

CHARACTERIZATION OF METHANE DIFFUSION THROUGH SIMULATED MARTIAN REGOLITH.

L. S. Sollitt¹ and L. W. Beegle², ¹Northrop Grumman Space Technology (R1/1132D, One Space Park, Redondo Beach, CA 90278, Luke.Sollitt@ngc.com), ²Jet Propulsion Laboratory, California Institute of Technology (M/S 183-601 4800 Oak Grove Dr., Pasadena, California 91109, Luther.Beegle@jpl.nasa.gov).

Introduction: Recent observations of the martian atmosphere indicate a concentration of ~10-30 ppbv of methane that may vary in concentration over the planets surface [1, 2]. However, methane is quickly lost to atmospheric chemical reactions (i.e. photolysis), with an atmospheric residence time on the order of 300 years requiring that $\sim 10^7$ moles are delivered to the atmosphere each year to keep the present concentration assuming conservative values for crustal permeability and oxygen fugacity [3, 4]. The potential sources of methane include 1) the product of subsurface microorganisms, 2) a result of subsurface volcanism, 3) very near surface hydrothermal activity, 4) a thermodynamic instability of subsurface deposits in the form of methane clathrate, or 5) generated by atmospheric reactions [3, 5-9]. The source of the methane must be in contact with the atmosphere replenish the atmospheric reservoir to deliver the ~800 kg/sol needed to be in steady state (compared to 2Tg/day generated from mostly biologic processes on the Earth). How deep in the subsurface the methane source is has yet to be detected. If the methane is produced biologically in the subsurface (>10 m), it should be decoupled from both diurnal and seasonal variations because of the insulating characteristics of the Martian soil and supply a steady state of methane [10, 11].

Recent measurement of large quantities of hydrogen in the upper meter of Martian surface by Mars Global Surveyor indicates that either water ice or hydrated minerals exist in concentrations that vary from 2-10% near the equator to above 20% pole-ward of 55° latitude [12-15]. In order for subsurface generated methane to reach the atmosphere, it must first diffuse through the Martian subsurface which consists of various sized particles or bedrock with fissures that have pore spaces which the methane gas can pass through. These transport pathways may become filled by ice crystals, and isolate the source from the atmosphere. The rate of diffusion through these materials is largely unconstrained and thus modeling efforts to understand potential sources of sub-surface methane generation and transport are poorly understood. With upcoming orbital missions to map the subsurface with RADAR (SHARAD and MARSIS) and perhaps a future orbital methane atmosphere mapper, we have conducted a series of experiments to understand the mechanisms of methane diffusion and transport through the Martian regolith.

Apparatus: Figure 1 shows a schematic of the experimental apparatus. Regolith is held in a vacuum

chamber at reduced pressure, 80 Torr, and at temperatures between 253 K and 300 K. The pressure was chosen because it potentially represents subsurface pressures and will help to reduce water sublimation at the experimental temperatures. The chamber is divided by a gate valve into two sections, an upper chamber for the regolith and a lower chamber that contains the methane. The regolith simulant is held up by two 5-micron molecular sieves. A third molecular sieve is placed in the junction between the gate valve and the regolith chamber to prevent contamination of the gate valve by dust.

Prior to an experiment run, the sample is prepared in the upper chamber, and the chamber is pumped down to 80 Torr of air with the sealed gate valve. The lower chamber is then filled with an identical pressure of methane. The run starts when the gate valve is opened. Small volumes of atmospheric gas ($\sim 10\mu\text{L}$) above the regolith are passed through a series valves and into a flame ionization detector (FID) operated at ambient atmospheric pressure. Due to the limited number of samples taken, the pressure drop in the regolith chamber was on the order of 0.1 Torr. For each data run, the maximum FID voltage observed during the sampling is recorded. Calibration runs have shown that this quantity scales as a cubic with the concentra-

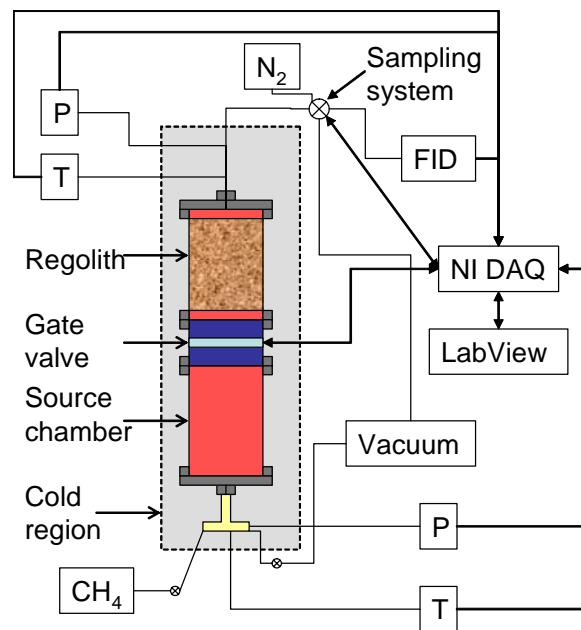


Figure 1. The experimental set up.

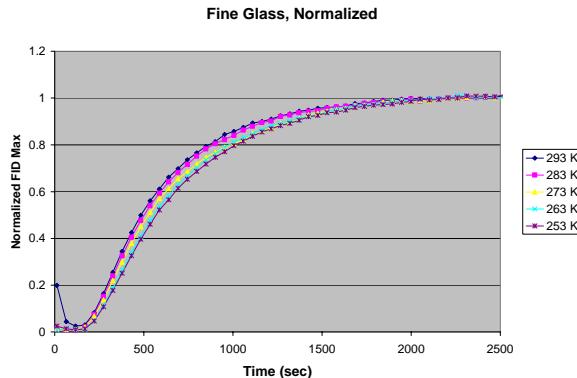


Figure 2. Time profiles of the maximum FID voltage for glass fines at various temperatures. As the temperature decreases, the equilibration slows.

tion of methane. The chamber is placed into a large freezer to control the regolith temperature. The system is controlled using LabView and a National Instruments DAQPad 6016.

The eventual objective of this experiment is to examine the diffusion of methane at various temperatures and water concentrations through a Mars regolith stimulant currently under development at JPL. So far, data collection has been limited to engineering runs with glass beads of known diameters:

- coarse glass with 98.3% of the diameters between 1 mm and 500 μm . The packing of beads results in an air/glass ratio of .65 for the simulated regolith length.
- medium glass with 77% of diameters between 125-250 μm , and 22.3% between 63-125 μm . The packing of beads results in an air/glass ratio of .64.
- fine glass consisting of 54.3% diameters < 45 μm ,

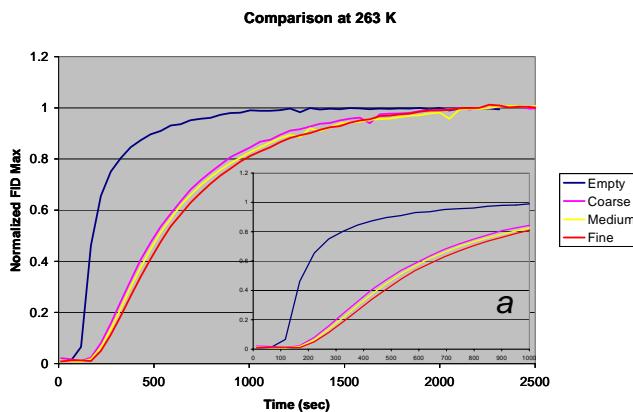


Figure 3. Time profiles of the maximum FID voltage for all three sizes of glass at 263 K, with the empty chamber for comparison. Inset (a) shows detail at shorter timescales. As the pore space is restricted, the equilibration slows.

33% between 45-63 μm and 12.7% between 63-125 μm . This material packed the tightest with an air/glass ratio of .61.

Experiment runs have been restricted so far to temperatures at or above 253 K due to the freezing of the gate valve mechanism.

Results: Figure 2 shows time profiles for the FID maximum in runs taken at various temperatures through the glass fines. In these (and subsequent) runs, the regolith chamber was filled with 20 cm of material. Here, the data have been normalized for each curve to emphasize the difference in equilibration timescales. As might be expected, the equilibration timescale increases as the temperature decreases.

Figure 3 shows equilibration profiles for fine, medium and coarse glass, as well as for the empty chamber at 263 K. During the period before about 1800 seconds, it would appear that equilibration is slower with decreasing glass size. This would seem to indicate that the smaller beads have a more efficient packing, resulting in a smaller amount of pore space available for methane diffusion.

The experimental runs performed so far have principally been to characterize the experiment. Currently we have begun to experiment on basalt samples mixed with water ice percentages, up to saturation, at around 20% ice/dirt ratios.

References: [1] Formisano, V., et al., (2004) *Science*. **306**(5702): p. 1758-1761. [2] Krasnopolsky, V.A., et al., (1997) *JGR-P*. **102**(E3): p. 6525-6534. [3] Lyons, J.R., C. Manning, and F. Nimmo, (2005) *GRL*. **32**. [4] Summers, M.E., et al., (2002) *Geophysical Research Letters*. **29**(24). [5] Bar-Nun, A. and V. Dimitrov, (2006). *Icarus*. **181** 320-322. [6] Onstott, T.C., et al., (2006) *Astrobiology*. **6** 377-395. [7] Prieto-Ballesteros, O., et al., (2006) *Geology*. **34** 149-152. [8] Krasnopolsky, V.A., J.P. Maillard, and T.C. Owen, (2004) *Icarus*. **172** 537-547. [9] Max, M.D. and S.M. Clifford, (2000) *JGR-P*. **105**(E2): p. 4165-4171. [10] Schorghofer, N. and O. Aharonson, (2005) *JGR* **110** [11] Mellon, M.T., W.C. Feldman, and T.H.Prettyman, (2004) *Icarus*. **169**, 324-340. [12] Feldman, W.C., et al., (2004) *JGR-P* **109**(E9). [13] Mitrofanov, I., et al., (2002) *Science*. **297** 78-81. [14] Feldman, W.C., et al., (2002) *Science*. **297**, 75-78. [15] Boynton, W.V., et al., (2002) *Science*. **297** 81-85. [16] Beegle, L.W. et al. (2007) *LPS XXXVIII*

Acknowledgements: The research described here was carried out at the Jet Propulsion Laboratory, California Institute of Technology, and was supported under internal RT&D funding. We would also like to thank J. Armstrong of Weber State University for many helpful discussions on methane diffusion.