MOLECULAR AND ISOTOPIC EVOLUTION OF INSOLUBLE ORGANIC MATTER OF THE ORGUEIL METEORITE UPON HEATING.

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Introduction: Understanding the origin of organic compounds in carbonaceous chondrites is crucial to assess how organic matter synthesis happened in the solar system, in protoplanetary disk and on the asteroids. It may also improve our knowledge of the emergence of life on Earth or in other places of the solar system. Insoluble organic matter (IOM) is the largest organic component recovered in carbonaceous chondrites, representing more than 75 wt. % of the total organic matter recovered from these meteorites. Despites a significant aqueous alteration on its parent body, the Orgueil meteorite contains an IOM that shows a significant enrichment in heavy isotopes of H and N. In particular, the D/H ratio it about 6 times higher than the protosolar value and shows variations at the micron and the molecular scales that point to a complex of origin [1,2]. This IOM is likely the assemblage of several components that have experienced different conditions in the protoplanetary disk, or even before in the parent molecular cloud, before being subjected to secondary aqueous alteration on the parent body [3]. In the meantime, its molecular properties relate to a rather condensed macromolecule made of small aromatic units with a high degree of cross linking, containing about 3 wt% of N [4]. The thermal behavior of the Orgueil IOM was investigated to improve the understanding of its isotope reservoirs and its molecular constituents.

Methods: We have subjected the Orgueil IOM to heating at 300°C and 500°C, for one hour, under an Ar flow [5]. The evolutions of structural and molecular properties were assessed by Raman, infrared and XANES spectroscopies, the H- and N-isotopic compositions by NanoSIMS.

Results: Upon heating, the IOM structure undergoes significant modifications that results in a depletion in aliphatic carbons and the development of larger aromatic units, with concomitant loss of carboxylic and alcohol groups. This is consistent with the sharp decrease in H/C elemental ratio, starting at 300°C, whereas N/C ratio remains constant within error bars, even after heating at 500°C. This indicates that N is likely involved in aromatic groups less prone to thermal decomposition. The structure of the residual IOM is not subjected to severe carbonization process as indicated by the persistence of quite broad G and D-bands of comparable intensities, even at 500°C, although the structural ordering increases as the result of aromatic unit growth.

NanoSIMS imaging shows contrasted evolution of H and N isotope distributions. The abundant D-rich hotspots contained in the Orgueil IOM are destroyed after heating at 500°C. Meanwhile, ^{15}N-rich hotspots, also commonly observed in this IOM, are much less affected by heating, at both 300 and 500°C. Hence, D and ^{15}N-rich organic reservoirs have different behavior toward increasing temperature. In the Orgueil IOM, D-rich moieties are related to aliphatic carbon and thermally labile whereas ^{15}N-rich moieties are recalcitrant. The H and N isotope compositions are decoupled, showing that the Orgueil IOM contains organic components formed in various environments of the protoplanetary disk or the parent molecular cloud.

Discussion: The evolution of Orgueil IOM upon heating echoes with observations on IDPs [6]. The organic matter in these objects tends to loose quickly its D-rich component as a consequence of heating during the atmospheric entry, whereas the ^{15}N enrichments are poorly affected. That would indicate that the D-rich and ^{15}N-rich organic components are similar in IDPs and carbonaceous chondrites. The evolution we observe is also similar to the evolution observed when comparing the IOM of several fragments of the Tagish Lake meteorite showing increasing degrees of parent body processing [7]. H/C and D/H decrease with increasing hydrothermal alteration, whereas both N/C and $^{15}N/^{14}N$ remain constant. That could indicate that temperature increase during the hydrothermal alteration on the Tagish Lake parent body has controlled the evolution of its IOM.

Our experiment, may bring constrains on the heating experienced by organic matter in the gas phase prior accretion on parent bodies. Orgueil IOM derives from micron sized organic grains formed in cold environments that could have been thermally reprocessed on their route to the location of the parent body accretion closer to the sun; we can estimate that they were not exposed to higher temperature than 300°C for more than 1 hour, in order to preserve D-enrichments; ^{15}N-rich precursors may have experienced up to 500°C.

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