The Size-Frequency Distribution of Small Craters on the Moon and Mars

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Introduction: The size-frequency distribution (SFD) of impact craters has long been used to date planetary surfaces. Radiometric and exposure ages from Apollo and Luna samples, correlated with crater populations, have anchored the lunar cratering chronology enabling systems of model crater retention age isochrons to be developed (e.g. [1][2]). Small craters (< 1 km diameter) are often the only craters available to date a young surfaces or a region of limited extent. These craters however are potentially less reliable as they preferentially suffer from post-impact modification, are influenced by target material properties, are more likely to be contaminated by secondary craters, and on Mars, influenced to a greater degree by the atmosphere prior to impacting the surface. The degree of contamination by secondaries in crater populations is a matter of debate (e.g. [3]) and the extent to which absolute model ages of small craters can be relied upon has been called into question [4]. Here we model populations of small recent craters ($D \sim 1$ - 10's m) on the Moon and Mars using the observed population of fireballs in the terrestrial atmosphere, and show that both lunar and martian crater counts can be reproduced by a predominantly primary production function.

Model: We use a Monte Carlo model further described in [5][6] to model crater populations. The projectile size distribution used for the Moon is a power-law derived from the observed annual flux of small near-Earth objects entering the terrestrial atmosphere [7]. This is scaled for Mars by a factor 2.6, the nominal ratio of the martian and lunar impact rate of [2]. Velocity distributions for the Moon and Mars are from [8] and [9] respectively. Williams et al. [5] showed this model provided a consistent result with the SFD of fresh craters on Mars derived from Mars Orbiter Camera (MOC) observations [10].

North Ray crater: To test our model against small lunar craters, counts were conducted on the ejecta of North Ray crater (Fig 1). North Ray crater was selected for its relatively young age constrained by Apollo 16 samples to be ~ 50 Ma [11]. We selected a small, 0.1 km^2, study area (all craters $\leq$22 m). Fig 1b shows the resulting cumulative crater frequency in log bins using the Craterstats software tool [12]. The crater retention age 58.9 ± 11 Ma is consistent with the results of [11].

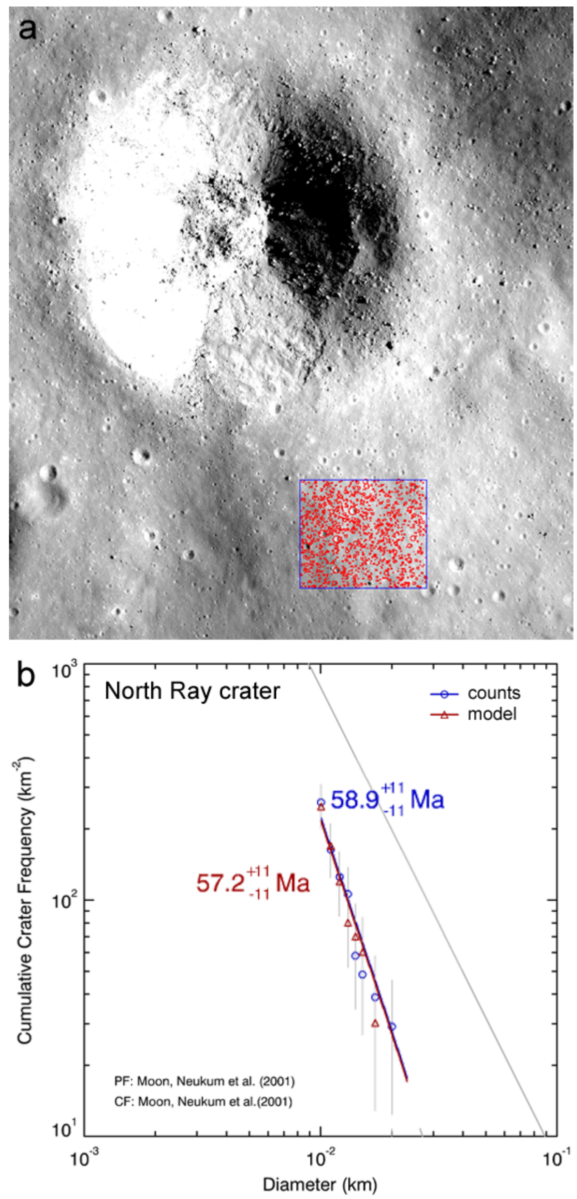

Figure 1: (a) Location of North Ray crater count area (350 m $\times$ 300 m blue box) in LRO NAC image M129187331 (NASAS/GSFC/Arizona State Univ.) (b) Cumulative crater frequency using the Craterstats software tool [12].

We then generated a population of projectiles with our model from the size distribution of terrestrial fireballs [7] and the velocity distribution of [8], for a 58.9 Ma period of time. This resulted in a total of 42895 craters for a surface area of 0.1 km^2. The resulting SFD of the model craters results in a similar

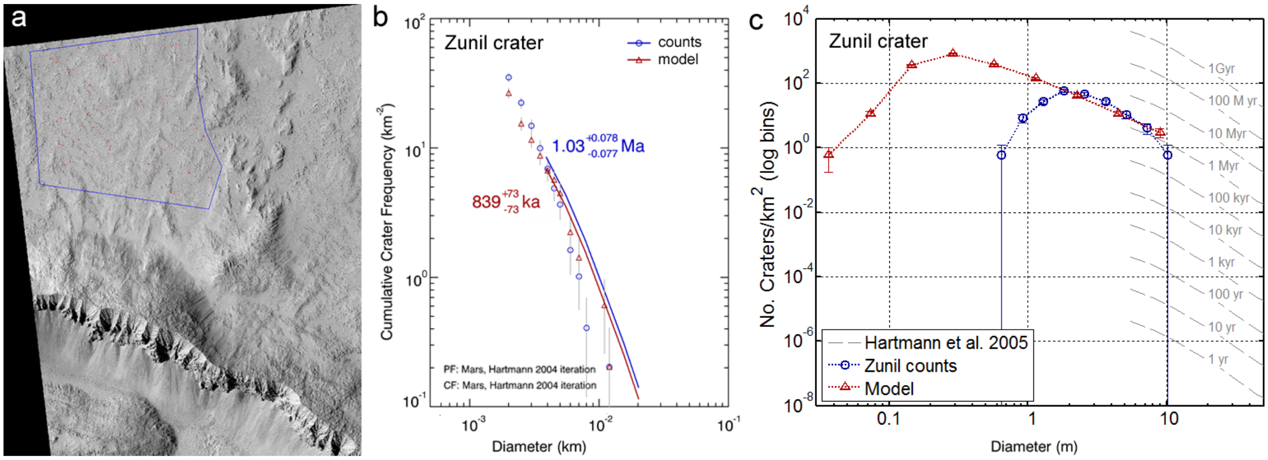

Figure 2: (a) Location of Zunil crater count area in HiRISE image PSP_001764_1880. (b) Cumulative crater frequency using the Craterstats software tool [12] and (c) log-differential plot with isochrons of [2].

crater retention age of 57.2 ± 11 Ma (Fig 1).

Zunil crater: A similar test is conducted for Mars (Fig. 2). The crater Zunil is selected because it is likely the last $D = 10$ km scale crater to form on Mars [3], and accumulation of small craters on its ejecta are likely to reflect predominately primary craters. Counts are conducted in a ~ 5 km^2 area north of the crater rim and yield an age of ~ 1 Ma based on the crater retention age of [2]. Cumulative and differential plots of crater frequency are shown in Fig 2. A crater population is again generated from a distribution of projectile sizes generated from the terrestrial fireball observations [7] with the velocity distribution of [9] for a duration of 1 Ma and a surface area of 5 km^2 accounting for deceleration and ablation in the martian atmosphere and possible fragmentation [6]. The resulting SFD of the modeled crater population has a similar crater retention age (839 ± 73 ka).

Discussion: The crater retention ages of our crater counts on the Moon and Mars are consistent with our model results which derive ages independently using the observed annual flux of projectiles in the terrestrial atmosphere. This confirms that the modeled crater retention age isochrons of [1] and [2] are capable of providing useful ages for the Moon and Mars using only small craters on young surfaces and indicates the cratering rate has been fairly constant over at least the last ~ 50 Ma as our model assumes the same annual flux of projectiles every year. Our modeled crater populations, which consist of primary craters only, have consistent slopes and ages with our crater counts, thereby implying a negligible component of secondaries in the crater count areas studied so far.

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