FACTORS CONTROLLING THE BULK DENSITIES OF ASTEROIDS.

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Introduction: The bulk densities which have been measured or inferred for the C-type asteroidal bodies 253 Mathilde [1], Phobos [2] and Deimos [3] lie in the range 1300 to 2200 kg m^{-3}. Spectroscopic evidence [1] relates these asteroids to CM chondrite meteorites which have densities of order 2100 kg m^{-3} [4]. Thus, despite the large errors associated with the asteroid density measurements (commonly up to 25%), these data imply that some asteroids have bulk porosities of order 30-40%. This is in marked contrast to the porosities of the apparently related meteorites, which are of order 15 percent [4]. We consider two processes which may have led to the low bulk densities of asteroids.

1) Low-velocity impact disruption: Melosh and Ryan [5] have recently shown that, for all asteroids larger than about 400 m in radius, the impact energy needed to disperse an asteroid is greater than the energy required to extensively shatter it. Thus the vast majority of present-day asteroids are probably gravitationally bound but strengthless rubble piles. We have modelled the motions under their mutual gravitational attractions of the fragments generated during typical fragmentation and re-accretion events using suitably scaled data on fragment size and velocity distributions [6]. We find that, because the sizes and velocities are systematically coupled (small fragments being ejected at the highest speeds), the largest fragments will re-accrete before the smaller fragments. The irregular shapes of these objects will ensure that relatively large spaces are left between them, the low velocities of re-accretion leading to little crushing of the fragments. The early-arriving fragments will be coated with a layer of later-arriving, smaller fragments which will to some extent fill in the gaps, but our simulations suggest that substantial internal porosity will be preserved by this process. This process is expected to operate to some extent in all asteroids, irrespective of composition.

2) Gas loss during aqueous alteration: We have investigated the physical consequences of aqueous alteration during the early histories of chondritic meteorite parent asteroids [7]. We find that substantial gas pressures may have evolved on time scales of up to 0.1 Ma, despite gas loss due to the finite permeability of these bodies. These pressure may have eventually exceeded the tensile strength of the parent body leading to fracture formation and gas loss. Fracture initiation will have been aided by impact events. The energetics of gas expansion and consequent entrainment and acceleration of small fragments are such that, for asteroids up to a few tens of km in radius, a significant fraction of the interior volume of the asteroid may have been discharged into space at escape velocity. Despite some readjustment of the residual material, this process could also have lead to substantial residual bulk porosity. The relative importance of these two processes is the subject of continuing study.

References: [1] J. Veverka et al. (1997) Science 278, 2109. [2] D.E. Smith et al. (1995) GRL 22, 2171. [3] P. Thomas et al. (1992) in Mars (U. of Arizona Press) p. 1257. [4] Consolmagno et al. (1997) M&PS 32, #4 (Suppl), A31. [5] Melosh, H.J. and Ryan, E.V. (1997) Icarus 129, 562. [6] A. Nakamura and A. Fujiwara (1991) Icarus 92, 132. [7] L. Wilson et al. (1997) LPSC XXIX, #1275.