The transition from complex craters to multi-ring basins on the Moon: Quantitative geometric properties from Lunar Reconnaissance Orbiter Lunar Orbiter Laser Altimeter (LOLA) data

David M. H. Baker,[1] James W. Head,[1] Gregory A. Neumann,[2] David E. Smith,[2,3] and Maria T. Zuber[2,3]

Received 31 October 2011; revised 22 January 2012; accepted 23 January 2012; published 22 March 2012.

[1] The morphologic transition from complex impact craters, to peak-ring basins, and to multi-ring basins has been well-documented for decades. Less clear has been the morphometric characteristics of these landforms due to their large size and the lack of global high-resolution topography data. We use data from the Lunar Orbiter Laser Altimeter (LOLA) instrument onboard the Lunar Reconnaissance Orbiter (LRO) spacecraft to derive the morphometric characteristics of impact basins on the Moon, assess the trends, and interpret the processes involved in the observed morphologic transitions. We first developed a new technique for measuring and calculating the geometric/morphometric properties of impact basins on the Moon. This new method meets a number of criteria that are important for consideration in any topographic analysis of crater landforms (e.g., multiple data points, complete range of azimuths, systematic, reproducible analysis techniques, avoiding effects of post-event processes, robustness with respect to the statistical techniques). The resulting data more completely capture the azimuthal variation in topography that is characteristic of large impact structures. These new calculations extend the well-defined geometric trends for simple and complex craters out to basin-sized structures. Several new geometric trends for peak-ring basins are observed. *Basin depth:* A factor of two reduction in the depth to diameter (d/D_r) ratio in the transition from complex craters to peak-ring basins may be characterized by a steeper trend than known previously. The d/D_r ratio for peak-ring basins decreases with rim-crest diameter, which may be due to a non-proportional change in excavation cavity growth or scaling, as may occur in the simple to complex transition, or increased magnitude of floor uplift associated with peak-ring formation. *Wall height, width, and slope:* Wall height and width increase with increasing rim-crest diameter, while wall slope decreases; decreasing ratios of wall width to radius and wall height to depth may reflect burial of wall slump block toes by impact melt redistribution during transient cavity collapse. Melt expulsion from the central basin may help to explain the observed increase in floor height to depth ratio; such central depressions are seen within the largest peak-ring basins. *Peak-ring height:* Heights of peak rings increase with increasing rim-crest diameter (similar to central peak heights in complex craters); peak-ring height to basin depth ratio also increases, suggesting that floor uplift is even larger in magnitude in the largest peak-ring basins. No correlation is found between peak-ring elevation and distance to the rim wall within a single basin, suggesting that rim-wall slumping does not control the topography of peak rings. *Offset of peak rings*: Peak rings often show minor offset from the basin center. Enhancement in peak-ring elevation in the direction of offset is generally not observed, although this could be a function of magnitude of offset. *Basin volume*: Volumes of peak-ring basins are about 40% smaller than the volumes predicted by geophysical estimates of the dimensions of

[1]Department of Geological Sciences, Brown University, Providence, Rhode Island, USA.
[2]Solar System Exploration Division, NASA Goddard Space Flight Center, Greenbelt, Maryland, USA.
[3]Department of Earth, Atmospheric and Planetary Sciences, MIT, Cambridge, Massachusetts, USA.

0148-0227/12/2011JE004021