

THE PECULIAR RELATIONSHIP BETWEEN METEORITIC ORGANIC MOLECULAR STRUCTURE AND DEUTERIUM ABUNDANCE G. D. Cody¹, M. L. Fogel¹, H. Yabuta¹, and C. M. O'D. Alexander²,
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Introduction: The vast majority of carbon contained within chondritic meteorites exists as an insoluble, macromolecular phase commonly referred to as Insoluble Organic Matter (IOM). It has long been recognized that IOM in type 1 and 2 chondrites is relatively enriched in deuterium, suggestive of an origin that has its roots in the cold interstellar medium. Recently it has been proposed that the relatively high deuterium content of meteoritic IOM (but still much lower than that due to ion molecule reactions in the cold ISM) may have resulted from reaction between IOM precursors and H_3^+ at higher temperatures in protosolar nebula, PSN [1].

Lake was due to low temperature oxidation that targeted aliphatic moieties exclusively. Subsequently, Alexander et al. [3] obtained stable isotopic abundances for these and a wide range of other chondrites spanning multiple classes, groups, and petrologic types.

In fig. 1 the NMR spectra of EET92042 (CR2), Orgueil (CI1), Murchison (CM2), and Tagish Lake are presented. Included in fig. 1 are the measured δD obtained by Alexander et al. [3]. It would appear that the progressive loss in aliphatic carbon (e.g. methyls, methylenes, methines, and various oxygenated saturates) corresponds with a huge reduction in the deuterium content. Superficially, this is consistent with the proposed exchange mechanism of Resumat et al. [1] based on bond energetics, i.e. deuterium enriched aliphatics (e.g. benzylic carbon) and relatively depleted aromatic hydrogen.

The fractional aromatic content of EET92042 is 0.49, Tagish Lake is 0.72 [2]; if a simple calculation is performed to determine what the δD of the aromatic carbon would have to be if the change in bulk δD is due to a loss of exclusively aliphatic carbon, a preposterously negative value is obtained. The trend observed in figure 1 is largely coincidental, i.e. there exists significant differences in the total δD in each of these samples that cannot be accounted for by simply losing deuterium rich aliphatic carbon.

Investigation into the CM group of meteorites reveals that IOM from the same group exhibit nearly identical molecular structures, e.g., fraction of aromatic carbon, COOH content, aliphatic structure...etc (Fig. 2). These meteorites have experienced a wide range in the extent of aqueous alteration, from essentially unaltered (Kivesvaara) to completely altered (MET01070) [4]. Evidently, such low temperature alteration has minimal effect on the macromolecular structure of IOM. The elemental and isotopic abundance of these have been measured [3], revealing that most of these CM's share similar δD and $\delta^{15}N$. The remarkable standout is Bells that is extremely enriched in both deuterium and ^{15}N . Aside from this enrichment, however, there is nothing exotic in Bells's molecular structure (Fig. 2) or elemental chemistry [3] that would differentiate it from the other type 1 and 2 CM's. This structural similarity necessarily implies that the formation mechanism for CM IOM as well as any subsequent chemical evolution that may have occurred to

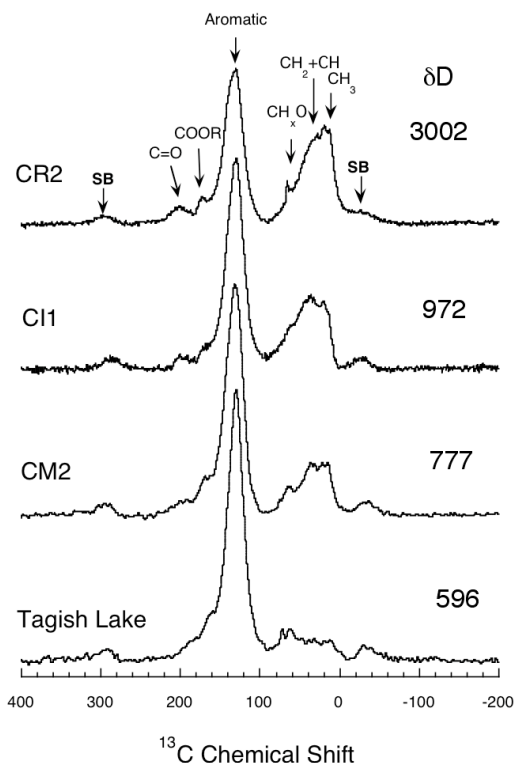


Figure 1. Solid state ^{13}C NMR spectra of EET92042 (CR2), Orgueil (CI1), Murchison (CM2), and Tagish Lake (C2). The bulk δD [3] of the IOM are listed on the right.

It is established that there exists a tremendous variation in organic structure moving across the CR, CI, CM, and Tagish Lake (ungrouped C2) chondritic IOM [2]. It was proposed that the enormous reduction in aliphatic carbon moving from the CR to Tagish

the CM IOM in the parent body must be essentially identical. The isotopic differences between Bells and the other CM's cannot be ascribed to any severe chemical reaction, beyond isotopic exchange.

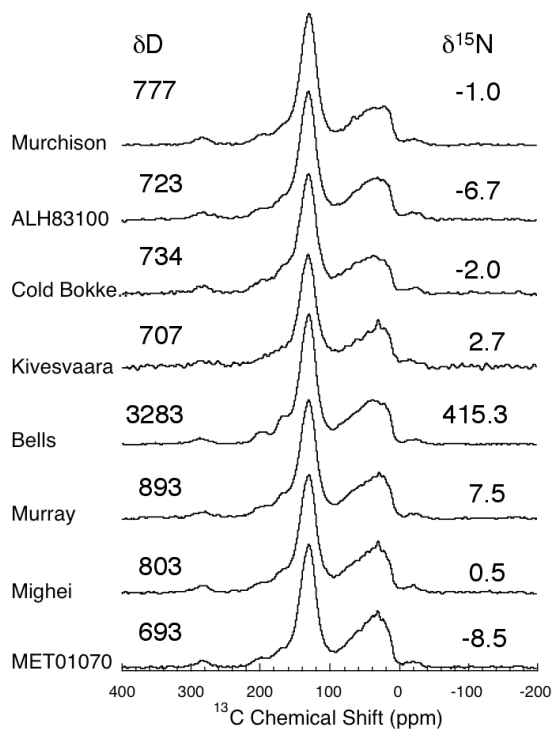


Figure 2: Solid state ^{13}C NMR spectra of IOM isolated from a variety of CM chondrites spanning type 2 and 1. The isotopic abundances [3] of deuterium and nitrogen (per mil) are included on the left and right sides, respectively.

Given the high abundance of oxygen containing functional groups, e.g. enols, ketones and carboxylic acids [2], it is expected that primitive IOM in type 1 and 2 chondrites has a very high capacity for proton exchange under either basic or acidic conditions during aqueous alteration. The enormous enrichment exhibited by Bells, therefore, could reflect deuterium enrichment during parent body alteration implying that the it was the fluid in the Bells parent body that was isotopically anomalous [6]. Alternatively, it is not inconceivable that Bells IOM was initially altered in an isotopically anomalous region of the PSN [1].

The situation becomes a bit more complex in the case of type 3 chondrites. Type 3 IOM exhibits a wide range in structure as a reponse to thermal alteration during parent body alteration [6], exhibiting significant loss in hydrogen, nitrogen, and oxygen [3] coupled the growth of large conjugated π systems. If variation in deuterium enrichment occurred exclusively during the

formation stage of IOM, then subsequent thermal alteration would be expected to exhibit similar isotopic trends. Allende IOM(CV3.6) is more extensively altered than Vigarano (CV3.4) (with T_{max} of 550 °C and 415 °C, respectively [6]). The apparent isotopic trend resulting from this metamorphism is towards lower δD . The IOM in WSG95300 (H3.4) is much more altered than the IOM in MET00452 (LL3.0) (with T_{max} of 460 °C and 200 °C, respectively[6]), but here the isotopic trend is reversed. These wild shifts in δD across group and accompanying metamorphism are most consistent with extensive isotopic exchange occurring during parent body alteration. These results clearly complicate any interpretation of isotopic enrichment as being a signature of primitive processes.

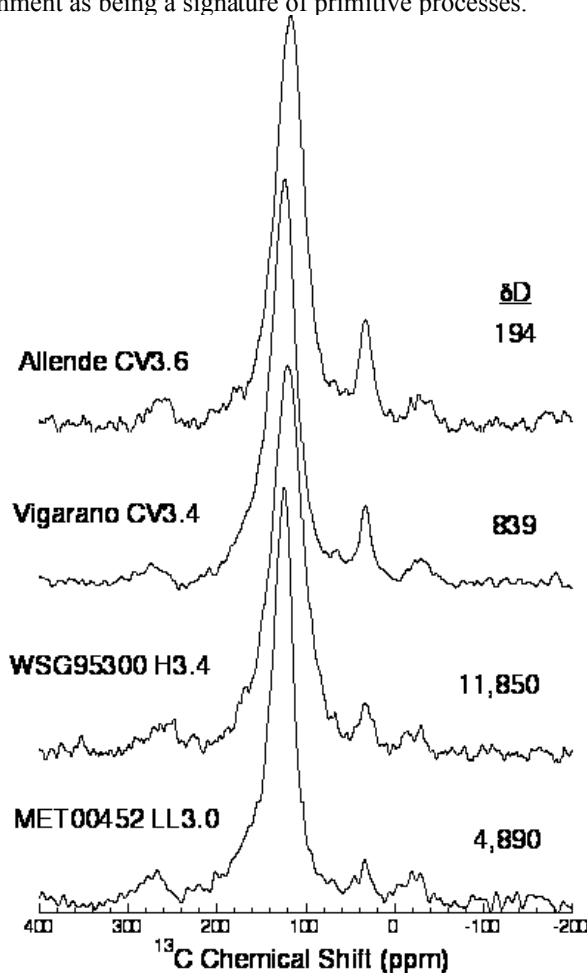


Figure 3: Solid state ^{13}C NMR spectra of type 3 IOM from the CV and ordinary chondrites. δD values are on the right (in per mil).

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 [3] Alexander C. M. O'D et al. GCA 71, 4380-4403.
 [4] Zolensky et al (1997)GCA,61, 5099-5115. [5] Eiler J. M. & Kitchen N. (2004) GCA 68, 1395-1412 [6] Cody et al. submitted.