DEPTH AND DIAMETER RELATIONSHIPS OF MARTIAN AND TERRESTRIAL PLANET COMPLEX IMPACT CRATER:

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Introduction: The goal of this study is to substantially improve our knowledge of the final, post-formation depth (d_r, average rim height to bottom of the floor) to diameter (D, rim crest to rim crest) function of complex impact craters. The focus of this study is Mars, but preliminary data for complex craters on all terrestrial planets is also discussed. This function is an essential benchmark for studies that utilize crater geometry as their basis.

In previous studies the "fresh crater" d_r/D function for crater populations was often used as a proxy to describe the final, post-crater formation d_r/D function. These studies employed an empirical approach that produced inconsistent results and, at best, yielded only an average fresh crater curve because they fit the curve to a population of fresh impact craters. The total number of fresh craters and their depth range were chosen by each investigator, and as a result varied from investigation to investigation [e.g., 1, 2, 3, 4, 5]. Further complicating the situation, the simple/complex transition can vary broadly from place to place on Mars [1, 3, 4], consequently, the inadvertent inclusion of craters in this transition when calculating the different segments of the curve would affect the slope of their curves. Furthermore, the affects of other processes on the morphology of craters larger than ~ 50 km can also affects crater shape [6].

In this study, the final, post-formation d_r/D function is determined for craters after the end of crater modification (see 19). Only the deepest and morphologically freshest craters (i.e., those with well-developed small-scale primary impact features such as secondary crater fields, or rays, and few superposed craters) are used. Such craters are rare because of the relatively low impact flux of bodies that produce impact craters of the size of complex craters [8], and because the initially steep interior slopes of newly formed craters are rapid reduced by slumping and sliding into the crater. While having the freshest morphology, these craters have probably existed on Mars for, at least, thousands of years with gravity acting on the fractured rock to reduce the initially steep interior slopes.

The d_r and D for 6047 craters (5077 measured from MOLA DEM data utilizing the IMPACT Program of [9] and 970 craters measured from MOLA shot data) found in globally distributed test areas are used in this study. The d_r/D of these craters is plotted in Figure 1 and also includes the craters identified as the deepest, freshest (15) and fresh (87) in this study (binned in geometrically increasing-diameter size bins), and the anomalously deep craters in Isidis and S. Utopia Planitia regions previously identified [3].

Results: The best-fit d_r/D function of the complex craters 12 - 49 km diameter identified in this study as the deepest and freshest complex craters is plotted in Figure 1 (top) and is $d_r = 0.381\ D^{0.52}$ ($r^2 = 0.98$). The high r^2 value suggests little dispersion of these craters from the function, indicating 1) a strong correlation between the two variables, and 2) that other factors, such as target properties or erosion/infilling processes, have had little effect on crater geometry. In addition, the geographic distribution of the deepest, freshest craters, 12 - 49 km diameter is globally random (e.g., the nearest neighbor statistic, R = 1.18 for large pristine crater), but is not for such craters < 12 km diameter [10]. This suggests that target material properties (e.g. strength) have an effect on crater d_r/D for craters < 12 km diameter, but not for ones > 12 km diameter.

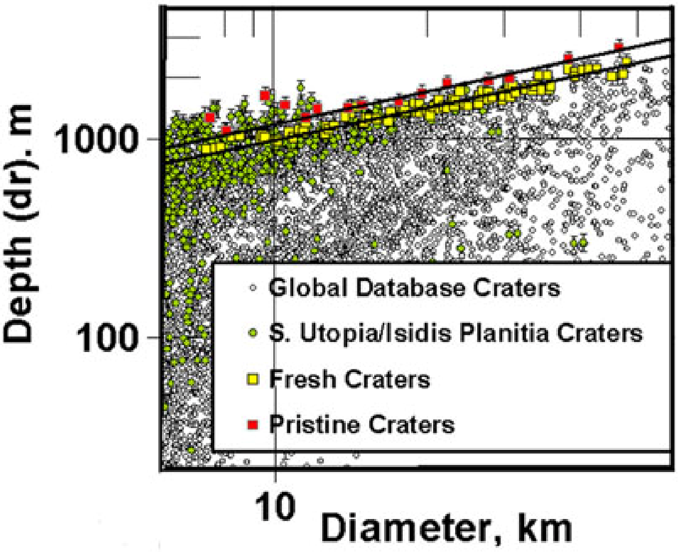

Figure 1. Scatter diagram showing d_r/D of craters in this study, including the deepest, freshest craters (i.e., pristine) (red squares), fresh craters (yellow squares), craters in the S. Utopia and Isidis Planitia region (green triangles) and their measurement error bars, and all other craters (open circles without error bars). Pristine craters average ~ 7 % +/- 3% deeper than the next deepest fresh craters. The best-fit curve is included for the pristine (top) and fresh (bottom) crater d_r/D functions.

For comparison purposes, we have also estimated the global fresh crater d_r/D function using the traditional method of identifying the freshest craters (in this case 4 freshest craters plus the deepest, fresh crater in the same bins as the deepest, fresh craters) in the size range of 12 to 49 km diameter and fitting a best-fit function through them. The best-fit curve for these fresh craters is also plotted in Figure 1 (bottom) and is $d_r = 0.315\ D^{0.52}$ ($r^2 = 0.82$). To further test for consistency, the best-fit fresh crater function and r^2 were also calculated using 1, 2 and 3 of the fresh craters (plus the deepest fresh crater) in each bin. We found that while the constant in the function decreases with number of fresh crater/bin (0.363, 0.356, and 0.333 respectively); the exponent remains nearly content at about 0.52 +/-0.004.

In addition, even though some regions, such as in south Utopia and Isidis Planitia where the simple/complex crater transition has been extended to ~ 11.8 km diameter because of anomalous (strong) target material [4, 5], the best-fit curves for deep, fresh craters above this transition are the same as in other regions (Figure 1).

Discussion and Conclusion: The data provide evidence for one global Martian complex crater d_r/D function. Such a global d_r/D function is suggested by 1) the limited dispersion (i.e., high r^2 value) from a best-fit function of the d_r/D values of the deepest, fresh craters, 2) earlier studies that found no statistically significant correlation of fresh complex crater d_r/D on different terrain types on Mars [1, 7], 3) the similarity in the slopes of the d_r/D function for the deepest, fresh and progressively fresher complex craters suggesting that all these craters are part of the same evolving crater population, and 4) the similarity in all regions of the dr/D curves of the deepest fresh complex craters including regions with anomalous target materials. While these data suggest one global complex crater function, small differences in the d_r/D function from region to region are possible, but they would have to be below the inherent errors of the data and hence undetectable with the available data.

Terrestrial Planets: The approach used for Martian craters has been applied to d_r/D data collected in previous studies for the terrestrial planets [e.g., 11, 12, 13, 14, 15, 16, 17, 18], and new data for the Moon collected in this study and have been used to estimate the simple/complex crater transition for each terrestrial planet. This approach produces results that are more readily inter-comparable (see earlier discussion). These transitions have been plotted against the acceleration of gravity for each of the respective planets in Figure 2 and show a relationship of $D_{transition} = 199\ G^{-0.60}$ ($r^2 = 0.98$).

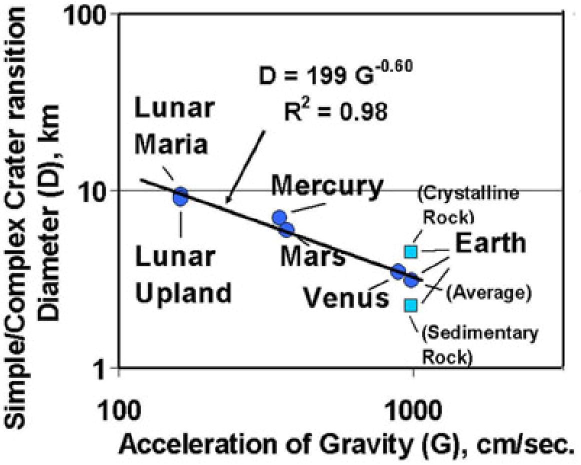

Figure 2. Plot of the relationship between the simple/Complex transition and strength of the gravity of the terrestrial planets.

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