

CARBON AND NITROGEN ISOTOPIC VARIATIONS IN THE ORGANIC MATTER OF
CM2 CARBONACEOUS CHONDRITES.

I. Gilmour, I.P. Wright and C.T. Pillinger. Planetary Sciences Unit,
Department of Earth Sciences, The Open University, Milton Keynes, MK7 6AA,
U.K.

The majority (70-90%) of the organic material present in CM2 carbonaceous chondrites exists as an acid- and solvent-insoluble macromolecule analogous to the kerogen found in some terrestrial sedimentary rocks. Degradative investigations designed to elucidate the structure of the macromolecule in meteorites have revealed it to be essentially aromatic in nature with a variety of cross-linking groups and side chains. However, little is known about the origin of the substance, which could be the result of nebular processing or a remnant of material left over from the interstellar medium. D/H isotope ratio measurements (eg. 1,2) reveal large deuterium enrichments in at least part of the organic material; it is widely believed that these could result from ion-molecule reactions on precursor interstellar molecules and as such suggest a pre-solar origin.

High resolution (ie. small temperature increment) stepped combustion experiments coupled with stable isotope measurements on terrestrial kerogens (3) provide information about the degree of cross-linking within the structure and in some cases can even suggest the primary origin of the organic matter contributing to the kerogen. Nitrogen release and isotope data follow the same trends as the carbon, thus conclusions can be drawn concerning the structural location of nitrogen.

The present investigation has examined carbon and nitrogen isotopic variations in some CM2 carbonaceous chondrites using high resolution stepped combustion over the low temperature regime (<600°C) in an effort to learn more about the nature of the meteorite macromolecule.

CARBON

Bulk carbon isotopic measurements on the insoluble organic matter in CM2 meteorites are remarkably constant, between -15 and -17‰ (4). In order to assess whether such values are a reflection of the homogeneity of the macromolecular material, samples of Murchison, Murray and Mighei were subjected to high resolution stepped combustion. All three meteorites gave essentially the same results and demonstrate considerable isotopic variation within the insoluble material. The stepped extraction shows evidence for three distinct releases; (i) carbon of $\delta^{13}\text{C}$ ca. -4‰ is liberated below 275°C, (ii) the maximum yield is obtained at between 375 and 400°C with a $\delta^{13}\text{C}$ of ca. -11‰ (Figure 1), (iii) at higher temperatures carbon released from all three meteorites becomes progressively lighter until the measured $\delta^{13}\text{C}$ is ca. -20‰.

Extensive studies of terrestrial kerogen have demonstrated that the temperature of combustion of organic material is dependant on the H/C ratio with the most hydrogenated (aliphatic nature) components being easiest to burn (5). The combustion temperature of the majority of the carbon in CM2 chondrites corresponds to an H/C ratio of ca. 1 on a correlation plot derived for terrestrial materials (5) suggesting that either the meteorite polymer contains some aliphatic side chains or that the aromatic rings are linked by single bridges rather than being highly condensed.

NITROGEN

High resolution stepped combustion experiments for nitrogen were performed on the Murray and Murchison carbonaceous chondrites. Previous bulk nitrogen isotopic measurements (summarised in 6) have revealed little variation in $\delta^{15}\text{N}$ in the insoluble organic material with $\delta^{15}\text{N}$ values averaging around +40‰. However, studies of the solvent extractable material have revealed $\delta^{15}\text{N}$ values as high as +90‰ (7). As with the carbon analyses both

Murray and Murchison show similar release profiles and isotopic variations. Both meteorites reveal a component that is released below 350°C that is significantly enriched in ^{15}N , with $\delta^{15}\text{N}$ values up to ca. +80%. (Figure 2). With increasing temperature, up to 500°C, the $\delta^{15}\text{N}$ values decrease reaching a minimum of around +20% in Murray. The nitrogen in organic materials is bound to carbon and thus during stepped combustion is likely to be released when associated carbon molecules are combusted. Consequently the relatively low temperature at which the ^{15}N -enriched nitrogen is released suggests that it is associated with primarily aliphatic, high H/C ratio, structures. The Murchison sample used was extensively solvent extracted prior to analysis suggesting that ^{15}N -enriched organic material is associated with the macromolecule as well as with the solvent-soluble material (7). The decrease in $\delta^{15}\text{N}$ with increasing temperature is probably due to the combustion of isotopically light nitrogen which is thought to be associated with the CCF xenon component (8).

High resolution stepped combustion experiments have revealed the macromolecular material present in carbonaceous chondrites to be extremely heterogeneous in both carbon and nitrogen isotopic composition. Further studies may help to elucidate the reasons for such heterogeneities and, in particular, determine whether they are indicative of material of more than one origin being present.

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