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Relative concentrations of lanthanides in minerals of the bastnaesite group

by

Michael Fleischer, 1908-

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This report is preliminary and has not been edited or reviewed for conformity with Geological Survey standards or nomenclature.

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Each of the tables is a compilation of analyses of the relative concentrations in atomic percent of the lanthanide elements (Ln) in the minerals of this group. Each table is arranged in order of increasing values of Σ (=sum of the atomic percentages of La+Ce+Pr). The entry 100Y/(Y+Ln) is the ratio of the atomic percent of Y x 100 divided by the sum of the atomic percents of Y plus all other lanthanides; it should be noted that this number is not directly comparable to the atomic percents of the other lanthanides. ΣRE_2O_3 is the sum of the weight percents of all the lanthanide oxides + Y_2O_3. Under method, the methods of analysis are abbreviated as follows: CH - chromatographic, OS - optical spectroscopy, XF - x-ray fluorescence. The rock names used are those of the authors quoted.

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	1	2	3	4	5	6	7	8	9	10
La	2.6	2.8	5.2	3.1	2.6	5.3	5.5	4.0	8.0	10.9
Ce	8.2	8.5	10.3	10.2	12.8	15.0	15.5	20.3	24.8	27.0
Pr	2.8	2.8	0.2	3.6	3.3	2.9	3.5	5.0	3.6	7.0
Nd	8.0	7.9	9.9	11.8	11.1	7.1	7.7	22.6	17.0	20.3
Sm	8.6	8.2	5.2	10.1	9.2	10.8	11.4	16.4	8.4	7.8
Eu	0.2	0.2	–	0.2	1.0	0.6	0.5	1.0	–	–
Gd	18.6	18.0	15.0	20.7	11.3	16.1	15.9	11.8	10.0	8.7
Tb	2.5	2.7	2.5	3.0	2.6	2.7	3.4	1.8	1.6	2.0
Dy	20.2	20.9	20.6	19.0	17.8	19.7	19.4	7.6	13.1	7.8
Ho	4.2	4.3	4.0	3.5	4.1	3.5	–	1.8	1.3	1.8
Er	13.0	12.7	13.4	9.3	11.8	9.7	10.2	3.7	5.5	4.4
Tm	1.2	1.1	1.6	0.6	1.7	0.8	0.8	0.5	1.3	–
Yb	8.8	8.6	9.5	4.1	8.1	5.2	5.4	3.0	5.4	2.3
Lu	1.1	1.3	2.6	0.8	2.6	0.6	0.8	0.5	–	–
100Y/(Y+Ln)	–	–	–	–	(51.7)	–	–	(34.5)	(20.2)	(29.1
Method	CH	CH	CH	CH	CH	CH	CH	XF	XF	–
Σ = La+Ce+Pr	13.6	14.1	15.7	16.9	18.7	23.2	24.5	29.3	36.4	44.9
La-Nd	21.6	22.0	25.6	28.7	29.8	30.3	32.2	51.9	53.4	65.
Sm-Ho	54.3	54.3	47.3	56.5	46.0	53.4	50.6	40.4	34.4	28.
Er-Lu	24.1	23.7	27.1	14.8	24.2	16.3	17.2	7.7	12.2	6.
ΣRE_2O_3, wt %	–	–	–	–	60.0	–	–	–	–	–
La/Nd	0.33	0.36	0.53	0.27	0.23	0.74	0.54	0.18	0.47	0.5

1/ Rare earths in [illegible]

(11-13). Semenov (1963), (11) pegmatite of alkaline granite, Kola Peninsula; (12) hydrothermalite of alkalic granosyenite, Mongolia, magnetite type; (13) hydrothermalite of alkalic granosyenite, Siberia, siderite type; (14) Kapustin (1966), carbonatite, Kovdor massif, Karelia; (15) Semenov (1963), supergene after parisite, hydrothermalite of alkaline granite, Ukraine; (16) Marchenko et al. (1968), quartz-fluorite in altered syenite, S.E. Ukrainian Shield; (17) Kapustin (1966), carbonatite, Vuorijarvi, Karelia; (18) Mineev (1968), exocontact of

	11	12	13	14	15	16	17	18	19	20
La	11.0	15.3	14.0	23.3	23.7	26.3	22.3	26.5	22.2	17.5
Ce	32.7	42.4	44.8	46.2	47.0	45.4	49.2	42.2	51.1	55.3
Pr	6.2	7.4	7.8	5.0	4.2	3.4	4.0	7.4	5.6	6.6
Nd	17.4	32.5	25.0	24.5	23.9	19.9	23.5	17.1	18.6	17.0
Sm	6.4	2.4	3.6	1.0	0.6	2.6	1.0	2.9	1.3	1.8
Eu	0.7	–	0.4	–	–	0.3	–	–	0.1	0.4
Gd	4.7	–	2.5	–	0.5	1.2	–	1.3	0.8	0.6
Tb	1.1	–	0.3	–	–	0.1	–	0.8	0.1	–
Dy	7.3	–	0.6	–	0.1	0.6	–	0.4	0.2	0.4
Ho	1.6	–	0.1	–	–	–	–	0.1	–	0.1
Er	5.1	–	0.3	–	–	0.2	–	0.2	–	0.3
Tm	0.8	–	–	–	–	–	–	0.1	–	–
Yb	4.3	–	0.6	–	–	–	–	0.8	–	–
Lu	0.7	–	–	–	–	–	–	0.2	–	–
100 Y/(Y+Ln)	(39.3)	–	(7.2)	–	–	(15.6)	–	–	–	–
Method	XF	XF	XF	XF	XF	–	XF	CH	XF	XF
Σ = La+Ce+Pr	49.9	65.1	66.6	74.5	74.9	75.1	75.5	76.1	78.9	79.4
La-Nd	67.3	97.6	91.6	99.0	98.8	95.0	99.0	93.2	97.5	96.4
Sm-Ho	21.8	2.4	7.5	1.0	1.2	4.8	1.0	5.5	2.5	3.3
Er-Lu	10.9	–	0.9	–	–	0.2	–	1.3	–	0.3
ΣRE_2O_3, wt %	–	–	–	73.6	–	–	74.0	–	–	~75
La/Nd	0.63	0.47	0.56	0.95	0.99	1.32	0.95	1.55	1.20	1.03

metasomatite, Tarbagatau, Kazakhstan; (19) Semenov (1963), supergene after huanghoite, hydrothermalite of alkali granosyenite, Mongolia; (20) Khomyakov (1964), siderite vein associated with granosyenite, W. Tannu-Ola, Siberia

Table 1. Rare earths in bastnaesite and bastnaesite-(Y), at. % - 3

	21	22	23	24	25	26	27	28	29	30
La	31.4	24.4	25.8	25.0	24.7	30.8	27.3	27.3	30.5	29.6
Ce	48.4	51.5	49.1	49.7	52.5	45.5	50.2	50.1	47.9	48.6
Pr	–	4.3	5.6	6.6	4.2	5.5	4.5	4.9	4.3	4.5
Nd	20.2	14.8	18.1	17.5	17.1	15.7	16.6	15.9	15.5	15.4
Sm	–	2.6	0.9	0.8	1.5	1.7	0.7	1.7	1.3	1.4
Eu	–	–	0.5	–	–	a	0.1	–	–	–
Gd	–	1.7	–	0.4	–	0.8[a]	0.4	0.1	0.5	0.5
Tb	–	0.2	–	–	–	–	–	–	–	–
Dy	–	0.5	–	–	–	–	0.1	–	–	–
Ho	–	–	–	–	–	–	–	–	–	–
Er	–	–	–	–	–	–	0.1	–	–	–
Tm	–	–	–	–	–	–	–	–	–	–
Yb	–	–	–	–	–	–	–	–	–	–
Lu	–	–	–	–	–	–	–	–	–	–
Y/(Y+Ln)x100	–	–	–	–	–	–	–	(1.4)	(0.3)	–
Method	OS	XF	XF	XF	XF	CH	XF	OS	OS	XF
Σ = La+Ce+Pr	79.8	80.2	80.5	81.3	81.4	81.8	82.0	82.3	82.7	82.7
La–Nd	100.0	95.0	98.6	98.8	98.5	97.5	98.6	98.2	98.2	98.1
Sm–Ho	–	5.0	1.4	1.2	1.5	2.5	1.3	1.8	1.8	1.9
Er–Lu	–	–	–	–	–	–	0.1	–	–	–
RE_2O_3	–	–	–	–	64.5	74.0	75.8	–	–	–
La/Nd	1.55	1.65	1.43	1.43	1.44	1.96	1.68	1.72	1.97	1.93

a) Eu+Gd calcd as Gd

(21) Clifford et al. (1962), granite, Franzfontein, S.W. Africa; (22) Tikhonenkova and Tikhonenkov (1962), fenite, Lovozero massif, Kola Peninsula; (23) Semenov and Barinskii (1958), hydrotherm of alkaline granite, Tuva; (24) Semenov (1963), hydrothermalite of alkalic granosyenite, Siberia; (25) Aleksandrov et al. (1965), Inner Mongolia; (26) Nedashkovskii et al. (1969), quartz-albite metasomatite, Far Eastern USSR; (27) Khomyakov (1964), carbonate vein associated with granosyenite, W. Tannu-Ola, Siberia; (28-29) Murata et al. (1957); (28) carbonatite, Mountain Pass, Calif.; (29) veins in pegmatized schists, Ruanda-Urundi; (30) Van Wambeke (1977), hydrothermal, carbonatite (?), Karonge deposit, Burundi, Africa compare (29)

Table 1. Rare earths in bastnaesite and bastnaesite-(Y), at. % - 4

(31) Semenov (1963), hydrothermalite of alkalic granosyenite, Mongolia; (32) Ganzeeva

	31	32	33	34	35	36	37	38	39	40
La	32.3	35.1	23.7	28.8	30.7	28.4	26.4	37.1	42.3	27.3
Ce	45.9	44.3	54.9	49.1	49.3	51.3	52.7	43.4	39.6	54.2
Pr	4.8	4.0	5.0	5.9	4.4	4.8	5.4	4.7	3.3	4.1
Nd	15.6	12.8	15.3	13.6	14.4	13.7	14.5	6.4	13.6	13.7
Sm	1.4	2.2	1.1	1.7	1.2	0.9	1.0	2.4	1.2	0.3
Eu	–	0.2	–	–	–	0.1	–	0.2	–	–
Gd	–	1.1	–	0.6	–	0.5	–	1.0	–	0.4
Tb	–	–	–	–	–	–	–	–	–	–
Dy	–	–	–	0.3	–	0.3	–	1.6	–	–
Ho	–	0.1	–	–	–	–	–	0.2	–	–
Er	–	0.2	–	–	–	–	–	1.5	–	–
Tm	–	–	–	–	–	–	–	0.2	–	–
Yb	–	–	–	–	–	–	–	1.1	–	–
Lu	–	–	–	–	–	–	–	0.2	–	–
Y/(Y+Ln)x100	–	(2.4)	–	–	–	–	(0.5)	–	–	–
Method	XF	–	XF	CH	OS	XF	OS	XF	XF	XF
Σ = La+Ce+Pr	83.0	83.4	83.6	83.8	84.4	84.5	84.5	85.2	85.2	85.6
La-Nd	98.6	96.2	98.9	97.4	98.8	98.2	99.0	91.6	98.8	99.3
Sm-Ho	1.4	3.6	1.1	2.6	1.2	1.8	1.0	5.4	1.2	0.7
Er-Lu	–	0.2	–	–	–	–	–	3.0	–	–
RE_2O_3	–	–	–	–	–	–	–	–	–	–
La/Nd	2.07	2.75	1.55	2.11	2.00	2.07	1.82	5.83	3.11	1.99

(1972), rare-earh-beryl metasomatite; (33) Gerasimorskii (1964), hydrothemal carbonate, N. Baikal; (34) Mineer (1968), quartz crystal pegmatite, Akzhalyc, Kazakhstan; (35) Murata et al. (1957), carbonatite vein in shonkinite, Mountain Pass, Calif.; ( ) Semenov (1963), supergene after cordylite, alkali syenite pegmatite, Narsarsuk, Greenland; (37) Murata et al (1957), granitic pegmatite, Cheyenne Canyon, Colo.; (38) Mineev, Makarochkin, and Zhabin (1962), supergene, after allanite, Il'men Mts, Urals; (39) Bastnaesite-(La), Vainshtein et al. (1961), carbonatite, E. Sayan; (40) Semenov (1963), hydrothermal lead-zinc deposit, southern Asia

Table 1. Rare earths in bastnaesite and bastnaesite-(Y), at % - 5

(41) Semenov, Kostyunina, and Kulakov (1967), quartz-fluorite pegmatite, Tarabagatau, Kazakhstan;

	41	42	43	44	45	46	47	48	49	50
La	26.4	41.0	37.3	29.4	35.3	31.4	20.1	39.3	45.3	27.5
Ce	55.5	40.8	43.1	53.3	48.6	51.8	63.9	45.0	39.3	54.5
Pr	4.0	4.2	6.1	4.0	3.1	4.2	3.4	3.3	3.1	5.9
Nd	11.1	11.1	12.0	12.7	12.3	9.1	10.7	10.7	10.0	10.2
Sm	1.4	1.4	1.1	0.4	0.4	1.7	1.1	0.7	1.2	1.4
Eu	0.1	0.1	-	-	-	-	-	0.1	-	-
Gd	0.5	-	0.4	0.2	0.2	1.1	0.8	0.5	1.1	0.4
Tb	-	-	-	-	-	-	-	0.1	-	-
Dy	0.4	0.5	-	-	0.1	0.4	-	0.3	-	0.1
Ho	-	0.5	-	-	-	-	-	-	-	-
Er	-	0.2	-	-	-	0.3	-	-	-	-
Tm	-	-	-	-	-	-	-	-	-	-
Yb	0.6	0.2	-	-	-	-	-	-	-	-
Lu	-	-	-	-	-	-	-	-	-	-
Y/(Y+Ln)x100	-	-	(0.8)	-	-	-	-	-	(3.3)	-
Method	XF	OS	XF	XF	XF	-	XF	XF	CH	-
Σ = La+Ce+Pr	85.9	86.0	86.5	86.7	87.0	87.4	87.4	87.6	87.7	87.9
La-Nd	97.0	97.1	98.5	99.4	99.3	96.5	98.1	98.3	97.7	98.1
Sm-Ho	2.4	2.5	1.5	0.6	0.7	3.2	1.9	1.7	2.3	1.9
Er-Lu	0.6	0.4	-	-	-	0.3	-	-	-	-
RE_2O_3	74.8	-	-	-	75.7	-	-	-	-	-
La/Nd	2.38	3.69	3.12	2.30	2.87	3.45	1.87	3.66	4.53	2.70

(42) McKie (1962), carbonatite, Wigu, Tanzania (monazite and goyazite present); (43) Kupriyanova (1968), albitite, Siberia; (44) Semenov (1963), hydrothermalite of alkalic granosyenite, Siberia; (45) Es'kova and Ganzeev (1964), calcitic veins, Vishnevye Mts, Urals, (46) Mineev (1968), pseudomorph after allanite, quartz crystal pegmatite, Akhzhalyau, Kazakhstan; (47) Van Wambeke (1977), Karonge deposit, Burundi, Africa; (48) Semenov, Khomyakov, and Bykova (1961), supergene after parisite, alkalic massif, central Siberia; (49) Bastnaesite-(La), see no. 43; (50) Mineev (1968), pseudomorph after monazite, Tarbagatau, Kazakhstan.

Table 1. Rare earths in bastnaesite and bastnaesite-(Y), at.% — 6

(51) Es'kova and Ganzeev (1964), calcite veinlet in fenite, Vishnevye Mts., Urals; (52) Shaw

	51	52	53	54	55	56	57	58	59	60
La	31.5	28.6	31.2	30.9	32.3	36.3	34.7	35.7	35.1	43.6
Ce	53.0	56.0	51.6	52.1	54.3	50.4	52.6	51.7	51.8	43.7
Pr	3.5	4.1	6.2	6.1	3.3	3.3	3.0	3.0	3.8	3.5
Nd	11.5	10.5	10.1	10.0	9.6	10.0	8.7	8.9	8.5	8.4
Sm	0.3	0.6	0.9	0.9	0.3	–	0.6	0.2	0.7	0.8
Eu	–	–	–	–	–	–	–	–	0.1	–
Gd	0.1	0.2	–	–	0.1	–	0.3	0.4	–	–
Tb	–	–	–	–	–	–	–	–	–	–
Dy	0.1	–	–	–	0.1	–	0.1	0.1	–	–
Ho	–	–	–	–	–	–	–	–	–	–
Er	–	–	–	–	–	–	–	–	–	–
Tm	–	–	–	–	–	–	–	–	–	–
Yb	–	–	–	–	–	–	–	–	–	–
Lu	–	–	–	–	–	–	–	–	–	–
Y/(Y+Ln)x100	–	–	–	–	–	–	–	–	–	–
Method	XF	–	–	–	XF	XF	XF	XF	XF	OS
Σ = La+Ce+Pr	88.0	88.9	89.0	89.1	89.9	90.0	90.3	90.4	90.7	90.8
La–Nd	99.5	99.2	99.1	99.1	99.5	100.0	99.0	99.3	99.2	99.2
Sm–Ho	0.5	0.8	0.9	0.9	0.5	–	1.0	0.7	0.8	0.8
Er–Lu	–	–	–	–	–	–	–	–	–	–
RE_2O_3	–	60.4	73.2	73.2	–	75.2	–	74.7	–	–
La/Nd	2.74	2.81	3.10	3.10	3.36	3.63	4.00	4.02	4.13	5.19

(1959), ore concentrate, Mountain Pass, Calif.; (53) Cheverdin (1960), albitized alkalic rocks, Borsuksai massif, Kazakhstan; (54) Nurlybaev (1976), alkalic rocks, Kazakhstan (same as 53(?)) (55) Zhabin and Svyazhin (1962), zoned aggregates, alkalic rocks, Vishnevye Mts., Urals. (56) Aleksandrov et al. (1965), hyroxyl-Basnaesite, veinlet in dolomitic carbonatite, eastern Yakutia; (57) Es'kova, Zhabin, and Mukhitdinov (1964), incrustation on chevkinite, Vishnevye Mts, Urals; (58) Es'kova and Ganzeev (1964), alkalic pegmatite, Vishnevye Mts, (59) Semenov and Barinskii (1958), granite pegmatite, Madagascar; (60) Murata et al. (1957), carbonate vein in shonkonite, Mt Pass, Calif.

Table 1 - Rare earths in bastnaesite and bastnaesite-(Y), at % - 7

(61) Somina and Bulakh (1972), carbonatite, E. Syan; (62) Kirillov (1964), hydroxy-

	61	62	63	64	65	66	67	68		
La	32.3	37.8	40.2	35.2	44.1	44.9	39.6	38.1		
Ce	56.2	53.1	48.9	53.7	44.6	44.5	52.9	52.8		
Pr	2.5	–	3.0	3.2	3.8	3.3	1.0	5.0		
Nd	6.3	4.7	7.7	7.8	7.0	7.0	6.2	–		
Sm	1.8	2.1	0.2	0.1	0.5	0.1	0.3	2.3		
Eu	a	–	–	–	–	a	–	a		
Gd	0.9[a]	–	–	–	–	0.1[a]	–	1.8[a]		
Tb	–	–	–	–	–	0.1	–	–		
Dy	–	1.8	–	–	–	–	–	–		
Ho	–	–	–	–	–	–	–	–		
Er	–	–	–	–	–	–	–	–		
Tm	–	–	–	–	–	–	–	–		
Yb	–	–	–	–	–	–	–	–		
Lu	–	–	–	–	–	–	–	–		
Y/(Y+Ln)x100	–	(0.1)	–	–	(0.1)	–	–	–		
Method	CH	OS	XF	XF	OS	CH	XF	CH		
Σ = La+Ce+Pr	91.0	91.4	92.1	92.1	92.5	92.7	93.5	95.9		
La–Nd	97.3	96.1	99.8	99.9	99.5	99.7	99.7	95.9		
Sm–Ho	2.7	3.9	0.2	0.1	0.5	0.3	0.3	4.1		
Er–Lu	–	–	–	–	–	–	–	–		
RE_2O_3	70.7	68.9	–	75.8	–	–	–	74.3		
La/Nd	5.17	8.09	5.22	4.52	6.30	6.46	6.34	–		

(a) Eu+Gd calcd. as Gd

bastnaesite, carbonatite, Vuorijarri, Karelia; (63) Semenov and Barinskii (1958), alkalic granite pegmatite, Vishnevye Mts, Urals; (64) Khalezova and Nazarenko (1939), quartz vein in fenite, Vishnevy Mts; (65) Murata et al. (1957), hydrothermal fluorite-barite vein, Gallinas Mts, N Mex.; (66) Svyazhin (1965), bastnaesite-(La), var. kyshtymite, fenitized granite pegmatite, Urals, (67) Khomyakov (1972), albite-aegirine metasomatite, Burpala massif, N. Baikal; (68) Kirillov and Ryzhova (1968), hydroxyl-bastnaesite, carbonatite, Karelia

Table 2. Rare earths in Parisite, at. %

(1) Khomyakov (1964), calcite veins, W. Tannu-Ola, Siberia; (2) Gerasimovskii (1964), hydrothermal, N. Baikal; (3) Khomyakov and Semenov (1971), siderite veins, Siberia; (4) Semenov, Khomyakov, and Bykova (1961), alkalic massif; (5) Semenov (1963), granite, Dunbei; (6) Semenov (1963), emerald-bearing pegmatite, Muzo, Colombia; (7) Khomyakov and Semenov (1971), calcite veins, Siberia; (8) Semenov (1963), granitized trachyte, Ravalli, Mont.; (9) Semenov (1963), syenite pegmatite, Narsarsuk, Greenland

	1	2	3	4	5	6	7	8	9	10
La	14.3	22.3	23.3	23.6	19.3	24.6	32.6	22.3	29.4	29.0
Ce	42.5	41.3	46.3	46.9	49.1	44.5	44.3	47.5	45.3	47.2
Pr	7.6	4.6	5.0	5.1	7.3	6.9	–	7.8	5.5	5.0
Nd	24.7	18.7	20.6	20.9	16.7	18.7	21.7	17.5	14.8	16.2
Sm	4.8	4.0	1.5	1.5	3.5	2.5	–	2.4	3.0	1.1
Eu	0.5	–	0.7	0.7	0.2	0.1	–	0.3	0.1	–
Gd	3.1	2.9	0.8	0.8	1.9	1.1	1.4	1.0	1.9	1.3
Tb	0.4	0.8	0.2	0.2	0.1	0.1	–	0.1	–	–
Dy	0.9	3.0	1.6	0.3	0.4	0.3	–	0.4	–	–
Ho	0.1	0.7	–	–	–	–	–	–	–	–
Er	0.3	1.0	–	–	0.5	0.1	–	0.1	–	–
Tm	–	–	–	–	–	–	–	–	–	–
Yb	0.8	0.7	–	–	1.0	1.1	–	0.5	–	0.2
Lu	–	–	–	–	–	–	–	0.1	–	–
100Y/(Y+Ln)	–	(18.8)	–	–	–	(7.2)	–	(7.1)	–	(1.5)
Method	XF	XF	XF	XF	XF	XF	XF	XF	XF	–
Σ = La+Ce+Pr	64.4	68.2	74.6	75.6	75.7	76.0	76.9	77.6	80.2	81.2
La-Nd	89.1	86.9	95.2	96.5	92.4	94.7	98.6	95.1	95.0	97.4
Sm-Ho	9.8	11.4	4.8	3.5	6.1	4.1	1.4	4.2	5.0	2.1
Er-Lu	1.1	1.7	–	–	1.5	1.2	–	0.7	–	0.[illegible]
ΣRE_2O_3, %	60	–	–	–	–	–	–	–	–	–
La/Nd	0.58	1.19	1.13	1.13	1.16	1.32	1.50	1.28	2.00	1.78

(10) Kuts (1971), fluorite-calcite vein in granosyenite, av. of 2;

Table 4 Rare earths in Parisite-2 At. %

(11) Vainshtein, Tugarinov, and Turanskaya (1956), hydrothermal veins, Mariupol, Ukraine; (12) Borovskii and Gerasimovskii (1945), nepheline syenite, Mariupol; (13) Balashov and Pozharitskaya (1968), carbonatite, E. Siberia; (14) Murata et al. (1957), carbonate vein, Mountain Pass, Calif.; (15) Chistov (1965), carbonatite, E. Siberia (16) Kapustin (1966), carbonatite, E. Sayan; (17) Semenov (1963), siderite veins, Mongolia; (18) Khomyakov (1972), albitized syenite pegmatite, Burpala massif, N. Transbaikal;

	11	12	13	14	15	16	17	18	19	20
La	29.2	32.5	31.2	31.0	28.1	33.3	29.6	34.4	35.3	29.9
Ce	50.9	44.4	47.9	49.5	54.2	50.1	55.7	51.5	51.0	55.3
Pr	3.8	7.1	5.2	4.2	4.5	4.0	3.2	3.1	3.0	4.5
Nd	14.6	16.0	14.2	14.0	12.1	10.8	9.9	10.2	9.8	9.7
Sm	1.5	-	1.5	1.3	1.1	0.9	0.3	0.5	0.9	0.3
Eu	-	-	-	-	-	-	-	-	-	a
Gd	-	-	-	-	-	0.7	0.5	0.3	-	0.3[a]
Tb	-	-	-	-	-	-	-	-	-	-
Dy	-	-	-	-	-	0.2	0.2	-	-	-
Ho	-	-	-	-	-	-	-	-	-	-
Er	-	-	-	-	-	-	0.3	-	-	-
Tm	-	-	-	-	-	-	-	-	-	-
Yb	-	-	-	-	-	-	0.3	-	-	-
Lu	-	-	-	-	-	-	-	-	-	-
100Y/(Y+Ln)	-	-	-	0.2	-	-	-	-	-	0.3
Method	XF	XF	XF	OS	OS	XF	XF	XF	XF	CH
Σ = La+Ce+Pr	83.9	84.0	84.3	84.7	86.8	87.4	88.5	89.0	89.3	89.7
La-Nd	98.5	100.0	98.5	98.7	98.9	98.2	98.4	99.2	99.1	99.4
Sm-Ho	1.5	-	1.5	1.3	1.1	1.8	1.0	0.8	0.9	0.6
Er-Lu	-	-	-	-	-	-	0.6	-	-	-
ΣRE_2O_3	-	-	-	-	58.5	59.0	-	-	-	-
La/Nd	2.00	2.03	2.20	2.21	2.32	3.10	3.00	3.38	3.61	3.09

a) Eu + Gd calcd as Gd

(19) Kapustin (1966), carbonatite, E. Sayan; (20) Somina and Bulakh (1972), carbonatite, E. Sayan

Table 2 [illegible]

21. Vainshtein, Pozharitskaya, and Turanskaya (1961), carbonatite, E. Sayan;
22. Pavlenko, Vainshtein, and Turanskaya (1959), albitized syenite, Burek-Kundus massif, E. Tuva.

	21	22								
La	35.8	36.5								
Ce	52.0	50.9								
Pr	3.3	4.1								
Nd	8.5	8.5								
Sm	0.4	–								
Eu	–	–								
Gd	–	–								
Tb	–	–								
Dy	–	–								
Ho	–	–								
Er	–	–								
Tm	–	–								
Yb	–	–								
Lu	–	–								
100Y/(Y+Ln)	–	–								
Method	XF	XF								
Σ = La+Ce+Pr	91.1	91.5								
La-Nd	99.6	100.0								
Sm-Ho	0.4	–								
Er-Lu	–	–								
ΣRE_2O_3	–	–								
La/Nd	4.21	4.29								

Rare earths in [illegible]

(1) Levinson and Borup (1962), syn.-(Y), granite pegmatite, near Cotopaxi, Colo.; (2) Mineev (1968), syn.-(Y), astrophyllite-bearing pegmatite, Tarbagatau, Kazakhstan; (3) Mineev (1963), syn.-(Y), exocontact metasomatite, riebeckite-albite granite, Tarbagatau; (4) see no. 2; (5-6) Mineev (1968), see no. 3; (7) Lozinski (1971), mixt. of syn.-(Y) + francolite, dinosaur bones, Mongolia; (8) Semenov (1959), syn.-(Y), hydrothermal deposit, N. Kirgizia; (9) Gurov and Gurova (1975), syn.-(Y), inclusions in fluorite, Ukraine

	1	2	3	4	5	6	7	8	9	10
La	-	0.5	3.0	3.0	5.3	10.1	42.2	12.1	20.3	19.5
Ce	-	1.9	0.5	9.5	21.0	24.0	8.9	40.6	36.0	39.7
Pr	-	0.2	1.3	2.9	3.2	4.5	5.9	6.4	4.2	6.6
Nd	-	0.9	2.1	9.0	15.3	12.3	21.6	16.1	20.5	24.8
Sm	-	4.4	4.1	7.8	3.9	6.1	2.3	6.3	4.5	3.8
Eu	-	3.3	0.9	0.3	-	-	2.4	0.3	-	0.6
Gd	15.0	11.6	9.0	16.4	9.3	6.2	4.1	5.4	3.7	2.5
Tb	-	2.7	2.1	2.1	1.0	2.3	0.7	1.3	-	0.2
Dy	29.1	22.4	21.2	18.1	11.3	11.5	4.7	6.2	3.1	1.3
Ho	-	6.2	7.0	3.8	2.7	3.2	1.2	1.0	0.8	0.1
Er	28.4	24.4	24.3	12.4	10.9	9.1	3.0	2.5	2.5	0.6
Tm	-	2.0	2.5	1.5	1.2	1.4	0.3	0.2	0.5	-
Yb	27.5	16.1	18.2	11.3	14.9	8.0	2.0	1.2	3.4	0.3
Lu	-	3.4	3.8	1.9	-	1.3	0.7	0.4	0.5	-
100Y/(Y+Ln)	(71.5)	-	-	-	-	-	(46.1)	(42.4)	(36.2)	-
Method	XF	-	-	-	-	-	CH	XF	OS	XF
Σ = La+Ce+Pr	-	2.6	4.8	15.4	29.5	38.6	57.0	59.1	60.5	65.8
La-Nd	-	3.5	6.9	24.4	44.8	50.9	78.6	75.2	81.0	90.6
Sm-Ho	44.1	50.6	44.3	48.5	28.2	29.3	15.4	20.5	12.1	8.5
Er-Lu	55.9	45.9	48.8	27.1	27.0	19.8	6.0	4.3	6.9	0.9
ΣRE_2O_3, wt %	46.1	-	-	-	-	-	-	26.9	-	-
La/Nd	-	0.52	1.42	0.33	0.35	0.81	1.95	0.75	0.99	0.79

(10) Khomyakov and Semenov (1971), ankerite vein, S. Siberia

Rare earths in syenites and syenite [illegible]

(11) Semenov (1963), alkali syenite pegmatite ;

	11									
La	21.5									
Ce	43.7									
Pr	5.5									
Nd	20.8									
Sm	3.5									
Eu	0.4									
Gd	2.5									
Tb	0.4									
Dy	0.6									
Ho	0.2									
Er	0.4									
Tm	–									
Yb	0.5									
Lu	–									
100Y/(Y+Ln)	(7.2)									
Method	XF									
Σ = La+Ce+Pr	70.7									
La-Nd	91.5									
Sm-Ho	7.6									
Er-Lu	0.9									
ΣRE_2O_3	–									
La/Nd	1.03									

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