

A COORDINATED MINERALOGICAL, SPECTRAL, AND COMPOSITIONAL STUDY OF ORDINARY CHONDRITES: IMPLICATIONS FOR ASTEROID SPECTROSCOPIC CLASSIFICATION. T.L. Dunn^{1,4}, T.J. McCoy², J.M. Sunshine³, and H.Y. McSween, Jr.⁴ ¹Department of Geography-Geology, Illinois State University, Normal, IL, USA (tldunn@ilstu.edu); ²Department of Mineral Sciences, National Museum of Natural History, Washington, DC, USA; ³Department of Astronomy, University of Maryland, College Park, MD, USA; ⁴Department of Earth and Planetary Sciences, Planetary Geosciences Institute, University of Tennessee, Knoxville, Tennessee, USA

Introduction: Over the past few decades, an ongoing debate has centered on identifying the source asteroids for the ordinary chondrites, the most common meteorites seen to fall to Earth. Visible/near-infrared spectroscopy has been the most widely-applied tool used in the search for these parent asteroids, due to the strong 1 μm and/or 2 μm absorption bands present in the dominant chondritic minerals olivine and pyroxene [1-5]. This approach directly compares spectral features (e.g., Band I and II centers, Band Area Ratios) in meteorites and asteroids. However, if robust relationships between these spectral parameters and mineralogical parameters (abundances and compositions) could be established, these comparisons could be made on the basis of the same criteria that are also primarily used in the classification of meteorites. Here we examine a large suite of ordinary chondrites, in which spectral and mineralogical data have been measured, to establish such relationships

Analytical Methods: Reflectance spectra of 48 H, L, and LL ordinary chondrites were acquired using a bidirectional spectrometer at Brown University's Keck/NASA Reflectance Experiment Laboratory (RELAB) [6]. Spectra were collected over a range of 0.32 to 2.55 μm at a sampling interval of 0.01 μm . An incident angle of 30° and an emission angle of 0° were used. X-ray diffraction patterns of the same 48 chondrites [7] were measured using an INEL X-ray diffractometer at the Natural History Museum in London, England. Mineral abundances were determined using a whole-pattern XRD fitting procedure [8,9].

Olivine and low-Ca pyroxene compositions in 38 of these ordinary chondrites were determined with a Cameca SX-50 electron microprobe at the University of Tennessee, using synthetic and natural mineral standards. Standard operating conditions during analysis included 15 kV potential, 20-30 nA beam current, and a 2 μm beam size. Counting time was typically 20 seconds.

Discussion: In the ongoing search for the parental asteroids of the ordinary chondrites attention has centered on the S(IV) subgroup, which is thought to contain objects with mineralogies similar to the ordinary chondrites [10]. The S(IV) asteroid 6 Hebe has been hypothesized to be the parent body of the H chondrites [11]. Like the S(IV) asteroids, our ordinary chondrites, when plotted in band area ratio vs. Band I center space

(Fig. 1), scatter along a mixing line between olivine and low-Ca pyroxene. This representation suggests that ordinary chondrites form a nearly continuous sequence between olivine-rich LL chondrites and relatively pyroxene-rich H chondrites [10].

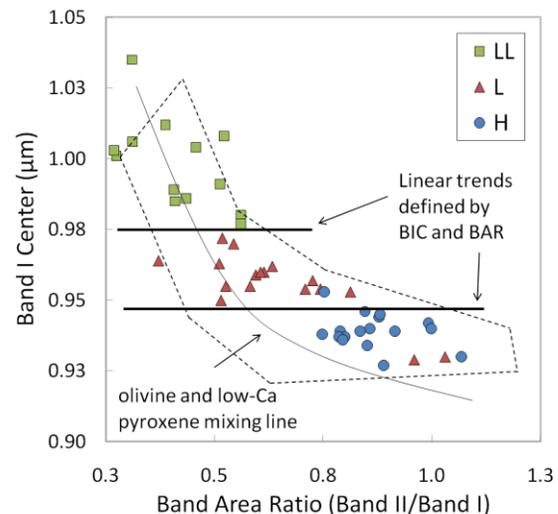


Fig 1. Spectral characteristics of 48 ordinary chondrites plotted on the current classification for S(IV)-type asteroids [8 and 9]. The H, L, and LL chondrites appear to form linear trends, shown as bolded horizontal lines, in which each group defines a restricted range of Band I center and a wider range of band area ratio.

However, examination of the ordinary chondrite spectral data from this study (Fig. 1) suggests that there is an alternative interpretation; the H, L, and LL chondrites appear to form roughly linear trends, in which each group defines a relatively restricted range of Band I center and a wider range of band area ratio (BAR) (Fig. 1). We suggest that this distinction mirrors the criterion (e.g., FeO in mafic silicates) originally used to distinguish the chemical groups of ordinary chondrites.

Because BAR is a measure of olivine and pyroxene abundances [12, 13], it is proportional to $ol/(ol+px)$ ratios. Our derived correlation for BAR vs. $ol/(ol+px)$ is essentially identical to that established by [12]. Given this proportionality, if two meteorites have identical BARs, and thus $ol/(ol+px)$ ratios, any differences in Band I center should be controlled almost entirely by the abundances of FeO in olivine and pyroxene. We can test this using the 38 chondrite samples for which both mineral abundances and silicate compositions were analyzed.

Figure 2 demonstrates the strong correlation between fayalite (Fa) in olivine and Band I center (BI), which is best described by a 2nd order polynomial fit: $Fa = -1284.9 X (BI)^2 + 2656.5 X (BI) - 1342.3$, with a R^2 of 0.92.

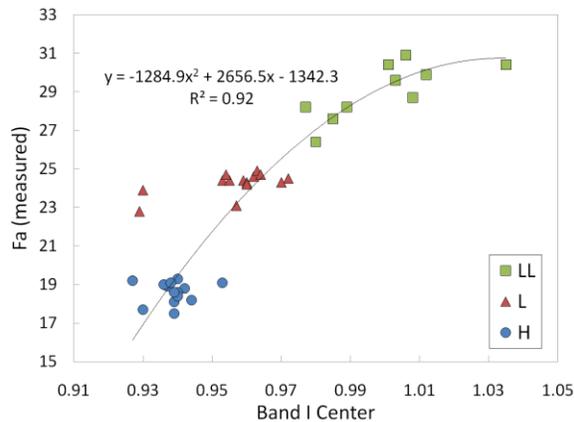


Fig. 2. Mol % Fa in olivine plotted as a function of Band I center for the 38 chondrite samples for which both modal abundances and mineral compositions were analyzed.

A similar conclusion is reached for ferrosilite (Fs) in pyroxene (not shown), which correlates with Band I center by a 2nd order polynomial fit: $Fs = -879.1 X (BI)^2 + 1824.9 X (BI) - 921.7$, with a R^2 of 0.91. Two L chondrites were not included in these correlations due to their anomalous Band I centers. Fa and Fs values derived using these equations correlate well with measured values. The correlations between both Fa and Fs and Band I center also support the observation that Fa and Fs are well-correlated with each other.

The correlation between mafic silicate compositions (Fa, Fs) and Band I center, along with the previously established linear relationship between BAR and ol/(ol+px), allows us to interpret asteroid spectra not simply in the context of BAR vs. Band I center, but in the context of FeO vs. ol/(ol+px) ratios - the same criteria used to classify ordinary chondrites.

In Fig. 3, we plot the spectrally-derived ol/(ol+px) vs. derived Fa compositions for the chondrites measured in this study. Dashed boxes represent the range of XRD-measured ol/(ol+px) (from this study) and the range of measured Fa and Fs contents in ordinary chondrites [14]. The solid grey boxes represent the least root mean square of the errors on these spectrally-derived values (0.03 for ol/(ol+px), 1.3 mol% for Fa, and 1.4 mol% for Fs.)

If we classified these meteorites using only spectrally-derived mineral abundances and silicate compositions, we would correctly classify 32 of 38 ordinary chondrites from VIS/NIR spectra. If the solid boxes, which account for the error of the technique, are used

as parameters for classification instead, all but the two L chondrite outliers and one H chondrite could be correctly classified. However, the overlap between L and LL chondrites implied by our derived data, and suggested by previous authors based on mineral chemistries [15], may make some L and LL chondrites difficult to distinguish.

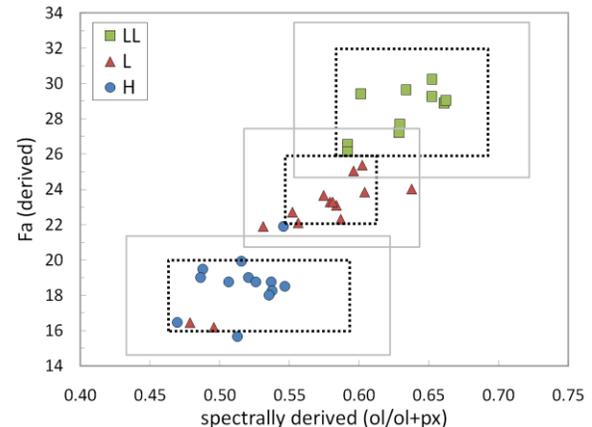


Fig. 3. Spectrally-derived Fa compositions vs. derived ol/(ol+px) in the 38 chondrite samples for which both modal abundances and mineral compositions were analyzed.

Conclusion: Correlation of mineralogical and spectral parameters in our suite of ordinary chondrites indicates that well-defined relationships exist between Band I center and FeO (expressed as Fa or Fs) and between BAR and ol/(ol+px). Our data suggest that 84% of chondrite-like asteroids should be correctly classified as potential H, L, or LL parent bodies using spectrally-derived silicate mineral compositions and abundances. With these tools, we can move beyond band parameters to directly discussing asteroid and meteorite properties using a common language of mineral abundance and composition.

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