A NEW MODEL FOR FRESH SIMPLE CRATER SHAPES FROM THE LUNAR MARIA

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Introduction: The shapes of impact craters reflect the properties of the impacting objects and the surfaces they strike, the dynamics of their formative impact events, their ages and the processes which modify them, and the bodies on which they are formed. Therefore these shapes are of considerable scientific interest. The widely accepted shape model for these craters has long been that they are approximately parabolic and have depths (d) of about one fifth their diameters (D). This model is commonly used for a variety of purposes, yet it has been shown to be rather inaccurate [1,2,3,4]. Using shadow measurements, Chappelow [1,2] found that most simple craters on Mare Serenitatis are shallower than $d/D = 0.2$ and are hyperbolic rather than parabolic - a shape intermediate between a parabola and a cone.

Similarly, Linné crater on the Moon has long been the prevailing archetype for fresh simple craters in general. Uncratered, with a sharp rim, well-defined ejecta features, and bright halo of ejecta, Linné is obviously a very fresh, apparently unmodified simple crater. However, [3] showed that Linné crater contains a flat bottom, is shaped like truncated cone, and is best fit by a power "law" with an exponent again placing it between parabolic and conical. Using shadows, [4] also found that Linné is hyperbolic in form. Thus the current model and type example for fresh simple craters leave much room for improvement.

The central purpose herein is to assemble a new model for pristine, simple craters that more accurately reflects their true shapes yet is still compact and easy to use. The new model will also provide a valuable benchmark for comparison with other craters - those formed under different conditions (e. g. secondaries), into different targets (e. g. lunar highlands) and different bodies (e.g. Mercury), and/or which have been modified by physical processes.

Methods: As the objective here is to develop a model for simple craters which are as close to their initial states as possible, and unaffected by other factors such as pre-existing topography or target inhomogeneities, nearly 100 simple craters (0.5<D<7 km) with sharp rims, well-defined ejecta features, relatively uncratered interiors and ejecta blankets, *and bright halos of surrounding ejecta* were identified on 5 lunar maria. Of these, 64 were found to be covered by appropriate LRO_NAC imagery and amenable to analysis with the Free Shadowfront Method (FSM) [4]. Where possible the FSM results were checked and compared with LRO_LOLA transects (n=28). The resulting mathematical crater shapes were normalized such that their radii equal unity, sampled at 201 points, then stacked and averaged, point by point.

Results: Following both analysis via the FSM and examination of LOLA data, an apparent dichotomy was noted between subject craters larger and smaller than D ~2.5 km. Most of the larger craters (10/13) contain sizeable bottom deposits resulting in flat floors (and an 11th contains a large slide), while few of the smaller ones do, and these are small to negligible in extent (e.g. Fig.1). In addition, the larger craters have eccentricities between 1.6 and 2.0 (excluding 2 outliers), while smaller ones have a significantly larger range ($1.4 \le e \le 2.4$) (Fig.2). Thus the new crater shape model comes in two parts:

$$z(r) = -0.118D + 0.118D\sqrt{1 + 31.400\frac{r^2}{D^2}}$$ for the smaller craters (0.5 km $D \le 2.5$ km), and:

$$z(r) = -0.087D + 0.087D\sqrt{1 + 56.794\frac{r^2}{D^2}}$$ for the larger ones (2.5 km $D \le$ ~7 km).

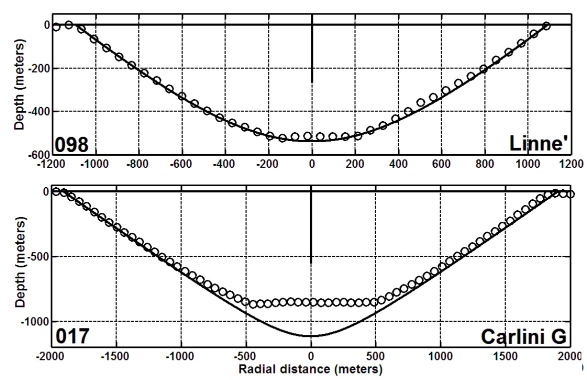
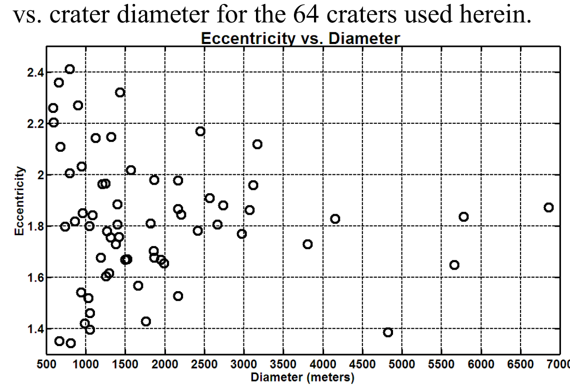


Fig. 1 (above): LOLA data compared with FSM results for ~2.2 km Linné and ~3.8 km Carlini G.

Fig. 2 (below): Shape parameter e (the eccentricity) vs. crater diameter for the 64 craters used herein.



These crater shapes are hyperbolic, and are illustrated in Fig. 3 and two craters which better fit these shapes than Linné does are shown in Fig. 4. They are located at 24.45°N/-31.88°E and 31.35°N/-63.54°E, respectively. These are compared with the current model and with Linné on Fig. 5.

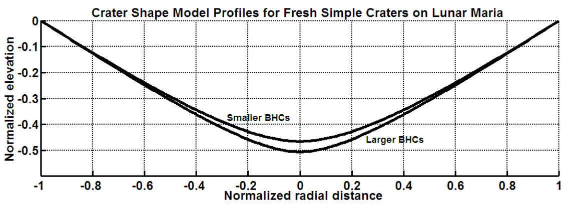


Fig. 3: To-scale illustration of the new model crater shapes. Smaller craters above, larger ones below.

Conclusions: At least for the Moon, the current shape model for fresh, simple craters (e = 1; d/D = 0.20) is found to be rather inaccurate, as is Linné as their paradigm. Proposed replacements for both are presented above.

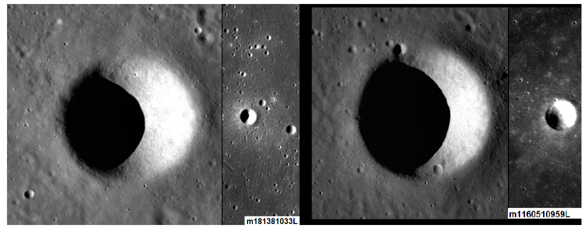


Fig. 4: Two craters which better represent very fresh lunar craters than does Linné. Sidebars show each in larger context.

References: [1] Chappelow, JE (2014) *45th LPSC*, abst. #2074. [2] Chappelow, JE (2015) *46th LPSC*, abst. #1079. [3] Garvin, JB et al. (2011) *42nd LPSC*, abst. #2063. [4] Chappelow, JE (2013) *MAPS* 48.

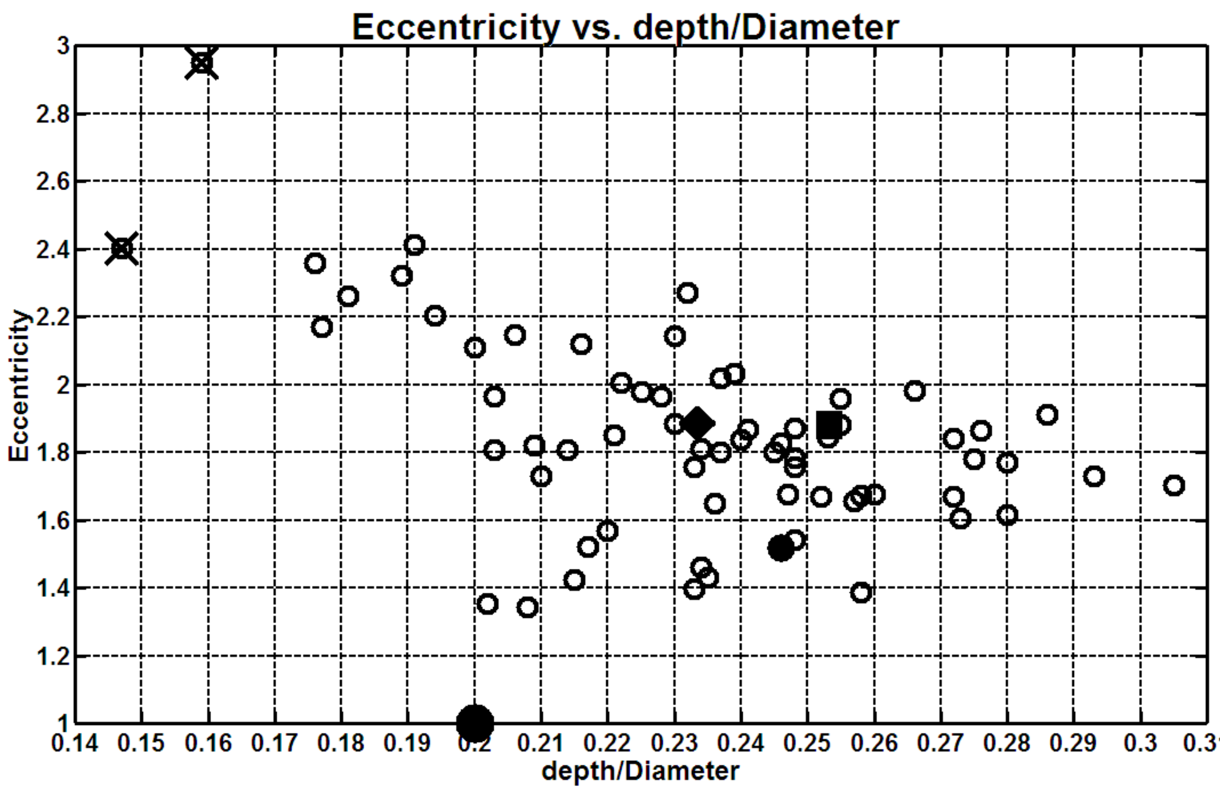


Fig. 5: Illustration of results. The currently-prevalent paradigm for simple craters (e = 1, d/D = 0.20) is the large symbol at bottom, Linné is the solid circle, the new model for smaller craters (D < 2.5 km) is the diamond, and for that for the larger ones is the square. Two craters whose shape parameters were considerably different were re-examined and found not to be fresh, but instead considerably agéd (crosses).