IMPACT MELTING AND PEAK-RING BASINS: INTERPLANETARY CONSIDERATIONS; Mark J. Cintala[1] and Richard A.F. Grieve;[2] [1]Code SN21, NASA JSC, Houston, TX 77058; [2] Geological Survey of Canada, Ottawa, Ontario K1A 0Y3

As described elsewhere in this volume, it is suggested that differences in scaling rates between the size of the transient cavity and the quantity of melt generated by large impacts might account for a variety of observations on the Earth[1] and the Moon.[2] Similar effects will occur on the other terrestrial planets, although the rates and scales will differ due to variations in gravitational acceleration and impact velocity, among other factors. One of the features of this model is melting deep into the displaced target volume along the axis of penetration of the projectile.[2] We have hypothesized that, upon cavity readjustment, the large, strengthless melt volume collapses essentially as fast as it is uplifted, flooding the interior of the crater and leaving a ring of unmelted massifs that mark the boundary of the melt zone. The result is a peak-ring basin. Since the volumes of both the crater and melt zone are functions of variables that change between the terrestrial planets, it is possible to evaluate the reasonability of this "differential scaling" hypothesis; in addition, it can also be used to predict the rim-crest diameters at which peak rings should appear.

Table 1. Variables used in the calculations of impact melting and crater dimensions. All targets were assumed to have a temperature of 273 K except for Venus, for which 700 K was used.

Planet	Target	V_i (km/s)	Gravitational acceleration (cm/s^2)
Mercury	Anorthosite	23.6	370
Venus	Diabase	19.3	891
Earth	Granite	17.8	981
Moon	Anorthosite	14.1	162
Mars	Anorthosite	12.4	371

Approach: The dimensions of transient cavities created by the impact of projectiles over a range of sizes are calculated, as are the volumes of impact melt and depths of melting. It is assumed that relative transient-cavity geometries (*e.g.*, depth/diameter ratios) are invariant with respect to the planets of interest. The diameters at which peak-ring basins are most abundant have been documented in the literature,[3] and serve as test cases: If it were the case that differential scaling controls peak-ring formation, then the volume of melt V_m relative to the volume of the transient cavity V_{tc} would be the same at the onset of peak-ring formation on the various planets or, equivalently, if the depth of melting d_m were the critical parameter, its ratio with the depth of the cavity d_{tc} should be the same.

Calculations: The method of determining the volumes of melt and depths of melting is described elsewhere.[2] As the quantity of melt generated during an impact is dependent on the characteristics of the target rock,[4] each planet's target material is approximated with an appropriate igneous rock. The volume of impact melt also is a sensitive function of impact velocity.[4] While a spectrum of velocities is associated with each planet and class of projectiles,[5] typical velocities (for objects with heliocentric eccentricities of 0.6)[6] are employed here. "Chondritic" projectiles (simulated with a dense basalt) are used in all cases. Values for these parameters as well as the gravitational accelerations for the five planets studied here are listed in Table 1. Transient-cavity dimensions are determined through use of a modified version[7] of Schmidt's scaling relationship,[8] coupled with an assumed depth/diameter ratio of 0.33,[1] a value for simple terrestrial craters determined from field studies.[9] Other values can be used and, if held constant for each planet, will not change the general conclusions found below. As the observed basins have been modified by various processes, an observationally derived relationship[10] relating transient-cavity diameter to final crater diameter is used to estimate the

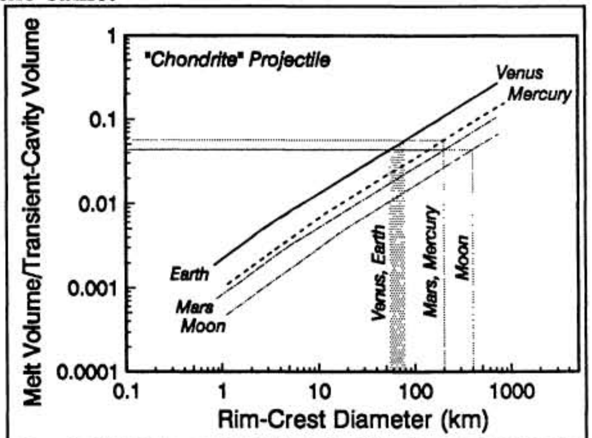

Figure 1. Melt volume expressed in units of transient-cavity volume as a function of final crater diameter for the five terrestrial planets. See the text for details.

diameter of the final crater from the calculated dimensions of the transient cavity. In applying this relationship, the simple-complex transition diameters of Pike are employed.[11]

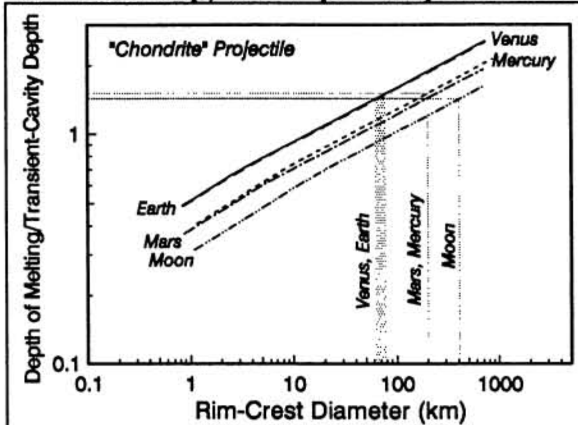

Figure 2. Depth of melting in units of the transient-cavity's depth as a function of the final crater diameter. Note the tight cluster of values on the ordinate for the three planets.

Results: The volumes of melt generated under these conditions for each planet are presented as a function of the final crater's diameter in Fig. 1. The relative positions of each of the curves is determined primarily, though not solely, by the sizes of the transient cavities for each planet. Each of these curves displays a slight break in slope, due to the lack of appreciable cavity enlargement during modification at the smaller diameters. The abundances of peak-ring basins is a maximum in impact structures with diameters ~200 km for Mercury and Mars, and ~400 km for the Moon.[3] Lines parallel to the ordinate are extended from each of these diameters to intersect the curves for the three planets; they are then extended to the ordinate. The values of V_m/V_{tc} for the three planets all lie within a relatively restricted range of 0.042 to 0.056. A similar plot for d_m/d_{tc} yields an even tighter group of values, clustering between 1.42 and 1.51. Such a result might be expected if impact melting were responsible for the formation of peak rings. It can be argued that such an agreement is fortuitous, given the number of variables involved in determining the relationship. Due to the model-dependency of the actual values of V_m/V_{tc} and d_m/d_{tc}, their use as absolute values cannot be defended. Nevertheless, the fact that all transient cavities are assumed to maintain the same geometry from planet to planet implies that the same basic result would hold for any fixed transient-cavity shape. This result lends support to the hypothesis that peak-ring formation might result from "differential scaling," and encourages an extrapolation to the Earth and Venus. When the same values of V_m/V_{tc} and d_m/d_{tc}, are applied to these two planets, the corresponding range of final diameters is ~54 to 80 km and ~61 to 82 km on the basis of V_m/V_{tc} and d_m/d_{tc}, respectively. These diameter values are in surprisingly good agreement with observational data,[1,12] given the number of variables and *a priori* assumptions involved.

Concluding Remarks: Many investigators have attributed interplanetary, diameter-dependent variations in crater and basin morphology to the overwhelmingly dominant influence of gravitational acceleration. The results of the calculations presented here support the suggestion that gravity does indeed play a major role in determining the morphologies of at least the largest craters. Its principal effects, however, are established very early in the excavation stage. By the time that conventional modification processes (*e.g.*,slumping, rebound, etc.) are well underway,[13] the final morphology of the central structure in a large event has been preordained. Subsequent modification processes, whether due to gravity, elastic rebound, or other agents, will be secondary in their effects. A case can easily be envisioned, for example, in which very high modal impact velocities and an easily melted target material are coupled with a low value of g to give rise to peak-ring basins on a relatively small planet. The formation of peak-ring basins, under this hypothesis, involves many important variables, only one of which is gravity.

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