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ENERGY COUPLING IN CATASTROPHIC COLLISIONS

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The prediction of events leading to the catastrophic collisions and disruption of solar system bodies is fraught with the same difficulties as are other theories of impact events; since one simply cannot perform experiments in the regime of interest. In the catastrophic collisions of asteroids, that regime involves bodies of a few tens to hundreds of kilometers in diameter, and velocities of several kilometers per second. For hundred kilometer bodies, gravitational stresses dominate material fracture strengths, but those gravitational stresses are essentially absent for laboratory experiments. Furthermore, there is reason to believe that the very nature of the material for the large bodies may be substantially different than laboratory specimens. Only numerical simulations using "hydro-codes" can in principle analyze the true problems, but they have their own major uncertainties about the correctness of the physical models and properties.

The bridges linking laboratory experiments to applications of interest are the scaling theories of catastrophic disruption. There are several possibilities for those theories, including that developed by *Holsapple and Housen* [1,2,3], that by *Mizutani and Takagi* [3], and the classical energy theory [1]. All have two fundamental features: a single choice for a measure of the magnitude of the effect of the impactor, and a measure of the resistance of the asteroid to fracture. Those two choices then totally determine the resulting scaling theory [1,2]. In the energy theory, the measure of the impactor is its kinetic energy, and the measure of the fracture resistance is a single fracture stress. In the *Holsapple and Housen* theory, the more general point-source coupling-parameter measure of the impactor (see [4]) is used, in conjunction with a rate-dependent fracture strength. That gives as a special case the classical energy approach. *Mizutani and Takagi* use a transmitted stress for the impactor measure , and a constant fracture strength. For large bodies, the measure of the resistance should include the gravitational stresses, as discussed in [1,2] and in the *Housen et al* abstract in these proceedings. In any case, the choice of any single scalar measure of the impactor infers that the impact can be modeled as a point source. That point-source assumption clearly must break down when the impactor dimensions approach those of the target body, and for very low impact velocities. The first observation is important in the collisional disruption problem since the cases of interest may include bodies of comparable size. The second observation is of particular importance since some experiments are conducted at only about a kilometer per second impact velocity. Testing the limits of those assumptions is therefore necessary to determine the limits of the scaling theories.

Here the question of the measure of the impactor and its energy coupling is investigated using numerical code calculations. The material model was that of a generic silicate rock, including high pressure melt and vapor phases, and includes material nonlinearity and dissipation via a Mie-Gruniesen model. A series of calculations with various size ratios and impact velocities will be reported. Here results are shown for an impactor with a diameter of 10 km, and a target body diameter of 100 km., with impact velocities of 1, 5 and 10 km/sec. The pressure profiles near the time the shock reaches the far antipodal point is shown in figs.1 and 2 for impact velocities of 1 and 5 km/sec.

Scaling information can be deduced from fig 3. Any point source approximation requires that all cases with variable impactor size and velocity should be indistinguishable when normalized to the correct point-source measure in the regions governed by that assumption (i.e. sufficiently far from the impact point). For an over-all measure of the solution we have chosen the kinetic energy of the target material as a function of time, ignoring that material jetting up and away from the impact site. The appropriate point-source scaling of the energy and time is as shown in the the labels of that figure. The classical energy scaling requires that the exponent μ of that scaling be equal to *2/3*, while the more general coupling parameter measure allows any value between *2/3* and *1/3*. The choice $\mu = 0.5$ was made for the plot, which gave the best results: the curves for the higher velocities superimpose after the initial short initiation phase. Thus, the point source approximation and a coupling parameter measure does hold, with $\mu \sim 0.5$ for velocities of *5 km/sec* or higher. However, the *1 km/sec* case is distinctly different, and cannot be compared to the higher velocity cases with the existing scaling theories. The limits on impact velocity and impactor/target size ratio for the various scaling theories will be discussed.

References. [1] Holsapple and Housen, *Memorie Della Soc. Astron. Ital. 57*, 65-85, (1986). [2] Housen and Holsapple, *Icarus 84*, 226-253, (1990). [3] Fugiwara et al, Asteroids II, pp 240-265, (1989). [4] Holsapple and Schmidt, J. Geophys. Res 92, 6350-6376, (1987).

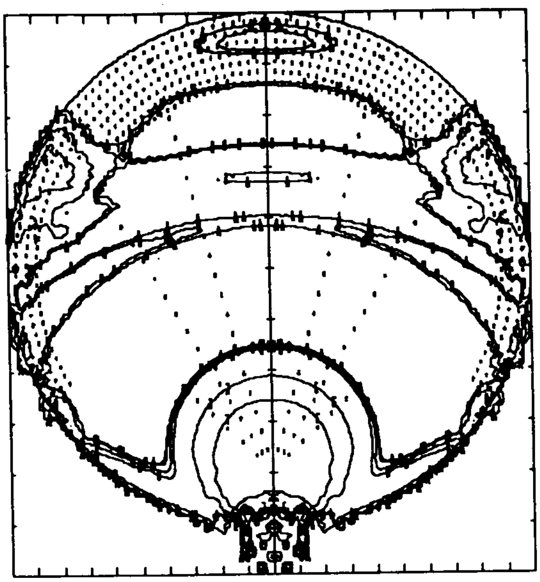

Figure 1. Pressure Contours for a 1 km/sec Impact of a 10 km into a 100 km Silicate Asteroid

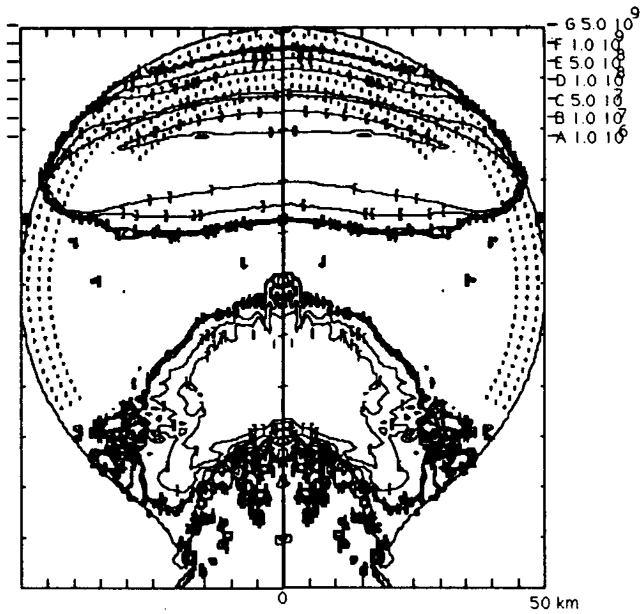

Figure 2. Pressure Contours for a 5 km/sec Impact of a 10 km into a 100 km Silicate Asteroid

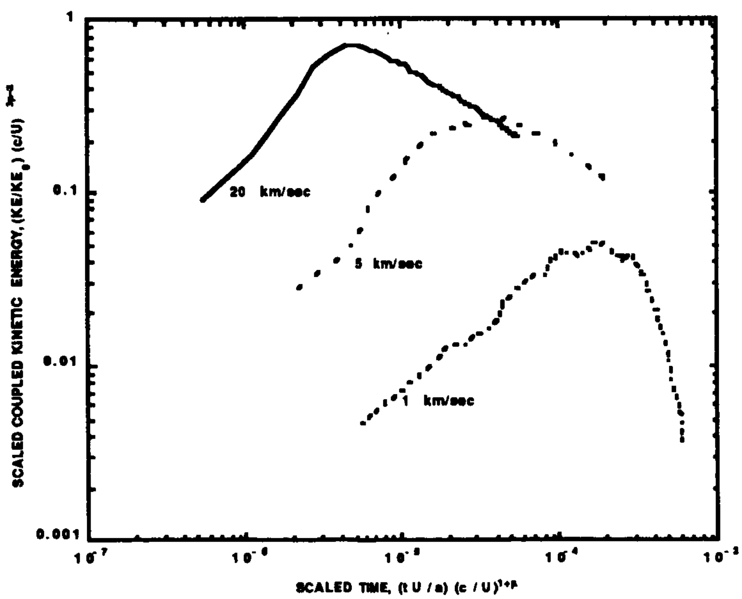

Figure 3. The Coupled Kinetic Energy For Three Impact Velocities