MODELING THE FORMATION OF THE LUNAR UPPER MEGAREGOLITH LAYER James E. Richardson[1] and Oleg Abramov[1], [1]Planetary Science Institute (PSI), 1700 E. Fort Lowell, Suite 106, Tucson, AZ 85719-2395, USA (jerichardson@psi.edu)

In the early 1970's, Nash et al. [1] and Hartmann [2] introduced the notion of a 'lunar megaregolith' layer, broadly defined as the entire cross-section of the upper lunar crust that has been heavily affected by impact cratering. In this work we divide this classic 'lunar megaregolith' layer into three distinct regions based upon their different formation processes and characteristics [3]. These are (Fig. 1):

- A **Surficial Regolith** layer, about 5-20 m in depth [4, 5], consisting of loose (low cohesion), unconsolidated fines and breccia, and characterized by frequent overturn and comminution caused by small meteoritic impacts;
- An **Upper Megaregolith** layer, about 1-3 km in depth [6, 7, 8], consisting of depositional layers of brecciated and/or melted material, and characterized by the *transport and deposition* of material via either transient crater gravitational collapse or impact ejecta ballistic sedimentation; and
- A **Lower Megaregolith** layer, about 20-25 km in depth [9, 10], consisting of bedrock that has been *fractured in place* by impacts, but not transported, and characterized by a fracture-density and fragment-size distribution that decreases rapidly with increasing depth.

The purpose of this study is to model the formation of the lunar **Upper Megaregolith** layer, the least-well characterized of the three layers listed above, using modern scaling relationships and a three-dimensional terrain, Monte-Carlo cratering model [11, 12]. In this model we divide the lunar surface into a 2000×2000 (6160×6160 km) matrix, having a pixel resolution of 3.08 km.

Lunar Highlands crater record modeling: The presence of an Upper Megaregolith layer is strongly inferred by the Lunar Highlands crater population, a record of the bombardment history that created it [1, 2]. Therefore, our first task was to develop an impactor population that accurately reproduces the Lunar Highlands crater population [13, 14], both for craters $\lesssim$250 km diameter, which are in a state of crater density equilibrium, and craters $\gtrsim$250 km diameter, which are not (Fig. 2). This model impactor population is assumed to originate in the Main Asteroid Belt (MAB), possesses the general Size-Frequency Distribution (SFD) shape of a collisionally evolved population, and is consistent with previously developed MAB population models [15]. Based upon

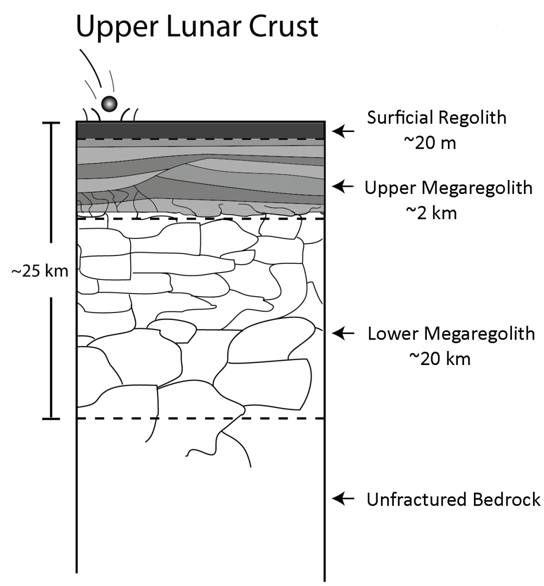

Figure 1: A cross-sectional diagram of the upper lunar crust (not to scale), in which we divide the classic 'lunar megaregolith' layer into three distinct regions.

these lunar surface simulations, we estimate that a total delivered impactor mass of $3.72 \pm 1.14 \times 10^{19}$ kg, or 0.0506 ± 0.0156 lunar weight percent (wt.%), is required to reproduce the observed Lunar Highlands cratering record, with a saturation ratio (total produced/final countable) for all craters $>$8 km diameter of 2.9 ± 0.3.

Upper Megaregolith layer modeling: Our second task was to then apply this developed MAB impactor population in multiple simulations of Upper Megaregolith growth on the lunar surface, to provide a statistical sample given the Monte-Carlo nature of this model, particularly at large basin sizes. Our five final lunar surface simulations yield an Upper Megaregolith depth of 1.4 ± 1.0 km at the point of best χ^2 fit between the model crater population and the actual Lunar Highlands crater population [13, 14]. This Upper Megaregolith layer consists of $\sim$60% crater collapse deposits and $\sim$40% impact ejecta deposits. It possesses a high degree of local variability, from 0 km (bare 'bedrock') in a few places, up to a maximum of 5.9 ± 0.4 km, with depths of 1-3 km produced over $\sim$55% of the modeled lunar surface (Fig. 3). These results provide an updated validation of the early modeling results of both Short and Forman [6], who estimated an Upper Megaregolith depth of 1.9 ± 0.5 km, and

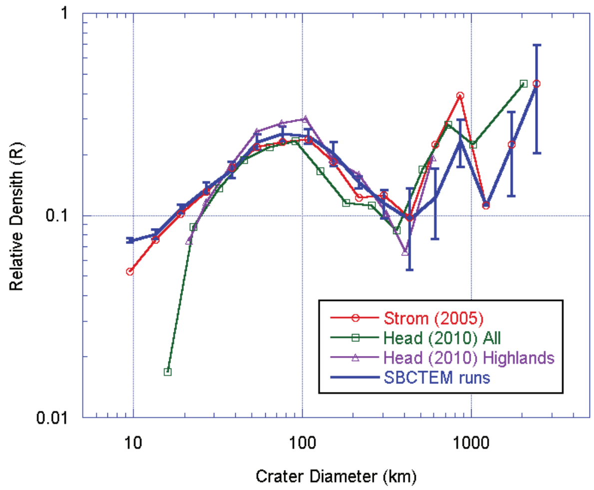

Figure 2: Small Body Cratered Terrain Evolutioin Model (SBCTEM) lunar simulation crater counts (*blue*) compared to actual lunar crater counts.

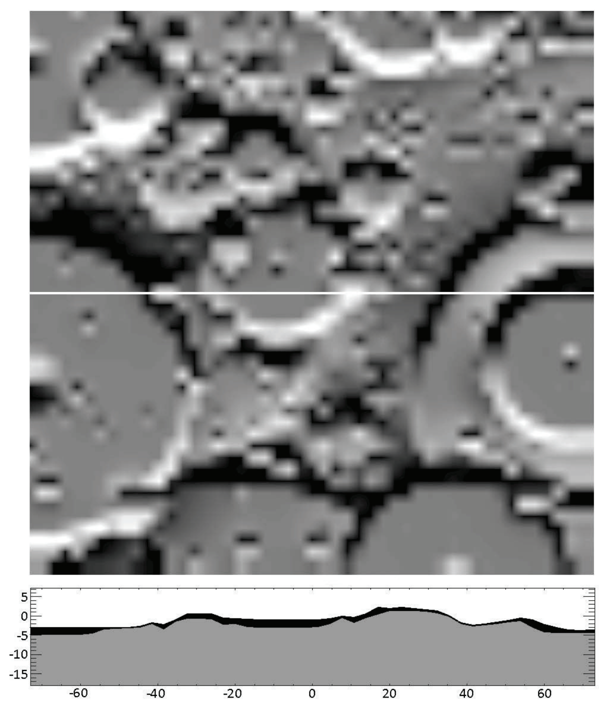

Figure 3: A cross-section (units in km) through a small portion of a lunar surface simulation, its location indicated by the white line through the terrain map, which dipicts a 148×148 km area.

Hoerz et al. [7], who estimated that 50% of the highlands is cratered to a depth of 2-3 km, as well as the observational results of Thompson et al. [8], who determined the Upper Megaregolith layer to be at least 2 km in depth.

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