PROPERTIES OF SUBSURFACE SOIL CORES FROM FOUR GEOLOGIC PROVINCES SURROUNDING MARS DESERT RESEARCH STATION, UTAH: CHARACTERIZING ANALOG MARTIAN SOIL IN A HUMAN EXPLORATION SCENARIO C.R. Stoker[1], J.D.A. Clarke[2], S. Direito[3], and B. Foing[4] [1]Space Science Division, NASA Ames Research Center, Moffett Field, CA 95033, [2] Mars Society Australia, c/o 43 Michell St Monash, ACT 2904, Australia/ Australian Centre for Astrobiology, Ground Floor, Biological Sciences Building, Sydney, NSW 1466, Australia; [3]Molecular Cell Physiology, Faculty of Earth and Life Sciences, VU University Amsterdam, De Boelelaan 1085, 1081 HV Amsterdam, The Netherlands; [4]European Space Agency (ESA), ESTEC SRE-S, Postbus 299, 2200AG Noordwijk, The Netherlands

Introduction: The DOMEX program is a NASA-MMAMA funded project featuring simulations of human crews on Mars focused on science activities that involve collecting samples from the subsurface using both manual and robotic equipment methods and analyzing them in the field and post mission. A crew simulating a human mission to Mars performed activities focused on subsurface science for 2 weeks in November 2009 at Mars Desert Research Station near Hanksville, Utah --an important chemical and morphological Mars analog site. Activities performed included 1) survey of the area to identify geologic provinces, 2) obtaining soil and rock samples from each province and characterizing their mineralogy, chemistry, and biology; 3) site selection and reconnaissance for a future drilling mission; 4) deployment and testing of Mars Underground Mole, a percussive robotic soil sampling device; and 5) recording and analyzing how crew time was used to accomplish these tasks. This paper summarizes results from analysis of soil cores.

Approach: We collected soil cores to average depth of 1 m using a hand operated percussive soil coring device. Cores were collected from 5 representative locations in each of the main geologic units surrounding the Mars Desert Research Station including Cretaceous Mancos Shale, Early Cretaceous Dakota Sandstone, Late Jurassic Morrison Formation (Bushy Basin Member), and Middle Jurassic Summerville formation. These soils and representative samples of the rocks from which they were derived were analyzed for mineralogy using an Xterra X-Ray Diffraction spectrometer (In Xitu, Inc.), a commercial version of the CHEMIN XRD instrument selected for Mars Science Laboratory. Chemical analysis of representative core subsamples for soluble ions that are biological nutrients was performed at the University California Davis Soil analytical laboratory using saturated paste extracts to obtain soil salinity, pH, and concentrations of Ca, Mg, Na, Cl, SO_4, HCO_3, CO_3, NO_3 and PO_4. Oxidizable organics in the soil were determined by the Wakely-Black method. The total number density and the population distribution of soil bacteria was determined by Phospholipid Fatty Acid analysis. DNA was extracted and analyzed in the field laboratory using PCR. These measurements allow a general characterization of the environment, and are representative of the type of environmental survey that can be performed by a human crew in a Mars mission.

Results: Table 1 and Figure 1 show results from the analysis of the soil cores, selected subsamples from depths of 50 cm or greater. Chemical analysis of soils shows sulfate the dominant anion in all soils and $SO_4 >> CO_3$. The cation patterns Na>Ca>Mg is seen with one exception where Ca > Na in the Summerville. In all soils, sulfate correlates with Na, suggesting the presence of sodium sulfates. Minerals observed with XRD include salts gypsum, thenardite, polyhalite and calcite. The Summerville soil contains calcite and sulfate cemented sandstone. All other soils are rich in phyllosilicates including montmorrilonite, illite and nontronite in addition to quartz and sulfates. Oxidizable organics are low in all soils and range from a high of 0.7% in the Mancos samples to undetectable at detection limit of 0.1% in the Morrison Formation soils. PCR analysis showed that all three domains of life (Archaea, Bacteria and Eukarya) were detected but not in all samples. PLFA analysis revealed cell density in the deepest depth sampled varies from between 3.0 $x10^6$ and 1.8 $x10^7$ cells per ml equivalent. Cell count does not appear to correlate with organic content or soil chemistry. Proteobacteria, Firmicutes and Actinomycetes are the dominant populations in all deepest core sections analyzed and anaerobic metal reducers and Eukaryotes were also detected in lower abudances in most cores.

Conclusions: The MDRS area is an excellent analogue for geomorphologic and sedimentary processes that occurred on Mars. The soils of the MDRS locality likewise have important similarities chemically and mineralogically with martian soils. Aspects of the mineralogy, in particular the presence of highly oxidized minerals and smectite clays, local acidic weathering and sulphates are also Mars-like. These features, in combination with the MDRS facility, make the area both a valuable analogue and a useful site to test exploration technologies and methodologies. Our soil measurements allow a general characterization of the environment, and are representative of the type of environmental survey that can be performed by a human crew in a Mars mission. The environment with its extremes of temperature, high salinity, overall lack of moisture, and diverse bedrock geology allows investigation of the distribution and fate of both inherited and introduced organic matter in different soil types. These soils host a diverse assemblage of extremophile microbes. Aeolian dust redistribution is inferred to have resulted in a relatively homogeneous distribution of labile salts across the surface. These are dominated by sodium sulphates with lesser amounts of calcium and magnesium sulphate.

Table 1a. Results from analysis of the soils-geology, mineralogy, and chemistry

Sample	Geology	Mineralogy	Ca (ppm)	Mg (ppm)	Na (ppm)	Cl (ppm)
S1	Tununk member Mancos Shale	Quartz, Montmorillonite	182.0	32.40	1054.0	262.00
S2	Morrison Formation, Bushy basin member	Quartz, Illite-Montmorrilonite, Polyhalite Thenardite	222.0	7.00	9847.0	23.00
S3	Dakota Sandstone	Quartz, Montmorrilonite, Gypsum, Nontronite	380.0	138.70	895.0	411.00
S4	Mancos Shale, Ferron Sandstone border	Gypsum, Quatrz Montmorrilonite, Nontronite	384.0	43.00	4639.0	149.00
S5	Sommerville Formation	Quartz, Calcite Gypsum	164.0	21.50	123.0	101.00

Table 1b. Results from soil analysis, cont.

Sample	HCO_3 (ppm)	CO_3 (ppm)	SO_4 (ppm)	NO_3 (ppm)	PO_3 (ppm)	Organic content (%)	Cell Count/gm
S1	42.9	<3	1806	847.50	6.4	0.6	2.1E6
S2	60.3	<3	22707	31.44	5.8	0.0	3.9E6
S3	74.2	<3	2597	425.50	<3	0.15	1.71E6
S4	105.4	<3	10987	332.50	<3	0.41	10.2E6
S5	30.7	<3	644	2.80	10.0	0.20	13.6E6

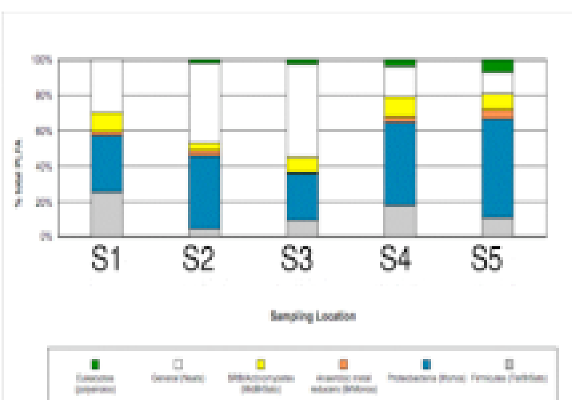

Figure 1. Distribution of bacterial groups for the soil cores. Colors represent: green =eukaryotes, white=general, Yellow=Actinomycetes, Orange=anaerobic metal reducers, blue=Proteobacteria, grey=Firmicutes

Acknowledgements: The Project is funded by NASA's Moon and Mars Analogs program and the European ESTEC and ILEWG sponsored EuroGeoMars program. We thank the US Mars Society and Artemis Westenberg for the facilities at MDRS. MDRS crews 89 and 92 provided field support.