HIGH FIDELITY MODEL OF LUNAR VOLATILE EXTRACTION INDICATES CHALLENGES AND SOLUTIONS TO ECONOMIC RESOURCE RECOVERY. P. T. Metzger[1] [1]Affiliation (include full mailing address and e-mail address if desired) for first author, [2]Affiliation for second author (full mailing address and e-mail address).

Introduction: Lunar regolith is a bad thermal conductor. Mixed chemistry ice changes its properties. As vapors diffuse the pore pressure increases the thermal conductivity by orders of magnitude. Physics-based modeling is needed to enable design of lunar volatile mining technologies.

Modeling Framework: A model is developed using Crank-Nicholson formalism extended from 1D to 2D axisymmetric. It can be extended to 3D cylindrical or cartesian. Gas diffusion and heat transfer have vastly different characteristic transport times so multiple, adaptive timesteps are incorporated for speed.

Thermal Conductivity: Realistic chemistry and abundance of lunar ices from LCROSS data modify the thermal conductivity and heat capacity. Guided by first principles, a thermal conductivity equation is developed for lunar regolith that is a function of both porosity and temperature. The data of [1] in Fig. 1 fit the model within expected experimental accuracy. For gas pore pressure, analysis reconciles extant data sets (Fig. 2) and finds an empirical model.

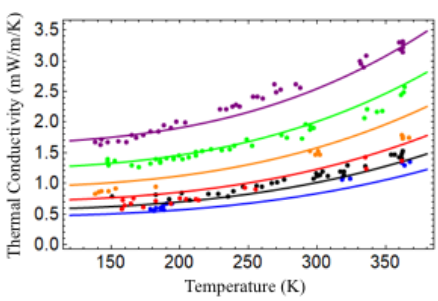

Figure 1. Data from [1] with crushed basalt as lunar simulant at six different porosities.

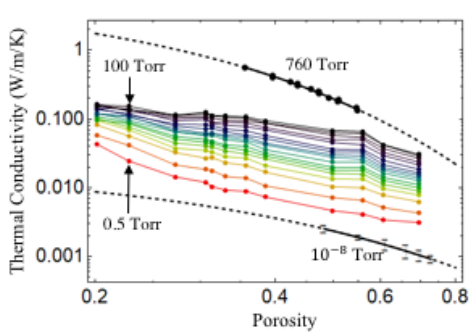

Figure 2. Top curve from [2]. Color curves from [3]. Bottom from [1]. All at T~300K. Dashes are the model. [3] does not fit the model apparently due to spherical particle shapes.

Predictions: The model was partially validated with LRO Diviner data of regolith cooling during the lunar night. It also replicates data from asteroid Bennu rotating in sunlight. Fig. 3 is a series of snapshots from a simulation of a coring devices screwed into the regolith heating the enclosed material.

Simulations of a heated tent over the lunar regolith predict days to target sublimation rate at each depth. The temperature gradient tends drive volatiles deeper into the regolith away from the capture system, so modeling is needed to design ways to avert this.

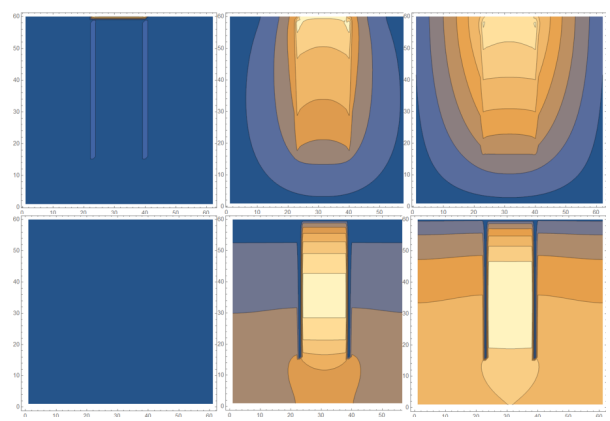

Figure 3. Cross section of coring device embedded in regolith, heating the interior and liberating volatiles. Top panel: temperature field. Bottom: pore pressure.

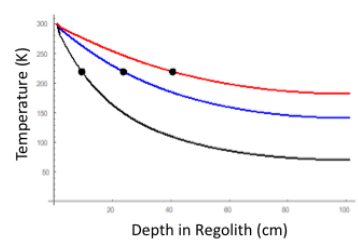

Figure 4. Temperature under heated tent on lunar surface after day 1 (black), 5 (blue) and 10 (red). Dots: depths where sublimation rate is achieved.

References: [1] Fountain JA, West EA (1970), *JGR* 75(20), 4063. [2] Chen, SX (2008), *Heat & Mass Trans* 44(10), 1241. [3] Presley MA, Christensen PR (1997), *JGR-Planets* 102(E3), 6551.