PETROLOGY OF THE "NORTHERN GRANITIC ROCKS"
WANIPIGOW RIVER AREA
SOUTHEAST MANITOBA

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Master of Science

by
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ABSTRACT

The Northern Granitic Rocks comprise a group of leucocratic to mesocratic, plutonic rocks which occur immediately to the north of the Rice Lake Greenstone Belt. An area of two hundred square miles has been mapped at a scale of 1:50,000 and several hundred samples have been studied to provide data on mineralogy, texture, specific gravity and chemical composition.

This appears to be a group of truly igneous rocks which are intrusive into the rocks of the Rice Lake Greenstone Belt. Compositional variation exists from an area of homogeneous trondhjemite, characterised by a high silica content and a high soda to potash ratio west of Wallace Lake, to more mafic, hornblende-bearing quartz diorites and diorites east of Wallace Lake.

Both field relationships and mineralogical characteristics suggest that the Northern Granitic Rocks are synkinematic intrusions. This suite of rocks bears a strong resemblance to the other quartz diorite plutons in the area and to granitic intrusions bordering greenstone belts in many shield areas of the world.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

CHAPTER I

INTRODUCTION

A. Location

This area of dominantly granitic rocks, stretching from north-west of Bissett eastwards to the Manitoba-Ontario boundary, forms the northern boundary of the Rice Lake Greenstone Belt. The area of study is shown in Figure 26. The northern part of the "Wedge Granitic Rocks", which lie south of Wallace Lake and Siderock Lake, is included for comparative purposes. Total area involved is of the order of two hundred square miles, mainly within township 24, ranges 13 to 17, and township 23, ranges 16 and 17.

B. Present Work

This thesis represents a contribution to "Project Pioneer", a detailed investigation of the area around Bissett, Manitoba, undertaken jointly by the Manitoba Department of Mines (Geology Division) and the Department of Earth Sciences at the University of Manitoba. Six weeks of field work was conducted by the author in the summer of 1968. The areal extent and inaccessibility of much of the terrain made the use of a helicopter necessary. In general, map and compass traverses were widely spaced, especially in the northern part of the area. An attempt was made to obtain regional coverage. This report is based in large part on the field notes and specimens of other Mines Branch geologists who carried out traverses within the area - namely, Dr. A. Turek, J. F. Stephenson, and S. A. Amukun.

Information was recorded on computer-oriented field data sheets. Several hundred rock samples were collected during the course of the work, and over a hundred thin sections were examined to provide petrographic data. This work was carried out during the winter of 1968-1969 at the University of Manitoba. Chemical analyses, modal determinations, and specific gravity measurements were used to establish trends within the body. Petrological and mineralogical data were complemented by Universal Stage optical examination.

C. Terminology

That part of the granitic massif north of the Rice Lake-Wallace Lake-Siderock Lake Greenstone Belt has by common usage been referred to as the "Northern Granite". This was largely a term of convenience, because no granites, in the strict sense of the word, are actually present. The term "Northern Granitic Rocks" is employed here to describe this group of silicic plutonic rocks, and to serve as a geographical name. Similar reasoning has led to the naming of the "Wedge Granitic Rocks".

The lensoid "inclusion" of diorite and gabbro south of Leaf Lake has been described as the "Wanipigow Diorite" by

Russell (1947), but the name in common usage - the "Jeep Gabbro" - will be used here since the Jeep Mine is located there.

D. Conclusions

The Granitic Rocks are subdivided into several rock units, primarily on the basis of composition. Modal, chemical, and specific gravity data suggest homogeneity, on a large scale at least, in the body of Biotite Quartz Diorite to the west of Wallace Lake. Chemically, the rock has affinities with trondhjemite, being more silicic than normal quartz diorite and having a soda to potash ratio in excess of that found in either quartz diorite or granodiorite. This segment of the Northern Granitic Rocks correlates chemically, texturally, and mineralogically with the other bodies of quartz diorite in the region, especially the Rice Lake Batholith. To the east of Wallace Lake, the rocks are richer in mafic minerals, and hornblende is present in addition to biotite. The biotite/hornblende ratio decreases eastwards towards the Mafic Diorite (Unit 20). Chemical, specific gravity, and plagioclase composition data appear to indicate that a series exists from east to west across the granitic body.

The rocks become increasingly gneissic towards the southern contact with the Rice Lake Greenstone Belt, and the foliation is bent around to assume as east-west orientation.

E. Origin of the Granitic Rocks

The Northern Granitic Rocks, from their intrusive contacts, content of xenoliths, evidence of flow, and chemical homogeneity appear to be truly igneous, at least in the western area.

Physicochemical data tentatively indicates emplacement at depth, at a water vapour pressure of 5000 bars or less. It is suggested that the variation observed in the granitic rocks from east to west reflects a differentiation series, developed within a rather small temperature interval. The more mafic easterly units may have been profoundly modified by contamination and assimilation.

Hietanen (1947) has described a similar series from the Turku district of S.W. Finland. Here compositional variation exists from gabbros and diorites, through charnockites, to hornblende trondhjemites and finally to trondhjemites. The anorthite contents of the plagioclase in this group are similar to those of the Northern Granitic Rocks. The charnockites are probably the result of a lower vapour pressure of water. A series from a central core of trondhjemite to a marginal tonalite phase was described by Compton (1955), from Bidwell Bar, California. He suggests that this results from contamination of an originally trondhjemitic magma by stoping of basic blocks.

The Northern Granitic Rocks appear to be synkinematic, after the description by Marmo (1967). Such rocks have the following characteristics:

1. They occur early in the intrusive cycle.

2. They are typically of quartz diorite or granodiorite composition, and are characteristically inhomogeneous.

3. They generally form huge batholiths, often grade without sharp contacts into country rocks, and usually have contacts concordant with the strike of the country rock.

4. The composition of their plagioclase is calcic oligoclase.

5. When present, their microcline porphyroblasts often replace the plagioclase, releasing calcium, which forms epidote.

6. They contain hornblende which is frequently reactive to biotite by addition of alumina.

Many of these characteristics are typical of the Northern Granitic Rocks. The sharp intrusive contacts of the group appear to represent one point of disagreement.

Synkinematic rocks are considered, by students all over the world, to be derived from sedimentary rocks, with homogeneous portions the result of palingenic remelting.

Anhaeusser et al. (1969) agree that the granitic assemblage of the shield areas is probably largely of secondary origin, from reworked primitive crust, but may be partly of juvenile origin from the mantle. From a survey of granitic rocks bordering greenstone belts throughout the world, they divide the granitic bodies into several sequences. The main period of granitic intrusion, early in the history of a greenstone belt, has the following features:

1. The intrusive bodies, mainly of quartz diorite or granodiorite composition, form circular or diapiric bodies.

2. Their emplacement appears to be responsible for much of the structural complication and metamorphism of the greenstone belt.

3. Their foliation is caused by the alignment of platy minerals, and is accentuated by xenoliths, becoming less pronounced towards the centre of the body.

4. They cause low grade metamorphism and have narrow contact aureoles.

5. The gold and sulphide mineralization is considered a result of the mobilization of chalcophile elements in the greenstones by strong thermal gradients set up by the granitic magmas.

This period of granitic intrusion appears to follow the early formation of migmatites, which possibly represent the remnants of an early crust, and to pre-date a later intrusion of more potassic rocks. The Northern Granitic Rocks appear to belong to the main period of intrusion. The authors suggest that theories of origin stemming from the geosynclinal concept and Alpine tectonics cannot be realistically applied.

The Steynsdorp Goldfield, South Africa, exhibits many of these features and many parallels can be drawn between this area and the Rice Lake Greenstone Belt, (Viljoen et al., 1969).

CHAPTER II

STRUCTURE

The structure of the Northern Granitic Rocks has already been described to a certain extent by the previous workers.

A detailed photogeological map of the area (D.T. Anderson, 1970, pers. comm.) indicates two prominent trends:

1. An east-west trend, pronounced towards the southern margin of the granitic body north of the Wanipigow River (see Figure 1). This represents the developed cataclastic foliation parallel to the Wanipigow fault and the regional shear direction in the Rice Lake Greenstone Belt.

2. A north-northeasterly trend, better developed in the north and west and becoming more northerly east of Wallace Lake. The foliation is roughly parallel to this direction and it is believed to have developed early in the tectonic sequence. W.D. McRitchie, (1970, pers. comm.) reports that this is a prominent regional joint direction and considers it to be a relatively late feature.

A. Foliation

The foliation generally trends in a series of arcs from almost north-south in the north of the area, sweeping around through a north-westerly intermediate position, to assume an east-west orientation towards the southern contact in proximity to the main fault (see Figure 1).

In his area of study north of the Wanipigow River, Davies (1963) recognizes several gneissic zones. Such a zone occurs along and subparallel to the southern contact of the granitic rocks and varies from one-quarter of a mile up to two miles in width. Such a boundary is by necessity arbitrary since gneissosity decreases in intensity northwards and the northernmost rocks in the area approach a massive texture.

Much of the foliation along the southern contact of the granitic body is the result of a penetrative cataclasis associated with the shear zones parallel to the Wanipigow fault. Bands of intensely sheared rock parallel to this east-west direction are common in this area. The effects of mineral deformation can be observed well into the granitic rocks and this cataclastic foliation is believed to be parallel to and superimposed upon the original, primary gneissosity. This original fluxion or flow structure, indicated by aligned and undeformed plagioclase euhedra, is observed in the north-west and northern portions of the area. This is illustrated in Plate 1.

The foliation is wrapped around boudinaged inclusions of basic rocks which are invariably drawn out parallel to it.

Dip of the foliation is rarely less than 80° and is predominantly to the east and north. A steep dip to the north is typical along the strongly sheared southern contact.

Lineations are best developed in this sheared area and usually occur as streaked-out clots of mafic minerals. They may reflect an original stretch lineation in the border zones of the granitic rocks but are probably the result of the later cataclasis.

B. Folds

Minor folds are sparsely developed within the granitic rocks. These are commonly minor anticlinal drag folds with axial planes parallel to the foliation, and axes vertical. They appear to be better developed in the migmatitic rocks in the east of the area and nearer the contacts in general. They are interpreted to be due to a coupling effect associated with the regional shearing. They are often sheared through the axial plane and are frequently smeared out. Larger scale folds, with much associated disturbance,occur around and to the east of Crystal Lake.

C. Faults

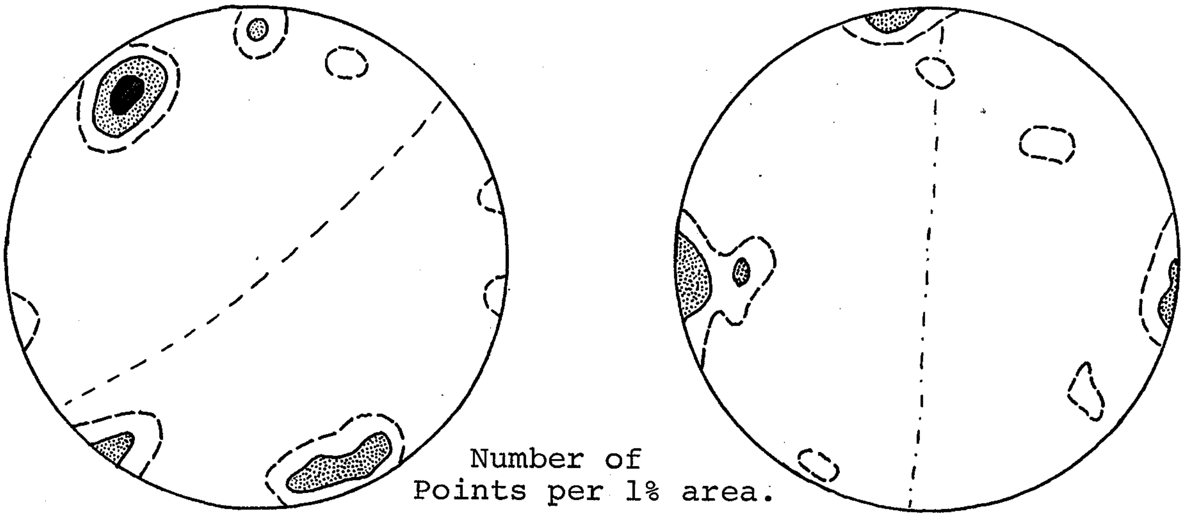
There is one large and prominent fault in the area- the Wanipigow River Fault - which trends across the centre of the map area in an east-south-east direction. W.D. McRitchie (1969) suggests the existence of a ten mile dextral lateral displacement along the line of this fault. Several smaller faults, parallel to this fracture, show a similar direction of movement. This directional sense is also indicated by the bending of the foliation as a drag feature in the Wedge Granitic Rocks adjacent to the fault plane. This fracture is the major fault in a zone of pervasive cataclasis due to regional shearing. Zones of intense shearing are common in the granitic rocks to the north and bands of mylonite occur in the "Wedge" rocks to the south. The fault appears to have been a late break within the zone of movement. Earlier shearing may have given rise to cumulative slip with a sinistral sense, as suggested by the arcuate trend of the foliation and the abrupt change of direction in the Jeep Gabbro.

Minor cross-faults appear to have been a late phase. They generally lie at an angle to the foliation, often forming conjugate sets and usually showing good displacement of the foliation or veins lying parallel to the foliation. They vary in size considerably from minor fractures to larger transcurrent faults. Epidote is commonly developed in the fault plane, especially in the more mafic rocks and also often vein quartz. The granitic country rocks are often reddened by retrogression of the feldspar.

D. Joints

Stereographic plots of poles to foliation and poles to joints from two structural domains within the Northern Granitic Rocks are shown in Figure 1. The northern subarea (U.T.M. northing 5660000 to 5664000, U.T.M. easting 321500

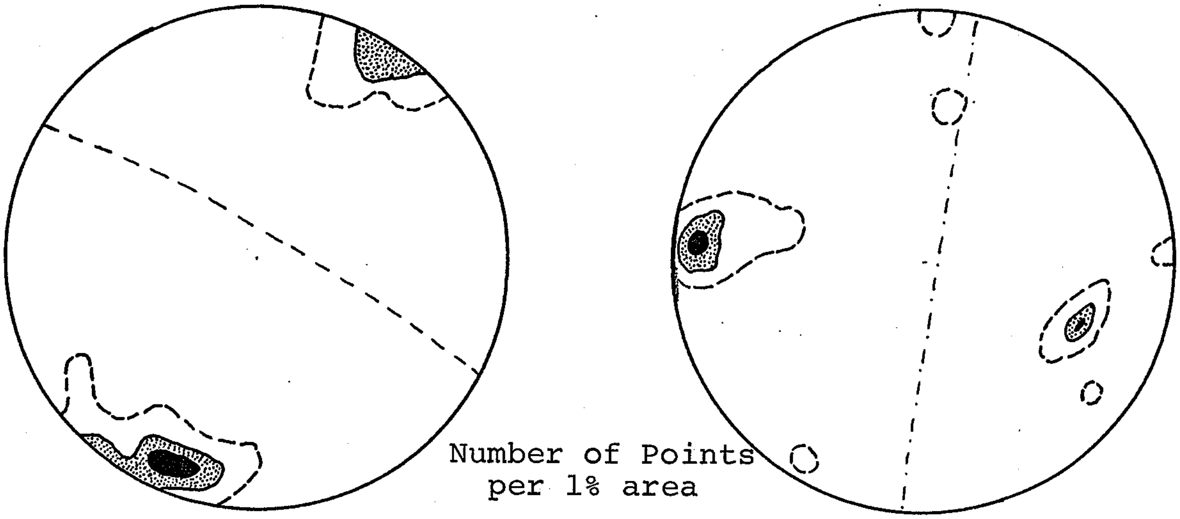
NORTHERN AREA



Poles to Foliation
(24 points)
Contours 1,2,3.

Poles to Joints
(52 points)
Contours 2,4,6.

SOUTHERN AREA



Poles to Foliation
(43 points)
Contours 2,6,10.

Poles to Joints
(40 points)
Contours 2,3,4.

Figure 1. Stereographic plots of structural data from two structural domains in the Northern Granitic Rocks.

to 328000) is located around Leaf Lake. The foliation within this area is dominantly north-easterly, parallel to the trend of the Jeep Gabbro in the area. The foliation in the southern subarea is west-north-westerly. This subarea (U.T.M. northing 5654000 to 5658000, easting 328000 to 332000) is located to the west of Wallace Lake.

Despite the different trend of the foliation in the two areas, the main joint direction appears to be oriented north-south in each case. This may indicate that it was a late structural feature, superimposed upon the already arcuate foliation.

E. Contacts

Contacts of the granitic rocks with the Rice Lake Greenstone rocks were examined in a number of localities. Where cataclasis had not effaced the relationship they were found to be intrusive and generally of a lit-par-lit type. Cross-cutting intrusive dykes are generally absent and there appears to be no decrease in grain size of the granitic rocks towards the contacts. Marginal contamination appears to have taken place in some localities and several hybrid zones occur in the eastern part of the area.

The grade of contact metamorphism lies within the epidote-albite hornfels and epidote-hornblende hornfels facies (W.D. McRitchie, 1970, pers. comm.) with local development of cordierite and staurolite but more widespread occurrence of hornblende, garnet, and oligoclase-andesine.

Greenstones are frequently recrystallised to dense black plagioclase-amphibole rocks. Garnets at Wallace Lake are developed in excess of one mile horizontally away from the contact of the granitic rocks, but the zone of contact metamorphism along the southern contact appears to be fairly narrow and effects soon grade off into the country rock. Later retrogressive overprint associated with the shear zones may be responsible for much of this. Xenoliths of sedimentary rock within the granitic rocks are also characterised by the presence of garnet.

Davies (1963) observed that the grade of metamorphism appeared to be higher around the Northern Granitic Rocks than around the other quartz-diorite bodies in the Rice Lake area.

F. Xenoliths

These are extremely common in the granitic rocks and are not confined solely to the border zones. They were found to be invariably parallel to the foliation, and varied in size from several inches to hundreds of feet. Mainly dark, dense gabbroic rocks, they were found to be sharply bounded and to occur as lensoid boudins, There is little sign of chilling in either rock at the contact, which possibly indicates deep-seated intrusion. They are believed to represent sheared remnants of an early dyke phase, which may have been related to the Jeep Gabbro. True xenoliths are also represented and volcanics are common. Other less common xenoliths include garnetiferous sediment, metaconglomerate and ultrabasic rocks. A pyroxenite xenolith, the chemical analysis of which is listed in Table 2, appears to be composed mainly of augite. Mafic inclusions of several distinct types occur in the "Wedge" rocks and show more diversity than those in the Northern Granitic Rocks. These include amphibolites, medium-grained dioritic rocks, and coarse-grained hornblendites. They contribute to an inclusion layering in the rocks.

G. Pegmatite and Vein Quartz

Pegmatites are common over the granitic body, both in the north and in the contact zones. They are usually variable both in width and orientation, but are generally narrow. They are cross-cutting at a small angle to the foliation. The pegmatites frequently have an aplitic margin and are simple in mineralogy, being mainly feldspathic. They appear in some cases to be folded by movement parallel to thefoliation and are often displaced by slip in this same direction.

Aplites are also common and they may in some cases be related to the pegmatite intrusions, of which there are possibly several generations. In the Wedge rocks, a younger pegmatite, pink in colour, cross-cuts the foliation which has a white pegmatite phase developed subparallel to it. Aplite and pegmatite, along with development of augen of K-feldspar, appear to increase in concentration towards the fault plane in this eastern area. The migmatites are characterized by this development of syntectonic pegmatite lamellae. The eastern rocks of the Wedge appear to have been partially granitized by pegmatitic solutions.

Vein quartz commonly occurs parallel to the foliation of the granitic rocks but rarely coalesces into large pods. The vein quartz, usually white, is always barren. Since the Northern Granitic Rocks are younger than the gold-bearing quartz veins of the Rice Lake group, two phases of vein quartz appear to have been developed at widely different times.

CHAPTER III

PETROLOGY

A. Modal Analyses

Subdivision of the granites into a series of units was made partly on the basis of mineral proportions, obtained by modal analyses, and partly on the basis of textural characteristics. The location of the map units can be found in Figure 26, (map in pocket), and a description of each follows the modal data.

These are listed as follows:

Unit 24	Biotite Quartz Diorite (I) (coarse-grained)
Unit 23	Biotite Quartz Diorite (II) (fine-grained)
Unit 22	Intermediate Hornblende Quartz Diorite
Unit 21	Granodiorite and Quartz Monzonite
Unit 20	Mafic Hornblende Diorite
Unit 19	Migmatite
Unit 18	Pegmatized Migmatite
Unit 17	Wanipigow Diorite (=Jeep Gabbro)

Units 1 to 16 are after Davies (1963) and refer to the rock units of the greenstone belt south of the granite contact. They include both the sedimentary and volcanic rocks of the Rice Lake Group, as well as the calcic intrusive rocks. The other quartz diorite bodies of the area occur in Unit 13 under this system. Figure 26 is thus a compilation map for the northern part of the greenstone belt, with, in addition, the newly proposed subdivisions of the Northern Granitic Complex.

Forty modal analyses, listed in table 1, are plotted on the compositional diagram of Bateman (1961) in Figure 3. Figure 2 illustrates the location of each of the points plotted.

Volume percent of the minerals present in each specimen was determined by macro- point counting. Samples were selected to provide as good a coverage of the granitic rocks as possible. This enabled subdivision to be based mainly on the compositional diagram, with support from examination of the hand specimen.

The rock slab was prepared by etching with hydrofluoric acid and selectively staining the potash felspar with saturated sodium cobaltinitrite solution, as described by Bailey and Stevens (1960). The mode was then determined by mounting the slab on a macro- point counting stage, and systematically traversing the surface with a binocular microscope. Points were 2 mm. apart, a total of 1300 being recorded whenever possible. According to Solomon and Green (1966), and Van der Plas and Tobi (1965), deviation would be around ±3 percent.

In the quartz/potash feldspar/plagioclase triangular diagram (Figure 3), the plotted points, recalculated to 100 percent, are seen to fall into compositional zones

TABLE 1

MODAL ANALYSES (Volume Percent)

Northern Granitic Rocks, Southeast Manitoba

Sample No.	Quartz	Plagioclase	K-Feldspar	Mafic Minerals
00-8-8(2)	30.19	60.15	0.92	8.75
00-8-23	25.00	70.00	0.00	5.00
00-8-27	35.62	48.50	3.37	12.62
00-8-32	29.56	52.95	0.00	14.69
00-8-35(1)	31.05	55.78	0.61	12.66
00-8-46(1)	29.42	60.14	0.00	10.71
00-8-47(1)	28.14	60.23	0.00	11.70
00-8-77	16.00	51.84	0.00	32.30
00-8-137	23.3	58.2	0.00	18.6
00-8-142	32.76	52.24	8.36	7.16
00-8-167	9.03	58.60	0.21	32.28
00-8-176	36.00	41.00	0.00	23.00
02-8-69	11.82	55.65	1.32	31.27
16-8-48	31.07	53.38	0.00	15.76

TABLE 1 (Continued)

Sample No.	Quartz	Plagioclase	K-Feldspar	Mafic Minerals
16-8-62	25.63	61.33	0.00	13.48
16-8-65	33.56	53.07	0.00	13.36
16-8-72	30.10	58.23	4.71	7.31
18-8-2	42.00	50.00	3.00	5.00
18-8-7	37.87	41.99	0.00	13.22
18-8-8	34.85	39.80	20.17	5.63
18-8-17	27.54	59.46	2.38	10.77
18-8-22(4)	29.92	43.58	0.23	26.60
18-8-28(1)	12.50	65.53	9.54	12.50
18-8-33(1)	16.98	51.85	0.00	31.15
18-8-36	23.82	49.37	9.84	17.26
18-8-38	22.40	38.87	25.53	13.82
18-8-41	22.51	37.54	26.90	13.33
23-8-1	4.74	55.58	0.00	40.01
23-8-8	6.42	50.00	0.00	40.93

TABLE 1 (Continued)

Sample No.	Quartz	Plagioclase	K-Feldspar	Mafic Minerals
23-8-21	24.88	46.57	0.00	28.53
23-8-36(1)	13.40	52.64	19.88	13.41
23-8-38(2)	24.08	69.48	0.00	5.98
23-8-51	27.82	60.30	0.00	11.87
23-8-57	28.19	55.07	0.00	16.74
23-8-66	26.88	63.44	0.00	9.68
23-8-120	34.10	62.41	0.00	4.23
23-8-139(1)	20.36	65.36	0.27	14.46
23-8-154	31.63	55.53	0.00	12.84

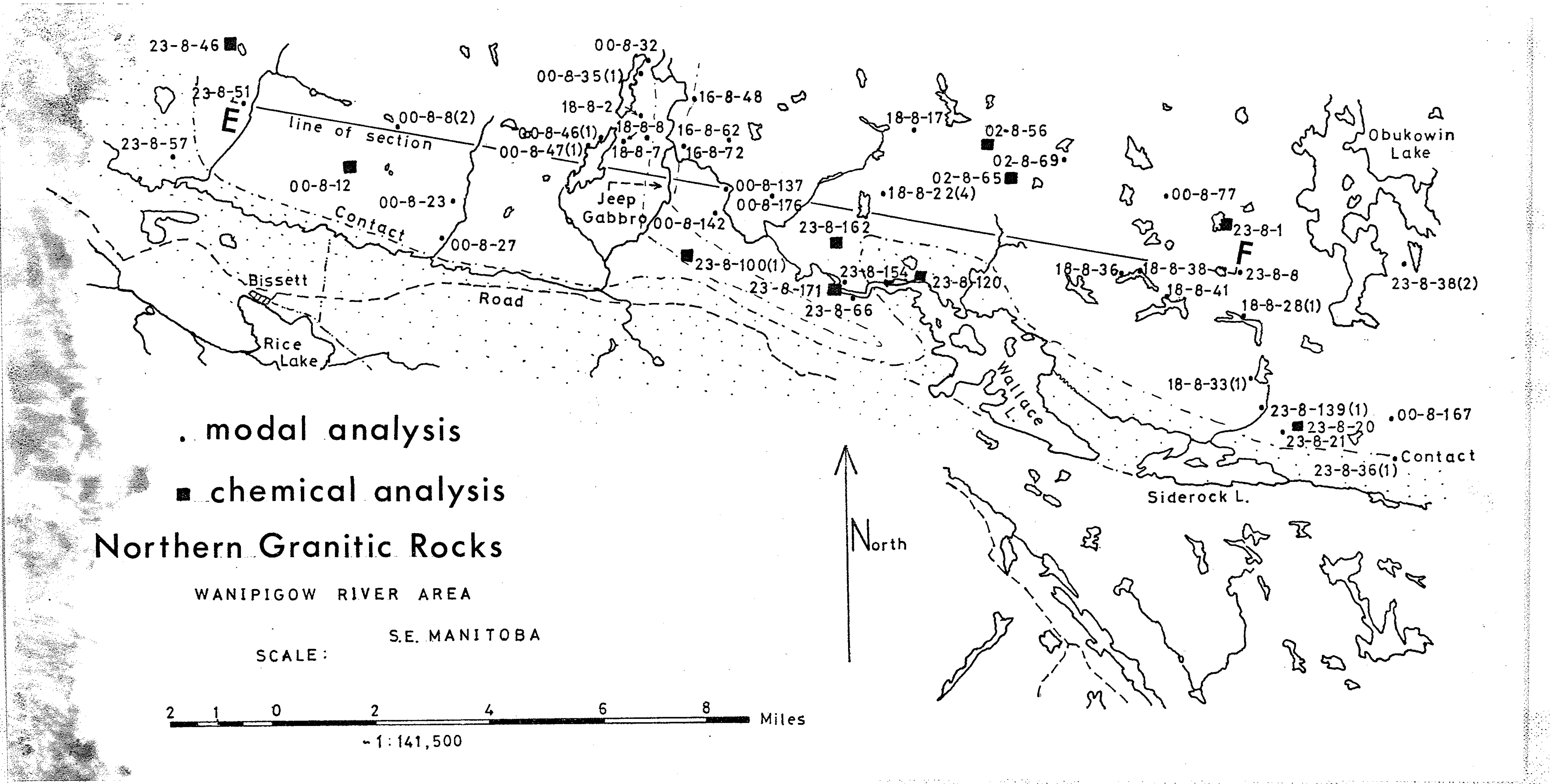


Figure 2. Map showing the location of all samples from the Northern Granitic Rocks (listed in Tables 1 and 2) for modal and chemical analyses.

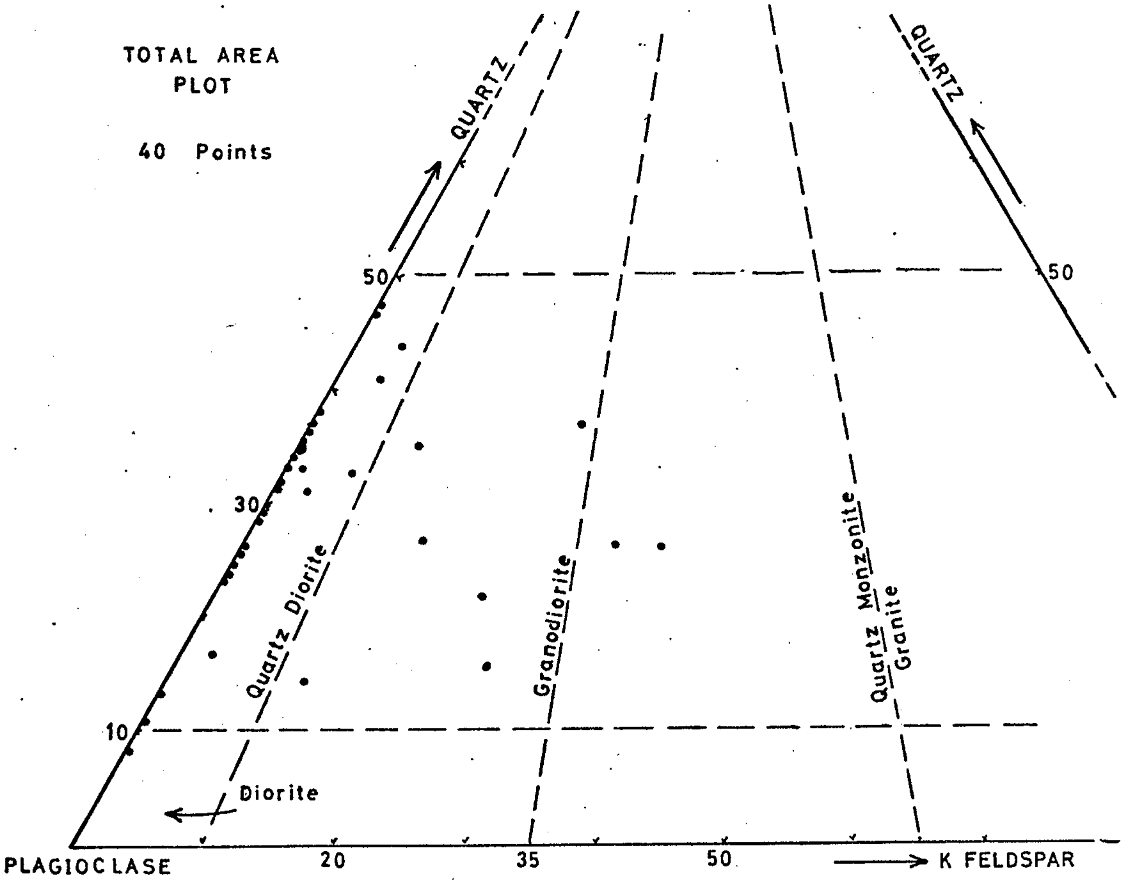


Figure 3. Relations of Modal Plagioclase/K Feldspar and Quartz (from Table 1) for all rock types in the Northern Granitic Rocks. Classification after Bateman (1963).

ranging from diorite to quartz monzonite. The wide scatter of points reflects the overall inhomogeneity of the granitic belt. The rocks are dominantly quartz diorites with a few percent of potash feldspar only, and a variable quartz to plagioclase ratio. Granites, in the strict sense of the term, are absent. There is a maximum in the quartz diorites at around 30 percent quartz, but few recognizable subsidiary maxima. This suggests that the granitic body is one variable rock body, and is not composed of a number of discrete intrusive events.

Figure 4 shows all the modal analyses for the total area plotted onto a quartz/total feldspar/mafics triangular diagram. The diagrams illustrate a scattering of modal points with no apparent groups or trend lines.

In Figure 5, the fields enclosing the mapped rock units appear to indicate an apparent trend from west to east as shown by the arrow. These fields are derived as follows:

1. The fields for the Mafic Hornblende Diorites and for the group of Granodiorites and Quartz Monzonites are derived directly from the compositional diagram (Figure 3). The location of these two units is shown in Figure 26, (map in pocket).

2. Units 23 and 24 are distinguished only on the basis of grain size; they are both Biotite Quartz Diorites. They occur to the west of Wallace Lake. For the benefit of Figure 5, which attempts to show compositional variation from east to west across the granitic body, they are

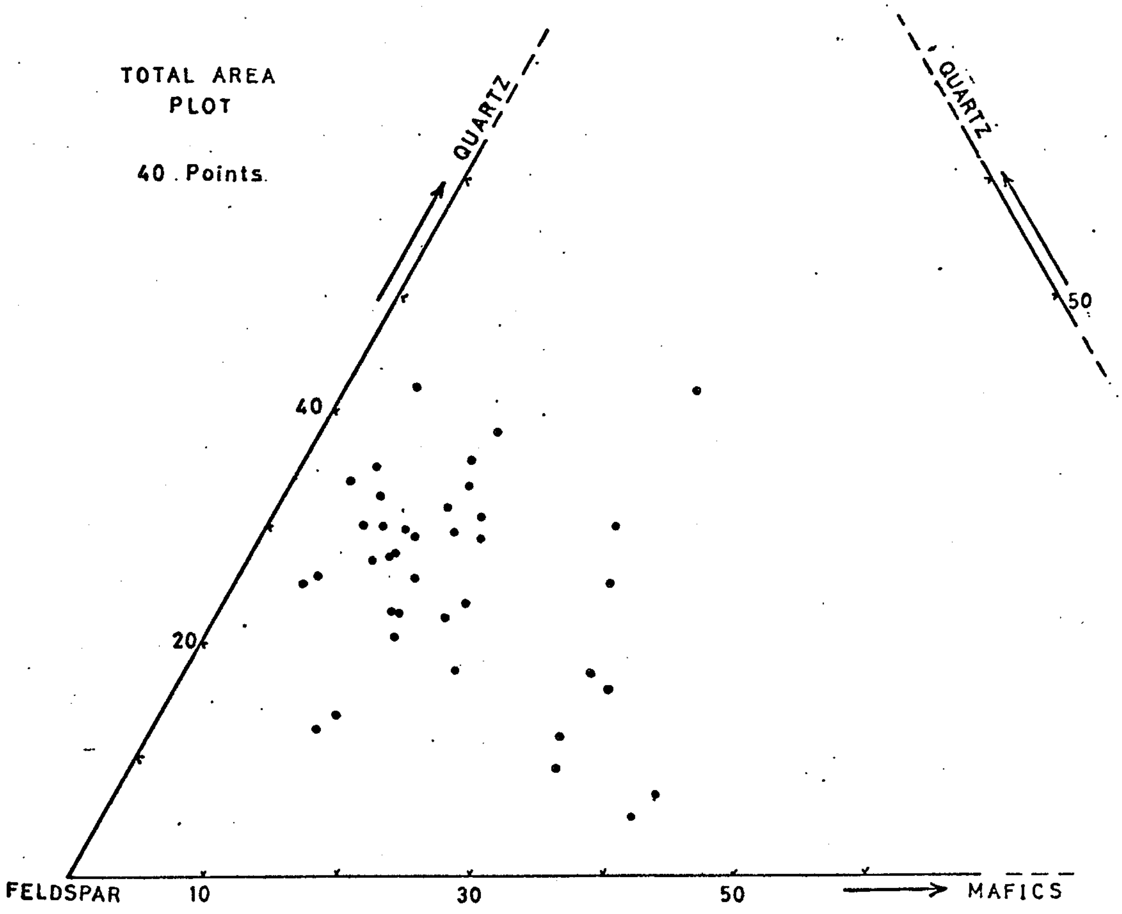


Figure 4. Relations of Modal Quartz/Feldspar (total) and Mafic Minerals (from Table 1) for all rock types from the Northern Granitic Rocks.

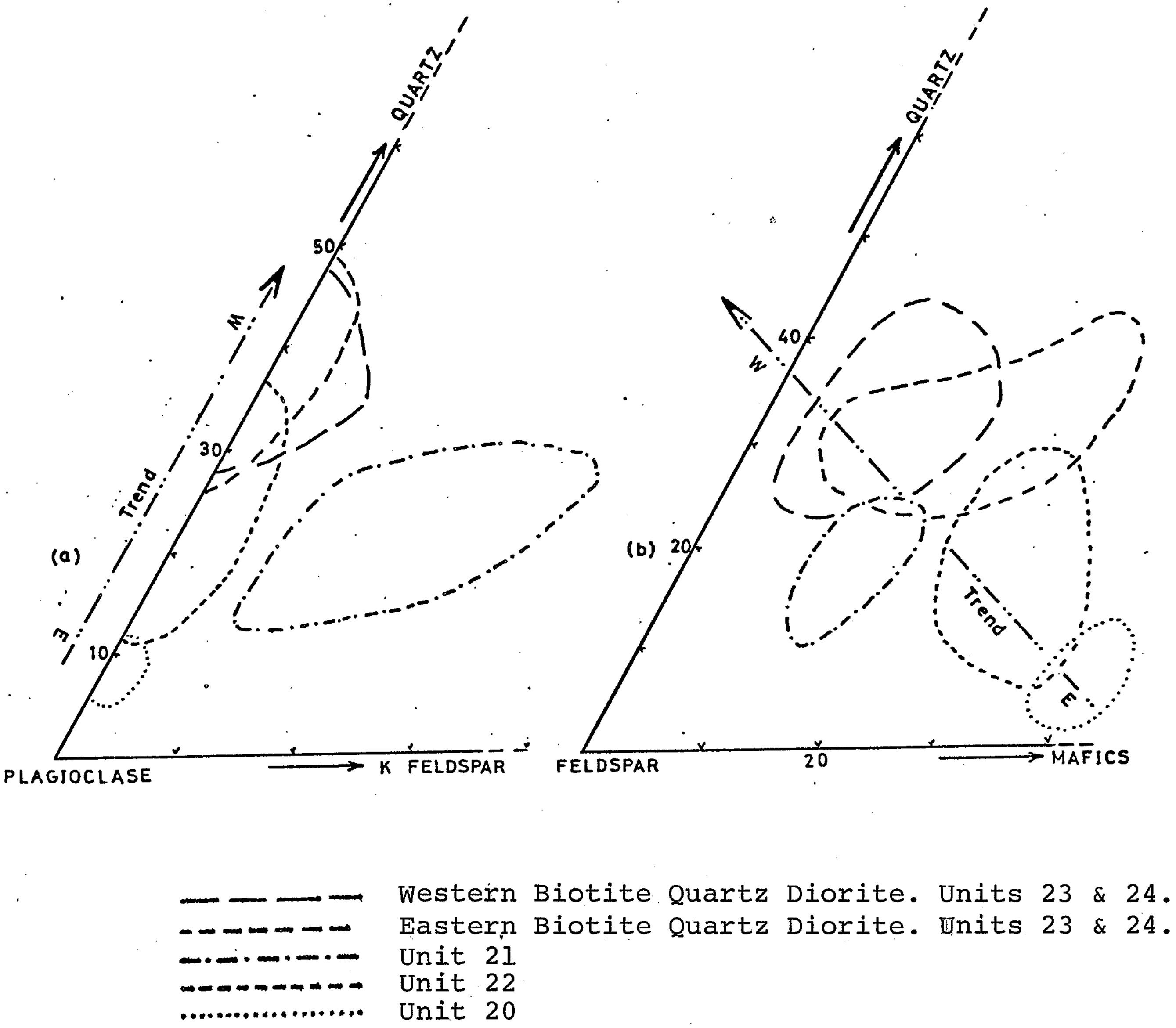


Figure 5. Fields of the mapped rock units (enclosing the modal points), showing a compositional trend from east to west in the Northern Granitic Rocks.

combined, and this combined group split into two portions to form (a) a western Biotite Quartz Diorite, to the west of the Jeep Gabbro, and (b) an eastern Biotite Quartz Diorite, to the east of the Jeep Gabbro.

3. A further subdivision is made into a group of intermediate Hornblende Quartz Diorites. This group, shown on Figure 26 (map in the pocket), falls between the Biotite Quartz Diorites and the Mafic Hornblende Diorites, both in space and in composition. It contains between 20 percent and 40 percent Mafic Minerals and is correspondingly poorer in quartz. It is unit 22.
Figure 5 shows that a variation exists from rather mafic quartz-poor rocks in the eastern part of the Northern Granitic Belt to more leucocratic varieties west of Wallace Lake. The relatively potassic group of Granodiorites and Quartz Monzonites plots off the trend line in Figure 5b, and reflects feldspar enrichment in the form of a variably developed growth of microcline. Figure 5 also indicates the similarity in composition of the Biotite Quartz Diorite on either side of the Jeep Gabbro, with a tendency for the rocks on the eastern side to be more mafic.

Figure 6 illustrates, by means of contoured maps, the overall percentage variation in quartz and the mafic minerals.

Rock Units

Following is a description of each rock unit,

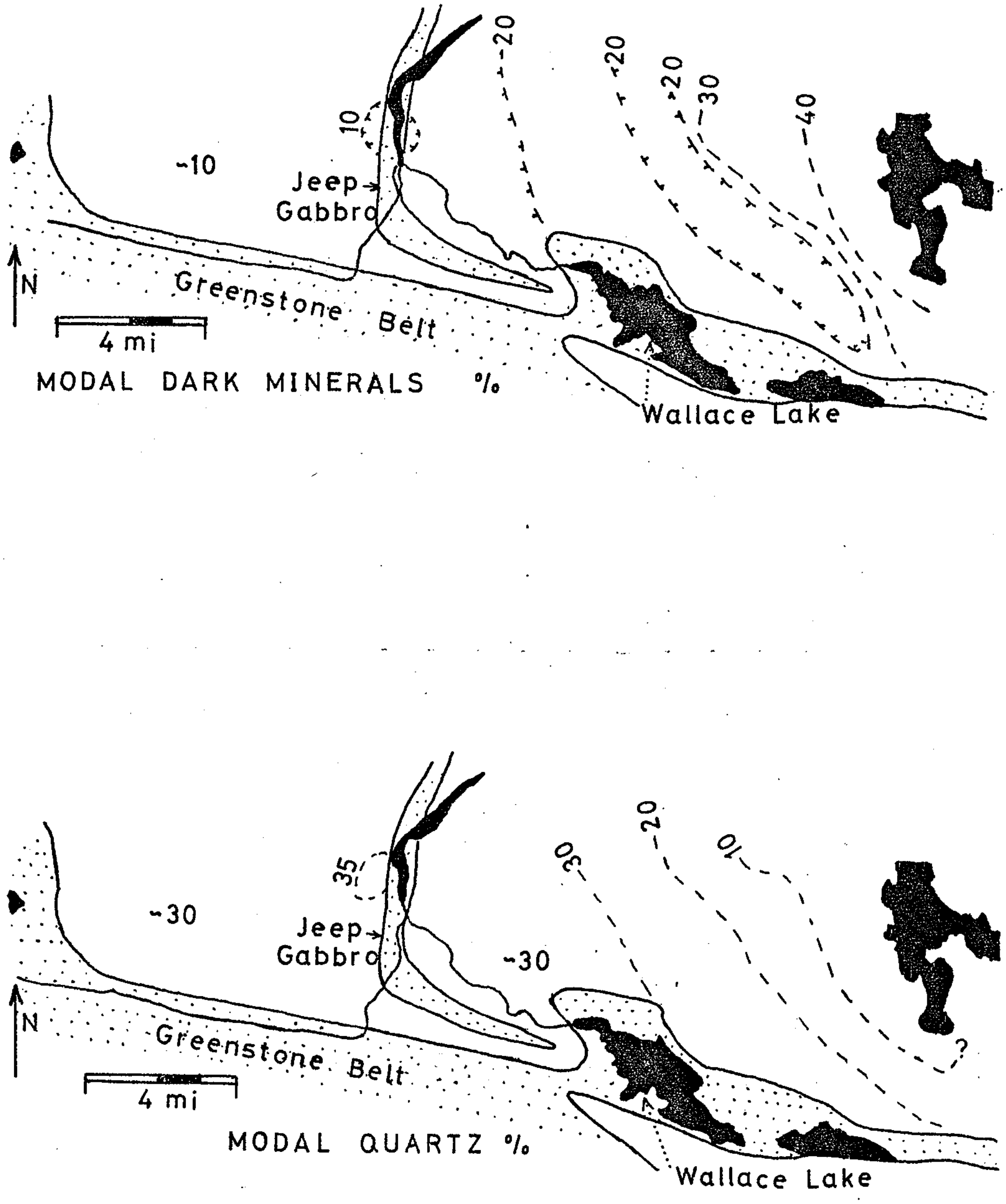


Figure 6. Variation in mineral proportions in the Northern Granitic Rocks. Contours as indicated.

distinguished partly by compositional variation as explained in the last section, and partly on the basis of field criteria. The microscopic and macroscopic features of each of these units will be discussed. Their distribution is shown on the main map (Figure 26), and they are listed at the start of the last section.

Unit 24 Biotite Quartz Diorite (I) (Coarse-grained)

This rock extends from the western contact of the granitic rocks eastwards as far as the eastern boundary of Township 24, Range 15, approximately north of Wallace Lake. Modal data for the areas both east and west of the Jeep Gabbro are shown in Figure 21. The body appears homogeneous on a large scale with, on the average, 30 percent quartz, 10 percent mafic minerals, and 50 percent feldspar, mainly oligoclase (An_{27}). It is medium to coarse-grained (greater than 3mm.) and sub-porphyritic in texture. The typical rock is white to grey in colour, often reddened by retrogression due to iron staining, and has poor foliation outlined by irregular, fine quartz stringers and streaky mafics, Biotite, the only mafic material, is frequently marginal to, and enveloped by, the euhedral plagioclase crystals. The latter are more euhedral when spaced apart in the xenomorphic matrix which consists mainly of mosaic quartz with a little microcline. This suggests that the last stages of crystallization took place in a static medium. Some interstitial microcline is common, infrequently representing more than 5 percent of the rock.

Unit 23 Biotite Quartz Diorite (II) (Fine-grained)

In the northern part of the granitic body, there is a predominance of a finer grained, light grey quartz diorite. There appears to be every gradation between this and Unit 24, and occurrences of one within the other are common. Euhedral plagioclase crystals are less well developed, and the texture tends to be more xenomorphic granular than subporphyritic. Mineral proportions and overall composition are identical to Unit 24; sample 00-8-12 (Table 2) is a chemical analysis of a member of this group. Foliation is usually poorly developed.

Unit 22 Intermediate Quartz Diorite

This unit is distinguished by its coarse grain size, its higher proportion of mafic minerals, and its lower quartz content. Hornblende is present although the content of the mineral remains low and erratic and biotite is still predominant. The nature of the boundary with the Biotite Quartz Diorites north of Wallace Lake is uncertain. The rocks are usually dark in colour, and coarse-grained. Foliation is poorly to well developed, and is frequently defined by the clumpy segregation of mafic minerals. Plagioclase crystals are subhedral, and are commonly found partly replaced by microcline. Quartz is in interstitial mosaics as a late phase.

Unit 21 Granodiorites and Quartz Monzonites

These rocks are light weathering, coarse-grained Granodiorites and Quartz Monzonites in which the pink microcline porphyroblasts are readily visible on the weathered surface. They appear to have been, originally, Quartz Diorites of Intermediate type, affected by post-solidification growth of microcline. These porphyroblasts are commonly over 1 cm. long and lie parallel to the foliation, (see Plate 2). This group, like the Intermediate Quartz Diorites into which they grade, have hornblende crystals frequently sieved with quartz blebs. There is a reaction relation between the biotite and hornblende, the latter mineral usually being predominant. The mafic minerals are commonly segregated into clumps and associated with much epidote and a little sphene. Plagioclase occurs in various stages of replacement by microcline and myrmekitic intergrowth is found at their mutual borders. This is possibly a later development. Potash metasomatism is, in all probability a marginal effect of the migmatite development to the south of the area of Granodiorites and Quartz Monzonites, and seems to have been responsible for the presence of the microcline.

Unit 20 Mafic Hornblende Diorite

In this group, the content of quartz is less than 10%. They are dark, coarse-grained rocks of high specific gravity. Foliation is crudely outlined by mineral orientation. These rocks contain up to 40% mafic minerals, mainly hornblende showing a little alteration to biotite. These minerals are identical to those in the other units. The small amount of quartz is late stage and interstitial to the early crstallizing plagioclase and hornblende. The latter two minerals appear virtually synchronous in the paragenetic sequence.

Unit 19 Migmatites

These rocks occur in the east of the area on either side of the Wanipigow River Fault. They owe their migmatitic nature to the development of syntectonic pegmatite lamellae parallel to the foliation and rounded, rather reddened augen of feldspar. The foliation is dominantly cataclastic, mineral alignment is advanced and light-weathering mylonite bands parallel to the foliation also contribute to the migmatitic character. The rocks are light on the weathered surface but frequently greenish on the fresh face due to the chlorite-epidote assemblage. All the minerals show evidence of strain; the plagioclase crystals are bent and broken and the quartz shows strain shadows. Inclusion layering also contributes to the mixed and heterogeneous nature of these banded rocks. This is best developed in the "Wedge Granitic Rocks" south of Siderock Lake where widespread boudins and layers of amphibolite, dioritic rocks, hornblendites and other possibly intrusive types occur. Hornblende bearing bands may be due to original sedimentary relics. All are obscured by the pervasive cataclasis. Aplite and pegmatite bands appear to become more common towards the fault where general permeation of pegmatitic materials is better developed. The structural disruptions may have provided access for solutions.

The "Wedge" rocks are believed originally to have been magmatic like the Northern Granitic Rocks and similarities in texture and mineralogy suggest that they are closely related.

C. Alteration

Saussuritization of the plagioclase, the common development of large crystals of epidote, and the reaction relation between hornblende and biotite are examples of late magmatic or deuteric alteration. These effects are similar to those induced by penetrative cataclasis, and the two processes may be either closely spaced in time or concurrent.

CHAPTER IV

PETROCHEMISTRY

Chemical analyses were carried out on six representative specimens of the Northern Granitic Rocks. The chemical analyses are listed in Table 2 and the sample locations are shown in Figure 2. Sample 23-8-100(1) comes from a granitic dyke in the vicinity of the Jeep Mine. For comparative purposes, three analyses of granitic rocks from other areas of the world are included in Table 2.

The four analyses from the western part of the area are uniformly trondhjemitic. This is described as a silicic, usually biotite bearing rock with a high soda to potash ratio. These four samples have a consistent silica content much higher than the normal tonalite, which is usually below 66%, and a much higher soda to potash ratio, consistently 3:1, than the average granodiorite. Analyses of trondhjemite from other areas, Hietanen (1947), confirms this chemical identity.

Figure 7 illustrates variation of the alkalis with silica. Potash shows a tendency to decrease irregularly with increasing silica, although specimen 02-8-65 appears

CHEMICALLY ANALYSED SAMPLES

Country Rocks:

23-8-46	Coarse-grained, light-weathering, leucocratic Biotite Quartz Diorite from north-east of Little Beaver Lake. (See Figure 2).
00-8-12	Medium-grained, light grey, massive Biotite Quartz Diorite.
23-8-100	Coarse-grained, light-weathering, leucocratic Biotite Quartz Diorite from a granitic dyke north-east of the Jeep Mine.
23-8-162	Coarse-grained, poorly foliated, dark grey leucocratic Biotite Quartz Diorite. Typical country rock.
02-8-65	Medium-grained dark grey, massive rock, fairly rich in biotite. Intermediate Quartz Diorite.
23-8-1	Coarse-grained, poorly foliated rock with a gabbroic texture and up to 40% mafic minerals. Mafic Hornblende Diorite.

Others

23-8-120	Rock resembling 23-8-162 from a boulder in a conglomerate immediately north of the western tip of Wallace Lake.
02-8-56	Pyroxenite inclusion from north-east of Wallace Lake.
23-8-171	Sample of grey, fine-grained diabase from the Wanipigow River area near the first portage west of Wallace Lake.

The geographical co-ordinates of each sample can be obtained from the data sheet corresponding to each sample number.

TABLE 2

CHEMICAL ANALYSES (IN WT. %) - NORTHERN GRANITIC ROCKS - S. E. MANITOBA

Oxide	Northern "Granitic" Rocks					
	23-8-46	00-8-12	23-8-100	23-8-162	02-8-65	23-8-1
SiO_2	72.75	69.40	69.55	69.50	60.25	48.45
Al_2O_3	15.40	14.88	15.27	16.21	15.04	19.18
Fe_2O_3	0.35	2.49	0.63	1.21	2.18	3.67
FeO	0.84	1.96	1.64	1.88	3.40	6.28
MgO	0.56	0.87	1.03	1.07	3.20	5.70
CaO	2.42	3.58	3.68	2.14	7.31	8.58
Na_2O	4.82	5.06	4.72	4.74	4.32	4.24
K_2O	2.38	1.57	1.56	1.77	2.43	1.13
H_2O	0.62	0.78	1.04	0.98	0.94	1.29
CO_2	0.00	0.12	0.56	0.17	0.19	0.00
TiO_2	0.14	0.33	0.21	0.34	0.56	1.04
P_2O_5	0.02	0.01	0.00	0.01	0.02	0.03
MnO	0.03	0.05	0.04	0.04	0.10	0.14
Total	100.33	100.12	99.93	100.26	99.94	99.73

Source Analyst: K. Ramlal, University of Manitoba 1969

TABLE 2 (Continued)

Oxide	Conglomerate Boulder * 23-8-120	Pyroxenite * 02-8-56	Diabase * 23-8-171	Tonalite S.Cal. + Batholith	Granodiorite S.Cal. + Batholith	Trondhjemite + Norway
SiO_2	70.70	52.85	49.35	62.2	73.4	69.30
Al_2O_3	14.28	2.19	14.51	16.6	14.1	16.81
Fe_2O_3	0.32	3.42	2.68	1.4	0.7	0.28
FeO	1.76	6.20	9.44	4.5	1.7	1.26
MgO	1.07	13.60	7.80	2.7	0.4	1.08
CaO	3.91	18.76	10.72	5.7	2.1	3.34
Na_2O	5.06	0.84	1.96	3.4	3.4	6.00
K_2O	0.88	0.14	0.20	1.6	3.5	1.39
H_2O	1.03	1.03	2.11	0.6	0.3	0.50
CO_2	0.52	0.30	0.00	0.0	0.0	0.15
TiO_2	0.18	0.11	0.72	0.4	0.2	0.23
P_2O_5	0.00	0.01	0.01	0.0	0.0	0.03
MnO	0.03	0.48	0.21	0.1	0.02	Tr
Total	99.74	99.92	99.71	99.69	100.01	100.37

* K. Ramlal, University of Manitoba, 1969
\+ Turner and Verhoogen (1960)

anomalously enriched, probably due to blastic growth of microcline. Three of the specimens have a very similar silica content and are represented on the diagram by one vertical line. The junction of the trend lines of calcium and total alkalis shows an alkali-lime index of 60.0 (Peacock, 1931) but this may be misleading due to the wide spread of silica values and uncertainty in the slope of the calcium growth line.

Figure 8 illustrates variation in the magnesium, ferrous and ferric oxides, as well as total iron, against silica content. The plotted points appear to fall on fairly well defined straight line trends and all bear an inverse relationship to silica.

Figure 9 shows a regular build-up in the minor elements with silica. Alumina, however, is rather irregular, the low content in 02-8-65 is probably due to microcline blastesis.

The horizontal co-ordinate in these diagrams approximates to an east-west traverse across the granitic belt. This is illustrated in Figure 2. The four samples with high silica demonstrate chemical homogeneity in the rocks west of Wallace Lake, with a regular decrease in silica and increase in mafic components east of that point. In combination, despite expected variation with silica, the rock types represented form a series and are genetically related.

Figure 10 to 13 are plots of the major oxide

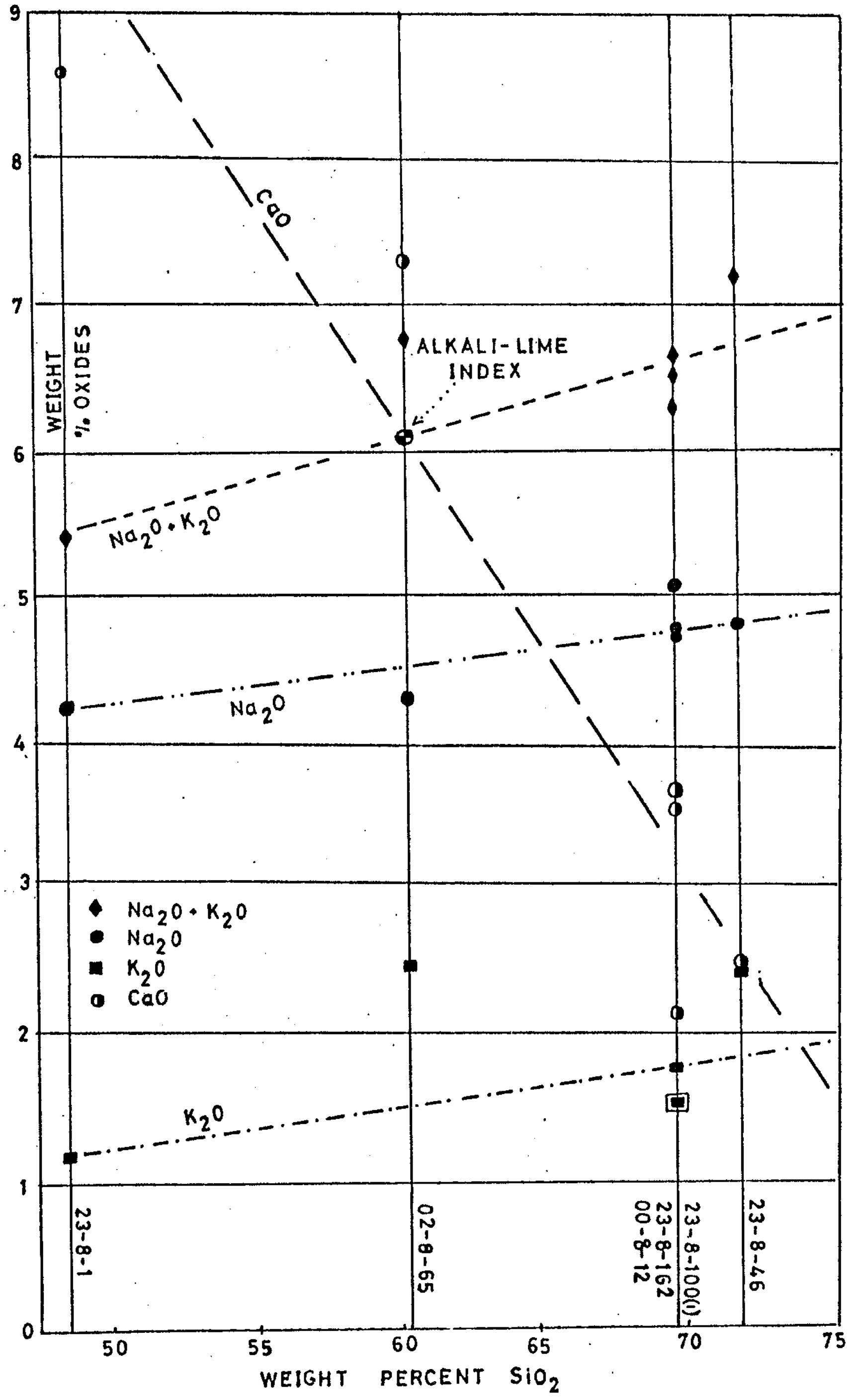


Figure 7. Variation of CaO, Na_2O, K_2O and total alkalis with SiO_2. (From Table 2)

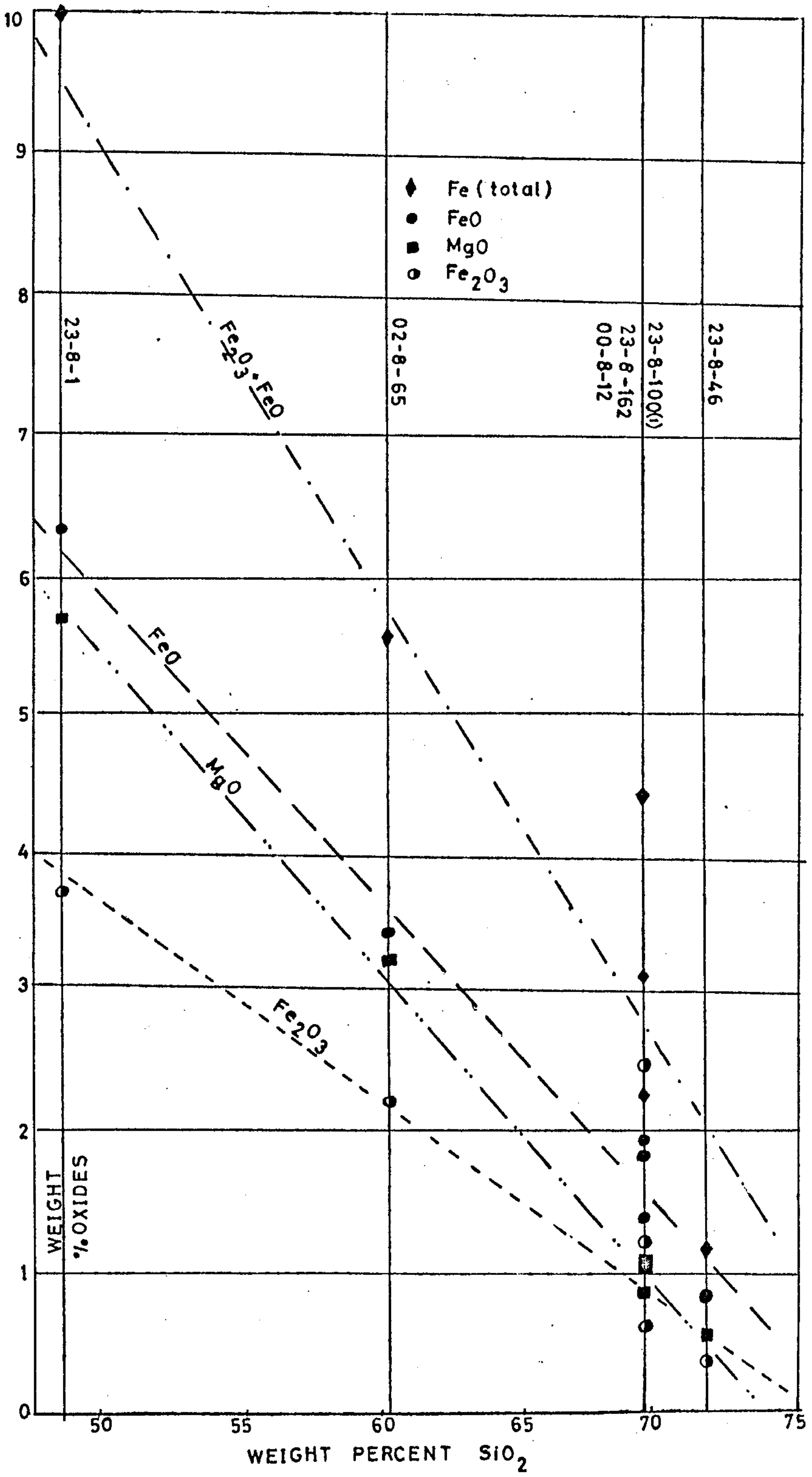


Figure 8. Variation of Fe_2O_3, FeO, MgO and total iron against SiO_2.

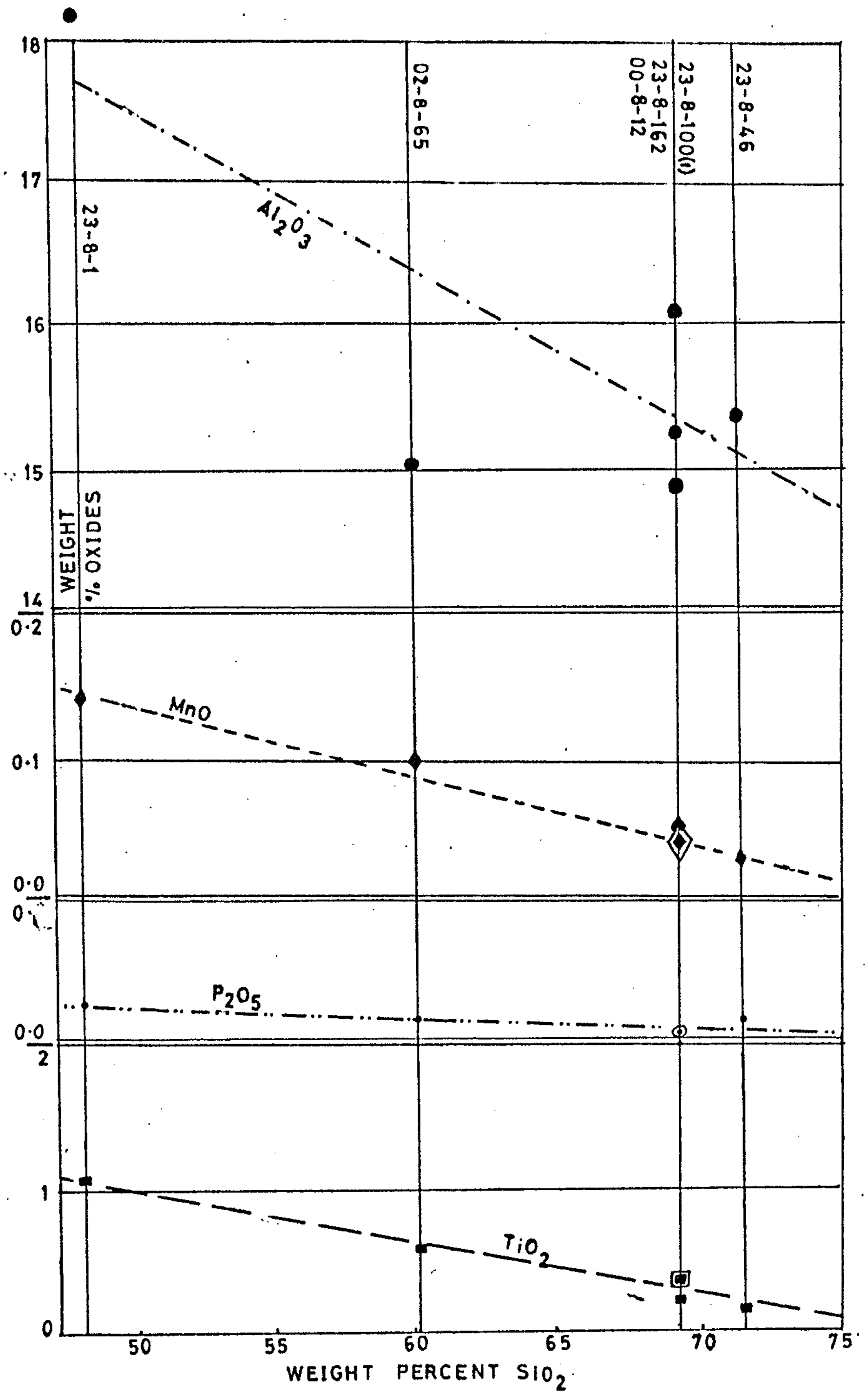


Figure 9. Variation of TiO_2, MnO, and Al_2O_3 against SiO_2.

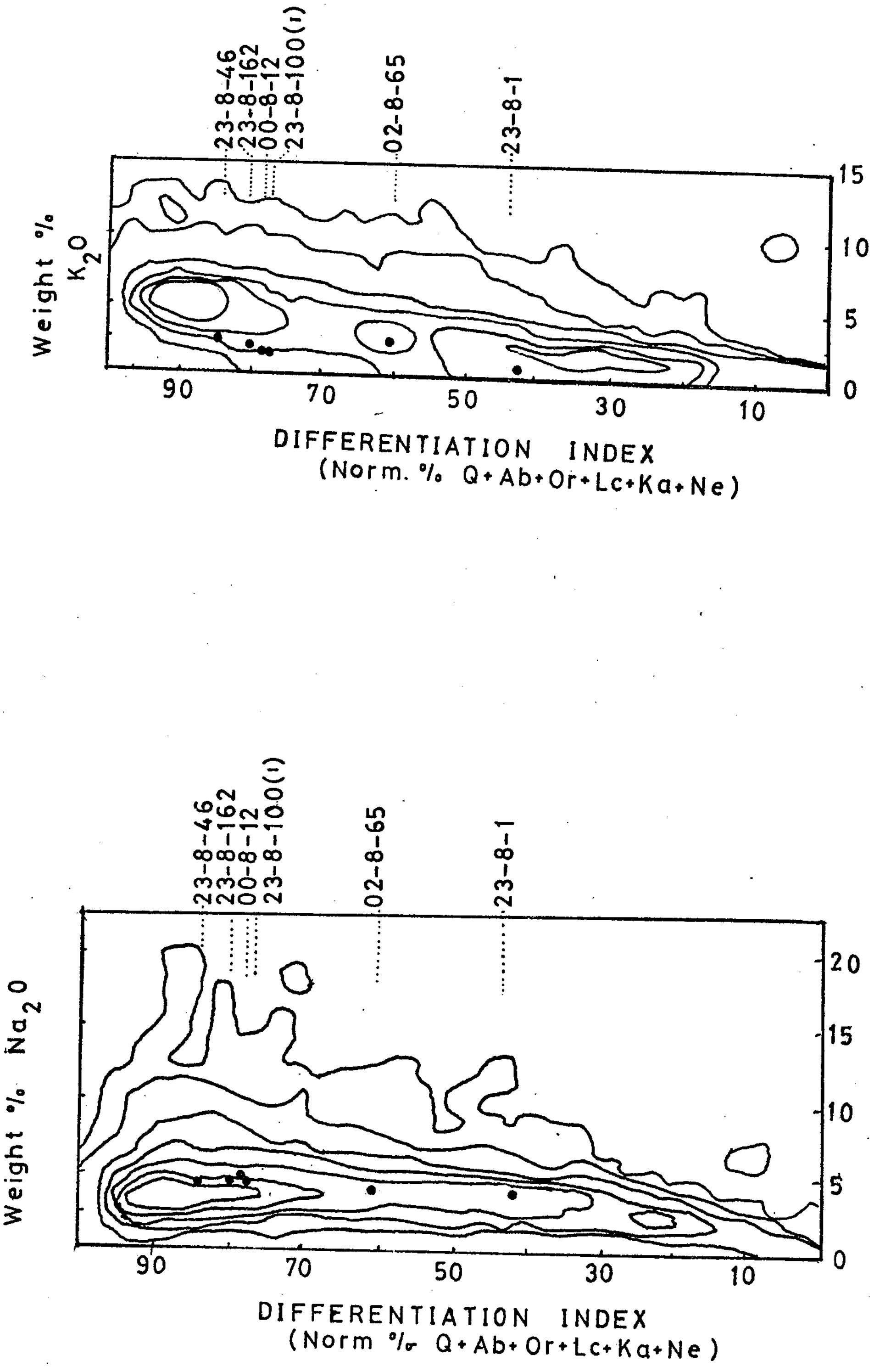


Figure 10. Weight percent of the alkalis against the Differentiation Index of Thornton and Tuttle (1960). Contours are of 5000 analysed rocks from Washington's Tables.

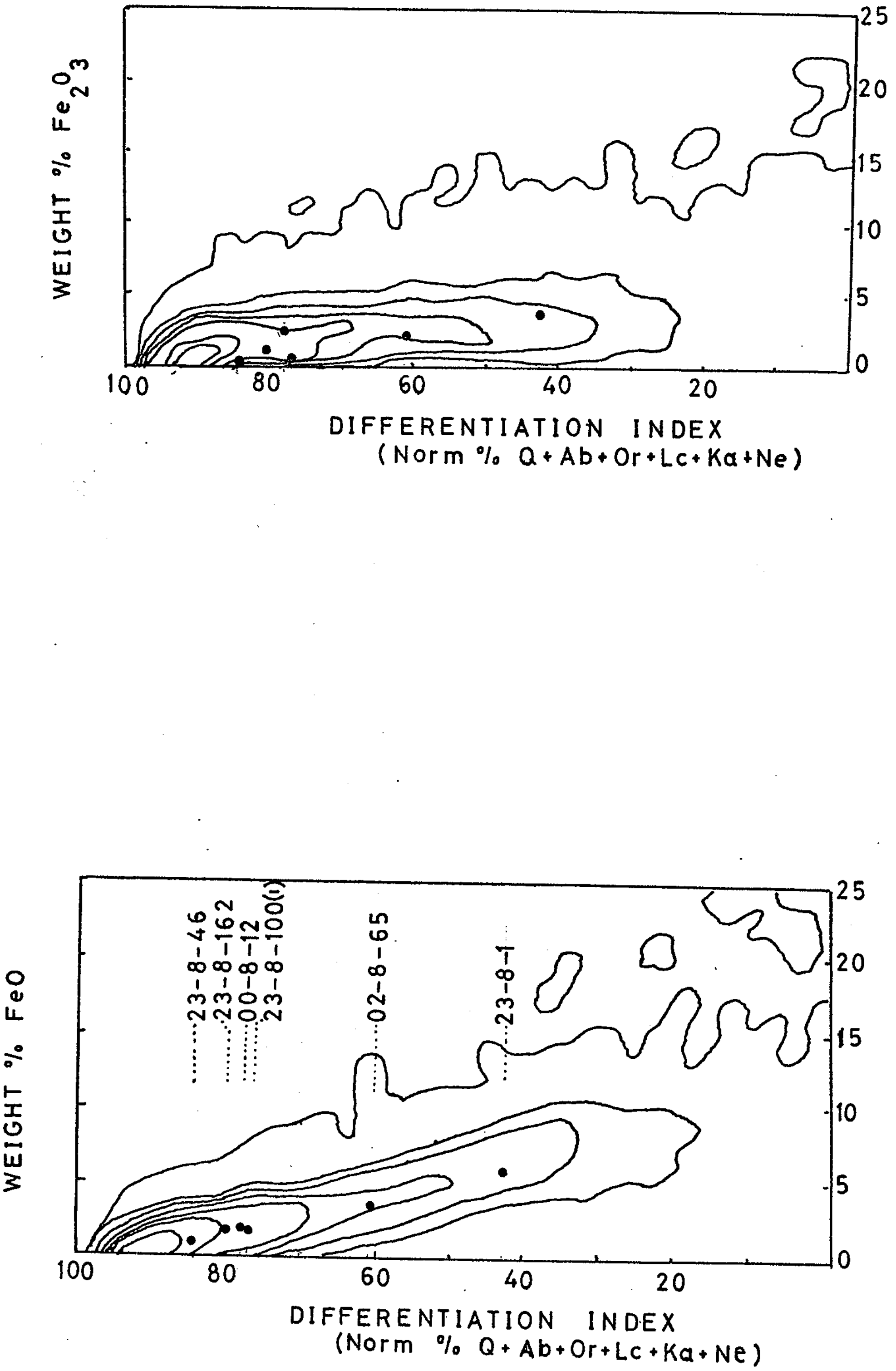


Figure 11. Weight percent Ferric and Ferrous oxides against the Differentiation Index of Thornton and Tuttle (1960). Contours are of 5000 analysed rocks from Washington's Tables.

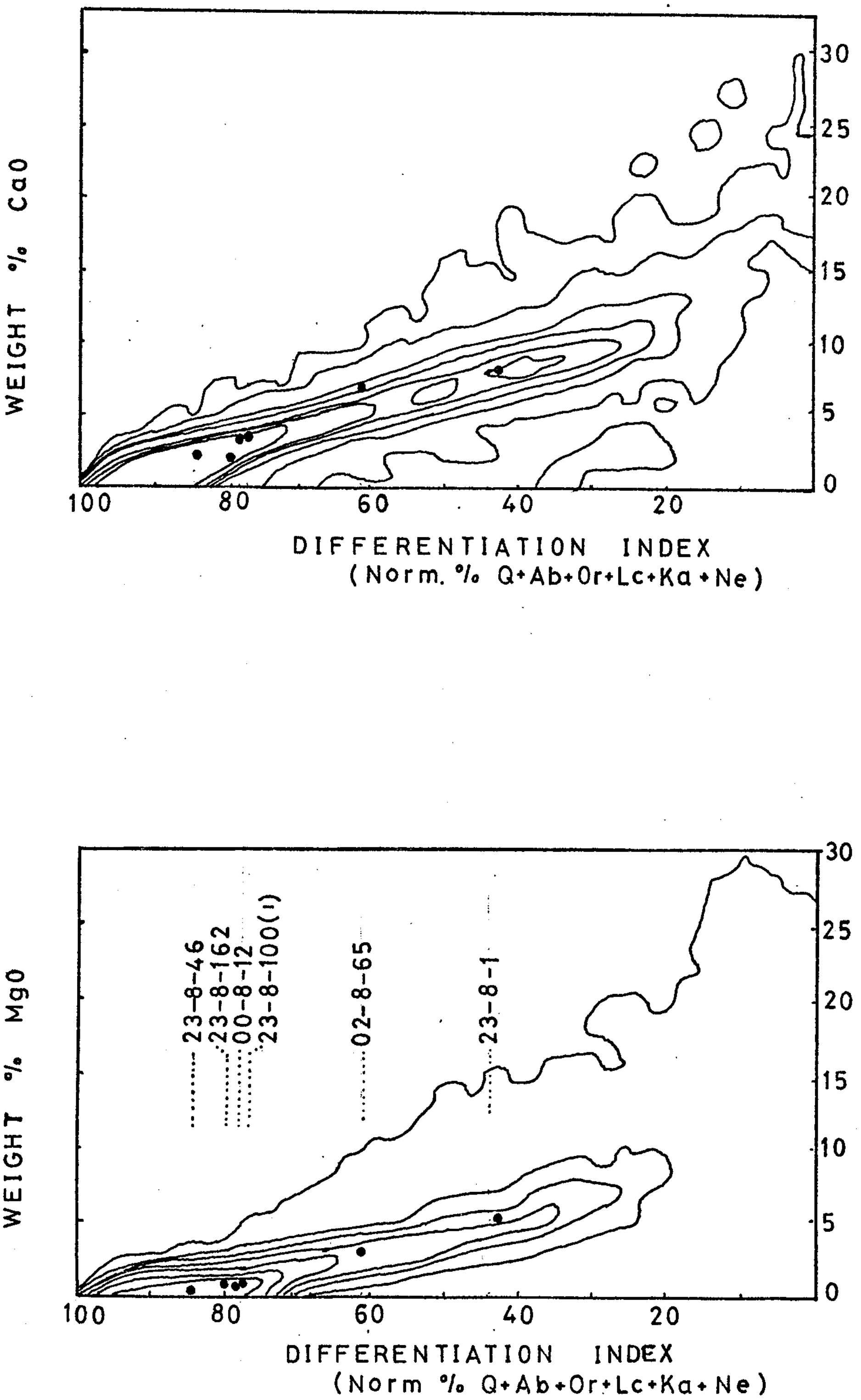


Figure 12. Weight percent CaO and MgO against the Differentiation Index of Thornton and Tuttle (1960). Contours are of 5000 analysed rocks from Washington's Tables.

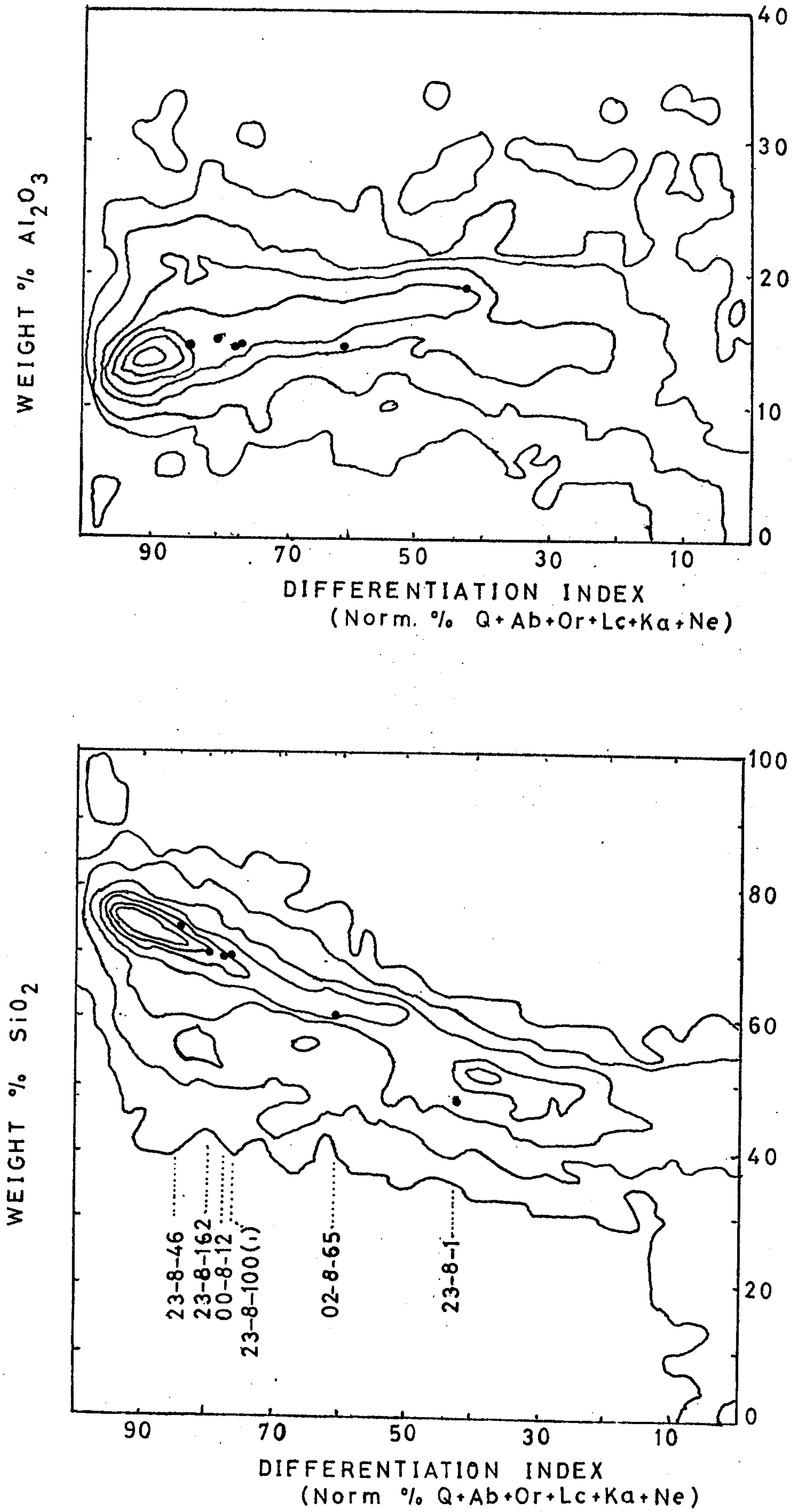


Figure 13. Weight percent of silica and alumina against the Differentiation Index of Thornton and Tuttle (1960). Contours are of 5000 analysed rocks from Washington's Tables.
are

variation against the differentiation index. This was presented by Thornton and Tuttle (1960) with contours from the five thousand analyses from Washington's tables. The regular chemical variation is consistent with other evidence that the rocks form a series and are related. The trends for ferric and ferrous iron, calcium, magnesium, alumina and silica coincide with the maxima for each element. The plots for the alkalis, however, indicate that the rock suite as a whole is relatively low in potash and enriched in soda. This reflects the trondhjemitic nature of the rocks.

In Figure14, the differentiation index is plotted on an east-west traverse across the granitic body. It is high from the western contact of the granitic rocks eastwards as far as Wallace Lake, then decreases rapidly and apparently regularly.

Figure 15 shows the six analyses recalculated to 100% and plotted on to a $FeO_{tot.}/MgO/Na_2O + K_2O$ triangular diagram. This shows a well-defined trend with rocks from west to east plotting in the order one to six. It provides additional evidence that the series constitutes a genetically related suite.

Table 3 lists the Niggli weight norms for the six chemically analysed rocks. Sample 23-8-1 is normatively undersaturated.

Figure 16 shows the six normative analysed points for the Northern Granitic Rocks, recalculated to 100%, plotted as projections to the four faces of the tetrahedron which

TABLE 3

NIGGLI NORMATIVE DATA

NORTHERN GRANITIC ROCKS SOUTHEAST MANITOBA

Normative Mineral	23-8-46	00-8-12	23-8-100	23-8-162	02-8-65	23-8-1
Quartz	27.1	23.8	25.3	26.8	7.6	-
Orthoclase	14.0	9.2	9.3	10.5	14.4	6.8
Albite	43.2	45.4	42.8	42.9	38.9	32.2
Anorthite	11.5	13.3	14.9	8.7	14.4	30.2
Nepheline	-	-	-	-	-	3.6
Hypersthene	2.6	3.7	5.0	5.1	12.7	-
Diopside	-	-	-	-	-	7.21
Olivine	-	-	-	-	-	14.75
Magnetite	0.3	2.6	0.6	1.2	2.2	3.86
Calcite	-	-	-	0.3	0.3	-
Wollastonite	-	1.2	-	-	8.2	-
Corundum	0.7	-	0.4	3.6	-	-
Sphene	0.2	0.5	0.2	0.4	0.7	1.46
Apatite	-	-	-	-	-	-
An Content Of Feldspar	21.02	22.65	25.82	16.86	27.01	48.38
Differentiation Index	84.3	78.4	77.4	80.2	60.9	42.55
Crystallisation Index	12.56	14.98	16.89	10.79	20.58	50.80

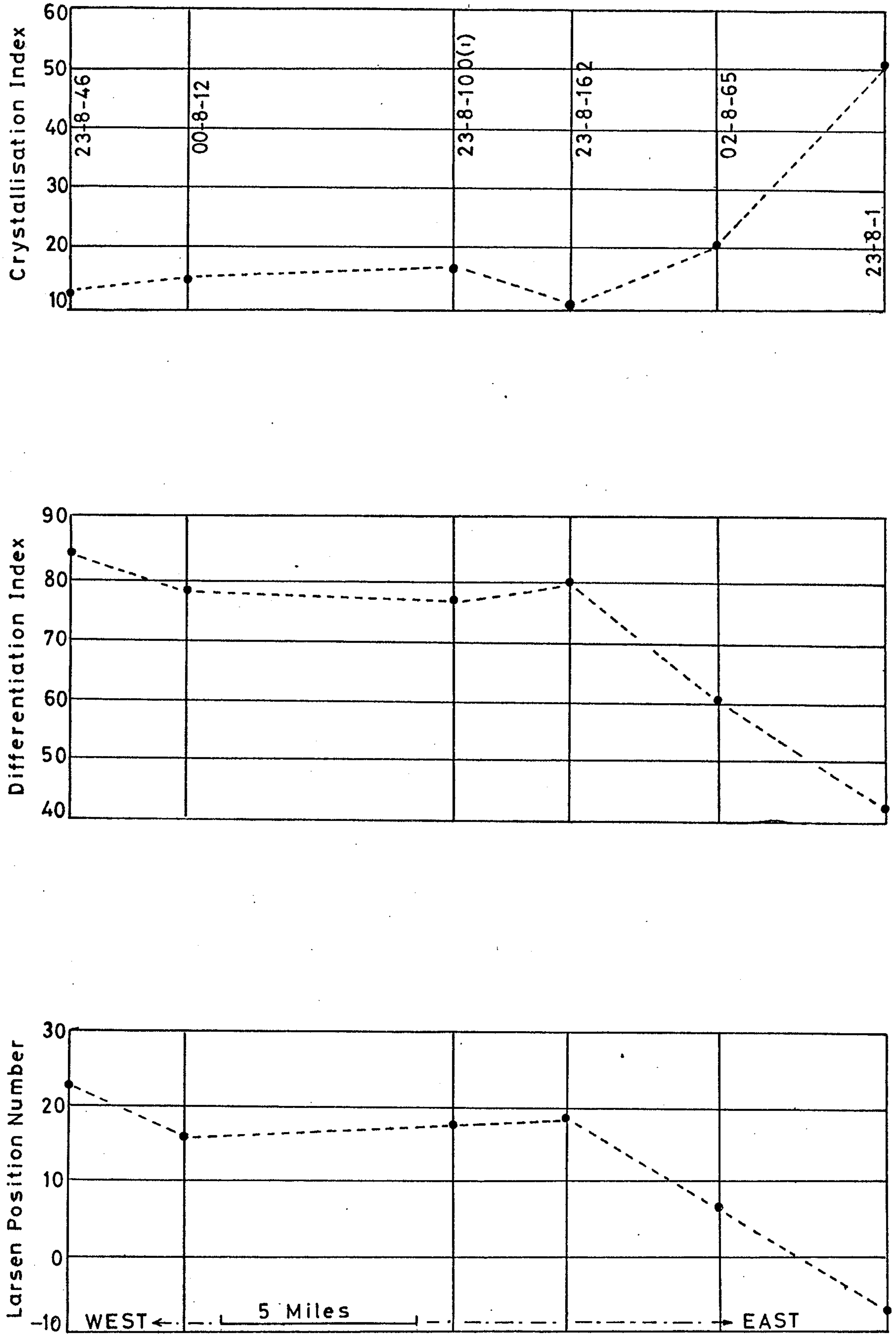


Figure 14. Variation of the three "Differentiation" Indices on an East-west traverse across the Northern Granitic Rocks.

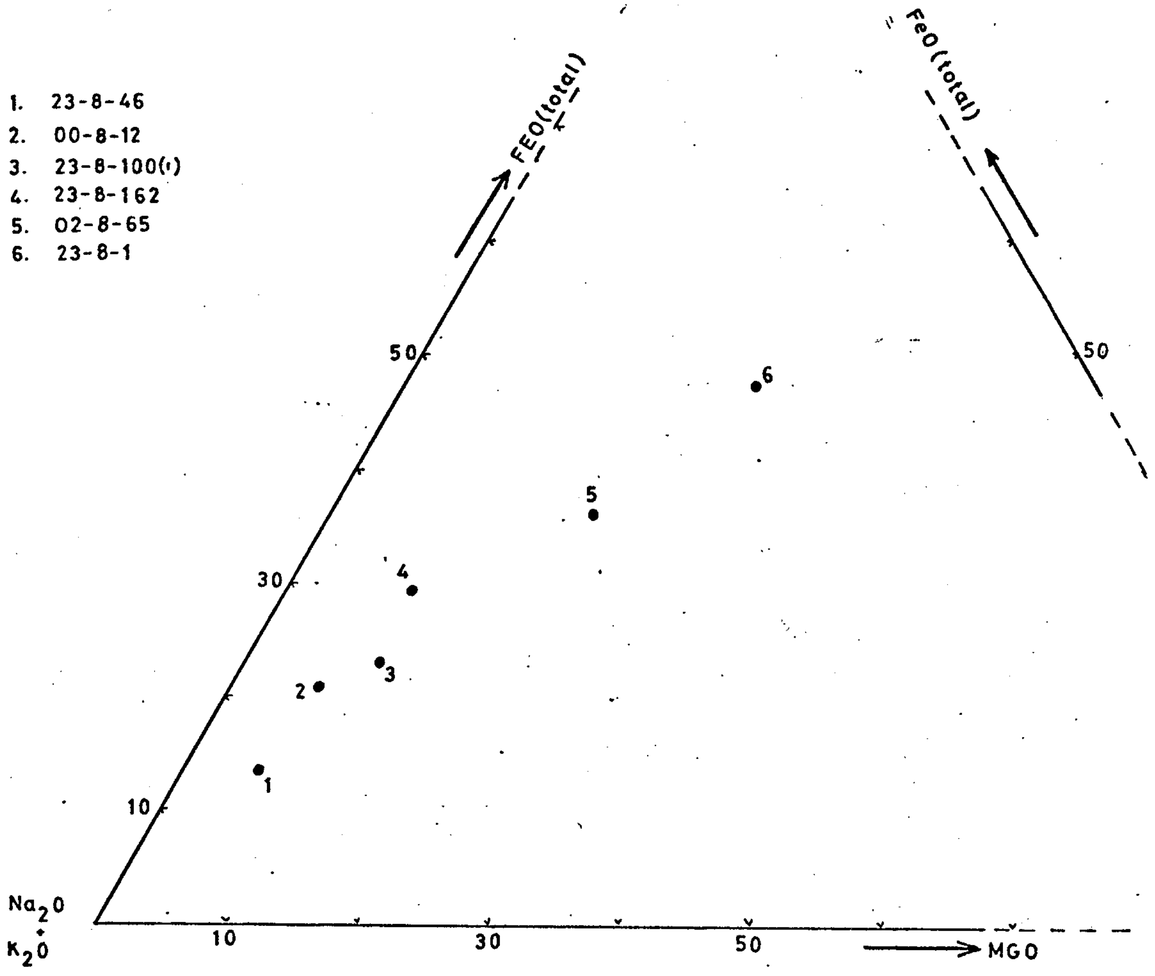


Figure 15. Triangular diagram for FeO (total), MgO, and total Alkalis, showing the six analyses from the Northern Granitic Rocks (recalculated to 100%).

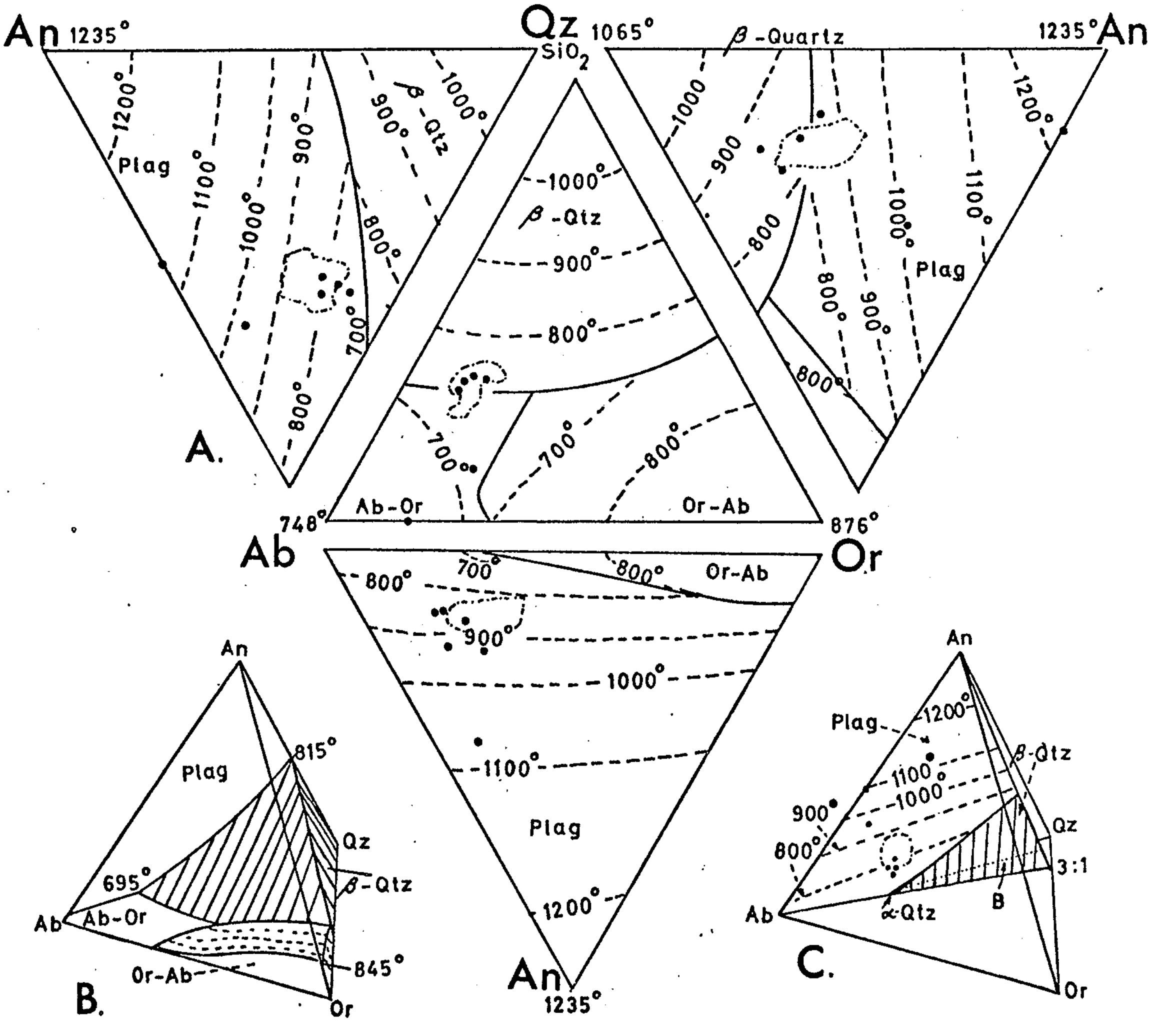


Figure 16. A. "Exploded" tetrahedron showing liquidus relations in the system Anorthite/Albite/Quartz and Orthoclase. Dots are from the Northern Granitic Rocks. Dashed field is of the Rice Lake Batholith (Paulus, 1968)

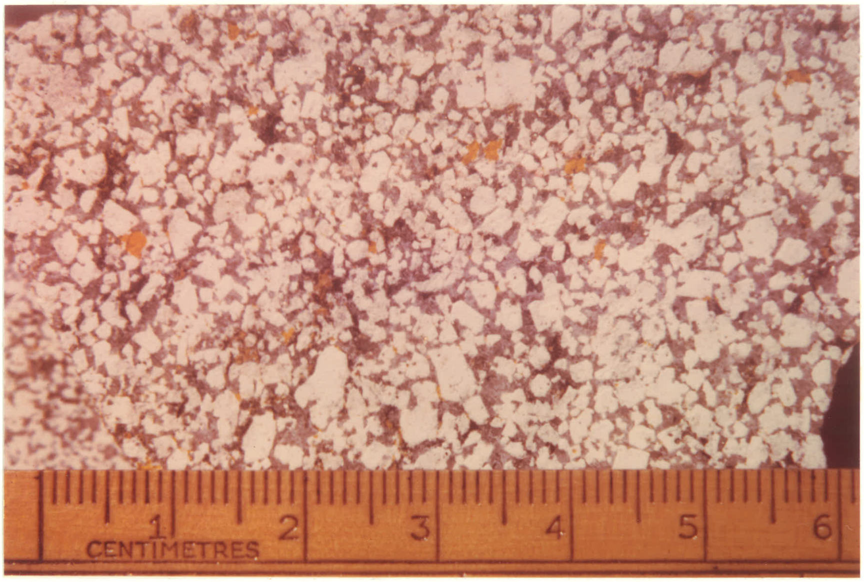
B. Three dimensional view of the tetrahedron.

C. Tetrahedron with the internal plane to which the analytical points require the least projection. Points represent normative weight percent components. (After Bateman et al. 1963) shows liquidus relations in the system Or/Ab/An/Qz/H_2O at 5000 bars pressure of water vapour (Bateman et al., 1963). These are compared to the dashed fields representing the thirty-seven analyses of Paulus (1968) from the Rice Lake Batholith. This is the oval quartz diorite pluton to the south of Wallace Lake (Figure 2), remarkable for its compositional homogeneity. The four analyses from the western part of the Northern Granitic Rocks (Figure 2) representing Units 23 and 24, plot within these fields and indicate a possible relation between this part of the Northern Granitic Rocks and the Rice Lake Batholith. The tetrahedron is shown in three dimensions in Figure 17b, while Figure 16c shows the internal plane to which the points require the least projection, based on a quartz to orthoclase ratio of 3:1. However, this is deceptive, in that the potassium, which is normatively calculated into the orthoclase, is actually present in the biotite. The Qz/An/Ab face of the tetrahedron shows the projected points most accurately in relation to the plagioclase-quartz cotectic. The assumption of a water vapour pressure of 5000 bars is based only on the proximity of the points to the cotectic and the fact that it is a maximum for fairly dry magmas intruded into the upper crust. Yoder (1968) has shown that this cotectic boundary pivots around the central part of the diagram with increasing pressure of water, rather than shifting away from the quartz vertex as the quartz-feldspar boundary does in the Qz/Ab/Or system. Since the projected points cluster around the central part of the quartz-plagioclase cotectic, estimates of water vapour pressure are hazardous. It is assumed that the intrusive magma was at least 50% liquid. This is necessary to account for the igneous texture (e.g. Plate 1).

The two points lying furthest from the quartz-plagioclase cotectic, a mafic hornblende diorite and an intermediate quartz diorite respectively, may be unmelted refractory material or early crystallizing residues from which later liquids were separated. In the latter case, if they are early members of the crystallization series, then Figure 16 would indicate, with qualifications, that crystallization began from a totally liquid magma at around 1100 degrees. The removal of hornblende and plagioclase caused the liquid to become enriched in albite and quartz. This continued towards the field of the Rice Lake Batholith rocks where separation of the solid and liquid phases ceased, as indicated by the cluster of rock composition points. The liquid would then move towards the eutectic in the system Qz/Ab/Or where a little microcline would crystallize at around 725 degrees centigrade.

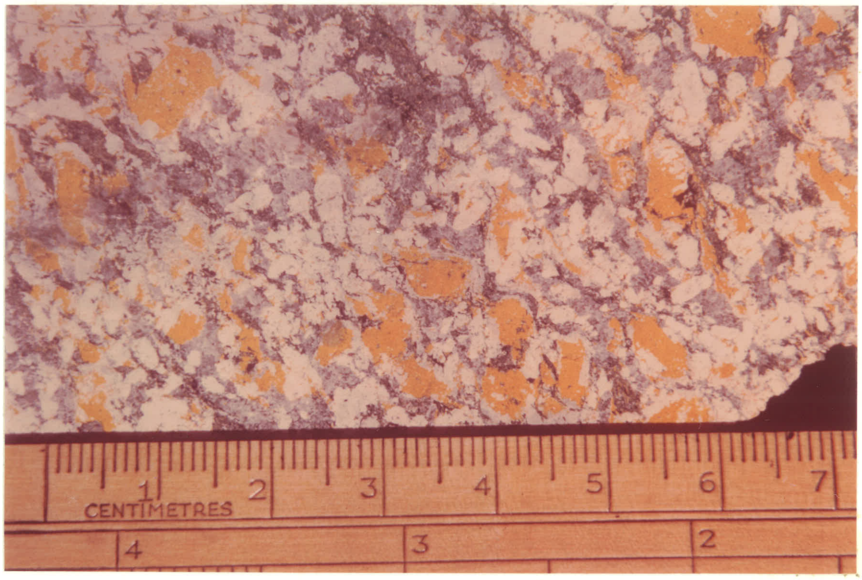
At the time of crystallization of the Northern Granitic Rocks, the magma appears to have been saturated in H_2O. This is suggested by the presence of up to 40% hornblende as a primary mafic mineral and by the amount of water available for deuteric alteration of the rock. The present water content of the rocks suggests that this aqueous phase may

PLATE I



Stained slab showing igneous texture and sparse interstitial microcline. From Biotite Quartz Diorite west of the Jeep Gabbro (Unit 24). 00-8-8

PLATE II



Stained slab showing replacement of plagioclase by microcline in Unit 21 (Granodiorites and Quartz Monzonites) 18-8-41.

have been lost during the last stages of crystallization, possibly associated with pegmatite intrusion.

Figure 17 shows the sequence of crystallization in certain acid plutonic rocks of the Needle Point Batholith (Wyllie and Piwinskii, 1968). From experimental data on rock samples at 2000 bars pressure of H_2O, a series of curves was drawn up, showing the onset of crystallization for each mineral species, against the Differentiation Index of the rock. Figure 17c shows the sequence in a typical volcanic rock. A temperature of around 1000 degrees is indicated for rocks of the same Differentiation Index as the Northern Granitic Rocks, when hornblende is the first mineral to crystallize. At 5000 bars, temperatures are likely to have been lower than this.

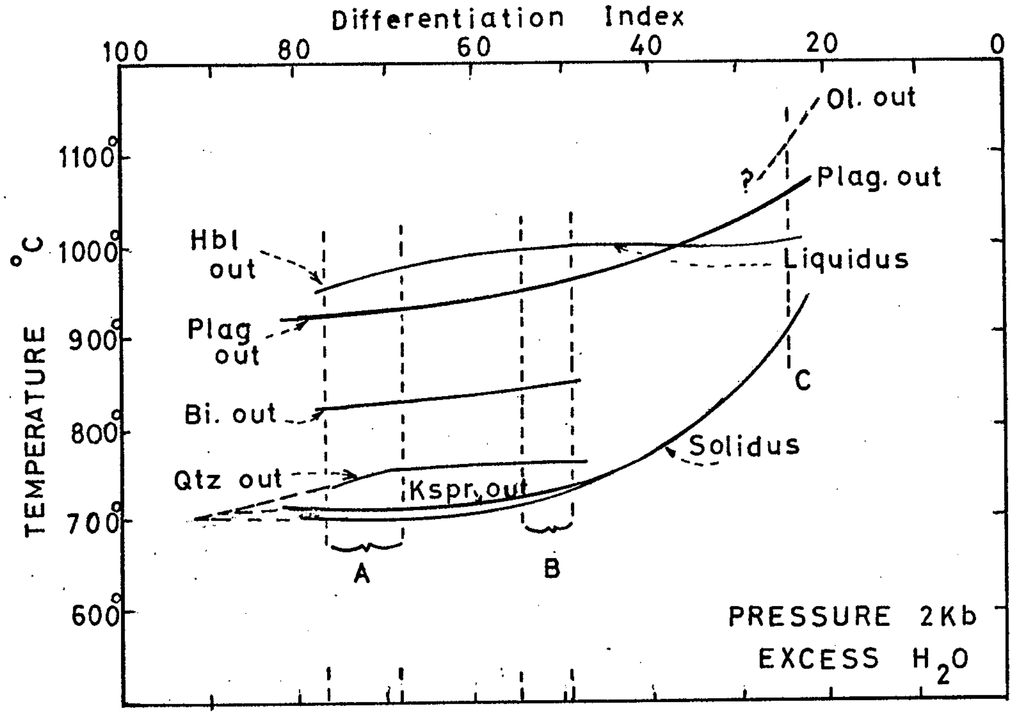


Figure 17. Diagram showing the sequence of mineral crystallization, determined experimentally, in rocks of varying Differentiation Index. A and B are acid plutonic rocks, C is a basalt. (After Wyllie and Piwinskii, 1968)

CHAPTER V

SPECIFIC GRAVITY

A. Analytical Techniques

Specific gravity determinations were carried out on fifty-six samples of granitic rock, chosen to provide a systematic coverage of the area. Samples were trimmed with a wire brush to remove lichen, weathered material and loose particles. Samples ranged in weight from 200 to 900 grams, averaging 450 grams. The balance was standardised before each determination and read to 0.01 gm. Error in the results is estimated to be 2.70 ± 0.01 gm/cm^3.

B. Results

The specific gravity data are listed in Table 4. Locations of samples determined are shown in Figure 18.

Specific gravity measurement is quite sensitive to compositional changes in granitic bodies and it is found that a range from 2.68 to 2.93 exists. The range in the western part of the area is from 2.68 to 2.72, equivalent to values obtained by Paulus for the quartz diorite of the Rice Lake Batholith. East of Wallace Lake the specific gravity is consistently above 2.72, rising to a high in the extreme north-east of the area. Figure 19 shows cross-sections

TABLE 4

SPECIFIC GRAVITY OF 55 SAMPLES FROM THE NORTHERN GRANITIC ROCKS

Sample	Specific Gravity (±0.01)
00-8-8(2)	2.68
00-8-12	2.72
00-8-23	2.72
00-8-27	2.71
00-8-30	2.76
00-8-46(1)	2.68
00-8-47(1)	2.70
00-8-57	2.68
00-8-65	2.72
00-8-70	2.69
00-8-74	2.76
00-8-77	2.77
00-8-122	2.76
00-8-129	2.74
00-8-137	2.70
00-8-142	2.67
00-8-167	2.81
00-8-176	2.69
00-8-180	2.67
00-8-187	2.66
00-8-204	2.66
02-8-65	2.77
02-8-69	2.74
02-8-71	2.83
16-8-6	2.71
16-8-37(1)	2.71
16-8-44	2.69
16-8-47	2.66
16-8-72	2.67
16-8-87	2.70
18-8-2	2.66
18-8-19	2.73
18-8-24	2.67
18-8-33(1)	2.77
18-8-36	2.75
18-8-70	2.73
23-8-1	2.93
23-8-8	2.80
23-8-17	2.74
23-8-21	2.78
23-8-47	2.69
23-8-57	2.74
23-8-65	2.68
23-8-75	2.70
23-8-96	2.67
23-8-100(1)	2.69
23-8-101	2.72
23-8-103(1)	2.71
23-8-118	2.68
23-8-127	2.78
23-8-129	2.68
23-8-139	2.73
23-8-145(1)	2.69
23-8-154	2.72
23-8-162	2.71

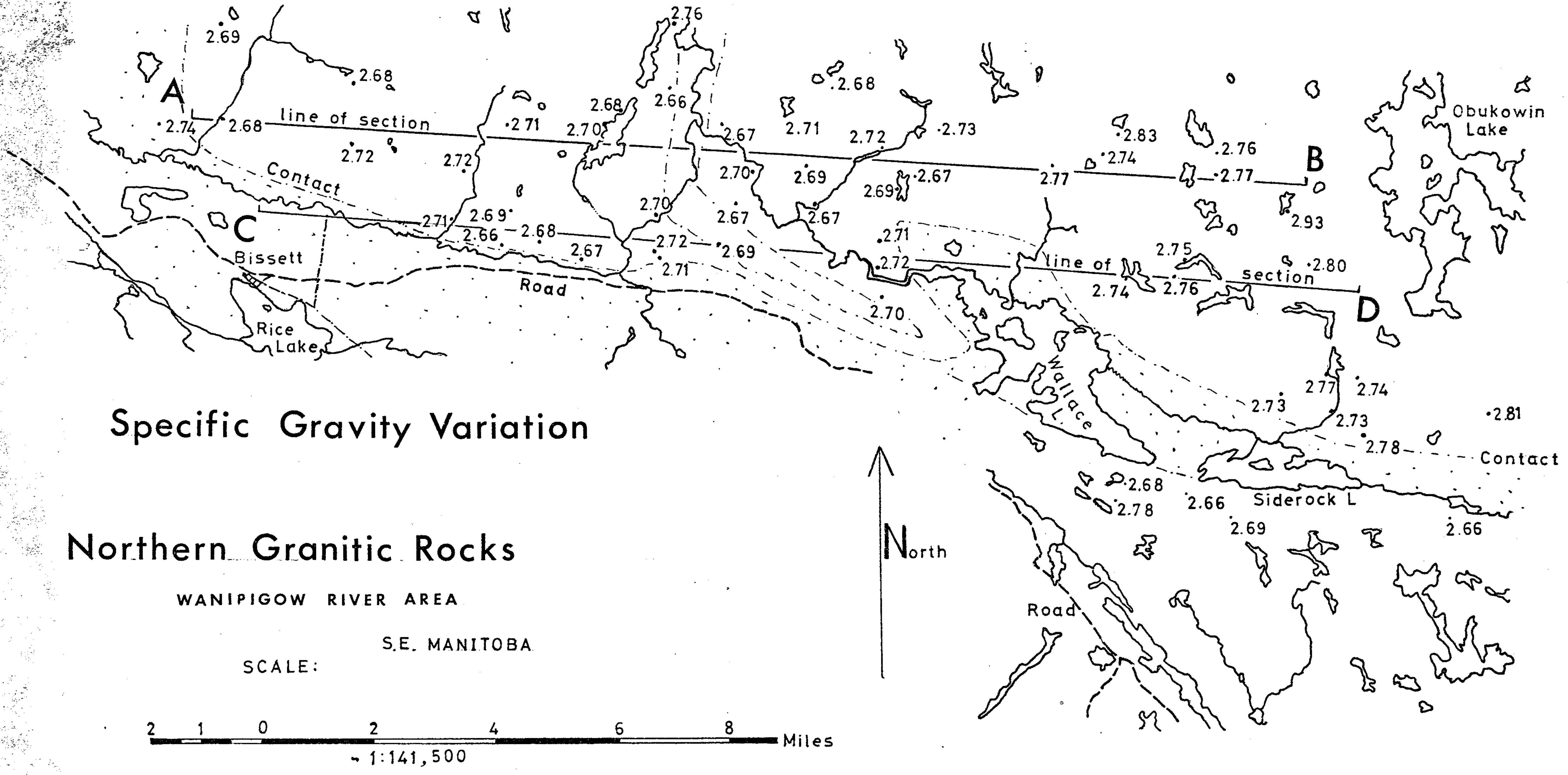


Figure 18. Map showing Specific Gravity values and sample determination locations.

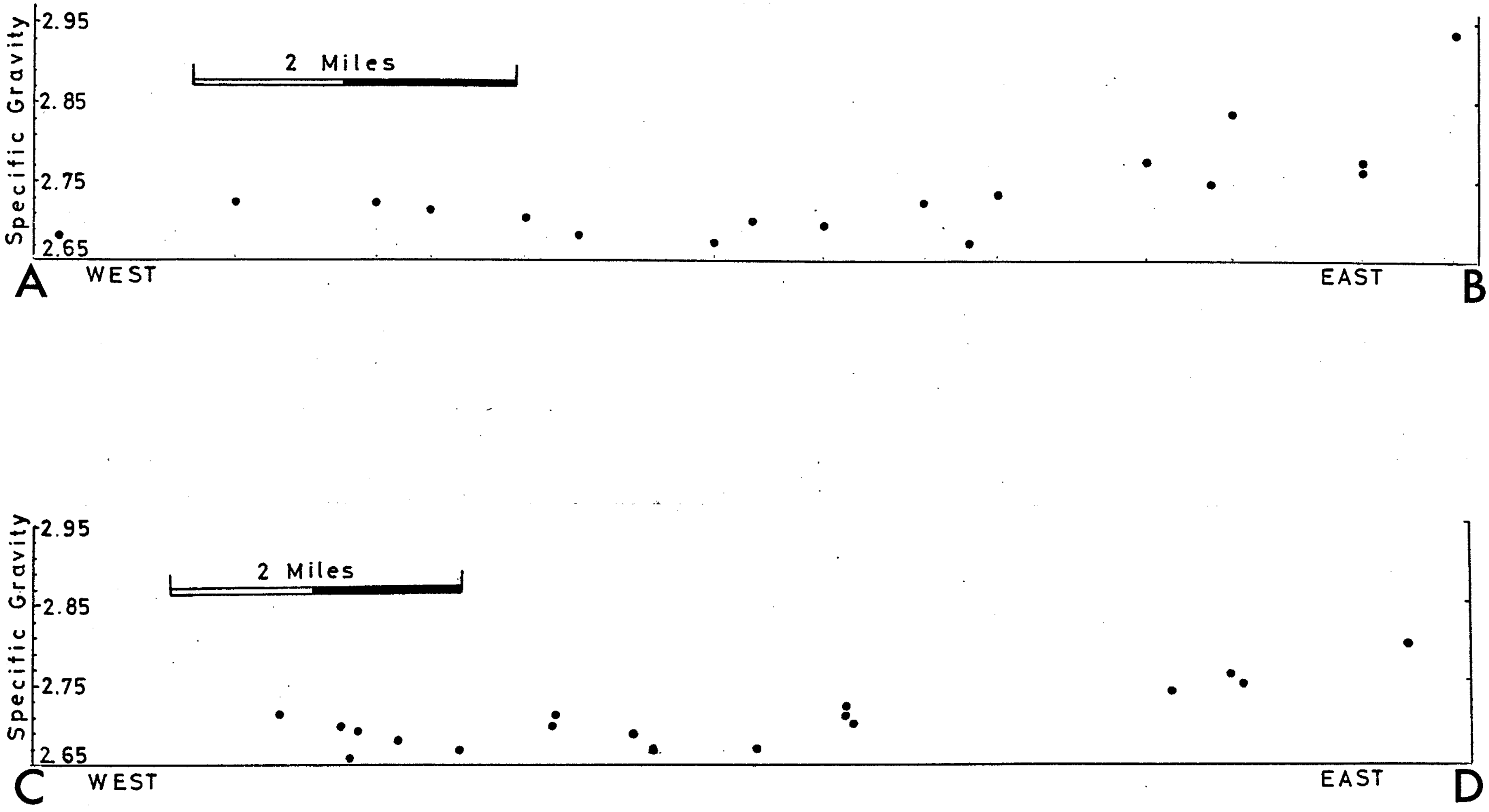


Figure 19. Cross-sections from A to B through Specific Gravity Values, as shown in Figure 20. Points lying within one-half mile of the section line are included.

from east to west. The marked rise in specific gravity east of Wallace Lake is distinct. On these sections specimens are plotted lying within a half-mile of the section line. Figure 20a shows the overall regional variation in terms of contours. This increase is due to the increase in mafic minerals, coincident with the decrease in quartz. The anorthite content of the plagioclase increases only slightly and is unlikely to have been an important factor.

South of the Wanipigow River, in the Wedge Granitic Rocks, specific gravities are low, partly due to the degree of alteration and intrusion of pegmatitic materials.

Overall, there is a close correlation between the mapped rock units and the specific gravity determinations.

Figure 20b shows the regional gravity variation over the area (W.C. Brisbin, pers. comm., 1970). This correlates well with the other evidence for a homogeneous area west of Wallace Lake. The northward extension of the gravity high north-east of Wallace Lake correlates with the area of more mafic rocks. It can be shown from the difference in specific gravities and in absolute values of gravity that the anomaly is located at a depth of around two miles below the maximum north of Wallace Lake.

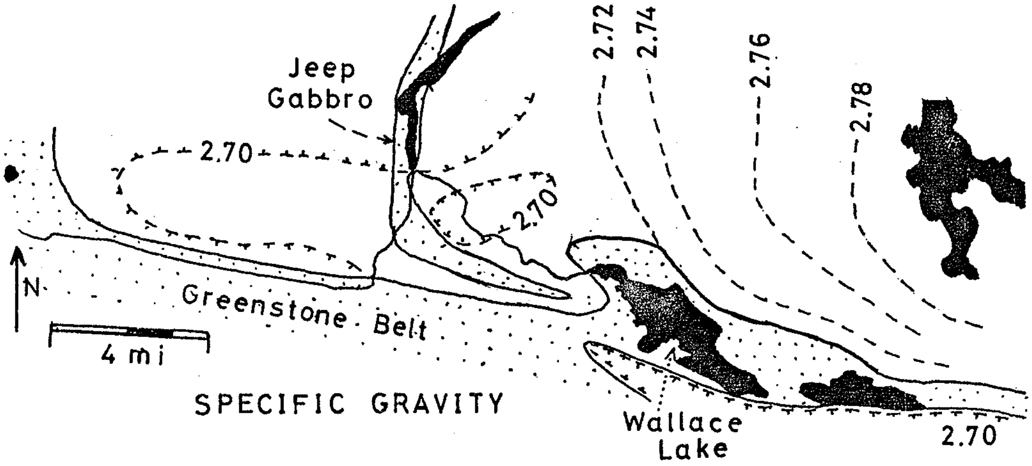


Figure 20a. Variation in Specific Gravity in the Northern Granitic Rocks. See Fig. 18 and Table 4. Contours as indicated.

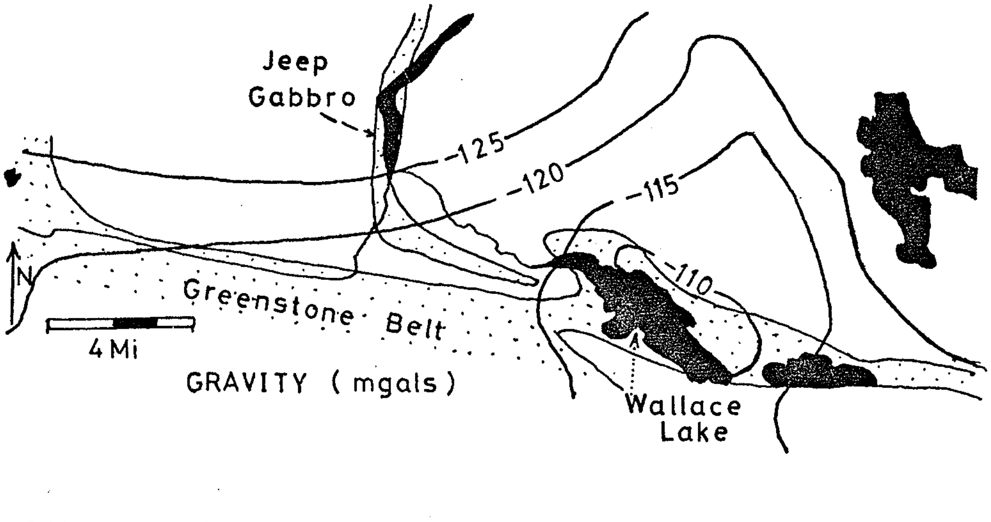


Figure 20b. Regional Gravity Variation in the Northern Granitic Rocks (W.C. Brisbin, pers. comm.,1970).

CHAPTER VI

AGE RELATIONS

This chapter is concerned with the age relations of the various granitic bodies in the Rice Lake area and the position which the Northern Granitic Rocks appears to occupy in the series.

A. Mafic Inclusions and the Jeep Gabbro

The time sequence of events in the area is still imperfectly understood and the relation between the Jeep Gabbro and the Northern Granitic Rocks remains uncertain. This body of gabbroic and dioritic rocks strikes almost north-south around Leaf Lake but swings around to assume a position parallel to the regional foliation in the south, before pinching out eastwards west of Wallace Lake.

Russell (1947) reported inclusions of granitic rock within the Jeep Gabbro, which would suggest that the latter is a later intrusion. However, Eakins (1949) could decide from a detailed study in the vicinity of the Jeep mine that "no evidence favouring either position in the geologic column was revealed". He notes that contacts are poorly defined and 95% of those observed in the field show no chilling effect of either rock type against the other. He tentatively correlates small intrusive bodies of quartz diorite in the Jeep Gabbro near the mine with the surrounding granitic rocks.

Little new evidence was added during the reconnaissance work described here. A possible chilled contact of the Jeep Gabbro was observed at one locality. Lensoid boudins of gabbro lying in the foliation of the Northern Granitic Rocks are thought to represent an early, deformed dyke phase, possibly related to the Jeep Gabbro. In places, these gabbroic inclusions are cut by stringers of granitic material.

The fact that the Jeep Gabbro contains gold-bearing quartz veins, similar to those occuring in the Rice Lake Greenstone Belt, would suggest that the enclosing Northern Granitic Rocks are younger. This depends on the assumption that there was only one period of mineralization and that the age difference determined by Turek and Peterman (1968), between the Northern Granitic Rocks and the age of mineralization in the greenstone belt, is real.

The conflicting evidence for the relationship may be reconciled by a process described by Sederholm as "palingenetic eruptivity". After early intrusion of the gabbro into the granitic rocks, the latter were remobilized to the fluid or semi-fluid state. This palingenetic magma was free to intrude only when suitable fractures opened up, presumably due to its high viscosity. Metabasite dykes, which have both intrusive and xenolithic characteristics, are thought to be the result of such a process in Scandinavia.

B. Relation of the Granitic Intrusions

Davies (1963) contrasts the sodic nature of the other quartz diorite intrusions in the Rice Lake area with the Northern Granitic Rocks, which he considered to be more potassic. He suggests that the latter group also differs in a number of other features:

1. They contain biotite rather than hornblende
2. They are characterized by sericitic alteration rather than saussuritization.
3. They have associated pegmatites rather than porphyritic dyke rocks.
4. They lie mainly outside the area of volcanic, sedimentary and calcic rocks.

The analyses presented from the Northern Granitic Rocks (Table 2) indicate that the latter are not potassic relative to the other quartz diorite bodies in the area. The main part of the complex, excluding the group of granodiorites and quartz monzonites (Unit 21), is trondhjemitic with an Na/K ratio of 3:1. This ratio, furthermore, is typical of the other quartz diorite bodies, as is the tendency for the silica percentage to be between 66% and 70%. The rocks west of Wallace Lake contain no biotite but this mineral occurs in the more mafic rocks to the north-east of Wallace Lake. The saussuritic alteration of plagioclase was commonly observed in the Northern Granitic Rocks. There is little information on pegmatite occurrence in the other bodies of quartz diorite. Quartz-feldspar porphyries do outcrop in proximity to the Northern Granitic Rocks; other relations may be obscured by the zone of shearing and movement on the Wanipigow River fault. It is doubtful if the Northern Granitic Rocks can be described as lying outside the area of volcanic, sedimentary and calcic rocks.

Figure 22 shows the six analyses from the Northern Granitic Rocks plotted on the oxide variation diagram of Davies (1963) for all his calcic rock types from the Rice Lake area. The horizontal co-ordinate is the Larsen Index. The points from the Northern Granitic Rocks plot very close to the trend lines established by Davies.

Figure 21 compares the modal data for the Biotite Quartz Diorite both east and west of the Jeep Gabbro with the field of the 37 samples of Paulus (1968) from the Rice Lake Batholith. Compositionally, rocks from the Rice Lake Batholith and the western part of the Northern Granitic Rocks are similar. This is also true of texture and of the composition of the plagioclase.

Davies (1963) suggests that the Northern Granitic Complex is considerably younger than the calcic intrusions, and that part of it was emplaced 1700 m. y. ago during the Hudsonian orogeny. This would make part of it at least considerably younger than the Rice Lake Batholith, which has yielded a K/Ar age of 2500 m.y. (Lowden, 1961). He considers it to be a complex type of intrusion with intermingled calcic and potassic components. Recent work by Turek and Peterman (1968) has produced an Rb/Sr age of 2550 ± 80 m.y.

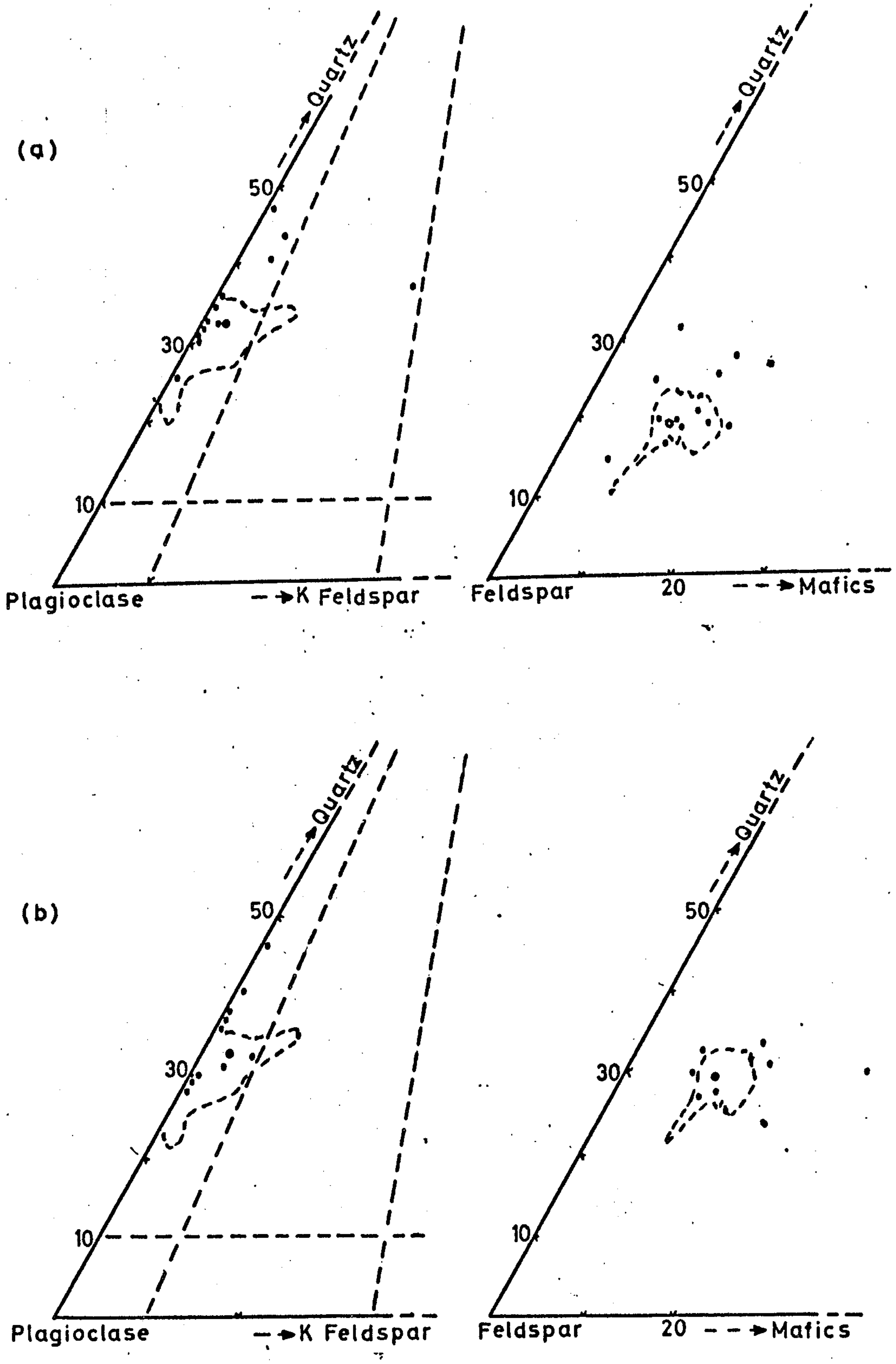
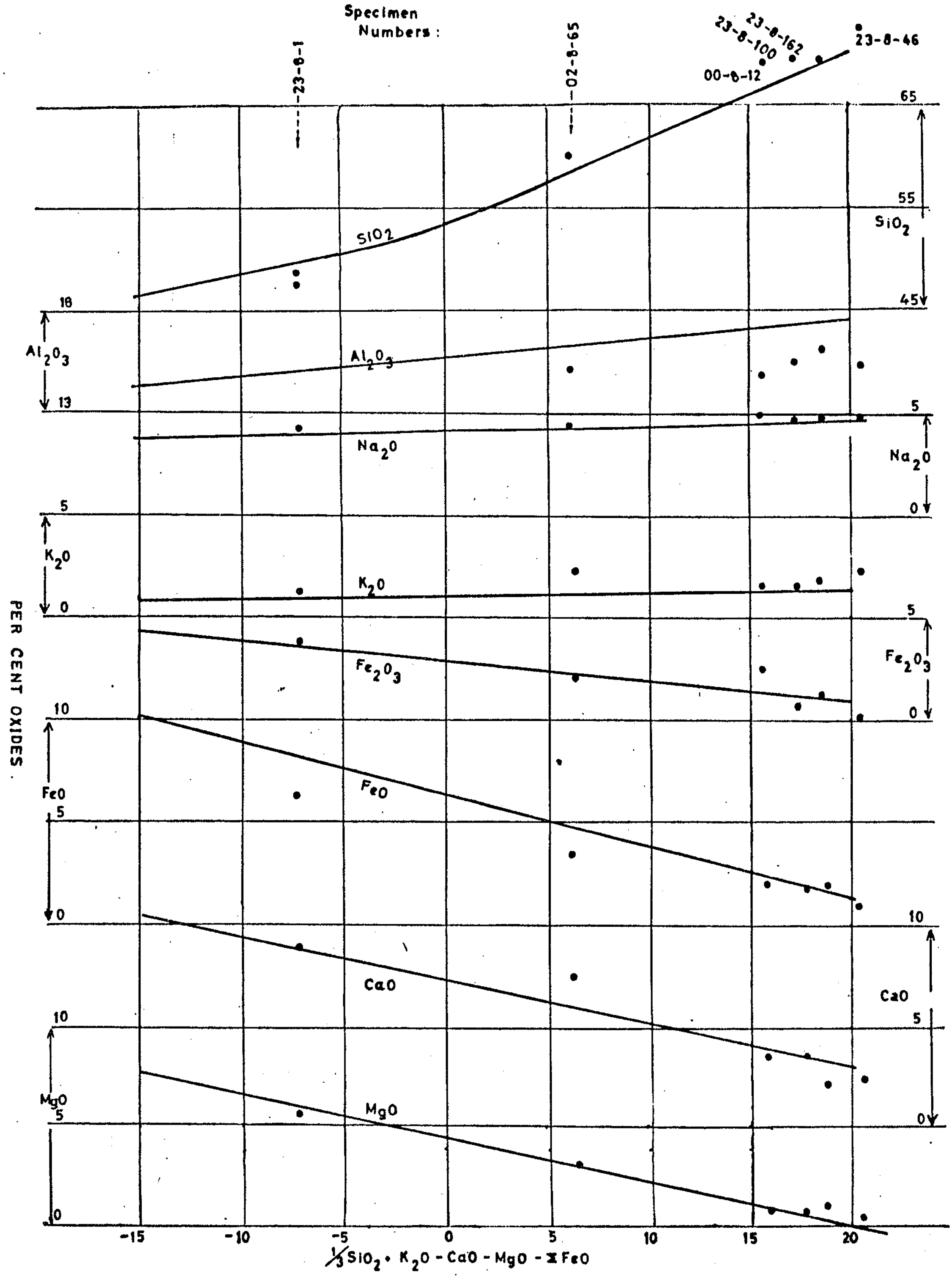


Figure 21 a. Modal data for Units 23 and 24 west of the Jeep Gabbro. o=average of the Rive Lake Batholith. Dashed field encloses the 37 samples (Paulus,1968).
b. Modal data for units 23 and 24 east of the Jeep Gabbro. o=average of the Rice Lake Batholith. Dashed field encloses the 37 samples (Paulus,1968).



LARSEN VARIATION DIAGRAM (after Davies 1963)

Figure 22. Diagram showing variation of the major oxides against the Larsen Position Number for soda-lime intrusions and volcanic rocks from the Rice Lake Area (after Davies, 1963). Plotted points are analyses from the Northern Granitic Rocks.

for the Northern Granitic Rocks. This indicates that the Rice Lake Batholith and the Northern Grantic Rocks are probably contemporary.

Davies (op. cit.) believes that the San Antonio Formation is older than the Northern Granitic Rocks. This group of conglomerates, feldspathic arkoses, and quartzites uncomformably overlies the Rice Lake Group. It also overlies the quartz diorite with a basal conglomerate (W. Weber, pers. comm., 1970). The San Antonio Formation contains much microcline in addition and also zircons found by Stanton (1941) to be characteristic of the Northern Granitic Rocks. The San Antonio Formation shows no contact metamorphic effects although the two units are in close proximity north of Bissett. Turek and Peterman (1968) obtain a minimum age of 2720 ± 185 m.y. for the San Antonio Formation. The folding observed in the San Antonio Formation is thought by all previous workers to have been due to the intrusion of the Northern Granitic Rocks.

In conclusion, the isotope ages obtained on the granitic rocks of the area are possibly metamorphic events, representing a remobilization. The Northern Granitic Rocks appear to be related to the other quartz diorite plutons in the area which are early intrusions, chemically related to the volcanics and dyke rocks of the Rice Lake Group. The quartz diorites pre-date the San Antonio Formation. The relation between the San Antonio Formation and the Northern Granitic Rocks is less clear.

C. Absolute Ages

Turek and Peterman (1968) have discussed the Rb/Sr geochronology of the Rice Lake-Beresford Lake area. The age of 2720 ± 185 m.y. obtained for the gold-quartz veins, provides a minimum for both the Rice Lake Group and the San Antonio Formation. The Northern Granitic Rocks are dated at 2550 ± 80 m.y. ($\lambda_{Rb^{87}} = 1.39 \times 10^{-11} yr^{-1}$). The authors suggest that these ages are consistent with the hypothesis that the emplacement of the Northern Granitic Rocks resulted in the low grade metamorphism of the Rice Lake Group and was accompanied by structural disruption in the form of folding and faulting, as indicated most clearly in the San Antonio Formation.

This determination for the Northern Granitic Rocks is not entirely satisfactory. Only two of the points on the isochron come from the Northern Granitic Rocks, the others come from the Wedge rocks to the south of Siderock Lake. The two points also represent samples from close to the sheared southern contact. The authors also point out that the most radiogenic sample comes from a small micropegmatite dyke. Exclusion of this point from the regression isochron results in a slight increase in apparent age and a large increase in uncertainty -2620 ± 220 m.y..

Further work therefore is required before the geochronology of the area can be finally determined. Each pluton in the area should be dated and also the granitic boulders in the sediments of the Rice Lake Group and the

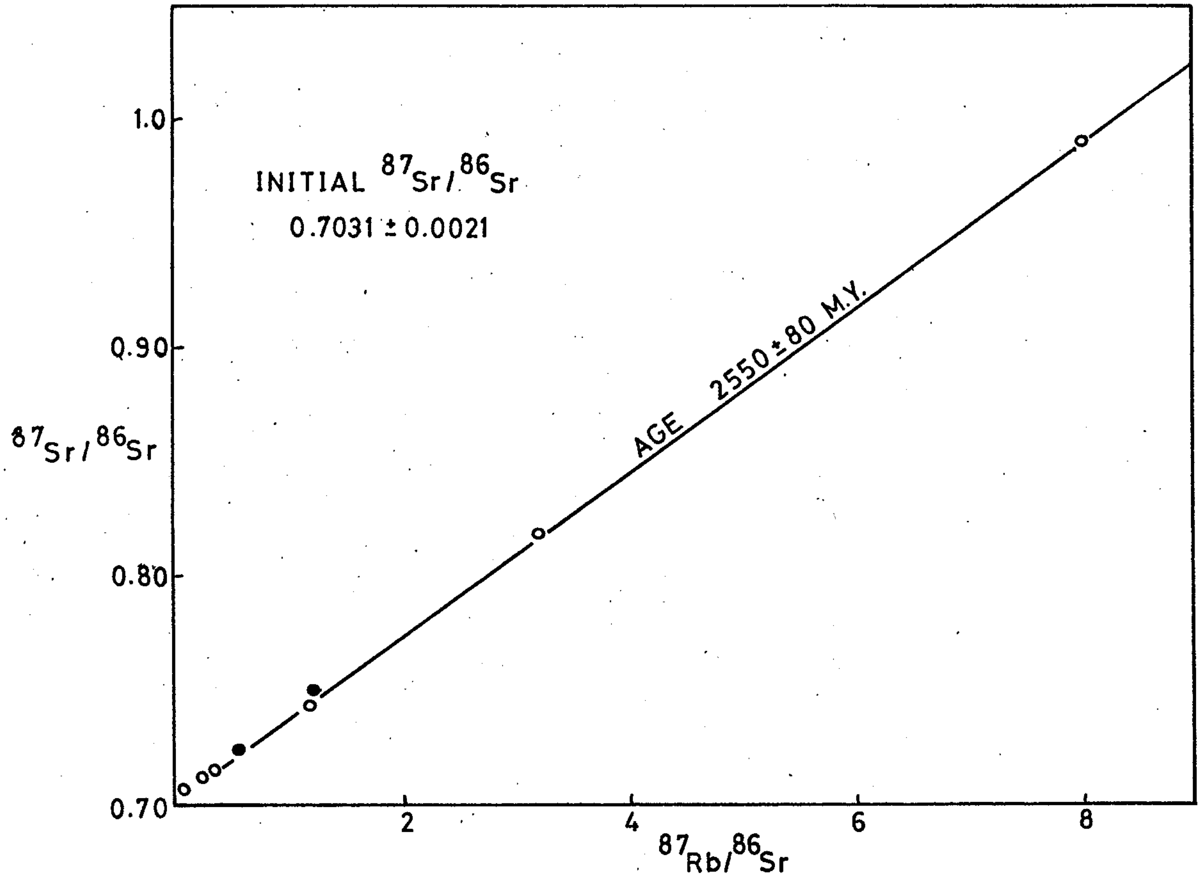


Figure 23. Rb/Sr isochron for the Northern Granitic Rocks. (After Turek and Peterman, 1968).

- • Sample from north of the Rice Lake-Siderock Lake Greenstone Belt.
- o Samples for south of the Rice Lake-Siderock Lake Greenstone Belt.

San Antonio Formation. It is possible that an early intrusion provided the motive force for secretion of the gold-quartz veins.

APPENDIX I

MINERALOGY

A. Felsic Minerals

1. Plagioclase

Plagioclase is quantitatively the most important feldspar and the most prominent mineral (see Table 1, Figure 3); alkali feldspars are restricted in development. The plagioclase crystals occur most commonly as large tabular phenocrysts, especially in the more quartz-rich rocks in the western part of the area. They frequently lend a subporphyritic texture to the rock and this is illustrated in Plate 1. In such rocks, the plagioclase crystals are frequently euhedral, widely spaced and oriented with few signs of cataclasis. This might indicate the crystals were intruded in a crystal mush in an essentially fluid medium. Protoclastic effects are commonly observed. However, in many rocks they have interfered with each others' growth and this texture indicates that the last phase of crystallisation at least took place in an essentially static medium. The plagioclase everywhere appears to have been early in the paragenetic sequence; hornblende, in the more mafic rocks in the east, is frequently interstitial to it. Regional variation in the composition of the plagioclase is illustrated in Figure 24. These determinations were done mainly on the Universal Stage, using where possible a method based upon measurement of the angle in the symmetrical zone in sections normal to X. The method of Slemmons (1962) by measurement of the angles between poles to twin composition planes and optic directions was also employed.

Measurement of refractive index against balsam and determinations of refractive indices of cleavage fragments were used as checks. The normative composition of the feldspar is also a good check in rocks of simple mineralogy. Determinations are ± 2% An; those done on the polarizing microscope by the method of Michel Levy are less accurate than this. Zoning effects and the effects of interstitial recrystallisation are complicating factors. The rocks contain mainly calcic oligoclase or sodic andesine, with a range in anorthite content from An 22% to An 35%. Optic axial angles indicate that the plagioclase is in the low temperature structural state. The lower anorthite content plagioclase occurs in the western part of the area studied, in the more felsic biotite quartz diorite. There is a gradual increase to around An 27% in the central part of the region north of Wallace Lake and this rises to over An 30% in the extreme east of the area.

Zoning is rather poorly developed and frequently gradational when present. It is best developed in the central part of the area where the nearest approach to

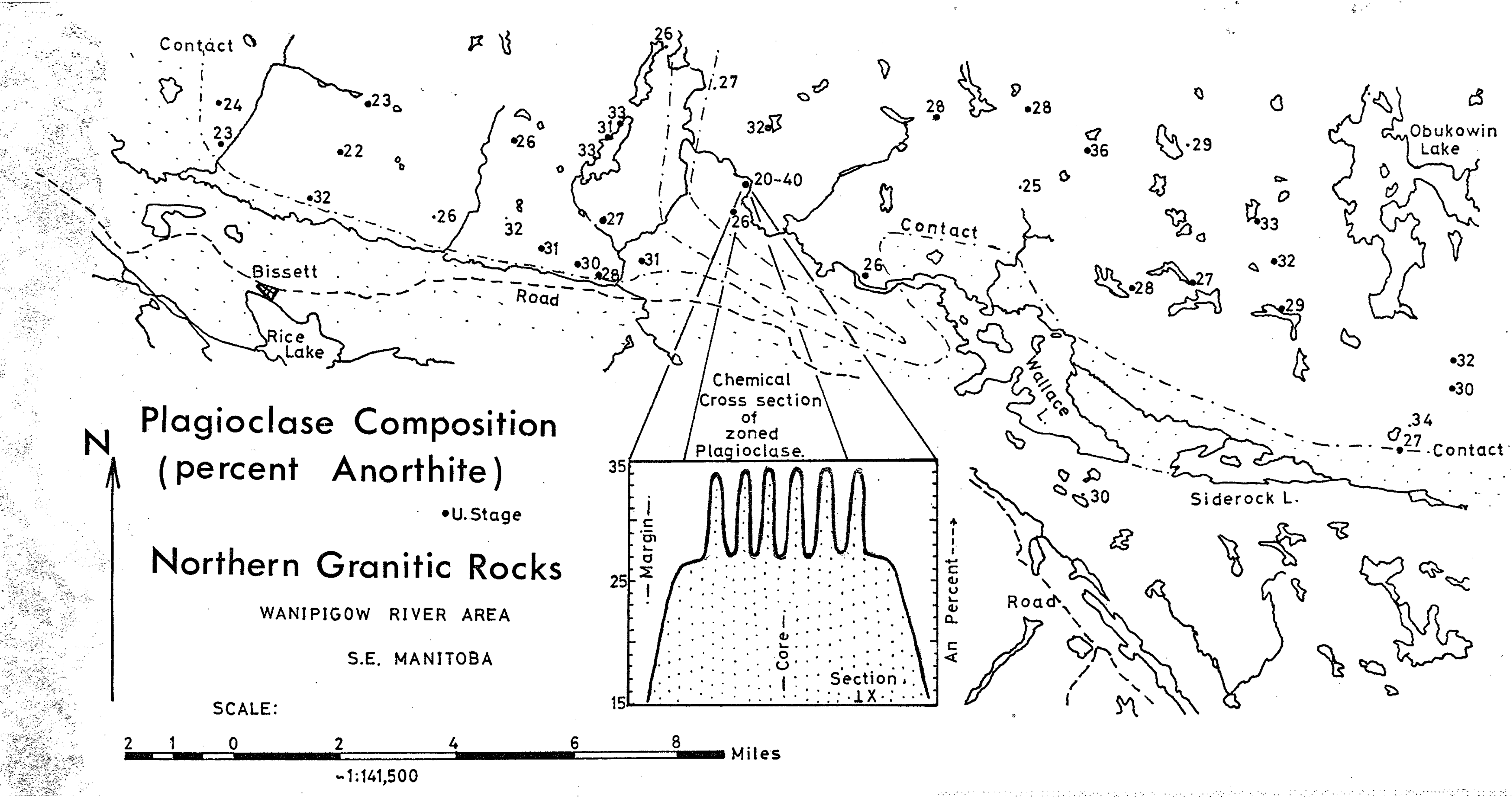


Figure 24. Regional Variation in Anorthite Content of the Plagioclase.

. Universal Stage Determination Inset of compositional cross-section through a zoned Plagioclase Crystal.

oscillatory zoning occurs. One such crystal is illustrated in Figure 27 as an inset. It contains several not too sharply defined zones where regular fluctuation in composition between An 27% and An 35% occurs. An 27% is the average composition of plagioclase in the area. After several such fluctuations,possibly in a convective overturn, the composition decreases evenly in anorthite content to the margin of the crystal. Twinning is developed in such crystals and appears to have accompanied crystal growth.

Twinning is not, however, well developed as a rule. The large, dull plagioclase phenocrysts, common in this rock association, are in the main poorly and irregularly twinned. Albite and pericline twins appear most abundant, simpler twin laws are infrequent. Twin lamellae are often bent and displaced by cataclasis while irregular, curving, marginal twins which wedge into the crystal core often appear to be secondary.

Granulation of grain boundaries, internal disruption leading to patchy extinction and breakage of the grains are the result of deformation, rotation, cataclasis and augen formation.

The plagioclase crystals are usually saussuritized, containing small, tabular, variably developed clinozoisite crystals parallel chiefly to the (001) and (010) cleavage directions.

They are often concentrated in the more calcic zones of zoned plagioclase crystals. Where zoning is poor, the core of the crystal is frequently the most heavily altered. This suggests that the core zones are more calcic but it might also represent a diffusion outwards of alteration products from the border zones of the crystal. The plagioclase is also frequently altered, intensely in some cases, to fine-grained sericitic material.

2. Microcline

Microcline is a common but not abundant constituent (see Table 1, Figure 3). In the biotite quartz diorites west of Wallace Lake, it occurs along with the quartz as a groundmass mineral but it rarely developed in proportions exceeding five percent. The main development occurs in the area immediately north and east of Wallace Lake where late or post magmatic growth of blastic microcline gives rise to the group of potassic rocks. This group of granodiorites and quartz monzonites represents the metasomatic transformation of the intermediate quartz diorites of the area. The plagioclase can be seen in every stage of replacement by the microcline. Patchy microcline develops centrally in the large plagioclase phenocrysts, this is illustrated in Plates I and II . The gridiron twinning of the microcline is aligned parallel to the twin directions of the original plagioclase, each patch being in optical continuity with every other. These planes within the mineral appear to have favoured potash metasomatism. The process continues by isolation of relict grains of plagioclase before development of a large, clear microcline porphyroblast. Other minerals are also replaced and incorporated. The large porphyroclasts can be up to 1.5 cm long and they are generally oriented parallel to the general and original foliation of the rock. A myrmekitic intergrowth is common at the boundary of the microcline, with worm-like quartz growths extending into the adjacent plagioclase. This is frequently accompanied by disappearance of the twinning in the plagioclase. This may represent an effect of the replacement process but may be a later modification of the grain boundaries.

The triclinicity of the microcline, measured by x-ray diffraction, was determined to be 0.91, a value typical of such acid plutonic rocks. The content of unexsolved anorthite plus albite was found to be 7% (Orville, 1967), a fairly high figure for this rock association. The microcline, however, is perthitic so that original plagioclase content is likely to have been higher. This also obviates temperature estimates of formation of the microcline.

The origin of the potash is problematical; its source is likely to be deep in the crust, possibly as a result of high grade igneous or metamorphic processes. Since these rocks occur in close proximity to the belt of migmatites which are parallel to the Wanipigow fault, the potassic rocks may be a marginal effect of their development. Local structural conditions such as fault intersections may have provided channel-ways for the potash-bearing solutions.

3. Quartz

Figure 6 illustrates the variation in modal quartz content from a level of approximately 30% west of Wallace Lake to 5% or less (Table 1) in the most mafic of the diorites in the eastern part of the area. It is always late magmatic and interstitial, forming equigranular xenomorphic mosaics around the other minerals. These mosaics appear to have been recrystallised but still show the effects of strain in the form of strain shadows and occasionally deformation lamellae. They become drawn out and elongated in the more cataclastic rocks. C-axis orientation plots of the mosaics showed little tendency for preferred orientation of the C-axes of the constituent grains, although they do tend to lie in the plane of the foliation in some cases. The quartz appears to embay other crystals and may be partly post-magmatic.

B. Mafic Minerals

1. Amphibole

The amphibole occurring in the dioritic rocks to the east of Wallace Lake varies greatly in habit and abundance. The exact point of entry of this mineral is obscure; the hornblende-to-biotite ratio increases greatly to the east of Wallace Lake. Crystals are usually large (up to 0.5 cm. in length); in some cases enclosing plagioclase crystals but mainly interstitial to the tabular plagioclase grains.

The amphibole is of constant appearance, being a strongly coloured common hornblende with maximum extinction angle of 19° and 2V of 72°. The latter indicates an Mg/Fe ratio of around 1:1 in the mineral (Deer, Howie and Zussman, 1966), which the analysis (23-8-1) of a hornblende-plagioclase rock tends to confirm. Pleochroism is as follows:

X	yellow-green
Y	dark green
Z	bluish-green

Twinning is fairly common; crystals are irregular, poorly terminated and often sieved in texture. The grains are often oriented within the rock and appear to be primary magmatic constituents. Subhedral apatite crystals are ubiquitous inclusions. The amphibole is distinctly in the process of alteration to biotite, the latter forming marginally and along cleavage planes in the hornblende. Sphene and epidote are frequent associates, the latter often occurring at grain boundaries. Chlorite also tends to form along cleavage planes, interleaved with the biotite and accompanied by stringers of iron ore. These alteration effects are believed to be dominantly late magmatic and deuteric.

The amphibole in the Jeep Gabbro is distinctly different, being actinolitic in nature and occurring as sheaf-like oriented laths with weak birefringence. Its extinction angle is 10-15°, and its 2V is 86°. The cross-cutting habit suggests a metamorphic origin and it appears to have been the retrograde product, along with the epidote, of a higher grade assemblage. This may have been a diopside-plagioclase association but indications are that an interstitial amphibole was the original mafic mineral.

2. Pyroxene

Pyroxene occurs only in an inclusion of coarse-grained ultrabasic rock north of Wallace Lake. The pyroxene is buff-coloured augite, indicated both by its optical characteristics and the chemical composition of the almost monomineralic rock 02-8-56 (Table 2).

3. Biotite

This occurs in virtually all of the rock studied. West of Wallace Lake it occurs alone, and is sparsely and evenly distributed. The biotite flakes, frequently at the margins of or enveloped by, the plagioclase phenocrysts, are usually aligned within the rock. Good biotite crystals of large size occur in some cases. Much of the biotite is probably the result of late magmatic alteration of hornblende. East of Wallace Lake, it is secondary after hornblende and frequently occurs with the latter mineral in mafic clumps. The biotite from both these areas is identical. The biotite is commonly dark reddish brown with pronounced pleochroism. The pleochroism is as follows:

X	straw-yellow
Y	dark reddish-brown

Z = Y

The biotite is greenish in places, possibly due to a content of ferric iron. The secondary biotite in the Jeep Gabbro is more foxy red in colour. Epidote is a common associate, occurring as dark granular or shapeless masses in close association with the biotite. Ocasionally it forms euhedra against the latter mineral. Very characteristic is the association in these rocks of sphene and biotite. Small sphene diamonds frequently border the biotite or lie in the cleavage, accentuating this as dark lines. It appears to be a reaction product of some type. Conversion of hornblende to biotite is a possible reaction, causing exsolution of calcium and titanium, but biotites in this association normally contain two to three times as much titanium as hornblende. Prograde transformation from biotite to hornblende seems precluded by the fact that the sphene is typically associated with the biotite rather than the amphibole. This is possibly the result of deuteric alteration or abnormal mineral compositions.

Apatite and zircon are frequent inclusions in the biotite.

4. Chlorite

Chlorite is by no means uncommon but tends only to occur in small quantities, generally in the more mafic rocks. As with the biotite, it appears to be a retrograde product in the mafic series. It frequently occurs as laths and fine streaks parallel to (001] in the biotite and in places completely replacing it. Where hornblende encloses both biotite and chlorite a non-equilibrium assemblage in response to decreasing temperature is indicated. The chlorite in this assemblage is commonly accompanied by fine blebs and granules of iron ore.

The chlorite is light apple green in colour with yellowish pleochroism and anomolous blue polarization colours. In the more cataclastic rocks, it occurs in ragged veins or in small, rather dirty, flakes associated with abundant epidote.

C. Accessory Minerals

1. Epidote

The epidote group of minerals are characteristic and ubiquitous constituents. Clinozoisite is commonly developed as small oriented tablets in the plagioclase. Usually epidote is a constant companion of the biotite, forming irregular grains, sometimes of large size. It is generally non-pleochroic; a lemon body colour only rarely is obvious. The crystals occasionally form euhedral outlines against the biotite. The epidote in such cases is probably a late stage or deuteric product of the mafic minerals. Epidote is also widely developed in veins where movement has taken place and here it entirely replaces the plagioclase and mafic minerals as a coarse granular mass. It is extremely common in the late minor faults. Epidote is also a prominent constituent of the cataclastic rocks as small granules.

2. Sphene

The typical occurrence of sphene is as small crystals in close association with the biotite and this has already been described. Apart from this widespread development, large euhedral sphene crystals were commonly observed in rocks close to the contact. These are frequently bordered by a dark rim which is possibly ilmenite. It is a strong possibility that they represent the effects of marginal contamination of the granitic rocks.

3. Apatite

Apatite is a very characteristic accessory in these rocks. It occurs in rounded to subhedral grains and appears to favour the mafic minerals, especially biotite. In this mineral, it is often surrounded by dark haloes. These are believed due to substitution of heavy elements of similar ionic radius, such as Uranium ($r = 0.97\text{Å}$) for the divalent calcium ($r = 0.99\text{Å}$), causing radioactive bombardment of the host material.

4. Zircon

Zircons are also common, chiefly as rounded to subhedral inclusions in biotite.

5. Ore Minerals

Magnetite is widespread as an accessory, but generally occurs only in small quantities. It appears to be more common in the more altered rock. Some specks of pyrite were visible in certain rocks close to the contact. This is possibly suggestive of some assimilation in that area. Vein quartz lenses are usually entirely barren of sulphides.

APPENDIX II

REGIONAL GEOLOGY

The location of the area of study is illustrated in Figure 1. The Northern Granitic Rocks form the northern boundary to the Rice Lake Greenstone Belt, the southern gneissic belt being the effective southern boundary. The greenstone belt narrows both eastwards and westwards from the Wallace Lake area and is axially intruded in this region by the Rice Lake Batholith.

The Rice Lake group comprises a succession of volcanic rocks, tuffs and volcanic breccias of great variety, interbedded with sedimentary rocks and intruded by basic dykes and sills.

The San Antonio Formation, a feldspathic arkose, unconformably overlies the Rice Lake Group but is not found in contact with the Northern Granitic Rocks.

Several abandoned mines and prospects occur in close proximity to the Northern Granitic Rocks. These include the Jeep Mine, the Vanson Mine and the Poundmaker Mine, all in the western part of the area.

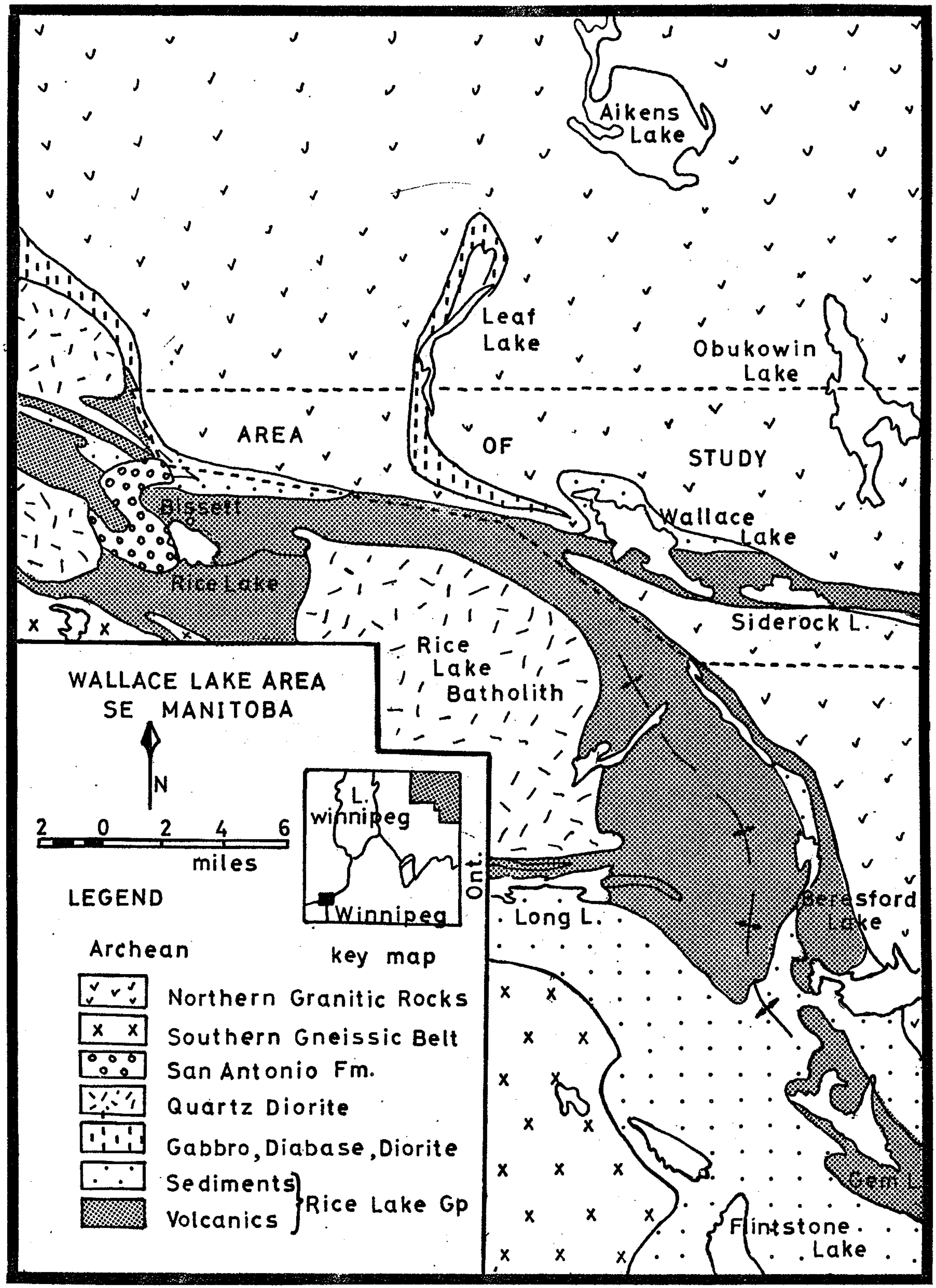


Figure 25. Regional map of the Rice Lake-Wallace Lake-Beresford Lake Area, showing the area of study.

APPENDIX III

PREVIOUS WORK

A survey of the work done up to and including 1932 may be found in "Geology and Mineral Deposits of a Part of S. E. Manitoba" by J. E. Wright, Geol. Surv. Canada, memoir 169. A four miles to the inch map covering the area was produced by Johnston in 1935. Much of the granitic body studied here is represented on the one inch to one mile maps 809A and 810A of Stockwell. These were published by the Geological Survey in 1944, and include the area south of the seventh base line. A short description of the Northern Granitic Rocks is included in the marginal notes. More detailed discussion of the western part in particular, of the granitic body, can be found in the Department of Mines and Natural Resources, Manitoba, report 49-3 by J. F. Davies on the Wanipigow River Area. Here he discusses in general terms the rocks of granitic character north of the Wanipigow River. These remarks are amplified by the same author in his Ph. D. thesis, submitted to the University of Toronto in 1963. Here he compares the group of granitic intrusions in the Rice Lake region, drawing a sharp distinction between the Northern Granitic Rocks and the adjacent quartz diorite bodies. He distinguishes the former group as being particularly potassic, in comparison to the sodic nature of the latter intrusions.

All the detailed information, prior to the Project Pioneer effort, available on the granitic rocks to the east of Leaf Lake stems from the work of Russell (Manitoba Department of Mines and Natural Resources, publication 47-1). The area mapped in this report includes ground well to the north of the area covered in this thesis.

Little of the information obtained during the Project Pioneer investigation has yet been published. A preliminary paper dealing with the Rb/Sr geochronology of the area was published by Turek and Peterman in 1968. A report by McRitchie (pers. comm., 1970) on the Siderock Lake Greenstone Belt is in the course of preparation.

APPENDIX IV

ACKNOWLEDGEMENTS

The author is indebted to Dr. A. Turek for suggesting this project and to Dr. W. D. McRitchie for much helpful advice and discussion. Drs. Turnock, Anderson, Brisbin and Cerny at the University of Manitoba provided much useful assistance and information and this help is gratefully acknowledged. The author also thanks Miss I. Berta and Mr. K. Ramlal for technical help, in the form of thin sections and chemical analyses respectively.

APPENDIX V

Chemically analysed samples not listed in Table 2.

23-8-20

This specimen is an intermediate hornblende quartz Diorite, (Unit 22). Chemically, it is similar to specimen 02-8-65. It comes from close to the contact of the granitic rocks in the area north-east of Siderock Lake. It is a poorly foliated, rather mafic rock with feldspars reddened by iron-staining. Much of the hornblende has been converted to epidote. The chemical analysis of this rock is as follows:

SiO_2	61.70
Al_2O_3	16.14
Fe_2O_3	2.38
FeO	3.60
MgO	2.20
CaO	5.89
Na_2O	3.96
K_2O	1.49
H_2O	1.79
CO_2	0.00
TiO_2	0.97
P_2O_5	0.02
MnO	0.09
	100.23

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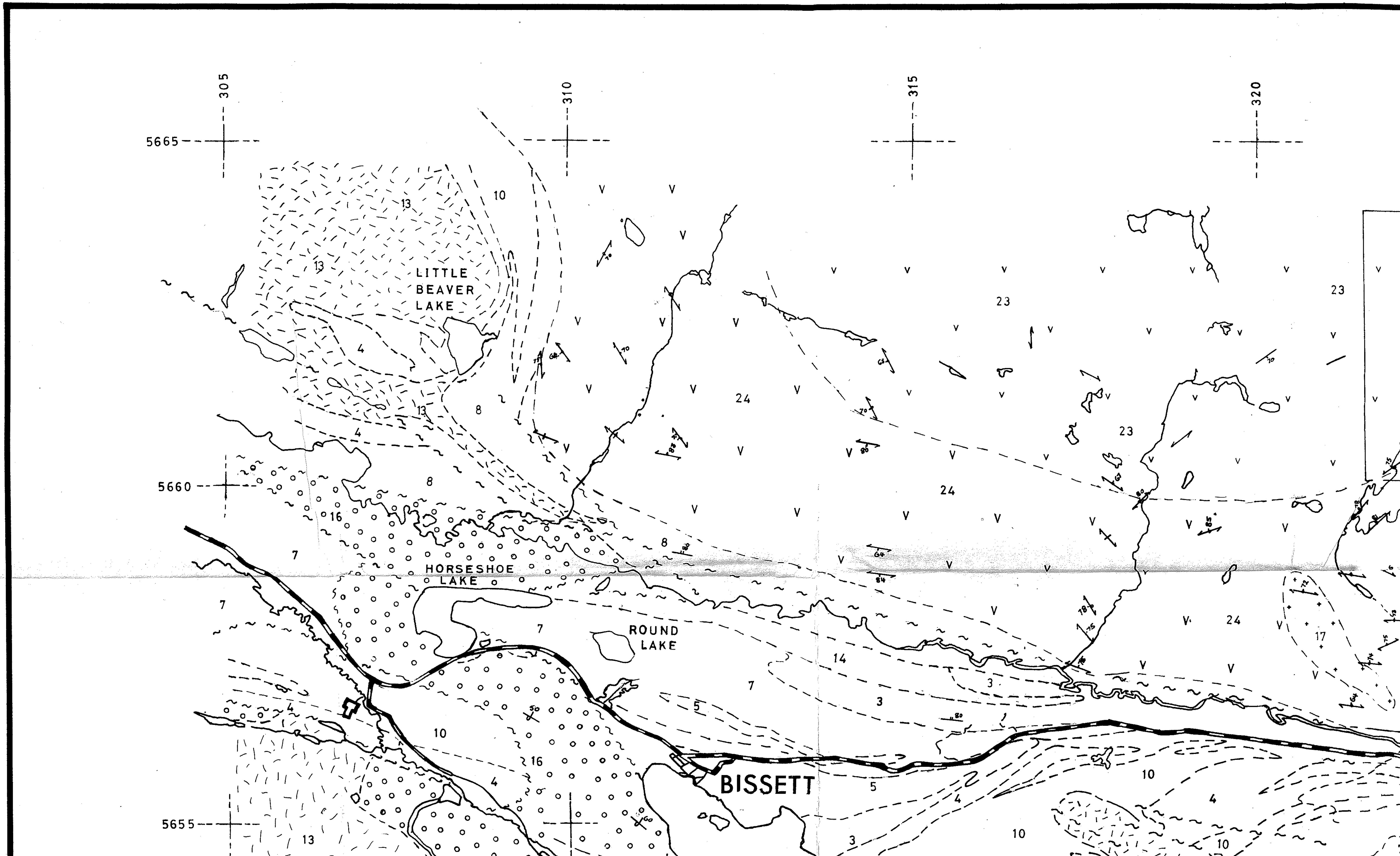
305
310
315
320
5665
5660
5655
LITTLE BEAVER LAKE
HORSESHOE LAKE
ROUND LAKE
BISSETT
10
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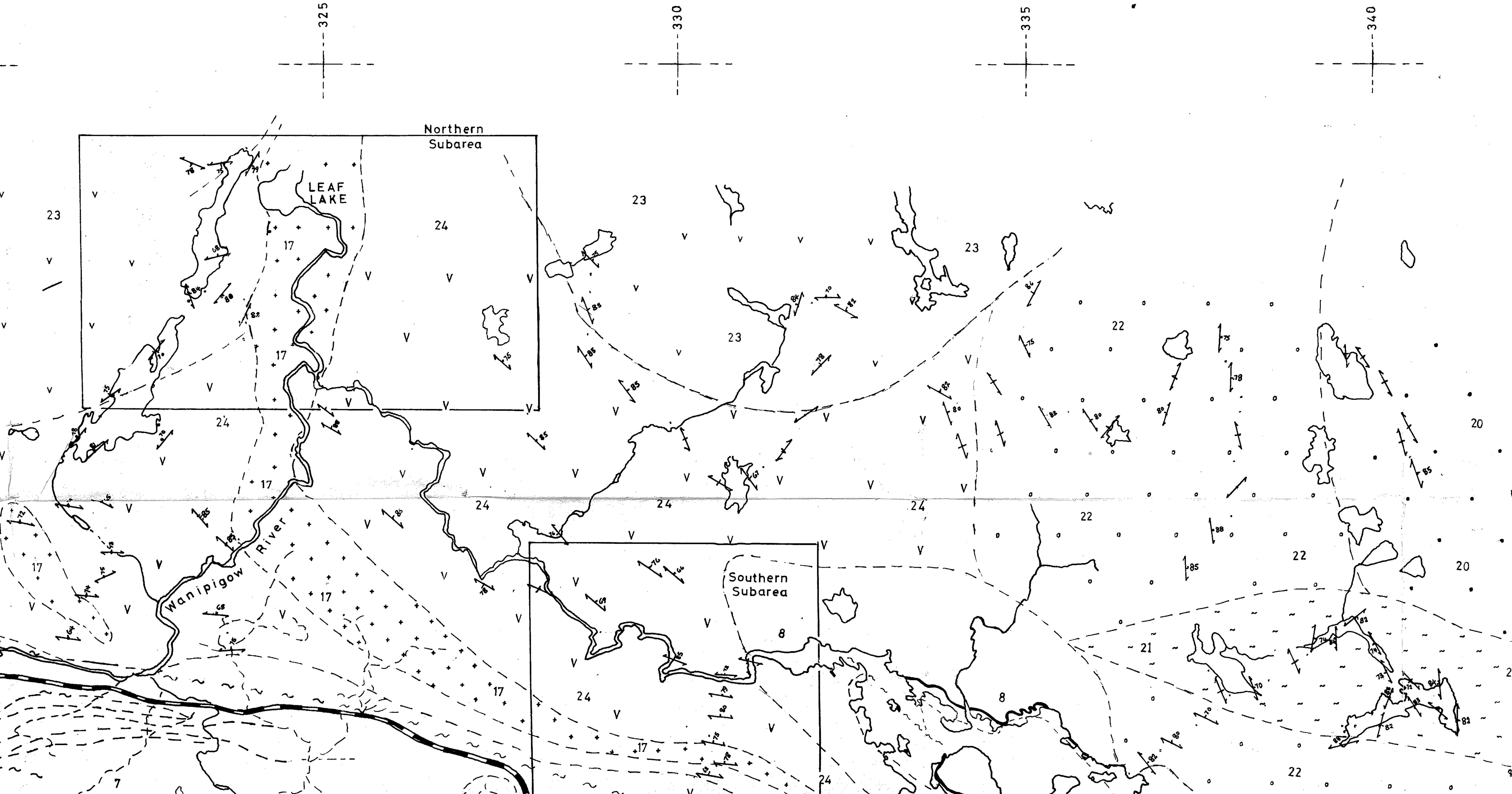
V


325
330
335
340
Northern Subarea
LEAF LAKE
Southern Subarea
Wanipigow River
23
24
17
22
21
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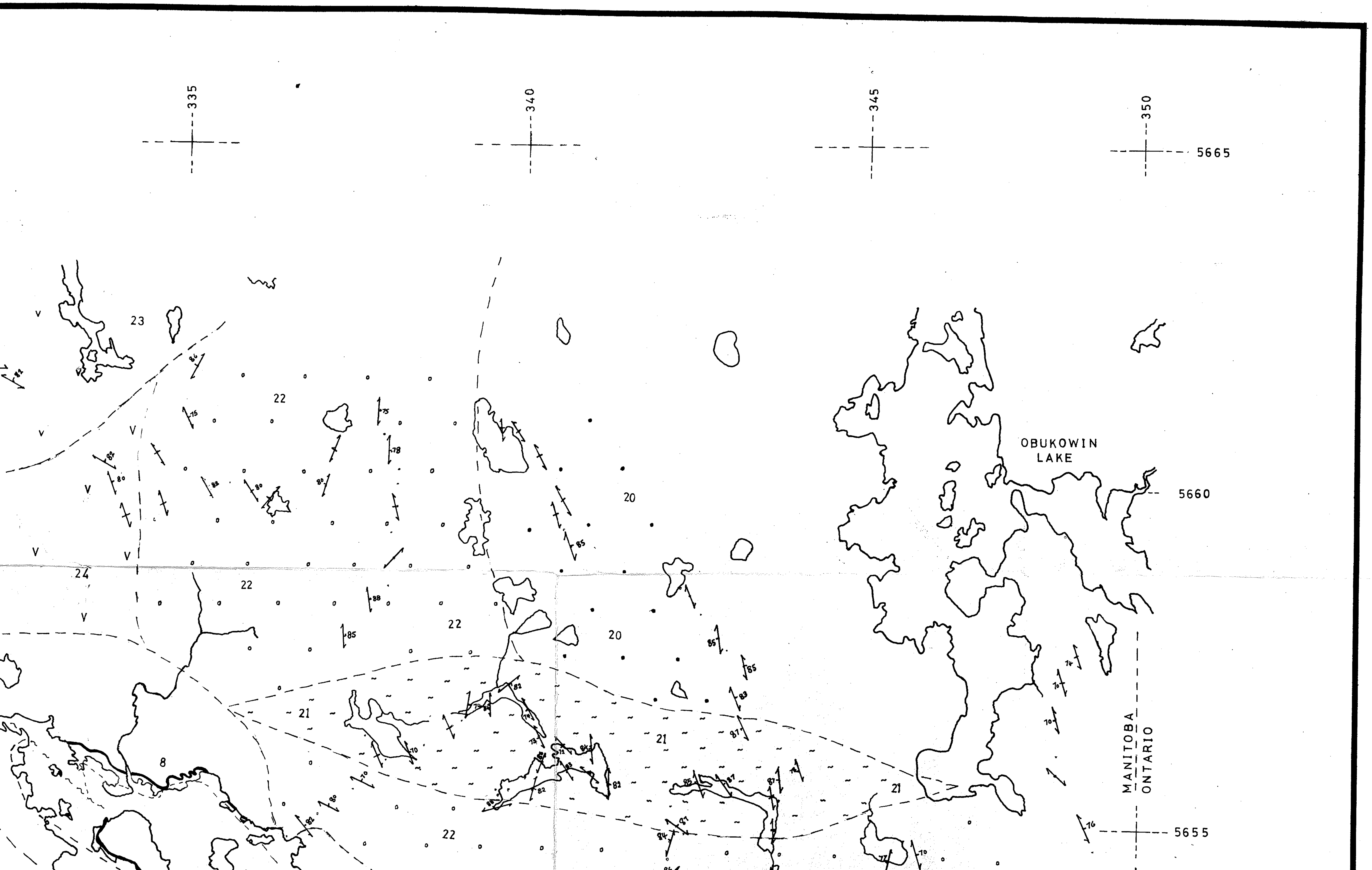
8
7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OBUKOWIN LAKE
MANITOBA
ONTARIO
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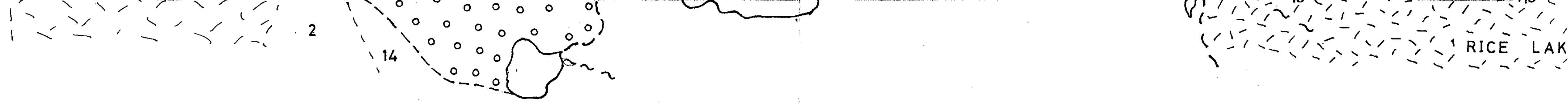


SYMBOLS:

Foliation (with dip)

Foliation (no dip)

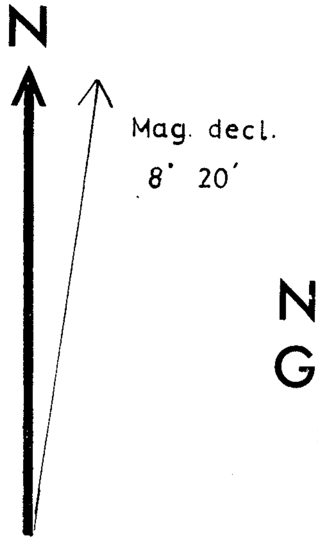
Lineation

Bedding

~ ~ ~ ~ Shear zone, Fault

Synclinal Axis

Anticlinal Axis

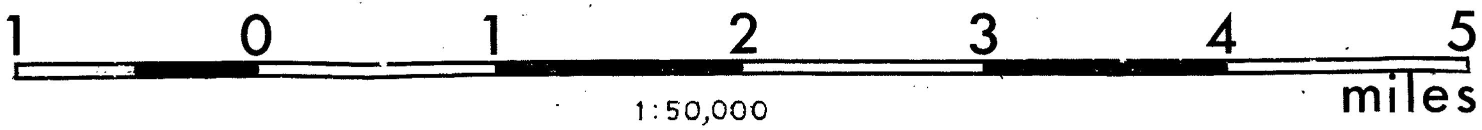


Northern Granitic Rocks

WANIPIGOW RIVER AREA

S.E. MANITOBA

Scale:



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LEGEND:

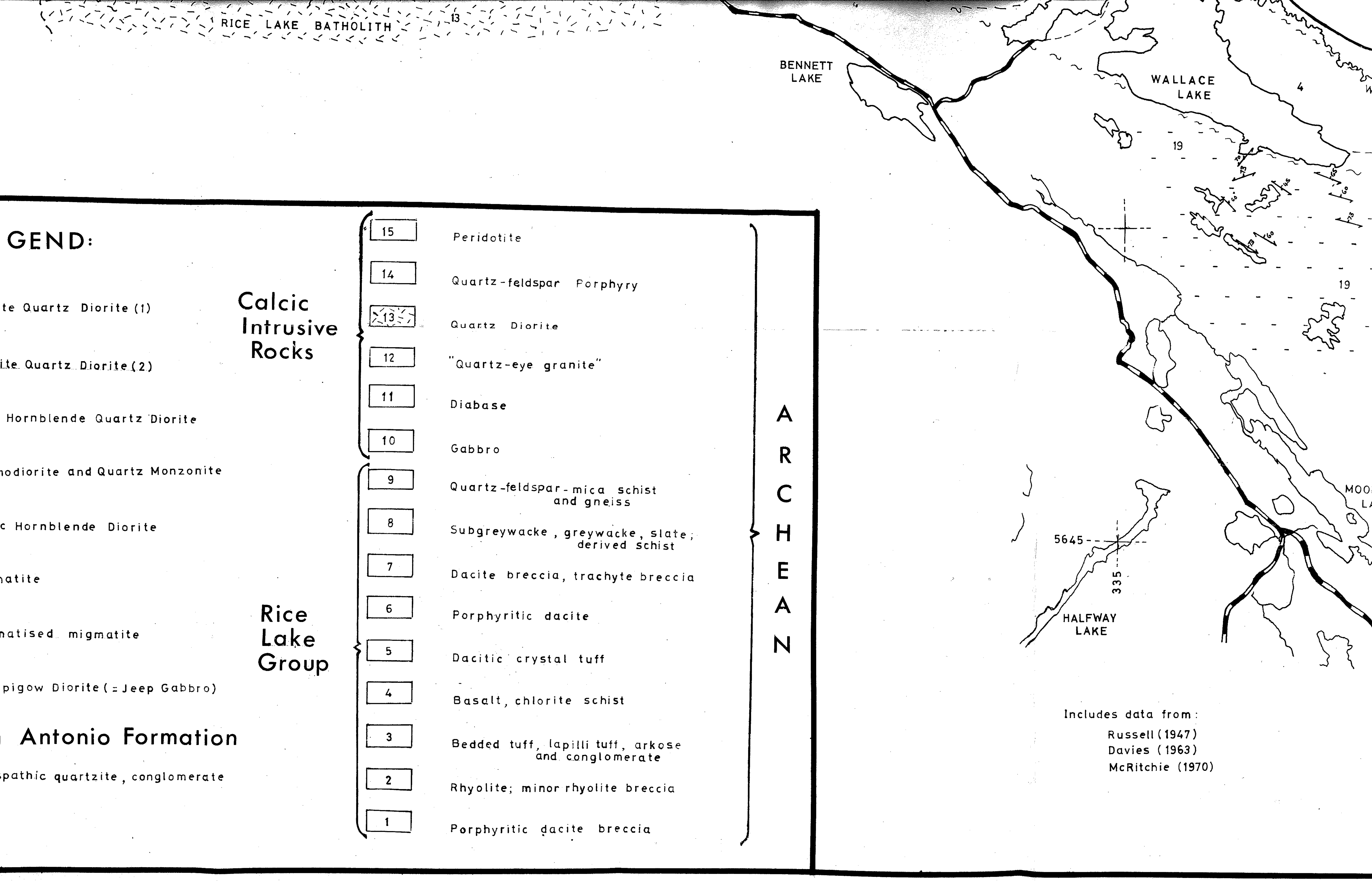
Northern Granitic Rocks	24	Biotite Quartz Diorite (1)
	23	Biotite Quartz Diorite (2)
	22	Int. Hornblende Quartz Diorite
	21	Granodiorite and Quartz Monzonite
	20	Mafic Hornblende Diorite
	19	Migmatite
	18	Pegmatised migmatite
	17	Wanipigow Diorite (= Jeep Gabbro)

Calc
Intru
Roc

Ric
La
Gr

San Antonio Formation

16	Feldspathic quartzite, conglomerate



GEND:

te Quartz Diorite (1)

ite Quartz Diorite (2)

Hornblende Quartz Diorite

odiorite and Quartz Monzonite

c Hornblende Diorite

atite

atised migmatite

pigow Diorite (= Jeep Gabbro)

Antonio Formation

pathic quartzite, conglomerate

Calcic Intrusive Rocks

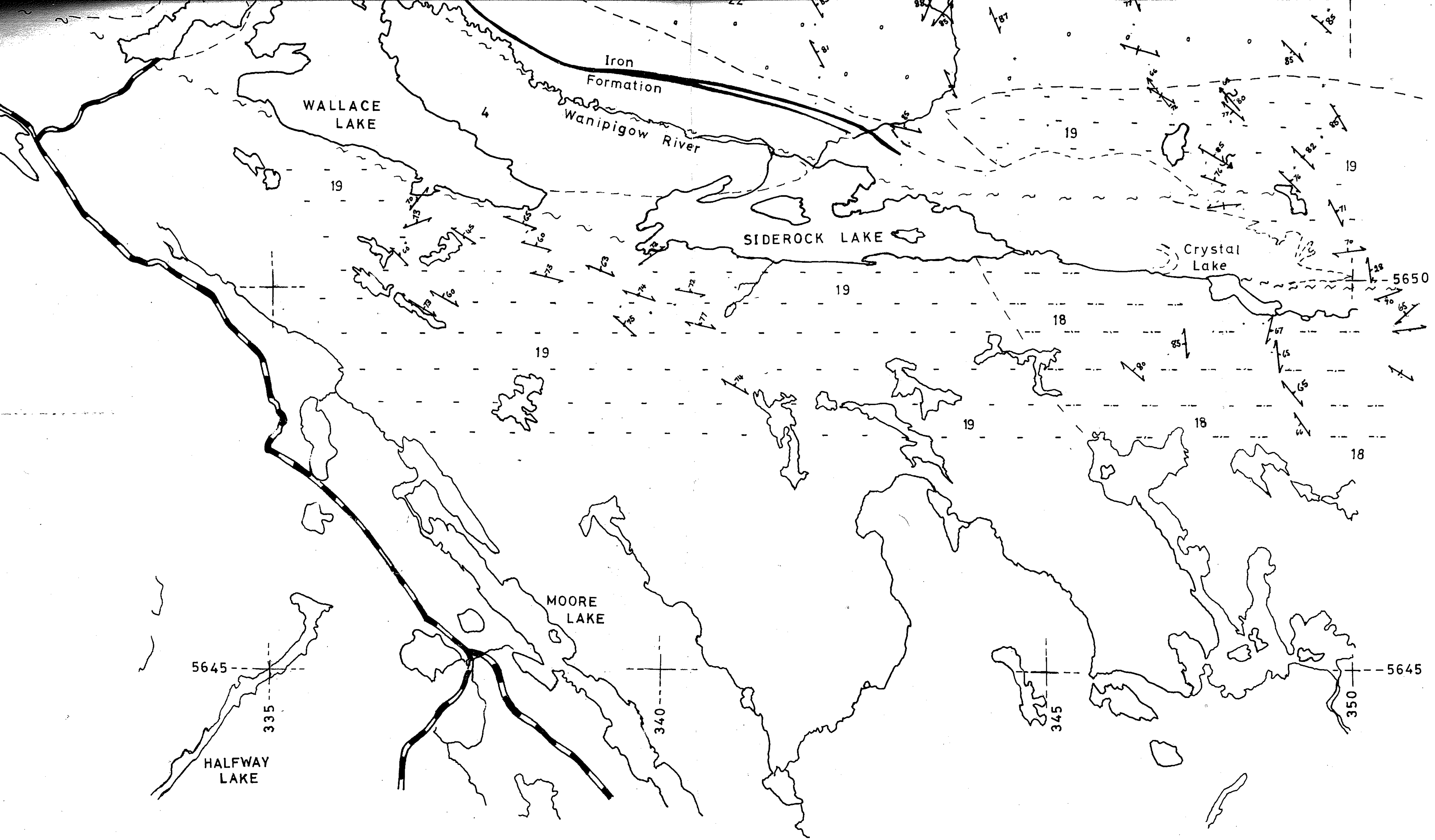
15	Peridotite
14	Quartz-feldspar Porphyry
13	Quartz Diorite
12	"Quartz-eye granite"
11	Diabase
10	Gabbro

Rice Lake Group

9	Quartz-feldspar-mica schist and gneiss
8	Subgreywacke, greywacke, slate; derived schist
7	Dacite breccia, trachyte breccia
6	Porphyritic dacite
5	Dacitic crystal tuff
4	Basalt, chlorite schist
3	Bedded tuff, lapilli tuff, arkose and conglomerate
2	Rhyolite; minor rhyolite breccia
1	Porphyritic dacite breccia

ARCHEAN

Includes data from:
Russell (1947)
Davies (1963)
McRitchie (1970)



Includes data from:

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Davies (1963)
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