DRILLING ON THE MOON AND MARS: DEVELOPING THE SCIENCE APPROACH FOR SUBUSURFACE EXPLORATION WITH HUMAN CREWS

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Introduction: DOMEX (Drilling on the Moon and Mars in Human Exploration) is using analog missions to develop the approach for using human crews to perform science activities on the Moon and Mars involving exploration and sampling of the subsurface. Subsurface science is an important activity that may be uniquely enabled by human crews. DOMEX provides an opportunity to plan and execute planetary mission science activities without the expense and overhead of a planetary mission.

Objectives: The objective of this first in a series of DOMEX missions were to 1) explore the regional area to understand the geologic context and determine stratigraphy and geologic history of various geologic units in the area. 2) Explore for and characterize sites for deploying a deep (10 m depth) drilling system in a subsequent field season. 3) Perform GPR on candidate drill sites. 4) Select sites that represent different geological units deposited in different epochs and collect soil cores using sterile procedures for mineralogical, organic and biological analysis. 5) Operate the MUM in 3 different sites representing different geological units and soil characteristics. 6) Collect rock and soil samples of sites visited and analyze them at the habitat.

Approach: A crew of 6, comprised of 3 scientists and 3 engineers, was deployed for 14 days at the Mars Desert Research Station (MDRS) November 14-28, 2009. The MDRS is a unique facility that is designed to look like a Mars lander from the Mars Direct architecture[1]. The facility houses a 6 person crew, providing their habitation needs, and laboratory space for sample analysis including wet lab, refrigeration, autoclave, oven, basic laboratory equipment and instrumentation. Ingress/Egress is provided through simulated airlocks and EVAs can be simulated using mock-up spacesuites.. MDRS is located in an important Mars analog site in South-central Utah. The area hosts exposed and nearly vegetation-free sediments deposited during the late Jurassic and Cretaceous geologic periods. Layered sediments were deposited from environments ranging from seafloor, floodplain, massive dunes, and evaporite sequences. The area exposes a rich array of mineralogies including sulfates and phyllosilicates and many types of concretions of particular interest as Mars analogs[2].

Equipment: Instrumentation used to support our mission included key instruments developed for flight use with support from the MIDP program including the Moon Mars Underground Mole (MUM)[3], the CRUX Ground Penetrating Radar[4], and the Terra X-Ray Diffraction Analyzer [5]. The MUM is a subsurface penetrometer designed for penetration through regolith using an internal hammering mechanism. The device contains a hammering front end, a rear optical compartment with light collection optics for a fiber optic Raman spectrometer, and a tether management system (Figure 1). The CRUX GPR (Figure 2) is a small ground penetrating radar consisting of an antenna system mounted on a sled that can be towed. It returns radar echoes diagnostic of subsurface structure to a depth of 10m. The Terra XRD analyzer (Figure 3) is a commercial instrument, ruggedized for field use, that is the prototype of the CHEMIN instrument on the Mars Science Laboratory[5]. In addition, we used a manually operated soil coring system to obtain sterile soil cores.

Other: Detailed timing records were maintained of all crew activities. Audio records were acquired before and after each major traverse activity describing goals and accomplishments. Daily reports written by the crew summarized each day's activities.

Results: At mission start the crew performed a regional survey to identify major geologic units that were correlated to recognized stratigraphy and regional geologic maps. Several candidate drill sites were identified. During the rest of the mission, successful GPR surveys were conducted in four locations. Soil cores were collected in 5 locations representing soils from 4 different geologic units, to depths up to 1m. Soil cores from two locations were analyzed with PCR in the laboratory. The remainder were reserved for subsequent analysis. XRD analysis was performed in the habitat and in the field on 39 samples, to assist with sample characterization, conservation, and archiving. MUM was deployed at 3 field locations and 1 test location (outside the habitat) where it operated autonomously for 2-4 hours at each site. Depths achieved ranged from 15 to 70 cm depending on the soil compressive strength and the presence and depth of subsurface indurated layers. Subsurface samples weighing 0.5 to 1 g were collected at the deepest depth encountered at each of the sites using the MUM automated sample collection system, and subsequently analyzed with XRD. Downhole inspection of holes produced by MUM with the Raman spectrometer was acquired on two of the holes and spectral features associated with selenite were identified in specific soil layers. Previously unreported fossilized remains of vertebrate fauna from the Jurassic era were discovered during our mission. Analysis of mineral biomarkers associated with this discovery are underway.

Figure 1. MUM operation in the field.

Figure 2. Collection of GPR data in the field during a simulated EVA operation.

Figure 3. Terra XRD instrument operated in the field during a simulated EVA operation.

References.
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