Introduction: Floor-fractured (FFCs) and concentric craters (CCs) are impact craters that underwent modification by volcano-tectonic processes such as viscous relaxation or magmatic intrusion following basin-forming events (Fig. 1) [1-6].

The Procellarum KREEP Terrane (PKT) is one of three major crustal provinces on the Moon [7]. Data from the Lunar Prospector Gamma Ray Spectrometer shows that the PKT is a geochemically distinct province whose boundary is marked by the abundance of rare earth elements (REEs; Fig. 2) [8]. There are two competing hypotheses for the origin of the PKT. 1) The presence of the PKT and the crustal asymmetry is attributed to the formation of a “Gargantuian Basin” later known as the Procellarum basin early in lunar history at ~ 4.1-4.2 Ga [9-10]. The Procellarum basin is bound by Mare Frigoris to the north, Mare Vaporum to the east, Mare Cognitum to the south and Oceanus Procellarum to the west (Fig. 3) [10]. 2) The presence of the PKT is attributed as solely the result of the Imbrium impact event [11-12]. In this model the proposed boundary of the Procellarum basin [10] is interpreted to be the outer ring of the Imbrium basin [11-12].

Both FFCs and CCs appear to be clustered within impact basins, with >60% of FFCs and CCs concentrated along the western boundary of the proposed Procellarum basin [10] (Fig. 2). Whether the spatial distribution of FFCs and CCs are random or genetically related to impact basins is not well understood. If the latter is true, then we can not only use FFCs and CCs as proxies for identifying ancient basin rims, but we can also infer local and regional variations in the strength of the lunar lithosphere. Therefore, the overarching goal of this study is to determine and analyze the statistical significance of the spatial distribution of FFCs and CCs with respect to impact basins.

Methods: We used the multi-distance spatial clustering analysis (Ripley’s K-function or RKF) tool (ArcGIS) to compute the spatial dependence of FFCs and CCs over a range of distances, particularly with respect to concentric peak rings of impact basins (Fig. 3).

The RKF computes two correlation values: observed K value and expected K value. If observed K value > expected K value, then the population is clustered. If the observed K value < expected K value, then the population is dispersed. The diff K value (observed K – expected K) determines the significance of clustering. The larger the diff K, the more significant the clustering of a given population. We also computed the diff K values for the Procellarum basin rim that we outlined using FFCs and CCs and that of Wilhelms (1987) [10].

Figure 2: Spatial distribution of FFCs and CCs. The PKT is outlined in red. Base map: Lunar Reconnaissance Orbiter Camera (LROC) Wide Angle Camera (WAC) GLD 100 DTM [13].
populations was calculated. **Base map:** LROC WAC GLD100 [13].

**Results and Discussion:** Based on the RKF analysis, we noted that the observed K value is > the expected K value for FFC and CC populations associated with all basins, statistically verifying our visual observation that FFCs and CCs are clustered within basins. Additionally, the diff K (i.e., the significance of clustering) is highest for FFCs and CCs associated with pre-Nectarian basins (i.e., the oldest basins which exhibit subdued topographic rims and weak gravity anomalies [14]) compared to relatively younger basins (Figs. 4-5). This correlation with pre-Nectarian basins suggests viscous relaxation is a plausible formation mechanism for FFCs and CCs. Since FFCs and CCs share the same geospatial distribution, but only vary in size, we interpret that these two landforms are on a continuum and that they were likely formed by the similar processes.

**Figure 4:** Spatial distribution of FFCs and CCs with respect to pre-Nectarian basins. **Base map:** LROC WAC GLD100 [13].

Diff K calculations show more significant clustering associated with our Procellarum basin rim compared to that of Wilhelms (1987) [10], thereby providing statistical evidence for the Procellarum basin as the origin of the enigmatic PKT.

The spatial distribution of 85% FFCs and CCs provides evidence for the existence of the Procellarum basin (a pre-Nectarian basin), consistent with that of previous studies [9-10] and the argument that FFCs and CCs occur in regions of subdued basin topography (i.e., thin and weak crust), in particular, where the crust-mantle interface was uplifted. The evidence for the existence of the Procellarum basin also addresses previous studies that noted the lack of floor-fractured and concentric craters associated with the Imbrium basin – since it is superposed within the Procellarum basin, at a time when the lunar lithosphere was likely relatively rigid, as evidenced by the presence of the Appenine mountains, which were uplifted during the Imbrium impact event [9-10].

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