INTERPLANETARY BASIN RING SPACING: CONSEQUENCE OF GRAVITY VS. STRENGTH SCALING? Steven K. Croft, Dept. of Earth & Space Sciences, UCLA, Los Angeles, CA 90024

One relevant data set used in constraining models of basin formation is the relative spacing of basin rings (1,2,3). Several researchers have noted $\sim 2 \times$ spacing for peak ring ($\equiv$PR, 2 rings) basins and $\sim\sqrt{2} \times$ spacing for multiring ($\equiv$MR, 3 or more rings) basins (4). Head (5) has documented a linear relation between the PR's and main outer rims ($\equiv$MOR) of PR basins on the Moon, Mercury and Mars, but the ratios of MR basin rings were treated discontinuously. New measurements of recognizable PR and MR basins on the Earth, the Moon, Mars, and Mercury (including three proposed MR basins) were made from recent large-scale maps in order to provide a multiplanetary data set measured in a consistent manner, and to investigate ring spacing as a function of diameter.

Figure 1 is a plot of ring diameters vs PR diameter (following Head). PR basins plot as points and MR basins plot as sets of connected points. While Head's linear fit satisfactorily represents the data between $\sim$150 and 400 km, points at either end of this range tend to fall low, and join in a smooth curve at the upper end to points representing the MOR's of the MR basins (corresponding to the Cordillera Mts. at Orientale). A function proposed as more appropriate to the entire range of MOR's for both PR and MR basins found by least-squares fit to basins on Mars, Mercury and the Moon is:

$$D_{pr} = 1.90\ D_r^{0.81} - 39 \qquad (1)$$

(all dimensions in km). Terrestrial basins are noticeably displaced from the other planets, but show a similar functional dependence.

The transition from central peak craters to PR basins occurs at $\sim$100-150 km, where a broken, often incomplete ring of massifs appears above crater floor materials surrounding the central peak. With increasing diameter, the central peak disappears while the PR becomes more prominent and complete (6). The transition from PR to MR basins occurs near 500 km. Examination of lunar basins near the transition (Apollo, Hertzsprung, & Humboldtianum) indicates that the intermediate ring ($\equiv$IR, corresponding to the Outer Rook Mts. at Orientale) arises similarly as an inconspicuous broken ring between the PR and the MOR. The IR also grows in prominence and completeness with increasing diameter. However, as seen in Fig. 1, the IR's exhibit a functional relation that is discontinuous with the PR basins. This functional discontinuity, plus the similar morphologies of the MOR's of PR and MR basins, plus the extent of negative free air gravity anomalies to the MOR's of both basin types (7), suggest that the MOR, rather than the IR, is the equivalent of the main rims of smaller craters. It is <u>not</u> suggested that the MOR represents the transient cavity rim. Instead, the form of eq. 1 may be derived from physical considerations in a manner that indicates the nature of at least the PR and the MOR.

For a given impact velocity, the total impact energy, E_t,

is partitioned into heat, comminution and plastic deformation (E_s), kinetic energy (E_k), etc., in relative fractions independent of E_t (8). The diameter of the comminuted zone or "strength diameter", D_s, varies as $E_s^{1/3}$. The diameter of the "gravity scaled" crater, D_g, varies as $E_k^{1/\alpha}$, where $\alpha = 4$ in the ideal case (9). E_k and E_s are fixed fractions of E_t, so D_g and D_s may be related:

$$D_g = KD_s^{3/\alpha}. \qquad (2)$$

For centimeter sized craters, practically all broken material is ejected, and the crater diameter, D_r, equals D_s. Above ∿1-10 m, increasingly more material is retained inside the strength crater so that $D_r \cong D_g$. At still larger diameters, the broken material between D_s and D_g begins to fail and flow, forming complex craters. Mass deficiencies related to the volume of the comminuted zone are found by gravity analysis to increase as D_r^3 for complex lunar craters (10). This implies that complex craters fail out to some fairly constant fraction of the strength diameter so that $D_r = fD_s$. Further, by comparison with subsurface structures of terrestrial complex craters (e.g., 11), and motions of particles in explosions forming complex craters (12), it can be argued that D_{pr} is related to D_g as: $D_{pr} = aD_g - D_o$. Substituting these expressions for D_s and D_g in eq. 2 and rearranging into the form of eq. 1 yields:

$$D_{pr} = K' D_r^{3/\alpha} - D_o'. \qquad (3)$$

Comparing the exponents of D_r in eqs. 1 and 3 implies that for PR and MR basins, $\alpha = 3.7$. Explosion craters with diameters of ∿2-50 m are found to have $\alpha = 3.4$ (13), and theoretical models of gravity dominated explosions in perfectly plastic materials yield $\alpha = 3.55$ (14). An $\alpha = 3.5 \pm 0.1$ is obtained from model crater collapse calculations based on observed lunar crater volumes (15). It is therefore proposed that PR's represent broken subsurface material rebounding just within the gravity controlled transient cavity wall, while the MOR's are structural scarps at some fixed position within the strength crater. IR's are speculated to arise from rim material collapsing against the central uplift.

References:

(1) Van Dorn W.G. (1968) Nature 220, 1102. (2) Hartmann W.K. & Wood C.A. (1971) The Moon 3, 3. (3) Melosh H.J. & McKinnon (1978) Geophys. Res. Let. 5, 985. (4) Howard K.A., Wilhelms D.E. & Scott D.H. (1974) Rev. Geophys. Sp. Phys. 12, 309. (5) Head J.W. (1978) Lunar & Planetary Science IX, 485. (6) Hodges C.A. & Wilhelms D.E. (1978) Icarus 34, 294. (7) Frontpiece (1977) Proc. Lunar Sci. Conf. 8th, Vol. 1. (8) O'Keefe J.D. & Ahrens T.J. (1977) Proc. Lunar Sci. Conf. 8th, 3357. (9) Gault D.E. (1978) EOS 59, 1121. (10) Dvorak J. & Phillips R.J. (1977) Geophys. Res. Let. 4, 380. (11) Pohl J., Stöffler D., Gall H. & Ernstson K. (1977) Impact & Explosion Cratering, 343. (12) Roddy D.J., Ullrich G.W., Sauer F.M. & Jones G.H.S. (1977) Proc. Lunar Sci.

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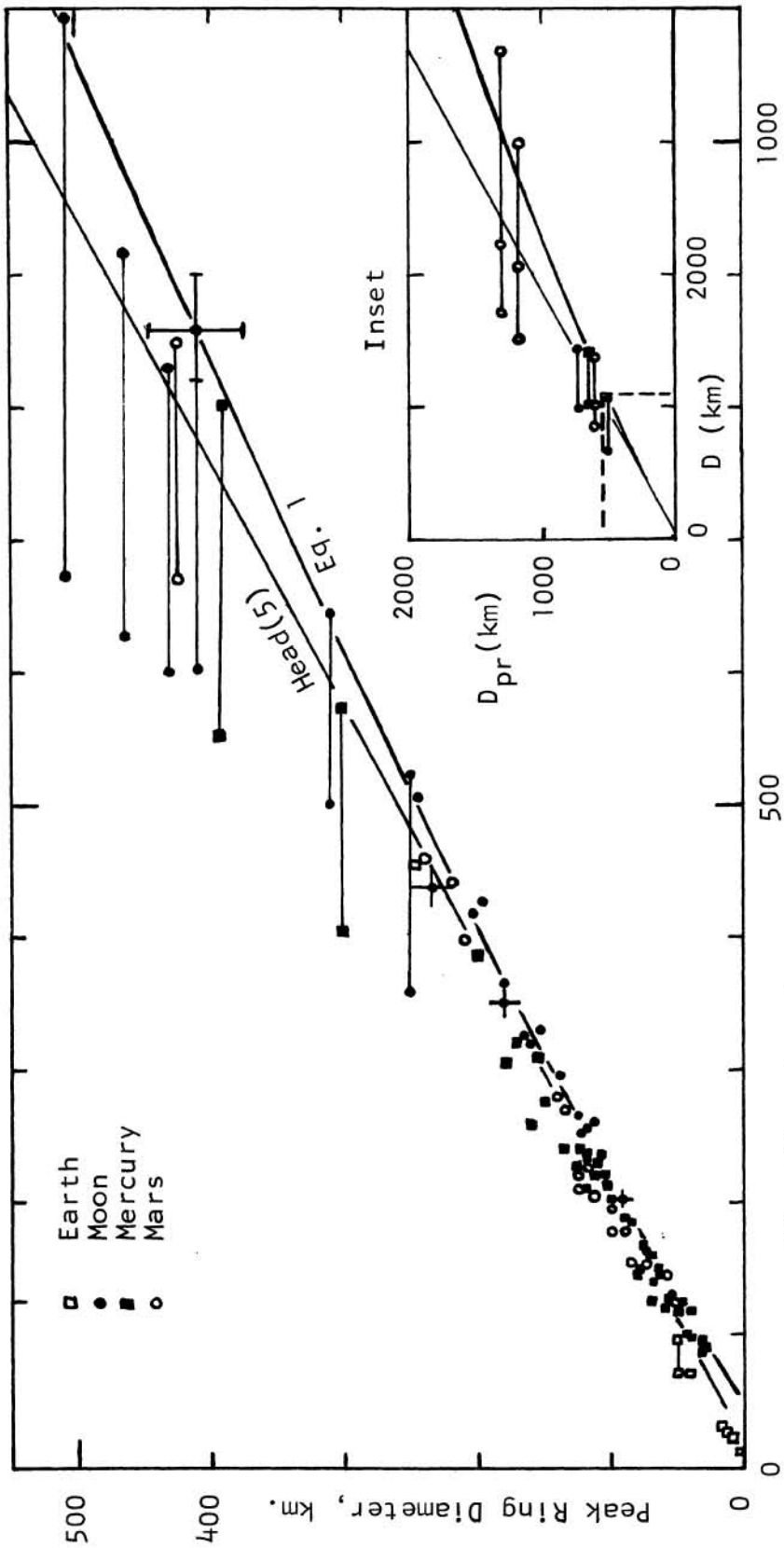

Figure 1. Plot of basin ring diameters vs. D_{pr} on the vertical scale for basins on the Earth, the Moon, Mercury, and Mars. Inset is extension of main diagram. Area of main diagram inside inset is indicated by dashed rectangle. Representative uncertainty estimates are shown on a few points for comparison.

Conf. 8th, 3389. (13) Nordyke M.D. (1962) J. Geophys. Res. 67, 1965. (14) Maxwell D.E. (1977) Impact & Explosion Cratering, 1003. (15) Croft S.K. (1979) Lunar & Planetary Science X, this volume.