IMPACT CHRONOLOGY OF THE MOON – RESULTS FROM THE LUNAR RECONNAISSANCE ORBITER CAMERA (LROC). H. Hiesinger[1], C. H. van der Bogert[1], J. H. Pasckert[1], J. B. Plescia[2], and M. S. Robinson[3], [1]Institut für Planetologie, Westfälische Wilhelms-Universität Münster, Wilhelm-Klemm-Str. 10, 48149 Münster, Germany, Hiesinger@uni-muenster.de; [2]Johns Hopkins University, Applied Physics Laboratory, 11100 Johns Hopkins Rd, Laurel, MD 20723, Jeffrey.Plescia@jhuapl.edu; [3]Arizona State University, School of Earth and Space Exploration, 781 E. Terrace Mall, Tempe, AZ 85287-6004, USA, robinson@ser.asu.edu.

Introduction: Accurate knowledge of the lunar cratering chronology (LCC) is required to derive absolute model ages across the lunar surface and throughout the inner Solar System [e.g., *1*]. Unfortunately, there are only a few data points at ages younger than about 3 Ga, and no data points at ages older than 3.9 Ga to constrain the LCC. We systematically performed crater size-frequency distribution (CSFD) measurements for Copernicus, Tycho, North Ray, Cone, and Autolycus craters to test and improve the LCC [*2-4*].

Results: *Cone crater:* Although exposure ages of Apollo 14 samples from Cone crater range from ~12 Ma [*5*] to ~661 Ma [*6*], several studies agree on a formation age of ~25-26 Ma [e.g., *7-9*]. From nine count areas around Cone crater, our absolute model age (AMA) is ~39 Ma, consistent with previous AMAs varying from ~24 Ma [*10*] to ~73 Ma [*11*], in addition to the exposure ages.

North Ray crater: Previous studies [*12,13*] found cosmic ray exposure ages of 50.3±0.8 Ma at North Ray, which agree with the cosmic ray exposure results of [*14*] (48.9±1.7 Ma). [*15*] reported an ^{81}Kr-Kr age of 50.6±3.8 Ma, similar to ^{22}Na-Ne ages and particle track ages. Microcrater frequencies suggest that North Ray formed more than 20 Ma ago [*16*]. Coarse fragments give ^{38}Ar-^{37}Ar cosmic-ray exposure ages between 30 and 50 Ma [*17*]. Thus, [*7*] concluded that North Ray formed 50.3±0.8 Ma ago. For North Ray, four individual count areas, as specified by [*2*], were counted independently by two counters, yielding ages of 46 and 47 Ma [*1*].

Tycho crater: Secondary craters from the Tycho impact event were suggested to have triggered a landslide at the South Massif at the Apollo 17 landing site [*17,18*]. Samples returned from the landslide and the Central Cluster revealed exposure ages of about ~100 Ma, which were interpreted as the formation age of Tycho crater [e.g., *13, 18-20*]. From the exposure ages, [*13*] concluded that Tycho is 109±4 Ma old. This age is identical to that of [*20*], and is similar to an exposure age of 96±5 Ma derived by [*19*]. CSFD measurements on NAC images of four areas on the continuous ejecta blanket (granular material, not impact melt) of Tycho yielded a combined AMA of 85 Ma – identical to our average AMA of three count areas on the landslide, but slightly younger than that derived from CSFD measurements on the ejecta blanket using WAC images (124 Ma). CSFDs of [*21*] yielded an AMA of 75 Ma for the ejecta blanket.

Copernicus crater: A faint ray of Copernicus material crosses the Apollo 12 landing site, which led [*22*] to propose that KREEPy glass in the samples was ejected by the Copernicus event, and could be used to date the impact. Exposure ages of the glass have an age of 800-850 Ma [*23-27*]. Radiometric ages also support an age of 800±15 Ma [*26,28-29*]. Analyses of 21 regolith samples show degassing ages of 700-800 Ma, which give an estimated 782±21 Ma age for the Copernicus impact event [*30*]. We used NAC images to count 9 areas on the ejecta blanket, which gave an AMA of 797 Ma. CSFD measurements for three ejecta blanket areas on WAC images yielded a similar age of 779 Ma. Our results fit the existing lunar chronology of [*3*] significantly better than their previous counts [*3*].

Autolycus crater: Rays from Autolycus and Aristillus craters cross the Apollo 15 landing site and presumably transported material to this location [e.g., *31,32*]. Thus, [*33,34*] proposed that the ^{39}Ar-^{40}Ar age of 2.1 Ga, derived from three petrologically distinct, shocked Apollo 15 KREEP basalt samples, date Autolycus crater. Aristillus crater is younger than Autolycus crater and as a result severely modified Autolycus crater and its ejecta deposits. Thus, a heating event in sample 15405 at 1.29 Ga was interpreted as the age of Aristillus crater [*35*]. The exact timing of the two impacts, however, remains under debate because [*36*] interpreted U-Pb ages of zircon and phosphate grains of 1.4 and 1.9 Ga from sample 15405 as the formation ages of Aristillus and Autolycus. If Autolycus crater is indeed the source of the dated exotic material collected at the Apollo 15 landing site, then CSFD measurements on the ejecta blanket of Autolycus crater offer a new calibration point to the lunar chronology, particularly in an age range that was previously poorly constrained. Using NAC images, we extracted CSFD measurements for 6 areas inside and on the ejecta blanket of Autolycus crater, yielding widely variable AMAs. None of our CSFDs yield AMAs that correspond either to the 2.1 Ga [*33,34*] or 1.9 Ga [*36*] sample ages. This either implies that the dated samples are not related to Autolycus or that the CSFD measurements are so heavily affected by resurfacing and secondaries from the Aristillus event that they do not represent the formation age of Autolycus crater. In either case, because of these uncertainties Autolycus cannot be used as a calibration point for the LCC.

References: [1] Hiesinger et al. (2012) JGR 117, 10.1029/2011JE003935. [2] Neukum (1983) Habil. thesis, U. of Munich. [3] Neukum et al. (2001) Space Sci. Rev. 96. [4] Robbins (2014), EPSL 403. [5] Bhandari et al. (1972) PLPSC 3. [6] Crozaz et al. (1972) PLPSC 3. [7] Stöffler and Ryder (2001) Chronology and Evolution of Mars. [8] Arvidson et al. (1975) Moon 13. [9] Stadermann et al. (1991) GCA 55. [10] Moore et al. (1980) Moon and Planets 23. [11] Plescia and Robinson (2011) LPSC 42. [12] Drozd et al. (1974), GCA 38. [13] Drozd et al. (1977), PLPSC 8. [14] Marti et al. (1973), PLPSC 4. [15] Behrmann et al. (1973), PLPSC 4. [16] Morrison et al. (1973), PLPSC 3. [17] Wolfe et al. (1975), PLPSC 6. [18] Lucchitta (1977), Icarus, 30. [19] Arvidson et al. (1976), PLPSC 7. [20] Guinness and Arvidson (1977), PLPSC 8. [21] Krüger et al. (2016), Icarus, 10.1016/j.icarus.2016.02.018. [22] Meyer et al. (1971), PLPSC 2. [23] Eberhardt et al. (1973), The Moon 8. [24] Alexander et al. (1976) PLPSC 7. [25] Silver (1971), EOS, Trans. Am. Geophys. Union 52. [26] Bogart et al. (1994), GCA 58. [27] Korotev et al. (2000), LPS XXXI. [28] Bogard et al. (1992), LPSC 23. [29] Wentworth et al. (1994), Meteoritics 29. [30] Barra et al. (2006), GCA 70. [31] Wilhelms (1987), USGS Spec. Pub. 1348. [32] Russ et al. (1972), EPSL 15. [33] Bogard et al. (1990), GCA 54. [34] Ryder et al. (1991), Geology 19. [35] Bernatowicz et al. (1978), PLPSC 9. [36] Grange et al. (2013), JGR 118.