CRUSTAL THICKNESS EVIDENCE FOR MORE PREVIOUSLY UNRECOGNIZED LARGE LUNAR BASINS

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Summary: Lunar topographic data revealed a large population of large impact basins not previously recognized by standard photogeologic mapping. Crustal thickness model data reveal the presence of even more. The total number of lunar basins > 300 km diameter may exceed 150, more than 3 times that determined by photogeologic mapping alone.

Introduction: Photogeologic mapping suggested the cumulative number of impact basins on the Moon larger than 300 km diameter was 45 [1]. Early analysis of Clementine topography revealed several new large impact basins not previously known [2,3]. A recent systematic search [4] for Quasi-Circular Depressions (QCDs) using ULCN 2005 [5] gridded topography suggested 92 $\geq$ 300 km diameter. While many of the Wilhelms basins have significant topographic structure and appear as QCDs in the ULCN data, 10 do not have obvious topographic structure and 10 others have a topographic structure that suggests a different basin center or ring diameter than was derived from photogeology [4]. A comparison of the cumulative frequency curves for basins identified by photogeologic mapping and those derived from topography shows general agreement down to a diameter of about 500 km; both follow a roughly -2 powerlaw curve. Below that the Wilhelm's listed basins [1] fall off the curve but the topographically-derived basins continue along it down to the cutoff diameter of 300 km. Most of the basins missed by photogeologists are at the smaller diameters.

Most previously unknown basins on Mars were found as QCDs in Mars Orbiting Laser Altimeter (MOLA) data [6,7,8] but additional presumably more deeply buried basins were found as Circular Thin Areas (CTAs) [9] in crustal thickness model data [10]. We examined lunar crustal thickness data [11] for CTA signatures that might be additional large impact basins not previously recognized in photogeologic or topographic mapping alone.

Evidence for basins in lunar crustal thickness data. Gridded data from the Wieczorek crustal thickness model [11] were colored, stretched, contoured and searched for Circular Thin Areas (CTAs) surrounded by thicker crust, using the same GRIDVIEW software used for the Mars studies [12]. Figure 1 shows results for one part of the Moon. Although there are some exceptions, nearly all the basins identified using ULCN topographic data [4] have an obvious crustal thickness signature, sometimes offset from the topographic basin. This suggests crustal thickness data is indeed useful for identifying large impact basins. Additional CTAs that may be new basins not previously identified in the topographic study are indicated by the red arrows in Figure 1. A preliminary search yielded some 56 possible new impact basins larger than 300 km diameter, over and above those found in the earlier topographic study[4].

Figure 2 shows cumulative frequency curves for basins $\geq$ 300 km diameter derived from different sources. The CTA population in Figure 2 is less than the topographic population, but still contributes significantly to a "total" population (CTAs plus QCDs, which include the visible basins having a topographic signature). This total population is a factor 3 greater than that based on the photogeologically determined basins only. The N(300) crater retention age for the lunar surface is probably at least 3.9, a significant increase over that suggested by the Wilhelms [1] list of basins (1.2) or even that suggested by our earlier topographic study (2.5).

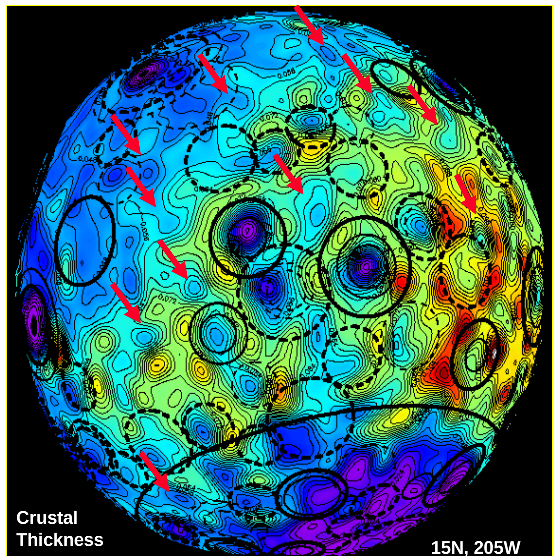

Figure 1. Portion of the lunar farside at 15N, 205W. Color is stretched lunar crustal thickness [11]. Thin crust in blues, thick crust in reds. Contour interval 4 km. Basins identified by Wilhelms [1] also found in ULCN topography [4] shown as solid black circles. Dashed black circles are new basins identified in the ULCN topography [4]. Red arrows indicate CTAs that may be additional new large basins.

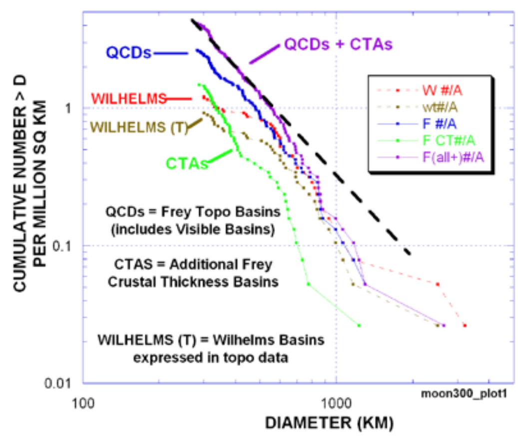

Figure 2. Cumulative frequency curves for basins > 300 km diameter from photogeology (Wilhelms [1]; both his total list [red] and those basins with a topographic signature [T, brown]), from ULCN topography (Frey [4], QCDs, blue), additional new candidate basins from crustal thickness data (CTAs, green, this work) and the inferred total population (CTAs and QCDs, purple, this work).

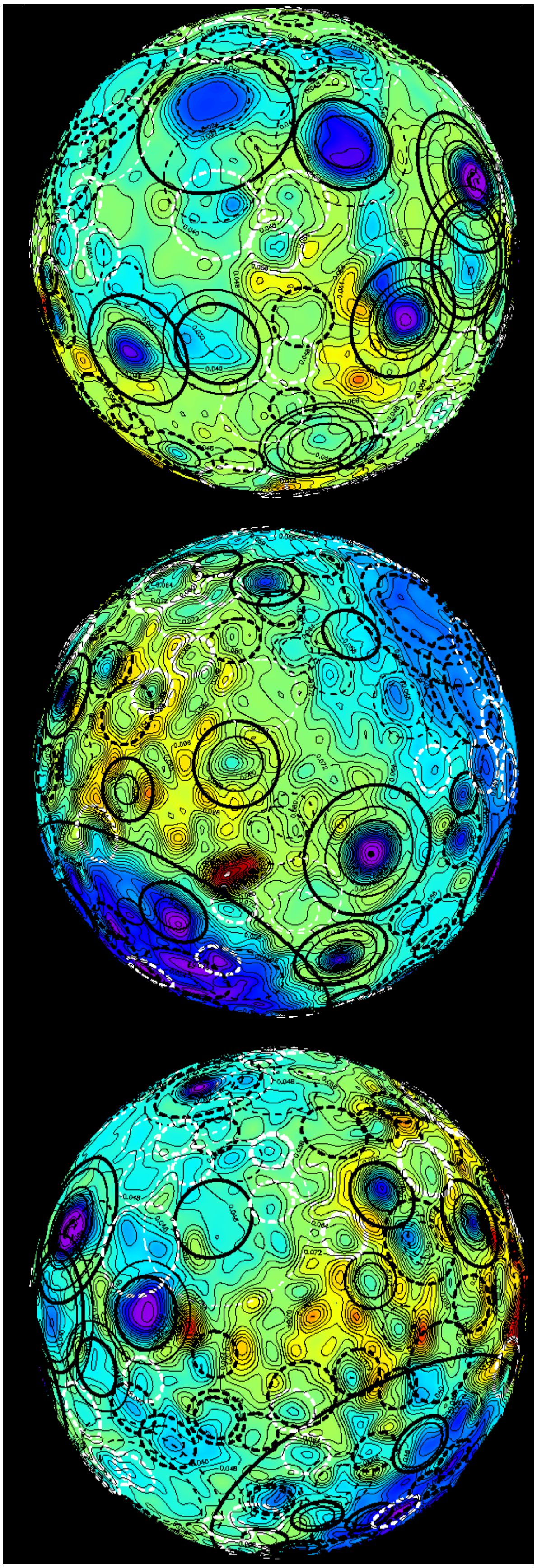

Figure 3 shows the global distribution of the new candidate basins ≥ 300 km diameter (dashed white circles) compared with the population inferred from the ULCN study [4] (black circles). As was the case with the topographic basins, there are more new basins on the lunar farside and at high latitudes than on the nearside. Although photogeologic mapping was apparently more successful in finding a larger percentage of the total population on the near side, there are a number of likely basins that were missed but which topography and crustal thickness can reveal.

Discussion: The total population of large impact basins on the Moon appears to be significantly greater (at least a factor 3) than the previously recognized "visible" (photogeologically-determined) population, and even larger than we previously suggested based on the larger number of topographically identified basins. This suggests the early large diameter impact rate on the Moon was at least 3 times greater than previously thought, which has important implications for scaling to impact rates for the Earth and other planets.

Given the coarse horizontal and vertical resolution of the topography and the topographic component of the crustal thickness data, the candidate basins so far identified are still likely an underestimate of the true number of large basins on the Moon. It is likely that even more subtle features will be found when LOLA topographic data and crustal thickness models derived from LOLA and improved gravity from LRO become available.

Conclusions: A large number of large basins not previously recognized by photogeologic mapping or even topographic mapping exist on the Moon, which are revealed by the current relatively low resolution lunar crustal thickness data. The large diameter impact bombardment of the Moon may have been at least a factor 3 greater than previously thought.

References. [1] Wilhelms, D.E, (1987) the Geologic History of the Moon, USGS Professional Paper 1348. [2] Spudis, P.D. et al. (1994) *Science 266*, 1848-1851. [3] Zuber, M.T. et al. (1994) *Science*, *266*, 1839-1843. [4] Frey, H.V. (2008) LPSC Abstract # 1344. [5] Archinal, B.A. et al. (2006) USGS Open File Report 2006-1376, Version 1.0. *).* [6] Frey, H.V. et al. (1999) *GRL. 25*, 4409-4412. [7] Frey, H.V. et al. (2002) *GRL. 29*, 1384, doi:10.1029/2001GL13832. [8] Frey, H.V. (2006*), JGR (Planets) 111*, E08S91,doi:10.1029/2005JE002449. [9] Edgar, L.A. and H.V. Frey (2008) *GRL. 35*, L02201, doi:10.1029/2007GL031466. [10] Neumann, G.A. et al. (2004) *J. Geophys. Research (Planets) 109*, E08002, doi:10.1029/2004JE002262. [11] Wieczorek, M.A. et al. (2006) *Rev. Mineral. Geochem. 60*, 221-364. [12] Roark, J. H. et al. (2000) *LPSC 31*, Abstract #2026.

Figure 3. Stretched crustal thickness data [11] with basins ≥ 300 km diameter identified in lunar topography [4] as black circles (newly identified basins shown dashed, basins previously identified by photogeologic mapping as solid) and new additional candidate basins found as CTAs shown as white circles. Thicker circles are stronger candidates. Blues are thin crust, reds are thicker crust. Contour interval 4 km. Most topographically derived basins have a crustal thickness signature, and there are many CTAs smaller than the 300 km diameter cutoff which are signatures of both known and likely previously unknown smaller basins.