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GEOLOGY OF CANADIAN BERYLLIUM DEPOSITS

Robert Mulligan

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By
Robert Mulligan

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PREFACE

Beryllium is one of the lightest metals and has unique properties for many traditional and potential uses. Canadian production has been negligible, but sub-economic occurrences are widespread, and recent technological developments have enhanced the possibilities of finding economic deposits.

This report presents the first compilation of published and unpublished geological data on all known Canadian occurrences many of which were examined by the author in 1959 and 1960. The report also includes summary descriptions of those types of beryllium deposits that have no known Canadian counterparts, as such information may assist mineral exploration for this metal.

Y. O. FORTIER,
Director, Geological Survey of Canada

OTTAWA, January 13, 1965

Wirtschaftsgeologischer Bericht Nr. 23 — Die Geologie der kanadischen Berylliumvorkommen.

Von R. Mulligan

Eine geochemische, mineralogische und geologische Beschreibung der Berylliumvorkommen in Kanada.

Прикладная Геология, Отчет № 23. — Геология бериллия в Канаде.

Р. Муллиган

Описывает геохимию, минералогию и геологию отложений бериллия в Канаде.

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[1] *See also* Supplementary list in pocket.

Illustrations

GEOLOGY OF CANADIAN BERYLLIUM DEPOSITS

Abstract

Beryllium occurrences are widespread in the Slave, Superior, and Grenville structural provinces of the Canadian Precambrian Shield, and are also found in the Churchill and Nain provinces. In the Cordilleran region they are mainly confined to the east marginal belt of the Western Cordillera; and in the Appalachian region, to the central New Brunswick and southern Nova Scotia batholithic belts.

Most occurrences are in pegmatite dykes containing beryl and/or (rarely) chrysoberyl and other beryllium minerals. Most of the richer berylliferous dykes of the Slave and Superior provinces are associated with lithium minerals, as parts of either regional or internal zoning sequences. The most important of these areas are the Preissac–Lacorne district, Quebec; the Cat Lake–Winnipeg River district, Manitoba; and the Yellowknife–Beaulieu River district, Northwest Territories. However, beryllium occurs much more extensively than lithium, although it has not been found in comparable concentrations. Some berylliferous pegmatites are associated with molybdenite, as, for example, at the Molybdenite Corporation mine at Lacorne, Quebec, where a small amount of by-product beryl represents the only current production of beryllium minerals in Canada.

Non-pegmatitic beryllium occurrences include quartz-greisen veins containing beryl, skarns containing helvite-danalite or beryllium vesuvianite, and a unique alkali-metasomatic deposit at Seal Lake, Labrador, that contains barylite and eudidymite in significant amounts. The berylliferous quartz-greisen veins are in the Appalachian and Cordilleran regions, and are commonly associated with wolframite and/or molybdenite.

Nearly all the beryllium occurrences are related to granitic intrusions (or syenitic in the case of the Seal Lake deposit). The formation of beryllium deposits and the types of deposit formed depend on the metamorphic, intrusive, and tectonic history of the area, the chemical composition of fluids resulting from consolidation of the intrusive bodies, and the chemical composition of the depositional environment.

In addition to the Canadian deposits discussed, a few foreign deposits, of types not known in Canada, are briefly described.

Résumé

Les venues de béryllium sont fréquentes dans les provinces géologiques Supérieur, des Esclaves et de Grenville du Bouclier canadien précambrien; et il s'en trouve aussi dans les provinces de Churchill et du Nain. Dans la région de la Cordillère, elles sont restreintes surtout à la zone est en bordure de la Cordillère de l'Ouest; dans la région des Appalaches, elles sont restreintes aux zones de batholites du centre du Nouveau-Brunswick et du sud de la Nouvelle-Écosse.

La majorité des gisements se trouve dans des dykes de pegmatite contenant du béryl avec ou sans chrysobéryl (rarement) ainsi que d'autres minéraux béryllifères. La plupart des dykes béryllifères plus riches des provinces des Esclaves et Supérieur sont associés à des minéraux lithinifères, faisant partie de successions régionales ou de zones internes. Les plus importantes de ces régions sont celles de Preissac-Lacorne (Québec), de lac Cat-rivière Winnipeg (Man.), et de Yellowknife–rivière Beaulieu (T.N.-O.). Cependant, le béryllium est beaucoup plus répandu que le lithium, bien qu'on n'en ait pas trouvé en concentrations comparables. Associées à la molybdénite, on trouve quelques pegmatites béryllifères, comme à la mine de la Molybdenite Corporation à Lacorne (Québec), où une petite quantité de béryl extrait comme sous-produit représente la seule production récente de minéraux béryllifères au Canada.

Les venues de béryllium non associées à de la pegmatite comprennent des veines de quartz à greisen contenant du béryl, des skarns contenant de l'helvite à danalite ou de la vésuvianite à béryllium, et un seul gisement alcalin métasomatique au lac Seal (Labrador) qui renferme d'importantes quantités de barylithe et d'eudidymite. Les veines de quartz à greisen béryllifère se trouvent dans les régions des Appalaches et de la Cordillère, et elles sont habituellement associées à la wolframite et la molybdénite.

Presque toutes les venues de béryllium sont reliées à des intrusions de granite (ou de syénite dans le cas du gisement du lac Seal). La formation des gîtes de béryllium et les types de gîtes formés dépendent du métamorphisme, des intrusions et de la tectonique de la région, la composition chimique des fluides résultant de la solidification des corps intrusifs et de la composition chimique des milieux de dépôt.

En plus d'étudier ceux du Canada, l'auteur décrit quelques gisements de pays étrangers, de types inconnus au Canada.

Chapter I

INTRODUCTION

No deposits are being mined primarily for beryllium in Canada at present. Beryl is recovered from a picking belt at the Lacorne molybdenite mine. Some years ago one or more shipments of beryl were made from the Lyndoch township occurrences near Quadeville, Ontario. Beryl has been stockpiled in southeastern Manitoba, and a serious attempt to develop mineable deposits was made there by Dalhart Beryllium Mines and Metals Corporation in 1956 and 1957. Some beryl was recovered and stockpiled from the Moose and Best Bet properties in the Yellowknife–Beaulieu area, Northwest Territories, but there is no record of shipments made. A ton or more of beryl may have been hand-cobbed from each of several pegmatites elsewhere. A small amount of gem-quality beryl has been selected from some of the occurrences, but on the whole, conditions at known Canadian occurrences are not considered favourable for the discovery of important gem deposits.

Beryl was until recently the only beryllium mineral known to occur in economically interesting deposits in Canada, or elsewhere. However, a unique deposit of barylite at Seal Lake, Labrador, is now in process of evaluation. Deposits containing beryllium minerals other than beryl have been discovered and developed in the United States of America. Appropriate methods for concentrating such ores have been developed, and production from such sources is increasing.

This report includes a description of seventy-seven localities where beryllium minerals have been found in single occurrences or compact groups. Some information is also given as to localities where beryllium has been found in significant concentration as a trace element. All reported occurrences that have come to the attention of the writer up to the end of 1959 are mentioned, although some are considered dubious. The notes are based on field observations and laboratory investigations by the writer and on the references cited. The localities are described in approximate order of their distribution from west to east, as shown on Map 1218A; some overlapping in eastern Canada has resulted from the grouping of deposits according to the geological provinces in which they occur. Locality numbers correspond to those on the map and Table I.

Because a primary purpose of this report is to assist in the exploration and discovery of beryllium deposits, the chapter on General Geology includes brief descriptions of foreign types of occurrence that have no known counterparts in Canada. Some of these types are comparable to Canadian occurrences, but have significant differences in variety of beryllium minerals.

History

In 1828 Wohler (in Germany) and Bussy (in France) simultaneously produced some spangles of beryllium, and 70 years later the French chemist, Lebau, prepared the first high-purity beryllium. The element was first called earth of beryl; later glucinum; and finally beryllium. In 1913 Fichter (in Germany) produced the first workable quantity of relatively pure beryllium. In 1916 Oesterheld (in Germany) published the equilibrium diagram of several beryllium alloys, and Hugh S. Cooper made the first sizable ingot of beryllium in the United States. In 1926 Michael G. Corson discovered the hardening effect of beryllium on copper and shortly thereafter beryllium found a place in industry (Eilertson, 1960).

Physical Properties

Beryllium is one of the lightest of metals. It has a high strength-to-weight ratio and a high melting point. Some of its properties are as follows: atomic number, 4; atomic weight, 9.01; density, 1.84 g/cc; melting point, 1,285°C; specific heat, 0.4 cal/G/°C; coefficient of expansion, 11.54×10^{-6} cm/cm/°C; thermal conductivity, 0.38 cal/cm^2/sec; electrical conductivity, 40–45 per cent of International Annealed Copper Standard; reflectivity, 55 per cent of white light; and modulus of elasticity, 44×10^{-6} p.s.i. Some nuclear properties of beryllium are: atoms per cubic centimetre, 1.24×10^{23}; neutron scattering cross-section, 6.9 barns/atom; and neutron absorption cross-section, 0.009 barn/atom (Eilertson, 1960).

Uses

The industry was founded on the ability of beryllium to harden and strengthen some soft and ductile metals and alloys, and beryllium has been used most extensively in this field. Most notable are the beryllium-copper alloys. These have many special qualities including: high strength; excellent castability, formability, and machinability properties; high electrical and thermal conductivity; high resistance to corrosion and fatigue; stability under load; freedom from elastic drift; and antisparking and non-magnetic characteristics. Copper containing 1.9 per cent beryllium offers maximum strength and hardness; 0.4 per cent beryllium, high conductivity; and 1.2 per cent beryllium, midway properties. Some of these alloys contain small amounts of a third element such as nickel or cobalt. Beryllium-copper is available in wrought, cast, or forged form.

Beryllium-copper is used widely for springs, bellows, diaphragms, electrical contacts, aircraft engine parts, plastic moulds, marine propellers, gears, bearings and bearing retainer rings, shims, precision castings, and rollers, and is finding numerous applications in miniature electrical and electronic components.

Beryllium-nickel alloys closely resemble stainless steels in density and corrosion resistance, and their strength and hardness compare with high-strength alloy steels. Applications for beryllium-nickel include precision watch and instrument springs, hypodermic needles, and surgical instruments. Beryllium-nickel is castable, and in cast form is used as a matrix in diamond-drill bits, hot-formed moulds for moulding plastics, and shapes for aircraft fuel pumps and business machines.

Beryllium added to aluminum in small quantities (0.01 to 0.5 per cent) contributes ease of casting and thermal stability. Beryllium-aluminum is used in dies.

Beryllium oxide has a high melting point, strength, hardness, electrical resistivity, stability at high temperatures, resistance to thermal shock, and exceptional thermal conductivity. It is similar to beryllium metal in some nuclear characteristics and is a very good moderator and reflector material. Beryllium oxide is also used in crucibles, refractory supports in electrical heaters, thermal radiation shields around graphite crucibles, linings in coreless induction furnaces, coatings on lamp filaments, and cathode heating elements in radio tubes (Eilertson, 1960).

Beryllium is used for windows in X-ray tubes. It has the lowest thermal-neutron cross-section of all the metals. It is used in nuclear reactors as a moderator material to lessen the speed of fission neutrons and as a reflector material to reflect neutrons back into the core and reduce leakage of neutrons from nuclear reactors. Its use in cans to hold uranium fuels is being tested. Beryllium is one of the lightest of metals and has unusually high stiffness, thermal conductivity, heat capacity, melting point, and strength-weight ratio. These and other favourable properties have led to research and development in search of structural applications particularly in aircraft, missiles, and space vehicles, but more research is needed for fuller utilization of beryllium in these fields. Potential and actual uses of beryllium include airframe structural parts, inertial guidance gyroscope and gimbal parts, and heat-sink applications such as a shield for the man-in-orbit space vehicle and airplane brake disks (Eilertson, 1960).

Toxicity

Some materials containing beryllium are toxic to humans. No ill effects from beryllium have been found in mining, sorting, or transporting beryl to markets. However, a disease known as berylliosis is caused by exposure to various compounds, dusts, fumes, or mists from beryllium materials and can be injurious to health if safety precautions are not taken. It is safest to regard beryllium metal and its compounds in powder form as potentially toxic. Simple and practical industrial procedures for control of the toxicity are available (Eilertson, 1960).

Beneficiation of Ores

Pegmatite deposits that can be mined for beryl alone are rare, and only a few deposits have been found that contain more than 100 tons of beryl; however, some of these deposits contain several thousand tons of beryl. In a few places

TABLE II World production of beryllium ore by countries[1]

(Short tons)

Country	1954–58 (average)	1959	1960	1961	1962	1963
North America: United States (mine shipments):						
Cobbed beryl	528	328	244	317	218	1
Other lower grade beryllium ore	—	97	265	805	760	750
Total	528	425	509	1,122	978	751
South America:						
Argentina	1,299	[2]3,336	[2]1,157	[2]1,488	[3]996	[3]718
Brazil (exports)	1,861	2,927	3,827	3,503	3,319	2,169
Total	3,160	6,263	4,984	4,991	4,315	2,887
Europe:						
Norway (U.S. imports)	1	4	—	—	—	—
Portugal	238	41	32	39	19	1
Sweden (U.S. imports)	—	41	—	—	—	—
U.S.S.R.[4] [5]	150	550	750	900	1,000	1,100
Total[4]	390	640	780	940	1,020	1,100
Asia:						
Afghanistan	21	—	11	—	—	—
India (U.S. imports)	1,291	—	1,000	885	150	—
Korea, Republic of	[3]2	—	—	6	—	—
Total	1,314	—	1,011	891	150	—
Africa:						
Congo, Republic of the	960	280	369	184	304	[3]510
Kenya	2	2	1	1	—	—
Malagasy Republic	323	474	701	836	743	[2]239
Morocco	3	—	—	—	—	—
Mozambique	1,187	1,559	1,649	1,073	627	[4]600
Rhodesia and Nyasaland, Federation of:						
Northern Rhodesia	11	2	2	—	—	—
Southern Rhodesia	710	440	539	396	559	249
Ruanda–Urundi	80	187	310	525	394	
South Africa, Republic of	330	203	326	192	360	[6]425
South-West Africa	424	170	413	252	159	61
Swaziland	—	2	6	7	—	2
Uganda	90	235	470	1,136	1,015	381
Total	4,120	3,554	4,786	4,602	4,161	2,467
Oceania: Australia	294	355	213	343	250	[4]150
World total (estimate)[1]	9,800	11,200	12,300	12,900	10,900	7,400

[1] This table incorporates some revisions. Data do not add exactly to totals shown because of rounding where estimated figures are included in the detail.

[2] Exports.

[3] United States imports.

[4] Estimate.

[5] Cobbed concentrates at about 11 per cent BeO.

[6] Ruanda–Urundi included in Republic of the Congo in 1963.

beryl is mined alone, but it is generally obtained as a by-product from mining for feldspar, mica, and spodumene and sometimes as a co-product from mining for columbite and tantalite (Eilertson, 1960).

Most of the beryl produced has been hand-cobbed, but such methods generally recover only a minor part of the beryllium present. Beryl, feldspar, and some other pegmatite minerals have densities so nearly the same that it is difficult to separate beryl by specific gravity methods. Flotation methods that recover beryl, phenacite, and bertrandite have been developed and a flotation mill has been erected at Lake George, Colorado (Siems, 1963). Direct-chemical extraction methods have been developed to treat the ores from Spor Mountain, Utah, and other chemical methods are under investigation.

Prices, Production, and Consumption

World production of beryllium ore is reported in Table II (after Eilertson: U.S. Bur. Mines, Minerals Yearbook, 1963, Table 5). This consists mainly of cobbed beryl containing 10 to 12 per cent BeO, but includes beryl-bertrandite-euclase ore containing about 3 per cent BeO produced in Colorado.

Imports of beryl into the United States are reported as 8,552 tons in 1962, and 6,243 tons in 1963. Other importing countries include France, West Germany, Netherlands, United Kingdom, and Japan. Prices for imported beryl ore, based on 10 to 12 per cent BeO, were quoted in 1963 at $29.00 to $32.00 per short ton unit of BeO, c.i.f. U.S. ports. Prices for domestic cobbed beryl were not published. Beryllium metal was quoted at $62.00 to $71.00 U.S. per pound, and beryllia at $15.00 to $26.00 per pound.

Chapter II

GEOCHEMISTRY, MINERALOGY, AND DETECTION METHODS

Distribution of Beryllium in Rocks

The cosmic abundance of beryllium is very low. This is generally attributed to its atomic structure. The nuclei of the light simple elements Li, Be, and B (*see* Table V) do not have a sufficiently high nuclear charge to screen them against penetration by thermally accelerated protons in stellar atmospheres, and are largely transformed into more stable nuclei (Goldschmidt, 1954, pp. 73–75; Rankama and Sahama, 1950, pp. 71–73). The resulting deficiency is inherited by planets and meteorites.

The crustal abundance was estimated by Goldschmidt (1954) at 2 parts per million and later at 6 ppm. The latter figure seems too high in view of available data as to its lesser concentration in igneous and sedimentary rocks and its known lithophile tendencies (*see* under heading Physical-Chemical Considerations). The figure of 3.5 ppm suggested by Beus (1956) seems more realistic. A rough compilation of data on abundance in igneous rocks, according to various authors, is presented in Table III.

Distribution in Igneous Rocks

Among igneous rocks, the granitic and syenitic rocks are consistently higher in beryllium content than are the basic and ultrabasic rocks (*see* Table III). Analyses by the Geological Survey of granitoid rocks sampled by the writer (Table IV) suggest that their average beryllium content is considerably less than 5 ppm. A large proportion of the granites sampled are associated with berylliferous pegmatites. These are not consistently higher than others not so associated. Norton, *et al.* (1958, Table IV) report an average of only about 3.1 ppm in two granite bodies associated with beryl-bearing pegmatites in South Dakota and Colorado. They also report an average of only 0.01 per cent BeO (36 ppm Be) in a granite body in the Sheeprock Range, Utah, which was considered to be of possible economic interest because of its known content of disseminated beryl. The data regarding concentration in silicic volcanic rocks (Acid extrusive, Table III) is considered especially significant. These rocks are commonly glassy or partly glassy and, where unaltered, furnish naturally chilled samples of magma, which contain many volatile and soluble compounds that would be depleted during crystallization (Coats, *et al.*, 1962, p. 963). Thus they should be especially rich in beryllium and other lithophile elements (Coats, *et al.*, 1962, p. 965), and therefore of particular value in defining geochemical provinces for such elements.

TABLE III | *Average Beryllium Content in Rocks* (parts per million)

	Compiled from the following sources:						
Rock type	Goldschmidt 1954	Sandell[1] 1952	Beus 1956	Warner 1959	Coats 1962	Norton[2] 1958	This report
I							
Igneous							
Ultrabasic	0	0(<0.3)	<0.2	<0.4			
Basic:							
Gabbro	2		0.3				
Basalt	2	1	0.3				
Intermediate:				2			
Diorite		1.6	1.8				
Granodiorite	2–4						
Acid:							
Granitic	2–20	3	5.0	7		4.4	<5
Extrusive	4–40	7?			3.6		
Alkaline:							
Syenite			6.0	3.6			
Nepheline sy.	2–220			9			
Feldspathoidal						24	
Pegmatite			20				<5
Average igneous		2		3.6			
Crustal abundance	6		3.5				
II							
Sedimentary							Rankama and Sahama, 1950
Sandstone and conglomerate						1	
Shale	6					1	3.6?
Clay			7				
Bauxite	<60						
Limestone						<0.3	

Coal

Coal ash: 4.5-Stadnichenko, *et al.*, 1956 200-Jedwab, 1960

Plant ash: to 100-Beus, 1956

---

[1] Includes some Canadian granites.

[2] Weighted averages of data in Table III.

TABLE IV *Beryllium Content of Canadian Granitic Rocks*
(Analyses by GSC spectrographic laboratory)

Sample No.	N.T.S. Block	Locality Identification	Remarks	Be (ppm)		
				>5	<5	N.F.
		New Ross area, N.S.				
457	11E8	West St. Mary's			x	
130	21A9	Nevertell Lake			x	
59–6	»	Morley's	pegmatite	?		
137.1						
+136.1	21A9–16	N.W. New Ross	muscovitic			x
136.2						
+137.2	»	» » »	biotitic			x
138.1	»	S.E. » »				x
119.1	»	Windsor Road south	biotitic		x	
C119.2	»	» » north	muscovitic		x	
131						
+133	»	Leminster				x
121.1						
+.4	»	Wallaback	pegmatite			x
121.2	»	»	muscovitic			x
121.3	»	»	pit			x
121.5	»	»	greisen		x	
122	»	»	red	11		
124	»	N.W. Wallaback	biotitic			x
130	»	Turner Tin	altered muscovitic	15		
		Southern New Brunswick				
116.1	21G2	N. St. George	red			x
102	21G7	McDougall Lake			x	
116.2	»	» »			x	
117.1	21G8	Square Lake	greisen	26		
117.3	»	» »	greisen + fluorite		x	
115	»	Wirral–Nerepis			x	
452	21G8	Eagle Rock	red	7		
454	21G14	Pokiok			x	
114	21J2	Keswick			x	
		Burnt Hill Mine area, N.B.				
113.3	21J7	Napadogan	pegmatitic		x	
113.1	21J7	»				x
109	21J10	Clearwater			x	
140	»	Hayesville			x	
104.2	»	Burnt Hill Brook			x	
104.3	»	» » »	greisenized	34		
105.1	»	» » Mine	greisen	19		
139	»	McLean-Burnthill			x	
106.1+2	»	E. Rocky Brook	greisenized	12		
107	»	» »			x	
108.1+2	»	W. Rocky Brook (Trout L.)			x	

TABLE IV (*Cont.*)

Sample No.	N.T.S. Block	Locality Identification	Remarks	Be (ppm)		
				>5	<5	N.F.
		Bathurst Area, N.B.				
59–10	21P12	Pabineau Lake	near Be occurrence	100		
458	21P5	S. of Pabineau L.		7		
		Precambrian Shield, general				
165.1	31E11	Kearney	pegmatite			x
165.2	”	” (Mt. Baldy)	”	15		
301X	31G13	Pednaud	pegmatite			x
59–13	31G13	Villeneuve	”	?		
59–15	31I13	Riviere du Poste	”	24		
60–13.3	31I13	Lac Dargie	”	?		
159	85I11	Hidden Lake				x
141.6	85I12	Blaisdell Lake	near Be occurrence	16		
		Cordillera				
402.1	82F2	Creston Salmo			x	
.2	”		pegmatite	5		
403	82F6	Nelson			x	
315	”	”		7		
319.1	”	”			x	
319.2	”	”	pegmatite			x
319.3	”	”	syenite		x	
234	82F10	Crawford Bay	pegmatite		x	
235	”	”	”		x	
317.2	82G13	Estella			x	
225	82L11	Fly Hill	pegmatite		x	
222.1	93L8	Topley			x	
216	93M4	Rocher de Boule			x	
217	”				x	
210.4	104N11	Boulder Creek, Atlin				x
446	”	Mt. Munroe, Atlin				x
447	”	Atlin Ruffner				x
304.5	104O–8	Ash Mountain	near Be skarn	9		
305.2	104O–8	”	composite Gr.		x	
306.2	”	”	muscov.-tourm. Gr.	8		
214.3	105B3	Topaz Mt. (Seagull)				x
213	105B2	Cassiar Batholith				x
307	105B1	” ”	pegmatite		x	
211	105C11	Canol				x
207.4	106D4	Dublin Gulch				x
207.2	”	” ”	quartz-veined			x
406	”	Lynx–Snowshoe			x	
421	105M15	Roop Lakes			x	
433.1	115P16	Highet Creek		5		
63X2	115O9	Mt. Barnham	tourm.-peg.	x		

TABLE IV (*Conc.*)

Sample No.	N.T.S. Block	Locality Identification	Remarks	Be (ppm)		
				>5	<5	N.F.
204.1	116B2	Unexpected M.C.	quartz-porphyry			x
204.3	"	"	quartz-porphyry (fluoritic)			x
436.2	"	Germaine Creek	quartz-porphyry	15		

Distribution in Sedimentary and Metamorphic Rocks, Organic Matter, Hot Springs

In sedimentary rocks, most of the beryllium is contained in fine clastic sediments and clay rocks; limestone is notably deficient. According to Goldschmidt (1954, p. 213) the content of ordinary shales is of the order of 6 ppm. Beus (1956, p. 41) reported 7 ppm is redeposited clays of the U.S.S.R. The beryllium content of the coarse clastic sediments appears to be considerably lower, according to the consensus of scanty information available. Likewise in rocks such as limestone and iron-formation, typically formed by precipitation from solution, the concentration appears to be predictably low. Beryllium was reported "not found" (limit of detection less than 5 ppm) in thirteen samples of greywacke collected by R. Kretz (pers. comm.) in a general area of berylliferous pegmatites in the Yellowknife–Beaulieu district. Samples taken by the writer of iron-formation cut by beryllium-rich granophyric stringers near Linklater Lake, Ontario contained no detectable beryllium (report by G.S.C. spectrographic laboratory) in a magnetic fraction and less than 5 ppm in a non-magnetic fraction.

Among residual deposits, bauxites rarely contain as much as 0.01 per cent BeO (36 ppm Be), and have apparently not been enriched in beryllium as much as they have in aluminum (Beus, 1956, p. 41; Warner, *et al.*, 1959, p. 28). However, Warner, *et al.*, found that some residual manganese ores contained 0.01 per cent BeO (36 ppm Be).

Various authorities have stressed the erratic distribution of beryllium in sedimentary rocks in general, and suggested that its distribution is influenced by the beryllium content of the rocks from which they were derived. Debnam and Webb (1960), for example, found between 10–20 ppm and 80–125 ppm Be in soils over some African berylliferous pegmatites, compared with 0.5–4 ppm over barren country rock.

Hot springs, with the exception of Saratoga Springs, N.Y., contain beryllium only in amounts comparable to the "Clarke"[1], according to Warner, *et al.* (1959).

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[1] Assumed average abundance in the earth's crust.

They found, however, that some tufa deposits contain anomalous amounts, notably in a manganese-iron-tungsten-rich layer at Golconda, Nevada, which was found to contain 0.016 per cent BeO.

Organic processes are believed to concentrate beryllium to some extent. In the ashes of U.S. coals Stadnichenko, *et al.* (1956) reported an average of 45 ppm Be, and Jedwab (1960) reported 200 ppm in the ashes of some Belgian coals. Goldschmidt (1954, p. 213) reported rare concentrations of as much as 8,000 ppm Be in coal ashes, but concentrations of only 4 ppm were more typical. According to Zubovic, *et al.* (1960) and Jedwab (1960) the most beryllium is found in coals low in ash content. They inferred that beryllium is more concentrated in the organic fractions of coals than in the inorganic fractions because of the high stability of its chelate.

Goldschmidt (1954, p. 218) implied a parallel concentration in the ash of forest litter. Rankama and Sahama (1950, p. 447) stated that ashes of wheat have been reported to contain as much as 2 per cent beryllium. Beus (1956) noted that beryllium concentrations up to hundredths of one per cent are found in the ashes of plants growing in regions of berylliferous pegmatites and some alkalic rocks.

Physical-Chemical Considerations

Many features of the behaviour of beryllium are explicable by its position in the periodic table of elements (Table V). It is one of the simplest and lightest elements and is strongly lithophile. That is, it occurs predominantly with its neighbors, the alkali and alkaline earth metals, aluminum, silicon, etc. which, in combination with oxygen, fluorine, carbon dioxide, etc., dominate in the common rock-forming minerals of the lithosphere, or outer crust of the earth.

The 'chalcophile' (sulfophile) elements, which have a more complex structure (note 18-electron outer shell in the Cu-Zn-Ga series, Table V), are concentrated mainly as sulphides under hydrothermal conditions. Beryllium does not occur as a sulphide, nor ordinarily in association with sulphides. The sulphur-bearing helvite-group minerals are essentially silicates of the sodalite type. Zinc, which is commonly associated with these minerals likewise there behaves as a lithophile rather than a chalcophile element. It can occur, like beryllium, in 4-coordination with oxygen; willemite (Zn_2SiO_4), for example, is isostructural with phenacite (Be_2SiO_4).

Like aluminum, beryllium adjoins the boundary (broken 'diagonal' line in periodic table) between typical cation-forming elements and elements that form anions or enter into anion-forming complexes. This is in agreement with its observed 'amphoteric' tendency to enter into anionic complexes with oxygen, fluorine, etc., in the presence of strong alkali-metal concentration. This property may be related to the fact that beryllium, although a bivalent cation, has an ionic radius such that it is in 4-coordination in the hydroxide, which has a very low solubility. The ionic radii of the elements, which vary according to both the number of electron shells and the number of electrons in the outer unstable shell (*see* Table V), largely govern their occurrence in mineral structures. The ionic

TABLE V | *Some Physical-Chemical Characteristics of Beryllium and Related Elements According to their Arrangement in the Periodic Table*

Normal Valence State	+1	+2	+3	±4	−3	−2	−1	0
Symbol	*H*							*He*
Atomic Number	1							2
Electrons in Shells	1							2–0
Symbol	*Li*	*Be*	*B*	*C*	*N*	*O*	*F*	*Ne*
Atomic Number	3	4	5	6	7	8	9	10
Electrons in Shells	2–1	2–2	2–3	2–4	2–5	2–6	2–7	2–8
Ionic radius(Å)	.68	.35	.23	.16		1.40	1.36	
Coordination Number	6	4	3	3				
Ionic Potential	1.5	5.5	13					
Ionization Potential (volts)	5.39	18.21	37.9	64.5		137.4	184	
Symbol	*Na*	*Mg*	*Al*	*Si*	*P*	*S*	*Cl*	*A*
Atomic Number	11	12	13	14	15	16	17	18
Electrons in Shells	2–8–1	2–8–2	2–8–3	2–8–4	2–8–5	2–8–6	2–8–7	2–8–8
Ionic Radius(Å)	.97	.66	.51	.42		1.85	1.81	
Coordination Number	6–8	6	4–6	4				
Ionic Potential	1.0	3.0	5.9	9.5				
Ionization Potential (volts)	5.12	15.03	28.4	45.1				
Symbol	*K*	*Ca*	*Sc*	*Ti*	*V*	*Cr*	*Mn*	
Atomic Number	19	20	21	22				
Electrons in Shells	2–8–8–1	2–8–8–2	2–8–9–2	2–8–10–2				
Ionic Radius(Å)	1.33	.99	.81	.68				
Coordination Number	10–12	6–8	6	6				
Ionic Potential	.75	2.0	3.7	5.9				
Ionization Potential (volts)	4.34	11.87	24.8	43.2				
Symbol	*Cu*	*Zn*	*Ga*	*Ge*	*As*			
Atomic Number	29	30	31	32	33			
Electrons in Shells	2–8–18–1	2–8–18–2	2–8–18–3					
Ionic Radius(Å)	.96	.74	.62					
Coordination Number	6	4–6	4–6					
Ionic Potential								
Ionization Potential (volts)	7.72	18	30.7					

radius of beryllium (0.34Å) is small enough that it can fit readily between four oxygen ions, hence the 'tetrahedral' coordination number of 4.

The only other closely related (cationic) elements whose ionic radii are such that they can occur in 4-coordination are silicon (0.42Å) and aluminum (0.51Å). Silicon is almost invariably present in 4-coordination and, because of its abundance in the lithosphere, generally dominates the mineral structures of igneous rocks. Aluminum, at the upper size-limit for 4-coordination, can occur in that configuration, as it does in the feldspars, or in 6-coordination as in corundum.

The stability of such a tetrahedral group depends on the strength of its internal bonds. Bivalent beryllium in 4-coordination with oxygen contributes an electrostatic charge which is +2 on the valence scale. Trivalent aluminum and tetravalent silicon, which contribute +3 and +4, respectively, thus form more strongly bonded and stable tetrahedral groups, and are better able to compete for available oxygen ions.

Furthermore, due to the requirement of electroneutrality in mineral structures, the greater negative charge of the beryllia tetrahedra ($(BeO_4)^{-6}$ compared with $(SiO_4)^{-4}$ and $(AlO_4)^{-5}$), which has to be balanced by other cations in a structure places greater restrictions on the number of possible linkages with other tetrahedral and larger groups.

For these reasons, in addition to its low relative abundance, beryllium in the presence of available silicon and/or aluminum is virtually excluded from the early products of crystallizing magmas, and is concentrated in late products and residual fluids.

The first result is a deficiency of beryllium in ultrabasic and basic rocks and a slight relative enrichment in granites and syenites. These rocks are mainly

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Explanation of Table V

Normal Valence State: Vertical columns comprise groups or families of elements that are chemically similar. Valence is governed by the number of electrons in the relatively unstable outer shell of the atom.

(The 'Periodic Table' illustrates the recurrent relationship between chemically similar elements and their atomic structures, as these are manifested by increasing atomic number.)

Atomic Number: Number of positive charges on the nucleus; equals total number of electrons in the surrounding shells of the atom.

Electrons in Shells: Number of electrons in the 'shells' surrounding the nucleus of the atom, from innermost to outermost.

Ionic Radius (After Ahrens, 1952; Green, 1953): A concept based on measured interionic distances in crystal lattices, taking O^{-2}=1.40Å as reference. Ions such as beryllium and its neighbours and the strong anions O^{-2} and F^{-1} may be regarded as spheres of definite size. The ways in which such spheres of different sizes may be 'packed' limits the possible geometric configurations of a crystalline compound.

Coordination Number: As stability depends on closeness of packing, the large abundant anions such as oxygen (O^{-2}) necessarily dominate the structure, and the smaller cations such as beryllium occur in the interstices. The number of nearest oxygen ions around a cation is the coordination number of that cation, with respect to oxygen.

Ionic Potential (Cartledge, 1928): The ratio of valence divided by ionic radius. A measure of bond strength in ionic structures, since the bond strength is directly proportional to the charge on the ions, but inversely proportional to the distance between them.

Ionization Potential (Volts) (Ahrens, 1952, p. 159): Energy required to ionize an element to valence state shown. A measure of force of attraction between nucleus and outer electron and of the polarizing effect of ions in crystals (Goldschmidt, 1954, p. 105).

The heavy broken line (Table V) is at the "diagonal" boundary between typical "metals" and typical "non-metallic" anion-complex-forming elements.

composed of feldspars and other minerals in which dispersal of beryllium is inhibited by its ionic size and charge characteristics. It is generally believed, however (Rankama and Sahama, 1950, p. 444; Beus, 1956, pp. 26, 27) that the main bulk of the beryllium in igneous rocks is actually dispersed in feldspars. This may be facilitated by the coparticipation of minute amounts of high-valence cations such as Ti, Zr, and the rare earths, as emphasized by Beus (1956). Similarly, Rankama and Sahama (1950, p. 126) suggested that the small amount of lanthalum sometimes present in potash feldspar may result from the substitution of La-Be for K-Si. The absence of beryllium from quartz (Sandell, 1952, p. 215) may be a consequence of the lack of opportunity for such coupled substitutions.

Considerably greater concentrations of beryllium may be attained in the micas and complex amphiboles of acid rocks, whose complex structures permit a wider range of possible substitutions involving various cations. Coupled substitutions in which partial replacement of Si^{+4} by Be^{+2} is balanced by corresponding replacements of O^{-2} by F^{-1} and/or OH^{-1}, whose radii are similar, may also promote the dispersion of beryllium in some minerals stable at the magmatic stage. The common occurrence of beryllium in muscovite from some granites (Beus, 1956, p. 27, reported up to 50 ppm) probably involves such substitutions.

The amount of beryllium that can be fixed in these ways is very limited in granites, but less so in some syenitic rocks, and syenites as a group are found to contain slightly more beryllium than granites. This is attributable to the commonly high content and prolonged participation of the high-valence cations (Beus, 1956, p. 31), and the common abundance of volatile constituents (Tyrrell, 1948, p. 169), in the alkali environment (*see* also Chapter III).

At the same time, the formation of independent beryllium minerals at the magmatic stage is normally inhibited by its low concentration and by the limited stability of such minerals at magmatic temperatures. Few occurrences of beryl as disseminations in granite are thought to be primary. Any remaining beryllium will pass into residual fluids and be concentrated in pegmatitic or pneumatolytic-hydrothermal deposits, depending on the course of late and post-magmatic processes in particular environments. This can best be discussed in connection with various types of deposits (Chapter III).

In sedimentary processes, the behaviour of beryllium appears to be governed mainly by its chemical characteristics in aqueous solution. Because the specific gravity of its minerals (notably beryl) is not much different from that of common rock-forming minerals, beryllium is not, in general, concentrated mechanically. The relative stability of beryllium minerals in the sedimentary environment may, however, account for an observed slight enrichment in residual soils over beryllium deposits.

In clays, the order of enrichment of the bivalent cations Be, Mg, Ca, etc., decreases regularly with ionic potential. The ionic potential of beryllium is nearly equal to that of aluminum, and beryllium tends to be concentrated with aluminum in clays and bauxites. According to the 'Electrostatic Valence' principle formulated by Wickman (Rankama and Sahama, 1950, p. 240), beryllium is exceptional among bivalent cations because, owing to its small ionic radius, it occurs in 4-coordination in $Be(OH)_2$ as in the silicates. This accounts for the very low solubility of the hydroxide, which should therefore be precipitated with aluminum among the typical hydrolyzates. However, Beus (1956, p. 41) and Warner, *et al.* (1959) found that bauxites were not enriched in beryllium as much as they were in aluminum. The relatively greater enrichment of beryllium in clay minerals may be attributable to its favourable sorption characteristics (Beus, 1956, p. 41).

Mineralogy

A fairly complete list of minerals that contain essential beryllium with their composition and physical properties is given in Table VI. The most important of these, and all the ones that occur in Canada, are described below.

Beryllium Minerals

Beryl $Be_3Al_2(SiO_3)_6$. The hexagonal crystal structure of beryl consists of Si_6O_{18} rings that are bonded by the Be and Al ions arranged between them. The rings, arranged one above another, form open channels that can accommodate ions of the alkali metals (Na, K, Li, Cs, Rb) and H_2O, etc. These alkalis can displace part of the beryllium, giving rise to beryl containing end-members such as $Na.Be_2Al.AlLi.Si_6O_{18}$ and its caesium-lithium analogue (Schaller, *et al.*, 1962). With increase in alkali and decrease in Be content, the specific gravity and indices of refraction increase, as shown on Figure 1.

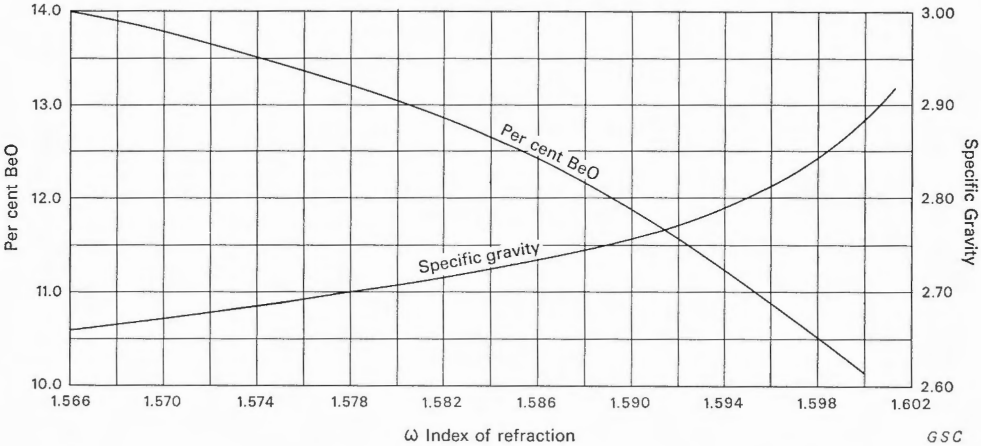


FIGURE 1. Relation between omega index of refraction, specific gravity, and BeO content of beryl (by W.T. Schaller and R.E. Stevens, *in* Norton, *et al.*, 1958).

Schaller, *et al.* (1962) also described an unusual alkali-rich variety of beryl from Mohave county, Arizona, which has the characteristic high indices and high content of Na and Cs, but has uncharacteristically high Be and an appreciable Fe^{+2} and Mg^{+2} content along with low Li and Al. Common low-alkali beryl is

TABLE VI *Properties of Beryllium Minerals*

Name	Chemical Composition	BeO Content (in %)	Symmetry	Specific Gravity	Hardness	Colour	Habit	Typical Occurrence and Locality
OXIDES AND COMPOUND OXIDES								
Bromellite	BeO	98.02	Hexagonal	3.02	9	White	Small prismatic	Calcite veins in hematitic skarns Sweden, Texas, (rare)
Chrysoberyl	Al_2BeO_4	19.8	Orthorhombic	3.50–3.84	8.5	Yellow, yellow-green, emerald green (in alexandrite)	Thick tabular or short prismatic. Commonly pseudohexagonal	Pegmatites (with phenacite and beryl). Skarns (with fluorite, vesuvianite, helvite, phenacite). Mica schist
SILICATES								
Phenacite	$Be_2(SiO_4)$	45.5	Trigonal	2.96–3.0	7.5	Colourless transparent, yellowish, brown	Rhombohedral short-columnar to acicular and radiating	Pegmatites; high temperature veins; skarns. Rare in schist, gneiss, near contact
Bertrandite	$Be_4(Si_2O_7)(OH)_2$	39.6–42.6	Orthorhombic	2.59–2.60	6	Colourless, white, yellowish	Prismatic or tabular	Pegmatites and greisens (with beryl, topaz). Disseminations with fluorite
Barylite	$BaBe_2\ (Si_2O_7)$	16	Orthorhombic	4.0	7	Colourless, white, yellowish	Prismatic or tabular	Contact deposits of manganese and zinc; alkali metasomatic deposits
Gadolinite	$(Y,Ca)_2Fe(BeSiO_4)(O, OH)_2$	5.5–12.9	Monoclinic	4.0–4.65	6.5–7	Brownish black, greenish black	Irregular crystals	Pegmatites (with allanite, and other rare-earth minerals)

Trimerite	$Be_3Mn_2Ca(SiO_4)_3$	17	Monoclinic	3.5	6–7	Pink	Tabular prisms	Skarns; Sweden (rare)
SULPHOSILICATES								
Helvite	$Mn_8(BeSiO_4)_6S_2$	11-14.2	Isometric	3.16–3.42	6-6.5		Tetrahedral	Pegmatites (with albite). Skarns (with magnetite, fluorite). Helvite in rhodonite veins, Butte, Montana
Danalite	$Fe_8(BeSiO_4)_6S_2$	12.7–14.7	Isometric	3.35–3.43	5.5–6	Yellow, brown, red, green, grey	Octahedral	Pegmatites (with albite). Skarns with magnetite, (fluorite)
Genthelvite	$Zn_8(BeSiO_4)_6S_2$	12.6	Isometric	3.66	5.5–6		Octahedral	Nepheline syenite pegmatites; pegmatite; skarn
ALKALI SILICATES								
Eudidymite	$Na(BeSi_3O_7)(OH)$	10.5-11.2	Monoclinic	2.54–2.55	6	Colourless, white	Tabular	Albitized nepheline syenite pegmatites and metasomatites
Epididymite	$Na(BeSi_3O_7)(OH)$	10.5–11.2	Orthorhombic	2.54–2.55	5.5	Colourless, white	Tabular	Albitized nepheline syenite pegmatites and metasomatites
Leucophanite	$Na_{1-n}Ca[Be(SiAl)_2O_6]F_{1-n}$	10–12	Orthorhombic	2.96	4	White, yellowish greenish	Tabular	Cavities of nepheline syenite pegmatites; Norway (rare)
Meliphanite	$Na_{1-n}Ca[Be(SiAl)_2O_6]F_{1-n}$	10–11	Tetragonal	3.0	5–5.5	Yellow	Tabular to short-prismatic	Cavities of nepheline syenite pegmatites; Norway (rare)
Chkalovite	$Na_2(BeSi_2O_6)$	11.3–12.7	Orthorhombic	2.6	6	Colourless, white	Irregular mono-crystal formations	Nepheline syenite pegmatites (with ussingite, aegirine, schizolite, natrolite). U.S.S.R., Greenland (rare)

TABLE VI — *Properties of Beryllium Minerals (Conc.)*

Name	Chemical Composition	BeO Content (in %)	Symmetry	Specific Gravity	Hardness	Colour	Habit	Typical Occurrence and Locality
ALUMINOSILICATES								
Beryl	$Al_2Be_3(Si_6O_{18})$	11–14.3	Hexagonal	2.63–2.91	7.5–8	Blue, green, yellow, brown, white, colourless, rose	From prismatic to short-prismatic and tabular	Pegmatites (greisens and quartz veins; rarely in schist near contact, calcite veins (emerald)); Colombia
Bityite	$Ca_4(Li,Be)_4Al_8[(Si,Al)_4O_{10})]_3(OH)_{20}$	2.3–8	Pseudo-hexagonal	3–5.5–3.0	5.5	White	Tabular	Pegmatites; Madagascar, U.S.S.R.(?) (rare)
Bavenite	$Ca_4(Be,Al)_4Si_9(O,OH)_{26}(OH)_2$	6.3–7.7	Orthorhombic	2.74	5.5	White	Flat prismatic, in radiating aggregates	Pegmatites and greisens (with beryl, as secondary mineral); Moravia, Italy (rare)
Euclase	$AlBe(SiO_4)(OH)$	17.0–21.8	Monoclinic	3.05–3.10	6.5–7	Colourless, pale green, blue	Prismatic, abounding in faces	Pegmatites, veins in limestone; schists; U.S.S.R., Austria, Germany, Brazil, etc.
Milarite	$KCa_2(Be_2Al)(Si_{12}O_{30})$	5.2	Monoclinic	2.55–2.59	5.5	Colourless, pale green	Prismatic	Alpine veins (with adularia, zeolites) (rare)
BORATES								
Rhodizite	$(Na,K)_2Li_4Al_4Be_3B_{10}O_{27}$?	9–15	Isometric	3.4	8	White, yellow	Dodecahedrons	Pegmatite; Madagascar, U.S.S.R. (rare)

Hamberite	$Be_2(BO_3)(OH)$	53.5	Orthorhombic	2.35	7.5	White	Prismatic	Boron-rich pegmatites; Norway, Madagascar, Kashmir, California
PHOSPHATES								
Beryllonite	$NaBe(PO_4)$	19–20	Monoclinic	2.8	5.5–6	Colourless, yellowish	From short-columnar to tabular	Albitized granitic pegmatites (with triphylite beryl, etc.); Maine (rare)
Hurlbutite	$CaBe_2(PO_4)$	21.3	Orthorhombic	2.88	6	Colourless, yellowish greenish	Irregular crystals	Albitized granitic pegmatites (with triphylite beryl, etc.)
Herderite	$CaBe(PO_4)\cdot(OH,F)$	15–16	Monoclinic	3.00	5	Colourless, yellowish, greenish	Prismatic	Albitized granitic pegmatites (with triphylite, beryl, etc.); Rhodesia, Maine, New Hampshire, Germany
Moraesite	$Be_2(PO_4)(OH)4H_2O$	25–28	Monoclinic	1.806	?	White	Acicular	Cavities of albitized pegmatites rich in phosphates, replaces beryl; Brazil, U.S.S.R. (rare)
Kolbeckite	Hydrous Be,Ca, Al,Si,phosphate	8.7	Monoclinic	2.4	3.5–4	Blue to grey	Short prisms	Quartz–wolframite vein; Germany (rare)
Roscherite	$(Ca,Mn,Fe)_3Be_3(PO_4)_3(OH)_32H_2O$		Monoclinic	2.9	4.5	Brown-green	Short prisms	Crusts in vugs; Saxony, Maine, Brazil
Faheyite	$(Mn,Mg,Na)Be_2Fe_2(PO_4)_46H_2O$		for properties *see* Lindberg and Murata, 1953					Crusts in vugs; Brazil (rare)

generally green, blue, or yellow, owing to pigmentation by iron or, especially in emerald, by chromium or vanadium. Alkali beryl is characteristically pale, white, pink (morganite), or colourless.

Common beryl usually occurs as long prismatic crystals, with terminal faces absent or poorly developed. Alkali beryl is more generally short-prismatic or pyramidal, or has poorly developed crystal form.

Some well-zoned Canadian lithium-beryllium pegmatites contain bluish or greenish prismatic beryl in outer zones and poorly formed to pyramidal white beryl in inner lithium-rich zones. The difference probably reflects a lower temperature of formation for the beryl of the inner zone. Studies of decrepitation temperatures of fluid inclusions (Weis, 1953) suggest a possible range of temperatures of formation from 500°–600°C to 200°–300°C for beryl from outer and inner zones, respectively.

Gem quality beryl has not been reported in significant amounts in Canada, but some fine aquamarines have been cut from a few pegmatitic occurrences (Waite, 1945). Emerald is deep green, aquamarine, blue-green, morganite, pink, and heliodor, yellow. Natural emerald is thought to be pigmented by chromium, and beryl of other colours by various minor ingredients (Deer, *et al.,* 1962). Gem-quality beryl has been produced artificially (Lefever, *et al.,* 1962).

Beryl may be difficult to distinguish from associated quartz and feldspar except by colour and crystal form. In these respects it resembles apatite, but is too hard to be scratched by a knife. It commonly has a finely textured sparkle, sometimes described as a greasy lustre, on fracture surfaces, and has no good cleavage. The specific gravity is only slightly above that of quartz and feldspar, but forms the basis of the Barlow beryl-quartz test (*see* under Detection and Identification for this and tests for beryllium). In thin section, beryl is generally identifiable by its relief, low birefringence, and uniaxial negative optical character, although these properties are similar to those of apatite. Beryl occurs characteristically in pegmatites and pneumatolytic-hydrothermal quartz veins, rarely in skarns, disseminations in granite, and schist or other wall-rocks.

Barylite $BaBe_2(Si_2O_7)$. Barylite is a very rare mineral, but has been found in sizable deposits in Canada at Seal Lake, Labrador (locality 65, Map 1218A). Elsewhere, it has been reported only from Långban, Sweden (Aminoff, 1923; Ygberg, 1941), Franklin Furnace, N.J. (Palache, 1935), and Vishnevye Gory, U.S.S.R. (Zhabin, *et al.,* 1960). As at Seal Lake, it is generally fine grained and of apparently metasomatite-alkaline affinity, but at Långban it was described as "av ½ tums Langd" (½ inch), and at Franklin Furnace was first noticed on a picking belt. The usual description is "small white (or colourless) platy crystals." The Franklin Furnace material was first noted for its "vivid blue fluorescence in ultraviolet light" (Palache, 1935). According to Evans and Dujardin (1961), the Seal Lake barylite can often be detected in high-grade hand specimens by its blue fluorescence.

A method of staining barylite, as described by Nickel and Charette (1962), follows:

Reagents

Etching Reagent: Concentrated hydrofluoric acid (HF), 48% solution.

Staining Reagent: 0.2% aqueous solution of sodium rhodizonate or potassium rhodizonate. The solution of either salt is prepared with cold water shortly before use, as it deteriorates rather rapidly. In practice, a solution prepared in the morning may be used for the remainder of the day, but is ineffective the following day.

Procedure

Rock slabs and thin sections: Suspend sample over hot fuming HF for 1 minute; rinse with water; immerse in staining solution for 2 to 5 minutes; rinse with water; dry, if necessary, but without heating.

Crushed samples: Immerse the sample in cold HF in a platinum or "Teflon" crucible for 1 minute to 5 minutes, depending on particle size (excessive etching will decompose finely pulverized barylite completely); decant HF and rinse with water; apply a staining solution for 2 to 5 minutes; decant and rinse with water; dry, if necessary, but without heating.

Other *barium* minerals might be stained by this procedure, as the reaction depends on barium ions (not beryllium), but barite was found to be unaffected, presumably because of its insolubility in HF.

Bertrandite $Be_4(Si_2O_7)(OH)_2$. Bertrandite has not been reported from Canada, but is one of the more common beryllium minerals, locally of commercial importance, and has probably been overlooked. It is generally in small crystals or fine-grained aggregates and is inconspicuous and difficult to detect. It is colourless, white, or yellowish, of varied habit but generally platy, with pearly lustre on 001 cleavage faces. According to Winchell (1951, p. 474), the best cleavage (001) is normal to the obtuse bisectrix, and has negative elongation and parallel extinction. The structure has been investigated by Ito and West (1932).

Bertrandite occurs characteristically as a late or secondary mineral in pegmatites, greisens, etc. In pegmatites, commonly in cavities, it grows on or forms pseudomorphs after beryl. Fluorite is a common associate, also topaz, tourmaline, tungsten minerals, and other beryllium minerals. Notable occurrences are: the Boomer mine, Park county, Colorado, and Tooele county, Utah (beryl-bearing quartz veins); Spor and Topaz Mountains, Utah (fluorite nodules in rhyolitic tuff); and Aguachile, Mexico (fluorite bodies in limestone).

Chrysoberyl $BeAl_2O_4$. The only definite Canadian occurrence of chrysoberyl is near Mont Laurier, Quebec (locality 52, Map 1218A), although it was reported also from Rivière du Poste (locality 57).

The orthorhombic tabular crystals are commonly twinned on 031 giving trillings or pseudohexagonal forms with feather-like striations (Dana and Ford, 1932). Cleavage is "110 distinct" (Winchell and Winchell, 1951, p. 89), "011, 010 imperfect" (Dana and Ford, p. 493), and "010, 001 and 100 imperfect" (Beus, 1956). Colour is variable, commonly yellow-green, and the mineral is pleochroic in thick section. The gem variety alexandrite is emerald-green in daylight but red or purple in transmitted or artificial light. Cat's-eye is a chatoyant variety.

Chrysoberyl is isostructural with forsterite, the positions of Al and Be in the crystal lattice corresponding to those of Mg and Si in forsterite. This may account for its unusual hardness and stability. According to Beus (1956) the crystal structure can be analyzed as aluminum beryllate. It is not attacked by acids but is etched by molten NH_4F (*see* tests for beryllium in section on Detection and Identification of Beryllium and its Minerals).

The occurrence of chrysoberyl in siliceous pegmatites must depend on special conditions involving greater availability of aluminum than of silica at certain stages. It occurs also in some 'desilicified pegmatites', skarns, and mica schists.

Chrysoberyl has been recovered along with beryl from the Wisdom Ranch pegmatite, Larimee county, Colorado, and probably from other pegmatites in Colorado. Other noteworthy localities of economic interest are York Mountains (near Lost River tin deposits), Seward Peninsula, Alaska (Sainsbury, 1962), and Clark county near Mesquite, Nevada (Eng. Min. Jour. Markets, vol. 35, No. 45, 1961; Holmes, 1963).

Eudidymite $NaBeSi_3O_7(OH)$. A rare mineral typical of beryllium-bearing alkali complexes, eudidymite, occurs in Canada at Seal Lake (locality 65, Map 1218A) in association with barylite. There it comprises as much as 1.4 per cent of the ore, representing as much as 0.14 per cent BeO value (Nickel, 1962, 1963b). Eudidymite is monoclinic. An orthorhombic mineral of the same composition is known as epididymite.

Helvite-Danalite-Genthelvite $(Mn,Fe,Zn)_8\ (BeSiO)_6S_2$. Intermediate members of the isomorphous series helvite-danalite-genthelvite occur in Canada at Needlepoint Mountain, Cassiar district, British Columbia (locality 3, Map 1218A) and at Walrus Island, James Bay, Quebec (locality 39). According to Warner (1959, p. 12) these minerals have a three-dimensional network similar to sodalite. Beryllium occupies the position normally held by aluminum in such structures, and this allows the divalent metals, to replace sodium. Sulphur replaces the chlorine of sodalite (Bragg, 1937, p. 269), which explains the unique association of beryllium with sulphur found in these minerals.

The minerals resemble garnet in physical properties, such as colour (red, yellow, brown) and form, though the crystal habits are slightly different. They are commonly admixed with garnet in skarns. They can be distinguished by their reaction with acids, yielding hydrogen sulphide, and more precisely by the Gruner

Helvite Test (Gruner, 1944), which is done by boiling a crushed sample in dilute sulphuric acid with a 'pinch' of arsenic trioxide (As_2O_3) for a minute to 2 minutes, and washing with water. Helvite is stained canary yellow by a film of arsenic sulphide (As_2S_3). Substitution of metallic antimony or arsenic trioxide yields a bright red stain.

Occurrences in pegmatites are rare. In addition to the well-known Iron Mountain district, New Mexico (Jahns, 1944), helvite-group minerals occur in the Victoria Mountains, Luna county, New Mexico (Holser, 1953); at the Miller mine, near Beaver, Utah (Sainsbury, 1962); in Cornwall (Kingsbury, 1961); near Oslo, Norway; in the Kola Peninsula, U.S.S.R.; and at many other localities. None are considered economic at present.

Gadolinite $(Y,Ca)_2Fe(BeSiO_4)_2(O,OH)_2$. Gadolinite has been reported only in minute quantity in Canada in pegmatites in Loughboro township, Ontario (locality 51, Map 1218A), and at Shatford Lake, Manitoba (locality 26). It occurs as rough black crystals and shapeless masses in pegmatites, commonly with other rare-earth minerals (allanite, euxenite, etc.). It has been mined as a source of rare earths in the Iveland (Setesdalen) area, southern Norway, and at Baringer Hill, Texas.

Phenacite Be_2SiO_4. Phenacite has been reported (Ellsworth, 1932, p. 248) in minute quantity at the Height of Land mine, Preissac township, Quebec (locality 42, Map 1218A), but none was found by the writer. It is a fairly common mineral of beryllium-bearing skarns, as well as pegmatites and pneumatolytic-hydrothermal veins. Occurrences are fairly widespread at Mount Antero and several other localities in Colorado. At Mount Wheeler mines, near Ely, Nevada, phenacite was reported (Stager, 1960; Eng. Min. Jour. Markets, Dec. 15, 1960) to make up more than half the beryllium content of the ore.

Phenacite (meaning deceiver) was named in allusion to its similarity to quartz. Its specific gravity and refractive indices are, however, substantially higher. The phenacite structure is similar to that of willemite. It is formed of linked tetrahedra of SiO_4 and BeO_4 with each oxygen of the independent SiO_4 groups forming part of two neighbouring tetrahedra of BeO_4 groups (Bragg, 1937). Zoltai (1960) has recently discussed the structure of phenacite and other beryllium minerals.

Minerals with Beryllium as an Accessory Constituent

Beryllium is present locally in more than trace amounts in a large number of minerals (Warner, *et al.*, 1959, lists 49), including some of the common rock-forming minerals. In exceptional cases, a number of less common minerals, notably those of the rare-earths, contain as much as 1 per cent Be or more, but only vesuvianite (idocrase) and allanite (orthite) contain significant amounts at all commonly.

Beryllium-bearing vesuvianite has been reported from four localities in Canada: Turnback Lake, Northwest Territories (locality 18q, Map 1218A); Ash

Mountain, Yukon Territory (locality 3a); Adams River, British Columbia (locality 8); and near Laurel, in Wentworth township, Quebec (locality 54). Elsewhere it is fairly common and is considered (Beus, 1956, p. 96) the main "collector" of dispersed beryllium in skarn deposits, but rarely contains as much as 1 per cent Be. Even these form only a small fraction of all vesuvianite occurrences. Structurally vesuvianite resembles garnet. The structural formula is given as

$$R_{12}'' R_4''' (OH_4) \left\{\begin{matrix} 2Si_2O_7 \\ 5SiO_4 \end{matrix}\right\}$$

and the general formula as $Ca_{10}(MgFe)_2(OH)_2Al_4Si_9O_{34}(OH)_2$ (Winchell and Winchell, 1951). The role of beryllium in the structure is apparently uncertain. A brown prismatic variety from Franklin Furnace, New Jersey, reported by Palache (1935) to contain 3.3 per cent Be (probably much less according to later analyses reported in Deer, *et al.*, 1962), is the only one of six varieties there that contains a significant amount. Warren and Modell (1931) suggested that the beryllium in it is partly in a general tetrahedral position in place of (Mg, Fe) in special octahedral position, and further that there are two sets of empty tetrahedral positions wherein Be might reasonably go. Beryllium-rich vesuvianite commonly contains fluorine and this may have some bearing on the structure.

Allanite (orthite) is a cerium-bearing complex alumino-silicate related structurally and chemically to epidote. Samples from some pegmatites have been found to contain more than 1 per cent Be.

Other uncommon minerals that locally contain appreciable amounts of beryllium include the following rare-element minerals: cyrtolite, chevkinite, euxenite, fergusonite, microlite, samarskite, steenstrupine, thorite, yttrotantalite, and zircon (variety: alvite); some rare borosilicates such as axinite, homilite, and hyalotikie, and zinc and manganese silicates willemite and rhodonite, an alumino phosphate, wavellite, the zeolite, stilbite, and clinohumite.

Of the common rock-forming minerals the feldspars rarely contain as much as .001 per cent Be. The feldspathoids, such as nepheline, more commonly carry a little more. Quartz contains practically none. The micas are considered the main primary collectors of beryllium in granites (Beus, 1956, pp. 27-31), but very rarely contain more than about .005 per cent. Alkaline pyroxenes, such as aegirine, and amphiboles, such as arfvedsonite, have been reported to contain as much as .04 per cent Be. Garnet from skarns may contain nearly 0.1 per cent rarely and epidote likewise a small amount. Cordierite from some pegmatitic occurrences has been found to contain 0.1 to 0.2 per cent Be. Clay minerals are ordinarily not enriched appreciably in beryllium, but some montmorillonite from Spor Mountain, Utah, and from Uganda contain as much as 5 per cent BeO (Siems, 1963, p. 2).

Detection and Identification of Beryllium and its Minerals

Recognition and Physical Tests

The silicate minerals, beryl, chrysoberyl, bertrandite, and phenacite are light-coloured glassy minerals that may be difficult to distinguish from the normally associated quartz and feldspars. They are hard, practically infusible, and not readily adaptable to simple physical or chemical tests.

The specific gravity and refractive indices of beryl are only slightly above those of quartz and the feldspars. But beryl commonly has a finely textured sparkle (sometimes described as a greasy lustre) that is rather distinctive. Beryl generally shows some development of its characteristic hexagonal prismatic crystal form, a greenish or bluish colour, and has no good cleavage. Apatite is similar in colour and shape, but is softer and can be scratched with a knife.

One physical test for beryl, the Barlow beryl-quartz test, is based on the specific gravity of beryl, which is slightly higher than the specific gravities of quartz and normally associated feldspar. In this test, small, equidimensional fragments of beryl and quartz are dropped into a tube containing bromoform or acetylene tetrabromide. A few drops of benzene are carefully poured on top, and the tube is left undisturbed for several hours. The result is a variable specific-gravity column in which the beryl fragments float at a lower level than the quartz. Benezene gradually evaporates and may have to be replenished for further tests.

The helvite-danalite minerals closely resemble garnet, have about the same specific gravity, and are commonly accompanied by garnet. Chemical tests have been described in the previous section on mineralogy.

Chrysoberyl, phenacite, the helvite-danalite minerals, and some others have specific gravities of about 3.0 or higher and can be concentrated, to facilitate identification, by the use of bromoform (sp. gr. about 2.9) or tetrabromoethane (sp. gr. 2.87–2.96). Bertrandite has about the same specific gravity as quartz and feldspar, and cannot be separated from them in this way.

Chemical Tests

Numerous chemical tests for beryllium have been described in recent literature (Feigl, 1958; Jedwab, 1957; McVay, 1960; Dressel and Ritchey, 1960; and others). Most are variations of the quinalizarin (1), quinizarin (2), or morin (3) tests which Warner, *et al.* (1959) described as (1) "Sensitivity 0.5 ppm Be, (2) 0.05 ppm Be—most specific, and (3) .001 ppm Be—least specific", respectively. A quinalizarin staining method was described by Ampian (U.S. Bureau of Mines R.I. 6016) as follows:

(1) Etch sample grains in 5 ml 0.75 per cent NaOH solution in nickel beaker.
(2) Evaporate to dryness and fuse.
(3) Leach and wash grains with distilled water.
(4) Add 0.03 g quinalizarin and 3 drops of 5 per cent NaOH.
(5) Cover and boil for 1 minute.

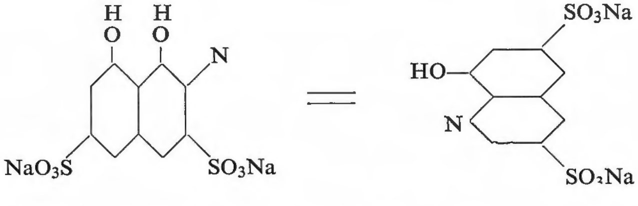
Beryl grains should be stained an intense blue.

A *quinizarin* method has been described by Dressel and Ritchey (U.S. Bureau of Mines Information Circular 7946, 1960). The test consists, briefly, of fusing a pulverized sample of rock with a sodium carbonate-sodium hydroxide flux in a wire loop, dissolving the fusion product in 5 to 10 ml of water, adding 10 drops of a dilute solution of quinizarin (not to be confused with quinalizarin) in alcohol, and observing under either long- or short-wave ultraviolet light in a viewing chamber, where a pink-to-orange fluorescence indicates the presence and tenor of the beryllium. The test takes only a few minutes to perform, and will detect as little as 0.013 per cent beryllium.

Another field test for beryllium minerals by the *morin fluorescence* method is described in the Bureau of Mines Report of Investigation 5620(2), which is obtainable from the U.S. Bureau of Mines free on request. This test consists of fluxing duplicate samples "... one with potassium bifluoride and one with potassium bisulfate—followed by dissolution of salts in water, conversion of the solution to an alkaline condition, addition of morin, and examination of the solution for fluorescence under short-wave ultraviolet light. This method provides a fast, dependable field test for beryllium minerals containing as little as 0.2 per cent beryl or its equivalent". Several other field tests for detecting beryllium minerals that have been successful to various degrees are reviewed in this report, including: a specific gravity test, a quinalizarin spot test, and a P-nitrobenzene-zorcinol spot test.

Both the quinizarin and the morin tests require an ultraviolet light source. The writer has not had much success with quinalizarin methods generally, though Ampian's procedure (*see* above) gave fairly good results on crushed beryl grains.

A different method, using the berillon[1] reagent, i.e.,



has been used with success by the writer on beryl, chrysoberyl, phenacite, and beryllian vesuvianite. This method was developed by A. H. Debnam and described by him (Debnam, 1961; and personal communication) as follows:

> The mineral fragments are sintered with ammonium fluoride in a 25 ml silica crucible[2] for 2 min. after which the heat is increased to drive off excess fluoride. If only one fragment is being tested the following additions are made directly to the fragment in the crucible: 5 drops of 0.2N HNO_3, 1 drop of 0.5 per cent berillon reagent (dissolved in water) and 2 per cent NaOH dropwise. If the mineral fragment is beryl a strong blue colour will develop in the solution after the addition of about 8–10 drops of NaOH. However, if the colour of the solution remains red-violet the fragment is not beryl. In the case where several fragments

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[1] Available from Hopkins and Williams Ltd., Chadwell Heath, Essex, England.

[2] Porcelain will do. (R.M.)

> have been treated, they are placed on a filter paper at least 1 cm apart. Onto each fragment 2 drops of 0.2N HNO_3, 1 drop of 0.5 per cent berillon reagent and 2–3 drops of 2 per cent NaOH are placed consecutively, so that after each addition the liquid soaks into the filter paper. A strong blue coloration develops on the paper beneath a beryl fragment, whereas only dark red-violet colours appear beneath other minerals.

It should be noted that the mineral fragments themselves are not stained. Therefore the test can be carried out on an outcrop only where a hollow exists so that the solutions collect in a pool. The writer has done this successfully using the direct heat from a propane torch to fuse and volatilize the NH_4F. The method has been adapted to colorimetric and titration analysis of soils and stream sediments in a technique described by Debnam and Webb (1960).

Chemical staining methods for helvite-danalite minerals (the Gruner method), and for barylite, have been described in the section on mineralogy earlier in this report.

Nuclear Detection Methods

A portable field instrument called the Berylometer, which is produced by Nuclear Enterprises, Ltd., Winnipeg, and by the Isotopes Specialties Company, Burbank, California, was developed by Brownell (1959) and others at the University of Manitoba (Smith, W. L., 1961). The instrument is based on the Be^9(gamma, neutron)Be^8 reaction. The gamma-rays are produced by an antimony-124 source in the bottom of the instrument, which, when held over beryllium minerals, releases neutrons from the beryllium, which are recorded on a scintillation counter and scaler. Immediate analysis of a sample is possible, inasmuch as the release of neutrons is directly proportional to the beryllium content regardless of its mineral form. A similar instrument based on the Be^9(gamma, neutron)Be^8 reaction was simultaneously developed in England, which uses boron trifluoride counters to detect and measure the neutron flux. Bowie, *et al.* (1960) claimed that the boron trifluoride counters have an advantage of greater stability, robustness, small bulk, and ease of handling. When used properly the Berylometer is perfectly safe. However, because it contains highly radioactive antimony-124, a licence for its use in Canada must be obtained from Atomic Energy of Canada, Ltd., Ottawa, which also sells the isotopes.

By comparison with the Geiger counter, the Berylometer is expensive and heavy, requires licensing, two operators, and careful handling for safety's sake, and the antimony-124 has to be renewed regularly. It is unlikely, therefore, that the Berylometer will have such popular use in beryllium prospecting as the Geiger counter has in uranium prospecting. However, for serious prospecting it has outstanding advantages in that beryllium alone is counted by the instrument and that direct beryllium analyses are obtainable.

A low-cost field instrument for the quantitative determination of beryllium by the same basic principles of activation analysis has been described by W. W. Vaughan and others (1960). The new instrument has been developed by the U.S. Geological Survey and as yet is not available commercially (Smith, W. L., 1961).

Spectrographic Methods

Beryllium is readily identified by visual spectrographic methods. Two semi-quantitative techniques used by the Geological Survey of Canada detect concentrations as low as "less than 0.01 per cent" (probably about .003) in the one instance and "less than 0.0005 per cent" in the other.

Chapter III

GENERAL GEOLOGY OF BERYLLIUM DEPOSITS

Canadian beryllium occurrences are shown on Map 1218A, and described in Table I and Chapter IV. Several foreign deposits of especial significance are described at the end of this chapter.

Classification of Beryllium Deposits

Beryllium deposits may be classified according to various criteria, such as morphological type, mineralogical and structural characteristics, and geological environment. Table VII lists a number of types of occurrences, including the known Canadian ones, classified according to commonly used designations, which are in general genetic in viewpoint. It is not a complete or authoritative list, but is intended to give some indication of the variety of known types, in terms of mineralogy, environmental petrology and conditions of formation. Foreign examples of common types that occur in Canada are not, in general, listed, nor are the ones listed necessarily the most important or best representatives of the types.

The distinctions between types are not always clear or rigidly applicable. The main distinction commonly made is between pegmatitic and non-pegmatitic deposits. As the broadest and most generally objective, this distinction influences the following discussion, but even it is arbitrary in many instances. For example, disseminations in granite, whether considered as primary or secondary, are commonly associated with pegmatitic phases of the granites. Moreover, there are deposits that are apparently gradational in character between pegmatites and typical "pneumatolytic-hydrothermal" vein and greisen deposits.

Berylliferous skarns are treated as pneumatolytic-hydrothermal deposits in this report. The hydrothermal veins, actually a distinct type, are also discussed in that context. However, several important deposits, each unique in some respects, are loosely grouped as "disseminated replacement deposits" for descriptive purposes.

TABLE VII *Types of Beryllium Deposits*

No.	Type	Host Rock	Essential Minerals	Beryllium Minerals	
				Main	Minor
1	Primary (?) dissemination in granite	Granite	Feldspars, quartzmica, micas	Beryl	
2	Granitic pegmatite				
	(a) Pegmatitic segregations in granite	Granite	Feldspars, quartz, micas, tourmaline	Beryl	Phenacite (in some examples)
	(b) Common unzoned	Granitoid Metasedimentary Metavolcanic	Feldspars, quartz, micas (†kyanite)	Beryl	
			Feldspars, quartz, micas (†corundum)	Beryl	
			Feldspars, quartz, micas (†sillimanite)	Beryl	Chrysoberyl
			Feldspars, quartz, micas		Chrysoberyl?
				—	Gadolinite
				—	
				—	Helvite
	(c) Common zoned	Granitoid Metasedimentary Metavolcanic	Feldspars, quartz, micas	Beryl	—
	(d) Associated with lithium (unzoned, spodumene)	Granitoid Metasedimentary Metavolcanic	Feldspars, quartz, micas, spodumene, tourmaline	—	Beryl
	Zoned, spodumene (outer zones)		Feldspars, quartz, micas, tourmaline	Beryl	
	Albite–lepidolite units		Feldspars, quartz, micas	Alkali beryl	
3	Pegmatitic quartz veins	Granitoid Metasedimentary Metavolcanic	Quartz, feldspars, mica	Beryl	
			Quartz, feldspar, mica	Beryl	Phenacite
4	Alkali pegmatites (a) (Aluminum rich)	Nepheline syenite	Feldspar, feldspathoids, muscovite, tourmaline	Beryl	—
	(b) (Aluminum poor)	Nepheline syenite	Albite, natrolite, aegirine, or eudialite, ussingite	Epididymite	Chkalovite Be–sodalite
5	Pegmatite /vein (slyudite)	Ultramafic	Plagioclase, phlogopite, margarite, quartz, chlorite, etc.	Beryl (incl. emerald)	Phenacite, bavenite, chrysoberyl

Other Accessory Minerals and /or Metals	Canadian Examples (Numbers in parentheses refer to Locality Number on Map and Table I)	Comparable Foreign Examples	References
Molybdenite	Pabineau Lake, N.B. (69)	Sheeprock Mts.?, Utah	Couchenour, 1963
	Wolf Lake (2) Winnipeg River (26)		
Sheet mica, kyanite	Tête Jaune (7), Yellow Creek (10)		
	Sept Mille Island, Harricanaw River (38)		Remick, 1962
	Mont Laurier (52)	Virgin Mts., Nev., Victorio Mts., N.M.	Holmes, 1963
	Rivière du Poste (57)	Wisdom Ranch, Col.	Hanley, 1950
	Loughboro Tp. (51), Shatford L. (26)	Baringer Hill, Tex.	
Rare-earths (allanite, etc.)	Some in Grenville provinces; Shatford L. (26)	South Norway	
	Walrus Island (39)		
	Numerous		
	Numerous	Kings Mountain, N.C.	
	Numerous		
Tin-tantalite	Chemalloy (26), Valor (42)		
Molybdenite	Lacorne Molybdenite Mine (42)		
Molybdenite	Height of Land Mine? (42)		
		Coimbatore, India	Goldschmidt 1954 (page 294)
		Lovozero, U.S.S.R. Ilimaussag, Greenland	Tikhonenkov, 1962 Sorenson, 1960
Molybdenite		Ural Mts., U.S.S.R.	Beus, 1956 (page 84)

TABLE VII | *Types of Beryllium Deposits (Conc.)*

No.	Type	Host Rock	Essential Minerals	Beryllium Minerals	
				Main	Minor
6	Pneumatolytic-hydrothermal (non-pegmatitic)				
	(a) High temperature quartz vein	Metamorphic and granitic	Quartz, muscovite, tourmaline	Beryl	
			Quartz, topaz, fluorite	Beryl	
	(b) Greisen-quartz vein	Schist, granite	Quartz, muscovite, topaz, fluorite	Beryl	
	Greisen-quartz vein	Schist, granite	Quartz, muscovite, topaz, fluorite	Bertrandite	Beryl
	Greisen-quartz vein	Limestone	Quartz, muscovite, topaz, fluorite	Phenacite, bertrandite	Beryl
	(c) Skarn (contact metasomatic)	Limestone (impure)	Magnetite, garnet, fluorite, chlorite, quartz	Helvite-danalite	
		Limestone	Magnetite, garnet, fluorite	Helvite, phenacite	Bromellite, euclase?
		Limestone	Calcite, garnet, pyroxene	Helvite	Be–idocrase
		Greenstone	Wollastonite, pyroxene, garnet	Danalite	
		Limestone	Rhodonite, pyroxene, garnet, zinc silicates, mica	Barylite, Be–vesuvianite (idocrase)	
		Limestone	Calcite, garnet	Be–vesuvianite	
		Limestone	Calcite, garnet, pyroxene	Be–vesuvianite	
7	Disseminated replacement deposits				
	(a) Alkali metasomatic	Sodic paragneiss (fenite)	Albite, sodic amphibole, pyroxene	Barylite	Eudidymite
	(b)	Rhyolitic tuff (nodules in)	Fluorite, opal, calcite, clay, topaz	Bertrandite	
	(c)	Limestone–rhyolite porphyry	Fluorite, calcite, quartz (chert)	Bertrandite	
	(d)	Schist		Beryl	
	(e)	Limestone	Fluorite, diaspore, tourmaline, white mica	Chrysoberyl	Euclase, etc.
8	Hydrothermal veins				
	(a)	Limestone	Calcite	Beryl (emerald)	Helvite
	(b) "Alpine veins"	Metamorphic	Quartz, orthoclase, zeolites	Euclase	Phenacite, milarite bavenite
	(c) Manganese veins		Rhodonite, rhodocrosite, quartz, fluorite	Helvite	

Other Accessory Minerals and /or Metals	Canadian Examples (Numbers in parentheses refer to Locality Number on Map and Table I)	Comparable Foreign Examples	References
Molybdenite	Jordan Falls (72) Height of Land (42)		
Wolframite, molybdenite	Burnt Hill mine (68)		
Wolframite, molybdenite, cassiterite	Burnt Hill area (68), Logjam (1), Yukon Tungsten (2), Square Lake (70)		
		Boomer mine, Col.	Sharp, 1960
Scheelite		Mt. Wheeler, Nev.	Stager, 1960
	Needlepoint Mt. (3)	Iron Mt., N.M.	Johns and Glass, 1944
		Quitman Mts., Tex.	Rowe, 1960
Scheelite		Victorio Mts., N.M.	Holser, 1953
Scheelite		Cornwall, England	Kingsbury, 1961
Franklinite, willemite, zincite		Franklin, N.J., Langban, Sweden (?)	Palache, 1935
	Adams River (8), Turnback Lake (18)		
Scheelite, tin	Ash Mountain (3a)		
Pyrochlore, sphalerite, Nb-mineral	Seal Lake (65)	Vishnevye Gora, U.S.S.R.	Zhabin, 1960
		Spor Mt., Utah	Stoatz, 1963
Fluorite (ore)		Aguachile, Mexico	Van Alstine, 1962
		Brazil	Rowe, 196-(not dated)
Cassiterite		Lost River, Seward Pen., Alaska	Sainsbury, 1963
Parisite		Muso district, Colombia	Oppenheim, 1948
		Switzerland	
Lead-zinc sulphides		Butte, Mon.	Hewitt, 1937

Geological Environment of Beryllium Deposits

Introduction—Factors Affecting Formation of Beryllium Deposits

Prevalent theories as to the genesis of beryllium deposits are based on the assumption that beryllium is concentrated in the residual fluids of crystallizing igneous rocks, together with the alkalis, silica, and alumina, various rare-earth and other lithophile metals, and the typical anion-forming (volatile) elements and complexes such as fluorine, hydroxyl, carboxyl (CO_3^{-2}), boron, and phosphorus. The relative atomic concentration of these substances, the temperature-pressure conditions prevailing, the structural developments, and the type of wall-rock encountered at various late and post-magmatic stages are considered the dominant influences in determining the degree of concentration that may be attained and the depositional type and mineral form in which beryllium may occur.

Distribution and Age of Deposits

Most of the known beryllium occurrences of the world, as in Canada, are in granite pegmatites, which are widely distributed in the Precambrian Shield areas and some belts of younger crystalline rocks (cf. Landes, 1935). The non-pegmatitic occurrences are mainly in the younger orogenic belts, characterized by large granitic intrusions. Most of the beryllium produced has come from granite pegmatites in the Shield areas of Southern Africa, eastern South America, and India. However, the Shield areas are not everywhere richer in beryllium than the nearest younger mountain-built regions. In the U.S.A., the Shield areas, except the Precambrian uplifts of the western states, are apparently poorer in beryllium occurrences than the younger Appalachian and Cordilleran regions. In the U.S.S.R., the granitic intrusions of the Karelian (Baltic) and Ukrainian Shields are said (Beus, 1957) to be poorer in beryllium than those of the Caledonian and later orogenic belts. According to Ginzberg (1959, p. 5), pneumatolytic-hydrothermal beryllium deposits are connected with the Alpine, Cimmerian, and Hercynian phases of tectogenesis, both in sedimentary-volcanic rocks and in the old granitoids.

In the Canadian Precambrian Shield, the Slave and Superior geological provinces, both about 2,500 million years old, contain most of the beryllium occurrences. Only a few are known in the younger Churchill province, mostly along its southern fringe west of Hudson Bay. Occurrences are, however, fairly numerous in the (youngest) Grenville province.

In the Appalachian region, beryllium deposits are apparently related to the widespread Devonian granites that mark the climax of orogenic development of the region. The known occurrences are on the east fringe of the central intrusive belt of New Brunswick and in the zone of satellite intrusions on the south fringe of the southern Nova Scotia batholithic area. In the Appalachian belt of the U.S.A., occurrences extend intermittently from the well-known localities of Oxford county, Maine, to Irishmans Creek, Virginia, and the tin-spodumene belt of North Carolina.

In the Canadian Cordilleran region, whose orogenic history is dominated by Mesozoic diastrophism and intrusion, the occurrences are in the east marginal belt of the western Cordillera, close to the eastern limit of major granitic intrusions. In the Cordilleran region of the U.S.A., the distribution of beryllium occurrences appears to outline a pattern of recurrent belts, similar to the metallogenic belts of Burnham (1959), which themselves show a spatial relationship to postulated tectonic-orogenic belts in that region. The associated intrusions range in age from the Precambrian of the Black Hills and Colorado to supposed Tertiary in some western areas. Jahns (1956, p. 1076) also has referred to contrasting "pegmatite provinces" in the southwest U.S.A. and in Scandinavia.

Thus the distribution of deposits conforms in a general way with the concepts of metallogenic provinces and epochs, although these can be only loosely defined in most areas.

Relation to Granitic or Syenitic Intrusions

The close spatial relationship of beryllium deposits, both pegmatitic and non-pegmatitic, to granitoid bodies is widely recognized. A genetic relationship has been inferred by most investigators, although a metamorphic origin has been postulated by some, notably for pegmatites whose composition strongly reflects wall-rock composition, or which have no apparent connection with larger intrusive masses (cf. Jahns, 1956, pp. 1064–1067).

For most Canadian occurrences, features such as regional zoning of rare-element pegmatites seem to indicate derivation from associated granite bodies, whatever processes were involved in the formation of the bodies themselves. However, the weakly berylliferous muscovite-kyanite pegmatites of Tête Jaune (location 7, Map 1218A) in particular and perhaps also Yellow Creek (location 10) and Fort Grahame (location 6), which are remote from large intrusions and have compositional features similar to their wall-rocks, may conceivably be essentially metamorphic in origin.

Original Beryllium Concentration in Parent Intrusion

A primary factor in the genesis of beryllium deposits is the original concentration of Be in the parent igneous body. Evidently many such bodies are so low in beryllium that it can be completely dispersed in the structure of the common silicate minerals. Irregularities in the distribution of beryllium involve the twin concepts of metallogenic provinces and epochs, and also, in a more local sense, the phenomenon of regional zoning.

Tectonic Environment

Beryllium deposits generally are in regions characterized by intense folding and faulting of the bedded rocks, and are dominated by the presence of granitic (or syenitic) intrusions. They are presumably derived from residual fluids resulting from the crystallization of these intrusions. As fluids tend to migrate to regions of lowest pressure, the apical portions of domical intrusions and any upward protuberances would, in the absence of disturbing factors, be favourable areas for the accumulation of such fluids. Asymmetrical or irregular shapes, contemporaneous deformation, or the existence of fractures at a relatively early stage of cooling would modify the tendency to apical concentration.

The relationship between time of development of fractures, and stage of crystallization-differentiation must influence the mode of occurrence of beryllium, in either primary disseminations, pegmatites, or pneumatolytic-hydrothermal deposits. Beus (1956, p. 38) described the conditions under which pneumatolytic-hydrothermal deposits develop as "thermodynamic conditions which preclude the formation of pegmatites". Beus and Sitkin noted (1959, p. 14, in translation) that berylliferous granites rarely occur in pegmatite fields, and are there in post-magmatically altered domes satellite to the main intrusive mass with which the pegmatites are connected.

The reasons why pegmatites are associated with some granites, and only "pneumatolytic-hydrothermal" deposits with others, appear obscure. The explanation would involve the temperature-pressure conditions under which liquid and vapour phases of residual fluids can exist. This complex subject has been reviewed by Jahns (1956, pp. 1080–1084) with reference to the origin of pegmatites.

The possibility of pegmatite development (also the character of pegmatites formed) is apparently related also to the depth of solidification of the parent body. According to Brotzen (1959, p. 78), "deeply eroded areas are characterized by pegmatites poor in volatiles, whereas intermediate areas are characterized by muscovite pegmatites, and areas which are laid bare only to shallow depths are characterized by the formation of greisen with fluorite and topaz".

Ginzberg and Rodinov (1960) differentiated pegmatites according to their "depth of formation". To each "depth facies" they attribute geological, structural, and textural characteristics as well as a particular type of mineralization. The essential criterion appears to be wall-rock composition in terms of metamorphic facies. It is noteworthy that few beryllium occurrences of the pneumatolytic-hydrothermal type are known in the Canadian Shield, where pegmatites are numerous. They are more common, relative to the number of pegmatites, in both the Appalachian and Cordilleran geological provinces where the depth of erosion and the average grade of metamorphism are comparatively low.

According to Ginzberg (1959), pneumatolytic-hydrothermal deposits are formed only in geosynclinal areas of the earth's crust and are dominantly connected with younger phases of tectonic development. The deposits are thought to be related to zones of deep dislocation near cratons. Nekrasov (1960) described a pneumatolytic-hydrothermal beryl deposit in a broad regional fault zone. The zone is at the junction between a marginal horst anticlinorium and a synclinorium of the Mesozoic fold belt. The most favourable parts are at points where transverse faults intersect longitudinal ones.

Wall-Rock Composition and Metamorphic Environment

The influence of wall-rock composition must be considered from the standpoint of original lithology and also of metamorphic condition. For the pegmatites of beryllium-rich districts in the Canadian Shield the influence of original lithology does not seem important, because there is little difference between the pegmatites in basic greenstone belts and those in quartzitic, argillaceous sedimentary belts. In both, the grade of metamorphism is roughly equivalent: albite-epidote-amphibolite in the greenstones and 'nodular' quartz-mica-andalusite-cordierite in the metasediments.

In parts of the Yellowknife–Beaulieu district many berylliferous pegmatites are emplaced in older gneissic granite, and in some other places the host-rock is the granitic body to which they are presumably related. In the Cordillera, the berylliferous pegmatites are virtually confined to a belt of old Palaeozoic and Proterozoic quartzitic argillaceous rocks of moderate metamorphic grade. The beryllium occurrences in the central part of the belt are in pegmatites that have commercial potential as sources of sheet muscovite. In this part, kyanite is present in the wall-rocks and also in some of the berylliferous pegmatites.

The association of berylliferous pegmatites with aureoles of knotted schists and gneisses around granitic intrusions is conspicuous in districts of the Precambrian Shield underlain by sedimentary rocks. In the Yellowknife–Beaulieu district (locality 18, Map 1218A), rare-element pegmatites have not been found outside such aureoles. Similar andalusite-cordierite-staurolite-bearing knotted gneisses are conspicuous also in the Nipigon, Ontario district (locality 34), in Montanier township, Quebec (locality 41), and at Jordan Falls, Nova Scotia (locality 71).

In greenstone terrains, the relation of pegmatites to metamorphic grade is less obvious and apparently less consistent. Davies (1958, p. 8) noted that the altered lavas south of Bird River (including the Bernic Lake area of rare-element pegmatites are recrystallized to streaky, crudely banded hornblende-plagioclase schists, unlike the massive fresh-looking andesites north of the river. In the Preissac–Lacorne district (locality 42) (Rowe, 1953, p. 4), the metavolcanic rocks in which most of the berylliferous pegmatites have been emplaced have been recrystallized to hornblende schist and amphibolite at the contact with the batholith. The influence of wall-rock composition is much greater in most non-pegmatitic deposits (*see* "Chemistry of the Pneumatolytic-Hydrothermal Process").

Association with Other Elements and Minerals

Berylliferous pegmatites occur in most lithium-rich districts, but also in many in which no lithium deposits are known. Niobium-tantalum minerals are present in most berylliferous pegmatites but generally in small amounts. Beryllium is found with molybdenum in a significant number of pegmatites and vein deposits. It is commonly associated with tungsten minerals, notably wolframite, in vein deposits and skarns, and with the tin mineral, cassiterite, in vein deposits, skarns, and some pegmatites. A number of radioactive and rare-earth-bearing pegmatites carry beryllium. Fluorite is a common accessory mineral in non-pegmatitic occurrences. Topaz is fairly prevalent at non-pegmatitic occurrences and appears sparingly in some berylliferous pegmatites. Tourmaline is abundant at most pegmatitic occurrences, but is much more widely distributed than beryl.

Chemistry of Residual Fluids and its Influence on Transportation and Deposition of Beryllium

The chemical balance of residual fluids from crystallizing magmas is determined primarily by the relative atomic proportions of the dominant constituents: Si, Al, K, Na. Where atomic alumina is in excess of total alkali K + Na (the so-called plumasitic rocks) (Goldschmidt, 1954, p. 293), the alkalis are able to combine with aluminum to form feldspar, in the presence of sufficient silica, or feldspar and feldspathoids, if silica is deficient. In either case, excess aluminum is available to enter into muscovite, tourmaline, and other minerals including beryl (Goldschmidt, 1954, p. 294), and even chrysoberyl (Bragg, 1937, p. 102), in which it occurs in 6-coordination. Thus in the granitic line of descent, beryllium is fixed in independent beryllium-aluminate-silicate minerals in the final stages of crystallization (disseminations in granite or pegmatites) or it carries over into pneumatolytic-hydrothermal solutions that enter into post-magmatic processes.

Similar developments may occur in plumasitic nepheline syenites. Pegmatitic derivatives of these in the Coimbatore district of Mysore, India, contain muscovite, beryl, and tourmaline (Goldschmidt, 1954, p. 294). However, the feldspathoids, with their complex structures and essential concentration of various anionic components (Tyrrell, 1948, p. 168), offer greater possibilities for the incorporation of beryllium and other rare cations. This may explain why nepheline syenites, although they commonly contain more beryllium than do granites, rarely contain independent beryllium minerals.

Where atomic alumina is less than the sum of the alkalis (the so-called agpaitic rocks of Goldschmidt, 1954, p. 294), the excess alkali (preferentially sodium) can combine with trivalent iron to form alkali pyroxenes such as aegirine, or amphiboles such as riebeckite and arfvedsonite. Such minerals can incorporate significant amounts of beryllium, and the common presence of accompanying rare-earth and other high-valence cations, combined with the alkaline character of the medium, is particularly favourable for the dispersal of beryllium. These rocks never contain minerals in which aluminum is in 6-coordination with oxygen, such as muscovite, tourmaline, or beryl. The rare beryllium minerals that they contain, such as epididymite, leucophanite, meliphanite, and chkalovite are aluminum-free. The agpaitic rocks are rare and, so far, unpromising as sources of beryllium. However, a similar chemical balance may be effected in limestone skarns, in which de-aluminization may take place in the contact zone of a plumasitic intrusion owing to the presence of abundant calcium (Goldschmidt, 1954, pp. 294–295).

Probably of comparable importance in the genesis of beryllium deposits is the influence of the anionic elements and complexes OH, F, CO_2, etc., that accumulate in the residual solutions during crystallization of the major components. These 'volatile' or 'fugitive' constituents exert a fluxing action, and by promoting fluidity and reducing viscosity, contribute to the segregation of different materials and the growth of coarse crystals. Some, such as fluorine, form volatile complexes with beryllium.

The role of fluorine in the collection and transportation of beryllium has been widely emphasized, notably by Beus and his colleagues. Ginzberg (1959) postulated the existence in postmagmatic solutions of alkali beryllates of the form $Na_2(BeF_4)$ that are stable only in an alkaline regime. Ganeev (1961) cited several authors who stated that fluoride complexes of the transitional elements Be, Al, Fe, Zr in aqueous solution are resistant to dissociation and hydrolysis. This is particularly true of $(Be\ F)^+$ and $(Al\ F_2)^+$, which alone of the fluoride complexes remains stable in the presence of free Ca ions. The effect of calcium in general is to destroy fluoride complexes to form fluorite, whose solubility is very low. Aluminum also has a greater affinity for fluorine than beryllium has. Its action in removing fluorine from solution to form such minerals as muscovite and topaz is considered important in the fixation of beryllium in aluminous rocks due to destruction of beryllofluoride complexes (Beus, 1956, p. 38).

Beryllium is thought to form soluble complexes also with other anions, notably OH^{-1} and CO_3^{-2}. Govorov and Stunzhas (1963) noted that complex potassium carbonate beryllates, such as $K_8(Be_4\ (CO_3)_6\ (OH)_3\ Cl)$, are stable in alkaline solutions at relatively high temperatures. They suggest that such compounds are important in the transport of beryllium in geological processes.

Types of Beryllium Deposits

Pegmatite Deposits

Pegmatites have been the main source of beryllium production, although other types of deposit are gradually becoming more important in some parts of the world. Beryl is by far the most important mineral, but chrysoberyl has been mined in a few places, mainly along with the beryl. No deposits are being mined primarily for beryllium in Canada at present. Beryl is recovered from a picking belt at the Lacorne molybdenite mine (locality 42, Map 1218A), and small shipments have been made from the Yellowknife–Beaulieu area (locality 18) from southeastern Manitoba, and from Lyndoch township, Ontario. Beryl is the only beryllium mineral so far known to be present in substantial amount in Canadian pegmatites. Chrysoberyl occurs in minor amount in Robertson township, Quebec (locality 52), and has been reported at Rivière du Poste (locality 57). Phenacite has been reported only at the Height of Land mine (locality 42), and only in insignificant amount. Gadolinite in Loughboro township (locality 51) and at Shatford Lake (locality 26) and presumably also the helvite at Walrus Island (locality 39) are very scarce.

The classification of beryllium-containing pegmatites in Table VII is descriptive of Canadian occurrences, rather than genetic. A major distinction is made between those pegmatites associated with lithium and others. The "pegmatite segregations" in granite correspond approximately to the "streaky syngenetic" pegmatites of Beus' (1956) classification. They are widespread, and might include many other of the common pegmatites emplaced in granite, as well as "primary disseminations" in granite as at Pabineau Lake (locality 69) and Burtt's Corners (locality 67), where minor pegmatite streaks have been noted. The irregularity of these pegmatite segregations and the diffuse nature of their boundaries with the host granite are distinctive features. In general, they appear in areas not characterized by extensive pegmatite development, but the pegmatitic albite granite stock south of Winnipeg River (locality 26) is an exception.

The distinction between zoned and unzoned pegmatites (Table VII) is also arbitrary. Some development of internal zoning is common, but is generally much less pronounced in simple berylliferous pegmatites than in lithium-beryllium pegmatites. The latter are also commonly involved in regional zoning sequences. The albite-muscovite-lepidolite units correspond most closely with Beus' (1956) "replaced spodumene-albite and lepidolite-albite pegmatites".

"Pegmatitic quartz veins" as at the Lacorne molybdenite mine (locality 42) are here distinguished from the "high-temperature quartz veins" at Jordan Falls (locality 72) by the presence of essential feldspar in them.

The pegmatite vein (slyudites) deposits of Table VII are those described as "granite pegmatites of the crossing-line" by Beus (1956). They are considered as typical non-pegmatitic pneumatolytic-hydrothermal deposits by some of his colleagues (Ginzberg, 1959).

Distribution

The distribution of berylliferous pegmatites in Canada has been dealt with in the early part of this chapter. It is necessary to add that the pegmatites of the Appalachian region are related to a different batholithic belt than are typical non-pegmatitic occurrences. The Cordilleran pegmatite occurrences are mainly in areas that are perhaps more highly metamorphosed than the areas with the non-pegmatitic deposits. The related intrusions are generally of Mesozoic (mid-Cretaceous ?) age, but the Hellroaring Creek pegmatite (locality 16) is of late Precambrian age (700 million years), according to the potassium-argon ratio (Lowden, 1961, p. 6) determined on muscovite.

External Structural Controls

According to Beus (1956, p. 43), the beryllium pegmatite fields are related to medium-depth granitic intrusions connected with major fold structures and regional fracture belts. Ginzberg and Rodinov (1960) stated that the tectonic environment of rare-metal pegmatites is characterized by flexural (not flow) folding and fault structure. The concordant or discordant relationships of pegmatites to wall-rock structures in many parts of the world have been cited as criteria for inferences about their mode of development. Most of the Canadian berylliferous pegmatites are discordant in strike and/or dip, and the inference is that they were emplaced in pre-existing or contemporaneously developed fractures.

In the Herb Lake district of northern Manitoba (locality 24), the attitude of pegmatite dykes, several of which contain beryl, at the Green Bay property suggests that they may occupy tension fractures related to regional faults (Mulligan, 1965). In some parts of the Yellowknife–Beaulieu district (locality 18), a large proportion of the rare-element-bearing dykes (especially the lithium-rich ones) (Fortier, 1946, 1947; Mulligan, 1965) strike northeasterly across the trend of latest open folding. In the Ross–Redout Lakes area (locality 18J) in particular, berylliferous pegmatites commonly strike northeast across the foliation of the gneisses. In contrast, beryl-free dykes farther east, which are closer to the Redout Lake mass of younger granite, are generally concordant. Elsewhere in the district the berylliferous dykes, which are generally closer to masses of younger granite than are the lithium-rich dykes, commonly strike parallel with or at right angles to the contact. The same is true in the Preissac–Lacorne district (locality 42), where the dykes are thought to be controlled by joint systems. At the Lacorne molybdenite mine, beryl is present in pegmatitic veins of the "east-west" set, one of three or more sets that cut the contact zone of a granitic plug.

On the whole it appears that the relationship of beryllium pegmatites to regional folds and faults is generally overshadowed by the influence of their close relationship with intrusive bodies.

Regional Zoning

Regional zoning of pegmatites, with respect to particular granitic intrusions, is apparent in several districts or sections of districts. The pegmatites of such regionally zoned sequences differ from one another in mineralogical type and complexity. In the general order of increasing distance from the central parts of the related intrusions, the varieties here considered the most important are: (1) simple granite pegmatites, with accessory beryl but negligible lithium minerals; (2) complex, generally well-zoned pegmatites, containing both beryl and lithium minerals; (3) pegmatites containing substantial amounts of lithium, as spodumene, with little or no beryl.

The simple beryl pegmatites are generally within the related granite body, or marginal to it. The complex pegmatites are most commonly marginal to the granite, or close to its contacts, and the simple spodumene pegmatites generally lie in the invaded rocks, well beyond the contacts.

In the Preissac–Lacorne district (Tremblay, 1950, and Fig. 2 (*in pocket*)) and in parts of the Yellowknife-Beaulieu district (Jolliffe, 1944 and Fig. 3 (*in pocket*)), for example, the simple granite pegmatites, with accessory beryl, occur within masses of late muscovite-bearing granite, or close to them whereas the simple spodumene-bearing dykes are almost all well outside the granite bodies. In the Nipigon district (Pye, 1956), spodumene dykes of simple internal structure lie farther from a major granitic intrusion than do the more complex ones, which, in turn, lie farther away than do the well-zoned dykes that carry both beryl and lithium minerals. Other examples of regional zoning can be observed in such places as the Cat Lake–Winnipeg River area (Davies, 1958 and Fig. 3) and the West Hawk–East Braintree district (Stockwell, 1933).

In the Preissac–Lacorne district, the regional zoning concept has been extended to include molybdenum-bearing pegmatitic quartz veins that are outside the zone of simple spodumene pegmatites. In the Ross Lake–Redout Lake area (Yellowknife–Beaulieu district) a zone of beryl-columbite-tantalite pegmatite has been recognized between the simple beryl-bearing and spodumene-bearing dykes.

Internal Zoning and Related Structures

In some places, beryl is erratically distributed in some otherwise simple granitic pegmatites that apparently have no systematic internal development. In other places, its distribution is related to zones or other internal structures that are, to some extent well defined. Zones are units of contrasting mineralogy and/or texture that are generally concordant with the pegmatite bodies and more or less symmetrically disposed within them. The most common and obvious zonal development in simple pegmatites is that of a quartz-rich core or series of core-pods lying within dominantly feldspathic units. Beryl may be distributed mainly within such quartz cores or at their margins, where it is commonly associated with concentrations of muscovite.

More complex zonal development is found in some lithium-beryllium pegmatites, in which beryl occurs mainly in the outer feldspar-rich intermediate or wall zones encompassing lithium-bearing inner quartz-rich zones. In these, the beryl is commonly found in quartz-muscovite or quartz-muscovite-cleavelandite segregations among the blocky feldspar crystals, but may be completely enclosed in large feldspar crystals. In some districts, notably the Cat Lake–Winnipeg River district, such pegmatites have tourmaline-rich wall zones lying outside the beryl-bearing part of the feldspar zone.

Some well-zoned lithium-beryllium pegmatites contain beryl crystals erratically distributed within an inner spodumene zone, as well as in outer feldspar zones. In such instances, the beryl of the inner zone occurs as stubby or pyramidal white crystals unlike the greenish or bluish prismatic beryl characteristic of the outer zone, and is probably of later development. A few apparently unzoned spodumene-rich pegmatites contain beryl crystals erratically distributed within them.

So-called 'replacement units' that are apparently indigenous to core units or core margins, but transgress zone boundaries, are present in some complex pegmatites. Typical of these is the sugar-grained albite-muscovite-lepidolite unit of the Chemalloy pegmatite (locality 26, and Fig. 5) which contains an appreciable amount of watery-white beryl, evidently formed later than the greenish beryl of the outer microcline zone.

Relationship Between Regional and Internal Zoning

In examples of regional zoning, beryl occurs characteristically in inner dykes within or close to the margins of related granitic intrusions. Lithium-rich dykes

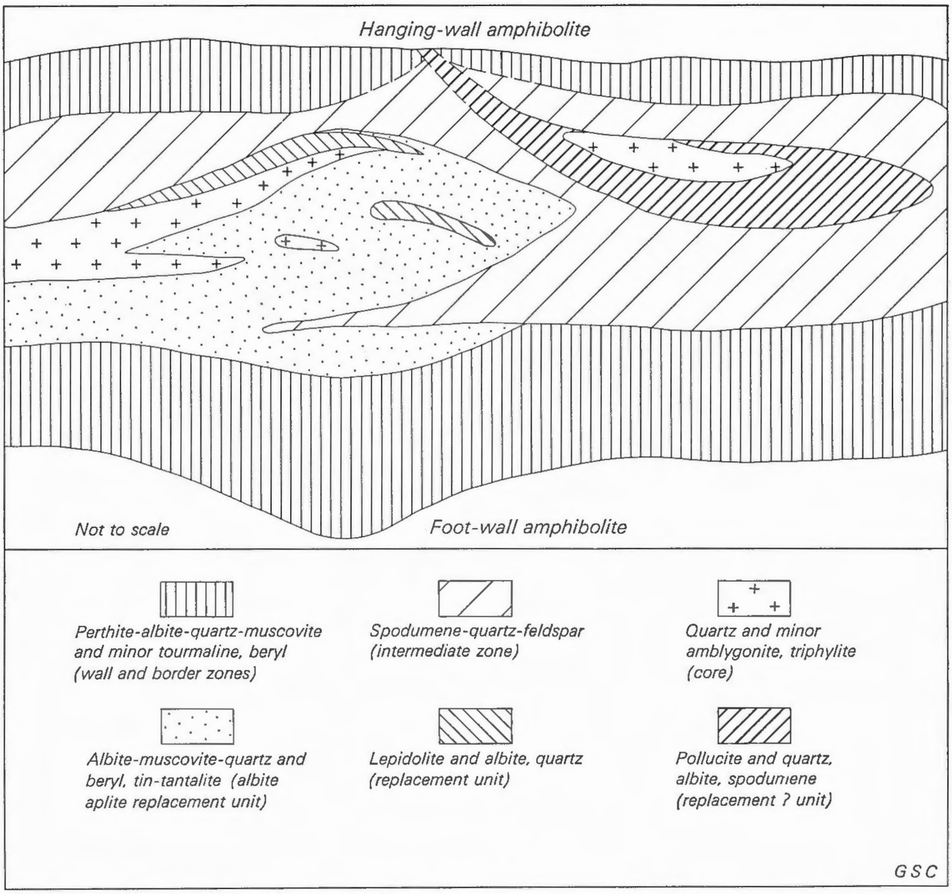

FIGURE 5. Generalized partial vertical section of Chemalloy pegmatite showing spatial relationships of internal units.

characteristically are farther from the intrusive body. In examples of internal zoning, blue-green low-alkali beryl is most commonly found in outer zones closer to the walls of complex dykes than the lithium minerals, which are concentrated in inner zones.

Moreover, the zonal sequence of diagnostic minerals, inward from the walls, of zoned pegmatites (black tourmaline-beryl-spodumene-lithia phosphates and micas) corresponds to the order of decreasing temperature of formation of these minerals, according to available information (cf. Brotzen, 1959, p. 76). The white alkali-rich beryl characteristic of inner zones likewise is generally considered to have formed at lower temperatures than the blue-green beryl of outer zones.

These relationships appear to support the view that berylliferous (and also lithium-bearing) pegmatites crystallized in a falling-temperature sequence from fluid media derived from the associated granitic intrusions. However, some simple unzoned berylliferous pegmatites such as the ones at Tête Jaune (locality 7, Map 1218A) and Yellow Creek (locality 10), which contain minerals such as kyanite in common with their wall-rocks and are remote from known major granitic intrusions, may be essentially metamorphic in origin.

Chemistry of the Pegmatite Process

In simple feldspar-quartz-mica pegmatites, and in feldspar-rich outer and intermediate zones of complex pegmatites, green alkali-free beryl is commonly found as inclusions in large soda/potassic feldspar crystals, or penetrating them. In such conditions it is apparently a primary mineral, roughly contemporaneous with the feldspar.

More commonly in such pegmatitic environments, beryl is concentrated in quartz ± muscovite ± cleavelandite segregations. This mode of occurrence suggests that its crystallization was delayed somewhat beyond that of the bulk of the primary soda-potassic feldspar. The presence of cleavelandite, especially, may attest the operation of a localized replacement system. However, as such segregations are generally isolated, there is little to suggest that they are the result of replacement in the sense of a massive redistribution of material. The affinity of beryl for muscovite may be due to removal of hydroxyl and/or halogens from beryllium complexes to form the muscovite. Normal alkali-free beryl in the core quartz of simple pegmatites can be included in this class. Such occurrences probably represent not so much an absolute concentration of beryllium as a favourable medium for its accumulation into coarse crystals.

Where beryl is associated with muscovite at the core margin, it probably represents the first major tendency to concentration in the pegmatitic process, corresponding with solidification of the quartz core.

The bulk composition of the fluid at this stage must involve: (1) overabundance of silica to form core; (2) increased concentration of Na (and Li) relative to K, evidenced by late albite and lithia micas in inner units; and (3) culmination in concentration of volatile constituents (evidenced by H_2O, CO_2 in fluid inclusions in beryl). The decreased activity of potassium may reflect not so much depletion as temperature conditions below those required for formation of potassic feldspar (some potassium must have been available to form muscovite). Aluminum, to form muscovite and beryl (in which it is in 6-coordination), likewise must be available in excess of the amount required to form albite (4-coordination).

Beryllium, not necessarily exhausted in the main stage of feldspar crystallization, continues to form beryl, but beryl found in lithium-rich core zones and late replacement units is characteristically an alkali-rich variety. It reflects the increased sodium and/or lithium content of the solutions.

Beryl concentrated at core margins (as at the Valor property, locality 42) is commonly associated with bands of aplite between coarse-grained units. This textural association is reminiscent of the sugar-grained albite replacement unit at the Chemalloy property (locality 26 and Fig. 5), in which a major part of the beryl in that pegmatite appears to be concentrated. Such an abrupt change to a fine-grained texture may record an increase in viscosity, perhaps occasioned by a sudden release of supersaturation in volatile constituents due to a sudden decrease in pressure (Brotzen, 1959, pp. 50, 86). The phenomenon may be connected with "resurgent boiling" (Jahns, 1956, p. 1094). Brotzen (p. 87) discounted the resurgent boiling theory and supported the theory of separation of two separate solvent phases, connected (p. 86) with the onset of the alkali replacement process.

The alkali replacement process is generally considered to involve the albitization of potassic feldspar by soda-rich residual solutions following the segregation of the quartz core. Beus (1956, p. 34) actually suggested that alkali beryl is formed metasomatically from microcline by the action of hydrous and halogen-bearing beryllium complexes in alkaline solution, and represents the general process in the following way:

$$\underset{\text{(microcline)}}{\mathrm{K\,Al\,SiO_3O_8}} + \underset{\text{(alkaline}}{\mathrm{NaOH}} + \underset{\text{solution)}}{\mathrm{H_2O}} + \mathrm{Na\,Be\,(ClF)}$$

$$\underset{\text{(albite)}}{\mathrm{Na\,AlSiO_3O_8}} + \underset{\text{(muscovite)}}{\mathrm{K\,Al_2\,[Al\,Si_2O_{10}]\,(OH)_2}} + \underset{\text{(beryl)}}{\mathrm{Al_2\,Be_3\,[Si_6O_{18}]}}$$

$$+ \underset{\text{(quartz)}}{\mathrm{SiO_2}} + \underset{\text{(alkali halides in solution)}}{[\mathrm{K,Na{-}Cl,F}] \uparrow + \mathrm{H_2O} \uparrow}$$

Brotzen (1959, pp. 82–84), remarking on the absence of fluorine-rich minerals from most pegmatites and their wall-rocks, discounted the role of halogens in the genesis of zoned pegmatites, generally. He considered CO_2 (the most common component, next to H_2O, of liquid inclusions) as a predominant influence, with particular reference to the segregation of quartz from feldspar, during the main part of the pegmatitic process, and the formation of quartz cores. The process is illustrated by the following general formula (Brotzen, pp. 82–84):

$$\mathrm{SiO_3^{-2}} + \mathrm{CO_2} \longrightarrow \mathrm{SiO_2} \downarrow \text{ (silica gel) } + \mathrm{CO_3^{-2}}$$

Progress of the reaction is favoured by the presence of potassium, released to the fluid phase by the albitization of early-formed potassium feldspar during the replacement process. Potassium, having a highly soluble carbonate, remains mobile and available for further replacement processes, such as the formation of muscovite and lepidolite, or eventual withdrawal from the system (Brotzen, 1959, p. 86). Lithium, whose carbonate is insoluble, is not further mobilized under these conditions and proceeds mainly to form spodumene or petalite at this stage.

In this view of the development of zoned pegmatites there does not appear to be any need to invoke a metasomatic origin for late alkali beryl of the core or core margin, nor is there much evidence for it. However, where the beryl content of a pegmatite appears to culminate in a typical 'replacement unit' as at the Chemalloy property (locality 26, on Map 1218A and Fig. 5), a redistribution of earlier-precipitated beryllium may be involved, as suggested by Beus (1956, p. 35).

Beryllium Phosphates and Other Pegmatite Minerals

According to Beus (1956, p. 35), the replacement stages are characterized also by the formation of a series of secondary minerals including silicates (phenacite, bavenite, and euclase), phosphates, and borate minerals (in boron-rich pegmatites). On the other hand, Brotzen (1959, p. 90) holds that the normal course of crystallization and concentration from the late aqueous phase (with the exclusion of silicate ions from kinetic competition and aqueous solvation of strongly dissociated compounds) would lead to the crystallization of beryllophosphates.

Bavenite and euclase are alumino-silicates like beryl. Phenacite, however, is aluminum free; its presence would seem to indicate exhaustion or immobilization of aluminum before that of silica. On the other hand, chrysoberyl, the silica-free aluminum-beryllium compound oxide, forms (Brotzen, 1959, p. 90) at the final stage of replacement. Chrysoberyl (also, incidentally, sillimanite) occurs in intimate association with silica at Mont Laurier (locality 52), which suggests that aluminum remained active there after the immobilization of silica.

Alkali Pegmatites

Deposits of beryllium are rare in alkali pegmatites and most contain it in only slight concentration. Presumably this is due to the greater possibilities for substitution of beryllium in the lattices of early-formed minerals, as discussed in the previous chapter. However, there appears to be no reason why redistribution and secondary concentration of beryllium might not take place as a result of metasomatic processes akin to the ones operating in the late stages of formation of granitic pegmatites (cf. Rowe, 196—, p. 34). In fact, the Seal Lake deposit (locality 65) may exemplify this type of development.

The behaviour of beryllium in alkali pegmatites is governed by the chemical balance of the rocks from which they were derived. Thus in pegmatites associated with agpaitic rocks, in which the atomic concentration of alkalis is greater than that of aluminum, the characteristic beryllium minerals are aluminum-free alkali, calc-alkali, and ferruginous beryllosilicates such as eudidymite, chkalovite, and beryllium sodalite.

Pneumatolytic-Hydrothermal Deposits

General Characteristics and Geological Environment

This group includes the following types of non-pegmatitic beryllium deposits: disseminations in granite (secondary), greisens, quartz veins, plagioclase-quartz veins (slyudite), and skarns ('contact metasomatic' or 'tactite'). These mutually related deposits, apparently derived from residual fluids of granitic plutons, are commonly classed as 'pneumatolytic-hydrothermal'. This deliberately vague term presumably implies that they were formed under temperature conditions somewhat lower than those of pegmatite deposits but higher than those of common metallic vein deposits. As they are typically found in areas in which pegmatites are not well developed, they are supposed to have formed under thermodynamic conditions precluding the development of pegmatites (Beus, 1956, p. 38). These conditions are considered to be a relatively shallow depth of consolidation and a relative abundance of volatile constituents (Beus, 1956; Brotzen, 1959; Ginzberg, 1959). According to Ginzberg (1959), pneumatolytic-hydrothermal deposits are formed only in geosynclinal areas connected with younger phases of tectogenesis than are the pegmatitic deposits. In Canada, they are more common in the Appalachian (Devonian orogeny) and Cordilleran (Mesozoic orogeny) regions than in the Precambrian Shield, and are generally in areas of lower average metamorphic grade than are the pegmatites of these regions.

The granitic bodies to which these deposits are related are commonly bi-micaceous or muscovite granite and alaskite. Many have small irregular pegmatitic phases and miarolitic cavities. Such features are taken to reflect a late tectonic stage of intrusion; the bodies are evidently post-deformational. These features may account for the absence of fractures at a suitable stage for pegmatite development.

Actually there is no general agreement on the distinction between the processes of pegmatite development and of pneumatolytic-hydrothermal deposits (cf. Jahns, 1956, pp. 1083–1084). At Mount Antero, Colorado, and Bagdad, Arizona (Warner, *et al.,* 1959, p. 59), a rather complete gradation is found from beryl-bearing granite through beryl-bearing schlieren, vugs, and small veins, to conventional pegmatites. The characteristics of the pneumatolytic-hydrothermal deposits resemble those of the late phases and replacement units of complex pegmatites. But whereas such units are thought to develop in closed systems, the secondary granitic disseminations, veins, greisens, and skarns, are thought by Ginzberg (1959, p. 5) to represent rather open-system conditions involving large-scale transfer of material. This is inferred from forms of spatial zoning found to characterize the depositional environment. Beus (1959, p. 38) and others concluded, for example, that beryl disseminated in a granite body was more concentrated in a deep albitized but only slightly greisenized zone than in the highly greisenized upper zone in which most of the tungsten is concentrated. The albitization and greisenization are attributed to autometasomatism by sodium- and fluorine-rich residual solutions trapped within the crystalline shell or at the contact with overlying rocks. The erratic operation of the process is illustrated by the patchy distribution of albitized granite at Sheeprock Mountains (Warner, *et al.,* 1959, p. 145), where beryl occurs only in grey albitized patches in otherwise red microcline granite. The only comparable Canadian occurrence, the beryl disseminations in granite at Pabineau Lake, New Brunswick (locality 69, Map 1218A) does not show clear signs of albitization nor of greisenization. However, greisenization is evident in connection with a number of beryl-bearing vein deposits.

Beryl is the characteristic beryllium mineral of granite disseminations, greisens, quartz veins, and certain disseminations in schist. In these, phenacite, chrysoberyl, and helvite-danalite minerals are exceptional and generally subordinate. Bertrandite may be important in greisens as at the Boomer mine, Colorado. It has generally been considered as a late or secondary development, but is evidently primary in some deposits at least. Wolframite, molybdenite, and cassiterite, in any combination, are common accessories in beryllium-bearing greisens and related quartz veins.

In Canada, there appears to be a gradation from 'pegmatitic quartz veins' with essential feldspar (Lacorne Molybdenite mine and Height of Land mine, locality 42 and Fig. 2) through 'high temperature quartz veins' without feldspar (Jordan Falls, locality 72), to more typical vein and greisen deposits with accessory sulphide minerals (Burnt Hill mine, locality 68, and Logjam Creek, locality 1). A corresponding decrease in grade of metamorphism of the country rocks is apparent. Molybdenite is accessory throughout but only the last type, the typical 'pneumatolytic-hydrothermal' greisens and veins, contain wolframite.

The occurrence of beryllium minerals other than beryl in veins and greisens as well as in skarns is thought to be primarily dependent on the chemistry of the depositional environment as discussed below. As no Canadian veins or greisens are known to contain significant amounts of such minerals, brief descriptions of typical foreign representatives that do are appended, along with certain types of disseminated deposits that have no known Canadian counterparts.

The helvite-danalite occurrence at Needlepoint Mountain (locality 3) is fairly typical of iron-rich skarns though it lacks the vesuvianite and the pronounced rhythmically banded structure of the Iron Mountain, New Mexico, deposit.

Chemistry of the Pneumatolytic-hydrothermal Process

Theories as to the origin of pneumatolytic-hydrothermal beryllium deposits invoke the presence of abundant volatile constituents in residual fluids after crystallization of the main minerals of the parent intrusion. These are supposed to act as agents for the concentration and transportation of beryllium and associated metals. Of the volatile agents the greatest importance is attached to fluorine. The common association of fluorine minerals, especially fluorite and topaz, gives rise to this inference, which is supported by theoretical and experimental considerations as to the affinity of beryllium for fluorine and the character of fluorine complexes of beryllium and other metals, notably tin and tungsten, common to such environments.

Changes in the chemical nature of the solutions resulting from reaction with country rocks determines the locus of deposition of the metals and the mineral form in which they are precipitated. On this basis the types of pneumatolytic deposits may be classified into groups according to the chemical nature of the country rocks, as follows:

1. Aluminous-siliceous rocks
    - (a) disseminations in granite
    - (b) greisens
    - (c) quartz-greisens and quartz veins
    - (d) disseminations in schist

2. Calc-carbonate rocks
   (a) quartz veins
   (b) calcite veins
   (c) manganese veins (rhodonite and rhodocrosite)
   (d) skarns—siliceous
   skarns—ferruginous
3. Ultramafic rocks
   (a) quartz-plagioclase veins (slyudite)

In granitic and metasedimentary aluminous-siliceous rocks, aluminum liberated in the process of greisenization is considered to be the essential precipitating agent of beryllium (Beus, 1956, p. 38). By combining with fluorine to form micas and topaz, it contributes to the breakdown of beryllium-bearing complexes. Because the granitic bodies to which such beryllium occurrences are related are commonly albitized (cf. Sheeprock Mountains, Warner, *et al.*, 1959, p. 59), the first stage in the process is supposed to be albitization of primary potassic feldspar. This albitization is ascribed to the accumulation of residual sodium, and decreased temperature favouring the relatively stable albite. The inference is that beryllium exists in residual solutions in a form such as Na_2BeF_4 (Ginzberg, 1959, p. 9), from which beryllium is precipitated by hydrolysis connected with subsequent changes in the acid-alkali regime of the solutions. The idea of autometasomatic or other post-magmatic action is implicit even in the supposed origin of the characteristic features of the related granitic bodies, minor pegmatite schlieren, miarolytic cavities etc. (cf. Ginzberg, 1959, p. 5).

In apparent contradiction to the hypothetical connection of beryl with albitization processes, however, Zalashkova (*in* Motobina, 1961) believed that the causes of concentration of beryllium are microclinization of plagioclase and muscovitization of biotite.

In calc-carbonate rocks such as limestone, the powerful action of calcium in removing fluorine from the solutions to form fluorite and in combining with available alumina and silica to form highly stable calcium alumino-silicates, virtually precludes the formation of beryl. Phenacite is the characteristic mineral formed in the presence of excess silica, or chrysoberyl in a silica-deficient environment. Phenacite, accompanied by bertrandite and associated with quartz veins, is present in limestone at the Mount Wheeler scheelite prospect in Nevada (Rowe, 196—, p. 32). Bertrandite occurs exclusively in the fluorite deposits in limestone at Aquachile, Mexico. Chrysoberyl occurs with fluorite, diaspore, tourmaline, white mica, and minor sulphides in veinlets cutting fluoritized limestone at the Lost River Tin mine area, Seward Peninsula, Alaska (Sainsbury, 1963).

In iron and manganese-rich skarns, however, helvite-danalite minerals are almost exclusive, and these minerals are found also in rhodonite rhodocrosite veins at Butte, Montana (Rowe, 196—, p. 29). Fluorite is characteristic, and where fluorine-rich vesuvianite occurs, it may carry most or all of the beryllium present. Examples of beryllian-vesuvianite skarns in Canada are at Turnback

Lake, Northwest Territories (locality 18q); Ash Mountain (locality 3a) and Adams River, British Columbia (locality 8); and Wentworth township, Quebec (locality 54). Neither these nor the famous deposit at Franklin Furnace, New Jersey, are known to contain helvite, but beryllian-vesuvianite does occur with helvite group minerals at Iron Mountain, New Mexico (Jahns, 1944), and in the Victorio Mountains, New Mexico (Holser, 1953). At the Victorio Mountains locality, beryl is present in a quartz-muscovite-tungsten vein cutting marble that contains a helvite and beryllian-vesuvianite bearing skarn.

Calcium-rich greenstones, as well as associated impure limestones, are the host-rocks of helvite and danalite-bearing skarns in Cornwall and Devon (Kingsbury, 1961, p. 938). Helvite occurs preferentially in the greenstone, which is richer in iron, and danalite in the limestone, which is richer in manganese. Granite and other aluminous rocks in the areas contain other beryllium minerals but no helvite-danalite.

In notable exception to the above principles are the valuable deposits of gem beryl in calcite-bearing veins cutting limestone at the famous Muso, Colombia, emerald locality (Oppenheim, 1948). However, these are distinguished by Beus (1956, p. 45) from the pneumatolytic-hydrothermal deposits and classed as hydrothermal, as are also the euclase and phenacite-bearing 'Alpine veins' of Switzerland and Germany. Kingsbury (1961, p. 939) also explained these as deposits, with albite, from aluminous solutions that were not affected by the host rocks.

The rare beryllium deposits in ultramafic rocks are exemplified by the famous emerald deposits of the Ural Mountains, U.S.S.R. They are classed by Beus (1956) as "desilicified pegmatites" or "pegmatites of the crossing-line", but by Ginzberg (1959, p. 9) as analogues of ordinary greisen (slyudity). Although the presence of phenacite and chrysoberyl suggests de-aluminization and desilicification processes akin to those operating in calcareous rocks, the processes are complex and the predominant mineral there also is beryl.

Bertrandite and Phenacite Vein Deposits

Bertrandite-beryl Greisen Veins, Colorado (Siems, 1963)

Bertrandite- and beryl-bearing quartz veins and beryl in sericite greisen occur at the California mine on Mount Antero, Chaffee county. Other minerals in the greisens are molybdenite and fluorite. The property is not producing. In 1961 the mine was acquired by the U.S. Beryllium Corporation.

In recent years, the largest United States producer of beryllium ore has been situated in Colorado. This is the Boomer mine operated by the U.S. Beryllium Corporation on Badger Flats, Park county. The geology has been described by Hawley and others (1960) and by Sharp and Hawley (1960). The orebodies are in greisenized rocks. The mine is close to the western contact of the Pikes Peak granitic batholith with Precambrian schists and gneisses. The metamorphic rocks are cut by pegmatites of simple composition, and small granite intrusives of Silver Plume and younger Pikes Peak age. The Boomer mine lies in a small fine-grained granite stock of Pikes Peak age. The surrounding district, at least ten square miles in extent, is beryllium-rich. Four areas of beryl deposits in this district are described in Table 3. The writer is indebted to C. C. Hawley of the U.S. Geological Survey for most of this information.

TABLE 3

General Description of Beryl Deposits, Lake George Area, Park County, Colorado

Area	Type of Wallrock	Type of Orebody	Mineral Associations
Boomer	Fine-grained Pikes Peak granite: small outlying stock. Blue Jay, and J. and S. mines are in metamorphics	Vein-like in greisen. 150 ft strike length, 1 to 8 ft width strike N 10–20°W dip NE. Small greisen bodies	Beryl, bertrandite, euclase, muscovite, quartz, fluorite, topaz. Small amounts of pyrite, sphalerite, molybdenite, wolframite, galena, etc.
Redskin Gulch	Fine-grained Pikes Peak granite	Ore shoots within greisen pipes, 8–10 ft wide, 200 ft long	Beryl, bertrandite, fluorite, topaz, quartz, muscovite
Mary Lee	Fine-grained Pikes Peak granite, main body on contact with metamorphics	Vein-like bodies and one small pipe, ore shoots 1 ft wide, 20 ft and over long	Beryl, bertrandite, fluorite, topaz, quartz, muscovite
China Wall	On contact of fine-grained Pikes Peak granite and metamorphics	Pods and irregular masses	Beryl, others unknown

The ore shoots occur in pipes and irregular masses of greisen within the main granite, in outlying stocks of the granite, and along the contacts of the granite with older metamorphosed rocks. No commercial deposit has been found in the metamorphics further than 100 feet from a granite contact. There are four different facies of the Pikes Peak batholith in the district (Hawley, oral communication):

(1) typical coarse-grained granite
(2) granular, medium-grained granite
(3) fine- to medium-grained, seriate, porphyritic granite
(4) fine-grained granite.

The beryllium deposits occur only in the last-named. The country rocks and greisens are cut by fluorite veins. These veins are not an immediate guide to ore because they are usually barren of beryllium. The principal prospecting guides in the area are the fine-grained Pikes Peak granite, the greisenized zones, and in metamorphic rocks, proximity to the granite contact.

Phenacite-bearing veins, Mount Wheeler, Nevada (after Silman, 1961)

Quartz veins containing purple fluorite, scheelite, phenacite, bertrandite, and minor amounts of beryl are found in the lower part of a bed of Cambrian limestone in the vicinity of Mount Wheeler in eastern Nevada. The rock in the upper part of the bed is grey to black, fine grained and argillaceous, but in the lower part the limestone has been re-crystallized and silicified, and is grey to white and medium to coarse grained. The beryllium-bearing veins range from ⅛ inch to 12 inches in width and occur singly or in vein zones, one of which is at least 750 feet long. The vein material contains up to 3.5 per cent BeO and the limestone host rock adjacent to the veins has been replaced to some extent by beryllium minerals. A granitic stock is exposed about 3 miles to the north.

Disseminated Replacement Deposits

Each of several important non-pegmatitic beryllium deposits has some features in common with the greisens, veins, and skarns previously described, but differs from them and from each other in several significant ways. In all, the beryllium minerals are fine grained and are disseminated through country rock. The deposits are all spatially related to granitic or syenitic rocks, and may be considered as replacements, probably of metasomatic origin. As in the typical pneumatolytic-hydrothermal deposits, the chemical composition of the host rocks was undoubtedly a major factor in their development. The four deposits included in this group are:

(1) Seal Lake, Labrador
(2) Spor Mountain, Utah
(3) Aguachile, Mexico
(4) Lost River area, Alaska

Seal Lake, Labrador

The Seal Lake deposit (locality 65) is related to a syenitic intrusion. The adjacent rocks are enriched in sodium ('fenitized') and consist largely of albite and sodium-rich pyroxenes and amphiboles. The chief beryllium minerals are barylite and eudidymite, both aluminum-free meta-silicates appropriate to an 'agpaitic' alkali environment. The deposit is unique, and of special importance as the only known beryllium deposit of significant size that is connected with alkaline rocks. It is described more fully in Chapter IV.

Spor Mountain, Juab county, Utah

Reference: Staatz, M. H., 1963; Siems, P. L., 1963.

Bertrandite is disseminated in rhyolite tuff of Miocene age that outcrops around the base of Spor and Topaz Mountains in the Thomas Range. The tuff bed is part of a sequence of rhyolitic volcanic rocks that overlie Palaeozoic volcanic rocks. The bertrandite is extremely fine grained and is most abundant in nodules several inches in diameter composed mainly of cryptocrystalline silica, fluorite, minor clay minerals, and manganese oxides. Most of the clay is montmorillonite and some contains essential beryllium. Dolomite pebbles and cobbles are found in a zone beneath the beryllium-enriched one, and probably acted as a precipitating agent for beryllium that was derived from rhyolitic minor intrusions and transported in solution through fractures. The porosity and permeability of the tuff probably contributed to its mineralization.

The largest orebody ("Roadside") is a zone about 5,000 by about 700 feet and 10 to 15 feet thick. About three million tons in this orebody are known to contain from 0.4 to 1.0 per cent BeO. The beryllium content is largely soluble in acids, probably because of the extremely fine grain-size of the minerals.

Fluorite-rich pipes have been mined at Spor Mountain and a uranium-bearing deposit is about a mile east. Topaz and beryl occur in rhyolite on nearby Topaz Mountain (Warner, *et al.*, 1959, p. 144).

Aguachile Mountain, Mexico

Reference: Van Alstine, R. E., 1962.

> The Aguachile deposit of Coahuila, Mexico is a bertrandite-bearing fluorite deposit of major size. It consists of several disconnected fluorite bodies that formed by replacement of brecciated, fractured and altered Cretaceous limestone along the contact of a ring-dyke of rhyolite porphyry. The fluorite is fine grained to earthy in most places and the ore is generally reddish grey due to the presence of minor amounts of finely-divided hematite. The bertrandite is extremely fine grained, grey to flesh-coloured to white, and resembles kaolinite in appearance, however it is hard and will scratch a pocket knife. Where it is sufficiently abundant to be seen with the naked eye, it occurs as a matrix for fluorite grains, as veinlets, and as the linings or fillings of tiny vugs. Calcite and quartz as chert are the most abundant gangue minerals. Aguachile Mountain, the site of the deposit, is a dish-shaped basin surrounded by a high rim and is a text-book example of the result of intrusive igneous doming of sedimentary rocks followed by cauldron subsidence and ring-dyke formation. The intrusive mass of quartz microsyenite that was responsible for the structure outcrops in the central part of the basin.[1]

"The bertrandite is a primary mineral, and the ore averages 0.3 per cent Be." (Siems, 1963).

Lost River area, Seward Peninsula, Alaska

Chrysoberyl is the chief beryllium mineral in the deposits of the Lost River area and areas nearby. The deposits consist of replacement

> ". . . veins, pipes, and stringer lodes in limestone in a zone about 7 miles long and 2 to 3 miles wide which is faulted and intruded by dikes and stocks" (of Cretaceous granite and rhyolite porphyry).
>
> The ores are remarkably alike and typically consist of the following minerals, in percent: fluorite, 45-65; diaspore, 5-10; tourmaline, 0-10; chrysoberyl, 3-10; white mica, 0-5; small amounts of hematite, sulfide minerals, manganese oxide, other beryllium minerals; and traces of minerals not yet identified. The ores generally are cut by late veinlets which are of the same mineralogy as the groundmass ore, or which consist of fluorite, white mica, and euclase. The ores are fine grained, and many of the individual mineral grains, except fluorite, are less than 1 mm in size. The beryllium content of bulk samples of ore ranges from 0.11 to 0.54 percent (0.31 to 1.50 percent BeO). High-grade nodules, composed principally of chrysoberyl, diaspore, fluorite, and mica, contain as much as 6 percent BeO.
>
> Geochemical reconnaissance has disclosed other areas of anomalous beryllium in stream sediments elsewhere on the Seward Peninsula, generally around biotite granites that have them associated with tin deposits; additional exploration probably will disclose other deposits.[2]

Tin ore at the Lost River mine locally contains as much as 0.5 per cent BeO.

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[1] Rowe, 196—.

[2] Sainsbury, 1963, p. 1.

Chapter IV

BERYLLIUM OCCURRENCES IN CANADA

In the following descriptions, the occurrences are identified by numbers in parentheses corresponding to the locality numbers on Map 1218A and in Table I.

Cordilleran Region

Beryllium occurrences are fairly numerous in a belt along the northeastern margin of the Western Cordilleran region marking the eastern limit of major granitic intrusions. This belt is underlain mainly by Proterozoic and early Palaeozoic rocks, unlike the areas farther west, and includes several old regionally metamorphosed complexes. However, the large batholiths of the region cut Mesozoic rocks and have, in general, Mesozoic ages as indicated by potassium-argon ratios (Lowdon, 1961; Lowdon, *et al.,* 1963). A beryl-bearing pegmatite near Kimberley (locality 16, Map 1218A) is an exception, for it, and some nearby intrusions and metamorphic rocks, have yielded potassium-argon ratios indicating a Precambrian age (Lowdon, 1961; Lowdon, *et al.,* 1963; Leech, 1962.).

(1) Logjam Creek, Jennings River Area, British Columbia 104 O/13 (lat. 59°59½′, long. 131°36′)

This locality is immediately south of the Wolf Lake area, Yukon territory, and was reported by W. H. Poole (personal communication). Beryl is present as small, poorly formed, rather opaque, bluish green crystals and shapeless masses. One specimen of granite contains a stringer about 2 inches long by nearly an inch wide composed mostly of beryl; some beryl is also visible in specimens of quartz.

In the general locality, a number of granitic dykes, 3 to 30 feet wide, and quartz veins were found cutting argillaceous quartzites near their contact with a granitic plug. The dykes are altered and laced with quartz veins, but are not obviously greisenized. Granite dykes both north and south of the plug contain accessory fluorite, and composite samples were reported (GSC spectrographic laboratory) to have “Be less than 0.01 per cent”. Some quartz veins both north and south of the plug contain visible beryl in fine crystals, and samples were reported to have “1–10 per cent Be”. They also contain as much as 1–10 per cent bismuth and tungsten and 0.1–1 per cent molybdenum. A quartz vein in the granite plug contains a metallic mineral that was identified as cosalite (a Pb Bi sulphide). A little wolframite was seen. No tin was reported from spectrographic analyses, but an appreciable content was found by X-ray fluorescence.

A thin section of a mineralized quartz vein showed fine green tourmaline in a narrow veinlet. A thin section of granite showed abundant quartz, perthitic untwinned potassic feldspar, albite, brown biotite, colourless muscovite, and minor fluorite. No beryl was found, but a few tiny biaxial grains with moderately high relief and birefringence, which might possibly be chrysoberyl, were associated with black opaque minerals. Some optically continuous plagioclase contains patches of altered potassic feldspar, but otherwise there is no suggestion of albitization. The granite plug appears quite ordinary; no pegmatitic phases, vugs, tourmaline, or evidence of greisenization were seen.

(2) Wolf Lake area, Yukon Territory 105 B (lat. 60°22½′, long. 131°20′)

Reference: Wolf Lake, Yukon Territory; *Geol. Surv. Can.*, Map 22-1957.

Beryl was noted as scattered small pale-green crystals in a pegmatite segregation in granitic rocks of the Cassiar batholith about 3 miles south of Ice Lakes. The pegmatite contains pink feldspar and feldspar-quartz intergrowths as much as 2 inches across, and is separated from somewhat graphic-textured granite by a zone of aplite, less than half an inch thick, with an outer, thread-like stringer of red garnet. Beryllium in faint traces was also reported in spectrographic analyses of three specimens from two localities about 18 miles farther south. One specimen was from a tourmaline-fluorite-cassiterite quartz vein. Tungsten and tin mineralization occur elsewhere in the map-area.

At the Yukon Tungsten mine (lat. 60°08′, long. 130°26′), a composite sample of vein quartz and muscovite-rich greisen was reported to contain less than 0.01 per cent beryllium. The veins contain abundant wolframite and fluorite and a little cassiterite and sulphides of bismuth, lead, and copper.

A sample of tourmaline-bearing pegmatitic schlieren in the Seagull Creek batholith near a topaz occurrence at lat. 60°04′, long. 131°08′, was reported to contain 0.035 per cent Be (GSC spectrographic laboratory). No beryllium was found (low limit 5 ppm) in the normal granite, nor in a composite sample of the Cassiar batholith taken along the Alaska Highway.

(3) Needlepoint Mountain, McDame Area, British Columbia (Low Grade Claims) 104 P/4 (lat. 59°08′, long. 129°46′)

References: Holland, S. S.; 1956, p. 11.
McDame, B. C.; *Geol. Surv. Can.*, PS Map 54-10.
Thompson, R. M.; *Can. Mineralogist*, vol. 6, pt. 1, 1957.

Helvite-danalite is present in a magnetite-rich skarn in impure limestone near its contact with granitic rock of the Cassiar batholith. The property lies at about 4,800 feet elevation, at the head of the east fork of the third mapped creek tributary to Cottonwood River east of Bass Creek. It is 2 miles northeast-by-east of the Cottonwood River bridge on the road to Dease Lake. The discovery was made by Gerald Davis and the claims were located in 1954 by J. J. McDougall of St. Eugene Mining Corp. Ltd. No work had been done except for sampling purposes, and no claim markers were found by the writer in 1958.

A lenticular body of black skarn about 300 feet long and 35 feet in maximum width lies within a thin lens of impure crystalline limestone. It extends southeastward from the contact of the latter with granite in a creek gully, becoming narrower and passing beneath overburden. A small granite tongue lies above the skarn and parallel with it. A limestone lens is overlain chiefly by argillite and underlain chiefly by blue-grey quartzites containing numerous quartz veins, all apparently dipping steeply to the northeast. Some patches of red and yellow gossan occur among the argillites, which are much contorted and faulted. There is, however, no evidence of a major fault along the creek bottom, which marks the contact.

The skarn is mostly black but in part banded. The massive black material is heavy and strongly magnetic, and is apparently composed largely of magnetite, with minor amounts of chlorite, garnet, and, locally, small irregular areas of fluorite and quartz. The beryllium mineral, classed as danalite by Thompson, is a sulphide-silicate of the helvite group containing about 14 per cent BeO. It is red to reddish brown and similar to garnet in appearance; it occurs as individual grains generally less than a mm and clusters or stringers occasionally 20 mm long.

According to Holland, "clusters of grains are as much as ½ inch across,. . . it is accompanied by a few small grains of native bismuth, . . . it appears to be localized in a massive magnetite-rich core in the centre of the widest part of the skarn lens at its northwest end . . . a visual examination of the skarn indicates that the beryllium content is low, considerably less than 1 per cent".

Composite samples of material collected by the writer, but not including pieces containing visible helvite, were reported from spectrographic analyses to contain .02 and .015 per cent Be. A specimen of the carbonate-rich phase contained 0.004 per cent. Samples of slightly mineralized hornfels from three localities above the skarn showed Be in a concentration of less than 0.01 per cent. Three others showed none. A sample of the granite in the vicinity showed no Be.

(3a) Ash Mountain, Jennings River Area, British Columbia 104 O/8 (lat. 59°18′, long. 130°31′)

Reference: Watson, K. de P., and Mathews, W. H. (1944), pp. 41-43.

Vesuvianite from a skarn in the pass a mile north of Ash Mountain contains as much as 0.012 per cent beryllium (GSC spectrographic laboratory). The skarn consists essentially of garnet, pyroxene, vesuvianite, and calcite. It is one of several skarns mentioned by Watson and Mathews at the contacts between limestone lenses in micaceous quartzites and a body of granite that forms part of the Cassiar batholith. It also contains a little scheelite and tin.

(4) Horseranch Range (Cassiar Beryl), British Columbia 104 P (lat. 59°21′, long. 128°52′)

References: Holland, S. S.; 1956, p. 9.
McDame, B. C.; *Geol. Surv. Can.*, PS Map 54-10.

Beryl occurs in pegmatites cutting sedimentary and foliated metamorphic rocks of the Horseranch range. The property was not visited by the writer, and the following description is mainly from the report by Holland.

The property consists of twenty-six claims located in 1955 by Einar Hagen of Watson Lake, and others. The claims lie between 5,000 and 6,000 feet elevation on the west side of the crest of the range, about 3½ miles northwest of the highest peaks (el. 7,300 feet). They are at the heads of three west-flowing creeks, locally known as Moosehorn, Camp, and Mica Creeks. Beryl is found in pegmatites in bluffs at the heads of the creeks, and in the talus below them.

Pegmatites ranging from a few inches to tens of feet in thickness intrude quartzites and mica schists in a zone 2,500 feet wide and at least 3 miles long. Most strike west to northwest parallel with the foliation of the rocks. The pegmatites are composed of feldspar, quartz, muscovite, subordinate black tourmaline, garnet, and minor beryl. Some of the narrower dykes are zoned. In one 12-inch dyke, beryl occurs with quartz and coarse feldspar in a core, which is surrounded by zones rich in tourmaline, garnet, and muscovite. However, most of the pegmatites are not zoned and beryl does not appear to occupy any preferred position within them. The beryl crystals seen are a fraction of an inch across and rarely more than an inch long, and are uniformly pale watery green. Most were seen in talus slides on the south side of the head of Camp Creek. The pegmatites were estimated to contain less than 1 per cent (maximum) BeO and to average less than 0.1 per cent.

(5) Dortatelle Creek, McConnell Creek Area, British Columbia 94 D/8 (lat. 56°25′, long. 126°07′)

Reference: Lord, C.S.; McConnell Creek map-area, Cassiar district, B.C., *Geol. Surv. Can.* Mem. 251, 1948.

Beryl was identified in a block of pegmatite in a moraine near the source of Dortatelle Creek. Pink pegmatite dykes are abundant in that vicinity, cutting old schistose and gneissic rocks of the Asitka Group, which is classed as "Lower Permian and (?) Earlier". The locality is near the northwest tip of a large granitic mass referred to as the Omineca batholith. Beryl crystals as much as three-quarters inch in diameter, were observed in a block of pegmatite from a dyke that was at least 3 feet wide, composed of pink feldspar and quartz with a little garnet and pyrite. Molybdenite occurs at two localities 0.8 mile to 2 miles south, and a little chromite was found in the ultramafic plug nearby.

(6) Fort Grahame, British Columbia 94 C/10
(lat. 56°30′, long. 124°30′ (approx.))

Reference: Dolmage, V.; Findlay River District, B.C., *Geol. Surv. Can.*, Sum. Rept. 1927, pt. A.

A well-developed crystal of pale bluish green beryl was seen in a pegmatite dyke in the Butler Range, west of Findlay River. Pegmatites are abundant in this region, particularly in an area 6 by 10 miles, 5 to 10 miles south of Fort Grahame, in which a number of mica deposits have been developed. The dykes are mostly lenticular and parallel with the foliation of the enclosing old Palaeozoic and (?) Proterozoic schists and quartzites. No large granitic bodies are exposed nearby.

The pegmatites are 20 to 200 feet thick and 50 to 1,500 feet long. They are uniformly white and are composed chiefly of pink potash feldspar, smoky quartz, muscovite, and subordinate biotite, and minor tourmaline, garnet, and pyrite. Some dykes contain large crystals of high-grade muscovite. Considerable development work has been done on some of them, and small shipments of mica were made prior to 1928.

(7) Tête Jaune Area (Bonanza Mine), British Columbia 83 D
(lat. 52°53′, long. 119°31′)

References: de Schmid, H. S.; White mica occurrences in the Tête Jaune Cache and Big Bend districts of British Columbia; *Canada Mines Br.*, Sum. Rept. 1913, p. 42.

Galloway, J. B.; Northeastern district (No. 2), *B.C. Dept. Mines*, Ann. Rept. 1920, p. 95N.

Lay, Douglas; Northeastern mineral survey district (No. 2), *B.C. Dept. Mines*, Ann. Rept. 1928, p. C188.

McEvoy, J.; *Geol. Surv. Can.*, Ann. Rept. 1898, vol. 11, pt. D, p. 39.

According to McEvoy and de Schmid, beryl was identified at the Bonanza mica mine, on Mica Mountain about 7 miles south of Tête Jaune Cache, and possibly in some of the other numerous pegmatite dykes in the general locality. The property is 5,300 feet above Fraser River. The dyke is about 15 feet wide where opened up and dips as much as 40 degrees with the schists in a direction S45°W. Quartz, feldspar, and muscovite are separated into large masses. Mica of "excellent quality" occurs in crystals as large as 18 by 11 inches, mostly near the hanging-wall; some was separated and shipped about 1898 (McEvoy). According to information received by Johnston (1915), topaz was also found.

McEvoy's map (GSC No. 676) shows the 'Mica mine' at the foot of the northeast-facing cirque of Mica Mountain. Lay (1928) in a description of the Tête Jaune claims stated that the old Bonanza mine was reported covered by a slide. In 1958 the old mica occurrences were relocated in the name of Georgian C. Short, of Calgary.

From a point about 500 feet below the steep bluffs southwest of the property described by Lay (1928), a good foot-trail was found leading along the cliffs into the cirque. No sign of any former buildings or workings was found, nor any pegmatite except under the cliffs at the precipitous head of the cirque. There a few large blocks of pegmatite were found in the talus and small stringers in the cliffs above snow-covered talus. An old pick was also found in the talus. This was on July 27, 1960, a year of heavy late snow. It seems probable that this is the old Bonanza property and that it has been, as stated by Lay, covered by a slide. The pegmatite found there consists of white feldspar in crystals as much as 4 inches across, streaks of quartz, muscovite crystals as large as 2 inches across, and a few garnets. No beryl was found but a composite sample of the pegmatite was reported (GSC spectrographic laboratory) to contain "Be, less than 0.01 per cent". None was detected in a composite sample of muscovite. It is therefore probable that some beryl occurs in the pegmatite there.

At the old workings described by Lay (1928), on the southeast side of the northeast ridge of Mica Mountain, a pegmatite sill that is about 20 feet thick where exposed, has been extensively worked. It is lenticular and dips and plunges with the enclosing micaceous quartzite and schist. The pegmatite is coarse and streaky, but not zoned or well segregated except for a 2-foot quartz band along part of the hanging-wall contact. A considerable amount of muscovite, in books as much as 5 inches across, had been sorted into piles. No beryl or unusual accessory minerals were found, but a composite sample was reported (GSC spectrographic laboratory) to contain "less than 0.01 per cent Be".

In the north-facing cirque of Mica Mountain (the DeWitt and Winter claims (?) mentioned by Spence), numerous large boulders of coarse undifferentiated pegmatite contain pseudohexagonal muscovite crystals up to a foot or more across. Some of these have well-formed quartz crystals, with C-axis perpendicular to the plane of the books, at their centres. The feldspar is in white commonly micropegmatitic crystals as much as a foot long. Quartz is plentiful. No beryl or other accessory minerals were found but a composite sample was reported (GSC spectrographic laboratory) to contain "less than 0.01 per cent Be, and 0.01–0.1 per cent Pb". The boulders of the north cirque have evidently come from the cliffs in the ridge above. Several pegmatite bodies and quartz veins outcrop on the ridge and elsewhere in the district, but of those sampled only one, on top of a ridge on the north side of Canoe River, was found to contain detectable amounts of beryllium.

The area is underlain by mica-rich schist and quartzites. Kyanite is locally abundant in them, and was also reported (Galloway, 1920) to be present in the pegmatites of Mica Mountain but was seen by the writer only in selvedges of some dykes. Similar schists are reported to extend southeastward to the Big Bend area of the Columbia River and southward through the Blue River country and to contain numerous kyanite occurrences.

(8) Adams Lake area, British Columbia 82 M/11
(lat. 51°36', long. 119°02')

Beryllian vesuvianite is present in two localities about 1½ miles north of Bischoff Lakes. The beryllian vesuvianite, which contains about 0.02 to 0.05

per cent beryllium, occurs as coarse crystalline masses with garnet and epidote in skarn at the contact between crystalline limestone of the Shuswap Complex and pegmatitic muscovite granite.

(9) Fly Hill, near Salmon Arm, British Columbia 82 L
(Between lat. 50 and 51°, long. 119 and 120°)

Reference: Vokes, F.M.; 1958.

In Vokes' project notes, the only reference to this reported beryl occurrence is to "John Thornton, deceased". The locality is described in Vokes' notes as "start of China Creek valley, a mile or so west of Salmon Arm". No beryllium was detected in a sample of pegmatitic granite collected by the writer from the base of Fly Hill west of Salmon Arm.

(10) Yellow Creek, Columbia Big Bend, British Columbia 83 D
(lat. 52°00′, long. 118°22′ (approx.)) 82 M

References: B.C. Ann. Rept., p. 258, 1952.
Spence, H. S.; *Canada Mines Br.*, Rept. 285, pp. 42–49, 1914.
Watson, K de P.; *Am. Mineralogist*, vol. 32, p. 94, 1947.

Watson reported seeing beryl in pegmatites at the head of Yellow Creek during field work in 1944, and finding spectrographic traces of beryllium in muscovite and biotite of the pegmatites and in kyanite and garnet of the wall-rock schist. No account of the 1944 field work in the area has been found by the writer. The locality is one of a number of commercial mica occurrences in the area described by Spence. It is described in the British Columbia Annual Reports as a kyanite occurrence. Kyanite is present in numerous localities in the district, mainly in the schists and gneisses that form the typical country rocks but also in pegmatites.

(11) Mount Begbie, near Revelstoke, British Columbia 82 L/16
(lat. 50°53½′, long. 118°15′)

Reference: Jones, A. G.; Vernon map-area, B.C., *Geol. Surv. Can.*, Mem. 296, pp. 33, 162 (1959).

Beryl occurs in a pegmatite dyke at the lower edge of the great snowfield on the northeast side of Mount Begbie, about 8 miles south of Revelstoke. It is associated with black and a little green and red tourmaline, garnet, and lepidolite, in a dyke that is nowhere more than 5 feet wide. The pegmatites in the vicinity are considered to be of late (Mesozoic) age, cutting old metasedimentary rocks of the Monashee Group.

The writer examined a large number of pegmatite dykes in that vicinity. Most contain abundant black tourmaline, some in crystals a foot long, with a little garnet and not much muscovite. The dykes are mostly lenticular sill-like sheets among the rather gently dipping micaceous quartzites, but some cut sharply across the bedding along what appear to be fault-fractures. One or two bodies are distinctly zoned, with continuous quartz cores. A little lepidolite was found in one dyke, but no beryl or coloured tourmaline was seen. The beryl-bearing dyke reported by Jones may have been covered by snow, as was most of the ground, for half a mile or more below the glaciers on July 31, 1959, when the writer was there.

Composite samples of the dykes were reported (GSC spectrographic laboratory) to contain "less than 0.01 per cent Be", as was also a sample from a tourmaline-bearing pegmatite at the base of Mount Begbie.

(12) Woolsey Creek, near Albert Canyon, British Columbia 82N (lat. 51°07′, long. 117°54′)

Reference: Gunning, H. C.; *Geol. Surv. Can.*, Sum. Rept. 1928, pt. A, p. 156, 1929.

Gunning found beryl in some of the pegmatites exposed on the Snowflake Trail a short distance from the railway. The trail follows a creek (shown as Silver Creek on old maps, Woolsey Creek on recent ones) about 2 miles west of Albert Canyon. It has apparently been obliterated by a logging road. The writer found a few small exposures of pegmatite and pieces of float but no beryl and little or no tourmaline. The area is one of sedimentary gneiss and schist, quartzite and granite-gneiss, cut by granite and pegmatite. It is of metallogenic interest that stannite occurs at the Snowflake mine, about 5 miles north of the railroad.

(13) Duncan River, British Columbia (Erdahl and Pinchbeck Claims) 82 K 10–11 (lat. 50°34′, long. 117°00′)

Reference: Lynott, W. J.; *B.C. Dept. Mines,* Ann. Rept. 1945, p. 107A.

Beryllium was detected by spectrographic methods in vein material, consisting of quartz, tourmaline, mica, amphibole, and carbonate, with scattered grains of scheelite and local concentrations of sulphides. Tin was also detected, but both it and beryllium are in the range 0.04 per cent or less and their mineral forms are not recognized.

(14) Midge Creek, Kootenay Lake, British Columbia 82 F 7 (lat. 49°22′, long. 116°49′)

Reference: Rice, H. M. A.; Nelson map-area, East Half, B.C.; *Geol. Surv. Can.*, Mem. 228, p. 35, 1941.

Beryl was found in large blue-green crystals, with garnet, magnetite, and black tourmaline in pegmatite dykes, which are reported by Rice to be abundant in that vicinity. The particular beryl locality is just south of Midge Creek about a mile from Kootenay Lake (Rice, personal communication).

(15) White Creek, East Kootenay District, British Columbia 82 F 16 (lat. 49°56′, long. 116°18′)

References: Rice, H. M. A.; 1941; Reesor, J. E.; 1958.

Rice reported that blue-green beryl occurs locally with black tourmaline in pegmatites along the borders of the White Creek batholith. A particular beryl locality is said to be west of peak 9,010 on the ridge between the sources of White and Skookumchuk Creeks.

Skookumchuk Creek
(lat. 49°58′, long. 116°12′)

Reference: Reesor, J. E.; 1958.

Beryl occurs in pegmatite dykes cutting Aldridge quartzite and dioritic intrusions west of Burnt Creek, a tributary of Skookumchuk Creek. North of the first west fork of Burnt Creek, pegmatite is very abundant in large dykes and loose blocks. The writer found a few very pale, glassy beryl crystals in three localities. The largest was about 2 inches in cross-section with several inches of its length exposed, but most were much smaller. Black tourmaline is abundant, and muscovite and garnet are fairly plentiful, but beryl appears to be rare. Two or three beryl crystals were also seen in pegmatite north of Burnt Creek, about 2 miles farther upstream.

A sample of garnet-epidote-scheelite skarn from lower Burnt Creek was reported (GSC spectrographic laboratory) to contain 0.0016 per cent Be, and a heavy mineral fraction 0.0010 per cent.

(16) Hellroaring Creek, East Kootenay, British Columbia 82 F 9
(lat. 49°34′, long. 116°11′)

References: Leech, G. B.; St. Mary Lake, Kootenay district, B.C.; *Geol. Surv. Can.*, Map 15-1957.
Rice, H. M. A.; Nelson map-area, East Half, B.C.; *Geol. Surv. Can.*, Mem. 228, 1941.

Beryl was found in several places in a pegmatite body exposed along the road to the Boy Scout property, which is about 3 miles south of St. Mary Lake. The pegmatite is part of a large mass that extends across the ridge from Hellroaring Creek to Angus Creek. Beryl is found also on Angus Creek. The ground, staked as the Linda claims, is held by Harold Bennett of Cranbrook, B.C.

The pegmatite exposed along the road is white and is partly segregated into masses of feldspar and quartz. Muscovite is fairly plentiful in places and bluish black tourmaline is locally common. Small blocks and stringers of galena and some pyrite were seen, and also a black stain, possibly a manganese mineral. A pocket of galena several feet in diameter is reported to be the locality where beryl was first noticed. Some cross-cuts from the Boy Scout property are said to enter the pegmatite. The beryl seen by the writer is very pale, nearly white, but boundary surfaces are commonly stained green or red. Some smaller crystals are well formed, but larger ones are irregular. The largest mass found was about 3 inches across. Most of the beryl seen was intimately associated with muscovite near the boundaries of quartz segregations. Columbite-tantalite occurs in crystals more than an inch across and minor amounts of tin were reported (GSC spectrographic laboratory) in composite samples of pegmatite.

The age of this pegmatite body, according to potassium-argon ratio determinations (Lowdon, 1961; Lowdon, *et al.*, 1963), is about 700 million years, i.e., Precambrian. This is in contrast with other similar intrusions in the region such as the White Creek batholith, whose indicated age is Mesozoic. The Hellroaring Creek body cuts the Proterozoic Aldridge Formation, but is not in contact with Cambrian or younger rocks.

Precambrian Shield

Slave Province

Beryllium occurs in widely-separated parts of the Slave structural province, which extends from Great Slave Lake nearly to Bathurst Inlet, and is underlain by rocks, chiefly sedimentary, of the Yellowknife Group, intruded by granitic rocks dated at about 2,500 million years (Stockwell, 1963).

(17) Ranji Lake area, Northwest Territories 86 B 3
(lat. 64°05′, long. 115°05′ (approx.))

Reference: Wright, G. M.; *Geol. Surv. Can.*, Map 1022A, 1954.

Beryl was observed in a sample of one of a number of pegmatitic granite bodies that outcrop in the area and also in the Ghost Lake area to the south. These areas are in the westernmost belt of Yellowknife Group metasedimentary rocks. The pegmatitic bodies locally contain abundant tourmaline (Wright, G. M., personal communication).

(18) Yellowknife–Beaulieu District, Northwest Territories 85 I–J
(lat. 62° to 63°, long. 112° to 114°30′)

References: Fortier, Y. O.; 1946.
Fortier, Y. O.; Preliminary map, Ross Lake, Northwest Territories, *Geol. Surv. Can.*, Paper 47-16, 1947.
Henderson, J. F.; Beaulieu River, District of Mackenzie, *Geol. Surv. Can.*, Map 581A, 1941.
Hutchinson, R. W.; Regional zonation of pegmatites near Ross Lake, District of Mackenzie, Northwest Territories, *Geol. Surv. Can.*, Bull. 34, 1955.
Jolliffe, A. W.; Yellowknife Bay, District of Mackenzie, *Geol. Surv. Can.*, Map 709A, 1942.
Jolliffe, A. W.; 1944.
Jolliffe, A. W.; Prosperous Lake, District of Mackenzie, *Geol. Surv. Can.*, Map 868A, 1946.
Lord, C. S.; Mineral industry, District of Mackenzie, Northwest Territories, *Geol. Surv. Can.*, Mem. 261, 1951.
Mulligan, R.; Lithium in Canada, *Geol. Surv. Can.*, Econ. Geol. Rept. No. 21, 1965.
Rowe, R. B.; 1952.

Beryl occurs in pegmatite dykes in numerous localities within a belt extending northwest from Hearne Channel to Duncan and Gordon Lakes, and from Prosperous Lake to Redout Lake (Fig. 3). The bedded rocks, chiefly sediments of the Archaean Yellowknife Group, are closely folded and intruded by somewhat gneissic granite and masses of younger, pegmatitic muscovite granite. Cross-folding, on north to northwest-trending axes, of previously folded strata coincided with intrusion of the pegmatitic muscovite granite. Many of the pegmatite dykes strike northeasterly across the trend of fold axes.

Metamorphic aureoles surround the large granite bodies, and are particularly conspicuous around the late intrusions, where they are marked by development of cordierite-andalusite-staurolite nodules in the schists. Chiefly within these aureoles lie hundreds of pegmatite dykes, as much as thousands of feet long and more than 100 feet wide. Several hundreds of these dykes contain rare elements including lithium, beryllium, columbium-tantalum, and tin. A regional zoning is apparent in the relative distribution of these elements, as lithium-bearing dykes are generally farther from the younger granite masses than those dykes containing appreciable amounts of beryl or columbite-tantalite. Some dykes, especially near Hearne Channel, are distinctly zoned internally and carry substantial amounts of lithium minerals in inner zones, with beryl and columbite-tantalite in outer intermediate or wall zones.

(*a*) *Bighill Lake Area*

(*lat. 62°30′, long. 114°½′*)

A number of beryl crystals associated with cleavelandite, quartz, and abundant muscovite were seen by the writer in a short spodumene-poor section of dyke just east of Bighill Lake.

(*b*) *Prosperous Lake Area*

Reference: Jolliffe, A. W.; Prosperous Lake, District of Mackenzie, *Geol. Surv. Can.*, Map 868A, 1946.

Six beryl occurrences are shown on GSC Map 868A around the south end of the large granite mass east of Prosperous Lake. They appear to mark the inner zone of a regional-zoning sequence (Fig. 3).

(*c*) *Prelude Lake Area*

(*lat. 62°39′, long. 113°58′ (approx.)*)

Within an area of 10 square miles, about 2 to 4 miles north of Prelude Lake, Jolliffe reported fifty-six beryl-bearing pegmatites in a total of one hundred examined. The area includes the former Dyke Group of claims. Two of the pegmatites were subsequently described by Rowe (1952).

The most northerly of three deposits that were given special mention (Jolliffe's Dyke No. 1, Fig. 7; also called Rowe's "Riber Pegmatite") was estimated by grain measurement to contain 2 per cent beryl in one area 50 by 5 feet (Jolliffe, 1944, p. 23). Rowe (1952, p. 32) determined the percentage as 0.42 in four beryl-bearing sections totalling 101,896 square inches. Jolliffe's Dyke No. 2 measured 0.5 per cent in an area 110 by 5 feet. On what appears to be the same dyke (Lily Pegmatite), Rowe determined the percentage of beryl to be 0.44 in 58,890 square inches. Dyke No. 3 (Jolliffe, 1944) was found to contain 0.3 per cent beryl in an area 200 by 10 feet. Much of the beryl is in crystals greater than 6 inches in maximum dimension. Rowe (1952) reported the dykes to be distinctly zoned. Tourmaline and some tantalite-columbite are present. Lithium minerals are apparently negligible.

(*d*) *Blaisdell Lake Area*

(*lat. 62°48′, long. 113°34′ (approx.)*)

According to Jolliffe, beryl was found in thirty-two of nearly fifty dykes examined in this area. The dykes are as much as 2,000 feet long and 10 feet wide. One dyke, three-quarters mile north of Blaisdell Lake, contains an estimated 4 per cent beryl in two sections, each about 30 feet long and 7 feet wide, and 1.5 per cent in an area 240 by 7 feet including these. Rowe estimated two beryl-rich sections to contain 0.44 per cent in 27,648 square inches and 1.34 per cent in 21,888 square inches. Most of the pegmatites carry tourmaline. Some are zoned but carry no appreciable amounts of lithium minerals.

Columbia Explorations, Ltd. carried out trenching and sampling in 1961 on eight or nine dykes on the peninsula west of the central part of the lake. The dykes, which cut a granite plug and associated metasediments, are commonly 20 feet wide and as much as 1,300 feet in exposed length. Dyke 2 shows some quartz core-pods, but most of the dykes are unzoned and some consist largely of aplite. Beryl crystals as much as 12 inches across and 18 inches long and some 6 inches in diameter were seen in Dykes 1 and 2. Elsewhere only small crystals were seen, and no areas of more than a few square feet were estimated by the writer to contain more than 1 per cent beryl.

A little amblygonite was found in Dyke 1, but none of the dykes has a significant content of lithium minerals. Tourmaline is fairly common in some dykes. Other accessory minerals identified are columbite-tantalite, manganiferous allaudite, and red apatite. The spectrographic laboratory of the Geological Survey reported that a composite of chips from all the dykes contained 32 ppm Be. A random sample of the associated granite was found to contain 16 ppm.

(*e*) *North of Blaisdell Lake*
(*lat. 62°50′, long. 113°34′*)

Several beryllium-bearing pegmatite dykes immediately southwest of "Schist Lake" form part of the ground held by General Lithium Corporation. At the east end of No. 2 dyke a few beryl crystals were found by the writer (1965), associated with spodumene and triphylite-hühnerkobellite minerals. Small white beryl crystals are also fairly common near the north wall at the west end of No. 5 dyke. They are in a cleavelandite-quartz-muscovite assemblage beyond the apparent limits of spodumene distribution.

(*f*) *Sparrow Lake*
(*lat. 62°37′, long. 113°37′ (approx.)*)

According to W.R.A. Baragar (pers. comm.), beryl is fairly abundant in some small interior pegmatites near the east shore of the lake, but is rare in the large dykes east of the granite contact.

(*g*) *Hidden Lake*
(*lat. 62°33′, long. 113°31′*)

The writer found a little beryl in a pegmatite cutting metasedimentary rocks on the north shore of the easternmost part of the lake. None was found in pegmatites cutting the east fringe of the granite stock that makes up the large peninsular part of the east shore. Spectrographic analysis of a composite sample of the granite in that area did not reveal any beryllium (< 5 ppm).

(*h*) *Thompson Lake*
(*lat. 62°37′, long. 113°29′*)

A pegmatite dyke on the peninsula north of the narrowest part of the lake has an exposed length of about 400 feet, including two covered sections, and averages 30 to 40 feet wide. It strikes about N55°W and dips steeply. It is not well zoned but consists chiefly of coarse, blocky potash-feldspar crystals, cleavelandite, and quartz, partly in fair-sized segregations. Spodumene occurs in some abundance in ragged pods, erratically distributed. Beryl crystals as much as 3 inches across are also fairly abundant in cleavelandite and quartz segregations several square feet in area. Columbite-tantalite also occurs as crystals about an inch across in several patches, generally associated with beryl.

Another dyke near the water's edge just west of the south peninsula is about 800 feet long and 40 feet wide. It consists largely of anastomosing stringers, each about a foot wide, of quartz, feldspar, and muscovite. A few small beryl crystals were seen in three or four places, mostly on the borders of these stringers.

At the nearby Thompson–Lundmark mine, lenses of pegmatite cut gold-bearing tourmaline-quartz veins (Lord, 1951, p. 285).

(*i*) *Sproule Lake Area*
(*lat. 62°44′, long. 113°29′*)

A zone of narrow pegmatite dykes extends some 1,600 feet southeastward from Sproule Lake, on ground known formerly as the "Bore Group" and more recently (1955) as the Taco claim. Jolliffe listed beryl as a minor occurrence in ten of thirty-four dyke-sections, in white to light green crystals as much as 2 inches across. Several dykes are well zoned. Other minerals present include spodumene, amblygonite, lithiophilite, and noteworthy amounts of cassiterite and tantalite-columbite in a few chosen places. The writer found beryl in any abundance only in dyke section 7 (Jolliffe, 1944). Sections 6 and 7 cut and offset narrow quartz veins.

Scattered beryl crystals also occur in spodumene dykes at the southwest corner of the main part of the lake.

(*j*) *Ross Lake–Redout Lake Area*
(*lat. 62°45′, long. 113°7′ (approx.)*)

Several hundred pegmatite dykes cut gneissic granodiorite in the area between Ross and Redout Lakes. A regional zoning is apparent (Fig. 3) with beryl-bearing pegmatites in a median position between simple granite pegmatites on the east and spodumene-bearing dykes on the extreme west. Columbium and tantalum minerals occur in the better-zoned dykes of the western part of the beryl zone, which generally strike northeasterly across the foliation of the gneisses. A mill was built some years ago to extract columbite-tantalite from the pegmatites on ground held originally by Peg Tantalum Mines, Ltd., and subsequently by Tantalum Refining and Mining Corp. of America, Ltd. According to company records, 3,750 pounds of concentrate were recovered by July, 1947, when operations ceased.

Beryl occurs in numerous dykes in the area but not in important concentrations. According to Hutchinson (1955, p. 15), the best concentrations and largest crystals are in well-zoned pegmatites that contain a core of quartz-perthite composition. The beryl is most abundant at the outer margins of this zone close to its contact with the next zone (generally the perthite-plagioclase-quartz-muscovite wall zone) but may also be scattered through the quartz-perthite core. Most of the beryl seen by the writer was in such zoned dykes, and most of these were within half a mile or so of the Peg Tantalum mill. However, the large partly mined-out dyke south of the mill, which consists of perthite-quartz-muscovite in random segregations from wall to wall, contains more beryl than any other single locality seen.

(*k*) *Lit 1 and 2 Claims, Buckham Lake*
(*lat. 62°20′, long. 112°40′*)

The above claims, formerly known as Lita 5 and 6 or "Campbell Pegmatites" (Jolliffe, 1944), cover pegmatites in a zone extending about 2,400 feet along the north shore of Buckham Lake. A few crystals of beryl were found in a zoned body known as No. 2 pegmatite (Rowe, 1952), which also carries some spodumene and columbite-tantalite.

(*l*) *Lit 3 Claim (McDonald Pegmatite), near Buckham Lake*
(*lat. 62°18′, long. 112°46′*)

This claim, originally staked as Lita 1 to 4, and subsequently known as the Ramona Group, lies about 5 miles southwest of the north end of Buckham Lake. It covers a pegmatite body averaging 25 feet in width over an exposed length of nearly 400 feet (Jolliffe, 1944). The dyke is distinctly zoned. Beryl, amblygonite, lithiophilite, and tantalite-columbite occur in the upper part of a central zone that is rich in coarse spodumene. This upper part contains discrete masses of cleavelandite and quartz, with muscovite distributed along the upper contact.

(*m*) *Tan Group, Blatchford Lake Area*
(*lat. 62°12′, long. 112°22′*)

The Tan claims, formerly the Buddy and Tan claims (Jolliffe, 1944), cover four pegmatite bodies grouped around a small lake just west of "Johnson" Lake, about 1½ miles east of the southeast corner of Blatchford Lake. The dykes are zoned and carry spodumene, locally amblygonite, cassiterite, and tantalite-columbite. One composite dyke ("No. 3 Pegmatite" (Rowe, 1952)) contains fine beryl crystals distributed around the margin of a pod of quartz.

(*n*) *Best Bet Claims, Drever Lake*
(*lat. 62°14′, long. 112°18′*)

The Best Bet property lies just northwest of the north-central part of a lake about 3 miles long that is locally known as Drever Lake. A quarry 260 feet long, 20 to 26 feet wide, and as much as 27 feet deep, and a shallow pit 50 feet long along the hanging-wall at the north end in 1957 occupied most of the outcrop area of a dyke more than 330 feet long (Mulligan, 1965). Most of the material removed presumably was milled at the Moose property to recover its columbite-tantalite content. The dyke is well zoned. A series of quartz pods that make up a discontinuous core contain amblygonite and coarse spodumene. Creamy-white beryl is scattered through a surrounding cleavelandite-quartz-muscovite zone. It is rather abundant in one area on the east or foot-wall side of the dyke and also in the north pit. The writer found crystals of beryl as large as 6 inches in cross-section, but saw only a few small beryl-rich patches. Beryl, found stockpiled at the Moose property, may be partly or all from the Best Bet. Columbite-tantalite occurs chiefly in the same muscovite-rich assemblage as the beryl, but was found also at the borders of coarse spodumene crystals projecting from the quartz core.

(*o*) *Moose Group, Hearne Channel* (*lat. 62°11′, long. 112°13′*)

References: Jolliffe, A. W.; 1944.
Lord, C. S.; Mineral industry, District of Mackenzie, N.W.T., *Geol. Surv. Can.*, Mem. 261, 1951.
Mulligan, R; Lithium in Canada, *Geol. Surv. Can.*, Econ. Geol. Rept. No. 21, 1965.
Rowe, R. B.; 1952.

The main workings and millsite are on the Moose No. 2 dyke, the easternmost part of two pegmatite bodies, and are immediately north of Hearne Channel, Great Slave Lake. A shaft was sunk on the dyke in 1946 and a mill built to recover columbite-tantalite. Several large open-cuts were made later, apparently mostly between 1951 and 1955, when the mill was destroyed by fire. The dyke is about 1,400 feet long and as much as 200 feet wide, and is broken into several sections. It is distinctly though irregularly zoned, consisting of microcline, cleavelandite, quartz, and muscovite. Amblygonite occurs in quartz pods that represent discontinuous cores.

Beryl occurs as white irregular crystals and masses commonly 6 to 8 inches in diameter, chiefly in cleavelandite-quartz-muscovite intermediate zones, with or without coarse microcline, and commonly associated with coarse spodumene. Some beryl was seen at an open-cut 31 feet across, south of a central muskeg-covered area.

In the southern section of the dyke, a quarry 36 feet across exposes a quartz-amblygonite core 13 feet wide. Irregular white beryl crystals are numerous in a cleavelandite-quartz-mica zone bordering this core. In the northern section of the dyke, an open-cut 96 feet across at the face has been quarried to a depth of 30 or 40 feet below the old head-frame. Beryl is prominent with coarse spodumene in cleavelandite on the west side of a quartz-rich indefinite core area. A few beryl crystals were also seen in a small prospect pit, 100 feet north of the shaft. More than a ton of coarse white beryl crystals are stockpiled at the main workings. No record has been found of any shipments.

Lord (unpublished report, GSC 1950) found beryl to be concentrated in small shoots, with one of 400 square feet containing nearly 0.5 per cent beryl.

Moose No. 1 dyke, about 4,800 feet west of No. 2, has an exposed length of about 900 feet, and is as much as 34 feet thick. Amblygonite occurs in a lenticular quartz core and coarse spodumene in an inner intermediate zone. Scattered beryl crystals were seen in an outer cleavelandite-microcline-quartz-muscovite zone.

(*p*) *Echo Group, Tanco Lake*
(lat. 62°26′, long. 112°11′)

Several large spodumene-bearing dykes lie less than half a mile east of the east arm of "Tanco" Lake, southeast of Francois Lake. One short lenticular dyke near the lake is distinctly zoned. Numerous beryl crystals as large as 3 inches across were seen at the edge of a rude core zone containing very coarse spodumene with pink cleavelandite and quartz segregations, and were also seen among the spodumene crystals.

(*q*) *Turnback Lake*
(lat. 62°43′, long. 112°40′ (approx.))

Vesuvianite from Turnback Lake was reported (Meen, 1939) to contain 1.07 per cent BeO and 2.03 per cent fluorine.

A sample of "skarn rock" from a carbonate bed in Yellowknife Group sediments on the west shore of the northeast arm of Turnback Lake was reported (GSC spectrographic laboratory) to contain 51 ppm Be. A thin section of this rock was found by the writer to consist mainly of colourless vesuvianite with interbands of quartz, and pink garnet (?) scattered thickly in the vesuvianite. The vesuvianite was checked by X-ray diffraction. The garnet (?) was considered too fine to separate. This is one of the very few nonpegmatitic occurrences of beryllium known in the Canadian Shield.

(19, 20, 21) Lac de Gras–Aylmer Lake District, Northwest Territories

Beryl has been reported as a minor constituent of pegmatites in a number of localities about 200 miles northeast of Yellowknife. Specific occurrences mentioned are at:

(19) lat. 64°44′, long. 110°19′; northeast of Paul Lake, Lac de Gras map-area (GSC Map 977A).

(20) lat. 63°44′, long. 109°55′; Reid Lake, Walmsley Lake map-area (GSC Map 1013A).

(21) lat. 62°59′, long. 108°32′; Aylmer Lake, Walmsley Lake map-area (GSC Map 1013A).

Churchill Province

Only a few beryllium occurrences have been found in the Churchill structural province and these are close to its southern border. The typical rocks are gneisses and granites, in part consisting of Archaean rocks reworked during the Hudsonian orogeny. Their indicated age is about 1,700 million years (Stockwell, 1963).

(22) *Birch Portage Area, Saskatchewan 63 L/15*
(lat. 54°53′, long. 102°38′)

Reference: Cheeseman, R. L.; 1962.

Beryl-bearing pegmatites cut metasedimentary hornblende-biotite gneisses and granulites of the Kisseynew Group on the west side of Sturgeon Weir River. Thirty-six berylliferous dykes were found in an area of 1½ square miles. The area is west of the Birch Portage Indian Reserve, about 40 miles west of Flin Flon.

The dykes range from 2 inches to 10 feet in width, averaging between a foot and 2 feet, and dip gently southwest. They consist of feldspar and quartz with accessory biotite, garnet, titaniferous magnetite, and monazite. The rock is pink with light grey patches with which minute beryl crystals are associated. Grain size of the essential minerals is as much as 10 inches. The dykes are not generally well zoned but wider dykes have composite structures, with beryl crystals normally confined to the centres. Beryl occurs as pale green to white crystals, commonly euhedral, and as large as 10 by 4 inches, but averaging a quarter to half an inch. As many as 10 average-sized crystals have been observed in a square foot of surface.

A fine-grained pink felsic granite to which the pegmatites are supposed to be related outcrops about 4 miles west of the pegmatite area.

(23) *Granville Lake, Manitoba 64 C/7*
(lat. 58°16½′, long. 100°37′)

Reference: Cranstone, D.; pers. comm., 1961.

Beryl was found in a pegmatite dyke 16 feet wide and with an exposed length of about 100 feet on an island in Granville Lake. The dyke consists of microperthite, quartz and muscovite, with accessory garnet, tourmaline, and apatite. A few green crystals of beryl were found in one place in a quartz core-pod.

(24) *Herb Lake District, Manitoba 63 J/13*

General References: Crowduck Bay, *Geol. Surv. Can.*, Map 987A, 1950.
Stockwell, C. H.; 1937.

Beryl occurs in spodumene-bearing pegmatites in two localities near the narrows leading into Crowduck Bay, Wekusko Lake, Manitoba. The area is about 10 miles north of the settlement of Herb Lake.

(*a*) *Green Bay Mining and Exploration Co.*
(lat. 54°51½′, long. 99°38′)

References: Mulligan, R.; Lithium deposits of Manitoba, Ontario, and Quebec, *Geol. Surv. Can.*, Paper 57-3, 1956.
Mulligan, R.; 1965.

The property lies north of a small lake about 2½ miles southeast of Crowduck Bay. The country rocks are greenstones and schists, folded on northeasterly trending axes and broken by faults. A small granitic stock lies about a mile southwest of the property.

Seven pegmatite dykes have been exposed by surface work over lengths of as much as 800 feet. They strike north to northwest, obliquely across a zone that trends about N60°E for some 7,000 feet. Several of the dykes have been diamond-drilled. The main or most westerly dyke is more than 600 feet long and up to 90 feet wide. The others are as much as 800 feet long, but are generally narrower and irregular. The dykes are zoned, consisting chiefly of coarse pink feldspar (mainly microcline), with quartz, muscovite, and some tourmaline, and a little biotite. Spodumene-quartz-cleavelandite assemblages occur interstitially to coarse feldspar in rude core-zones.

Beryl was noted only in outer zones, which consist chiefly of pink aplite and coarse feldspar, and carry most of the mica and tourmaline, plus some spodumene. The beryl is mostly in poorly formed white crystals less than an inch across. It was observed in only three of the dykes and is prominent only in small patches around the mid-section of the main dyke.

(*b*) *Sherritt Gordon Property*
(*lat. 54°51′, long. 99°44′*)

Reference: Rowe, R. B.; Lithium Deposits of Manitoba, *Geol. Surv. Can.*, Paper 55-26, 1956.

This property is half a mile west of the narrows of Crowduck Bay. Two pegmatite dykes cut a quartz-diorite body near its contact with biotite granite. The southernmost dyke is at least 900 feet long and averages 18.5 feet wide, according to diamond-drilling data. It is predominantly a spodumene-bearing unzoned dyke, but Rowe reported finding a few small crystals of golden beryl in broken rock in a small trench.

Superior Province

Berylliferous pegmatites are widely distributed throughout the Superior structural province west of about longitude 75°. The province is underlain chiefly by granites and gneisses with infolded belts of volcanic (greenstone) and sedimentary rocks. The indicated K-Ar age of the (presumably) latest intrusions is, as in the Slave province, about 2,500 million years (Stockwell, 1963).

(*25*) *Cross Lake Area, Manitoba 63 I/12*
(*lat. 54°34′, long. 97°51′ (approx.)*)

Reference: Davies, J. F., pers. comm., 1960.

Beryl occurs in pegmatite dykes in several places, including an island about half a mile north of Cross Island. A spodumene-bearing dyke on an island south of Cross Island also contains beryl.

(*26*) *Cat Lake–Winnipeg River District, Manitoba 52 L/11*

References: *Manitoba Dept. Mines Nat. Resources*, Mines Branch Publ.:
49-7 (Springer, G. D.; 1950).
54-1 (Davies, J. F.; 1955).
55-1 (Davies, J. F.; 1956).
56-1 (Davies, J. F.; 1957).
Mulligan, R.; Lithium deposits of Manitoba, Ontario and Quebec, *Geol. Surv. Can.*, Paper 57-3, 1956.
Mulligan, R.; Lithium in Canada, *Geol. Surv. Can.*, Econ. Geol. Rept. 21, 1965.
Rowe, R. B.; Lithium deposits of Manitoba, *Geol. Surv. Can.*, Paper 55-26, 1956.
Stockwell, G. H.; 1932 (reprint 1938, p. 127).

This district (*see* Fig. 4) lies near the Manitoba–Ontario boundary, east of Lac du Bonnet and about 80 miles northeast of Winnipeg. It is noted for the number and diversity of pegmatite-mineral deposits, many of which have been known and extensively studied since 1925. Attempts to mine tin commercially were made at one deposit at Bernic Lake and one at Shatford Lake, and small shipments of lithium minerals were made from deposits south of Winnipeg River and near Bernic Lake. Renewed exploration and development of lithium deposits starting about 1953 led to improved access and increased the number of known beryl occurrences. A major exploration and evaluation program for beryl was initiated by Dalhart Beryllium Mines and Metals Corp. on pegmatites near Greer Lake in 1957. The discovery of pollucite and lithium at the Chemalloy (formerly Montgary) property led to underground development in 1959–1961, and the discovery of beryl in an inner unit.

The consolidated rocks of the district are Precambrian (Archaean), and comprise metavolcanic and metasedimentary rocks of the Rice Lake Group, which are invaded by some basic intrusions and by a variety of younger granitic masses that underlie the greater part of the district. The bedded rocks lie in easterly trending infolded bands, the largest of which extends from Bird River to the south shore of Bernic Lake. One band underlies the west-flowing section of Winnipeg River above Lamprey Falls and another extends northwest through Euclid and Cat Lakes almost to the area north of Maskwa Lake.

The stratified rocks between Bird River and Bernic Lake form an east-trending syncline. Those of the Euclid Lake–Cat Creek belt form the northeast limb of a complementary anticline, whose axis passes close to the east end of Bird (Oiseau) Lake. Some elongated granitic bodies between Bernic Lake and Winnipeg River may mark the position of fold axes (Davies, 1957). A major fault follows the general course of Bird River and may extend southeastward through Starr Lake. A number of north- to northwesterly-striking faults offset the contacts of the Bird River–Bernic Lake sedimentary-volcanic belt. Sheared and silicified zones are common in several parts of the district.

The granitic intrusions comprise a variety of gneissic and massive granitic to dioritic bodies mostly between Bird River and Winnipeg River, and widespread batholithic bodies of pink to grey microcline granite. The youngest intrusions are pegmatitic albite granite. One of the most prominent outcrops of this rock lies south of Winnipeg River. It is characterized by intricately contorted banding, by large rectangular crystal-like aggregates of quartz and feldspar in graphic intergrowth (Mulligan, 1965, Pl. I), and by the occasional occurrence of beryl crystals in quartz-rich segregations. The banding is marked by thin layers of aplite rich in muscovite mica and, less commonly, of red garnet. Several beryl-bearing pegmatite dykes and one important lithium-bearing pegmatite dyke lie just south of the albite granite and have many features in common with it. These albite granite intrusions and the pegmatite dykes probably have a common genetic relationship to the widespread granite masses.

Beryl-bearing pegmatites are chiefly in metavolcanic rocks close to their contacts with large granitic bodies. They also occur, to a lesser extent, in marginal parts of the intrusions. The ones in the southern part of the district, near Bernic

Lake and Winnipeg River, are mainly complex, well zoned, and nearly flat-lying. Some have a domal or anticlinal structure. The three largest pegmatite bodies in the northern part of the district near Cat Lake, on the other hand, are steep-dipping, relatively homogeneous, simple spodumene dykes. To this extent, a regional zoning is apparent within the district, though it cannot be ascribed to any one geological feature.

(*a*) *Cat Lake Area*
(lat. 50°37′, long. 95°27′)

Beryl is a very minor constituent of some spodumene-bearing pegmatites near Cat Lake, which is now accessible by road. At the F.D. No. 5 claim a few small beryl crystals were found in microcline-quartz-plagioclase-biotite pegmatite. At the Eagle Group (Lithium Corporation of America) just north and west of Cat Lake, small, almost white beryl crystals are common in a pink cleavelandite-quartz-muscovite-tourmaline assemblage that appears to be a distinct dyke cutting across the main spodumene-bearing zone. At the Central claims just south of Cat Lake, pale green and white beryl crystals more than an inch wide are common in a muscovite-rich assemblage above the spodumene zone at the western limit of exposure. A few crystals were noticed in other dykes on the property.

(*b*) *Bernic Lake Area*
(lat. 50°26′, long. 95°25′)

Chemalloy Minerals Limited, Bernic Lake (formerly Montgary Exploration Limited)

References: Brinsmead, R.; 1960.
Davies, J. F.; 1957.
Hutchinson, R. W.; 1959.
Mulligan, R.; 1965.
Nickel, E. H.; 1961.
Wright, C. M.; 1961.

The Chemalloy property is at the northeast corner of the large western expanse of Bernic Lake. This is the site of the old Jack Nutt tin mine that was finally abandoned in 1930. At the surface, a number of pegmatite bodies contain abundant black tourmaline, and locally small concentrations of cassiterite, but little or no beryl. The pegmatites cut amphibolitized greenstone near the eastern tip of a granitic tongue that extends westward from Bernic Lake. The main pegmatite was encountered in drilling for tin concentrations, and does not outcrop on land. It is a gently dipping lenticular sheet, at least 1,500 feet wide and more than 2,500 feet long, with a maximum thickness of about 250 feet in the central explored area.

The pegmatite is well though asymmetrically zoned (Fig. 5). Beryl occurs in the wall zone and, more significantly, in an inner albitite unit. The wall zone is a well-defined unit as much as 50 feet thick that occurs at the hanging-wall and foot-wall. It consists chiefly of coarse perthitic feldspar with interstitial albite, quartz, and muscovite. Black tourmaline is common near the contacts and pale beryl occurs in scattered crystals and clusters. An intermediate zone, characterized by spodumene, is the main lithium-bearing unit. Quartz, accompanied in some places by amblygonite, forms an extensive sheet and scattered pods or lenses, which together make up the core of the pegmatite. A lepidolite unit and a pollucite unit each comprise one large lens and several smaller ones, lying generally within the spodumene unit, but transgressing its boundaries.

The 'albite-aplite' unit forms an extensive layer in the lower middle part of the pegmatite. In part it overlies the lower wall zone, underlying all the interior units, but in part it is itself underlain by the lower spodumene assemblage. It is prominently associated with the lepidolite unit and is in part interbanded with lepidolite. Typically, however, the unit consists of bluish grey massive rock that appears to be mostly fine grained but that locally shows the cleavage faces of crystals several inches across. These show microcline twinning in a few small patches, but the original crystals appear to be pseudomorphed by albite, and fine subequidimensional albite with a little quartz and fine scaly white mica makes up most of the rock in some places. In others, notably where beryl and tin-tantalite are present in considerable abundance, several specimens of the rock were found to consist almost entirely of fine scaly white mica. The beryl of this unit is white, locally with a pale pink tinge. Much is in good crystals an inch or more across. It is prominently (but not all) associated with brown quartz-muscovite assemblages. The main drift passed through the unit for 370 feet and muck samples of the material from the dump averaged 0.9 per cent BeO (K. Brown, pers. comm.).

Other Bernic Lake Occurrences. A dyke exposed across the small bay just east of the Chemalloy shaft contains white beryl in coarse irregular crystals and masses. This dyke has been trenched and is largely covered by broken rock. A considerable amount of beryl has probably been removed, and the original concentration is not known.

At the Buck and Coe claims, now part of Lithium Corporation of Canada's holdings at the east end of Bernic Lake, beryl is present as a minor component of the strongly zoned lithium-bearing dykes. Another small dyke there, unzoned and without lithium minerals, carries scattered beryl crystals that are commonly more than 5 inches across. At the large pit on the Buck claim, a few crystals are to be found in a mica-rich upper intermediate zone composed chiefly of quartz and feldspar. The inner zones carry spodumene, amblygonite, and triphylite. The wall zone consists largely of coarse tourmaline. Other zoned dykes at depth have been indicated by diamond-drilling. Beryl also occurs in a similar assemblage in a thinner dyke exposed at the edge of a swamp about 700 feet southwest of the pit.

(*c*) *Shatford Lake Area*
(*lat. 50°23′, long. 95°28′*)

Near the end of Shatford Lake a number of pegmatite bodies carry beryl. They are mostly in a belt of metavolcanic rocks that extends easterly along the south shore of the lake from a point about a mile west of the east end. The ground, now held by Contact Minerals Ltd., includes the site of the old Manitoba Tin Company's workings. Most of the dykes are unzoned and consist chiefly of feldspar and quartz, with muscovite and occasional curvilammelar purplish mica and biotite. Beryl, in crystals commonly as large as 2 inches across, is fairly abundant in limited areas.

A large dyke, about 3,500 feet west of the east end of the lake, carries beryl associated with coarse-curvilammelar lithia mica and a number of other rare minerals, including topaz, monazite, and columbite-tantalite. Euxenite was identified by the Manitoba Department of Mines, and a small fragment of black vitreous material was identified as gadolinite by the Geological Survey. The rare-earth minerals are in isolated dark patches of heavily stained, fractured feldspar. Beryl occurs as green and white crystals rarely up to a foot long, and is fairly abundant in limited areas.

At the west end of Shatford Lake, a number of pegmatites contain beryl. Some exploration was carried out in 1960. A flat-lying dyke contains beryl mainly in an inner quartz-rich zone (P. Howe, pers. comm.).

(*d*) *Winnipeg River Area*
(*lat. 50°21′, long. 95°19′*)

The vicinity of Greer Lake, south of Winnipeg River, was in 1957 the scene of the most aggressive assessment of beryllium occurrences to be carried out in Canada in recent years. The ground, controlled by Dalhart Beryllium Mines and Metals Corp., includes the Grace, Huron, and Annie claims. The deposits are in pegmatite dykes and stringers cutting granitic and volcanic rocks near a large stock of pegmatitic albite granite, to which the dykes are believed to be related. The stock also carries beryl in scattered quartz-muscovite segregations. The pegmatites are characteristically pink, and lack important lithium minerals, although the latter are prominent in a zoned dyke on the Bob (Silverleaf) claim nearby.

At the Huron claim, famed as the source of the uraninite from which the great age of Canadian Precambrian rocks was first established, yellow-green beryl in crystals as much as 18 inches across is abundant in the sides of a pit that exposes a flat-dipping coarse pegmatite body. Crystals of columbite-tantalite are also common. Cleavelandite-feldspar, black quartz, tourmaline, and some mica are associated with the minerals above.

On the Grace claims, and elsewhere on the property, some rich pockets of beryl have been found but are apparently limited in extent. The following estimated reserves have been reported (Northern Miner, Aug. 8, 1957, p. 3):

No. 1 Zone: 266,666 tons, 0.5 per cent beryl over an area 800 by 20 feet and 200 feet deep.

No. 6 Zone: 0.63 per cent.

No. 9 Zone: 0.48 per cent, over an area 400 by 20 feet.

At that time 20 tons of beryl were reported to be stockpiled, in addition to an unstated quantity of "milling ore".

Other beryl occurrences have been described on the Clare No. 1, Captain, and Top of the World claims, and elsewhere (Delury, 1930; McCartney, 1930) in the vicinity of Winnipeg River.

(27) *East Braintree–West Hawk Lake District, Manitoba 52 E 11*
(lat. 49°39′, long. 95°28′)

References: Mulligan, R.; Lithium deposits of Manitoba, Ontario, and Quebec, 1956, *Geol. Surv. Can.*, Paper 57-3.
Rowe, R. B.; Lithium deposits of Manitoba, *Geol. Surv. Can.*, Paper 55-26, 1956.
Springer, G. D.; *Manitoba Mines Br.* Publ. 50-6, 1952.
Stockwell, C. H.; 1932.

The locality given above is approximately that of the Lucy and Artdon claims, on which the only noteworthy beryl occurrences have been reported. The showings are about half a mile north of the Trans-Canada Highway at a point 6.6 miles east of the East Braintree turnoff, or about 80 miles east of Winnipeg.

On Lucy No. 1 claim Springer reported small and scattered beryl crystals in a dyke that has abundant black and bluish tourmaline in an outer zone enveloping a thin lenticular quartz-spodumene pod. The writer found no beryl there, but did find a few loose fragments near a water-filled pit, about 300 feet farther north. On the adjoining Artdon No. 2 claim, Springer reported beryl with spodumene in a dyke about 60 by 10 feet in exposed dimensions.

(28) *English River, Ontario 52 L*
(lat. 50¼°, long. 94½° (approx.))

Reference: Stockwell, C. A.; 1932 (reprinted 1938) p. 127.

Stockwell noted a few small crystals of beryl in a large pegmatite dyke on the east shore of English River 2 miles northwest of Separation Rapids, and in a small dyke cutting sediments 3 miles west of Oneman Lake.

(29) *Medicine Lake, Tustin Township, Ontario 52 F/13*
(lat. 49°51′, long. 93°46′)

This property, owned by E. Zabeski of Kenora, is on the east shore of Medicine Lake in Tustin township, about 35 miles east of Kenora. Pegmatite-streaked granite extends at least 500 feet south of a contact with greenstone. An area about 1,000 feet long adjoining the contact has been stripped and a number of trenches blasted out. The pegmatite phases consist of coarse, blocky, white and grey perthite crystals and large irregular masses of grey and smoky quartz, with some biotite and muscovite.

Beryl was found in noteworthy amount in two places. One about 40 feet long, near the cabin 200 feet from the lakeshore, contained a number of stained, altered-looking crystals along a shallow trench. The other, just west of the road, about 300 feet farther east, contained several well-formed yellow crystals as much as 2 inches across. They are associated with black quartz, cleavelandite, muscovite, and red and black garnet. A few crystals of beryl were also seen in a trench east of the road.

(30) *Zealand Township, Ontario 52 F/15*
(*lat. 49°49′, long. 92°44′*)

Reference: Satterly, J.; Geology of the Dryden-Wabigoon area, *Ont. Dept. Mines,* Ann. Rept. 50, pt. 2, p. 55, 1941.

According to Satterly, small green crystals of beryl were found in samples of pegmatite from lot 17, cons. VII and VIII, about 10 miles east of Dryden. In this vicinity, the writer found numerous large and small pegmatite-granite and quartz veins with contorted banded structures and abundant black tourmaline, but saw no beryl. Some beryl is said to occur also in tourmaline-rich pegmatites northwest of Ghost Lake, about 3 miles farther northeast.

(31) *Turtle Lake, Rainy River district, Ontario 52 B/15*
(*lat. 48°57′, long. 91°58′*)

References: Tanton, T. L.; Mineral deposits of Steeprock Lake map-area, Ontario, *Geol. Surv. Can.,* Sum. Rept. 1925, pt. C, p. 10.
Tanton, T. L.; Quetico (west half), Rainy River district, *Geol. Surv. Can.,* Map 534A, 1939.

According to Tanton translucent yellow-green crystals of beryl as much as 2 inches long are unevenly distributed in a pegmatite dyke composed of quartz, microperthite, dark mica, and minor garnet.

(32) *Lake St. Joseph Area, Ontario 52L*
(*lat. 51°, long. 91° (approx.)*)

Reference: Bruce, E. L.; Iron-formation of Lake St. Joseph, *Ont. Dept. Mines,* Ann. Rept. 1932, XXXI, pt. 8, p. 20, 1923.

According to Bruce one beryl crystal was found in the area, which has abundant pegmatite dykes along the south margin of a granite mass.

(33) *Linklater Lake, Caribou–Pikitigushi Area, Ontario 52 I*
(*lat. 50°33′, long. 88°47′*)

References: Chisholm, E. O. (1948) (Ontario Prel. Rept. 48-11).
Gussow, W. C.; Geology of the Caribou-Pikitigushi area, *Ont. Dept. Mines,* Ann. Rept. 1940, vol. XLIX, pt. 6, p. 5, 1942.

This locality is just south of the east end of Linklater Lake, through which the outcrop belt of the Linklater quartzite passes. According to Gussow, the formation is cut by numerous quartz veins, and granite and pegmatite dykes containing microcline, muscovite, minor tourmaline, and garnet, and, rarely, beryl. In an easterly striking zone that was stripped and trenched for 1,800 feet by San Antonio Gold Mines Ltd., numerous narrow bands of pink granophyric pegmatite cut impure arkosic quartzite with narrow bands of magnetic iron-formation. Samples of the stringers assayed up to 1.83 per cent tin (Chisholm). The stringers are contorted and have, in general, an augen rather than pegmatitic texture. They consist mainly of pink feldspar, minor quartz, muscovite, and locally tourmaline. Thin sections showed the feldspar to be mainly plagioclase, probably albite, commonly shattered and recrystallized. Muscovite is also distorted and outlines the augen structure of quartz-feldspar assemblages. Sections from the higher grade stringers contain abundant beryl in microscopic crystals, as well as tourmaline, a little cassiterite, and topaz. Samples of these were reported to contain up to 0.15 per cent Be and up to 0.2 per cent tin by spectrographic analysis (GSC spectrographic laboratory). Samples of the wall-rocks were reported to contain nil Be and less than 1 ppm tin on a magnetic fraction, and less than 5 ppm Be, 4.4 ppm tin, on a non-magnetic fraction.

Chisholm mentioned several other beryl-bearing pegmatites in the area.

(34) *Nipigon–Orient Bay, Ontario 52 H-42 E*
(*lat. 49°14′, long. 88°01′*)

References: Mulligan, R.; 1965.
Pye, E. J.; 1956, 1961.

Beryl has been found in two of the numerous pegmatite bodies west of Cosgrave Lake, near Jackfish River, south of the main lithium deposits of the district. They are in the northwest contact zone of a large granite batholith that intrudes Archaean metasedimentary rocks comprising biotite quartzite and quartz biotite schist. A rough regional zoning is apparent in the progression, from north to south, from unzoned simple spodumene pegmatites to complex lithium-beryllium, and simple berylliferous pegmatites. An analogous increase in grade of metamorphism of the country rocks from north to south has been noted. The higher grade manifests itself in the presence of nodules or knots of fine-grained amphibole, porphyroblasts of garnet, and possibly of staurolite and cordierite.

At the MNW property, beryl is scattered fairly consistently through an intermediate zone that envelops a core of quartz-spodumene. It is associated with muscovite, cleavelandite, and quartz. Crystals an inch or two inches across are common; one mass 18 by 14 inches in exposed dimensions was seen.

At the Swanson property, several areas of pegmatite are exposed in a steep-walled ravine. No definite dyke boundaries were seen. There is no suggestion of banding or zoning in the exposed areas although beryl seems to be restricted mainly to irregular pockets. These consist chiefly of pink-stained cleavelandite feldspar, quartz, and muscovite, with fairly abundant black tourmaline and masses of black friable material, part of which is hühnerkobellite. The beryl is largely stained and coated with black and greenish material and much of it is apparently altered. Crystals as large as 2 by 12 inches were noted.

(35) *Saga Lake, Ontario 42 L10*
(*lat. 50°41′, long. 86°52′*)

Reference: Moore, E. S.; Goudreau and Michipicoten gold areas, District of Algoma; *Ont. Dept. Mines*, Ann. Rept. 1931, XL, pt. 4; p. 82.

Pegmatites occur in abundance in parts of the Kowkash–Ogoki map-area and commonly carry tourmaline. Beryl is said to occur sparsely in some of the dykes near Saga Lake.

(36) *Gogama Area, Ontario 41 P/13*
(*lat. 47°50′, long. 81°52′*)

Reference: *Canada Min. Res. Br.* Ser. 125, 1952.

Pegmatites at the common corner of Wigle, Middleboro, Whalen, and Carter townships, 16 miles north of Gogama, were reported by the Redore Mining Co., to contain beryllium, tin, and columbium-tantalum. There is no record of systematic exploration. A specimen of molybdenite-bearing pegmatite from the Alike Lake area northwest of Gogama was found to contain 70 ppm Be (GSC spectrographic laboratory).

(37) *Steele Township, Ontario 32 E/4*
(*lat. 49°02′, long. 79°56′*)

References: Lumbers, S. B.; *Ont. Dept. Mines* G.R. 8, 1962.
Nickel, E. H.; *Mines Br.* Int. Rept. 63-34, 1963.

According to Lumbers, a pegmatite dyke in lot 5, con. V, Steele township, contains spodumene, rare molybdenite and columbite-tantalite, and traces of beryllium. The dyke is 825 feet in exposed length and 100 feet wide, and occurs in the Case batholith near its contact with metasedimentary rocks. It is the only complex zoned dyke of many within the batholith, several of which contain molybdenite. Samples submitted by Canadian Johns-Manville to the Mines Branch were found to contain fine beryl crystals, as well as spodumene, pollucite, and columbite-tantalite (Nickel, 1963). One sample assayed 0.37 per cent BeO.

(38) *Harricanaw River, Quebec*
a) (*lat. 50°20′, long. 79°00′*) *31L/11 32 L/11*
b) (*lat. 50°31′, long. 79°08′*) *31 L/7–8 32 L7–8*

References: Remick, J. H.; Quebec Prel. Rept., 458, 1961.
Remick, J. H.; Quebec Prel. Rept., 498, 1963.

Beryl was found in two of many small pegmatites that cut Archaean metasedimentary and metavolcanic rocks and foliated biotite granite that bounds the other rocks on the north. At locality (b) above (west shore of Ile des Sept Milles), several small veinlets are associated with purple-red zones in the granite. They contain about 2 per cent corundum, as well as beryl ("up to 4 per cent") (Remick, 1963) and brown mica, flakes of which surround the corundum crystals. The beryl crystals are yellow, and typically about three-quarters inch across. Some pegmatites in the district contain molybdenite.

(39) *Walrus Island, Paint Hills Group, James Bay, Quebec 33 D*
(*lat. 52°56′, long. 79°00′ (approx.)*)

References: Hoffman, G. C.; *Geol. Surv. Can.*, Ann. Rept. 1899, vol. 12 (new ser.), p. 15R.
Johnston, R. A. A.; p. 83, 1915.

According to Johnston, "Danalite has been observed in small crystals in a vein composed of orthoclase, spodumene, and quartz cutting syenite" at the above locality. The identification was apparently made on the basis of physical and chemical properties described by Hoffman, but has been confirmed by X-ray.

(40) *Delbreuil Township, Témiscamingue County, Quebec 31M (lat. 47°41′, long. 78°36′)*

Beryl is present in several localities in a massive pegmatitic body near the northeast corner of Lac Expanse (Lac Simard), on claims held by R. Legault of Lorrainville, Quebec. One trench in micropegmatite-aplite shows a few green crystals of beryl; nearby a patch of pinkish quartz about 5 feet in diameter has about a dozen green to white crystals in cleavelandite around its edge. At another locality a few scattered crystals of beryl occur with muscovite bursts in pink micropegmatite.

At the main showing, an L-shaped trench measures about 40 and 15 feet along the limbs and about 10 feet in width. About 80 crystals are exposed in pockets and as single crystals as large as 1.6 feet by 0.6 foot in exposed area, and many others, perhaps a majority, are several inches across. They occur in feldspar, in dark grey quartz, and in the interstices. Most are associated with muscovite. The feldspar is pink and perthitic-looking, in part in micropegmatite intergrowths as much as 4 feet long. Quartz is in irregular segregations. Little or no cleavelandite was seen and no zoning or systematic distribution of beryl is apparent. A little spodumene also occurs in limited areas that are apparently pockets distributed at random in the large pegmatitic mass on which the claims are located.

(41) *Abitibi–Témiscamingue Area, Quebec (lat. 48°, long. 77° to 79° (approx.))*

References: Denis, B. T.; Sabourin map-area, Témiscamingue county, *Quebec Bur. Mines,* Ann. Rept., 1934-C, 1935.

Freeman, P. V. (a); Béraud-Mazerac area, Rouyn-Noranda Abitibi East electoral districts, *Quebec Dept. Mines,* Prel. Rept. 340, 1957.

Freeman, P. V. (b); Darlens-Chabert area, Rouyn-Noranda electoral district, *Quebec Dept. Mines,* Prel. Rept. 341, 1957.

MacLaren, A. S.; Kinojevis, Témiscamingue county, Quebec, *Geol. Surv. Can.,* Paper 52-6, 1952.

Tiphane, M., and Dawson, K. R.; Villebon, *Geol. Surv. Can.,* Map 998A, 1950.

This area comprises a broad contact zone that extends roughly along the 48th parallel (the Abitibi–Témiscamingue county boundary, in part) between the so-called Pontiac schists and the large granitic area that extends to the south. A large number of minor beryl occurrences have been reported, most of which are mentioned in the references listed. A distinctly nodular character in the quartz-mica schists was noted at the Montanier township locality described below. Thin sections showed large yellow staurolite and a few kyanite crystals, with fairly abundant fine tourmaline crystals amongst the quartz.

In Montanier township at about lat. 48°06′, long. 78°30′, on the Rapide II road, a zoned dyke carries spodumene in a discontinuous core zone composed of quartz-rich pods. Beryl occurs as scattered pale-green crystals as much as 4 inches long. It is associated with muscovite and black tourmaline, mostly in the interior parts of the dyke; none was seen in the quartz-spodumene pods. Biotite in large thin books is common in the outer parts of the dyke.

The other occurrences are described as follows in the references:

(Freeman (*a*)) Scattered crystals associated with segregations of quartz in pegmatite:

- (i) a small island in Mourier Lake (Desroberts township).
- (ii) $1\frac{1}{2}$ miles east of Mourier Lake, in range VIII, Desroberts township.
- (iii) a small island just south of Carriere Bay in range IX, Jourdan township.
- (iv) range IX, Chabert township.
- (v) quartz vugs in Pontiac schist near pegmatite on Rapide 7 road east of Ferguson Lake (Beraud township).

(Freeman (*b*))

- (i) Small crystals in thin quartz veins cutting pegmatite on lot 1, ranges IX–X, Darlens township.
- (ii) One large crystal in pegmatite on lot 40, range V, Basserode township.

(Denis) Crystals of beryl were found at "three widely separated localities" in Sabourin map-area, which includes the townships of Laubanie, Sabourin, and Marrias.

(Tiphane and Dawson) Beryl occurs locally with tourmaline in muscovite pegmatite west of Grand Lake Victoria (Granet township).

(MacLaren) Pegmatites in Bellecombe township carry some spodumene, beryl, and molybdenite, but no economic deposits of these minerals have been found.

(42) *Preissac–Lacorne District, Abitibi County, Quebec*
(lat. 48°15′–48°30′, long. 77°45′–78°22′)

References: Brett, P. R.; Que. Prel. Rept. 428, 1960, 1961.
Dawson, K. R.; 1954.
Ellsworth, H. V.; 1932.
Latulippe, M.; Que. Publ. 532, 1956 and unpublished reports.
Leuner, W. R.; Que. Prel. Rept. 405, 1959.
Mulligan, R.; 1957, 1961, 1965.
Norman, G. W. H.; 1944.
Rowe, R. B.; 1953.
Tremblay, L. P.; 1950.

This district (*see* Fig. 2) lies between Amos and Val d'Or, Quebec. It contains two producing mines, one belonging to Quebec Lithium Corporation, the only Canadian lithium producer, and the other to Molybdenite Corporation, besides a number of other lithium, beryl, and molybdenite deposits. They are mainly in Lacorne and adjacent parts of Landrienne, Figuery, La Motte, and Preissac townships. Some beryl has been recovered at the Molybdenite Corporation mine.

The consolidated rocks, Precambrian (Archaean) in age, are metavolcanic and metasedimentary rocks, intruded by granitic and other rocks of the Preissac–Lacorne batholith and by younger diabase dykes. The batholith is a composite of several intermediate to acidic types. Of these, a muscovite granite averaging 40 per cent albite and 24 per cent microcline is the youngest, and the most abundant and important. The pegmatites are related to it and cut the other intrusive and invaded rocks. The ones near the contacts strike mainly either parallel with the contact, or at right angles to it. This orientation of pegmatites with respect to the contact, together with the orientation of pegmatites within the batholith, suggests a control by joint systems. Many of the lithium-bearing dykes lie less than 1½ miles southwest of, and approximately parallel with, a large fault zone known as the Manneville fault, which extends west-northwest through northeast Lacorne, southwest Landrienne, and Figuery townships. A molybdenite-bearing pegmatite vein at Lac Roy lies just south of it. The pegmatites contain, variously, spodumene, minor lepidolite and other lithia micas, beryl, molybdenite, and small amounts of columbite-tantalite, bismuthinite, and other minerals including pollucite. A rough regional zoning is apparent (Fig. 2) with beryl mainly in interior pegmatites, lithium minerals mainly in marginal and exterior pegmatites, and molybdenite in exterior pegmatite veins beyond the lithium zones. There is also a variation in the potash feldspar content of the pegmatites, the typical beryl-bearing dykes having more than the lithium-bearing dykes. Some complex dykes are well-zoned and contain beryl, lithium minerals, and pollucite.

(*a*) *Height of Land Mine, Preissac Township, Abitibi County*

Phenacite is associated in minute quantities with beryl at the old Height of Land molybdenite mine on lot 22, range X, about a mile north of Preissac village. This is the only known occurrence of this mineral in Canada. The old workings are scattered along the west bank of Kinojevis River, which passes through the western limit of the Preissac–Lacorne batholith at that locality. According to the old descriptions (Ellsworth, 1932), dykes of granite and pegmatite are in a zone as much as 90 feet wide along the river-bank. The dykes are said to be as much as 15 feet wide and to be cut by molybdenite and bismuthinite-bearing quartz veins, one of which is 15 feet wide at the site of the shaft in the southern part of the property.

The writer found the old shaft and dump now thickly overgrown and covered by decayed vegetation. About 100 pounds of beryl-rich material were found during a couple of hours digging in the dump. A number of crystalline aggregates contained individual crystals several inches across. The beryl is partly fresh, translucent, and bright green, partly yellowish or bluish altered-looking material. Some is associated with cleavelandite-type feldspar and muscovite; some is isolated in quartz. Molybdenite is in scattered books, also with cleavelandite, muscovite, and quartz. At one point, what appears to be the in-place contact between quartz and granite is just exposed.

No veins or dykes on the property were found to be well exposed. At the old north workings a big trench is largely filled and heavily overgrown. This is presumably the locality where the phenacite-bearing material was collected. No beryl was found by the writer and no phenacite recognized in specimens collected. Only 0.0014 per cent beryllium was found in a plus 2.9 specific gravity fraction of this material. According to Ellsworth, the phenacite was present as "minute transparent crystals" in a chloritic segregation in micaceous selvedge on the side of a quartzose pegmatite dyke. Beryl has been reported to occur also in minor amounts at several other localities along the contact zone of the Preissac–Lacorne batholith, in Preissac, Villemontel, Figuery, and La Motte townships (Rowe, 1953)

Lacorne Township. As in Preissac and adjoining townships, beryl occurs in pegmatite bodies that are related to the Preissac–Lacorne batholith, and are most numerous in Lacorne township. Most of these pegmatites are within a muscovite-bearing granite mass, or marginal to it, unlike the spodumene deposits, which are more commonly marginal or exterior pegmatites. The latter, as at the Quebec Lithium mine, rarely carry significant amounts of beryl. Four localities are selected for special mention here.

(*b*) *Lacorne Molybdenite Mine*

At the Lacorne molybdenite mine, in the southwest corner of the township, several hundred pounds per month of beryl have been recovered from a picking belt. The beryl is deep blue-green and occurs in compound crystal masses as much as a foot in maximum dimension. It is present in an 'east-west' set of veins, generally on the foot-wall associated with cleavelandite, muscovite, and quartz. The writer understands that these veins now provide most of the ore from which molybdenite and bismuthinite are recovered.

(*c*) *Massberyl Property*

The Massberyl property, in the southern part of lots 15 and 16, range VIII, was mapped and described by Rowe in 1952 and has been considered the most promising beryl property in the region. According to Rowe there are three main pegmatite bodies in an area 1,000 by 500 feet. One body 880 by 20 feet was estimated to contain 0.03 per cent of exposed beryl with 0.87 per cent in one beryl-rich area of 14,400 square inches. Another body, 760 by 20 feet, was estimated to contain 0.15 per cent beryl at the surface, with 3.09 per cent in a beryl-rich area of 13,824 square inches. A third beryl-rich area of 16,704 square inches in a smaller body contained 0.63 per cent beryl.

An area about 550 by 200 feet has been cleared and extensively trenched. Beryl crystals as large as 6 inches in cross-section are to be found here and there, but no such concentrations as described by Rowe are apparent. It seems likely that most of the beryl that was exposed in the various trenches has been removed. The beryl seen by the writer was mostly in and near quartz stringers and segregations in coarse perthitic pegmatite. Most was associated with muscovite. The quartz stringers and pods, especially in the northwest part, appear to represent intermittent cores in rudely zoned pegmatitic segregations.

(*d*) *Valor Property*

At the Valor property in the southern part of lot 22, range VIII, a zoned pegmatitic segregation some 400 by 75 feet, as exposed, cuts granitic country rock. Coarse spodumene is embedded in a cleavelandite-quartz-lepidolite aggregate in an irregular core zone about 125 feet long. This is commonly separated from coarse perthitic pegmatite and granite by banded aplite, and beryl is mostly distributed along these contact zones in narrow bands rich in muscovite and quartz. The beryl is in pale green crystals, commonly several inches across, and fairly abundant in a few small areas. It also occurs in rare, almost white, shapeless masses among the spodumene crystals in the core assemblage which also contains scattered crystals, up to 5 feet long, of pollucite. A little beryl was seen also in other small pegmatites on the property.

(*e*) *Lots 20–21, Range X*

Pegmatites in the central part of lots 20–21, range X, were considered by Latulippe (1956) to be among the most interesting in the area. The writer found numerous dykes and irregular streaks of pegmatite and aplite ramifying through granite. The pegmatite contains quartz stringers and quartz-muscovite segregations in irregular lenses and masses. Watery greenish yellow crystals of beryl as large as 4 inches across are scattered throughout, mostly associated with quartz segregations. About a dozen crystals were found in one area a foot square. No trenching appeared to have been done. Beryllium was reported "not found" (probably less than .001 per cent) in a composite sample of muscovite (GSC spectrographic laboratory). "Less than .01 per cent" was reported in muscovite from the Massberyl property (GSC spectrographic laboratory).

(*43*) *Assinica Lake, Quebec 32 J/11*
(*lat. 50°37′, long. 75°27′*)

Beryl occurs with spodumene in pegmatites cutting knotted sedimentary gneisses (Archaean) in an area 9 miles northwest of Assinica Lake, i.e., 80 miles northwest of Chibougamau. Sirmac Mines Ltd. (in the company's summary report on 1960 operations) reported assay results of bulk samples from trenches, only one of which contained an appreciable amount of beryllium (0.46 per cent over 6 feet). No. 5 dyke, 1,600 feet by as much as 400 feet, is reported to be zoned. It contains scattered beryl, tourmaline, and apatite in an aplitic wall zone, which grades inward into a coarse quartz-spodumene assemblage containing white beryl crystals 6 to 8 inches across.

Grenville Province

Like the Churchill structural province, the Grenville province consists mainly of granites and gneisses, but their indicated age is only about 950 million years. They mark the latest definitely Precambrian orogeny and are in part reworked (metamorphosed) rocks of the Southern, Superior, and Churchill provinces. Beryllium occurrences are widespread but lithium occurrences are remarkably rare.

(44) *Henvey Township, Parry Sound District, Ontario*
(lat. 45°48′, long. 80°32′)

Reference: Spence, H. S.; Pegmatite minerals of Ontario and Quebec, *Am. Mineralogist,* vol. 15, p. 513, 1930.

According to Spence, beryl was reported in small amounts at the old Besner feldspar mine about 2 miles northeast of Britt station.

(45) *Conger Township, Parry Sound District, Ontario*
(lat. 45°, long. 80° (approx.))

Reference: Ellsworth, H. V.; 1932, p. 171.

According to Ellsworth a few specimens of massive, greenish blue beryl and several smaller crystals were found on lot 5, concession B in a pegmatite dyke carrying thucolite and other radioactive minerals.

(46) *Butt Township, Ontario*
(lat. 45¾°, long. 79° (approx.))

Reference: Waite, G. G.; 1945.

Waite mentioned an occurrence of gem-quality (aquamarine) beryl from "Butt township, near Kearney". Various reports and rumours of beryl occurrence in the district have been heard by the writer but no definite information as to locality. A composite sample from a pegmatite on "Mount Baldy" in Proudfoot township to the west was found to contain 15 ppm Be (GSC spectrographic laboratory).

(47) *Calvin and Mattawan Townships, Ontario*
(lat. 46°15′, long. 78°53′; lat. 46°19′, long. 78°54′)

References: Barlow, A. E.; *Geol. Surv. Can.,* Ann. Rept. 1897, vol. 10 (new ser.), p. 631, 1899.
Ellsworth, H. V.; 1932.
Hoffman, G. C.; *Geol. Surv. Can.,* Ann. Rept. 1898, vol. 11 (new ser.), p. 14R.

Beryl is in a pegmatite dyke just south of the road on lot 13, con. IV, Calvin township. The dyke strikes approximately north and has been opened up by pits and trenches, now partly filled, over a length of about 200 feet. It cuts the foliation of enclosing granitic gneiss almost perpendicularly. The dyke is composed of coarse pink and white feldspar with quartz in irregular segregations and veins, and some muscovite. In the second pit from the north end, cleavelandite shows above the waterline, with abundant black tourmaline, quartz, and segregations of fine-grained garnet. One yellow-green beryl crystal, more than an inch across, was found in the rim of rock between the second and third pits, and several cavities show the shape of crystals previously removed.

Beryl was also reported (Barlow, 1899) to be present in a dyke about a mile northwest of Eau Claire station. Ellsworth (1932) described an occurrence of euxenite and polycrase in a dyke on lot 19 or 20, con. IX (possibly the same locality), but did not mention beryl. A small amount of beryl is also reported to have been found at the old Purdy Mica mine (lat. 46°19′, long. 78°54′) in Mattawan township about 3 miles north of Eau Claire.

(48) Monmouth Township, Haliburton County, Ontario (lat. 44°58′, long. 78°17′)

Reference: Satterly, J.; Mineral occurrences in the Haliburton area, *Ont. Dept. Mines,* Ann. Rept., 1943, vol. LII, pt. 2, p. 85, 1943.

This locality is apparently that of the reported radioactive occurrences on lots 15 and 17, con. XII, about a mile northwest of Tory Hill. According to Satterly hornblende-syenite pegmatites are cut by calcite-apatite veins. No uraninite or rare-element minerals were found. A variety of rare elements including beryllium were reported by the owners.

(49) Madoc Township, Hastings County, Ontario (lat. 44½°, long. 77½° (approx.))

Reference: Johnston, R. A. A.; p. 40, 1915.
Wilson, M. E.; 1959.

In his report Johnston stated "A small crystal of beryl was found in Madoc I-IV". No reference was given and no other mention of the occurrence has been discovered. The writer found no granite or pegmatite in lot 1, range IV, where an old fluorite mine lies in Palaeozoic limestone. Beryllium was reported "not found" ($<$.008) in a composite sample of Moira Granite (GSC spectrographic laboratory).

(50a) Lyndoch Township, Renfrew County, Ontario 31 F/6 (lat. 45°20′, long. 77°24′)

Reference: Hewitt, D. F.; pp. 36, 42, 1954.

The two main beryl occurrences of the area (one on lot 23, con. XV (north of Quadeville), and one on lots 30 and 31, con. XV) have been thoroughly described and shown diagrammatically by Hewitt. The ground is held by Canadian Beryllium Mines and Alloys Ltd. On lot 23 a large T-shaped open cut was made some years ago from which some beryl was shipped. A considerable amount of beryl is to be seen in a large bin of stockpiled material on the property. The lower arm of the cut was full of water in 1948, and the floor of the upper part was nearly covered by fine broken material and soil, in which trees more than 15 feet high were rooted. The writer saw beryl in only one small bare floor area about 3 feet long that appears to be near the east end of the quartz core. The beryl here forms dark blue-green, altered-looking crystals associated with quartz, cleavelandite, and red perthite. Some other patches of quartz and cleavelandite carry tourmaline but not visible beryl. A little shiny black material, probably euxenite, was seen near the centre of the upper pit. Cyrtolite, allanite, and columbian anatase have also been identified.

On lots 30 and 31, old workings occupy most of a length of about 600 feet of an irregular pegmatite body, from which several hundred tons of feldspar have been quarried at various times. About 29 tons of beryl are said to have been recovered from stockpiled ore and sold in 1950. The texture of the dyke is variable. Very coarse segregations of pink microcline perthite and quartz characterize the western part. One large pod consists chiefly of rose quartz, apparently part of an irregular quartz core. According to Hewitt, beryl was found only in the east workings, where the main pit is now largely covered by debris and heavily overgrown. Most of the beryl formerly exposed in the walls has probably been removed. Small crystals were found by the writer, however, in several places in small quartz segregations among pink perthite where pegmatitic material grades into granitic country rock on the north side of the main pit. Other minerals that have been identified from these workings include euxenite and columbite.

Hewitt listed several other reported beryl occurrences in the area, but stated that he was unable to find any beryl in them.

(50b) Raglan Township, Ontario 31 F/5
(lat. 45°18′, long. 77°37′)

Reference: Adams, F. D., and Barlow, A. E.; *Geol. Surv. Can.*, Mem. 6, 1910.

This locality is the old Craigmont corundum mine (lot 3, con. XVIII) in which Adams and Barlow (p. 326) reported chrysoberyl (presumably microscopic) among a list of accessory minerals in the corundum-syenite pegmatite. None was found by the writer in the field or in thin sections. No beryllium was found in spectrographic analysis of composites nor in a heavy mineral (+2.9) concentrate of material from lot 3. None was found at the Jewelville corundum locality a few miles east.

(51) Loughboro Township, Frontenac County, Ontario
(lat. 44°28′, long. 76°33′)

Reference: Ellsworth, H. V.; p. 232, 1932.

Gadolinite, a beryllium-bearing rare-earth mineral, was identified in the form of a single specimen weighing about one-quarter pound from a pegmatite dyke formerly worked for feldspar on lot 11, con. IX, about 2 miles west of Perth Road station. A few small specimens of euxenite were also found but no additional gadolinite, and operations ceased soon afterwards. The dyke was said to be typical of those mined for feldspar in the region, and to have no specially noteworthy features.

(52a) Robertson Township, Labelle County, Quebec
(lat. 46°30′, long. 75°33′)

References: De la Rue, E. Aubert; Nomininque and Sicotte map-areas, Labelle and Gatineau counties, *Que. Dept. Mines,* Geol. Rept. 23, 1948.
De la Rue, E. Aubert; Kensington area, Gatineau and Labelle counties, *Que. Dept. Mines,* Geol. Rept. 50, 1953.

Beryl and chrysoberyl occur in a pegmatite dyke on lot 25, range IV, at the north end of Lac des Iles, about 7 miles by road southwest of Mont Laurier.

The dyke is poorly exposed in a trench about 40 feet long and more than 10 feet in maximum depth. The trench is now mostly covered with debris and partly overgrown. The property is held by Mr. Phrase Arbic of Mont Laurier. The dyke is composed of feldspar, quartz, and muscovite, with plentiful black tourmaline and garnet. It appears to grade imperceptibly into garnetiferous quartz-biotite gneiss on the west, but more quartz-tourmaline pegmatite is exposed just beyond and also on top of a hill about 1,000 feet west; the intervening exposures are contorted gneiss.

The feldspar is white to pink but much of it is altered and stained in green and yellow shades. There is also much fine-grained green mica. These circumstances add to the difficulty of finding either beryl or chrysoberyl, neither of which is plentiful. Fine crystals and crystal aggregates of both were identified in specimens. They appear to be confined to quartz segregations among the feldspar, but it is not possible to make any inference as to their original habitat in the dyke structure. In one specimen sillimanite was found in long needles penetrating quartz.

(52b) Campbell Township, Labelle County, Quebec

Reference: Vokes, F. M.; *Geol. Surv. Can.*, Map 1045 A-M2, 1952.

The writer has not been able to find any authentic reference to the beryl occurrence in Campbell township shown on Vokes' map; the report cited on the map may refer to the one in Robertson township.

(53) Villeneuve Mine, Villeneuve Township, Papineau County, Quebec 31 G/15 (lat. 45°50′, long. 75°36′)

Reference: Ellsworth, H. V.; p. 240, 1932.

The Villeneuve mine on lot 31, range L, about 20 miles north of Buckingham is in a large pegmatite body. It has been worked extensively for mica and feldspar and still presents plenty of clean rock exposure. Beryl has been listed among a variety of accessory minerals found in the dyke, which consists chiefly of coarse white microcline and albite with abundant muscovite and black tourmaline. No beryl was found by the writer in the exposed faces or in the dump material examined, but beryllium (less than 0.01 per cent) was reported on spectrographic analysis of a composite sample (GSC spectrographic laboratory).

(54) Wentworth Township, Argenteuil County, Quebec 31 G/16 (lat. 45°51′, long. 74°28′)

Reference: Osborne, F. F.; Lachute map-area, *Que. Bur. Mines,* Ann. Rept. 1936, pt. C, p. 25, 1937.

This locality is Laurel, Quebec, near which beryl and leucophane were reported to have been found (Financial Times, Feb. 10, 1939). Osborne stated that a number of beryl claims had been staked in the vicinity. He found no beryl but reported that beryllium was detected in "small amount" in vesuvianite from near Laurel.

(55) *Cartier Township, Joliette County, Quebec* *(lat. 45°19′, long. 73°48′)*

Reference: Adams, F. D.; p. 149 J, 1895.

According to Adams, one small crystal of beryl was observed in a granite vein 6 feet wide cutting garnetiferous gneiss on lot 33, range I. The vein consists of quartz, orthoclase, biotite, and muscovite, with tourmaline, apatite, and garnet. Two openings were made, each about 8 feet deep. The writer was unable to find the locality or any information locally concerning it, although some pegmatitic float was seen in the general area.

(56a) *Maisonneuve Mine, Maisonneuve Township, Berthier County, Quebec* *(lat. 46°46′, long. 74°04′)*

Reference: Ellsworth, H. V.; p. 248, 1932.

A pegmatite on lots 1 and 2, range II about 10 miles northwest of St. Michel des Saints was developed many years ago as a mica mine. Ellsworth reported the finding of one good-sized crystal of beryl in place on the surface of the dyke, which consists chiefly of microcline, quartz, iridescent plagioclase, muscovite, biotite, tourmaline, and garnet. Samarskite is a common accessory mineral.

In 1960, the dyke had been recently stripped for a length of about 450 feet east of the old shaft and a width of 120 feet (maximum). It cuts directly across the foliation of granitic gneiss. It consists of coarse pink perthite and graphic perthite-quartz intergrowth, minor peristerite feldspar, quartz, muscovite, biotite, and tourmaline. The writer did not find any beryl, though E. R. Rose (pers. comm.) reported some. Beryl was not found (less than .003 per cent) in spectrographic analyses of samples from the pegmatite or of biotite-garnet-rich foot-wall material near the old shaft. Both samples contained .01–0.1 per cent yttrium and ytterbium, however.

(56b) *Brassard Township, Berthier County, Quebec*

Reference: Vokes, F. M.; *Geol. Surv. Can.*, Map 1045 A-M2, 1958.

This beryllium locality listed by Vokes is in error, and actually refers to the Maisonneuve mine.

(57) *Rivière du Poste, Maskinonge County, Quebec 31 P/4* *(lat. 47°, long. 73°50′ (approx.)) 31 I/13*

References: Ells, K. W.; 1899, *Geol. Surv. Can.*, vol. 11, n.s. 1898, pt. J with map No. 665 (Three Rivers Sheet).
Evans, N. N.; Chrysoberyl from Canada, *Am. J. Sci.*, vol. XIX, ser. 4, p. 316, 1905.
Johnston, R. A. A.; 1915.

Chrysoberyl was identified by Evans in material supplied by F. D. Adams from a point "1 mile below the junction of streams from Lac Long and Lac Clair". Great dykes and veins of pegmatite consisting of quartz, orthoclase, and muscovite, with black tourmaline, are said to cross the river at that point. One of the "scarce, well-defined crystals" was reported to measure 1½ by 1¼ inches. There is some doubt, however, as to the locality from which this material came. The old map (GSC No. 665) shows a "Long Lake" and "Long Lake River" corresponding to Lac Villiers and Rivière Villiers on recent maps. These join at Lac Fourche, which is about 15 miles north of the junction of the Matawin River on map 665 (pre-reservoir). The area searched by the writer was from Lac Fourche to the rapids below Lac Dargie, a distance of about 5¼ miles. Only small irregular quartz and pegmatitic stringers were found cutting the granitic gneiss country rock. No tourmaline, muscovite, or beryllium minerals were seen.

Prominent outcrops of pegmatite and quartz occur in the bluffs near the southwest corner of Lac Dargie. A fairly prominent black mineral in these was identified by the Geological Survey's X-ray laboratory as "tremolite-actinolite". A composite sample from this locality was reported to contain "less than 0.01 per cent Be" (GSC spectrographic laboratory); the heavy fraction (+2.9) was reported to contain 0.005 per cent Be, the light fraction nil. Seven other composite samples from outcrops along the river and in nearby hills were reported to contain no Be.

(58) Lyonne Area, Lac-St-Jean County, Quebec 32 A/7
(lat. 48°25′, long. 72°40′)

Reference: Bray, J. G.; Que. Prel. Rept. 387, 1959.

Bray reported a little beryl in a narrow pegmatite dyke east of de-la-Cache Lake. A pegmatite stringer about a foot wide was found by the writer at the edge of the bank, but no beryl was seen.

(59) Taché Township, Chicoutimi County, Quebec 22 D/12
(lat. 48°36′, long. 71°30′)

Reference: Ellsworth, H. V.; p. 252, 1932.

Beryl was found by Ellsworth in dump material from a pegmatite body on lot 13, range V, which was worked for mica prior to 1923. Topaz was also found, in greater abundance than beryl. Both are greenish and in masses 2 or 3 inches in diameter. Cleavelandite feldspar is prominent, and a little amazonstone, solid hydrocarbon, and radioactive brownish material were noted.

The locality found by the writer is on the shore of a small lake that covers most of the dump material; the pegmatite is not exposed. Accessible loose material seen was composed mainly of cleavelandite, commonly with solid hydrocarbon in angular cavities between the plates. Green topaz is fairly abundant and a small amount of fluorite is present. Only one small possible beryl crystal was seen, and none was found in thin sections, but a composite sample, mainly of muscovite was found to contain beryllium ("less than .01 per cent") on spectrographic analysis (GSC spectrographic laboratory).

(60) *Lac Xavier Mica Mine, Harvey Township, Chicoutimi County, Quebec, 22 D/10*

(*lat. 48°31′, long. 70°51′ (approx.)*)

According to information on file at the Quebec Department of Mines, a few crystals of beryl were found on the dump of the Lac Xavier mica mine, where a dyke 5 to 7 feet wide that is exposed for 130 feet cut anorthosite, and consists of glassy quartz, pink feldspar, garnet, and muscovite.

The writer was directed to an old quarry somewhere around lot 13 in range V, where an open cut 125 feet long has been made in feldspar-quartz-muscovite pegmatite cutting anorthosite. No beryl was found, but a sample of muscovite was found to contain beryllium (less than .01 per cent) on spectrographic analysis (GSC spectrographic laboratory). About 100 yards away, a more recent pit and some recent trenching has been done on a perthite-quartz-biotite pegmatite with minor muscovite. No beryl was found and no beryllium reported on spectrographic analysis of mica.

(61a) *Kenogami Township, Chicoutimi County, Quebec 22 D/6*

(*lat. 48°21′, long. 71°22′ (approx.)*)

Reference: Ellsworth, H. V.; p. 254, 1932.

Two small greenish beryl crystals one-quarter inch in diameter and between 1 inch and 2 inches long were found by Ellsworth in a small pegmatite stringer on lot 1, range II.

(61b) *Jonquière Township, Chicoutimi County, Quebec*

Reference: Ellsworth, H. V.; p. 253, 1932.

Ellsworth investigated a reported beryl occurrence on lot 21, north range, but was unable to find any beryl in pegmatite examined in that vicinity.

(62) *Mine du Lac Pied des Monts, Lacoste (?) Township, Charlevoix County, Quebec*

(*lat. 47°46′, long. 70°24′ (approx.)*)

References: de Schmid, H. S.; Feldspar in Canada, *Canada Mines Br.* Pub. 401, p. 45, 1916.
Ellsworth, H. V.; p. 250, 1932.
Obalski, J.; Mining operations in the Province of Quebec for year 1901, *Que. Dept. Col. Mines,* p. 21 (French ed.) 1902.

According to Obalski a few small crystals of beryl were found in pegmatite that was worked for mica prior to 1908. De Schmid stated that the locality de Sales township was given in error by Obalski. It is on a hill on the north side of Lac Pied des Monts, about 17 miles northwest of La Malbaie. Ellsworth did not find any beryl or radioactive minerals. He expressed the opinion that a uraniferous mineral reported by Obalski was thucolite.

(63) McGie Mica Mine, Bergeronnes Township, Saguenay County, Quebec 22 B/5

References: Ellsworth, H. V.; p. 294, 1932.
Greig, E. W.; *Que. Dept. Mines,* Geol. Rept. 32, 1952.

Ellsworth reported that beryl crystals as much as 3 inches in diameter were found in a pegmatite dyke several hundred feet long and 15 to 75 feet wide. The occurrence is in block G on the north side of Lac Charlotte, in the north corner of the township. Greig reported beryl in pegmatites on both the McGie workings and the Simard property, south of the lake, near the southern tip of the large pegmatite extending from the McGie property. The pegmatites cut mafic gneiss and quartzite and are unzoned. They contain tourmaline, garnet, and apatite as well as commercial mica. Small crystals of beryl were reported to occur sparingly also in some old mica workings north of Tadoussac.

(64) Watshishu River, Drucourt and Johan Beetz Townships, Saguenay County, Quebec 12 L/5
(lat. 50°16′, long. 62°43′ (approx.))

Reference: Longley, W. W.; North shore of the St. Lawrence, Mingan to Aguanish, *Que. Dept. Mines,* Prel. Rept. 184, p. 14, 1944.

Longley has reported a few beryl crystals in pegmatite at the following three places:

1) On an island off the point on the southeast side of the entrance to Quetachu Bay.
2) On a small island near the west side of the bay at the mouth of Watshishu River.
3) On the tip of a long point forming the east side of the same bay.

Some of the pegmatites were worked for feldspar about 1924. K. G. Ellard Grubstake Syndicate held 26 claims in the area in 1958 and announced the discovery of six beryl occurrences, with crystals as much as 2 feet long (Northern Miner, Sept. 11, 1958).

Grenville (?) and Nain Provinces, Labrador

The Seal Lake deposit lies in an area of erratic ages on the projected borderline between Grenville and Nain structural provinces. The Nutak deposit is within the Nain structural province.

(65) Seal Lake, Labrador 13 L/8
(lat. 54°20′, long. 61°57′)

References: Evans, E. L., and Dujardin, R. A.; 1961.
Nickel, E. H.; 1962, 1963b.
Nickel, E. H., and Charette, D. J.; 1962a.
Nickel, E. H., Rowland, J. F., and Charette, D. J.; 1963.

Barylite and eudidymite occur in a zone of soda-rich paragneiss associated with syenitic intrusions in the Letitia Group of andesitic volcanic rocks near Ten

Mile Lake. Beryllium mineralization occurs also in heterogeneous migmatites and metasomatized shear zones. A limited amount of work has indicated 11,000 tons per vertical foot of material averaging 0.35–0.40 per cent BeO. Niobium is also present, together with minor zinc and rare-earth minerals (Evans, E.L., and Dujardin, R.A., 1961). The beryllium and other rare minerals are fine grained (about 0.2 mm), and occur in aggregates or lenses parallel with the gneissosity of the rock.

According to Nickel (1963b), niobium is present in niobophyllite (a new mineral) as well as pyrochlore. Other accessory minerals include sphalerite, galena, and apatite. The principal minerals in the paragneiss are albite and arfvedsonite, with lesser amounts of aeigirine-augite. Quartz is rare in the main zone but more common in metasomatized zones in syenite.

(66) *Nutak Island Area, Labrador*
(lat. 57°25′, long. 61°30′)

This occurrence, reported by British Newfoundland Explorations Ltd., is on a small island east of Nutak Island. It is presumably a beryl-bearing pegmatite.

Appalachian Region

The Appalachian region is chiefly underlain by Palaeozoic rocks deformed at the close of the Ordovician Period by the Taconic orogeny, and again in Devonian time by the Acadian orogeny. The granitic batholiths of New Brunswick and Nova Scotia, to which the beryllium occurrences of those provinces are presumably related, were intruded during the Acadian orogeny, and have an indicated age range of 300 to 400 million years. The granite to which the Indian Head, Newfoundland, occurrence is related is probably Precambrian, and related to the Grenville structural province in northwestern Newfoundland.

(67) *Burtts Corner Area, York County, New Brunswick 21 J/2*
(lat. 46°04′, long. 66°58′)

Reference: Poole, W. H., Burtts Corner (west half), York County, N.B., *Geol. Surv. Can.*, Map 7-1957, 1957.

Beryl occurs in small crystals with tourmaline and a little molybdenite in pegmatite stringers cutting granite, on a ridge about 1½ miles west of Zealand Station. One large fragment found by Poole contained about 25 per cent light bluish green beryl, but the source is unknown.

(68) *Burnt Hill Mine, York County, New Brunswick 21 J/10*
(lat. 46°33′, long. 66°50′)

References: Poole, W. H., Hayesville, *Geol. Surv. Can.*, Map 19-60, 1960.
Victor, I.; Burnt Hill wolframite deposit, New Brunswick, Canada; *Econ. Geol.*, vol. 52, No. 2, p. 149, 1957.

Beryl occurs with topaz, wolframite, molybdenite, minor cassiterite, and a variety of sulphide and other minerals in a high-temperature quartz vein at the

Burnt Hill mine, on the south side of Southwest Miramichi River near Burnt Hill Brook. It is 16 miles by road north of Maple Grove station and about 40 miles north of Fredericton. It was operated as a tungsten mine at least as recently as 1955, but was not operating in 1959 and the workings were inaccessible. The writer found beryl in a number of places in the dump material, characteristically appearing as radiating bursts of slender needles as much as 2 inches long, associated with quartz, wolframite, topaz, and molybdenite. Practically all the beryl was in fragments of vein material to which some schistose country rock was attached. It thus appears to be characteristically localized near the vein walls.

The deposit is in argillite and quartzite at the southern tip of a body of pink alaskitic muscovite-bearing granite, one of several bodies that may be younger than the larger masses of porphyritic Devonian(?) biotite granite. Samples of these taken by the writer and contributed by Poole were found to contain anomalous amounts of beryllium (34, 19, and 12 ppm compared with "less than 5 ppm") only where the granites are greisenized and cut by quartz veins. A little beryl has been found (Poole, W. H., pers. comm.) in a few such places in the map-area.

(69) Pabineau Lake, Gloucester County, New Bruswick
(lat. 47°30′, long. 65°46′)

References: Alcock, F. J.; Jacquet River and Tetagouche River map-areas, New Brunswick, *Geol. Surv. Can.*, Mem. 227, p. 39, 1941.
Skinner, R.; Bathurst, Gloucester and Restigouche counties, N.B., *Geol. Surv. Can.*, Paper 53-29, 1953.
Wright, W. J.; Molybdenum prospect at Pabineau Lake, Gloucester County, N.B., N.B. Dept. Lands and Mines, Paper 40-1, 1940.

Beryl occurs with molybdenite, as small crystals disseminated in granite, northwest of Pabineau Lake about 10 miles southwest of Bathurst. Bedrock is not exposed but granitic boulders are widespread in the vicinity. According to Wright, molybdenite was found at fifteen points in an area 1,300 by 400 feet and at five points in pits sunk to bedrock. In one trench beryl was found as sheaves of crystals a quarter inch across and as much as 3 inches long associated with quartz and molybdenite. Some development work was done prior to and during 1939.

The writer was unable to find any trenches at the locality shown on Map 53-29. Some specimen material containing molybdenite but no visible beryl indicated strong traces of beryllium spectrographically. One of Alcock's specimens (Survey Collection No. 7-20) contains a clump of green beryl and scattered crystals as much as a quarter inch long, as well as molybdenite. These specimens all consist of a mosaic of slightly altered potassic feldspar (partly perthitic, no microcline), somewhat fresher plagioclase, abundant quartz with undulant extinction, and minor biotite and muscovite. The beryl is fairly euhedral and associated with some clear non-undulant quartz, and may mark a miarolitic cavity. The texture does not suggest albitization or greisenization.

(70) *Square Lake, Queens County, New Brunswick 21 G/8 (lat. 45°26′, long. 66°23′)*

References: Smith, J. C.; 1961.
Wright, W. J.; *N.B. Dept. Mines,* Paper 40-3, 1940.

In this locality, about 2 miles southwest of Welsford, New Brunswick, Wright (1940) reported that "wolframite and molybdenite have been found at 17 points over an area of less than 7 square miles, but careful search has not revealed the presence of tin or radium-bearing minerals. The minerals occur in quartz veins and greisen cutting granite". Beryl has been reported in association with the mineralization (Smith, J. C., 1961). The writer did not find any beryl but a sample of quartz-muscovite-topaz-fluorite greisen was reported to contain 26 ppm Be (GSC spectrographic laboratory).

(71) *Brazil Lake, Yarmouth County, Nova Scotia 20 P/13 (lat. 43°59′, long. 65°59½′)*

Reference: Taylor, F. C.; *Geol. Surv. Can.,* Map 44-1960, 1960.

At a point about 2,500 feet southeast of Brazil Lake crossroads, a pegmatite dyke at least 16 feet wide and 70 feet in exposed length contains spodumene and an estimated 0.5 per cent beryl. Scattered float indicates that the dyke may extend 1,000 feet northward.

(72) *Jordan Falls Area, Shelburne County, Nova Scotia 20 P/14 (lat. 43°52′, long. 65°13′)*

References: Oldale, H. R.; 1959.
Taylor, F. C.; *Geol. Surv. Can.,* Map 44-1960, 1960.

Beryl is present in some abundance, along with a little tourmaline and molybdenite, in parts of a high-temperature quartz vein about half a mile east of a point 3 miles by road north of Jordan Falls. In 1959 about 100 feet of the vein was exposed by stripping and trenching; another short section was exposed about 50 feet southwest on strike. Towards the northeast end the dyke splits around a horse of country rock; the maximum thickness of vein material is about 4 feet. The quartz is glassy, in part rose-coloured, and has the laminated structure commonly seen in pegmatitic veins. No feldspar was seen, but muscovite occurs locally in stringers along the vein walls. The beryl is pale green and occurs in small crystals and clusters, and in shapeless masses and stringers nearly a foot long. Most of it is in the northeast part of the vein; it is perhaps more abundant near the vein walls. The vein cuts micaceous quartzite and averages 4 to 5 feet wide.

A little beryl was also reported (Oldale, 1959) in some pegmatite dykes along Roseway River north of Shelburne.

(73) *Port Mouton Area, Queens County, Nova Scotia 20 P/15 (lat. 43°49′ to 44°, long. 64°40′ to 64°54′)*

References: Oldale, H. R.; 1959.
Wright, J. O., and Oldale, H. R.; 1960.

Beryl has been found in pegmatites in several localities along a 17-mile strip of coast-line from Sandy Cove to Western Head; the occurrences are in granite near its contact with quartzites and schists of the Meguma Group. Perhaps the best showings are on a point on the west shore of the southern part of Mouton Island, where a number of pegmatite stringers as much as 4 feet thick occur in biotite granite in an area 300 feet long and from 60 to 120 feet wide. The pegmatite is composed of pink perthitic feldspar, in some places in rectangular prisms as much as 6 inches across, white featureless feldspar, darkish grey laminated quartz, and muscovite. The muscovite is fairly plentiful in intermittent pods, mostly in the central parts of the stringers. Some garnets more than an inch across were seen. Pale green to white beryl was noted in eight scattered localities, mostly in fairly rich but small pockets. In these, crystals and crystal aggregates as much as 2 inches across and commonly 2 to 3 inches long are found in and among quartz segregations, and alongside large perthite crystals.

At Sandy Cove, east of Port Hebert, numerous crystals an inch or more across were seen in two places in narrow quartz stringers that contain much muscovite. The exposed rock is a granite-pegmatite complex notable for plumose quartz-muscovite structures. Some nests of tourmaline were seen in intervening boulders. Some beryl was seen in pockets in adjoining pegmatite containing rectangular crystals of graphic granite. One boulder about a quarter mile northeast showed fifteen crystals in about 6 square feet of surface.

Beryl was seen also in stringers at Hunts Point Wharf, and was reported (F. C. Taylor, personal communication) at Western Head and in boulders at Summerville Beach. The occurrences were investigated in 1959 by a party of the Nova Scotia Department of Mines using an electronic detector (Wright and Oldale, 1960).

(74) *New Ross Area, Lunenburg County, Nova Scotia 21 A*
(lat. 44°¾′, long. 64°½′ (approx.))

References: Chester Basin Sheet, Map-sheet 87; *Geol. Surv. Can.*, Map Publ. No. 1981, 1924.
Douglas, G. V., and Campbell, C. O.; 1942.
Ellsworth, H. V.; 1932, p. 255.
Faribault, E. R.; Lunenburg County, Nova Scotia, *Geol. Surv. Can.*, Sum. Rept. 1907, p. 82.
New Ross Sheet, Map-sheet 86; *Geol. Surv. Can.*, Map. Publ. No. 2259, 1931.
Oldale, H. R.; 1959.
Taylor, F. C.; *Geol. Surv. Can.*, Map 40-1961, 1962.

North of New Ross, an anticlinal wedge of Meguma quartzite partly separates porphyritic biotite granite on the northwest from a large area in which similar granite has been in part intruded by medium-grained pinkish muscovite-bearing granite, and/or altered to it. The latter locally has pegmatitic and aplitic phases, areas of greisen and quartz veins, and occurrences of rare metals, tin, and molybdenum.

On Reeves Farm (lat. 44°43′, long. 64°31′), about ⅜ mile south of a point 3 miles by road west of New Ross, a small amount of beryl was found among a large variety of minerals in a small pegmatite body. The body was first worked about 1906 for quartz crystals and subsequently investigated as a tin occurrence. An old pit, now full of water, occupies the whole outcrop area of the pegmatite, about 30 feet long by 8 feet wide at its widest point at the southwest end. Faribault reported in 1907 that the pit was then 18 feet deep, 12 feet long, and 10 feet wide. The pegmatite is a segregation in granite and pinches out at both ends. Among the minerals reported are amblygonite, lepidolite, tourmaline, topaz, fluorite, monazite, and columbite-tantalite. The loose material now lying nearby comprises deeply weathered feldspar, quartz and muscovite. A number of large rough quartz crystals were seen near the pit. The writer found only one small beryl crystal and a few flakes of lepidolite in the dump material.

The so-called "Morley's Pegmatite" outcrops just east of the Mill Road near its junction with Highway 12, and is shown on the New Ross Sheet to extend along Mill Brook nearly to the Levy Road. A sample of massive red feldspar in contact with granite from the outcrop mentioned was reported to contain less than 0.01 per cent Be (GSC spectrographic laboratory). No beryl was seen. Oldale (1959) reported an anomalous beryllometer assay there. A heavy mineral separate was reported to contain no detectable beryllium.

A sample of muscovite-bearing granite east of Wallaback Lake was found to contain 11 ppm Be. Another near the Turner tin prospect contains 15 ppm. Beryllium was detected ("less than 5 ppm") in several other samples from the "muscovite granite" area. None was detected in two samples of porphyritic biotite granite from west and north of New Ross. A composite sample of the manganese veins that cut the biotite granite northwest of Wallaback Lake was reported to contain 32 ppm Be. All samples were analyzed in the Geological Survey's spectrographic laboratory.

(75) Pioneer Mine, Caribou Gold District, Halifax County, Nova Scotia 11 E/2 (lat. 45°03′, long. 62°57′)

References: Faribault, E. R.; Moose River Sheet, Map-Sheet 50; *Geol. Surv. Can.,* Map Publ. No. 624, 1898.
Phipson, T. L.; On the gold ore of Nova Scotia; *Chemical News,* Sept. 1, 1871.

With reference to specimens from the "Pioneer mine", Phipson reported 0.33 per cent glucina (beryllium oxide) in an analysis of "green schistose rock which accompanies the white quartz in the Caribou district". Alumina is reported separately but the detailed procedure is not described. The writer was unable to find any record or any local information as to the whereabouts of the Pioneer mine. The schistose wall-rock of the mine dumps seen by the writer is apparently all of low metamorphic grade, and the quartz is milky, commonly crystalline, and vuggy, unlike the "high-temperature" quartz normally associated with beryl.

(76) Georgeville, Antigonish County, Nova Scotia 11 E/16 (lat. 45°49′, long. 62°01′)

Reference: Gross, G. A.; Uranium deposits in Gaspé, New Brunswick, and Nova Scotia; *Geol. Surv. Can.,* Paper 57-2, p. 21, 1957.

One small crystal, thought to be beryl, was found by the writer near the waterline in a pegmatite dyke that is accessible only at low tide. The dyke is one of a number of irregular segregations in the granite that outcrops along the beach northwest of Georgeville. Some of these segregations are roughly zoned and some contain radioactive minerals.

(77) *Indian Head Area, St. Georges Bay, Newfoundland 12 B (lat. 48°32′, long. 58°29′)*

Reference: Johnson, H., *et al*; Contributions to the economic geology of Newfoundland; *Geol. Surv. Can.*, Bull. 27, p. 46, 1954.

Beryl was reported as an accessory mineral with tourmaline, zircon, uraninite, gummite, and magnetite in a single pegmatite body at a sharp bend in the highway south of Oxback Pond. The pegmatite is coarse grained, with crystals 8 or 10 inches across, and has a dominant graphic texture and large plates of biotite. Ordinary pegmatites are numerous in the area and some contain magnetite.

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