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Geology and Mineralogy

This document consists of 22 pages.
Series A.

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

DATA ON THE HAFNIUM DIOXIDE CONTENT AND THE RATIO OF HAFNIUM TO ZIRCONIUM IN MINERALS AND ROCKS

By

Michael Fleischer

March 1954

Trace Elements Investigations Report 413

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USGS - TEI-413

GEOLOGY AND MINERALOGY

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DATA ON THE HAFNIUM DIOXIDE CONTENT AND THE RATIO OF HAFNIUM TO ZIRCONIUM IN MINERALS AND ROCKS

By Michael Fleischer

ABSTRACT

All published data on the hafnium content and hafnium/zirconium ratio in minerals and rocks have been compiled. The average ratio Hf/Zr is about 0.02 in the earth's crust. Minerals from alkalic rocks such as nepheline syenites have lower Hf/Zr ratios than does zircon from granitic rocks. Minerals from granitic pegmatites have the highest Hf/Zr ratios, especially some peculiar varieties of zircon such as alvite, cyrtolite and naegite, and the rare scandium silicate, thortveitite, which is the only mineral that is reported to contain more hafnium than zirconium.

INTRODUCTION

This report is a compilation of all published determinations of the hafnium content and the hafnium/zirconium ratio of minerals and rocks. The published literature has been scanned with the aid of the notched-card file on geochemistry of the U. S. Geological Survey. In addition, the following bibliographies on zirconium were checked:

Voress, H. E. and Croxton, F. E., 1951, Zirconium, a bibliography of unclassified literature. U. S. Atomic Energy Commission, TID-3010, 138 p., and supplement no. 1, 17 p.

Williams, G. C., Baker, E. G., Jr., Holzknecht, E. W., and Moody, R. G., 1950, Zirconium and hafnium--a bibliography. U. S. Atomic Energy Commission, NYO-1008, 236 p.

Few of the data are recent. The methods of determination and the authors' own estimates of error are given in the annotated bibliography. It is probable that determinations of hafnium by purely chemical methods or by determination of the density of the mixed oxides of zirconium and hafnium are of low accuracy.

Most of the determinations cited are by Von Hevesy and coworkers. Probably some samples are given more than once in the tables, as it is known that redeterminations were made on many of their samples. The sample descriptions are inadequate, so that it is not possible to be sure whether two sets of figures for material from a given locality refer to the same sample or to different samples.

Most of the samples that have been analyzed have not been well characterized as to the type of geological occurrence, so that only a few broad generalizations can be made as to the variation of the hafnium/zirconium ratio in rocks and minerals from different types of deposits. New analyses of carefully selected samples of known geological setting are highly desirable.

HAFNIUM AND ZIRCONIUM CONTENT AND THE RATIO Hf/Zr IN THE EARTH'S CRUST AND IN ROCKS

Estimates of the abundances of zirconium and hafnium are assembled in table 1. It will be noted that most of the recent estimates are the same. The estimates for zirconium are based on the analysis of many samples by Hevesy and Würstlin (13), but the estimates for hafnium are not so well established. Very few rocks have been analyzed directly for hafnium, as seen in table 2. The estimates for hafnium are based largely on analyses of zirconium minerals, especially of zircon, as given in tables 4 through 8, and it is rather uncertain whether the various rock types have been sampled well enough to give confidence in the values given for the ratio Hf/Zr.

HAFNIUM AND ZIRCONIUM CONTENT AND THE RATIO Hf/Zr OF MINERALS

The available data are given in table 4 for zircon, table 5 for zircon (varieties alvite, cyrtolite, etc.), table 6 for baddeleyite and other zirconium oxide minerals, table 7 for zirconium silicates, and table 8 for miscellaneous minerals. A list of the mineral names used in these tables is given in table 3, with the chemical formulas. In each table, the determinations are grouped by minerals and, for each mineral, geographically in the order North America, South America, Greenland, Europe, U.S.S.R., Asia, Australia, and Africa.

As the type of deposit is not stated for many of the samples, particularly for zircon in table 4, averaging by type of deposit is not here attempted. It should be noted that all or nearly all of the samples of zircon, variety alvite, etc., of table 5, and of thortveitite and other minerals of table 8 are from granitic pegmatites, whereas the baddeleyite from Brazil, table 6, and the zirconium silicates of table 7 are all from nepheline syenite pegmatites or similar alkalic rocks. The minerals from granitic pegmatites show very high Hf/Zr ratios; those from alkalic rocks distinctly low Hf/Zr ratios. Hevesy (7) and Hevesy and Jantzen (12) have given averages of their own determinations; these are tabulated in table 9.

Some of the samples that have high ratios of Hf/Zr have high contents of rare earths, uranium, and thorium. There is not, however, a close correspondence between radioactivity and hafnium content in most zircon.

In view of the very high Hf/Zr ratios of the minerals of tables 5 and 8, it is somewhat surprising that higher ratios are not reported for some of the zircon listed in table 4. New determinations of the hafnium content of zircon separated from analyzed pegmatite rocks, granites, granodiorites, and diorites might help to fill this gap in our knowledge. The Geological Survey, in the course of its work on the determination of geological age by analysis of zircon, has separated such zircon. This should be an excellent collection on which to determine Hf/Zr ratio.

Table 1.--Estimated abundances of hafnium and zirconium in the earth's crust and the ratio Hf/Zr.

No.	ZrO_2 (Wt. %)	HfO_2 (Wt. %)	Ratio Hf/Zr	References
1	0.030	0.00058	0.020	5
2	.030	.00058	.020	5
3	.028	.00058	.021	5
4	.031	.0029	.109	5
5	.030	.00058	.020	5
6	.034	.00047	.016	5
7	.031	.0029	.109	5
8	.031	.0029	.109	5
9	.035	.0035	.115	5
10	-	-	.034	7
11	-	-	1/ .020	13

1/ Ratio $\frac{HfO_2}{ZrO_2 + HfO_2}$

1. Mason, 1952 2. Rankama and Sahama, 1950 3. Polanski, 1948 4. Anderson, 1945 5. Goldschmidt, 1937 6. Fersman, 1933 7. Schneiderhöhn, 1934 8. Berg, 1929 9. Clarke and Washington, 1924.

Table 2.--Hafnium and zirconium content and Hf/Zr ratio of rocks.

No.	Material	ZrO_2 (Wt. %)	HfO_2 (Wt. %)	Ratio Hf/Zr	References
1	Average ultrabasic rock	0.008	-	-	13
2	Average gabbros	.019	-	-	13
3	Average diorites	.038	-	-	13
4	Average granites	.062	-	-	13
5	Rapakivi granites 1/	.12	0.0028	0.027	23
6	Igneous rocks 2/	.026	.00038	.017	9
7	Estimated average, eruptive rocks	.039	.001	.029	24
8	Zinc sulfide ore, Saxberg, Sweden 3/	.019	.0001	.008	17

1/ Spectrographic determination made on a mixture of 34 granites.

2/ X-ray spectroscopic determination on a mixture of 300 igneous rocks that contained 56.3 percent SiO_2.

3/ Spectrographic determination. The ore contained 30 percent SiO_2.

Table 3.--Compositions of minerals listed in tables 4 through 8.

Alvite 1/	$ZrSiO_4$ containing rare earths, BeO, U, and Th
Baddeleyite	ZrO_2
Caldasite	Zirconium oxide ore, chiefly baddeleyite
Catapleite	$(Na_2,Ca)ZrSi_3O_9 \cdot 2H_2O$
Cyrtolite 1/	See alvite
Elpidite	$Na_2(Zr,Ti)Si_6O_{15} \cdot 3H_2O$
Eudialyte-eucolite	$(Ca,Na)_5Zr_2Si_6(O,OH,Cl)_{20}$
Euxenite	$(Y,Ce,U)(Nb,Ta,Ti)_2(O,OH)_6$
Favas	Pebbles in gravel. Commonly baddeleyite, may also be zircon
Fergusonite	$(Y,Er)(Nb,Ta)O_4$
Hagatalite 1/	See alvite
Malacon 1/	See alvite
Naegite 1/	See alvite
Oyamalite 1/	See alvite
Pitchblende	UO_2 with UO_3, ThO_2
Polymignite	$(Ca,Fe,Y,Zr)(Nb,Ta,Ti)O_4$
Pyrochlore	$(Ca,Na)(Nb,Ti)_2O_6(OH,F)$
Rosenbuschite	$(Ca,Na)_3(Zr,Ti)Si_2O_8F$
Thalenite	$Y_2Si_2O_7$
Thortveitite	$(Sc,Y)Si_2O_7$
Wöhlerite	$NaCa_2(Zr,Nb)Si_2O_8(O,OH,F)$
Yamagutilite 1/	See alvite
Zircon	$ZrSiO_4$
Zirkelite	$(Ca,Fe)(Zr,Ti)_2O_5$ (?)
Zirkite	Commercial name for zirconium oxide ore

1/ Alvite, cyrtolite, hagatalite, malacon, naegite, oyamalite, and yamagutilite are names given to varieties of zircon. Some of the names are not well defined, but in general they apply to varieties of zircon that contain appreciable water and may contain rare earths, uranium, thorium, beryllium, and P_2O_5. Some of this material may not be zircon.

Table 4.--The hafnium and zirconium content and the Hf/Zr ratio in zircon.

No.	Locality	ZrO_2 (Wt. %)	HfO_2 (Wt. %)	Ratio Hf/Zr	Method of analysis 1/	References
1	Connecticut	-	1.0	-	XS	12
2	North Carolina, Henderson County	-	4.0	-	XS	8, 12
3	Do.	-	1.3	-	XS	10
4	Do.	-	-	0.016	S	4
5	Do.	-	1.0	-	D	22
6	Florida	-	-	0.027	S	4
7	Pennsylvania, Berks County	-	-	0.026	S	4
8	Oklahoma, fresh	2/ (66.5)	1.1	2/(0.018)	S	18
9	Oklahoma, metamict	2/ (59.5)	0.8	2/(0.016)	S	18
10	Do.	2/ (59.7)	0.6	2/(0.011)	S	18
11	Oregon, Coos Bay	-	-	0.023	S	4
12	Ontario	-	-	3/ 0.010	XS	13
13	Ontario, Renfrew	-	0.6	-	XS	12
14	Ontario, Eganville	-	1.2	-	XS	8, 12
15	Brazil	-	-	0.008	S	4
16	Do.	-	-	0.015	S	4
17	Do.	-	-	0.010	S	4
18	Do.	63.7	1.3	0.023	XS	10
19	Do.	-	1.0	-	XS	12
20	Brazil, Minas Gerais	-	1.0	-	XS	12
21	Brazil, Minas Gerais, Poços de Caldas	-	1.8	-	XS	12
22	Do.	-	1.0	-	D	22
23	Do.	-	-	3/ 0.014	C	20
24	Do.	-	-	3/ 0.014	C	20
25	Do.	-	-	3/ 0.017	C	20
26	Do.	-	-	3/ 0.017	C	20
27	Do.	-	-	3/ 0	C	20
28	Brazil, placer	64.	0.4	0.007	XS	8
29	Greenland	-	3.	-	XS	10
30	Greenland, Narsarsuk	-	0.8	-	XS	8, 12
31	Austria, Carinthia	65.	4.	0.07	XS	8, 10
32	France, Espailly	64.23	1.8	0.032	XS	10
33	Do.	-	1.1	-	XS	12
34	Do.	-	0.7	-	XS	12
35	Do.	64.83	1.2	0.021	XS	8
36	Italy, Lonedo	-	0.7	-	XS	12
37	Do.	-	0.7	-	XS	12
38	Italy, Novale	-	0.9	-	XS	12
39	Italy, Vesuvius	-	0.7	-	XS	12
40	Italy, Vicenza	-	0.8	-	XS	8

Table 4.--The hafnium and zirconium content and the Hf/Zr ratio in zircon--Continued.

No.	Locality	ZrO_2 (Wt. %)	HfO_2 (Wt. %)	Ratio Hf/Zr	Method of analysis 1/	References
41	Italy, Vicenza	-	1.8	-	XS	10
42	Norway	60.55	3.5	0.066	XS	10
43	Norway, Brevik	63.05	1.0	0.018	XS	8
44	Norway, Frederiksvärn	63.96	2.8	0.05	XS	10
45	Do.	65.2	1.0	0.018	XS	8
46	Norway, Langesundfjord	-	1.7	-	XS	10
47	Do.	-	2.2	-	D	22
48	Norway, Larvik	-	6.	-	XS	10
49	Do.	-	-	3/ 0.035	XS	13
50	______, Portusok	-	-	3/ 0.015	XS	13
51	______, Avigait	-	-	3/ 0.021	XS	13
52	______, Schluchtsee, acid	-	-	3/ 0.026	XS	13
53	______, Schluchtsee, basic	-	-	3/ 0.0024	XS	13
54	U.S.S.R.	-	0.2	-	XS	3
55	Do.	-	0.24	-	XS	3
56	Do.	-	0.35	-	XS	3
57	Do.	-	0.35	-	XS	3
58	Do.	-	0.5	-	XS	3
59	Do.	-	0.5	-	XS	3
60	Do.	-	0.6	-	XS	3
61	Do.	-	0.6	-	XS	3
62	Do.	-	0.6	-	XS	3
63	Do.	-	0.6	-	XS	3
64	Do.	-	0.7	-	XS	3
65	Do.	-	0.7	-	XS	3
66	Do.	-	0.7	-	XS	3
67	Do.	-	0.8	-	XS	3
68	Do.	-	0.8	-	XS	3
69	Do.	-	1.2	-	XS	3
70	Do.	-	1.2	-	XS	3
71	Do.	-	1.3	-	XS	3
72	U.S.S.R., zircon ores	46.	1.0	0.029	XS	2
73	Do.	44.	0.7	0.021	XS	2
74	Do.	59.	0.7	0.016	XS	2
75	Do.	-	1.0	-	XS	2
76	Do.	-	0.5	-	XS	2
77	Do.	-	0.8	-	XS	2
78	Do.	-	0.7	-	XS	2
79	U.S.S.R., Botogolski	-	0.5	-	-	15
80	U.S.S.R., Kukisvumchorr	-	0.7-1.0	-	-	15
81	U.S.S.R., Mariupol	-	0.5	-	-	15
82	U.S.S.R., Poachvumchorr	66.	1.6	0.028	XS	2

Table 4.--The hafnium and zirconium content and the Hf/Zr ratio in zircon--Continued.

No.	Locality	ZrO_2 (Wt. %)	HfO_2 (Wt. %)	Ratio Hf/Zr	Method of analysis 1/	References
83	U.S.S.R., Sludyanka (with allanite)	-	0.5	-	-	15
84	U.S.S.R., upper Tulia River	66.	1.0	0.018	XS	2
85	U.S.S.R., Urals, Ilmen Mts.	-	1.0	-	D	22
86	U.S.S.R., Urals, Miask	59.92	5.4	0.10	XS	10
87	Do.	64.22	1.1	0.020	XS	8, 12
88	U.S.S.R., Rojkow Kluitsch	-	0.5	-	XS	8
89	U.S.S.R., Vishnevye Gory	-	0.9	-	XS	3
90	India	-	-	0.020	S	4
91	Do.	62.3	2.7	0.05	XS	10
92	India, placer	64.	1.2	0.021	XS	8
93	Ceylon	-	2.0	-	XS	10
94	Do.	-	2.7	-	XS	8, 12
95	Do.	-	1.0	-	D	22
96	Ceylon, beccarite	-	2.1	-	XS	12
97	Ceylon, Walawe Ganga	-	2.0	-	D	22
98	Siam	60-67	3.5	0.060-0.067	XS	11
99	Do.	-	4.	-	XS	8
100	Korea, Sinpyori	66.0	0.79	0.014	-	6
101	Korea, Hukusinzan	63.4	1.9	0.034	-	6
102	Australia	-	-	0.019	S	4
103	Do.	-	4.5	-	D	22
104	Australia, Queensland	-	-	0.015	S	4
105	Tasmania	-	1.1	-	XS	8
106	Madagascar	-	3.	-	XS	10
107	Do.	-	0.9	-	XS	12
108	Do.	-	0.7	-	D	22
109	Madagascar, Diego Suarez	-	0.8	-	XS	8, 12
110	Madagascar, Mesatanana	-	2.0	-	D	22
111	Nigeria	-	2.3	-	D	22
112	Locality unknown	-	6.	-	XS	10

See also Morgan and Auer (21)

1/ Methods of analysis are designated as follows: C - Chemical separation as phosphate; D - Hf content computed from density of mixed oxides $(Zr,Hf)O_2$; S - Spectrographic; XS - X-ray spectroscopic.

2/ Analysis for ZrO_2 made on materials from the same locality similar to but not identical with the sample analyzed for Hf.

3/ Ratio $\frac{HfO_2}{ZrO_2 + HfO_2}$

Table 5.--The hafnium and zirconium content and the Hf/Zr ratio in varieties of zircon: alvite (A), cyrtolite (C), hagatalite (H), malacon (M), naegite (N), oyamalite (O), and yamagutilite (Y).

No.	Locality	ZrO_2 (Wt. %)	HfO_2 (Wt. %)	Ratio Hf/Zr	Method of analysis 1/	References
1	U. S. (C)	40.	9.	0.26	XS	10
2	U. S., Mass., Rockport (C)	-	>10.	2/ 0.22	XS	13
3	Do. (C)	44.	17.	0.44	XS	8
4	U. S., N. Y., Bedford (C)	-	ca. 5.	0.09- 2/ 0.11	XS	13
5	Ontario, Parry Sound (C)	-	2.36	-	XS	9
6	Norway, Kragerö (A)	34.	16.	0.54	XS	10
7	Do. (A)	-	3.	-	XS	10
8	Do. (A)	-	8.	-	XS	10
9	Do. (A)	-	15.	-	XS	10
10	Do. (A)	41.98	4.6	0.13	XS	8
11	? (A)	41.92	4.66	0.13	XS	1
12	? (A)	-	5.9	-	XS	3
13	Norway, Gjersted (A)	-	9.	-	XS	10
14	Norway, Hitterö (M)	62.8	5.	0.088	XS	11
15	Do. (M)	65.18	2.6	0.046	XS	8
16	Norway, Risör (A)	-	10.	-	XS	10
17	Norway, southern (A)	47.9	3/ 5.5	0.13	D	22
18	Do. (A)	48.4	3/ 6.0	0.14	D	22
19	U.S.S.R., Ilmen gory (M)	-	0.8	-	-	15
20	U.S.S.R., Blumovskaya (M-C)	-	1.8	-	-	15
21	U.S.S.R., Karelia (C)	-	2.3	-	XS	9
22	Do. (C)	-	1.8	-	-	15
23	U.S.S.R., Rozhkov Klucz (M)	-	2.6	-	-	15
24	U.S.S.R., Zap Oleninya varakh (C)	47.82	1.70	0.041	-	16
25	Japan, Hagata (H)	39.7	2.3	0.066	-	6
26	Japan, Mino (N)	48.30	7.	0.17	XS	10
27	Japan, Naegi (N)	49.8	3.5	0.08	XS	8
28	Japan, Oyama (O)	38.7	2.2	0.065	-	6
29	Japan, Yamaguti (Y)	ca. 40.2	ca. 3.4	0.097	-	6
30	Madagascar (M)	-	7.	-	XS	11
31	Do. (M)	53.2	4.	0.086	XS	8
32	Madagascar, Ahi-Kambana (M)	-	2.0	-	D	22

See also Morgan and Auer (21)

1/ Methods of analysis: D - By density of oxides; XS - X-ray spectroscopic.

2/ Ratio $\frac{HfO_2}{ZrO_2 + HfO_2}$

3/ It is stated in the same reference (22) that the oxides recovered from a large amount of these samples contained 2.2 percent HfO_2.

Table 6.--The hafnium and zirconium content and the Hf/Zr ratio in zirconium oxide minerals and ores.

No.	Name and locality	ZrO_2 (Wt. %)	HfO_2 (Wt. %)	Ratio Hf/Zr	Method of analysis 1/	References
1	Baddeleyite, Brazil	97.1	1.8	0.021	XS	10
2	Do.	97.7	1.2	0.014	XS	8
3	Baddeleyite, Brazil, fava	92.42	0.7	0.009	XS	8
4	Do.	91.12	2.	0.025	XS	10
5	Do.	59.	0.5	0.010	XS	8
6	Do.	74.	0.5	0.008	XS	8
7	Baddeleyite, Brazil, fava, shell	59.	1.	0.019	XS	10
8	Baddeleyite, Brazil, fava, core	74.	1.	0.015	XS	10
9	Baddeleyite, Brazil, Poços de Caldas	-	-	0.013	S	4
10	Do.	-	2.1	-	D	22
11	Do.	73.2	1.1	0.017	C	20
12	Do.	92.1	1.4	0.017	C	20
13	Fava, Brazil, Poços de Caldas	-	-	2/ 0.002	C	20
14	Do.	-	-	2/ 0.024	C	20
15	Caldasite, Brazil, Poços de Caldas	-	-	2/ 0.022	C	20
16	Do.	-	-	2/ 0.034	C	20
17	Do.	-	-	2/ 0.041	C	20
18	Zirkite ore, Brazil	-	-	0.012	S	4
19	Baddeleyite, Colorado 3/	-	-	0.068	S	4
20	ZrO_2 reagent	-	-	0.010	S	4
21	Polymignite, Norway, Frederiksvärn	28.71	0.9	0.036	XS	10, 11
22	Do.	29.11	0.6	0.024	XS	8
23	Zirkelite, Brazil	51.7	1.2	0.026	XS	11
24	Zirkelite, Ceylon	51.89	1.	0.022	XS	8

1/ Methods of analysis: C - Chemical fractionation of phosphates; D - By density of mixed oxides; S - Spectrographic; XS - X-ray spectroscopic.

2/ Ratio $\frac{HfO_2}{ZrO_2 + HfO_2}$

3/ Baddeleyite is not known to occur in Colorado, U.S.A.

Table 7.--The hafnium and zirconium content and the Hf/Zr ratio in zirconium silicates.

No.	Name and locality	ZrO_2 (Wt. %)	HfO_2 (Wt. %)	Ratio Hf/Zr	Method of analysis 1/	References
1	Catapleite, Greenland	30.65	0.2	0.007	XS	10
2	Do.	31.53	0.3	0.011	XS	8
3	Catapleite, Norway	31.52	0.3	0.011	XS	8
4	Catapleite, U.S.S.R., upper Tulia River	30.5	0.6	0.023	XS	2
5	Catapleite, U.S.S.R.	-	0.35	-	XS	3
6	Do.	-	0.1	-	XS	3
7	Catapleite, U.S.S.R., Pereval Lopar	-	ca. 0.3	-	-	15
8	Eudialyte, Greenland	14.30	0.19	0.015	XS	10
9	Eudialyte, Greenland, Narsarsuk	12-16	0.2	0.014-0.019	XS	11
10	Do.	12-16	0.6	0.042-0.057	XS	11
11	Do.	12-20	0.2	0.019	XS	8
12	Eudialyte, Greenland, Kangerdluarsuk	14.32	0.17	0.014	XS	8
13	Eudialyte, Norway	14.47	0.7	0.055	XS	10
14	Eudialyte, Norway, Barkevik	12.21	0.2	0.019	XS	8
15	Eudialyte, U.S.S.R., Kola Peninsula	13.	0.2	0.017	XS	2
16	Do.	19.	0.3	0.018	XS	2
17	Do.	13.	0.3	0.026	XS	2
18	Do.	-	-	2/0.021	XS	13
19	Do.	-	0.1	-	XS	8
20	Eudialyte, U.S.S.R., Poachvumchorr, altered	30.	0.4	0.015	-	15
21	Eudialyte, U.S.S.R.	13.5	0.12	0.010	XS	3
22	Do.	2.0	0.12	0.069	XS	3
23	Do.	2.7	0.12	0.051	XS	3
24	Do.	-	0.2	-	XS	3
25	Do.	-	0.1	-	XS	3
26	Do.	-	0.06	-	XS	3
27	Do.	-	0.35	-	XS	3
28	Do.	-	0.12	-	XS	3
29	Do.	-	0.06	-	XS	3
30	Do.	-	0.06	-	XS	3
31	Do.	-	0.06	-	XS	3
32	Elpidite, Greenland, Narsarsuk	20.1	0.4	0.023	XS	11

Table 7.--The hafnium and zirconium content and the Hf/Zr ratio in zirconium silicates--Continued.

No.	Name and locality	ZrO_2 (Wt. %)	HfO_2 (Wt. %)	Ratio Hf/Zr	Method of analysis 1/	References
33	Elpidite, Greenland, Narsarsuk	20.28	0.2	0.011	XS	8
34	Rosenbuschite, Norway, Langesund	19.80	0.3	0.017	XS	8
35	Wöhlerite, Norway, Langesund	17.55	0.7	0.046	XS	10
36	Do.	-	-	2/0.031	XS	13
37	Wöhlerite, Norway, Barkevik	15.61	0.5	0.037	XS	8

1/ Method of analysis: XS - X-ray spectroscopic.
2/ Ratio $\frac{HfO_2}{ZrO_2 + HfO_2}$

Table 8.--The hafnium and zirconium content and the Hf/Zr ratio in other miscellaneous minerals.

No.	Name and locality	ZrO_2 (Wt. %)	HfO_2 (Wt. %)	Ratio Hf/Zr	Method of analysis 1/	References
1	Thortveitite, Norway, Iveland	1.2	2.0	1.9	XS	11
2	Do.	-	-	2/0.20	XS	13
3	Do.	2.	0.5	0.29	XS	8
4	Thortveitite, Norway, Unneland	0.8	1.1	1.6	XS	11
5	Thortveitite, Madagascar, Befanamo	2.2	1.8	0.94	XS	11
6	Do.	2.0	3.2	1.8	XS	11
7	Do.	1.3	1.0	0.88	XS	8
8	Thalenite, Sweden, Österby	-	0.13	0.26	XS	13
9	Pyrochlore, Sweden, Alnö	2.8	ca. 0.1	ca.0.04	XS	11
10	Do.	2.90	tr	-	XS	8
11	Pitchblende	-	-	2/0.019	XS	13
12	Fergusonite and euxenite	-	-	2/0.05-0.06	XS	13

1/ Method of analysis: XS - X-ray spectroscopic.
2/ Ratio $\frac{HfO_2}{ZrO_2 + HfO_2}$

Table 9.--Averages of Hf/Zr ratios of minerals according to source (Data of Hevesy and Jantzen, 7 and 12).

Nepheline syenite minerals

Mineral	See table no.	Hf/Zr
Baddeleyite	6	0.014
Baddeleyite, favas	6	0.008
Catapleite	7	0.011
Elpidite	7	0.011
Eudialyte	7	0.011
Polymignite	6	0.023
Rosenbuschite	7	0.017
Wöhlerite	7	0.034
Zircon	4	0.017

Granitic minerals

Mineral	See table no.	Hf/Zr
Alvite	5	0.13
Cyrtolite	5	0.46
Malacon	5	0.08
Naegite	5	0.46
Thortveitite	8	0.57
Zircon	4	0.049

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		Ratio intensity Hf/Zr
1.	Zircon, granite, Minnesota	0.52
2.	Zircon, granite, New Jersey, Andover	0.41
3.	Zircon, granite, Wisconsin, Mellen	0.53
4.	Zircon, Wisconsin, Wausau	Hf trace
5.	Zircon, granite, Manitoba, Oxford House	0.45
6.	Do.	0.30
7.	Do.	0.25
8.	Do.	0.53
9.	Malacon, Colorado, Cheyenne Canyon	0.26
10.	Cyrtolite, New York, Bedford	0.51
11.	Malacon, Ontario, Hybla	0.42
12.	Alvite, Norway, Helle	0.70

As no determinations of the absolute content of zirconium and hafnium were made, these can be related to the determinations given in tables 4 and 5 only if no. 10 above is assumed to contain about 5 percent HfO_2 (table 5). If so, the zircon samples listed above have remarkably high hafnium content.

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