Evolution of Fluid Composition Inferred from Calcite in the Yamato 791198 CM Chondrite.

Wataru Fujiya (wataru.fujiya@vc.ibaraki.ac.jp)1, Yuto Aoki1, Takayuki Ushikubo2, and Ko Hashizume2.
1Faculty of Science, Ibaraki University, 2Kochi Institute for Core Sample Research, JAMSTEC.

Introduction:
Carbonate minerals are ubiquitous in CM chondrites and formed by aqueous alteration in the CM chondrite parent body [1]. Previous studies have revealed a large variation in C isotopic ratios of CM carbonates with δ13C values ranging from 20 to 90‰ (Fig. 1), however, the reason for this variability has remained poorly understood [2-9].

To trace the change in C isotopic ratios of carbonates with progressive alteration, here we conducted in-situ C- and O-isotope measurements by Secondary Ion Mass Spectrometry (SIMS) within single carbonate grains in Yamato 791198 (CM 2.4).

Experimental:
We obtained Cathodoluminescence (CL) images of seven calcite (CaCO₃) grains with an FE-EPMA. Then, we measured O isotopic ratios of the calcite grains with the Cameca ims-1280HR ion microprobe using a focused Cs⁺ primary ion beam of 30 pA and 3-4 μm in diameter. Next, we measured C isotopic ratios of the calcite grains using a focused Cs⁺ primary ion beam of 120 pA, 6-8 μm in diameter. The C-isotope measurements were performed just upon the points where the O isotope ratios were measured (if possible), or adjacent regions to those for the O-isotope measurements. Finally, we obtained quantitative chemical compositions and X-ray maps of Mg, Si, Ca, Mn, and Fe of the calcite grains using the FE-EPMA.

Results and discussion:
CL images and chemical compositions of calcite grains:
Fig. 2 shows representative calcite grains with a clear zoning of Mn, Mg, and Fe. This zoning is well correlated with CL images. The heterogeneous distribution of minor elements and CL intensity likely reflects the crystal growth of these grains.

Oxygen isotopic compositions:
The O isotope ratios significantly vary within individual grains (Fig. 3). For example, the grain in Fig. 1 has variable δ18O values of 37% (A), 27% (B), and 25% (C). The O isotope ratios plot on a single trend line in an O three-isotope plot with a slope of 0.61, reflecting a progressive O-isotope exchange between initially 16O-poor water and 18O-rich rock [10,11]. This δ18O change demonstrates that the crystal grew from a relatively dark CL core (A) to a red CL periphery (C). Interestingly, Mg, Mn, and Fe abundances do not change monotonically with the crystal growth (Fig. 4).

Carbon isotopic compositions:
The δ13C values of the calcite grains range from 17 to 32‰ (Fig. 5). This range is much smaller than that observed for different carbonate grains or bulk meteorite samples by previous studies [2-9]. Especially, the δ13C variations within individual grains are only 4‰ at most except for one grain.

Here we propose that the δ18O values of dissolved carbon species in aqueous solutions were locally heterogeneous, and did not significantly change during carbonate formation. Fujiya et al. suggested that the variable δ13C values of CM carbonates are attributed to the mixing between two carbon reservoirs with different C isotope ratios, namely, 13C-rich CO₂ ice and 13C-poor organic matter, with variable proportions [8]. Our new data are consistent with this argument.

Fig. 1: δ13C and δ18O variation of calcite in the LAP 031166 CM chondrite [8]. Note that each data point represents composition of one calcite grain.

Fig. 2: Representative calcite grains in Y791198.

Fig. 3: Oxygen isotopic compositions of calcite grains in Y791198. Data obtained for the same grain are represented by the same color.

Fig. 4: Minor element abundances of calcite grains in Y791198. Colors as Fig. 3.

Fig. 5: δ13C and δ18O variation of calcite in Y791198. Colors as Fig. 3. Also shown are data from previous studies [5-8].

References: