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

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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 <sup>13</sup>C/<sup>12</sup>C and <sup>15</sup>N/<sup>14</sup>N ratios, (3) the OH/O ratio; and (4) the <sup>17</sup>O/<sup>16</sup>O and <sup>18</sup>O/<sup>16</sup>O ratios.

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

The positive correlation between the <sup>d17,18O</sup> and <sup>d13C</sup> is explained in principle by the self-shielding effect of CO. The reduced photodissociation rate of the major isotopologue, <sup>12C16O</sup>, may result in the coherent enrichment in the organic matter of the three minor isotopes, <sup>17,18O</sup> and <sup>13C</sup>. However, a warm environment, as high as 60 Kelvin, is necessary to expect the <sup>13C</sup>-enrichment by the self-shielding effect to overcome the opposite fractionation effect by the competing reaction, namely the ion molecule reaction (<sup>12CO</sup> + <sup>13C+</sup> = <sup>12C+</sup> + <sup>13CO</sup> + 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.

[1] Hashizume K., Takahata N., Naraoka H. and Sano Y. (2011) Extreme oxygen isotope anomaly with a solar origin detected in meteoritic organics. *Nature Geoscience*. doi:10.1038/ngeo1070.

[2] Sakamoto, N. et al. (2007) Remnants of the early solar system water enriched in heavy oxygen isotopes. *Science* 317, 231-233.

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