Mineralogical Diversity in the S-type NEA Population. M. J. Gaffey[1,2] and V. Reddy[1,2], [1]Department of Space Studies, University of North Dakota, Grand Forks, ND 58203; [2]Visiting Astronomer at the Infrared Telescope Facility, which is operated by the University of Hawai'i under contract from the National Aeronautics and Space Administration, Mauna Kea, Hawai'i 96720. Email: gaffey@space.edu; Vishnu.kanupuru@und.nodak.edu.

Introduction: S-type objects are the most common taxonomic class in the near-Earth asteroid (NEA) population, and comprise ~65% of all classified NEAs [1]. The S-type taxonomic group is very mineralogically diverse, potentially including no less than ten mineralogically distinct assemblages/meteorite types within this group [2]. Many of the previous effort in studying S-type NEAs has been focused on linking them to ordinary chondrites [e.g., 3-7].

In an effort to understand the mineralogical diversity of the S-type NEA population we have observed a number of NEAs over the past five years to answer key geologic questions. Here we summarize some initial results of this mineralogical study of the S-type NEA population.

Observations: Near-infrared observations of the NEAs were obtained using the SpeX instrument [8], a medium resolution near-infrared spectrograph at the NASA Infrared Telescope Facility (IRTF) on Mauna Kea, Hawai'i. Spectral data of NEAs was obtained using a combination of *in situ* observing from the summit of Mauna Kea and remote observing from our lab at UND. In the low-resolution mode, SpeX covers the wavelength region between 0.7-2.5-µm with a spectral resolution of ~150.

Due to their inherent faintness, rapid motion across the sky, and short observing windows, NEAs present a unique observing challenge for planetary scientists attempting to characterize them. The combination of excellent observing conditions on Mauna Kea, coupled with SpeX's unique capability, has allowed observers to obtain high signal-to-noise ratio spectra and detect spectral features at a few percent level on NEAs as faint as V magnitude = 17.5.

Data Reduction: All SpeX data were subsequently reduced using IRAF and the PC-based SpecPR spectral processing program [9]. Eleven spectral parameters including temperature corrected Band I and II centers were calculated using SpecPR. Due to their close proximity to the Sun at the time of observation, the band centers of these NEAs are shifted to longer wavelength due to higher surface temperature than their main belt counterparts. The band centers were corrected by first calculating their surface temperature, and then using the correction methods described in [10] using data from [11]. The mineralogically diagnostic parameters (band centers, band area ratios / BARs) are essentially unaffected by known or modeled space weathering processes [12, 13, and this meeting]. Thus the spectral effects of space weathering - which can adversely affect analysis by curve matching – can be ignored during the present analysis.

Analysis: Figures 1 and 2 plot the spectral band parameters on the S-asteroid subtype diagram [2]. A significant fraction (9 of 20 or 45%) of the observed S-type near Earth asteroids fall in the S(IV) region of the plot. Which indicates mineralogy consistent with but not uniquely diagnostic of ordinary chondrites. The bold line is the olivine-pyroxene mixing line with the S(I) types being pure olivine and S(VII) being pure pyroxene assemblages. The rectangular box above the S(VII) region is the basaltic achondrite region. The region above the S(V) to S(VII) parallel to the olivine-pyroxene mixing line is the olivine-clinopyroxene mixing area as described by [2].

Two objects each (10%) fall in the S(II), S(III), S(V), and basaltic achondrite region and a single object is classified as S(VI). In the S(IV) region, a majority of the objects fall in the L and LL chondrite area of the boot shaped region (left side) and only a single object falls in the H chondrite area close to the right end. No pure olivine assemblages were found in this limited sample of S-type NEAs. One asteroid (2001 CV26) did not show a significant Band II but the Band I center of this object is shorter than those seen in Mg-rich olivine (1.04 µm). The quality of the data beyond 1.6 µm is poor and hence object has not been plotted on the Band-Band plot (Figure 3).

An LL-chondrite Excess?: An excess of LL-type assemblages relative to H- or L-type assemblages among the NEAs has been suggested [7]. This is puzzeling result since among ordinary chondrite meteorite falls, which are presumed to represent a sample of the near-Earth population, H-chondrites and L-chondrites are each about five times more common than LL-type chondrites [14]. A size distribution influence of the YORP effect that moves objects from the main belt into the resonances was invoked as a possible explanation for this discrepancy [7].

In their analysis [7] used a model to correct for the presumed effects of space weathering. However as discussed in [13 and this meeting], no single space weathering model can be applied to asteroid spectra. This raises the question of whether the results of [7] are adversely influenced by the space weathering correction that they applied.

In our mineralogical study, S(IV) sub-types dominate the S-type NEAs. The parent bodies of the ordinary chondrites would belong to this subtype. In the boot shaped S(IV) region, the H-chondrites plot to the lower right near the 'toe' region, the L-chondrites to the left of this region near the 'ankle' and the LL-chondrites to the top left, although there is significant overlap between the L and LL-types [15]. Based on the olivine-pyroxene ratio for the S(IV) subtypes (Figure 2) for this limited set of NEAs, it appears that LL- (or L- & LL-) chondrite-like assemblages dominate the NEA S-type population. The band-Band plot (Figure 3) tells a similar story.

Our mineralogic analysis supports the general findings of [7] and eliminates the possibility an artifact induced by their space weathering correction. However, several key questions remain unanswered. The most fundamental question concerns the discrepancy between the ordinary chondrite meteorite flux and the apparent overabundance of LL-chondrites in the NEA population. A second related issue is what fraction of these "LL" assemblages are actually better characterized as "L" or "L/LL" assemblages.

References: [1] Binzel R. P. et al. (2004) *Icarus 170*, 259–294. [2] Gaffey M. J. et al. (1993) *Icarus 106*, 573-602. [3] Binzel R. P. et al. (1996) *Science 273*, 946-948. [4] Jedicke R. et al. (2004) *Nature 429*, 275-277. [5] Nesvorný D. et al. (2005) *Icarus 173*, 132–152. [6] Hiroi T. et al. (2007) *Antarctic Meteorites XXXI*, NIPR, Tokyo, pp. 25. [7] Vernazza P. et al. (2008) *Nature, 454,* 858-860. [8] Rayner J. T. et al. (2003) *Publ. Astron. Soc. Pac. 115*, 362-382. [9] Clark R. N. (1980) *Publ. Astron. Soc. Pac., 92*, 221-224. [10] Burbine T. H. et al. (2009) *MAPS, 44*, 1331-1341. [11] Moroz L. et al. (2000) *Icarus 147*, 79-93. [12] Gaffey M. J. (2001) LPSC XXXII, Abstract #1587. [13] Gaffey M. J. (2009) Icarus, submitted. [14] Wasson J. T. (1974) *Meteorites*. Springer-Verlag, New York, 316pp. [15] Gaffey M. J. and Gilbert S. L. (1998) *MAPS 33*, 1281-1295. [16] Adams J. B. (1974) *JGR, 79*, 4829-4836.
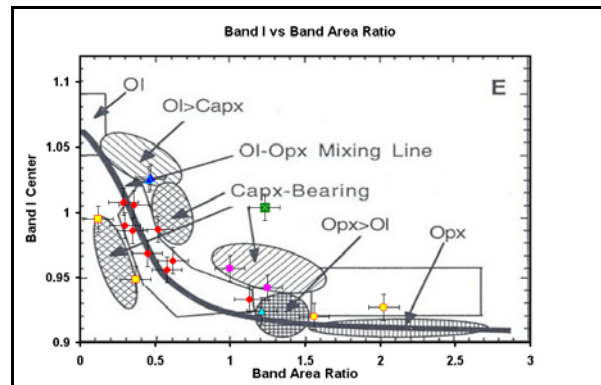

Figure 1. Band I vs. BAR plot showing the spectral parameters of NEAs. Objects have been color coded based on their subtypes.
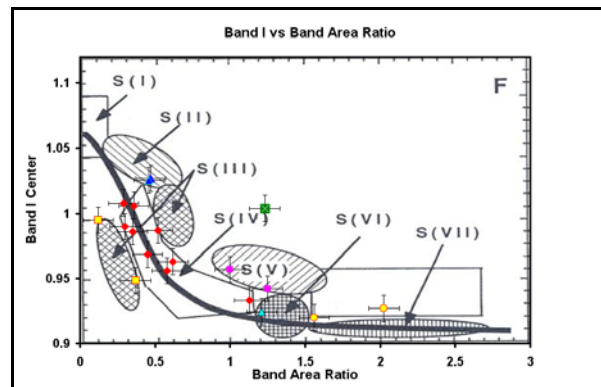

Figure 2. Band I vs. BAR plot showing the spectral parameters of NEAs. Objects have been color coded based on their subtypes.
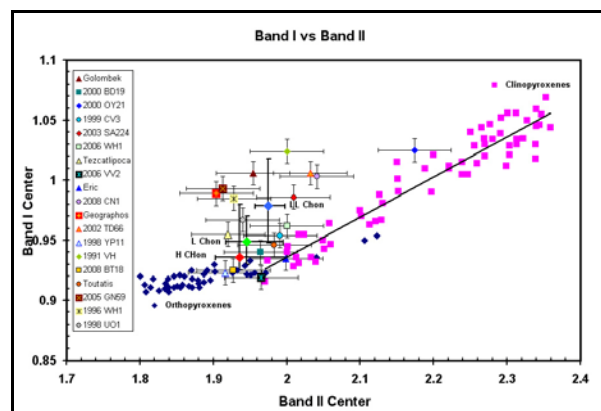

Figure 3. Band I vs. Band II plot (Band-Band plot) from [16] showing the spectral parameters of NEAs in this study.