Beryllium

By Robert F. Griffith [1]

BERYL supply, the only commercial source of beryllium, was the largest in history in 1952. The increase was from imports; domestic production remained at about its normal level. Record-high prices and the beryl expansion program, sponsored by the Defense Materials Procurement Agency, were largely responsible for the increased supply. Even though Government and industry stocks increased during the year, there was no complacency over future supply owing to the uncertainty of continued large imports. It has been estimated that the demand for beryl in the United States will increase by 1975 to about two and one-half times the quantity consumed in 1950.[2]

A program for the purchase of beryl from small domestic producers for the National Stockpile was announced by General Services Administration on October 7.

At the year end, construction of a beryllium-copper master-alloy plant at Elmore, Ohio, neared completion. The plant will again provide the country with a second producer of this strategic material.

TABLE 1.—Salient statistics on beryl [1] in the United States, 1943–47 (average) and 1948–52, in short tons

Year	Production [2]	Imports	Total supply	Exports		Consumption	Stocks		Average price per unit BeO	
				Beryl	Metal, alloys, and compounds [3]		Industry	Government	Domestic [4]	Foreign [5]
1943–47 (average)	206	2,222	2,428	2.7	66.4	1,944	517	3,400	$15.57	$10.36
1948	99	1,720	1,819	.1	13.0	1,970	1,042	198	26.87	17.41
1949	475	3,811	4,286	.3	94.0	1,029	2,322	1,076	32.10	22.52
1950	559	4,860	5,419	.1	110.5	3,007	2,621	(6)	30.51	25.43
1951	484	4,316	4,800	.3	94.8	3,388	1,417	(6)	33.34	31.67
1952	515	5,978	6,493	1.9	[7] 196.6	3,476	2,492	(6)	38.55	38.55

[1] Estimated 10 percent BeO content.
[2] Mine shipments.
[3] Beryl equivalent.
[4] F. o. b. mine, Colorado.
[5] C. i. f. United States ports.
[6] Restricted.
[7] Does not include an undisclosed quantity of secondary material exported to United Kingdom.

[1] Commodity-industry analyst.
[2] Resources for Freedom, vol. II, The Outlook for Key Commodities: U. S. Government Printing Office, June 1952, pp. 59–61.

DOMESTIC PRODUCTION

Mine Production.—Mine shipments of beryl in the United States during 1952 were the second largest on record, totaling 515 short tons. However, nearly one-fourth of this quantity was of lower grade than the generally accepted average content of 10 percent BeO.

TABLE 2.—Beryl shipped from mines in the United States, 1943–47 (average) and 1948–52, by States, in short tons

State	1943–47 (average)	1948	1949	1950	1951	1952
Colorado	(1)	(1)	144	97	97	54
New Hampshire	(1)	(1)	(1)	106	50	(1)
New Mexico	(1)		8	(1)	141	101
South Dakota	149	45	139	96	138	334
Other [2]	56	54	184	260	58	26
Total: Short tons	205	99	475	559	484	515
Value	$29,935	$26,600	$152,485	$170,550	$161,361	$233,757
Average value per ton	$146.02	$268.69	$321.02	$305.10	$333.39	$453.90

[1] Included with "Other" to avoid disclosure of individual company operations.
[2] Arizona (1949–51); Connecticut (1944, 1947); Georgia (1952); Maine (1943–44, 1947–52); Massachusetts (1943–44); North Carolina (1943–44, 1949, 1951); Virginia (1943–44); and States indicated by footnote 1.

The largest shipments recorded from one property were from the Harding mine, near Dixon, N. Mex. Shipments from this mine totaled 100 tons; of this quantity, 40 tons was reported to be subgrade, 6 percent BeO, beryl concentrate. South Dakota was by far the largest producing State, followed by New Mexico, Colorado, New Hampshire, Georgia, and Maine. The Government purchase depot at Rapid City, S. Dak., was active in obtaining beryl for the National Stockpile. Shipments from South Dakota, which included 92 tons by George C. Bland (Beecher lode), containing 8 percent BeO, accounted for nearly two-thirds of the total domestic production. Beryl production was reported by Keystone Feldspar & Chemical Co., Consolidated Feldspar Corp., John Fisher, J. A. Johnson, and eight other producers. Consolidated Feldspar Corp. was acquired by International Minerals & Chemical Corp. in December 1952.[3] Principal Colorado producers were Consolidated Feldspar Corp., from unspecified properties, and from lessees of properties controlled by Michael D. Lyons. Beryl Ores Co., Arvada, Colo., was actively engaged as a dealer in beryl ore, and this company continued to beneficiate low-grade ores and to grind beryl for use in the ceramic industry. Beryl production was reported from the Hogg mine and from the Foley mine in Georgia. A program for exploration, development, and mining of pegmatites in the Newry Mountain district, near Andover, Maine, was initiated by Beryllium Development, Inc., a wholly owned subsidiary of Beryllium Corp., Reading, Pa.[4] A large production of beryl was reported by this company from the Scotty mine on Plumbago Mountain near Bethel, Maine; however, this production was not shipped and is not included in the 1952 totals. A Reconstruction

[3] Mining World, vol. 15, No. 4, April 1953, p. 84.
[4] American Metal Market, vol. 59, No. 102, May 27, 1952, p. 1.

Finance Corp. loan of $125,000 was granted Idaho Beryllium & Mica Corp. for the production of mica and beryl from the company property at Deary, Idaho.[5] A sample shipment of 125 pounds of beryl was reported from this property in 1952. In Utah 17 beryl-bearing claims in the Sheep Rock Range, Juab and Tooele Counties, were leased by Brush Beryllium Co.[6] The beryl occurs in a large, fine-grained, granitic formation in contrast to the usual pegmatite occurrences. Exploration by diamond drilling is planned. A large beryl-bearing pegmatite dike north of Chewelah, Wash., was explored during 1952 on a property controlled by Earl Cannon and associates [7] and on Merikay mines, managed by Arthur Collins.[8] No shipments were recorded from either property. No beryl production was recorded from Arizona, California, Connecticut, North Carolina, or Virginia in 1952. Tungsten ores from the Hillside mine, Hillside, Ariz., which were reported to contain 2 to 3 percent of beryl, were investigated.

Exploration under the DMEA program resulted in the following certifications of discovery on beryl in 1952: Lewis W. Collingwood and Campbell & Ventling Mining Co., both in Custer County, S. Dak.; Beryllium Development, Inc., Oxford County, Maine; and Georgia-Carolina Mica Mining Co., Inc., Troup County, Ga.

The Small Defense Plants Administration announced December 26, 1952, that small business would be urged to expand beryl-ore production by 2,100 tons a year in the next 3 years. Small mine plants desiring to expand will be granted rapid tax writeoffs on the expansion.

Refinery Production.—The principal processors of beryl and manufacturers of beryllium products are:

Producer and plant location:	*Products*
Beryllium Corp., Reading, Pa	Beryllium-copper master alloy; beryllium-copper casting ingots, sand castings, strip, rod, wire, bar, forgings, and safety tools; beryllium-aluminum master alloy; beryllium-magnesium-aluminum master alloy, beryllium-nickel casting ingots; beryllium metal and oxide.
Beryl Ores Co., Arvada, Colo	Ground beryl; beryllium oxide and ceramic frit.
Brush Beryllium Co., Cleveland, Luckey, and Elmore, Ohio.	Beryllium-copper master alloy; beryllium-copper casting alloy ingots; beryllium-aluminum master alloy; beryllium metal and metal shapes; beryllium oxide, oxide crucibles, chemicals, and compounds.
Champion Spark Plug Co., Detroit, Mich.	Ceramics.
Lapp Insulator Co., Inc., LeRoy, N. Y.	Do.
A. O. Smith Co., Milwaukee, Wis	Do.
Ampco Metal Co., Milwaukee, Wis.	Beryllium-copper mill products.
Wilber B. Driver Co., Newark, N. J.	Do.
Riverside Metal Co., Riverside, N. J.	Do.
Slagle Beryllium Co., Darby Pa	Do.

[5] Engineering and Mining Journal, vol. 153, No. 5, 1952, p. 142.
[6] Mining World, vol. 14, No. 9, 1952, p. 95.
[7] Metal News, vol. 20, No. 3, March 1952, p. 5.
[8] Engineering and Mining Journal, vol. 153, No. 11, November 1952, p. 165.

Brush Beryllium Co. operated a Government-owned plant at Luckey, Ohio, for the Atomic Energy Commission. The commercial production facilities of the company are in a new plant at Elmore, Ohio, and fabrication work is done at Cleveland.

On November 28, 1952, Defense Production Administration Goals 195 and 196 announced objectives for expansion of production facilities for beryllium-copper alloy mill products and beryllium-copper master alloy.

CONSUMPTION AND USES

Commercial consumption of beryl in 1952 exceeded the 1951 consumption by over 100 tons. Total consumption, government and industry, was the highest in history. Although the Government was active in obtaining beryl for the National Strategic Stockpile and for the Atomic Energy Commission, there was a marked increase in the supply of beryl ore available for commercial use. The Emergency Procurement Service of the General Services Administration served as purchasing agent for the National Stockpile, and Brush Beryllium Co., Cleveland, Ohio, purchased beryl for the Atomic Energy Commission.

Beryllium has important applications in the form of an alloying element with copper, aluminum, nickel, magnesium, and iron; as beryllium oxide in the manufacture of specialized high-temperature refractory material and high-quality electrical porcelains; and as a metal in the atomic energy field as a moderator and as a reflector of neutrons, in radium-beryllium neutron sources, and in X-ray tube windows. In terms of quantity, the largest use is in the manufacture of beryllium-copper alloys. These alloys are unsurpassed in their ability to withstand fatigue and wear and at the same time conduct electrical current under high-temperature conditions. They are unique among copper-base alloys in that they can be worked in a relatively soft state and then brought to their final level of strength and hardness by simple low-temperature heat treatment. Applications include springs and contacts in tabulating machines and other electrical and electronic equipment, and use in diaphragms, bellows, and springs for aircraft air-speed indicators and altimeters, weather instruments, pressure gages, and other instruments and controls. Beryllium-copper has applications in large machine parts,[9] and beryllium-copper wire is finding increased use in a wide range of industrial applications.[10] Beryllium-copper is readily adapted to sand casting and other foundry techniques. Its ability to reproduce fine detail accounts for the successful application in pressure cast molds for plastics and precision casting. In 1952 an estimated 65 percent of all beryllium products was utilized for defense.

Beryllium oxide has a high melting point, unusual resistance to thermal shock, and thermal conductivity equivalent to that of certain metals and is an excellent electrical insulator at high temperatures. High-quality porcelains containing beryllium oxide are used for aircraft spark plugs and ultra-high-frequency insulators. Beryl is sometimes used directly in the production of high-grade dielectrics.

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[9] Richards, John T., Beryllium-Copper Useful for Large Machine Parts: Materials and Methods, vol. 35, No. 6, June 1952, pp. 97–99.
[10] Wire and Wire Products, vol. 27, No. 2, February 1952.

In the field of refractories, beryllium oxide is used as a liner in rocket combustion chambers and small, high-temperature electric furnaces and in the fabrication of laboratory ware. Although ceramics are usually thought of as heat-insulating materials, the thermal conductivity of beryllium oxide at high temperatures is about the same as nickel and considerably better than stainless steel. Because of its excellent heat transmission, very low neutron absorption, and refractory properties, beryllium oxide has potential applications in nuclear energy power-plant design.[11]

Beryllium metal has a density of 1.84 and a melting point of 1,284° C. It is the only stable light metal with a high melting point. It is also an excellent transmitter of sound, having a sound-velocity value twice that of aluminum or steel. Advances have been made recently in production of high-purity metal and in the fabrication of large and intricate parts. The metal finds numerous applications in the atomic energy field as a moderator and as a reflector of neutrons, similar to graphite and heavy water. As a construction material in a thermal (slow-velocity neutron) reactor, beryllium metal appears promising; however, this application and its use as a moderator are limited by the high price of reactor-grade material.[12]

A bibliography on the properties of beryllium is given; the physical, electrical, optical, magnetic, chemical, mechanical, and nuclear properties are reviewed; and methods of purification and fabrication are discussed.[13]

STOCKS

Beryl stocks in the hands of commercial consumers were the second largest in history at the end of 1952, having increased over 1,000 tons during the year. Government stocks increased substantially as a result of intensified efforts by the Emergency Procurement Service and Defense Materials Procurement Agency to meet National Stockpile objectives. Stocks of beryllium alloys and compounds held by producers were considerably above the 1951 level. Quantitative data on industry stocks of beryllium products or on Government stocks of beryl are not available for publication.

Although 1952 was a year of peak consumption and a year in which Government agencies were vigorously active in obtaining beryl for the National Stockpile, industry stocks increased substantially. These factors reflect the improved supply situation; principally from increased imports.

PRICES

A program for the purchase of beryl from small domestic producers was announced October 7, 1952, by General Services Administration. Government mica-purchase depots at Custer, S. Dak., Franklin, N. H., and Spruce Pine, N. C., were authorized to buy beryl under this program. Shipments up to 500 pounds of beryl, containing not less than 8 percent BeO, are purchased on the basis of visual inspection at a flat price of $400 per short dry ton. The beryl must be in

[11] Evans, George S., Wanted, Better Materials for Nuclear Reactors: Iron Age, vol. 169, No. 11, Mar. 13, 1952, pp. 93-97.
[12] See footnote 11.
[13] Udy, Murray C., Shaw, Homer L., and Baulger, Francis W., The Properties of Beryllium: Battelle Memorial Inst., AECD-3382; BMI-T-14, July 15, 1949, declassified with deletions May 20, 1952, 154 pp.

the form of clean crystals, cobbed free of waste. Shipments of 500 pounds or more are subjected to chemical analysis if the producer desires, but the producer is required to stand the cost of analysis. Shipments accepted by sampling and chemical analysis are purchased on the basis of short ton units (20 pounds) of contained BeO as follows: 8–8.9 percent, $40; 9–9.9 percent, $45; 10 percent and over, $50. Purchases of more than 25 tons of beryl a year from individual producers must be negotiated with DMPA through GSA. The program terminates June 30, 1958, or when deliveries under the program total 1,500 short dry tons, whichever occurs first. Quotations for beryl on the commercial market soon followed closely these record high prices. E&MJ Metal and Mineral Markets quoted domestic beryl in 1952, f. o. b. mine, per unit BeO, 10–12 percent BeO, as follows: January, $34–$37; December, $45–47.50. Prices quoted for imported ore, c. i. f. United States ports, were substantially the same. Even with these record high prices domestic production of beryl remained at about the same level. It is becoming increasingly evident that high prices for beryl will not alone greatly increase domestic production.

In addition to the principal consumers of beryl listed under Refinery Production, other markets include the following dealers and importers of beryl: Leonard J. Buck, Inc., New York City; C. G. Trading Corp., 122 E. 42d St., New York City; Derby & Co., Ltd., 285 Madison Avenue, New York City; Foote Mineral Co., 18 E. Chelten Ave., Philadelphia, Pa.; General Engineering and Supply Co., 1265 Dierks Bldg., Kansas City, Mo.; W. B. Groma, New York City; Metal Traders, Inc., 67 Wall St., New York City; Metallurg, Inc., New York City; Wm. H. Muller, New York City; Pewlew-Wilson Sons & Co., Inc., New York City; Philipp Bros., Inc., 70 Pine St., New York City; South American Minerals & Merchandise Corp., New York City; C. Tennant, Sons & Co., Empire State Bldg., New York City; Varlacoid Chemical Co., New York City; Wardell-Hatch & Co., Inc., New York City; and Watson, Geech & Co., Inc., 25 Broadway, New York City.

Beryllium-copper master alloy, 4 percent Be, remained steady throughout the year at $1.56 per pound of alloy ($32 per pound of contained Be plus the market price of the contained copper). Five percent Be beryllium-aluminum and beryllium-magnesium-aluminum master alloys were quoted at $70 and $60 per pound of contained beryllium, respectively, plus aluminum at market, with no charge for magnesium. Special "50–50" master alloys were quoted at $70 per pound of contained beryllium plus base metal at market. Beryllium metal was offered as follows: Lump or pebbles (technical) $65 per pound, (premium) $85 per pound; powder (technical) $95 per pound, (premium) $103 per pound. High-fired refractory-grade beryllium oxide was quoted at $18 per pound at the beginning of the year; however, in general, prices of oxide, other compounds, and alloys were nominal, depending upon quantity and quality.

Although beryl was exempted from price control the latter part of 1951, beryllium metal, alloys, and products remained under price control during 1952.

FOREIGN TRADE

United States imports of beryl in 1952 were the highest on record, exceeding by over 1,000 tons the previous high year, 1950. Imports were about equally divided between Western and Eastern Hemispheric sources. Shipments were received from Argentina, the first since 1948, and from India for the second consecutive year since 1946. Brazil, again the principal source of supply, accounted for 43 percent of the total imports, and an equal quantity was received from combined African sources. Since 1950 Portugal has become a small but consistent source of supply. Because of increased prices, the value of beryl imports was nearly double that in the previous high-value year, 1951. An appreciable production of beryl from Madagascar is shipped to France. United States Department of Commerce records indicate that no beryllium metal, oxide, carbonate, or other forms of beryllium were imported by the United States in 1952.

Exports of beryllium ore and concentrates, metal, scrap, primary forms, and alloys (except beryllium-copper) from the United States in 1952 totaled 20,014 pounds valued at $68,474. The principal recipients were: United Kingdom, Canada, West Germany, and France. Department of Commerce classification included beryllium-copper with copper alloys in 1952; export data were not shown separately. However, 376,838 pounds of primary beryllium-copper master alloy ingots were licensed for export; shipments were principally to United Kingdom. Including secondary forms, the total estimated value of beryllium-copper alloy exports for 1952 was $700,000. Canada was the only recipient of material classed as beryllium ore and concentrates. Shipments totaled 3,723 pounds, valued at $9,563.

TABLE 3.—Beryl imported for consumption in the United States, by countries, 1946–52, in short tons

[U. S. Department of Commerce]

Country	1946	1947	1948	1949	1950	1951	1952	Total (short tons)	Percent of total
Argentina	53		55				550	658	2.9
Australia	20	45						65	0.3
Brazil	996	722	1,545	3,264	2,703	1,094	2,590	12,914	57.0
British East Africa (principally Uganda)				11	11	47	18	87	0.4
French Morocco				22	77	23	118	240	1.1
India	119					449	196	764	3.4
Japan [1]				107	17	12		136	0.6
Mozambique			55	107	130	174	308	774	3.4
Portugal					28	97	105	230	1.0
Southern Rhodesia					464	692	931	2,087	9.2
Union of South Africa (includes South West Africa)			47	290	1,401	1,722	1,156	4,616	20.4
Other countries [2]			18	10	29	6	6	69	0.3
Total:									
Short tons	1,188	767	1,720	3,811	4,860	4,316	5,978	22,640	100.0
Value	$105,708	$114,667	$299,375	$858,308	$1,235,639	$1,366,772	$2,548,423		

[1] Country of export only; ore produced principally in Brazil and Argentina before, or during World War II.

[2] 1948, Chile less than 1 ton, Hong Kong (country of export only) 18 tons; 1949, Norway 10 tons; 1950, Canada 29 tons; 1951, Finland 6 tons; 1952, Finland 3 tons; Korea, Republic of, 3 tons.

Beryl is imported into the United States free of duty; a 25-percent duty is imposed on beryllium metal and compounds. Beryllium metal, compounds, alloys, scrap, ore, and concentrates remained on the positive list of products requiring export licenses to foreign destinations (excepting Canada).

Available data indicate only two small foreign producers of beryllium-copper, although there are several mills and foundries in a number of foreign countries that process beryllium-copper alloys. Other countries depend almost entirely on the United States for their primary supply of beryllium products.

TECHNOLOGY

The recovery of beryl, the only commercial source mineral of beryllium, has been entirely by hand-sorting (cobbing) methods. Probably not more than 30 percent of the beryl present in any one deposit is recovered because fragments and crystals of beryl less than 1-inch in diameter usually are not sorted from the gangue material. Government and industry were active in 1952 in investigations to recover beryl by modern milling methods. A flotation process for recovery of beryl was developed by the Bureau of Mines at Rapid City, S. Dak.; this process has been successful on a laboratory scale.[14] To span the hiatus between laboratory and commercial mill operation, pilot-plant studies will be conducted. Metallurgical development studies for recovering fine-grained byproduct beryl from the Kings Mountain, N. C., area were initiated by the Bureau of Mines under memorandum agreement with DMPA, dated September 29, 1952.

In processing beryl to BeO and master alloy, the efficiency or recovery of beryllium metal has been on the order of 67 percent. Efforts by industry to improve the recovery ratio have resulted in a reported 11-percent increase in the recovery of BeO and an 8-percent increase in the quantity of beryllium-copper master alloy yielded from a given quantity of BeO. Beryllium-bearing residues from past operations can be recycled for partial recovery of beryllium previously lost.

Considerable attention was directed toward developing substitutes for beryllium-copper in 1952; however, no entirely satisfactory substitute was developed. The most promising material investigated was a quaternary alloy of copper, nickel, aluminum, and silicon.[15] The improved beryl supply situation has resulted in industry directing its efforts toward finding new uses for beryllium-copper rather than developing substitutes.

Beryl is often difficult to identify in the field. Four methods were described in 1952 for the field identification of beryl.[16]

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[14] Runke, S. M., Mullen, D. H., and Cunningham, J. B., Progress Report on Pegmatite Investigations in South Dakota: Bureau of Mines Rept. of Investigations 4928, 1952, pp. 30–31.

[15] Substitutes for Beryllium Alloys: Nat. Research Council, Div. of Eng. and Ind. Research, Min. and Metals Advisory Board, Library of Congress, Publication Board Project, September 1952, 35 pp.

[16] Spector, F. D., and Brown, D. F., Simple Field Tests for Beryl: New Mexico Miner, vol. 14, No. 5, May 1952, p. 5.

Barlow, N. E., Field Tests for Beryl: South African Min. and Eng. Jour., vol. 62, No. 3077, pt. 2, Feb. 2, 1952, p. 987.

Brush Beryllium Co., Quick Spot Test for Beryllium: South African Min. and Eng. Jour., vol. 63, No. 3090, pt. 1, May 3, 1952, p. 363.

Chemical Age, Chemical Test for Beryl: Vol. 66, No. 1699, Feb. 2, 1952, p. 214.

Depending on the type of material, the beryllium content, and the equipment available, one of the following analytical methods is used for beryllium assays: Gravimetric, colorimetric, fluorometric, and spectrochemical.

Normally, gravimetric methods are used in ore analyses where speed is not a factor, where a relatively high degree of accuracy is desired on medium- to high-grade ores, and where equipment is not available for one of the other methods.[17]

A colorimetric method is used by the Brush Beryllium Co. as a rapid and reliable means of determining the BeO content of prospectors' samples. Although this method does not give as accurate results as are obtainable by several of the gravimetric types of procedure, it is nevertheless usable where a rapid and foolproof method is mandatory.[18]

A fluorometric method is used by the Atomic Energy Commission for determining the beryllium content of air in relation to health problems where a high degree of sensitivity is required.[19]

Spectrochemical (spectrographic) procedures are used for both qualitative and quantitative analyses. Quantitative analyses by this method are applicable where a large number of determinations are being made to justify the cost of the necessary equipment and the preparation of standard curves.[20]

RESERVES

United States beryllium reserves in deposits of a grade of 1.0 percent or more equivalent beryl consist of an estimated 12,000 tons of beryl in pegmatites and 3,000 tons of equivalent beryl in nonpegmatitic rocks, a total of 15,000 tons. Over 50 percent of the 12,000-ton beryl reserve in pegmatites is in South Dakota, principally in the Southern Black Hills in Pennington and Custer Counties.[21] Indicated beryl reserves in New England were increased substantially as a result of a Bureau of Mines investigation.[22] There is an estimated 270,000 tons of beryl in pegmatite deposits in the United States containing less than 1.0 percent and over 0.1 percent beryl. Of this 270,000-ton reserve, 240,000 tons are in the tin-spodumene belt of the Carolinas. Of the total reserves in pegmatite deposits, only an estimated 7,000 tons can be recovered by cobbing. This comparatively small quantity emphasizes the necessity for developing a metallurgical process to successfully beneficiate low-grade beryl ores.

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[17] Hillebrand, W. F., Lundrell, G. E. F., Bright, H. A., and Hoffman, J. I., Applied Inorganic Analysis: John Wiley & Sons, Inc., New York, 2d ed., 1953, pp. 516–523.
Liddell, Donald M., Beryllium: Handbook of Nonferrous Metallurgy. Recovery of the Metals: McGraw-Hill Book Co., Inc., New York, 2d ed., 1945, vol. 2, pp. 66–72.

[18] Brush Beryllium Co., Estimation of the Beryllium Oxide Content in Ores by the Colorimetric p-Nitrobenzeneazoorcinol Method: 4301 Perkins Ave., Cleveland 3, Ohio. 8 pp.

[19] Welford, George, and Harley, John, Fluorometric Determination of Trace Amounts of Beryllium: Am. Ind. Hygiene Quart., December 1952.
Fletcher, M. H., White, C. E., and Sheftel, M. S., Determination of Beryllium in Ores-Fluorometric Method: Ind. Eng. Chem., anal. ed., vol. 18, March 1946, p. 179.

[20] Marks, Graham W., and Jones, Betsy M., Method for the Spectrochemical Determination of Beryllium, Cadmium, Zinc, and Indium in Ore Samples: Bureau of Mines Rept. of Investigations 4363, 1948, 27 pp.

[21] Tullis, E. L., Beryl Resources of the Black Hills, S. Dak.: Bureau of Mines Rept. of Investigations 4855, 1952, 19 pp.

[22] Newman, G. L., Bumpus Pegmatite Deposit, Oxford County, Maine: Bureau of Mines Rept. of Investigations 4862, 1952, 15 pp.

TABLE 4.—Estimated United States beryl reserves, by States, in short tons

State	Pegmatite deposits			Nonpegmatite deposits	
	1.0 percent or more beryl	0.1 percent or more beryl	Cobbable beryl	1.0 percent or more equivalent beryl	0.1 percent or more equivalent beryl
Arizona				300	1,100
Colorado	1,400	3,500	1,300		100
Connecticut		2,100	50		
Idaho	100	400	100		
Maine	2,700	3,800	1,250		
Nevada		300			100
New Hampshire	600	1,100	500		
New Mexico	600	600	400	3,000	4,500
South Dakota	6,000	16,000	3,000		
Wyoming	100	200	50		
North and South Carolina (tin-spodumene belt)		240,000			
Total	11,500	268,000	6,650	3,300	5,800

The principal beryllium reserves in nonpegmatitic deposits are in tactite at Iron Mountain, N. Mex. Although these reserves are large, the beryllium industry is not adapted to the use of this type of ore. A large potential beryl reserve has been reported in the Sheeprock Mountains, Tooele County, Utah. The beryl occurs as small crystals disseminated throughout a granite stock over an area of about 1 square mile. The rock must be milled to recover the beryl. Insufficient data are available to include this deposit in reserves.

Reserves of beryl in foreign countries are not known with any degree of certainty. A value for world reserves has been calculated by assuming that the ratio between United States and world production should be the same as the ratio that exists between United States and world reserves. By using this factor, a world total of 210,000 tons of 1.0 percent ore and 3.8 million tons of 0.1 percent ore is obtained. The major sources of 1.0 percent ore are Brazil, 95,000 tons; Argentina, 31,000 tons; South Africa, 19,000 tons; Southern Rhodesia, 13,000 tons; India, 13,000 tons; Madagascar, 7,000 tons; and Australia, 6,000 tons. The principal sources of 0.1 percent ore are Brazil, 1.7 million tons; Argentina, 560,000 tons; South Africa, 350,000 tons; Southern Rhodesia, 230,000 tons; India, 230,000 tons; Madagascar, 120,000 tons; and Australia, 100,000 tons.

WORLD REVIEW

Argentina.—Five hundred metric tons of beryl was purchased from Argentina Trade Promotion Institute (IAPI) by Minerales & Metales Co. for shipment to the United States, the first exports to the United States since 1948. These exports came from an 8-year accumulation of beryl by IAPI, during which exports were not permitted; therefore, these shipments cannot be taken as a measure of production. The production rate is estimated to be about 30 metric tons per month.

TABLE 5.—World production of beryl, by countries,[1] 1946–52, in metric tons [2]

[Compiled by Lee S. Petersen]

County [1]	1946	1947	1948	1949	1950	1951	1952
Afghanistan					7	2	
Argentina	130	10	[3] 50				[3] 498
Australia	19	54	56	36	23	114	91
Brazil (exports)	1,294	1,027	1,783	3,078	2,625	1,533	2,523
Canada					[3] 26		
Chile			([3] [4])				([5])
France			2	([5])	([5])	([5])	([5])
French Morocco			51	211	56	84	129
India	112	([5])	([5])	([5])	([5])	215	([5])
Korea, Republic of	([5])	([5])				([5])	([4])
Madagascar	([5])	([4])	9	27	486	530	395
Mozambique	22	81	16	136	264	230	140
Northern Rhodesia					5	4	8
Norway				[3] 9		([5])	([5])
Portugal	([5])		[6] 10	3	52	102	78
Southern Rhodesia				23	846	1,007	1,076
South-West Africa	5	52	90	239	659	753	536
Tanganyika			[7] 2	1			([5])
Uganda		18	44	34	71	2	3
Union of South Africa				223	844	593	375
United States (mine shipments)	91	132	90	431	507	439	467
Total (estimate)	1,700	1,430	2,470	4,587	6,651	5,720	6,530

[1] In addition to the countries listed, beryl has been produced in a number of countries for which no production data are available; except for U. S. S. R., their aggregate output is not significant.
[2] This table incorporates a number of revisions of data published in previous beryl chapters.
[3] United States imports.
[4] Less than 0.5 ton.
[5] Data not available; estimates by author of the chapter included in total.
[6] Estimate.
[7] Exports.

Brazil.—Beryl-bearing pegmatites were discovered in the northern part of the State of São Paulo. Crystals about 1 foot in width were found in Bairro dos Pimentas, 3 miles from the city of São Luiz do Paraitinga.[23] A plant for producing beryllium oxide was scheduled to begin production in 1952. Located at Resende on the Paraiba River in the State of Rio de Janeiro, the plant is to be operated by Proberil, S. A., which was organized in São Paulo and financed by Brazilian and American capital. Initial annual production capacity is stated to be 90 tons of beryllium oxide. Beryl from the State of Minas Gerais will be processed. Deposits also are found in the States of Baia, Rio Grande do Norte, and Paraiba. Sulphuric acid used in the process is made at Barra Mansa in Minas.[24]

Canada.—Beryl-bearing pegmatites in Renfrew County, Ontario, were described,[25] and a beryl discovery in the Las La Hache district, British Columbia, was reported.[26]

France.—Pechiney (Compagnie de Produits Chemiques et Electrometallurgiques) processes beryl in France. The company has two ore-processing plants in the Province of Savoie—one at St. Jean de Maurienne, to produce beryllium-copper alloys; the other at Mauri-

[23] Mining World, vol. 14, No. 4, April 1952, p. 59.
[24] Metal Bulletin (London), No. 3683, Apr. 8, 1952, p. 21.
[25] Graham, A. D., Mineralogy, Internal Structure, and Genesis of Beryl Pegmatites, Renfrew County, Ontario: M. A. Thesis, 1952, Queen's University, Kingston, Ontario.
[26] Mining Record, vol. 63, No. 44, Oct. 30, 1952, p. 5.

enne, to produce beryllium metal. Beryl also, reportedly, has been stockpiled by the Government. Sources of ore are Madagascar, French Morocco, Brazil, and India. A small quantity of beryl has been produced from a mine near La Vedrenne, north of Minoges.

French Morocco.—The entire production of beryl came from the Angarf mine of Sociéte des Mines des Zenaga; 142 short tons were produced. Exports to the United States were 118 short tons and to France, 22 tons.[27]

Germany.—Heraeus-Vacuumschmelze, A. G., at Hanau a/Main processes beryl to master alloys. The capacity is reported to be small.

India.—Beryl is produced in Madras State from the mica mines at Saidapuram, from near Pattalai, or Padiyur, in the Coimbature district, and from the Nellore district.

Madagascar.—Exports of beryl in 1952 were 309 metric tons; France was the principal recipient. Production was largely by Marc Rollet from mines in the Malakialina area, near Fitampito.

Mozambique.—Beryl production was from Empresa Mineira do Alto Ligonha. A beryl discovery was reported from Mocuba, Zambesia Province.

Norway.—Beryl deposits occur in southern Norway; at Asedammen near the Swedish border; in the Evje-Iveland district; and in the Landbo-Gjerstad area. Some of the deposits have been worked; however, for the most part they can be developed economically only in conjunction with the sale of byproduct minerals.

Southern Rhodesia.—Beryl production has increased steadily since the initial production in 1949. Principal producing districts are Bikita tin fields, Salisbury Enterprise tin field, Miami mica field, and the Mtoko district.

Spain.—A beryl discovery in the La Coruna Province in northwestern Spain was reported.[28]

Surinam.—Exploration was conducted on beryl-bearing pegmatites near Rama, on the Surinam River, and in an area bordering the Marowijn River.

Union of South Africa (includes South-West Africa).—Since 1949, South Africa has become an important source of beryl. Production was at its peak in 1950 and 1951. The 1952 production declined approximately 35 percent, principally because of the depletion of known surface ores.

United Kingdom.—In England, Mallory Metallurgical Products, Ltd., (Wembley, Middlesex), Telegraph Construction & Maintenance Co., Ltd., (Greenwich), and the Beryllium Smelting Co., Ltd. (London) produced beryllium-alloy products from master alloys imported from the United States.

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[27] Bureau of Mines, Mineral Trade Notes: Vol. 36, No. 5, May 1953, p. 3.
[28] Mining World, vol. 14, No. 4, April 1952, p. 52.