LOW-DENSITY MATERIALS AND ASTEROIDAL MACROPOROSITY. G. J. Consolmagno[1] and D. T. Britt[2], [1]Vatican Observatory, V-00120, Vatican City State, gjc@specola.va. [2]Department of Geological Sciences, University of Tennessee, Knoxville, TN 37996, dbritt@utk.edu.

Introduction: Recent work by Britt et. al. (2002) and Britt and Consolmagno (2001) have suggested that the structure of asteroids can be estimated by scaling the asteroid's bulk density by the grain density of its meteorite analogue and subtracting the average porosity of its analogue. The result is an estimation of the macroporosity of the asteroid (i.e. porosity larger than the micron to millimeter scale found in meteorites). Using this method the asteroids with known bulk densities fall into three rough groups as shown in Figure 1.

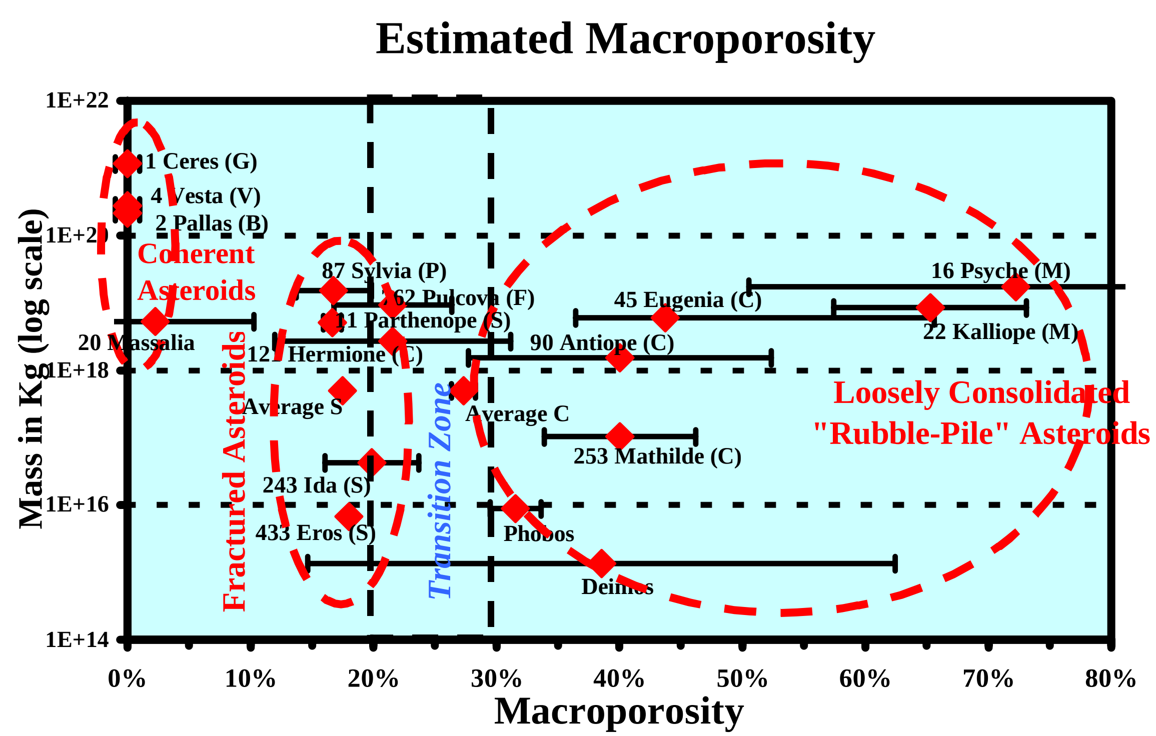

Figure 1: Estimated Macroporosity of Measured Asteroids

This work has raised a number of questions about the nature of asteroids and the interaction between asteroid mineralogy and structure.

Hydrated Meteorites and Asteroids: The relatively dark and primitive C-type asteroids tend to more likely to be rubble-piles than the lighter, more evolved S type asteroids. Interestingly, of the C type asteroids included in Figure 1, none have been observed to be hydrated (i.e. they lack the strong bound water spectral signature near three microns) [1]. About 40% of C-type asteroids are anhydrous [1]. Hydrated minerals are typically the least dense minerals found in nature and the abundance of hydrated minerals found in CI and CM carbonaceous chondrite meteorites make them the least dense meteorites. Shown in Table 1 are the grain densities of hydrated minerals common in CI and CM carbonaceous chondrites as well as the average grain densities of the carbonaceous chondrite subgroups. CI and CM chondrites have, as expected, grain densities in the range of their common hydrated minerals. CO and CV chondrites, which lack hydrated minerals show grain densities consistent with their olivine and pyroxene-rich chondrule mineralogy. Anhydrous asteroids like 253 Mathilde with bulk density of 1.3 g/cm3, requires very large micro and macroporosities to reconcile the apparent mineralogy with bulk density. For 253 Mathilde the calculation of estimated macroporosity used a hypothetical "dehydrated CM" analogue that does not exist in the meteorite collections and has not (yet?) been found in nature. The estimation of approximately 40% macroporosity for Mathilde is a lower bound since the known anhydrous meteorites are substantially more dense than a CM-like parent material. Using anhydrous carbonaceous chondrite grain densities would push Mathilde macroporosities to > 60%..

Another aspect of this issue is that the densities of common hydrated minerals are in the range of the grain densities of CI and CM chondrites. Less dense hydrated minerals (for example: Carnallite, 1.6 g/cm^3 $KMgCl_3 \cdot 6H_2O$ or Borax, 1.7 g/cm^3, $Na_2B_4O_5(OH)_4 \cdot 8H_2O$) are extremely rare in meteorites and cannot explain the low density in asteroids.

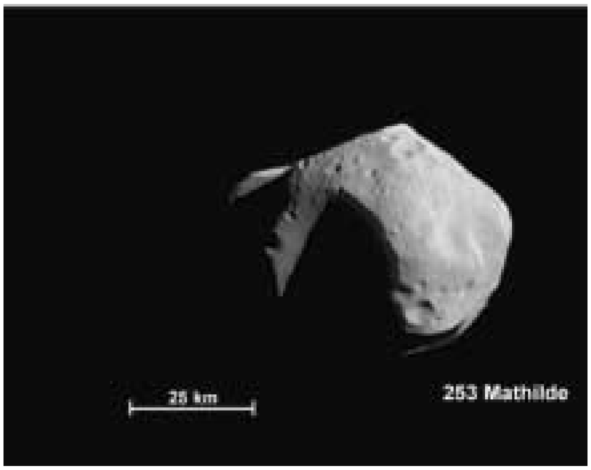

Figure 2: Asteroid 253 Mathilde

Compressing Asteroidal Materials: On the opposite end of the spectrum, recent work has suggested that some C-type asteroids may be much denser than their meteorite analogues [2]. For example the hydrated type asteroid 511 Davida was listed as having a bulk density of 3.66 ± 0.32 g/cm^3 [2]. The difficulty with these suggestions is that, while it is relatively easy to lower the density of an asteroid made of high-density material, it is virtually impossible to raise the density of an asteroid made of low-density material in any way short of adding an iron core.

The surface spectra of asteroids tends to be relatively homogeneous; thus, if an asteroid is indeed found to be denser than its surface materials, one would have to conclude that its surface is not typical of its bulk composition. This is almost certainly true for a differentiated body like Vesta, but hard to reconcile with the parent bodies inferred for ordinary or carbonaceous chondrites.

Can Tagish Lake be a reasonable analogue for hydrated, low density asteroids? Measurements of some (but not all) dark meteorites do show that they can have very high microporosities. Some samples of Allende, Orgueil, and Tagish Lake have porosities range from 25% to 40% or more, and an analysis of the breakup of Tagish Lake [3] confirms that it was both weak and porous. Furthermore, the porosity of micrometeorite material recovered in the Earth's atmosphere can also be very low [4]. This raises an interesting question: could the various C type asteroids of with densities only slightly greater than 1 be made entirely of similarly low-density, highly microporous material? In such a scenario, the necessity of a "rubble pile" structure might be entirely done away with.

However, while it is possible that some asteroids could be monoliths of highly macroporous material, there is a strong argument that at least the low-density asteroids observed so far are probably not merely large pieces of something like "Tagish Lake" or "Orgueil". Recall that these meteorites obtain their low densities primarily by being made of hydrous minerals. (Allende, which is comparably porous, has a bulk density greather than 3, typical of most anhydrous minerals). By contrast, as noted above the low density C type asteroids included in Figure 1, including Mathilde, Phobos, and Deimos, all have spectra known to lack a 3-micron feature indicative of bound water. They, at least, are NOT the source regions of Orgueil or Tagish Lake.

Furthermore, it is worth remembering that the idea of asteroids commonly being rubble piles is based on more than just density data. It includes both an analysis of the spin rate of hundreds of asteroids [4], and the odd shapes of NEA's which can be most easily explained by assuming they are essentially strengthless bodies subjected to tidal pulls during planetary close approaches.

Given these observations, our predictions are that the parent bodies of materials like Orgueil and Tagish Lake may eventually be found to also be rubble piles of 50% or more macro-porosity; such a body would have a bulk density of 0.75 g/cm3, comparable to what has been suggested as the density of comet nuclei.

References: [1] Rivkin A. S. (2001) personal communication [2] Michalak, G. (2001) *Astron. & Astrophys. 374,* 703-711. [3] Brown P. G. et al. (2001) *BAAS 33*, 1152. [4] Flynn G. J. (1995) Planet. Space Sci. 42, 1151-1161. [5] Harris A. W. (1996) *LPS XXVII,* 493-494.