The origin of meteoritic organics deciphered by the oxygen and carbon isotopes.

Ko Hashizume¹, Naoto Takahata², Hiroshi Naraoka³, Yuji Sano²

¹Earth & Space Sci., Osaka Univ., ²AORI, Univ. of Tokyo, ³Earth & Planet. Sci., Kyushu Univ.

Organic matter abundantly found in primitive meteorites may represent one of the important sources of volatiles on Earth present as ocean, atmosphere and lives. Part of the meteoritic organic matter possibly preserves primordial compositional records acquired upon its birth in the outer region of the proto-solar nebula and/or in the ancestral molecular cloud, though the exact origins remain open issues.

The isotope imaging of acid-insoluble organic matters (IOM) extracted from carbonaceous chondrites was carried out in this study [1]. We performed the imaging using the Cameca NanoSIMS50 ion-microprobe equipped at the Atmosphere and Ocean Research Institute, University of Tokyo. The same area was rastered four times to respectively obtain (1) the D/H ratio; (2) the 13C/12C and 15N/14N ratios, (3) the OH/O ratio; and (4) the 17O/16O and 18O/16O ratios.

Anomalous d17,18O(rel.SMOW) values as high as +534 +/- 109 permil were observed among the organic phases extracted from an Antarctic CR2 chondrite Yamato-793495. The d17O and d18O showed paralleled values, plotted in the three isotope diagram slightly above the slope-1 line, with an inclination of 1.057 +/-0.015. The 17,18O-rich domains showed positive d13C(rel.PDB) values, up to +288 +/-45 permil.

The positive correlation between the d17,18O and d13C is explained in principle by the self-shielding effect of CO. The reduced photodissociation rate of the major isotopologue, 12C16O, may result in the coherent enrichment in the organic matter of the three minor isotopes, 17,18O and 13C. However, a warm environment, as high as 60 Kelvin, is necessary to expect the 13C-enrichment by the self-shielding effect to overcome the opposite fractionation effect by the competing reaction, namely the ion molecule reaction (12CO + 13C+ = 12C+ + 13CO + 35K). Therefore, we propose that the organic matter exhibiting the non-mass-dependent O-isotope signature was formed in a rather warm gas medium, at temperatures of about 60 Kelvin or higher, such as the envelope of the solar-nebula illuminated by the proto-Sun.

The non-mass-dependent O-isotope anomaly, broadly observed among the solid planetary materials, was originally considered to represent the origins or formation processes of a subset of the rocky planetary materials. However, recent studies [1,2] suggest that the O-isotope anomaly is deeply connected to the origins of the low-temperature condensates, represented by the water ice and the organic matter. The oxygen isotope may become one of the most important tools to trace the entire history of the important ingredients for a habitable planet: from their origins; their circulation in the solar nebula; accretion to planets/asteroids; and the processes within the planets, namely the water-organics-rock interactions, possibly including the life-formation process.


Keywords: Organic Matter, Meteorite, Oxygen Isotope, Photodissociation, Isotope Imaging