EVOLUTION OF SCALE LENGTHS OF VOLATILE STRUCTURES IN COLD PERMANENTLY SHADOWED REGIONS. D. M. Hurley[1], [1]Johns Hopkins University Applied Physics Laboratory (Dana.Hurley@jhuapl.edu).

Introduction: Permanently shadowed regions (PSRs) of the Moon host volatiles buried amongst the regolith. In the coldest regions of the Moon, temperatures are cold enough that water ice not only is stable against sublimation for on the order of a billion years, but also is immobile to thermal diffusion (e.g., [1]). In these regions, impact gardening is expected to be the primary process affecting the distribution of water ice. Although measurements have confirmed the presence of ice on the Moon [2], comparison of data from neutrons, IR, UV, and radar indicates there is clearly heterogeneity in the distribution of volatiles laterally, with depth, and from one PSR to another (e.g., [3]). Future lunar missions, e.g., NASA's VIPER mission, will land on the Moon and rove in the polar regions to explore the lateral and depth distribution of water. The following model expands previous work [4] to statistically analyze the effects of impact gardening on the heterogeneity of water in the lunar polar regions with the goal of linking spatial scales of heterogeneity to clues about the local history of volatiles.

Model: A 3-D Monte Carlo model simulates the effects of impact gardening on topography and ice distribution in lunar regolith. The model is applied to putative ice sheets in the polar regions of the Moon where thermal diffusion can be neglected. Summing over a large set of runs, the model produces an expected average time evolution of ice retention, lateral distribution, and depth distribution over time.

Results: The model results are applied to VIPER or any other putative surface mission with mobility and subsurface access capability in lunar permanently shadowed regions that would sample volatiles in situ. The time evolution of the depth distribution, lateral distribution, appearance to neutron and radar measurements, accessibility by drill, and overall ice retention are discussed to enable interpretation of the data.

The model predictions for the attenuation of thickness of an ice layer over time is presented for multiple initial ice layer thicknesses (Figure 1), along with the average burial depth as a function of age (Figure 2). Figures 3-5 demonstrate examples of the implications in how those features would be observed in situ on the Moon.

Conclusions: A simplified view of impact gardening in extremely cold regions in persistent shadow on the Moon is applied to increase the understanding of heterogeneity in the distribution of ice deposits on the Moon. The model demonstrates the erosion of an ice layer by impacts as time progresses. The time soonest after emplacement is the most critical for ice retention. In some locations, the ice layer becomes protected from erosion by ejecta blankets emplaced over the layer. Impacts produce a heterogeneous distribution of ice on scales relevant for in situ sampling of ice deposits.

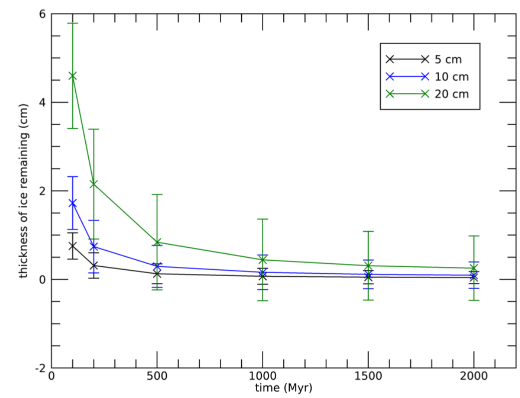

Figure 1. The thickness of the remaining ice layer decreases over time, and is <1 cm thick by 500 Myr for an initial ice layer < 20 cm thick.

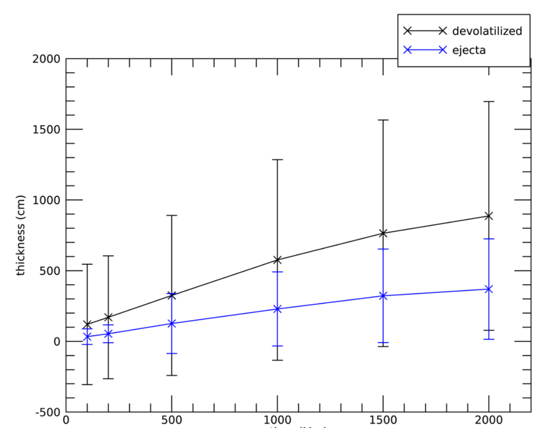

Figure 2. The amount of ejecta emplaced over an ice sheet is shown and how it increases with time. Assuming a deeper layer that is devolatilized through impacts, the black line shows the average amount of dry material over the ice sheet and how it evolves with time.

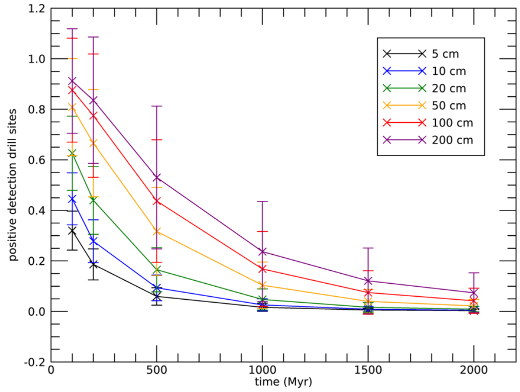

Figure 32. The average fraction of drill sites with accessible ice along a 100 m traverse assuming an initial ice layer with thickness spanning from 5 cm to 200 cm is shown as a function of age of the deposit. This assumes a 1 m depth of access for the drill.

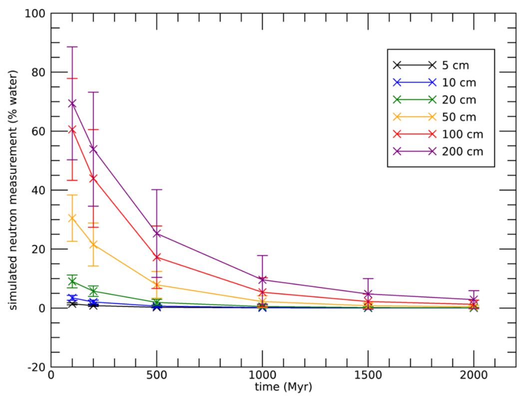

Figure 4. This is how an ice deposit would evolve over time as sensed by neutron spectroscopy depending on the initial thickness of the ice layer.

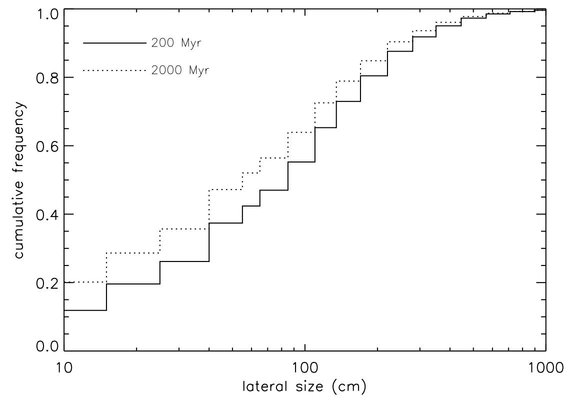

Figure 5. Cumulative distribution of lateral size of coherent ice blocks assuming 10 cm initial thickness and only ice within 100 cm of the surface.

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References: [1] Shorghofer and Taylor (2007) *J. Geophys. Res. 112*, E02010 [2] Colaprete, A. et al. (2010) *Science, 330,* 463-468. [3] Brown, H. M. et al. (2022) *Icarus 377*, 114874. [4] Hurley, D. M. et al. (2012) *Geophys. Res. Lett. 39*, L09203.