A possible highly fractionated and barium-rich micro-component in the Allende meteorite

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Rare-earth elements and Ba abundances for several fragments of the Allende meteorite were determined. Even for a powder sample carefully prepared, REE and Ba abundances determined were found to vary occasionally from portion to portion taken; a portion happened to demonstrate a very high Ba content and a considerably fractionated REE pattern as compared with the “representative” ones. This fact suggests the possible presence of Ba-rich micro-component with fractionated REE pattern in the Allende meteorite. Observations from other bulk samples of the same meteorite also corroborate this inference.

The fall of the Allende, Mexico, meteorite has provided us with a rare opportunity to investigate closely a Type III carbonaceous chondrite, because the minimum amount of the Allende shower is estimated to be of the order of four tons (CLARKE et al., 1970). A variety of studies on this unusual meteorite has been published (FIREMAN et al., 1970; MARVIN et al., 1970; WAKITA and SCHMITT, 1970; CLARKE et al., 1971; PODOSSEC and LEWIS, 1972; BUTLER, 1972). Copiousness of the material of this meteorite enabled one to prepare a possible reference meteoritic material. Such a powder sample was prepared with much caution by a working group directed by E. JAROSEWICH and R. S. CLARKE, JR., Smithsonian Institution.

This laboriously prepared powder was found to be very homogeneous in general, but, on the other hand, it was also recognized by us that, in spite of very careful preparation of the powder sample, it is not always homogeneous in respect of REE and Ba. This communication presents such results.

We have carried out determination of REE and Ba for several bulk samples by stable isotope dilution technique; four determinations were performed for fractions independently taken from the Smithsonian reference powder sample. Except for a few cases in determining the high Ba content, the accuracies of determinations are considered to be about 1%. Double circles in Fig. 2 represent the “standard” values obtained by NAKAMURA (1974) for the Smithsonian reference. (The Leedey chondrite values (MASUDA et al., 1973) are employed for normalization.) However, another determination of NMNH 3529 reference yielded the results (solid circles in Fig. 1) quite different from standard values; the amount taken for this determination was 1,013 mg. The extent of difference is far greater for Ba. While the average abundance of Ba in portions studied by NAKAMURA (1974; unpublished) is 4.90 ppm, the Ba abundance in the “abnormal” portion is as high as 995 ppm. The corresponding value in the Leedey chondrite is 4.21 ppm. Although we had no reason to suspect contamination during the chemical treatment, we could not help being conservative in concluding that this is due to a fortuitous presence of highly fractionated micro-component in the powder. Afterwards, however, a fragment of another whole-rock sample was analyzed for REE and Ba, and was also found to show a similar REE pattern (open circles in Fig. 1), with the Ba abundance of 108 ppm. Analysis of the third chip has shown the Ba abundance as high as 1,280 ppm, corroborating the heterogeneity of the Smithsonian powder. (Even in

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the terrestrial soil itself, the abundance of Ba is of the order of 400 to 500 ppm (unpublished). Thus we have been led to the conclusion that it is very likely that there is a highly fractionated micro-component in the Allende meteorite and that even the powder sample (< 100 mesh) very carefully prepared is not always homogeneous.

The REE pattern for this micro-component is given as the difference between the standard values (6) in Table 1) and the abnormal ones (1) in Table 1). The results of the calculation is shown in Fig. 3. It is seen that the odd component in question has a considerably simple REE pattern with negative Eu anomaly. This simple feature of the resultant pattern would be

**Table 1.** Abundances (ppm) of REE and Ba in the whole-rock samples of Allende

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
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<tbody>
<tr>
<td>La</td>
<td>1.506</td>
<td>0.731</td>
<td>0.663</td>
<td>0.876</td>
<td>0.532</td>
<td>0.507</td>
<td>0.448</td>
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<tr>
<td>Ce</td>
<td>3.33</td>
<td>1.732</td>
<td>1.693</td>
<td>2.12</td>
<td>1.414</td>
<td>1.325</td>
<td>1.140</td>
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<tr>
<td>Nd</td>
<td>1.708</td>
<td>1.142</td>
<td>1.032</td>
<td>1.193</td>
<td>1.042</td>
<td>1.004</td>
<td>0.875</td>
</tr>
<tr>
<td>Sm</td>
<td>0.470</td>
<td>0.357</td>
<td>0.313</td>
<td>0.334</td>
<td>0.335</td>
<td>0.330</td>
<td>0.282</td>
</tr>
<tr>
<td>Eu</td>
<td>0.134</td>
<td>0.114</td>
<td>0.110</td>
<td>0.115</td>
<td>0.113</td>
<td>0.113</td>
<td>0.104</td>
</tr>
<tr>
<td>Gd</td>
<td>0.522</td>
<td>0.440</td>
<td>0.384</td>
<td>0.397</td>
<td>0.417</td>
<td>0.414</td>
<td>0.371</td>
</tr>
<tr>
<td>Dy</td>
<td>0.637</td>
<td>0.506</td>
<td>0.451</td>
<td>0.462</td>
<td>0.493</td>
<td>0.504</td>
<td>0.450</td>
</tr>
<tr>
<td>Er</td>
<td>0.424</td>
<td>0.322</td>
<td>0.301</td>
<td>0.303</td>
<td>0.297</td>
<td>0.303</td>
<td>0.279</td>
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<tr>
<td>Yb</td>
<td>0.498</td>
<td>0.355</td>
<td>0.330</td>
<td>0.331</td>
<td>0.309</td>
<td>0.315</td>
<td>0.285</td>
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<tr>
<td>Lu</td>
<td>0.0786</td>
<td>0.0494</td>
<td>0.0495</td>
<td>0.0514</td>
<td>0.0459</td>
<td>0.0465</td>
<td>0.0423</td>
</tr>
<tr>
<td>Ba</td>
<td>995±30 (Sr, 16.5)</td>
<td>1280±30</td>
<td>108</td>
<td>165</td>
<td>87.2</td>
<td>4.85</td>
<td>12.4</td>
</tr>
</tbody>
</table>

(1) Bulk, SM-T1; (2) Bulk, ON; (3) Bulk, MS-W-IC [Tanaka and Masuda (1973)]; (4) "Matrix", MS-M-IC [Tanaka and Masuda (1973)]; (5) Bulk, SM-T2; (6) Bulk, SM-N [Nakamura (1974)]; (7) Bulk, MS-T2. The sets of values, (1), (5) and (6) are for the reference sample (NMNH 3529; split 5, position 4) prepared by the Smithsonian Institution.
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Fig. 3. Leedey-normalized REE pattern of the odd component accountable for the observed differences between "standard" and "abnormal" portions of the Smithsonian reference sample NMNH 3529; the numerical values of the ordinate refer to "abnormal" minus "standard" normalized against the Leedey chondrite values.

worthwhile to note.

Comparison of Fig. 1 with Fig. 2 suggests that, broadly speaking, the samples with somewhat U-shaped REE patterns have the high Ba contents. Moreover, our attention may also be paid to the fact that the matrix (TANAKA and MASUDA, 1973) of Allende (crosses in Fig. 1) shows the U-shaped REE pattern with comparatively high Ba content. According to B. MASON, who supplied this "matrix" material, it was separated as powder material with density greater than 3.32. Accordingly, it is conceivable that the Ba-rich micro-component with considerably fractionated REE pattern (TANAKA and MASUDA, 1973) is high-density constituent.

Certainly the Ba abundance of about 1,000 ppm in abnormal portion of the reference powder and in a different fragment (a bulk sample (2)) is amazingly high. If the presence of one percent odd component is accountable for such a high value, it should comprise 10 per cent Ba. If the amount of odd component in question is assumed to be 0.1 per cent, it should be composed of nearly 100 per cent Ba. Accordingly, 0.1% is the possible lowest amount of strange material in the abnormal fraction analyzed.

It is intriguing what kind of material the fractionated odd component is and how it was developed. As one of the possibilities, the material with REE pattern as seen in Fig. 3 could be developed as a residual melt of fractional solidification starting from the originally chondritic melt. Also the investigations by electron microprobe analyzer for lunar samples seem to be worth paying some attention. KEIL et al. (1971) found barian K-feldspar (8% Ba) in Apollo 12 samples, and ALBEE and CHODOS (1970) reported Ba-rich glass in Apollo 11 samples. Presence of about one percent barian K-feldspar as found by KEIL et al. (1971) could account for the Ba abundance in the abnormal portion under consideration. Even if so, it is enigmatic how such a material was added to the Allende chondrite. KEIL et al. (1971) mention that much of the barian K-feldspar appears to have crystallized late in the history of the rocks and from residual liquids rich in K2O and SiO2. Anyway, apart from the genetic problem, it is of much significance to search for Ba-rich micro-component which must be present in the Allende meteorite.

It is also known that the Allende meteorite comprises the white aggregates which are inferred to have condensed first from the solar nebula (MARVIN et al., 1970; CLARKE et al., 1971). Then it follows that this meteorite is a mechanical mixture of genetically mutually irrelevant components. This would be parallel with the suggestion by PODSEC and LEWIS (1972) that the condensation needs to have taken place in a region of space separate from that in which other parts of this meteorite were formed.

The above results are significant in indicating not only that it is considerably hard to homogenize completely the heterogeneous meteorite like Allende, but also that the Ba-rich micro-component with fractionated REE pattern is expected to be discovered in the Allende chondrite.

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REFERENCES


CLARKE, R. S., JR., JAROSEWICH, E., MASON, B.,


