THE ROLE OF TARGET PROPERTIES AND PROJECTILE VELOCITY ON FINAL CRATER MORPHOLOGY OF CRATERS ON MERCURY. Hannah C. M. Susorney[1], Olivier S. Barnouin[1,2], and Carolyn M. Ernst[2], [1]Department of Earth and Planetary Sciences, Johns Hopkins University, Baltimore, MD 21218, USA (hsusorn1@jhu.edu); [2]Johns Hopkins University Applied Physics Laboratory, Laurel, MD 20723, USA.

Introduction: The diameter at which impact craters transition from simple to complex morphology (D_t) with increasing size generally scales with the inverse of the body's surface gravitational acceleration [1]. Interestingly, however, Mercury and Mars have similar surface gravitational accelerations (about 3.7 m/s^2) but different transition diameters (11 km and 6 km) [1–4]. Previous studies have cited the different geologic histories of the two bodies and resulting crustal properties as the source for this difference [1,2].

The insertion of the MErcury Surface, Space ENviorment, GEochemistry, and Ranging (MESSENGER) spacecraft into orbit about Mercury has provided unprecedented high-resolution imaging of the surface from the Mercury Dual Imaging System (MDIS) and topography measurements from the Mercury Laser Altimeter (MLA). With both datasets, the role of target properties and projectile velocity on impact crater morphology [1,2,5,6] on Mercury can be studied.

Methods: Impact crater morphology was measured by co-registering MLA tracks and MDIS images. The depth (*d*) of the crater was measured from the top of the rim to the crater floor. The rim height (*h*) was measured as the height difference between rim crests and the surrounding terrain. Crater diameter (*D*) was measured with both MDIS and MLA data. Up to three individual MLA tracks were included for each crater (when available). The average of the individual MLA measurements and their standard deviation were obtained for each measured crater**.**

The degradation state of each crater was classified using MDIS images and the Trask [7] system, which identifies the freshest craters as class 5 and the most degraded craters as class 1. Craters were distinguished as hosted by either cratered terrain or smooth plains (as mapped by Denevi et al. [8]). To constrain the transition from simple to complex morphology, several morphologic indicators were noted, including the onset of flat floors, wall slumping, and wall terraces.

Transition Diameter: The transition diameter on Mercury can be observed in the relationship between depth and diameter (Figure 1). In addition to the observed morphologic indicators, the intersection of the power laws fit to the *d/D* and *h/D* data for simple and complex craters were used to calculate D_t, following the methods outlined by Pike [2]. Table 1 gives the results of the intersections of the fits and the median diameter of the appearence of complex crater morphologies.

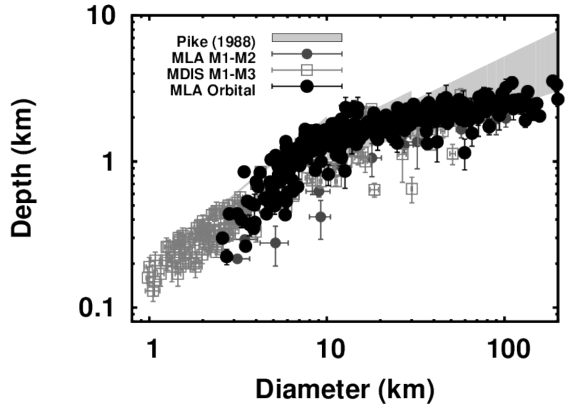

Figure 1. Comparison of the depth/diameter relationship in this study to results from the MESSENGER [4] and Mariner 10 flybys [2].

Table 1. Results of the estimation of the transition diameter (D_t) from simple to complex impact crater obtained with the method of Pike [2]. The intersection of fits to the *d/D* data produces a D_t value that is smaller than the smallest observed complex impact crater.

Morphologic Attribute	Statistic	Diameter ……(km)
d/D	Intersection of Fits	8.4
h/D	Intersection of Fits	14
Complex Crater	Smallest Complex	10
Simple Crater	Largest Simple Crater	16
Terraces	Median *D* of Overlap[1]	14
Flat Floor	Median *D* of Overlap[1]	9.6
Wall Slump	Median *D* of Overlap[1]	10
Final D_t	Geometric Mean	**11.7±2.8**

[1]The median *D* of the overlap between a crater with a terrace (or flat floor, or wall slump) and one without.

The new D_t, 11.7 ± 2.8 km, is similar to the D_t calculated from Mariner 10 (10.4 ± 4) [2] and MESSENGER flyby observations (~12 km) [6]. Both MESSENGER-derived results differ from the analogous figure for Mars (5.6 ± 3 km) [1, 3] and are larger then the D_t result from MLA data alone (8 km) [9].

The difference between the D_t values for Mercury and Mars is not the only observed morphologic difference between the crater populations. Both simple and complex impact craters are generally deeper on Mercury than on Mars [3].

Terrain Effects: Comparison of fresh craters (classes 4 and 5) on the two terrain types indicates that craters on average are deeper in the cratered terrain than in the smooth plains (Fig. 2). The difference is not as large as the difference in depth for lunar complex craters in the maria and the highlands [10], as previously noted from Mariner 10 results [6].

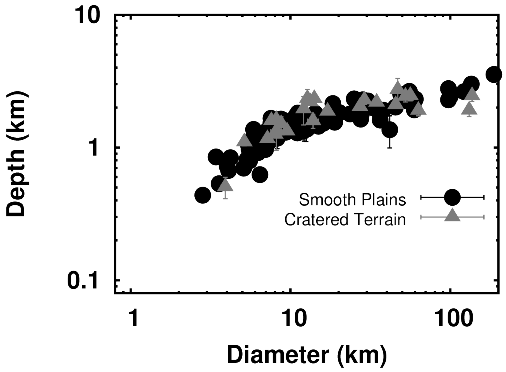

Figure 2. The *d/D* relationship for impact craters in smooth plains versus cratered terrain [8].

The difference in average depth between craters in the two terrains could reflect the enhanced porosity and weaker nature of the cratered terrain (because it is a battered megaregolith), as has been documented on the Moon [10]. The more muted differences in depth between geologic terrains on Mercury could be due to the more similar ages of cratered terrain and smooth plains on Mercury, the higher surface gravitational acceleration of Mercury, or the larger predicted range of impact velocities at Mercury.

Role of Impact Velocity: Fresh impact craters of similar diameter show large variations in depth (Fig. 3), a result that cannot be attributed to terrain differences. This difference can be illustrated by two craters: one at 83ºN, 318ºE (D = 28.3 ± 1.0 km; d = 2.3 ± 0.1 km); and another at 49ºN, 43ºE (D = 27.5 ± 0.4 km; d = 1.6 ± 0.1 km). Both are class 4, with no evidence for ejecta asymmetry, and occur within the smooth plains, but they differ in depth by 0.7 km.

The lack of observed ejecta asymmetry that can be attributed to impact obliquity indicates that such variations in depth may be the result of a large variation in projectile velocity. Dynamical models indicate that a large range in impact velocity is expected on Mercury (20-60 km/s) [12, 13]. Laboratory observations have noted an increase in transient crater depth with decreasing projectile velocity, due to the increased penetration of lower-velocity projectiles. The final impact crater depth is shallower for these low-velocity projectiles, though, since the steep walls of the deep transient craters collapse substantially [5,11]. The shallower craters observed on Mercury in similar terrains would correspond to lower-velocity projectiles, whereas the deeper craters would reflect a higher projectile velocity.

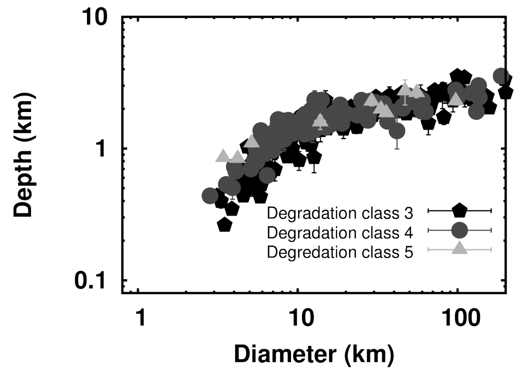

Figure 3. The depth/diameter relationship for craters in class 3 and above. Notice the large variation in impact crater depth for fresh (classes 4 and 5) craters.

The importance of impact velocity in influencing crater shape on Mercury is further reflected by the difference in average crater depth and transition diameter between Mercury and Mars despite the similar surface gravitational acceleration on the two bodies. The expected mean velocity of projectiles on Mars of 13 km/s is substantially lower then the mean expected projectile velocity on Mercury of 42 km/s [12], a difference that would yield shallower craters on Mars and deeper craters on Mercury, matching the observations. Further, a greater D_t would be expected on Mercury.

Conclusions: MESSENGER's orbital observations allow the re-evaluation of Mercury's impact crater morphology, including a new calculation of D_t, and an exploration of the roles of target properties and impact velocity on final crater morphology. The variations in depth of impact craters on Mercury may be the result of two different major geologic terrains and a large range of projectile velocities. The difference in D_t and average crater depth between Mercury and Mars may be explained by the large variation in expected mean projectile velocity between the two bodies.

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