

**SUBSURFACE SALTS IN ANTARCTIC DRY VALLEY SOILS.** P. Englert<sup>1</sup>, J. L. Bishop<sup>2,3</sup>, E.K. Gibson<sup>4</sup>, and C. Koeberl<sup>5,6</sup>. <sup>1</sup>University of Hawaii (penglert@hawaii.edu), <sup>2</sup>SETI Institute (Mountain View, CA), <sup>3</sup>NASA Ames Research Center (Moffett Field, CA), <sup>4</sup>NASA Johnson Space Center (Houston, TX), <sup>5,6</sup>Natural History Museum & University of Vienna.

**Introduction:** The distribution of water-soluble ions, major and minor elements, and other parameters were examined to determine the extent and effects of chemical weathering on cold desert soils. Patterns at the study sites support theories of multiple salt forming processes, including marine aerosols and chemical weathering of mafic minerals (e.g. Claridge and Campbell, 1977 [1], Keys 1980 [2], Keys and Williams 1981 [3], and many others). Periodic solar-mediated ionization of atmospheric nitrogen might also produce high nitrate concentrations found in older sediments. Chemical weathering, however, was the major contributor of salts in Antarctic Dry Valleys.

The Antarctic Dry Valleys represent a unique analog for Mars, as they are extremely cold and dry desert environments. Similarities in the climate, surface geology, and chemical properties of the Dry Valleys to that of Mars imply the possible presence of these soil-formation mechanisms on Mars, other planets and icy satellites.

**Methods:** Many samples were collected from soil pits and lake bottom depth profiles during field seasons in 1979/1980, 1990/1991, and 2005/2006. Sampling locations and sample characteristics are summarized in Table 1. The several sets of sediment and soil samples from Taylor and Wright Valleys were analyzed by Instrumental Neutron Activation Analysis, other geochemical analysis methods, and reflectance spectroscopy, e.g. (Gibson et al. 1983 [4]; Bishop et al. (1996) [5]; Bishop et al. (2001) [6]; Englert et al. (2012) [7].

**Results: Chemical alteration.**  $\text{SO}_4^{2-}$ ,  $\text{Cl}^-$ , and  $\text{NO}_3^-$  anions were detected in these samples and gypsum was found by XRD. Salt concentrations are compared with  $\text{SiO}_2$  abundance for 4 samples collected at different depths in a soil pit from the Wright Valley (Figure 1). Reflectance spectra of these 4 samples (Figure 2) are compared with spectra of salt minerals. Gypsum plus montmorillonite or hydrated silica appears to be present in most samples based on the spectral features. Additional hydrated salt components could be contributing to the 2.44  $\mu\text{m}$  band and the 2.09  $\mu\text{m}$  shoulder. Reflectance spectra of selected sulfate, phosphate, nitrate and perchlorate samples are shown in Figure 3.

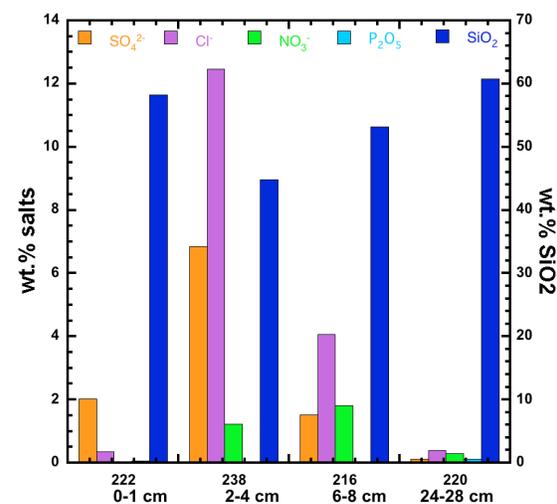
**Sulfur and solubles.** The sulfur values for some surface and shallow depth samples get within the order of magnitude of Mars Exploration Rover soil and rock sulfur abundances. Total sulfur abundance in 13 Taylor Valley samples is only  $\sim 0.02\%$  while the Wright Valley samples (51) generally have higher total sulfur

abundances, varying from a low of  $\sim 0.009 - 0.3\%$ . Prospect Mesa pit #1 and Don Juan Pond area samples have concentrations as high as 2.2% and 6.2% S (15.5%  $\text{SO}_3$  equivalent). Sulfur rich samples will be analyzed to reflect sulfur, calcium, and chloride chemistry with implications from and for Mars (e.g. Witherow et al. 2006 [8]; Green & Lyons 2009 [9]; Sgavetti et al. 2009 [10]).

Valley	Locality	Number of cores	Number of samples	Depth range [cm]	Total C & S	Soluble Ions	INAA
Taylor Valley	Lake Hoare	3	13	0-25	X		
			8	0-1	X		
	Lake Hoare bottom	6	59	0-47.5	X		X
Wright Valley	Lake Fryxell		11	0	X		X
			4	0	X		X
	Lake Brownsworth	7	104	0-80	X	X	
Wright Valley	Don Juan Pond	8	120	0-31	X	X	
			14	0-2			
	Don Quixote Pond	4	48	0-16		X	
			18	0-1			
TOTAL			406	0-80			

**Table 1.** Sampling locations, sample types, and analyses completed

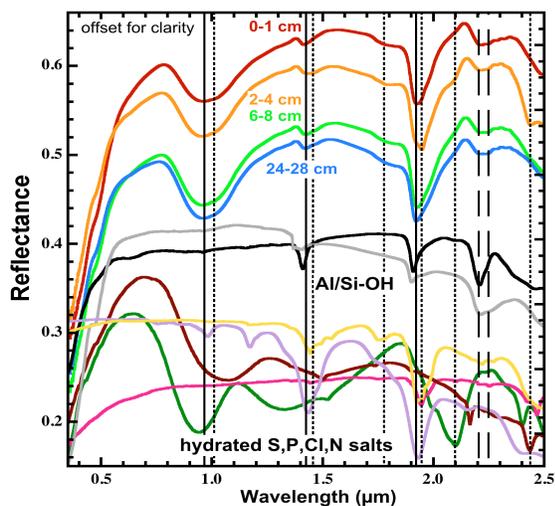
**Cores: local and depth variations.** Two of seven soluble salt depth profiles, including Soil Pit #1 (Gibson et al., 1983 [2]) and DQ 20 of the Don Quixote Pond in the Wright Valley South Fork, are presented in



**Figure 2.** Abundance of soluble anions and  $\text{SiO}_2$  in Wright Valley soil pit samples as a function of depth. Sample numbers are provided. Elevated levels of  $\text{SO}_4^{2-}$ ,  $\text{Cl}^-$  and  $\text{NO}_3^-$  anions were found at 2-4 cm below the surface where the  $\text{SiO}_2$  abundance is lower. Distribution maxima of these ions are at different depths.

Figure 4. Profiles are available for WV 11 of Prospect Mesa; DJ 39, WV 42, DJ 21, and WV 38 of the Don Juan Pond area in the Wright Valley North Fork. Soil Pit 1, WV 11, and DJ 39 (DJ Pond– unfrozen

brine/high salinity) show high ionic concentrations of NaCl, with Pit #1 and WV 11 having very high nitrate levels. The next most abundant cation, calcium, is most likely linked to the remaining chloride and sulfate. Magnesium, potassium and nitrate are generally low. Depth profiles from small ponds (#s 1,3,4) near Don Juan Pond demonstrate  $\text{NO}_3^-/\text{Cl}^-$  increases and their



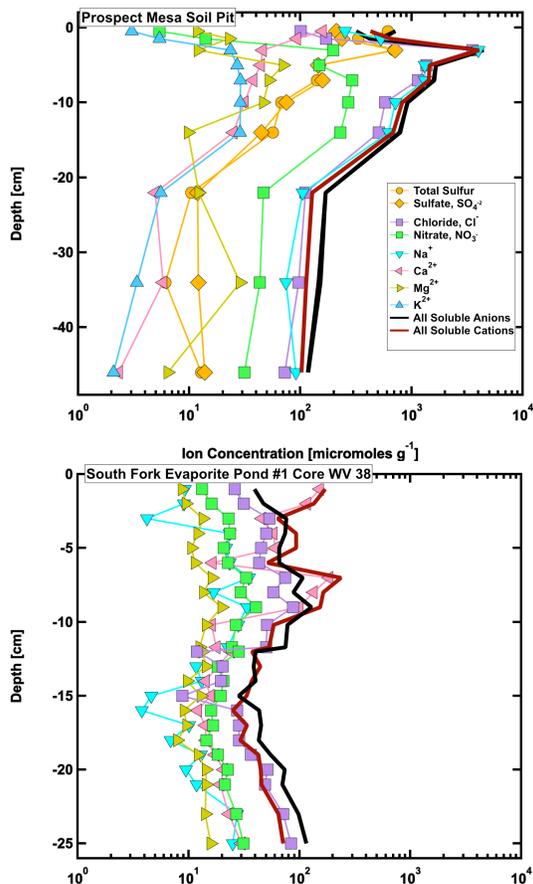
**Figure 3.** Reflectance spectra of Wright Valley soil pit samples. Spectra (0.35-2.5  $\mu\text{m}$ ) of four samples are compared to spectra of Al/Si-hydroxide species (montmorillonite and opal) and salts: gypsum (gold); szomolnokite (green); childrenite (brown), Mg perchlorite (purple), and K nitrate (pink).

connection to higher elevations. Salt concentrations are lower than expected for the elevation and in comparison to North Fork ponds of this study. The generally lower salinity of shallow groundwater feeding the ponds might have contributed to this. Wright Valley cores indicate a high local and depth profile salt variability (Gibson E.K. et al. 1983 [2]). The distribution of ions seems to be dependent on multiple factors including climate, hydrology, and sediment age. Calcium and magnesium salt production indicate chemical weathering, however, potassium concentrations, a major component of potential source rocks, are either low or absent. This could be explained by the low salinity of the ground waters that feed these ponds.

**Profiles and Provenance.** The soil profiles under investigation contain aeolian, salt, active, and permanently frozen zones. Their profiles and variability may reflect properties of other planetary surfaces especially the Martian near-surface environment. Expansion of geochemical investigations on the sample sets available is in progress in order to gain a better understanding of the soil provenance. Elemental abundance measurements allow the calculation of Chemical Indices of Alteration and relations to soil sources (Englert et al. 2012 [5]). Broadened knowledge of sedimentary processes in the Wright and Taylor Valleys will be useful for the interpretation of information obtained

from current missions to Mars and also to solar system satellites beyond Mars' orbit.

**Acknowledgements:** We thank the reactor institute for neutron irradiations in Vienna and RELAB at Brown University for measuring data used in this study.



**Figure 4.** Soluble salt depth profiles, Wright Valley (Gibson E.K. et al., 1983)

**References:** [1] Claridge & Campbell (1977) *Soil Sci.*, 123, 377-384. [2] Keys J.R. (1980), PhD Thesis, Victoria U. of Wellington. [3] Keys J.R. & Williams K. (1981) *GCA*, 45, 2299-2309. [4] Gibson E. K. et al. (1983) *JGR*, 88, A912-A928. [5] Bishop J. L. et al. (1996) *GCA*, 60, 765-785. [6] Bishop J. L. et al. (2001) *GCA*, 65, 2875-2897. [7] Englert P. et al. (2012) *LPS XLII*, Abstract #1743. [8] Witherow R.A. et al. (2006) *Antarctic Science*, 18, 497-505. [9] Green W.J. & Lyons W.B. (2009) *Aquatic Geochem.* 15, 321-348. [10] Sgavetti M. et al. (2009) *PSS*, 57, 614-627. Tosca N.J. et al. (2011) *JGR*, 116 doi:10.1029/2010JE003700.