ON THE SHAPES AND DEGRADATION STATES OF SIMPLE IMPACT CRATERS ON MARE SERENITATIS.

J. E. Chappelow[1]
[1]Meteorifics Inc., Fairbanks, AK (john.chappelow@saga-inc.com)

Introduction: In previous work [1] I have shown that simple impact craters can be well-represented by general conic sections (not just parabolae), and that under this assumption the shadowfronts they contain must consist of arcs of ellipses, which can be measured in spacecraft imagery. The analytic relationship between these shadowfronts and the approximating conic sectional shapes can be exploited to derive crater shapes and depths from the shadows in images regardless of whether the shadowfront crosses the crater center or not. The resulting crater shape is then fully specified in terms of the depth (d), the diameter (D), and the eccentricity (e) of the approximating conic section of revolution.

In [2] I established this method's accuracy and utility, and used the results to suggest that the existing paradigm for simple craters as parabolic needs tightening up. Here I apply this Free Shadowfront Method (FSM) to over 100 small (0.4km < D < 6km) simple craters on Mare Serenitatis on the Moon. The results show a rather remarkable correlation between the shapes of these 100+ craters and their subjective 'degradation states'. They also yield a model small simple crater shape that better approximates these craters than the parabolic shape does.

Methods: Applying my computer implementation of the FSM to simple craters found in about twenty suitable LRO_NAC images, I have assembled a small database of crater shapes found on Mare Serenitatis. The solar incidence angle for each crater was calculated from the sub-solar latitude and longitude and those of the target crater. The crater shape results were plotted on e vs. d/D axes (Fig. 1). Except for the 7 members of a small cluster of secondaries, the resulting craterforms were then normalized to D = 1, sampled at 100 points, and 'stacked' point by point to obtain a mean shape for these craters (plotted on Fig. 1). Clips of all of these craters (minus the cluster craters) were then sorted according to their positions along a best-fit straight line fit through the e vs. d/D data, organized into a "line-up" of craters (Fig. 2) and examined for any systematic variations.

Results: The most obvious result of all this is that none of these simple craters is very close to the current parabolic ideal (marked as a large white circle, Fig. 1). All but one (a distinct outlier) have eccentricity parameter values, e, considerably greater than unity, and the majority (90 of 117) have d/D less than 0.20. Thus, as a body, these craters are generally shallower and all significantly more cone-shaped than the existing paradigm. The mean, derived as described above, is d/D = 0.174, and e = 2.09, and is marked on Fig. 1.

One third (7 of 21) of the craters with d/D >0.22 also feature very bright halos of pristine ejecta, including Linne (marked "L"), and all 21 of these craters also feature sharp rims, and sharp, well-defined ejecta features (Fig. 2). Most of them contain few or no later, smaller impact craters in their interiors or on their ejecta, and they are deeper and more "bowl-shaped" (parabola-like) than the remainder of the sample craters.

On the other end of the distribution (d/D < 0.15 on Fig. 1, and the last 23 craters on Fig. 2) the craters are shallower, have little or no evidence of visible ejecta, generally rounded rims, and ubiquitous subsequent cratering. None of these craters features a bright ejecta halo or interior.

Between these extremes lies a region (0.15 < d/D < 0.22; n = 73 craters) of transition. In this region craters become increasingly space-weathered, cratered, and shape-modified (Fig. 2).

Conclusions: Although 124 craters does not necessarily represent a statistically large sample, certain observations may be made:

- The current, parabolic paradigm for simple impact craters does not well-approximate my sample of simple craters on Mare Serenitatis. These craters are all more hyperbolic, and mostly shallower, than the existing ideal. A better shape, *for this sample*, is given above.
- Inspection of Figs. 1 and 2 shows that plotting the results of my crater measurements on e vs. d/D axes has essentially sorted the craters by degradation state. This implies that crater shape, as embodied by d, D and e correlates closely with crater degradation state: shallower depths and larger eccentricity parameters correspond well with several morphologic features commonly associated with crater degradation states (and, likely, age) .
- All but one of the cluster of secondary craters is considerably shallower and more cone-shaped than the rest of the study population. Although 7 craters, all in one cluster, in no way constitutes a statistically significant sample, this suggests a potential for using crater shape measurements to differentiate secondary craters from primaries.

References: [1] Chappelow, JE (2013) *M&PS, 48,* 1863. [2] Chappelow, JE (2014) *45th LPSC*, Abst.#2074.

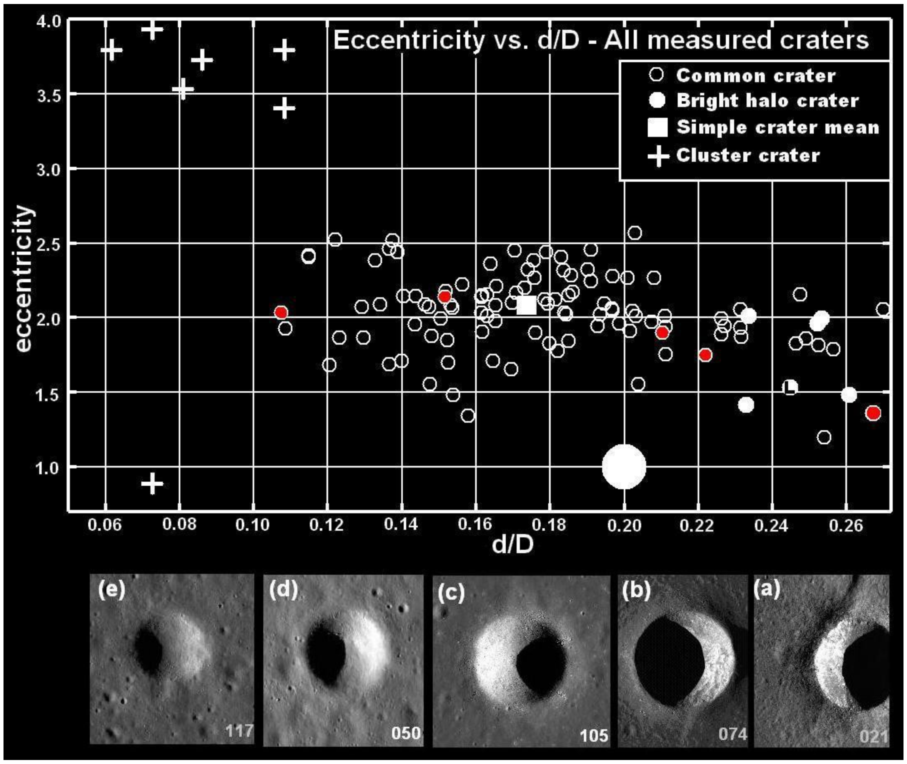

Figure 1: The 124 craters in this study plotted on e vs. d/D axes. The five crater clips shown below the graph demonstrate the progression from very fresh-looking craters (lower right) to very degraded ones (middle left). Each of these five correspond to the data point marked in red above it. A small cluster of very shallow, secondary craters appears at upper left, with one outlier, bottom left. The large white circle marks the existing ideal of d/D = 0.20, e = 1.0.

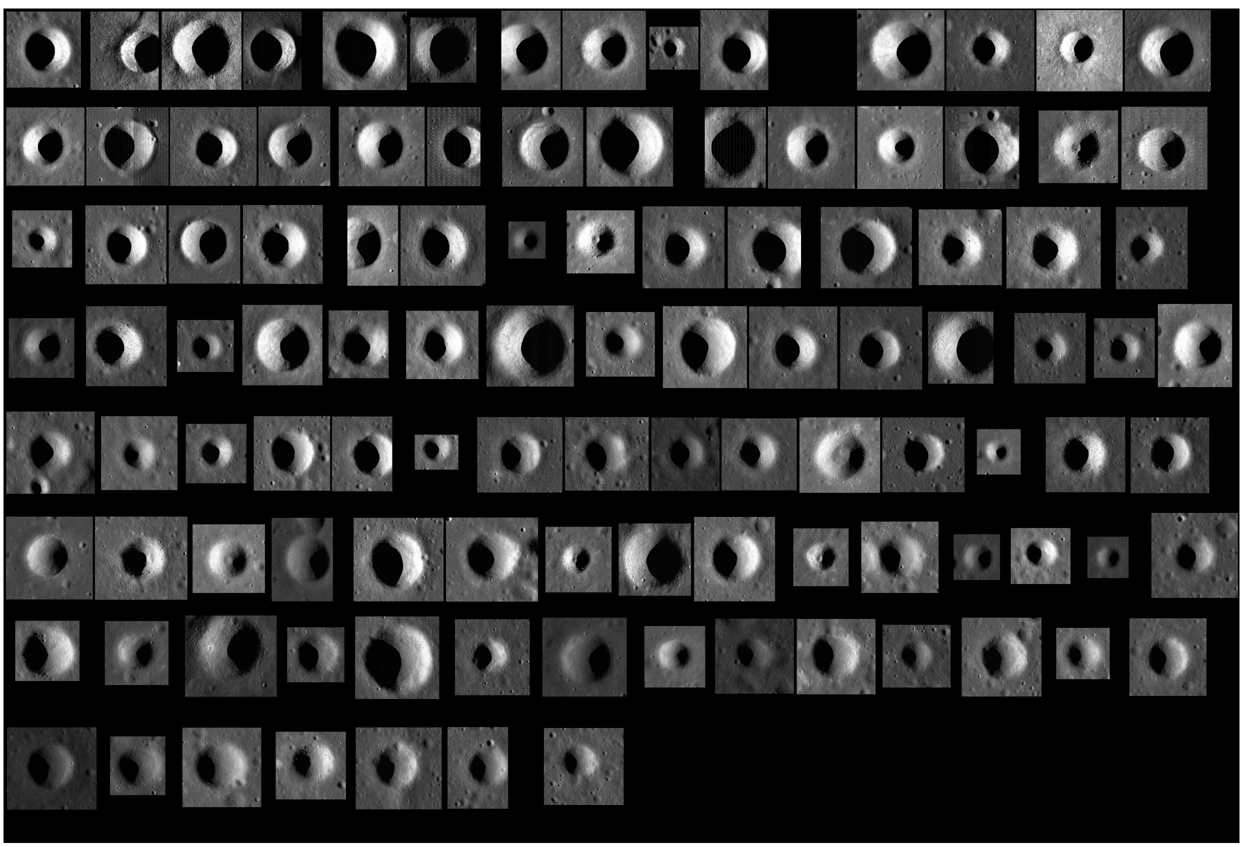

Figure 2: A “line-up” of the craters appearing in Fig. 1 (minus the secondary cluster), ordered according to their locations on Fig. 1. The deepest and freshest-looking are at top left, while the shallowest, most modified are at bottom right.