PRISTINE SIMPLE CRATERS ON MARS - TESTING A NEW SHADOW MEASUREMENT METHOD

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

Introduction: Over the past decade 200-300 *extremely* "fresh" (years-to-decades old), impact sites of small (2-200m) craters and clusters have been identified on Mars [e.g. 1,2]. At least 248 of these have been imaged and confirmed using the capabilities of the HiRise camera aboard Mars Reconnaisance Orbiter [3]. These present a unique opportunity to study the properties of naturally-formed simple impact craters virtually as they were formed. I recently attempted to apply a new shadow measurement method I have developed [4,5] in order to test that method, as well as estimate the shapes and dimensions of some of these craters, the very youngest that we know of. Herein I present the results of that attempt.

Methods: The new shadow measurement technique uses the shape of the shadowfront cast within a crater to find an approximating conic section for the crater's cross-sectional shape (Fig.1) [4,5]. This method yields the crater's shape in the form of depth, *d*, diameter, *D*, and the eccentricity of an approximating conic section, *e*. Like any method, it has its limits and provisos; exploring these was a major purpose of this work.

Very high resolution (~0.25m/pix) HiRise imagery of the new impact sites was obtained from the HiRise website at http://www.uahirise.org, and the images and craters evaluated for suitability for use with the shadow method. Suitable ones were measured using a computer implementation of the shadow method detailed in [5] (Fig.2). Several trials such as Fig.2 were run for each crater and the results averaged and are collected in Table 1, along with standard deviations were calculated for shape parameters *d*/*D* (the standard depth-to-diameter ratio) and the eccentricity *e*.

Measurements: Close examination of each of the 248 images revealed only four craters in two images, all members of clusters, amenable to shadow measurement (Fig.3). For the vast majority, (1) the sun was too high to cast a usable shadow (even though these craters appear to be exceptionally deep), (2) at the image's scale the crater was too small for measurement (< 14 pix or 3.5 m across), (3) the look-angle was too oblique, and/or (4) the craters were misshapen due to affects of target property inhomogeneities (e.g. variability in material competence, such as rock vs. regolith or dust). All of these illustrate, and help define, known limitations to the new method, here particularly in regard to image resolution (Figs.1 and 2). Only these four craters met all of these criteria:

	crater 1	crater 2	crater 3	crater 4
D (m)	4.15 ±0.09	3.73 ± 0.04	3.66 ± 0.11	3.20 ± 0.02
d (m)	1.39 ± 0.08	1.41 ± 0.05	1.25 ± 0.07	0.98 ± 0.05
d/D	0.34 ± 0.02	0.38 ± 0.01	0.34 ± 0.01	0.31 ± 0.01
e	0.38 ± 0.17	0.84 ± 0.09	0.90 ± 0.10	0.80 ± 0.10

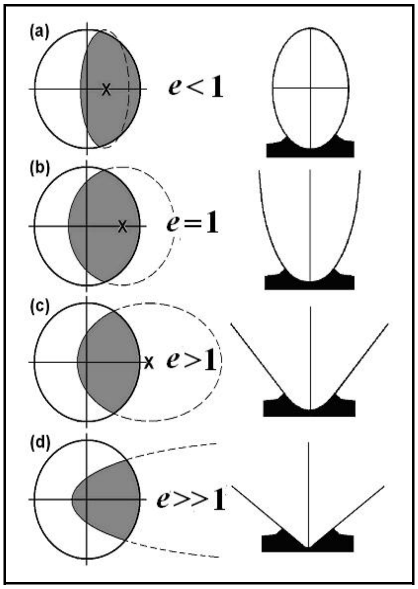
Table 1 - Shapes and dimensions of the four craters measured herein.

Results: Personal observations of simple crater shapes and shadows on several bodies indicate that most are not in fact parabolic, but hyperbolic in shape (see Fig.1) [5]. While these four craters do not constitute a statistically significant sample, their *d*/*D* and *e* values at least show that all are exceptionally deep (compared to the commonly accepted *d*/*D* of ~0.2), and are elliptical in shape, not hyperbolic or parabolic (Table 1, Fig. 1). Thus they are considerably more "bowl-shaped" than most craters. There is also no evidence of flat bottoms in any of the four. These results are not unexpected, since modification processes tend to shallow and alter older craters shapes in this direction.

Interestingly, several of the craters in Fig.3a clearly have flat bottoms, unusual features in such fresh, small craters. These craters vary in diameter from 4.8m to 13.2m, but (using the)their shadows indicate they are all 1.2-2m deep. Accounting for rim height, this strongly suggests that this surface is underlain by a much more competent substrate some 1-2m below the surface, and that the smaller craters measured above penetrate to, or near to, this layer.

A look at Table 1 also shows that, while diameter, depth, and their ratio *d*/*D*, can be repeatably obtained even for craters down to only 10-12 pixels across, the eccentricity, *e*, becomes highly sensitive to random error in the measurements required to define the crater rim and the shadowfront. Though these results show that all four of these craters are of the elliptical type (Fig.1a), *e* is not very significant quantitatively, and so I do not provide any plots of these shapes. Craters must be considerable larger (in terms of pixels) than this in order to obtain accurate crater shape information.via this technique. They also point out a need for lower sun-angle imaging of these sites by HiRise....

References: [1] Malin M.C. et al. (2006) Science, 314. [2] Daubar, I.J. et al. (2011) LPSC 42, Abst. #2232.
[3] Daubar, I.J. et al. (2013) Icarus, 225. [4] Chappelow, J.E. (2008), *39th LPSC*, Abst. #1441. [5] Chappelow, J.E. (2013) MAPS, in press.



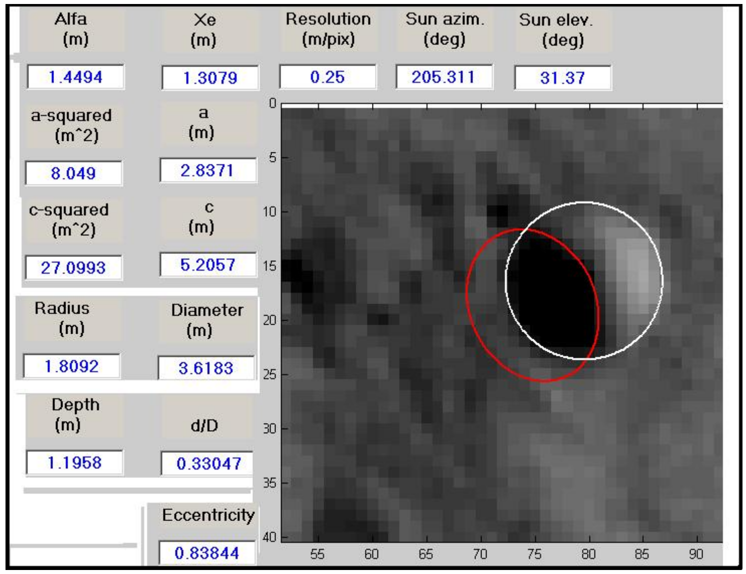


Fig.1 - Crater shapes (right) and their associated shadows. From top to bottom they are (a) elliptical (b) parabolic (c) hyperbolic and (d) conical craters. Corresponding eccentricity values are also given. All four of the measurablec-raters (Fig. 3) correspond to (1a). **Fig.2 -** An example of the output from a shadow measurement trial, this one taken from crater (see Fig.3, below. The effects of "pixillation", which sets the resolution limit on the shadow method, are evident in the image.

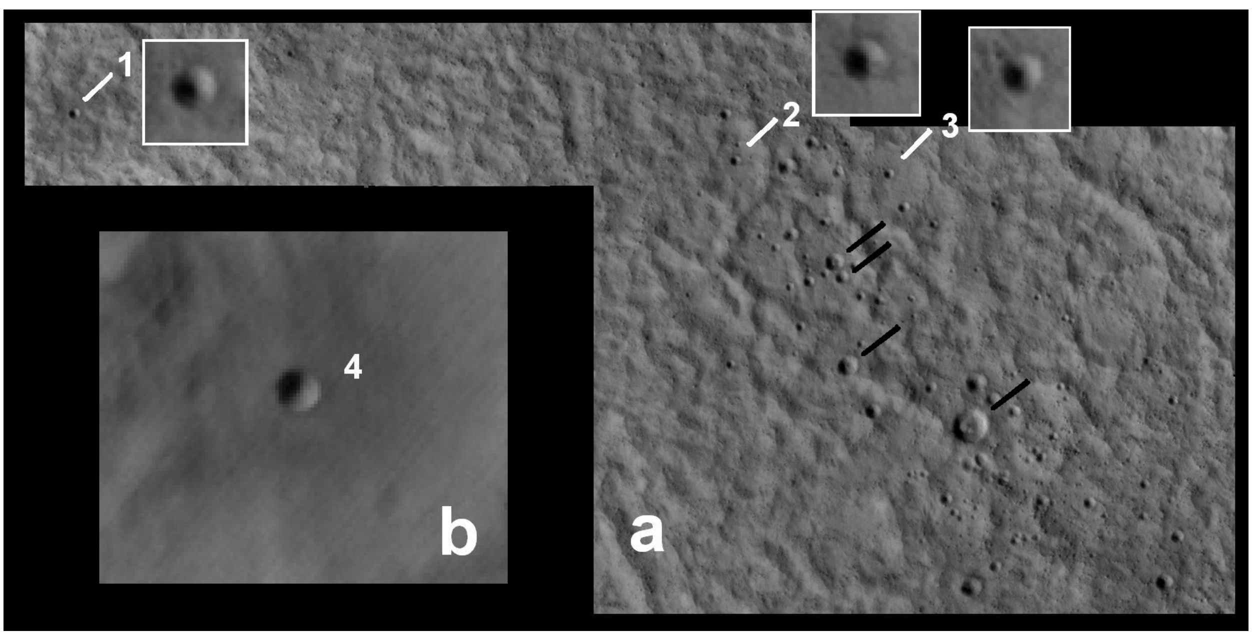


Fig. 3 - The four craters measured using their shadows: (a) Three craters (white arrows) in a cluster of ~20 craters larger than 3m. The shadows in four larger craters (black arrows) show that they contain flat floors, an unexpected feature in such small, extremely fresh craters. (b) The single crater, in a cluster of four, that was measured (from HiRise images (a) ESP_019830_2215 and (b) PSP_010255_1700. Credit: NASA/JPL/U. Arizona).