MORPHOMETRY OF SMALL IMPACT CRATERS IN THE LUNOKHOD 1 STUDY AREA.

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Introduction: Small impact craters are the dominant surface features on the Moon and were under extensive studies in 1960-70s [e.g., 1-6]. Those works showed that these are craters of a few meters to 1-2 km in diameter, having different morphology, which is a function of the crater age and size; their population can be subdivided into two parts: 1) growing with time production subpopulation, and 2) equilibrium subpopulation, within which the number of craters formed per unit time is approximately equal to the number of craters destroyed for that time. In those works morphology of the studied craters was mostly characterized in qualitative way (prominent, with sharp or subdued rims, deep, shallow, etc.). The key quantitative characteristics such as crater depth/diameter ratio and steepnes of the crater inner walls could be determined only in limited cases. Now with high-resolution (0.5-1.5 m) images taken by Lunar Reconnaissance Orbiter Narrow Angle Camera (LROC NAC) [7] and derived DTMs it is possible to revisit characteristics of small impact craters in a more quantitative way. This is important to better understand the processes of craters formation and evolution and develop accurate engineering models of lunar surface, which are necessary for reliable lander design and safe landing. We do this work through analysis of morphometry of small impact craters of the Lunokhod 1 study area, which is considered to be a typical sample of lunar mare terrain [8].

Work results: This work is based on analysis of LROC NAC images with resolution 0.46 to 1.6 mpx for the Lunokhod 1 area (8.7 km^2). The stereo pair M150749234/M150756018 was used at DLR, Berlin, to produce a DTM with 0.5 m horizontal resolution and 1 m vertical accuracy [9]. Fig. 1 shows ~8,000 craters ≥7 m in diameter for which we determined diameters (*D*) and depths (*H*) using this DTM, and calculated *H*/*D* ratios.

Fig. 2 is a diagram showing the craters' *H*/*D* plotted against *D*. Thick horizontal line represents *H*/*D* = 0.19, which is characteristic of a crater of parabolic cross-section with maximum inner slope steepnes of 35º, that is the angle of repose. We anticipate that all craters should have *H*/*D* below this value. It is seen on the diagram that craters of 7 to 20 m in diameter have noticeably larger range of H/D, that is probably an artefact due to insufficient accuracy of the DTM for the craters of this size. So below we work only with 932 craters >20 m in diameter (see arrows in Fig. 2).

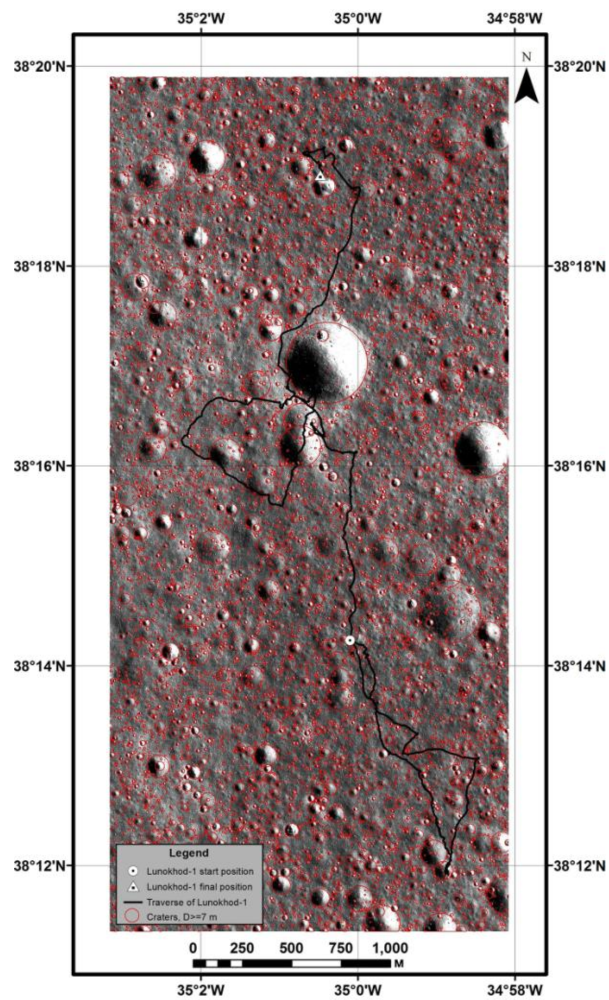

Figure 1. Craters ≥7 m in diameter in the study area.

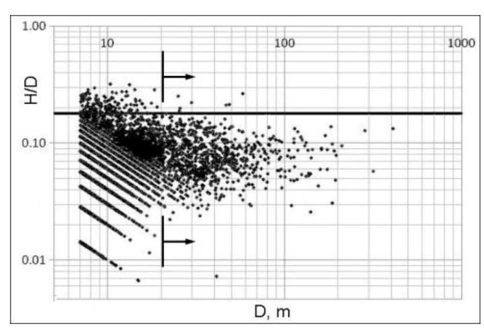

Figure 2. Diagram showing H/D as a function of D. Arrows show the domain of reliable H/D measurements.

We subdivided the subpopulation of these craters into four parts, 233 craters in each, with diameters: 1)

20 to 25.4 m, 2) 25.4 to 33 m, 3) 33 to 46.07 m, and 4) >46.07 m; for each part we considered *H*/*D* frequency distribution (Fig. 3). No systematic trend of *H*/*D* distribution is seen in Fig. 3. The Kolmogogov-Smirnov test showed that probability that *H*/*D* distribution is different between part 1 and part 2 is 70%, between part 2 and part 3 is 79% and between part 3 and part 4 is 98%.

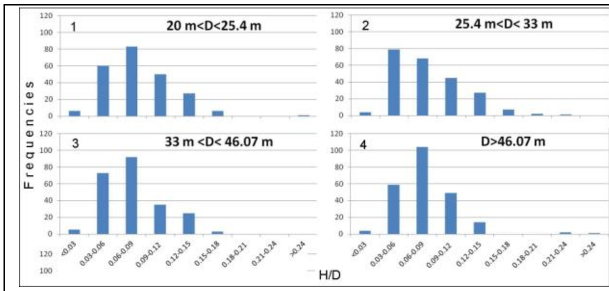

Figure 3. Distribution of H/D in four different in crater diameters parts of the studied crater subpopulation.

We also studied another important parameter of crater morphometry, the maximum steepness of crater inner walls. This was done using two techniques. First, within the three different in size parts of crater population (25.4 to 33 m, 33 to 46.07 m, and >46.07 m) we randomly selected samples consisting of 40 craters each. For each of these 120 craters using DTM we produced a topographic profile along diameter and found its steepest 0.05*D*-long section.. We measured the mean steepness within this section and referred it as the maximum slope. The measured maximum slopes were found to be from 7º to 28º and, as expected, correlate well with *H*/*D* values (Fig. 4).

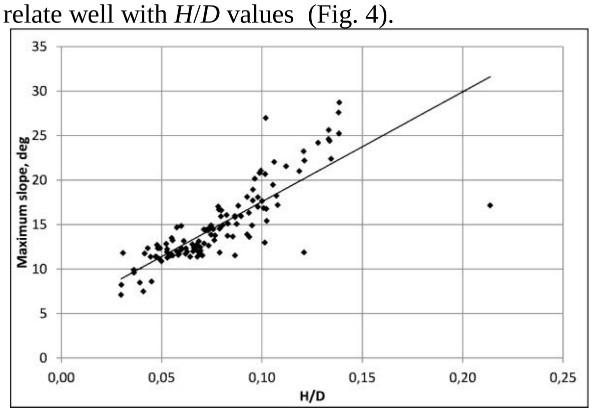

Figure 4. Mean slopes of 5% steepest sections of crater profile as function of crater *H*/*D*.

Another technique to measure maximum steepness of craters' inner walls involved DTM-derived artificial hillshade images with different simulated "Sun elevation". The highest "Sun elevation" at which in the given crater visible shadow appeared is considered as an estimate of the maximum steepness of the crater inner slope. Figure 5 shows an example of this approach: On the image with the 15° "Sun elevation" (Fig. 5a) craters 1, 2, 3, and 4 show shadow in their NW parts; at the 25° "Sun elevation" (Fig. 5b) only craters 3 and 4 show shadow while craters 1, 2 do not. This procedure was applied to all craters ≥20 m in diameter and the diagram showing the maximum slope steepnes as a function of H/D was produced (Fig. 6). Broad range of H/D in each maximum slope category may reflect the real variation of this parameter but partly may be due to our coarse binning of the maximum slope values.

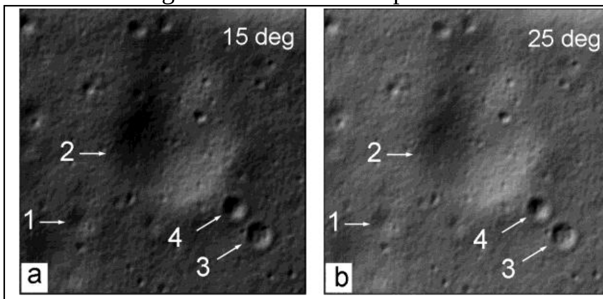

Figure 5. Hillshade images of craters produced for 15 and 25° of "Sun elevation".

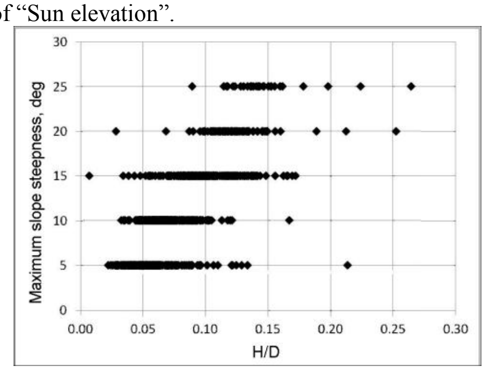

Figure 6. Diagram showing the maximum slope steepnes as a function of crater H/D.

Summary: Diameters, depths and maximum steepnesses of inner walls of small impact craters of the Lunokhod 1 study area were measured. We plan to continue this analysis in particular to estimate how significantly craters in their evolution from fresh to mature change their diameters and to revise the earlier suggested in [6] technique of estimation of crater age based on crater size and morphologic appearance.

References: [1] Trask N.J. (1968) *Booklet accompanying USGS maps I-616 to I-627*, 32-800. [2] Pohn H.A. and Offield T.W. (1970) *USGS Prof. Paper 700C*, C163-C169. [3] Shoemaker E.M. (1971) *Deputacion provincial Barcelona*. Instituto de investigaciones geologicas, 25, 27. [4] Florensky C.P. et al. (1972) In: *Modern Conceptions on the Moon*, Nauka, Moscow, 21-45. [5] Swann G.A. (1974) *Lunar Sci. V*, 761-763. [6] Basilevsky A.T. (1976) *Proc. Lunar Sci. Conf. 7th*, 1005-1020. [7] Robinson M.S. et al. (2010) *Space Sci. Rev.* 150, 81-124. [8] Florensky C.P. (1972) *Space Res. XII*, Academie Verlag, Berlin, 107-121. [9] Oberst J. et al. (2010) *LPSC XLI*, #2051.