NEW CRATER SIZE-FREQUENCY DISTRIBUTION MEASUREMENTS FOR COPERNICUS CRATER BASED ON LUNAR RECONNAISSANCE ORBITER CAMERA IMAGES. H. Hiesinger[1], C. H. van der Bogert[1], J. H. Pasckert[1], M. S. Robinson[2], K. Klemm[1], D. Reiss[1], and the LROC Team, [1]Institut für Planetologie, Westfälische Wilhelms-Universität Münster, Wilhelm-Klemm-Str. 10, 48149 Münster, Germany, [2]Arizona State University, Tempe, AZ, USA.

Introduction: Copernicus is a 93-km large impact crater on the lunar central nearside, located at 9.7° N and 20.1° E. Named after the Polish astronomer Nicholas Copernicus, it exhibits a prominent bright ray pattern that extends across large parts of the nearside hemisphere, including the Apollo 12 landing site. Because the rays are superposed on most of the materials they cross and because of the general sharply sculptured crater morphology, Copernicus is interpreted as a young Copernican crater [1].

The Apollo 12 landing site is covered with Copernicus ray material, which led Meyer et al. [2] to propose that KREEP glass in the Apollo 12 samples was actually ejected by Copernicus, and could be used to date the impact. Radiometric ages of samples 12032 and 12033 collected at Head crater have an age of 800-850 Ma [3-7]. While these ages are generally accepted to reflect the age of the Copernicus impact event, Stöffler and Ryder [8] point out a few problems with this interpretation. They argue that not all KREEP material at the Apollo 12 site may come from Copernicus; it may have come from different sources [7, 9]. This is because Copernicus itself does not seem to have excavated primarily KREEP material. In addition, the glass samples were only found at Head crater, but are not widely distributed at the Apollo landing site. As the Copernicus ray is clearly visible from orbit, it is reasonable to assume that the ray material should be widely distributed at the landing site, not only at Head crater. From these considerations, [8] concluded, that the age of Copernicus is either well-known at 800±15 Ma or, it can only be inferred to be younger than ~2 Ga.

Assuming a constant flux of impactors for the last 3 Ga [e.g., 8, 10-12] and using the radiometric age of North Ray crater (50.3±0.8 Ma) as a calibration point [e.g., 8, 13], the absolute model ages derived from crater size frequency distribution (CSFD) measurements for the floor of Copernicus and its continuous ejecta blanket are significantly older than the radiometric ages. For example, Neukum determined an absolute model age of 1.5 Ga ($N_{(1)}=1.3\times10^{-3}$) [11] and König [14] determined a model age of 1320±310 Ma ($N_{(1)}=(1.0±0.3)\times10^{-3}$). While radiometric ages and CSFDs of Tycho, North Ray, and Cone crater are consistent with a constant cratering rate over the last 3 Ga, cumulative crater frequencies at Copernicus crater are too high [e.g., 8, 10-12]. Neukum and König argued that either their counts were affected by a large number of secondary craters or the radiometric ages of the Apollo 12 samples do not date the Copernicus event [14].

Copernicus is an important anchor point for the lunar chronology. Thus, in order to ultimately better constrain the lunar chronology, we performed new crater counts for Copernicus. These counts will be compared to counts from the Apollo 12 landing site.

Data: For our investigation we used three image pairs from the Lunar Reconnaissance Orbiter Narrow Angle Camera (LROC NAC), M102271998, M102279188, and M102293451. The images have a pixel size resolution of 1.2 m and allow us to perform very detailed crater counts. The images were processed with ISIS 3 and imported into ArcGIS. Within ArcGIS, we used CraterTools [15] to perform our crater counts. The CSFDs were plotted with CraterStats [16]. We used the production function of [17] and the lunar chronology of [10]. As a result, we obtained absolute model ages (AMAs) for craters in the diameter interval of 10 m to 300 km [11]. For a detailed description of the technique of CSFD measurements, we refer to [e.g., 11, 18-20]. For our crater counts we paid particular attention to select homogeneous count areas and to avoid obvious secondary craters.

Results: We dated 8 units at Copernicus crater (Table 1), including four different interior melt pools, two areas on the floor, and two on the continuous ejecta blanket SW of the crater rim.

Table 1. Size of counting areas, number of craters counted, N(1), and the absolute model ages (AMAs) for each Copernicus unit.

Location	Area (km^2)	Craters	N(1) (x 10^{-4})	AMA (Ma)
Interior Pool 1	1.01×10^{0}	794	1.62	194
Interior Pool 2	9.30×10^{-2}	213	1.24	148
Interior Pool 3	2.01×10^{-1}	364	2.67	113
Interior Pool 4	2.92×10^{-1}	431	1.98	237
Crater Floor 1	1.64×10^{0}	714	3.75	447
Crater Floor 2	4.81×10^{-1}	415	3.00	358
			0.68	81
Ejecta 1	1.31×10^{0}	727	5.12	611
Ejecta 2	4.02×10^{0}	1147	7.14	852

Melt pool 1 is the largest pool dated. The AMA of this pool is 194 Ma (Fig. 1a). The AMAs of melt pools 2, 3, and 4 are 148 Ma, 113 Ma, and 237 Ma, respectively. Compared to the ages of melt pools at Tycho crater [22], we observe a much wider range of ages for individual melt pools. Similarly, the range of ages for two units on the floor of Copernicus is wider. We measured an AMA of 447 Ma for floor unit 1 and 358 Ma for floor unit 2 (Fig. 1b). While these ages appear to be different, they are within error of each other. However, contrary to Tycho crater, where the floor and the melt pools are of the same age, the ages of these units are different in Copernicus. In fact, for Copernicus, we find older ages for the floor units compared to the melt pools.

Our crater counts for two ejecta regions revealed ages of 611 Ma (Ejecta 1) and 852 Ma (Ejecta 2). Both ages are consistent with each other within the error (Fig. 1c). Particularly, the age of ejecta unit 2 is in excellent agreement with radiometric ages of proposed Copernicus material from the Apollo 12 landing site. However, due to the complexity of the obtained results, further age determinations are necessary to get better statistics on the range of ages.

Discussion: Secondary impact cratering at Copernicus has been described in numerous papers and endogenic craters in the size range of 10-20 m might also occur on the interior terraces [e.g., 12, 21]. Both processes complicate the determination of reliable ages of this crater. Additionally, strength differences between weaker ejecta blankets and more coherent melt pools and crater floor material, further complicate the CSFD measurements and the derivation of AMAs [23].

Conclusions: From our CSFD measurements performed for melt pools inside Copernicus crater, the hummocky crater floor and two areas on the proximal ejecta blanket, we conclude that: (1) the ages of melt pools exhibit a wider range than at Tycho crater; (2) the ages of two floor units also vary widely but within error of each other; (3) the ejecta blanket also shows wide variations in ages but within the error of each other; (4) the ejecta blanket units are significantly older than the floor and melt pool units; (5) at least the age of ejecta unit 2 is in excellent agreement with radiometric ages of Copernicus material form the Apollo 12 site; (5) the effects of secondary cratering and target strength differences, as well as possible contributions of endogenic craters need to be further investigated.

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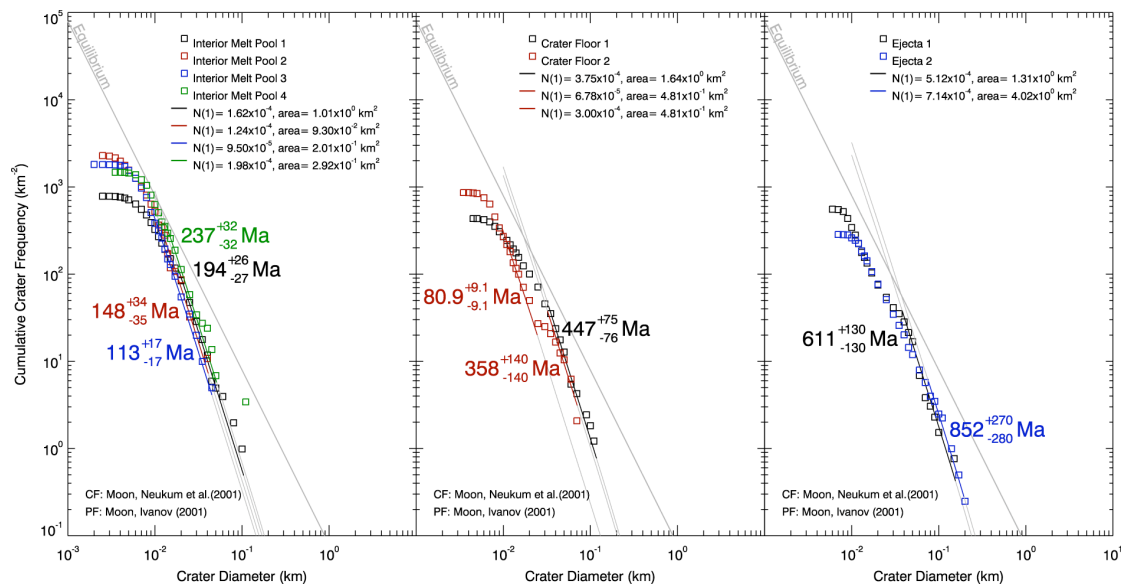

Figure 1. *CSFDs of (a) melt pools, (b) the crater floor, and (c) the proximal ejecta blanket of Copernicus crater.*