

COMPOSITION DIVERSITY OF ORGANIC MATTER IN TYPE 1, 2 AND 3 CHONDRITES BY INFRARED SPECTROSCOPY. Y. Kebukawa¹, G. D. Cody¹ and C. M. O'D. Alexander², ¹Geophysical Laboratory and ²Department of Terrestrial Magnetism, Carnegie Institution of Washington, 5251 Broad Branch Road NW, Washington, DC 20015, USA. Email: ykebukawa@ciw.edu

Introduction: The molecular structure of insoluble organic matter (IOM) isolated from chondritic meteorites provides a record of chemical and thermal processes that occurred in the parent bodies and possibly before accretion. Peak metamorphic temperatures correlate well with the Raman D- and G-band widths of IOM [1-4], and the intensities of the 1s- σ^* exciton obtained from carbon X-ray absorption near edge structure (XANES) [5]. CHON elemental and isotopic ratios of IOM show some correlation with parent body processes [6]. Infrared (IR) spectroscopy is a well-established technique for the identification of organic functional groups [e. g. 7, 8]. However, a systematic IR study of meteoritic organic matter for a wide variety of chondrites has not been performed. Here we report an IR study of 22 carbonaceous and ordinary chondrites which provide a unique perspective into the molecular structure of IOM.

Samples and Methods: IOM was embedded in sulfur and microtomed into 1.5 μm -thick sections (1 μm for Murchison, 2 μm for EET 92042 and ALHA 77307), deposited onto BaF₂ windows, and the sulfur sublimated off. Infrared absorption spectra were collected using a Fourier transform IR microspectrometer (Micro FTIR) with 10 \times 10 μm^2 aperture. All spectra are normalized to the peak height of the aromatic C=C band at \sim 1600 cm^{-1} relative to the baseline.

Results and Discussion: Based on common IR spectral features, we find that the spectra naturally fall into 4 groups (Fig. 1). This designation is not constrained by mineralogic and compositional designations of chondrite class, groups and petrologic types.

IR group A. All type 1 and 2 chondrites, except Y-86720 (heated CM2), fall into IR group A, which is characterized by broad 3400 cm^{-1} band due to O-H (including alcohol, carboxyl and water), a weak 3060 cm^{-1} band due to aromatic C-H, an intense band at \sim 2900 cm^{-1} due to aliphatic C-H stretching (including 2955 cm^{-1} due to CH₃ and 2925 cm^{-1} due to CH₂), an intense 1710 cm^{-1} band due to C=O stretching, an intense 1590 cm^{-1} band due to aromatic C=C, and fine structure vibrational modes in the range of 1500 to 1000 cm^{-1} (including 1450 and 1370 cm^{-1} due to

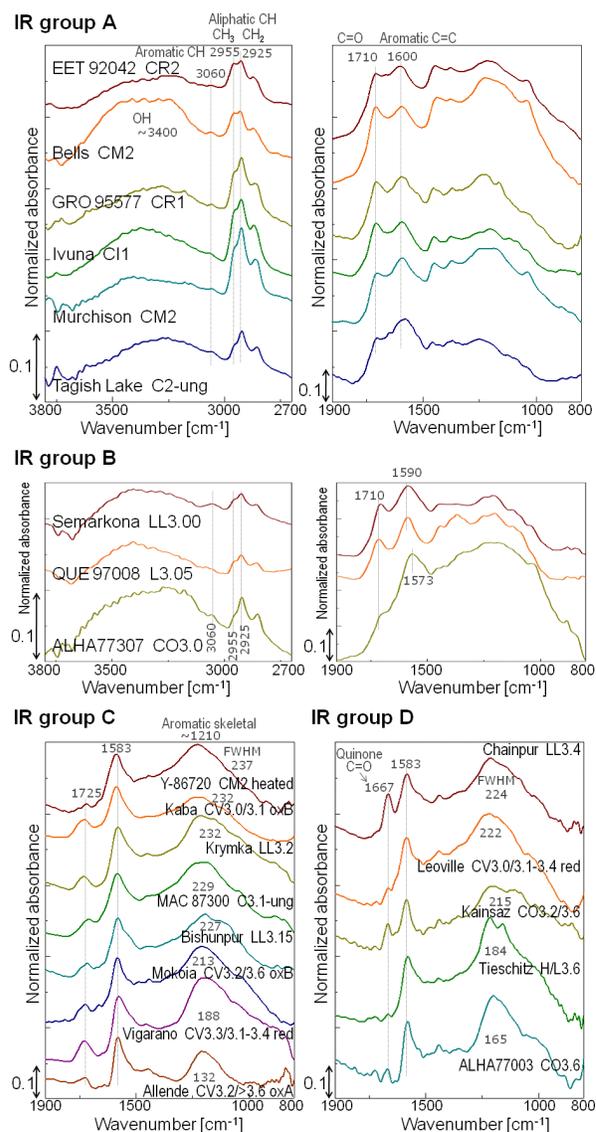


Fig. 1. Infrared absorption spectra of IOM normalized by the peak height of \sim 1600 cm^{-1} band.

aliphatic C-H bending).

The aliphatic C-H stretching vibration intensity increases with increases in the CH₂/CH₃ ratio, and appears to correlate with aqueous alteration. Tagish Lake (C2-ung) is unique in this group in that it has

weaker aliphatic C-H stretching intensity along with a high CH_2/CH_3 ratio. This is consistent with NMR spectroscopy, from which it was concluded that aliphatic, particularly methyl groups, were destroyed by chemical oxidation [9].

IR group B. IR group B is characterized by an intense O-H band, a relatively strong aromatic C-H band and a weak aliphatic C-H band. The CH_2/CH_3 ratio is higher and carbonyl band is lower than IR group A. Group B also exhibit an intense aromatic C=C band and a broad band spanning the 1500 to 1000 cm^{-1} region. The high oxygen content and the presence of appreciable aliphatic carbon indicates that IR group B has experienced minimal thermal metamorphism compared to the other type 3 chondrites studied (see below), consistent with their types of at or near 3.0.

IR group C. IR group C is characterized by a weaker carbonyl band, and a sharp intense aromatic C=C band that at lower frequency ($\sim 1583 \text{ cm}^{-1}$) than groups A or B, weak absorption in the 1400-1300 cm^{-1} region, and a relatively narrow band at $\sim 1210 \text{ cm}^{-1}$ most likely associated with multiple aromatic skeletal modes. Group C exhibits no or very weak O-H and aliphatic C-H stretching bands (data not shown).

The spectral region peaking at 1210 cm^{-1} clearly narrows across the IR group C (and D see below), and its band width (FWHM) correlates with a reduction in the Raman D-band ($\sim 1350 \text{ cm}^{-1}$) width (data not shown) [4]. Narrowing of this band indicates increasing organization of the aromatic structure (perhaps due to aromatic polycondensation) in response to increased thermal metamorphism.

It is significant that the C=O stretching band position is at a higher frequency ($\sim 1725 \text{ cm}^{-1}$) than IR group A and B ($\sim 1710 \text{ cm}^{-1}$), consistent with the formation of lactone-like structures that formed during thermal metamorphism in IR group C chondrite parent bodies. Y-86720 (heated CM2) was presumably like other constituents of the IR group A, but heating has converted Y-86720 IOM into material that is very similar in structure to group C IOM.

IR group D. IR group D is distinct from group C principally by exhibiting no intensity in the 1720-1710 cm^{-1} region, but exhibiting variable intensity at 1667 cm^{-1} that is likely due to quinonic C=O. Like group C, group D IOM also exhibit a sharp, intense aromatic C=C band at $\sim 1583 \text{ cm}^{-1}$ and a relatively narrow vibrational region peaking at $\sim 1210 \text{ cm}^{-1}$. The lack of carboxyl C=O (group C) and the presence of abundant quinone C=O clearly distinguishes the C & D groups.

The loss of carboxyl (abundant in A, B, and C) could be a result of either oxidative or reductive chemistry. However, the formation of quinone is a strong indicator of oxidation by O_2 . In this regard, Chainpur (LL3.4) and Kainsaz (CO3.2/3.6) exhibit the most intense quinonic C=O band suggesting a high $f\text{O}_2$.

Summary: FTIR analysis of chondritic IOM spanning class, group, and type provides a unique perspective on these complex organic solids. Whereas these FTIR data largely complement what has been discovered using Raman, NMR, and C-XANES data, the spectral separation of metamorphosed type 3 chondrites into clearly resolved C and D groups is something quite unexpected. These new data strongly suggest that considerable complexity exists during parent body processing. Possible pathways of IOM history suggested by IR spectra are shown in Fig. 2. Whereas these pathways are consistent with petrologic type, there is no obvious correlation with chondrite group nor apparent mineralogical oxidation state; e.g. both IR group C and D include oxidized LL chondrites, and the red/oxid CV's appear reversed in the molecular structure of their IOM. These IR spectra do support the idea, however, that there was a common precursor of IOM which was subsequently altered by various parent body processes.

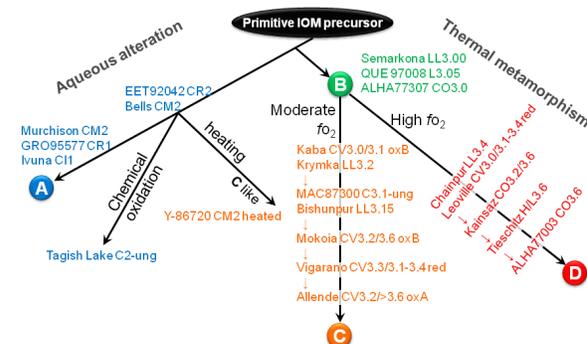


Fig. 2. Summary of chemical pathways indicated by IR spectra.

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