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THE RELATIONSHIP BETWEEN MANN-TYPE Nb–Be MINERALIZATION AND FELSIC PERALKALINE INTRUSIVES, LETITIA LAKE PROJECT, LABRADOR

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ABSTRACT

The Letitia Lake area is located in central Labrador about 160 km northwest of Goose Bay. This area contains several economically interesting Nb–Be showings, which are associated with peralkaline syenite intrusions of the Red Wine Intrusive Suite.

Four Nb–Be showings in the Letitia Lake area, including the Mann #1 and Two Tom Lake showings, are the focus of ongoing mapping and petrological studies. These studies indicate that the Nb–Be mineralization occurs at or near the contact that represents the unconformity between the Letitia Lake felsic magmatic rocks and overlying sedimentary rocks of the Letitia Lake or Seal Lake groups. The mineralization appears to be related to the last phase of the Letitia Lake Group peralkaline activity.

There have been 5 types of mineralization observed in the four showings studied. These include 1) lineated and foliated syenite, 2) aegirine–feldspar units, 3) aegirine–feldspar veins, 4) albite-rich felsic veins, and 5) disseminated units in syenite. Each type of mineralization is not found at all of the showings studied. The main Be-bearing minerals are barylite and eudidymite, whereas the Nb-bearing ore minerals are niobophyllite and pyrochlore.

A compilation of previous mapping and the mapping completed for this study has resulted in the outlining of the favourable 'unconformity' marker horizon. This will aid in the exploration for similar Nb–Be showings in the Letitia Lake area.

INTRODUCTION

The Nb–Be showings in the Letitia Lake area (Figure 1) have been the focus of rare-metals exploration since the discovery of the Mann showings in 1957 (Brummer, 1957). Subsequent exploration activity, which has been sporadic, has resulted in the discovery of several other Nb–Be showings, the most notable of which is the Two Tom Lake showing. This progress report outlines the geological setting of the Nb–Be mineralization in these showings, with the intention of proposing a geological model with which other showings could be discovered in the Letitia Lake and other areas.

The study area is located in Labrador, 160 km northwest of Goose Bay and 50 km east of the Smallwood Reservoir (Figure 1). It is accessible by float plane or helicopter.

Previous regional geological mapping in the immediate Letitia Lake area was carried out by Mann (1959), Marten (1975), Curtis and Currie (1981), and Thomas (1981). Outcrop- and property-scale maps were prepared by Mann (1959), Evans and Dujardin (1961) and Shewman (1967) for the Mann #1 showing, and by Smith (1968) for the Mann #2 showing. Sketch maps were prepared by Smith (1968) and Westoll (1971) for the Two Tom Lake area. The geology of the other showings and other localities having economic potential was previously determined from mapping on the regional scale.

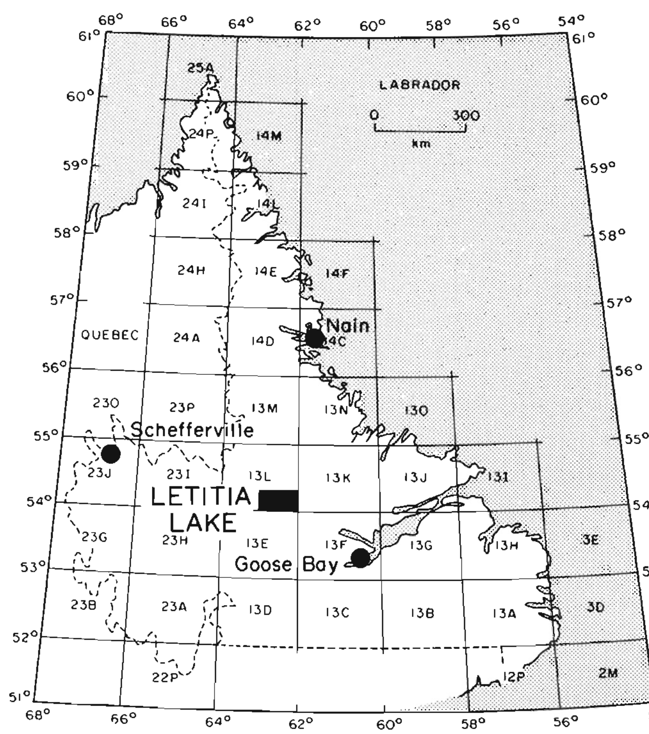
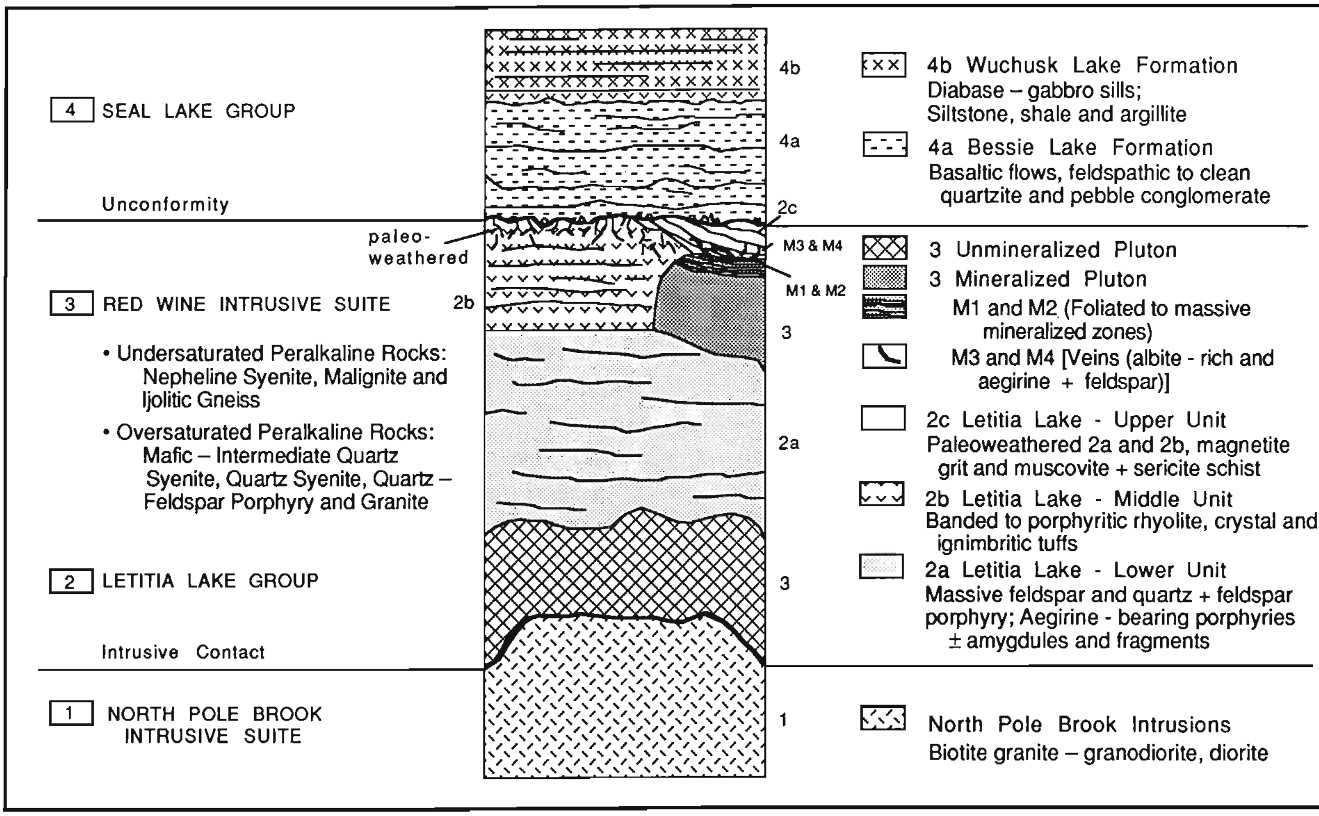


Figure 1: *Location of the Letitia Lake area.*

This project is a contribution to the Canada–Newfoundland Mineral Development Agreement, 1984–1989

Table 1: Table of formations for the Letitia Lake area



In addition to the exploration company assessment reports for the individual properties and the reports mentioned above, the following articles, pertaining to the Mann #1 and related showings, have also been published: Baragar (1969, 1981), Brummer (1960), Brummer and Mann (1961), Thomas (1980, 1981), Hill and Thomas (1983) and Miller (1986).

GEOLOGY

The Letitia Lake area occurs within the Grenville Structural Province, just south of the boundary with the Churchill Structural Province. This area is also considered to be part of the Grenville Front zone (Thomas, 1981), as defined for Labrador by Gower *et al.* (1980). The rocks in the map area have been divided into four groups by Thomas (1983). These are (Table 1): the Seal Lake Group, the Letitia Lake Group, the Red Wine Intrusive Suite (oversaturated and undersaturated) and the North Pole Brook Intrusive Suite. The Red Wine Intrusive Suite, which directly hosts the Mann-type showings, is intrusive into the Letitia Lake Group at several localities. The Seal Lake and North Pole Brook rocks occur at the upper (northern) and lower (southern) contacts, respectively, of the Letitia Lake Group.

Red Wine Intrusive Suite

The Red Wine Intrusive Suite has been subdivided into peralkaline undersaturated and peralkaline oversaturated phases by Thomas (1983). Curtis and Currie (1981) also indicate that the two phases are genetically related, but have named the oversaturated suite the Arc Lake Gneisses.

The undersaturated phase (nepheline bearing or nepheline normative) mainly occurs as two central complexes (Red Wine North and Red Wine South complexes; Curtis and Currie, 1981), which are exposed southwest of the current area of interest. Several small plugs and dikes occur within the study area, particularly near the Mann #2 showing. Nepheline, arfvedsonite amphibole, aegirine and eudialyte are the main peralkaline indicator minerals found in this phase (see Curtis and Currie (1981) for descriptions of these rocks).

The oversaturated phase (quartz bearing or quartz normative) is of special interest because the Mann-type showings are associated with the syenitic rocks of this phase. Members of this phase occur as small intrusions (< 5 km^2) and dikes (Figure 2). The main rock types are peralkaline syenite, containing little or no quartz, and peralkaline granite, containing abundant quartz. Riebeckite amphibole and/or aegirine are the main peralkaline indicator minerals found in this suite. Thomas (1981) describes these rocks in more detail.

Letitia Lake Group

The Letitia Lake Group is a sequence of felsic rocks consisting of quartz–feldspar porphyries, felsic volcanic rocks and derived sedimentary rocks. Recent geochemical studies, based on trace-element-concentration comparisons, indicate that these rocks have a peralkaline affinity (Thomas, 1981; Hill and Thomas, 1983), although peralkaline minerals such as aegirine and riebeckite are not abundant or are not found, and Na_2O values are low.

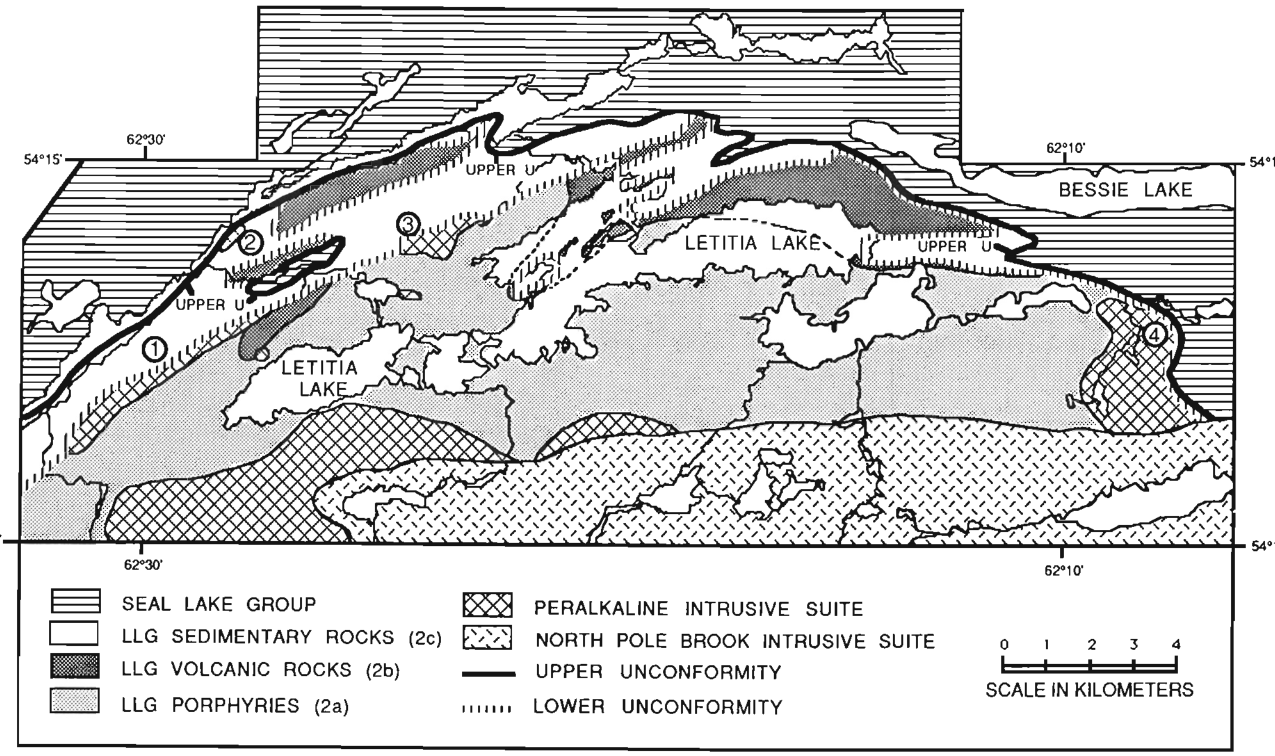


Figure 2: *Generalized geology of the Letitia Lake area. Note the location of the upper and lower unconformities. The numbered localities are the main Nb–Be showings in the study area: 1–Mann #2; 2–Michelin; 3–Mann #1; 4–Two Tom Lake. LLG–Letitia Lake Group.*

The Letitia Lake Group has been subdivided into the following units (Thomas, 1981):

1) a lower unit that consists of peralkaline quartz–feldspar and feldspar porphyry (Table 1); it appears to be an intrusive unit occurring as sills and dikes;

2) a middle unit of peralkaline, subaerial, porphyritic rhyolite, banded rhyolite, crystal tuff and ignimbritic tuff;

3) an upper unit composed of paleoweathered equivalents of the two older units; includes hematized volcanic rocks and porphyries, and volcanic-derived magnetite-bearing phyllite and graywacke; called 'regolith' by Marten (1975) and Thomas (1981).

Figure 2 is a compilation of Marten (1975) and Thomas (1983), including observations obtained from the field-work portion of this study. This figure generalizes the distribution of the three units defined above.

The porphyritic rhyodacite, Unit 4 of Thomas (1983), is interpreted in this study to be part of the lower unit of the Letitia Lake Group. It appears to be an extrusive, more mafic relative of the Letitia Lake Group feldspar porphyry. This interpretation explains the lower stratigraphic position, the transitional to peralkaline chemistry (Thomas, 1980), and the older age relative to the Red Wine Intrusive Suite. The late-stage nature of the peralkaline minerals in the porphyritic rhyodacite can be interpreted as late-stage magmatic rather than metasomatic. This interpretation is in keeping with the fact that the Letitia Lake Group in general has few or no peralkaline mafic minerals but has peralkaline chemistry.

Seal Lake Group

The Seal Lake Group is found in the northern portion of the study area, where it can be subdivided into the Wuchusk Lake and Bessie Lake formations. These formations have been described as follows (Marten, 1975; Thomas, 1981):

> *Wuchusk Lake Formation*—Consists of two subunits, one of which is predominantly siltstone, shale, argillite and chert (sedimentary subunits); the other is made up of conformable gabbro and diabase sills.
>
> *Bessie Lake Formation (also called Majoqua Lake Formation)*—Occurs as three subunits in the study area: the lowermost is a discontinuous subunit of pebble conglomerate, mainly made up of pebbles derived from the Letitia Lake Group; the remaining two subunits, quartzite–arkosic quartzite and mafic flows, are interbedded and make up the bulk of the formation.

The location of the Seal Lake Group, in the study area, is illustrated in Figure 2.

North Pole Brook Intrusive Suite

The North Pole Brook Intrusive Suite (NPBIS) consists of intermediate to felsic plutonic rocks that have been subdivided into biotite granodiorite–quartz monzonite, biotite granite and quartz diorite–diorite by Thomas (1981). The rocks of this suite that are found in the study area (Figure 2) are foliated and sheared. Intrusive relationships indicate that the North Pole Brook Intrusive Suite is older than the Red Wine Intrusive Suite and the Letitia Lake Group.

Structural Geology

The rocks of the Letitia Lake and Seal Lake groups record the occurrence of three periods of deformation in the study area (Thomas, 1981). The results of these three periods of deformation include:

1) isoclinal folds
2) complex fold interference patterns
3) shear zones
4) thrust faults

It is thus very difficult to follow individual volcanic–sedimentary units or markers to determine true thicknesses of units and the specific details of the stratigraphy. Therefore, all conclusions based on field evidence must be of a general nature.

Seal Lake Group–Letitia Lake Group Contact: a Discussion

Table 1 illustrates the unconformable relationship that occurs between the Seal Lake Group (Bessie Lake Formation) and the underlying Letitia Lake Group. The location of this contact has a direct bearing on this study because the main Nb–Be (Table 1) showings occur at or near it, as defined by Thomas (1983).

Brummer and Mann (1961) placed the contact between the Letitia Lake and Seal Lake groups at the interpreted unconformity marked by the Bessie Lake Formation basal conglomerate (Table 1), which contains pebbles of Letitia Lake Group rocks. Other mappers working in the area (Marten, 1975; Curtis and Currie, 1981) have placed the contact at the base of the paleoweathered unit, described above as the upper unit of the Letitia Lake Group. This paleoweathered unit (regolith) is composed of sedimentary rocks derived from the Letitia Lake Group, and *in situ* hematized Letitia Lake Group. The occurrence of a mafic to intermediate flow, and lenses of feldspathic quartzite, both thought to be similar to rocks in the Bessie Lake Formation, have been cited as evidence for this interpretation. Mafic to intermediate flows have not been reported in the Letitia Lake Group, thus this occurrence must be explained if the unconformity is to be placed at the base of the Bessie Lake conglomerate, rather than at the base of the regolithic unit. The complex structural history of the area may explain some of the apparent contradictions.

It should also be pointed out that the erosion-derived materials found in both the Bessie Lake Formation conglomerate and the regolith sedimentary rocks are mainly derived from Letitia Lake Group porphyritic rocks (porphyry-derived sedimentary rocks). Thus, the interpretation of Marten (1975) seems plausible, accepting the assumption that the porphyry-derived sedimentary rocks and the overlying conglomerate were formed during the same continuous erosional event. However, the hematized and oxidized Letitia Lake Group porphyries (i.e., porphyries exposed at the paleosurface) should not be included in the Bessie Lake Formation, as these rocks represent *in situ* Letitia Lake Group.

Thomas (1981) has chosen to place the porphyry-derived sedimentary rocks in the Letitia Lake Group, thus following the original interpretation of Brummer and Mann (1961). Hibbs (1980) supports this interpretation and lists the following reasons:

1) porphyry-derived sedimentary rocks appear to grade laterally into the paleoweathered porphyries;

2) Bessie Lake Formation conglomerate appears to grade laterally and upward into quartzite; both units overlie the porphyry-derived sedimentary rocks and paleoweathered porphyries;

3) pebbles of porphyry-derived sedimentary rocks have been found in the Bessie Lake Formation conglomerate.

These observations suggest that a second erosional event occurred after the deposition of the porphyry-derived sediments. They do not, however, indicate which of the two erosional events represents the most significant unconformity–that marked by the base of the porphyry-derived sedimentary unit, or that marked by the base of the Bessie Lake conglomerate. It appears that these contrasting interpretations cannot easily be resolved.

Some of the preliminary results from this study have some bearing on the location of the contact between the Seal Lake and Letitia Lake groups. Partial chemical analyses of the unit identified by Marten (1975) as an intermediate to mafic flow indicate that this unit has syenitic or trachytic affinities (MgO–0.8 percent; SiO_2–59.7 to 65 percent; completed analyses will be published at a later date). This volcanic unit in no way resembles the volcanic rocks of the Seal Lake Group, but appears to closely resemble the peralkaline syenite of the Letitia Lake Group. Thus the implication is that this trachytic unit is the extrusive equivalent of the syenite. Some of the 'felsic sediments' (porphyry derived) of Thomas' (1981) upper Letitia Lake unit may also be volcanic rather than sedimentary. These conclusions cast doubt on the use of the base of the regolith as the major unconformity.

In this report, the base of the Bessie Lake Formation, as delineated by the Bessie Lake conglomerate, will be used as the base of the Seal Lake Group (Figure 2). However, the presence of Letitia Lake Group-derived sedimentary rocks below this unconformity indicates that at least a minor unconformity, marked by the upper contact of the hematized and paleoweathered Letitia Lake Group porphyry, also occurs. The mapping to date (Thomas, 1981) has not subdivided the upper Letitia Lake unit into paleoweathered porphyry and porphyry-derived sedimentary rocks. Thus, this minor unconformity must be approximated by the contact between the upper and middle Letitia Lake units (Table 1; Figure 2).

Detailed mapping by Hibbs (1980) in a small portion of the contact zone indicates that the paleoweathered rocks are about 20 m thick (called true thickness by Hibbs) and the sedimentary rocks are approximately 10 m thick.

The older (lower) unconformity marks the upper limit of magmatic activity in the Letitia Lake Group. The line labelled 'lower unconformity' in Figure 2 reflects the best approximation of this lower unconformity based on a compilation of previous mapping and mapping carried out for this study. Figure 2 illustrates the proximity of the syenite associated with Nb–Be mineralization to this lower unconformity.

PERALKALINE SYENITE AND Nb–Be MINERALIZATION

The Nb–Be mineralization at the Letitia Lake showings occurs in several different modes:

1) *Sheared, lineated and gneissic 'syenite' and 'amphibolite' (Unit M1).* This unit is a banded rock consisting of alternating feldspar-rich and riebeckite-rich bands, which are oriented roughly parallel to the regional trends. Grain size varies from < 0.5 mm to 5 mm across in different bands in the same outcrop. The proportions of feldspar and amphibole also vary between different bands in the same outcrop. Bands vary from 1 cm up to several metres in width, and occur at all of the four main showings except the Michelin syenite.

2) *Aegirine–feldspar, massive to foliated unit (Unit M2).* This unit has only been found at the Mann #1 showing. It is a massive, fine grained (<0.5 mm), dark-gray unit, consisting of aegirine pyroxene and feldspar, which occur in roughly equal proportions.

3) *Aegirine–feldspar veins (Unit M3).* These veins are quite variable in appearance but always contain aegirine pyroxene and feldspar in roughly equal proportions. Feldspar commonly occurs as lath-like phenocrysts that range in size from < 0.5 to 10 mm in length. Aegirine usually occurs as a fine grained (< 0.5 mm) matrix to the feldspar, although it also forms large subhedral grains, up to 5 mm across, that occur in aggregates. These veins are commonly intimately associated with the feldspar-rich veins (Unit M4) in composite veins. Aegirine–feldspar veins are found at all showings except the Two Tom Lake showing.

4) *Albite-rich felsic veins (Unit M4).* This unit is usually made up of > 90 percent light-colored minerals (white, pink or light gray), including feldspar, barylite and eudidymite. Grain size is commonly 2 to 5 mm across. In some cases, aegirine or riebeckite mafic clots, up to 3 cm across, are developed. These veins occur at all of the main Letitia Lake showings, although they are rare at the Two Tom Lake and Mann #2 showings.

5) *High concentrations of disseminated mineralization in peralkaline syenite (Unit M5).* This mode of mineralization appears to relate to niobium mineralization in particular. Pyrochlore concentrations are higher in certain parts of the Michelin syenite. Nb–Be mineralization is common in the contact zones of the Michelin syenite where the syenite becomes mafic rich or fine grained. Figure 3 illustrates the relationship between the various modes of mineralization and the associated syenite.

The main niobium and beryllium ore minerals found at the Letitia Lake showings are:

Barylite–$BaBe_2Si_2O_7$
Eudidymite–$NaBeSi_3O_7(OH)$
Niobophyllite–$(K,Na)_3(Fe^{+2},Mn)_6(Nb,Ti)_2Si_8(O,OH,F)_{31}$ (this is a niobium-rich astrophyllite)
Pyrochlore–$(Na,Ca)_2(Nb,Ti)_2O_6(F,OH,O)$

Gaines (1977) reported that the ore minerals at the Mann #1 showing are < 0.1 mm across, and that most of the Be occurs in barylite and most of the Nb occurs as niobophyllite.

Four occurences of syenite in the Letitia Lake area have been identified as being associated with Nb–Be mineralization. These are informally named as follows:

1) Mann #1 syenite (Be 001*)
2) Mann #2 syenite occurrences (Nb 002*)
3) Two Tom Lake syenite (Ree 001*)
4) Michelin syenite (Nb 001*)

These syenites have been informally named after the Nb–Be showings associated with them. Each syenitic occurrence and the associated mineralization will be described below.

Mann #1 Showing–Syenite

The Mann #1 syenite contains the best known of the Nb–Be showings in the Letitia Lake area. It occurs as an elongate body 2.3 by 0.7 km in dimension. It is composed of two major textural phases: a fine grained phase dominates the northern portion of the pluton and a medium grained phase dominates the southern portion (Figure 4). The coarser grained syenite appears to be the younger, although definitive crosscutting relationships were not observed. The syenite crosscuts and occurs between the Letitia Lake Group quartz–feldspar porphyry (lower unit) and the feldsparphyric trachytic volcanic unit; this volcanic rock is assigned to the middle unit of the Letitia Lake Group.

The mineralization occurs in the following modes:

1) *Sheared, lineated and gneissic 'syenite' and 'amphibolite' (Unit M1).* This unit is interpreted to be either a major shear zone within the syenite (Thomas, 1981) or metasomatized metasedimentary rocks

* Newfoundland Department of Mines and Energy Mineral Inventory File numbers for NTS 13L/1.

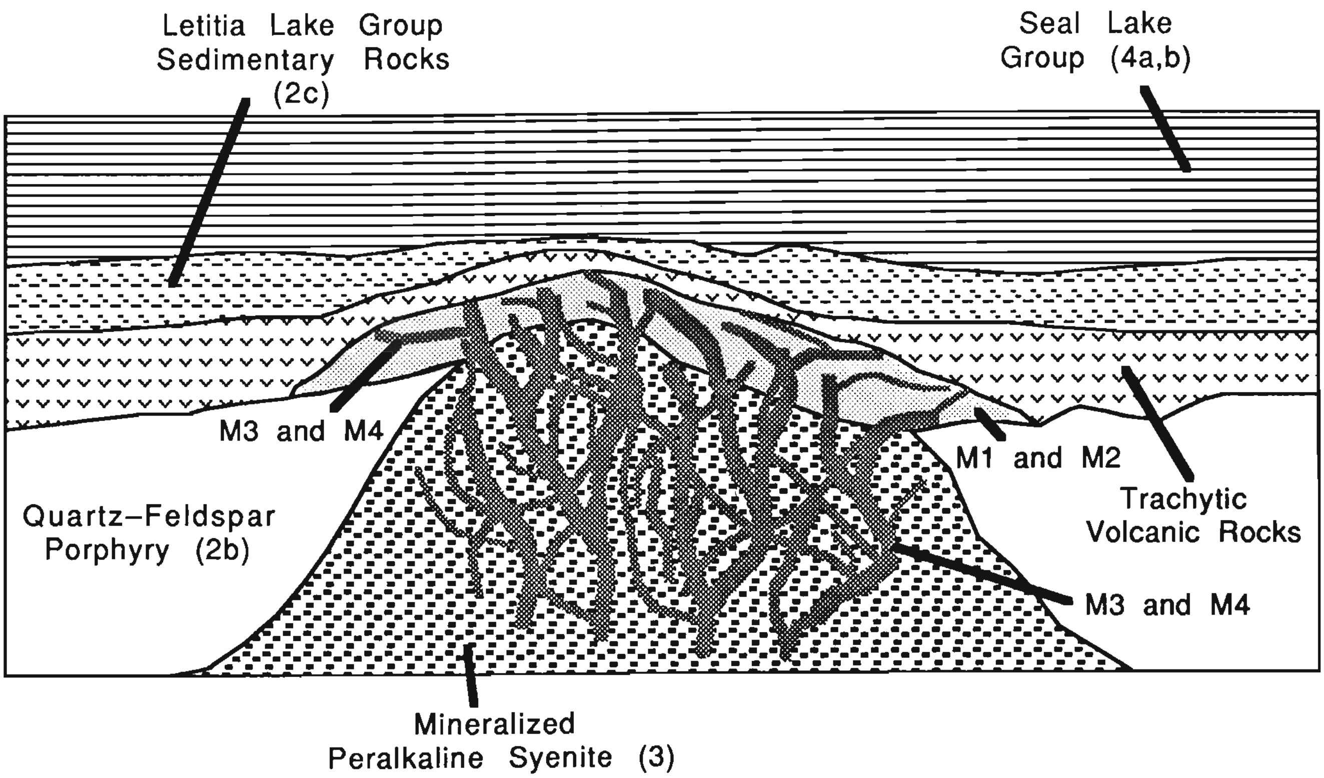


Figure 3: *Diagram illustrating the relationship between the Nb–Be mineralization, the host peralkaline syenite and the surrounding Letitia Lake Group. M1 to M5 refer to the units or modes of mineralization discussed in the text. The major map units are described in the text and in Table 1.*

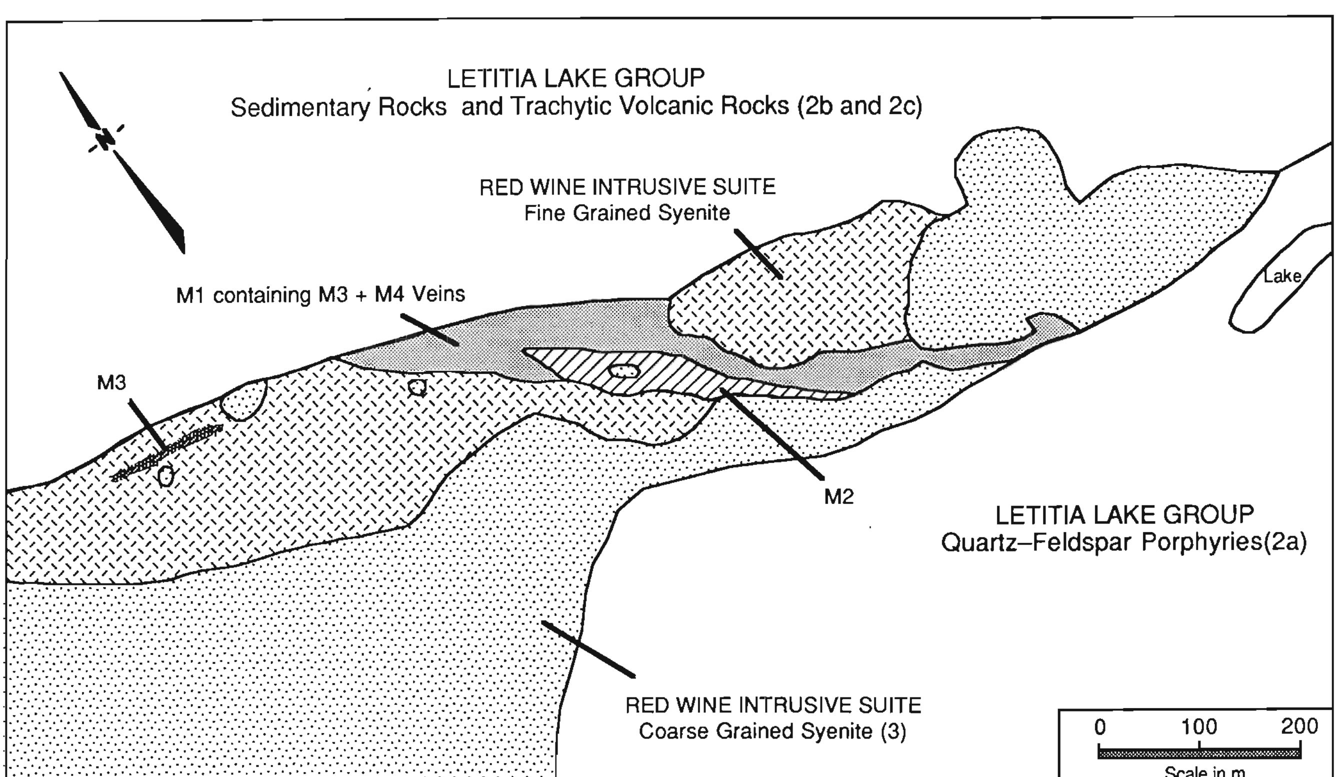


Figure 4: *Sketch map of the Mann #1 Nb–Be showing.*

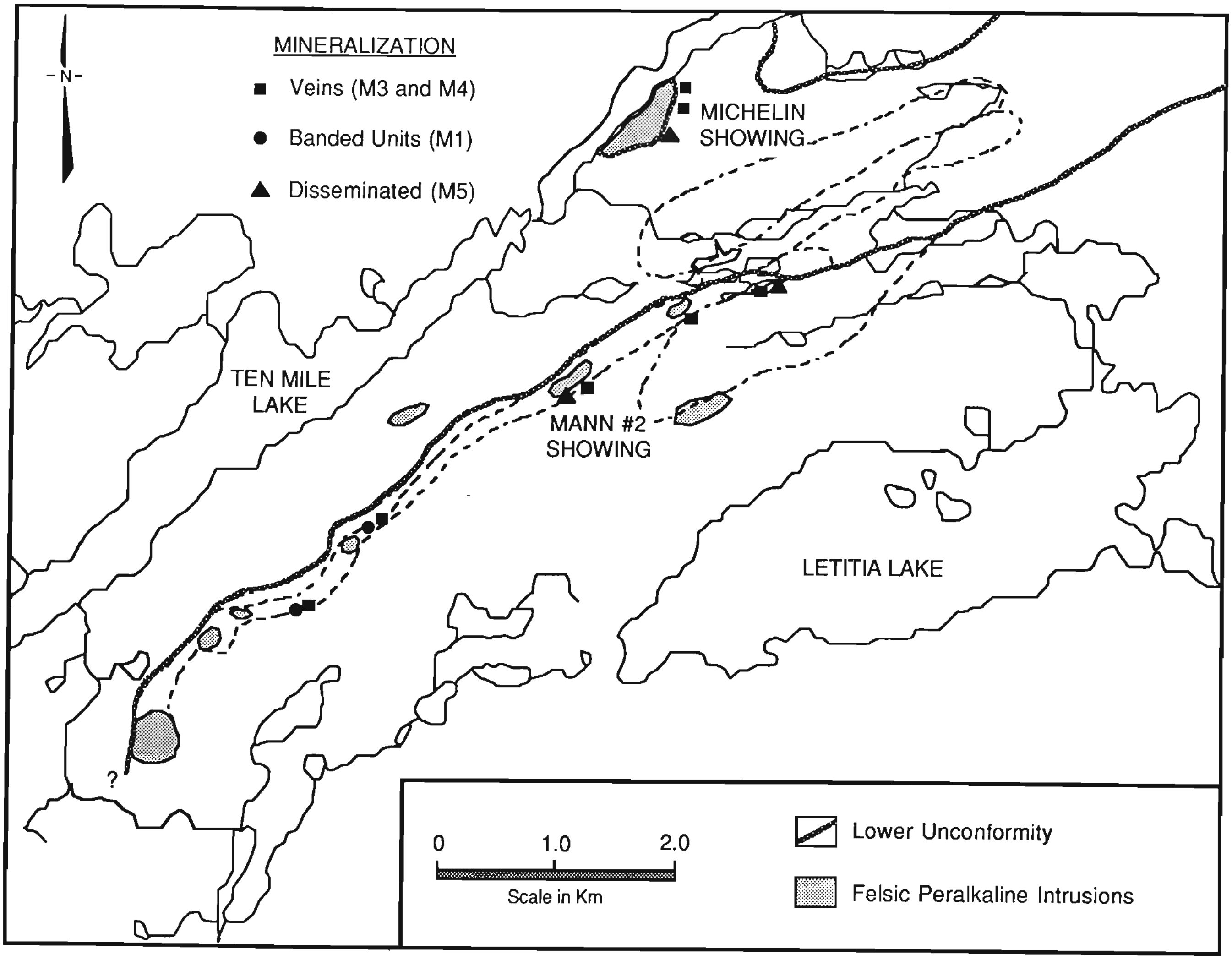


Figure 5: *Sketch map of the Mann #2 and Michelin Nb–Be showings; compare with western portion of Figure 2 to obtain the regional geological setting. Mineralization: veins–M3 and M4; banded units–M1; disseminated–M5. (See text for an explanation of the mineralization-mode classification.)*

(Brummer 1957). A third possibility is that this unit could be a metavolcanic unit of peralkaline-syenite affinity. A geochemical study to determine the origin of this mode of mineralization is in progress.

2) *Aegirine–feldspar, massive to foliated unit (Unit M2).* This relatively continuous unit locally contains quartz amygdules, and has been tentatively identified as a peralkaline volcanic rock. It appears to be conformable with Unit M1 and occurs south of it in all cases.

3) *Aegirine–feldspar veins (Unit M3).* Unit M3 occurs as 0.3- to 4-m-thick veins that appear to crosscut all syenite phases as well as the two massive mineralized units (Units M1 and M2). Some of the high-grade mineralization in the massive mineralized units may be due to metasomatism associated with the intrusion of the Unit M3 and Unit M4 veins.

4) *Albite-rich felsic veins (Unit M4).* Veins range in width from 0.1 to 4 m. They cut the syenitic phases and all other mineralized units, except the aegirine–feldspar veins. Units M3 and M4 are locally closely associated in composite veins.

The two conformable mineralized Units M1 and M2 bisect the syenite complex from east to west. Most of the veins of Units M3 and M4 occur within the mineralized conformable units or in the southern (stratigraphically lower in the regional sense) part of the syenite. The concentration of veins is so high in the zone, up to 100 m south of the conformable units, that they form interconnected branching networks in outcrop. Nb–Be mineralization has not been found within the Letitia Lake Group in the vicinity of the Mann #1 syenite.

Mann #2 Showing–Syenite Occurrences

Unlike the Mann #1 syenite, the Mann #2 syenite occurrences form small intrusive bodies that are less than 0.5 km long and 0.2 km wide (Figure 5). Mapping to date has located four small syenitic bodies and two nepheline-bearing bodies along the contact between the upper and lower units of the Letitia Lake Group over a distance of 7 km. Some of these units may be continuous, but large intervening areas of no exposure prevent a more certain interpretation. These peralkaline bodies occur at the same stratigraphic boundary as the Mann #1 syenite.

Mineralization associated with the Mann #2 showings is not as abundant as the Mann #1, but many of the same modes of mineralization occur. The most common styles of mineralization are the gneissic conformable units (Unit M1) and the aegirine–feldspar veins (Unit M3). In some localities, Nb–Be mineralization occurs without the commonly associated syenite.

The syenite outcrops are mostly medium grained, similar to those at the Mann #1 showing. The nepheline-bearing outcrops at the southwestern end of the zone do not appear to be associated with any mineralization; these outcrops contain nepheline syenite, malignite and ijolitic gneissic units.

Two Tom Lake Showing–Syenite

The Two Tom Lake syenite is a roughly circular body that has a diameter of approximately 2 km (Figure 6). Medium grained riebeckite syenite occupies the southern portion of this pluton, whereas the northern portion contains mineralized outcrops and some syenitic outcrops. This pluton occurs at the lower contact of the Bessie Lake Formation.

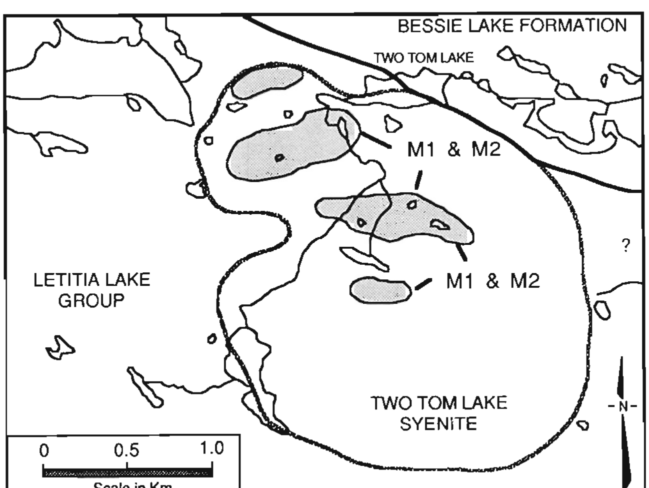


Figure 6: *Sketch map of the Two Tom Lake Nb–Be showing; compare with eastern portion of Figure 2 to obtain the regional geological setting. (See text for an explanation of the mineralization-mode classification.)*

The mineralized zone at this locality is almost exclusively banded, sheared or gneissic peralkaline rock of roughly syenitic composition (mineralized Unit M1); riebeckite, aegirine and feldspar are the major rock-forming minerals. In many instances, this mineralization is no different than that at the Mann #1 showing. In the Two Tom Lake showing, the mineralization occurs closest to the unconformity (base of the Bessie Lake Formation), whereas in the Mann #1 showing, only part of the mineralized unit occupies this position.

Michelin Showing–Syenite

The Michelin syenite (Figure 5) is an aegirine syenite that occupies an area of approximately 0.2 by 0.1 km. It occurs between the interpreted contact of the Bessie Lake Formation and the Letitia Lake Group (upper unit); tops are interpreted to be toward the north. Mapping in the area south of the Michelin syenite suggests that stratigraphic tops are toward the south. If this is the case, then the Michelin syenite is also at or near the contact between magmatic units and sedimentary units of the Letitia Lake Group. The complex folding and thrust faulting in this region (Thomas, 1981; Hibbs, 1980) and lack of outcrop are probably responsible for the apparently contradictory data.

Mineralization occurs disseminated in aegirine syenite or as felsic veins (Unit M4) in the syenite or nearby Letitia Lake Group sedimentary rocks.

CONCLUSIONS

The Nb–Be showings in the Letitia Lake area are hosted or closely associated with peralkaline, riebeckite- or aegirine-bearing syenites assigned to the Red Wine Intrusive Suite. The syenites that contain significant showings are located at, or very near to, the two unconformities at the top of the Letitia Lake Group. The unconformities mark the cessation of magmatic activity, both extrusive and intrusive, and the beginning of a cycle of erosion and sediment deposition. They are outlined in Figure 2, based on the compilation of the regional-mapping data and detailed mapping from this study. The best potential for Nb–Be mineralization occurs along this contact zone. (Several areas along this zone have not been properly explored or evaluated due to the poor exposure and lack of detailed mapping.) This preliminary exploration model can be used to outline targets for follow-up in the Letitia Lake area. The model could also be applied to occurrences of the Letitia Lake Group southwest of the study area.

Further study of the Letitia Lake Nb–Be showings will entail geochemical and petrographical study of the host syenites and non-mineralized syenites, as well as the mineralization itself. Geochemical data, in particular, will help better define the relationship between the various units of the Letitia Lake Group and the mineralization. It will also help to better determine the origin of the mineralization and help to build a geological–petrological model to aid in the exploration for similar mineralization.

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