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REPORT No. 21

GEOLOGY OF CANADIAN LITHIUM DEPOSITS

Robert Mulligan

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OF CANADA

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By
Robert Mulligan

DEPARTMENT OF
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CANADA

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PREFACE

Lithium, the world's lightest metal, is a highly versatile element with a wide variety of specialized uses, as mineral, industrial compound, and metal. Deposits in the United States, Europe, and South Africa have been mined for more than half a century, but Canadian deposits, though known for nearly 50 years, have received little attention. Increased interest in lithium since World War II has resulted in much new information on Canadian occurrences, and commercial production was finally attained in 1955 with the opening of the Quebec Lithium Corporation mine and mill near Amos, Quebec.

The author here presents the first compilation of published and unpublished data on all known Canadian lithium deposits and main occurrences. Many of the deposits were examined by the author in 1956 and 1957.

J. M. HARRISON,
Director, Geological Survey of Canada.

OTTAWA, January 11, 1961.

Wirtschaftsgeologischer Bericht Nr. 21.

DIE GEOLOGIE DER KANADISCHEN LITHIUMLAGER

Von Robert Mulligan

Beschreibt die Geologie und die mineralischen Vorkommen von Lithiumlagern in Kanada. Die meisten Lager befinden sich in granitischen Pegmatiten der tektonischen Provinzen Oberer See und Sklavensee des Kanadischen Schilds. Das bedeutendste Lithiummineral in diesen Lagerstätten ist Spodumen.

Экономико-геологический рапорт нр. 21.

Геология канадских местонахождений лития.

Автор: Роберт Муллиган.

Здесь описываются геология и минеральное содержание местонахождений лития в Канаде. Большая часть местонахождений располагается в гранитных пегматитах структурных областей Верхнего и Невольнического озер Канадского Щита. Сподумен представляет из себя главный минерал лития в этих местонахождениях.

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GEOLOGY OF CANADIAN LITHIUM DEPOSITS

Abstract

Lithium occurrences are numerous in Archaean metasedimentary and metavolcanic belts of the Superior and Slave provinces of the Precambrian Shield. The chief districts are near Lacorne, Quebec (where Quebec Lithium Corporation is in production); Nipigon, Ontario; Winnipeg River, Manitoba; and Yellowknife, Northwest Territories. The Churchill province, excepting the borderline Herb Lake deposits, appears barren, and the Grenville nearly so. Occurrences are rare in the Appalachian Region and insignificant in the Cordillera.

All significant occurrences are granitic pegmatites containing spodumene and rarely, lepidolite, amblygonite, and petalite. Many deposits contain several million tons of ore grading 1.2 per cent or more Li_2O.

Most occurrences are 'unzoned' dykes with spodumene crystals a few inches long oriented perpendicular to, and uniformly distributed between, the walls. Others are well-zoned bodies with tourmaliniferous wall zones, beryl-bearing intermediate zones, and spodumene-rich inner zones, locally containing quartz-amblygonite 'cores' and lepidolite assemblages. In these the spodumene is commonly coarser grained and random in orientation. Most zoned pegmatites are gently dipping sheets, whereas most unzoned ones are steep-dipping.

Regional zoning is apparent in several districts, simple 'unzoned' spodumene pegmatites lying farther from the central parts of associated granite bodies than lithium-free berylliferous pegmatites and complex zoned lithium-beryllium pegmatites.

Spodumene orientation, mineral sequence, and internal and regional zoning relationships are attributed to cooling crystallization from fluid media emanating from associated granites. Contrasts between zoned and unzoned pegmatites are attributed to differences in degree of restriction in the crystallization systems, most commonly dependent on attitudes of the enclosing fractures.

Résumé

Les venues de lithium abondent dans les zones archéennes métasédimentaires et métavolcaniques de la province Supérieur et de la province des Esclaves du Bouclier précambrien. Les principales régions minières se trouvent: près de Lacorne (Québec) (Quebec Lithium Corporation); à Nipigon (Ontario); à Winnipeg River (Manitoba) et à Yellowknife (Territoires du Nord-Ouest). La province de Churchill (mis à part les gîtes de Herb Lake, aux confins de la province) semble stérile, et la province de Grenville presque autant. Les venues sont rares dans la région appalachienne et insignifiantes dans la Cordillère.

Toutes les venues d'importance renferment des pegmatites granitiques contenant du spodumène et, rarement, de la lépidolite, de l'amblygonite et de la pétalite. De nombreux gîtes contiennent des millions de tonnes de minerai à 1.2 p. 100 ou plus de Li_2O.

La plupart des venues présentent des dykes non zonés, où des cristaux de spodumène de quelques pouces de longueur sont uniformément distribués, perpendiculairement aux parois. D'autres montrent des massifs bien divisés en zones latérales tourmalinifères, de zones intermédiaires à béryl, et de zones internes riches en spodumène, renfermant par endroits des noyaux de quartz et d'amblygonite associés à la lépidolite. Dans ces massifs, le spodumène a habituellement

un grain plus gros et est orienté au hasard. La plupart des pegmatites zonées offrent l'aspect de nappes à faible pendage, alors que celles qui ne sont pas zonées présentent une pente raide.

Un zonage régional est manifeste dans plusieurs districts miniers, où les pegmatites non zonées à spodumène se trouvent plus loin de la partie centrale des massifs de granite associés que les pegmatites à béryllium et sans lithium et que les pegmatites zonées complexes à lithium et béryllium.

L'orientation du spodumène, la distribution des minéraux et les relations entre zonages interne et régional résultent de la cristallisation par refroidissement des émanations fluides venant des massifs granitiques associés. Les contrastes entre les pegmatites zonées et non zonées proviennent des différences des degrés de restriction dans les systèmes de cristallisation, le plus souvent dépendants de la position des fractures encaissantes.

Chapter I

INTRODUCTION

All the presently commercial sources of lithium in the world, except the evaporites at Searles Lake, California, are granitic pegmatite dykes containing one or more of the major lithium minerals: spodumene, amblygonite, lepidolite, and petalite.

Lithium is a highly versatile element, unique among metals in its lightness, and having a number of other outstanding physical and chemical properties. These are the basis of a wide variety of specialized uses, as mineral, industrial compound, and metal.

Lithium deposits have been mined in Europe, South Africa, and the United States for more than half a century and lithium compounds have long been used in pharmaceuticals, in the manufacture of special glasses, and for alkaline storage batteries. However, the main expansion in application and production has taken place during and after World War II, and consumption has increased, perhaps tenfold, since 1948.

Significant production in Canada so far has been entirely from one mine, that of Quebec Lithium Corporation, near Amos, Quebec. In 1955 this company began producing a spodumene concentrate that was until late in 1959, shipped to the United States under a contract with Lithium Corporation of America. On cancellation of the contract, production was suspended, but was resumed on a reduced scale in late 1960 to supply a new lithium chemicals plant.

Interest in lithium deposits in Canada mounted during 1950-1956 and diamond-drilling and surface work were carried out on numerous previously known and newly discovered deposits. Most deposits are in the Preissac-Lacorne district of Quebec (where Quebec Lithium Corporation is now in production), the Nipigon district of Ontario, the Cat Lake-Winnipeg River and Herb Lake districts of Manitoba, and the Yellowknife-Beaulieu district, Northwest Territories. Other major fields are the Dryden, Lac La Croix, and Root Lake districts of Ontario, and the East Braintree-West Hawk district of southeastern Manitoba. More recent discoveries are in the Falcon Lake and O'Sullivan Lake districts of northern Ontario, and the Lac Expanse and Assinica Lake areas of Quebec.

Three properties, besides Quebec Lithium, were opened up by shafts and some underground development in 1956 and 1957, but by the end of 1957, operations on all three were suspended due to lack of markets for lithium ores or concentrates. The property of Chemalloy Minerals Ltd. at Bernic Lake in southeastern Manitoba was, however, reopened in 1959 and minor shipments of lithium and other minerals were made in 1960.

Field Work and Acknowledgments

This report is based primarily on field work done in 1956 and 1957, during which the writer visited the major districts and most of the accessible minor fields in the Precambrian Shield.[1] A detailed survey of deposits was not possible however, and the information here is derived in large part from published descriptions, private reports, and personal communication with many geologists, engineers, and prospectors.

Many of the deposits have been described in publications of the Geological Survey, provincial mining departments, and the technical press (*see* References). Some of these accounts are much more comprehensive than those given here. These reports are, in the main, still generally available.

Special acknowledgment of information and courtesies in the field is gratefully made to J. F. Davies of the Manitoba Mines Branch, E. G. Pye of the Ontario Department of Mines, and M. Latulippe of the Quebec Department of Mines. These geologists have carried out detailed mapping in the most important districts and contributed substantially to our knowledge of the pegmatite deposits.

Among others who contributed valuable direct information or assistance are: A. Beauchemin and B. Karpoff (Quebec Lithium), V. O'Neill (Molybdenite Corporation), R. B. Rowe (Dow Chemicals), J. Walters (Jean Lake), Mr. Chisholm (Nama Creek), M. Wilson and J. Mosschuck (M.N.W.), G. B. Darling (Lun Echo), W. Leamy, S. Guimond, and J. R. Bridger (Continental Mining and Exploration), H. Johnson (Central Claims), J. Donner (Lithium Mines and Chemicals), J. J. Papineau (Contact Minerals), R. W. Hutchinson (American Metals), Ken Brown (Quebec Metallurgical Industries), Don Brown (Manitoba Mines Branch), J. C. McGlynn (Geological Survey—formerly at Yellowknife, now Ottawa), J. R. Woolgar (Affiliated Lithium), J. M. Symes (Green Bay), J. F. V. Millar (Belco Engineering), J. Nicholson (British Canadian Lithium Mines), and L. Dempster (Zig Zag Lake).

History

Lithium was first identified in petalite at Uto, Sweden, by Johann Auguste Arfwedson in 1817. For many years the only substantial use was in beverages; lithium salts were supposed to have some therapeutic value. In the latter part of the century the use of lepidolite in batches for special glasses became common practice. Mining of lepidolite at Pala, California, started about 1890. Spodumene was mined at the Etta mine in South Dakota in 1898, and this part of the Black Hills district remained the principal American source of lithium until the opening up of the King's Mountain, North Carolina deposits, about 1942.

[1] The manuscript was originally completed in 1958, but some additions and revisions were made up to June 1961. Descriptions of most properties are believed to be substantially up to date, although ownership of some properties may have changed since 1958, and recent exploration may have disclosed new information at a few.

Another early use of lithium was in Bahn metal, a bearing alloy used in German railways. Invention of the Edison alkaline storage battery provided an important new use. The main present commercial uses were developed during World War II and subsequently, including greatly expanded applications in the field of ceramics.

A lithium deposit at West Hawk Lake, Manitoba, was known about 1916. Better deposits were discovered and developed in the Winnipeg River district of Manitoba in 1924 and some small shipments were made. Zoning and other unusual features of these deposits were the subject of a special study and report by C. H. Stockwell (1932)[1] of the Geological Survey.

Lithium deposits in the Preissac-Lacorne district of Quebec and the Yellowknife-Beaulieu district, Northwest Territories, were studied and reported on in 1941 by G. W. H. Norman (1945) and A. W. Jolliffe (1944) respectively. In 1951 a systematic study of rare-element pegmatites in Canada was initiated by R. B. Rowe (1952, 1953a, 1956) of the Geological Survey, and the study of lithium deposits was resumed by the writer in 1956.

A great upsurge in interest in lithium deposits began about 1950 and culminated in the commencement of production by Quebec Lithium Corporation in 1955. Exploration and development remained active during 1956, but by the end of 1957 other operations were generally suspended, owing to current saturation of the United States market for ores and concentrates.

Physical and Chemical Properties

Lithium, the lightest metal and the lightest element that is solid at ordinary temperatures, is a member of the alkali metals group of the Periodic System. The group, comprising lithium, sodium, potassium, rubidium and caesium, is chemically coherent. All members form univalent positive ions, strongly basic hydroxides, and generally soluble and fairly volatile compounds. All are soft, ductile, silvery-white metals that oxidize rapidly in air and react freely with water. Lithium reacts less violently than potassium or sodium, and does not present an explosive hazard.

The compounds of this group of elements give distinctive flame colorations, which, however, vary widely in intensity. The pervasive and persistent yellow colour due to sodium easily masks the crimson of lithium and the more delicate colours of the other elements in most natural materials. The alkali metals are readily identified by characteristic lines in the visible spectrum whose relative intensity parallels that of the flame colours.

Lithium is much less abundant and less widely distributed (*see* Table III) than sodium or potassium, but much more than caesium. It is less abundant in terms of weight than rubidium, but higher in atomic abundance and occurs in higher concentrations.

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[1] Names and/or dates in parentheses refer to publications listed in the References.

Potassium and rubidium are measurably radioactive, lithium and sodium are not, although lithium has a number of short-lived isotopes, in addition to the relatively stable Li-7 and Li-6, nearly 93 and 7 per cent respectively, of natural lithium.

Although lithium occurs mainly in association with the other alkali metals, in some respects it behaves more like an alkaline earth, particularly magnesium, and lithium tends to substitute for magnesium in some ferromagnesian minerals. Thus it does not enter into silicates of the feldspar type as do sodium and potassium in abundance, but is either concentrated in the dark minerals or forms independent minerals such as spodumene, a silicate of the pyroxene type.

This is presumably due to the small ionic radius (and consequent low coordination number) of lithium—almost the same as magnesium, whose ion just fills the space between six oxygen ions. However, the requirement of electro-neutrality limits the conditions under which lithium can substitute for magnesium in silicate structures, and is a controlling factor in determining the distribution of lithium in minerals and rocks.

Table I lists important elementary data for the alkali metals and some of their common associates. The small size of the lithium ion and its high (for a univalent element) ionization potential—a measure of anion affinity—to a large extent govern both the natural mode of occurrence of lithium and its behaviour in many applications.

The physical properties listed in Table II are mainly of interest with respect to certain uses of metallic lithium and some of its compounds, in which its lightness, solid and liquid range, and high heat-capacity are of paramount importance.

Table I

Elementary Data, Alkali and Related Metals

	Al	Ca	Fe	Mg	Li	Na	K	Rb	Cs
Valence	+3	+2	+2, +3	+2	+1	+1	+1	+1	+1
Atomic Number	13	20	26	12	3	11	19	37	55
Atomic Weight	26.98	40.08	55.85	24.32	6.94	23.00	39.10	85.48	132.9
Principal Isotopes	....	....	....	....	7, 6	23	39, 41	85, 87	133
Ionic Radii	0.51	0.99	0.74(+2) 0.64(+3)	0.66	0.68[1]	0.97	1.33	1.47	1.67
Coordination Number	4-6	6-8	6	6	6[2]	6-8	10-12	10-12	12
Ionization Potential, volts[3]	28.3	11.87	16.24	15.03	5.39	5.12	4.34	4.18	3.89

[1] Based on Li-F distance (Ahrens, 1952, p. 157).

[2] Most natural minerals (four assumed in glass, *Foote Prints,* vol. 22, No. 2).

[3] From Ahrens (1952, p. 158) for valence state shown.

Table II

Physical Properties of Alkali Metals

	Li	Na	K	Rb	Cs	Reference
Specific Gravity (20°C)	0.534	0.972	0.859	1.525	1.903	
Melting Point (°C)	186	97.6	63.5	39.0	28.5	
Boiling Point (°C)	1336	877.5	759	696	670	
Specific Heat (cal/gm)	1.010	0.333	0.184			
at	186°C	100°	63°			
Heat of Fusion (cal/gm)	32.81	27.2	14.7	6.1	3.8	(*Foote Prints*, vol. 25, No. 1, p. 19)
Volumetric heat Capacity (cal/cc)	0.479 @ 100°	0.310 @ 100°	0.153 @ 63°			(*Foote Prints*, vol. 28, No. 2, p. 28)

Uses

The chief industrial applications of lithium compounds are in ceramics and lubricants. Lithium glasses, glazes, and enamels have many specialized and superior characteristics. Lithium greases have highly superior temperature-viscosity characteristics. Other common applications are in electrolytes of alkaline storage batteries, in air-conditioning and refrigeration systems, as fluxes in non-ferrous welding and brazing, in paint manufacture, in dyes, in the synthesis of some pharmaceutical products, in lens coatings, and in special dry-cell batteries.

Lithium hydride provides a lightweight source of readily available hydrogen, and lithium hydroxide a light non-hygroscopic and efficient absorber of carbon dioxide.

In ceramics lithium is a versatile and widely used ingredient in glasses, glazes, enamels, and other ceramic bodies. It is used both in the form of prepared compounds and as natural minerals. Lepidolite has long been used in glass batches for special purposes, and petalite is particularly valuable in the fabrication of certain ceramic bodies. Amblygonite is used in opal glass and as an alumina-phosphate source in porcelain enamels.

The principal properties of lithium as a constituent of glasses, glazes and enamels are functions of the small size and high electrostatic field, further magnified by directional effects, of the lithium ion[1]. This is reflected in strong fluxing effect, lowered viscosity and extension of fields of glass formation. Substitution of lithium for sodium on a molecular basis also has a contracting or tightening effect, which contributes to an increase in hardness and refractive index, and a decrease in thermal expansion of glasses and glazes. The fluxing power of lithia also makes possible a reduction of total alkali, thus further lowering the coefficient of expansion (*Foote Prints,* vol. 22, No. 2, p. 1-13). Transparency to ultraviolet light, and high electrical resistance are other properties of certain glasses made possible by the use of lithium (Haw, 1955, p. 4). Decreased water solubility and increased resist-

[1] A coordination number of 4, as against 6 for natural lithium minerals, is suggested by the behaviour of the lithium ion in some types of glass.

ance to corrosion by acids and alkalies also result from the use of lithia in glass, glazes, and enamels. Ceramic bodies of low or even negative thermal expansion, with attendant high thermal shock resistance, are made possible by utilizing the thermal properties of beta-spodumene and eucryptite. The applicability of petalite to these is its greatest asset. In contrast, lithium is also used in porcelain enamel formulations in which it gives unusually high thermal expansion to match the expansion of the base metals on which such enamels are used.

The use of lithium in greases is based on the water-insolubility, gel-forming, and lubricity characteristics of lithium soaps of fatty acids, as compared with those of other metallic soaps used for this purpose. Formulations using lithium soaps have minimum change in consistency with wide variations in temperature, and do not emulsify with water. Thus they provide efficient lubrication under conditions in which other greases fail to do so. The inherent lubricity of lithium soaps themselves is also a basic factor in their application to powder metallurgy and in the fabrication of vinyl plastics (*Foote Prints,* vol. 25, No. 1, p. 7-8).

Lithium metal is used as a scavenger and grain-refining agent in non-ferrous metallurgy. New lightweight alloys of lithium with aluminum and magnesium have superior strength, ductility and heat resistance. Alloys of lithium with several other metals are under development.

Lithium as a catalyst facilitates the synthesis of polymers closely resembling natural rubber. Due to its high specific heat and boiling point, lithium metal has potential value as a heat-exchanger medium, but is highly corrosive in the liquid form.

In the field of nuclear energy lithium has a dual role. The bombardment of the isotope Li-6 by neutrons produces tritium, a reported constituent of the hydrogen bomb. In contrast to the high neutron cross-section of Li-6, Li-7 has one of the lowest. This is presumably one basis of its potential application as a heat-transfer agent in fission reactors. In the form of the hydride, lithium has a potential use as a high-energy lightweight fuel.

World Resources and Production

The main lithium producing areas of the world, exclusive of the U.S.S.R., are the United States and southern Africa. Canada was a major exporter from 1956 to 1959. Others are in South America, Oceania and Europe.

Canada

Production of lithium minerals in Canada virtually began with the opening of the mill of Quebec Lithium Corporation in 1955. Small amounts of lepidolite and amblygonite were mined in the Bernic Lake-Winnipeg River district after their discovery in 1924, and amblygonite was recovered and small shipments reported from two deposits in the Yellowknife-Beaulieu district between 1945 and 1955. Production of spodumene ore at Quebec Lithium was at the rate of about 1,000 tons per day from 1956 to 1959, during which time the concentrate was shipped to the United States under a contract with Lithium Corporation of America. On cancellation of the contract in late 1959, production was suspended, but resumed on a reduced scale in late 1960 to supply a new lithium chemicals plant.

At three other properties—Nama Creek in the Nipigon district, Lithium Corporation of Canada at Cat Lake, and Chemalloy (formerly called Montgary) at Bernic Lake—shafts were sunk and underground development work commenced, but by 1957 operations were suspended at all three, due to lack of markets. At the Chemalloy property, development work was resumed in 1959 and some trial shipments, chiefly of caesium ore, were made in 1960.

Canadian production, aside from the few tons shipped from Bernic Lake, Winnipeg River, and the Yellowknife district, has been entirely from the property of Quebec Lithium Corporation, as follows:

Year	*Li_2O (pounds)*	*Approximate Value at $11.00 per Unit Li_2O*
1955	114,376	$63 thousand
1956	4.8 million	$2.63 million
1957	5.1 million	$2.94 million
1958	3.8 million	$2.09 million
1959	2.5 million	$1.37 million

No official estimate of total resources has been made. The relatively few published reserves listed by the writer (Table VI) total 46.9 million tons of material grading higher than 1 per cent Li_2O.

United States of America

Most of the lithium produced in the United States until recently came from the southern Black Hills of South Dakota, in the area including the towns of Pringle, Keystone, and Custer. Spodumene, lepidolite, amblygonite, and small quantities of other lithium minerals have been mined from numerous pegmatites in this area for many years. More important deposits occur in North Carolina, in an area extending from a point just east of Lincolnton, southwest to a point near Grover on the state line. This area is roughly 25 miles long, with a maximum width of about 2 miles, and generally is referred to as the "Kings Mountain" district. Spodumene-bearing pegmatites occur in this area. Another important source of lithium is the brine of Searles Lake, California, which contains a small percentage of lithiums salts.

Other deposits of various lithium minerals are known in San Diego county, California (principally amblygonite and lepidolite); at the Harding mine in northern New Mexico (lepidolite and spodumene); in Gunnison and Fremont counties, Colorado (lepidolite); in Fremont county, Wyoming (lepidolite, amblygonite, and petalite); and in Connecticut, Maine, and Massachusetts.

Lithium minerals have been mined in the United States since 1889. Mining of lepidolite at the Stewart mine, Pala, California, had begun by 1892; amblygonite by 1902. Spodumene was first mined in 1898 at the Etta mine, Keystone, South

Dakota. From 1921 to 1928 the chief producer was the Harding mine, Taos county, New Mexico, where spodumene-lepidolite concentrates were produced. Recovery of lithium from brine at Searles Lake, California, began in 1938. With the development of new ore-dressing techniques during the war years (1939-1945), the spodumene deposits in the Kings Mountain area, North Carolina, began to be exploited. Since 1951 this area has been a major source. Lepidolite has also been produced in Gunnison county, Colorado.

Recorded production in the United States up to 1954[1] (partly estimated) is listed in the following table (after Browning, 1958).

Year	Li_2O (short tons)	$ Value
1935-39 (average)	88	48,280
1945-49 (average)	312	259,457
1950	747	579,922
1951	956	896,000
1952	1,088	1,052,000
1953	1,767	2,134,000
1954	2,459	3,126,000

The main operators in 1959 were (Schreck, 1959, p. 1):

Company	Mines	Imports from
1. Foote Mineral Company	Kings Mountain, N.C.	
2. Lithium Corporation of America	Kings Mountain, N.C.	Quebec Lithium Corporation (spodumene)
3. American Potash and Chemical Corporation	Searles Lake, Cal.	
American Lithium Chemicals, Incorporated	———	Southern Rhodesia (lepidolite)
4. Maywood Chemical Works	South Dakota	

The domestic reserves were estimated (Norton and Schlegal, 1955, p. 343) at 14,400,000 units indicated and 138,800,000 units inferred, Li_2O. More recently, Raynor (Canadian Institute of Mining and Metallurgy, Annual Meeting 1956) estimated the reserves in North Carolina alone at 35,000,000 tons, averaging 1.35 per cent Li_2O.

Other Countries

Yearly production of lithium minerals, in short tons, from some countries outside of North America is listed in the following table (after Schreck, 1959):

[1] The latest year for which figures are available.

Country	Mineral Produced	1955	1956	1957	1958	1959
South America:						
Argentina	Lithium minerals	110	165	22	186	(1)
Brazil	Spodumene (exports)	1,047	...	...	160	(2)500
	Amblygonite (exports)	789	...	552	...	(2)900
Europe:						
Portugal	Amblygonite	4	...	...	...	...
Spain	Amblygonite	125	57	7	...	...
Africa:						
Belgian Congo (includes Ruanda-Urundi)	Amblygonite	1,491	1,996	2,317	11	(1)
	Spodumene (exports)	28	72	1	...	...
Mozambique	Lepidolite	...	1,105	379	96	99
	Amblygonite	...	39	...	...	...
Rhodesia and Nyasaland (Federation of)	Eucryptite	12	...	56	398	
	Amblygonite	180	646	122	1,835	
Southern Rhodesia	Lepidolite	57,714	84,599	93,545	64,699	(1)
	Petalite	24,210	13,524	9,934	13,166	
	Spodumene	50	4,445	5,599	5,238	
South-West Africa	Amblygonite	1,414	831	535	534	242
	Lepidolite	1,832	1,139	882	1,043	2,168
	Petalite	5,278	3,675	5,325	7,405	2,787
Uganda	Amblygonite	...	...	6	...	...
Union of South Africa	Amblygonite	426	713	30	...	10
Oceania: Australia	Spodumene	4	...	...	...	...
	Petalite	...	...	...	76	...

(1) Data not available.
(2) Estimate.

Bikita Minerals, Limited, in Southern Rhodesia, Southwest African Mines Limited in S.W. Africa, and Minetain in Belgian Congo were among the chief African producers. Occurrences are known in several African countries besides those listed.

Australia has deposits near Pelgangoora, 60 miles southeast of Port Hidland, Western Australia. Occurrences are known in Hong Kong and Malaya.

Russia is reported to have lithium deposits in the Kalbin Range, in the western part of the Altai Mountains. Deposits have been mined in Sweden, Germany, France and Czechoslovakia.

Consumption, Prices and Economic Outlook

The chief importers of African lithium minerals, mainly lepidolite, amblygonite and petalite, in 1958 and 1959 were: United States, United Kingdom, West Germany, Netherlands, Japan, Belgium, France, and Italy.

Consumption of lithium compounds in the United States in 1956, in thousands of pounds lithium-carbonate equivalent, was, according to various estimates (Schreck, 1960):

Ceramics	2,300 – 5,000
Lubricating grease	3,000 – 3,500
Aluminum welding and brazing	250 – 1,520
Alkaline storage batteries	250 – 650
Air conditioning and refrigeration	400 – 1,500
Pharmaceuticals	250 – 500
Defence	1,730 – 20,000

Prices paid for lithium minerals are subject to negotiation and no recent figures are available. The following, given by Schreck (1960), are prices quoted in *Engineering and Mining Journal,* September, 1955: spodumene or lepidolite, $11-12 per short-ton unit; petalite, $11 per short-ton unit; and amblygonite $60-75 per short ton. The contract price established for Quebec Lithium Corporation concentrates shipped to Lithium Corporation of America was $11 per unit for 165 tons per day, grading not less than 4½ per cent Li_2O. It is generally supposed that any future contracts will be at considerably lower prices.

The current prices of lithium carbonate and lithium hydroxide, the principal basic compounds, are about 67 and 72 cents a pound respectively (Schreck, 1960). Lithium metal, 99.5 per cent pure, was quoted at $9 to $11 a pound in "Metal and Mineral Markets" of *Engineering and Mining Journal.*

There is no U.S. tariff on lithium minerals, but lithium compounds are dutiable at 12½ per cent and lithium metal at 25 per cent *ad valorem* (Schreck, 1960).

Little can be said regarding the economic outlook for lithium, since authoritative up-to-date figures for production and consumption in the United States, the chief market, seem to be impossible to obtain. Estimates vary widely and official figures are too old for prediction purposes by the time they are published. Some idea of the trend in United States consumption up to 1954 may be had from the mine production figures (see foregoing section "World Resources and Production"). However, it would appear that reserves and plant capacity have outstripped current demand.

A complicating factor in the market situation is the effect of United States Government purchases of lithium compounds (terminated in 1959). It is commonly supposed that Li-6 depleted compounds available to the industrial market after removal of Li-6 may fulfill a major part of the industrial requirements for lithium.

These factors, and the high cost of material at current rates of production, result in a limited demand, compared with the available supply. No open market yet exists for lithium ores, and production quantities and prices are fixed by individual contracts. However, in view of the great increase in consumption since 1948 and the continuing development of new uses, there is every reason to expect a continuing expansion, with attendant cost benefits resulting from quantity production.

There are very large known reserves in Canada of spodumene ore comparable in tonnage and grade to those being developed elsewhere. However, only those deposits close to large population centres or convenient to rail or seaway and Great Lakes transport and other facilities, can be considered potential producers at present. Three properties, besides Quebec Lithium, have been opened up by shafts and underground development, but only Quebec Lithium has been able to obtain a contract with American buyers. Such a contract has appeared to be the only justifiable economic basis for building a mill and going into production.

Other lithium minerals, especially petalite and amblygonite, might be marketable if found in deposits of sufficient size and grade to be economically recoverable.

A primary lithium chemicals plant was built by Quebec Lithium Corporation at the mine site in 1960. It was scheduled to produce, initially, 12,000 pounds per day of lithium carbonate from 50 tons of spodumene concentrate.

Technology

Hand-sorting of lithium ores, particularly for amblygonite, petalite, and lepidolite is believed to be the most common, if not the only current concentration practice in southern African countries, except perhaps the Belgian Congo. It was until recently carried on in some deposits in the Black Hills, and would appear to be economically competitive for very coarse material.

Flotation methods are, however, standard for most spodumene deposits now being worked. The methods and equipment are similar to those used for sulphide ores. Spodumene may either be activated and selectively floated, or depressed and recovered as underflow. The latter is said to be the practice at Foote Mineral's Kings Mountain mill. The practice at the Quebec Lithium plant has not been made public. Recoveries of up to 94 per cent and grades up to 5.5 per cent Li_2O have been claimed by Quebec Lithium. Ore dressing tests on a number of Canadian lithium ores have been carried out by the Mines Branch, Department of Mines and Technical Surveys, and reports on these investigations are published by that body. Lepidolite, also, has been concentrated by flotation in Colorado.

In the conversion of lithium minerals to industrial compounds, two principal processes are in use: the sulphuric acid process and the basic (or lime) process. In the former, spodumene concentrate or ore is heated above approximately 1,800°F to convert it to the beta form. The calcine is then reacted with sulphuric acid, and lithium becomes available as the soluble sulphate. The resultant solutions are purified and the lithium generally precipitated out as the carbonate. In the lime process, spodumene (or other lithium ore) and limestone are calcined together to form a clinker that is leached in water after grinding and the lithium is freed as a hydroxide. It is recovered by evaporating the excess water and crystallizing the hydroxide as a monohydrate. Of course, all other lithium compounds can be made from either the carbonate or the hydroxide. The latter is understood to be the process used by Foote Mineral Company, and the former by Lithium Corporation of America.

Reduction to lithium metal is accomplished by electrolysis of the fused chloride using a bright iron cathode and a graphite anode. When lithium metal over 98 per cent pure is required it must be refluxed in vacuum to drive off sodium and barium (Eigo *et al.*, 1955, p. 87). Commercial lithium metal contains 98.5 per cent Li.

Chapter II

GEOCHEMISTRY AND MINERALOGY

Geochemical Distribution

Lithium is a minor constituent in the atmosphere of the sun and some stars. It occurs in some abundance (5 to 300 ppm, according to reports) in meteoric silicates. In geochemical terminology Li is classed as a lithiophile element (Green, 1953), that is, it forms dominantly ionic bonds and occurs predominantly with the common rock-forming minerals of the lithosphere or outer crust of the earth. Thus, it is rarely associated with the heavy sulphide-forming metals in metalliferous veins.

The average lithium content of rocks is 65 ppm in igneous rocks and somewhat less in sedimentary rocks (Table III).

Table III

Relative Abundance Data, Alkali and Related Metals (in ppm)

(after Green, 1953)

	Ca	Fe	Mg	Li	Na	K	Rb	Cs
Igneous	36,300	50,000	20,900	65	28,300	27,000	350	7
Sandstone	39,500	9,900	7,100	17	3,300	11,000	273?	—
Shale	22,300	47,300	14,800	46	9,700	27,000	283	7.6
Limestone	304,500	4,000	47,700	26	370		0	
Ocean	400	.002	1,272	.1	10,500	380	.2	.002
Transfer[1] (per cent)	1.8	.00007	10	.3	62	2.4	.1	.05
Cosmic	38.3	639	362	.012	20	2.34	.022	.003
Meteoric sulphide		611,000						
Meteoric iron	500	907,800	32					
Meteoric silicate	19,700	156,400	158,200	300	7,790	1,990	9	0.1

[1] Abundance in ocean relative to calculated total supplied.

However, estimates vary rather widely; Horstman (1957, p. 3) reports averages of 29 ppm for igneous and 53 ppm for sedimentary rocks. Economically important concentrations are almost entirely in granitic pegmatites and closely associated with granitic bodies, so are counted with the igneous rocks. The oceanic concentration and transfer percentage are both seen to be low; it follows that lithium is concentrated in the products of weathering, particularly in the clay minerals, which bulk largely in shales. In sandstones, limestones, cherts, and laterites, for example, lithium occurs chiefly in impurities, specifically the clay fractions.

The clay minerals, kaolinite and montmorillonite, contain statistically more Li than do granitic rocks (Horstman, 1957, p. 6); and hectorite, a member of the montmorillonite group that occurs at Hector, California, contains about 1 per cent lithia.

Thermal and mineral waters often contain notable amounts of lithium, presumably leached from rocks penetrated (Rankama and Sahama, 1950, p. 428). Evaporites contain lithium in low concentration, and lithium recovered from the brines at Searles Lake, California, makes up a substantial part of the domestic production.

Lithium is concentrated in the ash of certain coals and in the mineral constituents of some plants.

Distribution in Igneous Rocks

Lithium is listed (Rankama and Sahama, 1950, p. 42) as sixteenth in atomic abundance in igneous rocks. In ordinary igneous and metamorphic rocks the small amount of lithium contained is distributed among the ferromagnesian minerals: biotite, amphibole, and pyroxene. On this basis, mafic rocks formed at relatively high temperatures might be expected to contain more lithium than granitic rocks. In fact, there is not much difference statistically, between averages for granite and for gabbro. However, the lithium-to-magnesium ratio in igneous rocks shows a decided increase through the series from gabbro to granite. This suggests that lithium enters, to any appreciable extent, only into those ferromagnesian minerals that are formed in the late stages of a falling-temperature differentiation sequence. The relative scarcity of such minerals in the late stages, and the limited degree of substitution possible in them result in the formation of independent lithium minerals wherever the lithium concentration in the final fluid phase reaches a sufficient value. This is the normal mode of occurrence of lithium in granite pegmatites.

Physical-Chemical Considerations

The main physical-chemical factor governing the terrestrial distribution of lithium is its small ionic radius, in conjunction with its ionization potential (*see* Table I). The radius is about 30 per cent less than that of sodium, the next smallest alkali metal; hence only limited substitution of lithium for other monovalent cations can take place. Thus alkali feldspars, in which most of the common monovalent alkaline metals are concentrated, contain lithium only in minute quantities.

Lithium does replace sodium to an appreciable extent in nepheline syenite (Goldschmidt, 1954, p. 133), and a compound analogous to feldspar in composition has been produced artificially (see next section—"Mineralogy").

Of the other major cations of rock-forming minerals only the divalent Mg and Fe, the trivalent Al (and Fe), and the tetravalent Ti have closely similar radii. Because of its relatively low charge, monovalent Li is virtually prevented from substituting for these cations in the strongly bonded crystals that are stable under high-temperature conditions. With falling temperatures, the resulting increase in ionic concentration of Li and decrease in that of Mg and Fe favour substitution for these elements, with the formation of more complex mineral structures. Thus Li appears in substantial concentration in micas and some alkaline amphiboles that are stable at comparatively low thermal levels.

In the presence of high lithium concentration it seems reasonable to suppose that a simple lithium silicate of the pyroxene type, as spodumene is, would form fairly early in a falling-temperature crystallization sequence, the minor remaining Mg and Fe tending to be incorporated in the dominantly-lithium-controlled structure. At somewhat lower temperatures in the presence of phosphorus, fluorine, and hydroxyl, lithium tends to combine with these 'volatile constituents', whose concentration is taken to mark the latest stages of magmatic differentiation.

Something of the effect of metamorphism on lithium distribution is suggested from a study by Grout (quoted in Horstman, 1957, p. 7). A sharp drop was found in lithium content between shale and shale inclusions at the contact of a granitic intrusion at Dewey, Montana, although inclusions near the centre of the batholith are relatively enriched. The inference is that the lithium ion is readily driven out of heated crystal structures in such rocks.

At the low-energy levels of weathering conditions, substitution of Li for major elements would not be expected unless ionic radii and electrostatic charge requirements are closely satisfied. As a small ion with low valence, Li is not readily adsorbed in exchangeable positions but must enter crystal structures for retention. It has been suggested (Horstman, 1957, p. 7) that in kaolinite a charge deficiency resulting from the entry of some Mg into vacant octahedral Al positions would favour entry of the monovalent six-coordinated lithium ion. Montmorillonite contains appreciable amounts of Mg replacing octahedrally-coordinated Al, and concomitant substitution of lithium would appear feasible.

Mineralogy

The chief lithium minerals and the essential rock minerals with which they are associated in pegmatite dykes are listed in Table IV, which summarizes their main physical properties. These lithium minerals are listed in approximate order of abundance, and are the only ones known to occur in significant quantities in Canada. Spodumene, amblygonite and lepidolite are the important ore minerals of pegmatitic lithium deposits in the United States of America and, with the addition of petalite, in the world.

Lithium occurs also in saline deposits and is recovered from the evaporites at Searles Lake, California. Some clays, notably that at Hector, California, contain significant amounts of lithium.

Rare lithium-bearing mica and amphibole from the wall-rocks of lithium pegmatites may be considered as metamorphic minerals.

Some lithium silicates of mineralogical interest have been produced artificially.

Table IV

Summary of Mineralogical Data

Most Common Lithium Minerals	Ideal Formula	Theoretical or Maximum Per Cent Li_2O	Usual Form and Habit	Usual Colour	Hardness	Specific Gravity	Fusibility
Spodumene	$Li_2O.\ Al_2O_3.\ 4SiO_2$	8.4	long prismatic, excellent cleavages parallel to length	green, white	6.5-7	3.17	3.5
Amblygonite (including montebrasite)	$2Li(OH, F).\ Al_2O_3.\ P_2O_5$	10.1	subequidimensional masses; 1 good, 1 poor cleavage at 75 degrees	white, grey	6	3.0-3.1	2
Lepidolite	$K(Li, Al, Fe)_3(Si, Al)_4O_{10}(OH, F)_2$	3.3-7.7	micaceous	lilac	2.5-4	2.8-3.3	2-2.5
Zinnwaldite	Iron-rich variety of lepidolite	3.3-5	curvilamellar, micaceous	purplish, brownish grey			
Other lithia micas		generally less than 1		pale lilac, yellowish, greenish			
Petalite	$Li_2O.\ Al_2O_3.\ 8SiO_2$	4.9	massive, pronounced lamellar habit	grey	6.5	2.4	5
Triphylite-lithiophilite	$Li_2O.\ 2(Fe, Mn)O.\ P_2O_5$	9.05	cleavable masses	greenish grey to dark purple	4-5	3.5	1.5
Rock Minerals							
Potash feldspar			1 good, 1 fair cleavage, at near 90 degrees	usually pink	6-6.5	2.5-2.6	5
Albite feldspar				usually white	6-6.5	2.62	4
Albite feldspar, variety: cleavelandite			radiating platy masses	white or pink			
Quartz			massive, no cleavage	colourless, grey translucent or white	7	2.65-2.66	infusible

Major Pegmatitic Lithium Minerals

Spodumene: Li Al $(SiO_3)_2$

Form: monoclinic, having the single-chain structure of the pyroxene group. The type structure is that of diopside but is slightly distorted due to the smallness of the Li ion. The c-axis is the same, presumably fixed by the SiO_3 chain. Li and Al are both surrounded by six oxygen ions (Bragg, 1937). *Cleavages:* prismatic perfect, also separation parallel to front pinacoid, splintery fracture. Generally in acute-edged long blades, also lamellar; terminal faces rare but square prisms not uncommon in coarse crystals, some of which are more than 40 feet long in South Dakota. *Colour:* green, buff, grey, white; gem varieties are green (hiddenite) or lilac-coloured (Kunzite). *Composition:* lithium aluminum silicate. Commonly contains Na and K, also Fe, Ca, Mg, Mn, especially in coloured varieties. Commonly intergrown with and includes quartz. *Analyses* (per cent Li_2O):

Locality	Li_2O	Analyst	Reference
Ontario Lithium	7.4		Pye (1956)
Quebec Lithium	6.85		Browning (1958)
	7.96		Browning (1958)
Silverleaf (Bear), Man.	6.4	R. J. C. Fabry	Ellsworth (1932)
Ontario Lithium	6.94	J. A. Maxwell	GSC Anal. Chem. Sec., Lab. No. A504
Echo Group, N.W.T.	7.74	J. A. Maxwell	GSC Anal. Chem. Sec., Lab. No. A505

Alteration: to pseudomorphous pale greenish or yellowish low-lithia micas, to clay minerals or to dark green or brown woody masses; to albite and eucryptite at Branchville, Conn. *Inversion:* to B-spodumene with incongruent melting at 690°C. *Diagnostic properties:* form, parallel habit, cleavage, splintery fracture, alteration, specific gravity. In flame it swells, throwing out fine branches and giving characteristic crimson flame coloration. Yields clear or white glass.

Amblygonite: Li Al PO_4 (F, OH)

Form: triclinic pinacoidal; subhedral crystals rarer than sub-equidimensional rounded masses and irregular angular forms. *Cleavage:* one perfect, two secondary, rarely good, intersect with the perfect cleavage at 75 degrees giving a stepped or 'rough' surface. *Twinning:* polysynthetic, yielding fine striations, common in Yellowknife-Beaulieu. *Lustre:* vitreous to greasy or pearly. *Colour:* white; grey in Yellowknife-Beaulieu, 'bluish' in New Ross. *Composition:* cell contents — Li_2 Al_2 $(PO_4)_2$ $(F, OH)_2$ (Dana and Dana, 1951, p. 823). The hydroxyl end of the series is sometimes called montebrasite. Contains variable amounts of Na. *Analyses* (per cent Li_2O):

Locality	Li_2O	Analyst	Reference
Theoretical	10.1		
Silverleaf (Bear), Man.	8.20	R. J. C. Fabry	Ellsworth (1932)
New Ross, N.S.	7.45	E. W. Todd	Ellsworth (1932)
Bernic Lake east, Man.	9.71	S. Courville	GSC Anal. Chem. Sec., Lab. No. A281
Montgary, Man.	10.00	J. A. Maxwell	GSC Anal. Chem. Sec., Lab. No. A508
Moose No. 2, N.W.T.	9.57	J. A. Maxwell	GSC Anal. Chem. Sec., Lab. No. A507

Alteration: coating commonly pink (Bernic Lake – Winnipeg River), grey micaceous (Yellowknife-Beaulieu). *Tests:* fuses easily, commonly with intumescence, yielding crimson flame and white bead. Staining test yielding yellow ammonium phospho-molybdate coating in hot solution of 5 gm NH_4 MoO_4, 100 cc water, 35 ml concentrated HNO_3 (Hosking, 1957, p. 275) found effective on Bernic Lake material.

Lepidolite, Zinnwaldite, and other Lithia Micas

Form: complex — monoclinic, triclinic, pseudohexagonal, perfect cleavage parallel to base. In part curvilamellar habit in Cat Lake – Winnipeg River, yielding medium to coarse tapering, ideally conical aggregates, but most commonly in aggregates of fine random scales. *Colour:* lilac characteristic, varying to steel-grey or brownish, especially in zinnwaldite type. Low lithia micas are pale green or yellow. *Composition:* variable according to a general formula —

$$K_2\ (Li_{1-4}\ Fe_{0-4}\ Al_{1-3})\ (Al_{0-2}\ Si_{6-8})\ F_4\ O_{20}$$

(based on Winchell, 1951, p. 370). The small lithium ion cannot substitute for K in the large spaces between the double sheets of micas; instead, it substitutes for aluminum in the central layers of the sheets.

Variations in structural type correspond with variations in lithia percentage. Most lithia micas contain less than 5.5 per cent Li_2O, but an assay of 7.26 per cent has been reported (Levinson, 1953). The theoretical maximum is 7.74 per cent. Iron-rich varieties, commonly classed as zinnwaldite, generally carry less lithia than iron-poor varieties. Biotite may also have an appreciable content of lithium (*see* under "Metamorphic Minerals", page 21). Some analyses are given in Table V.

Table V
Analyses of Lithia Micas

Li_2O	Fe Ox	MgO	MnO	Al_2O_3	SiO_2	K_2O	Na_2O	H_2O	F	Description	Locality	Analyst or Reference
5.36	0.63	0.73	0.87	24.36	49.28	11.24	0.66	0.87	8.92	Lepidolite	New Ross, N.S.	Ellsworth (1932)
5.44	2.52	0.36	4.19	21.16	47.89	10.73	1.34	1.90	7.41	Lepidolite	Leduc mine, Wakefield, Que.	Ellsworth (1932)
5.26	2.78	....	....	20.65	51.88	10.55	....	....	7.65	Zinnwaldite	Leduc mine, Wakefield, Que.	Winchell (1942)
5.39	2.64	....	....	19.95	50.31	10.14	....	....	7.65	....	....	
4.90	....	....	....	....	....	....	....	....	....	Zinnwaldite	Leduc mine, Wakefield, Que.	J. A. Maxwell, GSC Anal. Chem. Sec., Lab. No. A506
3.72	11.41	....	....	21.78	46.74	10.37	....	....	7.54	Zinnwaldite	Erzgebirge	Winchell (1942)
3.23	11.72	....	....	21.78	45.23	9.98	....	....	7.98	(Type locality)	Saxony	
1.06	0.23	0.28	2.05	31.80	47.18	10.50	2.94	2.40	2.15	Dark radiating mica	Silverleaf (Bear), Man.	Ellsworth (1932)
0.13	0.16	0.13	0.15	37.45	45.58	10.90	0.93	3.16	0.97	Lilac muscovite	Silverleaf (Bear), Man.	Ellsworth (1932)
3.39	0.24	0.52	0.90	31.80	49.06	11.03	1.92	1.95	4.30	Lepidolite	Silverleaf (Bear), Man.	Ellsworth (1932)
2.75	....	....	....	....	....	....	....	....	....	Grey radiating mica	Silverleaf (Bear), Man.	S. Courville, GSC Anal. Chem. Sec., Lab. No. A280
1.80	0.22	0.29	2.32	29.53	46.56	11.01	2.65	3.12	3.45	Curved mica (lilac)	Annie, Man.	Ellsworth (1932)
0.90	4.77	0.13	0.90	33.21	45.36	11.14	1.14	1.41	1.84	Curved mica (grey)	Annie, Man.	Ellsworth (1932)
0.78	....	....	....	....	....	....	....	....	....	Curved mica (grey)	Shatford Lake, Man.	S. Courville, GSC Anal. Chem. Sec., Lab. No. A284

Petalite (Castorite): Li Al $Si_4 O_{10}$

The analysis of petalite from Utö, Sweden, by Arfwedson in 1817 led him to the identification of lithium (*Foote Prints,* vol. 29, No. 2, p. 18). *Form:* monoclinic; crystals rare (castorite), usually massive, foliated; cleavage basal perfect. *Colour:* grey (Bernic Lake), white, pink. *Composition:* lithium disilicate. Theoretical Li_2O content is 4.9 per cent. Material from Bernic Lake assayed 4.73 per cent (analyst S. Courville, GSC Anal. Chem. Sec., Lab. No. 283). Its high Li-to-Al ratio is of value in glass and ceramic application. Irreversible dissociation into solid solution of silica in beta-spodumene is the basis of its application in ceramic compositions of high thermal-shock resistance. *Tests:* Field recognition difficult. Lamellar habit characteristic. Flame test requires acetylene torch, due to relative infusibility. Fluorescence test on warming (Hosking, 1957, p. 275) failed on Bernic Lake material.

Triphylite-Lithiophilite, Hühnerkobelite-Varulite, and Alteration Products

Form: orthorhombic, crystals rare; usually compact cleavable masses. *Cleavage:* 001 perfect, 010 and 110 good. *Colour:* greenish or yellowish grey on fresh surfaces, also salmon-pink (lithiophilite—Dana, 1932), resinous lustre. *Alteration:* to secondary minerals, yielding dark purple or brown ('purpurite') or black friable coatings characteristic. *Composition:* two isostructural series—(*1*) triphylite-lithiophilite [Li (Fe Mn) PO_4], (*2*) hühnerkobelite-varulite [(Na Ca Li) $(Fe\ Mn)_2$ $(PO_4)_2$].

Either series may contain variable amounts of Na or Ca, and Mg may proxy for (Fe, Mn). Triphylite-lithiophilite theoretically contains 9.5 – 9.6 per cent Li_2O. Material from Bernic Lake assayed 8.92 per cent (analyst S. Courville, GSC Anal. Chem. Sec., Lab. No. A 282). "Lithiophilite" from the Silverleaf (Bear) property assayed 6.99 per cent (analyst R. J. C. Fabry, ref. Ellsworth, 1932). Hühnerkobelite – varulite minerals contain little or no lithia, but "varulite" from Varutrask assayed 1.65 per cent (Dana and Dana, 1951, p. 670). Material from the Best Bet and Cota properties (Yellowknife-Beaulieu) identified as "hühnerkobelite and triphylite" gave a strong lithia flame whereas material identified as hühnerkobelite from a beryllium prospect in Nipigon district showed none. Progressive oxidation, first of Fe, then Mn, with concomitant leaching of alkalies to compensate valence, yields the following series: 1. (from triphylite-lithiophilite) ferrisicklerite-sicklerite, heterosite-purpurite; 2. (from hühnerkobelite-varulite) allaudite-manganallaudite, heterosite-purpurite. Ferrisicklerite-sicklerite minerals from Sweden, Finland, Pala, California, and Western Australia assayed from 3.26 to 4.89 per cent lithia (Dana and Dana, 1951, p. 673).

Rare Pegmatitic Lithium Minerals

Eucryptite ($LiAlSiO_4$), a lithium-aluminum orthosilicate of the nepheline group, containing about 10.9 per cent Li_2O, has commonly been considered a rare mineral. For many years it was known only from Branchville, Conn., but has recently been reported from Arizona, New Mexico, New Hampshire, and Bikita, Southern Rhodesia. It is described as colourless or white, hexagonal with distinct basal cleavage, and having a specific gravity of 2.667. It occurs in symmetrically-disposed crystals in albite at Branchville, Conn., where it is considered an alteration product of spodumene. At Bikita it is said to replace petalite and to fluoresce pink to red in ultraviolet light (Hurlbut, 1957). The mineral has not been identified in Canada, but could easily be overlooked.

Bikitaite ($LiAlSi_2O_6\ H_2O$), a new mineral recently reported (Hurlbut, 1957, p. 792) from the Bikita district, Southern Rhodesia, is described as colorless, with no good cleavages, having a hardness of 6, and a specific gravity of 2.34. It occurs in small amounts interstitial to quartz and eucryptite, and is considered to be an alteration product of eucryptite.

Rhodizite, the rare pegmatite mineral (probably $NaKLi_4Al_4Be_3$, B_{10}, O_{27}), occurs as minute red isometric crystals on red tourmaline near Murinsk, U.S.S.R., and near Mount Bity, Madagascar, where it is found with red tourmaline and spodumene and yielded an assay of 7.30 per cent Li_2O (Dana and Dana, 1951, vol. 2, p. 330).

Lithia micas having special associations or from particular localities are as follows: *Cryophyllite* occurs in the granite of Rockport, Mass., with danalite, and annite. *Polylithonite* occurs at Kangerdlwarsuk, Julienhaab district, Greenland. *Taeniolite* ($KLiMg_2Si_4O_{10}F_2$), contains 3.8 per cent Li_2O, and is found in veins at Narsarsuck, Greenland, and Magnet Cove, Arkansas. *Cookeite* $(OH)_6LiAl_3Si_2O_6$, is a micaceous mineral related to glauconite and found coating pink tourmaline, apparently as an alteration product; it occurs in Oxford county, Maine, Middlesex county, Conn., and at Varutrask, Sweden.

Cryolithionite is a fluoride of aluminum, sodium, and lithium, carrying 5.35 per cent lithium. It has been found in a cryolite-bearing pegmatite at Ivigtut, Greenland, and at Miask, U.S.S.R. (Dana and Dana, 1951, p. 99).

Manandonite is a micaceous, basic borosilicate of lithium and aluminum, holding 4.0 per cent lithium (Li_2O). It is found in Madagascar (Dana, 1932, p. 663).

Bityite, a silicate of aluminum calcium, beryllium, and lithium, holds 2.73 per cent lithium (Li_2O) and occurs in pegmatites in Madagascar.

Durangite is a fluoarsenate of sodium and aluminum, containing 0.65 to 0.81 per cent lithium (Li_2O). It is translucent and orange-red. It has been found in pegmatites associated with amblygonite, cassiterite, etc. (Dana and Dana, 1951, p. 829).

Jezekite is a fluophosphate of lime, soda, and aluminum with a little lithium (0.86 per cent). The mineral has been found in Saxony (Dana and Dana, 1951, p. 784).

Dickinsonite is a hydrous phosphate of manganese, iron, lime, sodium, potassium, and lithium. The lithium content is 0.17 to 0.22 per cent. The mineral is micaceous, and has been found in a pegmatite dyke in Connecticut (Dana and Dana, 1951, p. 717).

Fillowite is a hydrous phosphate of manganese, iron, calcium, and sodium. The content of lithium (Li_2O) is only 0.06 per cent. The mineral has been found in a pegmatite near Branchville, Conn. (Dana and Dana, 1951, p. 720).

Lithium also occurs in appreciable amounts in some alkali varieties of beryl and of tourmaline, in pollucite, leucite, psilomelane, lepidomelane, nepheline and heulandite.

Lithium in Saline Deposits and Evaporites

Lithium is recovered as a by-product from the brines of Searles Lake, Cal., in the form of dilithium sodium phosphate ($Li_2\ Na\ PO_4$), which contains 19 to 21 per cent Li_2O (Arundale, 1956, p. 467). Some saline deposits elsewhere also contain measurable amounts of lithium. The mineralogical form of such occurrences is nowhere known.

Lithium in Clay Deposits

Hectorite is an end-member of the montmorillonite group that occurs at Hector, Cal., and contains about 1 per cent Li_2O (Ross and Hendricks, 1945). Its formula is given as 16 $MgOLi_2O24SiO_2$ $6(FH_2O)$ Na_2O.

Some clay minerals elsewhere contain a little lithium, apparently as an essential component of the crystal lattice.

Lithium in Metamorphic Minerals

Lithium Amphibole (Holmquistite)

A fine acicular amphibole occurs in abundance locally in the schistose wall-rocks of spodumene pegmatites at the Quebec Lithium and Capital Lithium mines, and imparts a more or less purple colour to them. Specimens of this rock from Root Lake assay in excess of 1 per cent Li_2O. Part of the contained amphibole is pleochroic in purple colours, deeper for Z than for Y. The angle Z to C is small and 2V about X low, with distinct dispersion r greater than v. These properties are similar to those given for holmquistite from Utö, Sweden, by Sundius (1947), who reported a lithia content of 3.53 per cent and formula

$$(LiNa)_2(MgFe)_3\ Al_2Si_8O_{22}\ (OH)_2.$$

This formula is analogous to that of glaucophane.

Biotite

A rare alkali biotite from the contact of spodumene pegmatite with schist at Kings Mountain, North Carolina, is reported to contain 1.20 per cent Li_2O. It is brown, pleochroic, and has the characteristic low 2V of biotite. Another similar occurrence of biotite at Tin Mountain, South Dakota, contains 0.65 per cent Li_2O. Both contain appreciable amounts of rubidium and caesium (Hess and Stevens, 1937).

Artificial Products of Mineralogical Interest

"Lithium feldspar" ($LiAlSi_3O_8$), a polycrystalline powder of composition analogous to feldspar but differing in structure, has been produced by reaction of lithium chloride with alkaline feldspar (Scavencar and Sabatier, 1957, p. 308). The reaction is reversible and the product is unstable.

An "iron-spodumene" ($LiFeSi_2O_6$) and alpha-eucryptite have also been synthesized in related experiments.

Associated Minerals

The common rock minerals of lithium pegmatites are albite, potash feldspars, quartz, and muscovite mica. Albite is, especially in zoned dykes, commonly in the form of cleavelandite, whose thin, curved or wedge-shaped plates are commonly in radial bursts or complex intersecting arrangements.

Accessory minerals commonly present in lithium pegmatites, especially zoned dykes, are tourmaline, garnet, apatite, and beryl. Tourmaline is black, less commonly blue, and usually opaque; it is rarely translucent, and pink or green. Apatite is common in small shapeless blue grains. Beryl is green, white, or colourless. It is easily overlooked, but generally shows partly developed hexagonal crystal outlines, and has no cleavage. Fluorite and topaz are uncommon associated minerals. Columbite-tantalite is commonly present in small amounts, as is, less commonly, cassiterite. Columbite-tantalite, monazite, and other rare earth minerals and cassiterite occur in certain dykes in the Bernic Lake – Winnipeg River area. The caesium mineral pollucite occurs in substantial amount at the Montgary property. It contains some spodumene in fine veinlets.

Recognition and Tests

Spodumene is generally easy to recognize by its colour, crystal habit, and excellent prismatic cleavages. It has a distinctive silky appearance on the outer surface of diamond-drill core. On weathered surfaces, spodumene may be pink or buff-coloured, and alteration to a greenish mica or a brown woody mass is locally conspicuous.

Amblygonite closely resembles albite feldspar, and may even show similar striations due to polysynthetic twinning. However, it is noticeably heavier, commonly more chalky in appearance, and has bounding surfaces that are locally stained pink by alteration products. Petalite is difficult to distinguish from feldspar, except where its lamellar habit is pronounced. Triphylite-lithiophilite is characterized by a surface alteration to dark purple or brown secondary minerals.

Lithium minerals impart a characteristic crimson colour to a sufficiently hot flame. This is usually masked by a pervasive yellow colour due to sodium, but the latter can be filtered out by didymium glass, shade 1.7. Safety spectacles made of this material are available from safety supply dealers. The heat required can be judged from the fusibility of the mineral (*see* Table IV). Cheap propane or automatic gasoline torches are effective on amblygonite, triphylite-lithiophilite, and most spodumene, but for petalite and dilute mixtures of fine spodumene with rock minerals, the greater heat of an acetylene torch is needed.

A staining test for amblygonite is described by Hosking (1957, p. 275). The sample is heated to near the boiling point with occasional agitation for 5 minutes in a solution of 5 grams of ammonium molybdate, 100 cc cold water, and 35 ml concentrated HNO_3. The solution is then decanted and the sample washed with water. A yellow coating of ammonium phosphomolybdate adheres to the surface of amblygonite. The test was found effective on Bernic Lake materials.

A fluorescence test for petalite (Hosking, 1957), calls for gently warming the powdered samples on an iron plate in a dark room. Petalite grains are said to fluoresce a very pale blue. This test was found ineffective on Bernic Lake material.

Evaluation

The standard assay method has been chemical analysis, but instrumental methods using the flame photometer are now commonly used.

Visual estimates of spodumene content, by experienced personnel, may be fairly reliable under favourable conditions. This applies particularly to diamond-drill cores. Grain-count and grain-intercept-measurement methods are adaptable to dykes containing spodumene (Norton, 1956; Rowe, 1953b). The proportion of spodumene so determined must be corrected for specific gravity in calculating weight percentages.

In outcrops where most of the spodumene is parallel with the surface being examined, the content may appear higher than it actually is, owing to the tendency for a fracture surface to pass from a cleavage face of one spodumene crystal to that of another at a slightly higher or lower level.

Where the only minerals present in important amount are quartz, feldspar, and spodumene, specific-gravity measurements provide an objective method of determining the weight percentage of spodumene present in broken pieces of ore. The specific gravity of a specimen is the ratio:

$$\frac{\text{Weight in air}}{\text{Weight in air minus weight in water}}.$$

If the specific gravity of spodumene is assumed to be 3.17 and that of the quartz and feldspar mixture to be 2.63, the proportion of spodumene by weight is:

$$\frac{\text{Specific gravity minus 2.63}}{\text{3.17 minus 2.63}}.$$

Small errors in relative weights can cause serious error in calculated specific gravity, and such errors must be within about one part per thousand to give spodumene content within about 3 per cent on medium grades. A good commercial beam of 10-20 pounds capacity just about reaches that order of precision on 10-pound pieces. Further errors arise from the assumptions as to specific gravity of spodumene and quartz-feldspar gangue, but these tend to cancel out and are not so important. The reliability of the method is of course, like all other methods, contingent on the number and judicious choice of specimens to provide a representative sample.

Zones and other internal structures are present in some lithium-bearing dykes (*see* Chapter III). The recognition of such structures may facilitate the prediction of lateral and depth extension of surface deposits or of possible valuable concentrations beyond barren surface exposures.

Chapter III

GENERAL GEOLOGY

Definition of Terms

Granitic pegmatites are composed essentially of feldspar, quartz, and mica, in the same general proportions as in granite. They are, in part at least, coarser than normal granitic rocks, but are characteristically variable in granularity and may contain a large proportion of fine aplitic material. They are classified with respect to environment as follows:

1. Interior, i.e. wholly and well within intrusive bodies.
2. Marginal, i.e. close to or athwart contacts with invaded rock.
3. Exterior, i.e. wholly in invaded rock.

Regional zoning means a progressive spatial distribution of dykes having different mineralogical and/or structural characteristics, with respect to some major geological feature, usually a particular granitic intrusion.

The internal structure units of pegmatites commonly recognized are zones, replacement bodies, and fracture fillings. Of these, zones are the most important.

Zoned dykes are complex aggregates of quartz, feldspar, and accessory minerals, in which units of visibly contrasting mineralogy have a fairly consistent systematic arrangement. If the arrangement is symmetrical, the units form inner or *core* zones, outer or *border* and *wall* zones, and perhaps also *intermediate* zones.

In the case of lithium-bearing pegmatites, zoned dykes are distinguished from unzoned and imperfectly zoned or "intermediate" dykes (Pye, 1956), although virtually all lithium pegmatites have zoning characteristics to some degree. The basis of distinction is explained in the next section, "General Geological Features".

This purely descriptive usage differs from that of some writers who, in dealing with pegmatites in general, restrict the term 'unzoned' to homogeneous simple granite pegmatites, generally without significant rare-element concentrations, and include practically all lithium deposits in the class of zoned pegmatites.

Replacement bodies are mineralogical assemblages or units that are believed to have been formed by replacement of pre-existing pegmatite, with or without structural control.

Fractured fillings are units, generally tabular, that filled fractures in previously consolidated pegmatite.

The distinction of replacement units from zones and from fracture fillings appears to be more subject to individual interpretation than the differentiation of zones from one another.

In granularity, or grain-size, pegmatites have been classified (Cameron *et al.,* 1949, p. 16) as follows: *fine*—less than 1 inch; *medium*—1 inch to 4 inches; *coarse*—4 inches to 12 inches; *very coarse*—greater than 12 inches. In this report, and with special reference to spodumene, the size classification used is: *fine*—less than 2 inches; *medium*—2 inches to 12 inches; *coarse*—greater than 12 inches.

General Geological Features

Types of Deposits

The known lithium deposits of Canada, and all significant occurrences, are in granitic pegmatites containing one or more of the common lithium minerals.

No sedimentary or intrinsically metamorphic occurrences are known, although wall-rocks of lithium-rich dykes at the Quebec Lithium and Capital Lithium properties locally assay upwards of 1 per cent Li_2O, apparently all contained in the rare amphibole, holmquistite.

At the Gold Hill claim, in British Columbia, an insignificant occurrence of lepidolite may be from a vein deposit.

The lithium-bearing pegmatites can to some extent be subdivided into zoned and unzoned types. Unzoned pegmatites, in which spodumene is the only abundant accessory mineral, are the most common, but zoned dykes, of more complex character, are prominent in some districts. The distinction and characteristic features are discussed in following sections.

Distribution and Age

Most of the known Canadian lithium occurrences are in the Precambrian Shield (Fig. 1). Practically all of these are in the Archaean provinces; none has been reported from the younger Churchill province, except the borderline Herb Lake deposits, and only one minor occurrence is known in the Grenville.

The few known occurrences in Nova Scotia and British Columbia are much younger. Those in Nova Scotia are presumably Devonian and emplaced in Ordovician rocks. Those in British Columbia are thought to be Jura-Cretaceous, but to be emplaced in pre-Permian metamorphosed rocks.

The distribution of lithium deposits within fairly well defined districts, and the distribution of these districts conforms to the general concept of metallogenic provinces. Beryllium occurs with or near lithium in most districts, but is much more widely distributed. Noteworthy is the proximity of several lithium districts to important areas of gold deposits, as exemplified by the Preissac-Lacorne, Yellowknife-Beaulieu, Herb Lake, and Nipigon districts. Other metals rather commonly found in veins in or near lithium districts are molybdenum and tungsten.

The ages of pegmatites from three of the main lithium districts within the Canadian Shield are as follows (Wilson, *et al.,* 1956):

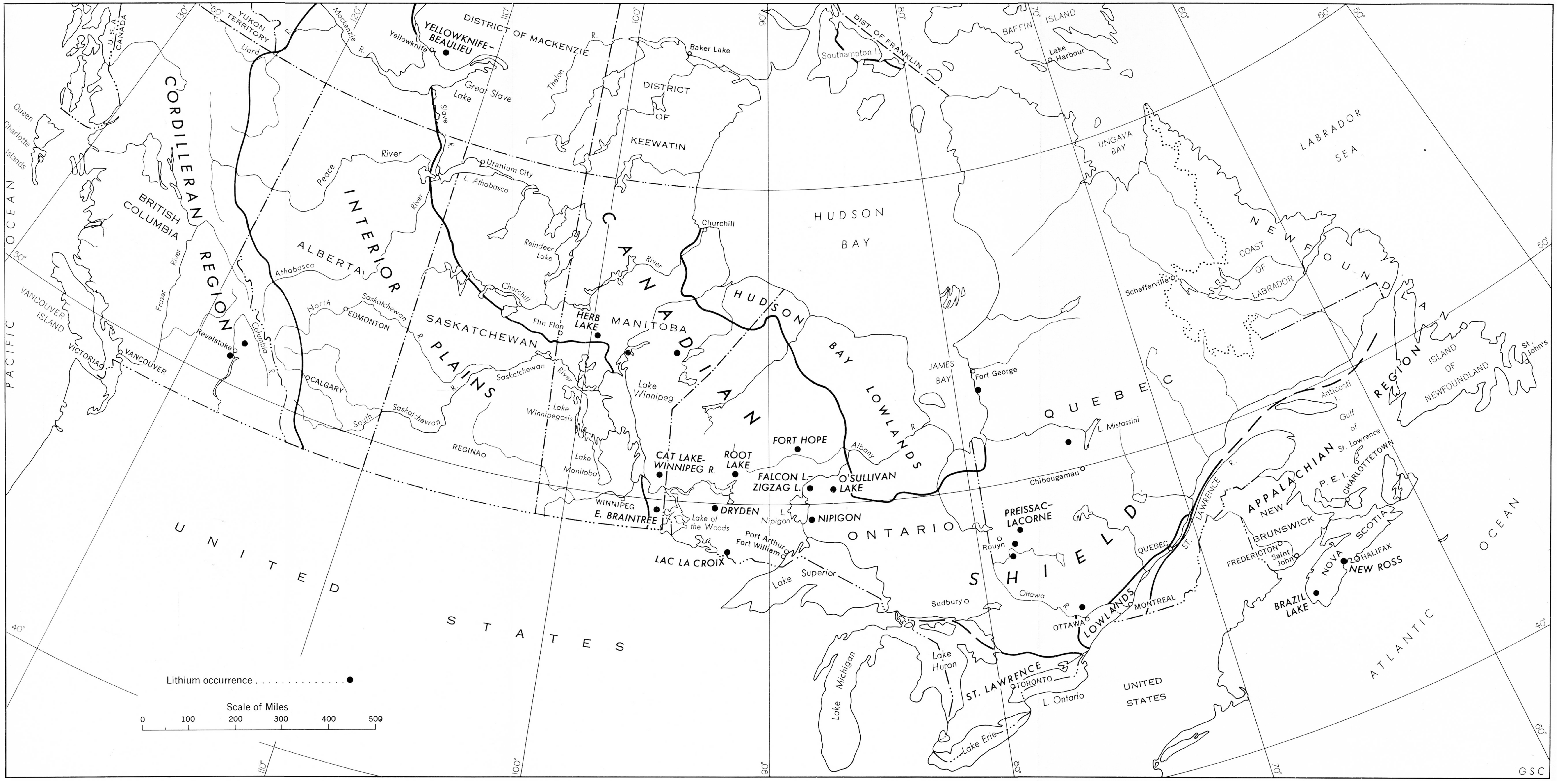

FIGURE 1. *Lithium occurrences in Canada*

Locality	District	Pb 207:206	A_{40}:K_{40}
R5, L11, Lacorne	Preissac-Lacorne	....	2.5 billion years
R9, L13, Lacorne	Preissac-Lacorne	....	2.5 billion years
Moose Property	Yellowknife-Beaulieu	....	2.2 billion years
Silverleaf	Winnipeg River	....	2.5 billion years
Huron	Winnipeg River	2.55	

These lie within the range of ages determined for the last major disturbance of the Archaean provinces, in which the pegmatites occur.

Regional Environment

Relations to Granitic Intrusions

The lithium-bearing pegmatites are all more or less closely associated with widespread intrusions generally ranging in composition from granite to granodiorite. Dioritic or more basic rocks are present in some districts but are subordinate to more acidic types. A close association with albite granite is considered to be significant in connection with the genesis of deposits in part of the Cat Lake – Winnipeg River and West Hawk – East Braintree districts, and albite predominates over potassic feldspar in the muscovite granite of the Preissac-Lacorne district, to which the pegmatites are presumably related. Pegmatitic albite-granite bodies in these districts locally show marked peculiarities in structure (Plates IA and IB), such as well-banded aplite, rectangular crystal-like aggregates of feldspar and quartz in graphic intergrowths, and occasional beryl crystals in quartz-muscovite segregations.

Metamorphic Environment

Most lithium deposits are in exterior pegmatites and intrude moderately to highly metamorphosed volcanic and sedimentary rocks, although some are found within the contacts of granitic intrusions. An association with knotted schists and gneisses is common in metasedimentary terrains. In the Yellowknife – Beaulieu River district for example, rare-element pegmatites are conspicuously restricted to metamorphic aureoles of granitic intrusions and have not been found outside them. In volcanic terrains the host rocks, derived from intermediate to basic flows, are commonly metamorphosed to the amphibolite grade. Where intrusive rocks are hosts to lithium pegmatites, which are usually marginal, they are generally considered to be older than, or early phases of, the intrusions to which the pegmatite bodies are genetically related.

Effect of Wall-Rock Composition

The composition of wall-rocks does not appear to be a controlling factor in the emplacement of lithium-bearing pegmatites, for among the various districts the host rocks are divided about equally between andesitic greenstones and quartzose metasedimentary rocks. Argillaceous or calcareous host rocks are uncommon. Possibly their competency is too low for the maintenance of open fractures.

The apparent restriction of lithium pegmatites to andesitic rocks in the Cat Lake – Winnipeg River district has been remarked upon (Davies, 1957). The distribution of greenstones with respect to regional structures and/or their predominance among the bordering rocks of granitic intrusions may be significant in this association.

In the Yellowknife-Beaulieu district the host rocks are nearly all metasedimentary, but the few lithium-bearing dykes in the Ross Lake – Redout Lake area are in or near a band of greenstone. There is general agreement that these dykes form part of a normal regional-zoning sequence, and their emplacement is not directly related to wall-rock composition.

Wall-Rock Alteration

Wall-rock alteration is not a conspicuous feature of lithium pegmatites, but three types of alteration seen in particular localities are considered noteworthy: (1) local tourmalinization of wall-rocks bordering dykes in the Dryden field, the Herb Lake district, and in one locality in the Yellowknife-Beaulieu district; (2) the development of lithium amphibole in wall-rocks at the Quebec Lithium property (Lacorne) and the Capital Lithium property (Root Lake); and (3) the conspicuous alteration of hornblende of the hornblende granodiorite to epidote and biotite at the selvedges of dykes at the Quebec Lithium property. This alteration is accompanied by bleaching. The bleached borders of dykes in contact with granodiorite in the Nipigon district and elsewhere may be attributable to similar alteration processes.

External Structural Control

The external structural controls that determined the size, shape, and attitude of lithium pegmatites are not well known in most cases. In a few areas where the structural environment of certain groups of dykes has been studied in some detail, a pattern emerges with sufficient clarity to suggest the dominant controlling factors. The tabular, dyke, or sheet-like bodies in contact with bedded rocks are generally discordant in strike or dip. The inference is that most of these bodies were emplaced along pre-existing fractures.

In the Lacorne district the proximity and parallelism of many dykes to a mapped regional fault suggest one major control, and a conformity to joint patterns in the granitic intrusions suggests another. In the Herb Lake district the attitude of dykes on the Green Bay property suggests that they may be tension fractures related to regional faults. In the Yellowknife-Beaulieu district the writer believed that many of the lithium-bearing dykes may be emplaced along tension fractures resulting from cross-folding. Rowe (1952) stated that some arcuate-shaped pegmatites were controlled by crests or troughs of folds. In the Ross Lake area of that district the pegmatites closest to the parent granitic body are large irregular bodies that conform to the gneissosity in the enclosing granitic rocks, whereas the pegmatites farther away are smaller, more regular bodies that are strongly discordant to the layering of the wall-rock complex. The lithium-bearing dykes are the extreme example of this latter group.

Regional Zoning

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

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

In the Preissac-Lacorne district (Fig. 4, facing p. 42), and in parts of the Yellowknife-Beaulieu district (Fig. 10, p. 84, and Plates VI, VII), for example, simple granite pegmatites with accessory beryl occur within or close to masses of late muscovite-bearing granite, whereas simple spodumene-bearing dykes are almost, if not all, in the surrounding metamorphic rocks. In the Nipigon district (Pye, 1956) spodumene dykes of simple internal structure lie farther from a major granitic intrusion than more complex ones, and these in turn are farther than well-zoned dykes that carry both beryl and lithium minerals. Other examples of regional zoning include the Cat Lake – Winnipeg River district (Davies, 1959), and the East Braintree – West Hawk district (Stockwell, 1933).

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

Internal Characteristics

Significant Mineralogical Features

Lithium Minerals

The kind of lithium mineral or minerals present, and their relative abundance, differ from one district to another, although spodumene is almost everywhere the most abundant and is the only essential lithium mineral of the typical unzoned pegmatites. Amblygonite is rare, except in the Yellowknife-Beaulieu, Cat Lake – Winnipeg River, and New Ross districts. It is the chief lithium mineral in the New Ross pegmatite, where spodumene has not been reported. Lepidolite and other high-lithium micas are also rather rare, but are of potential importance in the Cat Lake – Winnipeg River district. Other minor occurrences of lithia mica worth mentioning are in the Preissac-Lacorne district, the Fort Hope (Ontario) and Wakefield (Quebec) areas, and the Cordilleran and Appalachian regions. Petalite, so far as known, occurs only in the Cat Lake – Winnipeg River district and in one dyke in the Yellowknife-Beaulieu district. Triphylite-lithiophilite occurs as a minor mineral in the Cat Lake – Winnipeg River district and also in the Yellowknife-Beaulieu district.

Feldspar Composition

Albite is reported to be the dominant feldspar of lithium pegmatites in several districts, and it has been observed that lithium values decrease with increasing proportions of potassic feldspar. Certainly most lithium-bearing dykes are conspicuously white, whereas adjacent dykes or parts of the same dyke that are pink or red are commonly low-grade or barren. On the other hand, lithium-rich dykes in several important districts contain a large proportion of microcline, perthite, and orthoclase, not only in coarse crystals but also in the fine interstitial groundmass material. This is true of unzoned as well as zoned dykes. The potassic feldspar, particularly microcline, in these dykes is mostly white or grey, and pink colorations whether in potassic feldspar or albite, can usually be ascribed to alteration or staining. The principal observations on the feldspar composition in lithium pegmatites are given below.

The connection between lithium deposits and albite pegmatite in the Cat Lake – Winnipeg River and the West Hawk – East Braintree districts was first suggested by Stockwell (1932, p. 112-113), and was subsequently confirmed by Davies (1955, p. 21; 1957). The writer has noted large microcline crystals intimately associated with spodumene at the Montgary property, but much of the coarse feldspar, apparently pseudomorphous after microcline, is an aggregate of fine lath-shaped sodic plagioclase. This plagioclase is in addition to the abundant interstitial cleavelandite. Comparatively coarse microcline is fairly abundant in the unzoned Irgon dyke, but the fine interstitial feldspar in thin sections taken from the Irgon, Eagle, and Spot properties is all sodic plagioclase.

Pye (1956, p. 74) stated that the feldspar of the lithium-bearing dykes in the Nipigon district is predominantly plagioclase, usually albite. He has found (personal communication) that the feldspar of one dyke, systematically sampled from wall to wall, is invariably albite. The feldspar is sodic plagioclase in most thin sections of specimens from this district studied by the writer, but microcline in coarse crystals was noted in the Aumacho River dyke.

The feldspar in lithium dykes in the Root Lake and Lac La Croix fields (Pye, 1956, p. 73) and in the Falcon Lake field (private report, British Canadian Lithium Mines) is also predominantly albite.

The pegmatites of the Lacorne district, are composed chiefly of albite or oligoclase (Tremblay, 1950, p. 46; Rowe, 1953a, p. 11). On later pages, however, Rowe (1953a, p. 20, 24, 28) mentioned coarse perthite as a prominent constituent of some lithium deposits in this district. The writer considered coarse microcline (and/or perthite) to be the dominant feldspar of the lithium dykes that he examined in this district, although fine interstitial feldspar seen in thin sections is mostly sodic plagioclase, and cleavelandite is the dominant feldspar of some zoned deposits.

The pegmatites of the Yellowknife-Beaulieu district are reported to consist chiefly of microcline and cleavelandite (Jolliffe, 1944, p. 2), and chiefly of cleavelandite and perthite (Rowe, 1952, p. 13). From field observation the writer considered that microcline was generally the dominant feldspar of the lithium dykes in this district, although cleavelandite may be more abundant in the zoned dykes at the Moose and Best Bet properties. The few thin sections examined, mostly from the Ann dyke (Reid Lake), however, contained sodic plagioclase exclusively.

Tourmaline

The absence or remarkable scarcity of tourmaline from even the most complex zoned dykes is an outstanding feature of the Preissac-Lacorne and Yellowknife-Beaulieu districts, for tourmaline is conspicuous in wall zones and selvedges of pegmatites in most other districts. In both districts tourmaline is a prominent constituent of gold-bearing quartz veins of adjacent areas. In the Yellowknife-Beaulieu district some tourmaline-bearing gold-quartz veins are cut by pegmatite dykes and may coincide in age with the tourmaline phase of pegmatite formation. In the Preissac-Lacorne district the relative ages are unknown, and the presence of a little tourmaline in some of the molybdenite-bearing quartz veins at the Molybdenite Corporation mine complicates the relationships further, for this is contrary to what would be expected from the regional zoning relationship of the veins to the pegmatites of the district.

Internal Zoning and Related Structures

Internal structures are well developed in some lithium-bearing pegmatites, and are inconspicuous or absent in others. Zones are by far the most important structural units. Replacement bodies are probably of considerable importance in the most complex dykes, especially those containing lepidolite (see below), but the distinction of replacement bodies from zones is susceptible to individual interpretation and is avoided as far as possible in this report. Only two clear cases of fracture filling were noted, one in the Nipigon district and one in the Yellowknife-Beaulieu district. In each case a younger spodumene-bearing dyke cuts across an older one, and the spodumene is oriented perpendicular to the walls in each dyke.

Zones are, in the sense used in this report, marked partly by a predominance of certain of the essential minerals and partly by the presence of diagnostic rare-element or accessory minerals. Although differences exist among complex pegmatites, particularly with regard to mineral variety, the sequence of significant minerals is consistent. Based on this sequence, an ideally symmetrical well-zoned pegmatite of complex mineralogical type may be described, as follows (Fig. 2).

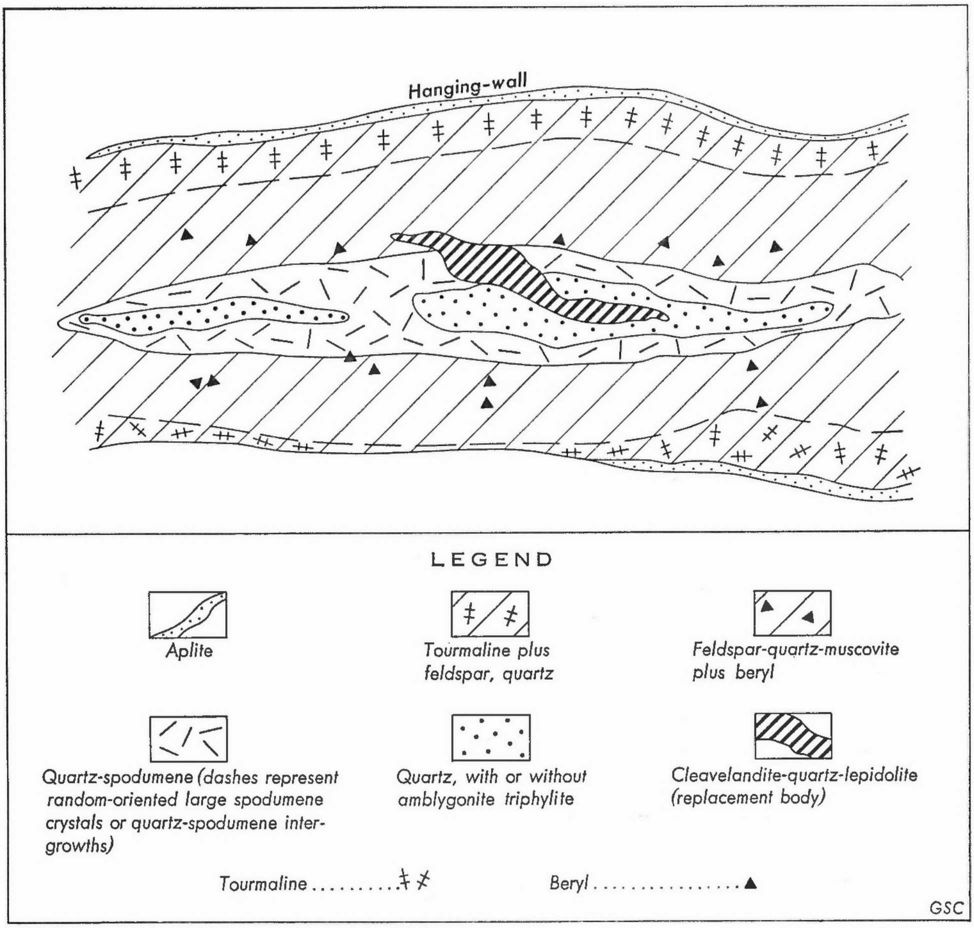

FIGURE 2. ***Diagrammatic vertical section of complex well-zoned lithium-beryllium pegmatite.***

The innermost zone is characterized by quartz, which is usually the most abundant mineral, and is commonly referred to as the "core". Coarse feldspar (albite, microcline, or perthite, with or without accessory minerals) may be present or may make up most of the innermost zone, but the proportion of quartz present is invariably higher in the innermost zone than in the outer parts of the dyke. The lithium phosphate minerals amblygonite and triphylite-lithiophilite are almost entirely confined to quartz cores. Lepidolite and the caesium mineral pollucite (Bernic Lake) are characteristically core minerals, but are commonly considered to form replacement units. Petalite is also found in quartz cores at Bernic Lake. Spodumene, in dykes in which it is the only lithium mineral present, is practically confined to an innermost quartz-rich zone. In dykes where other lithium minerals are present (Bernic Lake, Yellowknife) spodumene is commonly in marginal parts of the core or in more or less distinct intermediate zones just outside of it.

These inner zones are bounded by a zone in which feldspar greatly predominates. Some of the feldspar is in large, well-formed crystals and is commonly potassium-rich, but cleavelandite is also common. Muscovite is most abundant in the inner part of this zone, and beryl is found in quartz-rich segregations associated with muscovite and cleavelandite. This zone may extend to the walls of the dyke, forming the wall zone, or it may be confined by others and constitute an intermediate zone. It may itself be subdivided into several intermediate zones of variable lithology.

Tourmaline, if present in the dykes of the district, characterizes the next outer zone. This zone may merge imperceptibly with the feldspar zone, as in some of the Bernic Lake dykes where tourmaline crystals a foot or more long, oriented perpendicular to the wall, form up to 80 per cent of the zone. It may consist of one, or several sharply-defined narrow bands of solid tourmaline, as at the M N W (Nipigon) property, or of scattered crystals and nests of tourmaline in feldspar and quartz.

The outermost or wall zone is commonly a light-coloured, fine-grained mixture of feldspar and quartz, 1 inch to 4 inches wide, commonly described as a "chill-zone". The contact with the country rock may be marked by a bleached or otherwise altered border zone.

These zones may pinch out or swell, bulge abruptly, or telescope into one another, and core zones are commonly lenticular and discontinuous. All gradations exist, from the most complex of zoned pegmatites to typical unzoned dykes in which spodumene is the only uncommon pegmatite mineral and is distributed essentially from wall to wall. Even in these relatively homogeneous spodumene dykes, narrow spodumene-poor outer margins and internal bands (Fig. 3, Plate IIB), generally of aplite and/or coarse feldspar, are common.

Replacement bodies are less easily recognized than zones. Their identification as such carries implications as to structural and paragenetic relationships. Some albitization of pre-existing feldspar is evident, and cleavelandite and quartz commonly surround and vein broken and distorted spodumene crystals. Lepidolite and other lithia micas, where present, accompany such cleavelandite and quartz, and much lithia mica may have formed at the expense of spodumene.

A cleavelandite-lithia mica assemblage at the Silverleaf deposit has been described as a replacement body by Rowe (1956, p. 9), and this assemblage exemplifies the mode of occurrence of lepidolite-rich assemblages in several other pegmatites.

Granularity, Fabric, and Crystal Orientation

In grain size, spodumene ranges from fine needles measurable in millimetres to huge logs 10 feet long or more. Several crystals over 40 feet long were reported from the Black Hills district of South Dakota. Most simple feldspar-quartz-spodumene dykes in Canada have spodumene crystals between 2 and 12 inches long, and these are considered medium-grained (as defined at the beginning of this chapter).

Spodumene has strong crystallizing force in comparison with quartz and feldspar, and occurs in long prismatic forms to which quartz, and commonly much feldspar, are mainly interstitial.

Based on granularity, fabric, and degree of orientation in dykes, the following four characteristic, though gradational, modes of occurrence of spodumene are distinguishable: (1) parallel crystals consistently perpendicular to the walls; (2) parallel crystals within lenses or patches, the preferred direction varying from place to place within the dyke; (3) randomly-oriented crystals; and (4) radiating or random crystal-like masses of fine quartz-spodumene intergrowth. In these the fine spodumene needles are consistently perpendicular to the major axial planes of the masses.

A tendency to parallel orientation of spodumene crystals perpendicular to the walls of the dykes is an outstanding feature of spodumene-bearing pegmatites generally. This tendency is most marked in steep-dipping, medium-grained, unzoned dykes (Fig. 3), but is apparent even in the most coarse-grained dykes in

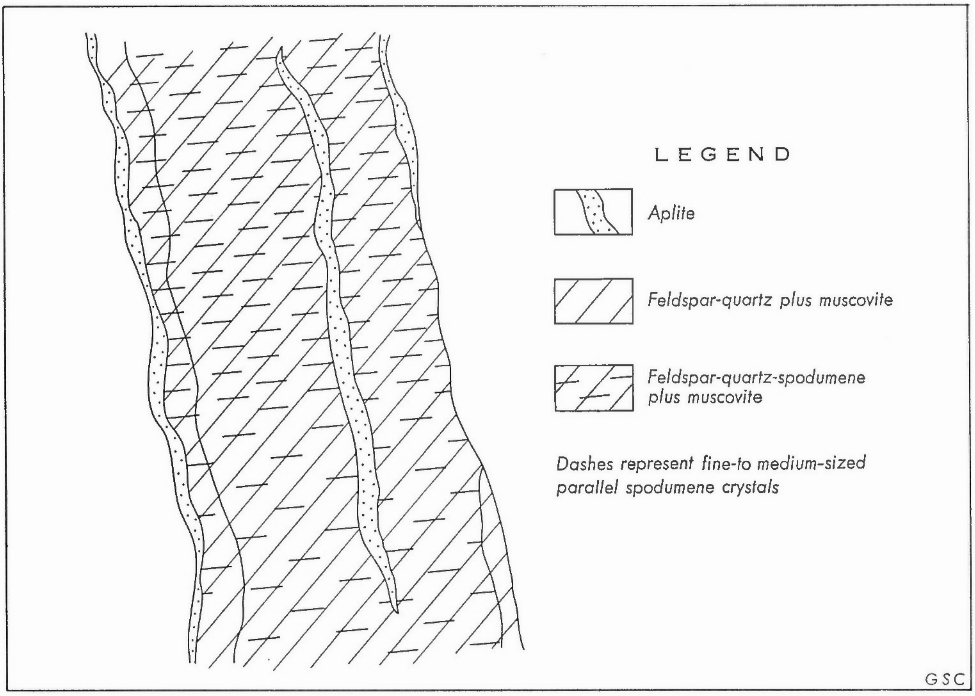

FIGURE 3. ***Diagrammatic vertical section of typical unzoned spodumene pegmatite.***

which most of the crystals are in random orientation. This preferred orientation provides one of the strongest indications of the degree of dip of the dyke. Variability in preferred direction between lenses and patches in the same dyke is most common in fine-grained unzoned dykes, such as the Irgon and Spot (Cat Lake) and the Root Lake deposits. Most occurrences of spodumene as fine parallel needles intergrown with quartz in crystal-like masses are complex zoned dykes but this mode of occurrence was noted also in essentially unzoned dykes at the Spot group (Cat Lake) and the Ann group (Yellowknife-Beaulieu district).

Influence of Dyke Attitude

Statistical interrelationship is apparent (*see* Table VI) between the attitude of lithium-bearing dykes, their grain size, degree of crystal orientation, internal structure, and environment. Most steep-dipping dykes, especially those lying outside the contacts of granitic intrusions, contain fine- to medium-grained spodumene, predominantly in parallel orientation and distributed essentially from wall to wall. In contrast, most gently dipping sheets, especially those lying mainly within the contacts of granitic intrusions, contain coarse spodumene crystals or crystal-like quartz-spodumene intergrowths in more or less random orientation, and confined to fairly well defined inner zones.

Interpretation

Because the Canadian lithium deposits are all essentially granite pegmatites the problem of their origin involves that of pegmatites generally and may be considered in terms of hypotheses as to the origin of pegmatites. The general problem of the origin of pegmatites has two aspects which, though partly interdependent, can to some extent be considered separately. They are: (1) the source and means of concentration of the pegmatite-forming material, and (2) the mode of development of the pegmatite bodies themselves.

Source and Concentration of Lithium

The salient observations bearing on the source of lithium are (1) the occurrence of lithium-bearing pegmatites in host rocks of widely-varying composition and without apparently anomalously high lithium content, (2) the confinement of these pegmatites to the metamorphic aureoles of particular granitic intrusions, and (3) their consistent position among the pegmatites of regionally zoned sequences related to these intrusions.

Considered together, these observations leave little doubt that the source of the lithium is in the granitic bodies with which the pegmatites are so generally associated.

However, the reasons why lithium deposits are associated with some batholiths, and not with others, are unknown. It appears that in many parts of the world (see for example Jahns, 1956, p. 1076) contrasting pegmatite provinces may be distinguished by the types of rare-element assemblages found in the pegmatites of different districts. It is not clear, although it seems to be generally assumed (Horstman, 1957, p. 3), that the granites with which lithium-bearing pegmatites are associated are inherently richer in lithium than others. Little information relevant to this question is available regarding Canadian occurrences, but a geochemical study of the Preissac-Lacorne batholithic intrusions (Siroonian *et al.*, 1959) has shown that the granites there are unusually rich in lithium (to 248 ppm) and that the lithium content of the micas decreases from the east (where lithium deposits are abundant) to the west (where they are scarce).

The high lithium content of many pegmatites, in contrast with that of the surrounding rocks, calls for an effective means of concentration. This raises the question whether the supposedly genetically-related granite is the ultimate source of the lithium, or merely acted as an agent of concentration. During crystallization of a melt of granitic composition, lithium tends to enter into late-formed ferromagnesian minerals, particularly biotite, and/or to accumulate in residual solutions, for reasons explained in Chapter II. Thus any magmatic or palingenetic view that admits a molten or otherwise fluid stage in the development of granite, offers the possibility of concentration of lithium into pegmatite-forming solutions. Views that deny a fluid stage in the development of granite do not, however, necessarily preclude the concentration, through metasomatic or 'granitization' processes, of lithium from large source areas into fluids identical with rest-magmas resulting from magmatic differentiation.

Of possible significance in this connection is the observation that in several districts (Yellowknife-Beaulieu, Cat Lake – Winnipeg River, Preissac-Lacorne, New Ross), the pegmatites are believed to be related to muscovite-bearing granites that are interpreted as the youngest of two or more phases of granitic intrusion. If the muscovite of such granite was derived from biotite, as by post-magmatic alteration, the transformation would probably entail the expulsion of some lithium, along with magnesium and iron, from the lattice. This mechanism may have played a part in the concentration of lithium. Perhaps a complex history of concentration and reconcentration is necessary to achieve the accumulations of rare elements found in the pegmatites of such districts.

Mode of Development of Lithium-bearing Pegmatites

Current theories as to the mode of development of pegmatites (Jahns, 1956, p. 1058) as understood by the writer, may be assigned to either of two general categories: (1) magmatic hypotheses, and (2) metasomatic hypotheses, or to various combinations of these.

In the magmatic hypotheses, pegmatites are supposed to have crystallized from a fluid medium injected into pre-existing or contemporaneously-formed spaces. In metasomatic hypotheses, on the other hand, pegmatites are supposed to have formed by reconstitution of pre-existing rock. The "hydrothermal replacement" hypothesis, which combines some magmatic and metasomatic processes, postulates the invasion and replacement of previously consolidated pegmatite (presumably magmatic) by later-formed hydrothermal solutions. The mineralogical and structural peculiarities of well-zoned pegmatites have been attributed to this mechanism by some investigators.

The details of the conflicting hypotheses, of the composition, physical state, and behaviour of hypothetical pegmatite-forming fluids, and of the mechanisms by which metasomatic reconstitution is supposed to have been accomplished, are too complex and too fundamental for adequate treatment within the scope of this report. They have been discussed at length by Jahns (1956, p. 1058-1084).

A substantial degree of agreement exists as to the relative temperatures of formation of some diagnostic minerals of well-zoned lithium pegmatites, and this is of prime significance in the following interpretation of geological features. The pertinent data are based partly on inversion temperatures and other measurable properties of specific minerals. As summed up by Brotzen (1959, p. 76) "available temperature estimates indicate that granitic pegmatites were emplaced at well above 600°C (graphic granite), that feldspar and the earliest beryl crystallized at about 600°C (pegmatoid zone), that muscovite started to form at about 500°C (core margin ?), that spodumene formed below about 500°C (alkali replacement and core margin), that beryl and muscovite continued to form until about 300°C ...., and finally that quartz (core) was brittle at about 270°C." Tourmaline, like beryl, appears to have formed over a wide range of temperatures, depending on composition, but the common black schorl of pegmatite wall-zones is generally conceded to be one of the earliest-formed pegmatite minerals (Brotzen, 1959, Plate II; Fersman, 1931, Figs. 64-65). The lithium-rich micas and phosphates, on the other hand, in view of their low melting or dissociation temperatures, are clearly to be expected among the last-formed pegmatite minerals.

In assessing the relative merits of the above hypotheses, as applied to Canadian lithium deposits, the following phenomena are considered by the writer to be especially important: (1) relationship between regional and internal zoning, (2) granularity and fabric, especially orientation of spodumene in pegmatites, and (3) interrelationship between attitude of pegmatites and their granularity, degree of crystal orientation, and complexity of mineralogy and internal structure. The significance of these phenomena is discussed in the following sections.

Relationship between Regional and Internal Zoning

The main indication of a relationship between regional and internal zoning is the fact that the sequence of mineral assemblages from innermost to outermost dykes in examples of regional zoning, is analogous to the sequence from outermost to innermost zones, in examples of internal zoning. This inverse relationship is most apparent in the relative distribution and mineral associations of beryl and spodumene (beryl in interior dykes regionally, in outer zones internally; spodumene in exterior dykes regionally, in inner zones internally).

Likewise, where the regional zoning pattern involves a progression from zoned to unzoned spodumene-bearing dykes the zoned dykes lie closer to the batholithic source than the unzoned ones. These unzoned dykes consist wholly of mineral assemblages that occur in the inner zones of zoned dykes. Furthermore, exceptions to regional zoning patterns, in particular the occurrence of lithium deposits in interior pegmatites, generally involve complex zoned dykes in which the characteristic mineral assemblages are all represented.

The relationships may be rationalized on the assumption (supported by independent evidence cited in the preceding section) that beryl and its associated minerals crystallized at an earlier, higher-temperature pegmatitic stage than lithium and its associates, and therefore are found closer to the source, in cases of regional zoning, and nearest to the walls, in cases of internal zoning. These relationships may be expressed in a concept of internal zoning as an added 'dimension' (in a descriptive, not a literal sense) of regional zoning.

Some other features, such as overlapping and telescoped zones, and the occurrence of late low-temperature minerals such as lepidolite characteristically as replacement bodies in inner lithium-rich parts of zoned dykes, find an explanation in the same broad zoning concept.

Thus the relationship between regional and internal zoning supports the premise that the lithium-bearing pegmatites developed in a falling-temperature crystallizing sequence.

Orientation of Spodumene Crystals

The universal tendency of spodumene crystals to parallel orientation perpendicular to the walls of dykes or zone boundaries is believed to be most readily explained as the result of primary crystallization. Growth of crystals is visualized as taking place from the walls inward in a fluid medium of low viscosity, occasioned by gradual loss of heat to the surrounding rocks. The random orientation of spodumene crystals in some dykes, can be explained in several alternative ways:

1. The material of the dyke or unit was injected in a partly crystallized condition. If so, already-formed crystals, particularly those that, like spodumene, have chain structures, would continue to grow lengthwise in the direction thus accidentally taken up.
2. Some of the spodumene crystals, growing downward from the upper wall or zone boundary in a fluid medium, became detached and sank, to assume the random orientation in which they are found.
3. Relative movement of the walls, or sudden changes in the rate of flow of fluid dyke-filling during the interval of spodumene crystallization could result in partial or complete disorientation of previously-formed crystals. Furthermore, such changes could cause interruptions in the crystallization of spodumene, and turbulence or other factors might cause changes in the direction of preferred orientation. This explanation is most adaptable to those steep-dipping and fine- to medium-grained dykes in which the preferred orientation of spodumene varies from band to band or from patch to patch.

Attitude of Pegmatites in relation to Granularity, Spodumene Orientation, and Internal Structure

From the common association of flat-lying pegmatites with coarse grain, random crystal orientation, and complex internal structure, and of steep-dipping dykes with the opposite features, the essential inference is that flat-lying openings are more likely to constitute structural traps for fluid material than steep-dipping fractures.

The flat-lying openings would then favour the operation of a closed or highly restricted system, and the crystallization of materials stable at successively lower thermal-energy levels would, after emplacement, take place in shells, from the walls inward, during cooling. Minerals containing volatile or 'hyperfusible' constituents, particularly the strong anion-forming elements—phosphorus, fluorine, and hydroxyl—are found chiefly in the innermost zones of complex dykes. The presence of trapped volatiles, the consequent fluidity, and the relatively quiescent conditions prevailing, would tend to promote thorough segregation of materials and growth of coarse crystals. At the same time, any disorientation of crystals that occurred in the course of emplacement, or after, would tend to be perpetuated, because few new centres of crystallization would develop.

On the other hand, steep-dipping openings would be more likely to extend to higher levels in the zone of fracture and permit the escape of fluids and their replenishment by material from a parent source. In such essentially open-system conditions, deposition of material stable at successively lower energy levels would tend to take place at successively greater distances from the source. In particular, lithium-rich fluids might be abruptly separated from material crystalline or highly viscous at the higher temperature of the source area, to penetrate far into a cooler upper and/or outer environment. The ensuing rapid decrease in pressure would favour the escape of highly volatile constituents and the fixation of lithium exclusively in the simple anhydrous aluminosilicate, spodumene. The thermal gradient with reference to the walls would be high; the crystals would tend to grow rapidly from a large number of points, and, supplied by passing fluids, would be strongly influenced towards orientation perpendicular to the walls. Thus a comparatively fine-grained, well-oriented structure would result.

Sudden changes in the rate of flow of material or in concentration of volatiles, occasioned by stress movements or other factors, would, according to the mechanism envisioned by Tremblay (1950, p. 45) cause abrupt changes in granularity. This would result in bands of alternating finer and coarser material, without any consistent progressive sequence. Thus the characteristic erratic interlayering of pegmatite and aplite in many unzoned dykes finds a ready explanation.

It is not implied that only flat-lying fractures can act as structural traps, or that only steep-dipping fractures can permit the free flow of material. The choice of these examples derives from the statistical data on which the interpretation is based. The essential inference is that varying degrees of restriction in lithium pegmatite-forming systems, due to structural factors, were instrumental in determining both peculiarities of granularity and fabric, and internal and regional zoning phenomena.

Conclusions Regarding Development of Lithium Pegmatites

Granularity, fabric, and internal and regional zoning relationships of lithium-bearing pegmatites in the Canadian Shield suggest that the component minerals were deposited from a fluid medium in a falling-temperature crystallization sequence. Statistical interrelationships between internal characteristics and attitude of individual bodies suggest further that varying degrees of restriction in pegmatite-forming systems due to structural factors, were influential in determining the type and complexity of pegmatite formed in a particular regional zoning environment. Similar ideas regarding a relationship between internal and regional zoning in the Cat Lake – Winnipeg River district have been expressed by Davies (1958) and, regarding a relationship between attitude and internal structure at the Montgary pegmatite, by Hutchinson (1959).

The foregoing conclusions regarding an essentially igneous mode of development of the lithium pegmatites have been reached by the writer despite an essentially metamorphic view of the origin of most simple granite pegmatites found typically in gneissic terranes. The interpretation is believed to be valid in a general way, although factors of possibly major importance have not been taken into account. Among these are differences in composition of material supplied by batholithic sources at different times and at different levels, expansion and subsequent contraction of thermal aureoles, and concomitant development of fractures during the period of pegmatite emplacement. Available information does not suggest that unzoned lithium pegmatites grade downward into or merge abruptly with zoned bodies, as might be expected from the foregoing interpretation. On the contrary, some show little change in character from their surface to drilled depths of 1,000 feet. At the Quebec Lithium property unzoned dykes extend downward from volcanic rocks into granodiorite without appreciable diminution in spodumene content. Some of the factors just mentioned or other unconceived circumstances may have played a large part in the development of these unzoned bodies, but nothing is actually known about their 'roots'.

The role of replacement processes in the development of lithium pegmatites has received only casual mention because such processes have been considered to be confined to limited late-stage modification of bodies developed essentially by primary crystallization. Replacement, presumably deuteritic, has obviously been operative in the emplacement of much, if not all, lithia mica and associated cleavelandite, and Stockwell (1933, p. 34) considered some spodumene-quartz intergrowths in the complex Silverleaf pegmatite to be of secondary, deuteritic origin. Fine-grained unaltered spodumene intergrown with quartz and cleavelandite in some pegmatites that also contain coarse-grained corroded spodumene crystals, as in the Montgary pegmatite, may also represent a second generation of spodumene. Otherwise the field evidence does not seem to suggest that any significant amount of spodumene in the simpler pegmatites, especially the homogeneous unzoned ones, is of secondary origin. Nor is there anything to suggest that amblygonite, as typically found in discrete masses in core quartz, is other than a product of primary segregation.

Some theoretical considerations suggest, however, that replacement processes may play a major role in the development of lithium-rich pegmatites. In particular, the existence of monomineralic quartz cores in some complex zoned pegmatites poses a problem difficult to explain in a simple progressive-crystallization hypothesis. One explanation, as outlined by Brotzen (1959, p. 81-87), is that early-formed potassic feldspar reacts with accumulating residual H_2O and CO_2 in the falling-temperature environment, with the net result that potassium, having the most soluble alkali carbonate, is removed in solution and is preferentially replaced in aluminosilicate structures by sodium (less soluble) and/or lithium (least soluble carbonate). Concurrently released silica* is dispersed in a colloidal state, and ultimately agglomerates to form the core.

The replacement principle involved might be applicable to unzoned spodumene pegmatites, many of which contain masses of potassic feldspar that might be unreplaced remnants.

* Silica would be released, at any rate, in the replacement of potassium feldspar by spodumene.

Chapter IV

DESCRIPTIONS OF LITHIUM DISTRICTS AND OCCURRENCES

The descriptions of individual properties and lithium occurrences are preceded by general descriptions of the areas (denoted as 'district' and 'field') in which most of the deposits occur in compact geographical groups. These areal descriptions embody the primary generalizations that can be made regarding the deposits and their environment, and form the basis for the broader generalizations made in Chapter III.

The distinction between 'district' and 'field' is loosely applied, following customary usage, but reflects in some measure the number, importance, and variety of deposits in the areal groups so far as the Precambrian Shield is concerned.

Ranking first in these respects are the Preissac-Lacorne, Cat Lake – Winnipeg River, Yellowknife-Beaulieu, and Nipigon districts, each with eight or more deposits of considerable variety and geological interest, and which contain most of the deposits of greatest known economic promise.

The East Braintree–West Hawk Lake and Herb Lake districts and some 'fields' each have several properties on which intensive exploration work has established the presence of sizable deposits, but the other 'districts' and 'fields' are so designated mainly for convenience in reference to geographical or geological environment. Deposits treated as individual occurrences are generally less thoroughly explored, but are not necessarily of lesser economic potential than other deposits.

Table VI (pages 110-115) summarizes the data on most Canadian lithium occurrences.

QUEBEC

Abitibi County

Preissac-Lacorne District

This district lies between Amos and Val d'Or, Quebec (Fig. 4), and is accessible by Highways 60, 61, and 45. It contains two producing mines, that of Quebec Lithium Corporation, the only Canadian lithium producer, and that of Molybdenite Corporation, as well as a number of other lithium, beryl, and molybdenite deposits. The lithium deposits are mainly in Lacorne township and adjacent parts of Landrienne, Figuery, and Lamotte townships.

The consolidated rocks, Precambrian in age, are metavolcanic and metasedimentary rocks, intruded by granitic and more basic rocks of the Preissac-Lacorne batholith and by younger diabase dykes. The batholith is a composite of several intermediate to acidic rock types, of which 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.

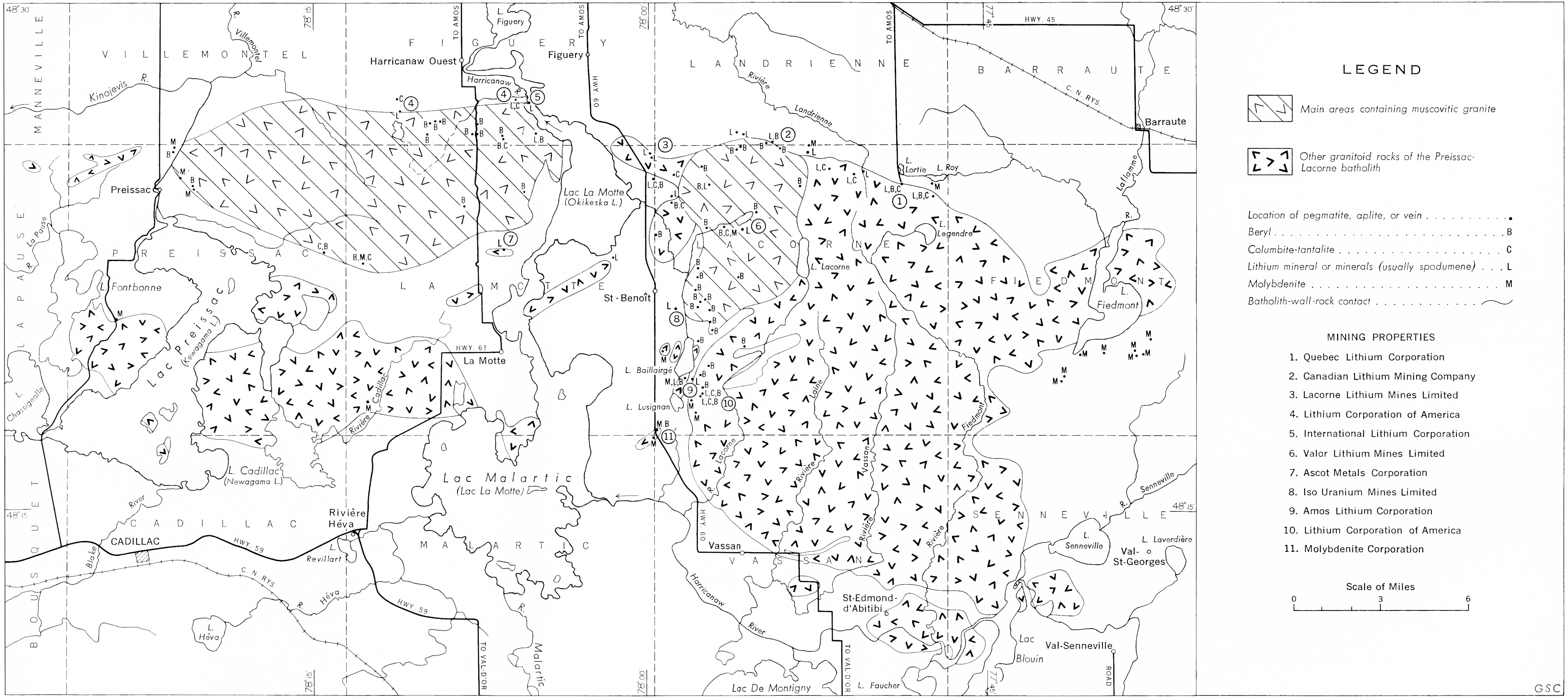

FIGURE 4. *Occurrences of lithium, beryllium, columbium-tantalum, and molybdenum minerals, Preissac-Lacorne district, Abitibi County, Quebec*

Most of the pegmatites near the contacts of the batholith strike either parallel with or at right angles to the contacts. These orientations, and the orientation of pegmatites within the batholith, suggest a control by joint systems. Many of the lithium 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 this fault.

Rare-element minerals found in some of the pegmatites include spodumene, minor lepidolite and other lithia micas, beryl, pollucite, molybdenite, and small amounts of columbite-tantalite and other minerals.

A rough regional zoning of the pegmatite minerals is apparent in this district. Beryl occurs 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 potash feldspar than the lithium dykes.

A few lithium-bearing dykes, that at the Valor property for example, lie well within the area mapped as muscovite granite and are apparently anomalous to the regional zoning pattern. However, in the Valor example at least, the dyke is distinctly zoned, complex in mineralogy and texture, and thus reflects the regional zoning pattern in its internal structure. Moreover the Valor deposit appears to be the keel of a pegmatite body that may have extended upward into older rocks above the present level of erosion.

Internal structures are absent or poorly developed in most dykes that carry substantial amounts of lithium. In the zoned dykes the internal structures are definite but complex, and zones are telescoped to a considerable degree.

The absence or scarcity of tourmaline is a noteworthy feature of the pegmatites of the Preissac-Lacorne district. Tourmaline is a prominent constituent of gold-quartz veins of the Val d'Or district to the south, but their age relative to the Preissac-Lacorne pegmatites is not known. Some tourmaline is present in east-west veins at the Lacorne Molybdenite property, south of the Lacorne batholith. These veins, composed chiefly of quartz, also carry a little beryl and white feldspar as well as minor molybdenite and other sulphide minerals. The absence of lithium minerals from this assemblage may signify that the regional spatial relationship of molybdenite veins to spodumene dykes may be due to structural or other causes not directly connected with paragenetic sequence. The siliceous molybdenite-bearing veins are, however, commonly regarded as the final phase of a differentiation series that gave rise to the pegmatite bodies (Norman, 1945) and the writer has found molybdenite-bearing quartz veins cutting spodumene-bearing pegmatite at the Iso-Uranium property.

Quebec Lithium Corporation

The property of Quebec Lithium Corporation covers the eastern and central lots of range VIII and IX and parts of range X, Lacorne township. The mine and mill plants are on lot 54, range IX, about ¼ mile south of Lac Lortie and 6 miles south by road from a point 17 miles east of Amos on Highway 45.

The property includes the former holdings of Lacorne Lithium Mines known as the "Ventures Zone", and those of Lithium Exploration Company, known as the "East Zone" (Rowe, 1953a).

Numerous parallel, spodumene-bearing pegmatite dykes lie within a band up to 2,000 feet wide that trends S76°E through the shaft area for more than 8,000 feet to the outcrops of the east zone. They cut amphibolitized greenstone and granodiorite along the margin of a northeast protrusion of the Lacorne batholith. They lie within about 4,000 feet of, and nearly parallel with, a large fault zone known as the "Manneville fault".

In the shaft zone, 10 or 12 subparallel or overlapping dykes strike mainly about N76°W and dip 50 to 75°S, cutting the greenstone-granodiorite contact, which slopes about 35 degrees northward (Fig. 5). Dykes are known to extend several hundred feet into granodiorite with good width and grade. They are as much as 2,000 feet long and 100 feet thick. Several of the dykes are exposed on the hill south of the mine, the original showing of Lacorne Lithium Mines.

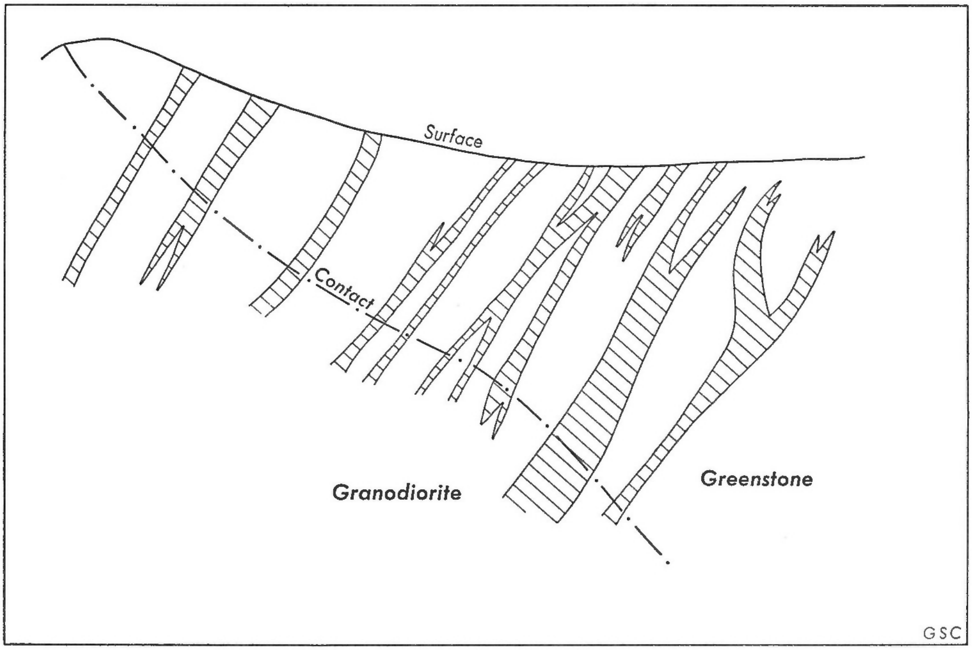

FIGURE 5. *Diagrammatic vertical section looking N76°W (Quebec Lithium Corporation). Unzoned quartz-feldspar-spodumene dykes (dipping steeply left) cut contact (dipping moderately right) between greenstone (upper right) and granodiorite (lower left).*

The dykes on the east zone comprise a main dyke, traced from the shaft zone by drilling, and a second dyke, 1,000 feet to the northeast. The main dyke is exposed at intervals for about 300 feet and has a width of about 15 feet. Like the dykes farther west it strikes N76°W and has been traced by drilling an additional 2,000 feet from the outcrop to the east boundary of the property.

The dykes are unzoned and are generally similar in composition and structure. They consist essentially of white feldspar, quartz, and spodumene, with only a little muscovite and other minerals. Coarse feldspar crystals lie mainly perpendicular to the dyke walls, their interstices being filled by spodumene crystals embedded in a fine-grained mixture of anhedral feldspar and quartz grains.

The coarse feldspar of the dykes is mostly potassic, the fine interstitial feldspar mostly albite. The potash feldspar seen in thin sections is quite unaltered and contains grains of plagioclase that appear to be inclusions rather than replacement products. Some plagioclase is much more fractured than adjoining potash feldspar grains.

A thin section of the contact between pegmatite and granodiorite from the east zone shows albite intergrown with abundant quartz in myrmekitic fashion, although the potash feldspar contains none. The granodiorite near the contact contains abundant green epidote associated with biotite in the interstices between feldspar grains.

Spodumene is the only important accessory mineral although beryl, fluorite, columbite-tantalite and other rare earths, molybdenite, and bismuth are occasionally found. The spodumene occurs essentially from wall to wall mainly with quartz, in bands separated by aplite and feldspar-rich stringers. The spodumene of the shaft zone is white, fine- to medium-grained, and oriented perpendicular to the local attitudes of walls and bands. The few coarse crystals are more random in orientation. The spodumene of the exposures in the east zone is pale green, medium-grained, and strongly oriented perpendicular to the granodiorite contacts. Some spodumene is locally altered to a dark green colour, especially near a watercourse underground, and leached spodumene and feldspar occur in the fissure.

A purple colour in amphibolite country rock locally near dyke contacts has been noted. A sample of this material provided to the writer contained, besides some brown biotite and green alkaline amphibole, abundant purple amphibole in fine acicular crystals. The purple absorption colour is much deeper for Z than for Y. The optic angle 2V is approximately 60 degrees about X, with Z about parallel to the elongation. The properties are comparable to those given by Sundius (1947, p. 268), for holmquistite, an amphibole of the glaucophane group containing 3.5 per cent Li_2O.

Yellow garnet is a locally conspicuous minor constituent of the dykes. Rare-earth minerals present in minute quantities include bright black vitreous grains, one specimen of which was identified as polycrase.

Based on observations plus a theoretical projection of the granodiorite-greenstone contact southward above the present level of erosion, Latulippe (1957) concluded that: (1) the richest concentrations of spodumene occur in the contact zone, (2) the dykes become weak, narrow, and low grade in the volcanics at about 600 feet above the contact, (3) the amount of pink orthoclase increases and that of spodumene decreases in the granodiorite 2,000 feet below the contact, (4) the spodumene of the dykes is generally light grey and finer grained in the volcanic rocks, and light green and coarser-grained in the granodiorite, and (5) those parts of the dykes in which spodumene is well oriented are of higher and more uniform grade than the parts where the crystals lie at random.

No estimates of total ore reserves have been published by the company. Fifteen million tons grading 1.2 per cent Li_2O were reported to be indicated by diamond-drilling to 850 feet depth within a 600-foot radius of the shaft. Ore mined during 1957 was reported to exceed 1.25 per cent. Exposures on the east zone have been estimated to contain 20 per cent spodumene, and a further large tonnage of mineable material is almost certainly available.

Initial development and mill installation at the Quebec Lithium property were completed in 1955. The company uses a flotation process and produces spodumene, feldspar, and mica concentrates. Production in 1957 was at the rate of about 1,000 tons of ore per day. Recoveries up to 94 per cent and grades of concentrate up to 5.5 per cent lithia have been reported. The spodumene concentrate was, until 1959, exported to the United States under a contract with Lithium Corporation of America. The contract called for 165 tons per day grading 4½ per cent or better Li_2O at $11 per unit. On cancellation of the contract by Lithium Corporation of America in November 1959, production was suspended, but resumed at a reduced rate on completion of a lithium chemicals plant at the property in 1960.

Canadian Lithium Mining Company Limited

The property of Canadian Lithium includes much of the western part of range X, and a few of the western lots of range IX, Lacorne township, also some adjoining parts of range I, Landrienne township.

A number of lithium-bearing pegmatite bodies cut granodiorite, and volcanic and metasedimentary rocks close to the north margin of the Lacorne granite batholith. They strike mainly northwesterly, about parallel with the contact and seem to be contained in a northwesterly trending belt about 2 miles long, in which a large amount of diamond-drilling has been done.

Near the southern border of lots 25 and 26, Landrienne township, several dyke-like masses composed of interbanded pegmatite and aplite contain spodumene in small pockets. On lot 25 a small pit reveals coarse, random-oriented, white and green spodumene, lepidolite, and a little beryl, associated with quartz, white cleavelandite, and coarse, massive, white feldspar. The spodumene crystals are distorted, and are veined and partly replaced by cleavelandite, lepidolite, and quartz. Lepidolite occurs chiefly as films along the contacts between the cleavelandite-quartz and the spodumene plates. The above assemblage is not recognizable beyond the boundaries of the pit. It is near the southern contact of the dyke and is separated from it by about 4 feet of aplite and cleavelandite-quartz muscovite pegmatite. One other small patch in the dyke contains a little purple curvilamellar mica associated with cleavelandite, quartz, and a little altered spodumene.

On lot 26 a parallel dyke more than 800 feet long and 100 feet wide consists of interbanded aplite and coarse feldspar-quartz-mica pegmatite. Spodumene is conspicuous only near the northwest limit of exposure. It is medium to coarse grained, partly altered and associated with quartz and coarse white euhedral feldspar in lenticular stringers. Some parallel orientation is noticeable but the attitude is variable and many crystals lie at random.

In the northern part of lot 35, range X, Lacorne township, a spodumene-bearing dyke is reported to have been outlined by diamond-drilling (M. Latulippe, personal communication). No exposures of pegmatite were found by the writer.

In the southern part of lot 38, range X, interbanded aplite and pegmatite form an anastomosing network among inclusions of dark grey granodiorite, the zone striking generally northwest. Fine-grained pale green spodumene with quartz occurs in parallel cross-orientations in discontinuous stringers about a foot thick. The pegmatitic phases contain some coarse perthitic microcline crystals. Interbanded aplite contains abundant disseminated, fine-grained red garnet, the resulting pink coloration standing in marked contrast to the greenish colour of spodumene-bearing lenses.

Lacorne Lithium Mines Limited

The property of Lacorne Lithium Mines comprises the east-west lots 57 to 61, the east half of lot 62, and the north-south lots 63 and 64, range X, in the northeast corner of Lamotte township.

Easterly and northeasterly striking pegmatite dykes cut granodiorite and diorite, which contain numerous inclusions of biotite schist. Some trenching has been done, and 16,952 feet of diamond-drilling was done in 1955 and 1956. Spodumene-bearing dykes have been explored in the following three areas: (1) on lots 60 and 63, where there is a curved dyke 1,200 feet long and 20 feet wide, and on lot 59, where there is another dyke 1,000 feet long and an average of 5 feet wide; (2) on lots 61 and 62, where there are at least six northeasterly striking dykes, up to at least 800 feet long and from 20 to 85 feet wide; and (3) at the east end of lot 61, where a series of discontinuous dykes strike eastward.

In localities 1 and 3, medium-grained spodumene is irregularly distributed throughout the dykes. In locality 2 it is confined to grey quartz which forms longitudinal and cross-stringers in the dykes and carries up to 40 per cent spodumene.

In exposures of several dykes seen by the writer east of Highway 60, coarse- to fine-sized spodumene was found mainly in pods of quartz with some euhedral, flesh-coloured feldspar, forming discontinuous cores. The outer parts of the dykes consisted of rather fine pegmatite or aplite with garnet and a few small beryl crystals.

Lithium Corporation of America (Figuery Township)

The main property of Lithium Corporation of America in Figuery township is in range II, about half a mile west of Harricanaw River.

At the showing on lot 36, range II, a dyke is intermittently exposed for about 300 feet by stripping and trenching. The dyke contacts are not exposed, but the steep northerly plunge of most spodumene crystals suggests a gentle southerly dip, parallel with an ill-defined zone boundary. The dyke is roughly zoned. An inner zone consists chiefly of quartz with medium- to coarse-grained green spodumene and long white perthite crystals in subparallel orientation. An outer zone consists of white cleavelandite, with quartz, coarse white feldspar, muscovite, and green spodumene. The spodumene is veined by quartz and cleavelandite. Garnet and tourmaline are present in small amounts, and rare rusty black equidimensional grains were identified as sphalerite.

The dyke is reported to be in a north protrusion of the Lamotte granite batholith (Ingham and Latulippe, 1957). Reported drilling results indicate a dyke length of 600 feet and width of 30 feet. The spodumene content of the inner zone has been estimated at about 20 per cent (Rowe, 1953a).

At another property owned by the company, 4 miles to the west, three dykes occur in the northern margin of the Lamotte batholith. One of these carries abundant spodumene across 10 feet as exposed in a surface pit (Ingham and Latulippe, 1957).

International Lithium Corporation

The property of International Lithium Corporation covers lots lying athwart Harricanaw River in range II and range III, Figuery township. Flat-lying lenses of pegmatite occur in an area about 300 by 400 feet, just outside the north margin of the Lamotte granite batholith. The main body of pegmatite is reported to be 12 feet thick and to average close to 1.0 per cent Li_2O.

The showing on lot 39, range II, Figuery township, is on the tip of a peninsula on Harricanaw River. A very small incomplete exposure shows distinct unsymmetrical banding across an exposed width of 14 feet. A low-grade cleavelandite-spodumene-quartz-muscovite band on the south side is succeeded in turn by a coarse, random-oriented, spodumene-quartz band, a finer-grained band in which spodumene plunges 15°N, a barren blue-striped quartz band, and an aplite-pegmatite band that is in contact with schist. The spodumene is mostly green and is broken and veined in two directions by fine cleavelandite and mica. Quartz biotite schist, dipping gently northward, is exposed on the south side of the point.

Valor Lithium Mines Limited

The property of Valor Lithium Mines covers parts of ranges VII, VIII, and IX, in the northwest quarter of Lacorne township.

At the main showing on the southern part of lot 22, range VIII, Lacorne township, aplite and pegmatite form irregular masses and stringers in granitic rocks of the Preissac-Lacorne batholith. This occurrence is well within the batholith and so is anomalous to the general regional zoning of the district. In an irregular core zone about 125 feet by 75 feet, pale green to white spodumene crystals up to 6 feet long in random orientation are embedded in cleavelandite-quartz lapidolite aggregates that vein the broken and distorted spodumene crystals. These aggregates make up about half the core area and contain about 50 per cent spodumene, along with small amounts of white beryl and grey-weathering pollucite, the latter in masses up to 5 feet long.

Where zoning is best developed (Plate IIA), normal muscovite-biotite granite is in gradational contact with a bleached border zone 1 inch thick. This is in contact with a fine-grained aplitic band about an inch thick, which grades into an intermediate feldspar-quartz-muscovite-beryl zone, and this in turn into the cleavelandite-quartz-spodumene-lepidolite (plus beryl, pollucite) core aggregate.

The aplite and/or bleached border zone is as much as 6 inches thick in places; in others it is absent. At one locality near its southwestern end the core assemblage merges with the intermediate zone and there contains abundant white to pale green beryl, associated with coarse muscovite. An irregular aplite band that marks the inner limit of this mixed zone has numerous small beryl crystals scattered along its contact. The aplite of such bands is commonly thickly peppered with fine-grained red garnet.

The 'core-zone' passes on strike into banded coarse perthitic pegmatite and aplite containing a few small patches of 'core' aggregate. Similar pegmatite bodies elsewhere on the property contain beryl but no visible lithium minerals.

Twenty-four holes totalling 8,466 feet were drilled on the property in 1955. The depth extension of the spodumene-bearing zone proved to be inconsiderable. The exposed body apparently represents the keel of a zoned pegmatite deposit.

Ascot Metals Corporation

The property of Ascot Metals Corporation, in range VII, Lamotte township, is about a mile west of the narrows of Lake Lamotte. A pegmatite dyke that cuts a biotite-granodiorite plug south of the Lamotte batholith is 800 feet long and 7 feet wide, as indicated by drilling. It dips northward, crossing a contact into peridotite at a depth of about 400 feet. The dyke is roughly zoned, with a discontinuous core of coarse spodumene-quartz-mica-feldspar pegmatite, an intermediate zone of medium-grained pegmatite with a little spodumene, a layer of coarse muscovite, and aplitic walls. It assayed 0.8 per cent Li_2O on drill core, compared with 1.75 per cent on surface samples, and apparently dies out on entering the peridotite.

Iso Uranium Mines Limited

Iso Uranium Mines Limited holds ground covering two occurrences of spodumene-bearing pegmatite.

One of these pegmatites, on lot 5, range V, Lacorne township, is intermittently exposed over several hundred feet in a northwesterly direction, is up to 40 feet wide, and is crossed by several trenches. It consists of interbanded aplite and coarse feldspar-quartz pegmatite with minor muscovite. Fine-grained lath spodumene, in longitudinal stringers between aplite and pegmatite, is oriented perpendicular to the walls and may compose 20 per cent of the stringers, which in turn make up about half the exposed dyke in some places. A few narrow stringers of quartz cut the dykes. One of these, about 2 inches thick, contains scattered nests of molybdenite.

The other spodumene-bearing pegmatite is on lot 60, range VII, Lamotte township, just south of a large diabase dyke. Two or three pegmatite stringers up to 2 feet thick strike northwesterly and dip northeasterly. They carry a little fine spodumene, oriented perpendicular to the walls, in patchy central bands.

Amos Lithium Corporation

The property of Amos Lithium Corporation is in the southern part of lots 7 and 8, range III, Lacorne township, near the southeast shore of Lake Baillarge.

Three main spodumene-bearing pegmatites cut granitic rocks and altered sedimentary and volcanic rocks that form oriented inclusions in the granitic rocks. The southern pegmatite body is an irregular dyke about 400 feet long and up to 12 feet wide, striking generally northwest. Random coarse spodumene forms up to 20 per cent of a vague discontinuous zone, and is mainly associated with cleavelandite and quartz. Other parts contain large white perthitic feldspar crystals and large masses of quartz. A banded aplite zone intervenes between the cleavelandite-quartz-spodumene assemblage and the wall-rock at one place. Fourteen diamond-drill holes totalling 3,280 feet were drilled in this dyke in 1955 to 1956 (M. Latulippe, unpublished report, Quebec Dept. Mines, 1956).

The central pegmatite body is about 750 feet farther north. It is exposed intermittently for about 800 feet in a northwesterly direction and is up to 45 feet wide. Near its northern end, where the land slopes toward the lake, irregular curving dykes and cross-stringers consist of contorted and banded aplite and coarse quartz-perthite pegmatite, with coarse spodumene largely altered to mica. Beryl crystals are fairly numerous in quartz segregations, but were not seen in the cross-dykes. A trench at the crest of the slope shows random coarse spodumene with coarse white perthite below a narrow band of coarse feldspar-quartz-muscovite that forms a flat-lying zone below a granitic hanging-wall. Quartz masses in the hanging-wall zone carry a few beryl crystals. The dyke appears to die out a short distance to the southeast.

The northern pegmatite body is three or four hundred feet farther northeast. It strikes about N30°W and dips steeply. Near the lakeshore it has been stripped across 50 feet or more and consists of well-segregated coarse white feldspar and quartz, with scattered, coarse, random spodumene crystals in patches of cleavelandite. A cleavelandite-quartz-muscovite assemblage along the walls carries beryl. Farther up the hill the dyke is about 30 feet wide and contains only a few scattered spodumene crystals. Columbite-tantalite crystals up to 2 by 4 inches have been found in this dyke. Five holes totalling 1,554 feet were drilled to intersect the dyke near the lakeshore.

Lithium Corporation of America (Lacorne Township)

This deposit is in the central part of lot 11, range II, Lacorne township. The showing was originally found by Mr. F. W. Schubb in 1944, and was subsequently held by Great Lakes Carbon Corporation. This company, in 1947, drilled seven holes to test the downward extension of the surface values, but apparently did not encounter encouraging results (Tremblay, 1950, p. 74).

A considerable amount of surface trenching has since been done on two main north-northwesterly-trending dykes, about 500 feet apart. The dykes dip from 75°W to vertical and cut gneissic biotite granite within half a mile northwest of its contact with a large mass of granodiorite-quartz monzonite.

The eastern dyke is fairly continuously exposed for eight or nine hundred feet, ranges in width from 10 to 36 feet, and dips about 75°W. The middle section is partly covered and much split up. The dyke is cut by six cross-trenches. It is poorly zoned in places, with bands rich in spodumene alternating with bands of feldspar-quartz-muscovite pegmatite and of aplite or fine granodiorite. The spodumene is associated with coarse white to pale pink feldspar (probably microcline), cleavelandite, quartz, and little muscovite. It is green, medium grained, and mostly oriented perpendicular to the dyke walls. It probably makes up 25 per cent or more of some bands that are up to 8 feet thick in places. Altered spodumene crystals, associated with much greenish muscovite, are scattered through leaner bands. Beryl occurs prominently in a few places as small green crystals, along with quartz in the muscovite-cleavelandite bands, and at one point near the east end of the southernmost trench a small mass of molybdenite was found. Tantalite-columbite and bismuthinite have been reported as minor constituents in these dykes (Tremblay, 1950, p. 74).

The second large dyke lies about 500 feet to the west. It is well exposed for about 400 feet and is up to 50 feet wide. It is crosscut by five deep trenches, which in 1957 appeared to be newly made. Fine- to medium-grained spodumene is mostly confined to narrow stringers of pegmatite and aplite in medium-grained granodiorite. Some stringers up to 11 feet wide may carry 10 to 15 per cent spodumene locally. Part of the spodumene is pseudomorphed by greenish muscovite. The associated coarse white feldspar locally appears perthitic. The southernmost trench reveals two bands, one white, the other pink, totalling 15 feet in width. Fine-grained spodumene is more prominent in the pink aplitic band than in the white band, which contains more coarse white feldspar.

Other Properties in the Preissac-Lacorne District

Other properties that have been drilled and are reported to contain some spodumene include the following: Valee Lithium Mining Corporation, ranges VIII and IX, Fiedmont township (east of Quebec Lithium); Gaitwin Explorations Limited, range IX, Lamotte township (south of Lacorne Lithium); Keyboycon (renamed Con-Key), ranges I and II, Landrienne township (north of Canadian Lithium); and Lithanium Mines, range II, southeast Figuery township, which reports a molybdenite occurrence but negligible lithium values.

Other Abitibi County Occurrences

Bellecombe Township

The pegmatites in Bellecombe township carry some spodumene, beryl, and molybdenite, but no economic deposits of these minerals have been found. Pegmatite, with biotite-muscovite granite and migmatite, forms part of a large intrusive mass lithologically similar to the Lacorne mass (MacLaren, 1952).

Montanier Township

The Wells-Lacourciere showing, in Montanier township, is about 15 miles south of the village of Cadillac. It is a few hundred feet northwest of the Rapide II road at a point 9.7 miles south of a guarded gate.

A pegmatite dyke reported to be 2,000 feet long strikes northwest from a point about 150 feet northwest of the road. It cuts biotite granodiorite where the contacts are exposed. The stratified rocks of the area are quartzose schists of the Pontiac Group, and boulders of quartz-biotite schist containing staurolite and kyanite porphyroblasts and small tourmaline crystals lie in the drift nearby. The dyke is exposed intermittently for about 1,500 feet and is 40 to 50 feet wide where best exposed. The dip is uncertain but is probably southwest.

The dyke is composed chiefly of white microcline, in coarse crystals, cleavelandite, and quartz, with some spodumene, and minor biotite, muscovite, tourmaline, and beryl. Some degree of zoning is evident, in that nearly all the spodumene is concentrated in quartz-rich pods that are mainly in the central part of the dyke. These pods are discontinuous and do not make up a major part of the dyke. The spodumene, which makes up as much as 15 per cent of the pods, is pale green to white, and weathers to a buff colour. It is coarse grained and random in orientation. Biotite, which occurs in thin radiating books up to 8 inches across and makes a lacy pattern on the outcrop, is largely in the outer parts of the dyke. Black tourmaline is in nests scattered outside the quartz pods. Muscovite forms thick books rarely more than 2 inches in diameter. Beryl occurs as scattered pale green crystals up to 4 inches long. It is mostly in interior parts of the dyke, but was not seen in the quartz-spodumene pods.

The dyke appears to split up into intersecting pegmatite stringers among granodiorite inclusions near its southeast end.

Témiscamingue County

Spodumene-bearing dykes occur in Delbreuil township, near the north shore of Lac Simard (Lake Expense).

In 1959 the writer made a brief examination of a dyke on ground believed to be held by Paul Viau, Rouyn, Quebec, less than ½ mile north of the central part of the north shore of the lake.

Over an exposed length of about 175 feet the dyke varies in width from 30 to 60 feet and strikes about east. It consists of pegmatite and aplite stringers with granite walls and inclusions. Spodumene occurs in white, green, and pink crystals up to 3 feet long in random orientation in a poorly defined central lenticular zone composed of quartz, sugary aplite, coarse feldspar and cleavelandite.

About 3 miles farther east, on ground then held by R. Legault of Lorraineville, Quebec, the writer saw spodumene in scattered pockets or patches in the large pegmatite mass that underlies that part of the area.

Papineau County

Wakefield Township

Leduc Mine

The deposit known as the Leduc mine is near the east boundary of the south half of lot 25, range VII, Wakefield township (Spence, 1916, p. 42; Ellsworth, 1932, p. 239). It is on the southwest slope of a ridge overlooking the south branch of Rivière Blanche. An old trail from a point on the main road near the east end of a narrow lake-like expanse of the north branch leads southward about ¾ mile to the deposit.

A pegmatite dyke cutting granitic gneiss is exposed by an old pit about 60 feet long, 12 feet wide, and 20 feet deep on its northeast or uphill side.

The attitude of the dyke is not readily apparent; it is described as striking northeast, but the pit trends about N15°W and appears to follow the boundary of a zone that dips somewhat into the hillside.

The dyke is coarse grained, and is composed of several kinds of feldspar (including cleavelandite and amazonite), quartz, tourmaline, and lithia mica. It is distinctly, though irregularly zoned. The mica and most of the tourmaline and amazonite occur in cleavelandite near the east boundary of a well-defined, though now discontinuously exposed quartz core.

The mica is purplish grey and is in large books commonly 8 inches wide and 2 inches or more thick. These books commonly meet at small angles, the wedge-shaped interstices being filled by white cleavelandite. The mica fuses readily, giving an intense lithium flame coloration without much of the usual sodium-yellow. It contains about 5 per cent Li_2O, which is higher than normal for lepidolite, but the iron and manganese contents approach those of zinnwaldite.

White microcline is the most common feldspar, occurring in large crystals and masses. Pale to deep green amazonite is in scattered subhedral crystals up to 18 inches long. Cleavelandite is commonly interstitial to these and is partly intergrown with quartz along the core boundary. Some scarce glassy feldspar, probably albite, shows a marked iridescence on cleavage faces.

Tourmaline is abundant, chiefly just outside the core boundary but also in the quartz. Probably most is black but a good deal is dark green, and a little light green and pink material was found, forming parts of some crystals. The crystals are commonly a foot or more in exposed length, are deeply striated, and randomly oriented.

The deposit was first mined for mica as long ago as 1885, the mica being mistaken for muscovite, and about a ton is reported to have been taken from one surface pit. Later attempts were made to exploit the deposit for gem tourmaline but without success, because of the fractured condition of the crystals. The amount of lithia mica in sight is negligible, and nothing was seen to suggest the presence of other lithium minerals, although their apparent absence is rather remarkable.

Assinica Lake

(Lat. 50° 37′, Long. 75° 27′)

Spodumene occurs on the property of Sirmac Mines Limited, 9 miles northwest of Assinica Lake, and 80 miles northwest of Chibougamau, Quebec. The company reported surface work in 1960 on four pegmatites, one of which is 1,800 feet long and 350 to 400 feet wide. It is zoned with a lithium-rich core, and consists of white feldspar, quartz, spodumene, and minor beryl (Northern Miner, Sept. 29, 1960, p. 1).

James Bay

On Walrus Island, Paint Hills group, about latitude 53°, near the east coast of James Bay, spodumene occurs in a micaless, orthoclastic, granitic veinstone cutting syenite (Johnston, 1915, p. 212).

SOUTHEASTERN ONTARIO

Spodumene has been reported in Lanark county, near Perth, "in a small rolled mass of granite" (Johnston, 1915, p. 212).

NORTHWESTERN ONTARIO

Nipigon District

All deposits of this district, except the Lun Echo dyke, lie east of Highway No. 11, in the general vicinity of Orient Bay, Ontario. They are contained within a belt that extends from a point west of Cosgrave Lake, through the Georgia Lake and Jean Lake areas to a point about 10 miles south of Beardmore (*see* Fig. 6). Pegmatite dykes intrude Archaean metasedimentary rocks comprising biotitic quartzite and quartz biotite schist, and granitic rocks that underlie large areas to the south and east of the district. Large masses of diabase that outcrop extensively are parts of a thick flat-lying intrusive sheet and associated steeply dipping dykes. The diabase is younger than the pegmatites, and cuts a number of them off at depth.

A rough regional zoning is apparent in the district. The Nama Creek and Jean Lake dykes, which are farthest from the granite, are mainly steep-dipping

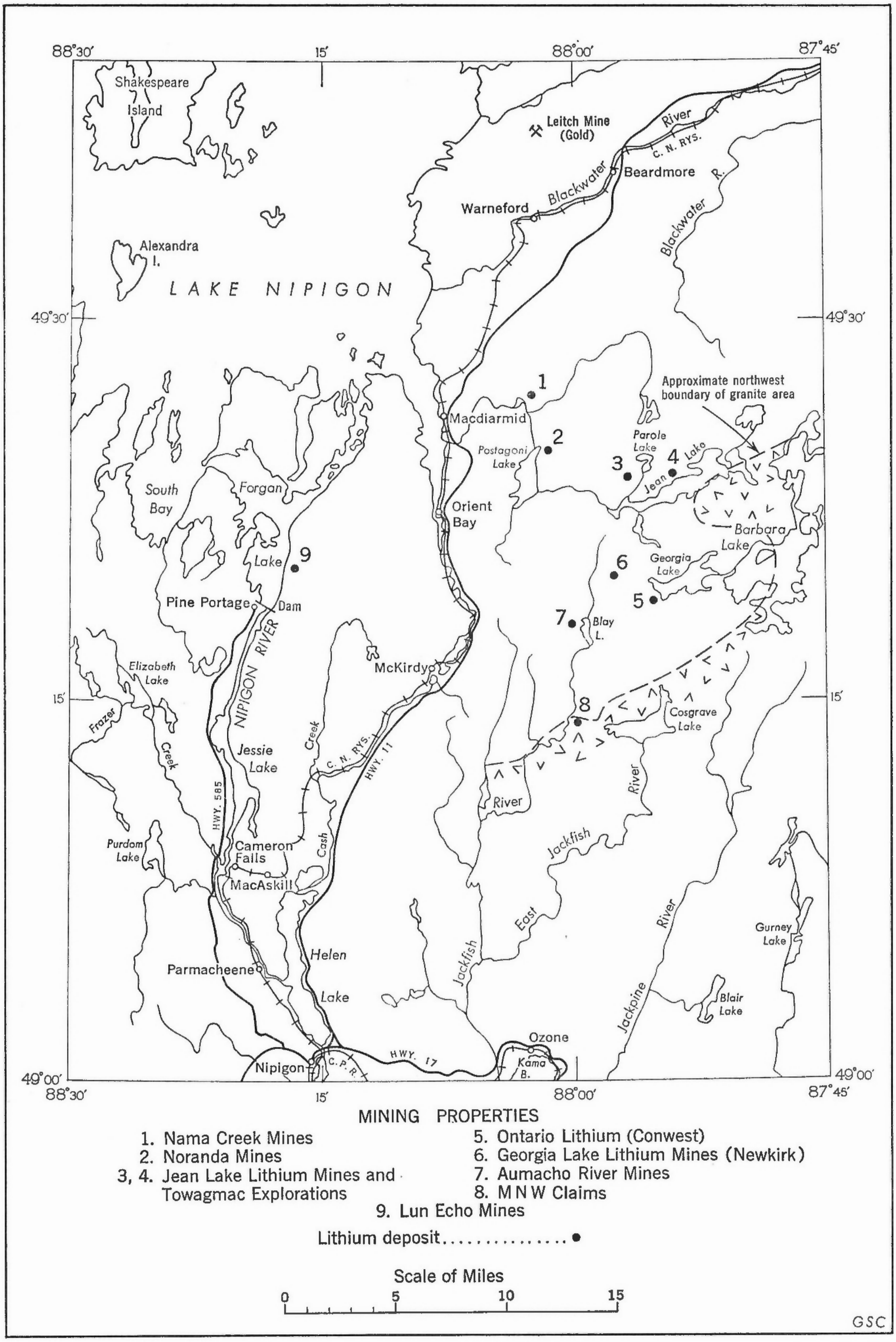

FIGURE 6. *Lithium deposits, Nipigon district, Ontario.*

and unzoned. They contain medium-grained spodumene in parallel orientation, essentially from wall to wall. Those farther south near Georgia Lake commonly have gentle dips and are imperfectly zoned, with coarse spodumene in random orientation mostly confined to ill-defined core zones. The M.N.W., the southernmost property, is wholly in granite, and is a typical zoned dyke. 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.

The dykes are composed essentially of quartz, white albite, and minor potash feldspar, and varying small amounts of muscovite. A little blue apatite in small grains is common, but tourmaline, beryl, and cleavelandite are conspicuous only in the M.N.W. dyke. Spodumene is the only lithium mineral of importance, but a little amblygonite is present in the M.N.W. dyke.

Alteration of spodumene to a dark green or brown, soft, woody mass is especially severe near large masses of diabase. Spodumene and feldspar are locally leached and altered to a deep red colour.

Nama Creek Mines Limited

(Lat. 44°27′, Long. 88°02′)

The property of Nama Creek Mines Limited lies just north of Little Postagoni River near its junction with Postagoni River. The claim map covering the property is the Beardmore South sheet, District of Thunder Bay (Ontario Department of Mines). The camp buildings and shaft are 4.5 miles by truck road east of a point 12.3 miles south of Beardmore on Highway No. 11.

A number of feldspar-quartz-spodumene dykes with minor muscovite cut biotitic quartzite and schist that strike mainly north of east and dip steeply. The 'north zone' on which the shaft is sunk comprises a series of northeasterly striking dykes arranged more or less *en échelon* and totalling some 2,800 feet in length. The dykes average 60 feet in width, and dip steeply northwest. A band of country rock interrupts the dyke near the shaft. A diabase dyke cuts the north zone near its northern extremity and a flat sheet cuts it at depth. Several oblique crosscutting fractures are marked by pale yellowish mica. The 'south zone' consists of a dyke whose northeast limit of exposure is 1,400 feet south and 400 feet west of the southeast extremity of the north zone. It also strikes northeast, is about 800 feet long, and 60 feet wide.

The dykes are all similar in mineralogy and structure. They are mineralogically unzoned and carry spodumene essentially from wall to wall, but are longitudinally banded. Medium-grained spodumene with interstitial fine quartz feldspar and a few coarse crystals of white feldspar occurs in bands and stringers separated by irregular stringers of aplite (Plate IIB). The spodumene, and most of the coarse feldspar crystals are consistently oriented perpendicular to the dyke walls. Most of the spodumene is light green, but part is altered to dark green and brown colours, and this alteration is thought to be related principally to the proximity to younger diabase bodies. Pale yellowish mica is conspicuous along oblique fractures in the dykes.

Drilling in 1955-56 on the north and south zones indicated reserves, according to company estimates, of 4.2 million tons grading 1.06 per cent Li_2O to a depth of 1,000 feet.

A power line, headframe, and surface buildings were installed and shaft-sinking started in 1956. This work was suspended early in 1957 at a depth of 503 feet.

Several pegmatite dykes that outcrop about 5,000 feet east of the camp area and on adjoining ground held by New Highridge Mining Company Limited are reportedly similar in character to those of the main zones, and also carry spodumene.

Noranda Mines, Limited

Several spodumene-bearing dykes outcrop on a property about half a mile east of the northern part of Postagoni Lake, held by Noranda Mines, Limited. The property was not visited by the writer.

According to Pye (personal communication) they are imperfectly zoned, a spodumene-rich core being in poorly defined contact with spodumene-poor or barren wall-zones. Specimens of feldspar taken at 2-foot intervals across a dyke proved to be all albite.

Jean Lake Lithium Mines Limited and Towagmac Exploration Limited

Jean Lake Lithium Mines Limited and the associated company, Towagmac Exploration Limited, hold 57 and 114 claims, respectively, within about 1½ miles of the north shore of Jean Lake. The claim map covering the properties is the Lake Jean sheet, District of Thunder Bay (Ontario Department of Mines). An access road, via the George Creek road and the power line to Postagoni Lake, was constructed to the camp at the outlet of Parole Creek in 1956 and 1957.

The country rocks are mainly poorly exposed quartz-biotite schists, but granite underlies much of the area southeast of Jean Lake and some granite outcrops north of the eastern part of the lake. Several spodumene-bearing pegmatite dykes outcrop on the properties. They strike in general about east and dip steeply. Those on the Jean Lake claims in the western part of the property are unzoned, and carry mostly medium-grained green spodumene, essentially from wall to wall, and strongly oriented perpendicular to the walls of the dykes. Those on the Towagmac claims in the eastern part carry mainly fine-grained white or buff spodumene in somewhat less regular orientation and show some development of spodumene-poor aplitic or pegmatitic outer zones. The easternmost of these dykes is bordered by granitoid rocks.

The dyke designated as Jean Lake No. 4 zone crosses the narrow south end of Parole Lake. It is exposed only in a few small isolated humps over about 100 feet in length and 12 feet in width. The dyke is strikingly cross-banded, owing to regularly spaced stringers of coarse white feldspar about a foot apart, and a foot thick. This dyke was drilled over a strike length of 1,200 feet, and showed substantial improvement in dimensions and grade with depth. According to company reports, results indicate 1.7 million tons grading 1.3 per cent lithia to a depth of 1,095 feet.

The dyke at No. 1 zone is south of the creek just east of Pomace Lake, about half a mile west of No. 4 zone. Two exposures which are separated by 15 feet of swamp have a total length of about 300 feet and an average width of 15 to 20 feet. Medium-grained green spodumene occurs throughout most of their length and width, associated with fine quartz and white feldspar. Scattered large crystals of white albite, masses of quartz, and pale green mica are prominent near contacts at the west end. The strike of the main part of the zone varies from about N40°E to N50°E and the dip, as indicated by a consistent northwest plunge of spodumene crystals, is 70 to 75° southward. A notable feature of the dyke is a cross dyke about 24 inches wide across the main section, in which medium-grained spodumene crystals are oriented perpendicular to the walls and to those of the main dyke. This is a rare, clear-cut example of a fracture filling. Nine holes drilled on this zone in 1956 yielded core-lengths up to 42 feet and grading up to 1.38 per cent Li_2O, according to company reports. Just south of No. 1 zone, another dyke (No. 2 zone ?) strikes southward up a hillside. It is up to 6 feet wide, as exposed, and carries coarse spodumene in random orientation.

Another dyke outcrops on an island in the central part of Jean Lake. It extends in a northeasterly direction through the length of the island, a distance of about 650 feet, dips 75°S, and is about 27 feet wide. At the northeast end, coarse pink feldspar forms cross-stringers. Local alteration of the spodumene here is clearly related to fractures. The dyke cuts metasedimentary rocks within about ¼ mile of their contact with granite. It carries some spodumene throughout, and has been explored by diamond-drilling.

The Foster dyke, the easternmost one in the Towagmac claims, is about ¾ mile north of Jean Lake. It was stripped and trenched over a length of 400 feet and a width of 50 to 75 feet, and strikes about N75°E. Toward the west end the dyke breaks up into anastamosing stringers in granodiorite and contains pink feldspar, but cores of stringers carry spodumene to the limit of exposure. Some drilling was done on this dyke late in 1956.

The "Low dyke" is about 1,500 feet southwest of the Foster dyke, and cuts fine quartz-biotite rock. It was stripped for about 100 feet along a strike of N65°E, and across a width of about 10 feet. The dyke is rather complex in structure, with fine-grained buff spodumene mostly in parallel orientation oblique to the strike of longitudinal stringers.

Ontario Lithium Company Limited (Conwest)

The property of Ontario Lithium Company Limited, known locally as the "Conwest property", consists of a large block of claims situated in the area near the southwest end of Georgia Lake. The Barbara Lake claim sheet (Ontario Department of Mines) covers the property.

A number of spodumene-bearing pegmatite dykes cut easterly-striking banded quartzites and quartz-biotite schists, which locally are nodular. Most are accessible by tractor trails from a campsite 10 miles east of the highway on "Camp 95" road, which leaves the highway at a point 4.6 miles south of Orient Bay.

The "Island Show", a reef on Georgia Lake, was the first reported discovery of spodumene in the district and was staked in 1955. Some drilling was done on this dyke in 1957. Some irregular pegmatite bodies carrying spodumene outcrop at the southwest end of the lake.

Another pegmatite body on the west side of Carrot Lake, about a mile farther southwest, was partly stripped and trenched. It is about 150 feet long and 70 feet wide, as exposed. It is a heterogeneous mass of aplitic, granitic and pegmatitic material, with pink-weathering spodumene in irregular stringers and patches as much as 15 feet across. The spodumene is rather coarse, in random orientation, and is mixed with quartz and white feldspar.

Several other dykes outcrop near and south of the road just west of the campsite. They are apparently gently dipping bodies and are partly cut up by intrusions of late diabase. The spodumene is coarse grained and random in orientation.

The "Jackpot" show covers a considerable area northeast of the small lake at the main campsite, across a swampy creek. This appears to be a complex multiple sill consisting of individual pegmatite lenses separated by narrow septa of quartz-biotite country rock, the whole dipping gently northwest. Parts of these pegmatite lenses carry well over 50 per cent spodumene, which is pale green to buff-coloured, and uniformly coarse grained. It is somewhat random in orientation, but near the hanging-walls of lenses, where the richest concentrations occur, the spodumene crystals are mostly well aligned and plunge steeply southeast. Drilling on this showing in 1955-56 proved its depth extension to be negligible, but revealed another similar flat-lying sill at depth, which has been traced along strike for 600 feet and down the dip for 750 feet. It is reported to contain about 2 million tons grading 1.09 per cent Li_2O.

Georgia Lake Lithium Mines

The property of Georgia Lake Lithium Mines, known as the "Dunvegan – Newkirk" property, consists of a block of claims situated about 1¼ miles west of Georgia Lake.

The country rocks are nodular quartz-mica schists, striking about east. Two outcrops of pegmatite were found, at about 1.8 and 2.5 miles by trail respectively, north of the road. At the first, a ragged dyke striking about N35°E has been stripped and trenched at intervals over a length of about 300 feet and a maximum width of 16 feet. It contains medium-grained spodumene in random orientation in irregular lenses. At the second, a dyke has been partly stripped over a length of 100 feet and width of up to 18 feet. It appears to strike east and to dip gently north. Random-oriented medium-grained spodumene occurs mainly with quartz in bands a few inches wide, separated by bands of aplite and coarse white feldspar, but no systematic zoning is evident.

According to Pye (1956), a dyke strikes N75°W for 2,600 feet across the Dunvegan and Newkirk claims and averages about 16 feet in width. The results of drilling in 1955-56 were reported by the company to be negligible.

Aumacho River Mines Limited

The property of Aumacho River Mines Limited consists of fifteen claims situated about 4 miles southwest of Georgia Lake. The drill camp and outcrop are at the north end of Blay Lake, about ½ mile south of a point 6.4 miles east of the highway on the 'Camp 95' road.

As exposed for about 150 feet, the dyke is in granite, pinches and splits irregularly, and ranges from 5 to 12 feet in width. Coarse, pale green and white spodumene in random orientation forms clusters within the dyke. Fairly well defined aplitic 'chill zones' at the contacts contain blue apatite in small, scattered grains, and a little tourmaline, with rather abundant muscovite. The feldspar, in part microcline-twinned, is in long white crystals oriented mostly at right angles to the dyke, and the spodumene-quartz masses are mainly interstitial. Similar spodumene-bearing pegmatite forms an isolated hump in a swamp about 300 feet to the south.

The dyke strikes northward into schist where it is reported to assume a north strike, a dip of 40°W and an average thickness of 15 feet. The ore reserves on the property, as indicated by drilling in 1955-56, are reported by the company to be 760,000 tons grading 1.63 per cent Li_2O.

M. N. W. Claims

The M.N.W. property consists of a group of claims situated near the south end of a ridge east of Jackfish River, about 1½ miles west of Cosgrave Lake. It is owned by Murray Wilson, of Nipigon, and associates, and was drilled under option by Consolidated Mining and Smelting Company of Canada Limited in 1955-56. It was optioned to Little Long Lac interests late in 1957.

A pegmatite dyke cutting granite is exposed for about 900 feet and ranges from 20 to 45 feet in width. It strikes north and dips vertically. The dyke is exceptionally well zoned.

Pure white spodumene in random-oriented large crystals, and fine quartz-spodumene crystal-like aggregates are embedded in quartz that forms a lenticular core zone 400 feet long, up to 35 feet wide, and 100 feet deep. An intermediate zone consists chiefly of pink cleavelandite and some coarse white feldspar, with quartz, coarse muscovite, and scattered white beryl crystals. The outer zones are marked by aplite with narrow bands rich in black tourmaline. The outermost band of tourmaline, about ½ inch wide, is in sharp contact with a band of white granitic material, 1 inch wide, that grades into normal granite over a narrow transition zone. The white band shows traces of a faint lineation that marks the granite and it is apparently derived from the normal granite by removal of femic constituents.

A small amount of waxy white amblygonite, some in large subhedral rectangular crystals, is present in the core zone. Also present are some isolated anhedral masses of similar looking white feldspar.

Sampling of surface trenches yielded lithia assays as high as 2 per cent over 30 feet in the core zone, which has been estimated to contain 40,000 tons of high-grade lithium ore.

Lun Echo Gold Mines Limited

The Lun Echo property described here consists of 37 claims situated within a mile east of Forgan Lake (Nipigon River) above Pine Portage. The property can be approached by boat from a camp 24 miles north by road from the highway junction west of Nipigon. It can also be reached from a point 3.6 miles south of Orient Bay on Highway 11, via 9.1 miles of good truck road plus a further 1½ to 2 miles on foot.

Several large pegmatite dykes cut quartz-biotite schist on this property. What appears to be the main dyke is exposed with few interruptions for nearly 1,000 feet, narrowing in width from a maximum of 60 feet to about 16 feet at the north end. In strike, it is somewhat erratic at the south end, but extends for about 600 feet at N50°E. The dip is about vertical. The dyke is apparently cut off at the north end by a mass of diabase. It is mainly coarse grained, consisting of white feldspar, quartz, and spodumene, with minor banded aplite. Spodumene occurs more or less abundantly throughout, as coarse, light green prismatic crystals, mostly in random orientation, but locally oriented perpendicular to the walls of the dyke. It is locally altered, especially at the south end where the dyke appears to fray out. The feldspar here is also altered and is brick-red in colour.

Another similar parallel dyke, about 25 feet wide, is exposed 450 feet to the west. The dykes are reported to be cut off at depths ranging from 85 to 650 feet by a thick sheet of diabase (Pye, 1956). Alteration of the spodumene, with a sharp drop in lithia content, is especially intense near the diabase.

Falcon Lake - Zig Zag Lake Field

Several lithium occurrences are known in the general vicinity of Falcon Lake and Zig Zag Lake, about 20 miles northeast of Lake Nipigon. Falcon Lake is a small lake 4 miles southwest of lat. 50°30′, long. 88°00′. Pegmatite dykes occur within and along the margins of an easterly trending band of metasedimentary and volcanic rocks bounded on the north and south by granite gneisses.

Motsen Claim Group

The Motsen claim group, lat. 50°28-29′, long. 88°06-10′ extends from about 1 mile to 3 miles west of Falcon Lake. The ground held by British Canadian Lithium Mines Limited in 1956 comprised claims 13569 to 13629, 13652 to

13666, and 13837 to 13847, plotted on the Falcon Lake sheet, Kowkash Mining Division (Ontario Department of Mines).

The property was not visited by the writer and the following information is from a private company report.

Most of the claim group is underlain by easterly trending bands of Precambrian sedimentary and metamorphosed sedimentary and volcanic rocks. They have been folded into a syncline that traverses the central part of the area and swings northerly, paralleling the north arm of Falcon Lake. In the south and southwest parts of the area gabbro diorite has intruded the folded rocks and cuts some of the pegmatite dykes.

The pegmatite dykes occur in four northeasterly trending zones from about 1 mile to 3 miles west of Falcon Lake, and lie within a central band of greenstone schists. Most dip steeply southeast, but a few dip gently. Remnants of country rock occur within the pegmatites, commonly on strike with the wall-rock, and up to 50 per cent of one dyke is a cherty dull green material, apparently consisting of altered rock fragments. There are two varieties of pegmatite, a white albite pegmatite and a red pegmatite rich in orthoclase, or, in places, perthite.

Spodumene occurs mostly in the white to grey-white albite-rich pegmatites, rarely in the other dykes.

The white, lithium-bearing pegmatites contain white or pink albite, glassy to milky quartz, a pale green mica, variable amounts of greenish spodumene, and minor green to blue-green beryl, black tourmaline, red garnet, and blue to reddish blue apatite. In places cleavelandite, orthoclase, and perthitic intergrowths were observed. Wall-to-wall zoning is generally absent, although in some of the spodumene-bearing dykes there is a barren border zone, 6 to 10 inches wide, and most of the dykes have a fine-grained margin less than ½ inch thick.

Several lenticular pegmatite bodies, 200 to 400 feet long and 18 to 20 feet wide at the surface, make up the east zone, about 1¼ miles west of Falcon Lake.

In the Discovery area, 2,400 feet farther west, surface exposures showed good grades in medium-grained spodumene, but preliminary drill-holes encountered diorite of unknown extent. Two main pegmatite bodies make up the west zone 5,000 feet west of the Discovery. One is estimated to be 300 feet long and 60 to 75 feet wide. Another, possibly longer, showed 35 to 45 feet true width in one intersection and averaged more than 1 per cent Li_2O throughout.

The westernmost zone, 2,400 feet farther west, comprises several small erratic bodies containing much orthoclase and little spodumene.

In all, eighteen diamond-drill holes totalling 5,241 feet were drilled in June and July 1956. No further work was contemplated at that time.

Dempster Property

Mr. Lorne Dempster reported the presence of lithium-bearing dykes on ground held by him along the south contact of the greenstone-metasedimentary belt passing through Zig Zag Lake. Exploration work was in progress on this property in 1958.

Lespard Property

Another lithium occurrence, also reported by Mr. Dempster, is on ground held by Walter Lespard at North Lamoune Lake, which is at 126 mile on the seventh baseline, about 4 miles south of Falcon Lake.

Fort Hope Area

Lithium-bearing pegmatite dykes outcrop about 14½ miles west-northwest of Fort Hope, which is about 90 miles north of Ombabiska, a station on the Canadian National railway line about halfway between Nakina and Armstrong.

Some exploration work, including a little drilling, has been done in recent years by several companies, according to Gordon F. Kydd (personal communication) but no published reference to this activity has been found. The area was not visited by the writer.

According to Prest (1942, p. 27) three pegmatite dykes north of Lily Pad Lakes (shown on the map accomanying Prest's report) carry appreciable quantities of lepidolite and spodumene, much coarse pink tourmaline, and some fluorite. Pegmatites of this type are said to be rare in the Patricia portion of Kenora district. The dykes intrude 'Upper Keewatin' basic lavas that strike south of east and dip steeply south. The dykes are classed with a group of 'Older Intrusives' of granite, porphyry, etc. that are distinguished from 'Younger Intrusives'—biotite granite, granodiorite and quartz-diorite—which make up extensive batholiths.

O'Sullivan Lake Field

The discovery of lithium-bearing dykes in the O'Sullivan Lake area was reported in the *Northern Miner**, in 1955. The locality is reportedly on Superb Lake, southwest of lat. 50°30′, long. 87°00′, about 25 miles northeast of Nakina, Ontario.

The general geology of the area has been described by Kindle (1932) who mapped gneissic granite and younger granite cutting metasedimentary rocks of the Marshall Lake Series near the reported occurrence.

Dryden Field

Spodumene has been found in two pegmatite dykes on the property of Lun Echo Gold Mines Limited, in Zealand township, south of Ghost Lake, about 10 miles northeast of Dryden. The country rocks are greenstones and chloritic mica schists that strike easterly and are in contact with granitic rocks underlying Ghost Lake.

Lun Echo Gold Mines Limited

The lithium deposit of Lun Echo Gold Mines Limited in the Dryden area is 10 miles northeast of Dryden, and is accessible by a side road from a point 6 miles

* Vol. XLI, No. 18, p. 904.

east of Dryden on Highway 17. The main zone is traceable at intervals for some 3,000 feet, and is roughly parallel with the easterly strike of chloritic mica schist and amphibolite that form the country rock. Stripping and drilling on the western part have disclosed an irregular branching dyke structure and suggest a rather gentle northward dip.

Coarse- and fine-grained green and white spodumene in random orientation, associated with very coarse grained white feldspar and quartz, occurs in irregular lenses and masses within the dyke. These are exposed here and there for about 2,200 feet along the general strike of the zone, and some parts are very rich. Other parts of the dyke, especially along contacts, are low grade or barren, consisting mainly of aplite with locally abundant black tourmaline and small grains of blue apatite. These contrasting assemblages constitute a general but crude form of internal zoning. Some of the spodumene is altered to dark green and buff colours, and some pale greenish mica appears to be pseudomorphous after spodumene. Both spodumene and feldspar are locally stained pink by alteration processes.

Some twenty-two short X-ray holes and a number of deeper ones were drilled into this dyke in 1956. Widths were reported to be about 20 feet. Tonnage and grade results have not been announced.

Another east-trending dyke outcrops about 1,000 feet south of a point near the west end of the one described above. It is traceable for several hundred feet and at one point is exposed over a width of 80 feet. In places it carries rich concentrations of coarse spodumene in swirling aggregations bordered by bands of aplite.

Root Lake Field

Spodumene occurs in a complex zone of pegmatite bodies a few miles north of Root Lake, which is about 60 air miles north of Sioux Lookout. An east-trending band of Keewatin metavolcanic and metasedimentary rocks about 1½ miles wide passes just north of Root Lake and may be co-extensive with a similar band at the west end of Lake St. Joseph. These rocks strike generally north of west and dip rather steeply north near the staked pegmatites. The band is bordered on the north and south by granitic batholithic rocks.

Capital Lithium Mines Limited

The Root Lake property of Capital Lithium Mines Limited, known as the "McCombe property", consists of twenty-eight claims lying athwart Roadhouse River, about 3 miles by tractor road northwest of Root Lake. The country rock is pillow lava and quartz-biotite-chlorite schist. The known lithium-bearing pegmatite bodies lie in an inward-dipping arcuate zone about 1,800 feet long, and may represent two or more dykes, or faulted sections of dykes. The vertical projection of this zone swings from a northerly to an easterly trend, cutting obliquely across the strike of the enclosing greenstone and schist. At several exposures, pegmatite bodies appear to be cut off obliquely on strike by greenstone. The contacts strike about east and the greenstone shows signs of shearing along the contacts.

The pegmatite, as seen in scattered exposures, is generally rather fine grained, consisting of albite feldspar, quartz, and spodumene, with scattered subhedral coarse white feldspar crystals. The dykes are not regularly zoned, but commonly have a banded structure, with aplite or barren pegmatite along the walls, and a little tourmaline in places. Spodumene occurs as random-oriented, fine white laths with dark grey quartz and scattered white feldspar crystals, in lenticular bands and patches. Lithia assays up to 1 per cent have been obtained from schist near dyke contacts. This schist contains biotite and abundant fine acicular mineral visible in hand specimen, but apparently no spodumene or lepidolite. The acicular mineral shows pale lavender absorption colors, deepest in the *Z* direction, and other optical properties comparable to those of the lithium-bearing amphibole, holmquistite.

Surface exposures of pegmatites are rather ragged and scattered, and most information regarding the structure of the pegmatite zone has been deduced from diamond-drill results. At least fifty-five holes totalling about 34,350 feet were drilled in 1956. The results have been reported to the writer as follows:

'A' zone: length 1,650 feet, average width 19.12 feet.
'B' zone: length 600 feet, average width 14.34 feet.
'C' zone: length 600 feet, average width 13.6 feet.
'D' zone: length 600 feet, average width 21.75 feet.

The reserves are stated to be 2.297 million tons grading 1.3 per cent Li_2O.

Consolidated Morrison Explorations Limited

The deposit on the Consolidated Morrison property lies about 5,000 feet due east of the McCombe deposit of Capital Lithium Mines Limited. A pegmatite dyke up to 30 feet wide has been traced for 100 feet. It is reported to be similar to the McCombe pegmatite but coarser grained and unzoned (Pye, 1956). Some drilling was done on the property in 1956 in an effort to indicate dyke extensions, and to explore for eastward extension of the dyke structure on the Capital Lithium property.

Lac La Croix Field

Several spodumene-bearing pegmatite bodies outcrop near Lac La Croix, about 70 miles east-southeast of Fort Frances, Ontario. They lie near the south margin of a band of Couchiching metasedimentary gneisses that trends easterly, tapering from a width of about 16 miles near the east end of the lake. Numerous subconcordant granite and pegmatite bodies interfinger with the gneisses from the surrounding granitic batholiths. One such pegmatite body has been mapped for nearly 10 miles along the general course of Maligne River, east of the lake, and in this body, at Twin Falls, the presence of spodumene in the district was first recorded by Tanton (1939). The property of International Lithium Company is about 3 miles west of Twin Falls, and lithium-bearing float has been reported at several places farther east along the general course of the dyke. Several other spodumene pegmatites occur along the north shore of the lake and on the Wisa Lake property, about 4 miles north near Namakan River.

International Lithium Mining Corporation

The property of International Lithium Corporation consists of eighteen claims situated on the south shore of Lac La Croix near its east end. Air service is available from Fort Frances, Ontario, or Crane Lake, Minnesota.

At the main surface showing a dyke forms a small island, 200 by 55 feet, near the drill camp, and another lies about 650 feet south of the lakeshore, about 3,400 feet to the east. Both strike about east, parallel with the metasedimentary country rocks, dip steeply, and line up roughly along strike. They are similar in mineralogy and structure.

The dykes are irregularly banded, longitudinally. Spodumene-bearing quartz-feldspar bands alternate with barren ones composed of aplite and coarse white feldspar. The spodumene is light to dark green, in places brownish and woody. Crystals are up to a foot long and are mainly oriented perpendicular to the dyke, but their attitude differs somewhat from band to band. The bands are interrupted by a few transverse quartz-filled fractures. A closely drilled section, 1,600 feet long, of the main zone is estimated by the company to contain 1.5 million tons grading 1.20 per cent Li_2O to a depth of 500 feet. A few other spodumene-bearing dykes outcrop nearby.

Lexindin Gold Mines

This property lies south of Wisa Lake, about 4 miles north of Lac La Croix. Several spodumene-bearing dykes that cut metasedimentary rocks appear similar to those of International Lithium. Alteration of spodumene to yellowish brittle mica on the surface of dykes is marked. Drilling was in progress during the summer of 1956.

MANITOBA

East Braintree - West Hawk Lake District

Several spodumene-bearing pegmatites have been found in an east-west band of metavolcanic rocks that extends about 20 miles from East Braintree to West Hawk Lake. The band averages 1.5 to 2 miles in width and is bounded on the north and south by granodiorite. A regional zoning of pegmatites near West Hawk Lake has been noted (Stockwell, 1933, p. 42). Microcline pegmatites are common in the volcanic-sedimentary assemblage near a granodiorite contact, but farther away albite pegmatites predominate, and at a still greater distance there are a few lithium pegmatites.

The main lithium deposits are on the Lucy and Artdon claims, which lie about ½ 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.

Lucy Group

The Lucy group and adjoining claims are controlled by North American Rare Metals, Limited. The main showing is on the Lucy No. 1 claim, where a pegmatite body striking about north and dipping gently east outcrops for 63 feet along the face of a low cliff. The body is distinctly zoned. An upper or hanging-wall zone contains abundant coarse black tourmaline, pink feldspar, quartz, and muscovite. Very coarse green spodumene crystals in random orientation are embedded in quartz in a lower lenticular zone exposed for 45 feet with a maximum width of 5 feet. The dyke appears to dip gently into the hill and is partly surrounded by patchy pink and white aplite containing nests and stringers of bright blue tourmaline. A large mass of gabbro lies to the south and contains an abandoned quarry. The area was extensively drilled in 1955-56, and the presence of several flat-lying lithium-bearing dykes at depth has been reported.

Pieces of spodumene, white amblygonite, pale lilac mica, and beryl are scattered near a small water-filled pit about 300 feet farther north.

Artdon Group

The Artdon group of claims adjoins the Lucy group on the west, and is held by Lithium Corporation of America. The writer was unable to find the occurrence. According to Springer (1952, p. 20), a lithium-bearing dyke outcrops on the Artdon No. 2 claim, which adjoins Lucy No. 1 on the west. Springer stated

> . . . the body is exposed for a length of 60 feet in an easterly direction and is about 10 feet wide. It has been explored by trenching and diamond-drill holes. The dyke is composed of coarse-grained pink and white feldspar, smoky quartz, biotite, white to pale green beryl, and white to pale green spodumene in crystals as much as 10 inches in length.

Deer Claim

Stockwell (1932, p. 126) described the dyke on the Deer claim, and others in the vicinity of West Hawk Lake, southeastern Manitoba, as follows:

> Of the three lithium-bearing dykes in the West Hawk Lake district, the largest is on the Deer mineral claim in the centre of sec. 16, tp. 19, range 17, 1,000 feet from the southwest shore of West Hawk Lake. The two other dykes are small. One is 4,400 feet north 25 degrees west of the dyke on the Deer claim and the other is 1,200 feet south 30 degrees east of the same dyke. All three cut volcanics. . . .
>
> The dyke on the Deer mineral claim strikes north 30 degrees west and is exposed by natural exposures, stripping, and open-cuts at two localities, a southeast locality and a northwest locality. At the southeast locality it dips 75 degrees to the southwest and varies from 5 to 10 feet in thickness. At the northwest locality it varies from 2 to 8 feet wide, is in irregular contact with the country rock, sends a branch dyke into the country rock, and holds a large inclusion of the country rock. The length of the dyke, as indicated by the two exposures, is 260 feet. The dyke is composed chiefly of an intimate mixture of quartz, albite, lepidolite, and spodumene. A few small crystals of pink tourmaline are also present. They are somewhat turbid and are not of gem quality. The deposit is of no economic value at the present time.
>
> The two other dykes are only from 6 inches to 1 foot wide. They are composed of albite and quartz with a small amount of lepidolite and, in one of them, a small amount of pink tourmaline which is not of gem quality. The dykes are of no economic value.

Cat Lake - Winnipeg River District

This district lies east of Lac du Bonnet and is about 80 miles northeast of Winnipeg *(see* Fig. 7). It is served by a railway line, highway, and newly constructed secondary roads and power lines. The district is noted for the large number and diversity of pegmatite mineral deposits, including beryl, tin, and rare

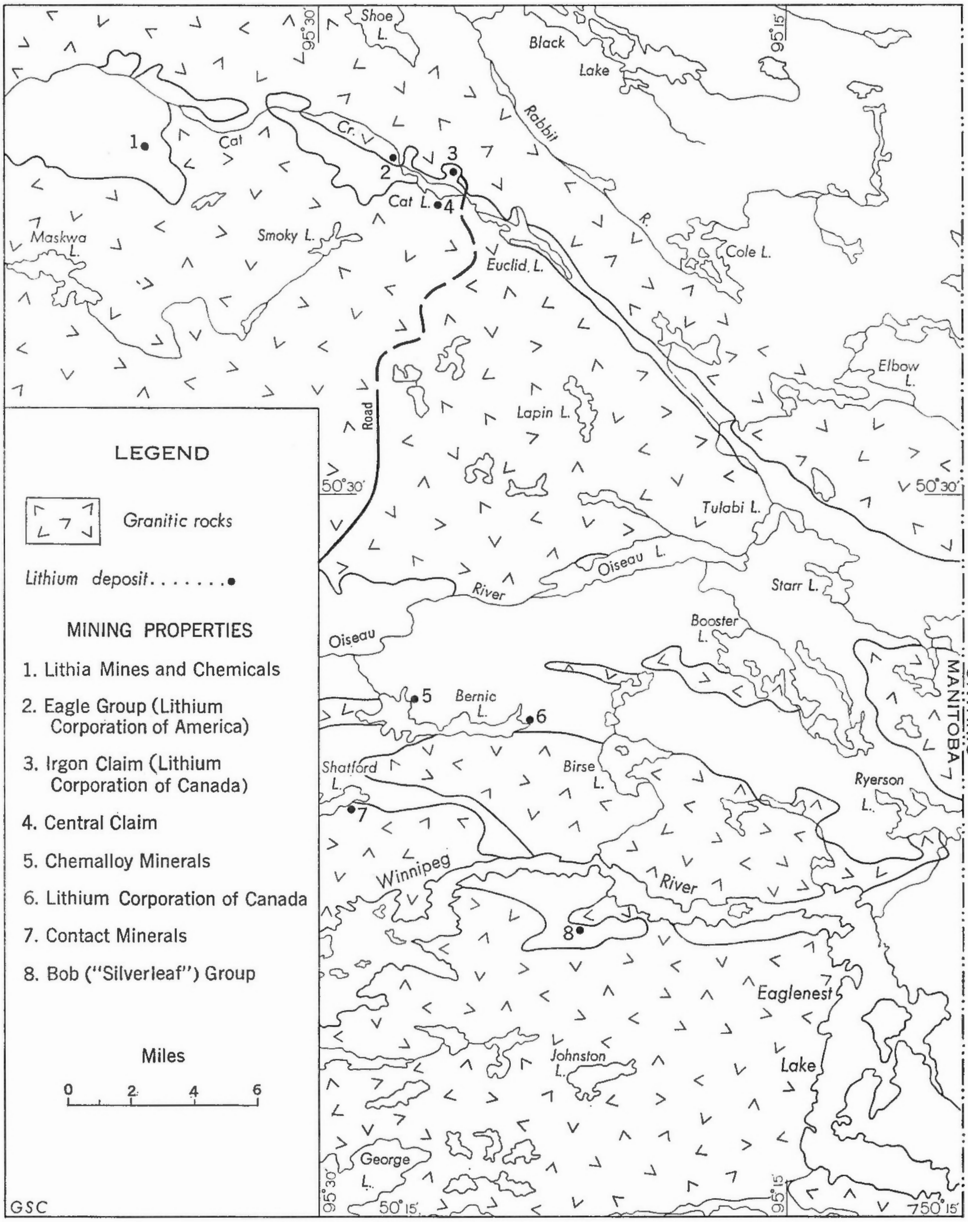

FIGURE 7. *Lithium deposits, Cat Lake — Winnipeg River district, Manitoba.*

earths, as well as all the more common lithium minerals. Many have been known and intensively studied since 1925. Some development work was done and small shipments of lithium minerals were made in earlier years, but it is only recently that exploration and development of lithium deposits on a large scale have been undertaken. This has resulted in the blocking out of several large deposits in the Cat Lake and Bernic Lake areas and renewed exploration of deposits near Winnipeg River.

The consolidated rocks of the district are Precambrian in age, 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 basic intrusions comprise gabbro and peridotite. Associated with them are potentially important chromite deposits near Bird (Oiseau) Lake, also north of Maskwa Lake, and near Euclid Lake. Copper and nickel occur also in the Bird River, Cat Lake, and Maskwa Lake areas. The bedded rocks lie in easterly trending infolded bands, the largest extending from Bird River to the south shore of Bernic Lake. Another 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 of 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 (Plate IB), 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.

Lithium-bearing pegmatites occur 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. Those 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 dome 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, and the mineralogical and structural characteristics of the pegmatites seem to be in large measure controlled by the attitudes of individual bodies.

Spot Group—Lithia Mines and Chemicals Limited

The property, comprising thirty-one claims of the Spot and adjacent groups, is 5 miles west of Cat Lake. The camp and main dyke are 1½ miles by tractor road northwest of a small lake used for aircraft landings. The property is held by Lithia Mines and Chemicals Limited, a subsidiary of Violamac Mines, which optioned the property from John Donner and Peter Osis. It is not accessible by road, but is crossed by the power line to Cat Lake.

Two major pegmatite dykes cut volcanic greenstones, that are intruded by coarse porphyritic gabbro, and underlie a limited area surrounded by a granite batholith.

The main or south dyke is exposed intermittently for 1,800 feet and drilling has established its continuation for a further 1,400 feet to its western termination in a body of granite. In its central part the dyke is broken up and apparently offset. It averages 12 feet in width, strikes N54°E and dips steeply. The dyke is essentially unzoned. Spodumene is distributed more or less uniformly throughout, but is locally segregated into bands with quartz and bluish white feldspar, separated by aplite bands from others in which it is associated with similar feldspar and little quartz. Local narrow aplite wall zones contain a little fine garnet and apatite. The spodumene is white and mostly in fine laths. These show a tendency to parallelism, but their orientation is variable from place to place. Drilling on the south dyke indicated 2.5 million tons grading 1.3 per cent Li_2O to a depth of 1,000 feet (*Precambrian,* Oct. 1955).

The 'north dyke' is about a mile northwest of the main dyke. It is exposed for about 750 feet and averages 15 feet thick. Its strike is N40°E and its dip is nearly vertical. Spodumene occurs mainly as fine needles intergrown with quartz. These two minerals form elongated pods and lenses, in which the spodumene is oriented perpendicular to the long directions of the pods. These aggregates are interstitial to coarse-grained feldspar masses and have random orientation. They weather buff or pink, thus contrasting with the white feldspar and grey quartz-mica-feldspar components that make up most of the dyke. This dyke has been drilled for 1,150 feet along strike to a depth of 400 feet. Its further extension longitudinally and vertically are unknown. The ore indicated by drilling results is reported as 1.5 million tons at 1.25 per cent Li_2O to a depth of 450 feet (*Precambrian,* Oct. 1955).

Several other minor lithium-bearing dykes outcrop on the property, mainly within the angle formed by longitudinal projections of the main dykes.

Eagle Group, Cat Lake

References: Springer (1950); Rowe (1956).

The Eagle group of claims lies west of Cat Lake and is now held by Lithium Corporation of America.

A zone of lenticular pegmatite dykes extends nearly ½ mile west from a granite bluff near the northwest end of the lake. The dykes are partly in greenstone, partly in granite, and dip steeply. Fine- to medium-grained white and light green spodumene is confined mainly to narrow quartz-rich stringers and pods that are interstitial to coarse white and pink feldspar masses and aplite bands. The spodumene laths are normally in parallel orientation perpendicular to the stringers, but this prefered direction varies from one small area to another, and in some places no parallelism is apparent.

The individual pegmatite bodies are up to 245 feet long and 30 feet wide, as exposed. They are mostly unzoned, but some, in granite, have well-defined borders of white aplite, a few inches to a few feet thick. Some have one wall zone of aplite, the other of coarse microcline-quartz-muscovite pegmatite.

Beyond a broad bushy gully, a bright red pegmatite body appears to be part of a cross-dyke cutting off the western extremity from the rest of the zone. This body contains quartz in large crystal-like grains, abundant coarse-grained pale to green mica, black and blue tourmaline, smoky quartz grains, and small white beryl crystals, as well as abundant coarse red feldspar.

A considerable amount of surface trenching and drilling has been done on the property.

Irgon Claim, Lithium Corporation of Canada—Cat Lake

References: Stockwell (1932); Springer (1950); Rowe (1956).

The Cat Lake property of Lithium Corporation of Canada consists of a single claim, the Irgon, situated 1,700 feet north of Cat Lake, township 19, range 15. It is about 50 miles by gravel road northeast of Lac du Bonnet. A power line was extended to the property, modern surface and camp buildings installed, and shaft sinking was begun in 1956 following completion of a diamond-drilling program. The shaft was sunk to a depth of 241 feet, and 1,200 feet of drift and six crosscuts into the ore zone were driven on the 200-foot level before work was suspended in 1957. The company reported ore reserves of 1.2 million tons grading 1.5 per cent Li_2O (*Northern Miner,* 1957).

A pegmatite dyke striking N80°E intrudes a band of metavolcanic greenstone about 600 feet north of the greenstone's contact with a large body of granite. It is about 1,200 feet long, up to 65 feet wide, and dips steeply. Much of the dyke was covered by broken muck in 1956. The remaining exposed surfaces are largely covered by lichens, which partly obscure the internal mineralogical and structural relationships. The dyke is unzoned, but has an irregular banded structure.

In the exposed central section, spodumene occurs in bands and long lenses composed of quartz, with some white feldspar and muscovite. Intervening bands consist mainly of white and pale pink feldspar, in part microcline, and of aplite in which are trains of fine red garnet and blue apatite. The spodumene is mainly in fine white or pale green laths, without marked parallelism. In some patches it is found in plates up to 4 inches long.

Stockwell (1932, p. 124) examined the dyke when it was "well exposed on a glaciated surface", and reported that spodumene-quartz bands vary from 1 foot to 10 feet in length and from 1 inch to 2 feet in width. He estimated the proportion of quartz-spodumene rock at 20 to 50 per cent of the whole, and its spodumene content at up to 50 per cent.

The dyke branches near its east end into three bands of pegmatitic material bordered by quartz-biotite schist on the north and amphibolite and greenstone on the south. The two northern branches are narrow and aplitic; one contains much garnet. The southern branch is 25 feet wide near its eastern limit, as exposed, and is made up of three distinct bands. Spodumene occurs in a central band bordered by aplite at the south wall and by coarse feldspathic pegmatite at the north.

Central Claim, Cat Lake

The Central claim is south of the middle part of Cat Lake, and is owned by H. Johnson of Bird River, Lac du Bonnet. The property can be reached via a side road that leaves the Cat Lake road at 1.7 miles south of the mine camp at Cat Lake.

Several pegmatite bodies cut microcline granite, part of a large batholith, within 1,000 feet of its contact with volcanic rocks that form a band underlying Cat Lake.

The main dyke is 1,000 feet south of Cat Lake. It lies in granite and appears to dip gently southward into a cliff face. The dyke has been exposed for nearly 300 feet, and is distinctly zoned.

Spodumene occurs mainly as random-orientated white to pale green crystals up to 24 inches long, embedded in coarse quartz-feldspar pegmatite. Some of it occurs as parallel needles intergrown with quartz in aggregates that are interstitial to feldspar masses. It is mainly confined to a zone up to 10 feet thick, which has its lower margin obscured by broken muck. Stockwell (1932, p. 125) stated that a band of albite aplite, 3 to 5 feet thick, formed the lowest visible part of the dyke, and that the spodumene-bearing zone was exposed through a length of 160 feet. White aplite, commonly sprinkled with small grains of blue apatite, is abundant, and a band of it several inches thick generally overlies the spodumene zone and separates it from the hanging-wall zone. The latter consists chiefly of coarse microcline, with some quartz and coarse muscovite. Pale beryl, apatite, and garnet are prominently associated with muscovite at the southern limit of exposure. A substantial amount of coarse-grained spodumene could easily be recovered from broken muck scattered below the cliff face.

Several small bodies of pegmatite have been exposed north of the main dyke, across from the creek that drains a former swamp. Two of these contain some spodumene and one contains a few beryl crystals.

Other Occurrences near Cat Lake and Bird River

A small dome-shaped outcrop on the FD5 claim, north of the west end of Cat Lake, consists of fine- to medium-grained microcline-quartz-plagioclase-biotite pegmatite, which contains a few beryl crystals and a lens of quartz-spodumene-microcline pegmatite about 25 feet long and 4 feet wide. The ground is held by Lithium Corporation of America.

A dyke on the north side of Cat Lake near the east end is 60 feet long and 5 feet wide and contains about 20 per cent spodumene for half its length. Three dykes at the southeast end contain spodumene and beryl in small amounts.

A dyke east of the road ½ mile south of the Bird River bridge outcrops on the end of a ridge and is visible from the road. It has been well trenched and is about 12 feet thick at the brow of the hill, but it splits up a few feet below the top, and pinches out about 50 feet down the slope. Coarse-grained, pale green spodumene in random orientation makes up most of a discontinuous, poorly defined core zone, bordered by aggregates of feldspar, black quartz, and aplite.

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

References: Davies (1957); Hutchinson (1959).

The Chemalloy property comprises a block of claims on the western part of Bernic Lake. The mine shaft and surface buildings are in claim Lith 11, on the point at the northeast corner of the large western expanse of the lake. This is the site of the old Jack Nutt tin mine, on which a shaft was sunk and drilling done in search of commercial cassiterite deposits and which was finally abandoned in 1930.

At the surface, on the point, a number of pegmatite bodies contain abundant black tourmaline, and locally small concentrations of cassiterite, but no lithium minerals. The main lithium-bearing pegmatite was encountered in drilling for tin concentrations, and does not outcrop on land. Lithium-bearing pegmatite intersections in drill-holes below the apparent foot-wall may represent separate, deeper bodies. A beryl-bearing dyke outcrops about 600 feet east of the mine. The pegmatites cut amphibolitized greenstone near the eastern tip of a granitic tongue that extends westward from Bernic Lake.

The main lithium-bearing pegmatite is a gently dipping sheet, at least 1,500 feet wide and more than 2,500 feet long, open to the west. Its hanging-wall is a fairly uniform convex surface that dips 10 to 15 degrees northward and eastward, also gently westward, from an apex near the outcrop under Bernic Lake. The foot-wall is undulatory, generally concave upward in the central explored area, but rolls down to the west of the outcrop area. Thus the pegmatite has an irregular dome shape, generally lenticular in section, with a maximum thickness of about 250 feet in the central explored area.

The pegmatite contains a large variety of unusual minerals, several in remarkable concentration. It is well zoned, but symmetry is incomplete, and the relationships between mineral assemblages are extremely complex (*see* Fig. 8). The outermost assemblage or wall zone is a well-defined unit, up to 50 feet or more 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 abundant at the contacts and pale beryl occurs in scattered crystals and clusters.

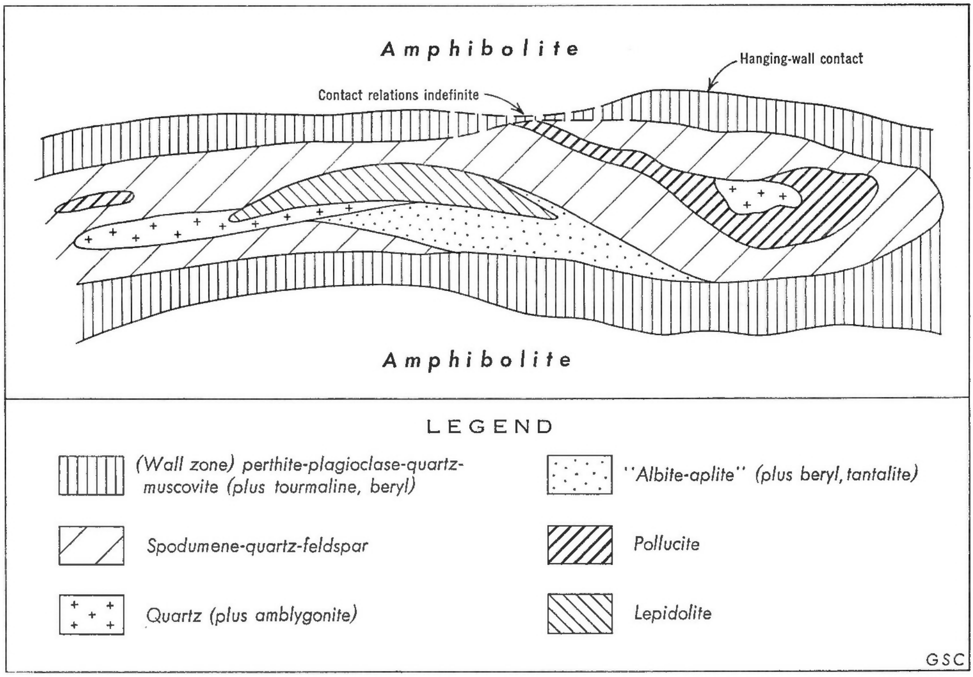

FIGURE 8. *Diagrammatic composite vertical section of Chemalloy Minerals Limited (formerly Montgary) pegmatite, showing relationship of main internal units.*

An intermediate zone, characterized by spodumene, is the main lithium-bearing unit. It is most continuous and richest in spodumene in the upper part of the pegmatite sheet, where it underlies the upper wall zone. The same or a similar assemblage locally underlies the innermost units. In part it overlies the lower wall zone, but elsewhere is separated from it by the 'albite-aplite' unit. In horizontal projection the spodumene zone in the main explored area has the form of a lenticular sheet up to 1,400 feet wide and more than 1,500 feet long. Its maximum overall thickness is more than 100 feet. This intermediate zone consists of interbanded pegmatite and aplite. The pegmatite phase is made up of microcline in crystals up to 10 feet long, and interstitial cleavelandite, quartz, muscovite, lithia micas, and spodumene. Spodumene occurs chiefly as fine white parallel laths intimately intermixed with quartz, the whole forming definite bands. Some, however, is as massive green crystals several feet long. Near quartz-amblygonite core pods, large spodumene crystals are rimmed by alternating bands of cleavelandite-quartz and lithia mica (Plate IV). The cleavelandite of these bands is in sheaves radiating outward from the surfaces of the spodumene crystal, and the lithia mica is in curvilamellar conical plumes, which also radiate outward nearly at right angles to the planes of the bands. This outermost band grades into the quartz-amblygonite assemblage.

Quartz, accompanied in some places by amblygonite, forms an extensive sheet and several scattered pods or lenses, together making up the core zone of the pegmatite. The main bodies lie beneath the upper spodumene band. Some are also partly underlain by the spodumene assemblage, into which they project as lenses. Several masses lie within a pollucite assemblage. In large part, however, the quartz assemblage is underlain by the 'albite-aplite' unit. The amblygonite is in creamy-white, waxy, irregular crystals or anhedral masses, commonly several feet across, scattered through the quartz, but only locally in appreciable concentration. Petalite, found in one locality, may also be a core accessory.

The contact between quartz-amblygonite and spodumene units is marked in part by cleavelandite-lithia-mica reaction rims about large spodumene crystals, as described above. Similar assemblages also surround large potassic feldspar crystals that are pseudomorphed, in their outer parts, by albite in fine needles, parallel with the crystal face. These assemblages are evidently late-stage replacement and/or exsolution phenomena.

The lepidolite unit comprises one large lens about 700 feet long, 200 feet wide, and 40 feet in maximum thickness, and several smaller lenses. It lies within the boundaries, laterally, of the spodumene zone and is mainly overlain and partly underlain by the spodumene assemblage. Elsewhere it is underlain in some places by core quartz, in others by the 'albite-aplite' unit. The unit is a fairly uniform fine-grained mixture of scaly purple lithia mica and subordinate quartz and/or albite. One typical specimen was found to contain about 70 per cent fine scaly purple mica with about 30 per cent quartz.

The pollucite (caesium mineral) unit, like the lepidolite unit, comprises one large lens and several smaller ones. It lies generally within the spodumene zone but in one area the main lens is in contact with the upper wall zone, and there also appears to penetrate to the hanging-wall contact. The unit consists in large part of nearly pure pollucite, but in part of mixed pollucite and spodumene ore. The nearly pure pollucite contains scattered thin stringers of very fine grained purple lithia mica and closely spaced, very thin, anastomosing stringers of white material, part of which is fine-grained spodumene. The unit nearly encloses, in its upper part, one notably large mass of quartz, typical of the core zone.

The 'albite-aplite' unit forms extensive layers in the lower middle part of the pegmatite. In part it overlies and grades into the lower wall zone, underlying all the interior units, but in part 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 is apparently mostly fine grained but 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; 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 wall zone, spodumene assemblage, and quartz core show, in general, a normal zoning sequence from the walls inward. The lepidolite, pollucite and albite-aplite assemblages are mainly contained by the spodumene unit, but their relationships to it, to the quartz core, and to each other, are problematical. The lepidolite unit is closely related spatially to the 'albite-aplite' unit whereas the pollucite unit is mainly contained by the spodumene unit. Similar assemblages elsewhere have commonly been regarded as replacement units; and some of the accepted criteria of replacement origin are discernible in the mutual relationships of the inner units at the Chemalloy pegmatite (Hutchinson, 1959). However, the degree of segregation of lepidolite from pollucite is not adequately explained by a simple theory that both units are the result of late-stage replacement by solutions originating within the pegmatite body.

Development work reported (*Northern Miner,* Feb. 26, 1961) includes about 2,000 feet of drifting and crosscutting from the 285-foot level of the shaft. Ore reserves have been estimated at 8 million tons averaging 2.0 per cent Li_2O, including about 200,000 tons of lepidolite ore and 150,000 tons of pollucite ore.

Lithium Corporation of Canada, Bernic Lake East

References: Davies (1955, 1957); Springer (1950); Stockwell (1932).

The east Bernic property of Lithium Corporation of Canada consists of a block of claims at the east end of Bernic Lake and includes the Buck, Coe, and Pegli claims. The Buck and Coe claims were originally staked in 1926. A surface plant and sorting and storage bins were subsequently installed, and a large open-cut was made on the Buck Claim.

Several pegmatite bodies intrude greenstone about ½ mile north of its contact with a large mass of granite. The dykes dip gently. They probably do not all outcrop, and the relationship of certain isolated exposures to one another is in doubt. The country rock is recrystallized andesite.

The dykes, like those of the Montgary property near the west end of the lake, are outstanding in complexity of zoning and variety of minerals. Locally more prominent than spodumene are the uncommon lithium silicates—petalite and lepidolite—and the phosphates—amblygonite or montebrasite, and triphylite or lithiophilite. Lithium minerals, where present, are confined essentially to cores and inner zones composed chiefly of quartz, and the dominant lithium minerals vary from dyke to dyke or from place to place in the same dyke.

Typically complex zoning is well displayed in a large pit on the Buck claim about 1,500 feet east of Bernic Lake. Here the lowest exposed zone consists chiefly of massive grey quartz in which are embedded a few irregular masses, up to 2 feet long, of white, locally pink-stained amblygonite, and of triphylite-lithiophilite-purpurite. Amblygonite also occurs in cleavelandite at the top of this quartz zone. Locally overlying this is a thin lenticular zone of quartz and cleavelandite, in which are embedded tabular crystal-like masses, about a foot across, of fine quartz-spodumene intergrowth. Above these assemblages, reddish feldspar, in part cleavelandite, characterizes several subzones that are made up of feldspar, quartz, and coarse pale mica, in variable proportions, and carrying scattered beryl crystals. These subzones merge with a zone 1 foot to 2 feet thick in which coarse black tourmaline, set mostly perpendicular to the hanging-wall, forms the dominant constituent. This tourmaline zone is locally separated from the greenstone hanging-wall by a 'chill-zone' 1 inch to 2 inches thick, consisting chiefly of fine-grained feldspar, quartz, and tourmaline. A considerable amount of material has been hand-sorted and stockpiled in bins on the property.

The pit referred to above is about 84 feet long by about 25 feet wide, including a lower bench about 36 by 10 feet on the east or hanging-wall side. The dyke strikes west of north from the edge of a swamp and dips gently northeast into a hillside. Over the top of the hill, about 100 feet beyond the top bench, what may be an extension along strike of the same dyke is partly exposed in a small pit. The dyke was drilled in 1936 and found to have a maximum thickness of 22 feet, narrowing at depth and pinching out to the north.

Across the swamp, about 700 feet southwest of the pit on the Buck claim, a similarly zoned dyke is partly exposed along the edge of a low bluff. It also contains much coarse black tourmaline next to the hanging wall, and this mineral is associated with coarse mica at one locality. A lower feldspar-quartz zone contains a few beryl crystals, and at the lower exposed edge of this zone a large mass of quartz contains a mass of purplish brown material, presumably alteration products of triphylite and conveniently referred to as 'purpurite'. A few feet northward along the bluff the dyke as exposed shows no tourmaline zone. A cleavelandite-mica-quartz zone in contact with greenstone contains rather abundant white beryl crystals and patches rich in blue apatite. An irregular mass of white amblygonite is embedded in grey quartz that makes up the lower part of the exposure.

Another dyke, which is partly exposed in a small pit near the cabins on the Coe claim, consists largely of grey lamellar petalite in association with quartz, feldspar, and mica.

Diamond-drilling in 1955-56 revealed a flat-lying sheet of pegmatite, 50 feet thick, about 250 feet below the dyke that is exposed on the east side of the Buck claim. A lithium-bearing band 1,700 feet long and 450 feet wide, with an average thickness of 16 feet, was outlined within this pegmatite. This band, in the central part of the dyke, consists of bands or lenses of lepidolite, petalite, quartz-spodumene intergrowth, and amblygonite, associated with quartz and cleavelandite. The zonal sequence is variable from hole to hole and incomplete, some holes showing only one of the above lithium minerals. The outer zones, however, are fairly symmetrically disposed and resemble those of the upper, exposed dyke. The company reports 800,000 tons of material averaging 2.13 per cent Li_2O.

The lithia content of specimens collected by the writer on the property were amblygonite 9.71 per cent, triphylite 8.92 per cent, and petalite 4.73 per cent.

Contact Minerals Limited, Shatford Lake

Reference: Davies (1957).

The property of Contact Minerals Limited consists of a group of claims, the Dyke group, situated on the south shore of the eastern part of Shatford Lake, and held by J. J. Papineau of Winnipeg, and associates. It includes the site of the original tin discovery of the district, and several pegmatite dykes that contain beryl and other unusual minerals. The dykes cut greenstone and granite near the contact of a mass of granite that extends south to Winnipeg River.

A lithium-bearing dyke is exposed mainly on Dyke 13, about 4,000 feet west of the east end of the lake. It has been well exposed by stripping and trenching over a length of 400 feet and a width of 80 feet at one point. It carries spectacular conical crystal aggregates of greyish, curvilamellar lithia mica, as large as 4 feet across, embedded in coarse-grained pink feldspar and quartz. The aggregates are conical in form, pointing mostly downward with the curved bases convex up (see sketches in Davies, 1957). The form is characteristic of zinnwaldite and the optical properties are comparable to lepidolite, but the specimens taken by the writer assayed only 0.78 per cent Li_2O. Beryl occurs in scattered crystals, and topaz occurs mainly as remnants of altered crystals.

Monazite and other rare-earth minerals are found in cavities that are lined with black alteration material. A little columbite-tantalite is also present.

Another zinnwaldite-bearing dyke, probably 600 feet long and about 15 feet wide, cuts pillow lava about 4,000 feet southeast of the east end of the lake (Davies, 1957). It is uniformly coarse grained, consisting of large pink feldspar crystals, masses of quartz, and books of biotite, zinnwaldite, and yellowish green mica. Scattered beryl crystals, some columbite, and a little purple fluorite are present.

Bob ('Silverleaf') Group, Winnipeg River

References: Stockwell (1933); Rowe (1956); Davies (1957).

The Bob group of claims is situated a mile southwest of a point on Winnipeg River about 4 miles above Lamprey Falls. Formerly known as the "Bear claim", it was discovered in 1925 and was worked for a few years by the Silverleaf Mining Syndicate (Canada) Limited. About 75 tons of lithia mica were shipped. It is currently held by Lithium Corporation of Canada, Limited. Some drilling was done during 1954 in search of lithium deposits beneath the swamp west of the open-cut.

The deposit is a pegmatite body that cuts altered pillow lava a short distance south of a stock of pegmatite gneiss. It outcrops on the side of a hill as a troughshaped body some 200 feet in maximum dimension, plunging westward into a swamp (see sketch in Stockwell, 1932, p. 115). A fault mapped by Stockwell was not recognized by the writer, and other features have been obliterated or confused by more recent open-cuts and muck piles. All old trenches in the swamp are overgrown and filled with water.

The pegmatite body features complex internal structures, involving zoning and replacement, and has been the subject of intensive studies and several technical papers (Stockwell, 1933). As the identification of units, and their relationships and sequence vary somewhat according to different interpretations, too rigid an application of generalized principles does not seem useful.

At the north end and along the east contact the body consists mainly of banded aplite and pegmatite with agglomerations of greenish mica; this assemblage presumably forms the lowest, or foot-wall, zone. At the south margin, what is apparently an uppermost zone consists of coarse-grained pink feldspar, quartz, and mica. On the south side of the open-pit this zone overlies, with striking contrast, a white quartz-spodumene zone, but farther west up the hill it overlies or merges with the lower aplite-pegmatite zone. Thus the central part of the dyke, which contains the lithium minerals, apparently pinches out to the west.

Quartz-feldspar-spodumene rock forms a distinctive unit. It was well exposed in the walls of the largest open-pit above the muck pile at the time of the writer's visit (1956). It is partly wrapped around by, and presumably overlies, the outer (lower) aplite-pegmatite zone. Spodumene is mainly in the form of fine laths set perpendicular to the long dimension of the crystal-like quartz-spodumene intergrowths in which it occurs. These intergrowths are tabular or vein-like masses up to 3 feet long, embedded in quartz, with some masses of cleavelandite-spodumene-quartz and pink microcline.

Curvilamellar and radiating purple lithia micas and grey zinnwaldite-type mica occur chiefly as vein-like and irregular masses in a zone at the upper edge of the spodumene-quartz unit (see sketches in Davies, 1957, p. 13). Some of the zinnwaldite is in radiating sheaves along stringers that follow a rectangular pattern and outline a sort of crystal structure.

Massive lepidolite rock occurs in patches in quartz-cleavelandite rock above the spodumene zone east of the open-pit and in massive quartz along the edge of the swamp. The massive rock consists chiefly of fine-grained, scaly purple mica with minor quartz. Some is in patches several inches in diameter surrounded by rims of radially diverging plumes of greyish purple zinnwaldite or lithia mica. Some of this latter material assayed 2.75 per cent Li_2O.

Among other minerals reported from this deposit are amblygonite, beryl, topaz, lithiophilite and columbite-tantalite; germanium was extracted from topaz from this deposit. (Papish, 1929, p. 471-472.)

Small occurrences of lithia mica and lepidolite were reported by Stockwell (1932) on the nearby Annie and Guy claims and on the Captain claims about 3 miles to the east.

Herb Lake District

References: Frarey (1951); Rowe (1956); Stockwell (1937).

Spodumene-bearing dykes have been found in three areas near Crowduck Bay, north of the settlement of Herb Lake, which is on the east shore of Wekusko Lake (Fig. 9).

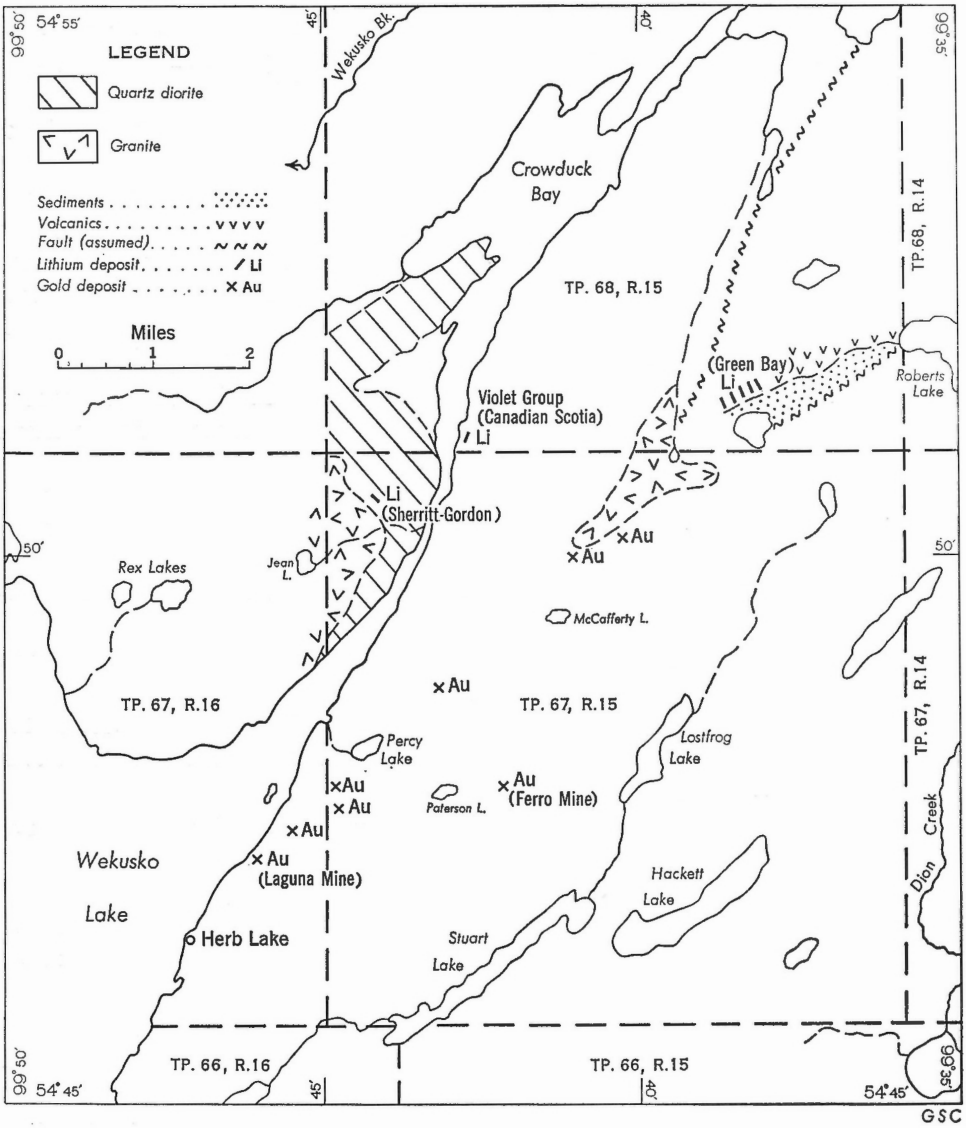

FIGURE 9. *Herb Lake district, Manitoba.*

The country rocks cut by the dykes are volcanic and intrusive rocks of the Amisk (?) and overlying Missi (?) Groups, and younger quartz-diorite, which are intruded by granitic stocks. The bedded rocks are folded on northeasterly trending axes, and broken by faults that trend from east-northeast to north-northeast.

The dykes on the Green Bay property lie between two such divergent faults. If they be regarded as conjugate horizontal shears, the attitude of the dykes corresponds to the theoretical attitude of resultant tension fractures.

Two former gold-producing mines and numerous gold-quartz occurrences lie within a belt that trends southwest from the Green Bay property for about 10 miles to Herb Lake, and quartz veins are exposed by prospect pits near some of the dykes.

Green Bay Mining and Exploration Company, Limited

The Green Bay property consists of twenty-six or more contiguous claims lying about 2½ miles southeast of Crowduck Bay, Wekusko Lake. The camp is accessible by an improved tractor road from a point about 4 miles north of the narrows.

The country rocks are greenstones and interbedded clastic rocks, striking northeasterly and dipping steeply. Seven known pegmatite dykes strike, in various northwesterly directions, obliquely across a zone that trends about N55°E for 7,000 feet from a point 1,500 feet northwest of the unnamed lake at lat. 54°52′, long. 99°38′. The west end of the zone is within a mile of the concave horseshoe-shaped end of a stock of quartz-eye granite or granodiorite. The zone lies east of a mapped northeasterly striking fault, and about ½ mile northwest of, and parallel with, another mapped fault.

The dykes are generally similar in mineralogy, consisting chiefly of coarse-grained feldspar, characteristically pink, and relatively minor amounts of quartz. The spodumene is mostly coarse grained and random in orientation. It occurs with quartz and cleavelandite interstitially to the coarse-grained feldspar crystals, which are, in part at least, microcline. Some spodumene is fine grained and embedded in pink aplite.

The dykes are zoned, and spodumene is mainly confined to crudely defined core zones. Outer zones consisting mainly of pink aplite and coarse-grained feldspar, contain most of the mica, tourmaline, and scattered beryl crystals, as well as some spodumene. Tourmaline and mica are also scattered through the core zones. Thus the zones are telescoped. Some dark biotite-like mica is present, as well as a pale greenish variety. Spodumene is locally altered, and both spodumene and feldspar are commonly stained pink by alteration products.

The main or most westerly dyke is exposed for about 600 feet, is up to 90 feet wide, and dips nearly vertically.

The spodumene is coarse grained and mostly randomly oriented, and is mainly in the central 30 feet of exposed dyke. This dyke has been explored by more than 10,000 feet of drilling, in three tiers, to a depth of 1,000 feet. The indicated tonnage, reported by the company, is 2,000,000, averaging 1.4 per cent Li_2O.

A good deal of stripping and trenching and some diamond-drilling has been done on the other dykes, which are exposed for lengths up to 800 feet. They are generally quite erratic in strike and in width, broken by cross-shears, and locally split into networks among greenstone inclusions. Several may be gently-dipping bodies. Coarse-grained spodumene is abundant in some lenticular bands and fine-grained spodumene is distributed through some aplitic patches. A considerable additional tonnage of mineable material is probably available, but not in any single large body.

Violet Group, Combined Developments Limited

The Violet group of thirty-one contiguous claims covers an area near the narrows of Crowduck Bay, Wekusko Lake. It is held by Combined Developments Limited, whose assets were acquired by Canadian Scotia Limited, late in 1956.

The country rocks are greywacke and fragmental rocks of the Missi (?) Group, striking east of north and dipping steeply east. The nearest exposed intrusive rock is quartz diorite that outcrops ¼ mile away, across the bay from the exposed pegmatite dykes. The main dyke, on which most of the drilling has been done, is well exposed near the camp on the lakeshore, and two other lithium-bearing dykes were found during surface exploration in 1955.

The main dyke is 300 feet east of Crowduck Bay and about ¾ mile north of the narrows. It is well exposed for about 420 feet and is more than 60 feet wide through most of this distance, with only one contact commonly exposed. It strikes N33°E, about parallel with the bordering schists and fragmental rocks, and is nearly vertical.

Throughout its exposed length, the dyke carries uniformly distributed medium-grained green spodumene, with quartz, and fine-grained white feldspar and about 20 per cent of coarse-grained, subhedral, light pink to white feldspar. The spodumene crystals lie consistently perpendicular to the dyke walls, and make up an estimated 20 per cent of the surface.

The dyke is typically unzoned, but at one point an outer band about 2 feet thick contains abundant pink feldspar and tourmaline. It is in contact with tourmalinized schistose wall-rock, and toward the inner part of the dyke the bordering spodumene and feldspar are conspicuously altered and stained.

The exposed part of the dyke has been stripped and opened up by several cross-trenches. Twenty-six diamond-drill holes, totalling 8,311 feet, were completed during the winter of 1955-56 on the 'main dyke structure', described as follows:

Main dyke—surface outcrop of 440 feet, overall length 1,350 feet.
Split dyke No. 1—overall length 1,300 feet.

The company reports the indicated tonnage as 3.3 million tons grading 1.2 per cent Li_2O, to the drilled depth, which is 550 feet below the level of Herb Lake. A further drilling program was started late in the year to explore for lateral and depth extensions.

Sherritt-Gordon

References: Stockwell (1937); Rowe (1956).

The property, now held by Sherritt-Gordon Mines Limited, consists of seventeen claims covering three pegmatite bodies that were staked originally as the Gold Reef group by P. Kobar in 1931.

The property is ½ mile west of the narrows of Crowduck Bay. Two dykes cut a quartz-diorite body near its contact with biotite granite. The most northerly dyke consists of intermittent pink pegmatite stringers carrying small concentrations of coarse-grained, randomly oriented, green spodumene.

The southern dyke, which appears white, is the important one. It has been described as follows (Rowe, 1956):

> Dyke No. 2, the most important, has been traced by diamond-drilling for a distance of 900 feet. Nineteen diamond-drill holes, placed at intervals of about 50 feet, intersected the pegmatite body at an average depth of about 50 feet, and a twentieth at about 150 feet. The pegmatite cut by the nineteen shallow holes contained an average of 13.57 per cent spodumene over an average width of 18.5 feet, and that cut by the deeper hole contained 23.1 per cent spodumene over 14 feet. Sink-float assays using a liquid medium of 3.1 specific gravity were used to determine the spodumene content.
>
> The surface width of the pegmatite body can be measured at one place where it is about 25 feet. The strike is north 65 degrees west and the dip at the surface about 65 degrees southwest.
>
> Six outcrops were found by the writer and five of these consist chiefly of perthite-cleavelandite-quartz-spodumene-muscovite pegmatite. Therefore, the bulk of the pegmatite body can be considered as spodumene-bearing from wall to wall for practical purposes. The spodumene crystals are apple-green and range up to about 1.5 feet in length. Crushing to plus ¼ minus ½ inch is reported to liberate most of the spodumene. In places many of the spodumene crystals are oriented with their long axes perpendicular or sub-perpendicular to the walls of the pegmatite body. The perthite is white to pink and occurs as crystals and aggregates of crystals up to 3 feet in length. White to pink cleavelandite, and quartz are fine grained, whereas most of the muscovite is medium grained and occurs in books. Black tourmaline, red garnet, and a blue-green mineral are present in places in small amounts, and a few small crystals of golden beryl were found in broken rock in a small trench.
>
> Spodumene grain counts on outcrops could be made in only three places, and the results are as follows:

Length of measurement in feet	*Per cent spodumene by weight*
15.0	14.1
3.5	18.3
3.0	15.6

> Sink and float concentration tests were made by Sherritt-Gordon and it is reported that a spodumene concentrate could be produced commercially by this method. The company has no immediate plans for working the deposit.

Other Manitoba Occurrences

Spodumene-bearing pegmatites have been found at lat. 54°45′, long. 95°12′ in the Oxford House – Knee Lake area (Barry, 1958), and at lat. 54°34′, long. 97°51′ in the Cross Lake area (C. K. Bell, personal communication).

NORTHWEST TERRITORIES

Lithium-bearing pegmatites have been noted within a broad belt that extends more than 200 miles northeast of Yellowknife, and comprises the following six map-areas: Yellowknife (85J), Beaulieu River (85I), MacKay Lake (75M), Walmsley Lake (75N), Lac de Gras (76D), and Aylmer Lake (76C).

So far as the writer is aware, the only ones that have been intensively examined or prospected are in the Beaulieu River and the adjoining eastern part of the Yellowknife and Prosperous Lake map-areas, collectively referred to as the "Yellowknife-Beaulieu district" (Fig. 10).

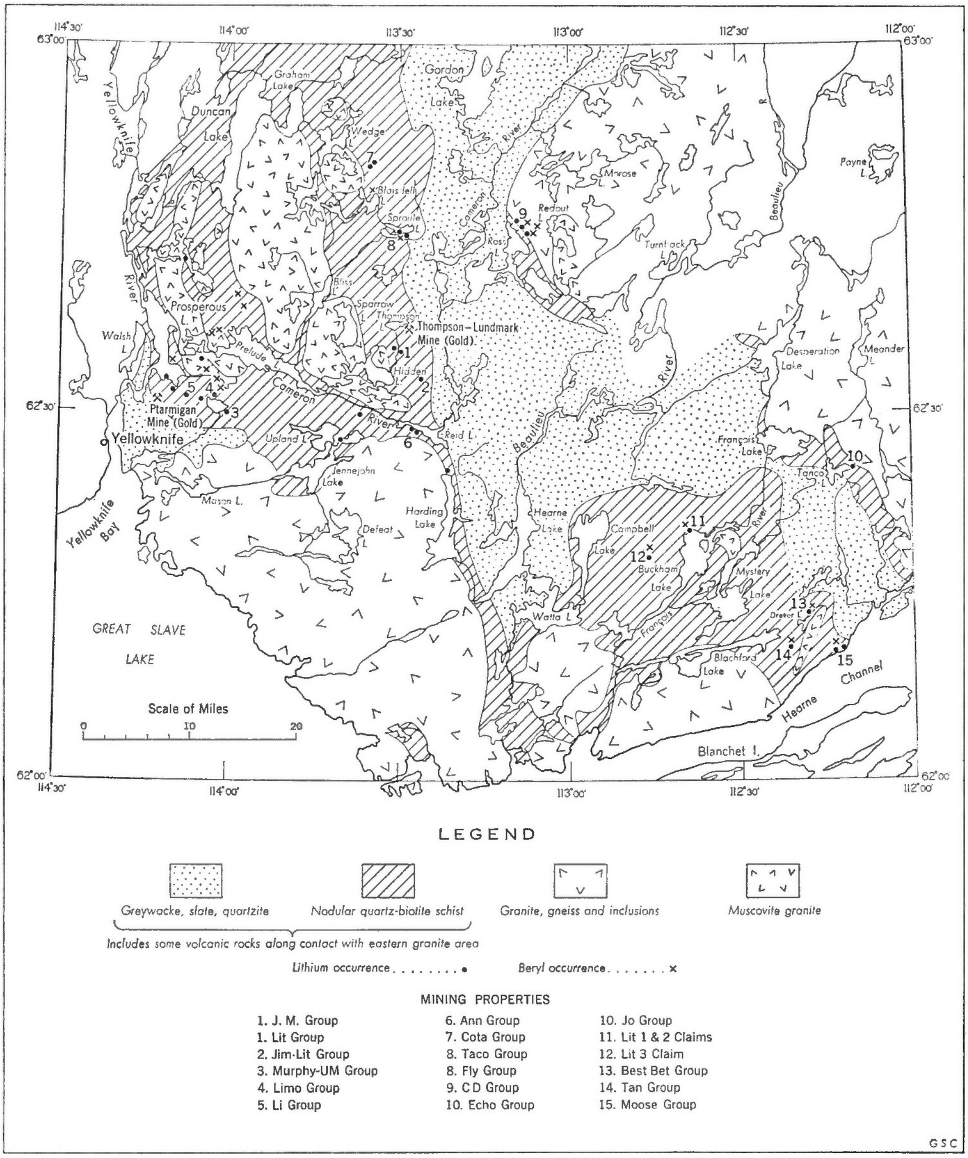

FIGURE 10. ***Main lithium occurrences and geological association, Yellowknife-Beaulieu district, District of Mackenzie.***

Yellowknife-Beaulieu District

References: Fortier (1946); Henderson (1946); Henderson and Jolliffe (1941); Jolliffe (1942, 1944); Rowe (1952).

The lithium deposits of the Yellowknife-Beaulieu district lie within a belt that extends northwesterly for 65 miles from Hearne Channel to a point about 37 miles northeast of Yellowknife, and a branch that extends west to the area south of Prosperous Lake, about 8 miles northeast of Yellowknife (Fig. 10).

Lithology

The rocks underlying this composite belt are chiefly sedimentary and metasedimentary. A band of volcanic rocks passes just northeast of Upper Ross Lake, and is cut by lithium-bearing dykes. The commonest rocks are greywacke and slate of the Archaean Yellowknife Group, and their metamorphic derivatives, nodular quartz-biotite gneiss, and impure quartzite. These, and the marginal parts of granodiorite bodies that delimit the belt, are cut by stocks of younger pegmatitic granite, with which the zones of relatively high metamorphic grade are chiefly associated. The rare-element pegmatites of the district are restricted to the metamorphic aureoles, and are presumably related to the younger granite.

Structure

The bedded rocks of the district are closely folded, in places isoclinally. Steep dips are the rule, and overturning is not rare. Faults and fractures are very numerous, and trend in various directions. These features are readily apparent from the air and on air photographs, and have been illustrated by trend lines on Geological Survey maps 46-23, 47-16A, 868A, and 709A. Regional and detailed studies by Jolliffe, Henderson, and Fortier indicate that cross-folding, on north- to northwest-trending axes, of previously folded strata was an important phase of the structural development of the district. Henderson (1943) stated that the sedimentary and volcanic rocks strike parallel with the granite contacts, but dip away from them at steep angles. He accounted for the second warping as being due to the intrusion of the granite. The thermal metamorphism, producing the knots, was accomplished after movement had ceased, and was attributed to the rise in temperature caused by the intrusion of the granite. Fortier (1946) called attention to a parallel trend of masses of pegmatitic muscovite granite to the axes of cross-folds, and stated that a prominent northwest-trending cleavage, parallel to the axes of cross-folding, has also affected the pegmatitic granite, in the Ross Lake – Hidden Lake area at least. He believed that the development of cross-folds, pegmatitic muscovite granite, nodules in the high-grade metamorphic rocks, and northwest-trending cleavage, were roughly coincident. The age of the rare-element pegmatites in relation to structural development is discussed below.

The district is noted for its history of complex and repeated faulting. The most persistent mapped faults strike northwest to north, and some have resulted in large horizontal displacements. In the Yellowknife Bay area such faults offset gold-quartz veins formed in early shear-zone faults, and also most late Proterozoic diabase dykes (Lord, 1951, p. 38). Thus they are in general younger than the rare-element pegmatites.

General Character of Pegmatites and Relationship to Structure

Pegmatites are extremely numerous and widespread in the district. Like the other rocks, they are exceptionally well exposed and, being much lighter in colour, show up clearly against the darker bedded rocks in aerial photographs (Plates V, VI, VII). Some of the pegmatites maintain a fairly uniform width through thousands of feet of exposed length, but many are short, erratic in strike, and lenticular in shape of outcrop, and *en échelon* outcrop patterns are common. Throughout the district, the lithium-bearing pegmatites strike predominantly northeastward, so that they generally cut directly or obliquely across the strike of the bedded formations. Most of the dykes dip steeply. These may occupy transverse tension fractures resulting from the cross-folding previously mentioned. In some places, however, the lithium pegmatites are concordant with the bedding. Rowe (1952) stated that some arcuate-shaped pegmatites were controlled by crests or troughs of folds. A lithium-bearing dyke in the Reid Lake area strikes northwest, and trends other than northeast for non-lithium-bearing pegmatites prevail in several localities. In the Ross Lake area, according to Hutchinson (1955, p. 10, 11) simple unzoned granite pegmatites, which are nearest the granite bodies, are more irregular in shape and variable in attitude than the more complex pegmatites farther away, and conform roughly to the banding of the granodiorite and included gneisses.

The pegmatite dykes are all 'granite pegmatites', composed essentially of potash and soda feldspars, quartz, and minor muscovite. Several hundred are known to contain lithium and/or other rare elements. Their mineralogy varies according to regional zoning patterns and the presence or absence of internal structures, particularly zoning.

Internal and Regional Zoning of Pegmatites

Internal zoning is characteristic of the dykes in the Buckham Lake – Drever Lake – Hearne Channel area, in the southernmost part of the district. Dykes in these areas are generally coarse grained. Many carry amblygonite in quartz cores; spodumene is transitional from core to intermediate zones; beryl and columbite-tantalite are chiefly in inner intermediate zones. The mineralogical sequences are less complete than in some other districts, and overlapping and telescoping of zones are common features.

In contrast with these, the dykes in the Bighill Lake, Hidden Lake, and Reid Lake areas, also those of the Cota group in the north and in the Tanco Lake area are, as a class, medium-grained, unzoned, simple spodumene-bearing dykes.

Internal structures other than zoning are rarely outstanding. Longitudinal banding is common, and a cross-banding is well developed at one locality east of Bighill Lake (Plate III). At the same locality is found a rare, unquestionable example of fracture filling.

Regional zoning of pegmatite dykes about stocks of younger granite is well marked in several parts of the district. In the Ross Lake – Redout Lake area, for example (Jolliffe, 1944; Rowe, 1952; Hutchinson, 1955), the sequence of types occurring southwestward from the Redout Lake granite is as follows: (1) graphic granite; (2) graphic granite with beryl; (3) beryl; (4) beryl and columbite-tantalite; and (5) spodumene. In the Prosperous Lake area, several beryl-bearing pegmatite bodies are grouped closely around the south end of the Prosperous granite mass, whereas numerous spodumene-bearing dykes with little or no beryl lie within an arcuate zone from about 1 mile to 2 miles south of the contact.

Regional zoning is not apparent in the Buckham Lake – Drever Lake – Hearne Channel area, where the dykes are complex in mineralogy and internally zoned.

Mineralogy of Pegmatites

The chief lithium-bearing mineral of the district is spodumene. It is essentially the only rare mineral of the unzoned dykes seen by the writer, although amblygonite has been reported in the Reid Lake dyke and in some east of Hidden Lake and in the Prosperous Lake area. Amblygonite occurs in substantial amounts in the cores of well-zoned dykes in the Buckham Lake – Hearne Channel area. It is uniformly grey and commonly shows fine striations due to polysynthetic twinning. Amblygonite is present in the dykes of the Bore group, at Sproule Lake (Jolliffe, 1944). Petalite is rare but has been reported in one dyke in the Ross Lake area (Jolliffe, 1944). Triphylite, largely altered to minerals of the Hühnerkobellite series, occurs in minor amount in dykes of the Cota group, north of Blaisdell Lake, and also in the Best Bet dyke, at Drever Lake. Lithiophilite, a closely-related mineral, is reported by Jolliffe as a minor constituent in the dykes of the Buckham Lake area and the Tan group, also at the former Bore group (Sproule Lake) and Dyke group (Prelude Lake) and at Blaisdell Lake. In the latter two localities it is associated with beryl and without spodumene. At Prelude Lake it forms aggregates up to a foot across. Lepidolite is notably scarce, but is reported to occur in one dyke (Jolliffe, 1944, p. 8).

Other pegmatite minerals of economic interest are beryl, columbite-tantalite and tapiolite, and cassiterite. Only the well-zoned lithium-bearing dykes carry appreciable amounts of beryl. In these it is mainly outside the lithium zones, but some is intimately associated with spodumene. Where regional zoning is pronounced, beryl occurs in dykes that are closer to bodies of younger granite than are the lithium dykes, as also are minerals of the columbite-tantalite series, and tapiolite. Attempts at commercial exploitation of columbium-tantalum minerals have been made at the Moose and Best Bet properties and at some properties in the Ross Lake area. In the lithium-bearing dykes these minerals are concentrated mainly in intermediate zones, associated with cleavelandite, muscovite, and beryl. However, at the Best Bet, and also at the Cota group, some columbite-tantalite was found in intimate association with, and in part enclosed in, spodumene. Cassiterite has been indentified as an interesting minor constituent of dykes at the Tan group and the Taco claim (Jolliffe, 1944).

The essential rock minerals are feldspars, quartz, and minor muscovite. The most abundant feldspar is coarse-grained, white to flesh-coloured microcline, in places perthitic. It is commonly in crystals several feet in length, lying roughly perpendicular to the walls of dykes, with spodumene and associated fine-grained feldspar-quartz mixtures interstitial to them. The fine-grained interstitial feldspar is mainly albite. Cleavelandite is abundant in the zoned dykes and is locally conspicuous in certain dykes at Bighill Lake and at the Echo group. Aplite makes up a major part of most dykes. Locally it carries fine-grained spodumene, and even a few large crystals. Muscovite is abundant only in the intermediate or outer zones of some dykes. Pale green or yellowish mica is locally conspicuous as an alteration product of spodumene. Among minor minerals identified in some pegmatites are garnet, tourmaline, fluorite, and lazulite.

Tourmaline is not a common or abundant mineral of the lithium pegmatites, for none was noted by the writer except in the selvedge of a dyke at Reid Lake. It is a common constituent of gold-quartz veins of the district (see "Age"). It is also prominent in the margins and selvedges of some of the muscovite-granite bodies, and of their "associated pegmatites" (Fortier, 1946, 1947), particularly east of Ross and Victory Lakes and southeast of Hidden Lake. Jolliffe (1944) mentioned tourmaline as a component of several dykes, of which those at Sproule Lake and at the Tan property carry significant amounts of spodumene.

Associated Vein Deposits

Vein deposits, particularly gold-quartz veins similar to those for which the Yellowknife Bay area is famous, are closely related in space and in geological environment to rare-element pegmatites in several parts of the district. Notable among these are gold-quartz veins at Thompson-Lundmark and Ptarmigan mines (Plates V, VI). They commonly contain abundant tourmaline. A vein at the Thompson-Lundmark mine is cut by a pegmatite dyke, and single crystals of beryl, spodumene, and lazulite have been found in certain quartz-tourmaline veins in the Prosperous Lake area (Henderson, 1946). Molybdenite occurs in several places near a northwest-striking fault about 4 miles southeast of the Thompson-Lundmark mine. Scheelite occurrences are numerous in basic rocks around Tibbitt Lake, farther southeast, and disseminated scheelite is found east of Ross Lake and south of Victory Lake.

Age

The age of the pegmatites in this district relative to that of the parent intrusions and associated gold-quartz veins, is known within close limits, mainly from data cited in the preceding paragraphs. According to Fortier (1946), intrusion of the pegmatitic muscovite granite accompanied cross-folding that affected the sedimentary and volcanic rocks and older granodiorite, and resulted in metamorphic aureoles of knotted schists in the sedimentary strata. Gold-quartz veins believed to be genetically related to the young granite contain abundant tourmaline, and are cut by pegmatite dykes comparable to those carrying rare-element minerals. All these are cut by late diabase dykes, by late north-northwest-trending faults, and by young veins of vuggy quartz that follow the late faults and contain little gold. The presence of tourmaline in the old quartz veins and its absence from both the unzoned and the zoned lithium-bearing pegmatites seen by the writer suggest that the tourmaline phase, normally the earliest in the development of zoned rare-element-bearing pegmatite dykes, coincided mainly with the earlier quartz-vein stage.

The absolute age of pegmatite of the Yellowknife region is about 2,200 million years (Wilson *et al.,* 1956). This compares with the age of granitic intrusions in other lithium-bearing areas of the Canadian Shield.

Economic Potential

The writer's field work in the Yellowknife-Beaulieu district was mainly restricted to a selection of lithium-bearing dykes on which some exploration work had been done prior to 1957, and which had not been reported upon previously by the Geological Survey. Time did not permit an accurate appraisal of tonnages or grades of lithium ores. Many of the dykes seen by the writer contain moderate to high-grade sections, and represent a reserve of many millions of tons of material comparable to that developed elsewhere. However, the remoteness of the area would seem to preclude large-scale exploitation of such deposits under present market conditions.

J. M. Group (Hidden Lake)

The J. M. group lies east of Hidden Lake and south of Thompson Lake, and adjoins the Lit group of Affiliated Lithium on the west (Plate V). It consists of fourteen claims, plotted along the east border of claim map 85 I-12, Yellowknife Mining Division, and held under option by General Lithium Corporation.

Nodular quartz-biotite schists strike west of north and dip moderately eastward. Three pegmatite dykes striking northeast by north in the south-central part of the property, carry spodumene in appreciable amounts.

Dyke D1, the most southerly, is exposed for more than 2,000 feet and is cut by seven cross-trenches, 64 to 110 feet long, and a 15-foot trench across one of the branches at the north end where the dyke apparently splits up. The trenches reveal a longitudinally banded internal structure. Fine-grained pegmatitic to aplitic phases, generally pink, alternate with coarse-grained pegmatite bands that are commonly grey, but are locally stained pink by secondary alteration products, especially along cross-fractures. The dyke splits around several minor septa and may be composite. There is no systematic zoning. Medium-grained spodumene, generally greenish, and locally much altered to dark green or brown micaceous material, occurs chiefly with rather coarse-grained grey or pink-stained feldspar, quartz, and very minor muscovite, in the pegmatitic bands. Some spodumene is also present in many of the aplitic bands, and greenish patches in these may contain appreciable amounts of fine-grained spodumene. The tenor of spodumene is highly variable, both across the dyke and along individual bands and lenses. In a few places along the dyke, the spodumene content was estimated to be well over 20 per cent but the average is believed to be much less.

Dyke D2 is about 400 feet west of, and roughly parallel with Dyke D1. It is exposed for about 1,200 feet. It has a somewhat irregular structure, branching and splitting around septa of country rock in several places. Four trenches across the main part of the dyke are from 20 to 40 feet long. This dyke is less distinctly banded than Dyke D1. Spodumene occurs in clumps within aplitic material as well as in parallel orientation in pegmatitic bands. Much of it is in crystals more than a foot long that are oriented perpendicular to the walls, and are flat lying. A 30-degree westward plunge of the spodumene crystals at the north end of the dyke, however, suggests that the dyke here dips about 60 degrees eastward. Some bands up to 5 feet wide in the central section of the dyke were estimated to contain 20 to 30 per cent spodumene, but the remainder was judged to contain much less.

A third dyke about 300 feet northwest of Dyke 2 converges northward toward the latter. It is exposed fairly continuously for about 575 feet, and varies from 24 feet wide in the central part to nil at the southern limit, where it appears to pinch out. A trench 15 feet long near the north end exposes fairly abundant medium- to coarse-grained green spodumene with grey feldspar and quartz in a central 3-foot band between outer bands of pink to grey aplogranite. A trench 24 feet long across the central section shows medium-grained pale green spodumene rather thinly scattered throughout. The spodumene, associated with quartz and aplite, occurs interstitially to coarse-grained grey and pink feldspar.

Development work on the group includes 848 feet of diamond-drilling. No work was done in 1957.

Lit Group (Hidden Lake)

The Lit group consists of forty-three claims lying 1 mile to 3 miles east of Hidden Lake and 1 mile to 3 miles south of Thompson-Lundmark Gold Mines (Plate V). The claims are plotted along the west border of claim map 85 I-11, Yellowknife Mining Division. The property is held by Affiliated Lithium Mines Limited, and was staked in 1955 by Noranium Minerals Limited.

The property was not visited by the writer and the following description is mainly from information supplied by J. R. Woolgar of Yellowknife.

Nodular quartz-biotite schists strike generally northwest to north with local sharp deviations to other trends, and beds are commonly overturned to the east. Numerous small quartz veins and stringers generally follow bedding planes.

Numerous pegmatite dykes strike mainly north to northeast, cutting obliquely across the formation, and commonly dip steeply northwest. Several diabase dykes, up to 40 feet wide, strike generally northwest and cut all the other rocks, including the pegmatites. Medium-grained spodumene is the main economic mineral in the pegmatites, though small amounts of other metals have been reported.

The mineralized dykes occur in two main zones. Zone No. 1, consisting of three main dykes, lies in the south-central part of the group. Dyke A, the largest in this zone, extends from 'Jonas Lake' through 'Chicken Leg Lake' toward the eastern boundary. It is 3,872 feet long and has an average width of 60 feet. It strikes generally N45°E and dips 85°NW. Trenching, stripping, and sampling were concentrated in the main section, 2,500 feet long and over 100 feet wide, where the spodumene content was highest and most uniform. Dyke B is 800 feet northwest of and parallel with Dyke A. It is traceable over 1,080 feet and averages 10 feet in width, with medium-grained spodumene throughout. Dyke C is 1,565 feet northwest of and parallel with Dyke A. It averages 30 feet in width over 1,600 feet, with the best mineralization in a northerly section, 550 feet long.

Zone No. 2 consists of a large dyke or series of dykes extending south from Grant Lake in the northwest part of the property. It has been traced for 6,600 feet, and has an average width of 25 feet. Spodumene concentrations, mostly coarse grained, occur mainly in the central part where a number of cuts were blasted. In the northern part spodumene was seen by the writer only within a few hundred feet north of the creek at the south end of Grant Lake.

Some further work was done on a weak zone of dykes in the southeast corner of the property.

Jim-Lit Group (Little Hidden Lake)

The Jim-Lit group lies about 2½ miles east of Hidden Lake and 2 miles west of Tibbitt Lake (Plate V). It comprises claims UM 1, 2, and 9, Bill 1-6, Jim 1-6, and Lit 1-9, plotted on claim map 85 I-11, Yellowknife Mining Division, and is held or optioned by General Lithium Corporation.

Nodular quartz-biotite schist strikes east of north with dips commonly overturned to the east. The three pegmatite dykes on which work has been mainly concentrated lie between Lit Lake and Little Hidden Lake. They strike about N40°E and all appear to have dips of about 45°NW.

Dyke 12, the largest, on claim Lit 2, is traceable for more than 1,000 feet northeast from near the shore of Lit Lake, including a continuous central section more than 500 feet long and averaging about 30 feet wide. It has been explored by four long cross-trenches and six short ones. A banded structure and cross-orientation of spodumene and coarse-grained feldspar crystals indicates a variable dip of about 45 degrees northwestward. Banding is especially marked at the north end on the hanging-wall side, where several bands of spodumene-bearing pegmatites about a foot thick alternate with 1-inch bands of aplite. The dyke is generally coarse in texture. Long grey to pink-stained feldspar crystals interspersed with coarse-grained spodumene and long streaks of dark grey quartz lie mainly in parallel orientation perpendicular to the long axis of the dykes. They mostly plunge up to 45 degrees southeasterly. Some spodumene is in random orientation. Crystals are up to 36 inches long and are commonly yellowish green and considerably altered. The tenor of the dyke as a whole was judged to be relatively high, and in several sections bands up to 14 feet wide at the surface were estimated to contain as much as 35 per cent spodumene.

Dyke No. 2 lies parallel with and about 900 feet northwest of No. 12. It is traceable for about 600 feet southwest from a bay of Little Hidden Lake, and varies in width from as much as 30 feet in the northern sections to about 6 feet near the south end. It has a variable dip of about 45°NW. It has been explored by seven cross-trenches. Septa and ragged horses of country rock are common in the broader northern half. The dyke is generally coarse grained, with long grey crystals of feldspar and green spodumene plunging 40 to 45°SE in several places. Much spodumene is altered to dark green or brown material and yellowish mica is locally abundant. The spodumene content was estimated to exceed 20 per cent in a few places.

Dyke No. 1, on claim Jim 2, is parallel with and about 160 feet northwest of No. 2. It is about 340 feet long, as exposed, and tapers generally from a width of 38 feet at the north end to a narrow stringer at the south. It is cut by six cross-trenches. The dip appears to be fairly consistent at about 45°NW. The dyke is fairly coarse grained, and contains long white feldspar and green spodumene crystals plunging generally southeast across it. Some northern parts of the dyke were estimated to contain more than 20 per cent spodumene. Some spodumene is altered and yellow mica is prominent in one place.

Development work claimed on the group includes 306 feet of diamond-drilling. No work was done in 1957.

Murphy-UM Group (Bighill Lake)

The Murphy-UM group forms part of a block of eighty claims covering the southeast shore of Bighill Lake and adjoining area (Plate VII). The claims are shown on claim maps 85 J/8 and 9, and 85 I/5 and 12, Yellowknife Mining District. The property is held by General Lithium Corporation.

Nodular quartz-biotite schists strike north of east and dip moderately to steeply southward. A regional fault, the Madeline Fault, strikes northwesterly through the northeastern part of the area. Two major zones of pegmatite dykes, the BA and BB zones, strike about N30°E and dip steeply.

The BA zone comprises an anastamosing, partly overlapping series of dykes in a belt extending about 4,000 feet southwestward from a point near the eastern tip of Bighill Lake. It is covered by claims UM 1, 2, and 36 and Murphy 3. The belt is up to 500 feet wide and individual dykes, designated "BA 1", "BA 2", "BA 3", and "BA 4", range generally from 10 to 30 feet wide, and exceptionally to 50 feet wide as at the north end of BA 1. With this exception the dykes appear to pinch out northwards and southwards. A covered area near a small lake separates BA 1 and BA 2 in the north from BA 4 in the south and divides BA 3 into two dubiously identified sections.

Within the zone the dykes differ considerably in character. They are mainly white to light pink, typical spodumene dykes, irregularly banded but unzoned; but zoning and other complex internal structures are locally developed and beryl is a conspicuous constituent at one place. The dykes are composed of grey to pink microcline with minor cleavelandite and quartz, a little muscovite, much sugary grained aplite, and variable amounts of spodumene. The spodumene is medium to coarse grained, greenish, and mostly in long flat-lying crystals oriented perpendicular to the surface trace of the dyke walls.

Dyke BA 4 marks the southwest limit of the belt. It is traceable for about 1,200 feet and is crosscut by six trenches, 5 to 42 feet long. It has a somewhat irregular branching structure and includes some horses of schist. Most of the spodumene is in interior bands of coarse-grained, microcline-cleavelandite-quartz pegmatite but outer granitic to aplitic zones locally contain fine- to medium-grained spodumene. Some of the better sections of the dyke were estimated to contain 30 per cent spodumene over widths up to 20 feet. Toward the south end mica pseudomorphs of spodumene are common and mica is a major constituent of the dyke.

The southern part of Dyke BA 3 is fairly well exposed for about 600 feet and is cut by four cross-trenches, 12 to 25 feet long. A further length of about 400 feet to the end of a small lake is suggested by three unmarked trenches in overburden. The well-exposed part shows an irregularly banded structure of pink to grey aplite and coarse-grained pegmatite. The spodumene is medium to coarse grained, and is mostly confined to scattered discontinuous stringers in coarse-grained pegmatite.

The northern part of Dyke BA 3 is exposed fairly continuously for about 900 feet and is cut by three marked, and several unmarked trenches, 13 to 26 feet long. It has a vaguely and irregularly banded structure, consisting of coarse-grained microcline pegmatite, with aplite wall zones locally well developed. Spodumene, in medium- to coarse-grained crystals lying perpendicular to the dyke walls, is mainly in intermittent stringers in coarse-grained pegmatite. It is fairly plentiful in the southernmost 200 feet of the dyke (as exposed), and at the last trench, marked "T 13", might amount to 25 per cent of a 14-foot central section. Some flesh-pink and grey cleavelandite is associated with quartz among the spodumene crystals. Somewhere near T 13, a trench marked "T 16" in an isolated exposure shows coarse-grained pink, perthitic-looking microcline, with plentiful quartz, cleavelandite, and muscovite. No spodumene was seen but creamy to pale green beryl in crystals up to 1¼ inches in diameter is conspicuous in the quartz-cleavelandite-muscovite assemblages. Some beryl is in cores surrounded by sericitic mica.

Dyke BA 1 extends as an irregular and ill-defined dyke or series of dykes for some 2,200 feet northeastward to the shore of Bighill Lake. It branches and splits around inclusions in several places and ranges from 50 feet wide to narrow stringers. It is explored by ten or more trenches, only two of which at the north end cross a substantial width of solid dyke. The southernmost exposures are of pink, simple microcline-cleavelandite-quartz-muscovite pegmatite, without spodumene; the remainder of the southern half of the dyke carries medium-grained spodumene in parallel cross-orientation in narrow discontinuous central bands. North of a covered central section a number of separate stringers converge into a solid, fairly definite dyke. Trench No. 7, across one of the stringers, reveals a patchy complex of pegmatite and aplite, with spodumene in both longitudinal stringers and cross-stringers. In the longitudinal stringers, which are wide and make up most of the dyke, long crystals of spodumene and microcline lie perpendicular to the long axes of the stringers. In the cross-stringers the spodumene is perpendicular to the axis of the cross-stringer which is, therefore, a fracture filling. The northern part of the dyke is an irregular, partly banded complex of pegmatite and aplite, mostly pink. Spodumene is plentiful only in a few scattered bands that are rarely more than 7 feet wide, but at T 5, coarse-grained spodumene may amount to 30 per cent in a central zone 27 feet wide.

Dyke BA 2 lies 100 to 250 feet northwest of BA 1 and extends as a fairly well defined dyke for some 1,500 feet southwest from a point near the shore of Bighill Lake. It is a simple pink pegmatite with only a few long aggregates of mica, which may be pseudomorphous after spodumene.

The BB zone is about 4,000 feet east of, and parallel with, the BA zone. It lies mostly within the Murphy 8, 10, and 12 claims. It extends as a complex of subparallel and irregularly branching dykes for about 3,000 feet from the corner of an L-shaped lake, southwestward past the east end of Egg Lake. It averages about 200 feet in width. At the south end a number of typical unzoned white pegmatite dykes horsetail out among the schists. They carry flat-lying, medium-grained spodumene in parallel cross-orientation, probably amounting to 25 per cent of the dykes, in a few places.

For several hundred feet north of the Egg Lake ravine the several dykes or branches designated "D8", "D7", and "D6" are chiefly pink, and carry medium-grained, cross-oriented spodumene in variable, but unimpressive amounts. In the northern part of dyke D8, however, three trenches up to 30 feet long have been blasted into much richer material, possibly averaging between 30 and 35 per cent spodumene. The dyke in this section consists of spodumene-quartz-feldspar pegmatite with a few randomly oriented large masses of pinkish white feldspar and quartz, and some longitudinal and cross-bands of greyish aplite about 4 feet wide. Dyke D7 in this central section is similar and is cut by three trenches. It carries spodumene crystals in parallel cross-orientation with feldspar over widths up to about 27 feet and grades up to an estimated 30 per cent.

Dyke D5 in the northern section of the zone is intermittently exposed and explored by several trenches. These are up to 20 feet long and carry medium- to coarse-grained spodumene along with a large proportion of feldspar crystals in parallel cross-orientation. Dyke D2 at the shore of the L-shaped lake has been opened up by an oblique trench 43 feet long. It consists of longitudinal pegmatite bands carrying some spodumene and alternating with bands of barren aplite. Two other short trenches reveal a little spodumene in a similar banded structure. Exploration work on the property includes 5,602 feet of diamond-drilling, mostly or entirely on the BA and BB zones.

Limo Group (Bighill Lake)

The Limo group consists of eighteen claims on and near the north shore of Bighill Lake (Plate VII). They are shown on claim map 85 J-9, Yellowknife Mining District. The claims are held by Affiliated Lithium Mines Limited, and were acquired in 1955 by Noranium Minerals Limited.

The Limo group was not visited by the writer and the following description is mainly from information supplied by J. R. Woolgar of Yellowknife.

Nodular quartz-biotite schists strike generally north of west across the property and dip moderately southwards. Numerous narrow quartz stringers follow the bedding planes of the schists. A regional fault, the Madeline Fault, trends about N30°W past the northeast corner of the group. Fourteen pegmatite dykes strike just east of north across the central part of the property and dip nearly vertically. Of these, ten contain spodumene, but only two contain enough to warrant sampling. Dyke No. 2 extends 1,800 feet from the lakeshore, and has an average width of 15 feet. It strikes N10°E, and dips 88°W. Pegmatites that occur on several islands are presumably extensions of this dyke and include the main enriched part. Dyke No. 10 lies farther west. It cuts across a peninsula and also outcrops for 700 feet on the mainland, with an average width of 20 feet. The most promising section appeared to be that on the peninsula where spodumene crystals, up to 4 by 8 inches, are coarser than elsewhere on the property. Development work consisted of slashing, trenching, and pitting on the above dykes. Some development work was done in 1957.

Li Group (Prosperous Lake)

The Li group consists of twenty-eight claims lying at the southeast end of Prosperous Lake (Plate VI), as shown on claim map 85 J-9, Yellowknife Mining Division. It is held by Affiliated Lithium Mines Limited, and was acquired by Noranium Minerals Limited in 1955, being formerly held as a gold prospect and subsequently prospected for columbium-tantalum deposits.

The property was not visited by the writer and the following description is mainly from information supplied by J. R. Woolgar of Yellowknife.

Nodular quartz-biotite schists strike generally northwest across the property and dip 25 to 65°SW. A regional fault, the Vega Fault, strikes N30°W through the southwest corner of the group. At least fifteen pegmatite dykes strike generally N25°E, of which twelve carry lithium minerals and three merit separate description.

Spodumene is the only major lithium mineral, though lepidolite and amblygonite are reported in places.

No. 1 dyke strikes N50°E through the north-central part of the group and dips steeply. It is 3,000 feet long and averages 25 feet in width. Spodumene crystals range from an inch to 2 feet in length. A possible extension of this dyke is traceable almost to the southwest corner of the property.

Dyke No. 15 lies near the shore of a bay of Prosperous Lake, in the northwestern part of the property. It strikes N45°E and dips 85°NW. It is traceable for 200 feet with an average width of 15 feet, and carries very coarse grained spodumene.

Development work, consisting of trenching and slashing, has been concentrated mainly on these two dykes.

No. 8 dyke, in the south-central part of the group, strikes N30°E and appears to be vertical. It averages 4 to 12 feet in width over a length of 300 feet, and carries coarse-grained spodumene, with minor lepidolite and amblygonite.

Ann Group (Reid Lake)

The Ann group and adjoining claims of the Kim, IL, and Bill groups, owned by Magnum Holdings Limited, lies along the south shore of Reid Lake. The main part of the dyke, which was originally staked by W. Bellis of Yellowknife, is on the Ann group and all the drilling that was done was on this group. It consists of six claims, whose positions are plotted on claim map 85 I-6, Yellowknife Mining District. A northwesterly striking pegmatite dyke cuts nodular quartz-biotite schist about ½ mile north of the contact with a large granitic batholith. The dyke extends northwest for about 3,000 feet from the shore of a deep bay, but is covered in several sections and may not be continuous. It varies from 10 to 70 feet in exposed width and appears to dip steeply southwestward. What may be extensions of the same dyke system outcrop on the opposite side of the bay, about 2,000 feet southeast. Eighteen cross-trenches have been cut in the northwest dyke system and several in the southeast exposures. The dyke is white or light coloured and in some areas consists of coarse-grained white or pale pink feldspar with interstitial quartz-cleavelandite-spodumene assemblages; in others it is predominantly aplite. The coarse-grained crystals are mainly transverse to the dyke walls. The spodumene is mostly medium grained and very pale green to white. Much of it contains abundant quartz blebs, partly in vermicular or sub-graphic intergrowths. It occurs chiefly in indefinite longitudinal bands separating others that consist chiefly of aplite or coarse-grained feldspar, and may compose up to 30 per cent of these in places. Elsewhere the spodumene occurs as fine needles in quartz-spodumene intergrowths within bands 30 feet wide as exposed. Amblygonite has been reported as present in this dyke. None was found by the writer in the field but a few small grains, not positively identified, were seen in one thin section. Fine-grained tourmaline is abundant in the schistose wall-rock and a little is present in at least one place in the dyke within an inch of the contact.

Cota Group (Blaisdell Lake Area)

Reference: Henderson and Jolliffe (1941).

The Cota group consists of twenty-one claims that lie about 3 miles north of Blaisdell Lake and which are plotted on claim map 85 I-13, Yellowknife Mining Division. It is held by General Lithium Corporation under option from Frank D. Nasso.

Pegmatite dykes designated Nos. 1 to 7 intrude more or less nodular quartz-biotite schist on claims 1, 2, and 3 in the central part of the group. The strike of the schists swings from about N70°E to N30°W. At the flexure the massive beds are slightly crumpled, but thinner-bedded, probably incompetent, members are closely drag-folded, and shear fractures continue in the northeasterly direction. The dykes strike about N40°E, mainly concordantly with the schists, and Dykes 1, 2, and 7 appear to weaken at their east ends where they intrude the northwesterly striking beds. They dip vertically.

Dyke No. 1 is exposed for about 700 feet and is 30 to 40 feet wide through most of that length. It is cut by two cross-trenches. Medium-grained green spodumene crystals lie consistently perpendicular to the walls of the dyke and occur virtually from wall to wall. They are embedded in a mixture of fine-grained feldspar and quartz, and are interbanded with long pink and white feldspar crystals. The spodumene, much of which is dark green and considerably altered, may amount to 20–25 per cent of the main section of dyke.

Dyke No. 2 is about 800 feet south of No. 1, and roughly parallel to it, though irregular in strike. It is exposed for about 800 feet and is mostly from 21 to 36 feet wide. It is cut by four trenches. Spodumene occurs throughout, mostly in ill-defined bands. The bands may carry as much as 50 per cent spodumene across widths of 11 feet in places. It is medium to coarse grained, and occurs in flat-lying crystals oriented perpendicular to the dyke walls. Pink aplite with scattered spodumene crystals and clusters is prominent in low-grade sections. A conspicuous feature of this dyke is the presence of dark green to black accessory minerals in crystals and irregular masses. These are mainly associated with spodumene and occur both in and out of spodumene crystals. The crystals are black, shiny, equidimensional grains up to 1½ inches across. Columbite has been reported in one specimen of such material but it appears to consist mainly of minerals of the hühnerkobelite series with some triphylite, which is probably the parent mineral. The black amorphous material appears to be partly the same, but is indistinguishable in the field from some altered spodumene. A few beryl crystals are associated with these minerals.

Three dykes, D3, D6, and D7, that lie *en échelon* about 400 feet south of D2, carry medium- to coarse-grained green spodumene fairly consistently throughout. No trenches were seen in these dykes. No. 5 dyke is about 1,200 feet west-southwest of, and in line with, D3. It is exposed for about 750 feet, and tapers gradually from a maximum width of 37 feet. It is interrupted in mid-section, where another short dyke appears a few feet to the south, and encloses a few remnants of country rock. The dyke has been explored by six cross-trenches, of which No. 4 and No. 5 make up a single composite trench. It is irregularly and indefinitely banded and contains lean aplitic phases. Green spodumene varies in granularity from fine to coarse. The crystals are notably more random in orientation in the coarser-grained phases. These are apparently the richest section, and were estimated to contain up to 30 per cent spodumene. Spodumene is not in evidence near the west end, but abundant, fine-grained, greenish mica is associated with pink aplite. Small white beryl crystals are fairly common near the north wall, associated with quartz and pink cleavelandite, and a dark greenish mass more than a foot in diameter may contain altered triphylite.

Dyke D4 is about 1,000 feet northeast of D5, near the shore of 'Dell' lake. It is perhaps 400 feet long and up to 20 feet wide. It carries some probable spodumene in the central part, but trenches near both ends show only disseminated greenish mica in a fine quartz-feldspar mixture that is interstitial to coarse-grained, pink feldspar crystals. One small stringer of dark material may be hühnerkobelite-triphylite. Exploration work claimed on the group includes 1,233 feet of diamond-drilling.

Taco Claim (Sproule Lake)

References: Jolliffe (1944); Fortier (1947); Rowe (1952).

The property was not visited by the writer, and the following description is mainly from the three sources referred to above.

The Taco claim lies just south of the central part of Sproule Lake. It is part of the former Bore group, held by Radium Luminous Industries, Ltd., and in 1955 was owned by McAvoy and Sons, Yellowknife. It is surrounded by the Fly group (see below). The claim is located on claim sheet 85 I-11, Yellowknife Mining Division, and is about 35 miles northeast of Yellowknife.

Nodular quartz-biotite schists strike northeast and have an overturned dip of 65 to 70°NW.

The pegmatite dykes strike northwesterly and dip 30 to 70°SW, within a northwesterly striking zone about 1,700 feet long and up to 200 feet wide. Individual dykes are up to 3½ feet wide and 500 feet long. Several are well zoned and comprise various assemblages of muscovite, plagioclase, cleavelandite, quartz, and spodumene (Rowe, 1952). According to Jolliffe (1944), muscovite makes up less than 5 per cent of most dykes. It occurs chiefly along the borders, less commonly within quartz in the central parts of dykes. Tiny blue-green tourmaline crystals occur in muscovite along dyke margins, and black bands less than an inch wide in the bordering sedimentary rocks may represent introduced tourmaline.

The lithium minerals are spodumene, amblygonite, and lithiophilite. A map and a mineral distribution table by Jolliffe (1944) lists thirty-four dyke sections, with spodumene described as "relatively abundant" in one, "present" in three, and "minor occurrence" in nine. Amblygonite is shown as present in three, and a minor occurrence in thirteen. Lithiophilite was found in three localities.

Spodumene occurs in rudely radiating columnar crystals up to a foot long within the central parts of certain dyke sections. Much of it, particularly the smaller crystals, is altered to a very fine grained, yellow-green, micaceous aggregate. Amblygonite is commonly concentrated near the hanging-wall. It occurs in equidimensional crystals up to 8 inches across, but averages less than an inch. Over lengths of 10 to 15 feet these two lithium minerals may constitute as much as a quarter of the dyke area.

Other rare minerals include beryl, cassiterite, and tantalite-columbite. Beryl occurs sparingly in a few sections as white to light green crystals up to 2 inches across. Cassiterite and tantalite-columbite are reported to be the only minerals of possible economic interest.

Fly Group (Sproule Lake)

References: Henderson and Jolliffe (1941); Fortier (1947).

The Fly group consists of eighteen claims covering the southwest part of Sproule Lake. The claims, shown on claim map 85 I-11, Yellowknife Mining Division, are held by Affiliated Lithium Mines Limited. The group surrounds the Taco No. 1 claim, owned by McAvoy and Sons, Yellowknife. Immediately to the west is the property of Garski Mines Limited, on which high gold values have been found in narrow stringers.

The property was not visited by the writer, and the following description is mainly from information supplied by J. R. Woolgar of Yellowknife.

Nodular quartz-biotite schists strike northeasterly near the pegmatite dykes that cut the formation at right angles. Narrow erratic quartz veins and stringers generally follow bedding planes.

The main dyke strikes N25°W for 1,200 feet from the southwest tip of Sproule Lake to Old Parr Lake, dips 45°SW, and is 1 foot to 12 feet wide. Spodumene occurs throughout the dyke, with scattered concentrations. Development work consisted of trenching and slashing in the best-looking parts. Another small narrow spodumene-bearing dyke lies astride the western boundary of the group.

CD Group (Ross Lake)

References: Jolliffe (1944); Fortier (1946, 1947); Rowe (1952); Hutchinson (1955).

The CD group consists of eighteen claims lying along and near the northeast shore of Upper Ross Lake. They appear on claim map 85 I-11, Yellowknife Mining Division. The ground is held by Fred Lypka, Gladys Splaine, and C. A. Desson.

The property was not visited by the writer. The lithium occurrences have been mentioned, but not described specifically, in the above references.

The deposits comprise pegmatite dykes or groups of dykes lying within 1,200 feet of the northeast shore of Upper Ross Lake in a belt about 7,800 feet long. Three are in granodiorite-amphibolite gneiss near or adjoining a band of altered basic flows and other volcanic rocks, and a fourth lies almost entirely within this band. The three northern pegmatites strike northeast; the southernmost pair of dykes strike nearly north. They are up to about 500 feet long (Hutchinson, 1955).

The dykes represent the outermost of a sequence of regionally zoned pegmatite dykes grouped about a mass of pegmatitic muscovite granite referred to as the "Redout Lake granite".

Concerning the southernmost dyke Hutchinson (1955, p. 17) stated: "Spodumene occurs only in the core where it occurs as coarse, elongated crystals up to

6 inches long and may constitute up to 20 per cent of the rock." From personal communication with Hutchinson the writer understands that the lithium-bearing dykes would be classed as imperfectly zoned or unzoned, according to the usage followed in this report. According to Jolliffe (1944, p. 10), petalite is prominent in one of the dykes in this area.

Echo Group (Tanco Lake)

The Echo group, owned by North American Lithium Company Limited, lies east of Tanco Lake, a large lake about 3 miles southeast of François Lake. It consists of eight claims and a fraction, which are plotted on claim map 85 I-8, Yellowknife Mining Division.

A number of pegmatite dykes, partly anastamosing and partly separate, cut more or less nodular quartz-biotite schist just southwest of its contact with a large granitic mass. Diabase dykes or irregular masses cut several of the pegmatite dykes, with minor offsets. The pegmatite bodies are typically unzoned, with spodumene the only economic rare mineral, but one dyke that contains some beryl has the character of a telescoped, zoned deposit.

The main or "East" dyke extends about 2,700 feet southeast from a prominent outcrop on the shore of 'Brown' lake. It is up to 65 feet wide as exposed, strikes N30°W, and appears to dip moderately to steeply northeastward. It is broken up and discontinuous in several sections and at one point is cut, with a small offset, by a diabase dyke. Medium-grained green spodumene is irregularly distributed throughout the pegmatite, possibly amounting to 50 per cent by volume in some stringers and patches, but probably less than 25 per cent across any particular section. Much is rather random in orientation, but in some places parallel orientation of crystals suggest a moderate northeastward dip, and in these places the spodumene is richest on the hanging-wall side.

Three ragged dykes diverge in a generally northwesterly direction from a point near the top of the hill about 200 feet west of the East dyke, and several other subparallel and crosscutting stringers outcrop a few feet farther southwest down the slope of the hill. These are all erratic in strike and dip and highly variable in spodumene content. The main or "Central" dyke of this system is traceable at intervals for some 1,200 feet, and has been explored by five cross-trenches, varying from 30 to 44 feet long. The dyke is considerably wider than this in places, but appears to dip about 45°NE for the most part and to roll broadly. Medium- to coarse-grained green spodumene in intimate mixture with quartz and feldspar, in part cleavelandite, is interstitial to rather coarse grained pink microcline. The proportions of these minerals vary widely; spodumene concentration may reach 50 per cent in some patches and 30 per cent across some dyke sections. Other dykes of this system are up to 900 feet long and locally up to 40 feet wide, and all contain some spodumene.

Two dykes lie about 1,600 feet southwest of the top of the hill, across a small draw (ravine). The smaller of these, about 170 feet long and up to 13 feet wide, has been trenched in three places. It is very coarse grained, consisting of pink microcline crystals up to 5 feet long with interstitial pink cleavelandite, quartz, and yellowish mica. At one trench spodumene occurs in subparallel 'logs' up to 6 feet long and 18 inches across exposed faces, in an ill-defined core zone with abundant quartz and pink cleavelandite. Beryl, in white crystals up to 3 inches across, occurs at the edge of the zone and also among the spodumene crystals.

Jo Group (Tanco Lake)

The Jo group lies south of the east arm of Tanco Lake. It consists of claims 92776 to 92783, shown on claim map 85 I-8, Yellowknife Mining Division, and held by W. Bellis of Yellowknife.

The property was not visited by the writer. The dykes were estimated (J. C. McGlynn, personal communication) to be about the same in grade as, and a little smaller than, the Echo group.

Lit 1 and 2 Claims (Buckham Lake)

References: Jolliffe (1944); Rowe (1952).

The Lit 1 and 2 claims are on the northwest shore of Buckham Lake near its northernmost tip, and cover ground originally staked as Lita 5 and 6 and described as "Campbell Pegmatites". They are now held by Beauport Holdings, Limited.

The property was not visited by the writer. Descriptions by Jolliffe (1944) and Rowe (1952) are summarized as follows.

Scattered exposures of pegmatite within an area 2,400 by 200 feet, lie nearly parallel in strike with nodular greywacke that strikes northeast and dips about 70°NW. They are up to 350 feet long and up to 50 feet wide.

The pegmatite bodies all carry about 50 per cent cleavelandite, 20 per cent quartz, 5 per cent muscovite, and variable amounts of coarse-grained microcline-perthite. Spodumene occurs in crystals up to nearly 4 feet long and may comprise as much as 15 to 25 per cent of the rock. The distribution of spodumene is not regular. Other rare-element minerals present include amblygonite, lithiophilite, beryl, lazulite, and tantalite-columbite.

Lit 3 Claim (Buckham Lake)

References: Jolliffe (1944); Lord (1951).

The Lit 3 claim is 5 miles southwest of the north end of Buckham Lake and consists of a single claim, which is shown on claim map 85 I-7, Yellowknife Mining Division. It covers a pegmatite body known locally as the "McDonald Dyke", staked originally as Lita 1 to 4, subsequently held as the Ramona group of De Staffany Tantalum Beryllium Mines Limited, and later acquired by Boreal Rare Metals Limited. The ground is now held by Beauport Holdings, Limited.

The property was mapped in detail by Jolliffe (1944) and described as follows:

> The pegmatite body strikes north 80 degrees west, has an average dip of 60 degrees to the south, and is apparently conformable with bedding in the enclosing nodular greywacke of the Yellowknife group. Its outcrop is nearly 400 feet long and 12 to 55 feet wide with a true average width for this length of about 25 feet. At both ends the pegmatite body

passes beneath drift that extends for 100 feet or more in either direction along the strike. No other pegmatite outcrops were seen.

Sections across the McDonald pegmatite show four main mineral zones, of which the two central ones are spodumene-bearing. Along either edge is a band consisting of quartz, feldspar, and light yellow muscovite in about equal proportions and with crystals uniformly about an inch across. The band along the foot-wall side is up to 3 feet wide, whereas that along the hanging-wall is up to 8 feet. These pass gradationally into a spodumene-rich central section, that may be divided into upper and lower parts of about equal width. In the upper (southern) half, the quartz and feldspar (mainly pink cleavelandite) occur commonly in discrete masses up to several feet across. Very little mica is present with these minerals, but 'books' up to 6 inches across and 3 inches thick of golden yellow muscovite occur at intervals along and near the upper contact with the even-granular hanging-wall zone. The lower (northern) half of the spodumene-rich section consists of intergrown quartz, cleavelandite, and a little muscovite up to several inches across. The crystal aggregates become smaller and the proportion of mica increases towards the foot-wall.

Beryl, amblygonite, and lithiophilite occur in the upper half of the central zone but together aggregate less than 1 per cent.

These differences in mineral content and grain size between the upper and lower halves of the central zone, are not displayed by the spodumene. Both parts contain about 30 per cent spodumene by weight, and the crystals (which are commonly elongated at about right angles to the walls) are equally large in each. Just north of the 50-foot picket a crystal face of spodumene is exposed for a length of 9.7 feet and is up to 0.75 foot wide. Immediately south of the same picket another face measures 8 feet by 2.3 feet. Between the 250- and 300-foot pickets numerous large crystals extend to within a foot or two of either wall; the largest crystal face measures 10.7 feet by 1 foot. About twenty other spodumene crystals in both halves of the central zone approach these dimensions; from these upper limits the crystals range in size to some that are only about an inch across. By far the greater proportion of the spodumene is in crystals more than a foot long. The mineral contains less than 5 per cent visible impurities (chiefly quartz stringers), and none of the dull dark green or yellow micaceous alteration products, common in other spodumene-bearing dykes, is evident. A 5-pound sample of spodumene chips collected throughout the pegmatite was analyzed (and found to contain) 5.70 per cent Li_2O.

The spodumene-bearing part of the pegmatite is about 400 feet long and averages 22 feet wide. The areal percentage of spodumene along traverse lines ranged from 6 per cent to 45 per cent and averaged 27 per cent. This is equivalent to 30.7 weight per cent spodumene.

Tantalite-columbite occurs mainly in the upper half of the spodumene zone associated with cleavelandite, quartz, beryl, amblygonite and spodumene.

Best Bet (Drever Lake)

References: Rowe (1952); Lord (1951).

The Best Bet property consists of two claims lying immediately northwest of the north-central part of Drever Lake, or 3½ miles northeast of the tip of Blatchford Lake. The ground, part of the former holdings of Boreal Rare Metals which acquired it from De Staffany Tantalum Beryllium Mines Limited, is now held by Beauport Holdings, Limited. The claims are shown on claim map 85 I-1, Yellowknife Mining Division.

A pegmatite dyke more than 330 feet long and up to 27 feet wide strikes slightly east of north and dips steeply to the west. It is roughly concordant with biotitic quartzite schist, about ¼ mile west of the contact of the latter with a long wedge-shaped body of granite. Most of the original outcrop has been removed by a quarry 260 feet long, 20 to 26 feet wide and up to 27 feet deep. Another shallow pit 50 feet long has been cut along the hanging-wall at the north end. On an upper bench at the south end of the main quarry the dyke is only 15 feet wide and pinches out a short distance beyond. The hanging-wall contact of the dyke is serrate, possibly as a result of faulting along northerly-dipping surfaces. The dyke is zoned but the zone boundaries are irregular and ill-defined. The hanging-wall zone is composed of pink to white cleavelandite, quartz, and muscovite, and occupies most of the west wall of the quarry. Disconnected quartz pods, which contain the visible amblygonite and most of the spodumene, roll up into it from the floor of the pit. Although long spodumene 'logs' transgress the zone boundary into the cleavelandite assemblage there is a definite tendency for the crystals to stop at the edge of the quartz core.

Spodumene crystals are up to 7 feet long, as exposed, are mainly green and altered, are rather scattered, and random in orientation. The largest amblygonite mass seen was 3 feet across. Creamy white beryl is scattered throughout the cleavelandite zone and is rather abundant in one area on the east or foot-wall side of the quarry. The associated cleavelandite occurs in radiating groups or rosettes. Columbite-tantalite in dusty bluish black irregular masses occurs commonly in quartz at the boundaries of coarse-grained spodumene crystals, and also associated with cleavelandite, muscovite and beryl, particularly in the north pit. It is partly crystalline, but is in places difficult to distinguish from dark grey micaceous and black amorphous alteration products that commonly coat amblygonite, spodumene and beryl and are a distinctive feature of the dyke. Part of this material has been identified as hühnerkobelite and is associated with minor triphylite, which is probably the parent mineral.

The amount of lithium minerals presently exposed in the quarry is evidently much less than in the original exposure. Lord (1951, p. 121) estimated that a medial zone, 115 feet long and averaging 12 feet wide, contained 50 per cent amblygonite, and an area near the north end of the sill, 45 feet long and 25 feet wide, contained 19 per cent spodumene and 12 per cent amblygonite.

Some diamond-drilling has been done on the dyke, and much of the material quarried was evidently hauled to the mill at the Moose property for treatment.

Tan Group (Blatchford Lake)

References: Jolliffe (1944); Rowe (1952).

The Tan group is 1½ miles east of the southeast corner of Blatchford Lake, and is now held by Beauport Holdings, Limited. It consists of three claims, part of the former holdings of Boreal Rare Metals Limited, which acquired them from De Staffany Tantalum Beryllium Mines Limited. They are plotted on claim map 85 I-1, Yellowknife Mining Division. The property was not visited by the writer, but according to descriptions by Jolliffe (1944) and Rowe (1952) the lithium-bearing deposits consist of four separate pegmatite bodies, up to 275 feet long and 20 feet wide, cutting metasedimentary rocks. The deposits are zoned. All contain spodumene and one also contains amblygonite. These lithium minerals occur in central zones with cleavelandite, quartz, muscovite, and locally microcline. Some beryl was seen as well as noteworthy amounts of columbite-tantalite and cassiterite. Thin tourmaline selvedges border one of the dykes.

Moose Group (Hearne Channel)

References: Jolliffe (1944); Rowe (1952).

The Moose group of thirty-two claims is on the north side of Hearne Channel, Great Slave Lake, about 72 air miles east-southeast of Yellowknife, and is now held by Beauport Holdings, Limited. The claims are plotted on claim map 85 I-1, Yellowknife Mining Division. The original claims were formerly held by Boreal Rare Metals Limited, which acquired them from De Staffany Tantalum Beryllium Mines Limited. The mineral deposits consist of two pegmatite dykes: Moose No. 2, situated on Moose claims 11 and 12, and Moose No. 1, situated near the corner of Moose claims 1, 5, and 6.

A large open-cut has been made on Moose No. 1 and several on Moose No. 2. A shaft was sunk on Moose No. 2 in 1946 and a mill erected on the shore at the south end of the dyke. The mill was designed to produce a columbite-tantalite concentrate, and treated ore from the Moose and Best Bet properties. It was destroyed by fire early in 1955. A considerable tonnage of amblygonite is stockpiled as well as some beryl, but it is not known whether any lithium minerals were shipped. The property was inactive in 1957.

The property was described in detail and No. 2 dyke mapped by Jolliffe (1944) and Rowe (1952). The dykes are typical irregularly zoned pegmatite bodies consisting of microcline, cleavelandite, quartz, and muscovite, with variable quantities of spodumene, amblygonite, some beryl, and minor columbite-tantalite and cassiterite. Amblygonite occurs as subequidimensional masses up to several feet across in quartz pods that represent discontinuous cores. It is grey, with a pearly or greasy to vitreous lustre, and finely striated due to polysynthetic twinning. The surface of the masses is coated with dark grey micaceous material. The spodumene occurs as green crystals up to 6 or 8 feet in length and 2 feet across, mainly in cleavelandite-quartz-muscovite intermediate zones but also projecting into quartz cores. The country rocks are nodular metasedimentary and greenish metavolcanic fragmental rocks.

No. 2 dyke, on which most of the work has been done, extends about 1,400 feet northward from the mill site near the shore of Great Slave Lake. It consists of several irregular pegmatite bodies, separated by areas of overburden and partly covered by broken rock. The maximum width is about 200 feet. The dip where apparent is steeply west. At an open-cut, 31 feet wide, south of a muskeg area, coarse-grained altered spodumene in subparallel crystals is exposed near both walls of the dyke. It is associated with coarse-grained, pink-veined, white microcline, pink cleavelandite, grey quartz, muscovite, and some white beryl. The quartz is in large segregations. The centre of the dyke is covered by loose muck. Farther south, coarse-grained randomly oriented spodumene is plentiful on the west side of the dyke, but lacking on the east side.

In the southern section of No. 2 dyke a quarry 36 feet across exposes a distinct quartz core about 13 feet wide. Masses of amblygonite up to 2 feet wide, associated with quartz, are plentiful in the broken muck that nearly fills the quarry. A bin nearby is full of hand-cobbed amblygonite. A cleavelandite-quartz-mica zone bordering the core contains numerous irregular crystals of creamy white beryl. On an upper bench spodumene is prominent west of the core, where east-plunging large crystals occur in a cleavelandite-quartz subzone that merges with the west cleavelandite zone. Farther south on the slope to the lake the quartz core pinches out abruptly.

The northern section of the dyke has been largely quarried out to a depth of 30 or 40 feet below the old head-frame, and the floor is covered with broken muck surrounding a deep, water-filled pit. The quarry face is 96 feet wide. It does not reach the hanging-wall, which dips moderately west, nor the foot-wall, which is about 50 feet farther east. No well-defined core is apparent, though quartz is prominent in the central part, where it forms irregular masses 6 feet or more in exposed section. Rounded masses of amblygonite up to 3 feet wide, which are present in the muck pile, evidently come from such quartz masses. The matrix of the quartz-rich zone is mainly cleavelandite. Spodumene occurs as large, altered green 'logs' plunging moderately eastward in cleavelandite of the central zone, and on both sides of the quartz-rich part. Beryl is prominent with spodumene in cleavelandite on the west side of the quartz-rich area. The east or foot-wall side of the dyke, for 50 feet or more, consists of barren coarse-grained pink perthite and quartz.

A prospect pit about 100 feet north of the shaft shows a small central quartz core. A few beryl crystals were seen but no amblygonite or spodumene. The dyke pinches out just beyond this pit.

Moose No. 1 dyke is about 4,800 feet west of No. 2, and about 1,400 feet north of a bay behind a group of islands. It is about 900 feet long, as exposed, up to 34 feet wide, strikes north and dips steeply. A quarry face at the south end shows about 5 feet of quartz core. Amblygonite that is abundant in the muck pile evidently came from this quartz zone. Flat-lying parallel 'logs' of spodumene up to 2 feet in cross-section lie in cleavelandite just west of the core, forming an intermediate zone on the foot-wall side only. The remainder of the dyke forms an outer zone consisting of cleavelandite, coarse-grained pink microcline, muscovite, and quartz, with scattered beryl crystals.

Medium- to coarse-grained spodumene is prominent in the dyke for about 200 feet farther north, but is mostly in a central band 6 to 8 feet across. No quartz core is exposed. The remainder of the dyke is mainly coarse-grained pinkish white feldspar and platy cleavelandite. The dyke may extend for some distance south of the quarry beneath muskeg, for a small inclusion of pegmatite was noted in a large diabase dyke just north of the lakeshore.

APPALACHIAN REGION

Nova Scotia

Except for a lithium-bearing dyke discovered in 1960 near Brazil Lake, Nova Scotia, the few lithium deposits of the Canadian Appalachian region that have been reported are near New Ross, Lunenburg County, Nova Scotia. They are in pegmatites associated with granitic rocks of presumably Devonian age that intrude quartzites (mostly in the Goldenville Formation) and slates (mostly in the Halifax Formation) of the Meguma Group (or Gold-bearing Series), of probable Ordovician age. Infolded remnants of the sedimentary rocks outcrop about 2 miles north and about 10 miles southeast of New Ross. They contain gold-quartz veins of the saddle-reef type, including those of the Gold River gold district. The granitic rocks comprise muscovite granite and biotite granite that underlie large areas to the southeast and northwest, respectively, of a contact extending southwest from the outcrop of sedimentary rocks north of New Ross. The pegmatite dykes, which carry a variety of rare and semi-rare elements including lithium, tin, tungsten, molybdenum, beryl, and radioactive elements, are in the muscovite granite. Three dykes containing lithium minerals are mentioned in old reports. The most important of these dykes, known as the "Reeves Farm occurrence", lies almost at the contact of the muscovite granite with biotite granite.

The district was not visited by the writer, and no recent descriptions have been found. The following account is from the old and sketchy references cited.

Reeves Farm, New Ross

References: Faribault (1908, 1924, 1931); Ellsworth (1932).

The occurrence known as the Reeves Farm deposit is about ⅜ mile south of the Dalhousie Road and 3 miles west of New Ross, Lunenburg County. It was first investigated in 1903 as a source of quartz crystals. Cassiterite was subsequently found, and a pit, dug in 1907, revealed the presence of amblygonite, lepidolite, and zinnwaldite, together with a large variety of minerals.

The deposit was described by Faribault (1908, p. 82) as follows:

> At the time of my visit, on August 7, the King pit on the Reeves' tin deposit was eighteen feet deep, and measured twelve feet long by ten feet wide. The deposit is a pegmatitic segregation in the ordinary light grey granite of that region. It is composed of crystalline masses of feldspar enclosing very large crystals of smoky quartz with a little mica and other associated minerals, included in the list given above. The feldspar constitutes the greater part of the dike. The large quartz crystals, the fluorite, the tin ore and other associated minerals occur chiefly in zones about the middle of the dike, in feldspar generally much decomposed. There is no well defined foot or hanging wall. The strike of the dike is N.65°E., and the dip is to the northwest and varies from 75° at the surface to 60° at the bottom of the pit. At the outcrop the dike was about eight feet in width and twelve feet in length, but the development shows that at one end at least it extends farther to the northeast under a cap of granite.

According to Ellsworth (1932, p. 256):

> Amblygonite was apparently much the most abundant of the unusual minerals found at this mine. At the time of the present writer's visit the dump was old, weathered, and partly overgrown with moss, but good-sized masses of the bluish amblygonite could still be found.

The amblygonite has been described by Walker and Parsons (1924) as follows:

> This mineral occurs in the pegmatite in masses several inches in diameter. It is devoid of crystal form, white or pale bluish in colour, and quite free from other minerals. The analysis by E. W. Todd shows that the mineral is unusually low in fluorine and very high in water. It is very similar in composition to some amblygonite from Montebras, France.

Walker and Parsons have also described lepidolite and zinnwaldite as follows:

> These micas occur in the solid albite in the form of irregular masses devoid of crystal outline . . . the lepidolite is violet, and the zinnwaldite amber-brown when of considerable thickness. In thin plates they are both colourless . . . Sometimes the two minerals are seen to merge into one another and to form part of a single cleavage plate.

Analyses of the amblygonite, lepidolite, and zinnwaldite, as recorded by Ellsworth (1932), are given in the "Mineralogy" section (Ch. II) of this report. Triphylite has also been reported at this site (Johnston, 1915, p. 229).

Other accessory minerals reported from the deposit include beryl, fluorite, topaz, tourmaline, monazite, columbite, apatite, and molybdenite. Numerous minor minerals whose source is identified only as "from the district" may also have come from this deposit.

Morley's Pegmatite

References: Douglas and Campbell (1942); Faribault (1931).

The deposit, which is described by Douglas and Campbell (1942) as "Morley's Pegmatite" is about ½ mile east of New Ross, Lunenburg County. As shown on Faribault's (1931) New Ross map it extends from a point ⅛ mile east of the Mill Road – New Ross Road junction in a direction N28°E almost to the Levy Road, a distance of nearly a mile. The notations "Pegmatite; Li, W, Fl; Rare Minerals", "Quarry", and "Jasper breccia" are printed on the map.

According to Douglas and Campbell (1942, p. 110):

> On the west flank of the pegmatite where it outcrops near the house of J. J. Morley there is a jasper breccia striking parallel to the pegmatite and dipping east 55°. The jasper breccia grades into the pegmatite. They have gradational contacts both with each other and with the surrounding muscovite granite. The breccia is quite probably the result of autobrecciation of an earlier phase of pegmatitic material.
>
> The strike and dip of the pegmatitic zone is that of a set of joints striking approximately 35° magnetic and dipping southeast at 60°. The pegmatite continues on this strike until it reaches Mill brook where for 400 feet there are echeloned outcrops of pegmatite paralleling a second set of joints striking 105° magnetic and dipping south at 70°. At this point a pit has been sunk on an outcrop of pegmatite, 35 feet in width. This outcrop was stripped and a sketch map made. The pegmatite here consists of large segregations of quartz, feldspar, and mica. No minerals of economic importance were found.
>
> An outcrop of pegmatite occurs on the west bank of Mill brook just below the Levy road. Due to overburden it is not possible to positively correlate this outcrop with the outcrops of pegmatite noted above.

Sefferensville

Ellsworth (1932, p. 256) described an occurrence of lithium mica near Sefferensville as follows:

> Lepidolite occurs in small amount as feathery masses in quartz and feldspar in a dyke about 1½ or 2 miles west of Sefferensville, a settlement 8½ miles from Chester

Basin. The dyke is entirely in the coarse biotite granite which covers this area. It outcrops in two places on the north side of a rather high hill near the top. One exposure shows a mass of solid white quartz 6 to 8 feet by 30 feet. At one point in this a pit 5 feet square and 8 feet deep has been sunk. A foot or two of pinkish feldspar shows on one side of the pit. The dump shows nothing but white quartz carrying a little black tourmaline and some smoky quartz which occurs as well-formed crystals reaching a diameter of several inches. The other pit 50 feet to the west of the one mentioned is 4 by 8 feet and 4 feet deep and the dump consists of mixed quartz, feldspar, and feathery lepidolite. The two exposures line up in a direction about east and west.

Brazil Lake, Yarmouth County

A pegmatite dyke 2,500 feet southeast of Brazil Lake crossroads contains spodumene and beryl. The dyke strikes about N40°E. It is at least 16 feet thick and is exposed for 70 feet along strike. The outcrop contains about 11 per cent spodumene and about 0.5 per cent beryl (Taylor, 1961). Pegmatite float along the Brazil Lake – Pleasant Valley road suggests that the dyke extends northward to that road or beyond.

CORDILLERAN REGION

Only two small occurrences of lithium minerals have been reported in the Cordilleran region, although pegmatite dykes carrying normally associated minerals are not rare. Granitic rocks are widely exposed in the western Cordillera. They, and the pegmatites associated with them, are chiefly of Mesozoic age, but pegmatites supposedly of pre-Permian age are common in the Shuswap Terrain and the Wolverine Complex. Lepidolite, the only lithium mineral reported, occurs at two localities near Revelstoke, British Columbia. One is a normal pegmatite deposit; the other is an unusual type of occurrence, apparently a vein deposit. The latter, in the Selkirk Mountains, is near an area in which beryl has been noted in some pegmatites and stannite occurs in some vein deposits.

Revelstoke District

Monashee Mountains

Reference: Jones (1959).

Lepidolite is mentioned as a minor component, along with tourmaline and beryl, of "younger" (Mesozoic) pegmatite bodies that cut gneisses of the Monashee Group in Vernon map-area (Jones, 1959). Mount Begbie, 8 miles south of Revelstoke, is the only specific locality mentioned.

Gold Hill Claim

Reference: Hoffman (1895).

Lepidolite was identified as aggregations of white, translucent, pearly scales, with small crystals of calcite, in cavities in a specimen of highly rust stained quartz from the Gold Hill claim, 10 miles northeast of Illecillewaet railway station (Hoffmann, 1895, p. 29R). This specimen was the first reported Canadian occurrence of lepidolite.

Table

Summary Data, Lithium Deposits

Name of Property	Owner, Agent, Etc.	Location	Stage of Exploration	Published Reserves (whole or part) Millions of tons @ per cent Li_2O	References	Lithium Minerals
Preissac-Lacorne District, Quebec.						
Quebec Lithium Corporation	—	Northeast Lacorne tp.	mining and milling	15.0 @ 1.2	Northern Miner, May 30/56	spodumene
Canadian Lithium	—	Northwest Lacorne tp. Southwest Landrienne tp.	drilled	—	—	spodumene minor lepidolite
Lacorne Lithium	—	Northeast Lamotte tp.	drilled	—	—	spodumene
Lithium Corporation of America	—	Lot 36, rge. 2, Figuery tp.	drilled	—	—	spodumene
International Lithium	—	Lot 39, rge. 2, Figuery tp.	drilled	—	—	spodumene
Valor Lithium Mines	—	Lot 22, rge. 8, Lacorne tp.	drilled	—	—	spodumene, lepidolite
Ascot Metals Corporation	—	Rge. 7, Lamotte tp.	drilled	—	—	spodumene
Iso Uranium Mines	—	Lot 5, rge. 5, Lacorne tp.	drilled(?)	—	—	spodumene
Amos Lithium	—	Lots 7-8, rge. 3, Lacorne tp.	drilled	—	—	spodumene
Lithium Corporation of America	—	Lot 11, rge. 2, Lacorne tp.	drilled	—	—	spodumene
Valee Lithium	—	Rge. 8, 9, Fiedmont tp., (east of Quebec Lithium)	drilled	—	—	spodumene
Montanier Township, Quebec						
Wells-Lacourciere	—	15 miles south of Cadillac	—	—	—	spodumene
Papineau County, Quebec						
Leduc Mine	—	Lot 25, rge. 7, Wakefield tp.	open-pit	—	—	lepidolite
Nipigon District, Ontario						
Nama Creek Mines	—	Postagoni River, south of Beardmore	shaft incomplete	4.3 @ 1.06	Northern Miner, Sept. 27/56	spodumene
Noranda Mines	—	Northeast Postagoni Lake	(?)	—	—	spodumene
Jean Lake Lithium Mines and Towagmac Exploration	—	North of Jean Lake	drilled	1.7 @ 1.30	Ann. Rept., May/56	spodumene
Ontario Lithium	Conwest	Georgia Lake	drilled	2.0 @ 1.09	—	spodumene
Georgia Lake Lithium Mines	Newkirk-Dunvegan	West of Georgia Lake	drilled	—	—	spodumene
Aumacho River Mines	—	Blay Lake	drilled	0.7 @ 1.63	Northern Miner, June 6/56	spodumene
MNW Claims	M. Wilson & Associates	Northwest Cosgrave Lake	drilled	0.04 to 2(?)	—	spodumene, amblygonite
Lun-Echo Gold Mines	—	Pine Portage, Nipigon River	drilled	—	—	spodumene
Falcon Lake—Zig Zag Lake, Ontario						
Motsen Group	British Canadian Lithium	Falcon Lake, lat. 50°30′, long. 88°00′	drilled	—	—	spodumene
—	L. Dempster	Near Zig Zag Lake	drilling(?)	—	—	—
—	W. Lespard	N. Lamoune Lake	—	—	—	—
Fort Hope Area	L. Dempster(?)	Lily Pad Lake, Northwest Fort Hope	—	—	—	spodumene, lepidolite
O'Sullivan Lake Area	—	Superb Lake, lat. 50°30′, long. 87°00′	—	—	—	—

VI

and Main Occurrences in Canada

Other Accessory Minerals	Dominant Grain-Size[1]	Crystal Orientation Mode of Occurrence[2]	Internal Structure[3]	Dip of Dyke	Host Rock	Remarks
—	medium	parallel, (1) + (2)	unzoned	moderate-steep	greenstone-granodiorite	Dykes cut contact. Published reserves for shaft area only.
—	medium, coarse	random, (4) + (2)	intermediate	steep(?)	granite	Data for observed exposures only.
—	—	—	intermediate	steep(?)	granodiorite	—
—	medium-coarse	subparallel	intermediate	low-moderate	granite(?)	(Main occurrence).
—	coarse, medium	random + parallel	zoned (unsymmetrical)	low(?)	quartz-biotite schist(?)	—
beryl	coarse	random	zoned	steep(?)	granite	—
—	coarse(?)	—	intermediate (?)	moderate(?)	granodiorite	—
—	fine	parallel	unzoned	steep(?)	—	(Main occurrence).
beryl, columbite-tantalite	coarse	random	zoned (irregular)	steep, + low(?)	granodiorite, schist	—
beryl (local), molybdenite, bismuth	medium, fine	parallel	unzoned	steep	granite-gneiss	—
—	—	—	—	—	—	—
beryl, biotite, tourmaline	coarse	random	zoned	(?)	granodiorite	—
tourmaline	(coarse books)	—	zoned	(?)	granite-gneiss	Some coloured tourmaline, several feldspars.
—	medium	parallel	unzoned	steep	quartz-biotite schist	Diabase cuts, alteration.
—	(?)	(?)	unzoned(?)	(?)	quartz-biotite schist	—
—	medium	parallel	unzoned	steep	quartz-biotite schist	Published reserves No. 4 zone.
—	coarse	random, parallel	unzoned-intermediate	low	quartz-mica schist	Description on main exposure.
—	medium	random	unzoned-irregular	moderate-low	nodular schist	—
tourmaline	coarse	random	intermediate	moderate	granite, schist	Crosses contact.
beryl, tourmaline	coarse to fine	(3) + (4)	zoned	steep	granite	—
—	coarse	random	unzoned	steep	quartz-biotite schist	Diabase cuts off, alteration.
'beryl, tourmaline'	—	—	'unzoned'	steep	greenstone schist	—
—	—	—	—	—	—	—
—	—	—	—	—	—	—
pink tourmaline	—	—	—	—	—	—
—	—	—	—	—	—	—

Table

Summary Data, Lithium Deposits and

Name of Property	Owner, Agent, Etc.	Location	Stage of Exploration	Published Reserves (whole or part) Millions of tons @ per cent Li_2O	References	Lithium Minerals
Dryden Field, Ontario						
Lun-Echo Gold Mines	—	South of Mavis Lake	drilled	—	—	spodumene
Root Lake Field, Ontario						
Capital Lithium	Continental Mining & Exploration	60 miles north of Sioux Lookout	drilled	2.3 @ 1.3	personal communication	spodumene
Consolidated Morrison	—	East of Capital Lithium	drilled	—	—	—
Lac La Croix Field, Ontario						
International Lithium	—	East end of Lac La Croix	drilled	1.5 @ 1.2	Northern Miner, June 10/56	spodumene
Lexindin Gold Mines	—	Wisa Lake, 4 miles north of Lac La Croix	drilled	—	—	spodumene
East Braintree—West Hawk Lake District, Manitoba						
Lucy Group	North American Rare Metals	½ mile north of Highway 12, 6.6 miles east of East Braintree junction (rge. 5, tp. 8)	drilled	—	—	spodumene, minor amblygonite
Artdon Group	Lithium Corporation of America	½ mile north of Highway 12, 6.6 miles east of East Braintree junction (rge. 5, tp. 8)	drilled	—	—	spodumene
Deer Claim	—	Sec. 16, tp. 19, rge. 17, (West Hawk Lake)	strip and open-cuts	(minor)	—	spodumene, lepidolite
Cat Lake—Winnipeg River District, Manitoba						
Spot Group	Lithia Mines & Chemicals	5½ miles west of Cat Lake	drilled	3.95 @ 1.28	Northern Miner, Handbook '57	spodumene
Eagle Group	Lithium Corporation of America	West of Cat Lake	drilled	0.6 @ 1.4	—	spodumene
Irgon Claim	Lithium Corporation of Canada	North of Cat Lake	shaft and laterals	1.0 @ 1.5	Northern Miner, Aug. 16/56	spodumene
Central Claims	H. Johnson, Lac du Bonnet	South of Cat Lake	surface	—	—	spodumene
Chemalloy Minerals Ltd. (Montgary)	—	West Bernic Lake	shaft	7.8 @ 1.85	Northern Miner, Sept. 13/56	spodumene, amblygonite, lepidolite & petalite
Buck, Coe, Pegli, etc.	Lithium Corporation of Canada	East Bernic Lake	drilled, open-cut*	0.8 @ 2.13	Northern Miner, Aug. 16/56	spodumene, amblygonite, lepidolite, petalite, triphylite-lithiophilite
Contact Minerals Ltd.	J. J. Papineau, Winnipeg	Shatford Lake	surface	minor	—	lithia mica ('zinnwaldite')
Silverleaf ('Bear', 'Bob')	Lithium Corporation of Canada	South of Winnipeg River	drilled, worked* post-1925	minor	—	lepidolite, spodumene, amblygonite
Herb Lake District, Manitoba						
Green Bay Mining & Exploration	—	2½ miles south east of Crowduck Bay	drilled	1.9 @ 1.4	Northern Miner, June 28/56	spodumene
Violet Group	Canadian Scotia Ltd. (ex Combined Development)	East of Crowduck Bay, north of narrows.	drilled	3.3 @ 1.2	personal communication	spodumene
'Gold Reef' (1931)	Sherritt-Gordon	½ mile west of narrows, Crowduck Bay	drilled	—	—	spodumene

VI

Main Occurrences in Canada—continued

Other Accessory Minerals	Dominant Grain-Size[1]	Crystal Orientation Mode of Occurrence[2]	Internal Structure[3]	Dip of Dyke	Host Rock	Remarks
minor tourmaline	coarse	random	intermediate	low-moderate	greenstone and quartz-biotite schist	—
minor tourmaline	fine	random to (2)	intermediate	moderate	pillow lava, quartz-biotite schist	Li-amphibole in selvedges.
—	—	—	—	—	—	—
—	medium	parallel	unzoned	moderate-steep	quartz-mica schist	—
—	medium	—	—	—	quartz-mica schist	—
tourmaline	coarse	random	zoned	low	greenstone	Flat-lying sheets at depth reported, exposures rare.
'biotite, beryl'	medium-coarse	—	—	—	—	Ref. Springer (1952).
minor tourmaline	—	—	—	—	greenstone	Ref. Stockwell (1932).
—	fine	parallel variable (2), (4)	unzoned	steep	greenstone, gabbro	—
local tourmaline, beryl	fine-medium	variable (2)	unzoned-intermediate	steep	greenstone-granite	—
—	fine-medium	random to (2)	unzoned	steep	greenstone	—
beryl	coarse, fine	random + (4)	zoned	low	granite	—
pollucite, beryl, tourmaline	coarse, fine	random + (4)?	zoned	low	greenstone	Not exposed.
tourmaline, beryl	coarse, (spodumene fine)	spodumene (4)	zoned	low	greenstone	Main reserves in unexposed sheet, amblygonite stockpiled (shipped?).
beryl, rare earths, topaz	mica, coarse, curvilamellar	some evidence	zoned	(?)	—	Mica, 0.78% Li_2O— mineralogical interest for Li
minor topaz, beryl	fine	spodumene (4)	zoned	low	greenstone	75 tons shipped.
tourmaline, beryl	coarse	random	zoned (telescoped)	steep	green schist, greywacke	—
—	medium	parallel	unzoned	steep	greywacke schist	—
—	medium-coarse	part parallel	unzoned	steep	quartz diorite	15-20% spodumene over 900 x 18 feet.

Table

Summary Data, Lithium Deposits and

Name of Property	Owner, Agent, Etc.	Location	Stage of Exploration	Published Reserves (whole or part) Millions of tons @ per cent Li_2O	References	Lithium Minerals
Yellowknife—Beaulieu District, N.W.T.						
JM Group	General Lithium	Hidden Lake	4,850 feet drilled	—	—	spodumene
Lit Group	Affiliated Lithium	Hidden Lake	—	—	—	spodumene
Jim-Lit Group	General Lithium	Little Hidden Lake	—	—	—	spodumene
Murphy-UM Group	General Lithium	Bighill Lake	5,600 feet drilled	—	—	spodumene
Limo Group	Affiliated Lithium	Bighill Lake	—	—	—	spodumene
Li Group	Affiliated Lithium	Prosperous Lake	—	—	—	spodumene
Ann (etc.) Group	Magnum Holdings Ltd. (ex W. Bellis)	South of Reid Lake	some drilling	—	—	spodumene, minor amblygonite
Cota Group	General Lithium	North of Blaisdell Lake	some diamond drilling	—	—	spodumene, + triphylite-hühnerkobelite
Taco Claim (ex Bore Group)	MacAvoy, Yellowknife	South of Sproule Lake	—	—	—	spodumene, amblygonite, lithiophilite
Fly Group	Affiliated Lithium	West of Sproule Lake	—	—	—	spodumene
CD Group	Lypka, Splaine, Desson	Northeast Upper Ross Lake	—	—	—	spodumene + petalite
Echo Group	North American Lithium Co.	Northeast of of Tanco Lake	—	—	—	spodumene
Jo Group	W. Bellis, Yellowknife	Tanco Lake	—	—	—	spodumene
Lit 1 and 2 Claims ('Campbell')	Beauport Holdings Ltd. (ex Boreal Rare Metals)	Buckham Lake	—	—	—	spodumene + amblygonite, triphylite-lithiophilite
Lit 3 Claim ('McDonald')	Beauport Holdings Ltd. (ex Boreal Rare Metals)	West of Buckham Lake	—	—	—	spodumene + amblygonite, triphylite-lithiophilite
Best Bet	Beauport Holdings Ltd. (ex Boreal Rare Metals)	Drever Lake	drilled, quarried*	—	—	spodumene, amblygonite + triphylite-hühnerkobelite
Tan	Beauport Holdings Ltd. (ex Boreal Rare Metals)	Blatchford Lake	—	—	—	spodumene, amblygonite
Moose	Beauport Holdings Ltd. (ex Boreal Rare Metals)	Hearne Channel	quarried, mill operated* post-1946, pre-1955	—	—	spodumene, amblygonite
New Ross District, Nova Scotia						
'Reeves Farm'	—	3 miles west of New Ross, Lunenburg Co. (Lake Ramsay)	pit dug 1907	—	—	amblygonite, lepidolite, zinnwaldite
'Morley's Pegmatite'	—	½ mile east of New Ross	'quarry' (?)	—	—	—
—	—	'Near Sefferensville'	—	—	—	lepidolite
Occurrences near Revelstoke, British Columbia						
(Monashee Mountains)	—	Mt. Begbie, 8 miles South of Revelstoke	—	—	—	lepidolite
Gold Hill Claim	—	10 miles northeast of Illicillewaet	—	—	—	lepidolite

[1] Fine: less than 2 inches. Medium: 2-12 inches. Coarse: more than 12 inches.

[2] (1)—parallel crystals perpendicular to walls. (2)—parallel crystals within lenses in patches, preferred direction varying from place to place within dyke. (3)—randomly oriented crystals. (4)—radiating or random crystal-like masses of fine quartz-spodumene intergrowth.

[3] For explanation of terms see "Definition of Terms", Ch. III.

VI

Main Occurrences in Canada—concluded

Other Accessory Minerals	Dominant Grain-Size[1]	Crystal Orientation Mode of Occurrence[2]	Internal Structure[3]	Dip of Dyke	Host Rock	Remarks
—	medium-coarse	parallel	unzoned	steep	nodular quartz-mica schist	—
—	fine-medium	—	—	steep	nodular quartz-mica schist	—
—	medium-coarse	mainly parallel	unzoned	moderate	nodular quartz-mica schist	—
—	medium	parallel	unzoned	steep	nodular quartz-mica schist	Minor beryl local, two major zones.
—	—	—	—	steep	nodular quartz-mica schist	—
—	medium-coarse	—	—	steep	nodular quartz-mica schist	—
—	medium, fine	mainly parallel	unzoned	steep	nodular quartz-mica schist	Local tourmaline selvedged.
beryl, columbite-tantalite	medium-coarse + fine	mainly parallel	unzoned-intermediate	steep	nodular quartz-mica schist	—
beryl, columbite-tantalite, cassiterite	—	—	—	—	nodular quartz-mica schist	Tourmaline; ref. Jolliffe (1944).
—	—	—	—	moderate	nodular quartz-mica schist	—
—	medium (?)	—	unzoned (?)	—	granite-gneiss, greenstone	—
beryl (local)	medium-coarse	mainly parallel	unzoned + zoned	steep-moderate	nodular quartz-mica schist	—
—	—	—	—	—	—	—
beryl, columbite-tantalite	coarse	—	zoned	steep	nodular quartz-mica schist	—
beryl, columbite-tantalite	coarse, fine	—	zoned	moderate-steep	nodular quartz-mica schist	—
beryl, columbite-tantalite	coarse	subparallel-random	zoned	moderate-steep	nodular quartz-mica schist	Treated at Moose Mill for columbite-tantalite, some amblygonite probably shipped.
beryl, columbite-tantalite, cassiterite	—	—	—	—	—	Tourmalinized selvedges.
beryl, columbite-tantalite	coarse	subparallel-random	zoned	moderate-steep	nodular quartz-mica schist	Columbite-tantalite, amblygonite cobbed, some shipped.
beryl, topaz, tourmaline, cassiterite, rare earths	—	—	zoned	—	granodiorite	No recent information.
—	—	—	—	—	—	—
—	—	—	—	—	—	—
beryl	—	—	—	—	—	—
—	—	—	—	—	—	—

*See "Remarks" column.

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PLATES

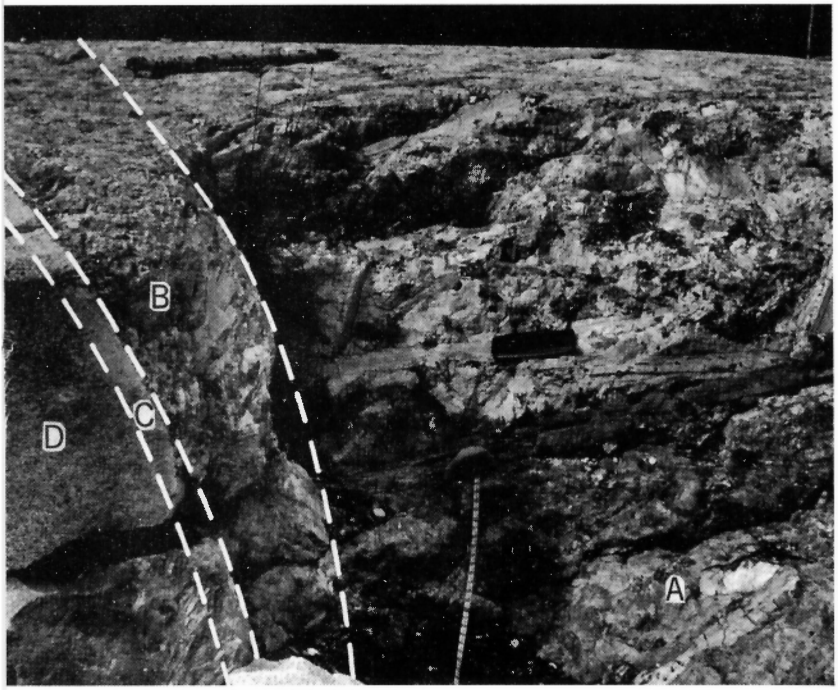
R.M. 2-2-56

A. *Contorted banding in aplite phase of albite-pegmatite stock south of Winnipeg River.*

PLATE I.

R.M. 2-5-56

B. *Rectangular crystal-like intergrowths of quartz and feldspar in albite-pegmatite stock south of Winnipeg River. Crystal by head of hammer is a simple twin.*



A.

R.M. 3-5-57

Zoned pegmatite, Valor Lithium Mines. Cleavelandite-quartz-spodumene-lepidolite (plus beryl and pollucite) core (A), feldspar-quartz-muscovite plus beryl intermediate zone (B); aplite wall zone and bleached border zone (C), and contact with biotite granite (D) at left. Note large randomly oriented spodumene crystals under and near notebook.

PLATE II.

B.

R.M. 1-12-57

Spodumene pegmatite, Nama Creek Mines—a typical 'unzoned' dyke. Medium-grained spodumene laths (dark) in parallel orientation perpendicular to the dyke walls (i.e. parallel with tape).

R.M. 2-8-57

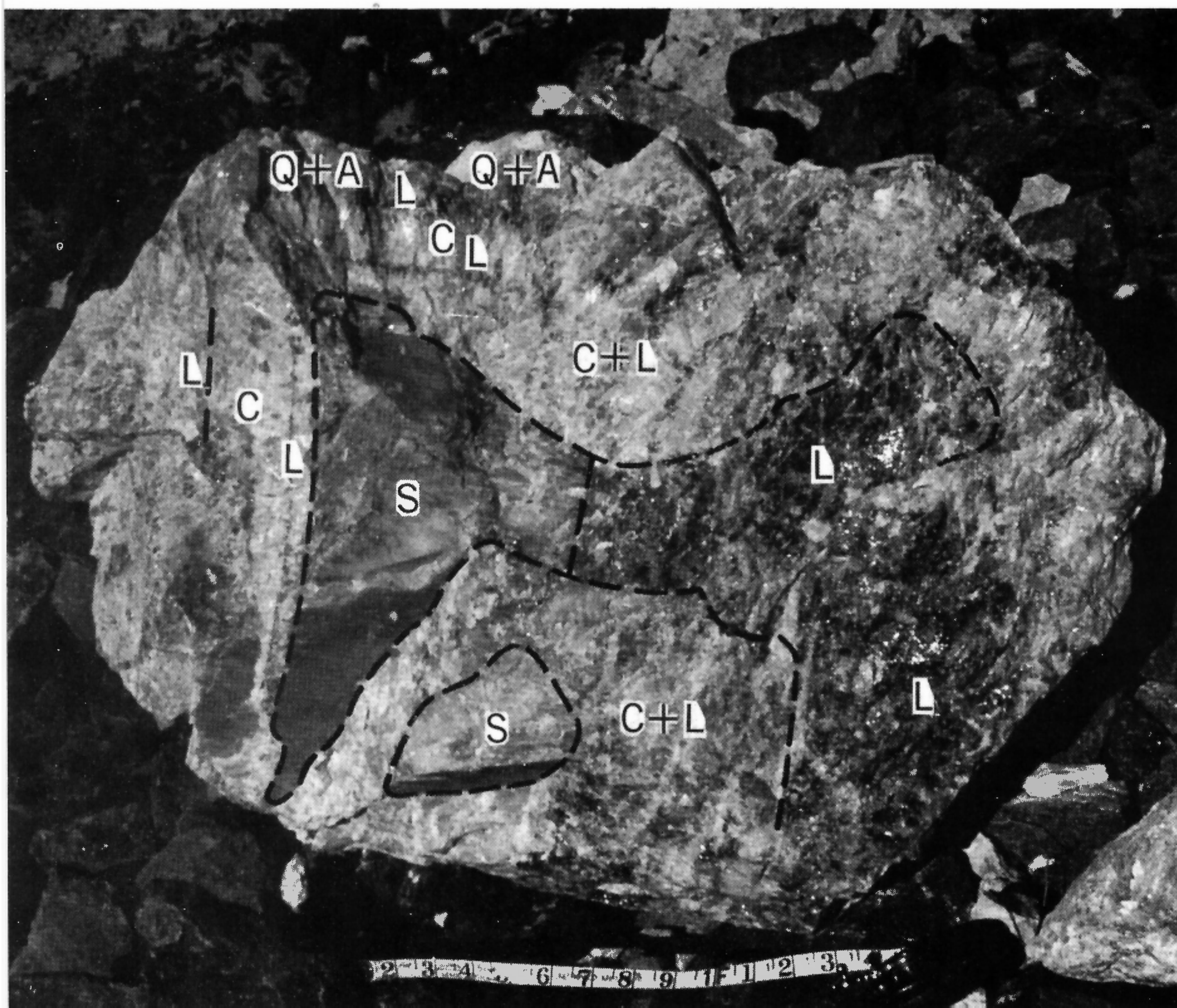
PLATE III.

Cross-banding in pegmatite. Alternate spodumene-quartz (dark) and microcline (light) lenses. B A zone, Bighill Lake, Yellowknife-Beaulieu district, Northwest Territories.

PLATE IV.

Part of a large spodumene crystal (S) partly replaced by cleavelandite-quartz and lithia mica, and rimmed by alternating bands of radiating cleavelandite-quartz (C) and lithia mica (L). The outermost band of lithia mica grades into quartz-amblygonite (Q+A) of the core unit, in upper edge of slab. Chemalloy Minerals Limited, Bernic Lake, Manitoba.

R.M. 3-12-57



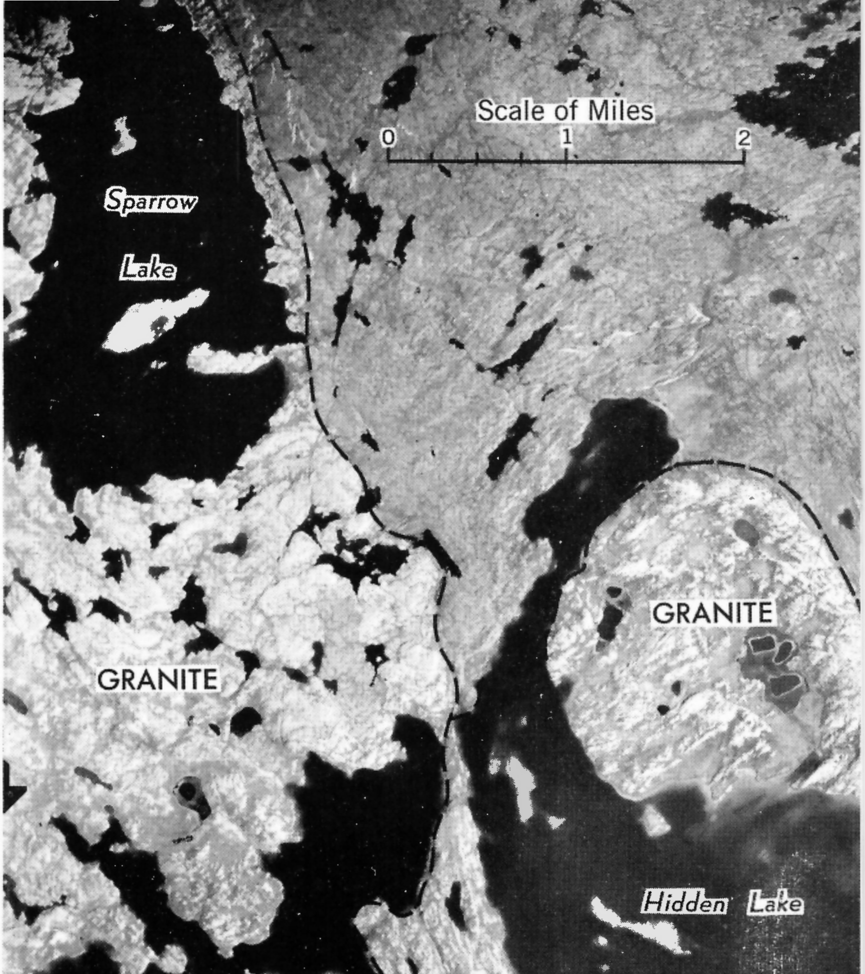
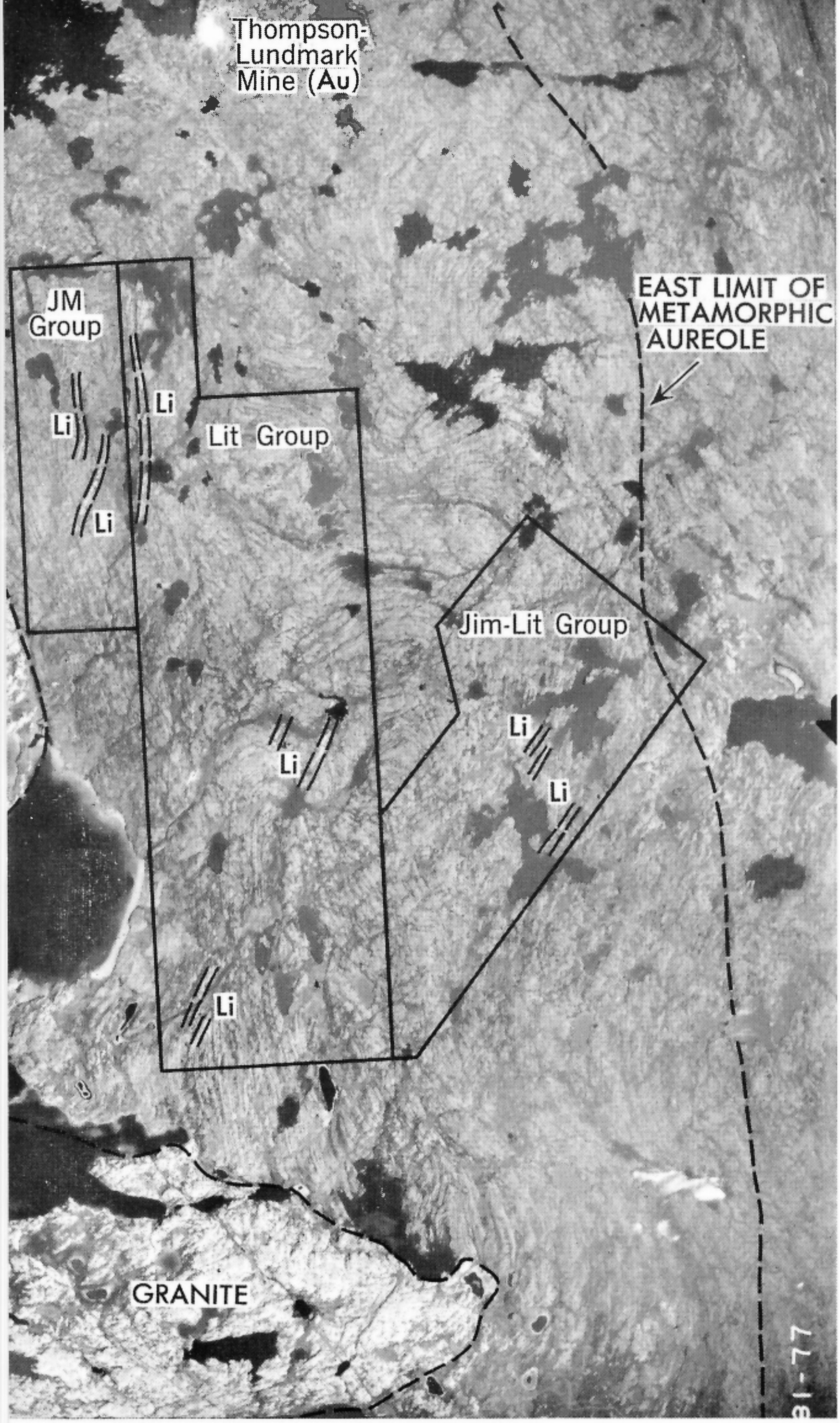


PLATE V.

Geological environment of spodumene-bearing pegmatites, Hidden Lake area Yellowknife-Beaulieu district, Northwest Territories. Note trend of dykes i



RCAF Photo A 13781-77

relation to bedrock structure and their distribution with respect to late granite and its metamorphic aureole.

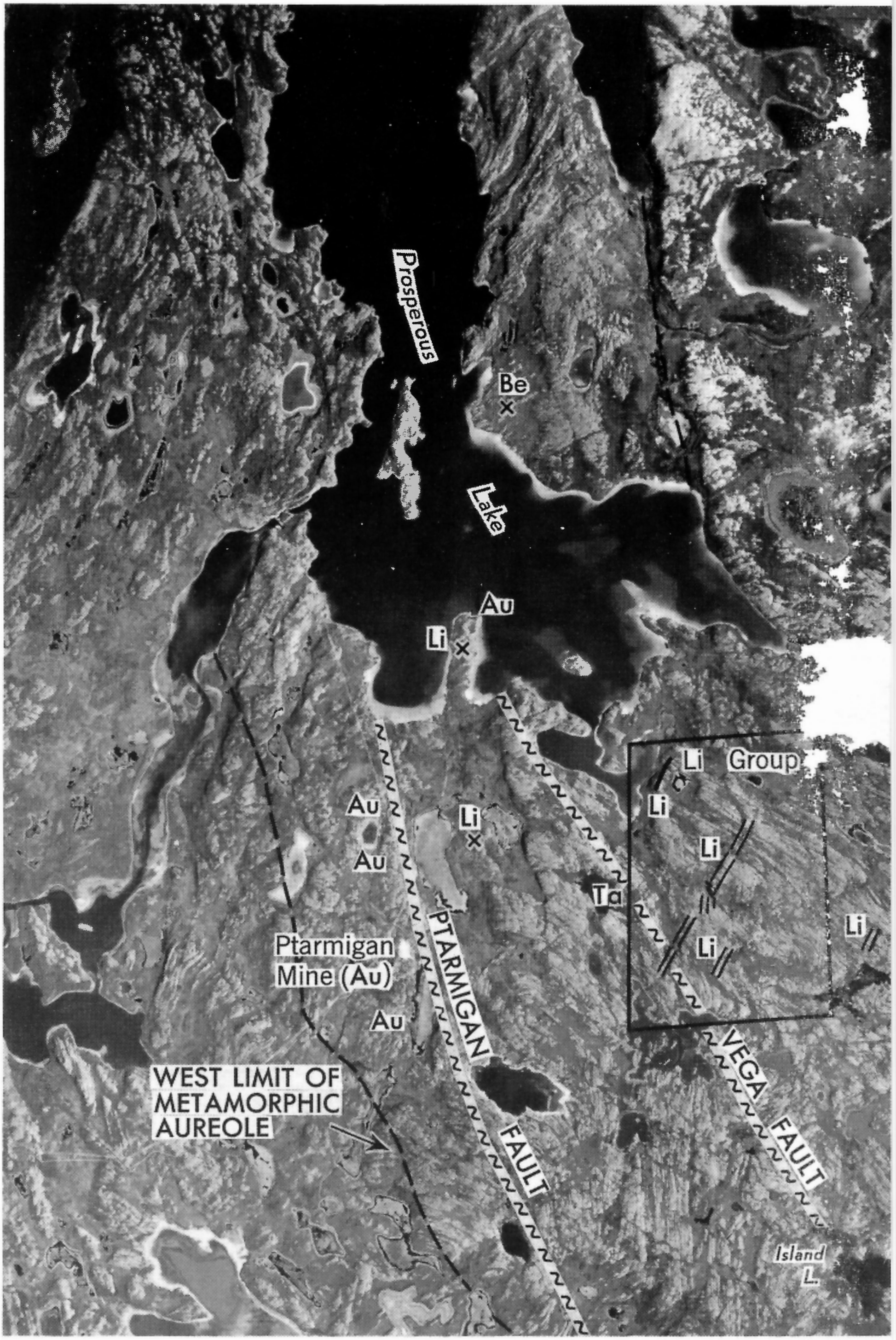


PLATE VI.

RCAF Photo A 13781-19

Geological environment of spodumene-bearing pegmatites south of Prosperous Lake, Yellowknife-Beaulieu district, Northwest Territories. Note distribution of lithium (Li) and beryllium (Be) with respect to late granite and related features. (Adjoins Plate VII).

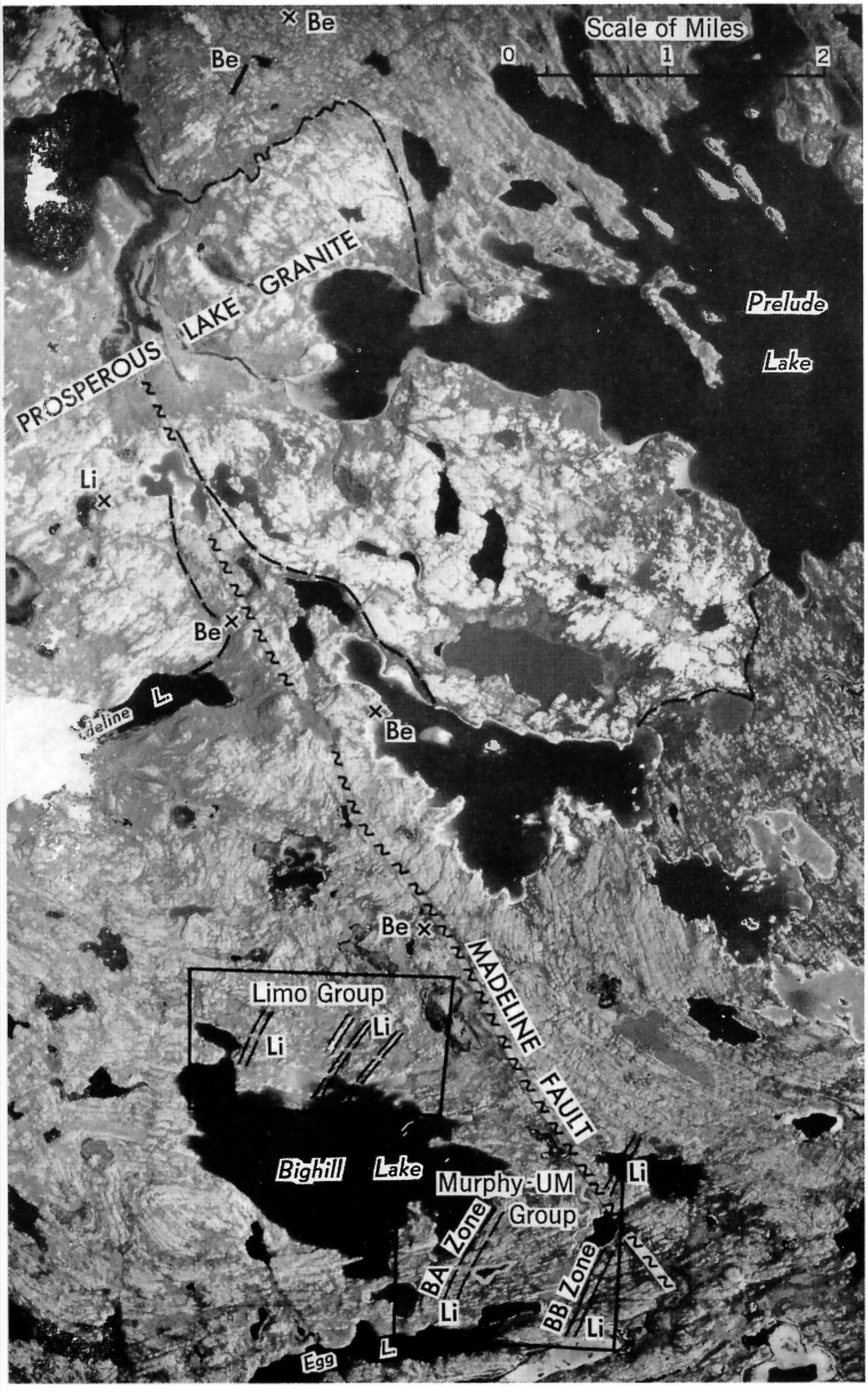


PLATE VII.

RCAF Photo 13781-34

Geological environment of spodumene-bearing pegmatites at Bighill Lake, Yellowknife-Beaulieu district, Northwest Territories. Note trend of dykes, bedrock structure, and distribution of lithium (Li) and beryllium (Be) with respect to Prosperous Lake granite.

GENERAL INDEX

INDEX TO PROPERTIES