THE POROSITY OF 433 EROS. D. T. Britt[1], D. Yeomans[2], and G. J. Consolmagno SJ[3], [1]Department of Geological Sciences, University of Tennessee, Knoxville, TN 37996, dbritt@utk.edu. [2]Navigation and Mission Design Section, JPL, Pasadena, CA 91109, Donald.k.yeomans@jpl.nasa.gov. [3]Vatican Observatory, V-00120, Vatican City State, gjc@specola.va.

Introduction: The highly successful NEAR-Shoemaker mission has returned a wealth of detail on asteroid 433 Eros and provided a number of important insights into asteroids in general [1,2,3]. Part of that detail is by far the most accurate assessment of mass and volume of any asteroid [2,3]. These results show that the bulk density of 433 Eros is 2.67 ± 0.03 g/cm^3 [2]. We can put that result into context by looking at density and porosity data from meteorite collections and use this to assess the implications for the structure of Eros and other S type asteroids.

Data: Several lines of evidence point to the bulk composition of 433 Eros being similar to L or LL ordinary chondrite meteorites [1]. First the NEAR-Shoemaker XRS data show major element ratios consistent with ordinary chondrites meteorites (except for an intriguing depletion in sulfur) [4]. Second, the MSI/NIS reflectance spectra data show absorption features diagnostic of a Gaffey S(IV) subclass with mineralogies consistent with ordinary chondrite meteorites. The ordinary chondrites are perhaps one of the best studied meteorite classes and we have the advantage of an extensive data base of ordinary chondrite density and porosity measurements [5,6,7,8]. Shown in Table 1 are the average grain density, bulk density, and porosity for the ordinary chondrite subtypes. Note that bulk density is the density of the meteorite with pore space while grain density is the density with no pore space. For L and LL ordinary chondrites, grain densities range from 3.75 to 3.56 g/cm^3 which are substantially denser than the Eros bulk density of 2.67 g/cm^3. This difference is shown graphically in Figure 1 along with bulk density data for other S type asteroids. The strong implication is that a significant portion of Eros's volume is occupied by pore space.

Discussion and Conclusions: To estimate the porosity of 433 Eros we can use the meteorite data as a guide. Assuming that 433 Eros has the mineralogy of an ordinary chondrite and a bulk density of 2.67 g/cm^3, we can derive the bulk porosity required to reconcile these two constraints. As shown in Table II, this would require a bulk porosity of 28.8% for L chondrite mineralogy and 25.0% for LL mineralogy. This bulk porosity is a bit misleading however. Almost all ordinary chondrites have some level of porosity, even though they are strong, coherent rocks that have survived the stresses of ejection from their parent asteroid, transportation to Earth, and entry through Earth's atmosphere. On average, ordinary chondrites show approximately 11% porosity and the average porosity values for each subclass are shown in Table 1. Porosities for individual L and LL chondrites can range from a few percent to as much as 35%, but distribution strongly peaks around 10% [5,6]. This porosity is in the form of cracks and voids within the meteorites on the order of a few microns to a few tens of microns. This small-scale porosity is called microporosity and apparently does not seriously effect the meteorite's cohesive strength. The implication is that microporosity would also not effect the parent asteroid's cohesive strength.

The other component of asteroid porosity is macroporosity, defined as the fractures and voids in a object that are larger than the scale found in meteorites. Subtracting the average meteorite analogue microporosity from the asteroid's bulk porosity yields an estimate of the macroporosity. For a L chondrite composition, 433 Eros is estimated to have a macroporosity of 18% and LL composition yields a macroporosity of 14.6%. These data are shown in Table II.

The implication is that 433 Eros has a bulk porosity of approximately 25-29%, but almost half of the bulk porosity is accounted for by the inherent microporosity of the ordinary chondrite material. The large scale macroporosity of the object is in the range of 14-18%. This level of macroporosity is consistent with a highly fractured object, but is probably not high enough to justify a "reassembled rubble-pile" structure [1,9]. There are numerous morphological indications of pervasive fracturing on 433 Eros including lineations, sinuous and linear elongated depressions, grooves, and ridges [1]. The most prominent feature is a ridge complex over 15 km long in the northern hemisphere that appears to be the result of compressional stresses, perhaps due to asteroidal-wide fracturing from a major impact event [1]. The estimated macroporosity is consistent with fracturing and modest tectonic movement of major blocks of material within the asteroid. The bulk density of 433 Eros is similar to the other measurements of S-type objects, 243 Ida and the Standish "Average S" [10]. Although these are not a lot of data points, the implication is that S asteroids, on average, are more likely to have structures consistent with the "coherent but fractured" model rather than the "reassembled rubble-pile" model.

In summary, the results of the NEAR-Shoemaker mission provide constraints that can be used to estimate the porosity of 433 Eros. Based on data from ordinary chondrites we estimate that 433 Eros has a bulk porosity of approximately 25-29% and a macroporosity of between 14-18%. This level of porosity is consistent with a coherent, but fractured object.

References:

[1] Veverka J. et al. (2000) *Science, 289,* 2088–2097.[2] Yeomans D. K. et al. (2000) *Science, 289,* 2085–2088. [3] Zuber M. T. et al. (2000) *Science, 289,* 2097–2100. [4] Trombka J. (2000) private communication. [5] Consolmagno G.J. and D. T. Britt (1998) *MPS 33*, 1231-1241. [6] Consolmagno G.J. et al. (1998) *MPS 33*, 1221-1230. [7] Flynn G. J. et al. (1999) *Icarus, 142*, 97-105. [8] Wilkinson S. L. and Robinson M. S. (2000) *MPS, 35*, 1203-1214. [9] Britt D. T. and Consolmagno G. J. (2000) *MPS, 35*, A34-A35. [10] Standish E. M. et al. (1995) JPL IOM 314.10-127.

Table I:

Meteorite Type	Grain Density	Bulk Density	Average Porosity
H	3.84	3.40	11.5%
L	3.75	3.34	10.8%
LL	3.56	3.19	10.4%

Table II:

Meteorite Type	Ave Grain Density	Eros Bulk Porosity	Meteorite Microporosity	Eros Estimated Macroporosity
H	3.84	30.5%	11.5%	20.0%
L	3.75	28.8%	10.8%	18.0%
LL	3.56	25.0%	10.4%	14.6%

Figure 1: Light Asteroids and Meteorites