THE POROSITY OF EROS AND IMPLICATIONS FOR ITS INTERNAL STRUCTURE. S. L. Wilkison[1], M. S. Robinson[1], P. C. Thomas[2], J. Veverka[2], T. J. McCoy[3], S. L. Murchie[4], L. Prockter[4], D. Yeomans[5], [1]Department of Geological Sciences, Northwestern University, Evanston, IL 60208, USA, [2]Cornell University, Ithaca, NY 14853, USA, [3]National Museum of Natural History, Washington, DC 20560, USA, [4]Applied Physics Laboratory, Laurel, MD 20723, USA, [5]Jet Propulsion Laboratory, Pasadena, CA 91109, USA.

Introduction: Color and spectral measurements of Eros from the NEAR MSI and NIS are consistent with an ordinary chondrite composition [1,2,3]. NEAR XGRS data also indicate that the composition of Eros is most consistent with undifferentiated ordinary chondritic material [4]. These results allow us to confidently compare the calculated bulk density of 433 Eros (2.67 ± 0.03 g/cm^3) [1,5] with that of ordinary chondrite meteorites (3.40 g/cm^3) [6] and the range of porosity of ordinary chondrites (0-15%) [7,8], to estimate the total porosity of Eros to be between 21-33%. We suggest that Eros is *heavily fractured*, but structural evidence indicates that the asteroid was not catastrophically disrupted and reaccumulated into a rubble pile structure.

Estimate of Eros's Porosity: Macroporosity (the void porosity between large pieces within an asteroid) and microporosity (the grain-sized scale porosity observed within meteorite samples as small cracks and voids) are two generalized classifications of porosity used to describe asteroids and meteorites [6,7,8]. To calculate the porosity range of Eros, we used the bulk density of Eros (2.67 ± 0.03 g/cm^3), the average bulk density of ordinary chondrites (3.40 g/cm^3), and the range of ordinary chondrite microporosity (0-15%). We estimate that the bulk (total) porosity of Eros is between 21-33% [9]. We also infer that the macroporosity of Eros may be as high as 33% (if the asteroid had no microporosity) but must be higher than 6% (if the asteroid had 15% microporosity) [9].

Using the median value of OC microporosity (6%), the average bulk density of ordinary chondrites, and the bulk density of Eros, we estimate that the bulk (total) porosity of Eros is 26%. If we also infer that Eros possesses 6% microporosity, the macroporosity would be 20% [9].

Implications for Internal Structure:

Porosity of Eros. We propose three states of structural modification of asteroids that may occur due to varying degrees of impact induced fracturing; the three models described below are assigned possible porosity ranges based on meteorite, lunar, and terrestrial analogs when feasible. Our estimate of Eros's porosity, the bulk density measurement [1,5], and morphologic observations of the surface give first order information regarding the internal structure of the asteroid and can help us determine which of these internal structure models may be applicable to Eros.

We define a *coherent but fractured* structure as one in which the asteroid is fractured by collisions, but is still a coherent body. If fragments exist, they have not undergone significant movement relative to the asteroid's original structure.

A *heavily fractured* asteroid (produced by several large collisions) results in a structure with fragments that have undergone small displacement. This definition is consistent with the [10,11] definition of a 'rubble pile' (see below for clarification). Presumably, this structure would have more macroporosity than the *coherent but fractured* structure due to an increase in the void spaces between the displaced fragments.

The term *rubble pile* has been variously used to describe different states among a spectrum of possible asteroidal structural evolution. Discussions of the possibility that asteroids may be composed of a loose agglomeration of material held together gravitationally dates back as far as Mariner 9 studies of Phobos and Deimos [cf. 12]. This idea was later expanded upon in reports in 1977-1979 [10,11,13] and the first use of the term rubble pile appeared in [11]. We use the term *rubble pile* to represent an asteroid that was disrupted into fragments and reassembled into a gravitationally bound body. This structure would have a higher macroporosity due to the voids created by the reassembly of the dispersed fragments.

Porosity ranges can be assigned to each of the structural models based on lunar, terrestrial, and meteorite analogs. For example, ordinary chondrite meteorites have (micro)porosities ranging (generally) from 0-15%, but cluster at 6% [7,8]. Thus we adopt this range of porosity (0-15%) for the *coherent but fractured* body, in which most of the total porosity would be microscopic. Lunar and terrestrial impact breccias have porosities up to 30% [cf. 9]; based on these analogs, we infer that that the *heavily fractured* asteroid model proposed above could have total porosity ranging from 15-30%. A lunar or terrestrial analog for the rubble pile model is problematic. Measurement of porosities of potential analogs such as fresh rockfall or landslide deposits is notoriously difficult, and the analogy may not avoid the effects of differences in compressive stresses between terrestrial rubble pile deposits and small asteroids. Unconsolidated terrestrial sediment porosities are generally greater than 30% [cf. 9]. Based on these analogs, we suggest rubble piles could have porosities well in excess of 30%. Modeling of asteroids that have undergone the collisional breakup and gravitational assembly process predicts porosities of ~40% [14]. However subsequent settling and relithification may lower this value to the range of ~30%. Admittedly, these porosity boundaries are rough, and will remain so until direct measures of asteroid interiors are obtained.

Morphology of Eros. Structural features such as lineations, chains of craters, ridges (Figure 1), sinuous and linear depressions, and pitted grooves (Figure 2) have been observed on Eros [1,15]. These lineations and their large variation in direction/orientation suggest a global fabric that was most likely created in many different collisional events throughout the history of the asteroid [1]. Morphological features suggest that Eros possesses internal tensile strength, unlike a rubble pile structure. Finally, the center of mass and center of figure of Eros nearly coincide, indicating homogeneity in mass distribution (density) within Eros [16,17], further supporting the implausibility of the rubble pile model.

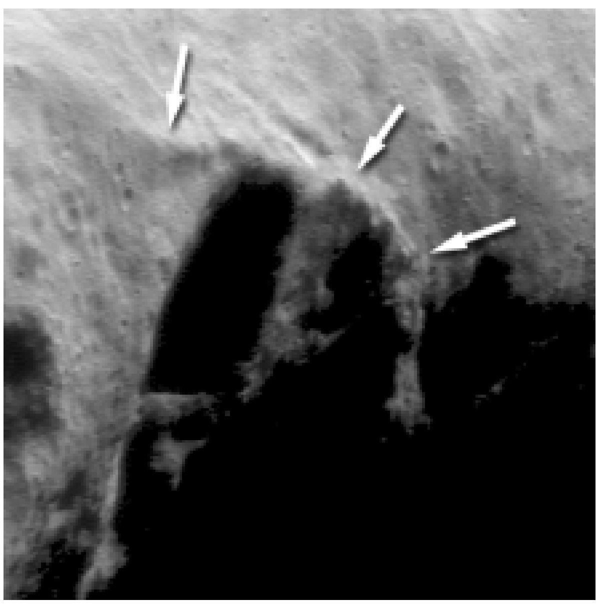

Figure 1. A ridge (Rahe Dorsum) with over 300 m of relief [18] that extends for 15 km [1] (MET 131968549-131969115B).

Conclusions: The macroporosity estimate of Eros indicates that the asteroid has undergone a high degree of impact-induced fracturing (eliminating the *coherent yet fractured* structural model). Potential terrestrial analogs and models of the breakup/reassembly process predict porosities greater than 30% for *rubble pile* asteroids [20-22]. The estimate for Eros's macroporosity is lower than 30%, thus indicating that the rubble pile model is not applicable. Homogeneity in the mass (and density) distribution of Eros further suggests the implausibility of the rubble pile model. Additional morphological evidence such as structural features indicates that Eros possesses internal tensile strength, eliminating the *rubble pile* model. We conclude that 433 Eros is a *heavily fractured* asteroid.

Figure 2. An example of the pitted grooves similar to those found on Phobos. Eros exhibits a pattern of complex grooves and fabric that suggests a competent material beneath the regolith [1] (MET 135343994-135345734).

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