

## A Framework for Spectral Reflectance Analysis of Carbonaceous Chondrite Meteorites (and Asteroids)

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### Abstract

Determining the mineralogy of dark (presumably carbonaceous chondrite-like) asteroids using 0.3-2.5  $\mu\text{m}$  reflectance spectroscopy has been hampered by a lack of knowledge of the spectral reflectance properties of these meteorites, and a general assumption that they are generally spectrally featureless. Here we show that most carbonaceous chondrite meteorites (CCs) do exhibit spectral properties that can be related to specific mineral components, and that different CCs often exhibit unique and mineralogically-diagnostic spectral features.

### 1. Introduction

The scientific importance of CCs includes the fact that they represent the least altered remnants of the early solar system that are delivered and available on Earth in appreciable quantities for study and analysis and because they can provide insights into solar system history and evolution, and prebiotic organic chemistry [e.g., 1, 2].

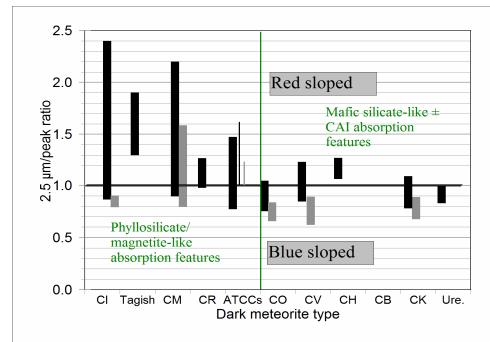
A number of studies exist that have systematically examined the spectral reflectance properties of different CCs in the 0.3-2.5  $\mu\text{m}$  region [e.g., 3-11]. By determining the range and diversity of spectral reflectance properties of different CC groups and comparing between groups, we have determined that most CC groups exhibit unique ranges of spectral reflectance properties that allows them to be discriminated. Here we focus on reflectance spectra of powdered CCs, as they are expected to be most representative of regolith-bearing asteroid surfaces.

### 2. Results

The most diagnostic spectral reflectance properties of CCs that can be used to discriminate them include absolute reflectance, spectral slope, and the position and shape of absorption features in the 0.7, 0.9-1.3, and 2  $\mu\text{m}$  regions. Using various combinations of

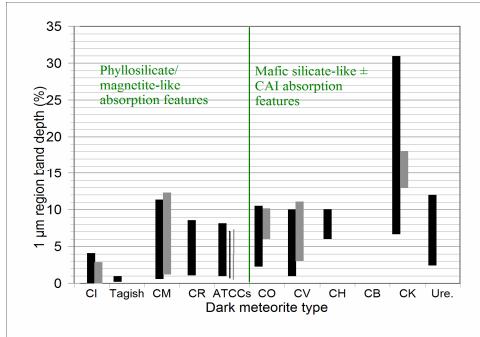
these metrics allows us to discriminate different CC groups with varying levels of confidence.

Figure 1 shows the range of slopes (as measured by the 2.5  $\mu\text{m}$ /visible region peak reflectance ratio) for different CCs and ureilites. It can be seen that there is significant overlap between groups but the aqueously-altered CCs are almost uniformly red sloped and show a wider range of slopes than unaltered CCs.



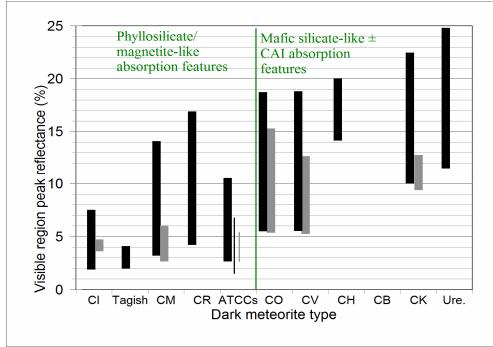
**Figure 1.** Spectral slope ranges for different CCs and ureilites. The black bars denote the range for powders, while the gray bars are for slabs or powders in which the finest powder fraction has been removed.

The 1  $\mu\text{m}$  region of CC reflectance spectra can be quite variable. Absorption bands in this region are nearly ubiquitous and are of two main types: (1) aqueously-altered CCs commonly exhibit absorption bands near 0.75, 0.9, and 1.1  $\mu\text{m}$  due to Fe-bearing phyllosilicates, while unaltered or thermally metamorphosed CCs show absorption bands near 1.05 and 1.25  $\mu\text{m}$  or near 0.95  $\mu\text{m}$ , due to olivine or pyroxene, respectively (Figure 2).



**Figure 2.** Same as Figure 1 for 1  $\mu\text{m}$  region maximum absorption feature depth.

Finally, when peak reflectance is used as a metric (Figure 3), there is a gradual positive correlation between reflectance and degree of thermal metamorphism, and a negative correlation with aqueous alteration. In other words, increasing aqueous alteration leads to generally lower reflectance, while increasing thermal metamorphism leads to generally higher reflectance.



**Figure 3.** Same as Figure 1 for reflectance at the visible region reflectance peak.

### 3. Discussion

These simple spectral metrics can be combined with other parameters for CC discrimination. These include: (1) determining whether absorption features in the 1  $\mu\text{m}$  region are phyllosilicate-like, olivine-like, magnetite-like, or pyroxene-line; (2) the presence or absence of absorption features in the 2  $\mu\text{m}$  region that

are attributable to pyroxene or Fe-bearing spinels in calcium aluminum inclusions (CAIs), and presence or absence of phyllosilicate absorption features in the 2.3  $\mu\text{m}$  region.

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