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Thermal Cycling and Regolith Evolution on the Moon and Airless Bodies

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Planetary regoliths are produced and modified by processes including impacts, thermal cycling, solar wind and energetic particle implantation, seismic shaking, volcanism, and volatile, gravitational or electrostatic transport. Consequently, regoliths record diverse scientific information regarding the histories of these processes and the environment of their host object through time. In this contribution, we will focus on the effects of thermal cycling, the most ubiquitous perturbation felt by airless bodies in the inner solar system. Modeling and experimental efforts show that thermal cycling, the magnitude of which is dictated by the object's topography, period around and distance from the Sun, can play a role in regolith formation by rock breakdown via thermal cracking (Molaro et al., 2012, 2017; Delbo et al., 2015). Post-formation processing by thermal cycling still remains as a gap in the current understanding of regolith evolution. Preliminary experimentation by Gamsky and Metzger (2010) suggested that thermal cycling may play a role compaction of lunar regolith simulant, consistent with observations by Apollo astronauts that below the top few centimeters of "fluffy" material, regolith becomes more compacted with depth, to a degree greater than can be explained by overburden pressure (Heiken et al., 1991). Similar experiments with glass spheres (Chen et al., 2006) show a densification trend with additional cycling or when the thermal amplitude was increased during a cycle. We build upon these initial experiments to gain a better understanding of the effects of thermal cycling under planetary conditions, such as utilizing a low-pressure chamber, varying the amplitude and absolute temperatures used in cycling, and adjusting the initial regolith density. Experiments are performed in the Simulated Planetary Ices and Environments Laboratory (SPICE Lab) at the Weizmann Institute of Science in ambient (23º C) conditions and in a cold room maintained at -40º C. Preliminary results are consistent with previous studies, in that thermal cycling of uncompacted materials results in a sample volume reduction that increases with increasing temperature amplitude. Experiments testing the effect of thermal cycling on initially compacted regoliths are currently underway.

This study will aid in developing an empirically driven model for thermally induced changes in regolith, from which we may constrain its role relative to other regolith processing mechanisms. This will be validated with remote observations from airless bodies. Cold spots, for example, which are regions of low thermal conductivity surface soil surrounding recent impacts on the Moon (Bandfield et al., 2011), appear to fade over the timescale of 150 kyr (Williams et al., 2016a). These features provide a natural laboratory to test the relative effects of competing processes. Observations and models of regolith development on Earth show that it is the product of the superposition of frequent small-scale processes and infrequent large-scale events (e.g., Wolman and Miller, 1960), and in the case of airless bodies we do not presently know which of these dominates.