LUNAR IMPACT BASINS: CRATER STATISTICS AND SEQUENCE FROM A LUNAR ORBITER LASER ALTIMETER (LOLA) CATALOG OF LARGE LUNAR CRATERS (≥20 KM).

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Introduction: The time sequence of visible impact basins on the lunar surface is important to understanding the stratigraphy and surface evolution of the Moon. The global catalog of craters with diameters ≥20 km on the Moon [1,2] we recently compiled using Lunar Orbiter Laser Altimeter [3] data enables us to calculate the crater statistics for many lunar basins, which provides the basis for re-examination of the stratigraphic sequence of basins [e.g., 4,5].

Methods: As a starting point for examining basin stratigraphy, we use Wilhelms [5] compilation of lunar basin stratigraphy. We include basins 300 km and larger, with the requirement that they have a mappable rim and central depression in LOLA data. Some basins that we eliminate from consideration may exist, but have been degraded beyond our ability to map them. In the crater catalog creation [1], basins were mapped on the basis of LOLA data alone, and a few additional basins not included by Wilhelms also met our recognition criteria (e.g., Fig 1; first suggested by [6]).

Determination of the superposed crater density for many lunar basins is complicated by the fact that many have experienced significant post-formation modification, particularly by mare volcanism. For this reason, finding a count area that provides reasonable counting statistics and complete population of post-basin craters requires careful analysis. For this reason, we have adapted the buffered crater counting technique [7] to derive 'buffered crater' ages for 10 of the basins, including Imbrium, Crisium, Nectaris, and Smythii, calculating the count area in buffers around clear basin material (usually the basin rim). In practice, the crater frequencies derived using the buffer technique differ only slightly from the traditional counting approach (Fig. 2).

Note that we follow the convention that N(20) is the cumulative number of craters of size ≥20 km, normalized to an area of 10^6 km^2.

Observations and Results: A portion of our observational results are shown in Table 1. Both Nectaris and most Nectarian basins have increased crater densities in our data compared to Wilhelms [5] (Table 1, Fig. 3). The systematic differences in density imply that the pre-Nectarian/Nectarian boundary should be refined to a higher N(20) density. Better quantitative agreement exists for younger basins, where count areas are typically larger and superposed craters less degraded. The reason for better agreement for older basins is less clear but may be a result of these basins being at saturation, so counts in these regions tend to cluster in crater density [e.g., 8].

Despite the quantitative differences between our observations and Wilhelms' [5], the sequence of basins derived are in reasonably good agreement, with a few exceptions. For example, Humorom appears significantly older than originally mapped and may be pre-Nectarian rather than Nectarian (Table 1). It is clear from these measurement that definitively separating basins that are close to the same age is difficult on the basis of crater statistics alone. It seems unlikely that extending the count statistics to smaller crater sizes will ameliorate this problem, as basin secondaries [9] and crater erasure become more prevalent at small sizes, making age determinations more uncertain.

References: [1] Kadish, S.J. et al (2010), *LPSC 42* (this meeting), 1006. [2] Head, J.W. et al. (2010), *Science*, *329*, 1504-1507. [3] Smith, D.E. et al. (2010), *Space Sci. Rev.*, *150*, 209-241. [4] Hartmann, W.K., Wood, C.W. (1971), *The Moon*, *3*, 3-78. [5] Wilhelms, D.E. (1987), *The Geologic History of the Moon,* USGS PP no. 1348. [6] Cook, A.C et al., 2002, *LPSC 33*, 1281. [7] Fassett, C.I., Head, J.W. (2008), *Icarus, 195*, 61-89. [8] Richardson, J.E. (2009), *Icarus* 204, 697-715. [9] Wilhelms, D.E. et al. (1978), *Proc LPSC 9*, 3735-3762.

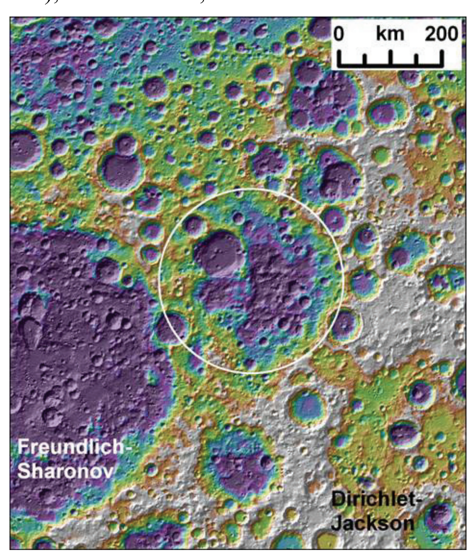

Fig. 1. The proposed Fitzgerald-Jackson basin (circle) [6] in LOLA data (170W, 25N; purple, low; white, high). It pre-dates Freundlich-Sharonov and has N(20)=207±38. This is an example of a possible basin that may have been cratered to saturation [8] for D~20 km craters.

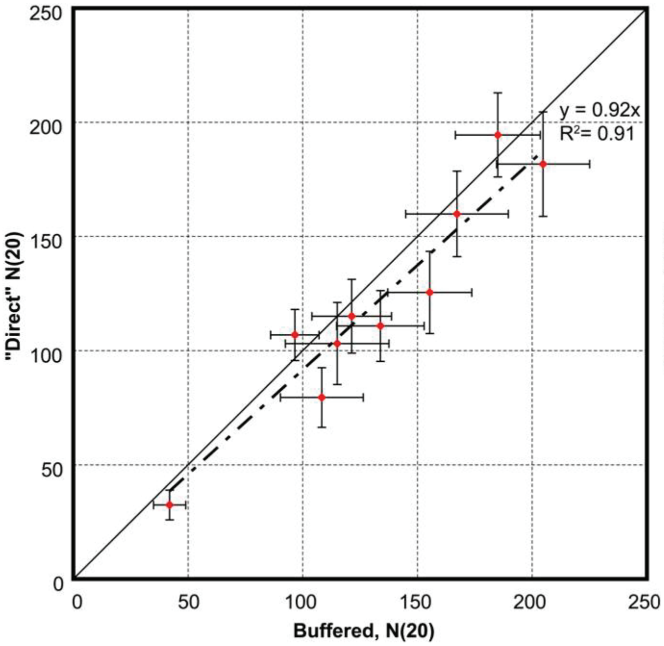

Fig 2. Comparison of basin crater densities from our mapping using a buffered counting approach [see 7], buffering around basin materials, compared with a traditional 'count area' method. In principle, the buffered approach should be a more accurate assessment of basin relative age, since it is a better assessment of the count area, but the difference is small (~8-10%) on average.

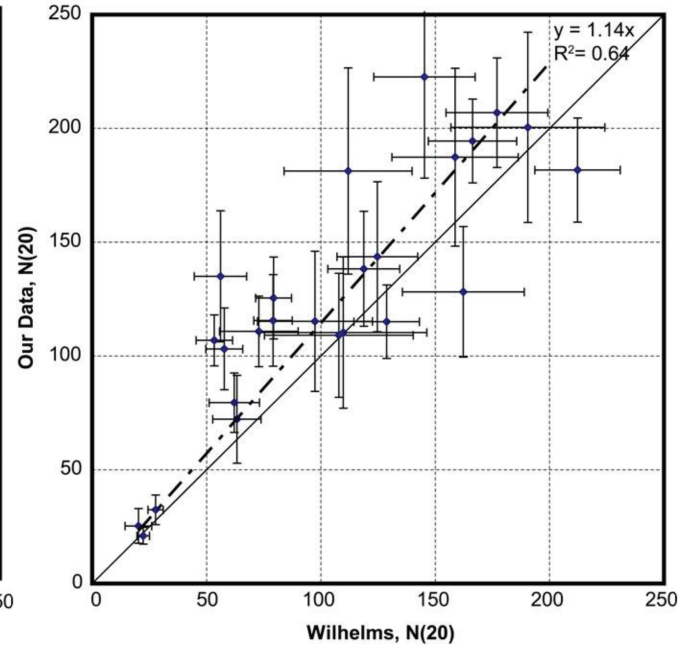

Fig 3. Comparison of superposed crater density from Wilhelms' data [5] and our new measurements. The solid diagonal line is 1-to-1 and error bars are sqrt-N. We consistently find a higher density of superposed craters than originally mapped . As an example, Nectaris, which is an important basin in the lunar stratigraphic scheme, was found to have N(20)=79±8 in [5] and has N(20)=125±18 in our data.

Basins	***Period***	***Not Separable?***	***Note***	***Our N(20)***	***Wilhelms N(20)***
SPA	Very Early		Stratigraphy (probable saturation of large craters)	*N/A*	
Werner-Airy, Lomonosov-Fleming; Poincare; Fitzgerald-Jackson (Fig.1)	PN	||||	Probable saturation densities	200-300	>175
Smythii*	PN	|||		194±18	166±19
Lorentz	PN	|||	Possible saturation densities	187±40	158±27
Australe*	PN	|||		182±23	212±18
Nubium*	PN	|||		160±19	N/A
Apollo	PN/{N?}			138±25	119±16
Humorum	PN/{N?}			135±29	56±11
Nectaris*	Beginning of N	||		125±18	79±8
Korolev	N /{PN?}	||		116±20	79±8
Freundlich-Sharonov*	N /{PN?}	||		115±16	129±14
Mendel-Rydberg*	N	||		111±16	73±17
Crisium*	N	|		107±11	53±8
Hertzsprung*	N	|		103±18	57±8
Humboldtianum*	N			80±13	62±10
Mendeleev	N			72±19	63±10
Imbrium*	Beginning of I			32±7	28±3
Schrodinger	I			25±7	20±5
Orientale	I			21±4	22±3

Table 1. Inferred sequence of some major lunar basins from their superposed craters (*'s from buffered areas). Note the discrepancy between the absolute density of craters larger than 20 km in Wilhelm's [5] counts of basins and in the new data, particularly for Nectarian basins. However, in general, the stratigraphic sequence derived is reasonably close to Wilhelm's [5] results, with the possible exception of Humorum and Freundlich-Sharonov.