A GLOBAL CATALOG OF LARGE LUNAR CRATERS (≥20 KM) FROM THE LUNAR ORBITER LASER ALTIMETER. S. J. Kadish[1], C. I. Fassett[1], J. W. Head[1], D. E. Smith[2], M. T. Zuber[2], G. A. Neumann[3], E. Mazarico[3]. [1]Dept. of Geological Sciences, Brown University, Providence, RI 02912, [2]Department of Earth, Atmospheric, and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, MA 02139, [3]Solar System Exploration Division, NASA/Goddard Space Flight Center, Greenbelt, MD 20771. (Seth_Kadish@brown.edu).

Introduction: Global crater catalogs are ideal data for the purpose of determining the relative ages of surfaces, and the timing of significant geologic events in a planetary body's history, as well as for shedding light on possible changes in the impactor populations over time. Specifically, these datasets allow for efficient and accurate analyses of surface ages via the production of size-frequency distributions that use spatially defined subsets of the global catalog. Here, we present the methodology, background, and data for a comprehensive crater catalog of lunar craters ≥20 km in diameter that we measured on the basis of Lunar Orbiter Laser Altimeter (LOLA) data.

Earlier catalogs were constructed using mosaics that were areally incomplete, and typically comprised of images taken at varying solar illumination geometries and different resolutions. These data made it difficult to produce consistent measurements across the entire surface area of the Moon, and some areas were left unexamined. For example, the catalog compiled by Wilhelms et al. (1978) lacked coverage of 18% of the lunar surface [1]. These limitations highlight the necessity of a global, homogeneous base layer in producing a global crater catalog.

The global topography data recently measured of the Moon using LOLA [2] have allowed us to make consistent measurements of all large lunar craters with no gaps in coverage. The LOLA data utilized was at a resolution of 64-pixels-per-degree, which corresponds to an equatorial resolution of 473.8 m/pix, which is more than sufficient to detect craters ≥20 km in diameter. A more recent 128-ppd dataset has also been created. This topographic dataset is excellent for recognizing even subtle topographic expressions of craters. In doing so, it circumvents traditional observational uncertainties imposed by heterogeneous image quality and illumination geometry.

Methods: To create the lunar crater catalog, the LOLA data were represented in ArcMap as two superposed rasters to produce a colorized shaded relief map in which colors provide direct elevation measurements and shading highlights topographic gradients. This was overlain then by a 20-km reference grid. The survey was performed by systematically scanning across the lunar surface, measuring all large craters in each scene. This global survey was repeated at four distinct scales – in latitudinal swaths of 15°, 30°, 60°, and 120° – to ensure that all craters from the 20-km lower limit to the massive basins were detected, and that multi-ring basins were not mistaken for multiple craters. An additional raster of the best available imagery was used when necessary to confirm the accuracy of measurements and to allow for morphological assessments of craters.

All craters, regardless of degradation state, were included in the catalog as long as they had a measurable rim and central depression. As such, the catalog includes fresh craters, as well as those that are degraded, embayed, or buried. Individual craters were measured using the CraterTools extension to ArcMap [3]. CraterTools calculates a best-fit circle based on a user input of three points on the crater rim, or by drawing a rim-to-rim diameter. Measurements are automatically corrected for the data frame map projection to provide accurate crater diameter and distance values. Non-circular craters were outlined manually.

Between 70°N and 70°S, the survey was performed in an equidistant cylindrical projection, preserving distances along meridians. As such, the reference grid could be easily used to identify all craters ≥20 km by comparing the crater diameters to the grid spacing along lines of longitude. To ensure that no craters were omitted, we measured all craters that appeared even close to this lower limit. The population of craters less than 20 km (generally 16 to 20 km in diameter) was removed from the final catalog upon completion of the survey. Poleward of 70° latitude, we mapped craters in polar projections, again including craters below the diameter cutoff for our survey. The polar and non-polar populations were merged to produce the final global catalog, which includes 5185 craters.

Results: *Initial results*: Initial results of this study were published in [4]. Fig. 1 shows the global map of craters and crater density (for craters ≥20 km). Our results are consistent with the concept that the densely cratered highlands were likely cratered to saturation equilibrium [e.g., 5]. The newly-cataloged data are also consistent with earlier measurements that suggest major differences in the size-frequency distribution of craters on the mare and in the highlands [6] (Fig. 2).

Crater Density in South Pole-Aitken Basin: On the basis of stratigraphy as well as crater data, South Pole-Aitken (SPA) basin has been interpreted as the oldest basin in the lunar cratering record [7]. Our data support this view, showing that, at large sizes (D≥~60-80 km), SPA has a comparable or higher density of superposed craters than the highlands outside the basin (Fig. 3). It is plausible that the explanation for this equivalence is due to the fact that both within and outside SPA, cratering proceeded to saturation early in lunar history.

At smaller sizes (D≤~60-80 km), there is a statistically robust divergence between the crater density of the area outside SPA and within the basin, as SPA's interior has a distinctly lower density than outside the basin (Fig. 3; see also 1b). We interpret this difference to signify that SPA experienced more resurfacing than typical highlands regions. Possible mechanisms for this resurfacing range from the formation of an unusual allotment of young basins (e.g., Schrodinger, Orientale) within and close to SPA, which may have erased craters (e.g., by ejecta emplacement), to mare/crypto-mare volcanism, which is known to have occurred but its importance is not well-constrained. The ultimate significance of these and other resurfacing mechanisms is currently unknown, but the magnitude of erasure had to have been substantial enough to affect the density of 20-64 km craters. Unraveling the removal of craters in this size range is important to understanding the geological history of SPA, and may have implications for the genesis of samples returned from within the basin.

Other Applications: We are applying this catalog to several other research problems, including:

1) verifying that basin secondaries are not making a major contribution to the observed density structure,

2) using this data to construct depth/diameter relationships, and to assess quantitative and qualitative models for crater formation and degradation,

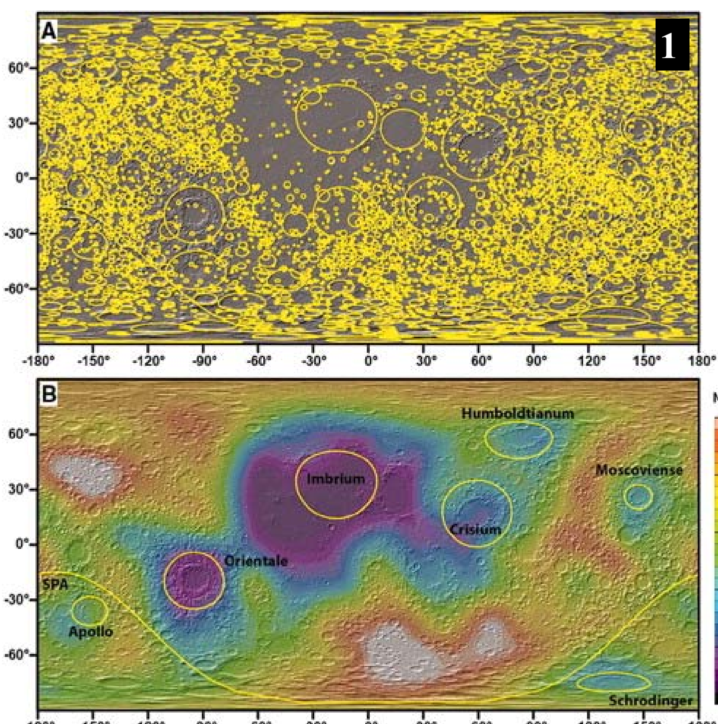
3) examining the relative stratigraphy of large impact basins, and updating earlier estimates for their superposed crater populations [7],

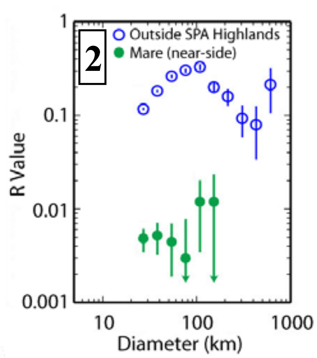
4) working on criteria for basin recognition and testing the existence of previously hypothesized basins (some of which are not observed in LOLA data),

5) comparing the structure of the large impact record to what is observed on Mercury and Mars, and

6) assessing the topography of proposed basin rings.

References: [1] Wilhelms, D.E. et al. (1978), *Proc. Lunar Planet Sci. Conf. 9th*, 3735-3762. [2] Smith, D.E. et al. (2010), *Space Sci. Rev.*, *150*, 209-241, doi: 10.1007/s11214-009-9512-y. [3] Kneissl, T. et al., (2010), *PSS,* in press, doi: 10.1016/j.pss.2010.03.015. [4] Head, J.W. et al. (2010), *Science*, *329*, 1504-1507, doi: 10.1126/science.1195050. [5] Richardson, J.E. (2009), *Icarus 204*, 697-715, doi: 10.1016/j.icarus.2009.07.029. [6] Strom, R.G. et al. (2005, *Science 309*, 1847-1850, doi: 10.1126/science.1113544. [7] Wilhelms, D.E. (1987), *The Geologic History of the Moon,* USGS PP no. 1348.





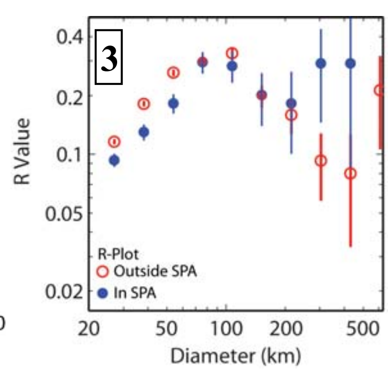


Fig. 1. (**A**) Craters (≥20 km) superposed on a hillshade rendering of lunar topography from LOLA (**B**) Crater densities from this map, calculated in neighborhoods of radius 500 km.

Fig. 2. An R-plot (showing areal density) of craters superposed on lunar nearside mare and representative highlands (outside SPA). This plot illustrates the difference in both density and shape of the size-frequency distribution [6] on these terrains.

Fig. 3. Differences between the region inside the SPA basin and its surrounding highlands. At large sizes, SPA is similar or more densely cratered than surrounding highlands, but at sizes <~70 km, SPA has a statistically significant deficit of craters, suggesting that resurfacing and erasure of craters has been important.