basin floor and reducing the W/r_r and h_{wall}/d ratios. This process is likely to become more important as the size of the crater and volume of melt increases, further decreasing the relative width and height of the walls and, perhaps, creating enhanced topography in the central portions of the basin from which the impact melt was expelled (section 6.4). Oblique impacts will likely have an effect on the re-distribution of impact melt by preferentially ejecting material downrange from the impact direction. Asymmetries in collapse caused by variations in preexisting and rim-crest topography and slumping are also important factors [*Hawke and Head*, 1977].

6.4. Largest Peak-Ring Basins

[61] With increasing rim-crest diameter, the d/D_r ratio for peak-ring basins continues to decrease, resulting in the largest peak-ring basins (Figure 14b) having d/D_r ratios less than a factor of two smaller than the smallest peak-ring basins (Figure 9a). This shallowing effect is less dramatic than that between complex craters and peak-ring basins and could represent continued reduction in the cratering efficiency of impact events forming peak-ring basins. This reduction in cratering efficiency and relative increase in impact melt production also results in increased impact melt retention with increasing basin size [*Cintala and Grieve*, 1998]. Re-distribution of this impact melt with the crater interior during cavity collapse has many implications for the observed basin geometries, as described below. Continued shallowing of basins could also be the result of even greater floor uplift in the largest peak-ring basins. An increase in magnitude of floor uplift is supported by the increase in height of peak rings with increasing rim-crest diameter (Figures 9c and 10b), similar to the increase in heights of central peaks within complex craters [*Pike*, 1977; *Hale and Grieve*, 1982].

[62] While the entire floor may be experiencing substantial uplift to reduce the overall basin depth, the increasing floor height to depth ratio (h_{floor}/d) for peak-ring basins (Figure 9d) suggests that the central portions interior to the peak ring are actually deepening. This floor deepening process is consistent with the observation of central depressions in some peak-ring basins (e.g., Korolev, Moscoviense and Apollo) on the Moon, on Mercury [*Baker et al.*, 2011b] and multi-ring basins on the Moon (e.g., the central depression of Orientale basin) [*Spudis*, 1993]. While the cause of these central depressions is not entirely clear, it is possible that they may be a consequence of large volumes of impact melt production and expulsion of this melt from the interior of the basin, as expected for large impact events [*Grieve and Cintala*, 1992; *Cintala and Grieve*, 1998; *Osinski et al.*, 2011]. As interpreted for the smallest peak-ring basins, the decrease in the W/r_r and h_{wall}/d ratios for peak-ring basins (Figures 10d and 10e) could reflect burial of the toes of slump blocks by re-deposition of impact melt on the basin floor. This is consistent with morphological observations, which show a general decrease in the amount of floor roughening exterior to the peak ring in peak-ring basins. The removal of melted material away from the center of the basin by the expulsion process would also act to deepen the central portions of the basin. However, thermal subsidence of the floor is thought to be responsible for at least some of the topography in the center of Orientale [*Solomon et al.*, 1982; *Bratt et al.*, 1985] and could potentially be contributing to some of the central floor deepening observed in peak-ring basins.

6.5. Onset of Multi-ring Basins

[63] The evolving geometric trends for the largest peak-ring basins are informative for evaluating the processes forming multi-ring basins (Figure 14d). To see how the trends of peak-ring basins compare with multi-ring basins, we calculated the geometric properties of the freshest multi-ring basin on the Moon, Orientale basin (19.90°S, 94.81°W), and plotted its depth and height ratios with those of proto-basins and peak-ring basins in Figures 9 and 10. Our measured ring diameters are slightly larger than the classic designations of 480, 620, and 930 km for the Inner Rook, Outer Rook, and Cordillera rings [*Wilhelms et al.*, 1987; *Spudis*, 1993]; our values are 484 km, 658, and 930 km. These differences, especially for the Outer Rook ring, are the result of our use of LOLA topography for identifying the best approximation of the crest of each ring. Although morphological arguments may favor a smaller diameter, we will use our measured values for consistency with our measurements of peak-ring basins, which are also based on topography data. Based on a collection of evidence from morphology, topography, and gravity of Orientale, the Outer Rook ring appears to best approximate the location of the rim crest of the transient cavity [*Head*, 1977; *Head et al.*, 1993]. If this is true, then the Inner Rook ring may represent the multi-ring basin equivalent of the inner peak ring of peak-ring basins [*Head*, 1977]. Thus, examining the geometric properties of the Outer Rook and Inner Rook rings in relation to the trends for peak-ring basins may help to decipher the processes controlling multi-ring basin formation.

[64] Several observations from comparisons between Orientale and peak-ring basins are apparent. First, comparisons of the diameters of the Inner Rook and Outer Rook rings show a distinct deviation from the trends of peak-ring basins. This is shown in a plot of peak-ring diameter versus rim-crest diameter (Figure 15a), where the diameter of the Inner Rook ring is much larger for its rim-crest diameter (i.e., the Outer Rook ring), when compared with a power law trend to peak-ring basins. This deviation in the peak-ring and rim-crest diameter is also apparent in the Inner Rook/Outer Rook diameter ratio (0.74), which is much larger than a peak-ring/rim-crest ratio of 0.55 for the largest peak-ring basins (Figure 15b) [*Baker et al.*, 2011a]. Second, the Outer Rook ring has a reduced depth for its diameter compared with peak-ring basins and the *Williams and Zuber* [1998] trend-line (Figure 9a). The depth of the Cordillera ring is more in-line with the peak-ring basin trend of *Williams and Zuber* [1998], while the depth of the Inner Rook ring is about 1 km shallower than expected for peak-ring basins of similar size (Figure 9a). This is also reflected in the d/D_r ratios (Figure 10a), which show the ratio of the Outer Rook ring to be slightly smaller than the trend of peak-ring basins (Figure 10a). Third, the peak-ring height to basin depth ratio for the Outer Rook ring (approximating the rim crest) and the Inner Rook ring (approximating the peak ring), is slightly smaller (∼0.8) than predicted by the peak-ring basin trend (Figure 10b). Fourth, the "wall heights" for the Outer Rook ring and Cordillera rings are very small relative to their total depths (Figure 10c), which fall far off the peak-ring