SMALL FLAT-FLOOR AND KNOB-FLOOR CRATERS ON THE MOON AND MERCURY: IMPLICATIONS FOR REGOLITH THICKNESS. A. Yu. Zharkova[1,2], M. A Kreslavsky[3], and J. W. Head[4], [1]Moscow State University of Geodesy and Cartography (MIIGAiK), Moscow, Russia, [2]Sternberg Astronomical Institute, Moscow State University, Moscow, Russia, a_zharkova@miigaik.ru, [3]Earth and Planetary Sciences, University of California – Santa Cruz, Santa Cruz, CA, 95064, USA, mkreslav@ucsc.edu, [4]Earth, Environmental and Planetary Sciences, Brown University, Providence, RI 02912, USA.

Introduction: The surfaces of the Moon and Mercury (as well as other large atmosphereless bodies) are covered with a layer of heterogeneous fragmental regolith material. The presence of this mechanically weak regolith layer leads to diverse morphologies of small impact craters: double-ring craters, craters with flat floors, and craters with central knobs ("knob-floor" craters). They were first documented on the Moon [e.g., 1, 2] long ago and used for regolith thickness estimates. New high-resolution images of the Moon have enabled more systematic measurements of regolith thickness on the Moon with small craters [3, 4]. The median inferred regolith thickness has been shown [4] to vary from 2.5 – 3 m in younger lunar maria to 7 – 8 m in highlands. We have applied the same method to small craters on Mercury seen in 15 – 20 m/pix images [5, 6] and obtained 25 – 40 m regolith thickness in the smooth plains on Mercury. However, the resolution of the images we used would not allow measuring typical lunar thicknesses, and therefore those results should be considered with caution, despite the fact that other lines of evidence suggest a higher regolith thickness on Mercury in comparison to the Moon [6, 7]. Here we report on preliminary results of regolith thickness measurements on Mercury with images of the highest available resolution. We also reassess the results [4] for the Moon.

Nature of small flat-floor and knob-floor craters on the Moon: The results of lunar regolith thickness measurements [4] have one striking peculiarity. Typical variations of thickness derived from different craters within the same site are reasonably narrow: the interquartile range [4] is about a factor of 2 wide. However, the highest measured values are extremely high, more than an order of magnitude higher than the median values for the same site. This suggests that those extreme estimates are outliers that likely do not represent true regolith thickness.

We examined a number of high-resolution LROC NAC images of the Moon focusing on small (< 1 km) fresh double-ring, flat floor and knob-floor impact craters. We found a number of convincing examples, where such morphologies were not related to regolith. Example in **Fig.1** is taken from Oceanus Procellarum. Two small knob-floor and flat floor craters suggest ~ 5 - 8 m thick regolith here, which is typical for younger mare surfaces [3]. The large crater in Fig. 1 has a prominent knob on its floor; however, the crater is too large to attribute knob formation to the weak regolith layer. Such morphology is rare; however, we encountered a number of examples of knobs in 50 – 500 m craters that are certainly unrelated to the regolith-substrate interface. They occur everywhere on the Moon, both on maria and highlands. The outliers in the data set in [4] are likely to be such craters. The mechanism of formation of knob-floor craters is not obvious. They are too small for formation of classic central peaks. Layered target rocks or random peculiarities (large slides) during the crater modification stage are possibilities. In some cases, it is not excluded that a low-velocity subsonic secondary projectile was incompletely destroyed.

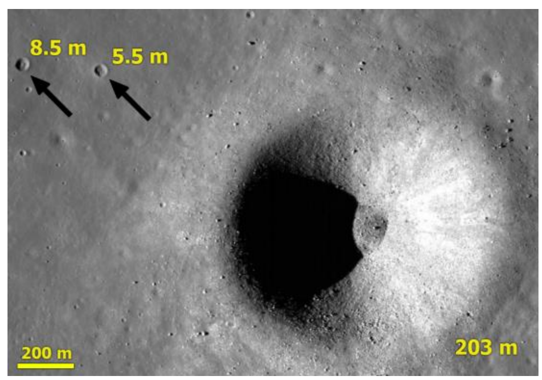

Fig. 1. From LROC NAC image M1188670635L

Within a very young volcanic unit in Oceanus Procellarum [8] we observed populations of 100s-m-size flat-floored craters. The depth of their flat floors is tens of meters, too thick for the young mare regolith. We interpret flat floors of these craters to be caused by the presence of a few-meter thick mechanically weak paleoregolith layer between volcanic units of different ages. This observation opens new possibilities for studies of stratigraphy of volcanic units on the Moon and possibly on Mercury.

Mercury data set and survey: We visually surveyed images obtained by the Narrow Angle Camera (NAC) of the Mercury Dual Imaging System (MDIS) instrument [9] onboard the MErcury Surface, Space ENvironment, GEochemistry and Ranging (MESSEN-

GER) orbital mission to Mercury. We chose the highest resolution images (<2.5 m/pix sampling) acquired toward the end of the mission (Feb.–Apr. 2015). Individual images are small (0.25 Mpix), have a considerable amount of smear, low signal-to-noise ratio (because of the short exposures needed to keep smear reasonable), and do not overlap: the distance between them (~15 km) is much greater than the image size (~0.5 – 1 km). Totally ~3000 such images have sufficient quality for our study. These images are scattered in a region delimited by 40 – 70°N and 210 – 320°E.

We documented all occurrences of small (< 1 km) double-ring, flat-floor and knob-floor craters in the surveyed images. On the basis of lunar experience, we distinguished morphologies related to the weak regolith layer and others. The results are less objective than in the case of the Moon due to the lower image quality.

Where possible, we measured the inferred weak layer thickness. We use two different methods. One is fitting two circles following the recommendations in [3] and assuming the slope of 31°. The other method is using shadow length from the crater rim to a place on the floor estimated to be located at the weak layer / strong layer interface level. In several cases we were able to use both methods, and the results were consistent within ~30%, which corresponds to the formal precision of geometric measurements. **Fig. 2** illustrates our ability to identify small double-ring craters and measure thin regolith, despite low image quality. Here flat-floor and double-ring craters give consistent estimates of 3 - 4 m regolith thickness.

Regolith thickness on Mercury: Regolith is thinner at the site in Fig. 2 than typical lunar mare regolith. This is not surprising, because this site is located at the proximal ejecta of a very young unnamed 34-km crater at 64.6°N 104.6°W. Morphologies observed in that crater are very similar to those in Copernican age craters on the Moon.

Typically, the inferred regolith thickness on Mercury is higher than on the Moon; estimates of 8 – 20 m are typical. Fig. 3 illustrates some of the difficulties inherent in thickness measurements. In this unique site a number of flat-floor and knob-floor craters are observed. A few craters give consistent thickness values of 13 – 16 m for the weak layer, while the largest crater gives ~37 m. We interpret the smaller craters to represent the 13 – 16 m thick regolith, while the large crater to be unrelated to the regolith layer. However, if only one knob-floor crater is observed in a frame, it may be difficult to judge whether the crater is related to thick regolith, or the knob formation is unrelated to regolith.

Despite the uncertainty discussed, our measurements clearly indicate a thicker regolith on Mercury in comparison to the Moon. This is consistent with independent evidence from topographic roughness contrasts [7]. A thicker regolith implies a higher regolith formation rate, which could be caused by a higher micrometeoritic bombardment intensity and/or a higher diurnal surface temperature amplitude. The higher regolith formation rate is also consistent with the observed higher rate of simple crater degradation on Mercury in comparison to the Moon [10].

References. [1] Oberbeck V. & Quaide W. (1967) JGR, 72, 4697. [2] Quaide W & Oberbeck V. (1968) JGR 73, 5247. [3] Bart, G. (2014) Icarus 235, 130. [4] Bart, G. et al. (2011) Icarus 215, 485. [5] Zharkova, A. et al. (2015) AGU FM, P53A-2099. [6] Kreslavsky M. & Head J. (2015) LPSC 46, #1246. [7] Kreslavsky M. et al. (2014) *GRL* 41, 8245. [8] Hiesinger H. et al. (2003) *JGR* 108, 5065. [9] Hawkins S. E. et al. (2007) Space Sci. Rev. 131, 247. [10] Fassett C. et al. (2017) GRL 44, 5326.

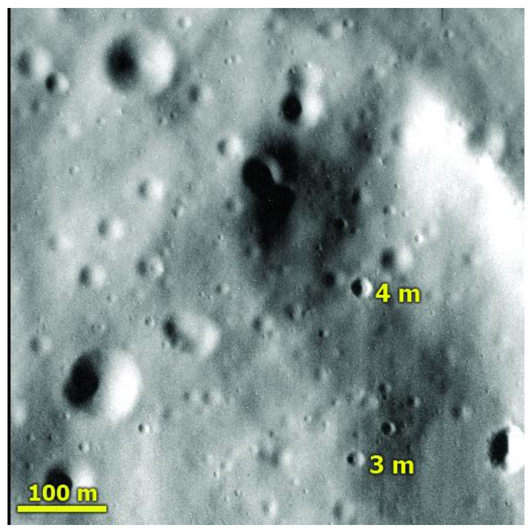

Fig. 2. From MDIS NAC image CN1067123670M

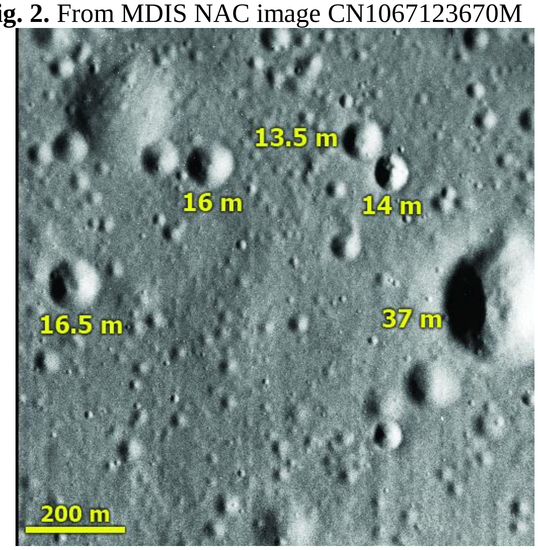

Fig. 3. From MDIS NAC image CN1066378907M