crater diameter, D_{tc} is the transient crater diameter, and D_{SC} is the simple to complex crater transition diameter on the Moon (~19 km) [*Pike*, 1988]). While there is a distinction between excavation diameter and transient crater diameter [*Holsapple*, 1993], *Wieczorek and Phillips* [1999] treat these equivalently, and we therefore chose to use the *Croft* [1985] scaling for converting to final crater diameters here. We find that the measured volumes of peak-ring basins on the Moon are about 40% smaller than the predicted volumes of their excavation cavities (Figure 13). If the geophysical constraints and scaling relationships of the geometries of the excavation cavities of lunar basins provide good estimates, then our observations suggest that large volume reductions of the transient cavities of peak-ring basins must occur during the modification stages of the impact event, which has been noted by previous authors [*Williams and Zuber*, 1998; *Wieczorek and Phillips*, 1999]. All of this translation must occur via vertical floor uplift due to a combination of gravitational collapse of the transient cavity, elastic rebound of the cavity floor and perhaps some contribution from mantle flow processes [*Melosh and McKinnon*, 1978].

6. Model of the Progression of Basin Geometries With Increasing Diameter

[56] The new geometric trends discussed in section 5 permit us to construct a general model for how the geometric properties of craters change in the transition from complex craters to peak-ring basins and finally to multi-ring basins. We illustrate this model schematically in Figure 14 and discuss how these trends may be interpreted, below.

6.1. Largest Complex Craters

[57] At diameters near the onset of protobasins (~150 km in diameter), the largest complex craters have a relatively high d/D_r ratio of around 0.030 (Figure 9a). The width of the crater walls make up about 30% of the crater interior (Figure 10e), with the crater floor materials (including the central peak) making up the other 70% of the crater interior (Figure 10f). Central peaks for the largest complex craters can reach heights of about 0.5 to as much as 0.8 of the total basin depth [*Pike*, 1977]. These high ratios of the central peak height to crater depth (h_{cp}/d) suggest that substantial uplift of the central points of the basin floor is occurring at these crater diameters. This floor uplift does not appear to be affecting the entire basin interior, however, as high d/D_r ratios are still maintained. The floor relief is also very low at h_{floor}/d ratios as little as 0.05, which is probably related to the substantial uplift of central peak material.

6.2. Onset of Peak Rings: Protobasins

[58] The onset of peak rings begins at the diameters of protobasins, which exhibit both a central peak and peak ring. Although the population of protobasins is small, these basin types are crucial to interpreting the transition to peak-ring basins. Most of the geometric properties of protobasins are similar to those of complex craters, with similar wall widths and height and depth to diameter ratios (Figures 9 and 10). The protobasin, Compton, however, exhibits a substantially reduced d/D_r ratio (0.015), suggesting that reduction in the d/D_r ratio as observed for the smallest peak-ring basins may start at the diameters of protobasins. The central peak heights of protobasins are generally less than those within complex craters, and this is probably due to redistribution of uplifted or collapsed material to form peak rings (Figure 14b) [*Hale and Grieve*, 1982]. The compromise between relative volumes of central peak material and peak-ring material is also reflected in the small peak-ring heights of protobasins relative to peak-ring basins (Figure 9c).

6.3. Onset of Peak Rings: Peak-Ring Basins

[59] At the onset of peak-ring basins, the d/D_r ratio is reduced from that of complex craters by a factor of two, resulting in values of around 0.015 to 0.020 (Figure 10a). This reduction in the d/D_r ratio marks an important geometric transition in the formation of peak-ring basins, which has been noted by previous authors [*Williams and Zuber*, 1998]. We interpret this reduction in the d/D_r ratio to be largely due to a combination of several factors. The first involves changes that affect the geometry of the excavation cavity. Crater scaling (i.e., changes in the aspect ratio of the excavation cavity with impact event size) is thought to be proportional with impact event size, even up to the diameters of peak-ring basins [e.g., *Wieczorek and Phillips*, 1999]. However, there is some evidence supporting shallowing of the excavation cavity due to non-proportional scaling of cavity geometries, particularly at a diameter-dependent change in crater morphologies such as in the simple to complex crater transition [*Schultz*, 1988]. As in the transition from simple to complex craters, the transition from complex craters to peak-ring basins may result from a similar non-proportional change in crater scaling. Regardless of whether crater scaling is proportional or non-proportional, reduction in excavation cavity depth due to collapse and modification of the excavation cavity appear necessary to account for the measured depth-diameter relationships of impact craters [*Pike*, 1980; *Schultz*, 1988] (Figure 13). The decrease in d/D_r ratio observed in the transition from complex craters to peak-ring basins could, therefore, result from increased listric faulting and inward translation of the basin wall, accompanied by an increase in uplift of the floor over a broader area due to increased impact energy and broader zone of impact melting within the central portions of the basin. The increase in wall slumping is supported by the observed increase in wall width (Figure 9e), decrease in wall slope (Figure 9f), and reduction of the h_{wall}/d ratio (Figure 9c). However, due to the topographic barrier of a peak ring and physical limitations of the run-out distances of slumped material, rim-wall slumping is unlikely to affect the very central portions of the basin (Figure 14b). More wholesale decrease in the floor elevation from a non-proportional change in crater scaling and floor uplift during the modification stage of the impact event is probably most important in producing the observed depth-diameter trends.

[60] The W/r_r ratio and h_{wall}/d ratios are also reduced from complex craters (Figures 10e and 10c). We interpret these trends to largely reflect re-distribution of impact melt within the basin interior. Impact melt is highly mobile during the impact event due to the large-scale translations and momentum transfers that occur during excavation and modification of the transient cavity. Based on observations of ejecta patterns from craters on Earth and the terrestrial planets, ejection of impact melt from craters has been