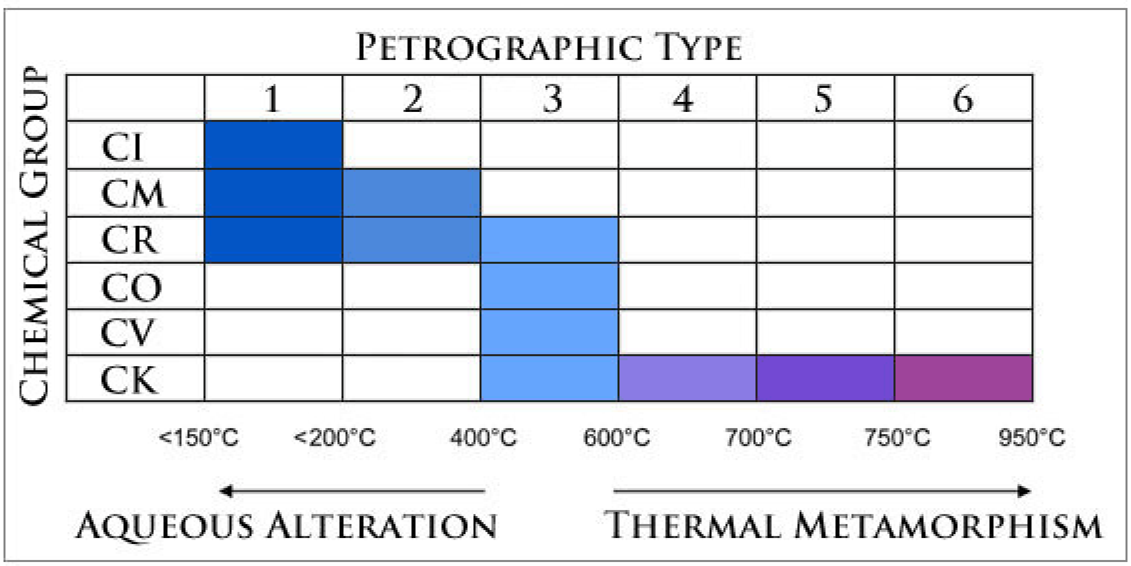
A Spectral Study of Least-processed Carbonaceous Chondrites

Minimal processing is good not only for healthy food but also for meteorites for the study of the least-altered, earliest Solar System materials. The geologic processes of aqueous alteration and thermal metamorphism on asteroid parent bodies are recorded in the chemistry of meteorites, so cosmochemists look to the chemically primitive carbonaceous ***chondrites*** when they want to better understand the characteristics of ancient material subjected to the least amount of processing since the time of accretion.

Margaret McAdam (University of Maryland and Northern Arizona University) and colleagues from Maryland, New York, Washington D.C., and Hawaii studied eight different CO3 carbonaceous chondrites. See the table below for the meteorite classification scheme.

Classification of Carbonaceous Chondrites



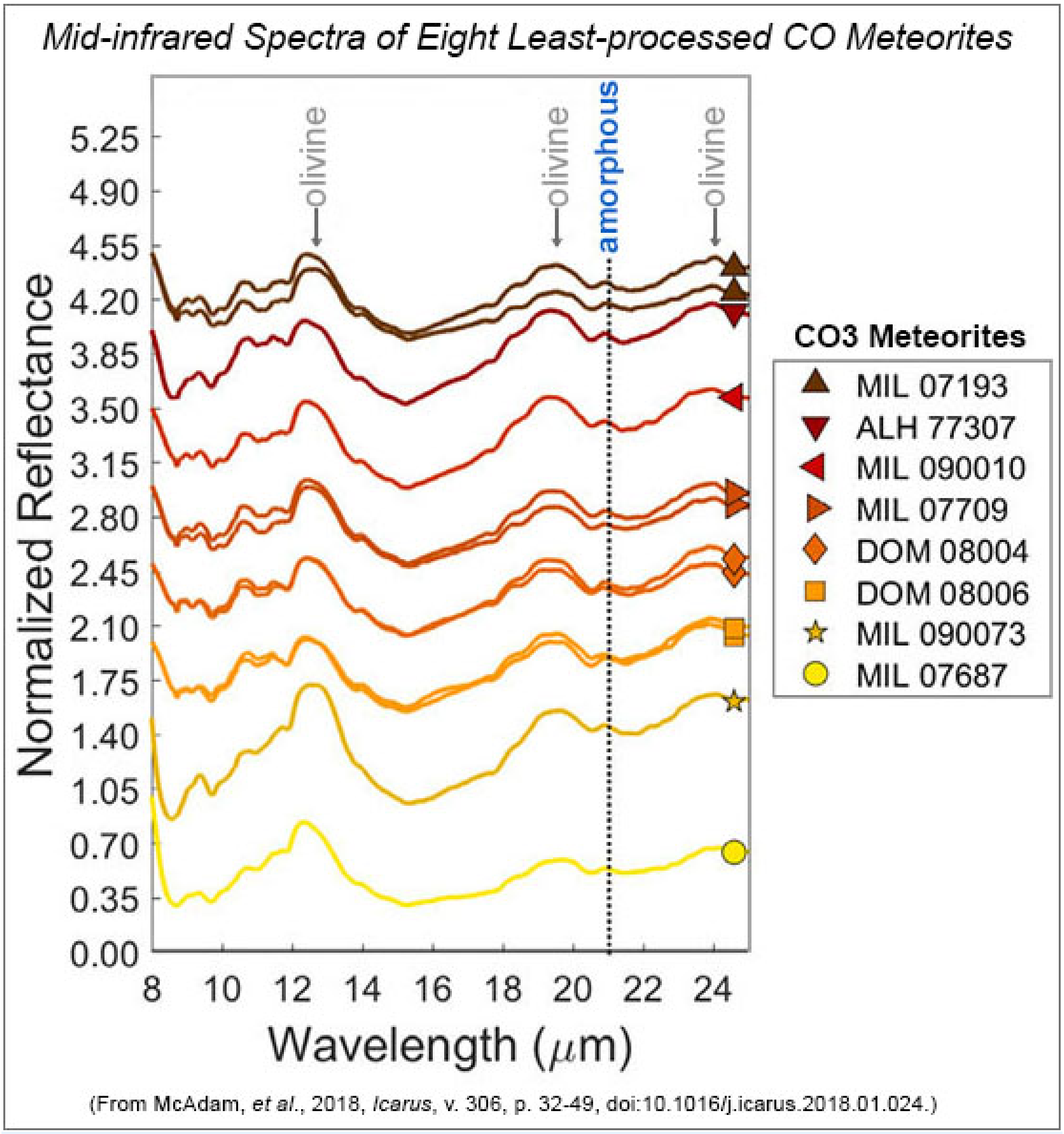
(Adapted from Sephton, M. A. (2002) *Nat. Prod. Rep.*, v. 19, p. 292-311. doi: 10.1039/b103775g)

Carbonaceous chondrites are classified by their bulk chemical composition, which places them into groups (CI, CM, etc.), and by the amount of aqueous alteration (petrographic types 1 and 2) and heating without much water (3 through 6). Colored boxes in the table signify which categories have been seen. Darker blue colors represent more aqueous alteration and redder colors represent increased thermal metamorphism. McAdams and coauthors studied a suite of CO3 meteorites.

McAdam and coauthors looked specifically at the ***amorphous*** iron-rich silicate material found in the matrix surrounding ***chondrules*** as well as in chronrule rims in the CO3 meteorites. Water and heat tend to destroy this amorphous material, so its very existence in a meteorite attests to minimal aqueous alteration and thermal metamorphism on the parent asteroid, or at least the region where the rock came from. The meteorites they studied contained amorphous material up to ~30 vol.%.

The team wanted to examine the amorphous iron-rich silicate material in the visible/near-infrared and mid-infrared spectral regions, which allows the cosmochemical data to be compared with astronomical data of asteroids collected with telescopes and spacecraft instruments. This is the first time that mid-infrared spectroscopy is reported for a group of least-processed CO type meteorites.

They found a 21-µm feature in the mid-infrared spectra in all of their meteorites, attributed to the Si-O vibrations of the amorphous iron-rich silicate material. The plot, below, shows the 21-µm feature as well as the characteristic features at 12.7-, 19.5-, and 24-µm caused by olivine and pyroxenes in the chondrules.



Mid-infrared spectra of eight carbonaceous chondrites (type CO3) presented by McAdam and coauthors. Spectra are normalized and offset for easier viewing. The meteorites are listed based on how much rust they have due to terrestrial weathering– from top (least) to bottom (more). The dashed line indicates the position of the 21-µm feature indicative of the Si-O vibrations in amorphous silicate materials. Additional details of each meteorite from the Meteoritical Database can be found in the reference links below.

The team also confirmed a weak, broad feature centered at 1.4-µm in the near-infrared that was previously identified and interpreted by Ed Cloutis (University of Winnipeg, Canada) and coauthors as caused by amorphous iron-bearing silicates.

By comparing this suite of CO3 meteorites to a variety of primitive meteorites from other chemical groups of carbonaceous chondrites, McAdam and colleagues concluded the 1.4- and 21-µm features are distinctive identifiers of least-processed meteorites from all chemical groups of carbonaceous chondrites.

In the grand quest for possible parent bodies of ancient, least-processed materials, the team related their meteorite data to the main-belt asteroid (93) Minerva. This carbonaceous asteroid has a 1.4-µm spectral feature, which the team interpreted as surface-exposed amorphous iron-bearing silicates. This interpretation leads to ideas of how the asteroid formed: Minerva either accreted cold or it was heated internally by decay of the short-lived ***radioactive*** isotope ^{26}Al, and developed an onion-shell thermal structure with stronger thermal metamorphism inside and least-processed materials preserved in its outer layer.

See Reference:

· McAdam, M. M., Sunshine, J. M., Howard, K. T., Alexander, C. M., McCoy, T. J., and Bus, S. J. (2018) Spectral Evidence for Amorphous Silicates in Least-processed CO Meteorites and Their Parent Bodies, *Icarus,* v. 306, p. 32-49, doi: 10.1016/j.icarus.2018.01.024. [***view abstract***]

Data links from the Meteoritical Database:

MIL 07193
ALH 77307
MIL 090010
MIL 07709
DOM 08004
DOM 08006
MIL 090073
MIL 07687

See also:

Cloutis, E. A., Hudon, P., Hiroi, T., Gaffey, M. J., Mann, P. (2012) Spectral Reflectance Properties of Carbonaceous Chondrites–5: CO Chondrites, *Icarus,* v. 220, p. 466-486, doi: 10.1016/j.icarus.2012.05.019. [***view abstract***]

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