ANCIENT BOMBARDMENT OF THE INNER SOLAR SYSTEM – REINVESTIGATION OF THE "FINGERPRINTS" OF DIFFERENT IMPACTOR POPULATIONS ON THE LUNAR SURFACE. C. Orgel (orgel.csilla@fu-berlin.de), Michael, G. G., Kneissl, T. Freie Universität Berlin, Department of Planetary Sciences, 12249 Berlin, Malteserstrasse 74-100, Building D, Germany

Introduction: The lunar cratering record provides valuable information about the late accretion history of the inner solar system. To learn more about the impacted projectiles, we can examine the crater size–frequency distributions (CSFDs) on the Moon. CSFDs are used to help us to find the so-called lunar "production function" (PF) [1, 2], which describes the population of craters forming on planetary surfaces. The PF is used to extrapolate the measured CSFDs to a reference diameter (~1 km) whose frequency will give an absolute age from the lunar "chronology function" (CF) [1]. However, our understanding of the origin, rate, and timing of the impacting projectiles is far from complete. The impact flux is imperfectly known during the period of 4.5 – 3.8 Gyr. If no changes occurred in the PF then the large basins were formed in a smoothly declining flux of planetesimals, whose material originated from the leftovers of planetary accretion [3, 4]. If the PF changed over time, this indicates that more than one impactor population may have formed the lunar cratering record and that could be consistent with an impact spike, called the Late Heavy Bombardment (LHB) or lunar cataclysm occurred around 3.9 – 4.1 Gyr [5-13].

Methods: We derive the impact CSFDs for each of 30 lunar basins [9] using the CraterTools add-in in ArcGIS 10.3 [16] and a new crater counting method, the buffered non-sparseness correction (BNSC) [15]. This method is a combination of buffered crater counting (BCC) [14] and the non-sparseness correction (NSC) techniques. It includes all craters overlapping the counting area. We thus use a larger number of craters which decreases the statistical noise (BCC). Each crater is referenced to an area excluding regions in the study area that have been resurfaced by larger craters and their ejecta blanket (~1 crater radius) (NSC). In order to compare the results with [9], we use their dataset along with their geologic mapping and crater counting and test the BNSC technique on non-sparsely cratered surfaces. The crater counts include the results of lunar crater catalog (≥ 20 km) [8] and additional craters beyond that database [9]. To ensure that secondary craters are not included from the age determination we perform randomness analysis [17]. We determined model ages of lunar basins using the lunar PF and CF from [1] as well as the Craterstats software [18]. Then, we studied the relation of the model ages to stratigraphical observations [9, 19]. Finally, to compare the impactor population, we derived the shape of integrated CSFDs of pre-Nectarian, Nectarian and Imbrian aged basins.

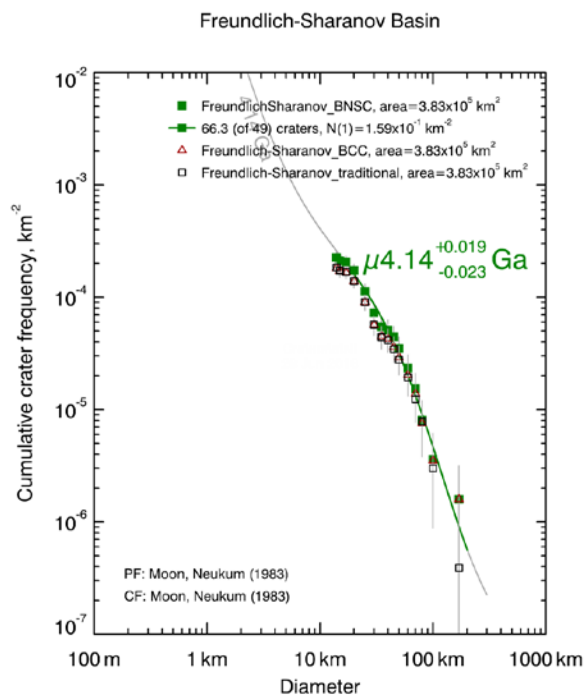

Figure 1. The model age of Freundlich-Sharanov Basin using the new crater counting technique (BNSC) fit better to the PF [1] (grey line) than the ages derived using the BCC and traditional crater counting methods.

Results: The derived ages of individual lunar basins using the BNSC technique showed some minor intraperiod differences in basin sequence in compare to [9] and [19]. The major findings list the Apollo and Freundlich-Sharanov basins Nectarian in age, instead of pre-Nectarian. Birkhoff Basin is much older than previously thought [9, 18] and Serenitatis Basin clearly belongs to pre-Nectarian period based on stratigraphy [9] and age determination. Generally, the calculated absolute ages using the BNSC technique fit better to the production function [1] than those ages derived from previous crater counting methods (Figure 1). The shape of summed CSFDs shows similarities and a better fit to the PF [1] in the case of the pre-Nectarian (excluding South Pole-Aitken Basin (SPA)) and Nectarian-aged basins (including Nectaris), but there is no effect of the BNSC method on the Imbrian-aged basins (including Imbrium) (Figure 2). This result is in contradiction to previous studies, where the summed CSFDs showed a change in the shape of CSFDs. Thus multiple impactor populations and various transition times have been interpreted in the early bombardment history of the Moon [5-13].

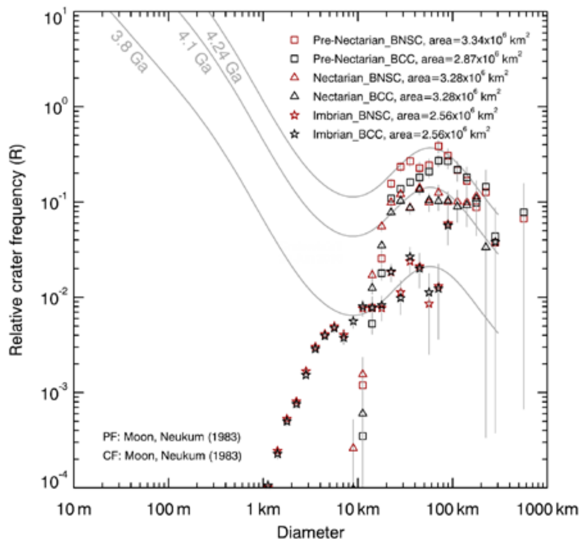

Figure 2. Summed crater size-frequency distributions for pre-Nectarian-aged basins (excluding SPA), Nectarian-aged basins (including Nectaris) and Imbrian-aged basins (including Imbrium). The red symbols show the results derived using the BNSC technique, while the black symbols represent the results of the BCC crater count technique. The shape of summed CSFDs of respective ages shows similarities using the BNSC method and a better fit to the PF [1]. This suggest one impactor population, which formed the lunar basins.

Conclusions: The shape of CSFDs from pre-Nectarian to Imbrian does not show changes over the time, thus we favor the hypothesis of a single projectile population. The question of the existence of LHB is still an unsolved problem and more statistical analysis should be done in the future. Additional sample return missions from the region of the SPA would be the key to improve the current understanding about the bombardment history of the inner Solar System [20].

Acknowledgement: This work was funded by the Deutsche Forschungsgemeinschaft (SFB-TRR 170, subproject A3-1.

References

[1] Neukum G. 1983. Habilitation thesis, Ludwig-Maximilians Universität München, Fakultät für Geowissenschaften, München, 186 pp. [2] Neukum et al. 2001. Space Sci. Rev. 96: 55 – 86. [3] Hartmann W. 1995. Meteoritics 30: 451 – 467. [4] Neukum G. and Ivanov. B. A. 1994. in: T. Gehrels ed. University of Arizona Press, 359 pp. [5] Tera et al. 1974. Earth Planet. Sci. Lett. 22. [6] Cohen et al. 2000. Science 290: 1754 – 1756. [7] Strom et al. 2005. Science 309: 1847. [8] Head et al. 2010. Science 329: 1504 – 1507. [9] Fassett et al. 2012. JGR 117: E00H06. [10] Marchi et al. 2012. Earth Planet. Sci. Lett. 325: 27 – 38. [11] Morbidelli et al. 2012. Earth Planet. Sci. Lett. 355 – 356: 144 – 151. [12] Bottke et al. 2012. Nature 485: 78 – 81. [13] Gomes et al. 2005. Nature 435: 466 – 469. [14] Fassett et al. 2008. Icarus 195: 61 – 89. [15] Kneissl et al. 2016. Icarus 277: 187 – 195. [16] Kneissl et al. 2011. Planet. Space Sci. 59: 1243 - 1254. [17] Michael et al. 2012. Icarus 218: 169 - 177. [18] Michael, G. Icarus 226, 885 – 890. [19] Wilhelms et al. 1987. U.S. Geological Survey Professional Paper 1348. [20] Ende et al. 2017 *this conference.*