TOWARDS A NEW CATALOG OF LOBED MARTIAN CRATERS COMPARED WITH A NEW GLOBAL CRATER DATABASE, COMPLETE TO 1.5 KM.

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Introduction: The first global database of martian craters was created from Viking images in the late 1980s by Nadine Barlow of craters $D \geq 5$ km. Since then, many other researchers have cataloged craters to smaller diameters but in isolated sections of the planet. The same is true of lobed craters – craters that have one or more lobate, layered debris apron surrounding them. To test the two main formation hypotheses of these uniquely martian craters, a uniform, global crater database complete to the same diameters as our lobed craters is necessary. Consequently, in support of our lobed crater research, we have begun to map all craters across the planet, and we estimate our statistical completeness to be ~1.5 km in diameter. We have noted several preliminary trends in the lobed craters.

Lobed Craters: Lobed craters are a so-far unique class of craters to Mars, having not been observed elsewhere in the solar system. They are characterized by one or more layers of smooth, continuous ejecta ("LE") that usually ends in a small bulge/rampart with sinuous perimeter (Fig. 1). Two different formation mechanisms have been proposed. One holds that they form when an impactor hits a volatile-rich sub-surface, the impact energy melts or vaporizes the volatiles, and the ejecta acts like a fluid as a result (*e.g.*, [1]). Another states that they form when the severity of the impact causes atmospheric vortes and winds [2].

Due to the implications of their presence indicating a volatile-rich (*e.g.*, water-ice) subsurface, we are working to create the first complete global catalog of all lobed craters $D \geq 1.5$ km to examine their morphology, morphometry, thermal inertia, geologic unit on which they are emplaced, and other properties from all available datasets from such missions as *Mars Odyssey*, *Mars Global Surveyor*, *Mars Express*, and *Mars Reconnaissance Orbiter*. With this large dataset, we hope to test the two formation mechanisms mentioned above and to determine which is more likely with the available data. However, to do this conclusively, we need to compare the properties of the lobed craters with the "background" crater population on the planet.

Previous Crater Databases: Dr. Barlow's original crater database [3] has become the foundational work for most other crater databases, including the recent compilation by Salamunićcar & Lončarić [4]. Dr. Barlow has since been revising her original catalog based on THEMIS and MOC imagery, though she is still limiting her completeness to 5-km-diameter craters [5]. Another researcher, Dr. Tomaz Stepinski, is working on automated computer algorithms to detect and catalog craters from MOLA gridded topographic data [6], and though parts of the planet are complete to ~2-3 km, we estimate completeness in a different way and compare our results with his and Dr. Barlow's in Fig. 2. We note all three databases are preliminary. To-date there is no planet-wide crater database complete to ~1.5 km, which we require to more completely understand the nature of lobed craters.

Our Crater Database: All craters for our database are identified manually in THEMIS Day IR mosaics (or Viking MDIM 2.1 where there are gaps in THEMIS coverage). With a resolution of ~250 m/px, we use *ArcGIS* software to outline each crater rim and lobe (if present) at ~500 m cadence. *Igor Pro* software is used to take the data and calculate best-fit circle and ellipse parameters for each crater. Each $D \geq 3$ km crater is re-identified in MOLA 1/128° gridded data to determine rim height, surrounding surface elevation, and floor depth. THEMIS data is used to classify crater iterior morphology and degradation state and the ejecta morphology.

Our crater database includes MOLA- and THEMIS-based latitude, longitude, diameter, and ellipse parameters; MOLA-based rim, surronding surface, and floor elevation from which derived rim-floor depth, rim height, and excavation depth are calculated; crater degradation state; crater interior morphology and two ejecta morphologies (one after [7], the other based on shape, such as "butterfly"); and whether or not the crater is an obvious secondary. In addition to those parameters, each lobed crater has additional columns that include the number of lobes, and then for each lobe the perimeter, area, equivalent circular ejecta radius, lobateness, and ejecta mobility (crater radii the ejecta traveled).

Preliminary Results: As of January 2009, we have completed all THEMIS identification, MOLA analysis of $D \geq 3$ km, and ejecta quantification and classification of $D \geq 5$ km craters for the northwest quadrant of Mars (0-90° N, 180-360° E). We have identified 36,223 craters, of which 22,978 are larger than 1.5 km. For comparison, Dr. Barlow has identified 5,429 craters in the same region larger than 5 km (we identified a comparable 5,479). Based on extrapolation from this, we expect our final total crater database to have ~180,000 craters larger than 1.5 km.

From a data source standpoint, we have identified and verified that there is a systematic offset between

THEMIS- and MOLA-derived crater diameters [8]. MOLA diameters consistently are ~0.5-1.0 km larger than THEMIS. We have verified our methods by comparison with Dr. Barlow and Dr. Stepinski, and so we believe this is a real feature inherent to the MOLA data. Our working hypothesis is that this is due to the topographic slope affecting sample return during data collection by the MOLA instrument, and subsequent interpolation.

We have also examined the preliminary distribution of lobed craters by latitude (Fig. 3). We identify a few features in this distribution, generally in comparison with [3]. First, we verify the relative enhancement of lobed craters in the high (>60°) northern latitudes. However, we find there are ~2-4× as many lobed craters in the mid and equatorial latitudes by percentage. We also identify a significant enhancement of double-layered lobes between ~45-65° N latitude. However, we do not observe an enhancement of multi-layered lobes at equatorial latitudes. Note that these are subject to change once we complete the North hemisphere.

Some other features we have identified include: (1) Ejecta mobility appears to be statistically greater for craters north of ~45° N, correlating with sub-surface hydrogen. (2) We find no lobateness trend with latitude, agreeing with previous studies, indicating a probable independence with volatile content. (3) Lobed craters appear to have a statistical cut-off point, with fewer than 1% being larger than $D > 50$ km, indicating a probable age or size depenednece. Additionally, the mode of multi-layered lobes' diameters is ~20 km, much larger than single and double. (4) We identify a new sub-class of double-layered ejecta where the inner layer is fairly circular and ends in a convex pancake-like shape, while the outer layer has a sinuous, rampart-like terminous. These craters are not observed south of 25-30° N latitude, despite the general double-layered lobed ejecta being present over the entire surface. More geographic analysis and complete coverage is necessary to make conclusions on this trend.

Conclusions: Crater cataloging on Mars has a decades-long history that has produced several different catalogs from different data sets with different information for each crater. To thoroughly analyze lobed craters – which may hold clues to sub-surface water and/or other volatiles – we have begun to create a new global database that we estimate is complete to ~1.5 km in diameter. We have already begun to mine the database for trends, and once complete, we hope to paint a more complete picture of the formation mechanism of lobed craters as well as to release our database to the martian research community.

References: [1] Carr M. H. *et al.* (1977) *JGR*, *82*, 4055-4065. [2] Barnouin-Jha O. S. and Schltz P. H. (1998) *JGR*, *103(E11)*, 25,739-25,756. [3] Barlow N. G. (1988) *Icarus*, *75*, 285-305. [4] Salamunićcar G. and Lončarić S. (2008) *P&SS*, *56*, 1992-2008. [5] Barlow, N. G. (2006) *Meteoritics Planet. Sci*., *41*, 1425-1436. [6] Stepinski T. F. and Urbach E. R. (2008) *Mars Crater Conf*., *11*, #1103. [7] Barlow N. G. *et al.* (2000) *JGR*, *105(E11)*, 26,733-26,738. [8] Robbins, S. J. and Hynek, B. M. (2008) *Mars Crater Conf*., *11*, #1107.

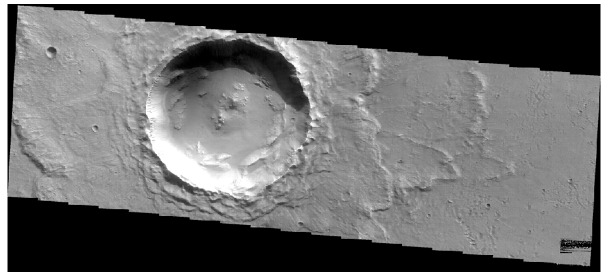

Figure 1: Example of a lobed 15.9-km-diameter crater with two distinct lobes and part of a third. THEMIS image V12446004 at 28.6° N, 319.6° E. Image has been rotated 90° so North is to the right.

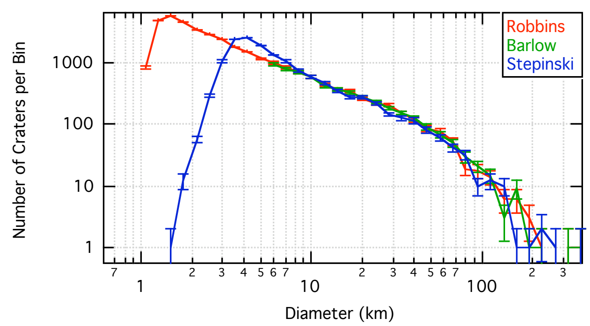

Figure 2: Incremental size-frequency graph comparing this work, Dr. Barlow's preliminary new database (personal communication), and Dr. Stepinski's preliminary database (personal communication). Error bars are $\sqrt{N}$.

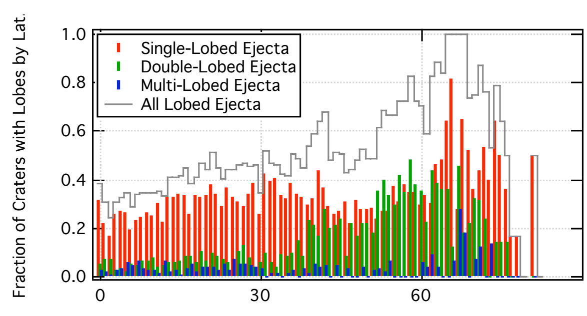

Figure 3: Fraction of craters ≥5 km per 1°-wide latitude bin that are lobed, sub-divided into single-, double-, and multiple-layers of lobes. There is a set of red, green, and blue lines below each "step" of grey showing the fraction of each.