METAMORPHIC PETROLOGY
OF THE BIRD LAKE AREA,
SOUTHEASTERN MANITOBA

A Thesis

Presented to

the Faculty of Graduate Studies

and Research

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In Partial Fulfilment

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Master of Science

by

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ABSTRACT

A total of 114 samples was collected from the Bird Lake and Cat Lake greenstone belts. Thin sections were made from 100 samples in order to determine mineral assemblages and textures. Chemical analyses were done on 25 samples to determine their bulk composition and its relationship to the mineralogy.

Five facies of metamorphism have been interpreted to be present in this area:

1. Albite-epidote hornfels facies
2. Hornblende-hornfels facies
3. Greenschist facies
4. Almandine-amphibolite facies (a. with epidote)
5. Almandine-amphibolite facies (b. without epidote)

Facies one and two are products of a first period of thermal metamorphism. A second period of metamorphism, dyamo-thermal type, produced facies three, four and five as well as a regional foliation that is parallel to the original bedding. A third period of metamorphism, dynamic type, produced a poorly developed secondary foliation and shears along which chlorite formed.

A gradient of intensity of deformation exists in this area. Recrystallization was greatest in the east and quartz-mica schists were developed. In the west the foliation is not well developed and the rocks have retained many of their original sedimentary features.

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CHAPTER I

INTRODUCTION

The scope of this work is to study the metamorphism of the Bird Lake and Cat Lake greenstone belts in the area shown in Figure 1. Also, it is the aim of the author to relate the metamorphism to the period of granitic intrusion and regional tectonism.

Due to the large area under study the amount of field mapping was limited. A total of 73 samples was collected from the Bird Lake greenstone belt (see Sample Location Map, in pocket). Sampling was done along the strike of this belt and along traverses across the strike in order to determine metamorphic variations in both directions.

Sampling in the Cat Lake extension of the Bird Lake greenstone belt was restricted to four localities, where 39 samples were collected (see Sample Location Map, in pocket).

PREVIOUS WORK

Geological investigations of the Cat Lake-Winnipeg River area have been made from 1912 when E. S. Moore of the Geological Survey of Canada first made a reconnaissance survey of the water routes. In 1920, H. C. Cooke mapped a small area in the vicinity of Bird Lake. Between 1922 and 1929 the area around Bird River was surveyed by J. F. Wright and many of the pegmatite deposits in this area were discovered. In 1948-1949, G. D. Springer of the Manitoba Mines

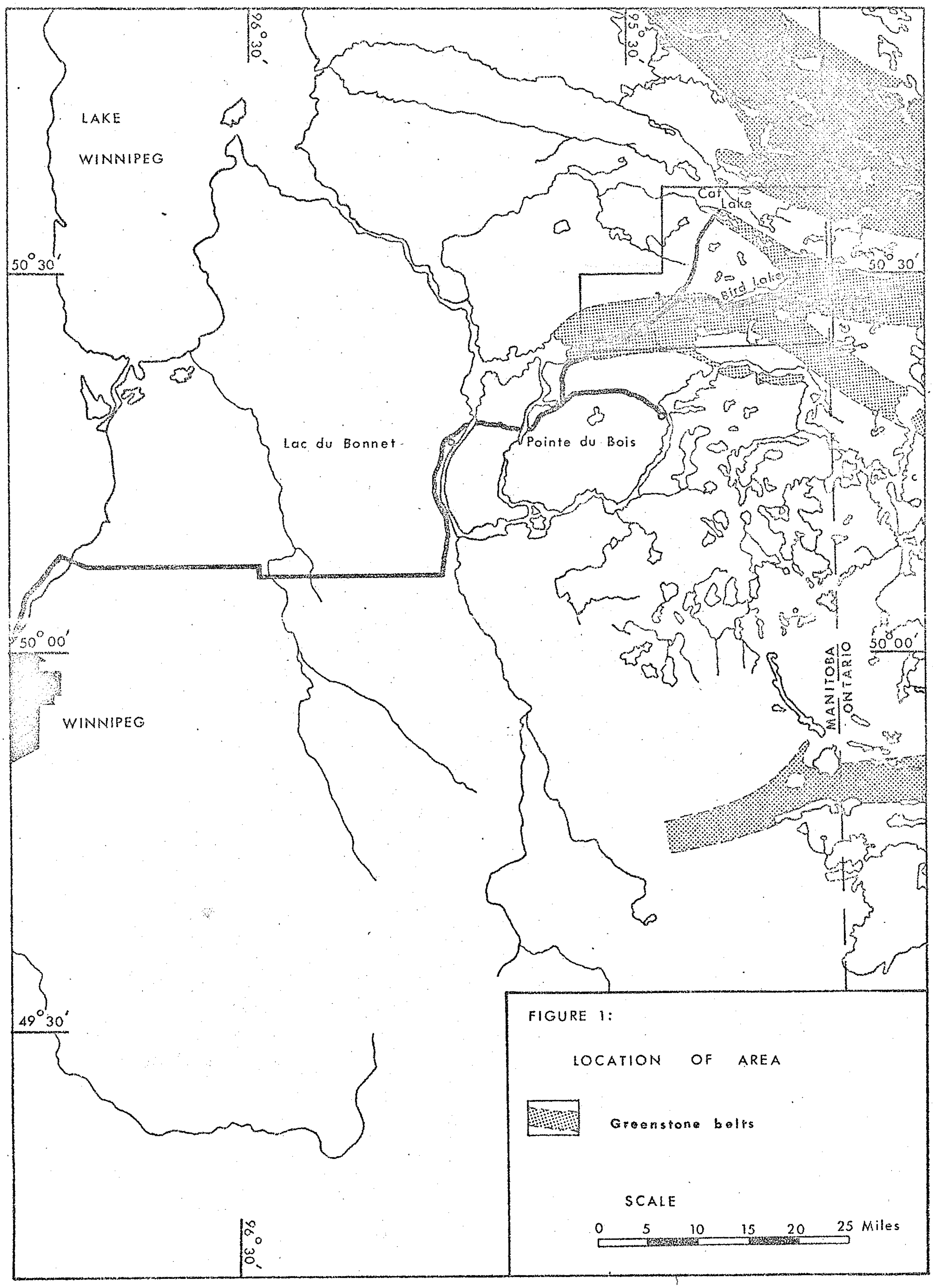


FIGURE 1:

LOCATION OF AREA

Branch mapped the area between Maskwa Lake and the Winnipeg River.

The area between latitudes 50° 25' and 50° 30' and longitudes 95° 10' and 95° 45' was mapped by J. F. Davies of the Manitoba Mines Branch (1951, 1954, and 1955).

K. Dwibedi of the University of Manitoba sampled along the road between Bird Lake and Werner Lake. He found sillimanite occurring in the rocks in the vicinity of Werner Lake. His work provided a basis for this present study.

ACKNOWLEDGEMENTS

The author wishes to express his appreciation to the Geological Survey of Canada for providing funds (grant number 40-66), for the field work. Also, the author wishes to thank the University of Manitoba Department of Earth Sciences for its help in preparing thin sections and doing the chemical analyses. Special appreciation is given to Miss I. Berta who prepared the thin sections and to K. Ramlal and R. Hill who did the chemical analyses.

The author wishes to express his appreciation to Dr. A. C. Turnock for his assistance during the writing of this thesis. Valuable assistance was also given by Dr. W. D. McRitchie of the Manitoba Mines Branch.

The author also acknowledges Drs. J. F. Davies and K. Dwibedi whose work provided a valuable basis for this thesis.

CHAPTER II

REGIONAL GEOLOGY

The regional geology of this area is shown in Figure 2. All consolidated rocks in this area are Precambrian (Archean) in age (Davies, 1952). The oldest rocks are a volcanic-sedimentary sequence comprising the Rice Lake Group. These rocks outcrop in an east-west trending belt along the Bird River and Bird Lake. A narrower belt splits off and extends northwesterly from Tulabi Lake to Cat Lake. Rocks comprising the Rice Lake Group are andesite, basalt, greywacke, arkose, quartzite and conglomerate. These rocks have undergone various degrees of metamorphism as described in Chapter III.

Intrusive into the Rice Lake Group is the Bird River Sill. This is a layered, sill-like body of hornblende-gabbro, peridotite and minor pyroxenite. The apparent width of the sill varies from 500 feet to 3500 feet and the peridotite forms the lower one-quarter to one-half of the sill (Springer, 1950).

Davies (1952), believes that the idea of a single sill is erroneous. This is substantiated by the fact that he has been able to trace out several sill-like bodies in the west-central part of the area.

The area between the greenstone belts at Bird Lake and Cat Lake is underlain by granitic rocks. Granitic rocks also occur to the north and south of these two greenstone belts. The granitic rocks

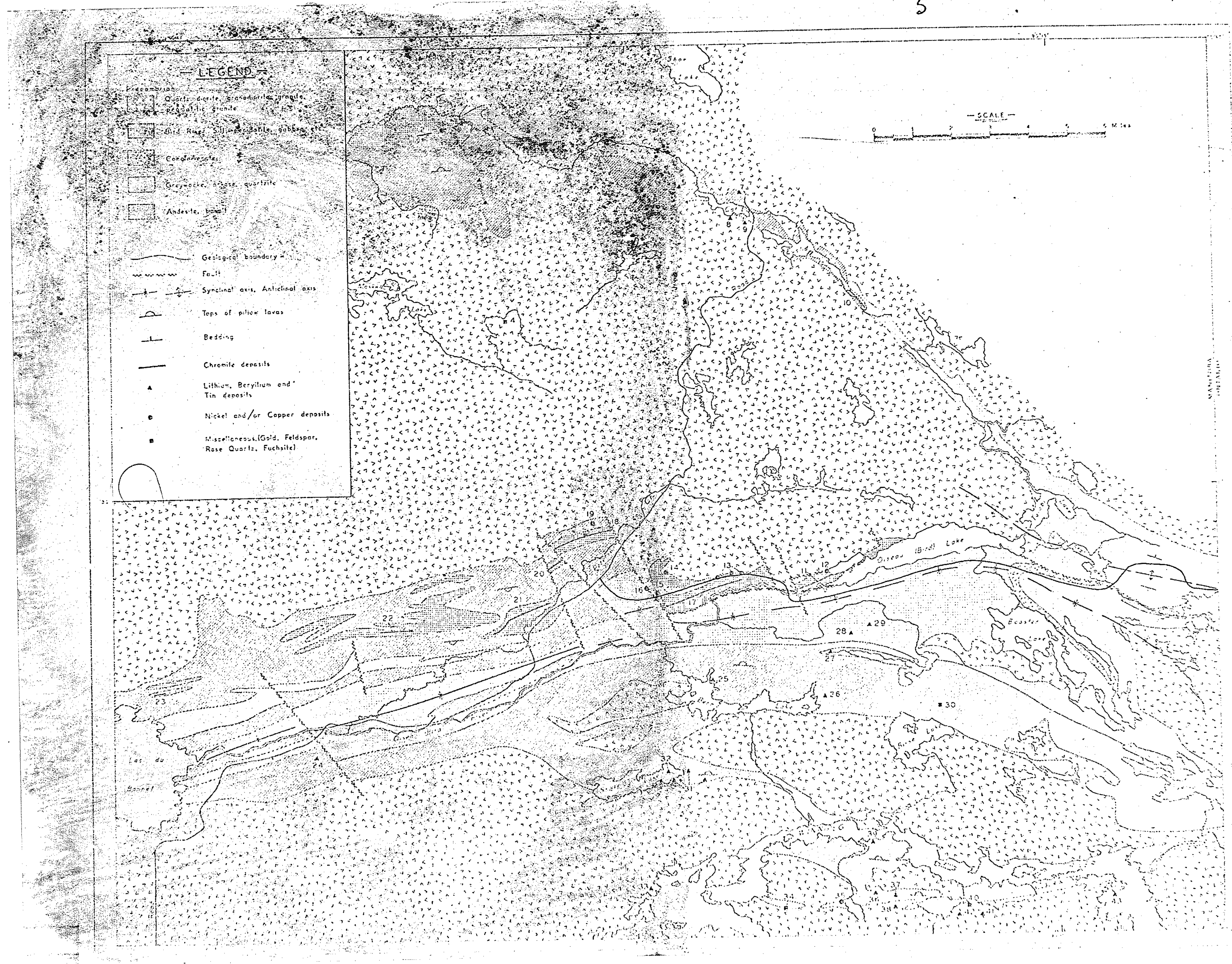


Figure 2: Geology of Cat Lake - Bird River - Winnipeg River Area.
(from Davies, et al, 1962)

include granite, grey biotite granite, quartz diorite, oligoclase granite, microcline granite and pegmatite. All granitic types are probably successive phases of the same period of igneous activity. Davies (1952), believes that there was no great interval of time between different intrusions.

Detailed descriptions for the rock types are given in Appendix I.

Both pillow lavas and structural features in the sedimentary rocks have been used to determine the structure of this area. The major structural feature is a synform-antiform pair of folds. This major fold structure has a south-easterly plunge. In the western part of the area, the rocks north of the Bird River constitute the southern limb of the antiform. The northern limb of this fold is located in the belt of rocks extending from Tulabi Lake to Cat Lake. The synform is restricted to the southern greenstone belt. In the east this synform is outlined by a conglomerate horizon but in the west the location of this fold is not precisely known. Both of these folds extend in a northwesterly-southeasterly direction across the study area.

Smaller scale synform-antiform pairs of isoclinal folds occur in the eastern area. Intraformational folds and small scale drag folds are present in the central area.

An east-west trending fault in the south-central part of the area marks the contact between the granite and sedimentary rocks and the contact between the Bird River Sill and the sedimentary rocks. This fault post-dates the granite. Evidence supporting this interpretation is that a cataclastic texture can be seen in the granite where it abuts against the fault.

Later, north-south trending faults cut the east-west fault, bedding and the regional foliation of the greenstone belts. These faults have displaced diabase dykes in the granitic rocks. Where these faults occur in the granite a cataclastic texture is present.

CHAPTER III

METAMORPHIC PETROLOGY

Sequence of Metamorphic Events:

In the Bird Lake and Cat Lake greenstone belts there are changes in textures, mineral assemblages and grain size from west to east. There are very fine-grained metagreywackes in the western and central areas, which continue into fine to medium-grained, quartz-mica schists and gneisses in the eastern area. In the western and central areas original bedding is still preserved. Further eastward there is a general increase in schistosity, and grain size, and bedding is almost totally absent. Locally, at or near the Manitoba-Ontario boundary a gneissosity is present.

In these metasedimentary and metavolcanic rocks, the mineral assemblages can be interpreted to have developed into five facies of metamorphism, viz:

1. Albite-epidote hornfels facies
2. Hornblende-hornfels facies
3. Greenschist facies
4. Almandine-amphibolite facies (a: with epidote)
5. Almandine-amphibolite facies (b: without epidote)

An initial period of thermal metamorphism (TM_1), produced facies one and two. The second period of metamorphism, which was dynamo-thermal metamorphism (DM_2), produced facies three, four, and five. Another period of dynamic metamorphism (DM_3), produced a weak secondary foliation, deformation of the regional foliation, cross-shearing and resulted in the growth of chlorite, with or without sericite, along the shears.

These conclusions are based on the interpretation of mineral and textural arrangements and their sequence of developement. Porphyroblasts of garnet, cordierite and plagioclase have been rolled, sheared and fractured during the second period of metamorphism (DM_2). The third period of metamorphism (DM_3), is represented by a poorly developed secondary, almost north-south foliation and a set of shears and faults that cut the regional east-west foliation.

Pegmatite bodies in this area are genetically related to the larger granitic plutons (Davies, 1955, 1956 and Wright, 1963). These pegmatite bodies which represent a late stage crystallization of these granitic plutons or a post granite stage of igneous activity have intruded the metasedimentary and metavolcanic rocks in this area. These pegmatite bodies have been sheared, faulted (Figure 3), shear-folded (Figure 4), and otherwise deformed. Where pegmatite veinlets are parallel to the original bedding, boudinage structure (Figure 5), is present. In the vicinity of granite plutons a foliation is present in the granitic injections in the metasedimentary rocks. These granitic injections have undergone retrograde metamorphism as the plagioclase has been partially altered to sericite, chlorite and calcite. It can be concluded that these granitic rocks were intruded into the metasedimentary and metavolcanic rocks prior to the second period of metamorphism (DM_2), and have been

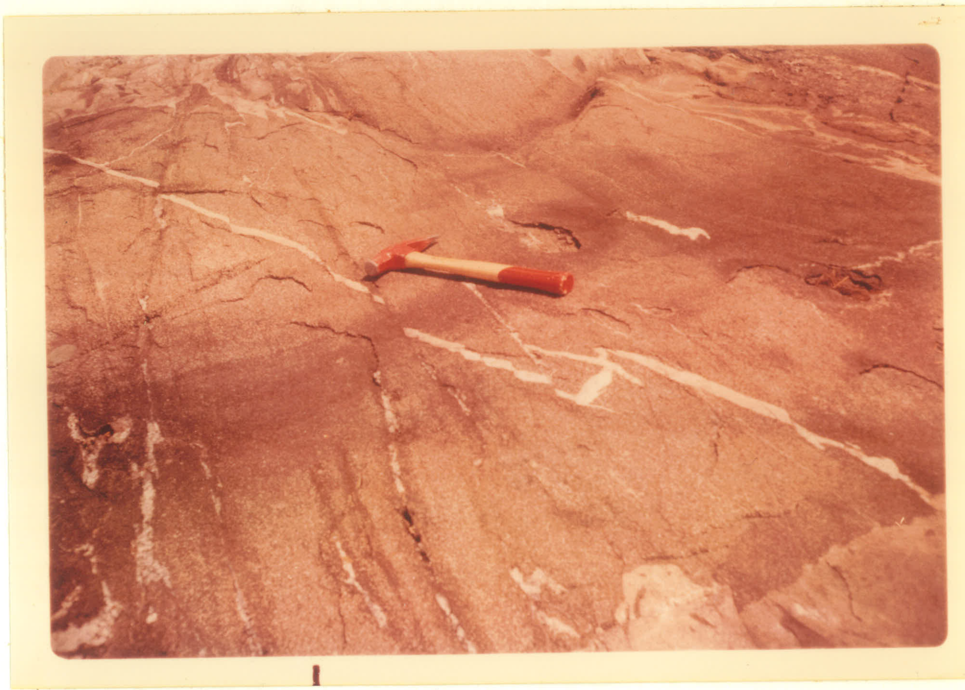


Figure 3: Late stage faulting of pegmatite and amphibolite, north shore of Bernic Lake.

Figure 4: Shear folding of pegmatite, north of Bernic Lake.

Figure 5: Rolled pegmatite boudins in the Cat Lake greenstone belt.

deformed by it.

Diabase dykes intrude both the granite and metasedimentary rocks. Where these dykes are present in the metasedimentary rocks they have been sheared, faulted and folded.

The first period of metamorphism (TM_1), was essentially thermal metamorphism. During this period porphyroblasts of albite, cordierite and garnet were formed. These albite, cordierite and garnet porphyroblasts commonly have rolled structures. Where they have been fractured, quartz, chlorite and/or sericite have grown.

Porphyroblasts of cordierite are subrounded in shape. These porphyroblasts contain inclusions of quartz, biotite, chlorite and magnetite. Occasionally the magnetite inclusions form distinct zones in the cordierite porphyroblasts. These magnetite zones in the cordierite porphyroblasts have no helicitic structure whereas the magnetite in the matrix does have a helicitic structure (Figure 6). The cordierite porphyroblasts were formed prior to the deformation period.

At Cat Lake, porphyroblasts of albite have been rotated and sheared (Figure 7). As a result of this later shearing, twin lamellae have been displaced and quartz has grown along the shear.

Garnet porphyroblasts at Tulabi Lake have been fractured. These fractures are parallel to the regional foliation. Chlorite has grown in the matrix and through these fractures (Figure 8).

The second period of metamorphism (DM_2) was a dynamo-thermal type. This produced a regional foliation (strike, azimuth 85^o-105^o) parallel to the original bedding in the sedimentary rocks and the

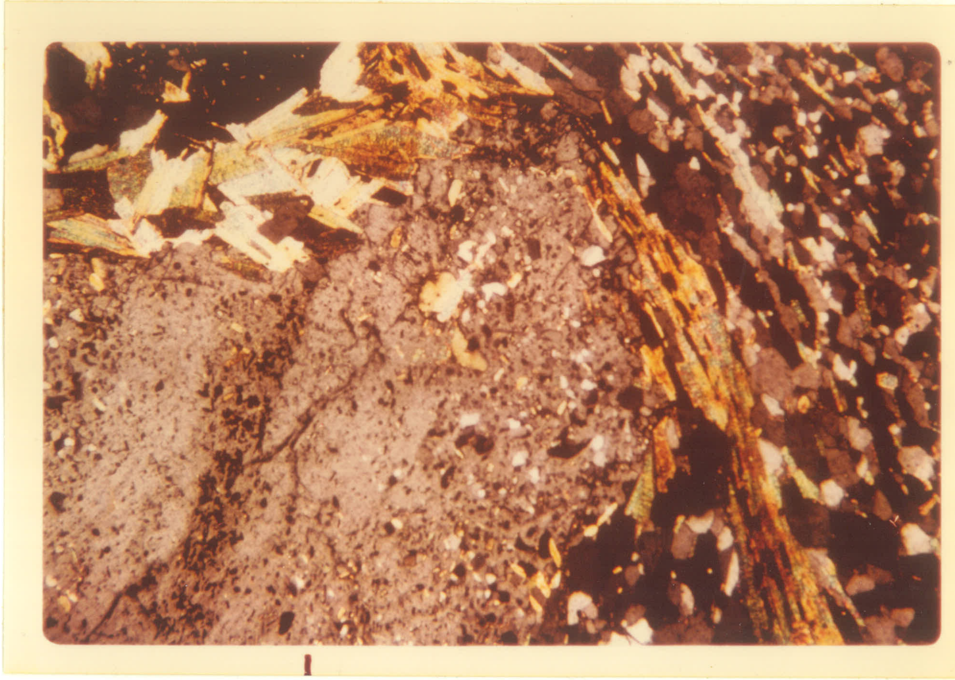


Figure 6: Zoned magnetite inclusions in a rolled porphyroblast of cordierite, SB68-12 (photomicrograph, low power).

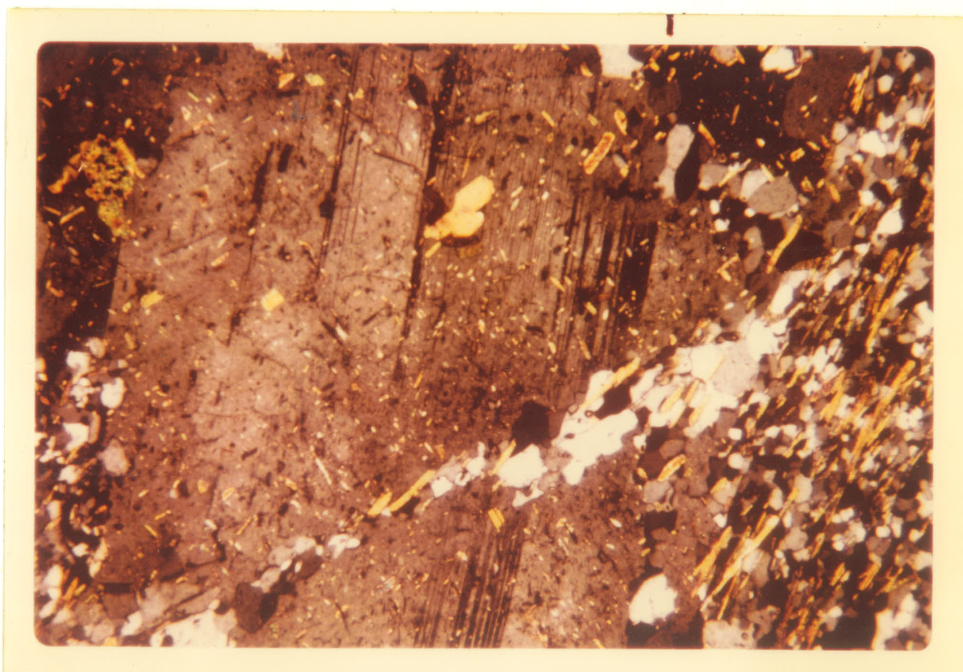


Figure 7: Sheared albite porphyroblast with displacement of twin lamellae, SB68-7 (photomicrograph, low power).

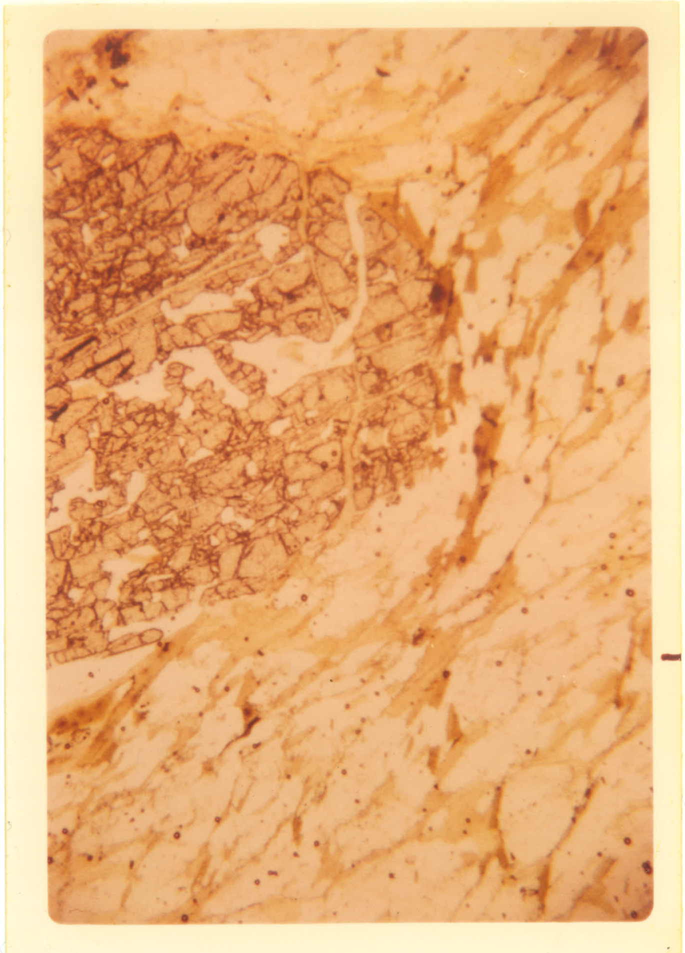


Figure 8: Rolled, garnet-porphyroblast showing late fractures and the growth of chlorite along these fractures, SB68-23 (photomicrograph, medium power).

original layering in the volcanic rocks. Dynamic-metamorphic effects were greatest in the eastern region, where quartz-mica and hornblende schists were developed (Figure 9). In contrast, in the western and central regions of this area these dynamic-metamorphic effects were minimal and relict bedding is still preserved (Figure 10). Also, where the volcanic rocks have been protected, pillow structures have not been deformed or foliated and there has been no recrystallization of these pillow structures.

Along the Bird River in the western region there has been low grade cataclastic deformation (DM_2). The plagioclase still retains a zonal appearance (Figure 11). There is some mortar structure and some rotation of the larger plagioclase crystals.

In the central area of the Bird Lake greenstone belt and at the western end of the Cat Lake greenstone belt this second period of metamorphism has been one of retrograde metamorphism. North of Bernic Lake there is the retrograde reaction of cordierite to sericite and magnetite (Figure 12). Turner and Verhoogen (1960, p.591), point out that white mica, pseudomorphic after cordierite, is indicative of a period of thermal metamorphism preceding hydrothermal or regional metamorphism. At the second Bird River Bridge (located approximately 2 miles west of Bird Lake) chlorite has formed along fractures in the cordierite porphyroblasts (Figure 13). The retrograde formation of chlorite from biotite is rare in this area.

At Cat Lake there is the formation of chlorite along twin planes and fractures in the albite porphyroblasts. Plagioclase in the central area is more commonly altered to sericite, epidote and calcite. This is in contrast to the plagioclase east of Bird Lake

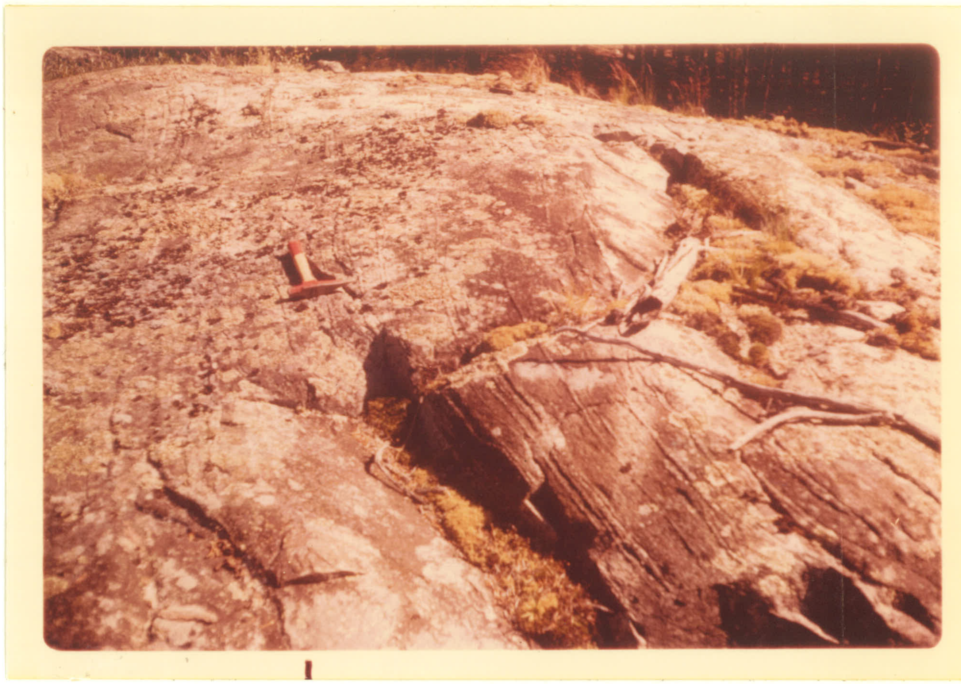


Figure 9: Quartz-mica schist, east of Star Lake.

Figure 10: Relict bedding in the greywacke, north of Bernic Lake.

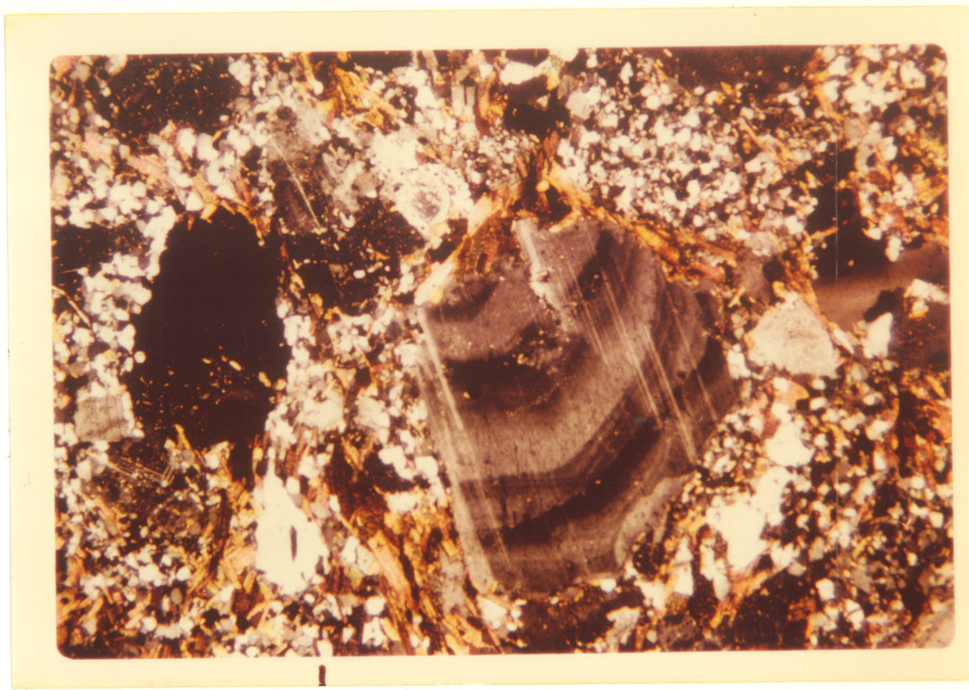


Figure 11: Zoned plagioclase that has been rolled and fractured, western end of the area, SB68-104 (photomicrograph, low power).

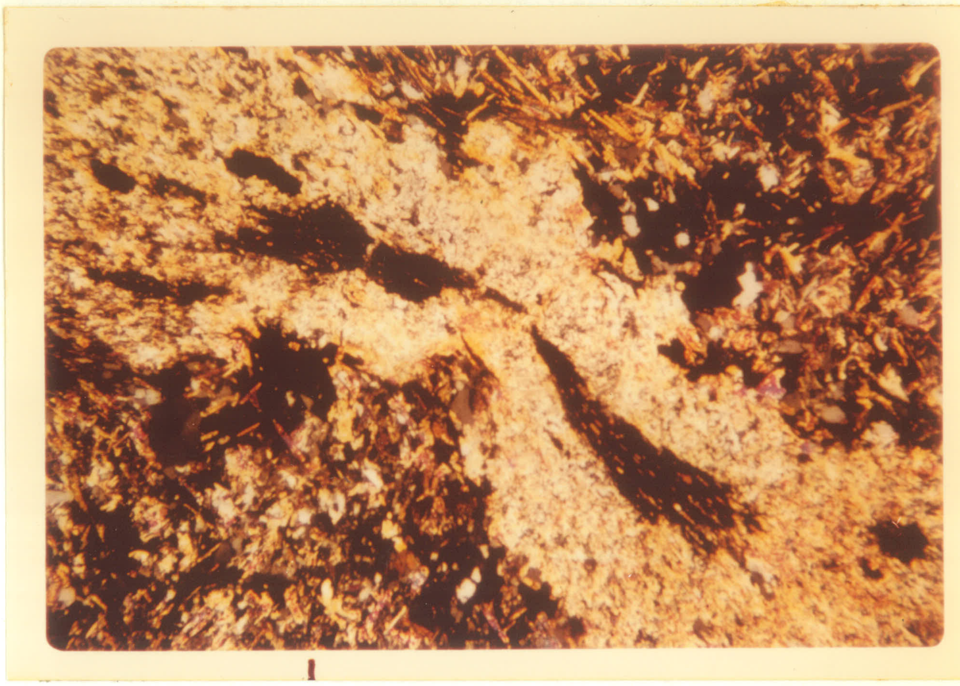


Figure 12: Retrograde formation of sericite and magnetite from cordierite, BE-2-4A (photomicrograph, low power).

Figure 13: Retrograde formation of chlorite from cordierite, SB68-87 (photomicrograph, low power).

where it is free of alteration except in the vicinity of granite contacts.

In the eastern region, dynamic-metamorphic effects were more intense. Textures and minerals formed during the period of thermal metamorphism (TM_1) are almost entirely destroyed by recrystallization and the development of the regional foliation. Only in a few places is there any relict bedding present (Figure 14). In a few places a gneissic structure has been developed in the sedimentary rocks near the eastern boundary of the area.

Hornblende in the eastern region is mainly poikiloblastic (Figure 15), as compared to a bladed or fibrous appearance in the central and western regions. Crystals of hornblende are euhedral to subhedral in the eastern region as compared to the subhedral to anhedral nature of hornblende crystals in the western and central regions. Hornblende in the eastern region has a preferred orientation that is parallel to the regional foliation.

At the Manitoba-Ontario boundary, the eastern boundary of the area, biotite has partially reacted to form hornblende. The excess titanium in the biotite has gone into the formation of sphene. Where chlorite is present it is in a stage of reaction to biotite.

Following this dynamo-thermal metamorphism (DM_2), where chemical conditions were favourable, anthophyllite formed. This is a late stage mineral, as it cuts across the regional foliation and previously formed cordierite porphyroblasts (Figure 16).

The <u>third period of metamorphism</u> (DM_3) was a dynamic-metamorphic type and occurred in only restricted localities. The major north-south faults, west of Bird Lake, were formed during this

Figure 14: Relict bedding in the quartz-mica schist, east of Star Lake.

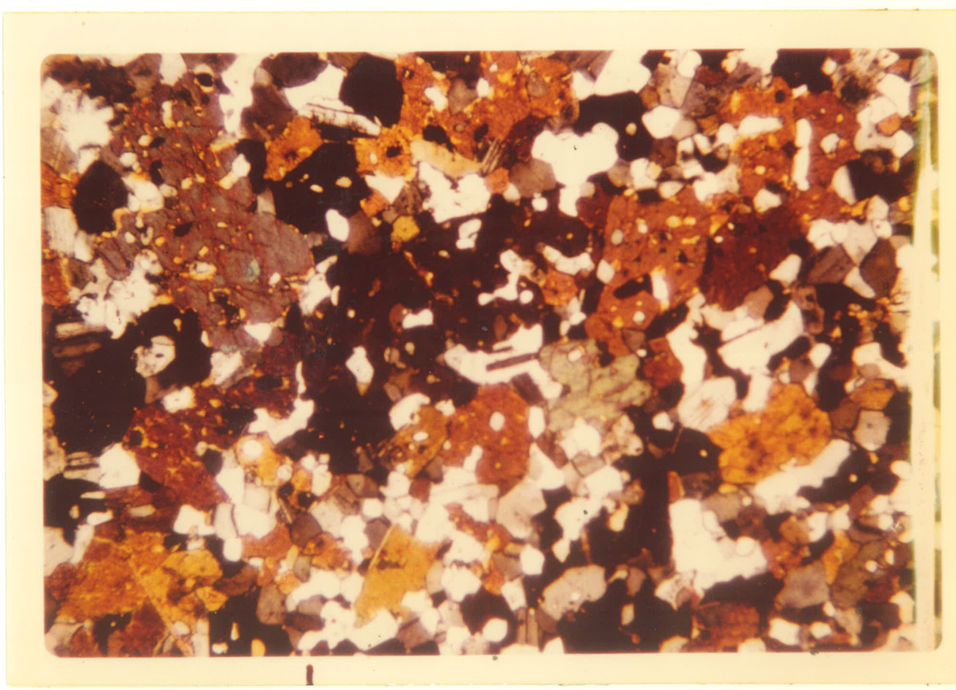


Figure 15: Poikiloblastic hornblende from the Manitoba-Ontario boundary. SB68-55 (photomicrograph, low power).

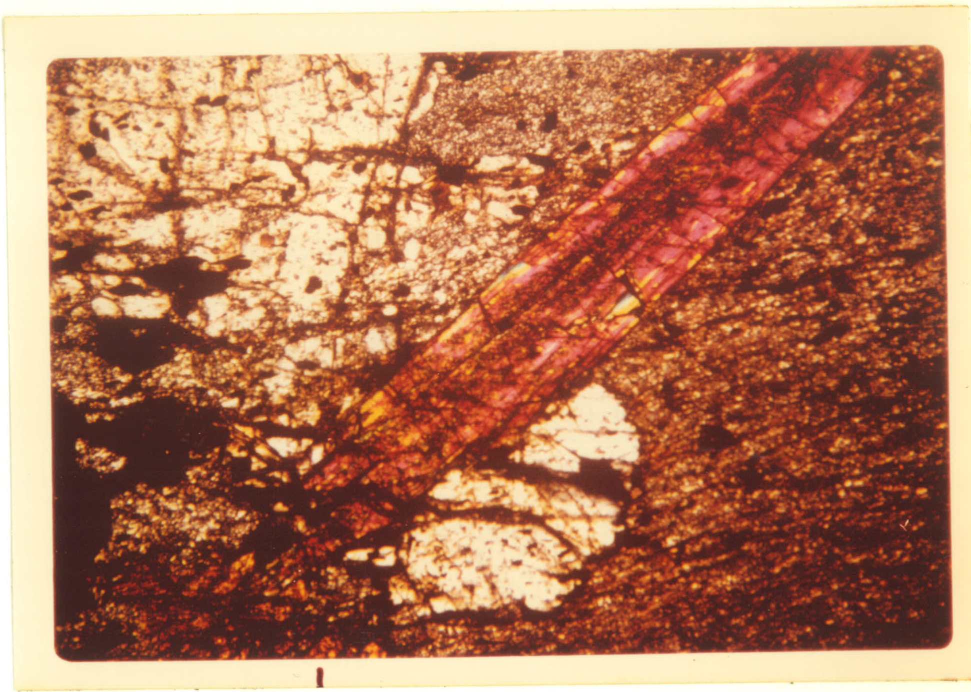


Figure 16: Blade of anthophyllite cutting through a previously formed cordierite porphyroblast, SB68-86 (photomicrograph, low power).

period of metamorphism. At locations SB68-(89, 49, 81), a weak secondary foliation was produced in the metasedimentary rocks. The second deformational period has produced a secondary foliation, which has a north-south orientation or has caused a kinking of the regional foliation (Figure 17). This period of metamorphism was probably accompanied by a high P_{H_2O}, enabling chlorite, with or without sericite, to form along the shears.

Facies of Metamorphism:

The five facies of metamorphism shown in Figure 18, were defined from the mineral assemblages that appear to represent the culmination (in terms of temperature), of all metamorphic events.

Albite-epidote Hornfels Facies:

The metasedimentary and metavolcanic rocks at Cat Lake (samples 4 to 9, Sample Location Map), have undergone albite-epidote hornfels facies metamorphism (as defined by Turner and Verhoogen, 1960, p. 510). Mineral assemblages are listed in Table 1. The albite (An_5) and cordierite are present as subhedral and anhedral porphyroblasts respectively.

The mineral assemblages are shown in Figure 19. Only one sample SB68-7, is plotted on the basis of a chemical analysis (see Appendix II).

This facies of metamorphism has been overprinted but not obliterated by two later periods of metamorphism (DM_2 and DM_3). They have produced two foliation that have been superimposed on the hornfels texture. The main or regional foliation (strike,

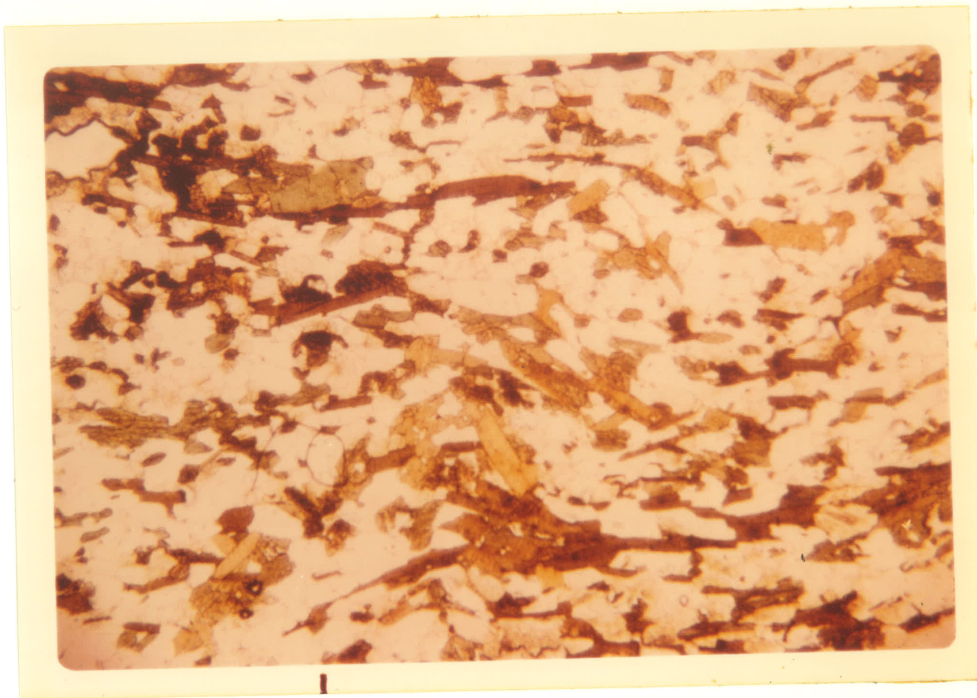


Figure 17: Deformation of regional foliation, formed during DM_2, by dynamic effects during DM_3, SB68-81 (photomicrograph, low power).

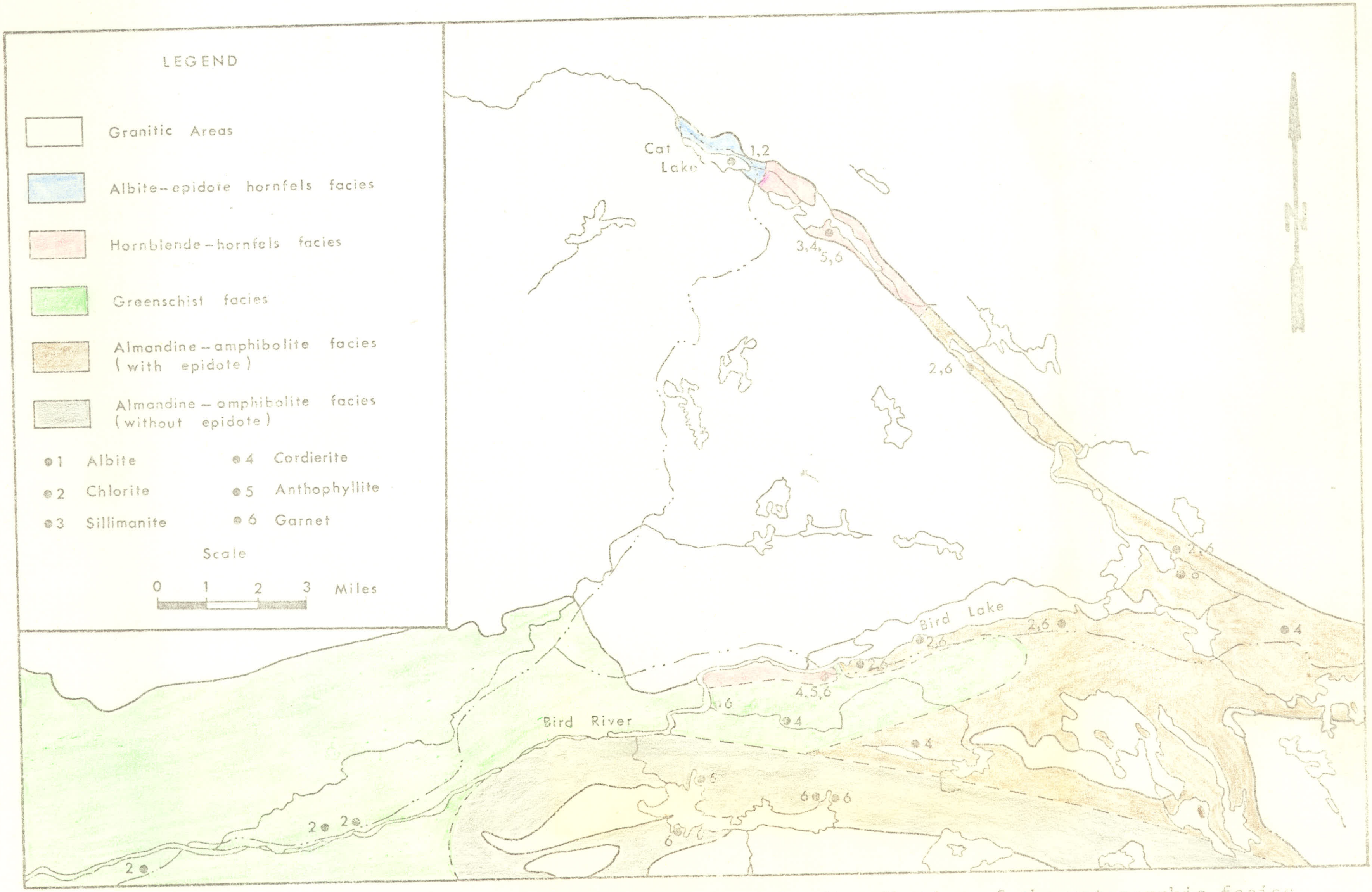
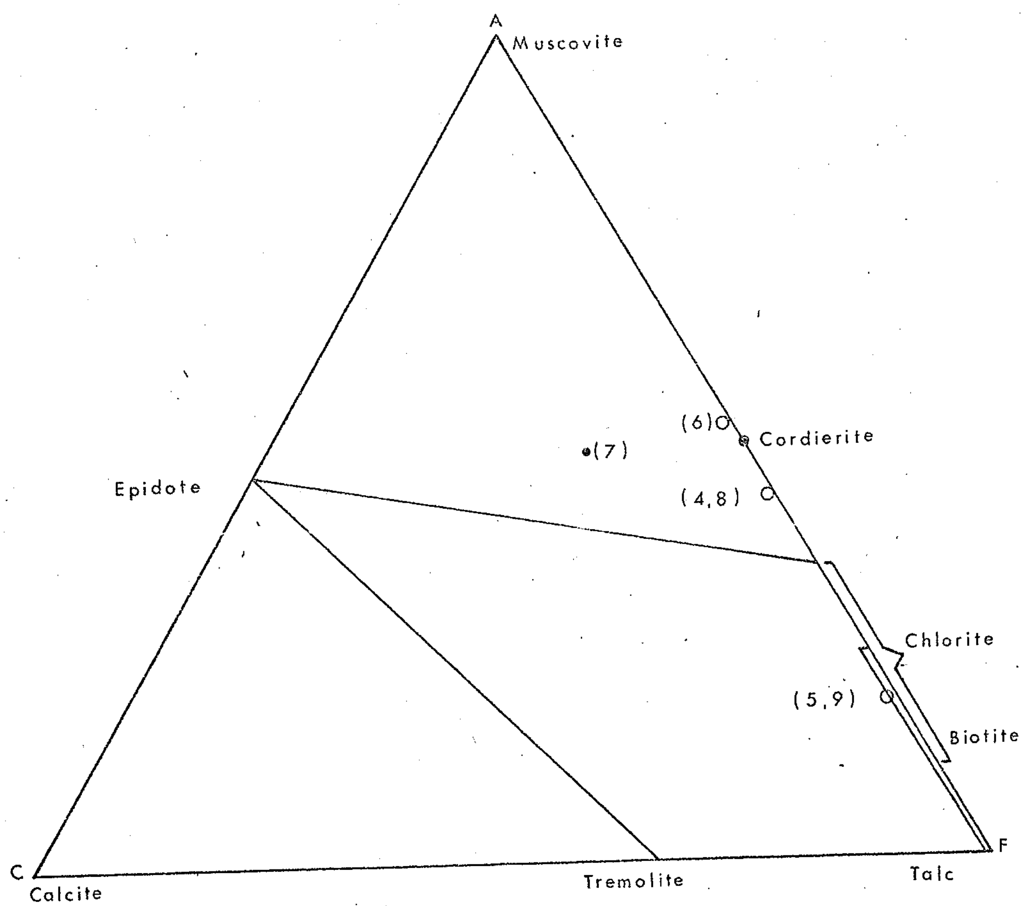


Figure 18: Map of the Bird Lake and Cat Lake area showing the distribution of the metamorphic facies.

Table 1: Mineral assemblages of samples SB68-(1-9), Cat Lake.

Sample Number	Mineral Assemblage
Metavolcanic Rocks:	
SB68-(1, 2)	Quartz-hornblende-plagioclase-biotite
SB68-3	Quartz-hornblende-plagioclase-sphene
Metasedimentary Rocks:	
SB68-(4, 8)	Quartz-biotite-muscovite-chlorite
SB68-(5, 9)	Quartz-biotite-albite-chlorite-muscovite
SB68-6	Quartz-biotite-muscovite-cordierite
SB68-7	Quartz-biotite-muscovite-chlorite-albite-epidote-calcite



• Point plotted on basis of chemical analysis

o Points plotted on basis of mineral assemblages

Figure 19: ACF diagram for the albite-epidote hornfels facies.

azimuth 120^{o}) is the result of shearing and crosses the original bedding at an angle of approximately 30^{o}. This shearing has resulted in the partial granulation of the albite porphyroblasts. The foliation produced by this shearing also cuts through quartz stringers (Locality SB68-6) that are present in the metasedimentary rocks.

A diabase dyke present in this area has been shear folded. Essentially all of the diabase dykes in the area are post granite, so it is probable that this shearing occurred after the intrusion of the granite and is a secondary feature which has been supterimposed on these rocks after the main period of thermal metamorphism.

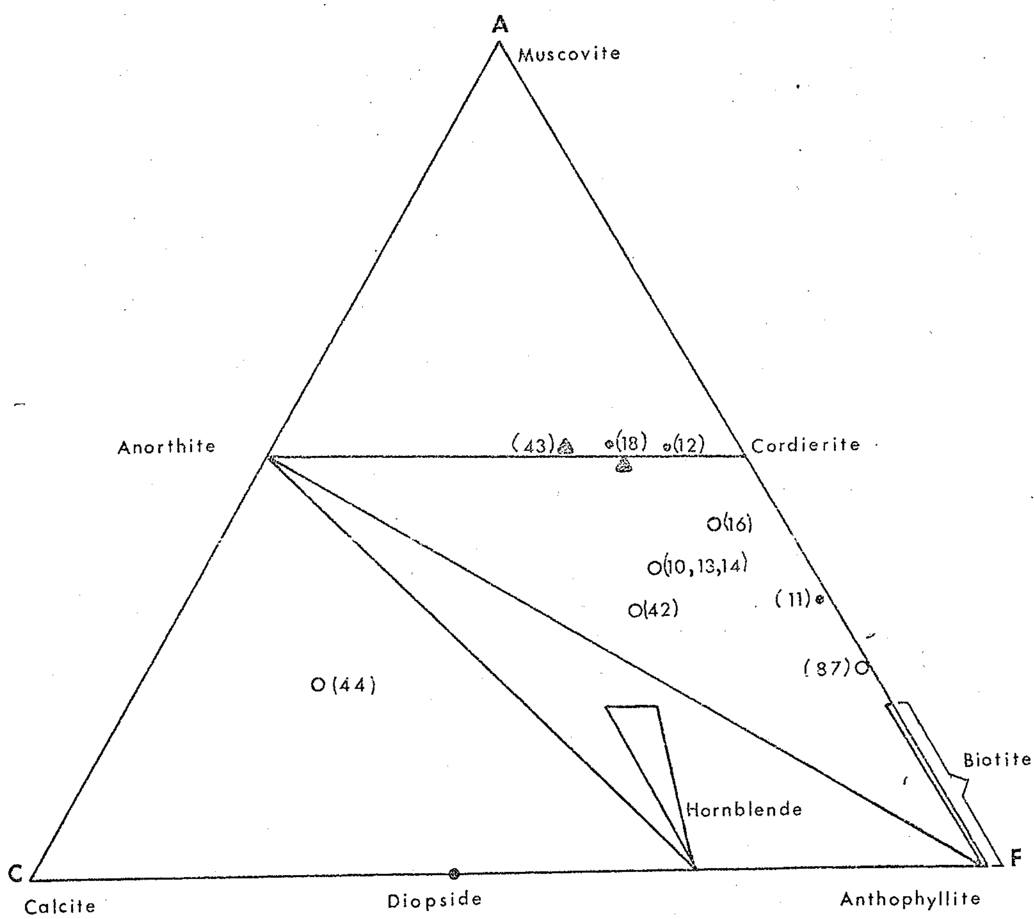
The secondary foliation occurs at almost 90^{o} to the regional foliation and is the north-south direction of deformation, interpreted as the result of DM_3. It is not well developed, but where it is present it has caused the bending of the regional foliation.

Hornblende-hornfels Facies:

The metasedimentary rocks at Euclid Lake and the second Bird River Bridge are assigned to the hornblende-hornfels facies (as defined by Turner and Verhoogen, 1960, p. 511). Mineral assemblages are listed in Table 2, and plotted on the ACF diagram for the hornblende-hornfels facies (Figure 20). Four samples are plotted on the basis of bulk chemical analyses (Appendix II). Two of the samples (SB68-12 and 18), from Euclid Lake fall into the three phase field indicating that cordierite, oligoclase and muscovite are in equilibrium. The third sample (SB68-11), is an anthophyllite rock, rich in MgO (see Appendix II). One sample (SB68-86), from the second Bird River Bridge falls into the three phase field indicating that cordierite, oligoclase and anthophyllite are in equilibrium. The

Table 2: Mineral assemblages at Euclid Lake, SB68-(10-18) and in the hornblende-hornfels area at the second Bird River Bridge, SB68-(40-45 and 85-87). Minerals in parentheses are retrograde minerals or minerals that have formed during DM_2.

Sample Number	Mineral Assemblage
SB68-10	Quartz-biotite-plagioclase-chlorite-cordierite
SB68-11	Anthophyllite-quartz-plagioclase-biotite
SB68-12	Quartz-biotite-plagioclase-cordierite
SB68-13	Quartz-biotite-plagioclase-cordierite-(chlorite)
SB68-14	Quartz-biotite-plagioclase-muscovite-cordierite-(chlorite)
SB68-15	Quartz-muscovite-biotite-hornblende-chlorite
SB68-16	Quartz-biotite-cordierite-plagioclase-muscovite-(chlorite)-(sillimanite)
SB68-18	Quartz-biotite-plagioclase-cordierite-muscovite-(chlorite)
SB68-(40, 43)	Quartz-biotite-plagioclase-diopside-epidote-calcite
SB68-41	Quartz-biotite-hornblende-calcite-epidote
SB68-42	Quartz-biotite-plagioclase-chlorite
SB68-44	Diopside-calcite-quartz-plagioclase
SB68-86	Quartz-biotite-cordierite-anthophyllite-muscovite-(chlorite)±garnet
SB68-87	Quartz-biotite-cordierite-anthophyllite-(chlorite)



- • Euclid Lake (Points plotted on basis of chemical analyses)
- ▲ Second Bird River Bridge (Points plotted on basis of chemical analyses)
- o Points plotted on basis of mineral assemblages

Figure 20: ACF diagram for the hornblende-hornfels facies.

second sample (SB68-43), falls into the three phase field indicating that cordierite, oligoclase and muscovite are in equilibrium.

Sillimanite is restricted to a single locality (SB68-16), at Euclid Lake. This sillimanite has a felty or fibrous, microlitic appearance (Figure 21). It is restricted to the more highly sheared zones in the rocks. This sillimanite formed during the second period of metamorphism (DM_2), and appears to have formed from cordierite and biotite. Also, there is a symplectic intergrowth of quartz and feldspar along the shears in the rock.

Diopside is present at the second Bird River Bridge. At this location diopside along with calcite forms a distinct layer in the metasedimentary rocks. This layer is approximately two feet wide and is composed of coarse-grained diopside and calcite. Interstitial quartz and plagioclase are also present. The assemblage diopside-calcite-quartz-plagioclase is characteristic of the hornblende-hornfels facies (Winkler, 1965). A cordierite-anthophyllite assemblage is also present but occurs approximately 500 feet south of the diopside zone.

Chlorite in samples SB68-16, 86, 87, 42, is retrograde after biotite or cordierite.

A discussion of the occurence of garnet in the hornblende-hornfels facies is given later.

Figure 22 is a Thompson diagram for the hornblende-hornfels facies. The bulk compositions (see Appendix II), fall into three fields on this diagram. The three phases that are present are

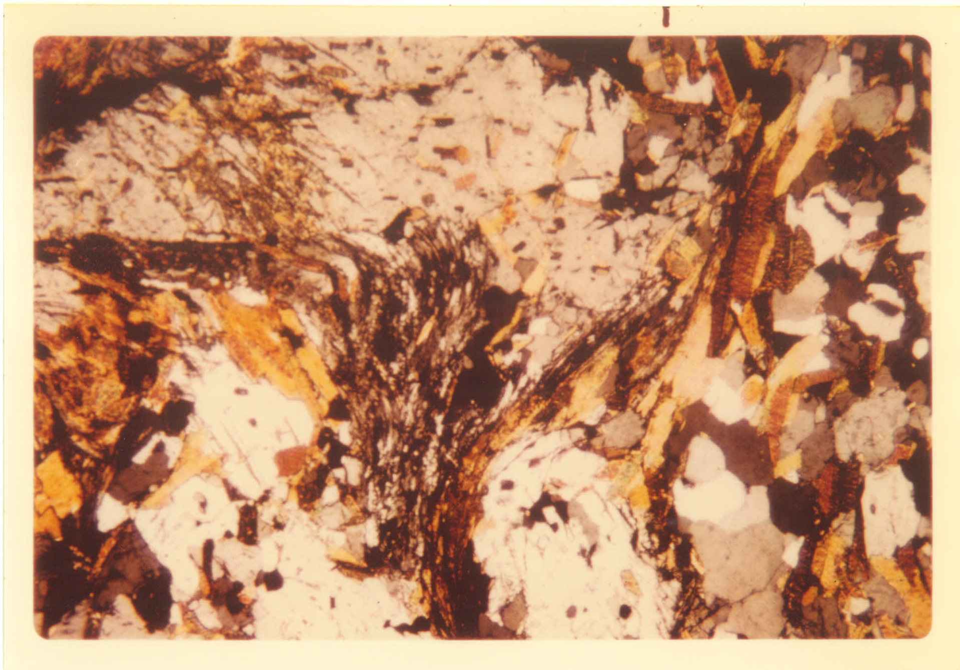
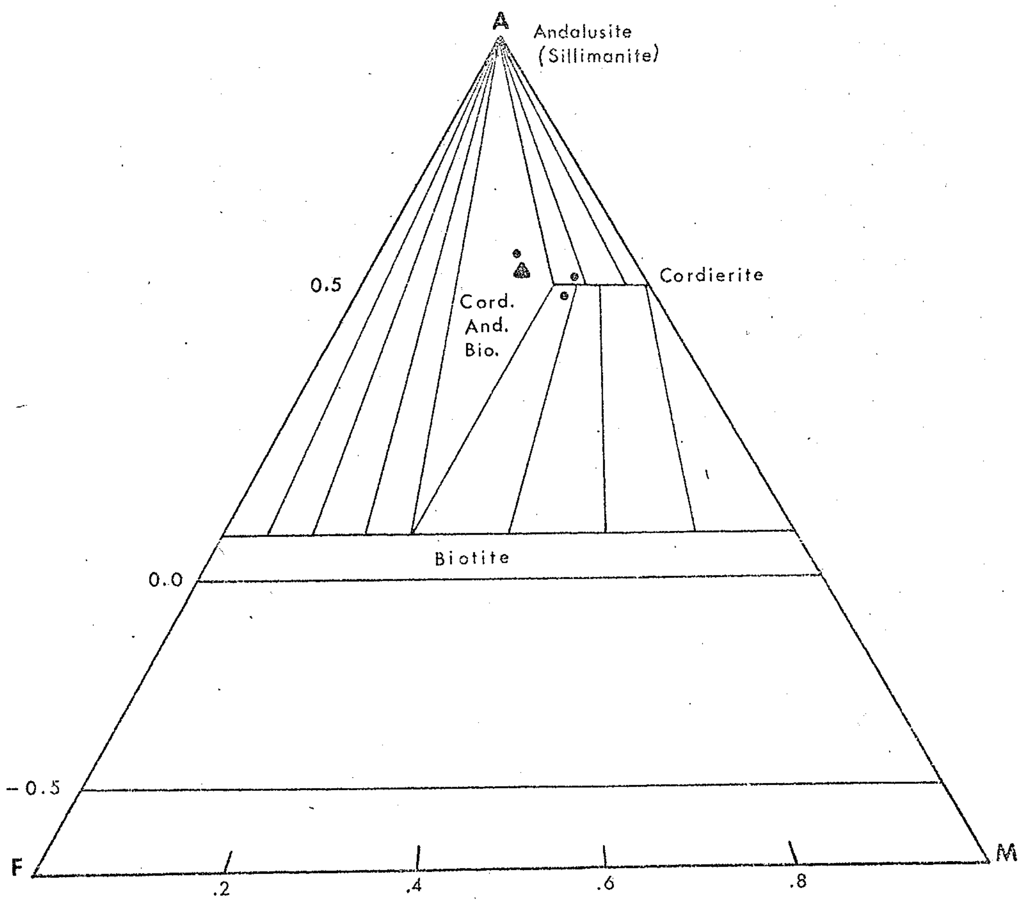


Figure 21: Secondary growth of sillimanite (DM_2). It has a microlitic appearance and is growing into the cordierite, SB68-16 (photomicrograph, medium power).



• Samples from Euclid Lake

▲ Sample from the second Bird River Bridge

Figure 22: Thompson projection for the hornblende-hornfels facies.

andalusite, cordierite and biotite. All three phases or combinations of these phases except a biotite-andalusite assemblage may be present in these rocks. Sillimanite occurs in place of andalusite.

Greenschist Facies:

Metasedimentary rocks in the central and western regions of the Bird Lake greenstone belt have undergone upper greenschist facies metamorphism (Turner and Verhoogen, 1960, p. 533). Mineral assemblages are listed in Table 3, and plotted in Figure 23.

In these rocks relict bedding is well preserved. The regional foliation, formed during the metamorphic period, DM_2, is due to an alignment of biotite and/or chlorite. In some areas the chlorite appears to be almost porphyroblastic (Locality BE-1-11).

Where cordierite porphyroblasts are present they have been almost completely altered to sericite and magnetite (Locality BE-2-4A).

In the volcanic rocks west of Bernic Lake chlorite is pseudomorphic after hornblende.

The third period of metamorphism (DM_3), is represented mainly by shears that cut across the regional foliation and relict bedding. Chlorite, with or without sericite, has grown along these shears.

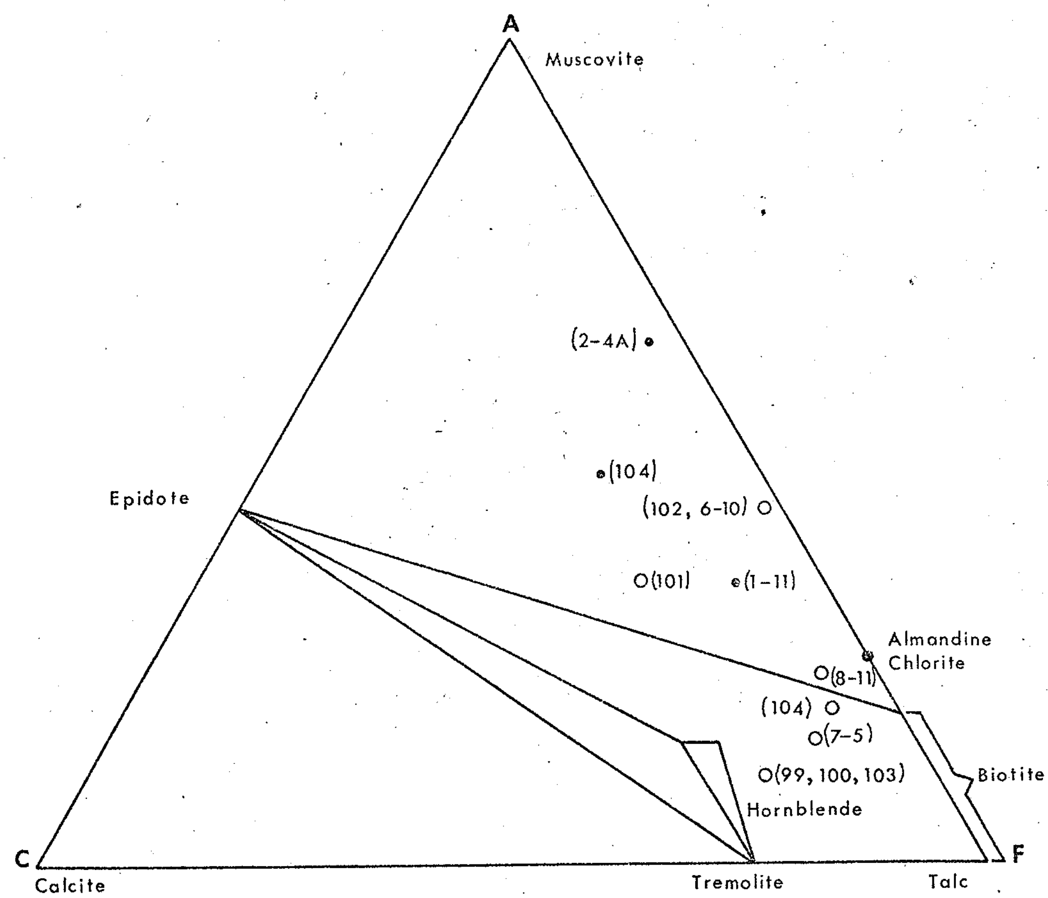
Almandine-amphibolite facies (a: with epidote):

Metasedimentary rocks south-east of Euclid Lake and south and east of Bird Lake have undergone almandine-amphiboite facies metamorphism (as defined by Turner and Verhoogen, 1960, p. 546). Mineral assemblages are listed in Table 4 and plotted in Figure 24.

In this area epidote occurs as distinct crystals as part of the equilibrium, metamorphic assemblage and is not an alteration product

Table 3: Mineral assemblages along the central and western parts of the Bird River, SB68-(99-104) and BE-1-11, BE-6-10, BE-2-4A, and BE-8-11, and BE-7-5.

Sample Number	Mineral Assemblage
BE-1-11	Quartz-biotite-chlorite-muscovite-tremolite-plagioclase
BE-6-10	Quartz-biotite-muscovite
BE-7-5	Quartz-biotite-hornblende-muscovite-chlorite-epidote-calcite
BE-2-4A	Quartz-biotite-chlorite-cordierite-sericite
BE-8-11	Quartz-biotite-garnet-epidote
SB68-99	Quartz-biotite-hornblende-plagioclase
SB68-100	Quartz-biotite-hornblende-plagioclase $\pm$ chlorite
SB68-101	Quartz-biotite-muscovite-plagioclase
SB68-102	Quartz-biotite-chlorite-muscovite
SB68-103	Quartz-biotite-hornblende-plagioclase-calcite
SB68-104	Quartz-biotite-hornblende-plagioclase-chlorite



• Points plotted on basis of chemical analyses

o Points plotted on basis of mineral assemblages

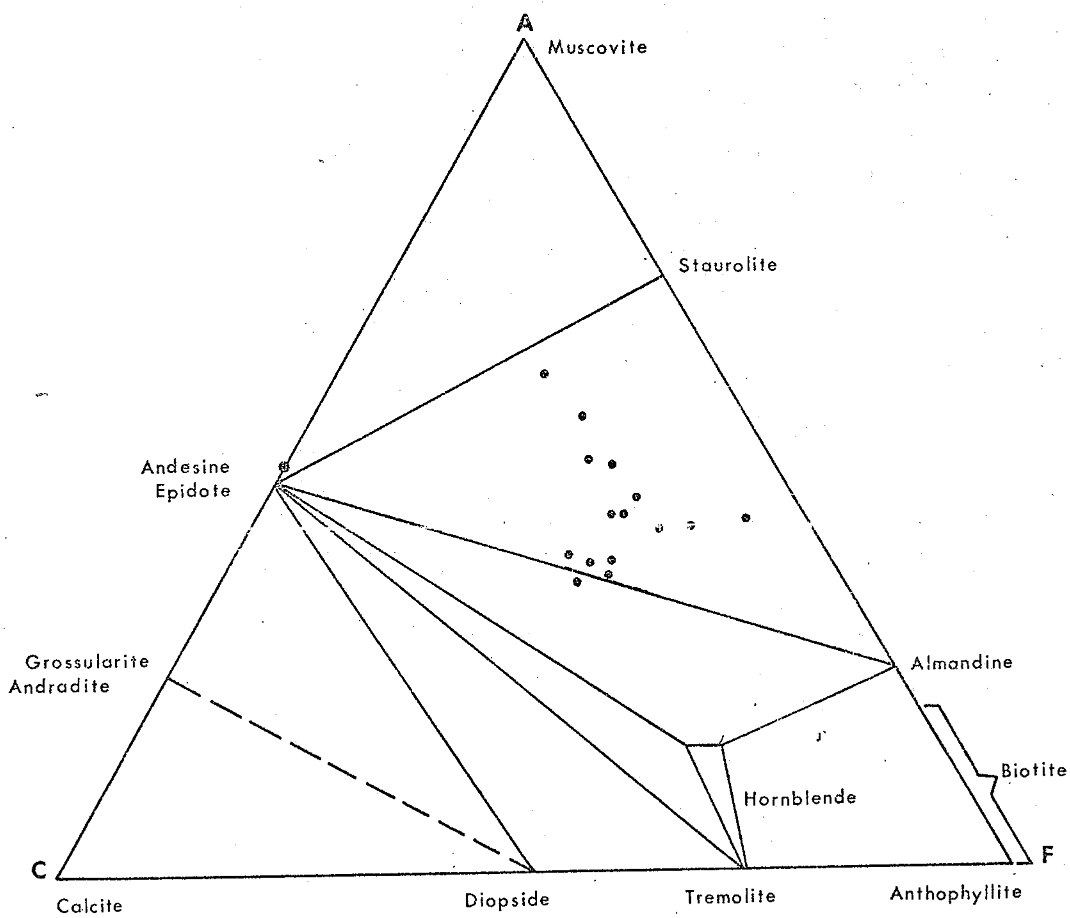
Figure 23: ACF diagram for the greenschist facies.

Table 4: Mineral assemblages east, south-east and north of Bird Lake. (Minerals in parenteses are retrograde minerals or relict minerals.)

Sample Number	Mineral Assemblage
SB68-20	Quartz-biotite-hornblende-plagioclase
SB68-22	Quartz-biotite-plagioclase-(chlorite)
SB68-23	Quartz-biotite-plagioclase-garnet-(chlorite)
SB68-(25, 73)	Quartz-biotite
SB68-26	Quartz-biotite-hornblende±plagioclase±epidote
SB68-27	Quartz-biotite-hornblende-plagioclase
SB68-(30, 31)	Quartz-biotite-hornblende-plagioclase-microcline-epidote
SB68-32	Quartz-biotite-muscovite-plagioclase-epidote
SB68-(33, 59)	Quartz-biotite-hornblende-plagioclase-orthoclase±epidote
SB68-(34, 35)	Quartz-biotite-plagioclase
SB68-36	Quartz-biotite-hornblende-plagioclase-garnet
SB68-(37, 78)	Quartz-biotite-hornblende-plagioclase-garnet-(chlorite)
SB68-38	Quartz-biotite-plagioclase-garnet-(chlorite)
SB68-(46, 47, 63, 64, 70)	Quartz-biotite-hornblende-plagioclase
SB68-48	Quartz-biotite-hornblende-garnet-calcite-(chlorite)
SB68-(49, 58, 60, 69, 94, 96, 97)	Quartz-biotite-hornblende-plagioclase±epidote±calcite±(chlorite)
SB68-(54, 55)	Quartz-biotite-hornblende-plagioclase-sphene-calcite-epidote
SB68-(57-81)	Quartz-biotite-plagioclase-epidote-orthoclase±hornblende-(chlorite)

Table 4: Continued

SB68-61	Quartz-biotite-plagioclase-epidote
SB68-65	Quartz-biotite-plagioclase-hornblende-diopside-epidote
SB68-(66, 77)	Quartz-biotite-hornblende-tremolite
SB68-71A	Quartz-biotite-plagioclase-garnet-orthoclase
SB68-71B	Quartz-hornblende-plagioclase-garnet-epidote-microcline
SB68-74	Quartz-biotite-hornblende
SB68-(72, 79)	Quartz-biotite-plagioclase-(chlorite)
SB68-80	Quartz-biotite-plagioclase-orthoclase-(cordierite)
SB68-(82, 90, 92, 98)	Quartz-biotite-plagioclase-muscovite



• Points plotted on basis of chemical analyses

Figure 24: ACF diagram for the lower almandine-amphibolite facies.

of plagioclase (Figure 25).

Diopside is present in lenses in the quartz-mica schists east of Bird Lake (Figures 26 and 27). It is in the form of anhedral crystals and is fine-grained. The presence of diopside is indicative of relatively high grades of metamorphism. According to Winkler (1965), diopside does not occur in rocks of the greenschist facies of regional metamorphism. In the eastern region, rocks containing diopside belong to the almandine-amphibolite facies of regional metamorphism.

Plagioclase, in the eastern region, occurs as subhedral to euhedral crystals that are essentially free of inclusions and alteration is slight. The most pronounced alteration of plagioclase occurs near the granitic plutons. Alteration products consist of epidote, calcite, sericite and chlorite.

The anorthite contents of the plagioclase occurring in the rocks assigned to the almandine-amphibolite facies are given in Table 5.

The anorthite content of plagioclase has been used by a number of authors as a criterium for determining the boundary between the greenschist and almandine-amphibolite facies of regional metamorphism. Turner and Verhoogen (1960), define the greenschist facies as having an anorthite content of less than 7%. The almandine-amphibolite facies and higher facies of regional metamorphism have an anorthite content greater than 15%. de Waard (1959), uses An_{10} as the boundary between the greenschist facies and the almandine-amphibolite facies. He was able to determine that the interval between An_5 and An_{20} occurs abruptly and occupies a narrow zone in the field. Based on the anorthite contents of the plagioclase in the area south-east of

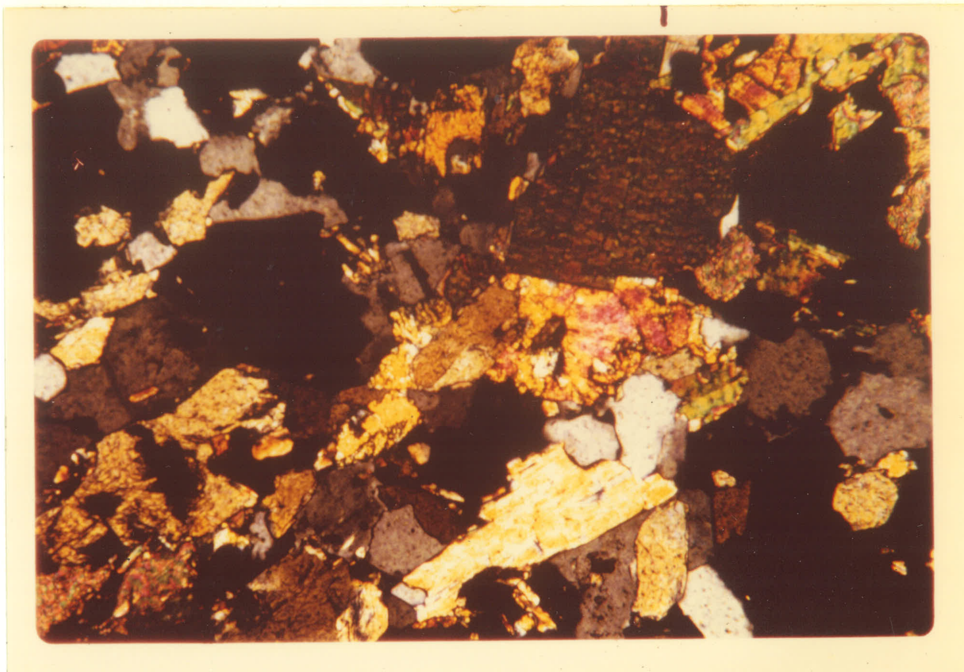


Figure 25: Epidote crystals associated with biotite and hornblende, SB68-49 (photomicrograph, medium power).

Figure 26: Diopside (dark green), layers in the quartz-mica schist, east of Star Lake.

Figure 27: Diopside (dark green), layers in the quartz-mica schist, Manitoba-Ontario boundary.

Table 5: Anorthite content of the plagioclase in the area east, south-east and north of Bird Lake. (determined by the Michel-Levy method.)

Sample Number	Anorthite Content
SB68-23	An_{44}
SB68-28	An_{40}
SB68-36	An_{26}
SB68-35	An_{33}
SB68-33	An_{42}
SB68-38	An_{35}
SB68-65	An_{46}
SB68-83	An_{34}
SB68-82	An_{35}
SB68-59	An_{38}
SB68-58	An_{42}
SB68-54	An_{56}
SB68-57	An_{43}

Euclid and Bird Lakes, these rocks have been metamorphosed under almandine-amphibolite facies metamorphism.

Biotite in the eastern region is reddish-brown to brown in colour and is generally coarser-grained than the biotite in the central and western regions. The darker shades of biotite are believed to be the result of a higher titanium content. Deer, Howie, and Zussman (1966), state that there is a general increase in Ti and Mg content of biotites with increasing grade of metamorphism.

Refractive indices of the biotite in the eastern sector are generally higher than those in the west. Oki (1961), reports that there have been observations of increased refractive index with increasing grade of metamorphism. Also, Hashimoto (1962), reports that there may be an increase in refractive index with increasing TiO_2 content of the biotite. The higher refractive indices in the east are probably the result of combination of an increased TiO_2 content and increase in the grade of metamorphism.

Relict porphyroblasts of cordierite are present at two localities (Locality SB68-80 and north of Rush Lake). At the Rush Lake locality these cordierite porphyroblasts are cut by the regional foliation.

The regional foliation that formed during DM_2 is best developed in the area east of Bird Lake. Relict bedding is almost totally absent. Both biotite and hornblende have a strong alignment and are coarser-grained than in other rocks in the area to the west.

Effects of DM_3 can be seen at localities SB68-80, 89 and 49. A weak secondary foliation has been superimposed on the regional foliation.

Almandine-amphibolite Facies (b: without epidote):

The volcanic rocks in the south-eastern portion of the Bird Lake greenstone belt are assigned to the almandine-amphibolite facies of regional metamorphism (Turner and Verhoogen, 1960). These rocks, in part, have recrystallized into well-lineated, hornblende-plagioclase schists. Mineral assemblages are listed in Table 6.

These rocks have a metamorphic facies similar to the almandine-amphibolite facies (with epidote), except that no epidote was observed.

Occurrence of Cordierite, Anthophyllite and Garnet:

Cordierite forms under thermal, low pressure conditions (Deer, Howie and Zussman, 1966). It is most commonly found in thermally metamorphosed areas and in regions of high grade metamorphism where pressure conditions were abnormal. In these regions it is usually associated with sillimanite.

Hypothetical stability fields (Turner, 1968), indicate that cordierite forms in a temperature range from 450°C. to the temperature of rock fusion under low pressure conditions. Cordierite, at pressures above 5 kilobars becomes unstable and the magnesium is accomodated in biotite and almandine.

Wynne-Edwards and Hay (1963), and Winkler (1965), suggest that cordierite in regionally metamorphosed terrains forms in lime-poor rocks (less than 1% CaO). These rocks are rare in Precambrian areas. Rocks in the Bird Lake area, in which cordierite appears, do not have a low lime content.

Cordierite is found in restricted localities at Euclid Lake and

Table 6: Mineral assemblages along the south-eastern edge of the Bird Lake greenstone belt.

Locality	Mineral Assemblage
BE-8-2	Quartz-hornblende-biotite-garnet-calcite
Bernic Lake	Quartz-plagioclase-hornblende-biotite$\pm$garnet

in the central and eastern regions of the southern greenstone belt. The cordierite is present as grey, to bluish-grey, ovoid porphyroblasts in the metagreywacke. These porphyroblasts range in size from 5 to 15 millimeter. In thin section these porphyroblasts have an irregular outline. They are intwinned. Inclusions of quartz, biotite, magnetite, chlorite and muscovite occur in these porphyroblasts. A feature of these cordierite porphyroblasts is that they have been rolled but inclusions in the porphyroblasts do not have any helicitic structure.

Although some occurrences of cordierite are near granitic bodies, there are other occurrences of cordierite far removed from any granitic body. Contact metamorphism of local extent cannot explain the occurrence of cordierite. All rocks in which cordierite is present have undergone some later dynamo-thermal metamorphism.

Anthophyllite occurs at two localities (SB68-11 and SB68-86, 87) and is associated with cordierite, with or without garnet.

According to Lal and Moorhouse (1969), three factors control the appearance of anthophyllite in metamorphic rocks. These are:

1. Low K_2O, CaO, and Na_2O content.
2. FeO/MgO + FeO ratio must be such that the composition falls in the anthophyllite-garnet-cordierite field in the AFM diagram.
3. $$\frac{FeO + MgO + MnO}{Al_2O_3 - (Na_2O + 2CaO)} > 1$$

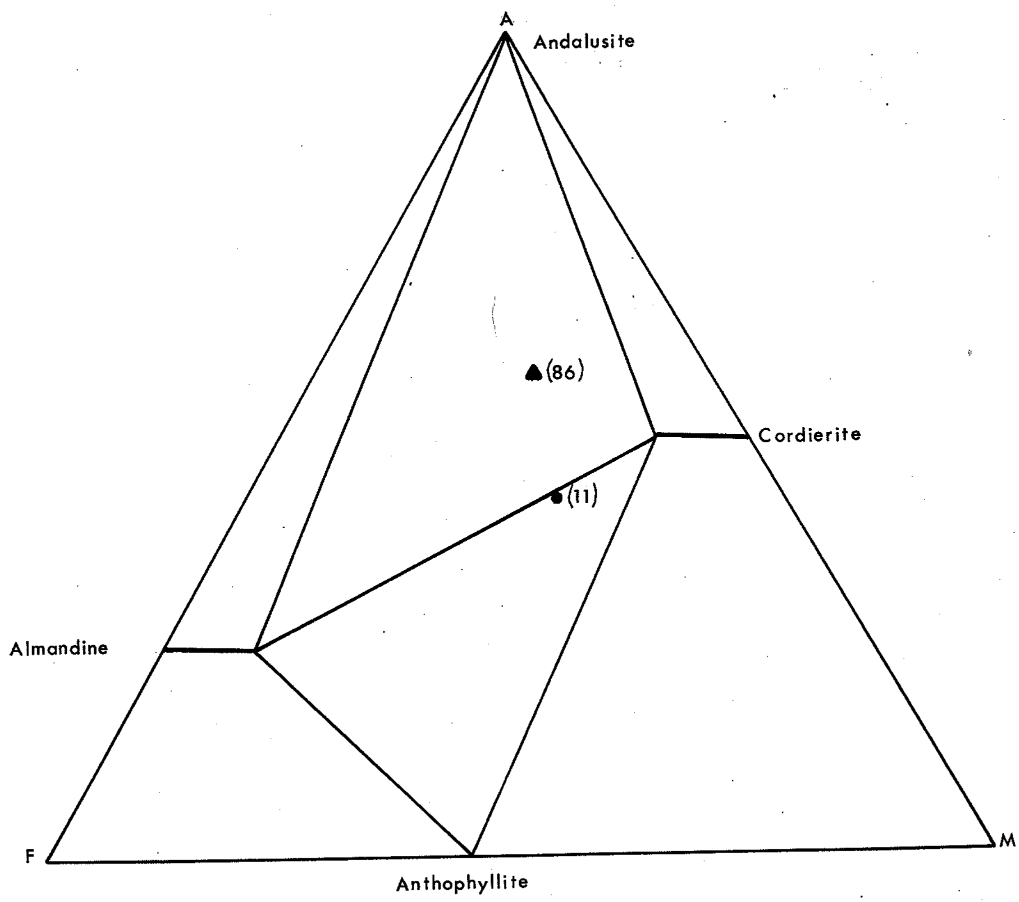
Anthophyllite-bearing rocks at the second Bird River Bridge location do not have a low K_2O, CaO, and Na_2O content. The FeO/MgO + FeO ratio is such that the composition does not fall in the anthophyllite-garnet-corierite field in the AFM diagram (Figure 28). However, the value of the third factor is greater than one. Therefore, an abundance of FeO and MgO is probably the controlling factor, providing pressure-temperature conditions are favourable, for the growth of anthophyllite.

Anthophyllite occurs in pods or argillaceous units within the metagreywacke. It is light to dark brown in colour and has a radiating or "star burst" pattern. Individual crystals range in length from less than 5 millimeters to greater than 10 millimeters in length (Figure 29).

In all instances anthophyllite crystals cross the regional foliation. A similar pattern is reported to occur in the Wollaston Lake Fold Belt (Money, 1968). Since the anthophyllite cuts across cordierite porphyroblasts and also crosses the regional foliation, it is interpreted to have grown after the period of dynamo-thermal metamorphism.

Fyfe (1962), studied the stability fields of talc, anthophyllite and enstatite. He found that at a temperature or 760^{o}C. there was a conversion of talc to anthophyllite and of enstatite to anthophyllite in the presence of water. Also, he believes that the upper stability limit of anthophyllite is 806^{o}C. at 1000 to 2000 bars pressure. From the work of Fyfe it would seem that anthophyllite forms under a high thermal gradient and at relatively low pressures. Therefore, anthophyllite is more characteristic of thermal metamorphism.

Salotti (1962), found that magnesium anthophyllite is meta-



● Sample from the second Bird River Bridge

▲ Sample from Euclid Lake

Figure 28: AFM plot for the rocks containing anthophyllite.

Figure 29: Anthophyllite crystals in an argillaceous unit at the second Bird River Bridge, SB68-86 (photomicrograph, low power).

stable in the presence of water vapour and is only stable below 660°C. The presence of magnesium anthophyllite in this area could be attributed to a late crystallization when the temperature fell below 660°C. and the water vapour had been used up in earlier crystallizing minerals.

Garnets are present in both the metasedimentary and metavolcanic rocks throughout the area. They are in the form of rounded or elliptical porphyroblasts. In thin section they have a characteristic diablastic or sieve texture. Inclusions of quartz and biotite are present in these garnet porphyroblasts.

Dwibedi (1966), found that the garnets in the eastern region were mainly a mixture of almandite and spessartite.

The use of garnet as an indicator of metamorphic grade has been questioned by many authors. Garnet is more a function of bulk composition rather than a function of pressure-temperature conditions (Tilley, 1926, Chinner, 1962, and Dwibedi, 1966). Garnet porphyroblasts appeared to have formed in rocks that are rich in MnO. Tilley (1926) found that garnets in contact aureoles form in rocks that are rich in MnO.

The cordierite-anthophyllite assemblage formed in both greywacke and argillaceous rocks.

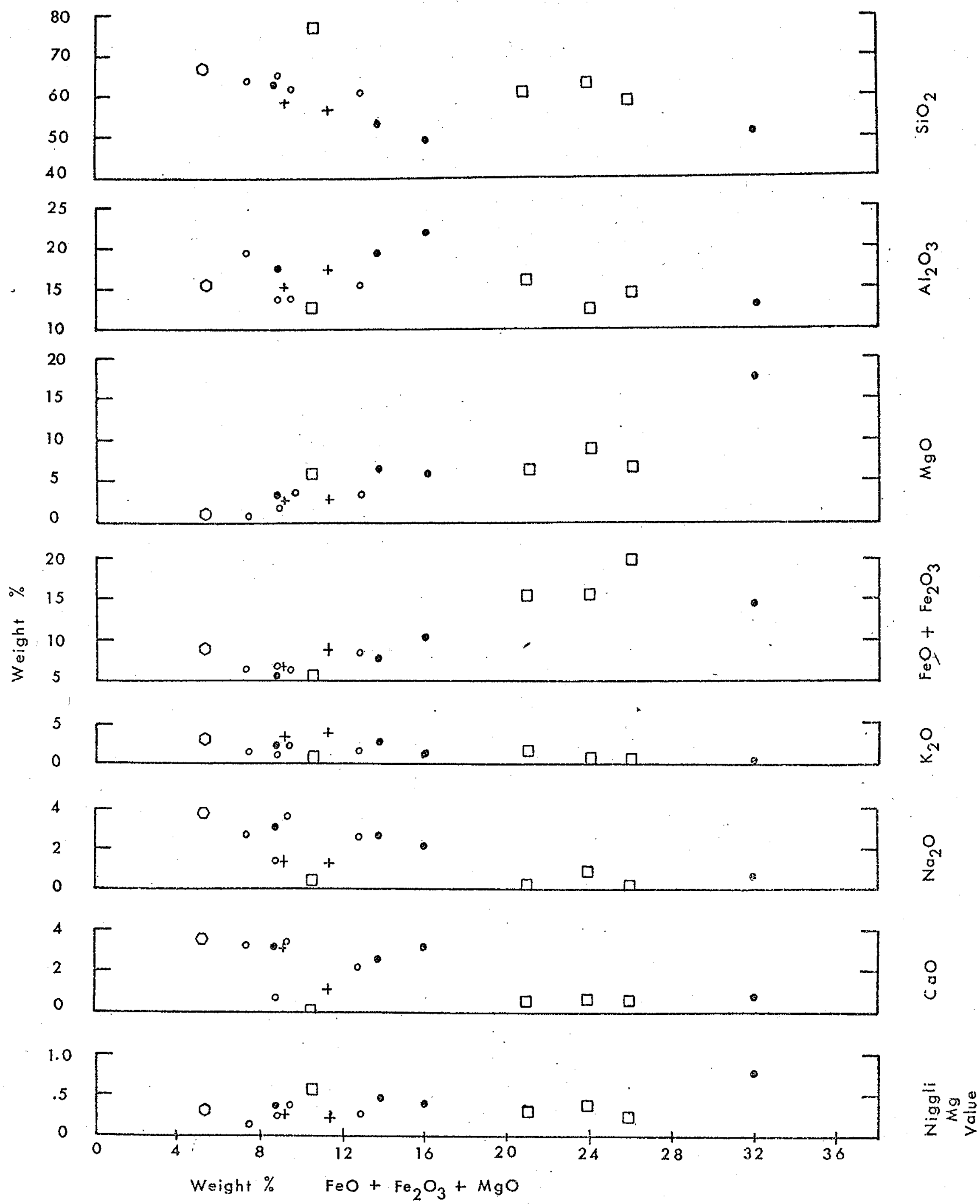
To explain anomalously large FeO and MgO contents in cordierite bearing rocks, Eskola (1914), postulated that the MgO and FeO were introduced by hydrothermal solutions generated by the intrusion of granite and granodiorite plutons. Tuominen and Mikkola (1950), believed that during deformation MgO and FeO were enriched at the hinges of folds. In this area there is no relationship between the occurrence of cordierite and anthophyllite with any of the fold structures. Cordierite and anthophyllite occur on the flanks of the folds rather than at the hinges of the folds. Lal and Moorhouse (1969), discuss the enrichment of MgO and FeO as due to the formation and removal of a granitic anatectic fraction, but there is no evidence of this in the Bird River area.

In comparison with other greywackes and argillaceous, sedimentary rocks, the cordierite-anthophyllite bearing rocks in the Bird Lake area have a higher alumina content. Comparison of MgO, total Fe, K_2O, CaO, and Na_2O reveals that the MgO content of the rocks in the Bird Lake area is slightly higher than that in other greywackes and argillaceous rocks. The other components compare favourably (Figure 30).

The author has seen no evidence of metasomatic processes or the formation of a granitic anatectic fraction that might be responsible for the majority of occurences of cordierite and anthophyllite in this area. In general, metasomatic processes, in this area, have resulted in the introduction of alkalies rather than MgO. The grade of metamorphism is generally low and the formation of a granitic anatectic fraction does not seem feasible.

A single sample (SB68-11), does contain a significantly higher amount of MgO. Also, the Niggli Mg value (Figure 30), is significantly higher than those of other greywackes and argillaceous rocks. For this sample, the ratio of MgO to total femic oxides has not remained constant. This high Niggli value could be explained by localized MgO metasomatism. This would concur with a late stage formation of anthophyllite.

Cordierite, anthophyllite and garnet occur together in only



o Average granodiorite (Nockholds, 1954)

∘ Greywackes (Pettijohn, 1957)

• Cordierite-anthophyllite bearing rocks (Bird Lake area)

□ Rocks from the Fishtail Lake area

\+ Shales, slates (Pettijohn, 1957)

Figure 30: Variation diagram in which weight % of oxides is plotted against weight % of FeO + Fe_2O_3 + MgO.

two localities (Euclid Lake and the second Bird River Bridge), and form a definite mineral assemblage at only one locality (second Bird River Bridge). The assemblage, cordierite-anthophyllite-garnet is generally related to contact metamorphism (Wynne-Edwards and Hay, 1963). Almandine-garnet will form in cordierite bearing rocks if the FeO/MgO + FeO ratio is high. Because of limited solubility of FeO in cordierite, a new phase, almandine appears. Increasing CaO content also modifies the bulk composition so as to permit the formation of garnet (Wynne-Edwards and Hay, 1963). Both of these requirements are met in the unit containing the cordierite-anthophyllite-garnet assemblage. Chemical conditions rather than pressure-temperature conditions are the controlling factors in the occurrence of this assemblage.

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APPENDIX I

PETROLOGY

Andesites and Basalts:

Andesites and basalts are found along the southern edge of the area and at Euclid and Cat Lakes. Most of these rocks have been recrystallized, and in part granitized where they occur adjacent to granitic plutons. Some pillows are preserved (Figure 31), but in most instances they have been sheared or stretched out into elongate, elliptical shapes. Where there has been the severest recrystallization, lineated, hornblende-plagioclase schists have developed.

The least altered rocks contain granular plagioclase (andesine), and blades of green hornblende. Biotite and chlorite occur as alteration products of the hornblende. Quartz, sphene, and magnetite are present as accessory minerals. In the more recrystallized rocks garnets have formed. These garnets may form up to 20% of the rock in the western part of the area.

Adjacent to the large mass of granite south of the Bird River in the western sector, much of the basalt has been entirely recrystallized and in part or whole, granitized and replaced by granitic material. Granitized pillows are present at the eastern end of Bernic Lake.

Figure 31: Pillow structures in the volcanic rocks, Bernic Lake.

Greywacke and Derived Schists:

Greywacke and derived, quartz-mica schists form the bulk of the sedimentary sequence in this area. In the central and western regions of the area greywacke is more prominent whereas the quartz-mica schists dominate in the eastern sector where the degree of metamorphism is greater.

The greywacke is a fine-grained, grey to black, finely schistose rock. It is thinly bedded with individual beds ranging from a fraction of an inch to an inch in thickness. Quartz, biotite, and plagioclase are the dominant minerals present. Epidote, magnetite, potassium feldspar and chlorite are present in minor amounts or as accessory minerals. Cordierite and anthophyllite have restricted occurrences. Garnet is also present in retricted localities.

The quartz-mica schists are medium-grained, dark rocks. Bedding is obscure unless interbedded, schistose greywacke is present. Quartz, biotite, hornblende and plagioclase are the main mineral constituents. Diopside layers are present near the eastern boundary of the area. Garnets are restricted to certain beds and localities. Chlorite, sphene, epidote, and potassium feldspar are present as minor constituents. Tremolite occurs in the east-central sector, south and south-east of Bird Lake.

Arkose:

Arkose occupies the central part of the sedimentary section of the Rice Lake Group, and stratigraphically overlies the greywacke and related rocks. Beds of greywacke are commonly interbedded with the arkose.

There are two distinct types of arkose in this area. The first type is a fine to medium-grained, well-bedded unit. These beds are an inch or less in thickness. The second type is a coarse-grained rock that is thickly bedded. White, grey, or blue, quartz "eyes" are a prominent feature of this type of arkose. These quartz "eyes" have a rolled structure and therefore are probably a secondary feature resulting from recrystallization during metamorphism.

The arkose consists mainly of alkali feldspar and quartz. Lesser amounts of sericite, muscovite, and biotite are also present. Epidote, magnetite, and tourmaline are present as accessory minerals. The feldspar is mainly microcline with albite and orthoclase also present.

Conglomerate:

Conglomerate (Figure 32), occurs in several bands in the western section of the area and as a relatively thin unit which outlines the synform in the eastern section of the area. This unit forms the upper horizon of the sedimentary sequence.

This conglomerate is characterized by light, cream coloured pebbles, ¼ to 6 inches in diameter, set in a quartz-feldspathic or micaceous matrix. These pebbles are usually well rounded or elliptical in shape. The long axis of the ellipse is parallel to the regional foliation.

Most of the pebbles have a granitic composition. They are composed mainly of quartz and feldspar. Lesser amounts of biotite, muscovite, epidote, magnetite and carbonate are also present. The

Figure 32: Conglomerate, showing pebbles in a foliated matrix, south of Star Lake.

matrix consists of a foliated aggregate of plagioclase and quartz with well aligned biotite also present in appreciable amounts.

Davies (1956), raises some doubt as to the origin of the conglomerate in the eastern section of the area. He suggests that some of the unusually shaped pebbles may be the result of injection of granite into the schist. The author believes this to be a true conglomerate and that the unusually shaped pebbles are the result of recrystallization and partial rotation during metamorphism.

Bird River Sill:

The Bird River Sill is a differentiated, layered, basic, intrusive body. This complex of peridotite, gabbro, and related rocks is a sill-like body that is intrusive into the Rice Lake Group. The concept of a single, once continuous, sill is believed to be erroneous (Davies, 1952). He believes that in addition to the normal peridotite-gabbro complex, there were separate intrusions of gabbro in the area. This would explain observed occurrences of gabbro north and south of the peridotite.

The peridotite is medium-grained and has a brownish weathering surface. On the fresh surface it is dark green with translucent flecks of more brilliant green also present. It has been largely altered to felted aggregates of fibrous chlorite, talc and tremolite. These mineral aggregates are often pseudomorphic after olivine and pyroxene. In the vicinity of Bird Lake, fibrous serpentine is also present. Near the top of the peridotite a chlorite horizon is present.

Some pyroxenite occurs at the top of the peridotite. It consists of augite with minor interstitial tremolite and minor carbonate.

The gabbro occupies the upper part of the sill as well as occurring locally as isolated bodies. There is a wide variation in texture with both fine-grained and pegmatitic phases present. The essential minerals present are hornblende and plagioclase. Titanomagnetite, carbonate, and biotite are present as accessory minerals.

Granitic Rocks:

Granitic rocks occupy the major portion of the area. The edges of all granitic intrusions trend parallel to the regional structure. None of the intrusions can be said, definitely, to cross-cut the older rocks, although stringers of granite do so.

There are several types of granitic rocks and the composition of these rocks is extremely variable. The main constituents are plagioclase, microcline, quartz, orthoclase and biotite. Accessory minerals include muscovite, apatite, epidote and sphene. Hybrid phases, pegmatitic phases and inclusions occur but are not common.

The various types of granite grade into one another. Nowhere in the area is there a sharp contact between two phases of granitic material. This has led previous authors to believe that, although there is more than one phase of granitic intrusion, there was no sharp break between individual granitic intrusions, and that some of these intrusions may have been contemporaneous.

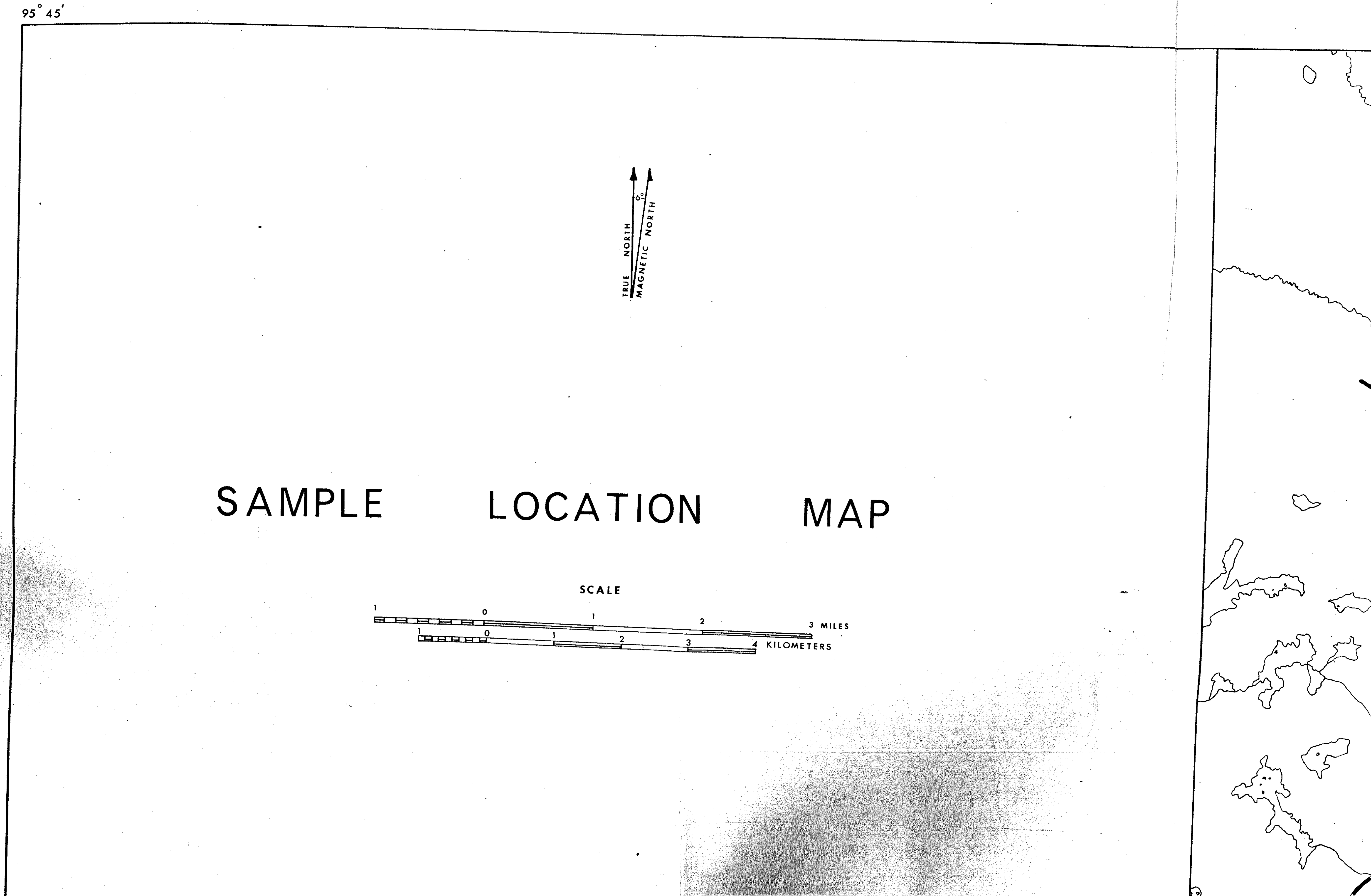
Pegmatite veinlets have intruded into the sedimentary and volcanic rocks. These veinlets are composed essentially of quartz and potassium feldspar, with lesser amounts of mica. It is believed that these veinlets represent a late stage of the granitic intrusion. The presence of these pegmatite veinlets also suggests that granitic bodies do not occur at any great distances or depths below the present surface.

APPENDIX II

CHEMICAL ANALYSES

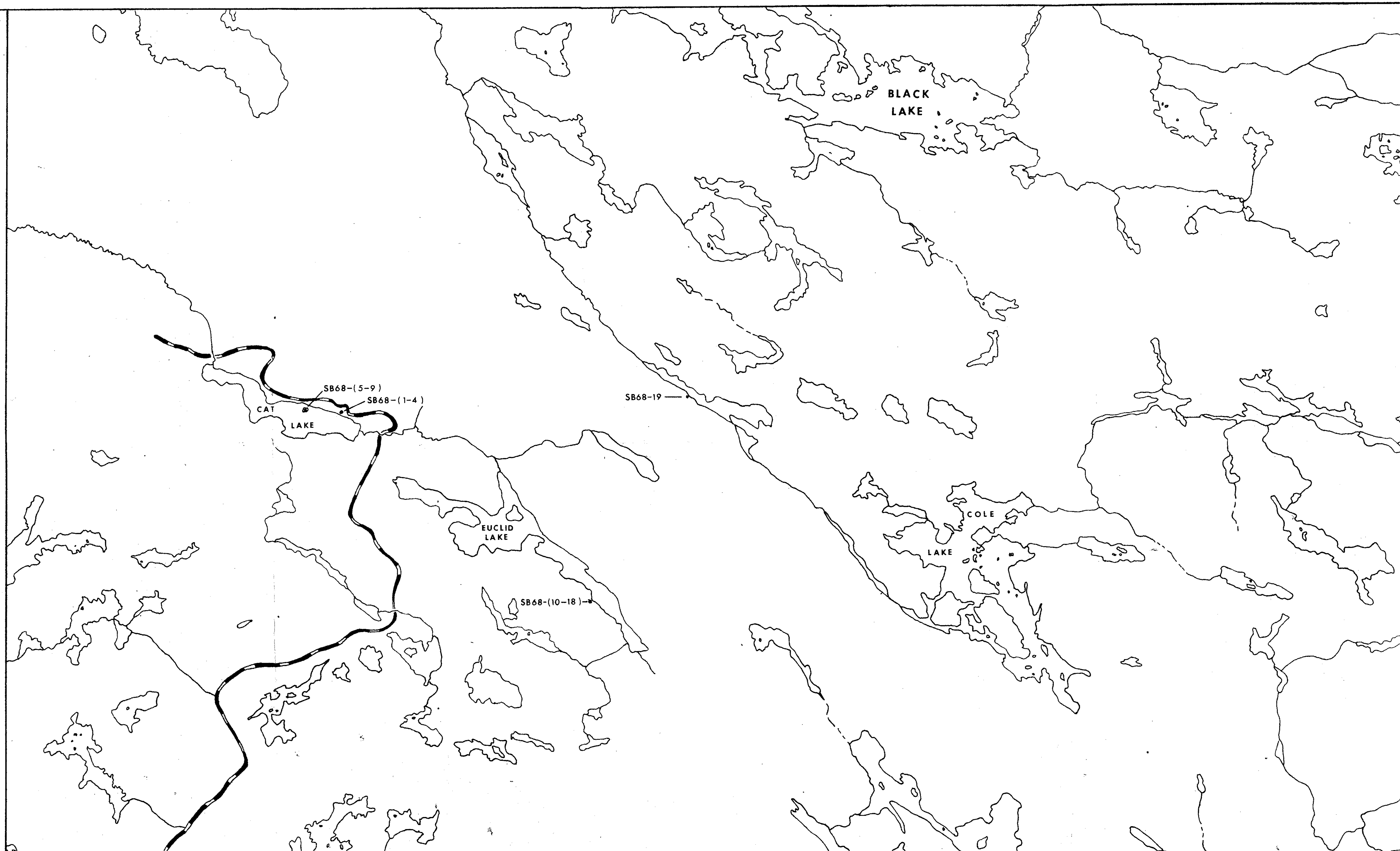
Sample Number	SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	H_2O	CO_2	TiO_2	P_2O_5	MnO	Total
SB68-59	60.85	15.56	2.13	3.52	4.22	5.84	3.83	2.70	1.03	0.05	0.53	0.38	0.10	100.14
SB68-65	58.35	16.70	0.40	3.00	5.50	7.92	3.33	1.38	1.13	0.09	0.53	0.51	0.05	99.39
SB68-31	49.75	16.50	2.90	9.00	4.95	8.72	1.25	3.52	1.83	0.11	0.57	0.39	0.67	100.16
SB68-18	62.30	17.47	0.87	4.68	3.25	3.12	3.07	2.11	1.39	0.10	1.16	0.48	0.05	100.05
SB68-78	66.95	13.60	1.19	4.92	3.47	2.26	2.43	2.39	1.50	0.06	0.43	0.89	0.23	99.72
SB68-97	62.60	13.68	1.61	4.52	4.17	6.23	2.90	1.89	1.11	0.06	0.49	0.45	0.15	99.86
SB68-82	67.70	16.21	0.83	2.92	0.73	2.84	4.10	2.49	0.84	0.20	0.36	0.32	0.06	99.60
SB68-35	63.90	15.05	1.09	4.48	4.00	2.48	3.03	3.09	1.83	0.20	0.51	0.35	0.05	100.06
SB68-54	53.05	15.66	2.72	5.64	5.75	9.18	3.50	1.02	1.38	0.05	0.63	0.45	0.17	99.20
SB68-86	49.10	21.82	1.46	8.68	5.88	5.20	2.35	1.12	2.07	0.18	0.95	0.57	0.12	99.50
SB68- 7	69.20	14.54	1.53	2.32	2.65	2.78	4.46	1.17	0.77	0.54	0.44	0.17	0.06	100.13
SB68-11	50.05	12.93	4.02	10.44	17.55	0.87	0.74	0.12	1.86	0.23	0.80	0.12	0.10	99.83
SB68-12	56.15	19.23	2.75	4.84	6.32	2.38	2.63	2.58	1.71	0.24	0.97	0.25	0.07	100.12

Sample Number	SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	H_2O	CO_2	TiO_2	P_2O_5	MnO	Total
SB68-43	62.45	16.43	1.86	2.88	3.60	4.57	2.73	3.08	0.98	0.12	0.61	0.24	0.10	99.65
SB68-58	59.20	16.26	3.34	3.64	4.32	4.45	3.81	2.61	1.06	0.14	0.62	0.33	0.10	99.88
SB68-61	61.30	15.86	2.54	3.24	4.35	4.37	3.37	2.79	1.07	0.17	0.56	0.30	0.11	100,03
SB68-71	64.50	14.12	2.65	4.16	2.88	4.88	0.32	3.02	1.37	0.21	0.55	0.26	1.07	99.99
SB68-72	65.95	13.90	1.99	3.52	5.25	1.07	3.82	1.26	1.65	0.41	0.56	0.22	0.05	99.65
SB68-81	63.35	15.56	2.21	3.44	2.93	3.64	3.56	2.16	1.50	0.21	0.64	0.28	0.07	99.55
SB68-84	69.40	12.19	1.92	2.64	3.77	3.11	1.95	2.24	1.30	0.35	0.53	0.33	0.05	99.78
SB68-94	65.90	19.90	2.16	3.16	3.98	4.84	2.80	1.98	1.03	0.23	0.41	0.19	0.11	99.69
SB68-45	53.10	0.06	1.07	2.52	19.15	21.44	0.08	0.00	0.97	1.34	0.00	0.04	0.27	100.04
SB68-104	64.50	15.65	1.62	3.32	3.80	3.74	3.06	2.02	1.45	0.14	0.43	0.15	0.04	99.92
BE1-11	60.35	12.26	3.66	4.40	8.90	2.56	1.89	2.60	1.83	0.18	0.48	0.31	0.08	99.50
BE2-4A	64.95	16.60	2.40	3.60	2.77	.81	1.84	3.21	2.04	0.72	0.60	0.14	0.09	99.77



33 Sample location map, Bird Lake Area

S. B. Butrenchuk


BLACK LAKE
SB68-(5-9)
SB68-(1-4)
CAT LAKE
SB68-19
EUCLID LAKE
SB68-(10-18)
COLE LAKE


95° 08′
50° 36′ 30″
BLACK LAKE
SB68-19
68-(1-4)
COLE LAKE
EUCLID LAKE
SB68-(10-18)
McGREGOR LAKE

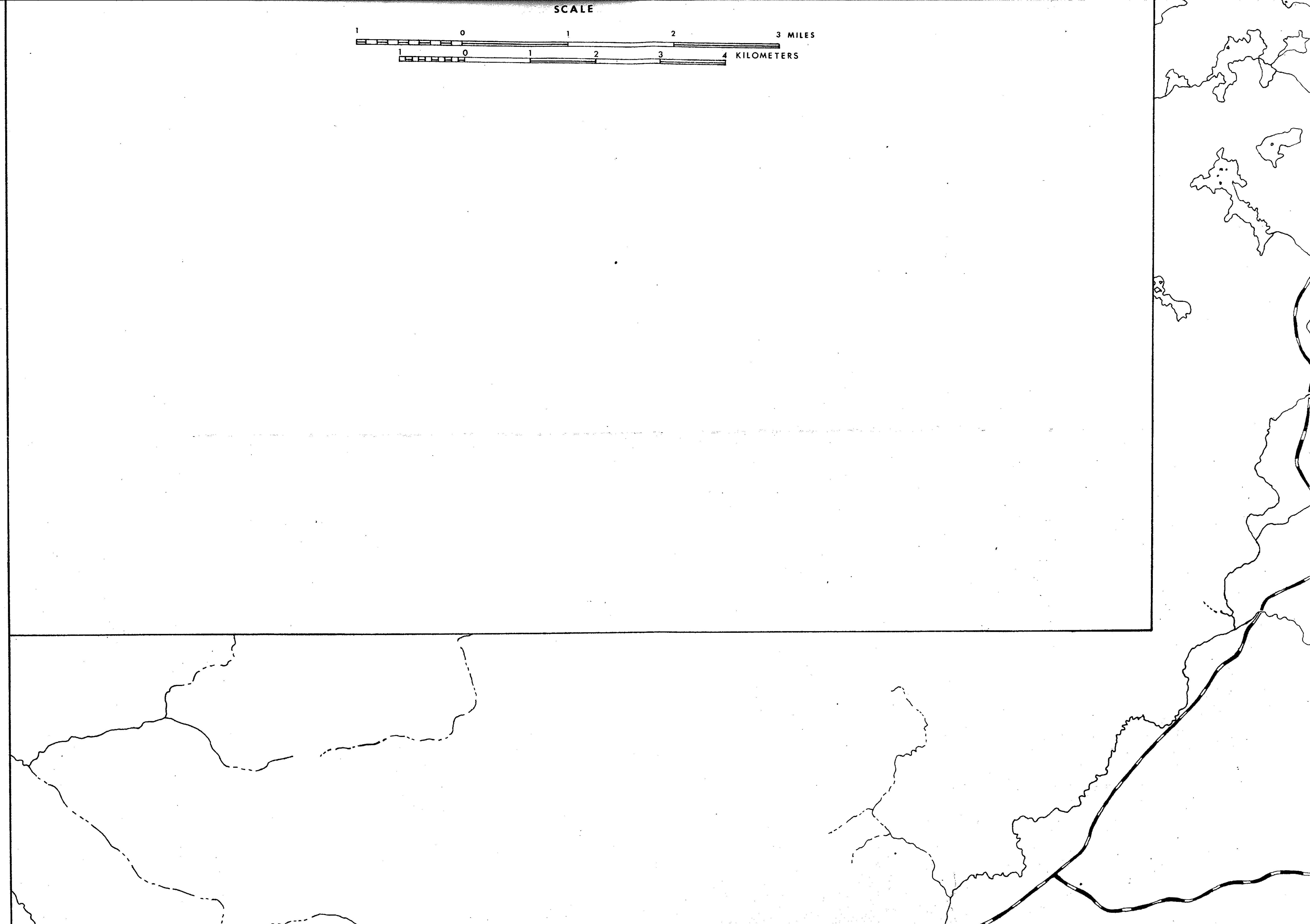
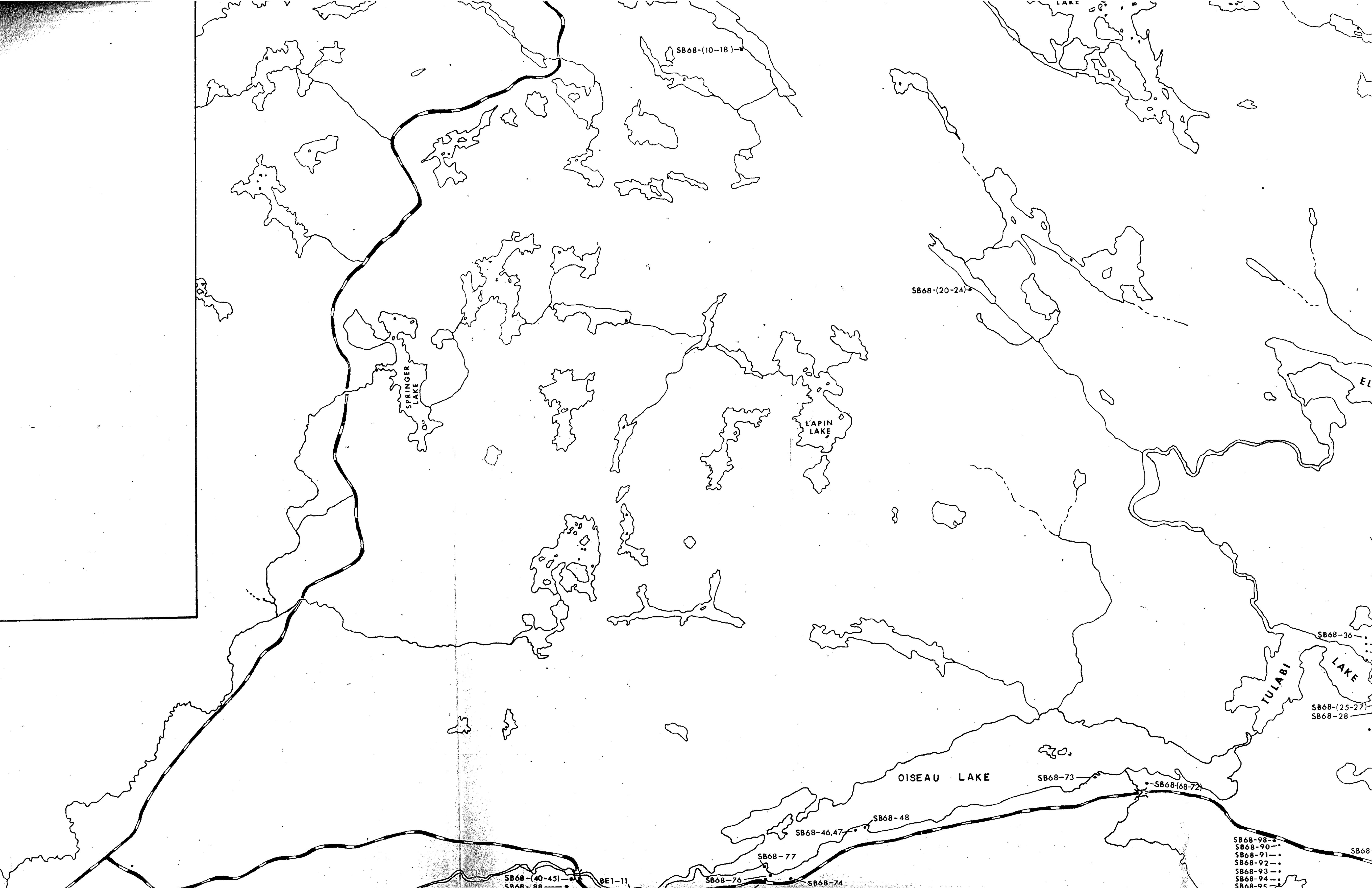


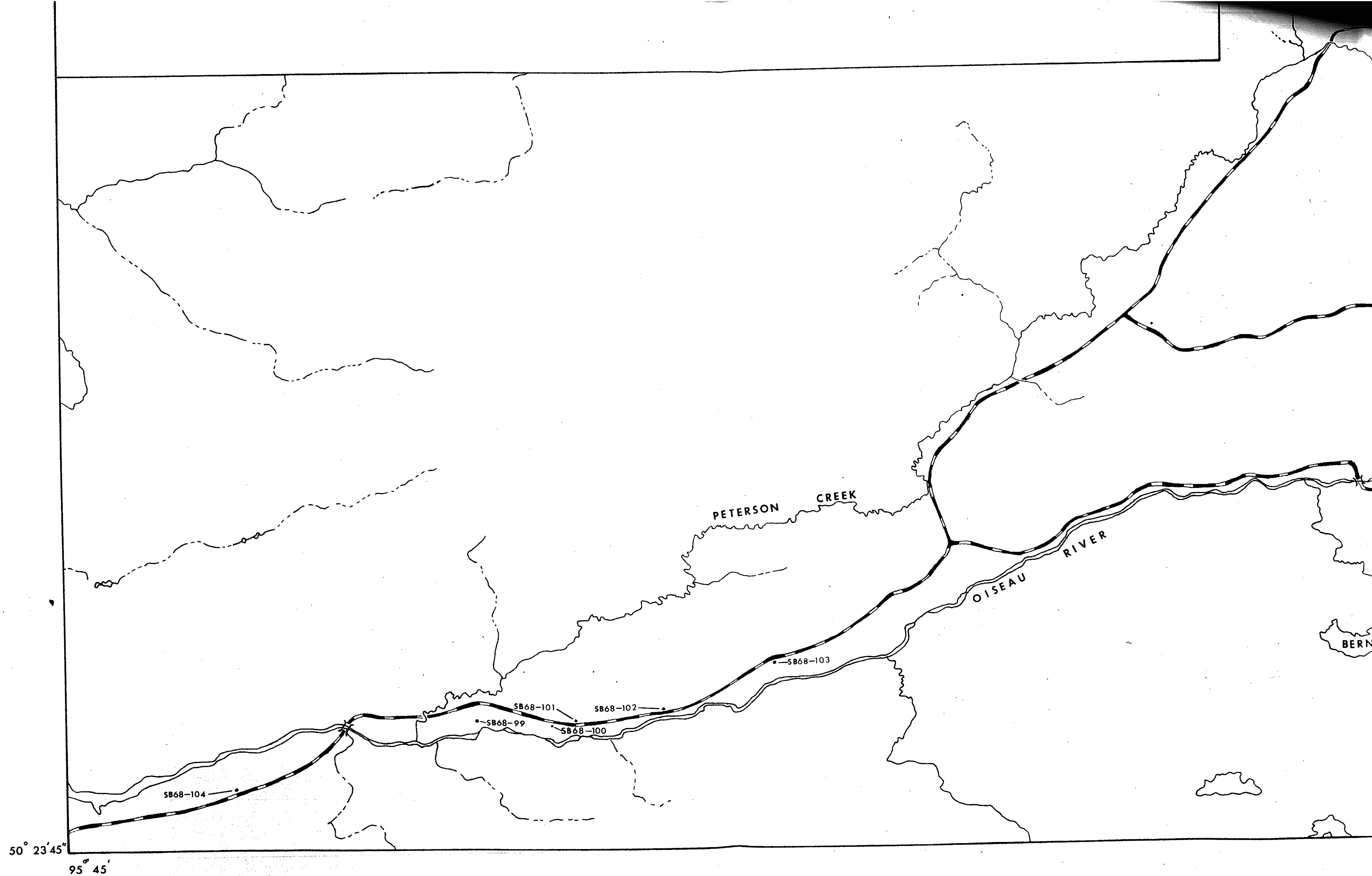
Fig. 33 Sample location map,
Bird Lake Area

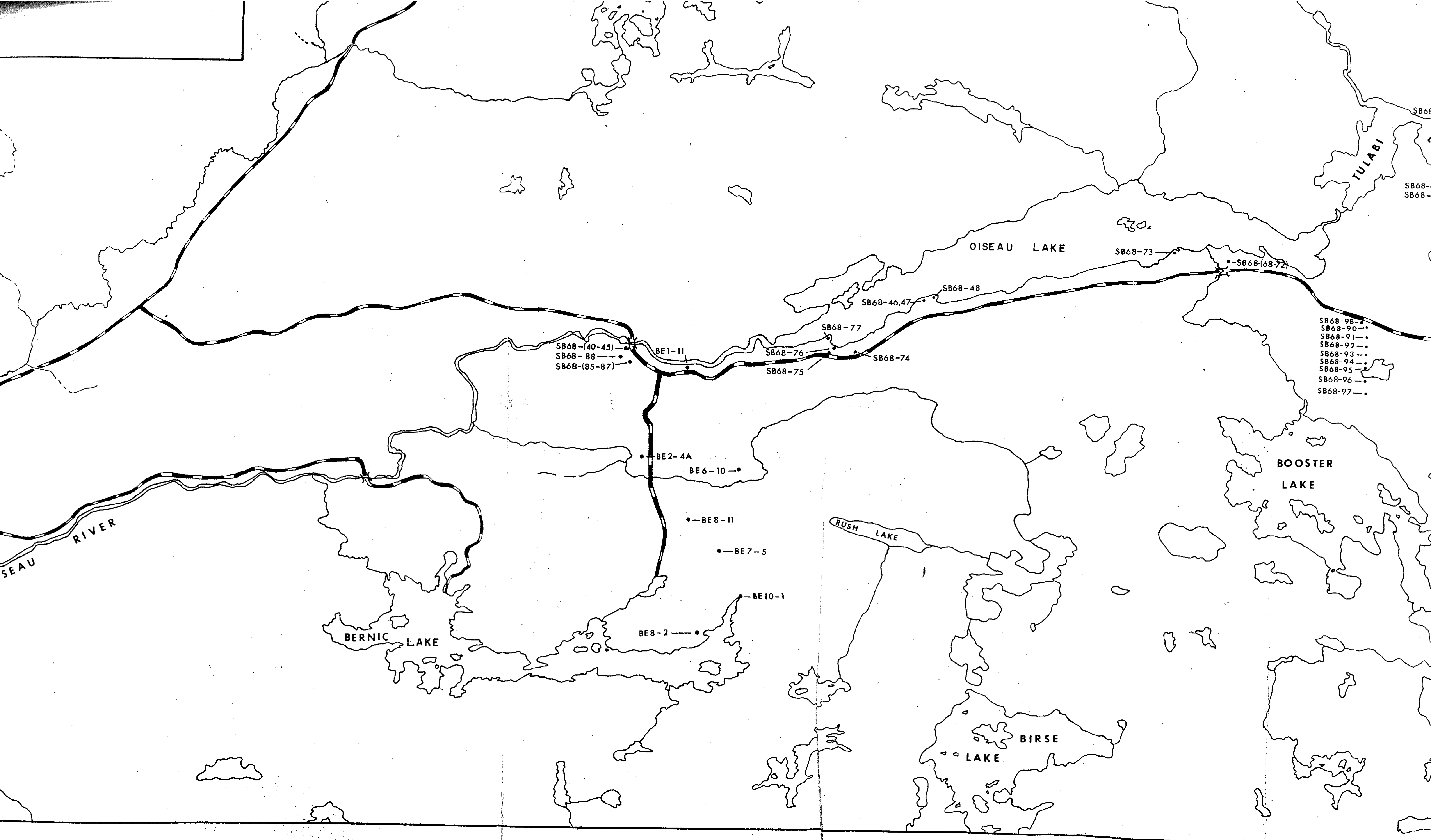
S. B. Butrenchuk



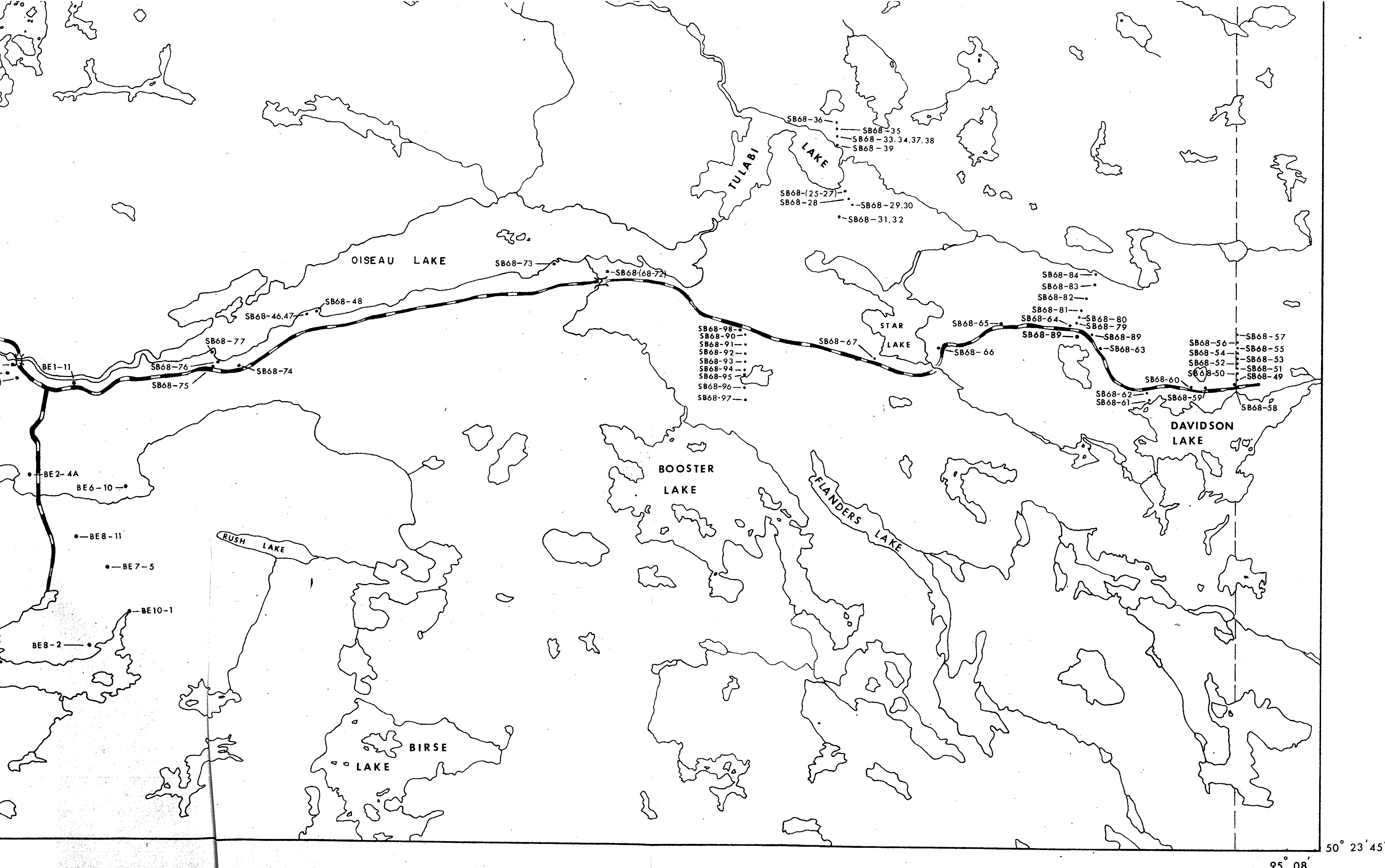
SB68-(10-18)
SB68-(20-24)
SPRINGER LAKE
LAPIN LAKE
OISEAU LAKE
SB68-73
SB68-(68-72)
SB68-48
SB68-46,47
SB68-77
SB68-76
SB68-74
SB68-(40-45)
SB68-88
BE1-11
TULABI LAKE
SB68-36
SB68-(25-27)
SB68-28
SB68-98
SB68-90
SB68-91
SB68-92
SB68-93
SB68-94
SB68-95

SB68-(10-18)
SB68-(20-24)
McGREGOR LAKE
LAPIN LAKE
ELBOW LAKE
MANITOBA
ONTARIO
SB68-36
SB68-35
SB68-33, 34, 37, 38
SB68-39
TULABI LAKE
SB68-(25-27)
SB68-28
SB68-29, 30
SB68-31, 32
OISEAU LAKE
SB68-73
SB68-(68-72)
SB68-48
SB68-46, 47
SB68-77
BE1-11
SB68-76
SB68-75
SB68-74
SB68-98
SB68-90
SB68-91
SB68-92
SB68-93
SB68-94
SB68-95
SB68-96
SB68-97
SB68-67
STAR LAKE
SB68-65
SB68-66
SB68-84
SB68-83
SB68-82
SB68-81
SB68-64
SB68-80
SB68-79
SB68-89
SB68-89
SB68-63
SB68-60
SB68-62
SB68-61
SB68-59
SB68-57
SB68-56
SB68-55
SB68-54
SB68-53
SB68-52
SB68-51
SB68-50
SB68-49


PETERSON
CREEK
OISEAU
RIVER
BERN
SB68-101
SB68-102
SB68-103
SB68-99
SB68-100
SB68-104
50° 23′45″
95° 45′



OISEAU LAKE
SB68-73
SB68-(68-72)
SB68-48
SB68-46,47
SB68-77
SB68-76
SB68-74
SB68-75
SB68-(40-45)
SB68-88
SB68-(85-87)
BE1-11
TULABI
SB68-98
SB68-90
SB68-91
SB68-92
SB68-93
SB68-94
SB68-95
SB68-96
SB68-97
BE2-4A
BE6-10
BE8-11
BE7-5
BE10-1
BE8-2
BOOSTER LAKE
SEAU RIVER
RUSH LAKE
BERNIC LAKE
BIRSE LAKE



SB68-36
SB68-35
SB68-33, 34, 37, 38
SB68-39
TULABI
LAKE
SB68-(25-27)
SB68-28
SB68-29, 30
SB68-31, 32
OISEAU LAKE
SB68-73
SB68-(68-72)
SB68-48
SB68-46, 47
SB68-77
BE1-11
SB68-76
SB68-74
SB68-75
SB68-98
SB68-90
SB68-91
SB68-92
SB68-93
SB68-94
SB68-95
SB68-96
SB68-97
SB68-67
STAR
LAKE
SB68-66
SB68-65
SB68-84
SB68-83
SB68-82
SB68-81
SB68-80
SB68-64
SB68-79
SB68-89
SB68-89
SB68-63
SB68-57
SB68-56
SB68-55
SB68-54
SB68-53
SB68-52
SB68-51
SB68-50
SB68-49
SB68-60
SB68-62
SB68-61
SB68-59
SB68-58
DAVIDSON
LAKE
BE2-4A
BE6-10
BOOSTER
LAKE
FLANDERS LAKE
BE8-11
BE7-5
RUSH LAKE
BE10-1
BE8-2
BIRSE
LAKE
50° 23′ 45″
95° 08′