CRATER WIDENING – IS SFD MORE STEEP THAN PRODUCTION FUNCTION? B. A. Ivanov, Institute for Dynamics of Geospheres, RAS, 119334, Moscow, Russia, baivanov@idg.chph.ras.ru, boris_a_ivanov@mail.ru.

Introduction: New LROC images and DTM expand our understanding of small (diameters less than ~100m) impact crater evolution [1, 2, 3]. The new data allow us to measure crater degradation [2, 3] and to discuss small crater equilibrium in the new data context.

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Small crater degradation: It is well known that the number of small craters per unit area is limited as older craters vanish due to degradation and younger crater overlapping. Key ideas and references one can find in [4, 5, 6]. The observation of just formed new impact craters [7] creates the basis for study of the crater shape evolution from the crater birth to the degradation toward the unobservable state.

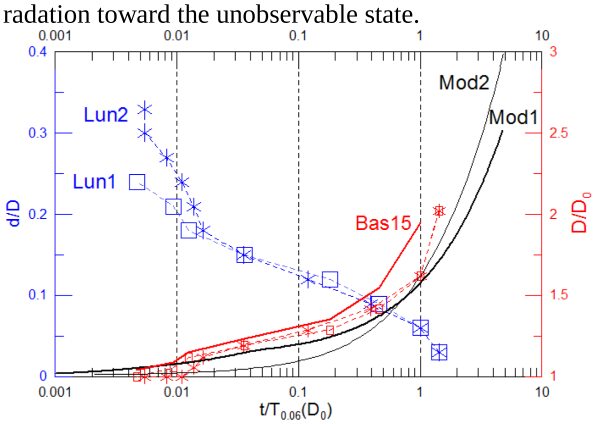

Fig. 1. Small lunar crater degradation expressed as *d/D* (left blue axis, blue signs) vs. relative time $t/T_{0.06}$ where $T_{0.06}$ is the diameter-dependent time when a crater degrades to *d/D*=0.06. The crater widening (right axis) is estimated assuming the constant volume for (1) truncated cones with observed *d/D* and slope angles (red signs) and (2) spherical segments [14] (red curve marked as Bas15. Soderblom's diffusion models (black curves) are computed for the constant diffusivity (Mod1) and diffusivity enhanced factor of 30 for steep angles (Mod2).

Observations. The massive crater count in Lunokhod 1&2 areas [2] with DTM-based depth, *d*, and crater slope, α, measurements demonstrates that small lunar craters with 20m<*D*<200m are in equilibrium – in all *D* bins statistics of *d* and α is the same. Hence the cumulative number of craters *N*(<*d/D)* as a time scale proxy. We normalize time with the value $t/T_{0.06}$ (Fig. 1).

Following Sasha Basilevsky [14] one can estimate the crater widening assuming the constant crater volume (Fig. 1). A crater with *d/D*=0.06 (C-class) may be a factor of 1.5 to 2 wider than the fresh crater (A-class). These simple estimates are supported with the crater degradation modeling.

Degradation modeling. We repeat the most simple model of the crater erosion due to smaller impacts. The downslope material motion is numerically simulated with the diffusion model [8, 9, 10]. To mimic the possible non-linear diffusion [11] we test the option to have 2 to 100 times faster diffusion at steep slopes – in the spirit of [2] where landslides at steep crater slopes move material faster than by small cratering mass motion in [8]. We find that the crater rim crest diameter (taken as the point of the maximum rim elevation) is increased factor of 1.5 to 2 before *d/D* decreases to the unobservable value of about 0.03 [2, 3]. The effect is visible but not discussed explicitly in [9], and missed in [8] where the author has used only one Bessel function having constant max and min distances. The correct expanding over Bessel functions is used in [10].

SFD near equilibrium: The main idea how the crater widening could affect the small crater SFD is shown in Fig. 2.

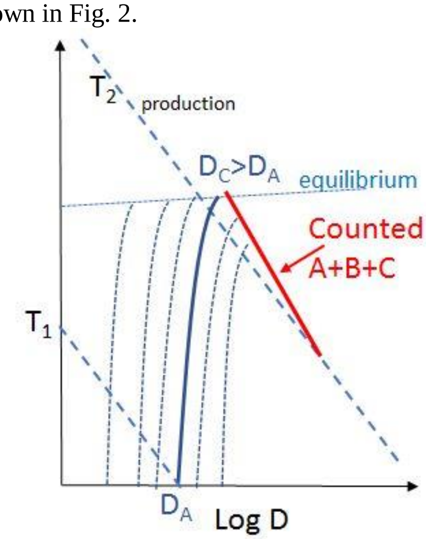

Fig. 2. The general draft of the main point: At the time moment T_1 a crater with the diameter D_A is formed. At the time T_2 this crater degrades (via class B) to the C-class and later vanishes from a crater count near to the equilibrium level. However, the crater diameter increases with aging ($D_C>D_A$) and before extinction the crater "moves" right to the next crater counting diameter bin.

Fig.2 shows that near to the equilibrium the number of craters (old C-class craters are in majority), counted in the given diameter bin is larger than the number of craters from the production function.

We have made an attempt to test the crater widening effect with a simple Monte-Carlo modeling. The model generates "craters" in a wide range of diameters with the random number generator. The SFD of fresh craters gives $N>D \sim D^{-3}$. Each crater evolves in a time according to the model, shown in Fig. 1.

The modeling run include 10 trials, 3 million "craters" from 1m to 100 m are generated in each trial. This number of craters allow us to use relatively narrow diameter bins D_{right}/D_{left} = 1.1. Number of craters in each bin is averaged over trials).

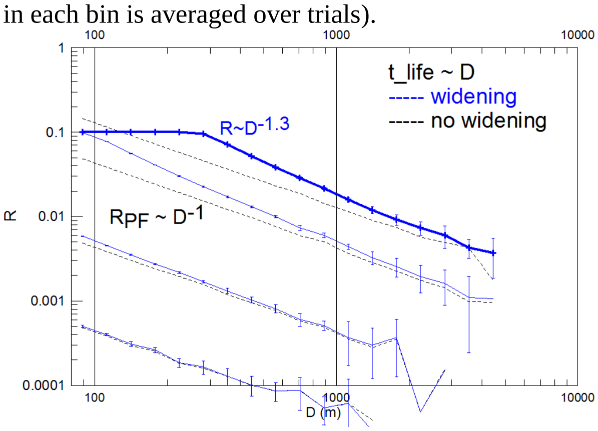

Fig. 3. Monte-Carlo modeling of the crater accumulation. In early time (craters are sparse and young) widening is not important. Close to equilibrium (R~0.1) old craters widens pushing SFD "up and right".

Fig.3 illustrates that (assuming the crater lifr time proportional to diameter) the population of all (A+B+C) craters is steeper ($R \sim D^{-1.3}$) than the production function ($R \sim D^{-1}$) for fresh (A-class) craters.

Discussion and conclusion: The small lunar craters widening as they evolve along A-B-C scale of freshness could affect the SFD near the equilibrium level. Tentatively the effect may be assumed from recent crater counts with LROC images (Figs. 4 and 5, "U" mark). The presence of the effect may be checked with new crater counts provided DTM will be used to sort craters by *d/D* and α.

(1) The problem is how exact may be measured the crater rim diameter for degraded craters. It seems only DTM may help to improve degraded crater's counts.

(2) Another problem is the possible influence of the widening effect on the production function construction. The problem should be investigated with the new high resolution images.

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References: [1] Robinson M, et al. (2010) *SSR*. 150(1):81. [2] Basilevsky A.T. et al. (2014) *PSS*, 92, 77-87. [3] Mahanti P. et al. (2015) *LPSC 46th*, #1615. [4] Richardson J.E. (2009) *Icarus*, 204, 697-715. [5] Fassett C.I. and B.J. Thomson (2014) *JGRE*, 119, 2255-2271. [6] Xiao Z. and S.C. Werner (2015) *JGRE*, 120, 2277-2292. [7] Speyerer E.J. et al. (2016) *Nature 538*, 215-218. [8] Soderblom L.A. (1970) *JGR*, 75, 2655-2661. [9] Fassett C.I., and B.J. Thomson (2014) *JGRE*, 119, 2255-2271. [10] Xie, M., and M.-H. Zhu (2016) EPSL, 440, 71-80. [11] Minton D.A. and C.I. Fassett (2016) *LPSC 47th*, abs. # 2623. [12] Hartmann, W. K. (1984) *Icarus*, 60, 56–74. [13] Basievsky A.T. (1976) *Proc. LPSC 7th*, pp. 1005-1020 [14] Basilevsky A.T. (2015) In: *Proc. 4th Moscow Intern. Solar Sys. Symp*. (4M-S3, A. Zakharov Ed.), p. 213-228 (in Russian). [15] Zanetti M. et. al. (2011) LPSC 42, #2330. [16] Zanetti M. et. al. (2013) LPSC 44, #1842. [17] Zanetti M. et. al. (2015) LPSC 46, #1209. [18] Xiao Z. and Strom R.G. (2012) Icarus 220, 254-267.

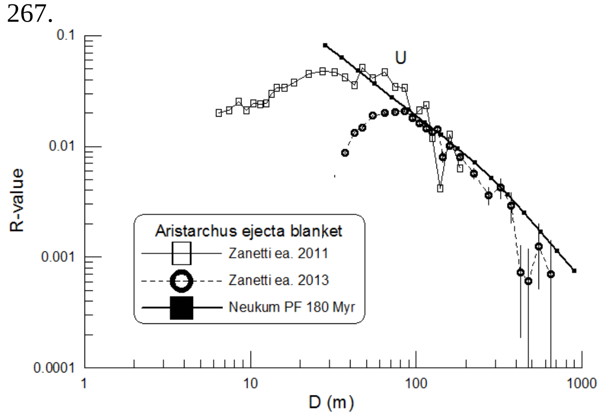

Fig. 3. Crater counts at the Aristarchus ejecta blanket [15, 16] with Neukum's PF for 180 Myr. "U" designates the possible SFD steepening near the equilibrium.

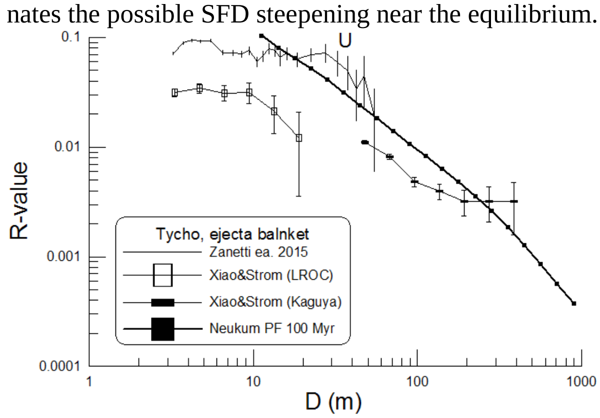

Fig. 4. Crater counts at the Tycho ejecta blanket digitized from [17, 18] in comparison with Neukum's PF for 100 Myr. "U" designates the possible SFD steepening near the equilibrium level.