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Aqueous alteration of primitive organic matter in the solar system: chemical and isotopic signatures of meteoritic IOM

Hiroshi Naraoka[1]; Yasuhiro Oba[2]

[1] Dept. of Earth & Planet. Sci. Kyushu Univ.; [2] Dept.Geol.Eng., Univ. Nevada-Reno

It has been believed that the primitive body in the solar system contains highly volatile materials including organic matters. The primitive materials were essentially subjected to aqueous and/or thermal alteration more or less on the parent bodies. However, it is poorly known what happened to the organic matter during the alteration, which is important to understand chemical evolution in the extraterrestrial environment.

Most organic carbon in carbonaceous meteorites generally exists as a solvent-insoluble macromolecular organic matter. This high-molecular organic material contains small amounts of hydrogen, nitrogen, oxygen and sulfur, now commonly called as insoluble organic matter (IOM). A variety of investigations have revealed that more than 60% of IOM carbon in Murchison is derived from aromatic structure up to ~10 rings with carboxyl and carbonyl groups as well as ether and alkyl linkages between them. The IOM has been considered as a source of solvent-extractable organic compounds through aqueous alteration on meteorite parent bodies. Experimentally, polycyclic aromatic hydrocarbons (PAHs) and carboxylic acids are generated by hydrous pyrolysis of IOM, suggesting that some solvent-extractable organic compounds could be formed during hydrous activity on the meteorite parent bodies. The generated compounds are closely related to the chemical structure of IOM containing relatively abundant aromatic and carboxyl carbon. During hydrous activities and/or thermal metamorphism, both N/C and H/C ratios of IOM could decrease toward to zero. Thus, the chemical composition of IOM is a sensitive indicator to evaluate thermal history on the meteorite parent bodies. Many isotope studies on IOM have been performed to investigate meteoritic organic synthesis as well as its origin, in which the isotopic composition in carbonaceous chondrites is highly heterogeneous chemically and spatially. In particular, the extreme D and 15N enrichment of IOM in CR and CM chondrites has been often inferred as an interstellar origin. Besides the original isotope source in interstellar and/or protosolor environment, planetary processes such as hydrous and thermal activities are expected to have influenced on isotope distributions of IOM. However, few concrete examples have not been demonstrated to show chemical and isotopic relationships of various IOM between different meteorites caused by alternation processes.

In this study, we clarify chemical variations as well as bulk carbon and hydrogen isotopic compositions of IOM using seven CM2 chondrites and the hydrous pyrolysis residue of the Murchison IOM with respect to their origins and alteration processes.