TWO MAJOR GROUPS OF CHONDRITIC REE ABUNDANCES SUITES: VARIABLE OCTAD EFFECT ON HEAVY REE

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Abstract: It has been found that heavy REE octad in a considerable fraction of Antarctic meteorites seems to bear a striking mutual resemblance in downward concave curvature when normalized by the Leedey chondrite. As one of possibilities, this may suggest that, in addition to the "Leedey-type" and related suites of chondritic REE abundances, there is another major group with respect to chondritic REE abundances, in particular, to heavy REE relative abundances. Alternatively, REE abundances with such a characteristic may indicate cognate relations of Antarctic meteorites studied.

There appears to be a close relationship between anomalies of Eu and those of Yb.

Employing neutron-activation technique, SCHMITT *et al.* (1963, 1964) determined the rare-earth elements (REE) in meteorites with considerably good precision. MASUDA *et al.* (1973) determined REE in chondritic meteorites more precisely by means of mass-spectrometric stable isotope dilution technique, and disclosed the fine structures of mutually normalized REE patterns of chondrites. At the same time, they suggested that, so far as relative abundances are concerned, the REE abundances in the Leedey chondrite studied by them can be regarded as "standard values" in normalization. NAKAMURA (1974) endorsed the judgment about the status of the Leedey chondrite. EVENSEN *et al.* (1978) analyzed fifteen chondrites, so that the coverage of major chondritic classes is complete. However, their data have a questionable point in showing unaccountable irregularities at Er, and, in addition, lack in Lu abundance. (Absence of Lu makes it difficult to recognize the Yb anomaly.)

The most essential points of REE abundances of chondrites are considered to be the fine structures of mutually normalized general patterns and the anomalies liable to occur specifically for Eu, Yb and Ce. Naturally, the absolute abundance levels of REE would be another significant point.

MASUDA *et al.* (1977) investigated REE, Rb, Sr and Ba abundances in three Yamato chondrites, j(7301), k(7305) and m(7304), showing a rather great fractionation for 7301. In the subsequent investigation, the same elements in another three Yamato meteorites were determined by MASUDA and TANAKA (1978). In this communication, the similar data on two Antarctic chondrites, Yamato-74362 and Allan Hills No. 9, are presented. Like other determinations by our group, mass-spectrometric stable isotope dilution technique was employed.

Table 1. Abundances (ppm) of REE, Ba and Sr in Antarctic chondrites.

	Yamato-74362	Allan Hills No. 9	Yamato-691*	Yamato-693*	Yamato-7301**	Yamato-7304**	Yamato-7305**	Leedey***
La	0.355	0.282	0.244	0.447	0.403	0.401	0.3625	0.378
Ce	0.904	0.746	0.633	1.142	0.963	1.024	0.942	0.976
Nd	0.667	0.550	0.473	0.880	0.611	0.730	0.695	0.716
Sm	0.214	0.1770	0.153	0.286	0.1848	0.2280	0.2259	0.230
Eu	0.0831	0.0775	0.0551	0.109	0.0623	0.0831	0.0743	0.0866
Gd	0.298	0.249	0.217	0.376	0.255	0.310	0.310	0.311
Dy	0.366	0.307	0.269	0.461	0.308	0.369	0.374	0.390
Er	0.235	0.200	0.178	0.297	0.1984	0.2374	0.2433	0.255
Yb	0.235	0.208	0.170	0.293	0.190	0.231	0.238	0.249
Lu	0.0378	0.0325	0.0272	0.0469	0.0316	0.0355	0.0371	0.0387
Ba	4.92	3.89	2.93	4.31		4.80	3.67	4.21
Sr	11.1	10.9	7.6	13.0		10.45	8.87	
Amount taken (mg)	257.6	263.1	568.1	529.0	281.5	670.6	686.2	
Type	L6	L6	E	C3	H4	L5	L5	L6

* MASUDA and TANAKA (1978).
** MASUDA *et al.* (1977).
*** MASUDA *et al.* (1973).

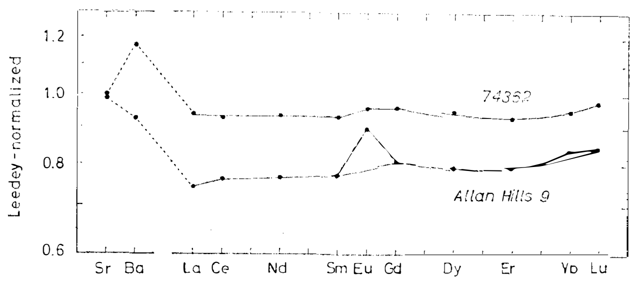

Fig. 1. The Leedey-normalized REE patterns for two chondrites studied in the present study; the normalizing value, 11.1 ppm, for Sr is from GOPALAN and WETHERILL (1971).

Table 2. Eu abundances in L6 chondrites (ppm).

Yamato-74362	0.0831
Allan Hills No. 9	0.0775
Leedey*	0.0866
Modoc*	0.0864
Peace River*	0.0862
Bruderheim*	0.0841
Holbrook*	0.0804

* MASUDA *et al.* (1973).

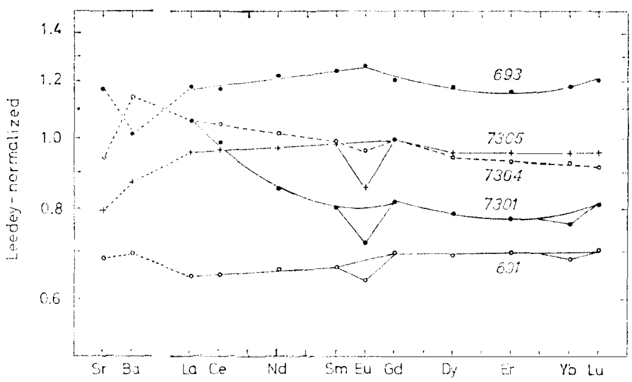

Fig. 2. The Leedey-normalized REE patterns of five Antarctic chondrites analyzed by MASUDA *et al. (1977) and by* MASUDA *and* TANAKA *(1978).*

Results of our present studies on Antarctic chondrites are shown in Table 1 and Fig. 1; both chondrites Yamato-74362 and Allan Hills No. 9 belong to L6 group. Of the L6 chondrites thus far studied (MASUDA *et al.*, 1973; present report), the Allan Hills No. 9 (AH9) is the lowest in REE absolute concentrations. A positive Eu anomaly is observed for this chondrite in accord with the general tendency for Eu in L6 chondrites to converge to the same level (MASUDA *et al.*, 1973). Nevertheless, Eu abundance in AH9 is the lowest (see Table 2). The REE patterns normalized by the Leedey chondrite for all of Antarctic chondrites previously studied by our group are presented in Fig. 2. Survey of Figs. 1 and 2 reveals that the Leedey-normalized REE patterns of Yamato-74362, AH9, Yamato-693 and -7301 are slightly downward concave for span encompassing Gd, Dy, Er, (Yb) and Lu; occasional deviations of Yb from smooth curves will be discussed below. Apparent similarity in this concave curvature for heavy REE span has drawn our attention. (It is also worth pointing out that a similar concave fractionation effect is not observed for light REE span, excepting the sample

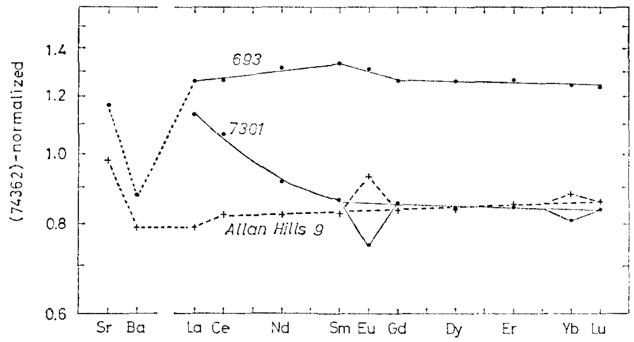

Fig. 3. The REE patterns of chondrites, Yamato-693, -7301 and AH9, normalized by Yamato-74362 in place of the Leedey chondrite.

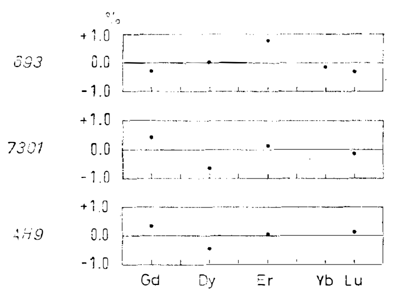

Fig. 4. Demonstration of extent of lineary for heavy REE span on an expanded scale, for each of REE patterns shown in Fig. 3.

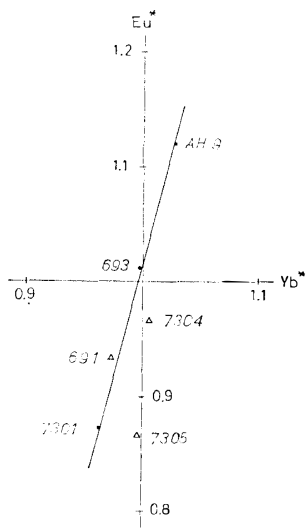

Fig. 5. Relationship between anomalies of Eu and Yb. Solid circles and open triangles refer, respectively, to anomalies calculated from REE patterns normalized by Yamato-74362 and by Leedey.

Yamato-7301.) Following this recognition, REE abundance suites for AH9, Yamato-693 and -7301 have been normalized by Yamato-74362, and the resultant patterns are shown in Fig. 3. High linearity for heavy REE span in this diagram would deserve ample attention. (The extent of linearity is quantitatively shown on expanded scale in Fig. 4.) At the same time, the deviations of Yb from straight lines for Yamato-7301 and AH9 become clearly visible. Moreover, parallelism between Eu and Yb anomalies would be worth paying special attention, because it is well known that Eu and Yb resemble each other often in physico-chemical properties. (For instance, both of them tend to be divalent cation under highly reduced conditions, and, at high temperatures they are more volatile than ordinary REE and stable as monatomic state in gaseous state.) In Fig. 5 is shown a relationship between Eu and Yb anomalies. The points for meteorites AH9, Yamato-693, -691 and -7301 fall closely on a straight line covering both positive and negative anomaly ranges; inclination coefficient of the straight line drawn in Fig. 5 is 3.82. However, Yamato-7304 and -7305 appear indifferent to such a trend. It would be conceivable that the binary anomalies corresponding to the straight line in Fig. 5 are related mainly with the condensation process (MASUDA and TANAKA, 1979) in the nebula, whereas the single Eu anomalies free from Yb ones would be explained favorably as related with thermal metamorphism in the parental body. It might be worth mentioning that REE patterns of AH9, Yamato-693 and -7301 (solid circles) falling on a straight line in Fig. 5 become straight for heavy REE span when normalized by Yamato-74362.

The deviation factors of Dy, Er and Yb as compared with the straight lines joining directly Gd and Lu in Figs. 1 and 2 can be evaluated (*cf.* Table 3). As self-evident from the concave pattern, the extent of deviation from unity is the greatest for Er. Although our data are void of Tb, Ho and Tm, let us here use the word "octad"; heavy REE octad here involves Gd, Tb, Dy, Ho, Er, Tm, Yb and Lu. (Rare-earth elements are divided into two octads, La through Gd and Gd through Lu, with Gd common to both octads.) It is true that the curvature for heavy REE octad is not so great, but as emphasized above, conformity in the concave curvature for heavy REE octad is significantly high. This fact may be interpreted as suggesting that the REE relative abundance suite as represented by Yamato-74362 is one of the major groups of chondritic REE abundances, together with the values for the Leedey chondrite. However, we cannot rule out a possibility that the validity of Yamato-74362 REE abundances as "representative" values is confined to Antarctic chondrites. If that is the case, those abundance values would be of help in examining the cognation of Antarctic meteorites. In this connection, it would draw our attention that the Antarctic meteorites with similar heavy REE octad features do not always belong to the

Table 3. Deviation factors of Dy, Er and Yb from the straight line joining directly Gd and Lu.

	Yamato-74362	Allan Hills No. 9	Yamato-693	Yamato-7301	Average
Dy	0.974	0.967	0.977	0.964	0.971
Er	0.952	0.952	0.962	0.951	0.954
Yb	0.970	—*	0.972	—*	0.971

* Anomalies are observed for Yb.

same meteoritic group; Yamato-74362 and AH9 to L6, Yamato-693 to C3, and Yamato-7301 to H4.

Thus it has been found that heavy REE octad in a considerable fraction of Antarctic meteorites appears to bear a striking mutual resemblance in downward concave curvature when normalized by the Leedey chondrite. Cosmochemical implications of this curvature are not clear at present, but it is likely that such a curvature may be related with the volatilities of heavy REE and with physico-chemical processes in solar nebula. Further discussions of the meaning of higher susceptibility of heavy REE octad to "concave fractionation" would be given elsewhere.

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