EFFECTS OF SUBSURFACE SAMPLING & PROCESSING OF MARTIAN SIMULANT CONTAINING VARYING QUANTITIES OF WATER.
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Introduction: The presence of water-ice in the Martian subsurface is a subject of much debate and excited speculation. Recent results from the gamma-ray spectrometer (GRS) on board NASA's Mars Odyssey spacecraft indicate the presence of large amounts of hydrogen in regions of predicted ice stability [1]. The combination of chemistry, low gravitational field (3.71 m/s^2) and a surface pressure of about 6.36 mbar at the mean radius, place limits on the stability of H_2O on the surface, however, results from the GRS indicate that the hydrogen rich phase may be present at a depth as shallow as one meter in some locations on Mars [2].

The potential for water on Mars leads directly to the speculation that life may once have existed there, since liquid water is the unifying factor for environments known to support life on Earth. Finding evidence of that water is one the primary objectives of the current MER mission and a number of future Mars missions as well. But the discovery of water, even in the subsurface of Mars, presents engineering challenges and scientific questions not previously encountered in planetary exploration.

Estimates for water contents in the Martian subsurface vary from as high as 50% [1] at the poles to < 4 % at the Viking landing sites [3]. Lubricant-free drilling has been considered as a means of obtaining water-rich subsurface samples on Mars, and two recent white papers sponsored by the Mars Program have attempted to identify the problems associated with this goal [4,5]. The two major issues identified were: the engineering challenges of drilling into a water-soil mixture where phase changes may occur; and the potential to compromise the integrity of in-situ scientific analysis due to contamination, volatilization, and mineralogical or chemical changes as a result of processing.

This study is a first attempt to simulate lubricant-free drilling into JSC Mars-1[3] simulant containing up to 50% water by weight. The goal is to address the following:

1) Does sample processing cause reactions or changes in mineralogy which will compromise the interpretation of scientific measurements conducted on the surface?
2) Does the presence of water-ice in the sample complicate (1)?
3) Do lubricant-free drilling and processing leave trace contaminants which may compromise our understanding of sample composition?
4) How does the torque/power required for drilling change as a function of water content and does this lead to unexpected thermal effects?

Experimental: JSC Mars-1 simulant was used in this study as an analog for Martian soil. Required drill power and torque were measured as a function of water content, and soil samples were examined by XRD before and after drilling to determine any compositional or mineralogical changes.

Understanding the water and volatile content of JSC Mars-1: JSC Mars-1 simulant closely resembles the composition of the regolith found at the landing sites of both Viking and Pathfinder. The primary difference is that the simulant is believed to contain a higher volatile content and large amounts of water [3]. Experiments indicated that JSC Mars-1 simulant in equilibrium with the Houston ambient contained as much as 14% water. Thus, it was necessary to insure that samples were maintained in a dry ambient to control water content.

It was also required that samples be dried in preparation for XRD analysis, so it must be demonstrated that the drying process does not effect the composition or mineralogy of the samples in order to interpret any effects observed as resulting from the drilling process alone. This demanded an understanding of the relative loss of volatiles versus liquid water from the simulant.

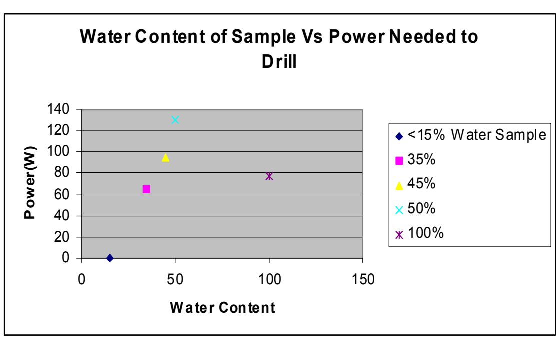
Tests were conducted to compare the loss of material from JSC-Mars-1 simulant induced by freeze-drying (thought to remove only water) to that removed in step-wise heating experiments. Even at fairly moderate drying temperatures, peaking below 270^{o}C, heating removed greater than 20% additional material from the sample by weight. These volatiles are thought to be in the form of sulfur containing compounds, CO_2, and water loss from hydrated minerals. A GC/MS was not available for the analysis of the evolved gases, however, the total sulfur content in the simulant was measured to be on the order of 400 ppm. While this value is higher than anticipated, it cannot account for the loss.

Experimental Setup: Dry JSC Mars-1 simulant was mixed with distilled water to create mixtures containing 2,4, 10, 35, 45, and 50% water, respectively.

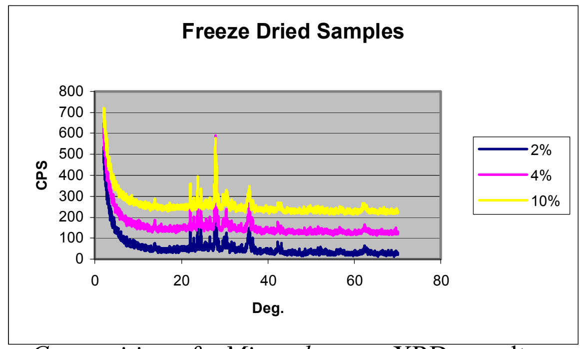
The mixing apparatus used was a Kitchenaid Ultra Power Series mixer with dough attachment. The kneading action allows the production of a consistent mixture with little or no clumping, pooling, or loss of fines. A typical test sample after drilling is shown in Figure 1. Note: The frost formation on top is a result of condensation from the wet Houston ambient.

Samples were frozen at –85°C overnight. Once thoroughly frozen, simulant mixtures were drilled on a mill using a 1.4 cm diameter wood auger composed of stainless steel and connected to a 360° rotational torque sensor. The sample was drilled at a rate of 500 revolutions/min with a decent rate of 6.45 centimeters/min. The final drill depth was 11.3 centimeters.

Results & Discussion: *Power Studies:* Figure 2 shows a plot of the peak power measured as a function of water content for samples of 10, 35, 45, and 50% water content, respectively. Unfortunately, the sensitivity of the torque sensor was insufficient to differentiate the torque required for samples containing less than 15% water. At water concentrations above 30%, the required power increases reaching over 100W for the conditions chosen here. Of course, conditions chosen for an in-situ mission would be dictated largely by power availability and mission lifetime constraints.



This brings up the important consideration of intermittent drilling in areas of high water content, particularly for missions relying on solar power. For water contents above 30%, local melting was observed in the drill core. Even with continuous motion, the torque, and therefore power, required to penetrate simulant of increasing water content increased as a result of melting and refreezing around the bit. The fact that the peak power required for a pure water sample is lower than for those containing soil simulant is misleading, as this is the peak power achieved before the bit became firmly frozen in place, even in continuous operation. Attempts to increase the power resulted in the warping of the bit.



Composition & Mineralogy: XRD results are available for only simulant mixtures containing less than 15% water at this time. These results compare favorably with those obtained from control samples of JSC Mars-1. Comparison of the sample spectra to those of the drill bit and sample fixture materials show no evidence of contamination. Figure 3 shows typical XRD patterns from drilled Martian simulant containing 2, 4, and 10% water, respectively. The results are essentially identical in each case, indicating little change in mineralogy.

Conclusions: The results discussed here only begin to address the issues for drilling and processing water – ice containing samples on Mars. While the XRD results are most relevant to in-situ examination of samples obtained from equatorial regions of Mars which might contain moderate to low water-ice contents, it is evident that higher torque and power would be required in regions of higher water-ice composition. Whether or not the use of such higher energy processing will lead to thermal conditions, which may affect the interpretation of composition and mineralogy of the sample, is yet to be seen.

References: [1] Boynton, W.V., et al. (2002) *Science*, 10.1126/1073722.[2] Andersen, D.T. et al., (2002) *J. Geophys. Res.*, 10.1029/2000JE1436[3] Allen, C.C., et al, (1998), *Space 98 Proceedings,* Am Soc. Civil Eng.[4] SPAD Study Team, (2003) *Planetary & Space Science*, in press.[5] Beaty, D. et al., (2003), *Presentation to MEPAG* .