DEGRADATION RATE OF SMALL CRATERS IN LUNAR HIGHLANDS. ***M. A. Kreslavsky***[1], ***N. A. Kozlova***[2], ***A. T Basilevsky***[3], and ***I. P. Karachevtseva***[2], [1]Earth and Planetary Sciences, University of California - Santa Cruz, 1156 High Str., Santa Cruz, CA, 95064, USA, mkreslav@ucsc.edu, [2]MIIGAiK Extraterrestrial Laboratory, Moscow State University of Geodesy and Cartography (MIIGAiK), Moscow, Russia, [3]Vernadsky Institute, Moscow, Russia.

Introduction: Small impact craters are the dominant surface features on almost all terrains on the Moon and many other bodies. On the Moon craters with diameter *D* smaller than a few hundred meters form an equilibrium population, that is the formation of new craters is balanced by obliteration of old ones: craters degrade getting shallower and softer with time and finally disappear. Since small fresh craters of the same *D* are approximately similar, crater depth can be used as a proxy for crater degradation state and therefore, its age. High-resolution digital topography models (DTM) that have become available recently enabled its quantitative analysis [1-3]. Here we report preliminary results from our new quantitative study for two typical highland sites.

Measurements: For morphometric measurements of small craters we used high-resolution DTM obtained by photogrammetric processing of stereo pairs of LROC NAC images. We chose two typical highlands areas referred in the official LROC PDS release as "LUNA20-1" (4ºN 56ºE, 137 km^2) and "FEOKTISTOV" (32ºN 140ºE, 194 km^2) DTM products. These DTM have 2 m/pix sampling. We identified all small impact craters sufficiently well resolved by the DTM (~9000 for both sites combined) and measured their *D* with Cratertool plugin for ArcGIS [4]. Size-frequency distributions (Fig. 3) suggest that the survey is close to complete for $D > \sim 20$ m and $D > \sim 30$ m for these sites, respectively. We applied an original ArcGIS plugin [5] for automated extraction of several other morphometric parameters: crater depth d' with respect to surroundings (Fig. 2), rim height $d\text{-}d'$, and missing volume. All these measurements are taken with respect to inclined plane approximating surrounding surface at the distance of *D* from the rim; this is essential due to the ubiquity of kilometer-scale slopes (6 - 10º) in the highlands [6].

We use d'/D as a measure of crater degradation state; traditionally used depth *d* with respect to the rim is not suitable for small craters, because degraded craters usually do not have apparent elevated rims. Since the craters degrade down to disappearance, identification of the most degraded craters cannot be objective.; We have found [1] that craters with $d'/D > 0.05$ are identified reliably; we use only such craters fro further quantitative analysis. **Fig. 1** shows size-frequency distributions for craters with $d'/D > 0.05$ for both sites (exclusion of craters with $d'/D < 0.14$ in Fig. 1 has a very minor effect; see the next paragraph). It is seen that the equilibrium crater density on the ancient farside highlands (FEOKTISTOV) is greater than on Crisium basin ejecta (LUNA20), although both are typical highland terrains. We assumed that the crater population is in equilibrium, *D* does not change in the course of degradation and cratering rate is described by Neukum production function (NPF) [7]. Under these assumptions, the spatial density of craters of a given size gives the time needed to reach $d'/D = 0.05$. This time, for example, for D~80 m craters is ~110 Ma (170 Ma) for LUNA20 (FEOKTISTOV) site.

Fast and Slow Degradation Regimes: Cumulative frequency distributions of d'/D are shown in **Fig. 2**. The distributions for both sites are remarkably similar to each other; moreover, they are also similar to those for mare sites studied in [1]. If we assume that the crater population is in equilibrium and that crater diameters are not changed in the course of degradation, the steepness of the distributions in Fig. 2 is proportional to the crater degradation rate [1]. Fresh craters with high d'/D degrade quickly, and the degradation rate decreases sharply in the course of degradation. When d'/D decreases down to ~0.14, the degradation rate becomes constant or only slowly decreasing. We have argued [1] that quick degradation of fresh (d'/D>~0.14) craters occurs primarily due to regolith slides and avalanches on steep crater walls, while further slow degradation (d'/D<~0.14) occurs due to regolith gardening processes. The particular transition d'/D~0.14 calculated as described in [1] is the same for highland (this study) and mare [1] craters.

Topographic Diffusion Model: Topography evolution caused by micrometeorite-induced regolith gardening has been shown [8] to be described by diffusion equation. In [9] degradation of larger (D = 0.8 - 5 km) mare craters has been successfully modeled with diffusion equation, and diffusivity estimate $K = 5.5$ m^2/Ma has been obtained. We tried to model degradation of small craters in the slow regime (d'/D<0.14) with diffusion equation. We chose a realistically-looking initial radial profile of an axially symmetric model crater (black line in **Fig. 3**) conveniently described by simple functions (a Gaussian dome with a paraboloid cavity; this enables analytic solution of the diffusion equation). For this model the initial $d/D = 0.2$ (with respect to the rim), and there is no missing volume. Under these assumptions, the time needed to evolve from $d'/D = 0.14$ (red curve in **Fig. 3**) to $d'/D = 0.05$ (green curve) is $0.048D^2/K$. We again assumed that the crater population is in equilibrium, D does not change in the course of degradation, and cratering rate is described by NPF [7]. The modeled size-frequency distribution is shown in **Fig. 1** with blue line. It is seen that K from [9] correctly predicts the order of magnitude for the equilibrium crater density, however, the modeled distribution is much shallower than the observed ones. Variation of K would shift the modeled distribution (Fig. 1) up or down, but would not change its slope: the slope is defined by the NPF slope and the fact that for diffusion the all times are proportional to D^2.

Discussion: The discrepancy between the model and the observed population is caused by failure of one or several model assumptions. Although the absolute value of cratering rate for small craters is not well defined, the slope of the NPF is hardly too wrong, and our *choice of NPF cannot account for the discrepancy*. Our assumption of constant D is certainly wrong: *craters expand in the course of degradation*. For the particular model shown in Fig. 3 this expansion is insufficient to account for the observed discrepancy. However, our measurements show that, unlike for the model in Fig. 3, real craters often have non-zero missing volume. Modeling shows that expansion of craters with missing volume is more pronounced than in Fig. 3. We are working on a more realistic diffusive evolution model that takes crater expansion into account. It is possible, however, that *crater evolution is not described by topographic diffusion*, for example, it is not excluded that deposition of ejecta from distal impacts plays a greater role in crater degradation than local transport induced by micrometeorites and described by the diffusion equation. Finally, it is not excluded, that the "equilibrium" *population of craters is not in the detailed equilibrium state*, for example, crater degradation and obliteration might be dominated by rare resurfacing episodes (earthquakes, large distal impacts, etc.) with gradual accumulation and minor degradation between them.

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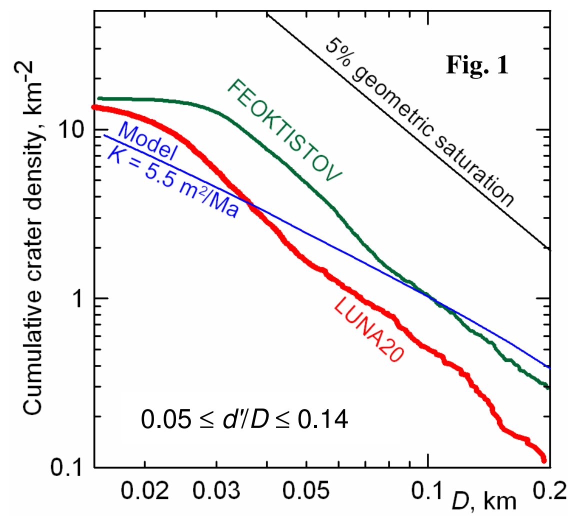

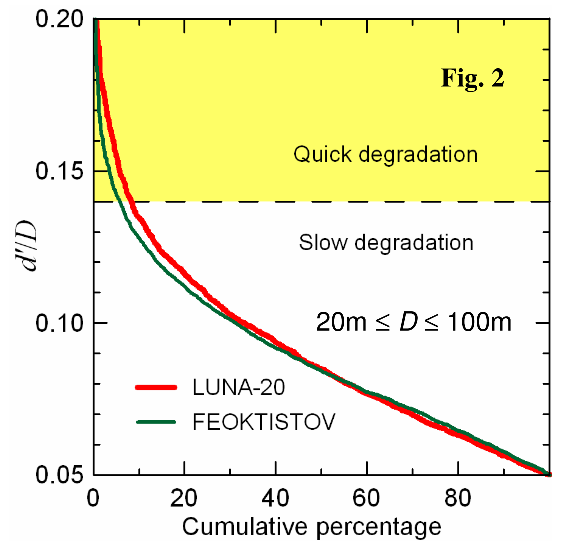

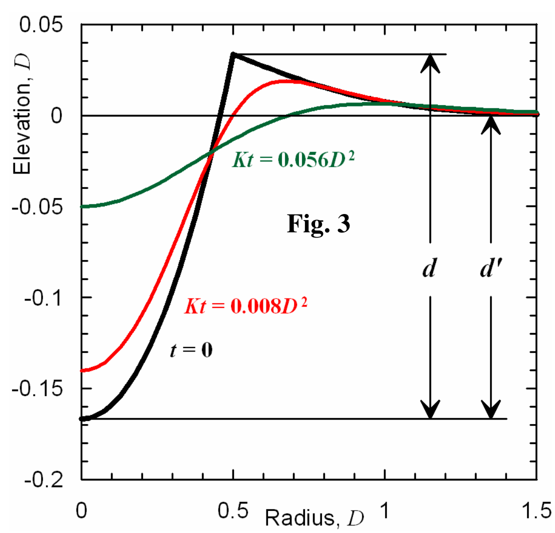

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