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RELATIVE PROPORTIONS OF THE LANTHANIDES IN MINERALS OF THE BASTNAESITE GROUP

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Abstract

Recalculation to atomic percentages of one hundred analyses of members of the bastnaesite group shows that all except bastnaesite-(Y) and synchysite-(Y) are cerium-selective, *i.e.*, they are enriched in the light rare earths. The minerals of the group from alkaline rocks and carbonatites show the normal increase in content of lanthanides of low atomic weight, except that synchysite shows less than normal increase.

Sommaire

Le calcul des pourcentages atomiques de cent analyses de minéraux du groupe de la bastnaesite révèle pour tous ceux-ci, sauf la bastnaesite-(Y) et la synchysite-(Y), un enrichissement en terres rares légères. Les minéraux provenant de roches alcalines et de carbonatites ont subi l'enrichissement normal en lanthanides de faible poids atomique, excepté la synchysite, dont l'enrichissement reste en dessous de la normale.

(Traduit par la Rédaction)

Minerals of the Bastnaesite Group

The bastnaesite group of fluocarbonates of the alkaline earths, lanthanides and yttrium includes the following minerals. In the formulas, Ce represents all the light lanthanides (La–Gd); Y represents Y + the heavy lanthanides (Tb-Lu):

bastnaesite- (=bastnaesite-Ce))	$Ce(CO_3)F$
hydroxyl-bastnaesite	$Ce(CO_3)(OH, F)$
bastnaesite-(La)	$(La, Ce)(CO_3)F$
bastnaesite-(Y)	$(Y, Ce, Dy)(CO_3)F$
parisite	$(Ce,La)_2Ca(CO_3)_3F_2$
cordylite	$(Ce,La)_2Ba(CO_3)_3F_2$
röntgenite	$(Ce,La)_3Ca_2(CO_3)_5F_3$
synchysite	$(Ce,La)Ca(CO_3)_2F$
synchysite-(Y)	$(Y,Ce)Ca(CO_3)_2F$
huanghoite	$CeBa(CO_3)_2F$

Two other possible members of the group are yttroparisite (parisite-(Y) of Nefedov (1941), which has not been confirmed, and synchysite-(Nd), reported by qualitative tests by Vorma *et al.* (1966).

Recent Data

The crystallographic and syntactic relations of the group were brilliantly resolved twenty-five years ago by Donnay & Donnay (1953), but there has been no recent review of the compositional variation of the lanthanides with paragenesis. Semenov (1963) listed the group as Ce-selective (*i.e.*, concentrating the light lanthanides), as would be expected for minerals with lanthanides in eleven-fold coordination. A similar conclusion can be drawn from data on bastnaesite and parisite, shown graphically by Fleischer (1965). Neither author, however, considered data for bastnaesite-(Y) and synchysite-(Y). Many new analyses have been reported in the past few years, so it seems desirable to summarize all the available data for these minerals. No data are available for röntgenite.

Some difficulties arise in the grouping in Tables 1, 2 and 3 by paragenetic types of occurrence. This is especially true of the bastnaesites grouped as 'hydrothermal', which includes bastnaesites from 'hydrothermalite of alkalic granosyenite', 'quartz-fluorite vein in altered syenite', 'hydrothermal lead-zinc deposit' and others, which perhaps should not be grouped together.

The data in the tables are given in terms of atomic percent of total lanthanides (La to Lu), excluding yttrium. The value given for 100 Y/(Y+Ln) is also in atomic percent (=Ln), but is not directly comparable with those for the lanthanides; Σ is the sum of atomic percents of La+Ce+Pr. The ratio La/Nd has been shown to be a useful indicator of paragenetic type of occurrence (Fleischer 1965).

Discussion

The variation of the proportions of lanthanides in minerals of the bastnaesite group, in which the lanthanides are major constituents, is not as good an indicator of conditions of formation as it is in minerals such as titanite, apatite or epidote, in which the lanthanides are minor constituents (Fleischer & Altschuler 1969). All the minerals in the group are strong-

TABLE 1. LANTHANIDES* IN BASTNAESITES FROM VARIOUS ROCKS

	bastnaesite-(Y), granite pegmatites and granites(9)†		bastnaesite, granite pegmatites and granite(7)		bastnaesite, hydrothermal (21)		bastnaesite, alkaline rocks (13)		bastnaesite+, carbonatites (15)	
	av.	range	av.	range	av.	range	av.	range	av.	range
La	4.3	2.6 - 8.0	25.0	10.9 -35.1	28.8	14.0 -44.9	34.4	24.4 -45.3	33.5	22.3 -43.6
Ce	14.0	8.2 -24.8	44.3	27.0 -52.7	48.1	44.3 -55.5	49.3	39.3 -56.0	49.1	39.6 -56.2
Pr	3.1	0.2 - 5.0	5.2	3.1 - 5.4	5.0	1.0 - 7.8	4.1	3.0 - 6.2	3.6	<0.1 - 5.0
Nd	11.5	7.1 -22.6	15.2	8.5 -20.3	15.7	6.2 -32.5	10.2	6.4 -14.8	12.5	<0.1 -24.5
Sm	9.8	5.2 -16.4	2.6	<0.1 - 7.8	1.4	0.1 - 2.9	1.0	0.2 - 2.6	1.0	<0.1 - 2.3
Eu	0.4	<0.1 - 1.0	0.1	<0.1 - 0.7	0.1	<0.1 - 0.5	-	<0.1 - 0.2	0	<0.1 - 0.1
Gd	15.3	10.0 -18.6	2.0	<0.1 - 8.7	0.5	<0.1 - 2.5	0.6	<0.1 - 1.7	0.2	<0.1 - 0.4
Tb	2.5	1.6 - 3.4	0.4	<0.1 - 2.0	0.1	<0.1 - 0.8	-	<0.1 - 0.2	0	0
Dy	17.6	7.6 -20.9	2.2	<0.1 - 7.8	0.1	<0.1 - 0.6	0.3	<0.1 - 1.6	0.1	<0.1 - 1.8
Ho	3.0	<0.1 - 4.3	0.5	<0.1 - 1.8	0.0	<0.1 - 0.3	-	<0.1 - 0.2	0	<0.1 - 0.5
Er	9.9	3.7 -13.4	1.4	<0.1 - 5.1	0.1	<0.1 - 0.3	0.1	<0.1 - 1.5	0	<0.1 - 0.2
Tm	0.9	0.5 - 1.7	0.1	<0.1 - 0.8	0	<0.1 - 0.1	-	<0.1 - 0.2	0	<0.1
Yb	6.6	3.0 - 9.5	0.9	<0.1 - 4.3	0.1	<0.1 - 0.8	-	<0.1 - 0.1	0	<0.1 - 0.2
Lu	1.1	<0.5 - 2.6	0.1	<0.1 - 0.7	0	<0.1 - 0.2	-	<0.1 - 0.2	-	-
	100.0		100.0		100.0		100.0		100.0	
100Y/(Y+Ln)	35.3(3)	20.2 -51.7	23.0(3)	0.5 -39.3	5.1(5)	0.1 -15.6	2.1(2)	0.8 - 3.3	1.3(3)	0.1 - 2.4
Σ[1]	21.4	13.6 -36.4	74.5	44.9 -90.7	81.9	65.1 -93.5	87.7	80.2 -92.1	86.2	74.5 -95.9
La-Nd	32.9	21.6 -53.4	89.7	65.2 -100.	97.6	95.6 -99.8	98.0	91.6 -99.8	98.7	95.6 -100.
Sm-Ho	48.6	34.4 -56.5	7.8	0 -28.1	2.2	0.3 - 7.5	1.9	0.2 - 5.4	1.3	0.1 - 4.1
Er-Lu	18.5	7.7 -24.2	2.5	0 -10.9	0.2	0 - 1.3	0.1	0 - 3.0	0.1	0.0 - 0.4
La/Nd	0.37	0.18- 0.74	1.64	0.54- 4.13	1.83	0.47- 6.46	3.37	1.65- 5.22	2.67	0.95- 8.09

* in atomic percent. + includes bastnaesite-(La) and hydroxyl bastnaesite. † The number in parentheses indicates the number of analyses; for 100Y/(Y+Ln) it refers to the number of analyses in which Y is reported. [1] Σ = La+Ce+Pr (at. %).

TABLE 2. LANTHANIDES* IN SYNCHYSITE-(Y) AND SYNCHYSITE FROM VARIOUS ROCKS

	synchysite-(Y), granites and granite pegmatites(6)†		synchysite-(Y), hydrothermal(2)		synchysite, alkaline rocks(2)	
	av.	range	av.	range	av.	range
La	3.7	<0.1 -10.1	16.2	12.1 -20.3	20.5	19.5 -21.5
Ce	9.5	<0.1 -24.0	38.3	36.0 -40.6	41.7	39.7 -43.7
Pr	2.0	<0.1 - 4.5	5.3	4.2 - 6.4	6.0	5.5 - 6.6
Nd	6.6	<0.1 -15.3	18.3	16.1 -20.5	22.8	20.8 -24.8
Sm	4.4	<0.1 - 7.8	5.4	4.5 - 6.3	3.7	3.5 - 3.8
Eu	0.8	<0.1 - 3.3	0.1	<0.1 - 0.3	0.5	0.4 - 0.6
Gd	11.3	6.2 -16.4	4.6	3.7 - 5.4	2.5	2.5
Tb	1.7	<0.1 - 2.7	0.6	<0.1 - 1.3	0.3	0.2 - 0.4
Dy	18.9	11.3 -29.1	4.7	3.1 - 6.2	0.9	0.6 - 1.3
Ho	3.8	<0.1 - 7.0	0.9	0.8 - 1.0	0.2	0.1 - 0.2
Er	18.2	9.1 -28.4	2.5	2.5	0.5	0.4 - 0.6
Tm	1.4	<0.1 - 2.5	0.3	0.2 - 0.5	-	-
Yb	16.0	8.0 -27.5	2.3	1.2 - 3.4	0.4	0.3 - 0.5
Lu	1.7	<0.1 - 3.8	0.5	0.4 - 0.5	-	-
	100.0		100.0		100.0	
100Y/(Y+Ln)	71.5(1)	-	39.3(2)	36.2 -42.4	7.2(1)	-
Σ	15.2	<0.1 -38.6	59.8	59.1 -60.5	68.2	65.8 -70.7
La-Nd	21.8	<0.1 -50.9	78.1	75.2 -81.0	91.0	90.6 -91.5
Sm-Ho	40.9	28.2 -50.6	16.3	12.1 -20.5	8.1	7.6 - 8.5
Er-Lu	37.3	19.8 -55.9	5.6	4.3 - 6.9	0.9	0.9
La/Nd	0.56	0.33- 1.42	0.89	0.75- 0.99	0.90	0.79- 1.03

* in atomic percent. † The number in parentheses indicates the number of analyses; for 100Y/(Y+Ln) it refers to the number of analyses in which Y is reported.

TABLE 3. LANTHANIDES* IN PARISITE FROM VARIOUS ROCKS

	granite (1)†	hydrothermal(7)		alkaline rocks(5)		carbonatites(7)	
		av.	range	av.	range	av.	range
La	19.3	23.6	14.3 -29.2	31.3	23.6 -36.5	32.1	28.1 -35.8
Ce	49.1	45.7	41.3 -50.9	47.8	44.4 -51.5	51.4	44.4 -55.3
Pr	7.3	5.8	3.8 - 7.8	5.0	3.1 - 7.1	4.1	3.0 - 5.2
Nd	16.7	18.7	14.6 -24.7	14.1	8.5 -20.9	11.3	8.5 -14.2
Sm	3.5	2.6	1.1 - 4.8	1.0	0.1 - 3.0	0.9	0.3 - 1.5
Eu	0.2	0.2	0.1 - 0.7	0.1	0.1 - 0.7	-	-
Gd	1.9	1.5	0.1 - 3.1	0.6	0.1 - 1.9	0.2	0 - 0.7
Tb	0.1	0.2	0.1 - 0.8	0	0.1 - 0.2	-	-
Dy	0.4	0.9	0.1 - 3.0	0.1	0.1 - 3.0	-	0 - 0.2
Ho	-	0.1	0.1 - 0.7	-	-	-	-
Er	0.5	0.2	0.1 - 5.0	-	-	-	-
Tm	-	-	-	-	-	-	-
Yb	1.0	0.5	0.1 - 1.1	-	-	-	-
Lu	-	-	0.1 - 0.1	-	-	-	-
	100.0	100.0		100.0		100.0	
100Y/(Y+Ln)	-	8.65(4)	1.5 -18.8	-	-	0.25(2)	0.2 - 0.3
Σ	75.7	75.1	64.4 -83.9	84.1	75.6 -91.5	87.6	84.3 -91.1
La-Nd	92.4	93.8	86.9 -98.5	98.2	95.1-100.	98.9	98.9 -99.6
Sm-Ho	6.1	5.5	1.5 -11.4	1.8	0 - 5.0	1.1	0.4 - 1.8
Er-Lu	1.5	0.7	0.1 - 1.7	-	-	-	-
La/Nd	1.16	1.26	0.58- 2.00	2.22	1.13- 4.29	2.84	2.20-4.21

* in atomic percent. † The number in parentheses indicates the number of analyses; for 100Y/(Y+Ln) it refers to the number of analyses in which Y is reported.

TABLE 4. LANTHANIDES IN CORDYLITE AND HUANGHOITE*

	cordylite	huanghoite A	huanghoite B
La	30.1	23.3	20.2
Ce	44.2	48.6	53.3
Pr	5.4	6.2	7.0
Nd	15.1	19.1	16.7
Sm	3.1	1.1	1.9
Eu	0.1	0.1	-
Gd	2.0	0.8	0.9
Tb	-	0.1	-
Dy	-	0.2	-
Ho	-	-	-
Er	-	0.2	-
Tm	-	-	-
Yb	-	0.3	-
Lu	-	-	-
	100.0	100.0	100.0
100Y/(Y+Ln)	-	-	-
Σ	79.7	78.1	80.5
La-Nd	94.8	97.2	97.2
Sm-Ho	5.2	2.3	2.8
Er-Lu	-	0.5	-
La/Nd	1.99	1.22	1.21

* in atomic percent.
Cordylite: alkali syenite pegmatite, Narsarsuk, Greenland (Semenov & Barinskii 1958). Huanghoite A: av. of 2, hydrothermal veins in association with alkaline granosyenites, China (Semenov & Chang 1961). Huanghoite B: carbonatite, Siberia (Kapustin 1973).

ly Ce-selective, except for bastnaesite-(Y) and synchysite-(Y). Bastnaesites and parisites show the normal large increase in light lanthanides, as indicated by the value of Σ, going from granite and granite pegmatite through hydrothermal, alkaline, and carbonatite samples; the few analyses for synchysite show a smaller increase. The only analysis of cordylite (Table 4) and the two analyses of huanghoite (Table 4) show high concentrations of light lanthanides but lower values of Σ than might be expected of barium minerals from alkaline rocks; burbankite and innelite, for example, give values of Σ 82.8 to 95.3.

Copies of the calculated atomic percentages for the 100 individual analyses summarized here, with references and localities, will be deposited as Open File Report 78-488 in the U.S. Geological Survey libraries at Reston, Virginia, Denver, Colorado and Menlo Park, California. Copies can be obtained for the cost of reproduction from: Open File Services Section, U.S. Geological Survey, Box 25425, Federal Center, Denver, Colorado 80225, U.S.A.

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