ICE DISTRIBUTION AT THE POLES OF THE MOON AND MERCURY: THE ROLE OF REGOLITH OVERTURN. P. G. Lucey[1] E. S. Costello[1,2], R. R. Ghent[3,4], S. Li[1], [1]Hawaii Institute of Geophysics and Planetology, University of Hawaii at Manoa, Honolulu, HI, USA, lucey@higp.hawaii.edu; [2]Dept. of Geology and Geophysics, University of Hawaii, Honolulu, HI, USA; [3]University of Toronto Dept. of Earth Science, Toronto, ON, Canada; [4]PSI, Tucson, AZ, USA.

Introduction: The difference between the distribution of ice at Mercury's poles and those of the Moon is stark. On Mercury, surface ice is present on all surfaces cold enough to preserve ice against sublimation for geologic time, and shallow buried ice is present where shallow subsurface temperatures are similarly low [1]. On the Moon however, the correlation between temperature and consistent evidence for ice is poor [2].

Recently, Li et al. [3] reported detections of near-IR absorptions due to surface water ice in the lunar polar regions using data from the Moon Mineralogy Mapper carried by the Chandryaan-1 spacecraft. These detections in regions of permanent shadow took advantage of sunlight scattered from crater walls and other topographic highs near the detection sites to allow spectroscopic measurements. Li et al. demonstrated that these locations with ice bands also showed highly anomalous values of laser reflectance and UV water sensitive ratio, and the vast majority showed maximum annual temperatures consistent with the preservation of surface ice for geologic time (Figure 1). This combination of ice sensitive parameters is a powerful argument for the presence of surface ice in the lunar poles.

However, the detections of ice only covered 3-4% of the polar areas both with sufficient illumination to detect ice and with temperatures low enough to preserve surface ice for long periods. At the lunar poles, surface ice is the exception and is patchy verging on non-existence.

The polar opposite differences between the two planets must be due to some fundamental difference in supply or loss. In this work, we studied the relative rate of regolith overturn on Mercury and the Moon to understand whether differences between these polar regions, assuming that overturn promotes loss rather than sequester [4].

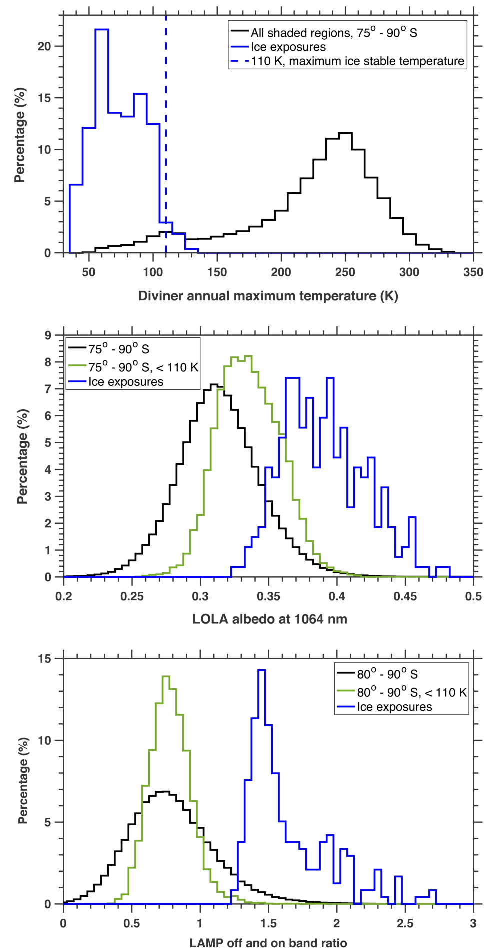

Fig. 1. Histograms of maximum surface temperatures, LOLA, and LAMP off/on band ratios for ice-bearing pixels (blue) and all shaded pixels from 75° to 90° latitude (black) in the southern polar region.

Methods: To investigate the volatile disparity between the Moon and Mercury we use an analytic model to describe the rate and magnitude of impact gardening as a function of time on each body [5]. The model describes the depth reached by impact gardening under exposure to the modern impact flux and consequent secondaries and is based on the pioneering Apollo-era lunar regolith mixing model presented by Gault et al. (1974) [6] with updated input parameters and an expanded input parameter space. We take advantage of the expanded parameter space in this work to calculate the rate of impact gardening on Mercury.

The model describes the maximum depth influenced by impact gardening as a function of time. Much as Gault et al. (1974) did, we assume the following: 1) the cumulative flux of objects onto the surface is a power-law, and 2) the production of craters follows a Poisson distribution, and 3) the size and shape of craters follow efficiency laws based on target material properties. We update the cratering efficiency laws and implement those presented by Holsapple (1993) [7].

Another important update to the Gault model is the inclusion of secondary cratering, which has been shown to have a significant impact on the rate of gardening on the Moon [4]. In our treatment of both the Moon and Mercury we implement the same treatment of secondary impacts, where secondary impactors follow a size distribution based on the McEwen et al. (2005) study of Zunil crater [8,9].

The model is validated using a variety of lunar features with constrained ages and depths. It is consistent with the thorough reworking of the top 3 cm of regolith calculated from the homogenous distribution of Al^{26} in Apollo cores [10] and calculated from size frequency distributions of splotches in LROC temporal pairs [11]. The model is also generally consistent with the rate at which anomalous surface features such as cold spots [12] and rays [13] are reworked into background regolith. Our calculations are in better agreement than those of Gault et al. (1974) with the meter and shallower reworking of surface-correlated space weathering products (Is/FeO and cosmic ray tracks) to depth vs. isotope dating compiled from Apollo cores [14,15].

To apply the model to Mercury, we use the model of the meteoroid flux of Marchi et al (2005) [16] who showed that the modern flux of large impactors of diameters 1 cm - 100 m is about ten times lower on Mercury than it is on the Moon.

Results: The result is shown in Figure 2. On Mercury it would take between 2 and 3 Gyr to garden to 1 m depth. On the Moon, gardening reaches 1 m depth in about 500 Myr; gardening reworks the lunar regolith about a factor of five faster.

Discussion: Assuming that ice is not replenished and also assuming that one gardening event obliterates all ice to the modeled depth, a 1 m thick ice deposit on Mercury would be affected but still be present after 1 Gyr. The same 1 m ice deposit on the Moon would be erased by impacts in 500 Myr. The model suggests that if the Moon ever had a Mercury-like deposit, it may have succumbed to impact gardening. Furthermore, the lesser gardening rate on Mercury provides a much longer time window for some large input of water to the environment, such as a comet, on the order of 3 billion years as opposed to about 500 million years for the Moon.

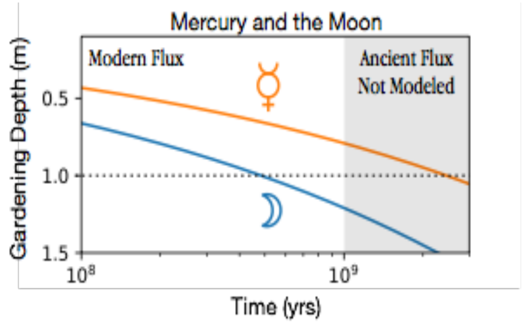

Figure 2: The gardening rate on Mercury and the Moon. Depths above the contours has been gardened at least once with 99% certainty by secondary impacts.

Conclusion: There is very significant difference in regolith reworking rates on the Moon and Mercury. It is plausible that the higher degradation rate and shorter time available for large icy impacts have drastically depleted any former Mercury-like deposit that may have existed on the Moon.

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