



CANADA



THE MINERALOGY OF THE BERNIC LAKE PEGMATITE, SOUTHEASTERN MANITOBA

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MINERAL SCIENCES DIVISION

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SOUTHEASTERN MANITOBA

by

E.H. Nickel^{*}

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SYNOPSIS

The Bernic Lake pegmatite is a complex zoned pegmatite which contains a large number of minerals, some of which are quite unusual. This mineralogical study has been directed primarily at those minerals that are most likely to be of potential economic interest.

The pegmatite contains a relatively large amount of pollucite, a cesium aluminosilicate. Lithium occurs in a number of minerals, chiefly spodumene, lithian micas and amblygonite. Appreciable amounts of rubidium have been found in the lithian micas and in microcline feldspar. Tantalum and tin occur largely as stanniferous tantalite which contains an unusually large amount of chemically combined tin. Beryl occurs in various parts of the deposit. Other minerals found in the pegmatite include quartz, albite, lithiophilite, tapiolite, microlite, cassiterite, apatite, rhodochrosite, magnetite, ilmenite, scheelite, zircon, stannite, tourmaline, clay minerals, and calcite.

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Direction des mines

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MINÉRALOGIE DE LA PEGMATITE DU LAC BERNIC
(SUD-EST DU MANITOBA)

par

E. H. Nickel*

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RÉSUMÉ

La pegmatite du lac Bernic se présente sous forme d'une pegmatite rubanée et complexe qui contient un grand nombre de minéraux, dont quelques-uns sortent tout à fait de l'ordinaire. La présente étude minéralogique a porté avant tout sur les minéraux qui sont les plus susceptibles de présenter un certain intérêt économique.

La pegmatite en question contient une quantité assez forte de pollucite, un aluminosilicate de césium. Le lithium s'y rencontre au sein d'un certain nombre de minéraux, tout particulièrement le spodumène, les micas lithinifères et l'amblygonite. D'assez grandes quantités de rubidium ont été découvertes au sein des micas lithinifères et du feldspath microcline. Le tantale et l'étain se présentent surtout sous forme de tantalite stannifère, qui contient une quantité extraordinairement élevée d'étain chimiquement combiné. Le béryl se rencontre dans diverses parties du gîte. Parmi les autres minéraux présents dans cette pegmatite, mentionnons le quartz, l'albite, la lithiophilite, la tapiolite, la microlite, la cassitérite, l'apatite, la rhodochrosite, la magnétite, l'ilménite, la scheelite, le zircon, la stannine, la tourmaline, les minéraux argileux et la calcite.

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INTRODUCTION

The Bernic Lake pegmatite is located about 100 miles northeast of Winnipeg, in the Lac du Bonnet Mining Division of Manitoba. The pegmatite is situated off the north shore of the western portion of Bernic Lake, a small body of water about four miles in length.

The historical background of the development of the deposit is rather interesting. In 1929 the property was staked by Mr. Jack Nutt, who formed the Jack Nutt Tin Mines Limited to investigate a reported cassiterite occurrence on the north shore of Bernic Lake. A 190-foot shaft was sunk, but there was no production. This company was succeeded in 1930 by the Consolidated Tin Mining Company Limited which did a small amount of work on the property, including some diamond drilling. One of the drill holes intersected the pegmatite body, including a section of spodumene. As there was little interest in lithium at the time, the company was dissolved and the property again became open for staking. Although the property was staked several times in the following years, no serious exploration was attempted until 1954, when the property was taken over by Montgary Explorations Limited. In 1957 the property was optioned to American Metal Climax Inc., which did extensive diamond drilling. This diamond drilling intersected the pollucite zone of the pegmatite, although this mineral was not recognized

until after American Metal Climax Inc. had relinquished its option. In 1959 Montgary Explorations Limited changed its name to Chemalloy Minerals Limited, and began a programs of underground development work.

The writer visited the property in the spring of 1960, with the prime purpose of collecting samples for mineralogical study. About 200 pounds of samples, representing a wide variety of rock types, were collected. The present study is therefore largely restricted to the mineralogy of the portion of the deposit explored up to that time, augmented by a few samples submitted later by the technical staff of the mine.

The Mines Branch has been involved in other programs dealing with material from the Bernic Lake deposit. These include ore dressing tests by the Mineral Processing Division, and chemical extraction tests by the Extraction Metallurgy Division. Products resulting from these beneficiation investigations were examined by the writer, and the results, when relevant, are included in this report.

ACKNOWLEDGMENTS

The writer appreciates the co-operation given by officials of Chemalloy Minerals Limited, in assisting in the collection of samples and in providing information. Mr. K.M. Brown and Dr. H.A. Quinn, mine manager and mine geologist, respectively, at the time of the writer's visit to the property, were particularly helpful in this respect. The chemical and spectrographic determinations given in this report were made by chemists of the Mineral Sciences Division of the Mines Branch and are specifically acknowledged in the text.

GEOLOGY

The geology of the area is covered in a Manitoba Mines Branch report by J.F. Davies.⁽¹⁾ The detailed geology of the pegmatite itself has been described by R.W. Hutchinson⁽²⁾ and, more recently, by R. Brinsmead.⁽³⁾ In brief, the pegmatite is a gently dipping, tabular body which varies from 60 to 200 feet in thickness and is at least 1500 feet in diameter, with the lateral limits not yet defined. The pegmatite consists of irregular zones, each of which has a distinctive mineral assemblage. The zones of greatest interest have been classified as "pollucite", "spodumene", "lepidolite" and "aplite" bodies.

(1) References are listed at the end of the report in the order in which they are numbered in the text.

DETAILED MINERALOGY

Pollucite - $(\text{Cs}, \text{Na}) (\text{Si}, \text{Al})_3 \text{O}_6 \cdot x\text{H}_2\text{O}$

Pollucite is the only mineral in the deposit found to

contain major amounts of cesium, although X-ray spectrographic

analyses have shown that some of the other minerals, notably

feldspar and mica, contain appreciable amounts of cesium. The

pollucite found to date occurs principally in one large body within the

pegmatite. The body itself consists of massive pollucite pods, up to

about 30 feet in diameter, in a complex interstitial assemblage

consisting principally of quartz and feldspar, with varying amounts

of mica, spodumene, apatite, beryl and amblygonite.

The pollucite in hand sample is greyish-white and, when

seen in direct contrast with the other white minerals in the deposit,

appears to have a faintly pinkish tint. It has a greasy lustre, and is

characterized by abundant minute fracturing.

In thin section, the majority of the pollucite is seen to

contain large numbers of extremely fine-grained disseminated

inclusions, which give the pollucite a cloudy, altered appearance.

Within the cloudy pollucite are small islands of clear pollucite up

to several millimetres in diameter which, in hand sample, have the

appearance of tiny vitreous "eyes". The pollucite is traversed by

many irregular veinlets which consist principally of spodumene,

feldspar and mica--singly and in combination. The spodumene and

feldspar are partially altered to a white, opaque material, probably

fine-grained mica or clay minerals. This alteration generally extends outward from the veinlets into the pollucite, where it passes over into the fine-grained disseminations (Fig. 1).

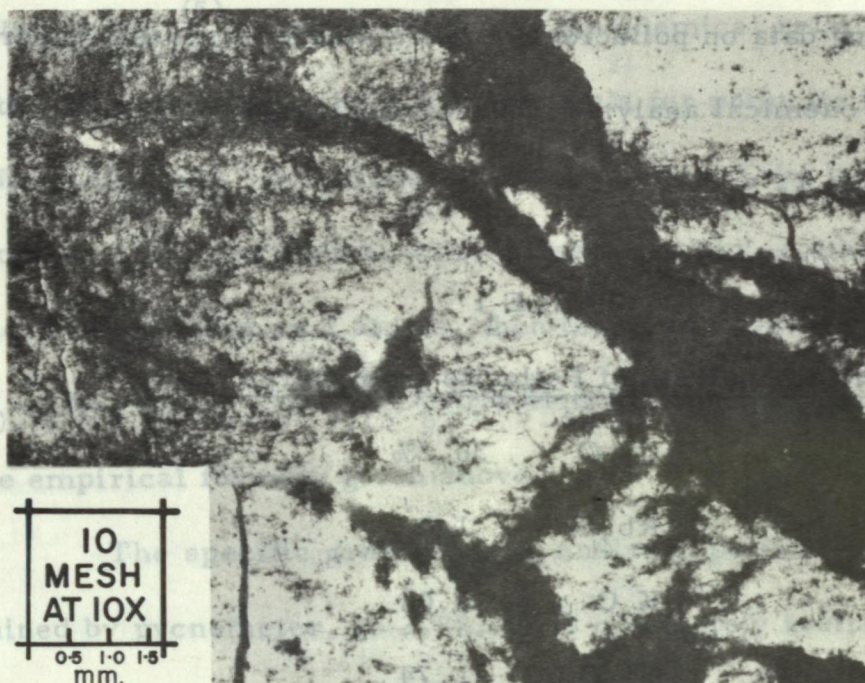


Figure 1. - Photomicrograph of thin section of pollucite, showing typical veining and alteration. The pollucite is transparent and therefore appears white in the photomicrograph; the other minerals are partially opaque, hence dark. The large irregular veinlets are altered spodumene; the fine-grained disseminations are probably mica or clay minerals.

In attempting to concentrate pollucite for analysis, it was found that the cloudy pollucite could not be effectively separated from the clear pollucite by heavy-liquid or magnetic separations. Therefore it was necessary to hand-pick the clear grains under a

stereomicroscope. The resultant hand-picked material was then separated in heavy liquids at densities slightly above and slightly below that of pollucite to remove any grains other than pollucite that might have been present. The analysis of the clear pollucite and some of its physical properties were reported earlier.⁽⁴⁾ The remaining data on pollucite are taken mainly from that report.

A chemical analysis of the concentrated pollucite is shown in Table 1.

TABLE 1

Chemical Analysis of Pollucite from Bernic Lake*

Cs_2O	36.2%
Rb_2O	1.0
K_2O	0.06
Na_2O	1.74
Li_2O	0.05
Al_2O_3	14.9
SiO_2	44.7
H_2O	<u>1.44</u>
	100.09

* Analysts: Dorothy J. Reed, Elsie M. Penner,
Frances E. Piercy

Recalculation of the analysis to conform to the pollucite formula with 6 oxygen atoms results in the following empirical formula for the analyzed pollucite: $\text{Cs}_{0.74}\text{Rb}_{0.03}\text{Na}_{0.16}\text{K}_{0.004}\text{Li}_{0.01}\text{Al}_{0.84}\text{Si}_{2.13}\text{O}_{6.00} \cdot 0.23\text{H}_2\text{O}$. Grouping together the cations of similar ionic size, we have: $(\text{Cs}, \text{Rb})_{0.77}(\text{Na}, \text{K}, \text{Li})_{0.17}(\text{Al}, \text{Si})_{2.97}\text{O}_6 \cdot 0.23\text{H}_2\text{O}$. According to Nel,⁽⁵⁾ who has discussed the chemical relationships in pollucite, the generalized theoretical formula for pollucite is:

$\text{Cs}_{1-x}\text{Na}_{x-y}\text{Al}_{1-y}\text{Si}_{2+y}\text{O}_6 \cdot x\text{H}_2\text{O}$. If, in the Bernic Lake pollucite, x is taken as 0.23, the mole fraction of water, and y is taken as 0.13, the excess of silicon over 2 atoms, then the theoretical formula should be: $\text{Cs}_{0.77}\text{Na}_{0.10}\text{Al}_{0.87}\text{Si}_{2.13}\text{O}_6 \cdot 0.23\text{H}_2\text{O}$. This is in good agreement with the empirical formula given above.

The specific gravity of the analyzed pollucite, as determined by pycnometer, is 2.88. It is completely isotropic and has a refractive index of 1.520. According to X-ray diffraction analysis, the pollucite is cubic, with a unit cell parameter of $a_0 = 13.66 \text{ \AA}$. The X-ray powder diffraction data are given in Table 2.

TABLE 2

X-ray Powder Diffraction Data for Pollucite
from Bernic Lake

(Iron-filtered cobalt radiation)

<u>Intensities</u> *	<u>d(A)</u> **	<u>hkl</u>
1	5.56	211
4	4.83	220
29	3.65	321
100	3.42	400
36	2.913	332
4	2.679	510, 431
4	2.492	521
11	2.414	440
7	2.212	532, 611
1	1.968	444
1	1.895	640
11	1.856	633, 552, 721
13	1.734	732, 651
1	1.703	800
1	1.679	811, 741, 554
1	1.632	653
1	1.587	831, 750, 743
1	1.547	752
2	1.524	840
1	1.475	921, 761, 655
1	1.408	932, 763
2	1.350	10.1.1, 772
2	1.3026	10.3.1, 952, 765
1	1.2172	11.2.1, 10.5.1, 963
2	1.1808	11.3.2, 10.5.3, 972, 776
2	1.1157	11.5.2, 10.7.1, 10.5.5
1	1.0865	11.6.1, 10.7.3
1	1.0597	11.6.3, 992, 976
1	1.0354	13.2.1, 11.7.2, 10.7.5

* Measured from diffractometer tracing.

** Obtained from 114.6 mm Debye-Scherrer camera.

Feldspar

Feldspar is one of the most abundant minerals in the deposit. In the samples investigated, two types of feldspar have been recognized--microcline and albite. These feldspars occur in a variety of forms.

Microcline - KAlSi_3O_8 . The microcline is generally coarse-grained, exhibits typical microcline twinning, and is lightly coloured in tints that range from pink to buff to grey. Much of it contains small, irregularly distributed laths of albite, which are particularly evident on large cleavage faces of the microcline. Therefore the term "perthite" could be applied to most, if not all, of the microcline.

All of the microcline appears to be altered to some degree. The least altered microcline contains a fine dusting of microscopic to sub-microscopic particles, which are generally most abundant along twin boundaries, and which probably consist of mica or clay minerals. The more highly altered microcline contains coarser mica in varying amounts, ranging up to samples in which the feldspar is practically obliterated. In extreme cases there are large irregular aggregates of greenish-yellow mica which have probably been formed by the complete replacement of the microcline. The higher degrees of alteration appear to coincide with the presence of beryl and tantalite.

In some samples, partial replacement of the microcline by albite appears to have occurred. Here, irregular veinlets of albite cut across coarse microcline, with the albite twinning parallel to the microcline twinning, suggesting that the growth of the albite was strongly influenced by the orientation of the microcline.

Albite - $\text{NaAlSi}_3\text{O}_8$. The majority of the albite appears to occur as fine-grained, compact masses to which the term "aplite" has been applied. The aplite has a sugary texture and varies in colour from white to light blue. Many of the aplite samples examined contain disseminated grains of the tantalum minerals, discussed below.

The albite is also found as coarse-grained aggregates of sub-parallel lamellae, i.e. cleavelandite. The cleavelandite is white in colour, and is associated with other coarse-grained minerals, particularly microcline, quartz, and curved sheets of mica.

As noted above, some albite also occurs as disseminated laths and as replacement veinlets in the microcline.

Rubidium and Cesium in the Feldspars. Three samples of microcline and three of albite, most of which were collected from the exploration drift in the mine, were analyzed for cesium and rubidium. The results (Table 3) show that the microcline contains significant amounts of cesium and rubidium, whereas the albite is much lower in these elements. This is to be expected because of the greater geochemical affinity of cesium and rubidium for potassium than for sodium.

TABLE 3

Cesium and Rubidium Contents of Feldspar Samples*

<u>Sample No.</u>	<u>Description</u>	<u>% Cs</u>	<u>% Rb</u>
N-13	Coarse, grey microcline	0.28	2.26
N-18	Coarse, pink microcline	0.17	2.14
6-24S	Grey, sericitized microcline	0.30	2.17
6-90S	Bluish-white aplitic albite	0.03	tr.
7-75S	White aplitic albite	0.10	0.08
SSW-1	Coarse white cleavelandite albite	0.06	0.03

* Analyses by X-ray spectrography by Dorothy J. Reed

Quartz

Quartz is probably the most abundant mineral in the pegmatite, and is found in all parts of the deposit. It varies in size from small grains and veinlets to large bodies tens of feet in diameter. It is translucent, and generally has a grey smoky appearance.

Spodumene - $\text{LiAlSi}_2\text{O}_6$

The spodumene occurs chiefly within the so-called spodumene bodies, which are irregular in form, and consist principally of feldspar, quartz and spodumene, with appreciable amounts of mica and amblygonite.

The spodumene is generally white in colour, and has a pearly lustre. It occurs in what appear to be large crystals up to

several feet in diameter. Microscopic examination of such samples indicates, however, that they usually consist of an aggregate of small sub-parallel spodumene crystals with abundant interstitial quartz. From the samples examined, it appears that the individual crystals average only a few millimetres in length, although a few measuring several centimetres have been observed.

Spodumene concentrated by means of heavy-liquid separations was found to contain 6.9% Li_2O . This is somewhat lower than the 8.0% Li_2O required by the formula $\text{LiAlSi}_2\text{O}_6$, and may be due in part to the presence of excess alumina or silica which is commonly found in chemical combination with spodumene. X-ray spectrographic analyses indicate that the spodumene contains only trace amounts of cesium and rubidium.

A small amount of spodumene has also been found as tiny irregular veinlets in the pollucite, as noted earlier. This vein spodumene is characterized by an abundance of fine-grained inclusions which render the spodumene partially opaque in thin section (see Fig. 1, page 5).

Lithium Micas

A wide variety of lithium-bearing micas occur in the deposit. Although the greatest concentration of lithium mica appears to be in the so-called "lepidolite body", lithium micas also occur in other parts of the deposits in various forms of aggregates, books and veinlets.

A number of micas have been analyzed chemically and spectrographically. The results, shown in Tables 4 and 5, indicate appreciable compositional variations with respect to both major and minor constituents.

TABLE 4

Chemical Analyses of Lithium Micas*

	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>
Li ₂ O	4.28%	2.41%	0.26 %	2.52 %	3.42 %
Na ₂ O	0.40	0.50	0.50	0.70	0.17
K ₂ O	8.68	9.22	10.01	7.84	8.61
Rb ₂ O	4.47	3.09	1.65	3.30	5.10
MgO	0.90	0.66	0.56	0.76	2.08
FeO	0.06	0.10	0.70	3.18	0.26
MnO	0.44	0.18	0.09	0.77	0.50
Al ₂ O ₃	26.65	27.22	36.67	26.46	28.31
SiO ₂	51.65	52.34	44.77	49.39	48.00
H ₂ O	2.13	2.70	4.18	3.70	2.74
F	<u>1.51</u>	<u>0.90</u>	<u>0.68</u>	<u>1.05</u>	<u>1.44</u>
Total	101.17	99.32	100.07	99.67	100.63
-O = F	<u>0.64</u>	<u>0.38</u>	<u>0.29</u>	<u>0.44</u>	<u>0.61</u>
	100.53	98.94	99.78	99.23	100.02

1. Curved violet lithian muscovite from shafthouse dump.
2. Fine-grained violet lithian muscovite from exploration drift.
3. Yellow muscovite from pollucite sub-level drift.
4. Curved grey lithian-ferroan muscovite from exploration drift.
5. Medium-grained violet lithian muscovite from "lepidolite body".

* Analysts: D.J. Charette, R.C. McAdam, Elsie M. Penner, M. June Young, and Frances E. Piercy.

TABLE 5

Minor Elements in Lithium Micas*

	1	2	3	4	5
Ca	0.04 %	0.1 %	0.06 %	0.8 %	tr
Ga	0.1	0.1	0.2	0.2	0.2 %
B	0.06	0.08	0.08	0.06	0.06
Sn	0.06	0.04	0.06	0.2	0.06
Ti	0.02	0.008	0.05	0.1	0.04
Be	0.004	0.003	0.003	0.01	0.005
Sr	tr	tr	tr	0.07	tr
Ge	tr	0.008	tr	tr	tr
Zr	n.d.	0.005	n.d.	n.d.	tr
Mo	n.d.	0.001	n.d.	0.04	n.d.
Zn	tr	tr	tr	0.4	tr
Ni	n.d.	n.d.	n.d.	0.03	n.d.
Cr	n.d.	n.d.	n.d.	0.8	n.d.
V	n.d.	n.d.	n.d.	0.005	n.d.

(Sample numbers correspond to those in Table 4;
tr = trace; n.d. = not detected.)

* Semi-quantitative spectrographic analyses by
Elizabeth M. Kranck.

The lithium oxide content, which is of particular interest, ranges from 0.26% to 4.28%. The mica from the so-called lepidolite zone contains 3.42% Li_2O . Although these micas have been called "lepidolites" in field use, X-ray diffraction studies of the analyzed samples indicate that they all have the muscovite structure except for No. 1, which has a mixed muscovite-lepidolite structure.

From a mineralogical point of view, therefore, use of the term "lepidolite" is not justified, and a more accurate expression would be "lithian muscovite". This view is supported by M.D. Foster,⁽⁶⁾ who states that only those micas containing more than 5% Li_2O can properly be termed lepidolites.

Sample 4 is distinguished from the others by its higher content of iron and other metals, including tin, zinc, and chromium. This mica has been called "zinnwaldite" in the field because of its iron content. Strictly speaking, however, the FeO content should be over 6% to justify the use of this name.⁽⁶⁾ A more correct name would be "lithian-ferroan muscovite".

A noteworthy compositional feature of all the mica samples is the high rubidium oxide content, which ranges from 1.65% to 5.10%. The gallium content, as indicated by semi-quantitative spectrographic analyses, is also relatively high (0.1 to 0.2% Ga).

The micas occur in a variety of forms. Some of the violet mica is extremely fine-grained, with an almost massive appearance. This is true of sample No. 2, Table 4. The violet mica from the "lepidolite body" (sample 5) is medium-grained, and occurs as flakes approximately one millimetre in diameter. Some samples consist almost entirely of closely-packed flakes; others of disseminated flakes in a quartz matrix. The yellow mica generally occurs as irregular masses consisting of medium-grained flakes.

Some of the coarse-grained mica exhibits quite unusual forms: curved sheets or books which, in extreme cases, have a botryoidal appearance (Fig. 2).

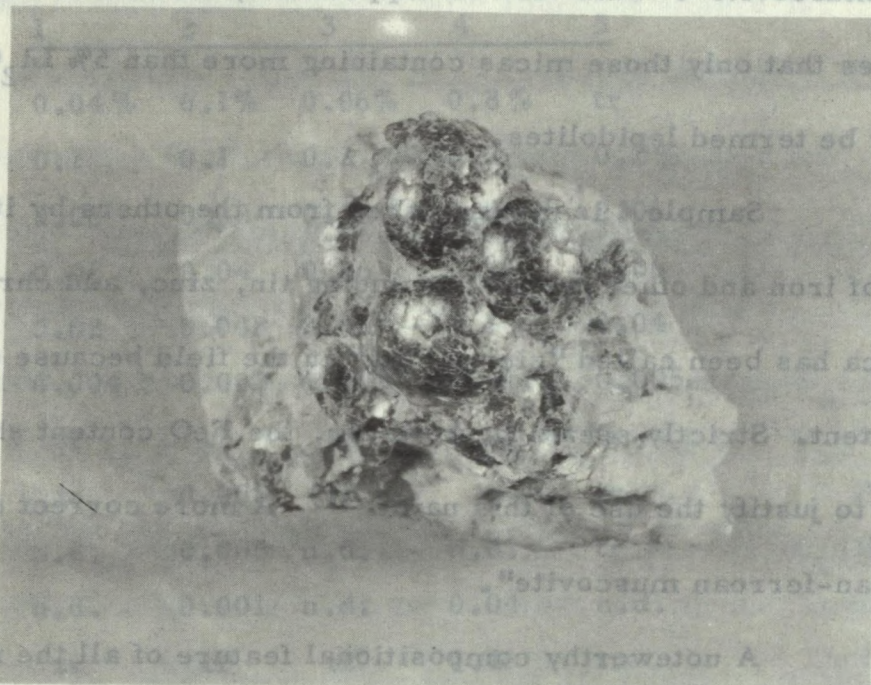


Figure 2. - Photograph, approximately full size, of violet lithian muscovite (Analysis No. 1), exhibiting botryoidal growth forms. The curvature of the mica aggregates is shown by the reflected highlights.

These forms occur in both the lithian muscovite and the lithian-ferroan muscovite (sample Nos. 1 and 4, respectively).

In the former, the structure is composed of tiny flakes arranged tangentially; in the latter, the structure is composed of larger sheets that are themselves curved. The tangential arrangement of the lithian muscovite flakes may be due to unusual conditions of growth rather than primarily to the chemical composition of the mica itself. In the case of the ferroan-lithian muscovite, however, the

pronounced curvature of the flakes suggests that the crystal lattice of the mineral may be deformed.

Amblygonite - $\text{LiAl}(\text{F}, \text{OH})\text{PO}_4$

The amblygonite is found chiefly in the spodumene-rich zones of the pegmatite. It occurs as massive irregular bodies, most of which range from 6 to 24 inches in diameter, but some of which are considerably larger. During the mining development, a body of practically pure amblygonite weighing over 100 tons was reported to have been encountered.

The amblygonite is white in colour, with a creamy cast relative to other white minerals in the ore. Its lithium oxide content, based on the chemical analysis of a sample, is 10.0%, which is very close to 10.2, the theoretical value for pure amblygonite. Trace amounts of cesium and rubidium were detected by X-ray spectrograph. The refractive indices of the amblygonite indicate that its composition is closer to the hydroxyl end of the solid solution series (montebrasite) than to the fluorine end (amblygonite).

Some of the amblygonite contains tiny colourless inclusions, both liquid and solid. The solid inclusions include some that have the appearance of mica. Mica also occurs as soft, grey veinlets in and rims around some of the amblygonite masses. This mica appears to be the product of secondary alteration of the amblygonite.

Lithiophilite - $\text{Li}(\text{Mn}, \text{Fe})\text{PO}_4$

Lithiophilite has been found only in relatively small amounts. In the samples examined it occurs, as rounded masses from a millimetre to several centimetres in diameter, in feldspar and quartz. The lithiophilite varies in colour from pink to tan to greenish-grey. A spectrographic analysis (Table 6) indicates that the mineral is intermediate in composition between the manganese end of the series (lithiophilite) and the iron end (triphyllite).

One sample of lithiophilite in quartz was found to be partially surrounded by a thin shell of extremely fine-grained apatite, which is probably an alteration product of the lithiophilite.

TABLE 6

Semi-Quantitative Spectrographic Analyses of
Lithiophilite and Beryl*

	<u>Lithiophilite</u>	<u>Beryl</u>
Li	p.c.	0.6%
Na	---	0.1
Be	---	p.c.
Mg	0.09%	0.01
Ca	0.8	---
Mn	p.c.	tr
Fe	10	0.08
Al	tr	7
Si	0.1	p.c.
P	p.c.	---
Nb	0.03	---
Ti	tr	0.004
Ni	---	0.01

* Analyst: Elizabeth M. Kranck

(Note: p.c. = principal constituent;
tr = trace amount.)

Beryl - $\text{Be}_3\text{Al}_2\text{Si}_6\text{O}_{18}$

Beryl is found in several environments: In smoky quartz, associated with spodumene and aplite; in the lepidolite zone; and in the border zones of the pegmatite. The beryl is snow-white in colour, and occurs chiefly as individual particles varying in size from a few millimetres to several inches. Only a few of the beryl samples examined occur as euhedral crystals; the majority have only a few or no crystal faces. The beryllium oxide content of the beryl, determined chemically as 13.2%, is considerably lower than that of pure beryl, which contains a theoretical 14.4% BeO. This may be due in part to the presence of alkalis, which can be accommodated in the structural channels parallel to the c-axis in beryl. In this beryl, the principal alkali, on the basis of spectrographic analysis, appears to be lithium (Table 6).

Tantalite - $(\text{Ta}, \text{Nb})_2(\text{Mn}, \text{Fe})\text{O}_6$

Two types of tantalite have been recognized. The one appears to be a normal tantalite and produces a characteristic tantalite X-ray diffraction pattern, while the other is a stanniferous tantalite, high in tin and with a distinctive diffraction pattern. These two types of tantalite could not be distinguished microscopically, either by their colour or reflectivity.

The tantalite is found chiefly in the upper portion of the aplite zone and in the coarse sericitized microcline. It occurs as disseminated grains ranging in size from less than a millimetre to

about 1 centimetre in diameter. The grains vary from highly irregular ones (Fig. 3) to fairly regular axe-shaped crystals (Fig. 4), but they practically all contain abundant silicate inclusions, chiefly muscovite. The colour of the tantalite ranges from reddish-brown to black.

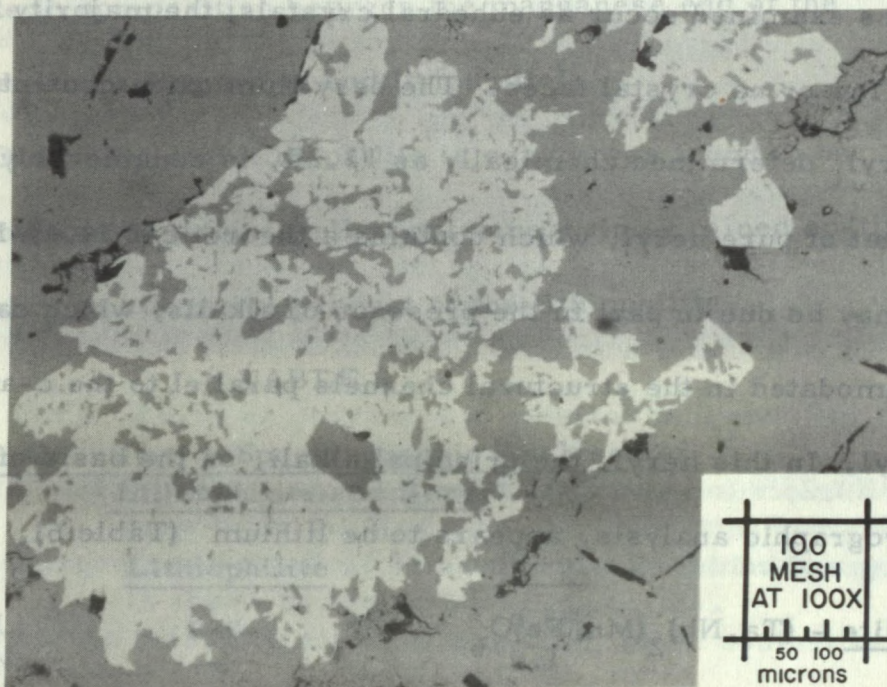


Figure 3. - Photomicrograph of polished section of tantalite, showing highly irregular grains with numerous silicate inclusions.

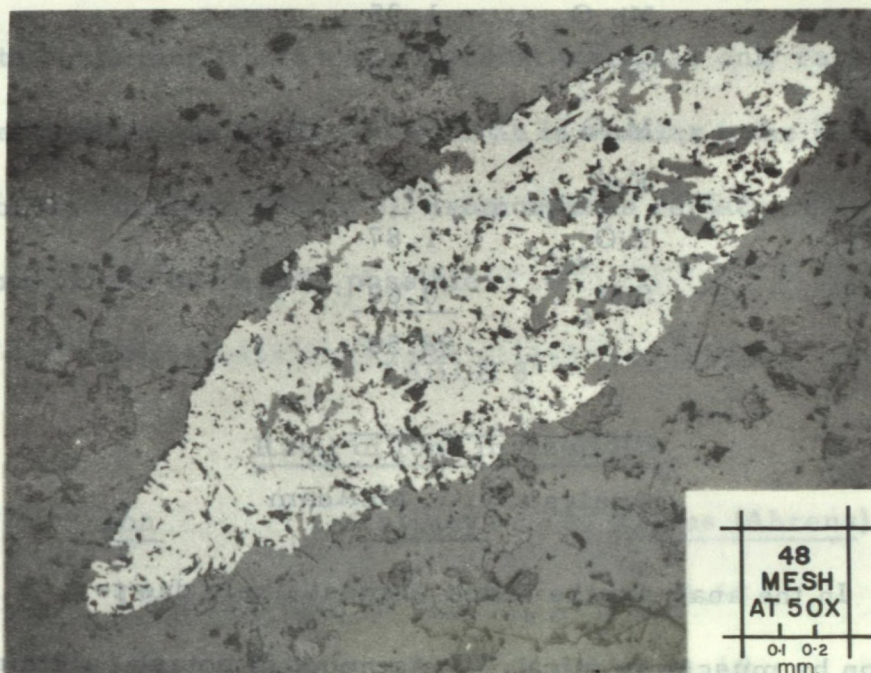


Figure 4. - Photomicrograph of polished section of axe-shaped crystal of tantalite containing a large number of tiny silicate inclusions.

Fine-grained black tantalite from a sericitized microcline was concentrated for analysis. Because of the fine-grained inclusions it was necessary to follow preliminary heavy-liquid and magnetic separations by fine pulverizing and repeated heavy-liquid separations in a centrifuge. The analysis (Table 7) shows that the tantalite is characterized by high Ta:Nb and Mn:Fe ratios and by a high tin content. The silica is due to silicate impurities in the concentrate.

TABLE 7

Chemical Analysis of Stanniferous Tantalite*

Ta_2O_5	70.05%
Nb_2O_5	1.35
SnO_2	13.20
MnO	9.04
FeO	2.39
TiO_2	1.87
SiO_2	<u>0.60</u>
	98.50

* Analyst: R.C. McAdam

In the analysis the silica is most likely due to contamination by muscovite mica. The amount of potash, alumina and water in muscovite corresponding to the 0.60% SiO_2 is 0.73%. If this is added to the analysis shown, the total is increased to 99.23%.

The presence of large amounts of tin in the tantalite is noteworthy. That this tin is in chemical combination with the tantalite, rather than being due to contamination by another tin mineral, is shown by the absence of diffraction lines of any tin minerals in X-ray powder patterns of the analyzed tantalite. Experiments have shown, for example, that as little as 1% cassiterite in tantalite should be detectable by this means.

It is not unusual for some tin to occur in tantalite. Kuznetsov, ⁽⁷⁾ for example, has found that tin has been reported in 118 out of a total of 124 columbite-tantalite analyses. However, tantalite containing tin as a major constituent has only rarely been reported. Since the ionic radius of tin is similar to the ionic radii of tantalum and niobium (Table 8), isomorphous replacements of these elements should be readily possible.

TABLE 8

Radii of Ions in Tantalite

<u>Ion</u>	<u>Valency</u>	<u>Radius (Ahrens)</u>
Ta	+5	0.68 A
Nb	+5	0.69
Ti	+4	0.68
Sn	+4	0.71
Mn	+2	0.80
Fe	+2	0.74

Since the normal valency of tin is 4, whereas that of tantalum and of niobium is 5, extensive replacement of tantalum and niobium by tin requires that this charge imbalance be corrected if neutrality is to be maintained. This could be done by the simultaneous substitution, by tin, of some of the divalent manganese and iron, whose ionic radii are also similar. Since there is a charge difference of 2 between tin and manganese (or iron), and

only 1 between tin and tantalum (or niobium), it would be necessary for tin to replace two (Ta,Nb) ions for every one of (Mn,Fe) replaced.

Applying this to the analysis of the tantalite given in Table 7, the atomic proportions have been calculated, with the tin divided in a 2:1 ratio between the (Ta,Nb,Ti) and (Mn,Fe) positions. The final column in Table 9 shows that this grouping approximately satisfies the generalized tantalite formula A_2BO_6 . The formula of the stanniferous tantalite can therefore be expressed as $(Ta,Nb,Sn_{2x})_2(Mn,Fe,Sn_x)O_6$.

TABLE 9

<u>Atomic Proportions in Stanniferous Tantalite</u>					
<u>Oxides</u>	<u>Wt %</u> *	<u>Elements</u>	<u>Wt %</u>	<u>At. Wt.</u>	<u>Atomic Proportions</u> **
Ta ₂ O ₅	70.05	Ta	57.36	180.95	1.58
Nb ₂ O ₅	1.35	Nb	0.94	92.91	0.05
TiO ₂	2.39	Ti	1.43	47.90	0.15
SnO ₂	13.20	Sn	10.40	118.70	0.44
					0.29
					0.15
MnO	9.04	Mn	7.00	54.94	0.63
FeO	1.87	Fe	1.45	55.85	0.13
		O	<u>19.32</u>	16.00	6.00
Totals	97.90		97.90		8.98

* From Table 7, SiO₂ not included.

** Calculated on the basis of O = 6.00.

The X-ray powder pattern of the stanniferous tantalite, although similar to that of normal tantalite, can be distinguished from it by the presence of some extra lines, as for example, lines 3 and 6 (Table 10), and by an apparent doubling of some of the lines, e.g. lines 9 and 10, 19 and 20, 28 and 29, and 32 and 33. A preliminary assessment of these features suggests that the stanniferous tantalite may have monoclinic symmetry, in contrast to the orthorhombic symmetry of normal tantalite.

TABLE 10

Comparison of the X-ray Powder Diffraction Patterns of the
Bernic Lake Stanniferous Tantalite and Normal Tantalite
(Cobalt radiation, iron filtered; camera diam. 114.6 mm)

<u>Line No.</u>	<u>Stanniferous Tantalite,</u> <u>Bernic Lake, Man.</u>		<u>Normal Tantalite,</u> <u>Tinton, S.D.</u>	
	<u>d (Å)</u>	<u>Intensity (Est.)</u>	<u>d (Å)</u>	<u>Intensity (Est.)</u>
1	7.29	tr	7.13	2
2	5.69	tr	5.30	1
3	4.73	3		
4	4.20	tr		
5	4.15	tr		
6	3.80	3		
7	3.64	5	3.66	7
8	3.53	tr	3.57	1
9	2.98	10	2.96	10
10	2.95	10		
11	2.85	3	2.86	3
12	2.55	4	2.53	4
13	2.49	5	2.49	5

(cont'd)

TABLE 10 (cont'd) -

<u>Line No.</u>	<u>Stanniferous Tantalite,</u> <u>Bernic Lake, Man.</u>		<u>Normal Tantalite,</u> <u>Tinton, S.D.</u>	
	<u>d (A)</u>	<u>Intensity (Est.)</u>	<u>d (A)</u>	<u>Intensity (Est.)</u>
14	2.45	tr		
15	2.37	4	2.38	3
16	2.26	2	2.28	tr
17			2.24	1
18	2.20	3	2.21	2
19	2.10	2	2.08	4
20	2.08	2		
21	2.02	tr	2.04	1
22	1.998	1		
23	1.905	4	1.898	3
24	1.824	4	1.831	3
25			1.796	1
26	1.767	6	1.772	4
27	1.750	4	1.735	5
28	1.723	6	1.721	5
29	1.711	5		
30	1.672	tr	1.672	1
31	1.576	tr	1.608	tr
32	1.549	5	1.534	4
33	1.535	4		
34	1.524	1	1.516	tr
35	1.493	2	1.484	2
36	1.476	1		
37	1.463	4	1.465	4
38	1.449	4	1.454	5
39	1.429	1	1.432	tr
40			1.393	tr
41	1.376	4	1.380	2

(concluded)

TABLE 10 (concluded) -

<u>Line No.</u>	<u>Stanniferous Tantalite,</u> <u>Bernic Lake, Man.</u>		<u>Normal Tantalite,</u> <u>Tinton, S.D.</u>	
	<u>d (A)</u>	<u>Intensity (Est.)</u>	<u>d (A)</u>	<u>Intensity (Est.)</u>
42	1.354	tr	1.347	tr
43	1.339	tr		
44	1.333	tr		
45	1.316	1	1.310	1
46	1.298	2	1.287	tr
47	1.276	2	1.268	2
48	1.252	2	1.242	2
49	1.237	2		
50	1.217	3	1.222	2

Because of its high tin content, the tantalite can properly be termed a stanniferous tantalite. The name "ixiolite" has been given by A.E. Nordenskiöld⁽⁸⁾ to very similar material from Finland, although more recently K. Amark⁽⁹⁾ has suggested that the tin reported in the original analysis was probably due to admixed cassiterite. The occurrence of stanniferous tantalite at Bernic Lake, however, may well justify reconsideration of the validity of the name ixiolite.

Tapiolite - $(\text{Ta}, \text{Nb})_2(\text{Mn}, \text{Fe})\text{O}_6$

Tapiolite has the same chemical formula as tantalite; crystallographically, however, it is tetragonal whereas tantalite is normally orthorhombic. These two minerals are practically

indistinguishable in appearance, although in polished section there is a slight difference in reflectivity, which is enhanced by oil immersion. The X-ray diffraction patterns of the two minerals are readily distinguishable. However, the diffraction pattern of tapiolite is quite similar to that of cassiterite, and can easily be mistaken for it (Table 11).

TABLE 11

Comparison of the X-ray Powder Diffraction Patterns of Tapiolite and Cassiterite from Bernic Lake

(Cobalt radiation, iron filtered; camera diam. 114.6 mm)

<u>Line No.</u>	<u>Tapiolite,</u> <u>Bernic Lake, Man.</u>		<u>Cassiterite,</u> <u>Bernic Lake, Man.</u>	
	<u>d (A)</u>	<u>Intensity (Est.)</u>	<u>d (A)</u>	<u>Intensity (Est.)</u>
1	4.60	3		
2	4.22	4		
3	3.36	10	3.35	10
4	2.71	2		
5	2.58	8	2.64	9
6	2.37	4	2.37	3
7	2.26	1		
8	2.11	1		
9	2.07	2		
10	1.896	tr		
11	1.745	8	1.762	10
12	1.715	tr		
13	1.678	4	1.674	2
14	1.653	tr		
15	1.576	1	1.590	1
16	1.559	tr		

(concluded)

TABLE 11 (concluded)

<u>Line No.</u>	<u>Tapiolite,</u> <u>Bernic Lake, Man.</u>		<u>Cassiterite,</u> <u>Bernic Lake, Man.</u>	
	<u>d (A)</u>	<u>Intensity (Est.)</u>	<u>d (A)</u>	<u>Intensity (Est.)</u>
17	1.534	1		
18	1.502	3	1.498	3
19	1.426	1	1.437	2
20	1.406	4	1.415	3
21	1.395	4		
22	1.289	2	1.320	1
23	1.269	tr		
24	1.259	tr		
25	1.210	4	1.213	4
26	1.187	1	1.184	tr
27			1.153	2
28	1.133	3		
29	1.120	2		

Tapiolite appears to be relatively rare. It has been observed only in sections containing tantalite and microlite, and then only in a few of those. It occurs in irregular grains which, like tantalite, contain numerous small inclusions (Fig. 5). Because the physical properties of tapiolite are very similar to those of tantalite, it was not possible to isolate the former for chemical analysis. It is not known, therefore, whether the tapiolite, like tantalite, has a high tin content.

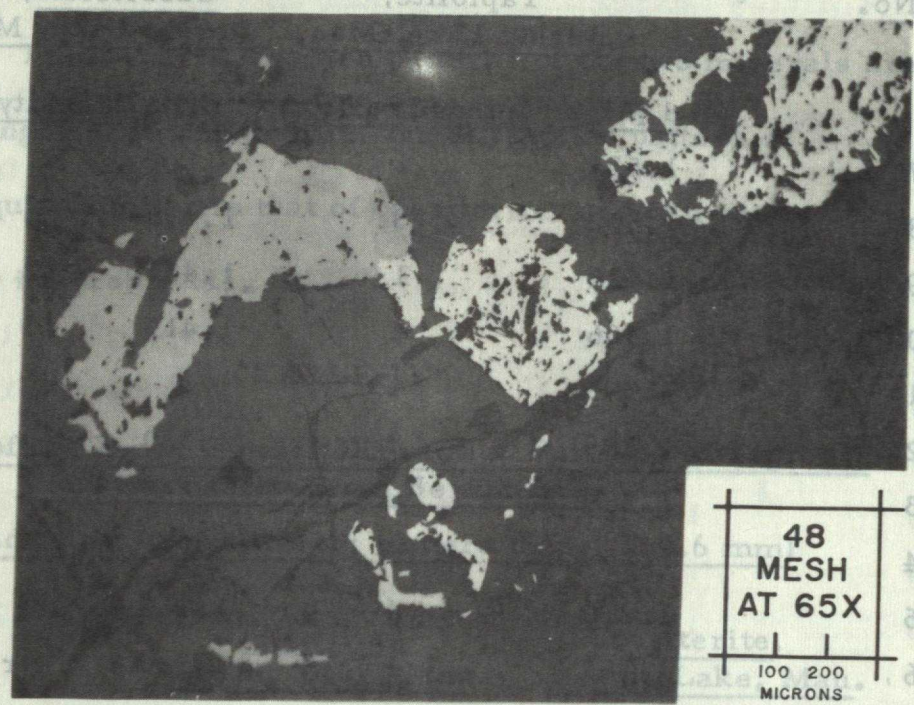
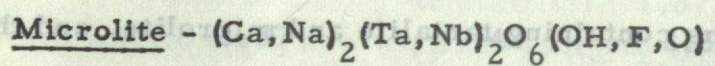


Figure 5. - Photomicrograph of polished section, showing grains of tapiolite (white) and microlite (light grey). Gangue minerals are dark grey and polishing pits are black.



The microlite, like tantalite, is found in the aplite and sericitized microcline, where it is closely associated with the tantalite (and with the tapiolite, where present) (Fig. 5). The grains of microlite are generally irregular in shape, although a few octahedral crystals have been found.

The microlite is creamy white in colour. It has a cubic structure with a cell parameter of $a_0 = 10.437A$, which is rather

high for a member of the pyrochlore-microlite series. This large cell parameter may be due to a low Ti content. Microlite concentrated from one of the samples was found to contain 71.5% Ta_2O_5 and 0.76% Nb_2O_5 , a Ta:Nb ratio of about 100:1. A heavy concentrate produced in the course of milling tests by metallurgists of the Mineral Processing Division was found to contain an appreciable amount of microlite. The microlite was concentrated further by heavy-liquid and magnetic separations, and analyzed spectrographically. The results are shown in Table 12. The tungsten content is attributable to some scheelite in the concentrate, and the zirconium may be due to contamination by zircon. Some of the minor elements may also be due to contamination by other minerals:

TABLE 12

Semi-Quantitative Spectrographic Analysis of Microlite Concentrate*

Ta	p.c.	Cu	0.2%
Ca	5%	Pb	0.2
W	5	Mn	0.1
Sn	4	Bi	0.06
Si	2	Cd	0.04
Nb	1	Ti	0.03
Fe	0.6	Mg	0.02
Al	0.4		

* Analyst: Elizabeth M. Kranck

Cassiterite - SnO_2

Cassiterite appears to be quite rare, since none was detected in any of the samples collected from the deposit. The only cassiterite found was in heavy concentrates produced during the course of milling tests on a sample of the ore sent to the Mineral Processing Division. This cassiterite is dark brown in colour, and virtually indistinguishable in appearance from the tantalite and tapiolite. It was initially distinguished from these, however, by its low magnetic susceptibility. Since no cassiterite was observed in the polished sections nor during the course of mineral separations of selected samples, very little can be deduced about its occurrence.

Apatite - $\text{Ca}_5(\text{F}, \text{OH})(\text{PO}_4)_3$

Apatite has been found in various parts of the deposit. It occurs chiefly as isolated grains and masses up to several inches in diameter. In general, the apatite is blue in colour and has a dull lustre, although one sample of fine-grained light brown apatite was also observed. A semi-quantitative spectrographic analysis of a sample of blue apatite indicated that it contains an appreciable amount of manganese (Table 13).

TABLE 13

Semi-Quantitative Spectrographic Analysis of Apatite*

Ca	p.c.
P	p.c.
Mn	2 %
Si	0.5
Sr	0.2
Al	0.2
Fe	0.15
Cd	0.1
Mg	0.05
Pb	0.05
Bi	0.01

*Analyst: Elizabeth M. Kranck

Rhodochrosite - MnCO_3

The rhodochrosite samples examined consist of small salmon-pink aggregates less than one inch in diameter.

The rhodochrosite is characterized by its well-developed cleavage as well as its colour.

Other Minerals

The remaining minerals were found in only very small amounts. Magnetite, ilmenite, scheelite, zircon and stannite were found only in heavy concentrates produced during the course of the ore dressing tests and were present in very small amounts. Since they were not found in any of the samples collected, the possibility that they may be contaminants introduced during the milling must be considered. Tourmaline was found in only one specimen--as tiny black crystals in association with apatite and lithiophilite. Clay minerals, varying in colour from white to green, were identified in a few samples; they appear to be chiefly feldspar alteration products. A small amount of calcite was observed in one of the samples, in close association with mica and clay minerals.

CONCLUSIONS

The Bernic Lake deposit is a complex zoned pegmatite consisting of a wide variety of minerals. The deposit has many features in common with the Varutrask pegmatite in Sweden, which has been described in a series of papers published in 1937, chiefly by P. Quensel. (10)

The mineralogical composition of the Bernic Lake pegmatite is extremely variable, and abrupt changes in mineralogy are encountered in passing from one zone to the next. For this

reason it is difficult to estimate the amounts of each of the minerals present. However, on the basis of the samples examined, and on the available geological information, a broad general assessment can be made. The most abundant minerals appear to be quartz, feldspar, mica, spodumene, and pollucite. Minerals occurring in minor but significant amounts include amblygonite, beryl, and tantalite. The remaining minerals have, to date, been found in only very small amounts.

The beneficiation of the Bernic Lake ore may be expected to present difficulties because of the complex mineralogy. Of the many metallic elements in the ore, the ones most likely to be of current interest are cesium, lithium, rubidium, tantalum, tin and beryllium. The mineralogy of each of these elements will be summarized briefly here, with some comments on the factors likely to affect beneficiation.

The cesium occurs largely in pollucite. The pure mineral contains about 36% Cs_2O , but foreign mineral inclusions and veinlets appreciably reduce the cesium content of the samples. It is unlikely that these can be effectively removed by normal ore dressing procedures because of their extremely fine grain size. With respect to removing any coarse-grained impurities, gravity methods would probably not be very effective, because the specific gravity of the pollucite is similar to that of the majority of the minerals in the deposit.

Beneficiation of the lithium-bearing minerals is complicated by the variety of such minerals in the ore, which includes spodumene, a number of lithium micas, amblygonite, and small amounts of lithiophilite. Most of the spodumene is intergrown with quartz, which suggests that fairly fine grinding may be necessary to liberate the spodumene. The lithium micas contain up to 4.3% Li_2O , which is less than is present in normal lepidolite. The very coarse-grained and the very fine-grained micas appear to be rather sparsely and irregularly distributed. The medium-grained violet mica from the so-called lepidolite body appears to occur in fairly high concentrations. However, its relatively low lithium content (3.42% Li_2O) limits the grade of the concentrates obtainable. The amblygonite is coarse-grained and has a high lithium content (10.0% Li_2O), but its distribution in the deposit appears to be irregular.

Appreciable amounts of rubidium (up to 5.1% Rb_2O) occur in a number of the minerals--micas, microcline, and pollucite. Since this element occurs in chemical combination with these minerals, it can probably be recovered only by chemical methods.

The tantalum and tin appear to occur principally in the form of stanniferous tantalite, and, to a lesser extent, in tapiolite, microlite, cassiterite and stannite. Tantalite, as well as the other tin and/or tantalum minerals, has a high specific gravity, which suggests the possibility of gravity concentration. However,

because of the large number of small inclusions in the tantalite, fine grinding will be necessary to effect liberation.

Beryl is the only beryllium mineral identified. Although it is relatively coarse-grained, its low density probably precludes its concentration by gravity methods.

In summary, it may be concluded that complex beneficiation procedures will probably be required to effect efficient recoveries of potentially valuable elements in the pegmatite.

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Note: As this report was completed, the Geological Survey of
Canada issued Paper 61-4, "Pollucite (Caesium) in Canada" by
R. Mulligan, which deals in part with the pollucite occurrence in the
Bernic Lake pegmatite.

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