IDENTIFCATION OF THE DEEPEST CRATERS ON MARS BASED ON THE PRESERVATION OF PITTED IMPACT MELT-BEARING DEPOSITS.

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Introduction: Crater-related pitted materials, thought to be impact melt-rich deposits formed from volatile-rich substrates, have been observed in high-resolution images of both the youngest and best-preserved craters on both Mars and Vesta [1–3]. To date, 205 such craters have been identified on Mars ranging from 1–150 km in diameter, and are randomly distributed between ~60°S and 60°N latitudes [1].

Because pitted materials likely represent the primary crater-fill deposits, and show a strong correlation with crater preservation [1–3], we explore their use to reassess depth-to-Diameter (d/D) scaling relationship using Mars Orbiter Laser Altimeter (MOLA) data. Constraining this relationship for the youngest and best-preserved craters on Mars is useful as a tool in planetary studies. Crater d/D can be used to specifically address the effect of target properties on crater morphology and the extent of erosion, degradation and deposition in various regions, or within specific craters on Mars [4–11].

Here we seek to measure the d/D ratio of as many pitted material-bearing craters ("PM craters" from here on) as possible to further test the assertion of Tornabene et al. [1] that PM craters are amongst the freshest and best-preserved craters on Mars. We will also compare the d/D relationship with previously published relationships [4–10]. If PM craters are indeed amongst the freshest craters on Mars, then their depths should be comparable or deeper then the estimated depth values derived from these previous relationships.

Methods: We evaluated 205 simple and complex PM craters from [1] with both the MOLA Mission Experimental Gridded Data Record (MEGDR) and Precision Experimental Data Record (PEDR) data in the Java Mission And Remote Sensing (JMARS) software package [12]. MOLA PEDR data were individually compiled as a shapefile for each crater using the Planetary Data System (PDS) Geosciences Node's web-based MOLA PEDR Query applet [13]. Each shapefile was then read into JMARS and the PEDR shots were carefully examined along with high-resolution visible images of each crater. Craters with poor MOLA PEDR coverage were discarded from our analysis.

Crater depth (d_r) was measured as the difference in elevation between the maximum rim elevation and the lowest floor elevation, while Diameter (D) values were used from the supplementary table in Tornabene et al. [1]. Central pits with elevations below the crater floor were avoided. As such, the lowest elevation on the floor off the central pit was used instead. Likewise, any overprinting primary or secondary impact craters on the host crater floors were avoided – again, using the next lowest elevation that clearly fell on "unmodified" host crater floor. After plotting all the d_r vs. D values, outliers (i.e., extremely deep or shallow craters) were assessed carefully with respect to pre-existing topography and post-impact modification. Craters with uneven or complex background terrains, or craters that overprinted other craters, specifically in the vicinity of the rim or the floor were noted, adjusted if possible or not used for the power law regression.

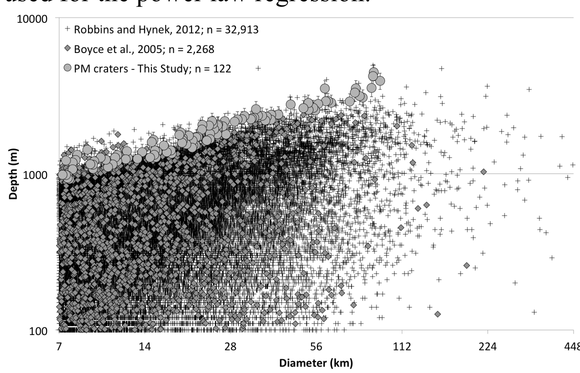

Fig. 1. Scatter plot of d_r/D of PM-bearing craters (gray circles), the d_r/D data from [6] (gray diamonds) and of [10] (crosses) showing that PM-bearing craters are amongst the deepest craters for their size on Mars.

Of the 205 PM-bearing craters, 122 made the final cut for analysis. The d_r/D of PM-bearing craters >7 km in diameter are plotted in Fig. 1. Based on poor MOLA PEDR data-coverage, pre-existing slope and topographic effects as described in our methods section, 81 of the 205 craters were dropped from our regression analysis. The two largest craters (Hale and Bakhuysen) were also dropped due to a lack of craters in our sample population with diameters between 100 and 150 km, resulting in 122 simple and complex (D ~2-100 km) craters that made the final cut. Also included in Fig. 1 are 2269 d_r/D measurements of Martian craters by [6], and the 32,913 d_r/D measurements of [10] in this the diameter range ~7-450 km.

Next, geometric binning of the PM-bearing crater diameters to bin the d_r/D data was used to derive a power law regression for the deepest craters in our sample population. This binning is based on a diameter-bin size that increases with increasing diameter to ensure that a maximum of 4 craters are available in each bin. In this manner, 18 bins were created starting with a 2-km bin size that increased to a maximum of 20 km in size. A initial power-law regression analysis of the deepest 10 complex craters and 8 simple craters for each bin indicated that there were 5 craters in each of the sub-populations that fall slightly below the best-fit trend line. As such, they were subsequently discarded to derive a maximum d_r/D relationship for complex and simple craters. For the start of the complex crater relationship, we avoid craters 12 km or less, which is based on the largest simple crater of ~11.8 km observed by [7]. Simple craters appear to go up to ~9 km in our sample population.

Results: The deepest PM crater d_r/D relationships are:

Simple: $d_r = 0.277\, D^{0.74}$ (n = 5 r^2 = 0.99)

Complex: $d_r = 0.349\, D^{0.57}$ (n = 8; r^2 = 0.99)

and the average relationship for all complex craters >12 km is: $d_r = 0.341\, D^{0.53}$ (n = 79; r^2 = 0.92)

A comparison with previous of d_r/D scaling relationships [5-10] shows that our deepest PM crater-derived relationship is deeper than previously reported ones, including [8]. The average PM-crater relationship for all complex craters is nearly comparable to the general relationship derived by [9]; however, a closer examination of these two shows that our PM-derived relationship estimates deeper craters at diameters less than ~32 km and shallower craters at diameters greater than ~42 km. The deepest PM crater-derived relationship is for simple craters is greater than estimates made by [5], but complexities due to target properties in the strength-dominated regime [7-10] make the derivation of a global relationship and comparisons difficult.

While the culled sample population (n = 122) appears to be randomly distributed (Fig. 2), the deepest sub-population of complex and simple craters (n = 13) are not, clustering in the Isidis-Elysium-Hesperia region with one outlier on Olympus Mons. A closer inspection reveals that these craters are within plains materials interpreted to be lava flows [14]. This observation suggests that target-strength effects may continue to play a role even within the gravity-dominated regime that governs complex crater collapse.

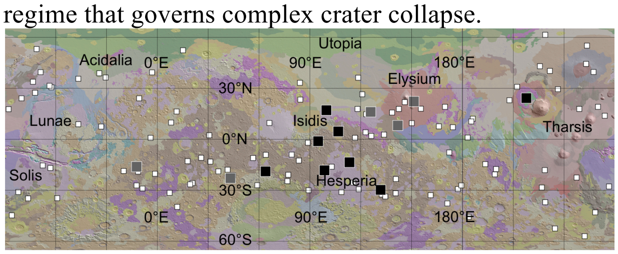

Fig. 2. Geologic map of Mars (see Skinner et al., 2006) and the distribution of all the culled (n = 122) PM craters (white) with the deepest simple (gray) and complex craters (black) in the sample population.

Conclusions: When compared to previous general d/D scaling relationships [5-10], the PM crater d/D relationships provides a consistently deeper estimate for complex craters. These consistently higher d/Ds provide additional corroborative evidence that pitted materials are primary crater deposits. However, evidence now suggests that the higher depth of some PM craters may still be influenced by target properties well past the transition from simple to complex morphologies. As such, the scaling relationships derived here in should be used as an upper limit for estimating crater depth.

Previously, painstaking d/D measurements involving 1000s of craters (up to 6000 craters for [5]) were required to constrain the deepest craters on Mars, which were often assumed to be the freshest craters on Mars. Our results support that the presence of PMs may be used as a criterion for identifying the best-preserved non-polar (± 60°N) craters on Mars. Thus, PMs may provide a chronological marker and distinctive morphologic criterion for evaluating crater preservation, and for use in a variety of mapping and geologic studies of the Martian surface.

Furthermore, Mars is a relatively active geologically, as such, the sample population of PM-bearing craters reported in [1] can be used to assess other crater-related scaling relationships, such as peak diameter, pit diameter, number of terraces, terrace spacing, ejecta blanket attributes. Continued studies of Martian PM-bearing craters are likely to provide additional insights into the impact process as a geologic process (e.g., distribution and morphometry of various impactites) and a reassessment of the strength properties of different hemispheres and regions as discussed by [6–10]. Such studies, with respect to the study of well-preserved lunar craters, may be more relevant to understanding terrestrial impact structures, which suffer from degradation, erosion and deposition via multiple, active geologic processes.

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