CHONDRITIC ORGANIC MATTER AS AN INDICATOR OF NEBULAR AND PARENT BODY PROCESSING: EXTENDED PYROLYSIS STUDIES FOR CM, CI, CR, CO, CV, ORDINARY, AND TAGISH LAKE GROUP METEORITES. H. Yabuta[1], G.D. Cody[1] and C.M.O'D. Alexander[2], [1]Geophysical Laboratory and [2]Department of Terrestrial Magnetism, Carnegie Institution of Washington, 5251 Broad Branch Rd. N.W. Washington DC, 20015 USA. (hyabuta@gl.ciw.edu)

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Introduction: Pyrolysis Gas Chromatography-Mass Spectrometry (Pyr-GC-MS) is a common method for analyzing insoluble organic matter (IOM) from carbonaceous chondrites [e.g., 1-4] especially for IOM derived from the primitive carbonaceous chondrite CI, CM2, and CR2. In this study, the established technique has been extended to 23 kinds of IOM from CI, CM2, CR2, CO, CV, ordinary chondrites and Tagish Lake. The aim is 1) a comprehensive identification of compositional characteristics of pyrolysates from IOMs within and across meteorite groups and 2) illucidation of modification mechanisms of IOM during alteration/metamorphism on the meteorite parent bodies.

Experimental: The chondritic meteorites analyzed were CM2 (Murchison, ALH83100, Cold Bokkefeld, Kivasvaara, Bells, Murray, Mighei), CR2 (MET01070, GRO95577, EET92042, Al Rais), CI (Ivuna), Tagish lake, CV (Kaba, Mokoia, Vigarano, Leoville, Allende, MET00430), CO (Kainsaz, ALH77003), and ordinary (OC) (Tieshitz, Krymka). The IOM was purified by CsF/HF demineralization of each meteorite powder. ~ 0.5 mg of IOM were loaded into quartz capillary tubes. Flash heating (610° C for 10 s) was performed under helium atmosphere using CDS 1000 Pyr-GC-MS (Agilent 6890).

Results and discussions: Over 170 compounds were identified from IOM in CM2, CR2, and CI chondrites, while one third or less of these compounds were identified from IOM in Tagish Lake, CV, CO, and OC chondrite. The common molecules included a series of PAHs and hetero-atom (O, N, S) containing aromatic compounds such as phenols, ketones, benzaldehydes, benzoic acid, dibenzofuran, pyrroles, pyridines, benzonitrile, and thiophenes. Of the distributions of compound groups in the pyrolysis products, the abundances of PAHs were similar (70 – 80%) for all IOM while the ratios of O- (8.5 – 25.3%), N- (0 – 11.7%), and S- (0.8 – 17.6%) containing compounds varied.

Pentagonal ring containing PAHs

Figure 1 shows the relative compositions of PAHs in 4 different types, alkylbenzenes (e.g., toluene and xylene), condensed ring (e,g., naphthalene, phenanthrene, and pyrene), biphenyls, and pentagonal ring (e.g., indene, acenaphthene, acenaphthylene, fluorene, and fluoranthene). Note that pentagonal ring containing PAHs are present in CR2, CM2, and CI, but are

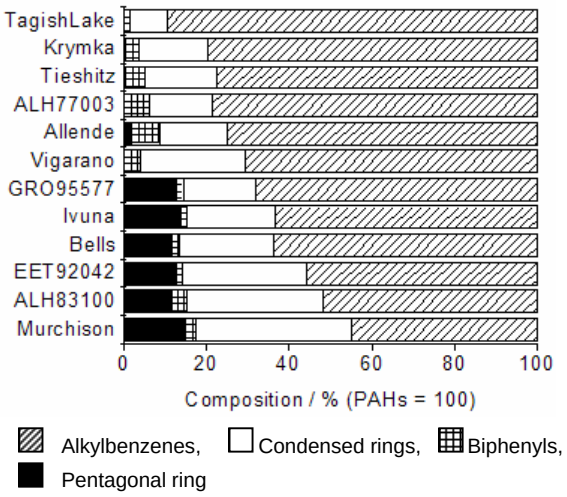

Fig. 1. Relative compositions of different types of PAHs identified from the representative 12 IOM by pyrolysis-GC-MS.

almost absent in CV, CO, OC, and Tagish Lake. This difference likely indicates modification of the IOM structure during thermal alteration on the parent bodies. Since pentagonal ring containing PAHs are as stable as hexagonal ones, pentagonal ring rupture is unlikely. Some pentagonal ring containing PAHs might have formed by cyclization of alkylated PAHs bound with hetero atoms in IOM. Although, the quite different carbon isotopic compositions of pyrene (condensed) and fluoranthene (pentagonal) extracted from Asuka 881458 (CM2) suggests that this was rare [5] and that the former type cannot interact with the latter type in the reaction pathway. On the other hand, condensensation could proceed relatively easily. For instance, it has been known that sulfur-mediated cyclotrimerization of acenaphthene into decacyclene ($C_{36}H_{18}$, an insoluble PAH) can occur in the range of 100 – 200 ºC in the natural environment [6]. Our results implies that the pentagonal ring containing PAHs might be the units that were primarily incorporated into the molecular condensation during thermal alteration.

O-containing compounds

Figure 2 shows a distribution of the total composition of O-containing compounds (phenols, ketones, benzaldehydes, benzoic acid, and dibenzofuran) for carbonaceous chondrite IOM. The abundances of O-containing compounds were roughly similar among the CM2s, but increased in order, Cold Bokkefeld (CM2)

< Ivuna (CI) < Bells (CM2) < Tagish Lake. This distribution roughly corresponds to the degree of aqueous alteration degree among carbonaceous chondrites. Cold Bokkefeld [7], Ivuna [8], the unusual CM2 Bells [9], and Tagish Lake [10] have all experienced extensive degrees of aqueous alteration. The abundances of individual O-containing compounds, such as phenol, benzoic acid, acetophenone, also appear to reflect differences in degrees of aqueous alteration among chondrites, e.g., the order of abundances of acetophenone were shown in order, Murchison (0.6%) < Cold Bokkefeld (1.5%) < Tagish Lake (4.0%). The abundances of O-containing compounds were also relatively high for some CV and ordinary chondrite, such as Kaba, Mokoia, and Krymka, which probably reflect the extensive aqueous alteration they experienced.

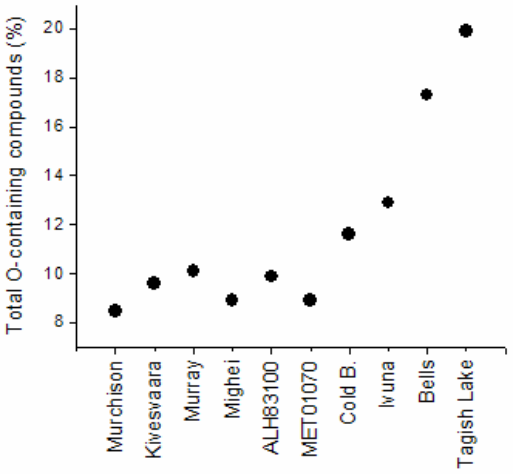

Fig. 2 Abundances of O-containing compounds identified by pyrolysis-GC-MS for 10 carbonaceous chondrite IOM.

N-containing compounds - Benzonitrile

The relative abundances of N-containing compounds in different groups (e.g., pyridines, methylpyrroles, and benzonitrile) varied regardless of chondrite groups. Pyridines were relatively abundant in two CR2 and Murchison. Benzonitrile was detected from IOM in every meteorite group. Most IOM from CV, CO, OC, and Tagish Lake, and a few IOM from CM and CI contained only benzonitrile. The resistance of benzonitrile to thermal alteration might be explained by reaction of organic acids or benzaldehyde with ammonia to nitrile [11]. In this study, the ratios of benzoic acid to benzonitrile for CM, CR, and CI were > 1 while those for CV, CO, OC, and Tagish Lake were < 1 or 0. Likewise, the ratios of benzaldehyde to benzonitrile for CM, CR, and CI were > 2 while those for CV, CO, OC and Tagish Lake were < 2. This evaluation shows that benzonitrile could be a reaction product of benzoic acid or benzaldehyde in the IOM structure with ammonia, ammonium salts or pyridine on the parent bodies during the progress of the thermal alteration.

S-containing compounds - Thiophenes

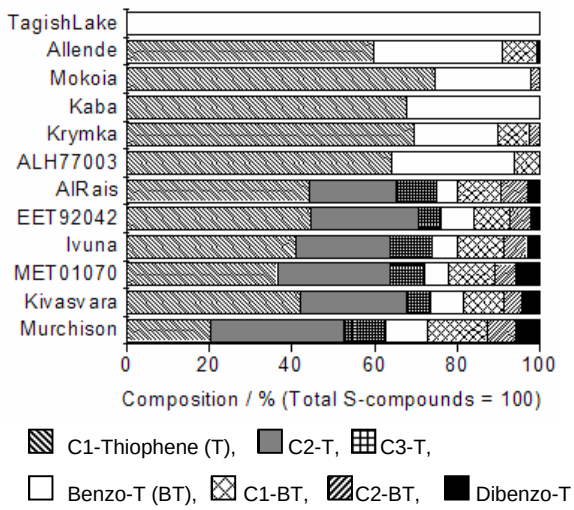

Fig. 3. Relative abundances of S-containing compounds identified from the representative 12 IOM by pyrolysis-GC-MS.

The relative abundances of S-containing compounds (alkylated thiophenes (C_1 – C_3) and alkylated benzothiophenes (C_1 and C_2)) were determined for IOM from CR, CI, and CM chondrites (Fig. 3). The abundance of these compounds reflect enrichment of alkyl C of IOM from these chondrite groups. In contrast, only C_1-thiophene and benzothiophene dominate the pyrolysates from CV, CO, OC and Tagish Lake, probably reflecting the loss of alkyl C during progress of parent body alteration. The disappearance of dibenzothiophene from these chondrites may be due to thermal cracking of the compound to benzothiophene, biphenyl, benzene, and dimerization [12].

Conclusion: The molecular distributionin the pyrolysate of IOM, in many cases, provides a robust signature of meteorite group and may provide unique information on chemical history of the respective meteorite parent bodies.

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