Crater Morphometry and Crater Degradation on Mercury: Mercury Laser Altimeter (MLA) Measurement and Comparison to Stereo-DTM Derived Results

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1. Overview and Summary
Examining the topography of impact craters and its evolution with time is useful for assessing how fast planetary surfaces evolve. New measurements of depth/diameter (d/D) ratios for 204 craters of 2.5 – 5 km diameter superposed on Mercury’s smooth plains are reported. The median d/D was 0.13, much lower than is expected for newly formed simple craters (~0.21). On the Moon, the craters that post-date the maria are much less modified and the median crater in this size range has a d/D indistinguishable from the fresh value. This difference in crater degradation is remarkable given that the smooth plains and maria likely have ages that are comparable, if not identical. Applying a model for topographic diffusional degradation, the results presented here imply crater degradation is at least ~2–3x faster on Mercury than the Moon, likely symptomatic of faster landform evolution on Mercury at all scales.

2. Methods
Depth/Diameter ratio of 2.5 to 5 km craters on Mercury was measured with two different topography data sets:

(1) MLA profiles
- Five northern smooth plain areas
- MDIS North Polar Mosaic as basemap
- Each crater mapped in CraterTools [1] in ArcMap; used only craters with MLA shot data from the final PDS release within 30% of the crater center retained in final count
- Crater depth determined using evolution difference between maximum and minimum MLA shot

(2) MDIS-derived stereo DTMs
- Lower altitude smooth plains
- Crater rims mapped on orthoimages associated with each DTM
- From mapped crater, elevation data were extracted and converted to radial profiles from co-aligned DTMs.
- Minimum and maximum elevations used to compute the depth

Comparing the diffusivities inferred above for 2.5 to 5 km craters on the Moon (~9 m²/Myr) and Mercury (~24 m²/Myr) suggests a factor of two-to-three enhancement in the topographic evolution of Mercury compared to the Moon. This may be scale-dependent [8], but represents our best current estimate for the relative rate of landform evolution between the two bodies.

3. Study Areas
Polar (cyan) and non-polar (red) measurement areas within smooth plains. Polar study area craters measured with MLA profiles; non-polar regions examined with MDIS stereo DTMs. Purple area outlines mapped extent of the smooth plains.

4. d/D on the Smooth Plains and Lunar Maria
Frequency distribution of depth/Diameter (d/D) values superposed on:
(a) northern smooth plains of Mercury using MLA profiles,
(b) other smooth plains on Mercury from MDIS data,
(c) combination of all smooth plains measurements,
(d) for craters that post-date the lunar maria from Fassett and Thomson, 2014 [4] measured using the Terrain Camera DTM [5].

5. Inferred Diffusion Rates
Frequency distributions of inferred degradation state (κt) for craters on:
(a) Mercury, derived from d/D
(b) the Moon, inferred by fitting diffusion profiles [4].
(c) Mercury, assuming these craters formed over an age of 3.7 Ga for Mercury’s smooth plains and a chronology model for porous crust [7],
(d) the Moon, assuming an average age of 3.44 Gyr for the maria region measured by [4].

6. Implications / Discussion
The more rapid degradation of craters and faster topographic evolution on Mercury inferred here are consistent with several independent observations of the surface of Mercury:
- Evidence suggests regolith thicknesses enhanced by a factor of 3 over the Moon [9,10].
- Optical maturation of rays is enhanced by a factor of up to four on Mercury compared to the Moon [11].

One enduring mystery about Mercury is that no part of its surface is as densely covered by craters of ~20 to 100 km in diameter as the lunar highlands. One common explanation is that Mercury resurfaced by volcanism at essentially global scales [12,13,14]. One alternative is that Mercury’s inter-crater plains experienced faster topographic evolution than the lunar highlands.

References:

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