MORE EVIDENCE FOR THE $2.0^{0.5}$D MEAN SPACING OF BASIN RINGS. R. J. Pike*, and P. D. Spudis†, U.S. Geological Survey, *Menlo Park, CA 94025, †Flagstaff, AZ 86001, & Dept. Geology, Ariz. State Univ., Tempe AZ 85287.

Introduction — This note continues our enquiry into the spacing of the concentric rings of planetary impact basins. A radial spacing increment, $x^{0.5}$D, where x is about 2.0 ± 0.25 and D is ring diameter, applies in three cases. This $2D^{0.5}$ interval separates (1) adjacent least-squares groups of basin rings [1, 2] as well as (2) adjacent rings of individual basins on Mars, Mercury, and the Moon [3-5], and (3) describes the ratios of ring diameters [6-11]. Here we present initial results on the latter two cases. Our supporting data and analyses are in [5, 11].

Data — Basin rings and arcs have been recognized and mapped by photogeology [6,12,13]. We measured average diameters for 296 rings of 67 basins on the three planets. Table 1 in [5] lists 64 basins, and Table 1 in [11] shows the scope of the observations. The numerical ranking of rings within each basin from I (innermost) to VII (outermost) by graphical analysis, a necessary prelude to statistical work, is described by [1]; see also [2-4].

Individual Basins — A functional dependence of basin ring size (Y) on radial ring position, or rank (X), was established by linear least-squares fits for each basin on Mars (n = 19 basins, 93 rings), Mercury (n = 16, 67), and the Moon (n = 15, 73) that has $\geq$ four rings. (Fits to the 14 three-ring basins are too poorly constrained to yield meaningful estimates of dispersion for slope of the equations, and hence ring spacing. Thus we made the calculations for only 50 basins and 233 rings.) The equations [4,7] are of the form $\log D_n = \log D_{IV} + (n-4) \log b$, where D_n is diameter of a ring of any rank n and D_{IV} is diameter of the main ring (both in km), ranks are similarly spaced integers (in arbitrary units), and b is slope. Diameters were weighted 1, 2, or 3 in the correlations according to quality of the photogeologic observations. Fits of the equation to each basin yield statistical estimates of the slope b* and diameter of the main basin ring D_{IV}* [5, Table 1]. The average spacing increment for adjacent ranked rings, x, is $(b^*)^2$. Rings III and V, which lie farther from ring IV than the nominal 2.0 spacing increment in grouped-data results [2], were not separated from the others. We had anticipated that inclusion of rings III and V would yield fits with slopes uniformly greater than $2.0^{0.5}$, but the small average excess observed, 0.012, may not be statistically significant.

Mean values of x for each planet lie close to the model spacing increment, 2.000, postulated by [7] for the Orientale basin: Mars, 2.008 +0.260 -0.217; Mercury, 2.000 +0.394 -0.312; and Moon, 2.029 +0.220 -0.192. The dispersion of slope, b*, given here by the ±95% confidence interval (C.I.), is somewhat greater than the intrinsically lower values derived from analyses of basin rings grouped by least squares [1,2]. The weighted mean x and C.I. values for all three bodies are 2.012 +0.286 -0.236. This observed 95% C.I., 1.776 to 2.298, lies well within one $2.0^{0.5}$D interval, 1.414 to 2.829, defined by distances midway between $\log_{10}$ model ring-spacing values, 1.0, 1.414, 2.0, 2.828, etc. Whether or not the observed mean 95% C.I. — though narrow — is small enough to differ significantly from one that might arise from random processes (cf. [4]) remains to be tested. We are devising formal statistical procedures to answer this question.

Ring-Diameter Ratios — The basic data are ratios of diameters of adjacent observed basin rings, D_n/D_{n-1}, where n is ring rank, an integer usually 1-7 [1]. The observed ratios fall into the two clusters of values found by [6], about 1.4 to 1.5 — generally for adjacent ranks (n = 169), and about 2.0 — usually for alternate ranks (n = 45) [11, Figure 1]. To supplement the few latter ratios we generated a second set of "alternate ring-rank" ratios (n = 103) by deliberately skipping one observed ring [11, Table 1, Figure 1]. The three subsets of ratios were subdivided further according to the presence/absence of rings III or V.

We calculated mean ($\bar{x}$) and standard deviation (s) in the $\log_{10}$ domain for each of the 18 subgroups of observed ratios [11, Table 2]. Nine other subgroups contained too few (<10) ratios for stable statistics. The statistics were repeated for two sets of ratios drawn from a table of random numbers [14], one set corresponding to ring ratios for adjacent ranks (1.189 to 1.682), the other to ratios for alternate ranks (1.682 to 2.378). (These $2.0^{0.5}$D intervals are defined in the last section.) We transformed all values of $\bar{x}$ and s to the domain of the spacing increment, **x**, so that statistics for both adjacent and alternate ranks are directly comparable.

The 267 observed ratios (**x** equivalents) for multi-ring basins [11, Table 2] cluster around Fielder's model increment of 2.000 [7]. The combined weighted mean for all three planets is 2.039 +0.382 -0.284, close to our values obtained for individual basins; the net excess of observed over model, +0.04, is statistically insignificant. Weighted means for individual planets are 2.091 +0.248 -0.221 (Moon, n = 82 ratios), 2.027 +0.393 -0.333 (Mars, n = 118), and 1.997 +0.319 -0.274 (Mercury, n = 67). The difference among "close," "wide," and "neither close nor wide" ring ratios, though not statistically significant, is strong enough to show up clearly in averaged x values of these subgroups: respectively 1.928 +0.353 -0.305 (n = 62 ratios), 2.117 +0.304 -0.265 (n = 92), and 1.976 +0.314 -0.270 (n = 91). The spacing for rings V/III is expectedly large, 2.287 +0.441 -0.364 (n = 22). However, because $\bar{x}$ for randomly-chosen ratios within one $2.0^{0.5}$ interval also is 2.0, observed values for average spacing are meaningless unless their dispersion occupies limits too narrow to have occurred by chance.

The spread of basin-ring ratios about the mean is significantly less than dispersion that might arise from random processes, with qualifications noted below. This difference indicates that the $2.0^{0.5}$D mean spacing of rings is real. We compared, by an **F**-test at the 95% C.I. [15], the standard deviation, s, of each subset in [11, Table 2] with s values from one of the two sets of randomly-generated ratios [14]. Results of the test are highly systematic by sample size and by planet: For six of seven subsets of $\geq$ 20 ratios, observed dispersion is significantly less than random dispersion (i.e., a "pass"), whereas of the 11 subsets containing $\leq$ 19 ratios, only three pass. Where sample size is adequate, dispersion of ring ratios is significantly less than that due to chance. Most subsets "failing" the test simply are too small — so small that their difference from random is "not proved" rather than "disproved," a critical distinction. All five lunar subsets pass the test; three of the five mercurian subsets pass; only one martian subset passes, partly because the sample (n = 32) is comparatively large. The $2.0^{0.5}$D spacing is strongest on the Moon — where basin rings are best known and displayed, weakest on Mars — where most rings are severely degraded, and intermediate (but still much weaker than on the Moon) on Mercury — where degradation is slow but the rings are not strongly developed or well displayed.

Interpretation — A constant mean spacing of basin rings, both inside and outside the main ring (IV) and on three different planets, carries some exciting genetic implications [1,2]. We do not repeat these arguments here save to emphasize our main hypothesis (see also [16,17]) that ring location, and perhaps ring formation, are more likely controlled by mechanics of the impact event itself than by such planet-specific properties as crustal layering or lithospheric thickness.

References — [1] Pike, R.J., & Spudis, P.D., 1984a, NASA TM-86246, 90-92; [2] Pike, R.J., & Spudis, P.D., 1984b, Lunar Planet. Sci. XV, 647-648; [3] Pike, R.J., 1981, NASA TM-84211, 123-125; [4] Clow, G.D., & Pike, R.J., 1982, Lunar Planet. Sci. XIII, 123-124; [5] Pike, R.J., Clow, G.D., and Spudis, P.D., 1984, Repts. Planetary Geol. Pgm. - 1984, NASA TM, in-press; [6] Hartmann, W.K., & Kuiper, G.P., 1962, Comm. Lunar Planet. Lab. 1, 55-66; [7] Fielder, G., 1963, Nature, 198, 1245-1260; [8] Hartmann, W.K., and Wood, C.A., 1971, Moon, 3, 3-78; [9] Howard, K.A., Wilhelms, D.E., & Scott, D.H., 1974, Rev. Geophys. Space Phys., 12, 309-327; [10] Wood, C.A., & Head, J.W., 1976, Proc. Lunar Sci. Conf. 7th, 3629-3671; [11] Pike, R.J., & Spudis, P.D., 1984c, Repts. Planetary Geol. Pgm. - 1984, NASA TM, in-press; [12] Spudis, P.D., & Strobell, M.E., 1984, Lunar Planet. Sci. XV, 814-815; [13] Schultz, P.H., Schultz, R.A., & Rogers, J., 1982, JGR 87, 9803-9820; [14] Rand Corp., 1955, A Million Random Digits, Free Press; [15] Natrella, M.G., 1963, Experimental Statistics, NBS Handbook 91, U.S.G.P.O.; [16] Croft, S.K., 1981, Proc. Lunar Planet. Sci. 12A, 227-257; [17] Pike, R.J., 1985, Meteoritics, in-press.