Percentage of Ordinary Chondrite Mineralogies among S-complex and Q-type Near-Earth Asteroids.

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Introduction:

A number of planetary science questions have been definitively answered in the last few years. Two of these questions are whether ordinary chondrites (H, L, LL) can be derived from S-complex asteroids and whether space weathering occurs on asteroidal surfaces and reddens their reflectance spectra. Both of these questions were answered by analyses of samples of (25143) Itokawa that were returned to Earth by the Hayabusa mission. The returned grains had an LL chondrite mineralogy [1] and evidences of space weathering [2].

However, it is still unclear on how abundant ordinary chondrite mineralogies are among the near-Earth asteroid population. To try to answer this question (and many others), the MIT-UH-IRTF Joint Campaign for NEO Spectral Reconnaissance [3] was instituted in 2000 to routinely obtain near-infrared reflectance spectra of NEAs. As part of this ongoing program, near-infrared data were obtained on over 500 NEAs. These spectra will be analyzed to try to understand how prevalent ordinary chondrite mineralogies are among S-complex and Q-type NEAs. Binzel et al. [4] has previously found that there was a continuum of spectral properties between ordinary chondrites, Q-type and S-type reflectance spectra.

Analysis:

Ordinary chondrite spectra have characteristic absorption bands centered at ~1 (Band I) and ~2 (Band II) µm that are due to olivine and pyroxene. The positions of the bands are functions of the mineralogy of the ordinary chondrite. Among ordinary chondrites, LL chondrites tend to have absorption band centers at the longest wavelengths since they are the most olivine-rich (which tends to move the Band I center to longer wavelengths and contain the most Fe-rich pyroxenes (which tends to move the Band II center to longer wavelengths). H chondrites tend to have band centers at the shortest wavelengths since they are the most pyroxene-rich and contain the most Fe-poor pyroxenes. S-complex and Q-type NEA spectra also tend to have reflectance spectra with characteristic absorption features due to olivine and pyroxene.

The Band I and II centers and uncertainties for ~50 ordinary chondrite meteorite spectra [5] were determined using a specially-written computer program [6]. This program was also used to determine the band centers and uncertainties for a set of ~170 S-complex and Q-type NEA high-quality spectra that had full wavelength coverage in the visible and near-infrared. The near-infrared spectra were primarily obtained as part of the MIT-UH-IRTF observing program while the visible data were obtained using numerous telescopes. The calculated asteroid band centers could then be directly compared to the ranges found for the H, L and LL chondrites.

Results:

Approximately 70% of the analyzed S-complex and Q-type NEA spectra had band centers (within uncertainties) consistent with those of ordinary chondrites. This is most likely a lower limit on the percentage of S-complex and Q-type NEAs with ordinary chondrite-like mineralogies. For example, the band centers for Itokawa have relatively large uncertainties and fall slightly outside the range for the measured LL chondrites. Many other NEAs have band centers that fall slightly outside the calculated ranges for ordinary chondrites.

There are many complications in directly comparing band centers of meteorites and asteroids. The measured meteorites might not be fully encompass the possible range of ordinary chondrite mineralogies. Some of the NEA spectra are slightly noisy and could have atmospheric artifacts. The continua that are divided out to determine the band centers are assumed to be linear, which may not be the case. Temperature effects are assumed to be negligible but could slightly alter the positions of the band centers for some of the NEAs observed at distances from the Sun where these objects have relatively low surface temperatures.

Approximately two-thirds of the bodies with ordinary chondrite-like band centers had their best matches with LL chondrites. This result is consistent with the work of Vernazza et al. [7] and Dunn et al. [8] who also saw that LL chondrite-like compositions dominate the interpreted mineralogies of S-complex and Q-type NEAs for a smaller sample size. Because H and L chondrites dominate meteorite falls, this result implies that the NEAs and meteorites sample two different populations. Since the observed NEAs have diameters of hundreds of meters to tens of kilometers in size, this would imply that meteorites are derived from smaller bodies that are not readily observable.

Conclusions:

The S-complex and Q-type NEA populations have band centers consistent with ordinary chondrite mineralogies (predominately LL chondrites). Further work needs to be done to conclusively determine the mineralogies of these bodies. Observations of small (< 100 meters) NEAs would be predicted to show an increase in the abundance of objects with H and L chondrite mineralogies.

References:

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