Formation of insoluble organic matter in type-1 and -2 chondrites: Radiolytic or thermal processes?

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Insoluble organic matter (IOM) extracted from primitive chondrites comes in the form of a polyaromatic solid with a structure and composition resembling that of terrestrial kerogens. It bears large D/H and $^{15}N/^{14}N$ isotopic ratios that point to a formation in a cold environment and ion-molecule reactions. However, the nature of the chemical and physical processes that led to its formation is still actively discussed: formation in the parent body by slight thermal metamorphism [1], inheritance from interstellar medium [2], or formation in the upper layer of the protosolar disk [3]. Post-accretional evolution of organic matter has also emerged as a critical issue, as it may disturb or even obscure pre-accretional information. In type 1 and 2 chondrites, evidence of short duration thermal heating of OM has been found using a variety of techniques [4].

In order to unravel pre-accretional from post-accretional processes, we have performed a survey of the composition and structure of IOM on a series of 27 CR, CM, CI, and ungrouped C2 carbonaceous chondrites (Tagish Lake, Bells, Essebi, Acfer 094) using infrared and multi-wavelength Raman micro-spectroscopy (244-, 514-, and 785-nm laser excitations [5]). Our results show that chondritic IOM from PCA 91008 (CM2), WIS 91600 (CM2), QUE 93005 (CM2), Tagish Lake (C2 ungrouped), and possibly Cold Bokkeveld (CM2) has been subjected to the past action of short-duration thermal metamorphism, presumably triggered by impacts. The IOM in most of the CM chondrites that experienced moderate to heavy aqueous alteration may have been slightly modified by collision-induced heating.

Even IOM from chondrites that escaped significant thermal metamorphism (e.g., the most primitive CR chondrites) displays Raman characteristics consistent with a formation by thermal processing. This process may have happened either in the protosolar disk or in the parent body. However, an alternative energetic process to thermal heating is ion irradiation. After thoroughly analyzing both of these scenarios, no conclusion can be drawn as to which is the most plausible mechanism nor whether the heating process took place prior or after accretion. Whatever the energetic process, our results suggest a two-step formation of chondritic IOM as (1) synthesis of simple precursors in a cold environment, which would account for the large D/H and $^{15}N/^{14}N$ isotopic ratios and (2) carbonization of these precursors that finally led to the polyaromatic structure.

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