RARE EARTH ELEMENT ENRICHMENT IN A CLAYEY SEDIMENT LAYER DEVELOPED AT AN ANTARCTIC BRINE POND: IMPLICATIONS FOR MARS AND PLANETARY RESOURCES. Z. F. M. Burton[1,2,3], J. L. Bishop[3], C. Koeberl[4], and P. A. J. Englert[5]; [1]Stanford University, Stanford, CA 94305, USA (zburton@stanford.edu), [2]University of Idaho, Moscow, ID 83843, USA, [3]SETI Institute, Mountain View, CA 94043, USA, [4]University of Vienna, A-1090 Vienna, Austria, [5]University of Hawaiʻi at Mānoa, Honolulu, HI 96822, USA.

The rare earth elements (REEs) are a group of 17 metallic elements designated “critical minerals” for economic and national security, essential to many advanced technological applications (e.g., magnets, batteries, catalysts, smart phones, renewable energy technologies) [1,2]. The REEs are also important in the context of planetary exploration and in-situ resource utilization [2]. Thus, processes that may result in extraterrestrial REE enrichment are of key interest. Here, we investigate REE distributions at an excellent Antarctic Mars analog site [3], and find relative REE enrichments in a phyllosilicate-containing layer.

Study Site: Sediments were collected from VXE-6 pond, ~1 km upslope of hypersaline Don Juan Pond in the South Fork of McMurdo Dry Valleys’ (MDV) Wright Valley (Figs. 1–3). VXE-6 pond is a seasonal saline water body in an endorheic basin, fed by shallow groundwater [4]. The basin is bounded by mountains of Devonian–Triassic orthoquartzite sandstone intruded by Jurassic dolerite dikes [5,6]. Mineral constituents of the sediments include quartz, plagioclase feldspar, diopside, and amphibole at all depths (though of lower abundance at 4–7 cm depth), mica/chlorite at 4–7 cm, and Ca sulfates at 8–10 and 12–15 cm [3].

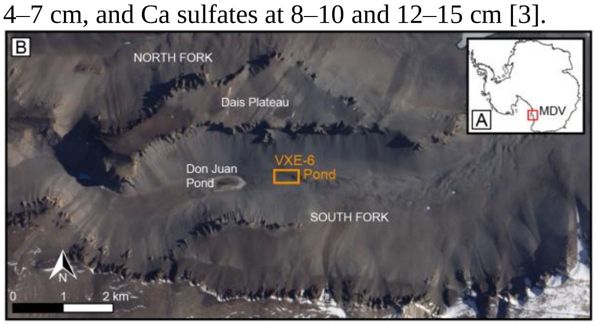

Figure 1. *(A) Location of MDV (red box) on the Antarctic continent. (B) VXE-6 pond study site location (orange box) within MDV’s Wright Valley. Photo credit: NASA EO-1, 2014; fig. modified from reference [3].*

Figure 2. *Area around VXE-6 site (South Fork, Wright Val.). Photo credit: Everett Gibson, NASA-JSC, 1980.*

Figure 3. *The seasonal VXE-6 pond and site of the soil pit. Photo credit: Everett Gibson, NASA-JSC, 1980.*

Methods: Rare earth element analysis of six VXE-6 soil pit samples (from depth intervals of 0–1, 1–4, 4–7, 8–10, 12–15, and 20–24 cm) was performed by Instrumental Neutron Activation Analysis (INAA) at the University of Vienna, Austria. INAA instrumentation, precision, and accuracy can be found in [7,8].

Results: INAA-derived REE abundances for all soil pit samples are provided in Table 1, while chondrite-normalized concentrations are plotted in Fig. 4. At the 4–7 cm depth, REE concentrations are approximately equal to that of the average upper continental crust (and lower than that of Australian, North Ameri-

Table 1. *Soil pit sample INAA rare earth elemental abundance data (Pr, Dy, Ho, Er data not collected). Green highlighting indicates layer of elevated REEs.*

Depth	Concentration (ppm)									
	La	Ce	Nd	Sm	Eu	Gd	Tb	Tm	Yb	Lu
0–1 cm	17.1	30.5	14.8	2.71	0.69	1.00	0.34	0.27	1.27	0.21
1–4 cm	15.3	26.6	10.8	2.59	0.70	2.07	0.36	0.20	1.26	0.20
4–7 cm	30.7	54.9	21.7	4.97	0.91	3.99	0.64	0.31	1.99	0.34
8–10 cm	18.9	33.8	14.5	3.20	0.69	2.70	0.46	0.25	1.44	0.22
12–15 cm	20.6	37.2	15.5	3.38	0.73	3.17	0.46	0.23	1.30	0.22
20–24 cm	20.8	40.4	15.2	3.14	0.75	2.99	0.44	0.25	1.41	0.24

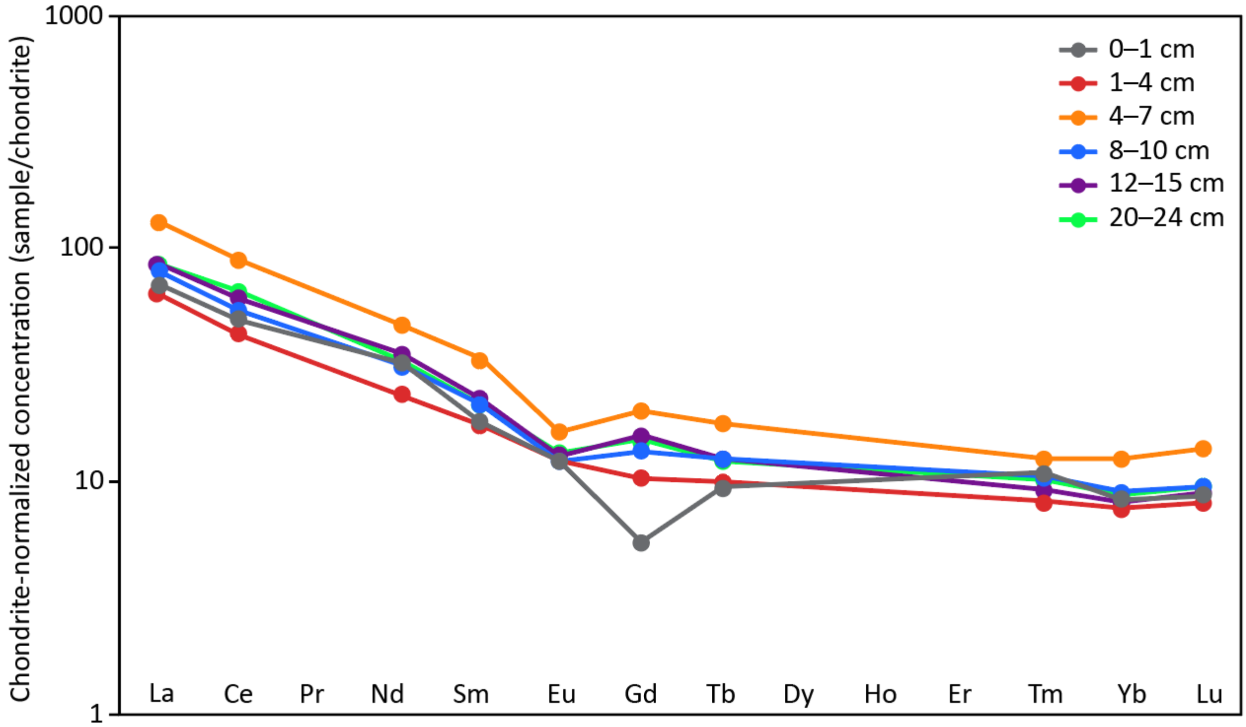

Figure 4. *Chondrite-normalized (using values of [9]) REE abundances for all soil pit samples from the VXE-6 pond site. Figure modified from reference [3].*

can, and European shales), while REE abundances at all other VXE-6 soil pit depths are depleted relative to average upper continental crustal values [10].

REE abundances at the clayey, mica-rich 4–7 cm soil pit depth are higher (for all rare earth elements analyzed) than measured abundances for any other sample depth (Table 1; Fig. 4). Namely, at the 4–7 cm depth, concentration of La is ~48% higher than at any other depth, Ce is ~36% higher, Nd is ~40% higher, Sm is ~47% higher, Eu is ~21% higher, Gd is ~26% higher, Tb is ~39% higher, Tm is ~15% higher, Yb is ~38% higher, and Lu is ~42% higher (Table 1).

Interpretation: Preferential concentration of REEs within the clay-like sediment layer at the VXE-6 brine pond site may be consistent with previous work documenting that a majority of REEs in a weathering profile are hosted in clay minerals and proto-clays [11]. Enrichments of the REEs in the clay/proto-clay layer at the VXE-6 site may be a result of the weak adsorption of REEs onto clay minerals—in fact, ion-adsorption deposits (or IAD clays) are the world's dominant source of heavy REEs [12]. Despite being notable for its higher REE concentration relative to the other VXE-6 soil pit samples, it should again be noted that the 4–7-cm-deep clayey layer characterized here contains REE abundances approximately equal to those of the average upper continental crust [10].

Implications for Mars and Planetary Resources: The VXE-6 pond site is a compelling analog for transient brines and bodies of water that may have existed in the martian past, and that may help explain mineralogical assemblages of salts, sulfates, and phyllosilicates observed at and near the martian surface [3]. Aqueous processes resulting in the development of the clayey layer at the VXE-6 site are thus relevant not only for understanding the presence of phyllosilicates on Mars [3], but also—as demonstrated by this study—for understanding possible mechanisms of REE enrichment on Mars. Identifying REE sources is relevant to planetary exploration, especially in-situ resource utilization.

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