NEW CRATER SIZE-FREQUENCY DISTRIBUTION MEASUREMENTS FOR AUTOLYCUS CRATER, MOON.

H. Hiesinger[1], J. H. Pasckert[1], C. H. van der Bogert[1] and M. S. Robinson[2], [1]Institut für Planetologie, Westfälische Wilhelms-Universität Münster, Wilhelm-Klemm-Str. 10, 48149 Münster, hiesinger@uni-muenster.de, [2]Arizona State University, Tempe, AZ, USA

Introduction: Accurately determining the lunar cratering chronology is prerequisite for deriving absolute model ages (AMAs) across the lunar surface and throughout the Solar System [e.g., 1]. Unfortunately, the lunar chronology is only constrained by a few data points over the last 1 Ga, i.e., Copernicus, Tycho, North Ray, and Cone craters and there are no calibration data available between 1 and 3 Ga and beyond 3.9 Ga [2] (Fig. 1). However, having a data point between 1 and 3 Ga would allow us to further constrain the lunar chronology functions and to potentially improve their accuracies.

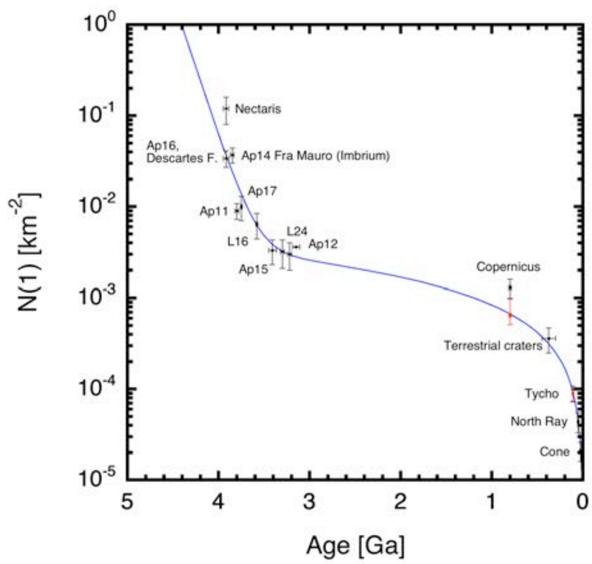

Fig. 1: The lunar chronology function [3] with updated data points for Copernicus and Tycho [1]

Rays from Autolycus (39 km in diameter) and Aristillus (55 km in diameter) cross the Apollo 15 landing site and presumably transported material to this location [e.g., 4,5], although [6] did not find evidence of ray material in neutron fluence data. Schultz [7], however, proposed that at the Apollo 15 landing site about 32% of any exotic material would come from Autolycus crater and 25% would come from Aristillus crater. In addition, [8] argued that compositional similarities between the studied samples and the KREEP rocks of the Apennine Bench, which were the target rocks of Autolycus, make this crater a highly probable candidate for delivering exotic material to the Apollo 15 site. What then, are the ages of Autolycus and Aristillus craters? Bogard et al. [9] and Ryder et al. [8] proposed that the ^{39}Ar-^{40}Ar age of 2.1 Ga derived from three petrologically distinct, shocked Apollo 15 KREEP basalt samples (15434,25, 15434,29, 15358), date Autolycus crater. In particular, on the basis of these ages it has been proposed that these samples were heated and delivered to the landing site by the impact of Autolycus crater [8,9]. Aristillus is younger than Autolycus and has severely modified Autolycus and its ejecta deposits. On the basis of crater densities, [10] argued that Aristillus might even be younger than Copernicus crater, but a heating event of sample 15405 at 1.29 Ga was interpreted as the age of Aristillus crater [11]. Grier et al. [12] reported that the OMAT characteristics of these craters are indistinguishable from the background values despite the fact that both craters exhibit rays that were used to infer relatively young, i.e., Copernican ages [13,14]. Thus, both optical maturity (OMAT) characteristics and radiometric ages of 2.1 Ga and 1.29 Ga for Autolycus and Aristillus, respectively, suggest that either these two craters are likely not Copernican in age or that the Copernican Period started much earlier [e.g., 8]. Hawke et al. [15] have demonstrated that both Autolycus and Aristillus exhibit compositional rays that have reached complete optical maturity, thus supporting earlier results of [16-18]. Thus, assigning a Copernican age to these two craters on the basis of immature crater rays [e.g., 13,14] is incorrect and, hence, extending the Copernican System to 2.1 Ga [e.g., 8] is not justified. The exact timing of the two impacts, however, remains under debate because [19] interpreted newer 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 is indeed the source of the dated exotic material collected at the Apollo 15 landing site, than performing crater size frequency distribution (CSFD) measurements on the ejecta blanket of Autolycus offers the possibility to add a new calibration point to the lunar chronology, particularly in an age range that was previously unconstrained. High resolution images from the Lunar Reconnaissance Orbiter (LRO) Narrow Angle Cameras (NAC) provide new opportunities to investigate such CSFDs on individual geological units at lunar impact craters. We report new CSFD measurements for Autolycus crater, which complement our results for Copernicus, Tycho, North Ray [1], and Cone crater [20].

Data and Method: We used LRO NAC images M1111799019L/R, M1127113703L/R, and

M1129474696R to perform CSFD measurements. The images have a pixel scale of 1.32-1.36 m on the surface and incidence angles of 53-74°. The images were calibrated and map-projected with ISIS 3 and imported into ArcGIS. Within ArcGIS, we used CraterTools [21] to perform our CSFD measurements. The crater size-frequency distributions were then plotted with CraterStats [22], using the lunar production and chronology functions of [3]. Because the PF is only valid in the diameter interval of 10 m to 100 km [3], only craters larger than 10 m were fitted. However, we counted down to smaller crater diameters. The technique of CSFD measurements has been described extensively [e.g., 3, 23-25]. For our crater counts, we mapped several homogeneous areas on the ejecta blanket and the interior of Autolycus crater and particularly paid attention to avoid obvious secondary craters (Fig. 2). However, because the area is heavily contaminated with secondary craters from Aristillus, it is not possible to completely avoid incorporating some secondary craters into the CSFD measurements. This should be kept in mind when interpreting the results.

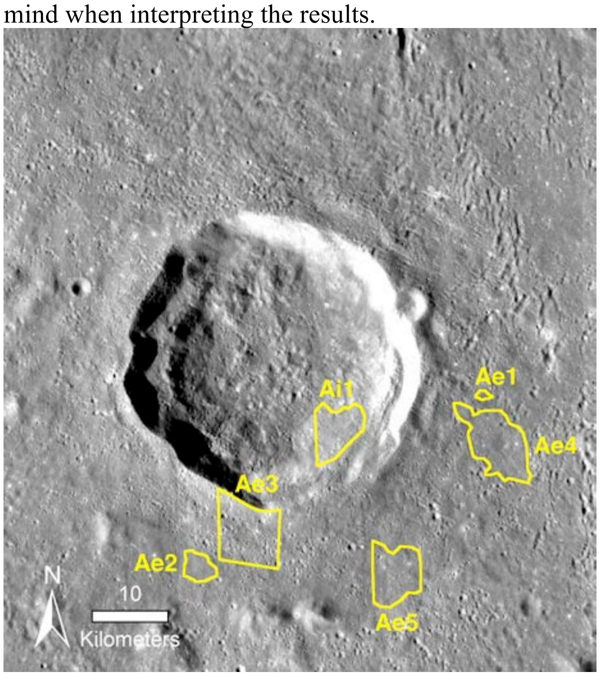

Fig. 2: WAC Mosaic of Autolycus with count areas investigated in this study. Count areas were selected away from obvious crater chains and clusters to minimize effects of secondary cratering from Aristillus, which is to the north-northwest.

Results: On the basis of our CSFD measurements we determined widely variable AMAs for Autolycus crater. We determined ages of 3.72 and 3.85 Ga for the interior (Ai1) and ejecta area 3 (Ae3). The CSFDs appear to be affected by secondary craters and are inconsistent with measurements of adjacent mare basalts. For those basalts, ages of 3.50 and 3.34 Ga have been determined [23,26]. Thus, we consider the ages for Ai1 and Ae3 implausible and reject them. Count areas Ae1 and Ae2 were selected because they are particularly smooth and show only few impact craters. Consequently, their ages are very young (<~0.5-0.6 Ga). These ages appear too young, considering the fact that Aristillus superposes Autolycus and the results of OMAT studies [12]. Ejecta areas Ae4 and Ae5 yielded ages of 3.20 and 3.45 Ga, respectively. Although these ages are the most reasonable ages obtained so far, i.e., that are least affected by secondaries from Aristillus, they are much older than the 2.1 Ga sample ages that were linked to the formation of Autolycus crater [8,9].

Discussion and Conclusions: Large parts of the ejecta blanket of Autolycus are covered with secondary craters from Aristillus crater. These craters occur in clusters, as crater chains, are elongated, and show herringbone patterns. This superposition of the Aristillus deposits makes it extremely challenging to reliably date Autolycus crater. Areas little affected by the deposition of Aristillus ejecta are rare and small. They might have also been modified, although it remains unclear to what extent. Our CSFD measurements for individual parts of the ejecta blanket and floor of Autolycus crater yield a wide range of AMAs. However, none of our CSFDs yield ages that would correspond to the 2.1 Ga age derived from the Apollo 15 samples [8,9]. We also did not determine AMAs that would be consistent with a 1.9 Ga age [19]. This either implies that the dated samples are not related to Autolycus or that the CSFD measurements are so heavily affected by resurfacing and secondary cratering from Aristillus that they do not represent the formation age of Autolycus. In either case, because of these uncertainties Autolycus can not currently be used as a calibration point for the lunar chronology function. A dedicated mission to either sample terrains with ages of 1-3 Ga or in situ dating such surfaces is of high priority to further constrain the lunar chronology.

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