BRIDGING THE GAP BETWEEN OBSERVATIONS AND NUMERICAL MODELS OF PEAK-RING BASIN FORMATION. G. S. Collins[1], D. M. H. Baker[2], J. W. Head[2] and R. W. K. Potter[2], [1]Department of Earth Science and Engineering, Imperial College, London, UK (g.collins@imperial.ac.uk), [2]Department of Earth, Environmental and Planetary Sciences, Brown University, Providence, USA.

Introduction: Peak-ring basins provide important insight into the formation of large craters, as they are transitional between complex craters with central peaks and larger multi-ring basins. Here we synthesize recent morphometric and gravity observations of lunar peak-ring basins and compare these with recent numerical simulations of peak-ring basin formation. In our analysis we compare two working hypotheses for the formation of peak rings and plot a course for future modeling efforts to test these hypotheses.

Peak-ring basin observations: Recent work [1-3] has updated the catalogs of peak-ring basins on the Moon and used Lunar Orbiter Laser Altimeter (LOLA) gridded topography data to measure a number of morphometric characteristics of these basins (Fig. 1).

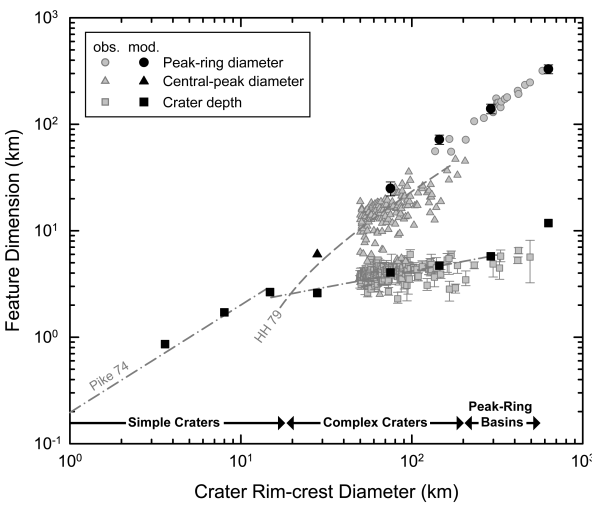

Figure 1. Morphometric measurements of final craters from iSALE simulations of lunar crater formation compared with observations. Crater observations are from [1,3]; trend lines from [4,5].

The most fundamental observation is the well-known decrease in depth-to-diameter ratio as crater size increases [4]. In addition, the diameters of central peaks [5] and peak rings [1] follow distinct trends with rim-crest diameter on the Moon and other terrestrial planets. An important new observation is that the onset of peak-ring basins is marked by a discontinuity in the central feature diameter trend; i.e., peak-ring diameters are consistently larger than central-peak diameters over the size range where both crater types occur (Fig. 1). Beyond this transition, the ratio of the peak-ring diameter to rim-crest diameter for peak-ring basins follows an increasing trend, which is a common characteristic on all terrestrial planets [6, 7].

Topographic profiles also show a geometry for peak-ring basins that is distinct from the flat floors of smaller complex craters (Fig. 2). Instead, the floor interior to the peak ring is lower than the floor annular to the peak ring. This characteristic topographic profile is even more exaggerated on Mercury [3].

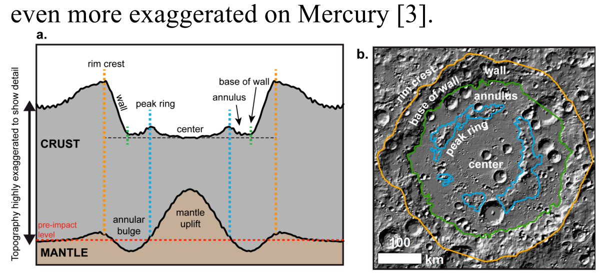

Figure 2. Main topographic and crustal features of a peak-ring basin. (a) Radially averaged LOLA topographic profiles and profile of the crust-mantle relief [8] for Korolev basin on the Moon (417 km diameter). Dashed lines show the positions of features outlined in (b), which is a LOLA gridded hillshade map of Korolev basin.

The deep crustal and mantle structure also has an abrupt transition between complex craters and peak-ring basins [8]. Bouguer gravity anomalies derived from the Gravity Recovery and Interior Laboratory (GRAIL) mission [9], indicate all peak-ring basins show central mantle uplifts with diameters that correlate with the diameter of the peak ring (Fig. 2). Outward of this central mantle uplift is a collar of thickened crust, which is thickest near the midpoint between the peak-ring and rim crest and thins again to near the pre-impact crustal thickness around the position of the rim crest (Fig. 2).

Comparing observations with numerical models: A suite of iSALE simulations of lunar impact crater formation, based on a similar simulation suite of terrestrial impact crater formation [10], were compared with morphometric observations (Fig. 1) and, for the specific simulation of a ~250 km diameter basin, with observed topographic and crustal thickness profiles (Fig. 3).

Simulated rim-to-floor depth as a function of diameter is very consistent with observations (Fig. 1), as is peak-ring diameter (error bars for peak-ring diameters are ±5% of the crater rim-crest diameter). The central-peak diameter for the 28-km diameter crater is consistent with the observational trend. However, the 75-km diameter crater is modeled to have a peak ring with a diameter generally larger than the observed central-peak diameter trend; peak rings are also not observed to occur at these small crater sizes on the Moon [1]. Reconciling models and observations at this size range is an important avenue for future work.

While the numerical simulations are able to reproduce observed final crater morphometry and qualitative crust-mantle structure (Fig. 2) quite well, quantitative comparison of the crust-mantle structure reveals a systematic difference between the models and observation (Fig. 3). The observed diameter of the mantle uplift for all peak-ring basins correlates remarkably well with peak-ring diameter; however, in the simulation, the diameter of the mantle uplift is smaller than the peak-ring diameter. In addition, the annulus of thickened crust surrounding the mantle uplift is observed to be thickest midway between the rim crest and the peak ring and extends from the edge of the mantle uplift to near the rim crest; whereas, in the reference simulation, the annulus of thickened crust reaches a maximum directly beneath the peak ring and extends outward to near the location of the contact between the basin wall and floor. Reconciling these differences in the predicted topography of the crust-mantle interface should provide important clues for refining current numerical simulations and interpretations/models of gravity data over large impact basins on the Moon and other planetary bodies.

Toward a model for peak-ring basin formation: Two working hypotheses have evolved in the literature for peak-ring basin formation: one is based largely on numerical models [e.g., 11, 12] and the other, a conceptual geological model, is based largely on peak-ring observations, with facets similar to the model of [13] and the "nested melt-cavity model" [14].

Major differences between the hypotheses occur in the modification stage of impact basin formation. In particular, the conceptual geological model places emphasis on the role of impact melt in modifying the basin interior during collapse of the transient cavity and does necessarily not require an over-heightened central peak. Peak rings are formed out of the deformation that occurs at the convergence and uplift of the inward-collapsing transient cavity walls and the uplifted center of the basin. In contrast, the numerical model predicts that peak rings are formed by collapse of an over-heightened central peak that is thrust outward and on top of the collapsed transient cavity walls. Under this hypothesis, impact melting plays a minor role in the formation of peak rings but may contribute to aspects of basin morphology post-impact during cooling and contraction processes.

By comparing recent observations of lunar craters with current numerical simulations of impact basin formation we propose a path forward for rigorously testing these hypotheses to converge on a definitive model for peak-ring basin formation.

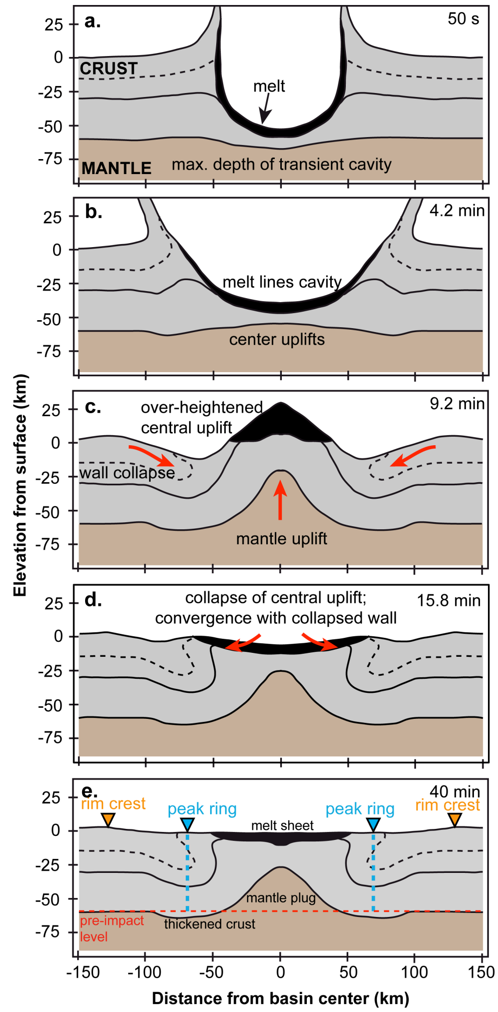

Figure 3. Schematic representation of an iSALE simulation of a 20-km diameter impactor impacting into a 60-km thick lunar crust, resulting in a ~250 km diameter peak-ring basin.

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