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GEOCHEMISTRY OF BERYLLIUM

by

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ABSTRACT

This is a review, with annotated bibliography, of the mode of occurrence of the element beryllium. It is not a list of specific ore deposits, but a summary of the types of minerals and rocks in which beryllium has been reported to occur. In addition, the unpublished spectrographic studies of the Geological Survey on mill products are summarized, and data are given on domestic production and reserves and on foreign production.

Beryllium is now obtained solely from beryl, mined from granitic pegmatites. Other beryllium minerals, all confined to granitic and syenitic pegmatites, are not likely to be possible sources, but contact-metamorphic deposits of helvite of commercial grade might possibly be found. Suggestions are made for further investigations, particularly of methods of concentrating low-grade beryl ores, and of the occurrence of beryllium in American coals.

INTRODUCTION

This report on the occurrence of beryllium is one of a series of similar reports prepared by the Geological Survey discussing possible sources of rare or uncommon elements that had special war uses.

Beryllium is a chemical element with atomic number 4, and atomic weight 9.02. It belongs to the second group of the periodic table and is bivalent in its compounds.

GEOCHEMICAL CONSIDERATIONS

General Statement

Beryllium is a relatively rare element. Recent estimates (1, 6, 13) give 0.0005 to 0.0006 percent Be for the content in the earth's crust. Earlier estimates (4) were somewhat higher, but were based on few data. Beryllium is a lithophilic element, found almost exclusively in igneous and sedimentary rocks. In contrast to dispersed elements such as gallium or indium, beryllium is so concentrated during the process of magnatic differentiation that it is a major constituent of many minerals. These minerals, almost without exception, occur in granitic or syenitic pegmatites, or in contact metamorphic deposits.

The empirical ionic radius 5 of beryllium is 0.34 A., so much lower than those of most metals that there is little possibility of isomorphous substitution by beryllium excepting for such high valence atoms as Si^{+4} (0.39 A.) or V^{+5} (0.4 A.). Such possible substitutions involve complex valency adjustments within the crystal lattice. It is therefore not surprising that beryllium is present in appreciable amounts only in the late residual phases of magnatic activity.

Occurrences in specific minerals and rocks

The following list includes all the minerals that have been reported to contain as much as 0.004 percent Be (0.01 percent BeO). The mineral beryl is the only commercial source at present and is therefore discussed first under (1). The other minerals have been divided into two groups: (2) Minerals in which beryllium is an essential constituent, and (3) Minerals in which beryllium is an accessory constituent. Within each group, the minerals are subdivided into chemical classes and are listed alphabetically within each class. Unless otherwise indicated, the data given are from volume 1 of the Seventh Edition of Dana's System of Mineralogy and from the mineralogical file of the Section of Chemistry and Physics, Geological Survey.

Index of minerals listed

Index of minerals listed - (Continued)

(1) Beryl

Beryl, the only source of beryllium at present, has the ideal composition $Be_3Al_2Si_6O_{18}$ with 5.0 percent Be (14.0 percent BeO). Complex isomorphous replacement, including the introduction of water and the alkalies, causes the beryllium content of the mineral to be lower than this, down to a minimum of about 3 percent Be. The common range of beryllium content in beryl is 3.8 to 4.6 percent Be.

Beryl occurs in minable amounts almost exclusively in granitic pegmatites. A review of world deposits has recently been published in Russian (23).

(2) Minerals in which beryllium is an essential constituent

(a) Oxides

<u>Bromellite</u>, BeO, containing 36 percent Be, is a very rare mineral that occurs in a contact-metamorphic skarn.

<u>Chrysoberyl</u>, $BeAl_2O_4$, containing 7.1 percent Be, is an uncommon mineral that occurs in small amounts in granitic pegmatites and placers derived from them, also in mica schists.

(b) Carbonate and borates

<u>Hambergite</u>, $Be_2(OH)BO_3$, containing 19.2 percent Be, is a rare mineral that occurs in small amounts in granitic and syenitic pegmatites.

<u>Rhodizite</u>, perhaps $(Na, K)_2Li_4Al_4Be_3B_{10}O_{27}$, containing 3.6 to 5.4 percent Be, is a very rare mineral that occurs in small amounts in granitic pegmatites.

<u>Tengerite</u>, a hydrated carbonate of yttrium and beryllium, containing 3.5 percent Be, occurs rarely in granitic pegmatites as an alteration product of gadolinite.

(c) Phosphates, Antimonate

Beryllonite, $NaBePO_4$, containing 7.1 percent Be, is a rare mineral that occurs in small amounts in granitic pegmatites.

Herderite, $CaBePO_4(OH, F)$, containing 5.6 to 5.9 percent Be, is an uncommon mineral that occurs in small amounts in granitic pegmatites.

Kolbeckite is a very rare hydrated silicophosphate of beryllium, calcium, and aluminum, containing 3.1 percent Be. The only known occurrence is in a quartz-wolframite vein.

Swedenborgite, $NaBe_4SbO_7$, containing 12.6 percent Be, is a very rare mineral that is found at one locality in a contact metamorphic deposit.

(d) Silicates

Aminoffite, a calcium beryllium aluminum silicate containing 2.2 percent Be, is a very rare mineral that occurs in veins in magnetite in a contact metamorphic deposit.

Barylite, $BaBe_2Si_2O_7$, containing 5.7 percent Be, is a very rare mineral that occurs in small amounts in contact metamorphic deposits.

Bavenite, $Ca_4BeAl_2Si_9O_{26}.H_2O$, containing 1.1 percent Be, is a very rare mineral that occurs in small amounts in granitic pegmatites.

Bertrandite, $Be_4Si_2O_7(OH)_2$, containing 15.1 percent Be, is an uncommon mineral that occurs in very small amounts as an alteration product of beryl in granitic pegmatites.

Bityite, perhaps $Li_2BeCa_3Al_9Si_6O_{27}(OH)_7$, containing 0.8 percent Be, is a very rare mineral. The only known occurrence is in a granitic pegmatite.

Chkalovite, $NaBeSi_2O_6$, containing 4.1 to 4.6 percent Be, is a very rare mineral. The only known occurrence is in a syenitic pegmatite.

Epididymite and its dimorph eudidymite, $HNaBeSi_3O_8$, containing 3.7 percent Be, are rare minerals that occur in small amounts in nepheline syenites.

Euclase, $BeAlSiO_4(OH)$, containing 6.1 percent Be, is an uncommon mineral occurring in small amounts in granitic pegmatites and in placers.

Gadolinite, $Be_2Y_2FeSi_2O_{10}$, containing 3.2 to 4.7 percent Be, is an uncommon mineral that occurs in granitic pegmatites, but only rarely in large amounts.

Harstigite, $(Ca,Mn)_7Be_4Si_6O_{21}(OH,F)_4$, containing 4.0 percent Be, is a very rare mineral that occurs in contact metamorphic deposits.

The helvite group, $(Mn,Fe,Zn)_4Be_3Si_3O_{12}S$, including helvite, danalite, and genthelvite, and containing 3.8 to 5.4 percent Be, are uncommon minerals that occur, generally in small amounts in granitic and syenitic pegmatites (5). A recently discovered contact metamorphic deposit contained sufficient helvite to be considered as a possible source of beryllium (10), and other similar deposits may have been overlooked.

Leucophanite, $(Ca,Na)_2BeSi_2(O,OH,F)_7$, containing 4.0 percent Be, is a very rare mineral that occurs in small amounts in augite-syenite pegmatites. The chemically similar mineral meliphanite, $(Ca,Na)_2$ Be $(Si,Al)_2(O,F)_7$, containing 3.4 to 5.0 percent Be, is a very rare mineral that occurs in small amounts in syenitic pegmatites.

Milarite, $K_2Ca_4Be_4Al_2Si_{24}O_{60}.H_2O$, containing 1.8 percent Be, is a very rare mineral that occurs in small amounts in granitic pegmatites.

Phenakite, Be_2SiO_4, containing 16.4 percent Be, occurs rather commonly, but only in very small amounts, in granitic pegmatites.

Trimerite, $Be(Mn,Ca)SiO_4$, containing 6.1 percent Be, is a very rare mineral that occurs in small amounts in contact metamorphic deposits.

(3) Minerals in which beryllium is a minor, accessory constituent

(a) Oxides

Cassiterite, SnO_2, has been reported (2, 11) to contain spectrographic traces of beryllium.

Uraninite has been reported to contain beryllium (14), but no sample tested contained more than 0.004 percent Be.

Microlite, $Ca_2Ta_2O_7$, has been reported to contain up to 0.12 percent Be. Euxenite, fergusonite, samarskite, and yttrotantalite, which are complex columbate-tantalates of the rare earths, have been reported to contain up to 0.2 percent Be. They occur in granitic pegmatites.

(b) Halides

Fluorite, CaF_2, does not generally contain beryllium, but some samples from granitic pegmatites have been found to contain traces of beryllium (26).

(c) Phosphates

Wavellite, $Al_6(PO_4)_4(OH,F)_6 \cdot 9H_2O$, has been found (26) to contain beryllium. Material from Tennessee contained 0.10 percent Be; some from Arkansas may contain even more beryllium (26). Wavellite is a common mineral that occurs, usually in small amounts, as a secondary mineral.

(d) Silicates

Aegirite, approximately $(Na,Ca)(Mg,Fe''')Si_2O_6$, a pyroxene from syenitic pegmatites has been reported (7) to contain up to 0.04 percent Be.

Allanite, $(Ca,Ce)_2(Al,Fe)_3Si_3O_{12}(OH)$, is widely distributed in various rock types, generally in small amounts. Most samples contain a few hundredths of a percent of beryllium, but exceptional samples have been reported to contain up to 2.0 percent Be.

Alvite is a rare, dubious zirconium silicate that contains up to 5 percent Be, according to old analyses.

Arfvedsonite and barkevikite, soda-rich amphiboles that occur in syenitic rocks, are reported (7) to contain up to 0.01 percent Be.

Axinite, a complex borosilicate, has been reported (7) to contain 0.04 percent Be. It is a common mineral that occurs in small amounts in pneumatolytic deposits and in the contact zones of some granites.

Clinohumite, $Mg_9Si_4O_{16}(OH,F)_2$, is an uncommon mineral that occurs in small amounts in contact-metamorphic deposits. Material from one deposit is reported (22) to contain 0.6 percent Be.

Erdmannite is a dubious rare silicate of the rare earths reported to contain 1 to 1.5 percent Be.

Foresite is a dubious rare zeolite that occurs in a granitic pegmatite Two analyses show 0.35 percent Be.

Garnet, $Ca_3(Al,Fe)_2Si_3O_{12}$, is a very common mineral. Garnet from contact metamorphic deposits may contain traces to 0.04 percent Be (5, 26).

Hyalotekite is a very rare complex borosilicate of lead and barium known only from one contact metamorphic deposit. It contains 0.37 percent Be.

Idocrase (vesuvianite), a complex calcium aluminum silicate, is a common mineral that occurs in moderate amounts in contact metamorphic deposits. Beryllium has been determined in a number of samples (5, 7, 15, 20, 26, 28). Nearly all contain a few hundredths of a percent or less of beryllium; a few contain more. The highest verified content is 0.39 percent Be (5); the report (15) of a sample with 3.3 percent Be is questionable.

Mica Group - Various members (muscovite, biotite, zinnwaldite, lepidolite) of the mica group that occur in granitic pegmatite have been found (7, 26) to contain traces to 0.04 percent Be.

Nepheline, $NaAlSiO_4$, is a common mineral that is one of the principal constituents of nepheline syenite rocks. Analyses (7, 25) show that most nephelines contain beryllium, the maximum percentage found being 0.014 and the average 0.005 percent Be.

Steenstrupine is a very rare complex phosphate-silicate of the rare earths, sodium, and calcium, that occurs in syenite pegmatite and is reported to contain 0.43 to 0.68 percent Be.

Thorite, essentially $ThSiO_4$, is a rare mineral that occurs in granitic pegmatites. It is reported (14) to contain up to 0.01 percent Be.

Tourmaline, a complex borosilicate, is a very common mineral that occurs in granitic pegmatites. It contains traces to 0.04 percent Be (7, 26).

Tscheffkinite (chevkinite) is a rare, complex silicate of cerium, lanthanum, and titanium that occurs in granitic pegmatites. It is reported to contain up to 0.7 percent Be.

Rocks

The average content of beryllium in the earth's crust has been estimated to be 0.0005 to 0.0006 percent Be. Most rocks have lower beryllium contents than this. The average content of all eruptive rocks may be 0.0002 percent Be (7). Higher concentrations are shown by granites, which average perhaps 0.0007 percent Be (7, 9, 17, 18, 19, 20, 21) and by nepheline syenites, which may average 0.001 to 0.004 percent Be (7, 9, 19). Contact metamorphic deposits containing pneumatolytic minerals show a concentration of beryllium (see 5) but few quantitative data are available. Beryllium apparently follows aluminum in sedimentary processes, as bauxites generally contain a few thousandths of a percent (7, 21). Clays and clay schists appear to have slightly lower beryllium contents than bauxite (9), but bentonite may contain a few hundredths of a percent of beryllium (26).

Coal ashes

The ash of coal samples commonly contains detectable amounts of beryllium. Spectrographic study of the ash of 13 English and German coals (8) showed up to 1 percent Be and 10 of the 13 examined had 0.01 percent Be or more. Studies of the ashes of Russian coals (12, 29) give much lower figures for the beryllium content. Beryllium has been detected in the ash of certain American coals (26), but no quantitative data are available.

Results of Mill Product Studies

The beryllium content of more than 1000 samples from over 200 mines, mills, and geological occurrences was determined spectrographically by Rabbitt (26) as part of the Geological Survey's Trace Elements investigations. One sample of ore from a tungsten prospect in Yavapai County, Arizona, contained 2 percent BeO. Two others, both contact-altered limestones in the vicinity of alkali-syenite intrusives, contained .2 percent and .3 percent BeO, respectively. Fifteen other samples contained BeO in amounts ranging from .02 to .08 percent BeO. All the samples are listed in Table 1 of this report.

Taken together with the investigations of beryllium occurrences made during the war, the results corroborate long-standing conclusions regarding the distribution of beryllium in minerals and rocks. Beryllium is concentrated chiefly in granitic pegmatites, and is rarely found elsewhere in significant amounts. The high values obtained for the two samples of contact-altered limestone, however, are of interest because they indicate that concentrations of beryllium in contact-metamorphic deposits may be less rare than a perusal of the literature would suggest, and that contact aureoles around alkali-syenite intrusives should receive the same attention as those around granitic intrusives. Hydrothermal deposits in general appear to carry only traces of beryllium. BeO to the extent of .02 percent or more was found only in samples from mills or localities out of a large number examined. A single sample of a manganese concentrate showed .02 percent BeO, but other samples of manganese ores, concentrates, and tailings showed only traces of beryllium.

Table

Best beryllia values from spectrographic testing of mill products and other samples.

Occurrence	Location	Product	Beryllium-bearing material	Percent BeO
Mill product		Pb-Zn concentrates	Mill heads	.02
" "		" "	Mill tailings	.03
" "		Manganese concentrates	Coarse concentrate from double log washer	.02
" "		Gold, silver	Tailings from cyanidation	.02
" "		Gold	Composite of tailings	.02
" "		"	Composite of heads, oxidized ore	.02
" "		Lepidolite, muscovite, columbite-tantalite, microlite, cassiterite: from pegmatite	Lepidolite flotation concentrate	.05
			Muscovite flotation concentrate	.05
			Tailings from flotation	.06
			Tn-Sb-Sn table concentrates	
			(a) from muscovite ore	.04
			(b) from lepidolite ore	.04
" "		Cu, Pb, Sn alloys and metals	Slag from treatment of scrap metal	.05
Wind River Intrusive	Cornudas Peaks, N.Mex.	None	Altered limestone at contact with nepheline syenite	.2 (.14 chem. analyses)
Sierra Diablo Intrusive	Sierra Diablo, N.Mex.	None	Altered limestone at contact with nepheline syenite	.3
Sierra Diablo Intrusive	" " "	"	Gray-green porphyry	.02
Mill product		Tin	Tin-spodumene pegmatite	.08
Wolframite prospect	Near Bagdad, Ariz.	Wolframite	Tungsten ore	.05
Wolframite prospect	Near Bagdad, Ariz.	"	" "	.2

Best sources of beryllium

At present, beryllium is produced entirely from beryl, and all commercial deposits are in granitic pegmatites. During the war there was considerable interest in the contact-metamorphic beryllium deposits of Iron Mountain, New Mexico, in which beryllium occurs largely in the form of helvite (5, 10), but investigation has shown that the grade of much of the beryllium-bearing rock is low and the tonnage of beryllium present probably is only moderately large. In addition, metallurgical difficulties in treating the ore remain to be solved.

Figures for domestic production of beryl and for amounts of beryl and helvite present in known domestic deposits are given in table 2. Domestic beryl has been produced almost entirely as a byproduct of operations for feldspar, mica, or lithium minerals. Estimates of tonnages of beryl present in known deposits are given under two headings -- hand-separable beryl, and milling beryl; i.e., beryl recoverable only by milling and flotation. Only the hand-separable beryl can be classified as reserves at the present time. The figures were furnished by various members of the Geological Survey. They are based in part on records of past production, but in large part on measurements of crystals in exposures of pegmatites and on calculation of the ratios between the areas occupied by beryl crystals and the total areas of the exposures. Some of the figures for grades and tonnages of beryl-bearing material are based on exploration and sampling by the U. S. Bureau of Mines.

Figures for foreign production of beryl are given in table 3. The data are mostly from Minerals Yearbook, Mineral Trade Notes, and from information furnished by the Foreign Economic Administration, War Production Board, and other federal agencies. All production figures are for beryl concentrates with a minimum average content of 8 percent BeO. Most of the concentrates are reported to have averaged 10 percent BeO or more. Foreign production is partly byproduct, partly from operations conducted primarily for beryl. Few data on grades are available. According to local report, the productive deposits of northeastern Brazil showed an average recovery of about .3 percent beryl from rock mined. The few data available for Indian deposits suggest grades, in terms of beryl recovered from rock mined, of .5 percent to 8 percent. Rock mined from the remarkable deposit of Las Tapias, the principal source of Argentiné beryl and probably the most productive single deposit in the world, appears to have yielded in excess of 9 percent beryl, if a mining width of 6 feet is assumed for purposes of calculation.

The only guides to reserves in foreign countries are production and import figures, together with comments and rough forecasts contained in reports of various government agencies. Brazil and Argentina furnished the bulk of pre-war production and, together with Australia and India, supplied the bulk of war requirements. In early 1946, reserves in Australia, Argentina, Madagascar, and Union of South Africa were reported to be virtually exhausted. India and Brazil appear to have the largest known reserves of hand-separable beryl, but reserves and production for U. S. S. R., China, and Korea, have not been published. Canada may have sizeable reserves, but production to date is very small.

Table 2.

Beryllium-bearing minerals — production and resources

A. Beryl — United States production and resources

State	Production*: Period covered	Production*: Weight short tons	Amounts of beryl in known deposits — Mostly beryl separable by hand: Measured and Indicated Short tons	Inferred Short tons	Grade of beryl-bearing pegmatite, in percent beryl 2/	Mostly milling beryl: Measured and Indicated Short tons	Inferred Short tons	Grade of beryl-bearing rock, in percent beryl	Total beryl, short tons
Maine	through 1944	200±	220	220	0.2 to 1.0	30	355	0.16 to 0.5	825
New Hampshire	through 1944	100±	40	15	0.1 to 47.0 1/	30	25		110
Massachusetts	through 1944	6±		5					5
Connecticut	through 1944	20±				720	140	0.04 to 1.14	860
Virginia	1929–1943	9±		45					
Idaho						76	280±	0.2 to 3.0	356
South Dakota	1879–1943	1229		540 to 1460	0.05 to 2.0		2600 to 2900	0.05 to 2.0	3140 to 4360
Wyoming	to 1943	<1		5			5±	low	
Colorado	to Jan. 1945	450±	53	300±	0.5 to 2.0	1000	2000±	0.5 to 2.0	3353±
New Mexico	to 1943	37±	365	320					685
								Grand total	9334 to 10,554

1/ This figure applies only to a remarkable beryl-rich shoot within a pegmatite at one locality.
2/ Estimates of grades are mostly rough approximations.

B. Resources of helvite and associated beryllium-bearing minerals, and grades of beryllium-bearing material

	Indicated resources of beryllium-bearing rock short tons	Inferred resources of beryllium-bearing rock short tons	Grade in percent Be
Iron Mtn.,	3,500	1,000	0.7
New Mexico	64,000	100,000	0.2

Table 3

Foreign production of beryl

Country	1939	1940	1941	1942	1943	1944
Anglo-Egyptian Sudan	- - - - - - very small - - - - -					
Argentina	299	520	2,186	925	530	275 3/
Australia	6	2	3	?	558	500 2/
Brazil	276	1,472	1,703	1,634	2,027	1,185
British E. Africa	—	—	—	—	—	11 3/
Canada	- - - - - - very small - - - - -					
India and 1/ dependencies	9	52	—	119	1,463	1,000 2/
Madagascar	?	?	?	?	67	
Portugal	?	?	35	?	14	60 3/
Spain	—	4	?	?	?	?
Southern Rhodesia	- - - - - - very small - - - - -					
Southwest Africa	?	?	20	39	36	11
Union of S. Africa	?	5	?	34	78	?
United States	86	110	143	244	323	352

From Minerals Yearbook, except as noted.

1/ From records of Geological Survey of India, Mineral Trade Notes, March 20, 1946.
2/ Estimated from United States imports.
3/ Estimate.

Suggestions for further investigations

Further investigations should be directed first toward increasing our knowledge of the beryl supplies present in domestic deposits. During the war most of the known domestic beryl-bearing pegmatites were examined by the Geological Survey. A large number were mapped and studied in detail, and some were explored by the Bureau of Mines and other agencies, but in several parts of the country there are large pegmatite-bearing areas that have not been investigated adequately for beryl. Wartime investigations indicate, however, that the largest amounts of beryl are in deposits of milling grade, hence the development of techniques for milling beryl-bearing pegmatite and concentrating the beryl by flotation is a prerequisite to sizeable beryl production. At the present time, operations would have to be supported largely by recovery of feldspar and other minerals from the pegmatites.

The long-range outlook for beryl production is involved with the trend in the feldspar industry toward recovery of feldspar by flotation. If despite the development of this process, the industry continues to rely on pegmatites for raw material, certain beryl-bearing pegmatites may ultimately be mined, but if granites supplant pegmatites as the principal sources of commercial feldspar, only a large increase in the price of beryl, or the development of low-cost processes for concentration, is likely to bring the beryl-bearing pegmatites into production. Even granting the development of the necessary techniques, the immediate outlook for mass milling of beryl-bearing pegmatites in general is not bright, as these pegmatites appear unable to compete with other pegmatites that are larger, richer in feldspar, and structurally more favorable to low-cost mining.

In addition to studies of resources of beryl, certain other potential sources of beryllium should be investigated. The disposition of beryllium in the production of aluminum from bauxite should be studied to determine whether beryllium is concentrated in the waste products. Nepheline syenite has been suggested as a raw material for the production of aluminum. If a plant is built for extraction of aluminum from nepheline syenite ore from clay, the disposition of the beryllium present should be studied. Systematic studies of the beryllium content of American coal ashes should be made. Contact metamorphic deposits should be examined for the presence of helvite and associated beryllium-bearing minerals. Garnet-bearing contact deposits should be examined carefully, as helvite is readily mistaken for garnet.

Annotated Bibliography of Occurrences of Beryllium

Descriptions of individual deposits are not included. The original papers were seen except those for which reference to an abstract journal is given.

1. Anderson, J. S. Chemistry of the earth:
J. Proc. Roy. Soc. New South Wales 76, 329-345 (1943)

A summary. The earth's crust is estimated to contain 0.0005 percent Be. This would place beryllium forty-first in abundance of the elements.

2. Borovick, S. A. and Gotman, J. D. Content of rare and other elements in the cassiterites of different genesis from U. S. S. R. deposits according to spectrum analysis data.
Compt. rend. acad. sci. U. R. S. S. 23, 351-354 (1939)

Beryllium was detected in small amount in some cassiterites, but was absent in most.

3. Brandes, W. Das natürliche Vorkommen des Berylliums. (Occurrence of beryllium in nature.)
Z. prakt. Geol. 41, 35-39 (1933)

A brief review, with a list of beryllium minerals and their temperatures of formation.

4. Clarke, F. W. and Washington, H. S. The composition of the earth's crust.
U. S. Geol. Survey Prof. Paper 127, 117 pp. (1924)

The beryllium content of the earth's crust was estimated on very little evidence to be 0.001 percent Be.

5. Glass, J. J., Jahns, R. H., and Stevens, R. E. Helvite and danalite from New Mexico and the helvite group.
Am. Mineral. 29, 163-191 (1944)

Contains a summary of available data on the occurrence of the minerals of the helvite group and on the beryllium content of various minerals from Iron Mtn., New Mexico.

6. Goldschmidt, V. M. Geochemische Verteilungsgesetze der Elemente. IX. Die Mengenverhältnisse der Elemente und der Atom-Arten. (The principles of the geochemical distribution of the elements. IX. Abundance of the elements and isotopes.)
Skrift. Norsk. Videnskaps-Akad. Oslo, Mat.-Nat. Klasse 1937, No. 4, 148 pp.

The earth's crust, including the sedimentary rocks, is estimated to contain 0.0006 percent Be.

7. Goldschmidt, V. M. and Peters, Cl. Geochemie des Berylliums. (Geochemistry of beryllium.)
Nachr. Ges. Wiss. Gottingen, Math.-Phys. Klasse 1932, Heft 4, 360-376.

A detailed spectrographic study of a large number of samples. The average content for all eruptive rocks is probably about 0.0002 percent Be. Granites average perhaps 0.0004 percent Be, nepheline syenites 0.004 percent Be; other rocks have much lower beryllium contents. Beryllium is notably high in contact metamorphic deposits. In sedimentary processes, beryllium follows aluminum. Two bauxites had 0.0004 and 0.004 percent Be. Many minerals were analyzed; the following contained up to 0.04 percent Be; muscovite, biotite, zinnwaldite, tourmaline, nepheline, aegirine, barkevikite, axinite, and idocrase (vesuvianite).

8. Goldschmidt, V. M. and Peters, Cl. Ueber die Anreicherung seltener Elemente in Steinkohlen. (The enrichment of rare elements in coals.)
Nachr. Ges. Wiss. Gottingen, Math.-Phys. Klasse 1933, Heft 4, 371-387.

Spectrographic analysis of the ashes of twelve English and German coals. Three had 0.1 -1.0 percent Be, four had 0.1 percent, two had 0.01 - 0.1 percent, one had 0.01 percent, two had 0.001 percent. The ashes of lignites had lower contents of beryllium.

9. Goldschmidt, V. M., Hauptmann, H. and Peters, Cl. Ueber die Berücksichtigung "seltener" Elemente bie Gestein-Analysen. (Consideration of "rare" elements in rock-analyses)
Naturwissenschaften 20, 362-365 (1933)

The following new determinations are given: (1) A mixture of 11 German gabbros 0.0001 percent Be (2) A mixture of 14 german granites 0.0007 percent Be (3) A mixture of 22 nepheline syenites 0.001 percent Be (4) A mixture of 24 greisens 0.0003 percent Be (5) A mixture of 36 clay schists 0.0005 percent Be.

10. Jahns, R. H. and Glass, J. J. Beryllium and tungsten deposits of the Iron Mtn. district, Sierra and Socorro Counties, New Mexico.
U. S. Geol. Survey Bull. 945-C, 45-79 (1944)

A study of the helvite deposits.

11. Larionov, J. and Tolmacev, J. M. On the chemical composition of cassiterites.
Compt. rend. acad. sci. U. R. S. S. 14, 303-306 (1937).

Qualitative spectrographic study showed the presence of beryllium in 5 pegmatite cassiterites and its absence in two hydrothermal cassiterites.

12. Nagarenko, V. A. The occurrence of vanadium, beryllium, and boron in the ash of some coals.
Trav. lab. biogeochim. acad. sci. U. R. S. S. 4, 265-270 (in German 271) (1937); Chem. Abstracts 32, 7770 (1938).

Very small amounts of beryllium were found in 4 of 21 samples examined.

13. Noddack, Ida and Noddack, Walter. Die geochemischen Verteilungskoefficienten der Elemente. (Geochemical distribution of the elements.)
Svensk. Kem. Tidskr. 46, 173-201 (1934)

The earth's crust is estimated to contain 0.0005 percent Be.

14. Oftedal, Ivar. Beryllium in radioactive minerals.
Norsk. Geol. Tids. 19, 341-342 (1939).

Beryllium was present (less than 0.01 percent Be) in thorites, uraninites and other radioactive minerals. This may be a source of neutrons, hence suggests the possibility of nuclear fission as a natural phenomenon.

15. Palache, Charles and Bauer, L. H. The occurrence of beryllium in the zinc deposits of Franklin, N. J.
Am. Mineral. 15, 30-33 (1930)

An analysis of idocrase is given that shows 9.2 percent BeO. This figure has been stated (private communication from Prof. E. S. Larsen) to be in error.

16. Pieruccini, Renzo. Spectrographic determination of beryllium in some sedimentary rocks of the Toscan-Emilian Appenines (in Italian)
Spectrochim. Acta 2, 269-290 (1943); Chem Abstracts 39, 471 (1945)

Some sedimentary rocks contained 0.0001 to 0.00002 percent Be.

17. Rankama, Kalervo. The geochemical differentiation in the earth's crust.
Bull. comm. geol. Finlande No. 137, 39 pp. (1946)

A discussion of the concentration of certain elements, including beryllium, in the refusion of granitic rocks, with the conclusion that the beryllium content might be expected to increase in the youngest granites. A compilation of analysis of granites for Be is included.

18. Sahama, Th. G. The chemistry of the East Fennoscandian rapakivi granites.
Bull. Comm. Geol. Finlande No. 136, 15-67 (1945)

Spectrographic analyses of ten rocks. Beryllium was not detected in 5, 0.0003 percent BeO was reported in 3, and 0.001 percent BeO in 2, including a sample representing a mixture of 54 granites.

19. Sahama, Th. G. Spurenelemente der Gesteine im südlichen Finnisch-Lapland., (Trace elements in the rocks of southern Finnish Lapland)
Bull. comm. geol. Finlande, No. 135, 86 pp. (1945)

Average beryllium contents (spectrographic) are given for 23 types of rocks. Granitic rocks averaged 0.0003 percent BeO, syenitic rocks 0.0006 percent BeO. Basic rocks contained less beryllium. Certain aluminous schists contained 0.0003 percent BeO.

20. Sandell, E. B. Determination of small amounts of beryllium in silicates.
Ind. Eng. Chem., Anal. Ed. 12, 674-675 (1940)

This includes the following determinations: a granite contained 0.0005 percent Be, an idocrase 0.06 percent Be, a nepheline syenite less than 0.0002 percent Be.

21. Sandell, E. B. and Goldich, S. S. The rarer metallic constituents of some American igneous rocks.
J. Geol. 51, 99-115, 167-189 (1943)

Chemical analyses of 7 granites, 1 rhyolite, and a composite of 5 granites gave 0.0002 to 0.0014 percent Be, average 0.0007 percent Be.

22. Schäfer, Raimund William. Ueber die metamorphen Gabbrogesteine des Allalingbietes im Wallis zwischen Zermatt - und Saasthal. (Metamorphic gabbro rocks of the Allaling region, Wallis.)
Mineralog. Petrog. Mitt. 15, 91-134 (1896)

Analyses are given of two humites that contained 1.68 and 1.04 percent BeO.

23. Sinegub, E. S. Beryl (in Russian)
Nemetallicheskie Iskopaemye S. S. S. R., Acad. Sci. Vol. 2, 129-161 (1943); Chem. Abstracts 39, 3226 (1945)

A review of beryl deposits of the world and their genetic types.

24. Szelényi, Tibor. Beryllium in bauxites Math. naturw. Anz. ungar Akad. Wiss 56, 231-246 (1937); Chem. Abstracts 32, 1616 (1938).

Spectrographic determination showed 0.002 to 0.004 percent Be in Hungarian bauxites. Some clays had beryllium contents equal to or lower than those of the bauxites.

25. Tolmacev, J. M. and Filippov, A. N. Presence of rubidium, beryllium, gallium, and strontium in nephelites.
Compt. rend. acad. sci. U. R. S. S. 3, 366-369 (in English 368-369) (1934)

Spectrographic study following chemical concentration showed 0.0003 to 0.012 percent Be, average 0.005 percent Be, in 8 nephelines.

26. U. S. Geological Survey, Section of Chemistry and Physics.

Unpublished data.

27. Washington, H. S. Beryllium in minerals and igneous rocks.
Am. Mineral. 16, 37-41 (1931)

It is suggested that beryllium is more common, especially in nepheline syenites, than is generally supposed.

28. Zilbermintz, V. A. and Roshkova, E. V. Zur Frage des Vorkommens von Beryllium in Vesuvianen. (The occurrence of beryl in vesuvianites) Centralbl. Mineral., Geol. 1933A, 249-254.

Beryllium was found to be present in 6 of 14 idocrases (vesuvianites) tested; quantitative determinations on three of these gave 0.065, 0.035, and 0.003 percent Be.

29. Zilbermintz, V. A. and Rusanov, A. K. The occurrence of beryllium in fossil coals. Compt. rend. acad. sci. U. R. S. S. 2, 27-31 (1936).

Spectrographic study of the ash of 603 Russian coals. Only 39 contained more than 0.0004 percent Be, and only 3 contained over 0.004 percent Be, the maximum found being 0.04 percent Be.