A THICKER REGOLITH ON MERCURY.

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The scale-dependence of roughness contrasts, and the morphology of small craters in smooth plains suggest that regolith on Mercury is thicker than on the Moon.

Introduction: The surface of the Moon is covered with a layer of regolith, fragmental, highly heterogeneous material. Formation, modification and transport of the regolith occur due to meteoritic and micrometeoritic impacts and a number of other processes [1]. There is no doubt that a similar regolith layer exists on Mercury; however, observations about its nature and thickness have been limited by the absence of high-resolution information. Here we analyze data obtained by the MESSENGER mission to Mercury and outline two lines of evidence suggesting that the regolith on Mercury is significantly thicker than on the Moon.

Scale dependence of roughness contrasts: High-precision data from orbital laser altimeters have been used to map kilometer- and sub-kilometer-scale topographic roughness of the entire Moon [2] and for the northern circumpolar area of Mercury [3] where MLA data are dense and of highest quality. The primary feature of kilometer-scale roughness maps for both bodies is the dichotomy between topographically smooth volcanic plains (maria on the Moon and smooth plains [4,5] on Mercury), and topographically rough terrains (highlands on the Moon and cratered and intercrater plains [6] on Mercury). The roughness contrast between these smooth and rough terrains is higher at larger scales (longer baselines) and lower at smaller scales (shorter baselines) (**Fig. 1**). The observed decrease of the contrast at sub-kilometer baselines has been explained [2,3] by the fact that topography at these scales is primarily controlled by regolith formation and transport and is thus less sensitive to bedrock geology; the topographic roughness is defined by equilibration of roughening due to formation of sub-kilometer-size craters and smoothing due to regolith gardening. **Fig. 1** shows that this roughness contrast decrease on Mercury occurs at longer baselines than on the Moon. This suggests that on Mercury the equilibrium between cratering and regolith gardening is reached at scales a factor of 3 longer. This in turn suggests more intensive regolith gardening and/or a thicker regolith on Mercury; we test this hypothesis by examining small fresh regolith impact craters.

Morphology of fresh small craters: Many fresh small (10 to 100 m) craters on the Moon, mostly on maria, have specific morphologies characteristic of impacts into a layered target with a weaker (regolith) layer on top of stronger (bedrock) material [7]. These morphologies include central-mound, flat- and hummocky-bottom, and concentric double-ring craters (**Fig. 2**); they can be used to estimate thickness of the regolith [8]. Thickness of lunar regolith measured with this method [9] varies from 2 - 5 m for maria to 5 - 8 m for highlands.

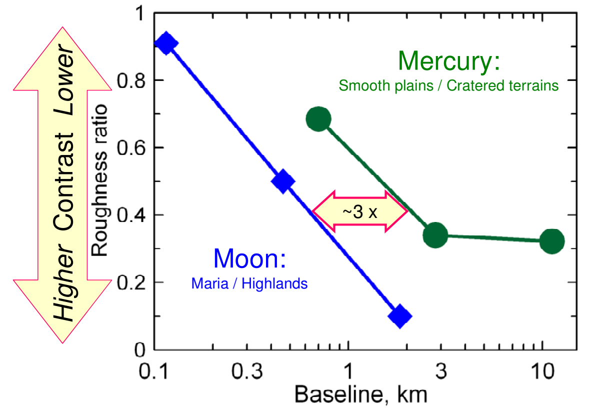

Fig. 1. Ratio of topographic roughness of smooth and rough terrains as a function of spatial scale. A small ratio means a high roughness contrast between smooth and rough terrains.

We are systematically searching for similar morphologies on Mercury with high-resolution MDIS NAC images. Thus far, we have surveyed ~800 individual 1 Mpix MDIS images with resolutions better than 14 m/pix and found over 100 craters with similar morphologies, but with diameters larger than on the Moon (**Fig. 2**), and ~100 ambiguous craters, where such morphologies are suspected, but not clearly seen given image noise and resolution. In comparison to the Moon, such craters are not abundant: 49% of surveyed images within smooth plains [5] and 89% of them outside the smooth plains do not have craters with such morphologies. Inside and outside smooth plains, 22% and 4% of the images, respectively, contain craters with clear morphologies of this kind (Fig. 2); the rest of the images (29% and 7%, respectively) contain ambiguous craters. The weak layer thickness estimated with the same method [8] ranges from 20 m to 90 m.

Do these estimates indeed indicate a thicker regolith layer on Mercury? A small proportion of craters 100s of m size in the lunar highlands have impact melt pools on their floors [10,11], which are clearly seen in sub-meter resolution LROC NAC images. At the order of magnitude lower resolution of MDIS NAC, such melt pools can be misinterpreted as flat floors or hummocky floors of the craters. Some unusually large landslides or a small crater superposed over a larger one could mimic the central mound. It is quite possible that all sporadically occurring ~15 central-mound and flat-floored craters that we documented outside the smooth plains are unrelated to the regolith layer. In smooth plains, however, the specific morphologies appear systematically, a few craters per images, and this does not appear to be a rare sporadic phenomenon. Moreover, in some places we see a consistency of estimated weak layer thickness between several craters located close to each other. These preliminary observations suggest that we do observe a ~25 - 40 m thick regolith in smooth plains on Mercury. Continuation of the survey will update these preliminary results.

Discussion: What would cause a thicker regolith on Mercury in comparison to the Moon? The typical density of large (>10 km) craters on smooth plains [5] is similar to the lunar maria. A higher escape velocity and gravity increase the relative rate of formation of secondary craters per each primary; these increase the cumulative density of 10s and 100s of m crater-forming impacts and this increases the regolith formation rate in comparison to the Moon. The micrometeoritic bombardment on Mercury has been argued to be orders of magnitude more intensive than on the Moon [12,13], which is probably the main contributor to a thicker regolith. Such an intensive gardening could be responsible for the quick disappearance of the characteristic crater morphologies and the low number of such craters. If diurnal thermal expansion makes a significant contribution to regolith formation through disintegration of rocks [14], then the higher day/night temperature amplitude on Mercury also speeds up regolith formation.

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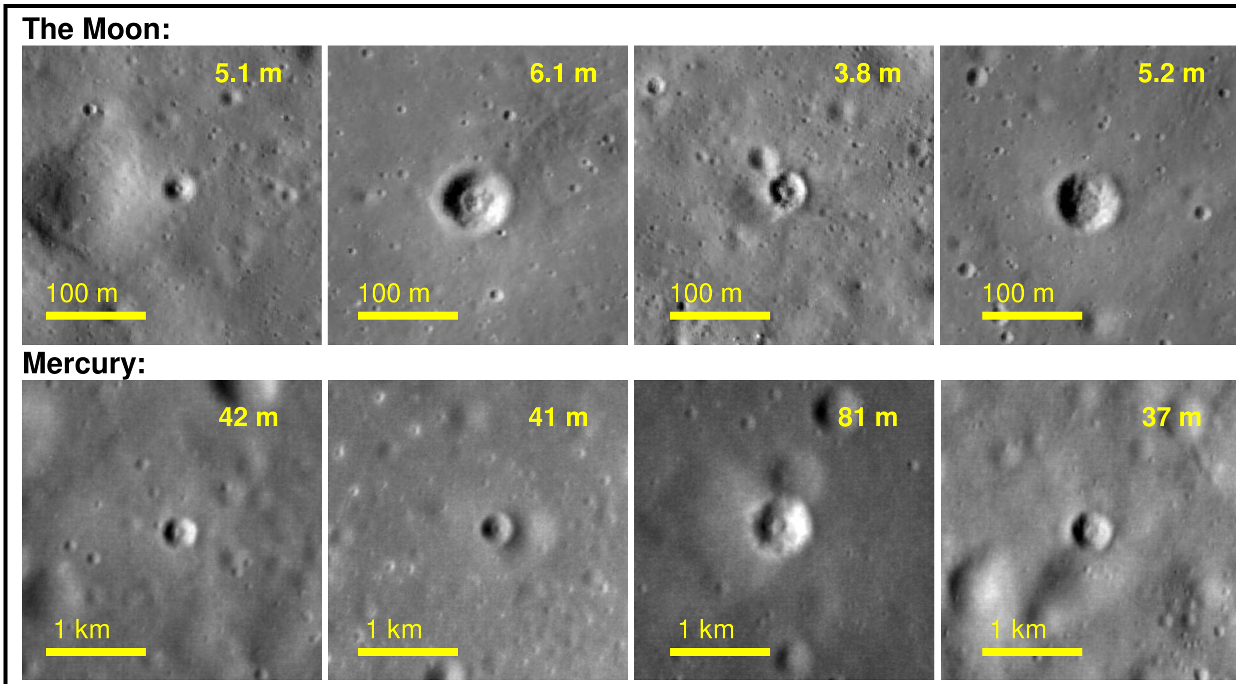

Fig. 2. Upper row, four examples of mare craters on the Moon that show morphological evidence of layered target. Lower row, examples of craters on Mercury with similar morphologies. Note one order of magnitude difference in scales between the Moon and Mercury. Regolith thickness estimated according to [8] for each crater is listed in each image.