REGIONAL LUNAR STRATIGRAPHY DERIVED FROM CSFDs EXTRACTED FROM THE >5 KM GLOBAL CRATER CATALOG.

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Introduction: Previous studies cataloged and analyzed the size-frequency distributions of craters >20 km in diameter [1,2]. These studies showed that the crater size-frequency distributions (CSFDs) reflect the occurrence of large-scale geological events throughout the history of the Moon, such as the major resurfacing of the lunar nearside by mare basalt flooding. A new catalog of craters with diameters 5-20 km in diameter augments the previous work and allows analysis of smaller areas [3,4]. Povilaitis et al. [3,4] also use the areal crater density contrast between the 5-20 km and >20 km diameter ranges to gain insight into the relative densities of small and large craters across the Moon (*Fig. 1*), and to generate maps of areas on the Moon where saturation equilibrium may occur for different crater diameter ranges. Here, we present the analysis of CSFDs (*Fig. 2*) extracted from six regions of interest defined by [3,4] to examine the geological and stratigraphic importance of these regions (*Fig. 1*). We use the methods of [5, 6] and the production function (PF) of [5], which is valid for craters up to 300 km in diameter. The lunar chronology is calibrated to sample ages up to ~3.9 Ga [7], such that older ages represent extrapolation of the current chronology functions. Thus, the absolute model ages (AMAs) for ancient highlands areas have an intrinsic uncertainty. Regardless, the relative timing of the events is established by the relative crater densities of these units. One other caveat to the analysis presented here is that large areas may encompass more than one geological unit, possibly causing mixed ages [8]. As such, one goal of our analysis is to evaluate whether the ages derived from large regions are consistent with studies of smaller areas.

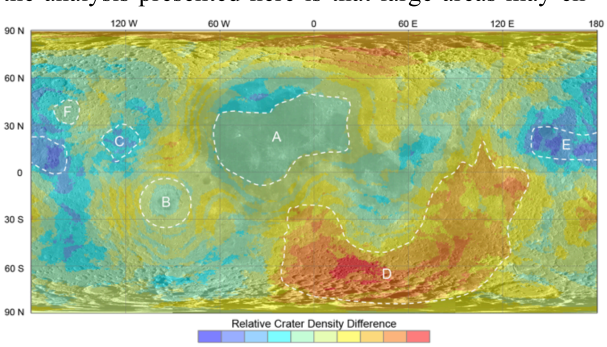

Figure 1. *Map of the relative crater density difference between the catalogs of 5-20 km and >20 km diameter craters. The blue areas represent relatively abundant 5-20 km with respect to >20 km diameter craters, whereas the red areas contain a greater density of large craters relative to small craters. Areas of interest are marked with white dashed borders. The CSFDs for these areas were extracted and are presented in Fig. 2.*

Results: ***Nearside Mare (A):*** Area A includes Mare Imbrium and Oceanus Procellarum, where most basalt emplacement occurred from 3.3-3.7 Ga [9] and 3.3-3.6 Ga [10], respectively. A formation age of the Imbrium impact at 3.91 Ga [11] provides an upper limit for the emplacement of basalts in the Imbrium basin. Our CSFD shows that basalt emplacement affected crater diameters up to at least 105 km, with initial flooding in this area occurring at about 3.88 Ga (*Fig. 2A*), consistent with the onset of mare volcanism at about 3.9 Ga. Major resurfacing occurred at 3.75 Ga for craters 5-45 km in diameter. Ages younger than 3.75 Ga are recorded locally by craters smaller than 5 km, as summarized by [12].

Orientale Basin (B): Two AMAs can be fit to this CSFD, including 3.86 Ga and a resurfacing event at 3.74 Ga (*Fig. 2B*), consistent with the formation of Orientale and the eruption of mare within the basin [7,13]. [13] dated the Orientale ejecta blanket and melt sheet to 3.64-3.68 Ga and mare volcanism within Orientale to 3.58 Ga using the PF of [6]. Our AMAs (*Fig. 2B*) use the PF of [5], but give 3.75 and 3.67 Ga when converted to the PF of [6], and are statistically within error of the values of [13].

Orientale Secondaries (C): A slight excess of craters with diameters of ~9-16 km may be representative of a population of secondary craters formed by the Orientale impact event (*Fig. 2C*). Whereas, craters larger than 45 km in diameter can be fit with an AMA of 4.28 Ga (*Fig. 2C*), which is within error of the proposed age of the South Pole-Aitken Basin that [14] derived using the same chronology and production functions.

Nearside Highlands/Mare Australe (D): The CSFD in *Fig. 2D* can be fit with three different AMAs depending on the crater diameter range: 77-300 km with 4.27 Ga, 30-50 km with 4.19 Ga, and 13-23 km with 4.13 Ga. This youngest AMA approaches, but is still older than, previous age determinations in Mare Australe [10,15]. The basalt ponds range from 3.08-3.91 Ga, with the largest number (51%) having erupted 3.6-3.8 Ga [10]. Twenty-three percent of the ponds show evidence of resurfacing, which likely indicates older buried basalt units [10]. Thus, the older ages we derived could represent older buried basalt ages and/or the admixture of the surrounding highlands age. Although the CSFDs exceed relative crater densities of R=0.3 (10% geometric saturation [16,17]), they can be fit with the PF, which indicates that R must be >0.3 to reach saturation levels at these larger diameters.

Central Farside (E): This CSFD (*Fig. 2E*) cannot be fit with specific AMAs, because it does not follow the PF, nor does it follow any equilibrium function (e.g., 16-18). A portion of the larger craters may follow a 4.13 Ga isochron. However, because this portion of the PF has a similar slope as the standard equilibrium condition, it is not possible to say whether this area is in production or equilibrium. This area has a complex CSFD because of the high density of large basins. The non-sparseness of the craters allows the ejecta blankets of subsequent large craters to resurface nearby smaller craters, causing a deficiency of smaller craters in the overall CSFD that expresses itself as a slope shallower than the PF, but is not saturation equilibrium [5,19].

Farside Highlands (F): Craters larger than 20 km can be fit with an AMA of 4.28 Ga, while craters ~9-20 km could either be in saturation equilibrium or have an age consistent with the larger crater bins (*Fig. 2F*), and is similar to that of the SPA basin [14].

Conclusions: CSFDs extracted from the global catalog of lunar craters >5 km in diameter provide an overall view of the regional stratigraphy that is consistent with smaller scale local studies. Our results also indicate that saturation equilibrium is a size-dependent process, with smaller craters attaining lower levels of geometric saturation than larger craters (e.g., *Fig. 2C*). A series of potential basin formation AMAs between 4 and 4.28 Ga argues against the occurrence of a late heavy bombardment. An age similar to that for the SPA basin was observed across the highlands (*Fig. 2D, F*) suggesting that the SPA event resurfaced large portions of the Moon. Sample return from the SPA basin would provide a calibration point for more robust determination of AMAs on ancient surfaces [e.g., 20].

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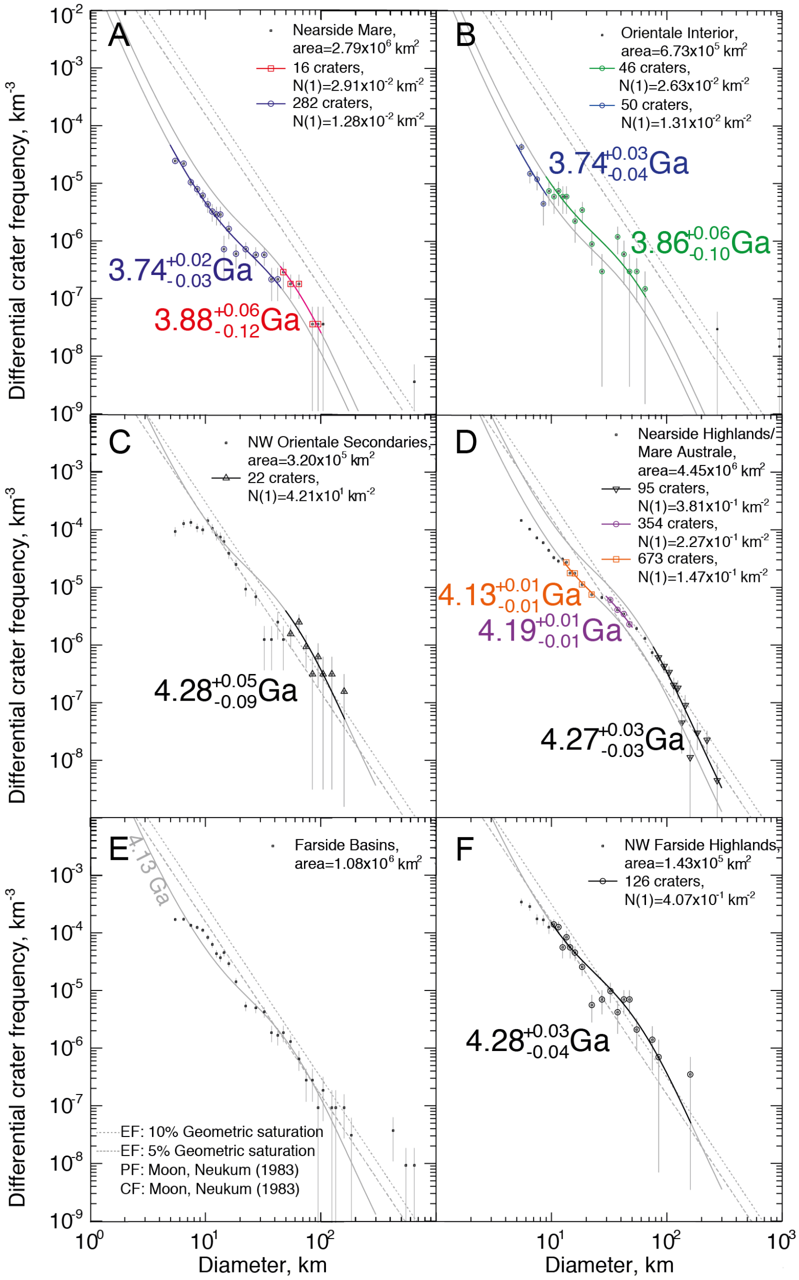

Figure 2. *Differential crater size-frequency plots and absolute model age fits for the areas shown in Fig. 1. (R-plots, not shown, were used to aid determination of the fit ranges.)*