Porosity as a significant factor for asteroid survival

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Most asteroids, for which porosities have been inferred, have porosities ranging from 20 % to > 50 %, with a mean around 30 % porosity (Britt et al. 2002). Since porous targets react differently to hypervelocity impact cratering and disruption than non-porous targets of the same mass, porosity is likely to play a role in asteroid survival. Measurements show the threshold collisional specific energy, Q^*_D, required to produce a disruption with the largest fragment equal to one-half the original target mass is much higher for porous targets (Table). Ordinary chondrite meteorites, with a mean porosity of ∼9 % (Britt et al. 2002), disrupted at the NASA Ames Vertical Gun Range (AVGR), required almost twice as much impactor kinetic energy per unit target mass to produce an equivalent disruption as did targets of low-porosity terrestrial basalt or granodiorite (Flynn and Durda 2004). Limited data from hypervelocity disruption of three CM2 carbonaceous chondrites (Flynn et al. 2009), all to the right of the ordinary chondrite points on a Q^* vs. M_L/M_T plot, indicate CM2 meteorites, with a mean porosity of 23 % (Consolmagno et al. 2008), have even higher Q^*_D, ∼1900 to 2100 J/kg. The CI carbonaceous chondrites, e.g., Orgueil, with a density of 1.5 g/cm^3 (Britt and Consolmagno 2003) and porosity of 35 % (Consolmagno et al. 2008), are the most porous known meteorites, approaching the C-type asteroid Mathilde, which has a bulk density of 1.3 and > 50 % porosity (Britt et al., 2002). However, the CI meteorites are so scarce than none have yet been studied in impact experiments. As an extreme end member for high-porosity, rigid targets, Flynn et al. (2014) disrupted eleven terrestrial pumice targets, obtaining a Q^*_D of ∼2300 J/kg. However, porosity increases the target's cross section. The "Required Disruption Energy" to produce a largest fragment mass equal to one- half the target mass for spherical asteroids of 10-m, 1-km, and 100-km radius having the same physical properties as the basalt, ordinary chondrite, and CM2 meteorites, and pumice are shown in Table. While hydrocode modeling suggested weak, porous asteroids could have shorter collisional lifetimes than nonporous asteroids (Asphaug et al. 1998), our hypervelocity impact results on moderately porous meteorites suggest that, at least at the target size we disrupted, porosity leads to longer survival in the same impactor environment compared to non- porous targets. This may help explain the large fraction of high porosity asteroids (Britt et al. 2002).

Table: Disruption Results

Target	Porosity (%)	Bulk Density (gm/cm^3)	Q^*_D (J/kg)	Required Disruption Energy 10 m	1 km	100 km
Low-porosity basalt	∼0 %	3.0	700–800	9.4×10^9	9.4×10^{15}	9.4×10^{21}
Ordinary Chondrite	∼9 %	3.2	1419	19.0×10^{10}	19.0×10^{16}	19.0×10^{22}
CM2 Carb. Chondrite	∼23 %	2.25	∼1900–2100	19.8×10^{10}	19.8×10^{16}	19.8×10^{22}
Terrestrial Pumice	∼70 %	0.9	∼2300	8.6×10^9	8.6×10^{15}	8.6×10^{21}

References: Asphaug, E. et al (1998) Nature, 393, 437–440; Britt, D. T. et al. (2002) in Asteroids III, U. of Arizona Press, 485–500; Britt, D. T. and G. J. Consolmagno (2003) Meteoritics & Planet Sci., 38, 1161–1180; Consolmagno, G. J. et al. (2008) Chemie der Erde, 68, 1–29; Flynn, G.J. and D.D. Durda (2004) Planet. & Space Sci., 52, 1129–1140; Flynn, G.J. et al. (2009) 40th LPSC, Abs. #1164; Flynn G.J. et al. (2014) 45th LPSC, Abs. #1950.