CHEMICALLY ACTIVE HORIZON IN A SOIL PIT FROM AN INTERMITTENT POND SITE IN THE DRY VALLEYS REGION, ANTARCTICA AND IMPLICATIONS FOR SOIL PROCESSES ON MARS.

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Introduction: The cold and extremely xeric conditions in the Antarctic Dry Valleys (ADV) region provide an excellent analogue for conditions expected on Mars. This region, about 4,000 km^2, is one of the largest snow- and ice-free regions in Antarctica, which itself is over 95% covered by ice. The ice-free ADV region receives annual precipitation of 5-10 cm in the form of snow [1], but possible annual sublimation is over 50 cm [2]. This, combined with mean annual air temperatures of -18°C and lows of -55°C [1,3], means that persistence of liquid water is rare. Nonetheless, unfrozen waters do occur locally, mostly within closed basins without effluent streams. These bodies of water are most commonly sourced from glacial meltwater [2], though deep groundwater charging also occurs [4].

This study explores the mineralogy and geochemistry of a soil pit from the center of an intermittent pond site, referred to as the VXE-6 pond [2], in the South Fork of the Wright Valley in the ADV region (Fig. 1). The VXE-6 pond exists at the lowest point of the VXE-6 basin, which lies East and above the Don Juan basin and is separated from the Don Juan basin by a low divide [2] (Fig. 1). The pond is fed by shallow groundwater, potentially similar in nature to the Recurring Slope Lineae (RSL) observed on the Martian surface [5,6]. We examined sediment samples from various depths and characterized mineralogical and geochemical changes with depth via visible/near infrared (VNIR) and mid-IR reflectance spectroscopy and Instrumental Neutron Activation Analysis (INAA).

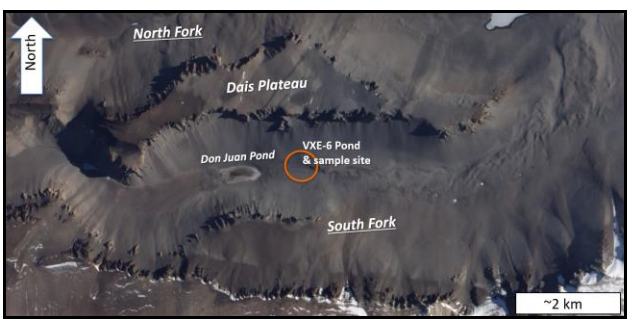

Figure 1. Study area in ADV's Wright Valley; VXE-6 pond and soil pit location indicated by orange circle.

Methods: In this study, we examine sediment samples from six depth intervals from a soil pit dug within the dried up VXE-6 pond site. VNIR spectra of sediment grains were measured using an ASD spectrometer at the SETI Institute. The RELAB facility at Brown University was used to obtain bidirectional reflectance spectra from 0.3-2.55 µm and FTIR reflectance spectra from 1-25 µm for particulate samples, as detailed in previous work, e.g., [7]. Instrumental Neutron Activation Analysis (INAA) of sediment samples was conducted at the University of Vienna as in [7].

Results: Spectra from crushed sample fractions indicate the presence of bands near 1.4, 1.9, and 2.9 µm due to H_2O vibrations (Fig. 2). Bands in the 2.1-2.5 µm region indicate OH combination vibrations in spectra of the samples from depths 4-7, 8-10, and 12-15 cm but not at depths 0-1, 1-4, or 20-24 cm. A band near 1 µm indicates Fe^{2+} in all samples, likely indicating pyroxene in these sediments. Spectra of samples from depths 8-10 and 12-15 cm contain bands highly characteristic of gypsum in the region 1.45-1.55 µm and 4.4-4.8 µm.

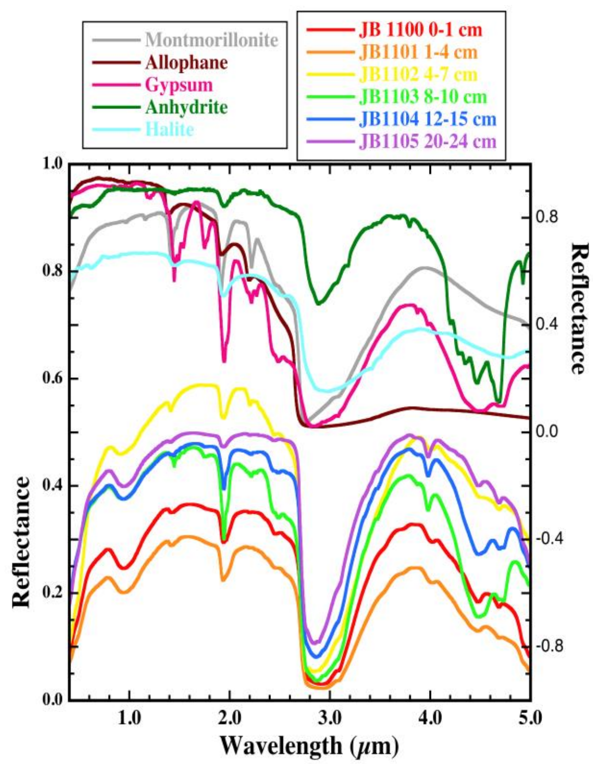

Figure 2. Reflectance spectra of six samples from the VXE-6 pond soil pit compared to spectra of montmorillonite, allophane, gypsum, anhydrite, and halite.

Broad bands near 1.4 and 1.9 µm are characteristic of allophane or hydrated salts such as NaCl (plus water), and are present in samples at depths of 0-1, 1-4, 4-7, and 20-24 cm. Bands characteristic of anhydrite in the region 4.4-4.8 µm seem to suggest anhydrite in samples at depths 0-1, 1-4, and 20-24 cm. The highest reflectance for the sample at 4-7 cm is likely due to the presence of bright materials, such as a salt, clay, or fine-grained particles.

Quantification of the H_2O band near 1.9 µm indicates the highest normalized H_2O absorptions for the sample at 8-10 cm depth, and lowest absorptions for the samples at 4-7 and 20-24 cm depth (Fig. 3). The lower H_2O absorptions at 4-7 cm corroborate the inference of a bright salt mineral at this depth, with less water in its structure.

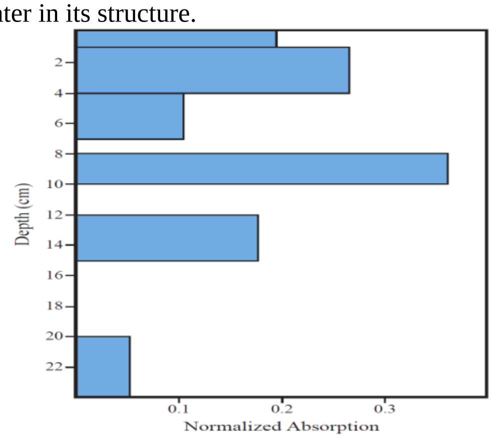

Figure 3. Normalized H_2O band depths at ~1.9 µm.

Information from elemental abundances data show clear patterns with depth (Fig. 4). Abundances of the elements K, U, Cs, Fe, Th, Co, Zn, Rb, Zr, Ba, and Sr, are notably higher for the 4-7 cm depth sample. This likely indicates the transition zone from surficial salt to gypsum at depth, and may be a site of active alteration.

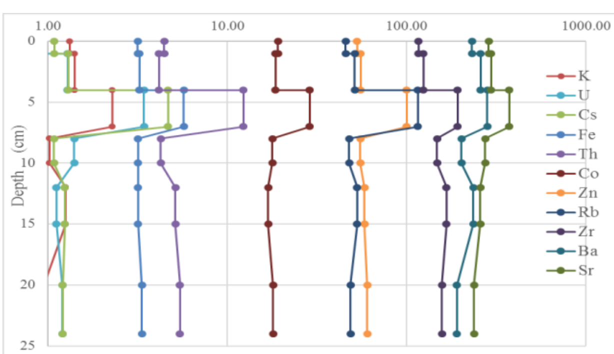

Figure 4. Elemental abundances at various depths; Note elevated abundances at 4-7 cm.

Examination of rare earth elemental abundance data yields similar results, whereby the sediment sample from 4-7 cm depth contains notably higher abundances for all rare earth elements (Fig. 5). This may suggest that the 4-7 cm depth represents a zone of active alteration, where rare earth elements are preferentially precipitated from increasingly basic solutions [8].

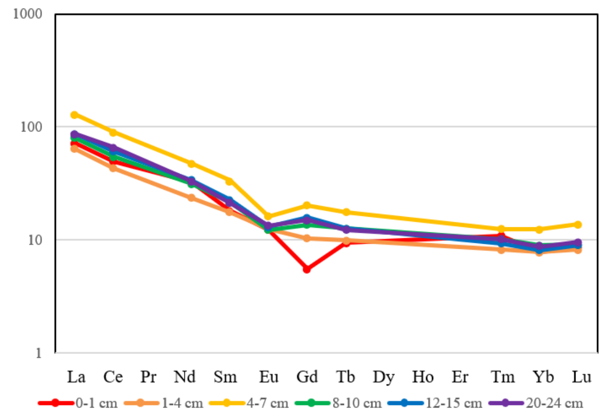

Figure 5. Rare earth element distributions for soils at various depths; Note elevated REEs at 4-7 cm.

Conclusions and Implications for Mars: We measured spectra and chemistry of samples collected at the site of an intermittent salt pond in Antarctica's Dry Valleys region. Spectral results suggest allophane, anhydrite, and hydrated NaCl are present at shallowest depths, gypsum at intermediate depths, and anhydrite at deepest depths. A chemically active zone occurs at the transition from shallow to intermediate depths. This zone has higher reflectance and lower H_2O absorption and has high concentrations of numerous major and trace elements, as well as highly elevated levels of rare earth elements compared to the sediments above and below this zone. These results suggest a salt layer where active alteration is occurring.

The changing spectral features seen in this salt pond could be applied to remote sensing data from Mars, and could aid in the search for paleosalt ponds on the Martian surface.

We may also be able to use chemistry and mineralogy of the salt pond samples with depth in order to monitor changes in the Antarctic climate.

References: [1] Thompson et al. (1971) *N. Z. J. Geol. Geophys., 14(3)*, 477-483. [2] Harris (1981) *Ph.D. Dissertation*, 341 pp. [3] Bull (1965) *Amer. Geophys. Union, 9*, 177-194. [4] Toner and Catling (2017) *J. Chem. & Engin. Data, 62(3)*, 995-1010. [5] McEwen et al. (2011) *Science 333(6043)* 740-743. [6] Ojha et al. (2015) *Nature Geosci. 8(11)*, 829-832. [7] Bishop et al. (2014) *Phil. Trans. R. Soc. A 372(2030)*, [8] Nesbitt (1979) *Nature 279(5710)*, 206-210.

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