REE abundances in chondrules from Murchison and Yamato-793321 (CM) meteorites: Constraints on the formation of CM chondrules

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Except a few cases [1, 2], almost no REE data have been reported for individual chondrules from CM chondrites. In order to obtained the trace element constraints on the formation and evolution of chondrules from Murchison and Yamato-793321 (CM) meteorites, abundances of REE, Ba, Sr, Rb and K were precisely determined by isotope dilution mass spectrometry (IDMS) together with petrographic examinations. The experimental procedures are similar to those previously described [2,3].

Petrography

12 chondrules (11 porphyritic and a radial pyroxene) from Murchison and 16 chondrules (9 porphyritic, 5 barred olivine and 2 granular olivine) from Yamato-793321 were used for present study.

20 among 28 chondrules show porphyritic texture (PO, POP and PP) mainly consisting of Fe-poor olivine(Fo>95),pyroxene(En>95)phenocrysts and altered mesostasis. Barred olivine (BO)(Fo=16~99) chondrules have altered interstitial phase, and a few BO chondrules carries partly altered olivine bars. Radial pyroxene (RP)(En=95, Wo=1) and granular olivine (GO) (Fo=99) chondrules consist of unaltered olivine, pyroxene but altered mesostasis.

Altered interstitial phase of CM chondrules are occupied with phyllosilicate and PCP(Poorly Characteristic Phase), and other unusual hydrous minerals are also noted. Exceptionally, one PO chondrule has unaltered mesostasis composed of true glass.

Isotope dilution analysis

The results of IDMS analyses indicate that these CM chondrules have considerable variations of absolute and relative abundances of alkalis, alkaline earths and REE (K, Rb <0.1~0.9 X CI; Sr, Ba 0.1~2.2 X CI; Nd 0.5~5.5 X CI). Regardless of depletions of alkalis, following REE fractionations are observed.

1) 7 among 28 chondrules show grossly unfractionated REE pattern with irregularities of L/HREE and negative Eu (>-30%) and positive Ce (<+22%), Yb (<+194%) anomalies, which is similar to those typically observed in chondrules from CV, CO and UOC meteorites (Fig. 1a) [3, 4]. Such REE patterns have been interpreted to have originated by high-temperature nebula condensation process [3].
2) 15 chondrules show smooth fractionation from LREE to HREE (CI normalized Sm/La ratio = 1.3~3.3) with a negative Eu anomaly (> -71%) (Fig. 1b).
3) 6 chondrules show REE patterns accompanied with LREE depletion (Sm/La= 1.3~2.4), but with positive Ce (<+13%), Yb anomaly (<+101%) and L/HREE irregularity. (Fig. 1c).

The smoothly LREE-depleted fractionation with a negative Eu anomaly (Fig. 1b, c) have rarely been found for meteoritic chondrules. We observed no clear distinction of REE fractionation features between Murchison and Yamato-793321 chondrules. Two alternative interpretation for the REE fractionation are considered as follow.

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Aqueous alteration

In order to detect any effect of alteration on REE abundances, we carefully examined the relationships between REE fractionations and the alteration features of these chondrules (Degree of alteration from petrographic observation; Constituent minerals and redistributions of major elements; Leaching of K, Rb, Sr and Ba). However no apparent correlations were identified.

Because REE behaviors during aqueous alteration have not been well known in detail, it might be prudent not to rule out a possibility that the observed REE features are due to alteration.

Igneous process

Smoothly fractionated REE patterns may be interpreted as being due to solid/liquid separation of the dust aggregate in the nebula [5] or even by an igneous activity on a planetesimal [6]. We suggest that the nebula setting includes the condensation process and this can explain the nebula REE signatures.

It is pointed out that textural types of chondrules show the correlation to REE fractionation. Most REE patterns of PO (POP, PP), GO and RP chondrules have smooth REE fractionations except for a few cases, but all BO chondrules show abundance patterns indicative of volatility controll. This difference in REE fractionation between PO and BO chondrules may be a important to understand the formation processes of the CM chondrules.

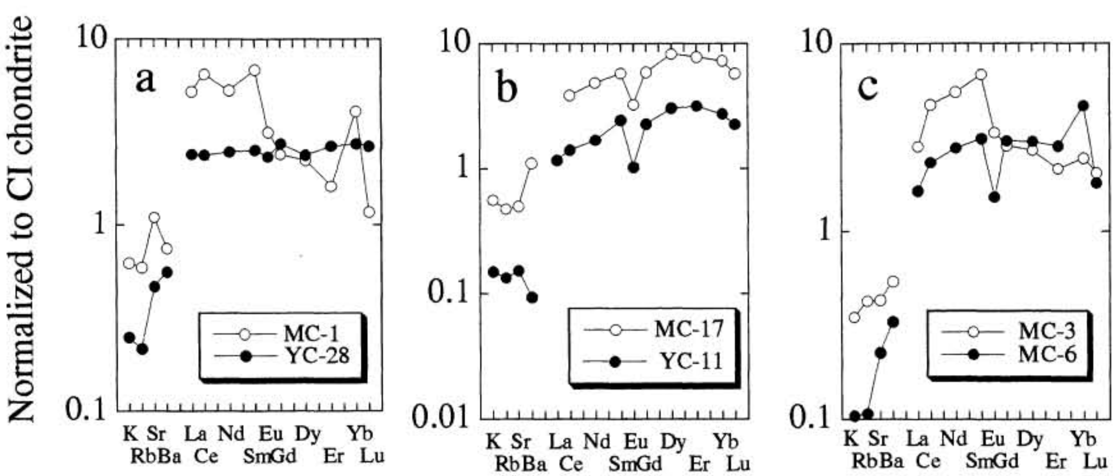

Fig. 1. Representative REE patterns of chondrules from CM meteorites, Murchison (MC) and Yamato-793321 (YC).

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