Centrifuge Impact Cratering Experiments: Scaling Laws for Non-Porous Targets

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A geotechnical centrifuge has been used to investigate large-body impacts onto planetary surfaces. At elevated gravity, it is possible to match various dimensionless similarity parameters which have been shown to govern large-scale impacts. Observations of crater growth and target flow fields have provided detailed and critical tests of a complete and unified scaling theory for impact cratering. Current work is directed toward the determination of scaling estimates for non-porous targets. Scaling estimates for large-scale cratering in rock proposed previously by others have assumed that the crater radius is proportional to powers of the impactor energy and gravity, with no additional dependence on impact velocity. The energy exponent is typically reported to be 0.28 to 0.29 while estimates of the gravity exponent range from 0.11 to 0.17. The size scaling laws determined from ongoing centrifuge experiments differ from earlier ones in three respects. First, a distinct dependence of impact velocity is recognized, even for constant impactor energy. The effects of velocity are smallest for nonporous targets, which approach (but do not reach) the asymptotic case of pure energy scaling. The porosity of materials like dry sand result in velocity-dependent energy losses. Hence, the velocity dependence is greatest for these materials. Second, the present energy exponent for low-porosity targets, like competent rock, is lower than earlier estimates. Although the difference might appear to be small (the present estimate is 0.26 versus the values of 0.28-0.29 mentioned above), the effect of this difference can be significant when extrapolating many orders of magnitude in energy up to kilometer-sized craters. Third, the gravity exponent is recognized here as being related to both the energy and the velocity exponents.