

CONCURRENT BIRTHS OF THE ORGANIC MATTER AND THE OXYGEN ISOTOPE ANOMALY IN THE SOLAR NEBULA. K. Hashizume¹, N. Takahata², H. Naraoka³ & Y. Sano², ¹Department of Earth and Space Sciences, Osaka University, Toyonaka, Osaka 560-0043, Japan (kohash@ess.sci.osaka-u.ac.jp). ²Atmosphere and Ocean Research Institute, University of Tokyo, Kashiwa, Chiba 277-8564, Japan. ³Department of Earth and Planetary Sciences, Kyushu University, Fukuoka 812-8581, Japan.

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 [1-7] acquired upon its birth in the outer region of the proto-solar nebula [8,9] and/or in the ancestral molecular cloud [10,11], though the exact origins remain open issues.

The primary objective of this study is to search for the non-mass-dependent O-isotope anomaly possibly recorded in the meteoritic organics. The O-isotope anomaly is widely observed among essentially all available planetary materials in the inner solar system [12], and between the Sun and the planetary materials [13,14]. Clayton [15] advocated that the variations could be produced by the self-shielding effect of carbon-monoxide that occurred at the very first stage toward the production of the planetary solid materials. Recent O-isotope evolution models that implement the above-mentioned effect propose that the isotope fractionation occurred at the surface layer of the outer solar nebula [16] or in the ancestral molecular clouds [17], which correspond to the proposed places where the meteoritic organics were born.

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

The $^{18}\text{O}/^{16}\text{O}$ image of the IOM sample extracted from an Antarctic CR2 chondrite Yamato-793495 is shown in Fig. 1. Anomalous $\delta^{17,18}\text{O}_{\text{SMOW}}$ values as high as +500‰ were observed among the organic phases, *i.e.*, domains enriched in C, H and N [18]. The $\delta^{17}\text{O}$ and $\delta^{18}\text{O}$ showed paralleled values, plotted in the three isotope diagram slightly above the slope-1 line [19] (Fig. 2), with an inclination of 1.057 ± 0.015 (1σ).

We note here a couple of interesting features recognized by the multi-isotope imaging. The $^{17,18}\text{O}$ -rich domains within the rastered area often showed positive $\delta^{13}\text{C}_{\text{PDB}}$ values, up to $+288 \pm 45\%$ [18]. Several D- ^{15}N -rich domains were observed within the same area, with

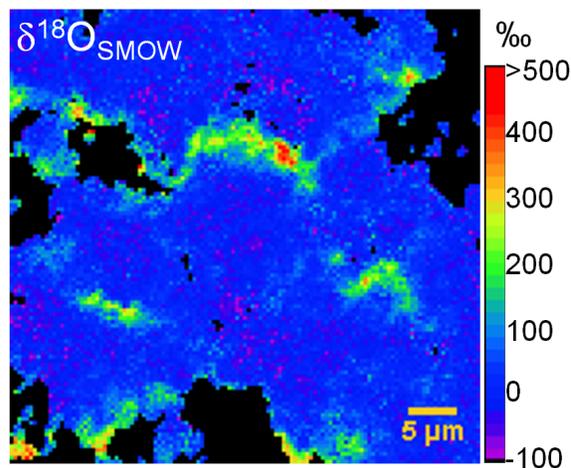


Fig. 1. The $^{18}\text{O}/^{16}\text{O}$ isotope image of the acid-insoluble organic matter extracted from Yamato-793495 (CR2). An area of $50 \times 50 \mu\text{m}^2$ was rastered by a 30 pA Cs primary ion beam [18]. Respective pixels in this figure represent mean compositions of $390 \times 390 \text{ nm}^2$ -size areas. Domains pasted in black represent areas where the counts of the secondary O-ions were smaller than $0.2 \times$ the average counts (9.4×10^5 ^{16}O -counts/pixel).

$\delta\text{D}_{\text{SMOW}}$ and $\delta^{15}\text{N}_{\text{AIR}}$ values up to $8957 \pm 557\%$ and $665 \pm 64\%$, respectively. However, no correlations were observed between δD or $\delta^{15}\text{N}$ values and $\delta^{17,18}\text{O}$ or $\delta^{13}\text{C}$ values.

The positive correlation between the $\delta^{17,18}\text{O}$ and $\delta^{13}\text{C}$ is explained in principle by the self-shielding effect of CO. The reduced photodissociation rate of the major isotopologue, $^{12}\text{C}^{16}\text{O}$, may result in the coherent enrichment in the organic matter of the three minor isotopes, $^{17,18}\text{O}$ and ^{13}C . However, a warm environment, as high as 60 Kelvin [21], is necessary to expect the ^{13}C -enrichment by the self-shielding effect to overcome the opposite fractionation effect by the competing reaction, namely the ion molecule reaction ($^{12}\text{CO} + ^{13}\text{C}^+ \leftrightarrow ^{12}\text{C}^+ + ^{13}\text{CO} + 35\text{K}$) [9,21]. Therefore, we propose that the non-mass-dependent O-isotope fractionation occurred in a rather warm (≥ 60 K) gas medium, such as the envelope of the solar-nebula illuminated by the proto-Sun. The D- ^{15}N -enrichments observed among the meteoritic organics suggest that part of the organics may originate from colder environments [11,22], such as the dense interstellar clouds. However, such a place

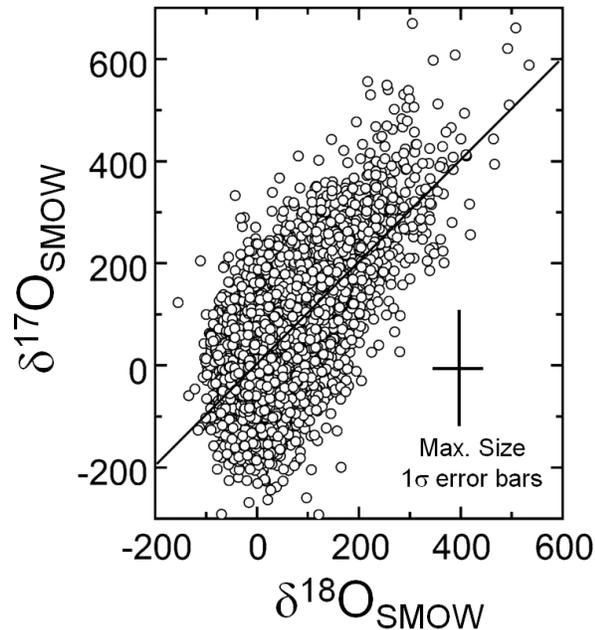


Fig. 2. The oxygen three-isotope diagram for the acid-insoluble organic matter extracted from Yamato-793495 (CR2), shown in Fig. 1. Data for pixels with ^{16}O counts smaller than 0.2x the average count (pixels pasted with black color in Fig. 1) are omitted. The 1σ error bars shown in the figure denote error bars for a pixel with the smallest ^{16}O counts, that is, the maximum size of the error bars put on respective data points shown in this figure. The diagonal line in the figure represents the slope-1 line [19].

is unlikely to be the place for the birth of the non-mass-dependent O-isotope anomaly.

We have examined so far the isotope imaging of IOM samples from two meteorites, Yamato-793495 (CR2) and Murchison (CM2). No indication of a non-mass-dependent O-isotope fractionation was observed in Murchison IOM, although many spots with D and ^{15}N enrichments were detected, confirming the previous study [4]. The difference in the appearance of the O-isotope anomaly between the two meteorites could be either due to (i) larger amounts of $^{17,18}\text{O}$ -rich organics accreted to the CR parent body, or (ii) preferential elimination of the $^{17,18}\text{O}$ -rich isotope signature in the CM parent body due to the chemical weathering associated to the aqueous alteration. The first option may indicate presence of a local/temporal process in the solar nebula that partially eliminated the organics, the carrier of the non-mass-dependent O-isotope signatures. The second option may give us a fine view of the rock-water-organics interaction that occurred in the meteorite parent body. The studied CR2 chondrite is suggested from the trace element study to have exper-

rienced a mild thermal metamorphism in the parent body [23]. We may understand the reason for the prominent O-isotope anomalies detected among the organics extracted from the studied CR2 meteorite, if we speculate, based on the above suggestion, that this meteorite experienced a smaller degree of the aqueous alteration. Differences in the chemical compositions and the molecular structures among the organics with different origins, the ^{13}C - $^{17,18}\text{O}$ -rich and D- ^{15}N -rich components, are apparently important clues to further examine these options.

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