DETECTING PRIMARY CRATERS AMONG CLUSTERS OF SECONDARIES

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INTRODUCTION -

•Sorting secondary craters out of populations of primaries has been a long-term and contentious problem in Planetary Science, particularly in the context of crater counting methods.

•Secondary craters are typically identified via qualitative means: clustering, irregular morphologies (Fig.1, background image), herringbone patterned ejecta, and "blockiness" (e.g. [1], [2]), [3], [4]).

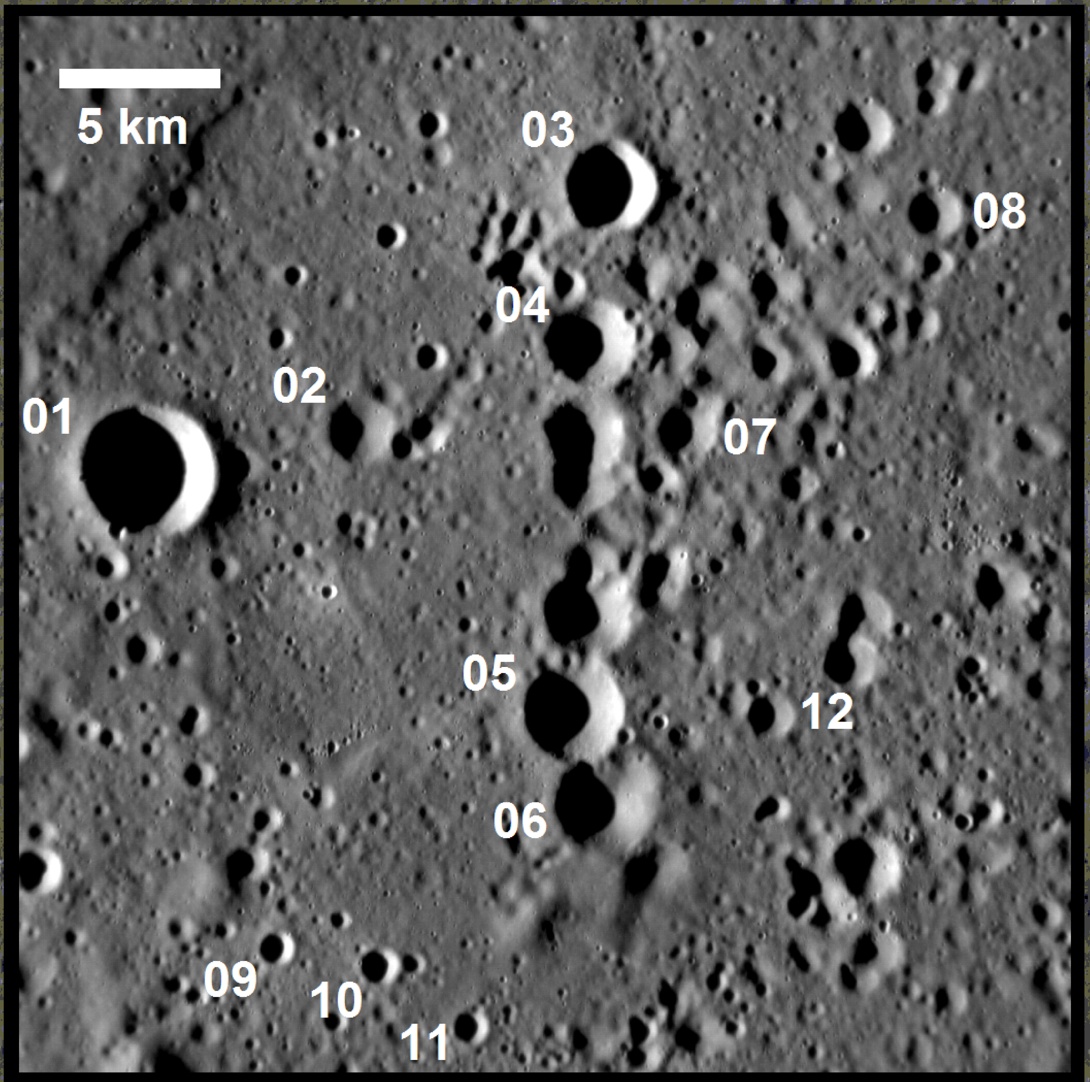

Figure 1: Detail of MESSENGER image EN1033974656M of the mercurian surface centered at about 3.3°N, 80.0°E. A cluster/chain of secondary craters dominates the scene.

•However, clusters of secondary craters themselves may include embedded primaries, which would not be counted if entire clusters were to be excluded (e.g. from a crater count).

•Here such a cluster is "parsed" for primaries, using a new tool for separating primary from secondary craters.

METHODS -

•The Free Shadowfront Method (FSM) is a technique for determining the dimensions (depths [*d*] and diameters [*D*]) and shapes of simple impact craters (including secondaries) from analysis of the shadows within them [5,6].

•The FSM yields the crater cross-sectional shape in terms of *d*, *D*, and the eccentricity (e) of an approximating geometric conic section, which is almost always a hyperbola, not a parabola (Fig.2).

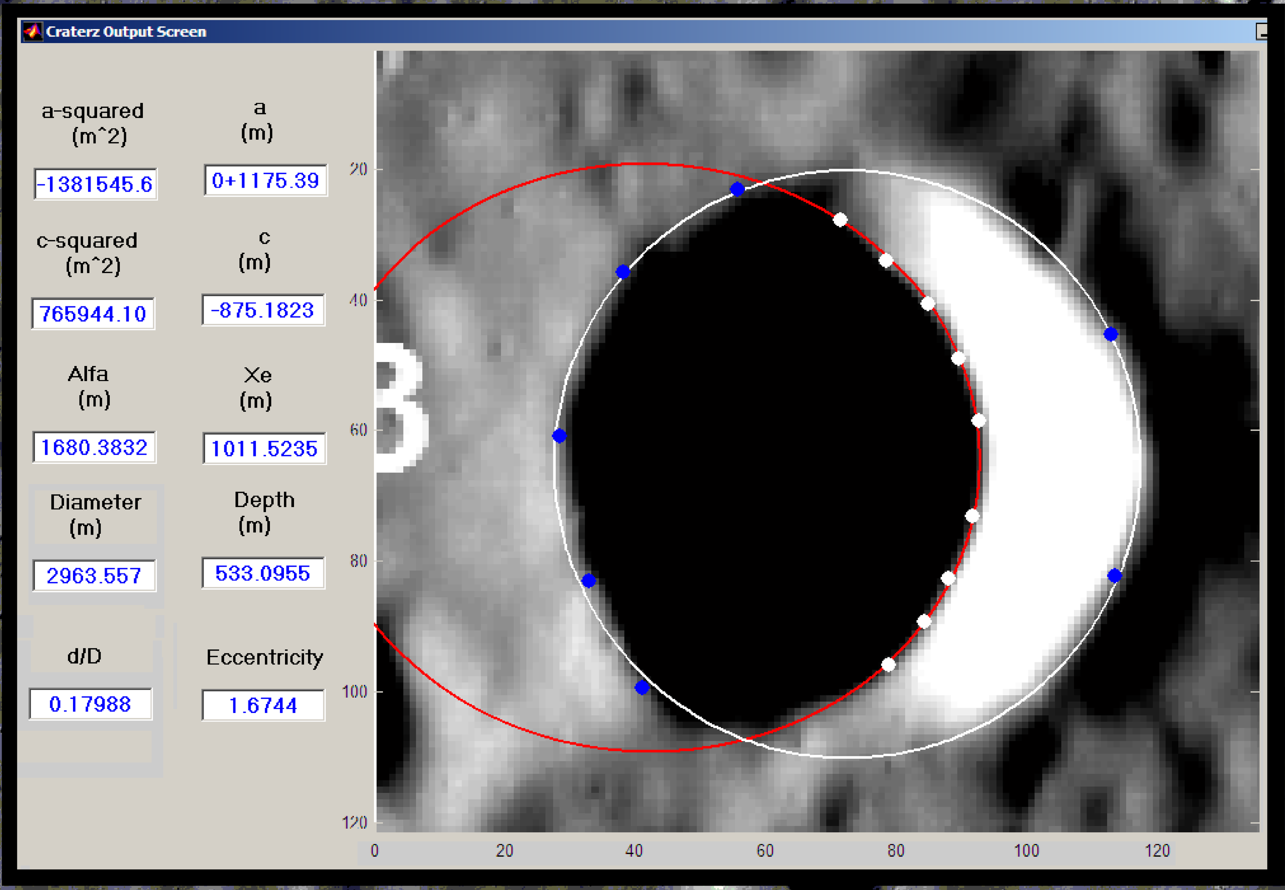

Figure 2: A screen shot of the FSM results for Crater 03 (Fig. 1), showing the rim circle and shadowfront ellipse, and the points selected for their determination.

•165 lunar primary simple craters measured in previous work [6,7] and 29 recently analyzed lunar secondaries were plotted on *e* vs. *d/D* axes (Fig.3) creating a template useful for sorting primary and secondary simple craters (Fig.3).

•12 craters within or near a mercurian crater cluster found in MESSENGER image EN1033974656 (Fig.1), and amenable to FSM analysis were measured and also plotted on Fig.3.

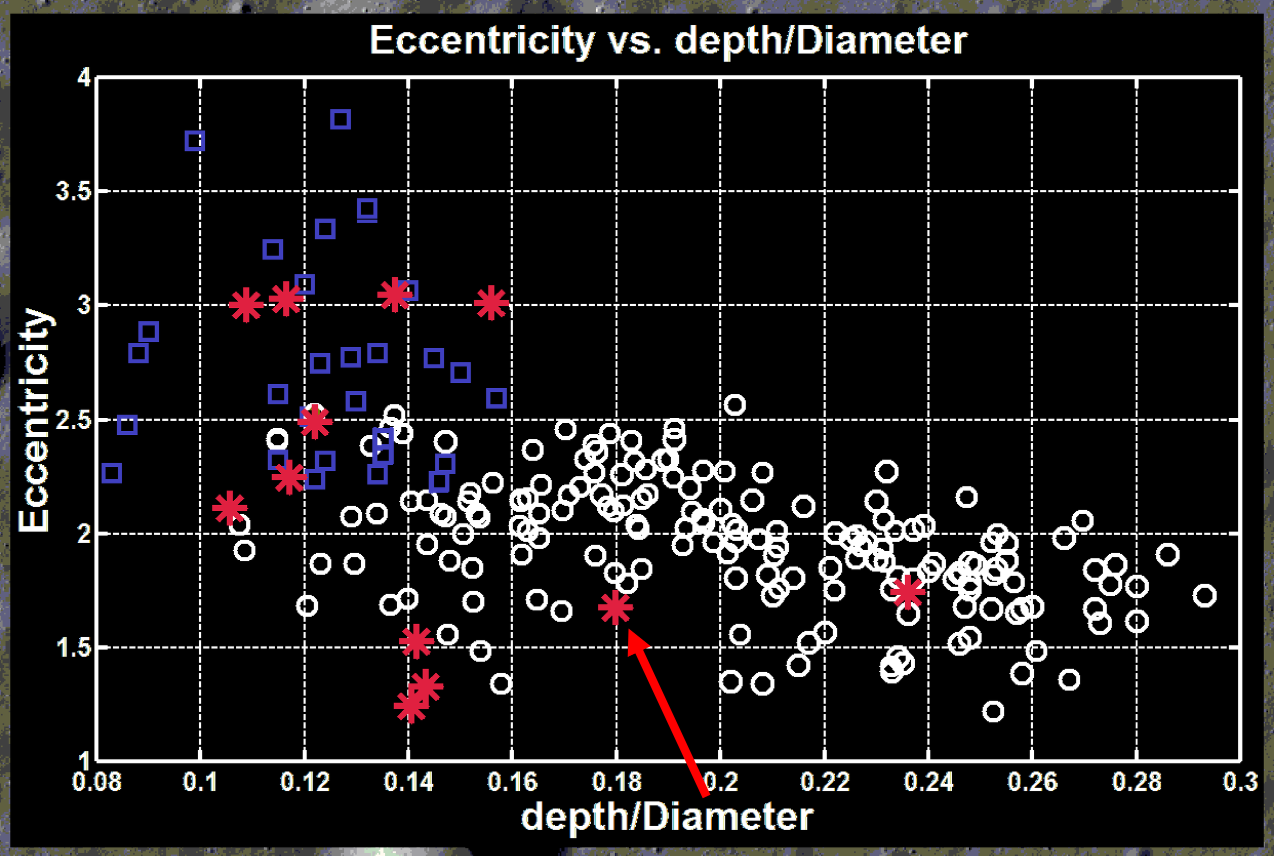

Figure 3: Eccentricity vs. d/D of the 12 clustered craters studied herein plotted over 29 recently collected and measured lunar secondary craters (blue squares) and 165 simple lunar craters measured in refs [6] and [7] (white circles), all of which are believed to be primaries. Note that the primary craters in the figure generally become more degraded from right to left, and that the secondaries cluster toward shallower depths and higher eccentricity (e) values. Note also Crater 03 at d/D = 0.18, e = 0.167 (red arrow)..

•By inspection of Fig.3, 4 of these craters are almost certainly secondaries, 5 are primaries, 2 are likely secondaries, and 1 is indeterminate.

RESULTS -

Table 1: Results of FSM measurements of the 12 craters numbered in Fig. 1.

Crater#	Type?	Lat	Long	ecc	d/D	TYPE	Notes/Comments
01	Prime	3.42	79.65	1.742	0.236	Prime	An obvious probable primary
02	????	3.45	79.82	3.001	0.109	Sec'd	
03	Sec'd	3.63	80.00	1.674	0.180	Prime!	This one is a hidden primary!
04	Sec'd	3.50	79.98	3.046	0.137	Sec'd	
05	Sec'd	3.23	79.98	3.012	0.156	Sec'd	Here d/D is not definitive, eccentricity is
06	Sec'd	3.15	80.00	2.248	0.117	Sec'd	
07	Sec'd	3.44	80.06	3.028	0.117	Sec'd	
08	Sec'd	3.59	80.24	2.111	0.106	Sec'd	Here eccentricity is not definitive, d/D is
09	????	3.05	79.76	1.245	0.141	Prime	
10	????	3.04	79.84	1.525	0.142	Prime	
11	????	3.00	79.91	1.327	0.143	Prime	
12	????	3.20	80.10	2.491	0.122	Sec'd	

Table 1: Column 2 is the "best guess" crater type (primary or secondary) based only on qualitative inspection of the image. Column 7 is the type determined from both qualitative properties and the measured crater shapes (e and d/D).

•Its large size, sharp rim, and long shadow all indicate that Crater 01 is a primary - consistent with its shape in terms of *e* & *d/D* (Table 1, Fig.3).

•Its large *d/D* value (0.236) suggests that 01 is a very young crater [6].

•Craters 04-08's positions within the cluster indicate that they are secondaries – their depths and shapes, *e* & *d/D*, agree with this conclusion.

•Craters 02 and 12 lie outside the main cluster, however they are qualitatively - *and quantitatively* - consistent with secondaries.

•Craters 09-11 lie well outside the cluster, but their positions and appearances suggest that they may be related. However, their eccentricity values are entirely inconsistent with secondary craters – they are apparently primaries.

•Its position aligned with the main chain of craters within the cluster, 3 of which are proven secondaries, would seem to strongly indicate that Crater 03 is also a secondary - HOWEVER, ITS DEPTH AND SHAPE PLACE IT FIRMLY IN PRIMARY CRATER TERRITORY (Figs. 2 & 3; Table 1). It is almost certainly not a secondary.

CONCLUSION -

•The crater cluster studied here contains at least one significant *primary* crater which would not likely be detected by simple inspection. Exclusion of craters like this one together with clusters of secondaries has the potential to skew crater counts if the area of the clusters is not excluded as well.

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References: [1] Wilhelms, John, & Trask (1987) The Geologic History of the Moon, *USGS Prof. Paper 1348*. [2] McEwen et al. (2006) *Ann. Rev. Earth & Planet. Sci.*, *34*. [3] Oberbeck & Morrison (1974) *The Moon*, *9*. [4] Bart & Melosh (2007) *GRL*, *34*(7). [5] Chappelow, JE (2013) *MAPS* 48. [6] Chappelow, JE (2018) *MAPS*, forthcoming. [7] Chappelow, JE (2015) *46th LPSC*, abst. #1079.