RARE EARTH ELEMENT ABUNDANCES & CHEMICAL ALTERATION IN MICROENVIRONMENTS OF THE MCMURDO DRY VALLEYS. A. Foerder[1], P. Englert[1], J. L. Bishop[2,3], C. Koeberl[4,5], E.K. Gibson[6], [1]University of Hawai'i at Mānoa (Honolulu, HI; afoerder@hawaii.edu, penglert@hawaii.edu), [2]SETI Institute (Mountain View, CA), [3]NASA Ames Research Center (Moffet Field, CA), [4]Natural History Museum (Vienna, Austria), [5]Department of Lithospheric Research, University of Vienna (Vienna, Austria), [6]NASA Johnson Space Center (Houston, TX).

Introduction: The McMurdo Dry Valleys (MDV) region are the Earth's coldest and driest desert; the mean annual air temperatures range from -25 to -20° C and the mean annual precipitation, in the form of snowfall, is 15 g/cm^2/yr [2,5]. The region is desolate and liquid water is scarce. Investigations of chemical and mineralogical alteration of MDV soils have found more extensive physical alteration than chemical alteration. This is not to say that chemical alteration is not occurring, and possibly more so than previously thought. The aim of this study is to investigate soil provenance and the extent of chemical weathering by examining Rare Earth Element (REE) abundance in soils and their corresponding source rocks in the extreme conditions of the MDV. Because MDV conditions are not conducive to chemical alteration, special focus is given to microenvironments exhibiting data different from expected abundances and patterns.

Rare Earth Elements: A rare-earth element is one of 17 elements, 15 of which are known as lanthanides, the other two being scandium and yttrium. They are of particular interest to geologists because of their immobility during chemical alteration processes, largely attributed to the small relative size of their ionic radii. Elements with larger ionic radii, such as potassium, are more mobile and soluble whereas elements with smaller ionic radii, such as REEs, tend to be more immobile and less soluble. These characteristics permit REEs to be effective tools for tracing soil provenance. Our work focuses on the abundance of ten REEs (La, Ce, Nd, Sm, Eu, Gd, Tb, Tm, Yb, and Lu).

Methods: For this study, we analyzed surface samples collected on or near lakes Vanda (V), Brownworth (B), and Fryxell (F) [8], and cores from ponds in Upper Wright Valley (UWV) [9]. These samples are compared to potential source rocks in the MDV, based on the availability of REE data. Source rock data include REEs from granitoids [1], Beacon Sandstone [4], and Ferrar Dolerite [3]. Minor and trace elemental abundances of the samples for our study were determined using standard Instrumental Neutron Activation Analysis (INAA) [7]. REE abundances were normalized to Solar System averages as in [6].

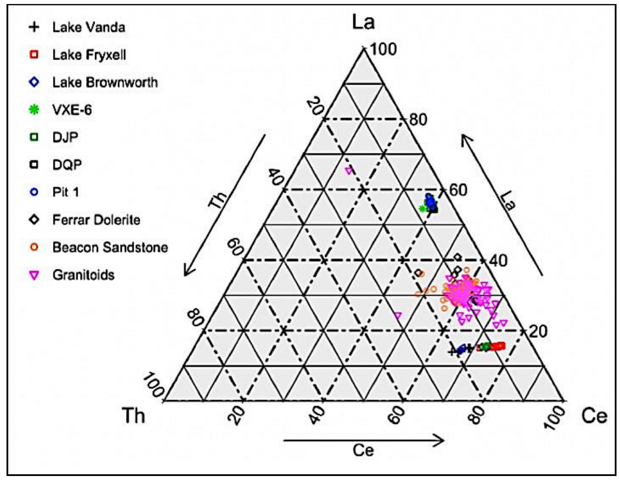

Figure 1. *Ternary diagram of Th, La, and Ce abundances at Lakes Vanda, Fryxell, and Brownworth; Source rocks: Ferrar Dolerite, Beacon Sandstone, and Granitoids; and ponds VXE-6, Don Juan, Don Quixote, and Soil Pit 1 (2km E of Lake Vanda). Th, La, and Ce were selected for the ternary diagram because these data were available for the most samples.*

Results: Figure 1 shows variations in Th, La, and Ce for the source rocks and collected samples. All of the source rock data points overlap, displaying comparable abundances of Th, La, and Ce, with Granitoids exhibiting slightly lower abundances and Ferrar Dolerite slightly higher. The surface sediments collected near lakes all group in a similar region of the diagram, as do the core samples from UWV, with the exception of the Don Juan Pond samples, which are in the same region as the surface sediments. These consistent trends across the surface sediments indicate that similar geologic histories governed processes at these very different sites in both Wright Valley and Taylor Valley. The separate cluster for all of the Wright Valley core samples indicates that subsurface processes are distinct from surface processes

Variations of REE abundances between different core samples are attributed to the local geologic setting of cores. Core 39, for example, is located farthest from Don Juan pond at the base of an alluvial fan. Core 33 sits in the path of a wet encrustation, and Core 2074, the anomaly, sits in the center of Don Juan pond where the highest salinity and lowest REE abundance is reported.

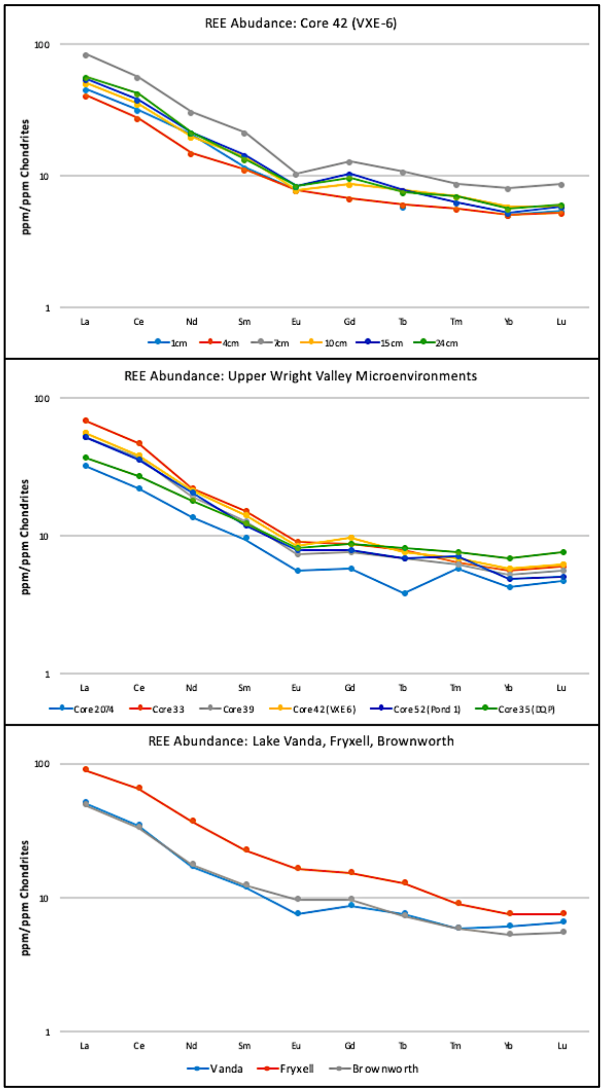

Figure 2. *Top: REE abundances of Core 42 (VXE-6 Pond), depth distribution. Middle: REE abundances of cores taken in Upper Wright Valley. Bottom: REE abundances of surface samples from Lakes Vanda, Brownworth, and Fryxell.*

Figure 2 displays REE abundance for La, Ce, Nd, Sm, Eu, Gd, Tb, Tm, Yb, and Lu normalized to Solar System abundance [6] for the core samples and surface sediments shown in Figure 1. The REE abundances in Figure 2 exhibit generally comparable trends, with variations in total abundance. Core 2074 from Don Juan Pond has the lowest Tb abundance of all cores presented in this study. This could be due to an effect of dilution by high salt content. It also suggests that REEs are fairly immobile and not very susceptible to chemical alteration. The top plot of Figure 2 shows the REE distribution as a function of depth for Core 42 (VXE-6 Pond). Samples at 1 cm, 10 cm, 15 cm, and 24 cm depths exhibit similar REE abundance trends, while samples at 4 cm and 7 cm depths experience comparatively low (4 cm) and high (7 cm) REE abundances, with the sample at 4 cm not experiencing a negative Eu anomaly, which is likely due to Na_2O enrichment. Generally, a negative Eu anomaly is attributed to CaO and Na_2O depletion [10]. A horizon of elevated elemental abundance in the 4-7 cm depth range suggests a clay layer undergoing active alteration [11]. Elevated REE abundance in the 4-7 cm depth range corroborates these findings.

Implications: Due to the extreme cold and aridity of both the McMurdo Dry Valleys and Martian landscape, terrestrial analysis of REE rock and soil data in the MDV could be compared to Martian rover REE rock and soil data to test the efficacy of microenvironments in the MDV as analogs for martian microenvironments.

Additionally, due to their immobility, REEs could be well-suited for tracing soil provenance in terrestrial and martian landscapes. Coordinating REE analyses with geochemical and mineralogical analyses of MDV microenvironments could aid in understanding alteration in the Dry Valleys and also help constrain and reconstruct Mars' geochemical history. From this, the scientific community could move closer to answering questions regarding the potential of life and habitability outside of Earth.

References: [1] Allibone A. H. (1993) *NZ Journal of Geology and Geophysics 36:* 299-316. [2] Horowitz N. et al. (1972) *Science 17:* 242-245. [3] Morrison A. D. & Reay A. (1995) *Antarctic Science 7:* 73-85. [4] Roser B.P. & Pyne A.R. (1989) *Wholerock Geochemistry, DSIR Bulletin 245:* 175-184. [5] Tedrow, J.C.F. and Ugolini F.C. (1966) *A.G.U. Antarctic Res. Series, NO. 8:* 161-177. [6] Anders E. and Grevesse N. (1989) Abundances of the elements: Meteoritic and solar. *Geochim.et Cosmochim. Acta 53,* 197-214.[7] Koeberl C. (1993) *J. Radioanal. Nucl. Chem. 168,* 47–60.[8] Bishop et al. (2014) *Phil. Trans. R. Soc. A, 372,* 20140198. [9] Gibson E.K. et al. (1983) JGR, *88,* A912-A928. [10] Nyakairu G. and Koeberl C. (2000) *Geochem. J. 35,* 13-28. [11] Burton et al. (2019) *LPSC*, Abs. #1086.

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