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Open-File Report 78-530

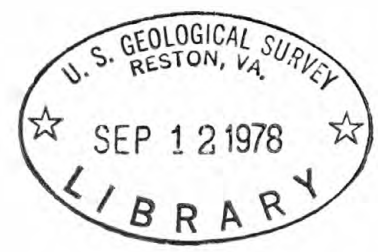
Relative concentration of lanthanides in titanite (sphene)

by

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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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Explanation of tables, Open File Report no. 78-530

Relative concentration of lanthanides in titanite (sphene)

The table is a compilation of 271 analyses of the relative concentrations in atomic percent of lanthanide elements (Ln) and yttrium in the mineral titanite (sphene). The table is arranged in order of increasing value of Σ (= sum of the atomic percents 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 the lanthanides; it should be noted that this number is not directly comparable to the atomic percents of all the lanthanide oxides + Y_2O_3 . Under method, the methods of analysis are abbreviated as follows:

CH = chromatographic

EP = electron microprobe

MS = mass spectrometer,

OS = optical spectroscopy

XF = x-ray fluorescence

Titanite - 1 (At. %)

- (1) Goldsmith, Snyder, and Conklin (1961), granitic gneiss, Conn.; (2) Staatz et al. (1977), thorite vein, Hall Mt. district, northern Idaho; (3) Orsa et al. (1967), biotite-plagioclase gneiss, Bashmachka, Middle Dnepr region; (4) Batieva (1976), alkalic granite Kola Peninsula; (5) Orsa et al. (1967), microclinized biotite-plagioclase gneiss, Middle Dnepr region; (6) Semenov and Barinskii (1958), granite pegmatite, Ireland, Norway; (7) same as (4); (8) Lyakhovich (1968), biotite granite, Urals; (9) same as (6); (10) Kufs (1973),

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---------------------|--------|--------|-------------------|--------|-------------------|------|--------|------|------|--------|
| La | - | - | 1.7 | 1.2 | 1.2 | 1.8 | 1.3 | 2.6 | 2.8 | 1.4 |
| Ce | - | - | 2.5 | 3.7 | 5.0 | 6.3 | 8.6 | 8.4 | 8.5 | 11.0 |
| Pr | - | - | 0.2 | 1.4 | 3.2 | 4.1 | 2.6 | 2.9 | 2.7 | 1.7 |
| Nd | - | - | 12.3 | 6.4 | 11.4 | 12.1 | 15.2 | 4.6 | 9.8 | 18.6 |
| Sm | - | - | 4.7 | 7.2 | 6.9 | 6.4 | 8.5 | 6.8 | 7.3 | 9.8 |
| Eu | - | 8.3 | a | 0.8 | a | 0.5 | 0.8 | 2.7 | 0.7 | - |
| Gd | 7.4 | 20.4 | 16.5 ^a | 10.8 | 14.8 ^a | 9.5 | 13.3 | 12.9 | 18.1 | 13.0 |
| Tb | - | - | 0.9 | 4.9 | 3.2 | 1.5 | 2.2 | 2.1 | 2.5 | 2.5 |
| Dy | 33.6 | 26.0 | 16.1 | 21.6 | 13.9 | 10.9 | 20.3 | 17.4 | 16.6 | 8.6 |
| Ho | 7.1 | 5.7 | 8.8 | 7.9 | 5.8 | 2.7 | 3.4 | 4.8 | 3.5 | 2.9 |
| Er | 14.0 | 18.1 | 18.0 | 13.7 | 16.0 | 12.6 | 9.4 | 14.2 | 11.4 | 12.5 |
| Tm | 3.2 | 3.7 | 0.2 | 4.6 | 3.0 | 2.4 | 2.4 | 1.5 | 1.4 | 1.9 |
| Yb | 31.6 | 16.0 | 17.9 | 12.3 | 15.3 | 24.5 | 9.3 | 16.7 | 12.9 | 14.0 |
| Lu | 3.1 | 1.8 | 0.2 | 3.5 | 0.3 | 4.7 | 2.7 | 2.4 | 1.8 | 2.1 |
| 100Y/(Y+Lu) | (86.0) | (75.3) | (66.2) | (71.4) | (72.6) | - | (61.6) | - | - | (71.3) |
| Geochem | OS | OS | CH | - | CH | XF | - | XF | XF | OS |
| $\Sigma = La+Ce+Pr$ | 0 | 0 | 4.4 | 6.3 | 9.4 | 12.2 | 12.5 | 13.9 | 14.0 | 14.1 |
| La-Nd | 0 | 0 | 16.7 | 12.7 | 20.8 | 24.3 | 27.7 | 18.5 | 23.8 | 32.7 |
| Sm-Ho | 48.1 | 60.4 | 47.0 | 53.2 | 44.6 | 31.5 | 48.5 | 46.7 | 48.7 | 36.8 |
| Er-Lu | 51.9 | 39.6 | 36.3 | 34.1 | 34.6 | 44.2 | 23.8 | 34.8 | 27.5 | 30.5 |
| ΣRE_2O_3 | - | - | - | 8.00 | - | - | 2.49 | 0.37 | - | 2.48 |
| La/Nd | - | - | 0.14 | 0.18 | 0.10 | 0.15 | 0.09 | 0.57 | 0.29 | 0.08 |

(a) Eu + Gd calcd. as Gd

hornblende-biotite granite, St. Ignat'evka,
Azov Sea region.

Titanite - 2

(11) Belkov and Batieva (1971), granodiorite, Panskikh, Kola Peninsula; (12-13) Batieva (1976), alkaline granites, Kola Peninsula; (14) Lyakhovich (1968), biotite granite, Tuva; (15) Semenov, Kostyunina, and Kulakov (1967), quartz-fluorite pegmatite, Betpakdel, Kazakhstan; (16) Lee et al. (1969), granitoid, Snake Range, White Pine Co., Ne (17) Goldsmith, Snyder, and Conklin (1961), granitic gneiss, Conn.; (18) Belkov and Batieva (1971),

| | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---------------------|--------|--------|--------|------|--------|--------|--------|-------------------|--------|------|
| La | 3.3 | 2.9 | 2.0 | 1.9 | 1.6 | 3.4 | 4.0 | 8.3 | 1.6 | 2.3 |
| Ce | 10.6 | 10.4 | 11.7 | 12.6 | 12.7 | 13.6 | 16.8 | 10.6 | 16.1 | 14.3 |
| Pr | 2.1 | 3.3 | 3.3 | 3.6 | 4.8 | 3.3 | - | 2.2 | 4.0 | 5.9 |
| Nd | 14.5 | 18.9 | 18.6 | 6.5 | 16.2 | 33.2 | 38.2 | 15.0 | 22.1 | 29.1 |
| Sm | 8.3 | 8.4 | 8.8 | 10.8 | 9.0 | 19.1 | 7.8 | 13.2 | 8.5 | 13.5 |
| Eu | a | 0.8 | 0.9 | 0.4 | 0.2 | 1.9 | 1.6 | a | 1.1 | 1.1 |
| Gd | 12.9 | 12.9 | 1.8 | 14.1 | 10.9 | 12.1 | 7.5 | 11.7 ^a | 10.3 | 18.3 |
| Tb | 6.1 | 4.2 | 4.7 | 2.1 | 1.4 | 0.3 | 0.7 | 6.9 | 4.5 | 1.0 |
| Dy | 12.7 | 17.8 | 16.3 | 16.2 | 12.3 | 8.7 | 14.5 | 9.3 | 12.9 | 9.4 |
| Ho | 4.1 | 2.1 | 3.2 | 3.6 | 2.1 | 1.2 | 1.4 | 4.6 | 2.6 | 2.0 |
| Er | 10.4 | 8.1 | 7.9 | 11.9 | 10.3 | 1.7 | 3.3 | 8.0 | 6.2 | 3.1 |
| Tm | 2.0 | 2.0 | 2.6 | 0.2 | 1.5 | 0.4 | 0.7 | 3.1 | 1.1 | - |
| Yb | 9.4 | 6.4 | 6.6 | 13.8 | 13.3 | 0.9 | 3.2 | 7.1 | 7.5 | - |
| Lu | 3.1 | 1.8 | 1.6 | 2.3 | 3.7 | 0.2 | 0.3 | - | 1.5 | - |
| 100Y/(Y+Lu) | (67.3) | (51.6) | (54.9) | - | (61.8) | (17.7) | (38.2) | (40.3) | (42.5) | - |
| Method | CH | - | - | XF | XF | OS | OS | CH | - | XF |
| $\Sigma = La+Ce+Pr$ | 16.0 | 16.6 | 17.0 | 18.1 | 19.1 | 20.3 | 20.8 | 21.1 | 21.7 | 22.9 |
| La-Nd | 30.5 | 35.5 | 35.6 | 24.6 | 35.3 | 53.5 | 59.0 | 36.1 | 43.8 | 51.6 |
| Sm-Ho | 44.1 | 46.2 | 45.7 | 47.2 | 35.9 | 43.3 | 33.5 | 45.7 | 39.9 | 45.1 |
| Er-Lu | 25.4 | 18.3 | 18.7 | 28.2 | 28.8 | 3.2 | 7.5 | 18.2 | 16.3 | 3.1 |
| ΣRE_2O_3 | 1.07 | 1.04 | 2.36 | 5.0 | 8.04 | 2.04 | - | 0.44 | 2.19 | 0.62 |
| La/Nd | 0.23 | 0.16 | 0.11 | 0.29 | 0.77 | 0.10 | 0.10 | 0.55 | 0.07 | 0.08 |

(a) Eu+Gd calcd as Gd

granodiorite, Strcl'na River, Kola Peninsula; (19) Bekolo (1966), pegmatitic granite, Uman area; (20) Lyakhovich (1968), diorite-granodiorite, eastern Sayan

Titanite - 3

- (21) Belkov and Batieva (1971), granodiorite, Umba River, Kola Peninsula; (22) Lee et al. (1969), granitoid, Snake Range, White Pine Co., Nev.; (23) Lunts (1972), pegmatite of alkalic granite, northeastern U.S.S.R.; (24) Mason (1975), gneiss, Goldthab region, W. Greenland; (25) Batieva (1976), alkalic granite, Kola Peninsula; (26) same as (22); (27) same as (21); (28) same as (24); (29) same as (23); (30) Staatz et al (1977), granite pegmatite, Kingman, Ariz.

| | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
|---------------------|---------------------|--------|--------|---------|--------|--------|-------------------|---------|--------|--------|
| La | 3.1 | 2.0 | 10.8 | 2.7 | 6.8 | 3.4 | 3.6 | 5.0 | 9.8 | 6.2 |
| Ce | 15.9 | 20.0 | 14.0 | 19.5 | 15.7 | 21.7 | 19.7 | 17.6 | 17.9 | 18.3 |
| Pr | 4.5 | 2.8 | 0.7 | 4.1 | 3.9 | 2.1 | 4.1 | 6.1 | 1.3 | 4.6 |
| Nd | 20.8 | 27.1 | 14.8 | 23.1 | 22.7 | 31.5 | 29.2 | 30.3 | 9.4 | 21.0 |
| Sm | 9.7 | 18.5 | 7.2 | 10.0 | 9.6 | 15.2 | 9.7 | 8.8 | 3.4 | 9.2 |
| Eu | a | 1.1 | - | 1.8 | 0.9 | 2.0 | a | 4.2 | - | 1.8 |
| Gd | 15.8 ^a | 17.8 | 9.1 | 11.2 | 11.0 | 9.7 | 11.1 ^a | 8.0 | 9.0 | 8.7 |
| Tb | b | 0.5 | - | 1.9 | 1.8 | - | 3.3 | 1.2 | 3.3 | - |
| Dy | 9.7 | 6.9 | 17.5 | 10.4 | 13.5 | 9.4 | 7.8 | 7.8 | 21.2 | 11.3 |
| Ho | 3.8 | 0.5 | 4.5 | 2.6 | 1.4 | 0.9 | 1.7 | 1.9 | 3.4 | 3.9 |
| Er | 7.4 | 1.7 | 14.0 | 6.6 | 7.5 | 1.9 | 3.8 | 4.5 | 11.8 | 5.5 |
| Tm | 1.3 | 0.3 | 0.4 | 0.9 | 1.1 | 0.6 | 1.4 | 0.6 | 2.0 | 0.5 |
| Yb | 7.2 | 0.7 | 6.2 | 5.2 | 3.8 | 1.3 | 3.1 | 4.0 | 6.6 | 7.4 |
| Lu | 0.8 | 0.1 | 0.8 | - | 0.3 | 0.3 | 1.5 | - | 0.9 | 1.6 |
| 100Y/(Y+Lu) | (40.5) ^b | (15.8) | (64.5) | (>26.8) | (45.7) | (25.4) | (37.2) | (>24.4) | (60.7) | (50.8) |
| Method | CH | OS | XF | MS | - | OS | CH | MS | CH | OS |
| $\Sigma = La+Ce+Pr$ | 23.5 | 24.8 | 25.5 | 26.3 | 26.4 | 27.2 | 27.4 | 28.7 | 29.0 | 29.1 |
| La-Nd | 44.3 | 51.9 | 40.3 | 49.4 | 49.1 | 58.7 | 56.6 | 59.0 | 38.4 | 50.1 |
| Sm-Ho | 39.0 | 45.3 | 38.3 | 37.9 | 38.2 | 37.2 | 33.6 | 31.9 | 40.3 | 34.9 |
| Er-Lu | 16.7 | 2.8 | 21.4 | 12.7 | 12.7 | 4.1 | 9.8 | 9.1 | 21.3 | 15.0 |
| ΣRE_2O_3 | 0.12 | 3.43 | 8.29 | 2.99 | 6.43 | 1.36 | 0.33 | 3.11 | 7.28 | 2.65 |
| La/Nd | 0.15 | 0.08 | 0.73 | 0.12 | 0.30 | 0.11 | 0.12 | 0.16 | 1.03 | 0.30 |

(a) Eu+Gd calcd as Gd

(b) Tb+Y calcd. as Y

Titanite - 4

(31) Lyakhovich (1962, 1968), biotite granite, Shmakov massif, Maritime Province, U.S.S.R.; (32) Kostin and Volzhenkova (1965), oligoclase-quartz veins in gabbro-anorthosite; (33) Belkov and Batieva (1969), syenite, Sakharov alkalie massif; (34) Lyakhovich and Barinskii (1961), granite, Maiborskii massif, Gornyi Altai; (35) Belkov and Batieva (1971), microclinized granodiorite, Krasnoshelele, Kola Peninsula;

| | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 |
|---------------------|------|--------|------------------|------|------------------|------|--------|--------|--------|---------------------|
| La | 4.9 | 8.9 | 4.8 | 4.7 | 7.8 | 4.2 | 4.1 | 7.2 | 3.5 | 8.0 |
| Ce | 19.3 | 14.7 | 21.0 | 19.2 | 18.2 | 18.4 | 16.2 | 21.7 | 24.7 | 21.6 |
| Pr | 5.4 | 6.2 | 4.1 | 6.3 | 4.6 | 8.2 | 10.7 | 4.0 | 4.9 | 4.2 |
| Nd | 10.0 | 17.1 | 26.8 | 12.5 | 22.4 | 20.9 | 20.1 | 23.5 | 33.6 | 25.1 |
| Sm | 9.7 | 13.2 | 8.8 | 12.6 | 7.4 | 9.4 | 10.6 | 7.8 | 13.9 | 9.8 |
| Eu | 0.4 | - | a | 1.2 | a | 0.9 | 3.3 | 0.7 | 0.9 | a |
| Gd | 12.4 | 4.9 | 9.0 ^a | 10.8 | 8.8 ^a | 8.3 | - | 7.3 | 8.8 | 12.6 ^a |
| Tb | 2.2 | 2.0 | 4.9 | 1.8 | 6.2 | 1.6 | 1 | 3.5 | 0.2 | b |
| Dy | 13.1 | 11.3 | 7.8 | 10.0 | 11.3 | 10.3 | - | 7.4 | 6.4 | 5.4 |
| Ho | 3.0 | 3.1 | 2.1 | 2.1 | 1.7 | 2.2 | 13.7 | 2.7 | 0.8 | 1.7 |
| Er | 8.0 | 10.5 | 5.2 | 7.5 | 4.7 | 6.9 | - | 5.6 | 1.3 | 5.4 |
| Tm | 1.5 | - | 1.1 | 1.5 | 0.9 | 1.2 | - | 1.5 | 0.3 | 0.8 |
| Yb | 8.5 | 8.1 | 3.6 | 7.7 | 4.9 | 6.4 | 21.3 | 5.5 | 0.6 | 4.0 |
| Lu | 1.6 | - | 0.8 | 2.1 | 1.1 | 1.1 | - | 1.6 | 0.1 | 1.4 |
| 100Y/(Y+Lu) | - | (46.6) | (43.6) | - | (38.8) | - | (78.4) | (44.7) | (13.5) | (48.9) ^b |
| Method | XF | - | CH | XF | CH | XF | XF | - | OS | CH |
| $\Sigma = La+Ce+Pr$ | 29.6 | 29.8 | 29.9 | 30.2 | 30.6 | 30.8 | 31.0 | 32.9 | 33.1 | 33.8 |
| La-Nd | 39.6 | 46.9 | 56.7 | 42.7 | 53.0 | 51.7 | 51.1 | 56.4 | 66.7 | 58.9 |
| Sm-Ho | 40.8 | 34.5 | 32.6 | 38.5 | 35.4 | 32.7 | 27.6 | 29.4 | 32.0 | 29.5 |
| Er-Lu | 19.6 | 18.6 | 10.7 | 18.8 | 11.6 | 15.6 | 21.3 | 14.2 | 2.3 | 11.6 |
| ΣRE_2O_3 | 3.90 | - | 1.99 | 1.25 | 0.90 | 1.61 | 0.98 | 1.19 | 2.32 | - |
| La/Nd | 0.49 | 0.52 | 0.18 | 0.37 | 0.35 | 0.20 | 0.20 | 0.31 | 0.10 | 0.32 |

(a) Eu+Gd calcd. as Gd

(b) Tb+Y calcd. as Y

(36) Lyakhovich (1962, 1968), granite pegmatite, Gornyi Altai; (37) Aleksiev and Ivanov (1970), albite pegmatite, Sredna Gora, Bulgaria; (38) Batieva (1976), alkalie granite, Kola Peninsula; (39) Lee et al. (1969), granitoid, Snake Range, White Pine Co., Nev.; (40) Vetrin and Eline (1968), granite, S.E. Kola Peninsula

Titanite - 5

(43) (41) Lee et al. (1969), granitoid, Snake Range, White Pine Co., Nev.; (44) Lyakhovich and Barinskii (1961), biotite granite, Ol'gin massif, Maritime Province, U.S.S.R.; (45) same as (41); (46) Lyakhovich (1968), biotite granite, eastern Sayan; (47) same as (41), xenolith; (48) Kovalenko et al. (1971), vein granite, Ongon, Khairkhan; (49) Batiera (1976), alkalic granite, Kola Peninsula; (50) Marchenko (1965), aegirine-crocidolite syenite,

| | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 |
|---------------------|--------|--------|--------|------|--------|------|--------|---------------------|--------|--------|
| La | 2.7 | 2.8 | 5.0 | 4.7 | 4.0 | 4.6 | 3.8 | 7.9 | 5.3 | 5.4 |
| Ce | 26.8 | 27.3 | 24.5 | 23.5 | 30.6 | 23.7 | 27.5 | 23.5 | 26.5 | 25.0 |
| Pr | 3.8 | 3.9 | 4.8 | 6.3 | - | 7.1 | 5.4 | 5.8 | 5.4 | 7.1 |
| Nd | 26.0 | 37.1 | 33.2 | 11.5 | 29.7 | 24.7 | 37.3 | 22.3 | 23.6 | 20.3 |
| Sm | 7.5 | 10.2 | 13.7 | 11.1 | 13.5 | 11.9 | 10.3 | 8.9 | 6.7 | 11.3 |
| Eu | 1.5 | 1.5 | 1.4 | 0.4 | 1.9 | 1.3 | 1.6 | a | 0.6 | 1.1 |
| Gd | 9.7 | 9.7 | 8.7 | 12.8 | 9.2 | 11.3 | 7.3 | 9.5 ^a | 7.3 | 11.5 |
| Tb | 0.2 | 0.2 | 0.2 | 2.3 | - | 1.4 | 0.2 | b | 2.4 | 1.6 |
| Dy | 9.4 | 4.7 | 6.2 | 11.2 | 8.9 | 7.8 | 4.8 | 5.7 | 9.1 | 9.2 |
| Ho | 0.9 | 0.7 | 0.8 | 2.2 | 0.8 | 1.0 | 0.7 | 4.5 | 1.8 | 1.4 |
| Er | 1.4 | 0.9 | 0.8 | 6.4 | - | 3.1 | - | 5.8 | 4.8 | 3.6 |
| Tm | 0.3 | 0.3 | 0.3 | 1.2 | 0.3 | 0.3 | 0.2 | 0.2 | 1.3 | 0.5 |
| Yb | 0.7 | 0.7 | 0.4 | 5.3 | 1.1 | 1.6 | 0.9 | 5.8 | 3.9 | 1.7 |
| Lu | 0.2 | - | - | 1.1 | - | 0.2 | - | 0.1 | 1.3 | 0.3 |
| 100 Y/(Y+Lu) | (14.7) | (14.7) | (13.3) | - | (32.6) | - | (11.5) | (33.6) ^b | (42.2) | (60.9) |
| Method | OS | OS | OS | XF | OS | XF | OS | CH | - | CH |
| $\Sigma = La+Ce+Pr$ | 33.9 | 34.0 | 34.3 | 34.5 | 34.6 | 35.4 | 36.7 | 37.2 | 37.2 | 37.5 |
| La-Nd | 60.4 | 71.1 | 67.5 | 46.0 | 64.3 | 60.1 | 74.0 | 59.5 | 60.8 | 57.8 |
| Sm-Ho | 37.0 | 27.0 | 31.0 | 40.0 | 34.3 | 34.7 | 24.9 | 28.6 | 27.9 | 36.1 |
| Er-Lu | 2.6 | 1.9 | 1.5 | 14.0 | 1.4 | 5.2 | 1.1 | 11.9 | 11.3 | 6.1 |
| ΣRE_2O_3 | 2.13 | 2.45 | 2.72 | 2.60 | 0.77 | 1.27 | 2.37 | 7.06 | 4.74 | 1.48 |
| La/Nd | 0.10 | 0.08 | 0.15 | 0.41 | 0.14 | 0.19 | 0.10 | 0.35 | 0.23 | 0.26 |

(a) Eu+Gd calcd as Gd

(b) Tb+Y calcd. as Y

Azov area.

Titanite - 6

(51) Belkov and Batiava (1971), tonalite, Voron'ye River, Kola Peninsula; (52) Lyakhovich (1968), diorite-granodiorite, Urals; (53) Belolipetskii and Elina (1967), vein of alkalic granite, Kola Peninsula;
 (54-55). Batiava (1976), alkalic granite, Kola Peninsula; (56) Kufs (1973), biotite granite, Radolooka, Azov Sea area; (57) Lee et al. (1969), granitoid, Snake Range, White Pine Co., Nev.;

| | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 |
|---------------------|-------------------|------|--------|------|--------|------------------|--------|------|--------|--------|
| La | 11.0 | 4.9 | 10.1 | 6.9 | 6.5 | 4.2 | 3.2 | 8.7 | 4.7 | 7.5 |
| Ce | 22.1 | 25.7 | 23.7 | 26.3 | 28.5 | 27.2 | 32.2 | 28.8 | 35.8 | 28.3 |
| Pr | 4.9 | 7.6 | 4.4 | 5.4 | 4.5 | 8.1 | 4.6 | 2.8 | - | 4.9 |
| Nd | 22.6 | 12.5 | 19.1 | 25.3 | 27.7 | 33.7 | 31.3 | 47.7 | 23.0 | 25.0 |
| Sm | 6.2 | 11.0 | 10.5 | 6.6 | 7.2 | 8.1 | 9.0 | 3.0 | 10.9 | 7.2 |
| Eu | a | 1.0 | 0.4 | 0.7 | 0.7 | a | 1.8 | 0.6 | 2.4 | 0.7 |
| Gd | 10.4 ^a | 9.8 | 7.0 | 5.7 | 7.3 | 7.6 ^a | 8.5 | 3.6 | 10.6 | 7.2 |
| Tb | 8.8 | 1.5 | 1.3 | 2.2 | 3.3 | 1.5 | - | 0.5 | - | 2.7 |
| Dy | 4.7 | 10.0 | 10.1 | 8.9 | 6.6 | 3.7 | 5.7 | 2.8 | 10.3 | 7.2 |
| Ho | 1.5 | 2.2 | 1.9 | 1.3 | 1.5 | 0.9 | 0.8 | - | 1.0 | 1.5 |
| Er | 4.0 | 6.1 | 5.7 | 5.0 | 3.6 | 2.1 | 1.6 | 1.5 | - | 4.2 |
| Tm | 0.3 | 0.7 | 0.6 | 0.7 | 0.5 | 0.7 | 0.3 | - | - | 0.7 |
| Yb | 3.5 | 6.0 | 4.3 | 3.7 | 1.9 | 1.8 | 0.8 | - | 1.3 | 2.8 |
| Lu | - | 1.0 | 0.9 | 1.3 | 0.2 | 0.4 | 0.2 | - | - | 0.1 |
| 100Y/(Y+Lu) | (25.6) | - | (79.3) | - | (34.8) | (24.9) | (16.9) | - | (36.0) | (43.7) |
| Method | CH | XF | XF | - | - | CH | OS | XF | OS | - |
| $\Sigma = La+Ce+Pr$ | 38.0 | 38.2 | 38.2 | 38.6 | 39.5 | 39.5 | 40.0 | 40.3 | 40.5 | 40.7 |
| La-Nd | 60.6 | 50.7 | 57.3 | 63.9 | 67.2 | 73.2 | 71.3 | 88.0 | 63.5 | 65.7 |
| Sm-Ho | 31.6 | 35.5 | 31.2 | 25.4 | 26.6 | 21.8 | 25.8 | 10.5 | 35.2 | 26.5 |
| Er-Lu | 7.8 | 13.8 | 11.5 | 10.7 | 6.2 | 5.0 | 2.9 | 1.5 | 1.3 | 7.8 |
| ΣRE_2O_3 | 0.25 | 2.13 | 3.25 | 3.89 | 3.06 | 0.88 | 2.10 | 3.68 | 0.68 | 5.16 |
| La/Nd | 0.49 | 0.40 | 0.53 | 0.27 | 0.24 | 0.12 | 0.10 | 0.18 | 0.43 | 0.30 |

(a) Eut Gd calcd as Gd

(58) Mikhailov and Mineev (1970), metasomatic diopside vein, Emeld'zhak, Aldan; (59) same as (57), lamprophyre dike; (60) same as (54-55).

Titanite - 1

(61) Semenov and Barinskii (1958), granite, Borsichevochny Range, Transbaikal; (62) Aleksiev, Khisina, and Pavlova (1969), leucogabbro, Plana pluton, Bulgaria; (63) Marchenko, Khvostova, and Chashka (1969), yttriotitanite, Precambrian pegmatite, ^{Crimea}; (64) Batiava (1976), alkalie granite, Kola Peninsula; (65-66) Kuts (1973), Azov Sea region; (65) biotite granite, Saltych'ya; (66) migmatite, Kuibyshev; (67) Orsa et al. (1967), biotite-

| | 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 | 70 |
|---------------|------|--------|--------|--------|------------------|--------|------------------|--------|--------|--------|
| La | 7.5 | 11.9 | 9.3 | 8.1 | 5.3 | 11.1 | 7.4 | 13.6 | 9.0 | 12.7 |
| Ce | 23.2 | 23.3 | 28.6 | 29.3 | 32.2 | 28.3 | 30.2 | 26.2 | 29.6 | 26.9 |
| Pr | 10.2 | 6.0 | 4.7 | 5.5 | 6.1 | 4.4 | 6.2 | 4.5 | 5.9 | 5.2 |
| Nd | 27.9 | 17.8 | 21.3 | 20.5 | 31.7 | 24.6 | 28.7 | 21.6 | 27.7 | 26.2 |
| Sm | 9.4 | 6.2 | 7.7 | 6.9 | 7.3 | 7.7 | 8.5 | 6.6 | 8.2 | 11.7 |
| Eu | 0.8 | 1.1 | 0.3 | 0.6 | a | 0.7 | a | 0.7 | - | 1.2 |
| Gd | 7.5 | 7.8 | 6.6 | 7.3 | 7.3 ^a | 5.5 | 8.8 ^a | 5.8 | 4.6 | 4.8 |
| Tb | 0.9 | - | 0.9 | 3.2 | 0.7 | 0.9 | 1.1 | 2.2 | - | 0.5 |
| Dy | 5.6 | 7.9 | 6.5 | 6.8 | 3.2 | 6.8 | 4.4 | 9.4 | 6.9 | 4.6 |
| Ho | 1.2 | 4.2 | 1.0 | 2.2 | 0.8 | 1.4 | 1.4 | 1.5 | 0.8 | 1.1 |
| Er | 2.3 | 6.4 | 4.8 | 4.4 | 2.4 | 10.0 | 3.2 | 4.4 | 2.5 | 2.3 |
| Tm | 0.4 | - | 1.0 | 1.3 | 0.6 | 0.6 | - | 0.7 | 0.6 | 0.4 |
| Yb | 2.6 | 7.4 | 6.6 | 3.0 | 2.3 | 3.1 | 0.1 | 2.3 | 4.0 | 2.2 |
| Lu | 0.5 | - | 0.7 | 0.9 | 0.1 | 0.9 | - | 0.5 | 0.2 | 0.2 |
| 100Y/(Y+Lu) | - | (50.3) | (49.6) | (40.3) | (27.4) | (29.1) | (21.1) | (37.6) | (41.5) | (29.8) |
| 100Ce/(Ce+Pr) | XF | XF | XF | - | CH | OS | CH | - | OS | OS |
| 100Ce/(Ce+Pr) | 40.9 | 41.2 | 42.6 | 42.9 | 43.6 | 43.8 | 43.8 | 44.3 | 44.5 | 44.8 |
| 100Nd/(Nd+Pr) | 68.8 | 59.0 | 63.9 | 63.4 | 75.3 | 68.4 | 72.5 | 65.9 | 72.2 | 71.0 |
| 100Sm/(Sm+Pr) | 25.4 | 27.2 | 23.0 | 27.0 | 19.3 | 21.0 | 24.2 | 26.2 | 20.5 | 23.9 |
| 100Eu/(Eu+Pr) | 5.8 | 13.8 | 13.1 | 9.6 | 5.4 | 14.6 | 3.3 | 7.9 | 7.3 | 5.1 |
| 100Gd/(Gd+Pr) | - | 1.52 | 5.1 | 4.11 | 1.08 | 0.97 | - | 3.07 | 2.94 | - |
| 100Tb/(Tb+Pr) | 0.27 | 0.67 | 0.44 | 0.40 | 0.17 | 0.45 | 0.26 | 0.63 | 0.32 | 0.48 |

calcd. as Gd migmatite, Tyaginka, Middle Dnepr region; (68) same as (64); (69) Stantz et al. (1977), quartz monzonite, Darby Mts., Alaska; (70) Goldsmith et al. (1961), granitic gneiss, Conn.

Titanite - 8

(71) Lyakhovich (1962, 1968), biotite granite, Talitsk massif, Gornyi Altai; (72-74) Kufs (1973), Azov Sea region; (72) biotite granite, Radolooka; (73) xenolith of granodiorite in granite, Saltch'ya; (74) hornblende-biotite granite, Svobodnoe; (75) Belkov and Batiera (1971), tonalite, Vron'ye River, Kola Peninsula; (76) same as (72), biotite granite, Saltch'ya; (77) Sahama and Vahatalo (1941), placer, Pulmionnieme, Finland; (78) Orsa et al. (1967),

| | 71 | 72 | 73 | 74 | 75 | 76 | 77 | 78 | 79 | 80 |
|---------------------|------|--------|------------------|--------|------------------|------------------|--------|------------------|--------|--------|
| La | 7.1 | 5.9 | 8.1 | 11.2 | 9.0 | 6.8 | 10.8 | 8.6 | 10.5 | 8.9 |
| Ce | 28.3 | 30.9 | 30.9 | 29.1 | 31.4 | 33.1 | 28.6 | 31.7 | 30.7 | 31.5 |
| Pr | 9.7 | 8.3 | 6.2 | 5.3 | 5.4 | 6.3 | 7.1 | 6.5 | 5.9 | 6.9 |
| Nd | 13.8 | 28.8 | 32.6 | 25.5 | 25.6 | 28.1 | 21.0 | 28.7 | 19.3 | 30.6 |
| Sm | 11.7 | 8.2 | 8.9 | 7.8 | 6.0 | 8.7 | 6.7 | 7.1 | 4.1 | 6.5 |
| Eu | 1.0 | - | a | 0.6 | a | a | 1.3 | a | 0.6 | - |
| Gd | 10.1 | 7.5 | 7.4 ^a | 4.6 | 8.3 ^a | 6.2 ^a | 6.5 | 7.3 ^a | 7.3 | 6.0 |
| Tb | 1.4 | 1.1 | 0.2 | 1.0 | 2.0 | 1.3 | 1.6 | 1.3 | 1.3 | b |
| Dy | 7.1 | 4.9 | 2.1 | 6.8 | 2.8 | 3.2 | 6.3 | 3.2 | 8.0 | 3.8 |
| Ho | 1.3 | 1.1 | 0.7 | 1.2 | 1.3 | 1.7 | 1.6 | 1.3 | 1.5 | 1.7 |
| Er | 3.1 | 1.7 | 1.4 | 3.4 | 2.9 | 2.4 | 3.1 | 1.8 | 4.0 | 2.1 |
| Tm | 0.6 | - | 0.1 | 0.4 | 1.3 | - | 1.2 | - | 0.8 | - |
| Yb | 4.1 | 1.3 | 1.3 | 2.2 | 2.6 | 1.9 | 3.0 | 2.5 | 4.8 | 2.0 |
| Lu | 0.7 | 0.3 | 0.1 | 0.9 | 1.4 | 0.3 | 1.2 | - | 1.2 | - |
| 100Y/(Y+Lu) | - | (22.8) | (19.9) | (29.9) | (26.9) | (23.6) | (34.3) | (19.9) | (39.0) | (14.5) |
| Geochem | XF | OS | CH | OS | CH | CH | XF | CH | CH | CH |
| $\Sigma = La+Ce+Pr$ | 45.1 | 45.1 | 45.2 | 45.6 | 45.8 | 46.2 | 46.5 | 46.8 | 47.1 | 47.3 |
| La-Nd | 58.9 | 73.9 | 77.8 | 71.1 | 71.4 | 74.3 | 67.5 | 75.5 | 66.4 | 77.9 |
| Sm-Ho | 32.6 | 22.8 | 19.3 | 22.0 | 20.4 | 21.1 | 24.0 | 20.2 | 22.8 | 18.0 |
| Er-Lu | 8.5 | 3.3 | 2.9 | 6.9 | 8.2 | 4.6 | 8.5 | 4.3 | 10.8 | 4.1 |
| ΣRE_2O_3 | 2.75 | 0.88 | 1.26 | 1.26 | 0.85 | 1.08 | - | - | 4.60 | 0.71 |
| La/Nd | 0.51 | 0.20 | 0.25 | 0.44 | 0.35 | 0.32 | 0.52 | 0.30 | 0.54 | 0.29 |

(a) Eut Gd calcd as Gd

b) Tb+Y calcd. as Y

biotite-plagioclase migmatite, Osokorovka R, Middle Dnepr region
 (79) same as (72), migmatite, Listvyanka; (80) Bazhenov and Bazhenova (1975), quartz-feldspar migmatite at contact, Il'men Mf. alkaline complex, Urals.

Titanite - 9

(81) Kovalenko et al. (1971), biotite granite, Ongan, Khairkhan; (82) Lyakhovich (1968), diorite-granodiorite, Tuva; (83) Aleksiev and Ivanov (1970), amphibole-biotite granite, Sredna Gora, Bulgaria; (84) Mikhailov and Mineev (1970), diopside vein, Eme'dzhat, Alder; (85) Lyakhovich (1968), gabbro, Urals; (86) Vainshtein, Tugarinov, and Turanskaya (1956), granite, Salych'ya, Azov region; (87) Smith (1970), nephelinite, Shombale volcano, Kenya;

| | 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 | 90 |
|---------------------|---------------------|------|------|------|------|--------|--------|------------------|------------------|---------------------|
| La | 10.5 | 5.8 | 5.6 | 2.3 | 8.4 | 13.3 | 12.9 | 7.4 | 7.3 | 11.4 |
| Ce | 31.9 | 31.4 | 33.0 | 42.8 | 34.4 | 32.0 | 25.6 | 37.8 | 39.1 | 34.1 |
| Pr | 5.0 | 10.6 | 9.6 | 4.4 | 8.3 | 5.9 | 12.8 | 6.9 | 5.7 | 6.7 |
| Nd | 24.8 | 16.4 | 21.8 | 20.9 | 27.7 | 26.7 | 25.0 | 30.3 | 30.6 | 22.8 |
| Sm | 6.8 | 10.0 | 7.6 | 7.4 | 2.7 | 9.6 | 12.1 | 6.4 | 5.9 | 6.2 |
| Eu | a | 2.8 | - | 1.1 | 0.3 | - | - | a | a | a |
| Gd | 7.0 ^a | 12.3 | - | 11.3 | 8.6 | 6.7 | 11.6 | 5.9 ^a | 6.3 ^a | 5.5 ^a |
| Tb | b | 1.1 | 10.1 | 2.0 | 1.1 | - | - | 0.9 | 0.3 | b |
| Dy | 3.4 | 5.5 | - | 4.9 | 3.7 | 3.5 | - | 1.4 | 2.6 | 3.9 |
| Ho | 1.8 | 0.7 | - | - | 0.5 | - | - | 0.9 | 0.3 | 2.1 |
| Er | 4.4 | 1.8 | 5.3 | 2.0 | 2.5 | 1.6 | - | 1.2 | 0.8 | 3.8 |
| Tm | 0.1 | 0.2 | - | - | 0.4 | - | - | 0.2 | 0.1 | 0.1 |
| Yb | 4.3 | 1.2 | - | 0.9 | 1.2 | 0.7 | - | 0.6 | 0.9 | 3.3 |
| Lu | - | 0.2 | 7.0 | - | 0.2 | - | - | 0.1 | 0.1 | 0.1 |
| 100Y/(Y+Lu) | (32.5) ^b | - | - | - | - | (17.6) | (13.0) | (24.0) | (19.0) | (22.0) ^b |
| Method | CH | XF | XF | XF | XF | XF | EP | CH | CH | CH |
| $\Sigma = La+Ce+Pr$ | 47.4 | 47.8 | 48.2 | 49.5 | 51.1 | 51.2 | 51.3 | 52.1 | 52.1 | 52.2 |
| La-Nd | 72.2 | 64.2 | 70.0 | 70.4 | 78.8 | 77.9 | 76.3 | 82.4 | 82.7 | 75.0 |
| Sm-Ho | 19.0 | 32.4 | 23.0 | 26.7 | 16.9 | 19.8 | 23.7 | 15.5 | 15.4 | 17.7 |
| Er-Lu | 8.8 | 3.4 | 7.0 | 2.9 | 4.3 | 2.3 | - | 2.1 | 1.9 | 7.3 |
| ΣRE_2O_3 | 1.48 | 0.36 | 0.43 | 0.38 | 0.24 | - | 0.88 | 0.30 | 1.16 | 3.66 |
| La/Nd | 0.42 | 0.35 | 0.25 | 0.11 | 0.30 | 0.50 | 0.52 | 0.24 | 0.24 | 0.50 |

(a) Eu+Gd calcd. as Gd

(b) Tb+Y calcd. as Y

(88) Vinogradov and Eline (1968), granite, N.W. Kola Peninsula;

(89) Kuts (1973), albite metasomatite, Andreevka, Azov Sea region.

(90) Kovalenko et al. (1971), biotite granite, Khairkhan.

Titanite - 10

(91) Protsenko (1970), adamellite, Chafkal massif, Uzbekistan; (92) Vinogradov and Elina (1968), granite, N.W. Kola Peninsula; (93) Putalova (1965), quartz syenite, Batpakh massif, Kazakhstan; (94) Kukhareenko et al. (1965), pyroxenite, Afrikanda, Kola Peninsula; (95) Smith (1970), trachytic pitchstone, Murat, France; (96) Marchenko (1967), albified granosyenite, Kal'chik R., Azov region; (97) Balashov and Turanskaya (1960), amphibole

| | 91 | 92 | 93 | 94 | 95 | 96 | 97 | 98 | 99 | 100 |
|---------------------|------|------------------|------------------|-------|--------|--------|------|--------|------|------|
| La | 15.2 | 9.6 | 12.2 | 10.0 | 14.6 | 11.0 | 15.0 | 13.0 | 8.5 | 11.9 |
| Ce | 33.9 | 36.0 | 36.7 | 38.0 | 39.7 | 35.1 | 32.7 | 34.8 | 36.9 | 32.8 |
| Pr | 3.8 | 8.1 | 5.0 | 6.3 | - | 8.3 | 6.8 | 6.9 | 9.3 | 11.0 |
| Nd | 14.7 | 31.1 | 31.7 | 30.4 | 42.3 | 26.1 | 28.9 | 23.8 | 27.2 | 21.1 |
| Sm | 3.5 | 5.3 | 5.5 | 5.3 | - | 6.1 | 8.0 | 6.5 | 6.5 | 6.6 |
| Eu | - | a | a | 1.3 | 3.4 | - | - | 2.2 | 0.4 | 1.7 |
| Gd | 3.4 | 3.7 ^a | 5.7 ^a | 7.5 | - | 7.0 | 4.8 | 4.2 | 4.9 | 7.4 |
| Tb | - | 0.5 | - | - | - | 2.8 | - | 0.6 | 0.4 | - |
| Dy | 16.2 | 2.2 | 0.7 | 0.9 | - | - | 3.1 | 4.1 | 2.9 | 3.7 |
| Ho | - | 0.6 | 0.7 | - | - | 1.5 | - | 0.6 | 0.4 | - |
| Er | 6.3 | 1.1 | 1.1 | - | - | - | 0.7 | 1.5 | 1.3 | 2.1 |
| Tm | - | 0.3 | - | - | - | - | - | 0.2 | 0.1 | 0.3 |
| Yb | 3.0 | 1.3 | 0.4 | 0.3 | - | 2.1 | - | 1.0 | 0.9 | 1.2 |
| Lu | - | 0.2 | 0.3 | - | - | - | - | 0.6 | 0.3 | 0.2 |
| 100Y/(Y+Lu) | - | (15.2) | (47.0) | (9.0) | (17.4) | (29.9) | - | (16.3) | - | - |
| Method | XF | CH | CH | XF | EP | CH | XF | OS | XF | OS |
| $\Sigma = La+Ce+Pr$ | 52.9 | 53.7 | 53.9 | 54.3 | 54.3 | 54.4 | 54.5 | 54.7 | 54.7 | 55.7 |
| La-Nd | 67.6 | 84.8 | 85.6 | 84.7 | 96.6 | 80.5 | 83.4 | 78.5 | 81.9 | 76.8 |
| Sm-Ho | 23.1 | 12.3 | 12.6 | 15.0 | 3.4 | 17.4 | 15.9 | 18.2 | 15.5 | 19.4 |
| Er-Lu | 9.3 | 2.9 | 1.8 | 0.3 | - | 2.1 | 0.7 | 3.3 | 2.6 | 3.8 |
| ΣRE_2O_3 | - | 1.40 | 3.93 | - | 3.2 | 4.81 | 3.45 | 0.70 | 1.90 | 0.39 |
| La/Md | 1.04 | 0.31 | 0.38 | 0.33 | 0.34 | 0.42 | 0.52 | 0.55 | 0.31 | 0.56 |

(a) Eut Gd calcd. as Gd

Lužavrite, Lovozero massif, Kola Peninsula; (98) Kuts (1973), hornblende-biotite granite, Svobodnoe, Azov Sea region; (99) Lyakhovich (1968), biotite granite, Armenia; (100) Panov and Tarnovskaya (1973), biotite granodiorite, N.E. Transbaikal

Titanite - 11

(101) Ivantishin et al. (1964), migmatite, Ukrainian shield; (102) Vinogradov and Elina (1968), granite, N.W. Kola Peninsula; (103) Lyakhovich (1968), diorite-granodiorite, Urals; (104) Mikhailov and Mineev (1970), contact metamorphic diopside rock, Aldan; (105) Kuts (1973), albitic metasomatite, Andreevka, Azov Sea region; (106) Smith (1970), nephelinite, Lemogret Volcano, Tanzania; (107) Panov and Tarnovskaya (1970), biotite granodiorite,

| | 101 | 102 | 103 | 104 | 105 | 106 | 107 | 108 | 109 | 110 |
|---------------------|-------|-----------------|------|------|--------|--------|------|--------|--------|------|
| La | 10.4 | 13.2 | 6.2 | 12.0 | 9.2 | 11.4 | 6.9 | 9.5 | 17.4 | 8.3 |
| Ce | 35.2 | 37.2 | 39.6 | 42.1 | 40.9 | 34.1 | 38.9 | 40.5 | 28.9 | 39.8 |
| Pr | 10.1 | 5.6 | 10.4 | 2.1 | 6.3 | 11.3 | 12.0 | 7.8 | 12.0 | 10.3 |
| Nd | 32.6 | 29.1 | 19.0 | 20.0 | 26.9 | 22.2 | 25.2 | 26.3 | 18.0 | 19.4 |
| Sm | 5.9 | 5.5 | 10.0 | 3.6 | 6.0 | 10.7 | 5.0 | 7.6 | - | 7.7 |
| Eu | 1.3 | a | 1.1 | 1.0 | 1.8 | - | 1.5 | - | - | 1.0 |
| Gd | 4.5 | 38 ^a | 7.2 | 9.8 | 4.2 | 10.3 | 5.1 | 7.5 | 7.3 | 5.3 |
| Tb | - | 0.5 | 0.7 | 0.9 | 0.5 | - | 0.9 | - | - | 0.6 |
| Dy | - | 2.4 | 3.6 | 5.3 | 2.3 | - | 2.1 | - | 8.5 | 3.5 |
| Ho | - | 0.2 | 0.6 | 0.9 | 0.5 | - | 0.3 | - | 3.7 | 0.5 |
| Er | - | 1.6 | 1.6 | 0.9 | 0.7 | - | 1.2 | - | - | 1.5 |
| Tm | - | 0.1 | - | - | 0.1 | - | 0.1 | - | - | 0.3 |
| Yb | - | 0.7 | - | 1.4 | 0.5 | - | 0.7 | 0.8 | 4.2 | 1.5 |
| Lu | - | 0.1 | - | - | 0.1 | - | 0.1 | - | - | 0.3 |
| 100Y/(Y+Lu) | (7.4) | (21.8) | - | - | (15.4) | (10.5) | - | (25.4) | (44.9) | - |
| Method | CH | CH | XF | XF | OS | EP | OS | CH | XF | XF |
| $\Sigma = La+Ce+Pr$ | 55.7 | 56.0 | 56.2 | 56.2 | 56.4 | 56.8 | 57.8 | 57.8 | 58.3 | 58.4 |
| La-Nd | 88.3 | 85.1 | 75.2 | 76.2 | 83.3 | 79.0 | 83.0 | 84.1 | 76.3 | 77.8 |
| Sm-Ho | 11.7 | 12.4 | 23.2 | 21.5 | 15.3 | 21.0 | 14.9 | 15.4 | 19.5 | 18.6 |
| Er-Lu | - | 2.5 | 1.6 | 2.3 | 1.4 | - | 2.1 | 0.8 | 4.2 | 3.6 |
| ΣRE_2O_3 | - | 2.23 | 0.80 | 0.56 | 1.16 | 0.97 | 1.31 | 0.98 | 4.39 | 2.07 |
| La/Md | 0.32 | 0.45 | 0.33 | 0.60 | 0.34 | 0.52 | 0.28 | 0.36 | 0.96 | 0.43 |

(a) Eu+Gd calcd as Gd

M.E. Transbaikal; (108) Marchenko (1967), granite, Salt'ycha, Azov Sea region; (109) Aleksiev, Khising, and Pavlov (1969), monzodiorite, Plana pluton, Bulgaria; (110) Lyakhovich (1968), leucogranite, Urals.

Titanite-12

(111) Ivanova et al. (1970), ijolite, Khibina massif, Kola Peninsula; (112) Mikhailov and Mineev (1970), diopside vein, El'konka, Aldan; (113) Lyakhovich (1968), biotite granite, E. Transbaikal; (114) Vinogradov and Elina (1968), granite, M.W. Kola Peninsula; (115) Panov and Tarnovskaya (1973), porphyritic granite, Umidzhikan complex, N.E. Transbaikal; (116) Smith (1970), av. of 3 nephelinites, Mt. Efinde, W. Africa; (117) Lee et al. (1969), granitoid, Snake Range, White Pine Co., Nev.; (118) Lyakhovich (1962, 1968), granite,

| | 111 | 112 | 113 | 114 | 115 | 116 | 117 | 118 | 119 | 120 |
|---------------------|--------|------|------|--------|------|--------|--------|------|-------|--------|
| La | 25.2 | 2.6 | 11.8 | 11.2 | 7.5 | 17.8 | 9.4 | 11.2 | 11.8 | 18.2 |
| Ce | 29.4 | 51.0 | 39.1 | 40.9 | 42.1 | 31.7 | 46.1 | 40.0 | 40.6 | 36.6 |
| Pr | 3.9 | 5.1 | 8.2 | 7.5 | 10.2 | 10.5 | 4.5 | 8.9 | 7.7 | 5.6 |
| Nd | 22.6 | 29.8 | 22.9 | 25.5 | 21.2 | 17.2 | 26.8 | 27.1 | 31.6 | 26.3 |
| Sm | 1.3 | 3.8 | 4.0 | 4.3 | 5.8 | 9.9 | 6.1 | 4.9 | 3.6 | 7.9 |
| Eu | - | 0.5 | 0.3 | - | 0.3 | 3.3 | - | 0.5 | 1.1 | 0.8 |
| Gd | 8.5 | 3.2 | 6.9 | 4.0 | 6.5 | 9.6 | 2.4 | 3.6 | 3.4 | 1.8 |
| Tb | 1.9 | 0.5 | 0.4 | 0.9 | 0.9 | - | - | 0.5 | - | - |
| Dy | - | 2.2 | 2.7 | 2.3 | 2.7 | - | 2.3 | 2.1 | - | 1.7 |
| Ho | - | - | 0.6 | 0.4 | 0.4 | - | 0.4 | 0.4 | - | 0.5 |
| Er | 7.2 | 1.3 | 1.6 | 1.6 | 1.5 | - | - | 0.8 | - | - |
| Tm | - | - | 0.3 | 0.1 | 0.1 | - | 0.5 | - | - | 0.1 |
| Yb | - | - | 1.0 | 1.3 | 0.7 | - | 1.1 | - | 0.2 | 0.4 |
| Lu | - | - | 0.2 | - | 0.1 | - | 0.4 | - | - | 0.1 |
| 100Y/(Y+Lu) | (16.3) | - | - | (18.4) | - | (12.1) | (17.9) | - | (3.9) | (11.8) |
| Method | CH | XF | XF | CH | OS | EP | OS | XF | XF | OS |
| $\Sigma = La+Ce+Pr$ | 58.5 | 58.7 | 59.1 | 59.6 | 59.8 | 60.0 | 60.0 | 60.1 | 60.1 | 60.4 |
| La-Nd | 81.1 | 88.5 | 82.0 | 85.1 | 81.0 | 77.2 | 86.8 | 87.2 | 91.7 | 86.7 |
| Sm-Ho | 11.7 | 10.2 | 14.9 | 11.9 | 16.6 | 22.8 | 11.2 | 12.0 | 8.1 | 12.7 |
| Er-Lu | 7.2 | 1.3 | 3.1 | 3.0 | 2.4 | - | 2.0 | 0.8 | 0.2 | 0.6 |
| ΣRE_2O_3 | 0.14 | 5.52 | 2.16 | 1.37 | 1.13 | 1.12 | 1.46 | 1.76 | - | 0.45 |
| La/Nd | 1.12 | 0.09 | 0.52 | 0.44 | 0.35 | 1.03 | 0.35 | 0.41 | 0.37 | 0.69 |

Konev massif, Urals; (119) Kukharevko et al. (1965), diopside-amphibole rock, Afrikanda, Kola Peninsula; (120) Staatz et al. (1977), gneissic monzonite, Zane Hills, Alaska

Titanite - 13

(121) Lyakhovich (1968), diorite-granodiorite, Urals; (122) Smith (1970), trachyte, Tristan de Cunha; (123) Lyakhovich (1968), leucocratic granite, Ukraine; (124) Aleksiev, Khisina, and Pavlova (1969), monzodiorite, Plana pluton, Bulgaria; (125) Bazhenov and Bazhenova (1975) pyroxene-amphibole syenite, Il'men Mts, Urals; (126) Mikhailov and Mineev (1970), contact metamorphic diopside rock, Dzheltula River, Aldan; (127) Lyakhovich (1962), granite, E. Transbaikal; (128) Lyakhovich (1968), diorite-granodiorite, Urals; (129) Vinogradov and

| | 121 | 122 | 123 | 124 | 125 | 126 | 127 | 128 | 129 | 130 |
|---------------------|------|-------|------|--------|--------------------|------|------|------|--------|------------------|
| La | 8.4 | 16.6 | 14.7 | 2.9 | 11.6 | 12.2 | 12.2 | 15.8 | 17.6 | 19.0 |
| Ce | 41.0 | 35.7 | 35.0 | 52.4 | 42.9 | 42.6 | 40.6 | 36.1 | 37.8 | 39.9 |
| Pr | 11.1 | 8.2 | 10.9 | 5.3 | 6.7 | 6.4 | 8.5 | 9.4 | 6.2 | 2.8 |
| Nd | 23.7 | 24.2 | 20.6 | 23.4 | 24.9 | 25.7 | 23.7 | 29.0 | 24.6 | 22.8 |
| Sm | 6.5 | 5.2 | 8.0 | 3.9 | 4.5 | 7.3 | 4.1 | 3.8 | 3.7 | 2.6 |
| Eu | 0.6 | 2.6 | 0.7 | 1.0 | - | 0.7 | 0.3 | - | - | a |
| Gd | 5.1 | 7.5 | 6.3 | 5.4 | 4.3 | 3.9 | 3.4 | 2.8 | 3.8 | 6.9 ^a |
| Tb | 0.4 | - | 0.5 | - | b | - | 0.5 | 0.3 | 0.7 | - |
| Dy | 2.1 | - | 2.1 | 1.7 | 2.9 | 1.2 | 2.8 | 1.8 | 2.1 | 4.0 |
| Ho | - | - | - | - | 0.5 | - | 0.6 | - | 0.4 | - |
| Er | 0.8 | - | 0.6 | 1.9 | 1.7 | - | 1.7 | 0.7 | 1.5 | 2.0 |
| Tm | - | - | - | - | - | - | 0.3 | - | 0.1 | - |
| Yb | 0.3 | - | 0.6 | 2.1 | - | - | 1.0 | 0.3 | 1.5 | - |
| Lu | - | - | - | - | - | - | 0.3 | - | - | - |
| 100Y/(Y+Lu) | - | (7.4) | - | (27.5) | (133) ^b | - | - | - | (16.1) | (12.1) |
| Method | XF | EP | XF | XF | CH | XF | XF | XF | CH | CH |
| $\Sigma = La+Ce+Pr$ | 60.5 | 60.5 | 60.6 | 60.6 | 61.2 | 61.2 | 61.3 | 61.3 | 61.6 | 61.7 |
| La-Nd | 84.2 | 84.7 | 81.2 | 84.0 | 86.1 | 86.9 | 85.0 | 90.3 | 86.2 | 84.5 |
| Sm-Ho | 14.7 | 15.3 | 17.6 | 12.0 | 12.2 | 13.1 | 11.7 | 8.7 | 10.7 | 13.5 |
| Er-Lu | 1.1 | - | 1.2 | 4.0 | 1.7 | - | 3.3 | 1.0 | 3.1 | 2.0 |
| ΣRE_2O_3 | 1.68 | 3.9 | 2.5 | 1.22 | 1.29 | 1.28 | 2.16 | 2.32 | 0.90 | 0.45 |
| La/Nd | 0.36 | 0.69 | 0.71 | 0.12 | 0.47 | 0.47 | 0.51 | 0.54 | 0.72 | 0.83 |

(a) Eu+Gd calcd as Gd

(b) Tb+Y calcd as Y

Elina (1968), granite, N.W. Kola Peninsula; (130) Ivanova et al. (1970), urtite, Khibina massif, Kola Peninsula.

Litanite - 14

(131) Kukhareenko et al. (1965), ore pegmatite, Afrikanda, Kola Peninsula; (132) Bazhenov and Bazhenova (1975), hybrid biotite syenite, Il'men Mts, Urals; (133) Mikhailov and Mineev (1970), diopside veins, Emel'dzhak, Aldan; (134) Bazhenov and Bazhenova (1975), quartz-feldspar migmatite, Il'men Mts, Urals; (135) Marchenko (1967), granite, Pishcherik, Azov region; (136) Nadezhdina et al. (1963), metasomatically altered traprock, Greater Botuobi River, Siberia; (137) Khvostova (1962), granite pegmatite, Emel'dzhak, S. Yakutia; (138) Panov and

| | 131 | 132 | 133 | 134 | 135 | 136 | 137 | 138 | 139 | 140 |
|---------------------|--------|--------------------|------|--------------------|--------|---------------------|--------|------|--------|------|
| La | 14.9 | 14.4 | 11.4 | 15.7 | 13.6 | 12.6 | 12.5 | 7.9 | 16.5 | 14.1 |
| Ce | 40.7 | 41.8 | 45.9 | 40.4 | 41.4 | 43.4 | 40.6 | 43.1 | 41.0 | 40.9 |
| Pr | 6.1 | 5.5 | 4.5 | 5.8 | 6.9 | 6.0 | 9.0 | 11.3 | 5.1 | 7.7 |
| Nd | 26.3 | 26.6 | 23.8 | 26.2 | 29.3 | 18.6 | 24.2 | 19.1 | 20.0 | 22.5 |
| Sm | 3.9 | 4.6 | 4.6 | 4.1 | 4.3 | 5.9 | 4.4 | 4.2 | 4.3 | 3.0 |
| Eu | 1.0 | - | 1.2 | - | - | - | 0.5 | 1.8 | 0.7 | 0.2 |
| Gd | 4.8 | 2.9 | 3.7 | 3.0 | 4.3 | 7.6 | 2.9 | 4.9 | 5.1 | 2.9 |
| Tb | 1.4 | b | 0.5 | b | - | b | 0.4 | 0.8 | - | 0.5 |
| Dy | - | 1.9 | 2.9 | 2.0 | - | 5.9 | 2.5 | 3.0 | 2.7 | 4.2 |
| Ho | - | 0.5 | 0.3 | 0.7 | - | - | 0.4 | 0.5 | - | 0.5 |
| Er | 0.6 | 1.2 | 1.0 | 1.4 | 0.2 | - | 1.2 | 1.7 | 2.1 | 2.2 |
| Tm | - | - | - | - | - | - | 0.2 | 0.2 | - | 0.3 |
| Yb | 0.3 | 0.6 | 0.2 | 0.7 | - | - | 1.0 | 1.3 | 2.5 | 0.8 |
| Lu | - | - | - | - | - | - | 0.2 | 0.2 | - | 0.2 |
| 100Y/(Y+Ln) | (15.4) | (6.7) ^b | - | (9.0) ^b | (31.6) | (25.8) ^b | (13.5) | - | (29.1) | - |
| Method | XF | CH | XF | CH | CH | CH | XF | OS | XF | XF |
| $\Sigma = La+Ce+Pr$ | 61.7 | 61.7 | 61.8 | 61.9 | 61.9 | 62.0 | 62.1 | 62.3 | 62.6 | 62.7 |
| La-Nd | 88.0 | 88.3 | 85.6 | 88.1 | 91.2 | 80.6 | 86.3 | 81.4 | 82.6 | 85.2 |
| Sm-Ho | 11.1 | 9.9 | 13.2 | 9.8 | 8.6 | 19.4 | 11.1 | 15.2 | 12.8 | 11.3 |
| Er-Lu | 0.9 | 1.8 | 1.2 | 2.1 | 0.2 | - | 2.6 | 3.4 | 4.6 | 3.5 |
| ΣRE_2O_3 | - | 1.81 | 6.68 | 0.77 | 0.87 | 0.20 | 4.10 | 1.21 | 1.71 | 1.70 |
| La/Nd | 0.57 | 0.54 | 0.48 | 0.60 | 0.46 | 0.68 | 0.52 | 0.41 | 0.83 | 0.63 |

Tarnevskaya (1973), porphyritic biotite granite, N. E. Transbaikalia;
 (139) Aleksiev, Khisina, and Pavlova (1969), granodiorite, Plana pluton,
 Bulgaria; (140) Lyakhovich (1968), syenite, Armenia.

Titanite - 15

(141) Vinogradova (1967), amphibole-biotite granodiorite, N.W. Kola Peninsula; (142) Mikhailov and Mineev (1970), contact-metasomatic diopside rock, Kontykon, Aldan; (143) Bazhenov and Bazhenova (1975), pyroxene-amphibole migmatite, I'men Mts., Urals; (144) Borodin (1960), pyroxenite, Karelia; (145) Lyakhovich (1962, 1968), biotite granite, E. Transbaikal; (146) Kukhareenko et al. (1965), pyroxenite, Afrikanda, Kola Peninsula; (147) Borodin (1960), amphibole-pyroxene rock, Kola Peninsula; (148) Kukhareenko et al. (1969), gabbro, Eletsar

| | 141 | 142 | 143 | 144 | 145 | 146 | 147 | 148 | 149 | 150 |
|---------------------|--------|------|---------------------|------|------|------|------|------------------|------|--------|
| La | 17.4 | 16.7 | 12.2 | 12.8 | 13.4 | 12.8 | 10.8 | 17.4 | 11.8 | 18.4 |
| Ce | 39.2 | 43.7 | 43.6 | 40.9 | 40.9 | 41.0 | 43.0 | 43.2 | 47.4 | 39.1 |
| Pr | 6.1 | 2.5 | 7.4 | 9.6 | 9.1 | 9.6 | 9.6 | 3.3 | 4.7 | 6.6 |
| Nd | 23.8 | 24.4 | 25.3 | 24.0 | 21.9 | 24.0 | 27.2 | 26.4 | 26.9 | 23.0 |
| Sm | 3.4 | 3.7 | 4.2 | 6.1 | 4.6 | 6.0 | 5.2 | 4.6 | 4.3 | 4.6 |
| Eu | 0.3 | 0.8 | - | 0.8 | 0.5 | 0.8 | 0.7 | a | 0.8 | 0.4 |
| Gd | 3.8 | 3.4 | 3.7 | 3.1 | 3.9 | 3.1 | 2.1 | 3.9 ^a | 2.5 | 3.5 |
| Tb | 0.6 | 0.5 | b | 0.4 | 0.5 | 0.4 | 0.3 | - | 0.3 | 0.3 |
| Dy | 2.0 | 2.0 | 1.6 | 1.5 | 2.7 | 1.5 | 0.6 | 1.2 | 1.0 | 1.9 |
| Ho | 0.4 | 0.2 | 0.7 | 0.3 | 0.6 | 0.3 | 0.2 | - | - | 0.3 |
| Er | 1.5 | 0.9 | 0.3 | 0.3 | 0.7 | 0.3 | 0.3 | - | 0.3 | 0.8 |
| Tm | 0.1 | 0.2 | - | - | 0.1 | - | - | - | - | 0.2 |
| Yb | 1.4 | 1.0 | - | 0.2 | 0.9 | 0.2 | - | - | - | 0.7 |
| Lu | - | - | - | - | 0.2 | - | - | - | - | 0.2 |
| 100 Y/(Y+Lu) | (16.0) | - | (10.1) ^b | - | - | - | - | (27.8) | - | (10.0) |
| Method | - | XF | CH | XF | XF | XF | XF | CH | XF | OS |
| $\Sigma = La+Ce+Pr$ | 62.7 | 62.9 | 63.2 | 63.3 | 63.4 | 63.4 | 63.4 | 63.9 | 63.9 | 64.1 |
| La-Nd | 86.5 | 87.3 | 88.5 | 87.3 | 85.3 | 87.4 | 90.6 | 90.3 | 90.8 | 87.1 |
| Sm-Ho | 10.5 | 10.6 | 10.2 | 12.2 | 12.8 | 12.1 | 9.1 | 9.7 | 8.9 | 11.0 |
| Er-Lu | 3.0 | 2.1 | 1.3 | 0.5 | 1.9 | 0.5 | 0.3 | - | 0.3 | 1.9 |
| ΣRE_2O_3 | 0.90 | 1.52 | 0.68 | - | 1.20 | - | - | - | 3.22 | 2.16 |
| La/Nd | 0.73 | 0.69 | 0.48 | 0.53 | 0.61 | 0.53 | 0.40 | 0.66 | 0.44 | 0.80 |

(a) Eu+Gd calcd. as Gd

massif; (149) Mikhailov and Mineev (1970), diopside vein, El'konka, Aldan; (150) Kuts (1973), hornblende-biotite granite, Granitnoe, Azov Sea region.

Titanite-16

(151) Serdyuchenko and Molera (1960), injection gneiss, S. Yakutia; (152.) Lyakhovich (1968), diorite-granodiorite, E. Sagan; (153) Bazhenov and Bazhenova (1975), pyroxene syenite, Il'men Mts., Urals; (154) Aleksiev and Chernokolo (1967), granosyenite, Rossen pluton, Bulgaria; (155-156) Bazhenov and Bazhenova (1975), Il'men Mts., Urals., (155) mica-rich metasomatite; (156) quartz-feldspar vein in syenite; (157) Lyakhovich (1968), syenite,

| | 151 | 152 | 153 | 154 | 155 | 156 | 157 | 158 | 159 | 160 |
|---------------------|--------|------|---------------------|--------|---------------------|---------------------|------|--------------------|---------------------|--------|
| La | 14.3 | 12.4 | 14.8 | 36.0 | 15.0 | 15.1 | 13.7 | 13.3 | 14.5 | 16.0 |
| Ce | 42.7 | 44.4 | 44.8 | 24.9 | 39.9 | 42.7 | 43.1 | 44.9 | 44.0 | 43.2 |
| Pr | 7.1 | 7.4 | 4.6 | 3.6 | 9.7 | 6.8 | 7.9 | 6.5 | 6.2 | 5.7 |
| Nd | 27.7 | 22.3 | 24.0 | 17.9 | 19.7 | 21.2 | 21.7 | 22.6 | 24.1 | 23.2 |
| Sm | 4.0 | 4.2 | 3.9 | 4.3 | 4.7 | 4.4 | 4.2 | 3.6 | 4.3 | - |
| Eu | - | 0.5 | - | - | - | - | 0.6 | - | - | 2.1 |
| Gd | 3.9 | 3.2 | 3.8 | 5.3 | 5.1 | 4.3 | 3.1 | 3.2 | 3.5 | 7.1 |
| Tb | - | 0.4 | b | - | b | b | 0.4 | b | b | - |
| Dy | 0.1 | 2.6 | 1.7 | 2.0 | 2.8 | 3.2 | 2.2 | 2.4 | 2.9 | 2.0 |
| Ho | - | 0.4 | 0.9 | 2.4 | 1.0 | 0.7 | 0.4 | 1.6 | - | - |
| Er | 0.1 | 1.1 | 1.5 | 0.3 | 2.1 | 1.6 | 1.3 | 1.9 | 0.5 | - |
| Tm | - | 0.1 | - | - | - | - | 0.1 | - | - | - |
| Yb | 0.1 | 0.9 | - | 3.0 | - | - | 1.0 | - | - | 0.7 |
| Lu | - | 0.1 | - | 0.3 | - | - | 0.3 | - | - | - |
| 100 Y / (Y+Lu) | (38.4) | - | (10.6) ^b | (39.6) | (15.2) ^b | (16.7) ^b | - | (7.8) ^b | (11.4) ^b | (21.2) |
| Method | XF | XF | CH | XF | CH | CH | XF | CH | CH | OS |
| $\Sigma = La+Ce+Pr$ | 64.1 | 64.2 | 64.2 | 64.5 | 64.6 | 64.6 | 64.7 | 64.7 | 64.7 | 64.9 |
| La-Nd | 91.8 | 86.5 | 88.2 | 82.4 | 84.3 | 85.8 | 86.4 | 87.3 | 88.8 | 88.1 |
| Sm-Ho | 8.0 | 11.3 | 10.3 | 14.0 | 13.6 | 12.6 | 10.9 | 10.8 | 10.7 | 11.2 |
| Er-Lu | 0.2 | 2.2 | 1.5 | 3.6 | 2.1 | 1.6 | 2.7 | 1.9 | 0.5 | 0.7 |
| ΣRE_2O_3 | 4.25 | 2.45 | 2.54 | 2.05 | 1.23 | 2.40 | 2.48 | 0.31 | 1.45 | 1.05 |
| La/Md | 0.61 | 0.56 | 0.62 | 2.02 | 0.76 | 0.71 | 0.60 | 0.59 | 0.60 | 0.69 |

(b) Tb+Y calcd. as Y

E. Sagan; (158-159) Bazhenov and Bazhenova (1975), Il'men Mts., Urals; (158) hybrid amphibole miaskite; (159) hybrid biotite syenite; (160) Steatz et al (1977), syenite, Hamilton, Mont.

Titanite-17

(161) Bazhenov and Bazhenova (1975), pyroxene-Seldspar pegmatite, Il'men Mts, Urals; (162) Panov and Tarkovskaya (1973), porphyritic granite, Amudzhkan complex, N.E. Transbaikal; (163) Kats (1973), hornblende-biotite granite, Granitnoe, Azov Sea region; (164) Bazhenov and Bazhenova (1975), amphibole Senite, Il'men Mts, Urals; (165) Ivanova et al. (1970), juvite, Khibi massifs, Kola Peninsula; (166) Lyakhovich and Barinskii (1961), akerite syenite, Dzhezkendin

| | 161 | 162 | 163 | 164 | 165 | 166 | 167 | 168 | 169 | 170 |
|---------------------|--------------------|------|-------|--------------------|------------------|------|-------|------|------|------|
| La | 14.1 | 9.0 | 20.6 | 14.8 | 21.8 | 15.1 | 19.1 | 9.3 | 13.6 | 17.5 |
| Ce | 45.0 | 45.8 | 37.1 | 45.0 | 37.9 | 43.7 | 40.0 | 48.6 | 44.2 | 44.1 |
| Pr | 5.8 | 10.2 | 7.3 | 5.2 | 5.4 | 6.4 | 6.2 | 7.5 | 7.7 | 3 |
| Nd | 24.8 | 18.8 | 24.2 | 26.0 | 21.0 | 22.5 | 22.5 | 23.6 | 19.7 | 25.1 |
| Sm | 4.6 | 4.1 | 4.5 | 3.8 | 4.0 | 3.9 | 5.8 | 3.6 | 6.8 | 3.1 |
| Eu | - | 0.6 | 1.0 | - | 2 | 0.5 | 1.1 | 1.0 | 1.6 | 0.1 |
| Gd | 3.2 | 5.6 | 2.7 | 2.4 | 2.9 ^a | 3.8 | 2.6 | 2.0 | 2.0 | 3.1 |
| Tb | b | 1.2 | 0.2 | b | - | 0.5 | - | 0.4 | - | 0.1 |
| Dy | 1.9 | 1.9 | 0.9 | 1.6 | 3.5 | 1.8 | 1.8 | 1.4 | 2.8 | 1.1 |
| Ho | - | 0.4 | 0.9 | 0.2 | 0.4 | 0.4 | 0.5 | 0.4 | - | - |
| Er | 0.6 | 1.5 | 0.3 | 0.7 | 1.8 | 0.6 | - | 1.0 | 1.6 | 0.1 |
| Tm | - | 0.1 | - | - | - | - | 0.1 | 0.2 | - | - |
| Yb | - | 1.2 | 0.2 | 0.3 | 1.3 | 0.8 | 0.3 | 0.8 | - | - |
| Lu | - | 0.2 | 0.1 | - | - | - | - | 0.2 | - | - |
| 100 Y/(Y+Ln) | (9.9) ^b | - | (5.8) | (8.1) ^b | (8.3) | - | (7.2) | - | - | - |
| Method | CH | OS | OS | CH | CH | XF | OS | XF | XF | XF |
| $\Sigma = La+Ce+Pr$ | 64.9 | 65.0 | 65.0 | 65.0 | 65.1 | 65.2 | 65.3 | 65.4 | 65.5 | 65.1 |
| La-Nd | 89.7 | 83.8 | 89.2 | 91.0 | 86.1 | 87.7 | 87.8 | 89.0 | 85.2 | 91.1 |
| Sm-Ho | 9.7 | 13.2 | 10.2 | 8.0 | 10.8 | 10.9 | 11.8 | 8.8 | 13.2 | 8.1 |
| Er-Lu | 0.6 | 3.0 | 0.6 | 1.0 | 3.1 | 1.4 | 0.4 | 2.2 | 1.6 | 0.1 |
| ΣRE_2O_3 | 1.04 | 1.43 | 0.95 | 1.34 | 0.49 | 1.30 | 2.59 | 0.67 | 3.00 | 0.6 |
| La/Nd | 0.57 | 0.48 | 0.85 | 0.57 | 1.04 | 0.67 | 0.85 | 0.39 | 0.69 | 0.6 |

(a) Eu+Gd calcd. as Gd

(b) Tb+Y calcd. as Y

massifs, Aldan; (167) Staatz et al. (1977), nepheline syenite, Granite Mt, Alaska; (168) Es'kova and Ganzeev (1964), pyroxene-microcline veins in Senite, Vishnerye Mts, Urals; (169-170) Mikhailov and Mineev (1961), diopside veins, Aldan; (169) Ungra River; (170) El'konko

Titanite - 18

(171) Vinogradova (1967), amphibole granodiorite, N.W. Kola Peninsula; (172) Staatz et al (1977), placer, Zanc Hills, Alaska; (173) Vinogradov and Elina (1968), granite, N.W. Kola Peninsula; (174) Raade (1969), biotite granite, Nedre Eike church, Norway; (175) Lyakhovich (1968), gabbro, Urals; (176) Lyakhovich (1962, 1968), biotite granite, Tigereck massif, Gornyi Altai; (177) Bazhenov and Bazhenova (1975), sandyite, Il'men Mts, Urals; (178) Nadezhdina et al. (1963),

| | 171 | 172 | 173 | 174 | 175 | 176 | 177 | 178 | 179 | 180 |
|---------------------|--------|--------|------------------|--------|------|------|---------------------|---------------------|------|------------------|
| La | 14.4 | 21.3 | 14.9 | 13.0 | 14.6 | 14.5 | 15.9 | 14.3 | 11.8 | 22.2 |
| Ce | 45.2 | 38.5 | 44.7 | 47.6 | 44.6 | 44.3 | 42.7 | 48.2 | 46.0 | 40.0 |
| Pr | 6.0 | 5.8 | 6.3 | 5.3 | 7.0 | 7.5 | 7.8 | 4.0 | 8.8 | 4.8 |
| Nd | 22.1 | 24.4 | 21.4 | 21.3 | 20.6 | 21.6 | 19.3 | 24.7 | 14.3 | 23.2 |
| Sm | 3.3 | 5.4 | 3.4 | 4.1 | 3.8 | 3.4 | 4.8 | 3.8 | 6.7 | 4.0 |
| Eu | 0.3 | 0.7 | a | 0.7 | 0.4 | 0.3 | - | - | 0.6 | a |
| Gd | 3.1 | 2.4 | 3.5 ^a | 2.0 | 3.2 | 2.6 | 3.6 | 5.0 | 5.6 | 4.4 ^a |
| Tb | 0.7 | - | 0.7 | 0.2 | 0.5 | 0.5 | b | c | 0.7 | c |
| Dy | 2.4 | 1.0 | 2.5 | 1.4 | 2.1 | 2.0 | 3.8 | c | 3.0 | c |
| Ho | 0.5 | - | 0.5 | 0.3 | 0.4 | 0.3 | 0.6 | - | 0.5 | 0.1 |
| Er | 1.0 | - | 1.1 | 1.4 | 1.0 | 1.0 | 1.5 | - | 0.9 | 1.0 |
| Tm | - | - | - | 0.2 | 0.2 | 0.2 | - | - | 0.2 | - |
| Yb | 1.0 | 0.5 | 1.0 | 1.6 | 1.4 | 1.5 | - | - | 0.9 | 0.3 |
| Lu | - | - | - | 0.7 | 0.2 | 0.3 | - | - | - | - |
| 100Y/(Y+Ln) | (10.3) | (11.3) | (10.6) | (18.2) | - | - | (11.0) ^b | (32.7) ^c | - | (17.7) |
| Method | - | OS | CH | XF | XF | XF | CH | CH | XF | CH |
| $\Sigma = La+Ce+Pr$ | 65.6 | 65.6 | 65.9 | 66.1 | 66.2 | 66.3 | 66.4 | 66.5 | 66.6 | 67.0 |
| La-Nd | 87.7 | 90.0 | 87.3 | 87.4 | 86.8 | 87.9 | 85.7 | 91.2 | 80.9 | 90.2 |
| Sm-Ho | 10.3 | 9.5 | 10.6 | 8.7 | 10.4 | 9.1 | 12.8 | 8.8 | 17.1 | 8.5 |
| Er-Lu | 2.0 | 0.5 | 2.1 | 3.9 | 2.8 | 3.0 | 1.5 | - | 2.0 | 1.3 |
| ΣRE_2O_3 | 1.32 | 2.85 | 1.52 | 2.44 | 0.91 | 1.10 | 0.61 | - | 2.84 | 0.22 |
| La/Nd | 0.65 | 0.88 | 0.70 | 0.61 | 0.71 | 0.67 | 0.82 | 0.58 | 0.83 | 0.96 |

(a) Eu+Gd calcd. as Gd

(b) Tb+Y calcd. as Y

(c) Tb+Dy+Y calcd. as Y

metasomatically altered trap rocks, Greater Botuobi River, Siberia; (179) Mikhailov and Mineev (1976), diopside vein, Byllimikh, Aldan; (180) Rass (1964), amphibolitized pyroxenite, Kaksherov massif, Maritime region, USSR

Titanite - 19

(181) Narlybaev (1976), nepheline syenite, Esil'sk massif, Kazakhstan; (182-184) Bazhenov and Bazhenova (1975), Il'men Mts, Urals; (182) amphibole Senite; (183) pegmatite in pyroxenite syenite; (184), hybrid biotite-amphibole rock; (185) Lyakhovich (1968), syenite, E. Sayem; (186) Panov and Tarnovskaya (1973), porphyritic granite, Amudzhikan complex, N. E. Transbaikal; (187) Es'kova and Ganzeev (1964), Vishnerye Mts., Urals, fenitized granitic pegmatite;

| | 181 | 182 | 183 | 184 | 185 | 186 | 187 | 188 | 189 | 190 |
|---------------------|------|---------------------|---------------------|---------------------|------|------|------|------|---------------------|-------|
| La | 14.4 | 18.4 | 16.4 | 16.4 | 16.1 | 14.2 | 14.3 | 13.4 | 18.4 | 20.8 |
| Ce | 46.0 | 44.3 | 43.7 | 44.9 | 44.5 | 42.5 | 44.4 | 51.3 | 43.6 | 40.7 |
| Pr | 7.1 | 4.8 | 7.4 | 6.2 | 7.0 | 11.1 | 9.1 | 3.1 | 5.9 | 6.4 |
| Nd | 17.0 | 17.6 | 20.2 | 22.7 | 22.3 | 22.2 | 23.7 | 28.4 | 21.7 | 23.8 |
| Sm | 6.7 | 3.4 | 4.1 | 3.7 | 3.3 | 2.7 | 3.3 | 1.8 | 3.1 | 4.0 |
| Eu | 0.3 | - | - | - | 0.6 | 0.3 | 0.4 | 0.3 | - | - |
| Gd | 4.2 | 3.6 | 3.1 | 3.2 | 2.1 | 2.9 | 2.7 | 1.1 | 3.2 | 2.7 |
| Tb | 0.4 | b | b | b | 0.2 | 0.8 | 0.4 | - | b | - |
| Dy | 2.3 | 3.1 | 1.8 | 1.2 | 1.6 | 1.4 | 1.1 | 0.6 | 2.1 | 1.1 |
| Ho | 0.3 | 1.2 | 1.4 | 0.1 | 0.3 | 0.3 | 0.2 | - | 0.8 | 0.3 |
| Er | 0.8 | 2.2 | 1.9 | 1.6 | 1.0 | 0.9 | 0.4 | - | 0.8 | - |
| Tm | - | - | - | - | 0.1 | 0.1 | - | - | - | - |
| Yb | 0.5 | 1.4 | - | - | 0.8 | 0.5 | - | - | 0.4 | 0.2 |
| Lu | - | - | - | - | 0.1 | 0.1 | - | - | - | - |
| 100Y/(Y+Lu) | - | (15.5) ^b | (17.5) ^b | (10.6) ^b | - | - | - | - | (11.2) ^b | (5.1) |
| Method | - | CH | CH | CH | XF | OS | XF | XF | CH | OS |
| $\Sigma = La+Ce+Pr$ | 67.5 | 67.5 | 67.5 | 67.5 | 67.6 | 67.8 | 67.8 | 67.8 | 67.9 | 67.9 |
| La-Nd | 84.5 | 85.1 | 87.7 | 90.2 | 89.9 | 90.0 | 91.5 | 96.2 | 89.6 | 91.7 |
| Sm-Ho | 14.2 | 11.3 | 10.4 | 8.2 | 8.1 | 8.4 | 7.9 | 3.8 | 9.2 | 8.1 |
| Er-Lu | 1.3 | 3.6 | 1.9 | 1.6 | 2.0 | 1.6 | 0.6 | - | 1.2 | 0.2 |
| ΣRE_2O_3 | 1.18 | 0.86 | 2.49 | 1.01 | 2.01 | 2.39 | 1.63 | 1.84 | 1.04 | 2.44 |
| La/Nd | 0.85 | 1.05 | 0.81 | 0.72 | 0.76 | 0.64 | 0.60 | 0.47 | 0.85 | 0.87 |

(b) Tb+Y calcd. as Y

(188) Mikhailov and Mineev (1970), diopside vein, Emel'dzhek, Aldan;
 (189) Bazhenov and Bazhenova (1975), sandyrite, Il'men Mts.,
 Urals; (190) Staatz et al (1977), garnetiferous syenite,
 Granite Mt., Alaska

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(191-192) Bazhenov and Bazhenova (1975), Il'men Mts, Urals, (191) pyroxene-amphibole syenite; (192) hybrid amphibole miaskite; (193) Lyakhovich and Barinskii (1961), alkaline syenite, eastern Sayan; (194) Kochingon (1975), nepheline syenite pegmatite, Pambar Range, Armenian S.S.R.; (195) Zolotarev (1963), ultrabasic alkalic rock, Kola Peninsula; (196) Bazhenov and Bazhenova (1975), pyroxene-amphibole syenite, Il'men Mts, Urals; (197) Staatz et al.

| | 191 | 192 | 193 | 194 | 195 | 196 | 197 | 198 | 199 | 200 |
|---------------------|--------------------|---------------------|------|------|------|---------------------|--------|--------|---------------------|------|
| La | 18.5 | 16.8 | 16.4 | 15.6 | 17.4 | 20.6 | 21.0 | 14.8 | 18.1 | 21.0 |
| Ce | 44.6 | 45.7 | 43.1 | 45.3 | 44.3 | 44.2 | 41.6 | 45.1 | 45.1 | 42.7 |
| Pr | 5.0 | 5.7 | 8.8 | 7.4 | 6.7 | 3.7 | 6.2 | 9.0 | 5.7 | 5.2 |
| Nd | 22.6 | 21.9 | 20.5 | 22.8 | 23.2 | 21.3 | 20.6 | 18.7 | 19.0 | 23.3 |
| Sm | 3.1 | 2.8 | 3.1 | 3.1 | 3.2 | 2.8 | 5.8 | 5.3 | 3.1 | 3.8 |
| Eu | - | - | 0.2 | 0.4 | 0.5 | - | - | 0.4 | - | 0.4 |
| Gd | 2.5 | 3.1 | 2.5 | 2.4 | 2.7 | 2.8 | 1.9 | 3.6 | 3.6 | 1.8 |
| Tb | b | b | 0.4 | 0.3 | 0.4 | b | 0.6 | 0.3 | b | 0.3 |
| Dy | 1.2 | 1.9 | 2.1 | 1.5 | 0.9 | 2.0 | 0.7 | 1.7 | 2.6 | 0.8 |
| Ho | 0.4 | 0.4 | 0.4 | 0.1 | 0.1 | 0.5 | 0.2 | 0.1 | 1.1 | 0.2 |
| Er | 1.1 | 1.3 | 0.9 | 0.7 | 0.3 | 1.3 | 1.1 | 0.6 | 1.7 | 0.4 |
| Tm | - | - | 0.1 | - | - | - | 0.3 | 0.1 | - | - |
| Yb | 1.0 | 0.4 | 1.3 | 0.4 | 0.3 | 0.8 | - | 0.3 | - | 0.1 |
| Lu | - | - | 0.2 | - | - | - | - | - | - | - |
| 100 Y/(Y+Ln) | (8.8) ^b | (11.5) ^b | - | - | - | (13.2) ^b | (15.5) | (14.1) | (10.0) ^b | - |
| Method | CH | CH | XF | XF | XF | CH | OS | XF | CH | XF |
| $\Sigma = La+Ce+Pr$ | 68.1 | 68.2 | 68.3 | 68.3 | 68.4 | 68.5 | 68.8 | 68.9 | 68.9 | 68.9 |
| La-Nd | 90.7 | 90.1 | 88.8 | 91.1 | 91.6 | 89.8 | 89.4 | 87.6 | 87.9 | 92.2 |
| Sm-Ho | 7.2 | 8.2 | 8.7 | 7.8 | 7.8 | 8.1 | 9.2 | 11.4 | 10.4 | 7.3 |
| Er-Lu | 2.1 | 1.7 | 2.5 | 1.1 | 0.6 | 2.1 | 1.4 | 1.0 | 1.7 | 0.5 |
| ΣRE_2O_3 | 1.29 | 0.78 | 3.50 | 2.51 | 0.40 | 1.63 | 2.79 | 0.1 | 0.67 | 1.59 |
| La/Nd | 0.82 | 0.77 | 0.80 | 0.69 | 0.75 | 0.97 | 1.02 | 0.79 | 0.96 | 0.90 |

(1977), gneissic monzonite, Zane Hills, Alaska; (198) Semenov (1967), ignolite pegmatite, Tuva; (199) Bazhenov and Bazhenova (1975), mica-rich metasomatite, Il'men Mts, Urals; (199) Lyakhovich (1968), biotite granite, Armenia

Titanite - 21

(201) Bazhenov and Bazhenova (1975), pyroxene-Seldspar pegmatite in Senite, Il'men Mts., Urals; (202) Mikhailov and Mineev (1970), diopside vein, Kolyokon, Aldan; (203-204) Lyakhovich (1962), granites, Megrin massif, Armenian S.S.R.; (205) Lyakhovich and Barinskii (1961), granosyenite, Megrin massif; (206-207) Bazhenov and Bazhenova (1975), Il'men Mts., Urals, (206) pyroxene senite; (207) sandyite; (208) Marchenko (1967), granite,

| | 201 | 202 | 203 | 204 | 205 | 206 | 207 | 208 | 209 | 210 |
|---------------------|--------------------|------|------|------|------|--------------------|--------------------|--------|------|------|
| La | 22.1 | 11.2 | 17.0 | 20.8 | 19.1 | 17.1 | 16.8 | 15.3 | 14.4 | 13.9 |
| Ce | 43.1 | 50.8 | 44.4 | 42.3 | 43.8 | 47.2 | 46.5 | 48.6 | 46.9 | 47.8 |
| Pr | 3.7 | 7.1 | 9.7 | 6.0 | 6.3 | 5.0 | 6.0 | 5.6 | 8.3 | 8.0 |
| Nd | 23.6 | 19.8 | 22.7 | 23.1 | 22.7 | 20.4 | 23.3 | 20.6 | 22.8 | 21.7 |
| Sm | 2.7 | 3.8 | 4.7 | 3.8 | 3.3 | 3.4 | 3.3 | 3.5 | 3.0 | 3.5 |
| Eu | - | 0.9 | 0.3 | 0.4 | 0.2 | - | - | - | 0.3 | 0.5 |
| Gd | 2.3 | 3.7 | 0.9 | 1.8 | 1.2 | 2.9 | 3.3 | 5.3 | 1.9 | 2.3 |
| Tb | b | - | 0.2 | 0.3 | 0.1 | b | b | - | 0.2 | 0.4 |
| Dy | 1.1 | 1.8 | 1.2 | 0.8 | 1.8 | 1.9 | 0.8 | - | 1.3 | 1.1 |
| Ho | 0.5 | - | 0.3 | 0.2 | 0.3 | 1.0 | - | - | 0.2 | 0.3 |
| Er | 0.9 | 0.9 | 0.4 | 0.4 | 0.4 | 1.1 | - | - | 0.4 | 0.4 |
| Tm | - | - | - | - | 0.1 | - | - | - | - | - |
| Yb | - | - | 0.2 | 0.1 | 0.3 | - | - | 1.1 | 0.3 | 0.1 |
| Lu | - | - | - | - | 0.4 | - | - | - | - | - |
| 100 Y/(Y+Lu) | (5.5) ^b | - | - | - | - | (8.2) ^b | (5.2) ^b | (28.5) | - | - |
| Method | CH | XF | XF | XF | XF | CH | CH | CH | XF | XF |
| $\Sigma = La+Ce+Pr$ | 68.9 | 69.1 | 69.1 | 69.1 | 69.2 | 69.3 | 69.3 | 69.5 | 69.6 | 69.7 |
| La-Nd | 92.5 | 88.9 | 91.8 | 92.2 | 91.9 | 89.7 | 92.6 | 90.1 | 92.4 | 91.4 |
| Sm-Ho | 6.6 | 10.2 | 7.6 | 7.3 | 6.9 | 9.2 | 7.4 | 8.8 | 6.9 | 8.1 |
| Er-Lu | 0.9 | 0.9 | 0.6 | 0.5 | 1.2 | 1.1 | - | 1.1 | 0.7 | 0.5 |
| ΣRE_2O_3 | 0.95 | 0.84 | 1.23 | 1.59 | 2.29 | 1.26 | 0.44 | 1.04 | 2.69 | 1.83 |
| La/Nd | 0.90 | 0.57 | 0.75 | 0.90 | 0.84 | 0.84 | 0.72 | 0.74 | 0.63 | 0.64 |

(b) Tb + Y
calcd. as Y

Temyuk, Azov region; (209) Kochinyan (1975), nepheline syenite, Pambak Range, Armenian S.S.R.; (210) Lyakhovich and Barinskii (1961), diorite-granodiorite, Konev massif, Urals

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(211) Es'kova and Ganzeev (1964), calcite-fluorite vein in miaskite, Vishnevye Mts, Urals;
 (212) Lyakhovich (1968), biotite granite, Gornyi Altai; (213) Bazhenov and Bazhenova (1975),
 hybrid biotite-amphibole rock, Il'men Mts, Urals; (214) Kochingyan (1975), nepheline syenite,
 Pambak Range, Armenian S.S.R.; (215) Mineev (1968), quartz crystal pegmatite, Azhailgan,
 E. Kazakhstan; (216) Nadezhkina (1968), subalkalic rock, Greater Botuobinje River, Siberia;

| | 211 | 212 | 213 | 214 | 215 | 216 | 217 | 218 | 219 | 220 |
|---------------------|------|------|--------------------|------|------|---------------------|-------|------|-------|------|
| La | 13.0 | 16.6 | 17.6 | 14.0 | 14.6 | 22.3 | 19.8 | 16.2 | 19.1 | 21.4 |
| Ce | 47.1 | 53.2 | 46.4 | 46.0 | 47.7 | 37.7 | 44.5 | 49.4 | 48.9 | 42.4 |
| Pr | 9.6 | - | 6.0 | 8.2 | 8.0 | 10.3 | 6.2 | 5.0 | 2.6 | 7.0 |
| Nd | 22.4 | 19.7 | 20.6 | 23.0 | 19.8 | 20.2 | 23.2 | 19.1 | 21.0 | 19.7 |
| Sm | 3.1 | 3.9 | 3.2 | 3.1 | 3.0 | 4.9 | 3.3 | 4.3 | 4.9 | 3.8 |
| Eu | 0.6 | 0.5 | - | 0.3 | 0.3 | a | 0.3 | 0.7 | 0.5 | 0.5 |
| Gd | 1.9 | 2.2 | 3.0 | 2.1 | 2.5 | 4.6 ^a | 0.8 | 2.7 | 1.9 | 2.4 |
| Tb | 0.2 | 0.4 | b | 0.2 | 0.2 | c | 0.4 | 0.3 | - | 0.3 |
| Dy | 1.2 | 0.3 | 1.4 | 1.4 | 1.6 | c | 0.8 | 1.2 | 0.9 | 1.8 |
| Ho | 0.2 | 0.4 | 0.2 | 0.2 | 0.3 | - | 0.2 | 0.3 | - | 0.3 |
| Er | 0.5 | 1.1 | 1.6 | 0.5 | 0.9 | - | 0.3 | 0.4 | - | 0.4 |
| Tm | - | 0.3 | - | - | 0.1 | - | - | 0.1 | - | - |
| Yb | 0.2 | 1.1 | - | 0.4 | 0.9 | - | 0.2 | 0.3 | 0.2 | - |
| Lu | - | 0.3 | - | - | 0.1 | - | - | - | - | - |
| 100 Y/(Y+Ln) | - | - | (8.7) ^b | - | - | (31.1) ^c | (3.6) | - | (8.4) | - |
| Method | XF | XF | CH | XF | XF | CH | XF | XF | OS | XF |
| $\Sigma = La+Ce+Pr$ | 69.7 | 69.8 | 70.0 | 70.0 | 70.3 | 70.3 | 70.5 | 70.6 | 70.6 | 70.8 |
| La-Nd | 92.1 | 89.5 | 90.6 | 92.5 | 90.1 | 90.5 | 93.7 | 89.7 | 91.6 | 90.5 |
| Sm-Ho | 7.2 | 7.7 | 7.8 | 6.8 | 7.9 | 9.5 | 5.8 | 9.5 | 8.2 | 9.1 |
| Er-Lu | 0.7 | 2.8 | 1.6 | 0.7 | 2.0 | - | 0.5 | 0.8 | 0.2 | 0.4 |
| ΣRE_2O_3 | 2.09 | 1.80 | 0.99 | 3.12 | 3.15 | - | 1.65 | 1.69 | 2.04 | 0.40 |
| La/Nd | 0.58 | 0.84 | 0.85 | 0.73 | 0.74 | 1.10 | 0.85 | 0.85 | 0.91 | 1.08 |

a) Eu+Gd calcd as Gd

b) Tb+Dy+Y
calcd. as Y

(217) Lyakhovich and Barinskii (1961), alkalic syenite, Megrin
 massif, Armenia; (218) Khomyakov (1972), syenite, Burpala massif,
 Baikal; (219) Stutz et al. (1972), syenite, Selawik Hills, Alaska;
 (220) Lyakhovich (1962, 1968), diorite-gneodiorite, Tongul massif,
 W. Tuva

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(221) Es'kova and Ganzeev (1964), calcite-fluorite vein in miaskite, Vishnevye Mts., Urals; (222) Kapustin (1966), carbonatite, Kovdor, Karelia; (223-224) Bazhenov and Bazhenova (1975), Il'men Mts., Urals; (223) amphibole Senite; (224) biotite miaskite; (225) Borodin (1960), ijolite, Afrikanda, Karelia; (226) Bazhenov and Bazhenova (1975), biotite miaskite, Il'men Mts., Urals; (227) Lyakhovich (1962, 1968), diorite-granodiorite, Chelyabinsk massif, Urals

| | 221 | 222 | 223 | 224 | 225 | 226 | 227 | 228 | 229 | 230 |
|--|------|------|--------------------|--------------------|------|---------------------|------|------|--------------------|-------|
| La | 15.3 | 16.3 | 19.0 | 16.1 | 14.9 | 18.6 | 24.3 | 20.8 | 15.2 | 13.6 |
| Ce | 47.6 | 46.5 | 46.4 | 47.5 | 47.8 | 46.0 | 39.5 | 44.3 | 46.9 | 49.4 |
| Pr | 7.9 | 8.0 | 5.5 | 7.3 | 8.3 | 6.8 | 7.7 | 6.5 | 9.8 | 8.9 |
| Nd | 21.6 | 22.7 | 19.6 | 20.0 | 21.1 | 19.1 | 19.3 | 21.1 | 18.0 | 20.4 |
| Sm | 2.8 | 2.8 | 3.3 | 3.3 | 2.9 | 2.9 | 3.4 | 2.9 | 3.2 | 4.2 |
| Eu | 0.5 | 0.3 | - | - | 0.3 | - | 0.3 | 0.3 | - | 0.4 |
| Gd | 1.9 | 1.8 | 2.9 | 2.5 | 2.5 | 3.1 | 2.5 | 2.1 | 3.1 | 1.4 |
| Tb | 0.2 | 0.3 | b | b | 0.4 | b | 0.4 | 0.3 | b | 0.1 |
| Dy | 1.2 | 0.9 | 1.4 | 2.0 | 1.0 | 1.9 | 1.4 | 0.9 | 1.1 | 0.7 |
| Ho | 0.2 | 0.1 | 0.5 | 0.2 | 0.2 | 0.4 | 0.2 | 0.2 | 0.8 | - |
| Er | 0.5 | 0.2 | 0.8 | 0.7 | 0.3 | 0.6 | 0.4 | 0.4 | 1.9 | 0.4 |
| Tm | - | - | - | - | - | - | - | - | - | - |
| Yb | 0.3 | 0.1 | 0.6 | 0.4 | 0.3 | 0.6 | 0.5 | 0.2 | - | 0.5 |
| Lu | - | - | - | - | - | - | 0.1 | - | - | - |
| 100Y/(Y+Ln) | - | - | (5.8) ^b | (5.2) ^b | - | (11.9) ^b | - | - | (6.6) ^b | (4.1) |
| Method | XF | XF | CH | CH | XF | CH | XF | XF | CH | XF |
| $\Sigma = \text{La} + \text{Ce} + \text{Pr}$ | 70.8 | 70.8 | 70.9 | 70.9 | 71.0 | 71.4 | 71.5 | 71.6 | 71.9 | 71.9 |
| La-Nd | 92.4 | 93.5 | 80.5 | 90.9 | 92.1 | 90.5 | 90.8 | 92.7 | 89.9 | 92.3 |
| Sm-Ho | 6.8 | 6.2 | 8.1 | 8.0 | 7.3 | 8.3 | 8.2 | 6.7 | 8.2 | 6.8 |
| Er-Lu | 0.8 | 0.3 | 1.4 | 1.1 | 0.6 | 1.2 | 1.0 | 0.6 | 1.9 | 0.9 |
| $\Sigma \text{RE}_2\text{O}_3$ | 0.91 | 0.35 | 1.16 | 1.70 | - | 1.12 | 1.52 | - | 1.28 | 3.00 |
| La/Nd | 0.71 | 0.72 | 0.97 | 0.81 | 0.71 | 0.98 | 1.26 | 0.99 | 0.85 | 0.66 |

(b) Tb+Y
calcd. as Y

(228) Semenov and Barinskii (1958), sphene-nepheline-apatite rock, Khibina massif, Kola Peninsula; (229) Bazhenov and Bazhenova (1975), hybrid biotite-amphibole rock, Il'men Mts., Urals; (230) Serdyuchenko and Moleva (1960), diopside-scapolite skarn, S. Yakutia

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(231) Rass (1964), ore pyroxenite, Koksharov complex, Maritime Province; (232) Nurlybaev (1976) alkali syenite, Karsakpaysk massif, Kazakhstan; (233) Es'kova and Ganzeev (1964), nepheline pegmatite, Vishnevye Mts., Urals; (234) Aleksiev and Chernokals (1967), leucomonzonite, Rossen pluton, Bulgaria; (235) Lyakhovich (1962, 1968), diorite-granodiorite, E. Sayan; (236) Panov and Tarnovskaya (1973), biotite gneiss, N.E. Transbaikalia; (237) Khomyakov

| | 231 | 232 | 233 | 234 | 235 | 236 | 237 | 238 | 239 | 240 |
|---------------------|--------------------|--------|------|--------|------|------|------|--------------------|---------------------|---------------------|
| La | 21.3 | 29.7 | 16.6 | 13.9 | 20.3 | 16.7 | 20.4 | 17.6 | 21.4 | 22.4 |
| Ce | 46.3 | 38.1 | 47.9 | 53.3 | 44.3 | 47.9 | 48.9 | 49.5 | 47.3 | 48.6 |
| Pr | 4.6 | 4.9 | 8.2 | 5.7 | 8.5 | 9.2 | 4.5 | 6.8 | 5.5 | 3.2 |
| Nd | 20.3 | 17.5 | 19.4 | 14.3 | 19.7 | 16.1 | 20.7 | 17.9 | 18.2 | 19.8 |
| Sm | 2.6 | 2.1 | 3.3 | 5.5 | 3.0 | 2.5 | 2.0 | 3.5 | 3.4 | 1.6 |
| Eu | a | - | 0.4 | - | 0.5 | 0.4 | 0.5 | - | - | a |
| Gd | 2.8 ^a | 3.0 | 1.7 | 3.9 | 1.6 | 2.9 | 1.3 | 3.1 | 2.3 | 2.3 ^a |
| Tb | b | - | 0.3 | - | 0.3 | 1.0 | 0.2 | b | c | b |
| Dy | 0.6 | 2.9 | 1.4 | 1.5 | 1.2 | 1.5 | 0.8 | 0.8 | c | 0.8 |
| Ho | 0.2 | - | 0.2 | 0.8 | 0.2 | 0.2 | 0.1 | - | 1.6 | 0.3 |
| Er | 1.0 | 0.9 | 0.4 | - | 0.4 | 0.8 | 0.2 | 0.8 | - | 0.7 |
| Tm | - | - | - | - | - | 0.1 | 0.1 | - | 0.3 | - |
| Yb | 0.3 | 0.9 | 0.2 | 1.1 | - | 0.6 | 0.2 | - | - | 0.3 |
| Lu | - | - | - | - | - | 0.1 | 0.1 | - | - | - |
| 100Y/(Y+Ln) | (9.2) ^b | (10.0) | - | (16.0) | - | - | - | (8.9) ^b | (10.3) ^c | (12.4) ^b |
| Method | CH | - | XF | XF | XF | OS | XF | CH | CH | CH |
| $\Sigma = La+Ce+Pr$ | 72.2 | 72.7 | 72.7 | 72.9 | 73.1 | 73.8 | 73.8 | 73.9 | 74.2 | 74.2 |
| La-Nd | 92.5 | 90.2 | 92.1 | 87.2 | 92.8 | 89.9 | 94.5 | 91.8 | 92.4 | 94.0 |
| Sm-Ho | 6.2 | 8.0 | 7.3 | 11.7 | 6.8 | 8.5 | 4.9 | 7.4 | 7.3 | 5.0 |
| Er-Lu | 1.3 | 1.8 | 0.6 | 1.1 | 0.4 | 1.6 | 0.6 | 0.8 | 0.3 | 1.0 |
| ΣRE_2O_3 | 0.61 | 1.10 | 0.80 | 0.78 | 2.52 | 1.88 | 1.72 | 1.16 | 0.61 | 0.44 |
| La/Nd | 1.05 | 1.69 | 0.86 | 0.97 | 1.02 | 1.04 | 0.98 | 0.99 | 1.18 | 1.13 |

(a) Eut Gd calcd. as Gd
 (b) Tb+Y calcd. as Y

(1972), regirized syenite pegmatite, Burpala massif, N. Cisbaikalia;
 (238-239) Bazhenov and Bazhenova (1975), Il'men Mts., Urals;
 (238) hybrid amphibole mica schist; (239) sandyite; (240) Rass
 (1964), ore pyroxenite, Koksharov complex, Maritime Province

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(241) Nurlybaev (1976), pseudoleucite syenite, Esil'sk massif, Kazakhstan; (242) Khomyakov (1972), Burpak massif, N. Cisbaikal, aegirized metasomatite; (243) Es'kova and Ganzeev (1964), Vishnevye Mts, Urals, calcite vein in fenite; (244) Same as (242), massive syenite; (245) Lyakhovich and Barinskii (1961), Lyakhovich (1968), syenite, E. Sayan; (246) Khomyakov (1972), syenite, Burpak massif; (247) Bazhenov and

| | 241 | 242 | 243 | 244 | 245 | 246 | 247 | 248 | 249 | 250 |
|---------------------|-------|------|------|------|------|------|---------------------|------|------|------|
| La | 15.6 | 20.4 | 14.6 | 16.5 | 21.4 | 16.8 | 20.6 | 18.7 | 22.9 | 20.9 |
| Ce | 56.6 | 48.3 | 49.8 | 54.5 | 45.5 | 54.7 | 49.0 | 51.7 | 43.7 | 46.7 |
| Pr | 2.0 | 5.7 | 10.3 | 3.8 | 8.0 | 3.4 | 5.5 | 5.0 | 9.0 | 8.0 |
| Nd | 20.1 | 18.9 | 14.7 | 19.6 | 16.7 | 19.5 | 18.0 | 15.3 | 16.3 | 19.2 |
| Sm | 2.9 | 2.5 | 4.0 | 2.3 | 2.7 | 2.1 | 2.4 | 3.7 | 2.6 | 2.4 |
| Eu | - | 0.8 | 0.7 | 0.4 | 0.3 | 0.3 | - | 0.5 | 0.3 | 0.3 |
| Gd | 1.9 | 1.6 | 2.7 | 1.5 | 1.5 | 1.8 | 2.6 | 2.6 | 2.3 | 1.4 |
| Tb | - | 0.2 | 0.2 | 0.2 | 0.3 | 0.2 | b | 0.3 | 0.5 | 0.2 |
| Dy | 0.9 | 0.9 | 1.8 | 0.8 | 1.1 | 0.8 | 1.2 | 1.1 | 1.1 | 0.6 |
| Ho | - | 0.1 | 0.2 | 0.1 | 0.3 | - | 0.3 | 0.3 | 0.2 | - |
| Er | - | 0.3 | 0.7 | 0.2 | 1.0 | 0.2 | 0.2 | 0.4 | 0.6 | 0.2 |
| Tm | - | - | - | - | 0.2 | - | - | - | - | - |
| Yb | - | 0.3 | 0.3 | 0.1 | 0.8 | 0.2 | 0.2 | 0.4 | 0.4 | 0.1 |
| Lu | - | - | - | - | 0.2 | - | - | - | 0.1 | - |
| 100 Y / (Y+Lu) | (1.5) | - | - | - | - | - | (10.8) ^b | - | - | - |
| Method | - | XF | XF | XF | XF | XF | CH | XF | OS | XF |
| $\Sigma = La+Ce+Pr$ | 74.2 | 74.4 | 74.7 | 74.8 | 74.9 | 74.9 | 75.1 | 75.4 | 75.6 | 75.6 |
| La-Nd | 94.3 | 93.3 | 89.4 | 94.4 | 91.6 | 94.4 | 93.1 | 90.7 | 91.9 | 94.8 |
| Sm-Ho | 5.7 | 6.1 | 9.6 | 5.3 | 6.2 | 5.2 | 6.5 | 8.5 | 7.0 | 4.9 |
| Er-Lu | - | 0.6 | 1.0 | 0.3 | 2.2 | 0.4 | 0.4 | 0.8 | 1.1 | 0.3 |
| ΣRE_2O_3 | 0.66 | 1.90 | 0.64 | 2.66 | 2.43 | 2.24 | 0.97 | 1.48 | 3.27 | 2.50 |
| La/Nd | 0.77 | 1.07 | 0.99 | 0.84 | 1.28 | 0.86 | 1.15 | 1.22 | 1.41 | 1.09 |

(b) Tb+Y
calcd. as Y

Bezhenova (1975), hybrid biotite-amphibole rock, Il'men Mts., Urals; (248) Khomyakov (1972), syenite, Burpak massif; (249) Panov and Tarnovskaya (1973), porphyritic granite, Amidzhikan complex, N.E. Transbaikal; (250) Lyakhovich and Barinskii (1961), alkali syenite, Lovozero massif, Kola Peninsula

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(251) Khomyakov (1972), syenite, Burpala massifs, N. Cisbaikal; (252) Panov and Tarnovskaya (1973), biotite-hornblende diorite-monzonite, N.E. Transbaikal; (253) Kapustin (1966), carbonatite, Kovdor, Karelia; (254) Kochinyan (1975), nepheline syenite pegmatite, Pambak Range, Armenian S.S.R.; (255) Serdyuchenko and Pap (1969), Precambrian crystalline rocks, Byeloruss SSR (256), Lyakhovich and Barinskii (1961), Illimakh massifs, Aldan; (257) Ivanova et al. (1970), foyaitite, Khibina massifs, Kola Peninsula; (258)

| | 251 | 252 | 253 | 254 | 255 | 256 | 257 | 258 | 259 | 260 |
|---------------------|------|------|------|------|------|------|-------|-------|---------------------|------|
| La | 18.3 | 25.8 | 18.3 | 21.1 | 25.5 | 23.4 | 21.1 | 23.2 | 27.7 | 31.6 |
| Ce | 52.0 | 40.8 | 50.5 | 48.6 | 50.6 | 47.4 | 50.2 | 49.6 | 46.2 | 39.4 |
| Pr | 5.5 | 9.2 | 7.0 | 6.3 | - | 5.4 | 5.1 | 3.6 | 2.6 | 6.8 |
| Nd | 15.1 | 17.4 | 18.7 | 18.4 | 9.9 | 16.4 | 15.3 | 20.8 | 16.4 | 13.9 |
| Sm | 4.2 | 2.0 | 1.9 | 2.2 | 6.4 | 2.8 | 2.1 | 1.6 | 2.0 | 1.9 |
| Eu | 0.6 | 0.4 | 0.4 | 0.3 | - | 0.4 | - | 0.2 | a | 0.3 |
| Gd | 2.3 | 1.9 | 1.8 | 1.6 | 4.6 | 1.6 | 0.9 | 0.5 | 2.6 ^a | 2.4 |
| Tb | 0.4 | 0.7 | 0.2 | 0.1 | - | 0.3 | - | 0.1 | b | 1.0 |
| Dy | 1.1 | 0.8 | 0.7 | 0.8 | 3.0 | 1.2 | - | 0.4 | 0.9 | 1.2 |
| Ho | - | 0.1 | - | - | - | 0.3 | 0.4 | - | 0.2 | 0.2 |
| Er | 0.3 | 0.5 | 0.3 | 0.3 | - | 0.8 | 0.2 | - | 1.0 | 0.7 |
| Tm | - | - | - | - | - | - | - | - | - | 0.1 |
| Yb | 0.2 | 0.3 | 0.2 | 0.3 | - | - | 0.3 | - | 0.4 | 0.4 |
| Lu | - | 0.1 | - | - | - | - | - | - | - | 0.1 |
| 100Y/(Y+Lu) | - | - | - | - | - | - | (1.4) | (1.0) | (12.2) ^b | - |
| Method | XF | OS | XF | XF | XF | XF | CH | - | CH | OS |
| $\Sigma = La+Ce+Pr$ | 75.8 | 75.8 | 75.8 | 76.0 | 76.1 | 76.2 | 76.4 | 76.4 | 76.5 | 77.8 |
| La-Nd | 90.9 | 93.2 | 94.5 | 94.4 | 86.0 | 92.6 | 91.7 | 97.2 | 92.9 | 91.7 |
| Sm-Ho | 8.6 | 5.9 | 5.0 | 5.0 | 14.0 | 6.6 | 7.2 | 2.8 | 5.7 | 7.0 |
| Er-Lu | 0.5 | 0.9 | 0.5 | 0.6 | - | 0.8 | 1.1 | - | 1.4 | 1.3 |
| ΣRE_2O_3 | 1.44 | 2.50 | 2.17 | 2.48 | 0.85 | 0.96 | 1.10 | 0.28 | 0.40 | 2.37 |
| La/Nd | 1.22 | 1.48 | 0.98 | 1.14 | 2.58 | 1.42 | 1.37 | 1.12 | 1.69 | 2.28 |

(a) Eu+Gd
calcd. as Gd

(b) Tb+Y
calcd. as Y

Befieva (1976), alkalic granite, Kola Peninsula; (259) Rass (1964), ore pyroxenite, Koksharov complex, Maritime Province; (260) Panov and Tarnovskaya (1973), gneodiorite-granite, N.E. Transbaikal

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(261-262) Panov and Tarnovskaya (1973), N.E. Transbaikal; (261) granite porphyry, Amana complex; (262) granodiorite-granite; (263) Porthov, Ganzeev, and Bursuk (1967), syenite pegmatite, Burpala massifs, N. Cisbaikal; (264) Kukhareenko et al. (1965), ijolite pegmatite, Lesnaya varaka, Karelia; (265) Aleksiev and Chernokolo (1967), monzonite, Rossen pluton, Bulgaria; (266) Ivanova et al. (1970), Khibinite, Khibina massifs, Kola Peninsula; (267)

| | 261 | 262 | 263 | 264 | 265 | 266 | 267 | 268 | 269 | 270 |
|---------------------|------|------|--------|-------|--------|-------|-------|------|------|-------|
| La | 32.1 | 27.9 | 16.7 | 16.8 | 29.3 | 20.8 | 17.1 | 22.8 | 33.4 | 16.3 |
| Ce | 39.0 | 40.0 | 42.2 | 58.0 | 47.8 | 55.3 | 60.1 | 53.2 | 42.4 | 42.5 |
| Pr | 7.0 | 10.3 | 19.5 | 4.0 | 3.3 | 4.4 | 3.5 | 5.0 | 6.3 | 23.4 |
| Nd | 13.8 | 16.5 | 18.7 | 17.1 | 10.7 | 15.8 | 15.2 | 15.5 | 11.5 | 15.8 |
| Sm | 1.6 | 1.8 | - | 1.6 | 2.8 | 2.1 | 1.4 | 1.9 | 1.7 | - |
| Eu | 0.3 | 0.2 | - | 0.6 | - | - | 0.4 | 0.3 | 0.3 | - |
| Gd | 2.2 | 1.4 | 2.7 | 1.9 | 4.2 | 0.8 | 2.3 | 1.0 | 2.0 | 1.9 |
| Tb | 0.5 | 0.5 | - | - | - | - | - | 0.2 | - | - |
| Dy | 1.3 | 0.7 | - | - | 1.0 | - | - | 0.1 | 1.0 | - |
| Ho | 0.3 | 0.1 | - | - | 0.8 | 0.4 | - | - | 0.2 | - |
| Er | 0.8 | 0.3 | - | - | 0.1 | 0.2 | - | - | 0.7 | - |
| Tm | 0.1 | - | - | - | - | - | - | - | - | - |
| Yb | 0.9 | 0.3 | 0.2 | - | - | 0.2 | - | - | 0.4 | 0.1 |
| Lu | 0.1 | - | - | - | - | - | - | - | 0.1 | - |
| 100Y/(Y+Ln) | - | - | (16.6) | (4.4) | (19.7) | (2.1) | (0.5) | - | - | (5.3) |
| Method | OS | OS | XF | XF | XF | XF | XF | CH | OS | XF |
| $\Sigma = La+Ce+Pr$ | 78.1 | 78.2 | 78.4 | 78.8 | 80.4 | 80.5 | 80.7 | 81.0 | 82.1 | 82.2 |
| La-Nd | 91.9 | 94.7 | 97.1 | 95.9 | 91.1 | 96.3 | 95.9 | 96.5 | 93.6 | 98.0 |
| Sm-Ho | 6.2 | 4.7 | 2.7 | 4.1 | 8.8 | 3.3 | 4.1 | 3.5 | 5.2 | 1.9 |
| Er-Lu | 1.9 | 0.6 | 0.2 | - | 0.1 | 0.4 | - | - | 1.2 | 0.1 |
| ΣRE_2O_3 | 2.90 | 4.09 | 5.10 | - | 0.91 | 1.61 | - | 2.64 | 1.93 | 2.45 |
| La/Nd | 2.32 | 1.69 | 0.90 | 0.99 | 2.73 | 1.32 | 1.13 | 1.47 | 2.91 | 1.03 |

Kukhareenko et al. (1965), ijolite pegmatite, Ozernaya varaka, Karelia; (268) Mikhailov and Mineev (1970), diopside vein, Emerald'zhok, Aldan; (269) Panov and Tarnovskaya (1973), granodiorite-granite, N.E. Transbaikal; (270) Porthov, Ganzeev, and Bursuk (1967), syenite pegmatite, Burpala massifs, N. Cisbaikal.

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