REINVESTIGATING THE CRATER SIZE-FREQUENCY DISTRIBUTIONS OF THE APOLLO 11 LANDING SITE. W. Iqbal[1], H. Hiesinger[1], C. H. van der Bogert[1], [1]Institut für Planetologie, Westfälische Wilhelms-Universität, Wilhelm-Klemm-Str. 10, 48149, Münster, Germany, iqbalw@uni-muenster.de

Introduction: The lunar cratering chronology uses crater size-frequency distributions (CSFDs) to derive absolute model ages (AMAs) for geological units across the Moon, and is adapted for use on the surfaces of various other Solar System bodies [e.g., 1,2,3,4,5,6]. New data collected by recent lunar missions, as well as additional and improved analyses of lunar samples, allow us to reevaluate and possibly improve the lunar chronology [e.g., 4,5,6,7,8,9]. Here, we report newly measured CSFDs, i.e., *N*(1), and AMAs for the Apollo 11 landing site using Lunar Reconnaissance Orbiter Camera (LROC) images, and compare these with previously determined values.

The Apollo 11 landing site in Mare Tranquillitatis is an important calibration point for the lunar chronology. The lunar module landed between rays of ejecta from the distant and relatively young craters Theophilus, Alfraganus, and Tycho [10]. Stöffler et al. (2006) [6] proposed organizing the sampled basalts into five different chemical classes representing four groups of radiometric ages: Group A (3.58 Ga), a high potassium basalt; Group B1-B3 (3.70 Ga), a complex group; and the two oldest groups Group B2 (3.80 Ga), and D (3.85 Ga). Despite their differences in age, all of these groups are rich in titanium [6,11,12,13]. These radiometrically determined basalt ages were correlated with the cumulative number of craters equal or larger than 1 km in diameter or *N*(1), as summarized in [6]. These correlated values serve as one of the calibration points for the fit of the lunar cratering chronology function. Since this work, new data including multispectral, topographic, and high-resolution image data with various illumination geometries have been collected, which we use to refine our understanding of the geology of the Apollo 11 landing site and improve the lunar chronology.

Methods: New CSFDs for the Apollo 11 region were measured on both LROC Wide Angle (WAC) and Narrow Angle Camera (NAC) data. ISIS 3 was used to calibrate and map-project the images [14]. The WAC mosaic has a pixel scale of ~100 m, whereas the NAC data we used are 1.17 m/pixel. The incidence angles of the images range from 60° to 80°. The images were imported into ArcGIS, and the extension CraterTools [15] was used to perform measurements. For the CSFD measurements, obvious secondary craters were avoided, and a randomness analysis was used to determine whether clustering of craters might indicate unidentified contamination by secondaries. Finally, Craterstats [4,15,16] was used to plot CSFDs of the data using the lunar production and chronological functions of [4]. The production function (PF) is valid for the diameter interval of 10 m to 100 km [4]. The CSFD data are presented in both cumulative and relative plots [4,17,18]. We determined the AMAs as cumulative fits with pseudolog binning so that they can be directly compared with previous results using the same fitting approach.

We combined Clementine spectral data, the LOLA digital elevation model, and albedo contrasts of the images to define different geological units surrounding the Apollo 11 landing site. These units were used to investigate the sample collection areas in detail. For our crater counts, we mapped several homogenous areas surrounding the landing site using LRO-NAC data (red areas, Fig. 1). The area mapped in blue is the same as used by [3] for the initial derivation of the lunar chronology. We mapped this area on LRO-WAC data. The radiometric ages of the returned samples from the Apollo 11 landing sites [6,10,12,13] were compared with the newly measured CSFDs.

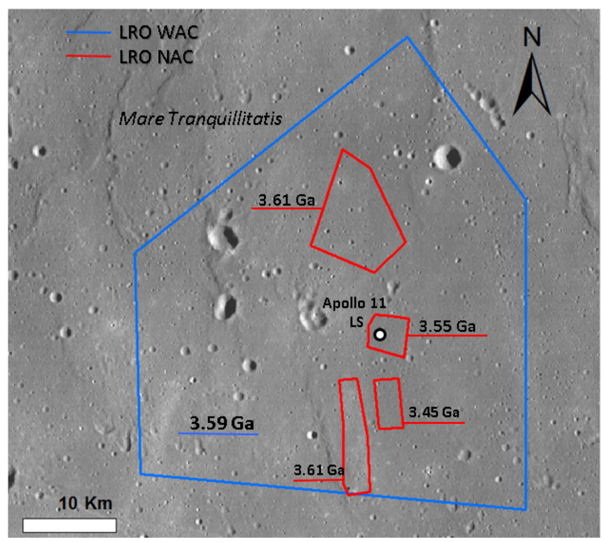

Figure 1. *Count areas at the Apollo 11 landing site. The blue area is the same as that defined by Neukum (1983) for the initial calibration of the lunar chronology. We recounted this area using LRO WAC data. The red areas are newly defined and measured using NAC data. The results are consistent with earlier values; the NAC count areas show a wider range of ages consistent with the range of radiometric sample ages.*

Results and Discussion: The absolute model ages (AMAs) determined with our new CSFDs are 3.59±0.02 for both the original count area defined for the WAC-scale measurement and for the combination of the craters measured within the red areas at NAC resolution (Fig. 2). The individual NAC count areas give ages that range from 3.45 to 3.61 Ga (Fig. 1). Overall, craters with a diameters smaller than 50 m are in equilibrium, so they are not used to fit AMAs.

The *N*(1) values we determined lie between the previously measured values of 9×10^{-3} and 6.4×10^{-3} reported by Neukum et al. (2001) and Stöffler et al. (2006) as Apollo 11 'old flows' and 'young flows' respectively [2,3,4,6]. Our new values of *N*(1) are 6.55×10^{-3} for the WAC count area and 6.47×10^{-3} for the combined NAC count areas. Hiesinger et. al (2000) [7] measured a value of 7.60×10^{-3} for the much larger mare basalt unit (T17) which surrounds the Apollo 11 landing site and gives an AMA of 3.63 Ga, showing consistency with the current results. Whereas, Robbins (2014) [5] measured a *N*(1) value of 8.14 $\times10^{-3}$ on the LRO WAC data of Apollo 11 landing site. The newly obtained ages via CSFD measurements are consistent with the radiometric ages of the Group A basalts [6,13]. These basalts are classified as High-K basalts and show a radiometric age of 3.58 Ga [6,13] and belong to the lava flows at the surface of the Mare Tranquillitatis. The results showing higher *N*(1) values for the LRO NAC data likely belong to the older Imbrian basalt units.

Our ongoing project will complete an updated geological map of the landing site for comparison with the sample collection locations, to investigate whether sample ages can be revised [6,12,13]. We will then correlate them with our new CSFDs measurements of the area to potentially improve the accuracy of the lunar chronological curve. We are in the process of applying the same method to other landing sites.

References: [1] Hartmann, W. K. (1970) Icarus 13: 299-301. [2] Neukum. G. et al. (1975) The Moon 12, 201-229. [3] Neukum, G. (1983) Habil. thesis, U. of Munich. [4]Neukum, G., et al. (2001) Space Sci. Reviews 96, 55-86. [5] Robbins, S. J. (2014) Earth and Planet. Sci. Lett. 403, 188-198. [6] Stöffler, D., et al. (2006) Reviews in Mineral. & Geochem. 60, 519-596. [7] Hiesinger, H., et al. (2000) JGR 105, 29239-29275. [8] Hiesinger, H., et al. (2012) JGR 11, E00H10. [9] Hiesinger, H., et al. (2015) LPSC 46, #1834. [10] Aldrin, E. E., et al. (1969) NASA Report, 11-11-23. [11] Geiss, J., et al. (1977) Royal Society of London., A 285(1327), 151-158. [12] Beaty, D. W., et al. (1980) Proc. Lunar Planet. Sci Conf. 11th: 23-35. [13] Walton, W. J. A., et al. (1977) NASA, JSC Report. [14] Anderson et al. (2004) LPSC 35, #2039. [15] Kneissl, T., et al. (2011). Planet. Space Sci 59,1243-1254. [16] Michael, G. G., et al. (2016) Icarus 277, 279-285. [17] Michael, G. G. et al. (2010) Earth & Planet. Sci Lett. 294, 223-229. [18] Group, C. A. T. W., et al. (1979) Icarus 37, 467-474

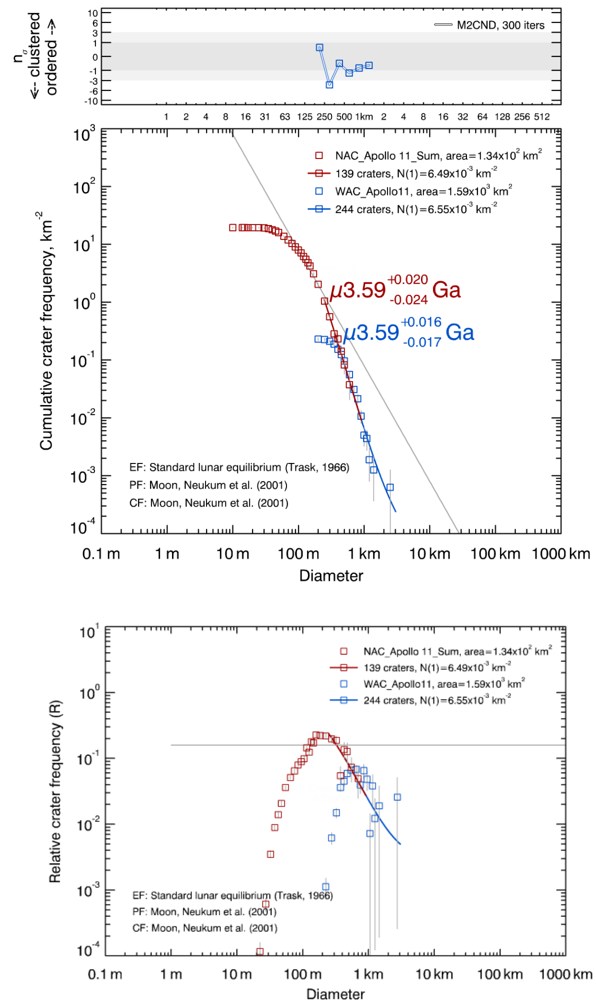

Figure 2. *New CSFD measurements of the original Apollo 11 count area using WAC data (blue) and a combined CSFD distribution for four new NAC-scale count areas (red) in (a) cumulative form with cumulative fits for determination of absolute model ages. The randomness analysis of the WAC count area shows no obvious secondary crater contamination (panel above). (b) Relative crater frequency plot of the same distributions.*