ADVANCEMENTS IN SCALING MODELS FOR EJECTA BLANKETS OF LUNAR IMPACT CRATERS.

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Introduction: The lunar surface is littered with impact craters ranging from <100 meters in diameter to large impact basins. Understanding how these craters form and distribute ejected material is critical to understanding the geologic evolution of planetary surfaces. Two models are widely used to scale the thickness of a crater's ejecta blanket (as a function of distance from the crater) to its diameter: McGetchin et al. (1973) [1] and Housen et al. (1983) [2]. Despite their frequent use, the accuracy of the two models has not been evaluated using modern data sets. With the launch of the Lunar Reconnaissance Orbiter, precise measurements of the lunar surface have now been made. Here we use data from LRO's Lunar Orbiter Laser Altimeter (LOLA) to assess the accuracy of the two scaling models, and where necessary, revise them to fit current data.

Background: The morphology of impact craters can be separated into two broad categories, which generally correlate with their size. Small craters (less than ~10 km in diameter for the Moon [e.g., 3]) are generally bowl shaped, while complex craters (greater than ~10 km) show increased interior deformation such as central peaks and terraces. The size of an impact crater is a function of impact velocity, composition of both the impactor and target material, impact angle, and size of the impactor. Numerous studies have found empirical relationships between the physical and morphometric properties of a crater and its diameter [3, 4]. Here we focus on two models that relate the thickness of crater "ejecta" to its diameter [1, 2]. While we retain the term ejecta for consistency with these models, we recognize that with both simple and complex craters, structural uplift during the impact events is the major component of impact crater rims, and only ~20% of rim material is actual ejecta [5].

Methods: In order to assess the accuracy of each scaling law, we compared each model to topographic profiles of lunar craters. We selected 100 lunar impact craters with diameters ranging from 2.9 km (an unnamed crater near Fahrenheit) to 96 km (Copernicus). The selected craters have an average diameter of 15.2 km. The criteria used for selection was that craters must be fresh impacts (not damaged by other impacts or geologic processes) and have a diameter greater than 1 km. The majority of the selected craters occur within lunar mare instead of the lunar highlands due to the relative age of each area. Selection was conducted from the LRO Camera (LROC) WAC mosaic and LOLA hillshade global lunar maps from the WMS servers in ArcGIS. Craters selected were subsequently logged with their name, diameter, latitude, and longitude in excel.

From each crater we selected, a north-south and west-east topographic profile was made that passes through the crater center using LOLA gridded data from the March 2014 DEM map file with a resolution of 118 meters. Each scaling law was then compared to the topographic profile. The McGetchin et al. (1973) scaling equation has the form,

$$t = T * \left(\frac{r}{R}\right)^{B}$$

where t is the thickness of ejecta material (actually ejecta+uplift [5]) from the crater, R is the radius of the crater, T is the rim height: $0.04R$ (for simple craters), and $0.14R^{0.74}$ (for complex craters), with variable B empirically determined as -3 ±0.5, and r is designated as:

$$r = (R - X + L)\ (right\ side)$$
$$r = (R + X - L)\ (left\ side)$$

where L is the distance from the crater, and X is the measured distance from the crater rim along the topographic profile. The differing r values are for each side of the crater. The Housen et al. (1983) scaling equation has the form

$$t = R * \left[A * \frac{e_r - 2}{2\pi}\right] * \left[(sin2\theta)^{e_r - 2}\right] * \left[\left(\frac{r}{R}\right)^{-e_r}\right] * \left[1 + \left(\frac{4e_r - 5}{3}\right) * \left(\frac{\frac{r}{R}}{sin2\theta}\right)^{e_r - 2} * \left(\frac{D}{\frac{r}{R}}\right)\right]$$

and is used for both simple and complex craters [2, 6]. For variables e_r, A, D, and Θ, the values of 2.61, 0.32, 0.83, and 45° were used, respectively [2]. These equations were used for each topographic profile taken, with analysis conducted in excel.

Results: Our preliminary analysis suggests that both models underestimate the ejecta thickness of lunar craters, though to different extents. The McGetchin et al. model somewhat underestimates ejecta thickness for simple craters, especially near the rim (Fig. 1). However, that model completely fails with complex craters, underestimating the ejecta thickness by a kilometer or more near the rim (Fig. 2). This mismatch results primarily from the scaling of the rim height *T*, although the -3 dependence on radius also underestimates the rate at which the ejecta thickness decays. The Housen et al. scaling models provide an adequate fit for simple craters, but in some cases underestimates ejecta thickness for complex craters. Quantification of the quality of these fits is in progress.

References: [1] McGetchin T. R. et al. (1973). *Earth &Planetary Sci.* 20, 226-236. [2] Housen K. R. and Schmidt R. M., (1983). *JGR*, 88, 2485-2499. [3] Pike R. J. (1977) *Impact and Explosion Cratering*, 489-509. [4] Hale W. and Grieve R. A. W. (1982) *JGR* 87, A65-A76. [5] Sharpton V. (2014). *JGR*. 119. 154-168. [6] Kumar A. et al. (2011). *LPI Intern Abstract.*

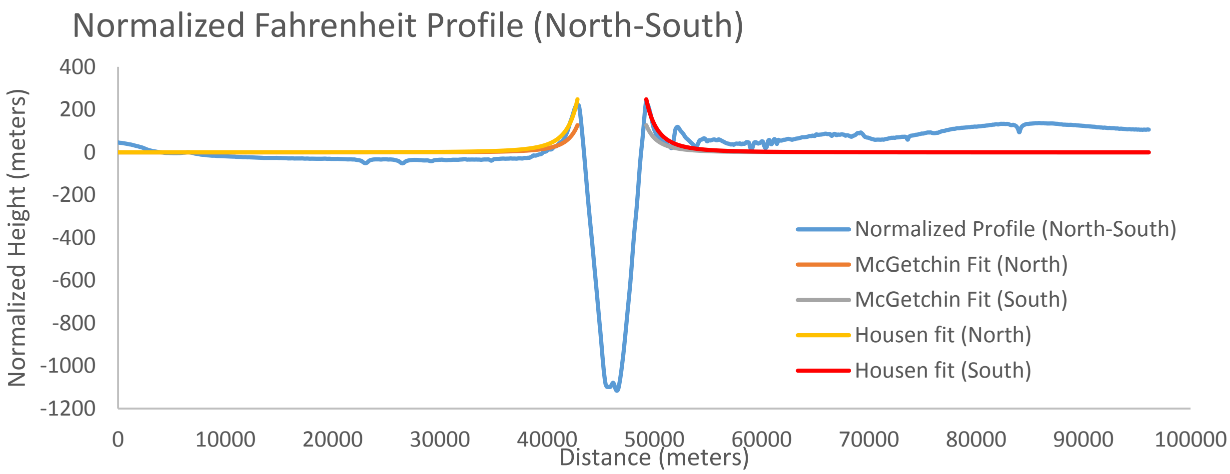

Figure 1 - A normalized topographic profile of Fahrenheit, a simple, 6-km diameter crater located within Mare Crisium (13.1N, 61.7E). Both the McGetchin et al. and Housen et al. models are applied to a north-south cross section view of the crater. The Housen et al. model also shows a near-perfect fit for the crater, with the exception of preexisting (i.e., non-crater) topography.

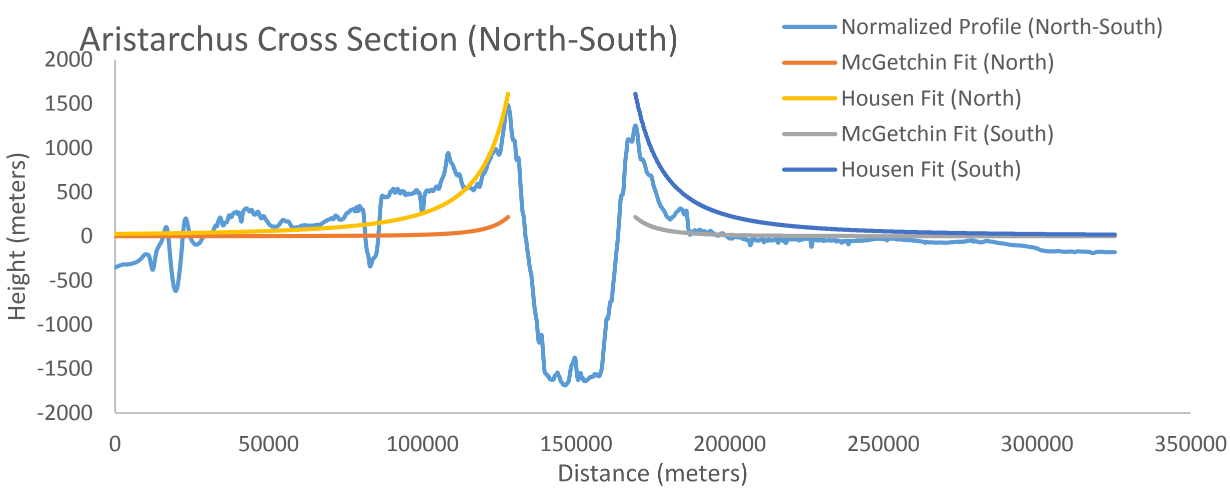

Figure 2 - A normalized topographic profile of Aristarchus, a 40 km impact crater located in Oceanus Procellarum (23.7N, 47.7W). Scaling models from McGetchin et al. and Housen et al. show the fits for a complex crater. The Housen et al. scaling equations shows a better fit, with the McGetchin et al. model failing. Preexisting (non-crater) topography (the Aristarchus plateau) causes an overestimate of the southern rim face. The McGetchin et al. scaling equation's failure shows the need for improved accuracy and curve fitting to determine the correct T and B multiplier values for complex craters.