

# DID DIOGENITES FORM FROM DIOGENITES?: A CASE OF THE YAMATO DIOGENITES

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**Abstract:** It has been found that the REE distribution in Y-74010 is considerably different between two adjacent fragments, sizes of which are at least 500 mg, a fact indicative of patchy heterogeneity. In addition, it is worthwhile to note that the abundance ratios between two fragments in question are a linear function of atomic number. On the other hand, Y-74013 can be interpreted as a mixture of two distinct constituents, *i.e.*, relatively coarse-grained pyroxene and much finer pyroxenic remnant component. It is noted that these two constituents of Y-74013 can correspond to two different kinds of parts represented by macroscopically separated patches of Y-74010 mentioned above. These observations coupled with the basically linear abundance ratios relative to atomic number suggest that (1) intense melting took place for a parental body of the Yamato diogenites, (2) two separate components reflect the coexisting solid and liquid phases and (3) the solid phase was formed from liquid, transiently as a low-Ca clinopyroxene, which subsequently changed into orthopyroxene as a finally stable form.

Also it is an interesting fact that the apparent REE partition function pertaining to Y-692 appears to show discrete (quantum-like) effect.

## 1. Introduction

We determined precisely the rare-earth elements (REE) in several Yamato diogenites (MASUDA and TANAKA, 1978; MASUDA *et al.*, 1979). Major purpose of this paper is to investigate the REE data obtained by us for the Yamato diogenites and to discuss their relationship and its possible implications for the genesis of those meteorites. Mineralogical examination of the Yamato-74 achondrites has been carried out by TAKEDA *et al.* (1978). As was observed for Yamato-692 (TAKEDA *et al.*, 1975), diogenites examined show granoblastic texture (TAKEDA *et al.*, 1978). These authors suggested pyroxene recrystallization with little change in mineral composition.

## 2. Experimental and Results

By chance, two adjacent chips A and B of Y-74010, size of which are about 500

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mg, were studied. The Y-74010B was found not only to have the highest REE abundances among the samples studied, but also there is a considerable difference in REE relative abundance between Y-74010B and Y-74010A. In Fig. 1 is shown the relationship between the abundance ratios of A to B and order of atomic number. It is seen that the abundance ratio changes linearly with atomic number, with a break between Nd and Sm, perhaps at Pm. It should be noted that a linear relation with or without a sharp break at a certain atomic number is observed for the REE abundance ratios between clinopyroxene and coexisting silicate melt (MASUDA, 1967; TANAKA and NISHIZAWA, 1975; SHIMIZU, 1980). This can suggest that Y-74010B and Y-74010A correspond to coexisting silicate melt and solid phase (presumably low-Ca clinopyroxene), respectively. However, it is true that the present crystal structure of diogenite pyroxene is represented by orthopyroxene (TAKEDA *et al.*, 1978). We shall return to this problem later.

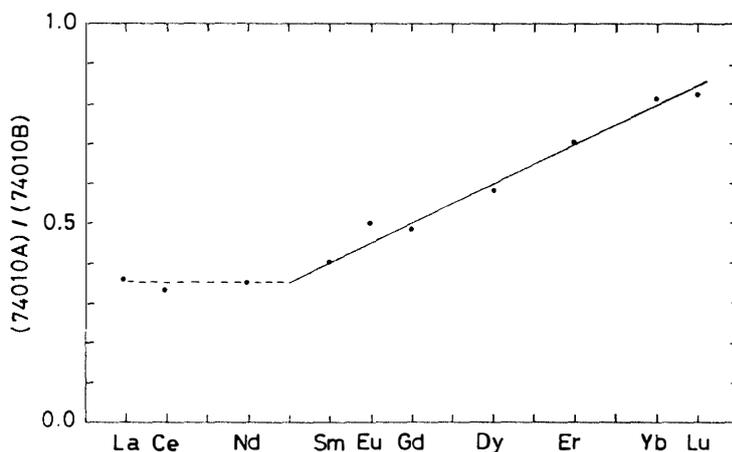


Fig. 1. The REE abundance ratio pattern of Y-74010A relative to Y-74010B.

For Y-74010, emphasis should be placed on that two chips under consideration existed as adjacent, distinct patches. But unfortunately we failed to make any preliminary visual inspection about those samples, for we did not expect any distinction like this, prior to the REE determination. (General mineralogical description has been given by TAKEDA *et al.* (1978).)

For the Y-74013 diogenite, we determined REE for a whole-rock sample and for a relatively coarse-grained, hand-picked orthopyroxene separate. The REE abundance ratios of Y-74013 hand-picked orthopyroxene to Y-74010B as employed above are shown in Fig. 2. Also the abundance ratio in this diagram changes linearly with the change in atomic number. Some difference from Fig. 1 is that any break is not observed in Fig. 2, but the line is simply rectilinear over the whole range of atomic number, excepting rather small deviation of Eu.

Here let us examine whether it is possible for us to expect the presence of the

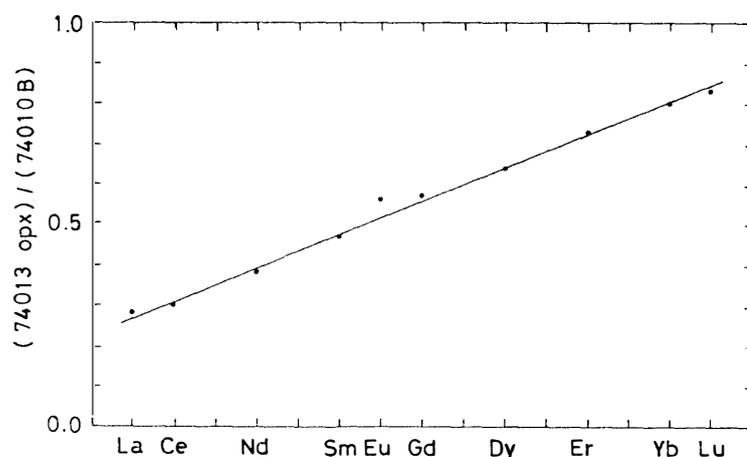


Fig. 2. The REE abundance ratio pattern of Y-74013 hand-picked orthopyroxene relative to Y-74010B.

phase equivalent to Y-74010B in the whole-rock material of Y-74013 itself, too. Let us assume that the Y-74013 whole-rock sample (WR) analyzed is composed of two ingredients; one, the component represented by hand-picked orthopyroxene (OPX) and another, much finer-grained residual component (mostly pyroxenic) (F), which would escape hand-picking. Assuming that the fraction of "OPX" component is  $\alpha$ , the REE abundances in the "F" component can be estimated as  $(WR - \alpha \times OPX) / (1 - \alpha)$ . According to our trial-and-error wise examination, if  $\alpha$  is taken as 0.600, the REE abundances in F turn out to be almost identical with those in Y-74010B (Fig. 3 and Table 1). The agreement between Y-74010B and Y-74013F is especially good for Ce, Sm, Gd, Dy and Er (see Table 1). It may be worth mentioning that the agreement of resultant values is remarkable for middle REE, but the seemingly systematic deviations for lightest and heaviest REE might be of some significance. Anyway, it can be concluded that the relationship observed for two Y-74010 chips is parallel with the results derived from the whole-rock sample and the hand-picked pyroxene separate of Y-74013.

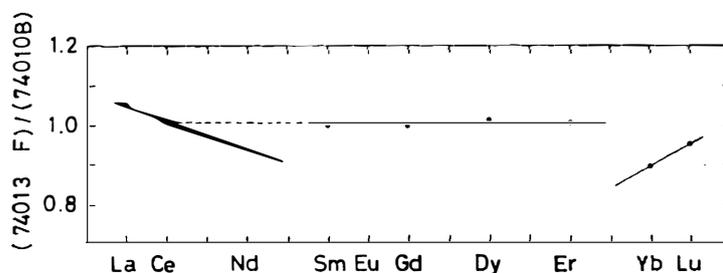


Fig. 3. REE abundance ratios of residual component F estimated from Y-74013 to Y-74010B (see text and Table 1).

Table 1. Ratio of REE abundances calculated for the residual component F of Y-74013 to Y-74010B.

La	1.052	Gd	0.998
Ce	1.007	Dy	1.015
Nd	0.942	Er	1.008
Sm	1.007	Yb	0.897
(Eu	1.89)	Lu	0.951

$\alpha$  (see text) is assumed to be 0.600.

### 3. Discussion

The simplest and consistent interpretations of facts observed for Y-74010 and Y-74013 are that (1) these Yamato diogenites are from the same diogenitic parental body, (2) it encountered an intense melting which could cause almost complete melting of some part of the parental body, (3) the Yamato diogenite samples retain the heterogeneity in the REE distribution reflecting the incomplete separation of pyroxene crystals from pyroxenic melt, and (4) the pyroxene crystals which formed at the earlier stage of solidification of the melt are inferred to have been separated passing through the transient or metastable stage of clinopyroxene, which in turn changed into orthopyroxene as a finally stable phase.

According to our inference, the material as represented by Y-74010A is the solid phase which coexisted with the liquid phase represented by Y-74010B. For the nature of the solid phase under consideration, there can be two possibilities; one is the residual solid phase in partial melting and another is the solid phase produced from the coexisting liquid phase. To interpret the relationship observed for REE abundance ratios, the latter is favorable, because a stable solid phase usually remains in partial melting and a transient or metastable solid phase is prone to appear in the partial crystallization of silicate melt (SHIMIZU, 1980, and unpublished). (This could be regarded as a case of Ostwald's step rule.) It might be conceivable that the clinopyroxene mentioned above had a form similar to a high-temperature form of pigeonite.

The chondrite-normalized REE pattern of the Yamato diogenites on an average suggests that the pyroxenes of diogenitic parental body were *primarily* formed as orthopyroxene and the secondary melting process is interpreted to have brought about the patchy distributional heterogeneity of REE, pattern of which indicates the passage through the stage of clinopyroxene in a transient or metastable state. It is considered that this matter depends largely on the difference in cooling rate, and that the secondary melting and cooling processes took place more quickly than the primary ones.

Figure 4 shows the abundance ratios between Y-692 and Y-74010B. Gross aspects seen in this diagram are similar to those of Fig. 2. However, it intrigues us very much that points fall on either of two subparallel lines; La, (Eu), Dy, Er, Yb and

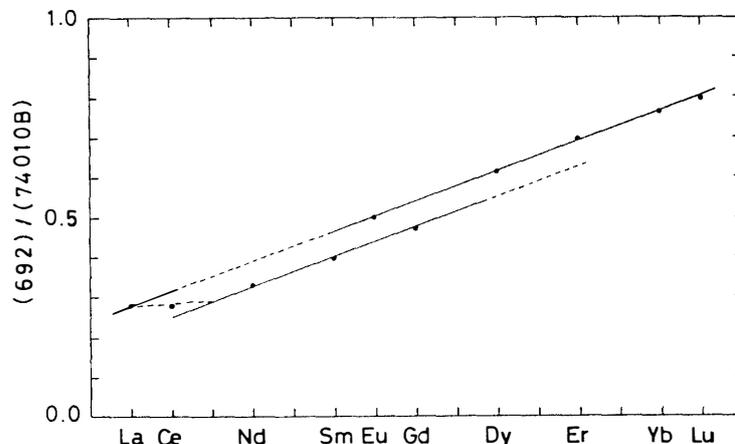


Fig. 4. The REE abundance ratio pattern of Y-692 relative to Y-74010B.

Lu on the upper line and Nd, Sm and Gd on the lower line. (Falling of Eu on the upper straight line may be fortuitous.) The distance between the two regression lines is far greater than the experimental errors which are less than 2% in relative magnitude. The disparity between the subparallel lines corresponds to two units in terms of the increment per atomic number for these lines. A kind of quantum-like, discrete shift like this is rare but real (MASUDA, 1978), and collection of similar cases would shed more light on the understanding of quantum-like effects as observed here and lead us to more essential comprehension based on basic sciences.

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