ASSESSING THE RELATIONSHIP BETWEEN CRATER DEPTH AND DIAMETER ON MERCURY WITH TOPOGRAPHIC MEASUREMENTS BY MESSENGER. Olivier S. Barnouin-Jha[1], Maria T. Zuber[2], Jürgen Oberst[3], Frank Preusker[3], David E. Smith[4], Gregory A. Neumann[4], Sean C. Solomon[5], Steven A. Hauck, II[6], Roger J. Phillips[7], James W. Head, III[8], Louise M. Prockter[1] and Mark S. Robinson[9], [1]JHU/APL, Laurel MD 20723; [2]Dept. of Earth, Atmospheric, and Planetary Sciences, MIT, Cambridge, MA 02139; [3]DLR, Rutherfordstrasse, 2, 12489 Berlin; [4]NASA Goddard Space Flight Center, 8800 Greenbelt Road, Greenbelt, MD 20771; [5]Dept. of Terrestrial Magnetism, Carnegie Institution of Washington, Washington, DC 20015; [6]Dept. of Geological Sciences, Case Western Reserve University, Cleveland, OH 44106; [7]Planetary Science Directorate, Southwest Research Institute, Boulder, CO 80302; [8]Dept. of Geological Sciences, P.O. Box 1846, Brown University, Providence, RI 02912; [9]School of Earth and Space Exploration, Arizona State University, Tempe, AZ 85287.

Introduction: Several factors influence the shape of craters when they are first formed. These include the density, strength, porosity, nature of porosity (macro- versus micro-porosity), heterogeneity, and curvature of the target surface [e.g., 1-4]; the mass, velocity, and impact angle of the projectile [e.g., 2, 5, 6]; and the surface gravitational acceleration [e.g., 7]. The dimensions of craters traditionally used to investigate these influencing factors [e.g., 8] include the crater diameter, D, the diagonal distance between rim-crests, and the crater depth, d, the difference in elevation between the average height of the rim crest and the deepest point in the crater.

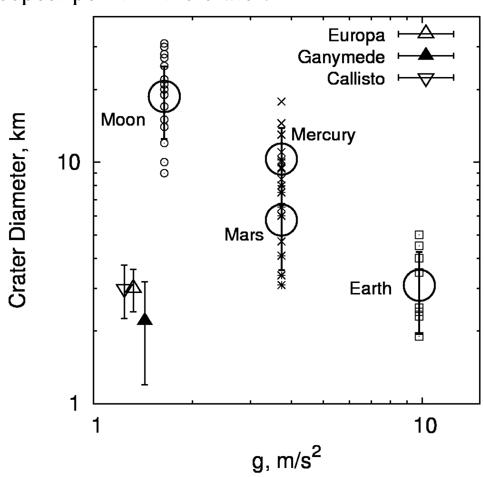

Figure 1. Diameter at which craters transition from simple bowl-shaped to complex craters as a function of surface gravitational acceleration for the Moon, Mercury, Mars, Earth, Europa, Ganymede, and Callisto [9, 10]. Large symbols are the geometric means of all the variables considered when assessing this transition. Small symbols represent the subsets of data used to derive the geometric mean [see 15].

By carefully measuring these parameters for the freshest craters possible on several planetary surfaces including Mercury, Pike [9] demonstrated that the gravitational acceleration at the target body surface plays a major role in the transition from simple bowl-shaped craters to complex craters possessing terraces, central peaks, and flat floors. These studies also reveal that despite the similarity in surface gravity between Mars (3.72 m/s^2) and Mercury (3.70 m/s^2), the crater diameter, D_t, at which this transition occurs is nearly a factor of 2 greater on Mercury than on Mars (Fig. 1). Pike [9] suggested that the cause might be differences in the strength (cohesion) of the surface of Mercury relative to Mars, which is richer in volatiles and perhaps weaker. Schultz [11] posited that differences in both impact velocity and projectile-to-target density ratios may be additional contributors to the observed differences in D_t. On Mercury, the typical impact velocity is expected to be 23-40 km/s; while on Mars it is 12-15 km/s [11]. Moreover, lower density cometary projectiles at Mercury may be more likely than at Mars, where impacts by asteroids are probably more common [11].

Assessing the shape of craters on Mercury not only yields information on how the impact conditions on Mercury might differ from those on Mars, but also provides a quantitative basis to assess crater modification. Providing such a framework is particularly important in the case of Mercury, where it remains difficult to discern what is responsible for the depletion of craters on some of the intercrater plains [12]. This depletion has been attributed to either impact (e.g., ejecta infilling, impact erosion, and seismic shaking) or endogenic (e.g., volcanism) processes. Careful analyses of topographic observations and images of craters at various states of preservation may provide a quantitative route to assess how these processes alter the surface of Mercury, possibly leading to insights on the thermal evolution of this planet.

The objective of this study is therefore twofold: (1) to gain additional insights on why D_t for Mercury is so much greater than for Mars, and (2) to provide a framework for quantifying how craters on Mercury have been modified after formation.

Approach: The data collected by the MESSENGER spacecraft during its two flybys of Mercury provide a glimpse into how topographic and imaging observations made with the Mercury Laser Altimeter (MLA) and Mercury Dual Imaging System (MDIS) will be important for assessing the morphology of both fresh and degraded craters alike on Mercury. We combine observations from both instruments (e.g., Fig. 2), as well as images acquired from Mariner 10 and the Arecibo Observatory. All estimates of d are from MLA measurements. Determination of D is from MDIS or Mariner 10 images, and from MLA when Arecibo radar provided the only images available. Results are shown in Fig. 3. MDIS data also permit careful assessment of crater degradation using well-established criteria [e.g., 12], providing some new, albeit preliminary, views on the factors that are responsible for the formation and subsequent evolution of craters on Mercury. Additional stereo data and shadow measurements will be added in the future to complement the results using MLA and associated images, but use of these data will be first verified with the measurements from MLA.

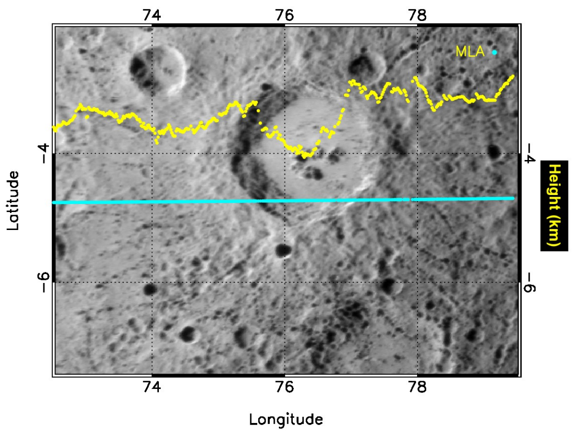

Figure 2. Example of MLA transect overlaid on an MDIS image. The cyan line indicates the location of the transect; the yellow dots show the elevation. This is an 88-km-diameter, fairly fresh (Type 4) complex crater whose depth and diameter were measured using this combination of MDIS and MLA data.

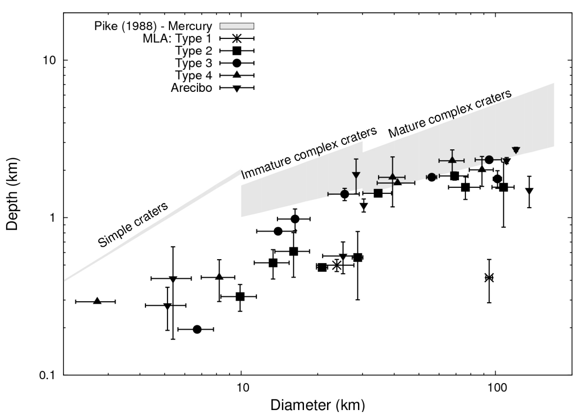

Figure 3. Depth and diameter measurements for craters on Mercury from MLA and MDIS data, and Arecibo data where indicated. Craters are classified according to degradation state (Type 5 = very fresh, Type 1= highly degraded).

Results: A preliminary assessment of our results indicates:

1. Small, fresher craters that are simple (< 10 km diameter) might be distinctly shallower than previously inferred. This may be because the small craters encountered by MLA were not the freshest, with at best a Type 4 classification. But shadow-length measurements from MDIS images of fresher craters give a similar result [13]. Moreover, greater depths inferred from Mariner 10 data could have been a result of low image resolution (0.4-1 km per pixel), which in some instances is comparable to the depths of the craters being measured, as well as uncertainties in the viewing geometry.

2. Large craters (> 14 km diameter) follow trends that are somewhat similar to those seen before in Mariner 10 data.

3. Crater degradation effects are measurable through a combination of topography (including roughness) and imaging (including color data) that will provide quantitative measures of whether and how either subsequent impacts or volcanic processes alter d.

4. The value of D_t may be slightly larger on Mercury than reported from Mariner 10 data [9].

Conclusion: Previous data indicated that small craters are very deep on Mercury relative to Mars, suggesting that the upper crust of Mercury is stronger than its martian counterpart [9]. A stronger crust also would restrict crater collapse, preventing the onset of the formation of complex craters, thereby enhancing D_t. as observed. The new result that simple craters might be shallower than previously reported, and more akin to small craters on Mars, would indicate that the bulk strength of Mercury's upper crust may not be significantly different from that of Mars. Consequently, the observed difference in D_t between Mercury and Mars may be due to other factors.

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