

Soils and weathering processes in Antarctic Dry Valleys

P. Englert (1), J.L. Bishop (2,3), S. Patel (2,4), E.K. Gibson (5), and C. Koeberl (6)

(1) University of Hawaii at Mānoa, Hawaii, USA (englert@hawaii.edu/+1-808-956-6322), (2) SETI Institute, California, USA, (3) NASA Ames Research Center, California, USA, (4) San Jose State Univ., San Jose, California, USA, (5) NASA Johnson Space Center, Texas, USA, (6) Natural History Museum & University of Vienna, Austria

Abstract

The Antarctic Dry Valleys (ADV) represent a unique analog for Mars, as they are extremely cold and dry desert environments [1,2]. Elevated clay and salt components just below the surface indicate an active subsurface alteration environment where liquid water is seasonally present. 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.

1. Introduction

Physical or mechanical weathering predominates in general over chemical weathering processes in the ADV [3]. Although chemical alteration is a secondary process it plays an important role in formation of clays and salts. In order to better understand Martian surface processes, systematic soil and rock collections were completed over time followed by extensive analysis. Sampling locations and sample characteristics are summarized in Figure 1 and Table 1, respectively.



Figure 1: Sample locations in the Antarctic Dry Valleys.

| 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 | | |
| | Lake Hoare bottom | 6 | 59 | 0-47.5 | X | X | |
| | Lake Fryxell | | 11 | 0 | X | X | |
| Wright Valley | Lake Brownworth | 4 | 0 | X | | X | |
| | Lake Vanda | 7 | 104 | 0.80 | X | X | X |
| | | | 7 | 0 | | | |
| Wright Valley | Don Juan Pond | 8 | 120 | 0.31 | X | X | |
| | | | 14 | 0.2 | | | |
| Wright Valley | Don Quixote Pond | 4 | 48 | 0.16 | | X | |
| | | | 18 | 0.1 | | | |
| TOTAL | | | 406 | 0-80 | | | |

Table 1: Samples under investigation

2. Chemical alteration

Reflectance spectra of ADV soils from Lakes Fryxell and Brownworth (Figure 1) illustrate differences in the mineralogy (Figure 2). The VNIR spectra show Fe^{2+} (electronic) pyroxene bands for less altered soils/sediments. Features due to H_2O , OH , SO_4 and CO_3 are observed in more altered surface sediments. The mid-IR spectra show vibrational bands of quartz, pyroxene, and feldspar. Orthopyroxene/clinopyroxene ratios are ~40/60 for most samples with higher pyroxene abundances near Lakes Vanda and Brownworth [4].

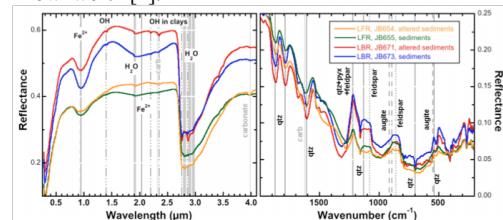


Figure 2: Reflectance spectra of Lakes Fryxell and Brownworth

SO_4^{2-} , Cl^- , and NO_3^{2-} anions were detected in ADV samples and gypsum was found by XRD and VNIR spectra. Salt concentrations are compared with SiO_2 abundance for 4 samples collected at different depths in a soil pit from the Wright Valley (Figure 3). Reflectance spectra of these 4 samples are compared with spectra of clays and salt minerals (Figure 4). Gypsum plus montmorillonite or hydrated silica appear to be present in these samples based on the spectral features. Additional hydrated salt (e.g. sulfate, phosphate, nitrate and perchlorate)

components could be contributing to the 2.44 μm band and the 2.09 μm shoulder.

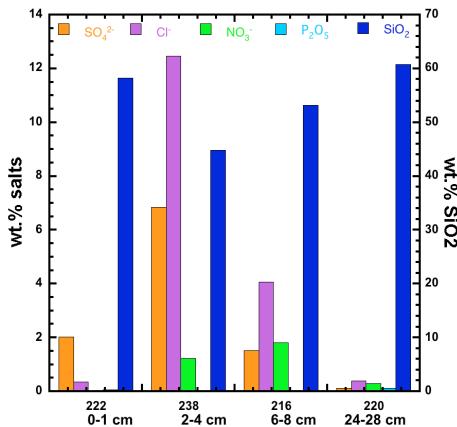


Figure 3: Abundance of soluble anions and SiO₂ in Wright Valley soil pit samples as a function of depth. Sample numbers are provided. Elevated levels of SO₄²⁻, Cl⁻, and NO₃⁻ anions were found at 2-4 cm below the surface where the SiO₂ abundance is lower. Distribution maxima of these ions are at different depths.

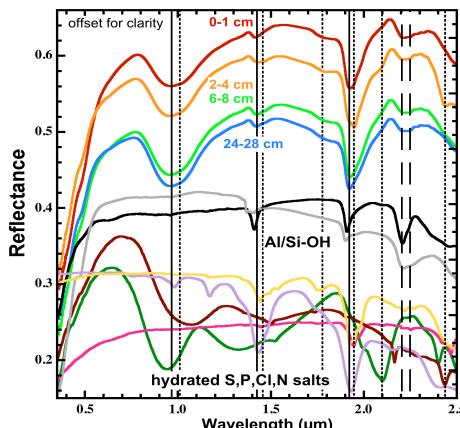


Figure 4. Reflectance spectra (0.35-2.5 μm) of Wright Valley soil samples are compared to spectra of Al/Si-hydroxide species (montmorillonite and opal) and salts: gypsum (gold); szomolnokite (green); chlidenite (brown); Mg per- chlorite (purple), and K nitrate (pink).

The S values for some surface and shallow depth samples are similar to Mars Exploration Rover soil and rock S abundances. Total S abundance in 13 Taylor Valley surface samples is only ~0.02 wt.%, while the Wright Valley surface samples (51)

generally have slightly higher total S abundances, varying from a low of ~0.009 – 0.3 wt.%. In contrast, the subsurface samples from Prospect Mesa pit #1 and the Don Juan Pond area have concentrations as high as 2.2 and 6.2 wt.% S (15.5 wt.% SO₃ equivalent). Reflectance spectra of these samples indicate increased levels of hydrated sulfates. Additional analyses for these S-rich samples are underway to determine associations of S, Ca and Cl with implications for Mars [5, 6, 7].

3. Summary and Conclusions

The soils under investigation contain aeolian, salt, active, and permanently frozen zones. Coordinated chemical and spectroscopic analyses indicate that clays, sulfates and other salts are present at elevated abundances a few cm below the surface. Continued analyses are expected to reveal associations among these components, increase our knowledge of geochemical provenance in the ADV, and contribute to our understanding of the Martian near-surface environment. Elemental abundance measurements allow the calculation of Chemical Indices of Alteration and relationships to soil sources [8, 9, 10]. 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.

References

- [1] Horowitz, N.H. et al., *Science* 176, 242-245, 1972;
- [2] Morris, E.C. et al., USGS Interagency Report: Astrogeology 52, 156 p, 1972; [3] Campbell, I.G. & Claridge, G.G.C., Elsevier Science Publishers, Amsterdam, 368p, 1987; [4] Englert, P. et al., Met. Soc. 74th annual meeting abs. # 5396, 2011; [5] Witherow, R.A. et al., Antarctic Science 18, 497-505, 2006; [6] Green, W.J. & Lyons, W.B., Aquatic Geochemistry 15, 321-348, 2009; [7] Sgavetti, M. et al., Planetary and Space Science 57, 614-627, 2009; [8] Allibone, A.H. et al., NZ J. Geol. Geophys. 36: 299-316, 1993; [9] Lee, Y.I. et al., *Geochim. Cosmochim. Acta* 68: 4319-4333, 2004; [10] Englert, P. et al., 43rd LPSC abs. #1743, 2012.

