

The carbon and oxygen isotope compositions of the carbonatite were analysed by the conventional phosphoric acid method (McCrea, 1950). The isotopic ratios were measured in a Delta+ mass spectrometer at the Department of Earth and Space Sciences, University of Science and Technology of China. The results are reported relative to the PDB and SMOW standards with an overall analytical precision better than  $\pm 0.2\%$  for both  $\delta^{13}\text{C}$  and  $\delta^{18}\text{O}$ .

#### 4 Results

As shown in Table 1, the whole-rock samples of carbonatites are rich in REE with a large range from 1 wt% to 20 wt%, averaging at 8 wt%. The chondrite-normalized REE patterns for carbonatites show a strong LREE enrichment curve inclining steeply to the right without Eu anomaly (Fig. 2), as is typical of carbonatites elsewhere in the world (Nelson et al., 1988; Woolley et al., 1989; Zaitsev et al., 1998). The  $(\text{La/Yb})_{\text{N}}$  ratios range from 139 to 1776 with an average of 814, indicating that LREE and HREE had been extremely fractionated during the evolution of carbonatite magma. In addition, the difference in REE content for different samples is as large as 14 times, revealing that the distribution of total REEs in the

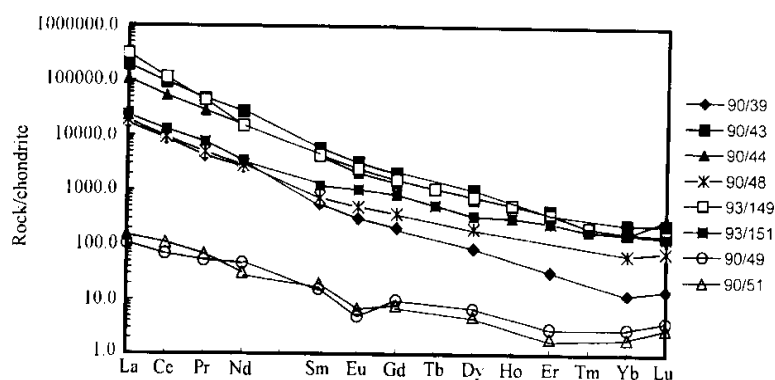


Fig. 2. Chondrite-normalized REE patterns of the representative samples from the carbonatite dyke at Bayan Obo (the chondrite REE data are after Boynton, 1984). Samples 90/39, 90/43, 90/44, 90/48, 93/149 and 93/151 are carbonatites, and samples 90/49 and 90/51 are fenites.

carbonatite dyke is highly heterogeneous. This agrees with the observation from thin sections that bastnaesite is locally concentrated up to 15%–25%. Calcite from the dyke is rich in Sr and Mn, which are typical of carbonatites. However, REEs in the calcites could not be detected by means of the EMPA (Yang et al., 1998a), indicating that REEs mainly reside in such REE minerals as bastnaesite.

REE patterns for fenites are obviously different from those of carbonatites, with lower REE content and negative Eu anomaly, declining gently to the right (Fig. 2). Even though HREEs of the fenites remain relatively plane, their LREE content had been slightly enriched, and Eu anomaly decreased, compared with the sedimentary quartz sandstone (Institute of Geo-

**Table 1** REE contents ( $10^{-6}$ ) of carbonatites and related fenites from Bayan Obo

Sample No	90/39	90/43	90/44	90/48	93/149	93/151	90/49	90/51	CD13-3	CD13-4	CD13-5
Rock type	Cbt	Cbt	Cbt	Cbt	Cbt	Cbt	Ft	Ft	Ft	Ft	Ft
La	5082.1	59295.0	33280.0	5925.0	94810.0	7207.0	28.8	33.2	1274.0	1628.0	217.8
Ce	7021.2	75534.9	42832.5	7655.9	90630.0	10370.0	56.2	67.5	1863.0	2673.0	706.2
Pr	509.9	5835.0	3456.5	603.0	5392.0	936.0	6.1	6.5	168.4	276.5	90.1
Nd	1592.0	16418.0	9438.5	1702.3	6538.0	2066.0	14.6	58.8	360.6	767.7	455.4
Sm	109.9	1146.7	797.0	143.2	492.0	240.2	3.7	3.2	29.4	172.4	149.4
Eu	22.8	236.5	155.0	37.1	49.0	77.4	0.4	0.6	8.0	60.3	51.4
Gd	52.6	512.5	346.0	93.8	458.0	211.7	2.7	2.6	21.1	162.0	134.8
Tb					52.0	25.7			2.9	18.0	15.2
Dy	28.6	338.0	217.4	65.8	565.6	110.7	1.4	1.5	13.4	104.5	75.4
Ho					39.7	23.2			2.8	19.1	9.5
Er	35.8	394.5	267.5	56.5	79.5	55.0	0.8	0.4	5.0	38.5	22.8
Tm					7.0	6.0			0.7	5.3	2.8
Yb	2.7	52.0	34.5	14.3	36.0	34.9	0.4	0.4	3.2	25.8	12.3
Lu	0.5	8.0	10.0	2.5	5.1	4.6	0.1	0.0	0.6	3.4	1.6
ΣREE	14458.0	159771.1	90834.9	16299.3	199153.9	21368.4	115.2	174.8	3753.0	5954.5	1944.6

Notes: Samples 93/149, 93/151, and CD13-3 to CD13-5 were analyzed with ICP at the Geology Department of Peking University. Cbt—carbonatite; Ft—fenite. Sample 93/149 was also analyzed with wet chemistry by Zhang Peishan,  $\Sigma\text{REE}_2\text{O}_3$  given as 23.90 wt%.