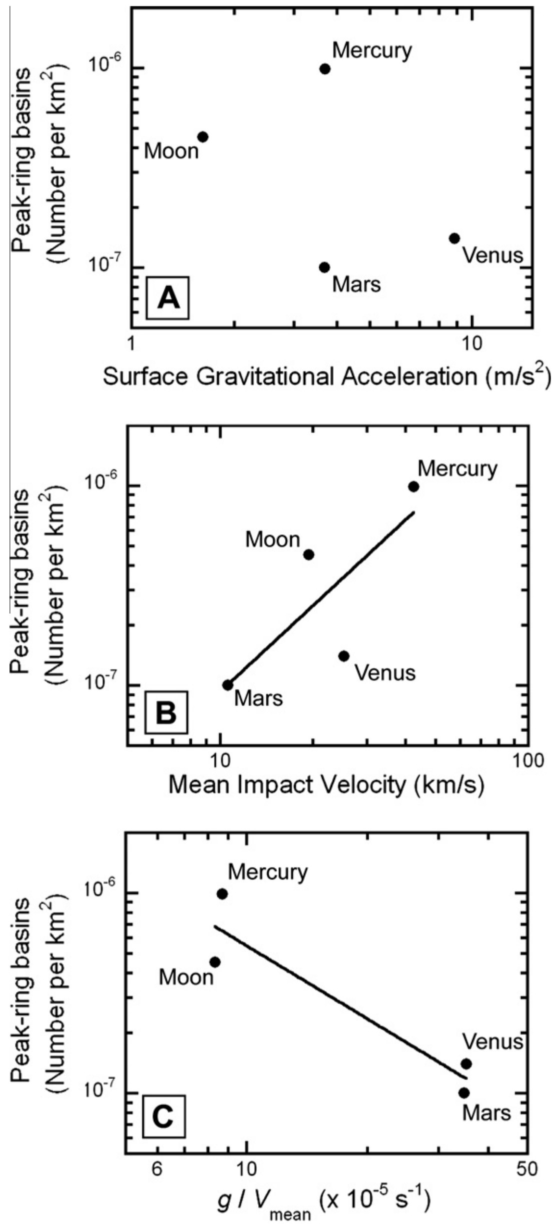

Fig. 7. Plots of the surface density of peak-ring basins on the Moon, Mercury, Mars, and Venus (Table 1) versus surface gravitational acceleration (g) (A), mean impact velocity (V_{mean}) (B) and the ratio of g/V_{mean} (C). As in Fig. 6, solid lines are power law fits formed by minimizing the sum of the squared errors in the ordinate. The fits are displayed to emphasize general trends in the data and are not meant to be statistically rigorous representations. We did not include a fit for gravity due to lack of a clear trend. No correlation with gravity is observed (A), while there is a slight correlation with velocity (B). A stronger correlation is found when gravity and velocity are combined (C). The basin records on Venus and Mars are likely incomplete (see discussion in Section 6.3), which complicates full understanding of these first-order correlations.

The number of peak-ring basin per unit area is plotted versus the planet's mean impact velocity and gravitational acceleration in Fig. 7. Again, power law fits to the data are given to illustrate the general trends in the plotted data. There appears to be no correlation between the number of peak-ring basins and the planet's gravitational acceleration (Fig. 7A), while there is a weak correlation with mean impact velocity (Fig. 7B). Increasing the densities of peak-ring basins on Venus and Mars, which have certainly been affected to some degree by resurfacing events, would act to strengthen this correlation with mean impact velocity; however, to what degree the densities of basins have been modified by crater obliteration processes is uncertain. A much improved correlation is found when gravitational acceleration is combined with velocity (Fig. 7C).

7. Peak-ring basin formation models

While there have been numerous models attempting to explain the transition from complex craters to multi-ring basins, a consensus on the process of ring formation in peak-ring basins and multi-ring basins has not been reached. Two major models for the formation of peak-ring basins have been proposed: (1) hydrodynamic collapse of an over-heightened central peak (Melosh, 1982, 1989; Collins et al., 2002) and (2) modification and collapse of a nested melt cavity (Grieve and Cintala, 1992; Cintala and Grieve, 1998; Head, 2010). As discussed by Baker et al. (2011), while much progress has been made in advancing hydrocode models simulating the hydrodynamic collapse process (Melosh, 1989; Collins et al., 2002, 2008; Ivanov, 2005), the model currently makes no explicit predictions on the ring and rim-crest diameter systematics of peak-ring basins on the terrestrial planets. This is largely due to poor constraints on the parameters governing the timescales of fluidization of the target material and subsequent freezing of this material to produce peak-ring structures (e.g., Wünnemann et al., 2005). While it is possible that future models will offer more explicit predictions of ring and rim-crest spacing, the current uncertainty in the models make it difficult to test against the morphologic trends observed from our basin catalogs.

Given these uncertainties with the hydrodynamic collapse model, we now use our observations of the new lunar catalog to test another model of peak-ring basin formation, the "nested melt-cavity" model, which explains ring formation as the result of nonlinear scaling between impact melt and crater dimensions. The nested melt-cavity model is based on a suite of papers by Cintala and Grieve (Grieve and Cintala, 1992, 1997; Cintala and Grieve, 1994, 1998) who invoked a combination of terrestrial field studies and impact and thermodynamic theory to show that for given impactor and target materials, impact-melt volume will increase at a rate that is greater than growth of the crater volume with increasing energy of the impact event (Grieve and Cintala, 1992). The maximum depth of melting was also shown to increase relative to the depth of the transient cavity with increasing transient cavity diameter (Cintala and Grieve, 1998), approaching depths of around 15–20 km for impact events near the onset diameters (100–200 km) of peak-ring basins (Cintala and Grieve, 1998; Baker et al., 2011). For further descriptions of the quantitative aspects of this model, the reader is referred to the work by Cintala and Grieve (1998) and references therein.

This nonlinear scaling of impact melt has been shown to be important during the modification process in the formation of peak-ring basins on the terrestrial planets, including Earth, the Moon, and Venus (Grieve and Cintala, 1992, 1997; Cintala and Grieve, 1994, 1998). Further development of this model and its extension to multi-ring basins by Head (2010) has suggested that a melt cavity nested within the displaced zone of the growing transient crater (the "nested melt cavity") exerts a major influence on the formation of peak rings and development of exterior rings during crater modification. The volume and depth of impact melting in complex craters is generally not sufficient to modify the uplifted morphology of the crater interior. However, with increasing size of the impact event and thus increasing volume of melt and depth of melting, a melt cavity is fully formed within the displaced zone and is sufficiently deep to retard the development of an ordinary-sized central peak (Cintala and Grieve, 1998). During rebound and collapse of the transient crater, the entire impact melt cavity is translated upward and inward. Unlike rebound in complex craters,