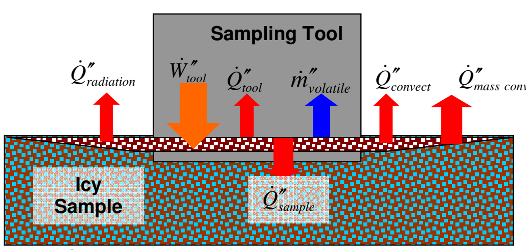
H_2O SUBLIMATION ALTERATION OF ICY MARTIAN SAMPLES DUE TO MECHANICAL WORK, HEAT AND MASS TRANSPORT. G. S. Mungas, G. H. Peters , J. A. Smith, G. H. Bearman, L. W. Beegle, C. Stuthers, J. Glucoft, Jet Propulsion Laboratory, California Institute of Technology (M/S 306-336 4800 Oak Grove Dr., Pasadena, California 91109).

Introduction: Recent orbital data indicates that H2O ice is present in the upper meter of the Martian regolith. The concentration ranges between 2-10% in the equatorially and above 55% in the northern latitudes where Phoenix is scheduled to land. This is interesting for two reasons: 1) The Equatorial ice should be unstable given the current conditions present and 2) there may be enough ice present for ISRU for future human space missions. Acquiring samples and analyzing them for their ice composition is a goal identified by MEPAG. However, the act of aquiring the sample alters it. Understanding the physical properties, namely the sublimation temperature, thermal conductivity and diffusion of ice under martian conditions is vitally important to understand the hydrological cycle and the affects of sample acquisition on in situ measurements. Recent work [1] has demonstrated one such case of potential for significant sample alteration during drilling under Mars relevant environmental conditions in which vigorous sublimation due to mechanical heating was observed.

Sample alteration due to induced sublimation during sample handling is inherently a coupled heat and mass transport problem. In general, mechanical power imparted during the sample handling process is converted into mechanical alteration and heat. This heat release is conducted into the sample and the sampling tool, absorbed to convert volatiles into a gas through the enthalpy of melting and sublimation, convected away through cuttings that are not collected, radiated away, and in some cases used to chemically alter the sample (Fig. 1). Heat conduction into the sample raises the sample temperature and increases the volatile sublimation rate particularly at the transition interface between pore space occupied by volatiles and pore space that is



$$\dot{W}_{tool}=e_{i,j}\frac{dV}{dt}=\dot{m}_{removal}\int c\,dT+\dot{m}_{melt}h_{melt}+\dot{m}_{evap}h_{evap}+\dot{Q}_{conduction}+\dot{Q}_{radiation}+\dot{Q}_{convecti}$$

$$+\sum_{k}\frac{d}{dt}\int e_{mechanical}dV+\sum_{m}\frac{d}{dt}\int e_{chemical}dV$$

Fig 1. Power balance of sampling tool heat and mass transfer interactions with an icy sample.

desiccated. This sublimation loss effectively alters the volatile content of the sample. In our particular case, the sublimation loss of water is of particular importance given its higher volatility relative to other volatiles of interest (i.e. longer chain organic molecules). Herein we are interested in understanding and bounding sublimation losses of samples due to various sample handling configurations and interactions with samples under Mars relevant environments.

Sample Sublimation: To accurately estimate sublimation losses, clearly the vapor pressure at the transition boundary is the key driving parameter (diffusivity porosity, and soil cohesion can typically be reasonably bounded). Furthermore, given the very strong dependence of vapor pressure with temperature, knowledge of the thermal environment (i.e. temperature of the transition boundary which is strongly influenced by thermal boundary conditions and the medium's thermophysical properties) must be carefully understood.

While obtaining heat and mass transport properties of the various interacting media is very important (e.g. thermal conductivity, specific heat, density, porosity, and diffusivity of the various interacting media) , perhaps even more challenging is determining the various interactions and the couplings that can occur at boundaries between the different media:

1) Thermal power generated at the interface due to friction between the sampling tool and the icy sample
2) Heat coupling at this interface between the sampling tool and icy sample
3) Alteration of the vapor pressure gradient at the transition boundary due to various sampling configurations and their resultant influence on fluid boundary conditions.
4) Changing media boundary conditions over time (i.e. loss of desiccated regolith due to sampling tool interactions or environmentally induced sublimation)

Similar and analogous complicated boundary conditions arise in common engineering heat and mass transport problems. A standard approach to solve these type of problems as well as provide predictive insight of the overall transport process is to develop semi-emperical models that allow the scaling of experimental results [2].

Medium Transport Properties: While soil density, specific heat, porosity, and diffusivity typically can be bound within narrow ranges, a soil's thermal conductivity can vary significantly.

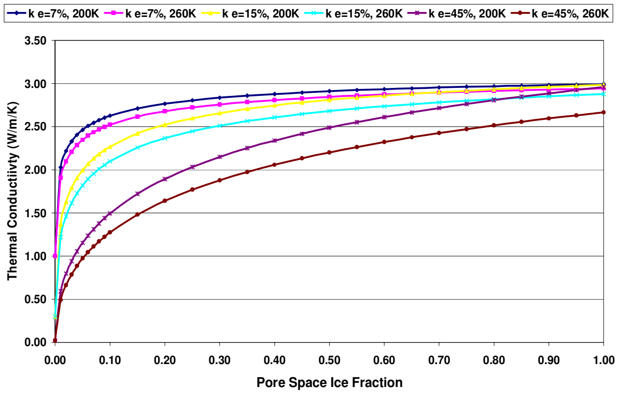
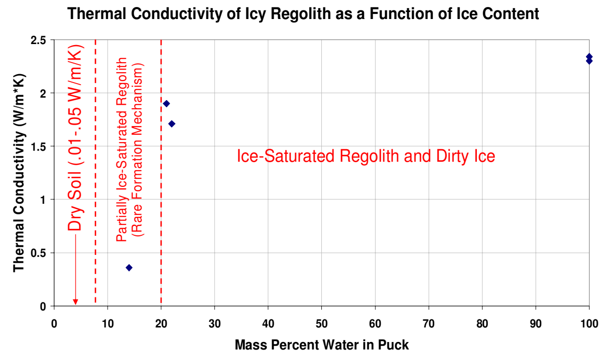


Figure 2. Icy Regolith Thermal Conductivity vs. Pore Space Ice Fraction for porosity = 7%, 15%, 45% and Ice Temperatures of 200K and 260K.

In Figure 2, the variation in a bulk icy regolith thermal conductivity vs. pore space ice fraction and regolith temperature (in particular ice temperature) is illustrated using the model from [3]. The variation in thermal conductivity of an icy regolith rapidly asymptotes to a n effective average between k_{grain} and k_{ice} even with a small mass fraction of ice. It's worth noting that this model is effectively a bulk volume average and does not factor in the way in which ice may preferentially form in icy regolith. Ice will distribute to minimize Gibbs free energy thus preferentially condensing within the smallest pores, grain cracks, and contact points between grains [3]. One would, therefore, expect that even in low ice concentrations, the initial formation of ice in regolith would tend to significantly improve intergrain thermal contact (rather than just filling empty pore volume for example). It's this variation in intergrain thermal contact that is associated with large potential variations in regolith thermal conductivity (tends to lower particulate thermal conductivity by ~1-2 orders of magnitude as compared to individual grain thermal conductivities). The consequence of initial ice formation in regolith suggests that Fig. 2 most likely represents a lower bound on icy regolith thermal conductivity (noting that the upper bound is defined by the thermal conductivity of ice-saturated regolith). Figure 3 illustrates the thermal conductivity of a JPL lunar simulant with varying mass concentrations of H_2O illustrating a similar trend in thermal conductivity. Note that particularly for icy regolith composites (permafrost and dirty ices); the thermal conductivity of the medium varies over a narrow range of 1-3 W/m/K.

Preliminary Mass Transport Experiments: To estimate sublimation loss at a moving ice table boundary as a function of ice table temperature, dessicated regolith thickness and mass transport properties, and various atmospheric fluid boundary conditions, the experiment shown in Figure 4 has been developed. A



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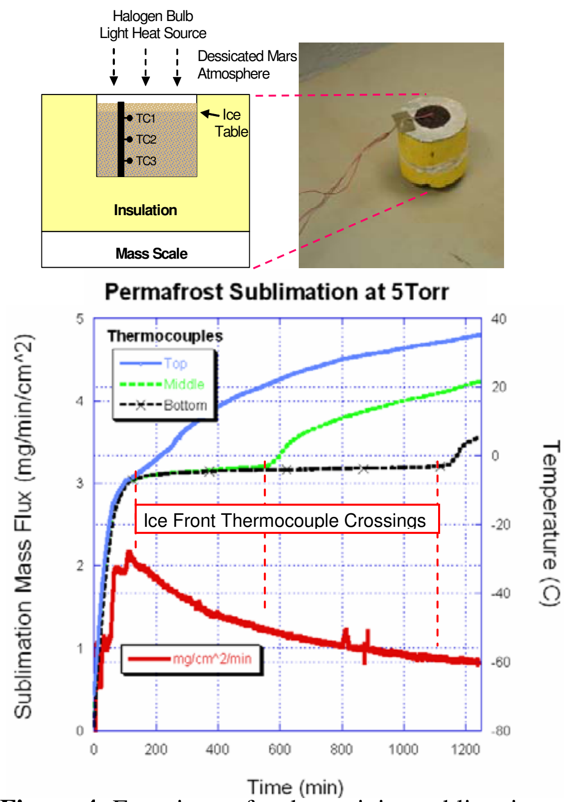

Figure 4. Experiment for determining sublimation rate as a function of ice table temperature.

Halogen light source is used to drive the heat and mass transport process in order to acquire the correlated measurements of sublimation rate of the ice table vs. temperature when the ice table front crosses a precision thermocouple mounted orthogonal to the heat flux.

References: [1] Zacny, K.A., Quayle, M.C., and Cooper, G.A. (2004) *JGR, 109,* E07S16. [2] Heat and Mass Transfer (2002). F. Incroprera, D. Dewitt. [3] M. Mellon, B. Jakosky, S. Postawko, (1997) *JGR 102*, pg. 19,357 – 19469.

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