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Evaluation of large craters and basins for lunar production functions

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Introduction: Large craters and basins that are present on the lunar surface are remants of its early impact history. The relative ages of geological surfaces can be determined with crater size-frequency distribution (CSFD) measurements using a production function (PF), since the impact record on the lunar surface is related to time. Widely used PFs were developed by Neukum (1983) and Neukum et al. (2001) [1,2] and are valid for crater diameters between 0.01–300 km. However, to understand the earlier history of the Moon, when larger impacts were more abundant, an extension of the valid crater diameter range to larger diameters would be beneficial. It could provide input for understanding the number of impactor populations [e.g., 1-4] and the stability of the impact rate on the Moon [e.g., 1,2,5,6]. However, the precise determination of the main basin rim diameter, especially for multi-ring basins, is challenging due to their complex and degraded morphology.

Method: The diameters of large craters and basins were measured based on topographic (~100 m/pixel) and gravity data. We used the Lunar Reconnaissance Orbiter (LRO) Wide Angle Camera (WAC) image mosaic [7], LRO Lunar Orbiter Laser Altimeter Digital Elevation Model (LOLA DEM) [8], and the WAC DEM color-shaded relief map [9,10]. In addition, the following geophysical data were used: Gravity Recovery and Interior Laboratory (GRAIL) [11] data, a crustal thickness map (Crustal Thickness – Model 1) [12], and a Bouguer anomaly map [11].

In order to have a consistent measurement of the main basin rim diameter, we follow the approach of Neumann et al. (2015) [13]. They [13] compared the Bouguer anomaly, which reflects changes in the subsurface and/or crustal thickness, with well-preserved basin structures. They suggest that double the diameter of the Bouguer anomaly is consistent with the main or reference rim for multi-ring basins.

The ArcGIS CraterTools add-in [14] was used to perform the CSFD measurements, which were then further analyzed with Craterstats2 [15]. The count area is the entire Moon, but due to significant differences between mare and highlands areas, we subdivide the count area "Entire Moon" into "Highlands" and "Mare".

Results & Discussion: We identified 311 craters and basins with diameters between 100-1250 km over the entire Moon. We do not include the South Pole Aitken (SPA) basin as it is unclear which topographic ring is its reference rim and it is assumed to have formed in an even earlier era of lunar basins [16]. The CSFD measurements (Figure 1) of the entire Moon and the highlands are consistent up to diameters of 250 km. However, while the highlands distribution progresses relatively smoothly towards large basin diameters, the CSFD of the entire Moon shows a "step" between 400-700 km. The CSFD of the mare areas is significantly different from the two other areas. Craters <200 km are less abundant than on the other two areas, and craters and basins >250 km are more abundant. The CSFD measurements for the entire Moon and the lunar highlands are better represented by the PF of [2] using the valid crater diameter range of 100-300 km. The mare areas could not be fitted with either PF.

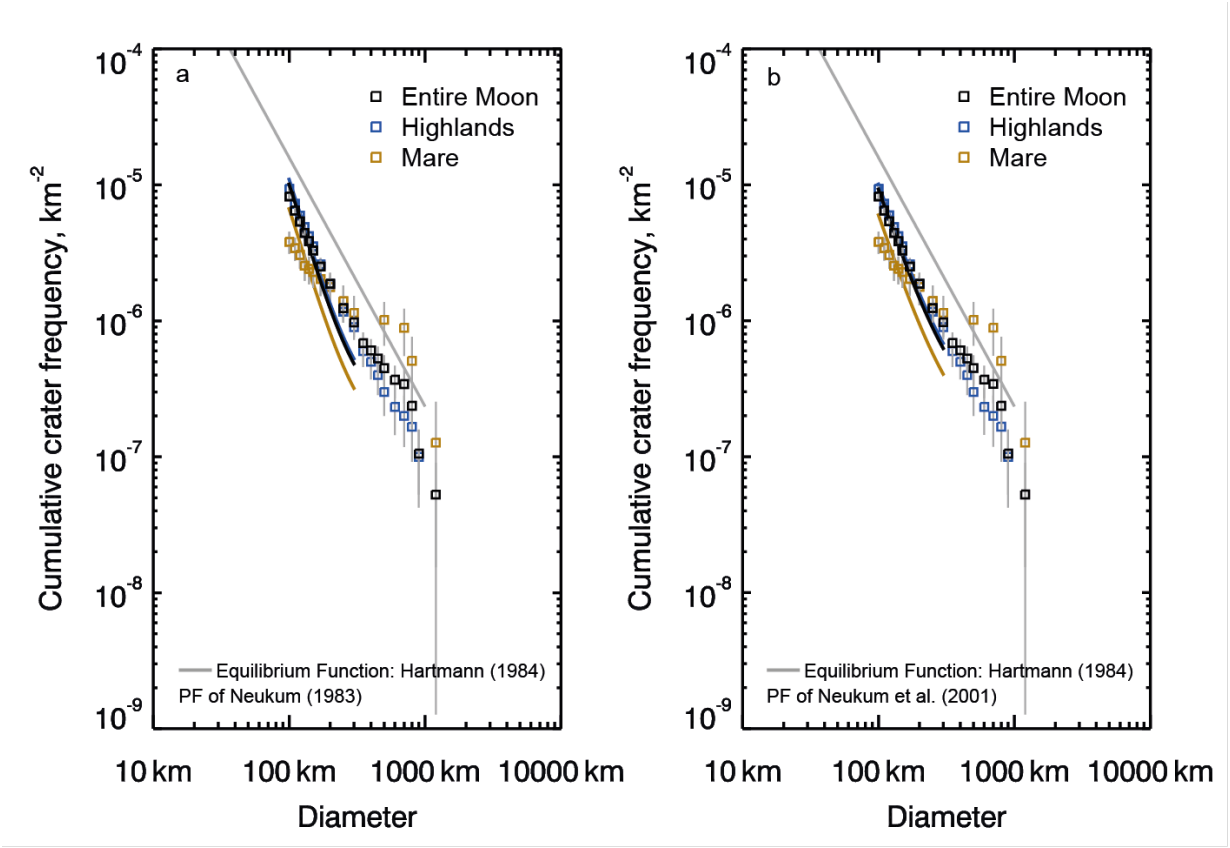

Figure 1: Cumulative CSFD plots for large craters and basins compared with existing PFs (black and blue curves) (a) [1] and (b) [2] in the valid crater diameter range of 100-300 km. The gray line represents the equilibrium function of [17].

The significant difference between the CSFDs on highlands and mare areas may result from:

(1) lava flooding [18,19], causing an incomplete identification of basins on the mare areas

(2) asymmetries in cratering rate, e.g. due to the rotation and inclination of the Moon [20,21]

(3) larger basin diameters resultant on the lunar nearside due to a different subsurface temperature and crustal thickness [16]

Conclusion: The CSFD measurements indicate that large craters and basins are still in production and, therefore, an extension of PFs for craters and basins from 300-1250 km could be possible. This extented crater diameter range would allow to draw conclusions about the number of impactor populations and the stability of the impact rate in the early lunar history. However, the influence of resurfacing processes on mare units compared to the highlands is not yet entirely understood and a more detailed analysis of the mare regions is necessary.

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