THE RELATION OF 433 EROS TO OTHER S ASTEROIDS: EVIDENCE FROM REFLECTANCE SPECTROSCOPY AT 0.33-2.5 \( \mu \text{m} \). Scott L. Murchie, Applied Physics Laboratory, Johns Hopkins University, Laurel, MD 20723; Carlé M. Pieters, Dept. of Geological Sciences, Brown University, Providence, RI 02912.

In 1999 the NEAR spacecraft will perform the first rendezvous with an asteroid, the S-type 433 Eros. Data returned by \( \gamma \)-ray, X-ray, and NIR spectrometers will be used to address the questions of Eros's surface composition and the link between S-asteroids and meteorites. In order to properly frame these questions, it is necessary to understand how Eros's spectral properties compare with those of other S asteroids. In this review we integrate previous measurements of Eros to derive a composite spectrum from 0.33-2.5 \( \mu \text{m} \), and we use this spectrum to assess Eros's mineralogy and the spectral class of S asteroids to which it belongs. Eros exhibits 1-\( \mu \text{m} \) and 2-\( \mu \text{m} \) mafic mineral bands (Bands I and II) centered near 0.96 and 1.96 \( \mu \text{m} \). For such a Band II position, the center wavelength of Band I is longer than expected for pure pyroxene, suggesting an additional phase with an absorption longward of 1 \( \mu \text{m} \). The area ratio of Band II/Band I is also somewhat smaller than for pure pyroxene, suggesting an additional absorption near 1 \( \mu \text{m} \). Both the band centers and areas indicate a mafic mineral composition rich in orthopyroxene with a component of olivine. The values of these attributes place Eros as a member of the S(IV) spectral class of Gaffey et al. [1]. The continuum slope and band strength are typical of S-asteroids of comparable size, suggesting that 433 Eros is representative of small S(IV) asteroids.

The Spectrum of Eros. To derive a composite visible-NIR spectrum of Eros, we digitized and smoothed the NIR spectrum of Eros obtained by Larsen et al. [2] using an FTIR. These data were scaled to the 0.33-1.06 \( \mu \text{m} \) spectrum of Pieters et al. [3] in the region of wavelength of overlap, and normalized to unity at 0.56 \( \mu \text{m} \). Estimated normal albedo was derived by multiplying the normalized spectrum by the \( p_0.56\mu\text{m} = 0.19 \) determined by Zellner et al. [4]. The resulting composite spectrum is shown in Fig. 1. Continuum slope, band centers, and band depths and areas were determined for this spectrum using the same techniques as those described in Gaffey et al. [1]. Although Eros exhibits rotational variations in the extended visible wavelength region suggestive of varying olivine abundance [3], the averaged spectrum was used in this analysis.

Asteroid Spectral Classification. The most detailed classification of S-asteroids was completed by Gaffey et al., who merged 8-, 24-, and 52-color spectra covering the wavelength range 0.33-2.5 \( \mu \text{m} \) for 39 S asteroids. From these data they calculated continuum slope and centers, depths, and areas of Band I (near 1 \( \mu \text{m} \)) and Band II (near 2 \( \mu \text{m} \)). On a graph of Band I center vs. Band II/Band I area, laboratory mixtures of orthopyroxene and olivine plot along a curvilinear trend (Fig. 2). Departure of the Band I center above this trend may be related to the presence of other components such as Ca-rich clinopyroxene. Projected onto the same graph, plots of the S asteroid spectra cluster around the olivine-orthopyroxene mixing line. Gaffey et al. divided the spectra into groups S(I) through S(VII), in which they inferred a high olivine content to be progressively replaced by orthopyroxene, with clinopyroxene content varying between groups. Spectra of meteorites of different composition also plot in different domains on this graph; ordinary chondrites occupy a region comparable to group S(IV). This classification and nomenclature are a potentially powerful tool for relating Eros to other S asteroids, because it is based on spectral attributes which have mineralogic significance.

We independently tested the reproducibility and compositional interpretation of these groupings by plotting the same asteroid spectra onto diagrams of Band I center vs. Band II center (Fig. 3). On this type of diagram orthopyroxenes and clinopyroxenes occupy narrow ranges of admissible values [5]. Departure of the Band I center above the pyroxene field is caused by addition of an absorption longward of 1 \( \mu \text{m} \) such as that exhibited by olivine or glass. When the S asteroid spectra are projected onto this graph, the wavelengths of the Band II centers are consistent with orthopyroxene being the dominant pyroxene. Lower numbered groups (e.g. S(II)) exhibit progressively greater departure of the Band I center from the pyroxene field, as expected for the progressively greater olivine contents inferred by Gaffey et al. Each group also occupies a reasonably distinct portion of the diagram; the greater overlap than in Fig. 2 is probably a result of uncertainty in determination of Band II center. These results substantiate the reproducibility and compositional distinctions of the groupings, and suggest that the Gaffey et al. classification is an appropriate tool for relating Eros to other S asteroids.

Eros Compared to Other S Asteroids. Eros is compared with the other S asteroids in Figs. 2 and 3. In Fig. 3, the Band II center appears consistent with pyroxene of low-Ca composition transitional between ortho- and clinopyroxene. The Band I center departs above the pyroxene field in a manner consistent with a significant olivine component. This interpretation is supported by the intermediate location of Eros on the orthopyroxene-olivine mixing line in Fig. 2. Among the 7 classes of Gaffey et al., Eros groups closely with S(IV), and lies at the edge of the domain occupied by ordinary chondrite on this plot.

S asteroids in general and S(IV) bodies in particular exhibit correlations of Band I depth and continuum slope with asteroid diameter (Figs. 4 and 5). Band I of Eros is relatively strong as is the case with small S asteroids, and the continuum is quite red as is typical of small S(IV) bodies. Eros's consistency with other S asteroids of similar size and spectral attributes strongly suggests that it is "representative" of small S(IV) bodies.

In Gaffey et al.'s compositional interpretation of their spectral classes, S(IV) bodies exhibit the greatest similarity to ordinary chondrites of any S asteroids. The trends of S(IV) properties with diameter and the
weaker bands and redder continuum than for ordinary chondrites have been used as evidence for a stony-iron composition instead [1,6]. However these differences can also be accounted for qualitatively by a space weathering model with a free iron component [7]. Eros is thus an excellent target for NEAR to assess the relationship, if any, of ordinary chondrite materials to the S asteroids.