MORPHOLOGIC TRANSITIONS FOR CRATERS AND BASINS ON 13 SOLAR SYSTEM BODIES, Richard J. Pike, U.S. Geological Survey, Menlo Park, CA 94025

New data from the outer satellites are consistent with the view that both planetary-surface gravity and target material strongly influence the morphology of impact craters and basins [1,2]. The measurements, from recent work by Basilevsky [3] and myself on the Voyager I and II pictures, describe the morphologic transitions from simple to complex craters and from complex craters to multiring basins. The resulting log-log graphs of onset diameter, D (km), both for central peaks in craters and for concentric rings in basins, against gravitational acceleration, g (cm/sec^2) (Figure 1), show three distinct linear trends and may suggest a fourth.

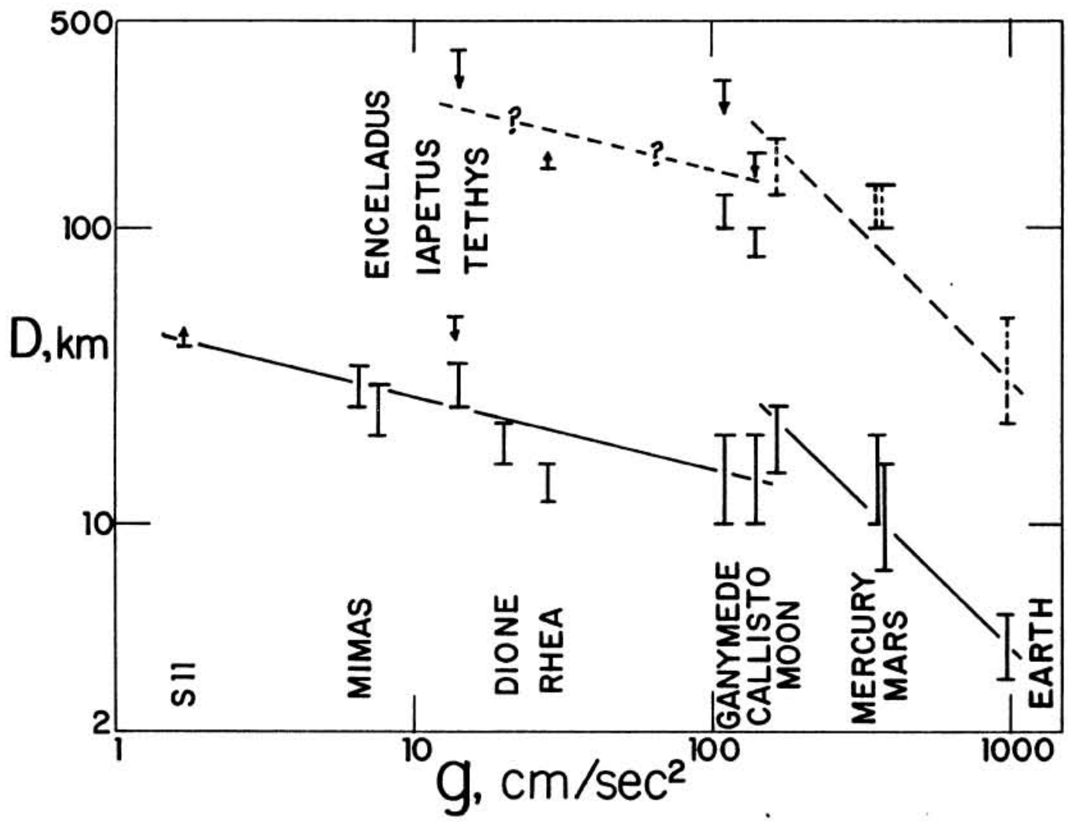

Figure 1. Log-linear relations between transition diameter, D, in km, and planetary surface gravity, g, in cm/sec^2, for impact craters (two lower trends) and multiring basins (upper two), redrawn from Basilevsky [3], with author's additions: new data for Tethys, Enceladus, and Iapetus from Voyager II; also queried trend and revised data for basins on Callisto and Ganymede (see text). Compare with Figure 3 in [2].

MORPHOLOGIC TRANSITIONS FOR CRATERS

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The onset diameter of complex craters on the Moon, Mars, Mercury, and the Earth is linearly dependent on gravity. Basilevsky's D:g data for craters on the silicate bodies [3] agree with previously published results [2]; linear equations fitted to both sets of points slope at nearly 1.0. Basilevsky's D:g graph for impact basins on the same four planets, while tentative, closely resembles a similar, hitherto unpublished result of mine, and parallels the D:g trend for craters. My data, which place the smallest basins ($\geq$ two concentric rings) on each of the four silicate planets at 140 km (Moon: Antoniadi), 65 km (Mercury: unnamed basin at 00°N, and 99°W), 45 km (Mars: feature 12-Xm), and 24 km (Earth: the Ries), yield the D:g equation

$$D = 1.96 \times 10^4 g^{-0.98}. \qquad (1)$$

On the icy satellites, however, the gravity-dependence of onset diameter for central peaks in craters differs substantially from that established for silicate bodies. Basilevsky's data [3] on six satellites of Jupiter and Saturn (Callisto, Ganymede, Rhea, Dione, Mimas, and S11) describe a trend that slopes at only -0.25. The difference in slope indicates that gravity has a smaller influence on the onset of central peaks than it does on rocky planets. Although Basilevsky's D-values for the icy satellites are preliminary, his data for craters on Ganymede and Callisto agree with those published earlier [2]. Moreover, preliminary measurements of D made here for craters on Tethys, Enceladus, and Iapetus from Voyager II images (Figure 1) also are consistent with Basilevsky's calculated least-squares fit.

Only four estimates of D for impact basins on icy satellites are available (Figure 1). Basilevsky's graph shows measurements for Callisto, Ganymede, and Rhea, to which is added the basin on Tethys. At this time, the data are tentative. For example, other data for craters [4] and craters and basins [5] on Ganymede and Callisto suggest that Basilevsky's maximum D values for these bodies (Figure 1) may be too high, and can be replaced by intervals of about 100 km to 120 km and 80 km to 100 km, respectively. Also, I obtain a tentative maximum basin size on Rhea of 900 km, not a minimum of 200 km. The 400 km value for Tethys is likely a maximum. All-in-all, these four measurements are only consistent with a D:g trend of slope -0.25; they by no means define it.

Basilevsky [3] interpreted the new data on crater and basin transitions as indicating an influence of target material on the D:g relation, a conclusion in agreement with [2]. However, twelve of the 13 points that describe D:g for craters are reasonably well described by the -0.25-sloping line; Rhea, the Moon, Tethys, and Iapetus (poor resolution) lie slightly off this trend. Only the terrestrial data obviously do not follow the -0.25 trend at all. According to this interpretation, craters and basins on Earth differ substantially in their D:g characteristics from those on all other bodies. A convincing explanation for the unique behavior of the impact-cratering process on Earth would be required before this alternative could be seriously considered.

Regardless of which, if either, of the above interpretations better explains the D:g data, the -0.25 relation initially observed by Basilevsky [3] suggests a type of scaling already known to students of impact cratering. Gault and Wedekind [1] found from laboratory experiments that diameters of small impact craters in a low-strength target increase with decreasing gravity according to an approximately -0.25 law. Further work is needed to ascertain any possible genetic conncection between the two similar slopes. Providing impact craters on Earth are not unique, and both the -1.0 and the -0.25 D:g trends shown here are real, then the date in Figure 1 may reflect the influence of both gravity and target strength. Conceivably the 0.25 scaling applies to weak targets, which include loose sediments and ice, whereas the 1.00 scaling is more valid for strong targets, such as silicate rock.

In conclusion, the previous D:g model for impact craters [2], which comprised three parallel trends corresponding to different crustal strengths, must be revised in the light of the new data from Voyager. Craters on planets with weak (e.g. icy) crusts follow a shallower D:g trend than craters on silicate planets, rather than a lower, but parallel, trend. Ringed basins seem to conform to a similar pattern.

References:

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