The oxygen isotopic and chemical composition of the primitive Asuka CM chondrites

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CM chondrites (CMs), the most abundant group of carbonaceous chondrites, generally experienced varying degrees of secondary aqueous alteration and consequently are typically classified into subtypes 2.7-2.0 [1,2]. In contrast, there are a number of CMs which are known to have been subjected to heating subsequent to aqueous alteration. Recently, we reported on three CM chondrites, Asuka (A) 12085, A 12169, and A 12236 [3] which have clearly escaped both aqueous alteration and later heating. As a consequence of this study, we have proposed new criteria for defining subtypes of 3.0-2.8 for CMs. A 12169, A 12236, and A 12085 are classified as subtype 3.0, 2.9, and 2.8, respectively. Here we mainly report the bulk oxygen isotopic and chemical compositions of these CMs after [3], and discuss the primordial nature of CMs and the genetic relationships between CM and CO chondrites.

The three Asuka CMs analyzed in this study have the following oxygen isotope compositions: A 12169: δ^{17}O -4.07 ‰; δ^{18}O 1.32 ‰; A 12085: δ^{17}O -4.83 ‰; δ^{18}O -0.31 ‰; A 12236: δ^{17}O -4.33 ‰; δ^{18}O 0.80 ‰. The three Auska CMs plot away from the field of “normal” CM chondrites and close to the field of CO falls. It therefore seems likely that the CM group extends from almost pristine examples that plot close to the CO field, to highly aqueous altered examples that have isotopically heavy oxygen isotope compositions. This supports the original suggestion that the anhydrous CM precursor material was CO-like, at least in terms of its oxygen isotope composition [4]. Rubin et al. [1] noticed that CMs of lower subtypes (highly altered) have heavier oxygen isotopic compositions than those of higher types. Our results extend it to cover primitive CMs, and the oxygen isotopic compositions are positively related to the alteration degree (subtypes). We are currently undertaking further oxygen isotope analyses of the Asuka CMs and we will discuss these new results at the meeting.

We obtained the bulk chemical composition of A 12236. It plots within the area of CMs on a diagram of atomic Al/Mn versus (Zn/Mn)x100 ratios and is obviously different from CO and other chondrites. The bulk chemistry of A 12236 is close to those of Paris (CM2.7), Murchison (CM2.5), Nogoya (CM2.2), and the CM-mean value. This suggests that the bulk chemistry was not changed during aqueous alteration of CM chondrites, as previously noted by Rubin et al. [1]. These relationships are consistent with alteration having taken place under essentially closed system conditions within the CM parent body.

The CM and CO chondrites constitute a CM-CO clan [5]. However, since the CMs so far reported were aqueously altered unlike the COs, it has been difficult to compare the precursor materials of both groups. The Asuka CMs studied here are important samples as they provide a unique insight into the nature of CM precursor material prior to the onset of secondary alteration. Although the oxygen isotopic compositions of the primitive CMs are close to COs, the primary materials of the CMs and COs were different from one another, especially chondrule size, the abundances of matrix, inclusions, and opaque minerals [3], and their bulk compositions, as mentioned above. However, the precursor material to the CMs, appears to have been isotopically nearly identical to that of the COs. Although the parent bodies to both groups may have accreted in a similar region of the nebula, CMs and COs were derived from different parent bodies and CMs contained a higher content of volatile constituents (water ice?).

These chondrites are also significant in view of the imminent return of sample material from the asteroids Ryugu and Bennu. The mineralogy of the surface materials on Ryugu show many similarities to the least altered CM chondrites, with the notable exception of porosity [6]. As a consequence, studying the characteristic features of these least altered CMs and defining their relationship to other chondrite groups, such as the COs, is of particular importance.

References

[1] Rubin A.E. et al. 2007. Geochimica et Cosmochimica Acta 71, 2361-2382. [2] Rubin, A.E., 2015. Meteoritics & Planetary Science 50, 1595-1612. [3] Kimura M. et al. 2020. Polar Science (in press), [4] Clayton R. N. and Mayeda T. K. 1999. Geochimica et Cosmochimica Acta 63, 2089–2104. [5] Kallemeyn, G.W. and Wasson, J.T. 1982. Geochimica et Cosmochimica Acta. 46, 2217-2228. [6] Grott, M.et al. 2019. Nature Astronomy. 3, 971-976.