fe ₂ O ₃	5.27	5.22	8.25	5.11	5.39	5.41
MgO	3.81	3.82	4.53	3.35	3.65	3.44
CaO	4.76	4.95	6.27	9.83	7.46	6.55
Na ₂ O	2.19	2.11	1.76	1.79	1.93	2.05
K ₂ O	1.27	1.4	2.88	1.61	1.51	1.58
SO ₃	0.294	0.1	0.489	6.7	2.94	1.48

Table 1. Major element chemistry. Elevated abundances highlighted in green, lower abundances highlighted in orange.

Major element chemistry (Table 1) corroborates previous findings [10] that the 4-7 cm interval is a horizon of elevated elemental abundance (aside from Si), perhaps indicating a clay layer undergoing active alteration. Elevated Al_2O_3 here further indicates clay, possibly montmorillonite, as suggested by spectra. CaO and SO_3 data confirm previous spectroscopic interpretations of gypsum at 8-10 and 12-15 cm depths [10]. Variations in the major element concentrations correspond well with the minor and trace (including rare earth) element trends [10].

Comparison of spectra for samples prepared differently was undertaken to ensure consistency of the measurements (Fig. 3). Sample fractions FD and FA were prepared in 1983 [9], while GA was prepared in 2018. As expected, the finest-grained material has higher reflectance, while the generally darker coarse-grained material has lower reflectance. Overall the spectral signatures are similar for all samples.

Conclusions and Implications for Mars: Sediments influenced by a transient brine pond in Antarctica's Dry Valleys are a direct analogue for saline bodies of water that were active on Mars. Spectroscopy and geochemistry of sediment horizons in the MDV suggest

surficial perchlorates and/or chlorides atop a cms-thick chemically active clay layer, gypsum at intermediate depths, and perchlorates/chlorides and some anhydrite at greatest depths. We suggest evaporitic activity within the ephemeral pond formed salts at shallow and deeper depths, while clay formed via precipitation of elemental components from water. This activity very closely matches activity inferred to have formed similar sulfates (especially gypsum) and chlorides on Mars.

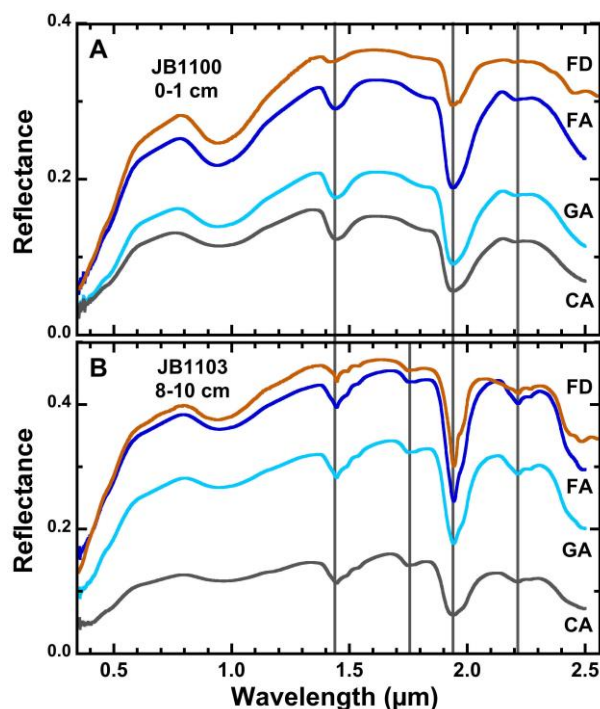


Figure 3. VNIR spectra of 4 different sample preparations: FA (fines), GA (ground) and CA (coarse) were measured under ambient conditions (SETI), while FD (fines) was measured under dry conditions (RELAB).

References: [1] Doran P. et al. (1998) *JGR*, 103, 28-48. [2] McKay, C. et al. (1998) *Antarctic Science*, 10, 31-38. [3] Wharton R. et al. (1983) *Phycologia*, 22, 355-365. [4] Ehlmann B. & Edwards C. (2014) *Ann. Rev. Earth Planet. Sci.*, 42, 291-315. [5] Osterloo et al. (2008) *Science*, 319, 1651-1654. [6] Murchie S. et al. (2009) *JGR*, 114, E00D06, doi:10.1029/2009JE003342. [7] McKelvey & Webb (1962) *N.Z. J. Geol. Geophys.*, 5, 143-162. [8] Claridge G. & Campbell I. (1984) *N.Z. J. Geol. Geophys.*, 27, 537-545. [9] Gibson et al. (1983) *JGR* 88, A912-A928. [10] Burton et al. (2018) *LPSC, Abs. #1086*. [11] Bishop et al. (2014) *Phil. Trans. R. Soc. A*, 372, 20140198.

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