MINERALOGICAL VARIATIONS AMONG HIGH ALBEDO E-TYPE ASTEROIDS: IMPLICATIONS FOR ASTEROID IGNEOUS PROCESSES. Michael J. Gaffey[1] and Michael S. Kelley[2], [1]Space Studies Department, University of North Dakota, Box 9008, Grand Forks, ND 58202, email: gaffey@space.edu; [2]Department of Geology and Geography, Georgia Southern University, Statesboro, GA 30460; email: mkelley@GeorgiaSouthern.edu

The link between the E-type asteroids and the enstatite achondrites (aubrites) was first proposed for the original E-asteroid, 44 Nysa [1]. The association was based on the high albedos and the featureless spectra shared by the E-asteroids and the aubrites. Among the plausible geologic and meteoritic materials, only enstatite (the magnesium end-member of the pyroxene solid solution series) is sufficiently abundant to comprise asteroid-sized bodies [2]. However, the presence of a weak 0.89 μm absorption feature in the spectrum of 44 Nysa indicates that its pyroxene contains a small amount of Fe^{2+} but still substantially more than any aubrite present in the meteorite collection [3].

The original E-class was defined based on its high albedo and flat to slightly reddish spectrum [4,5]. In the absence of albedo data, the E-type was degenerate with the M- and P-types, and together these were designated as X-types. Recently, a taxonomy has been proposed to identify E-types in the absence of albedo data [6]. In this newer classification system three subdivisions of the X-type have been proposed, including Xc, Xe and Xk. Of nine albedo-defined E-types [d], this newer non-albedo based taxonomy produced the following classifications: X – 1 asteroid; Xc – 2 asteroids; Xe – 5 asteroids; and Xk – 1 asteroid. Although the Xe subtype includes the largest number of albedo-defined E-types, most of the remaining 24 Xe-types can be excluded based on their low measured IRAS albedos, ranging from 0.116 to 0.329, which are below the lower albedo limit of the E-class (0.34) and substantially below that of the lowest albedo an actual E-type asteroid (0.41) [5]. The present discussion will be limited to unambiguous E-type asteroids determined on albedo criteria.

Currently spectral data with useful resolution and wavelength coverage exist for eight E-type asteroids. Figure 1 shows a representative sample of the spectral diversity among the E-type asteroids. There are at least three spectrally distinct subtypes among the E-asteroids. All subtypes are characterized by high albedos but there is no indication of any systematic albedo variations between the different subtypes.

The first subtype (designated E[I]) is characterized by a slightly reddish or curved VNIR spectral curve lacking any discrete diagnostic mineral absorption features. Asteroid 214 Aschera (Figure 1) is an example of this subtype. This type of spectrum is characteristic of an aubrite pyroxene or aubritic pyroxene-plus-feldspar assemblage. Aubrites are mantle rocks from a highly reduced (E-chondrite-like) parent body(ies) which has undergone melting and differentiation. The corresponding feldspar-rich basaltic rocks have not been identified in the meteorite collections and may have been erupted as gas-driven pyroclastic materials at velocities sufficient to escape their parent bodies and thus never formed discrete lithologic units [7]. The E[I]-subtype probably represent mantle (and possibly crustal) material from a differentiated, highly reduced parent body of approximately enstatite chondrite composition. Based on melting experiments on enstatite chondrites, the parent bodies of this E-subtype attained temperatures in excess of 1400°C [8]. The parent bodies of aubrites would probably be found among asteroids of the E[I]-subtype.

The second subtype (designated E[II]) exhibits a relatively strong feature centered near 0.49 μm, occasionally with a weaker feature near 0.96 μm. Asteroids 64 Angelina and 3103 Eger [9] are examples of this subtype. Asteroid 434 Hungaria also probably belongs to this subtype, but differences in the published spectra need to be reconciled. These features are characteristic of the calcium sulfide mineral, oldhamite [10]. The absorption feature probably arises from the presence of a trace of bivalent iron in the sulfide. Oldhamite is present only in highly reduced assemblages such as aubrites [8,11]. Given the strength of the absorption 0.49 μm feature, and the low absorbance of enstatite, the amount of oldhamite needed to produce the features present in type E[II] spectra should be quite low if the phases are fine-grained intimate mixtures. However, a mixing experiment suggested [10] that 5% oldhamite was insufficient to reproduce the feature in the spectrum of 64 Angelina.

The third subtype (designated E[III]) has a flat or slightly reddish spectral curve and exhibits a weak but well-defined ~0.88-0.90 μm absorption feature characteristic of an enstatite pyroxene containing a trace amount of Fe^{2+}. Asteroids 44 Nysa (Figure 1) and 317 Roxana are examples of this subtype. Although the estimated bivalent iron content is quite low (perhaps only a few tenths of a mole percent), it is still much higher than that found in the enstatite in either aubrites or enstatite chondrites. The parent body of this E-subtype must have an oxidation state intermediate between the E-chondrites (~Fs_0) and the F-chondrites

(~Fs_{3-5}). The melting temperature would be essentially identical to that of the E-chondrites.

Although the geochemical behavior of oldhamite in highly reduced igneous systems is not completely understood [e.g., 8,11], it seems likely that it will be significantly enriched in early partial melts from enstatite chondrite source materials. The E[II] asteroids may be composed of basalt equivalents from E-chondrite-like parent bodies which underwent at least partial melting. The E[I] asteroids probably formed in the cumulate mantles of E-chondrite-like parent bodies which underwent extensive melting and differentiation. The E[III] type asteroids derive from slightly more oxidized parent bodies or from oxidized parent bodies which underwent extensive reduction during their igneous processing. To date no meteoritic samples from E[III] asteroids have been recognized in the meteorite collections.

This work was supported in part by NASA Planetary Geology and Geophysics grants NAG5-10345 and NAG5-13792.

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Figure 1: Asteroid spectral data are from the SMASS [12,13] and SMASSIR [l4] surveys. The oldhamite spectrum is from [10]. The curvature and absorption features the asteroid spectra are enhanced by plotting the data at expanded vertical scales. The two vertical lines indicate the central wavelengths of the absorption features in the oldhamite spectrum.