McMurdo Dry Valleys, Antarctica – A Mars Phoenix Mission Analog.

L. K. Tamppari[1], R. M. Anderson[2], D. Archer[3], S. Douglas[1], S. P. Kounaves[2], C. P. McKay[4], D. W. Ming[5], Q. Moore[2], J. E. Quinn[5], P. H. Smith[3], S. Stroble[2], and A. P. Zent[4]. [1]Jet Propulsion Laboratory/Caltech (4800 Oak Grove Dr., Pasadena, CA 91109, leslie.tamppari@jpl.nasa.gov), [2]Tufts University, Medford, MA, [3]University of Arizona, Tucson, AZ, [4]NASA Ames Research Center,, Moffett Field, CA, [5]NASA Johnson Space Center, Houston, TX.

Introduction: The Phoenix mission (PHX; May 25 – Nov. 2, 2008) studied the north polar region of Mars (68° N) to understand the history of water and potential for habitability. Phoenix carried with it a wet chemistry lab (WCL) capable of determining the basic solution chemistry of the soil and the pH value, a thermal and evolved-gas analyzer capable of determining the mineralogy of the soil and detecting ice, microscopes capable of seeing soil particle shapes, sizes and colors at very high resolution, and a soil probe (TECP) capable of detecting unfrozen water in the soil.

PHX coincided with an international effort to study the Earth's polar regions named the International Polar Year (IPY; 2007-2008). The best known Earth analog to the Martian high-northern plains, where Phoenix landed, are the McMurdo Dry Valleys (MDV), Antarctica (Fig. 1). Thus, the IPY afforded a unique opportunity to study the MDV with the same foci – history of water and habitability – as PHX. In austral summer 2007, our team took engineering models of WCL and TECP into the MDV and performed analgous measurements. We also collected sterile samples and analyzed them in our home laboratories using state-of-the-art tools. While PHX was not designed to perform biologic analyses, we were able to do so with the MDV analog samples collected.

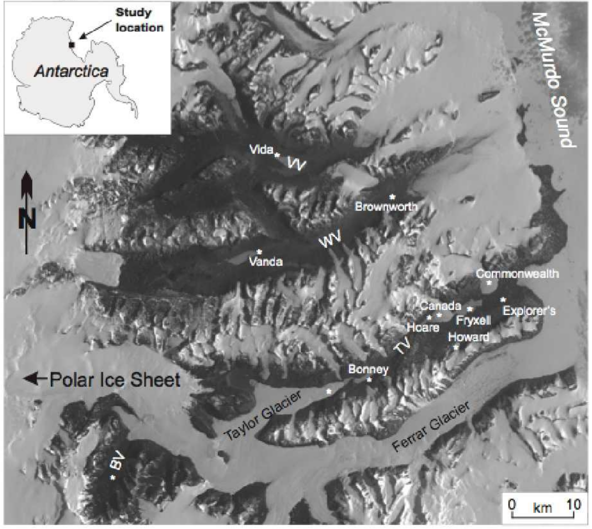

Fig. 1. McMurdo Dry Valleys. BV = Beacon Valley; TV = Taylor Valley.

Field and sampling locations: The MDV are perhaps the coldest and most arid region on Earth. The more coastal valleys are in the subxerous soil moisture regime, such as Taylor Valley (TV), and get warm enough in the summer such that the upper layers of ice-cemented ground thaw. But in the further-inland, higher-elevation valleys in the ultraxerous soil moisture regime, such as Beacon Valley (BV), ground temperatures exceed freezing only at the immediate surface [1]. The upper layer of permafrost in these valleys is not ice-cemented due to the extremely arid conditions [2]. This section is termed "dry permafrost" and thus, is very like the soils on Mars. These valleys are so extreme in climate that no vascular plant life exists.

BV has previously been recognized as a good analog valley to Mars. However, our team chose a small valley (1.7 km long) that enters into BV, called Universtiy valley (UV; Fig. 2) for our high-elevation study location, while TV was chosen as our coastal study location. Within each valley, 2 sampling pits were dug (examples in Fig. 3), and samples were gathered at different soil horizons.

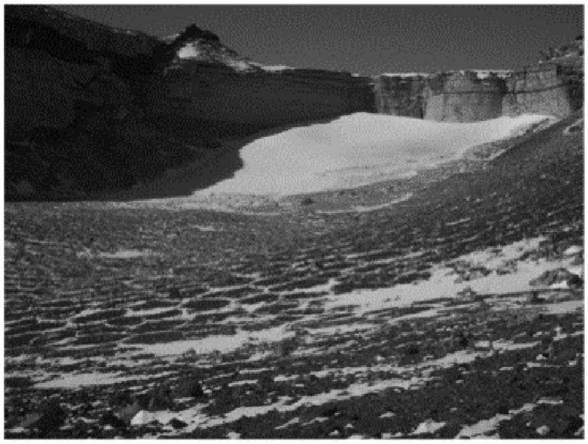

Fig. 2. UV, looking toward the head of the valley.

Sample Analyses and Discussion: Soils in Lower TV formed in glacial till with possible influences from volcanic ash and lake sediments from Lake Fryxell. Parent materials included gneiss, schist, diorite, sandstone, and possibly pyroclastic ash. The mineralogy of sand and silt fractions is dominated by feldspars, mica, quartz, pyroxene, and amphibole along with trace amounts of kaolinite and vermiculite [3]. The clay content increases with depth going from 4% clay (by volume) at the surface to 45% clay content in the ice-cemented soil. The clay fraction is dominated by amorphous or short-order aluminosilicates along with mica, feldspar, amphibole, kaolinite, and vermiculite, weathering products of primary igneous and volcanic parent materials. Specific surface area of the soils also increased with depth, which we interpret to be a result of the increasing clay content. The high amorphous content in the clay fraction of lower horizons (above the ice-cemented soil) suggests translocation of clays and aqueous alteration of primary phases to form amorphous materials.

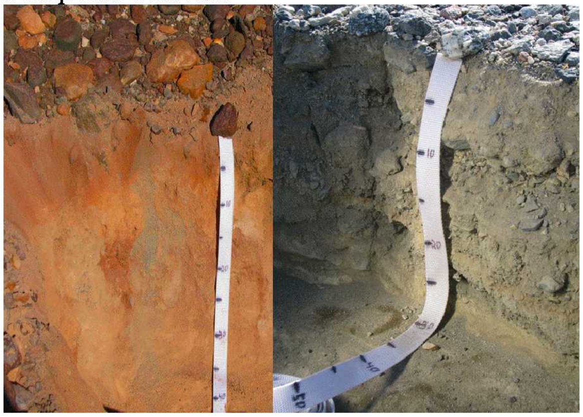

Fig. 3. Soil pits sampled: UV on left; TV on right.

UV soils that formed in glacial till consist of sandstone and diorite. Sand and silt fractions were dominated by quartz with lesser amounts of feldspar, pyroxene, and illite. Silt fractions also contained trace amounts of laumontite, pyrophyllolite, chlorite, and kaolinite [3]. These phases, with the possible exception of kaolinite, represent local parent rock fragments or primary weathering products. Clay fractions are dominated by illite with lesser amounts of amorphous materials, quartz, pyrophyllite, kaolinite, chlorite, and hematite. Amorphous aluminosilicate phases, hematite, and possibly kaolinite formed by pedogenic processes. The clay content reaches a maximum of 30% at 10-19cm below the surface and a minimum of 7% immediately above the ice layer. The specific surface area of UV soils showed little variation, which is most likely due to the low weathering rates for UV soils and the correspondingly low clay mineral concentrations. Aqueous alteration probably occurred in thin films of water (adsorbed from the atmosphere or from surface snow at the surface and from sublimation of ground ice at depth) interacting with diorite particles in the upper horizons of UV soils. *In situ* dielectric permittivity measurements in BV indicated diurnal variations in unfrozen H_2O content, likely in response to the evolving subsurface temperature field.

Chemical analyses of leachable ions showed that the soils in both valleys, in terms of leachable ionic species, are dominated by Ca^{2+}, Mg^{2+}, Na^+, SO_4^{2-}, NO_3^-, and Cl^-. The pairing of the ions (salts) though varies significantly between the lower and upper elevation valleys. In TV the soils are dominated by NaCl and Na_2SO_4. In UV, the soils are dominated by $CaSO_4$ with lesser amounts of Mg/Na-nitrate salts, and salt concentrations generally peak in the layer just below the pavement. Soil salt profiles vary within a given valley.

We also assessed trends in total biomass (living plus dead) and viable biomass (upper bounds). In TV, we found that microbial numbers were highest (~10^9 cells/g soil) at 9-12 cm depth, corresponding to a horizon with lithic fragments, possibly a buried pavement. Numbers peaked again after an intervening drop, at the layer just above the ice-cemented ground (20-24 cm). Similar trends were seen in UV. Here, higher biomass just below the pavement may be due to continued input of inocula from the weathering of the nearby sandstone cliffs, which have endolithic microbial communities [4], and from wind-borne particles.

Perchlorate. Unexpectedly, high levels of perchlorate (ClO_4-) were present in both valleys [5], and correlated to nitrate. supporting an atmospheric source. and supporting the hypothesis that ClO_4^- is globally formed, but can accumulate only in hyperarid environments. The discovery of natural ClO_4^- in the MDV is similar to the PHX discovery of ClO_4^- on Mars [6].

Conclusions: In TV soils, summer temperatures lead to the free movement of liquid water vertically within soils and horizontally in soils along the ice-cemented soil boundary. In UV soils, temperatures are below zero throughout the entire year, preventing free flowing water. Nonetheless, UV – the best Mars analog location – shows soil pedogenesis, salt distribution, and living microbes, each requiring water.

In UV, water is only available from surface snow and humidity or as vapor through sublimation of ground ice. We hypothesize that water condenses as thin films around cold soil particles and their attached microbial cells. With distance upward away from the ice and downward away from the surface, this water would become progressively scarce, making the mid regions of the soil profile a less hospitable place for life.

The results from this study move us one step closer to understanding the habitability potential on Mars.

References: [1] Marchant, D.R., Head III, J.W. 2007. *Icarus*, **192**, 187–222. [2] Bockheim J. G. *et al.*, (2007), *Perma. & Peri. Proc. 18,* 217-227. [3] Quinn, J. E., (2010), *LPSC XLI.* [4] Nienow, J.A., and Friedmann, E.I. (1993). *Antarctic Microbiology* pp.343-412, Wiley-Liss, Inc. [5] Kounaves, S. P. et al. (2009), *Environ. Sci. & Tech.*, submitted. [6] Hecht M. H., *et al.* (2009) *Science 325,* 64.