ESTIMATION OF CRATER DEGRADATION RATE BASED ON CRATER STATISTICS. Yiren Chang[1], Minggang Xie[2], Zhiyong Xiao[2,1],and Xiaolin Tian[3], [1]Lunar and Planetary Science Laboratory, Macau University of Science and Technology, Macau (changchang19940104@gmail.com), [2]Planetary Science Institute, School of Earth Sciences, China University of Geosciences, Wuhan, China, [3]Macau University of Science and Technology, Macao SAR, China.

Introduction: All crater morphologies are observed in either fresh or degraded landforms [1,2]. Lunar craters evolve under the influence of the following two factors [1]: (1) the formation of impact craters by projectiles; (2) downslope movements of materials due to gravity. Although burial by lava flows can be locally important, the first affective factor is often the exclusive agents of degradation on the Moon [2]. Soderblom [3] provided the theoretical basis for the description of crater degeneration. For degradation caused by topographic diffusion, sharp terrain (or high topographic roughness) features (e.g., crater rims and central peaks) are the first to be relaxed, crater cavity is gradually filled and slopes become gentler as the visible crater diameter is enlarged [4]. As time goes on, craters are degraded and eventually fade into invisibility as their original domain is overlapped by large numbers of relatively small craters [5,2]. Fassett and Thomson [6] extracted topographic profiles for impact craters with diameter from 800 m to 5 km on lunar mare using Kaguya digital terrain models, and then characterized the degradation states of these craters using a topographic diffusion model. In their topographic diffusion mode, degradation state is described by diffusion age, kt, where k is the diffusivity, and t is time. They linked the diffusion age of crater populations to the surface age of mare units, and obtained a numerical relationship between surface age and degradation states of superposed craters. This method allows estimating ages for individual craters based on their degradation states, providing a constraint on the age of mare units, and enabling the modeling of how lunar terrain evolves as a function of its topography.

However, recent observations and theoretical calculations suggested that both k and kt are not independent on crater size. The equilibrium onset diameters reported by Xiao and Werner [7] are smaller than those predicted for same-aged surfaces by the crater degradation model of Fassett and Thomson [6]. In addition, Basilevsky et al. [8] studied the degradation state of secondary craters of Copernicus (diameter D = 93 km) and Tycho (D = 86 km) on the Moon. Their modeling results showed that the survival time of impact craters is proportional to the square of the crater diameter. Additionally, an analytic model of topography degradation showed that kt is almost proportional to crater diameter (Equation (7) of [9]). All these lines of evidence suggest that crater degradation rates depend on crater size.

Fassett and Thomson [6] obtained a numerical relationship between diffusion age $K = kt$ for a given age:

$$K_{FT}(t) = 435.83t^5 - 3621.2t^4 + 11204t^3 - 16811t^2 + 17546t \quad (1)$$

where the unit of t is Ga [4]. Equation (1) indicates that the diffusion age given by Fassett and Thomson [6] is only related to age t and is independent on crater diameter.

The updated analytic model of topography degradation given by Xie et al. [9] shows that diffusion age is not only depended on age t but also on crater diameter (D_0):

$$K(D_0,t) = \left(\frac{D_0}{800}\right)^{4.13+b} K_{FT}(t) \quad (2)$$

where D_0 is the original diameter, and b is the slope of production function. The value of b is determined to be about -3.2±0.1 [9].

Recent observations using high-resolution topography data suggested that depth-diameter ratio of small simple craters increases with diameter [10]. However, Fassett and Thomson [6] assumed a constant depth-diameter ratio of 0.218 (this corresponds to craters with diameter of ~2 km) for their studied craters. Therefore, their modeling results would have overestimated and underestimated the diffusion ages of original craters smaller and larger than ~2 km, respectively. In addition, Equation (2) depends on original diameter (D_0), but the enlargement of craters by degradation increases the diffusivity k with time, as well as kt. Therefore, in this research, we consider the above two factors to improve the understanding of the dependence of crater degradation on crater sizes and ages.

Method: Craters on the ejecta blanket of craters with known diffusion age given by Fassett and Thomson [6] are mapped, and the age of these craters can be derived by using the production and chronology functions of Neukum et al. [11]. Then, we will investigate the dependence of diffusion age on time and crater sizes.

We selected 29 craters with different diameters and degradation states at Mare Serenitatis from the dataset of Fassett and Thomson [6]. These craters are isolated in the spatial distribution to ensure that the diffusion age derived by Fassett and Thomson [6] is reliable.

High-resolution images (up to less than 1 m/pixel) obtained by the Lunar Reconnaissance Orbiter Camera Narrow Angle Camera (NAC) [12] are used in this study. The images are downloaded and radiometric calibrated in USGS Pilot at https://pilot.wr.usgs.gov/. In order to reduce the effect of varying illumination conditions on crater statistics, we selected images with the incidence angle between 60° and 70°. If no images are found within this range, the images with most proximal incidence angle to this range are selected.

NAC images are imported into ArcGIS, and then subsequently-formed craters within about one crater radius from the crater rim are collected using three-point via the CraterTools extension [13]. Obvious secondary craters, which have irregular and distinguishable shapes (e.g., shallow floors, occurrence in chains, herringbone-shaped ejecta, and floor mounds [14]), are excluded. After completely mapping the superposed craters, a crater model age is derived using the production and chronology functions of Neukum et al. [11].

Result: The diffusion ages of the craters studied here can be derived from Equation (1). Then using the diffusion ages derived by Fassett and Thomson's model, the value of b in Equation (2) can be determined. If diffusion age is independent of crater size, the value of b in Equation (2) should be -4.13. Our preliminary results suggest that the value of b is not -4.13 but generally decreases from ~-2.4 to ~-3.8 with increasing diameter.

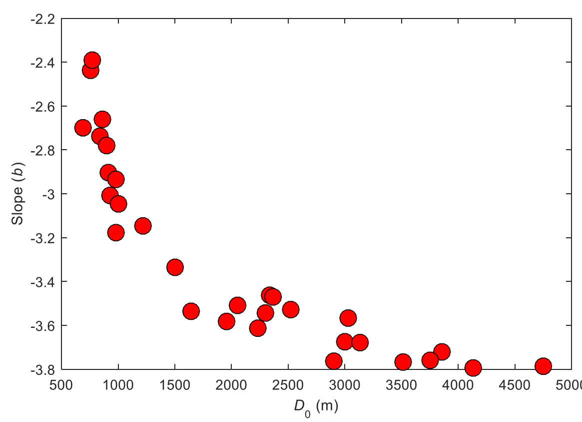

Figure 1 The relationship between slope b and original diameter.

Discussion and Conclusion: In general, our results confirm the dependence of diffusion age on crater size. According to Xie et al. [9]'s results, the value of b is -3.2. The inconstant value of b derived here may be due to the fact that crater depth-diameter ratio increases with diameter, whereas Fassett and Thomson [6] assumed a constant depth-diameter ratio.

Future work: The depth-diameter ratio of 0.218 is correct only for crater diameter of ~2 km according to Stopar et al. [10] and Xie et al. [9]. In our future work, we will map more craters of this size and derive their model ages. Combining the diffusion age determined by Fassett and Thomson [6] and the model age derived here can improve the relation between diffusion age and time for craters of ~2 km in diameter. Then the dependence of diffusion age on crater size and time can be revised (i.e., revised version of Equation (2)).

Acknowledgement: The project was financed by Science and Technology Development Fund of Macao (No. 99/2016/A3)

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