THE TECTONIC SIGNIFICANCE OF SOME INTRUSIVE ROCKS IN THE KENORA - WESTHAWK LAKE AREA, ONTARIO

A Thesis

Presented to the

Faculty of Graduate Studies and Research

University of Manitoba

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

George Oliver Vagt

1968

ABSTRACT

This thesis presents a detailed analysis of the geometry, character, and origin of the foliation in three intrusive rock bodies in the Winnetka Lake area situated in the tectonically deformed Kenora-Westhawk Lake greenstone belt, Kenora District, Ontario. The intrusive bodies are, the Winnetka Lake stock, the Granite Lake porphyry and the gneissic granodiorite.

Mesoscopic and microscopic studies of the structural elements indicate that the Winnetka Lake stock and the Granite Lake porphyry are characterized by a steep dipping closely spaced penetrative foliation that has a cataclastic origin. This foliation is interpreted to have originated by slip along the penetrative surfaces and is therefore of post-solidification or tectonic origin. This interpretation is in accord with an emplacement of the Winnetka Lake stock and the Granite Lake porphyry which occurred prior to the tectonic event that resulted in the development of the foliation.

The gneissic granodiorite is characterized by a foliation, the properties of which are consistent with a flow origin during the intrusive emplacement of the body. The geometric and kinematic analysis of the two types of foliation in the bodies provides the basis for interpreting that the gneissic granodiorite produced the regional deformation in the host rocks so the gneissic granodiorite is interpreted to be syntectonic .

The preliminary structural investigation of the tectonic

significance of the foliation in several other intrusive bodies situated in the greenstone belt in the High-Shoal Lakes area indicated that the High Lake porphyritic granodiorite is of pretectonic origin and the High Lake grey granodiorite, the Snowshoe Bay granodiorite and the Indian Reserve granodiorite are of syntectonic or posttectonic origin.

TABLE OF CONTENTS

LIST OF PLATES

PAGE.

LIST OF TABLES

CHAPTER I

INTRODUCTION

Introduction

The main purpose of this thesis is to establish the geometry, character and origin of the foliation in several granodioritic plutons situated in the Kenora-Westhawk Lake greenstone belt of western Ontario.

The body of the thesis deals with a detailed study of three of the intrusive rock bodies near Winnetka Lake. These are the Winnetka Lake stock, the gneissic granodiorite, and the Granite Lake porphyry, (plate 2, in pocket). The final portion of the thesis deals with a preliminary study of four intrusive rock bodies in the High-Shoal Lakes area; the High Lake porphyritic granodiorite, the High Lake grey granodiorite, the Snowshoe Bay granodiorite, and the Indian Reserve granodiorite, (plate 3, in pocket).

Location

The location of the thesis area is shown in plate 1. The detailed study area near Winnetka Lake includes the northeast corner of Forgie township and the northwest corner of Boys township, approximately 20 miles west of the town of Kenora, Ontario. The preliminary study area at High Lake and near the northwest corner of Shoal Lake includes the west central portion

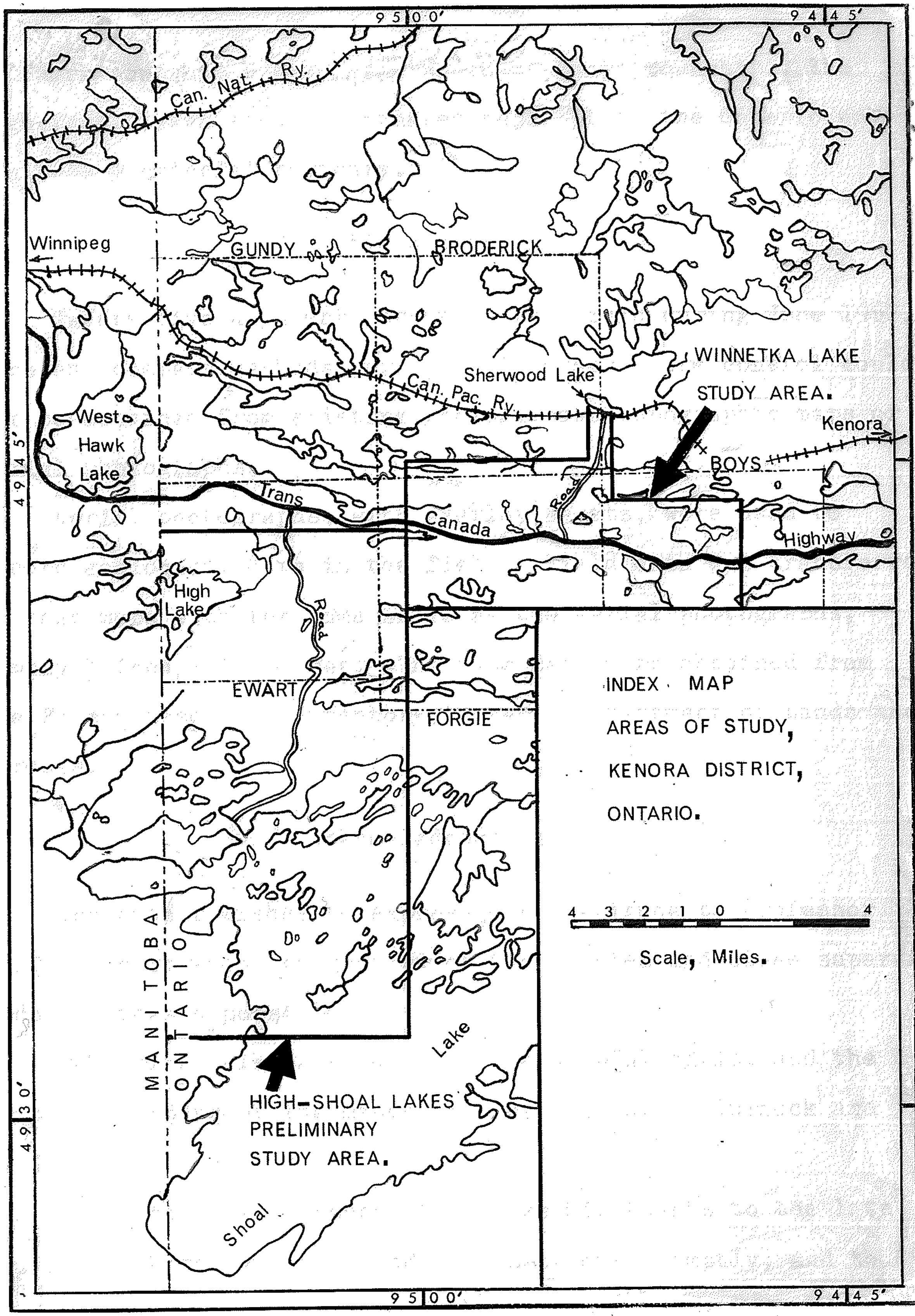

95°00'
94°45'
Can. Nat. Ry.
Winnipeg
GUNDY
BRODERICK
WINNETKA LAKE
STUDY AREA.
Sherwood Lake
Can. Pac. Ry.
West
Hawk
Lake
Kenora
BOYS
Trans
Canada
Highway
Road
49°45'
High
Lake
Road
EWART
FORGIE
INDEX MAP
AREAS OF STUDY,
KENORA DISTRICT,
ONTARIO.
4 3 2 1 0 4
Scale, Miles.
MANITOBA
ONTARIO
Lake
49°30'
HIGH-SHOAL LAKES
PRELIMINARY
STUDY AREA.
Shoal
95°00'
94°45'

PLATE 1

of Ewart township and an area south of Ewart township. The High-Shoal Lakes area is situated adjacent to the Ontario and Manitoba provincial boundary.

Field Work

Twenty-five days were spent in the field during June 1967. Pace and compass methods were used in areas where control could not be obtained from existing geologic and topographic maps or aerial photographs.

Aerial photographs, with overlay sheets, were used to record geological data in the field. Field data was transferred to base maps with the same scale as the aerial photographs, namely 1 inch = 1320 feet. The base maps were obtained from the Forest Resources Inventory, Ontario Department of Lands and Forests.

Acknowledgements

The author wishes to express his gratitude to Professor W. C. Brisbin whose suggestion of the problem and close supervision made the thesis possible.

The writer also acknowledges the helpful advice and the critical reading of the manuscript by Drs. A. C. Turnock and J. C. Davies.

The author also wishes to express his thanks to the late Mr. J. A. Berta, who provided thin sections promptly, and to

Mr. and Mrs. Frank Kosloski of Granite Lake, who provided excellent accomodation.

CHAPTER II

GENERAL GEOLOGY

Previous Work

Lawson (1885), Parsons (1911-1912), Greer (1930), and Thomson (1937) were responsible for most of the early work in the Lake of the Woods region.

Lawson (1885) subdivided the volcanic rock sequence into four units on the basis of lithology. Parsons (1911-1912) reported on the gold properties. Greer (1930) was the first to use a genetic classification for the metamorphosed volcanic and sedimentary rocks. Thomson (1937) mapped the north-central part of the Lake of the Woods including Boys township.

The most recent and complete mapping is that of Davies (1965). Nearly all of the thesis area is included in an area mapped by him on a scale of 1 inch = 1/2 mile.

Lithology

The Kenora-Westhawk Lake greenstone belt is part of the great sequence of precambrian metamorphosed volcanic and sedimentary rocks in the Lake of the Woods region to which Lawson (1885) assigned the name Keewatin. The rocks of the greenstone belt consist predominantly of metamorphosed flows, tuffs, and agglomerates of basic, intermediate and acidic composition. Minor amounts of metamorphosed clastic sedimentary rocks also occur.

Numerous granodiorite plutons with circular or elliptical outlines on the surface occur throughout the greenstone belt. They range in size from a few hundred yards to several miles across. Previous authors have interpreted that all of the circular or elongate plutons are intrusive into the greenstone belt.

The area north of the greenstone belt is underlain by an igneous-gneissic rock complex, a portion of the southern edge of which is in the area of study. The shape and limits of the large bodies of gneissic granodiorite in the complex have not previously been determined. Previous work, however, has established the intrusive character of the gneissic granodiorite (Davies 1965, p. 18). Evidence in the thesis area which indicates the intrusive character of the gneissic granodiorite is in the form of a hybrid zone which is characterized by assimilated volcanic and sedimentary rocks adjacent to the greenstone belt. The hybrid zone is situated along the south contact of the gneissic granodiorite north of Winnetka Lake (plate 2).

Davies (1965) described the acid intrusive rocks of Ewart, Forgie, Gundy and Broderick townships under two relative age groups (Table 1). The age division was based on the degree of metamorphism and the general appearance of the rocks.

Within the thesis area the only acid intrusive body identified as belonging to the earlier age group is the High

TABLE 1 (from Davies, 1965)

TABLE OF FORMATIONS

CENOZOIC

RECENT	Lake, stream, and swamp deposits.
PLEISTOCENE	Sand, gravel, clay.

PRECAMBRIAN

PROTEROZOIC	Diabase.

Intrusive Contact

ARCHEAN

Later Acid Intrusive Rocks.

Pink quartz monzonite and granodiorite, with some grey foliated granodiorite.

Intrusive Contact

Quartz monzonite; grey granodiorite; gneissic hornblende-biotite granodiorite, with aplite, pegmatite, and dark inclusions; grey granodiorite with much pink granodiorite; tonalite and diorite[1]; border phase of hybrid rocks and *lit par lit* gneiss; granodiorite with large feldspar "eyes".

Intrusive Contact

Crowduck Lake Group

Argillite and cherty argillite; arkose, arkosic greywacke, impure sandstone (tuff?); conglomerate; reworked agglomerate; volcanic rocks.[2]

Unconformity

Earlier Acid Intrusive Rocks

Porphyritic intrusive rocks; porphyritic granodiorite; quartz porphyry; feldspar porphyry.

Intrusive Contact

Basic Intrusive Rocks

Quartz-hornblende diorite; hornblende diorite; diorite with much injected granodiorite; gabbro.

Intrusive Contact

Keewatin Group

Metasediments: Arkose[3]; greywacke, arkosic greywacke (tuff); conglomerate, reworked agglomerate; iron-rich greywacke; slate, iron-rich slate; siliceous siltstone, cherty sedimentary rocks (tuff); garnet-rich greywacke.

Acid Volcanic Rocks[3]: Bedded rhyolitic and dacitic tuff, minor flows and agglomerate; massive fine-grained rhyolitic and dacitic tuff; porphyritic (quartz) rhyolite flows with minor tuff, agglomerate, and quartz porphyry dikes; rhyolitic agglomerate.

agglomerate; massive fine-grained rhyolitic and dacitic tuff; porphyritic

Intermediate Volcanic Rocks[3]: Andesite; porphyritic andesite; andesite-dacite agglomerate; andesite-dacite tuff, agglomerate and flows.

Basic Volcanic Rocks[3]: Andesite; basalt; tuff, lapilli tuff; agglomerate and tuff; interbanded lensy tuff, flows and sediments; hornblende-biotite-plagioclase schist; gabbro, coarse-grained tuff and flows (possibly gabbro).

---

[1]Some of these rocks may be older than the upper sedimentary unit.

[2]Part of the volcanic rocks may belong to the Keewatin group.

[3]The basic, intermediate, and acid volcanic rocks, and the metasediments are interbanded.

Lake porphyritic granodiorite which Davies (1965, p. 21) believed to be pre-Timiskaming. Davies placed all of the other intrusive rocks including the gneissic granodiorite with the later acid intrusive rock group and was of the opinion that the gneissic granodiorite was Algoman (Davies 1965, p. 21). The author presumes that the earlier acid intrusive rocks are Laurentian.

Structural Geology

Folding

The layering in the metamorphosed volcanic and sedimentary rocks of the greenstone belt in Ewart and Forgie townships generally strikes east-west except at the noses of folds. All dips are steep. A well defined foliation which is in the form of a steep dipping penetrative schistosity also strikes east-west and is mainly parallel to the layering. The foliation is believed to be of tectonic origin (Davies 1965, p. 27). The layered and foliated rocks exhibit an irregular fold pattern which probably indicates that the rocks have undergone complex deformation, possibly by cross folding.

Davies (1965, p. 25) was the first to report the presence of slip folding in the metamorphosed volcanic and sedimentary rocks. He and Buckingham (1968) suggested that the slip folding represents a second period of deformation which has been superposed on northwest striking isoclinal folds producing refolded folds.

The peculiar "s" and "z" shaped hook fold pattern in the metamorphosed volcanic and sedimentary rocks of Ewart and Forgie townships is believed to be the product of the refolding mechanism. Davies (1965, p. 27) states:

> "Carey (1962, p. 101), however, points out that hook folds are characteristic of strongly folded areas. Earlier fold axes, in the event of two periods of folding, are parallel to the units 'hooked' by the second period of folding. In the present area this would suggest an earlier stage of folding in which fold axes were in a northwest-southeast direction. Carey also outlines some of the extremely complex patterns that are possible in areas characterized by two periods of folding."

W. C. Brisbin (1965) carried out a detailed analysis of the geometry of the folds and arrived at the following conclusions:

(1) The foliation surfaces are of tectonic origin.

(2) The geometry of the folds is consistent with two periods of folding.

(3) The second period of folding was caused by shearing or passive slip on the foliation surfaces.

(4) The direction of slip during the second period of folding was close to the dip line of the foliation.

The direction of slip during shear deformation was determined by studies of the shear elongation of agglomerate and conglomerate fragments and pillows in Ewart township. Brisbin (1965) states:

> "The greatest component of movement is down the dip of the foliation; however, a small horizontal component parallel to the strike of the foliation is present."

In his explanation of the second period of folding Brisbin (1965) states:

> "The shear folds have been interpreted to be produced during a period of widespread intrusion of granitic diapirs in the Superior province of the Precambrian shield."

Faulting

Prominent northeast-southwest lineaments and some northwest-southeast lineaments occur throughout the Winnetka Lake area. Field evidence for faulting in Ewart and Forgie townships, and in adjacent Gundy and Broderick townships to the north, is generally not present. Davies (1965, p. 29) states:

> "The field mapping indicated that fault zones may be extremely narrow, and the adjacent rocks may or may not be schistose. Evidence of faulting, if present, would probably be missed in the course of normal mapping procedures."

Steep northeast and northwest striking joints are common throughout the thesis area. North-northeast striking joints, which are generally parallel to some of the well defined lineaments, predominate throughout the three plutons of the Winnetka Lake area.

Metamorphism

The basic and intermediate volcanic rocks in the thesis area have been metamorphosed to the lower or middle zone of the greenschist facies of regional metamorphism. The basic volcanic rocks situated adjacent to the acid intrusive rock bodies have been metamorphosed to the amphibolite facies of regional metamorphism and consist mainly of plagioclase and hornblende. Minor amounts of biotite, magnetite, chlorite, sericite and epidote also occur. Garnets are commonly found in a greywacke unit which is part of a metamorphosed volcanic and sedimentary rock belt near the north end of Forgie township. The garnets indicate that temperatures of the upper greenschist facies and lower almandine amphibolite facies were probably reached.

The most important secondary minerals in the intrusive rocks are chlorite, sericite, epidote and recrystallized quartz. The secondary minerals, in conjunction with cataclastic effects which are mentioned later, indicate that low grade dynamic metamorphism has modified some of the intrusive rocks.

CHAPTER III

STATEMENT OF THE PROBLEM

Previous work has established that the east-west striking and steeply dipping foliation, which pervades the Precambrian metamorphosed volcanic and sedimentary rocks, is of tectonic origin. Interpretation of previous work has established that the intrusive bodies are of two relative ages; however, these interpretations did not take account of the character and origin of the foliation within the igneous masses and its relationship to tectonic events. The previous work then, has not completely resolved the historical sequence of intrusion and tectonism. The object of the thesis is to study the geometry, character, and origin of the foliation in the three intrusive bodies of the Winnetka Lake area in order to establish this sequence.

The geometry of the foliation was determined by a field and mesoscopic study. The interpretation of the character and origin of the foliation was based on a microscopic study of textures and structures of the plutons. The nature of the foliation in each intrusive body provided the basis for interpreting whether the body was emplaced pretectonically, syntectonically or posttectonically where these terms refer to the tectonic event which resulted in the development of diastrophic foliation in the rocks which were host to the plutons.

The petrologic and structural data, for all of the rock types in the area of study which bear on the problem are presented in the following chapters.

The systematic collection of rock specimens and of orientation data for the foliation and joints was based on sampling at points every 1000 feet along north-south traverse lines that were approximately 2000 feet apart in the Winnetka Lake area (plate 2, in pocket). The orientation data is presented in later chapters on lower hemisphere Schmidt equal area diagrams.

CHAPTER IV

PETROLOGY AND STRUCTURAL GEOLOGY OF THE METAMORPHOSED VOLCANIC AND SEDIMENTARY ROCKS

Introduction

The outcrop patterm of the metamorphosed volcanic and sedimentary rocks in the Winnetka Lake area is shown in plate 2, (in pocket).

Petrology

Davies (1965) separated the metamorphosed volcanic rocks into three units, basic, intermediate and acidic. The three rock units occur in the thesis area; however, only the basic and intermediate volcanic rocks are in contact with the intrusive rocks, and as such, are the only rock types important to the investigation of the relationship between the tectonic foliation in the metamorphosed volcanic rocks and the foliation in the acid intrusive bodies.

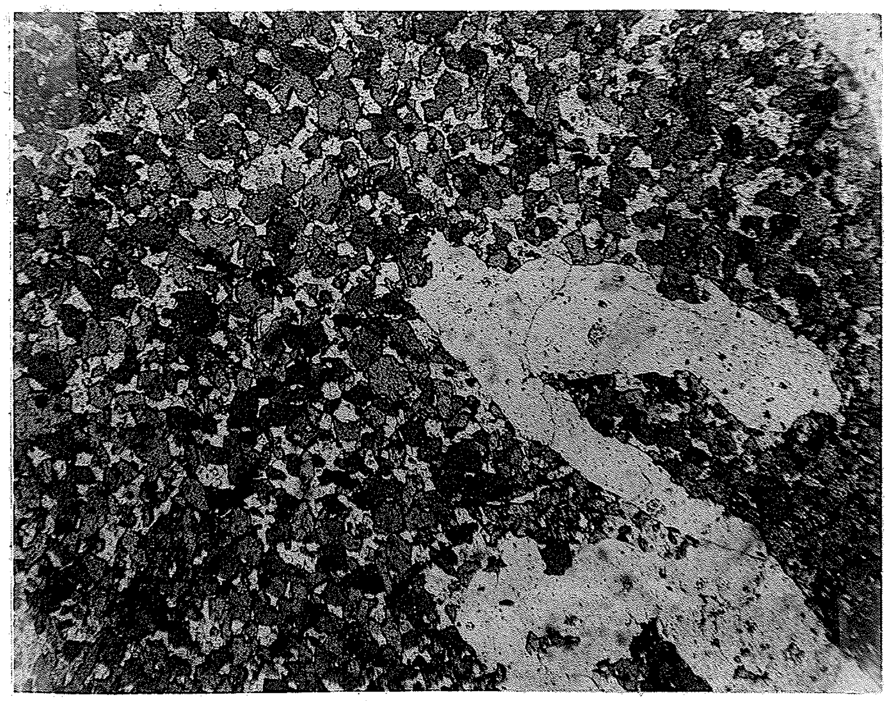
The metamorphosed basic volcanic rocks are dark grey-green in color on the fresh and weathered surface and are fine to medium grained. The rocks consist predominantly of interlayered lensey tuff, flows and sediments. The metamorphosed basic volcanic rocks consist of about 60 percent hornblende and about 40 per cent plagioclase. The hornblende has been almost completely recrystallized. The recrystallization process has produced a relatively coarse grained (0.08 mm.) mosaic texture (plate 4). Plate 4 shows that there is a very weak tabular alignment of hornblende grains from the upper left to the lower right hand corner which is the general east-west direction in the photomicrograph. The metamorphosed basic volcanic rocks were probably basalt in composition in their premetamorphic state.

The metamorphosed intermediate volcanic rocks are light green to dark grey-green in color on the fresh and weathered surface. The rocks are fine to coarse grained and commonly contain siliceous looking fragments. The rocks predominantly consist of andesite-dacite tuff, agglomerate and flows. These rocks were probably andesite-dacite in composition in their premetamorphic state.

The metamorphosed sedimentary rocks are dark grey in color and fine to medium grained. The rocks consist of greywacke and arkosic greywacke. A garnet bearing zone about 50 feet wide occurs in the greywacke within 100 feet of the north contact of the basic volcanic rocks situated on the north side of the Winnetka Lake stock.

Contact Relationships

The layering in the metamorphosed volcanic and sedimentary rocks generally strikes east-west except at the noses of folds (plate 2, southwest corner), and at the east end of the Winnetka Lake area where the basic volcanic rocks and the intermediate



Photomicrograph (x40), (ordinary light), showing folded quartz vein material in a thin section of a basic volcanic rock that has been cut horizontally. The rock is metamorphosed to the amphibolite facies. Note the mosaic texture formed by grains of hornblende which form lineations perpendicular to the plane of the photograph. The specimen was taken from a location about 5 feet south of the south contact of the Winnetka Lake stock near Winnetka Lake.

PLATE 4

volcanic rocks arc around the north and south contacts respectively, of the Granite Lake porphyry.

Although the contact between the metamorphosed basic volcanic rocks and the Granite Lake porphyry was not observed, the Granite Lake porphyry is interpreted to be intrusive into the rocks of the greenstone belt. The main reason for this interpretation is the occurrence of the above mentioned arcuate outcrop pattern of the greenstones about the Granite Lake porphyry, and the common occurrence of quartzo-feldspathic vein material in the greenstones on the side nearest the Granite Lake porphyry.

Observations indicate that the metamorphosed basic volcanic rocks exhibit a host rock relationship to the Winnetka Lake stock (plate 5).

The contact between the metamorphosed volcanic and sedimentary rocks and the gneissic granodiorite was not observed; however, a hybrid zone which contains assimilated volcanic and sedimentary rocks occurs between the two rock types and this is interpreted to indicate that the gneissic granodiorite is intrusive into the metamorphosed volcanic and sedimentary rocks (plate 2, in pocket). The compositional layering in the hybrid rocks makes them resemble granitized sedimentary rocks (plate 6).

Structural Elements

Important structural elements in the metamorphosed volcanic and sedimentary rocks are: foliation, small folds, two types of lineation, faults, and layering.

View showing intrusive nature of the Winnetka Lake stock (on the right) into the veined metamorphosed basic volcanic rocks (on the left). This location is on the Trans-Canada Highway, south of Winnetka Lake.

PLATE 5

View of horizontal surface which shows that the rocks of the hybrid zone, situated along the south boundary of the gneissic granodiorite west of the Sherwood Lake road, resemble granitized sedimentary rocks. The strike of the compositional layering is east-west.

PLATE 6

The steeply dipping foliation surfaces in the metamorphosed volcanic and sedimentary rocks are generally parallel to the contacts between the metamorphosed volcanic and sedimentary rocks and the intrusive bodies. However, at the northwest extremity of the Winnetka Lake stock the foliation was observed to be nearly at right angles to the contact between the metamorphosed volcanic and sedimentary rocks and the Winnetka Lake stock. The significance of this contact relationship is discussed in the next chapter.

Small folds formed by passive slip commonly occur in the basic volcanic rocks which have been locally metamorphosed to the amphibolite facies. Folded granitic veins with axial planes parallel to the foliation of the host rocks are shown in plate 7. Folded, recrystallized, and strained vein quartz occurs on the microscopic scale (plate 4). The axial planes of the micro-folds are parallel to the mesoscopic foliation planes in the basic volcanic rocks although this is not distinct in plate 4.

Elongated pillows and hornblende mineral grains form lineations in the plane of the foliation that plunge approximately 80 degrees in the azimuth 100 degree direction (plate 8).

Direct evidence of faulting occurs in the metamorphosed basic volcanic rocks along the east contact of the Winnetka Lake stock. Slickensides, gouge material and well weathered schistose zones are common. Based on this evidence the north-east trending air-photo lineaments in the metamorphosed basic volcanic rocks and throughout the nearby intrusive rocks in the study area are presumed by the writer to be of fault origin.

Plan view showing folds in granitic veins produced during passive slip of the host pillowed basalt of the basic volcanic rock sequence. The photograph was taken about 200 feet east of the eastern extremity of the Winnetka Lake stock.

PLATE 7

Vertical view, looking north, showing elongated pillows and hornblende grains in the metamorphosed basic volcanic rocks. The photograph was taken about 300 feet north of the northwest nose of the Winnetka Lake stock.

PLATE 8

The layering (bedding) in the metamorphosed volcanic and sedimentary sequence is parallel to the foliation; strikes and dips of these planar features are shown on the geologic map of the Winnetka Lake area (plate 2). The work of Davies (1965) and Brisbin (1965) suggests the strong possibility of more than one period of deformation and, as well, that the final period of folding was a result of passive movements nearly parallel to the dip line of the foliation surfaces.

Concluding Statements

The volcanic and sedimentary rocks of the greenstone belt, as indicated by their direct and indirect host rock relationship to the intrusive rocks, are the oldest rocks in the Winnetka Lake area.

The generally invariant east-west strike and steep dip of the penetrative foliation, and the invariably steep plunging lineations in the rocks of the greenstone belt within the area of study, are features interpreted by previous authors in other parts of the greenstone belt to be a result of shear deformation. All of the volcanic and sedimentary rocks of the greenstone belt are therefore concluded to have been subjected to passive slip on the foliation surfaces.

The near vertically elongate pillows in the basic volcanic rocks of the Winnetka Lake area have an attitude similar to that of the elongate pebbles and pillows in Ewart township which were previously studied (Brisbin 1965). It may be inferred from the similarity in orientation of the linear features in the volcanic and sedimentary rocks of the two areas that the strain has been up and down the dip of the foliation surfaces.

CHAPTER V

PETROLOGY AND STRUCTURAL GEOLOGY OF THE WINNETKA LAKE STOCK

Introduction

The Winnetka Lake stock was classified by Davies (1965) as one of the later acid intrusive rock bodies (Table 1). The stock was considered to be part of the large body of intrusive gneissic granodiorite which underlies Gundy and Broderick townships.

The main body of the stock is situated in Forgie township and was mapped to the eastern boundary of the township (Davies 1965). The detailed work for the thesis project included the mapping of the eastern extension of the Winnetka Lake stock into Boys township. The stock trends east-west and is approximately 5 miles long and 2 1/4 miles in width at its widest point. The stock is surrounded by metamorphosed basic volcanic rocks, except at the boundary extending from the north central to the northeast extremity of the stock; however, no contacts were observed as a result of the heavy surface cover in the area.

Two small acid intrusive rock bodies occur south of the Winnetka Lake stock in the study area. One body is located along the southwest shore of Granite Lake; the other body is located at Ridge Lake. These two small rock bodies have mesoscopic structural, compositional and textural similarities with the Winnetka Lake stock and are therefore considered by the writer to be related in origin to the Winnetka Lake stock.

Petrology

The Winnetka Lake stock exhibits compositional zoning but is granodiorite in average composition. Davies (1965, p. 19), in commenting on the composition of the stock, states:

> "In the field the relative proportions of plagioclase, microcline, quartz and biotite (plus hornblende) can be estimated; and a variation, from granite in the centre to hornblende diorite at the edges, was suspected near Spitsi Lake. To the east the variation is less obvious, and the average composition is probably granodiorite to quartz monzonite."

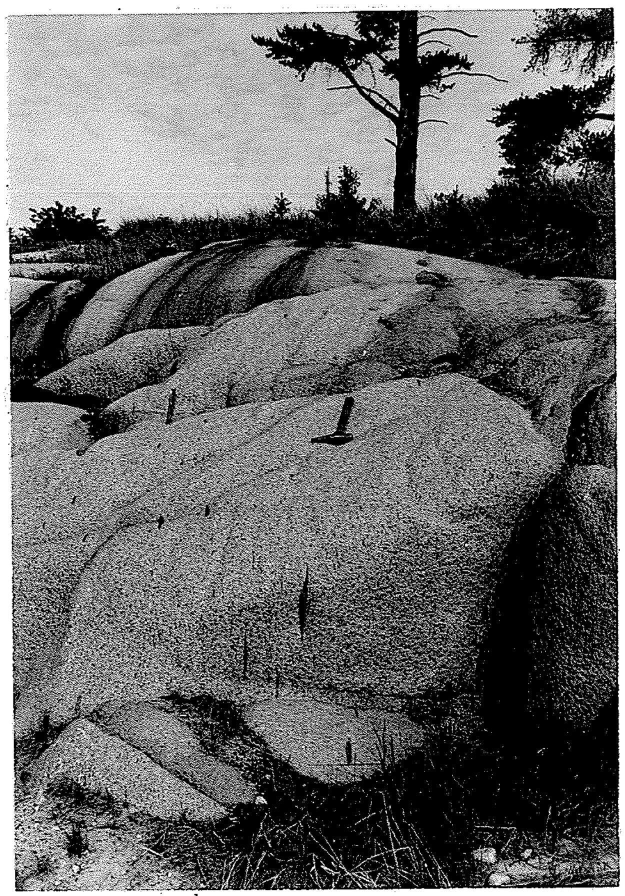
The average composition of three specimens taken west of the Sherwood Lake road, based on a visual microscopic estimate of the mineral percentages is: oligoclase-andesine 45 per cent, microcline 14, quartz 23, biotite 8, hornblende 5, epidote 3, and sphene, apatite and zircon comprise less than two per cent.

The Winnetka Lake stock is grey in color and medium to coarse grained. The stock contains sharply defined, tabular and vertically elongate, fine grained, dark inclusions, composed primarily of hornblende and biotite, which are interpreted to be metamorphosed volcanic (greenstone) fragments (plate 9). The inclusions are evenly distributed throughout the stock and comprise about one percent of the volume of the stock.

Structural Elements (Mesoscopic)

Foliation

The Winnetka Lake stock is characterized by a very well developed penetrative foliation parallel to the east-west striking



View looking west parallel to the foliation in the Winnetka Lake stock showing inclusions. The photograph was taken one mile west of Caribou Lake on the Trans-Canada Highway.

PLATE 9

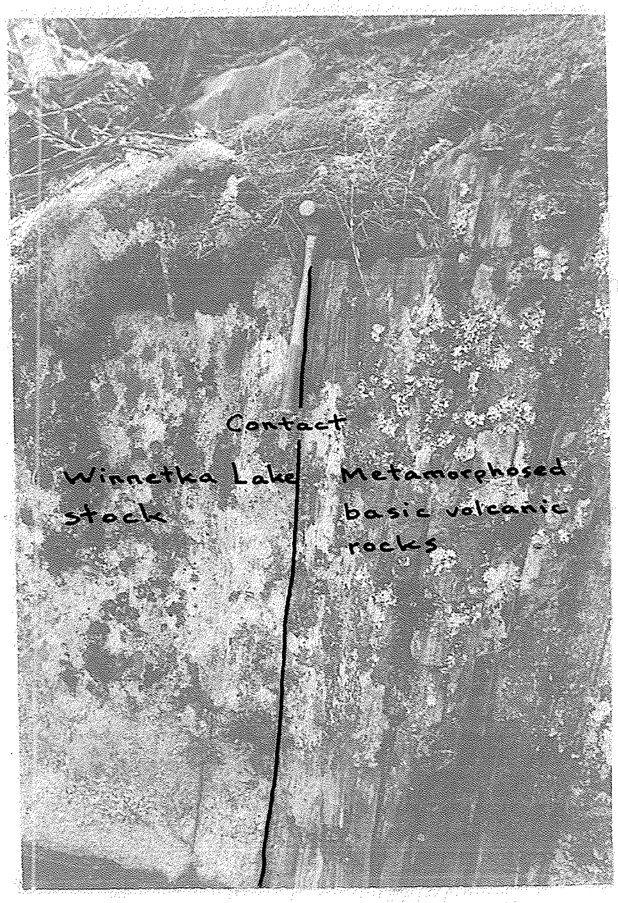
steeply dipping tectonic foliation of the host volcanic and sedimentary rocks (plate 10). The attitude of the foliation in the two rock types in plate 10 is 106°/85° north. Thirty-six readings on the strike and dip values of the foliation in the Winnetka Lake stock were plotted and show an average attitude of 106°/85° north (plate 11). The penetrative foliation in the Winnetka Lake stock departs from the general east-west strike only at the eastern extremity of the body where it changes direction to a strike of 080 degrees (azimuth) (plate 2). The foliation, however, retains its very steep dip.

The tectonic foliation of the host volcanic rocks at the northwest extremity of the Winnetka Lake stock, as observed in plan view, passes directly into and is continuous with the penetrative foliation in the Winnetka Lake stock.[1] At this location the strike of the foliation is at a high angle to the strike of the contact between the two rock types.

The foliation in the Winnetka Lake stock primarily results from the alignment of individual grains or lenticular aggregates of quartz and feldspar and of plates of biotite. The lenticles are also aligned in the tabular sense. The vertically elongate and tabular inclusions within the stock are aligned parallel to the foliation surfaces, and the foliation surfaces pass through the inclusions. The foliation in the inclusions primarily results from the linear alignment of hornblende grains.

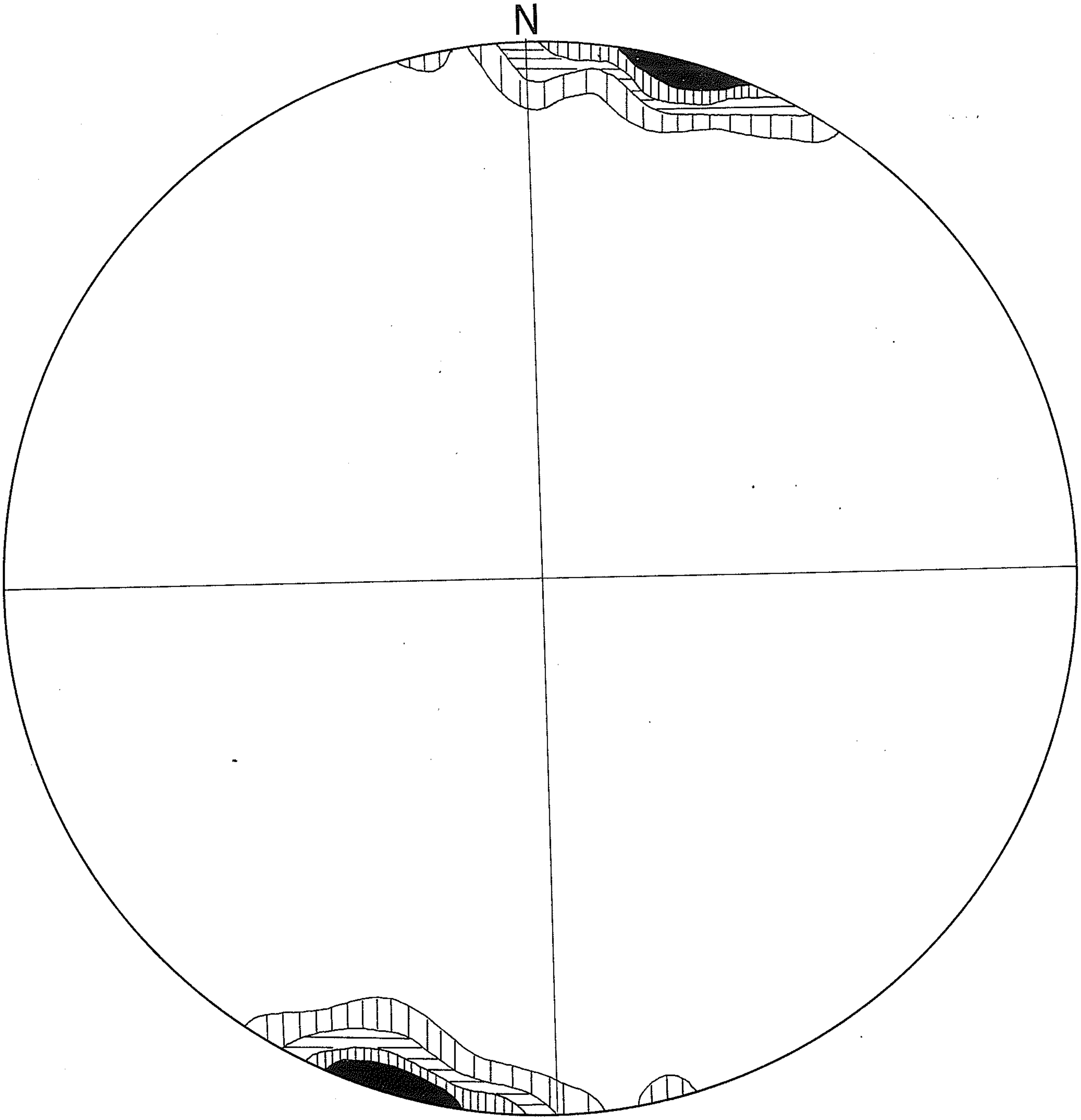
---

[1] W. C. Brisbin, personal communication.



Vertical exposure looking east, showing the similar steep dipping foliation in the Winnetka Lake stock and the metamorphosed basic volcanic rocks. The photograph was taken at the south side of the northwest nose of the Winnetka Lake stock.

PLATE 10



Foliation Distribution
Winnetka Lake Stock
Lower Hemisphere Equal Area Projection
(36 poles to foliation surfaces)
Contours: 5%, 10%, 15%, and 20%.
Sample points at 1000 foot intervals
along north-south lines 2000 feet apart.

PLATE 11

Lineations

Lineations are in the form of individual mineral grains and aggregates of mineral grains within the stock; in addition, the inclusions with their contained minerals exhibit a well developed preferred orientation.

The most conspicuous lineation is formed by the inclusions, the longest axis and the tabular faces of which are aligned. A three dimensional view of an inclusion shows that the longest axial dimension (x axis) is nearly vertical and the intermediate axial dimension (y axis) is nearly horizontal, striking parallel to the foliation (plate 12). The mineral grains of hornblende and biotite, which are the dominant minerals in the inclusions, exhibit a nearly vertical preferred orientation parallel to the longest axial dimension (x axis) of the inclusions.

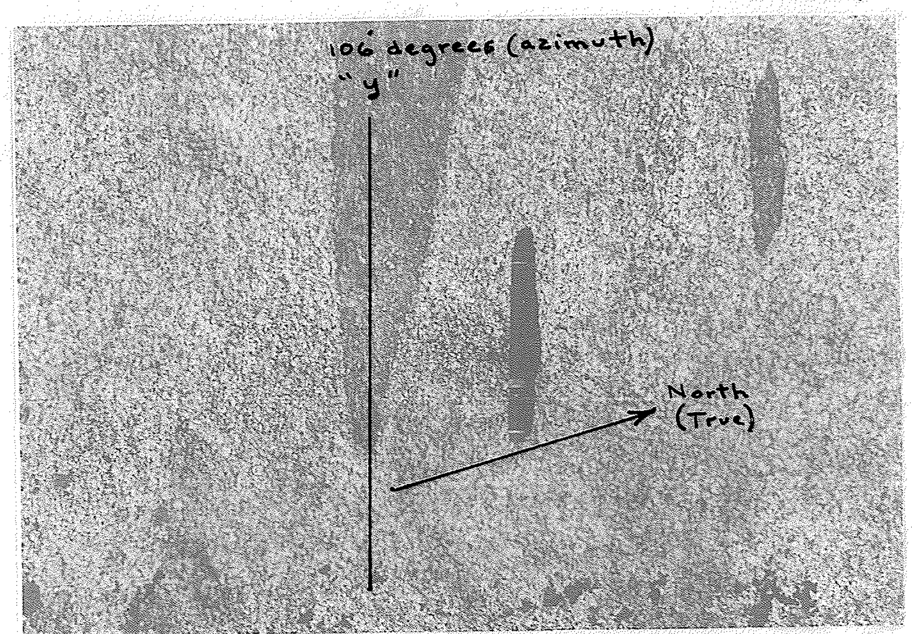
Mineral grains of feldspars and hornblende within the stock are near vertically elongate parallel to the elongate inclusions.

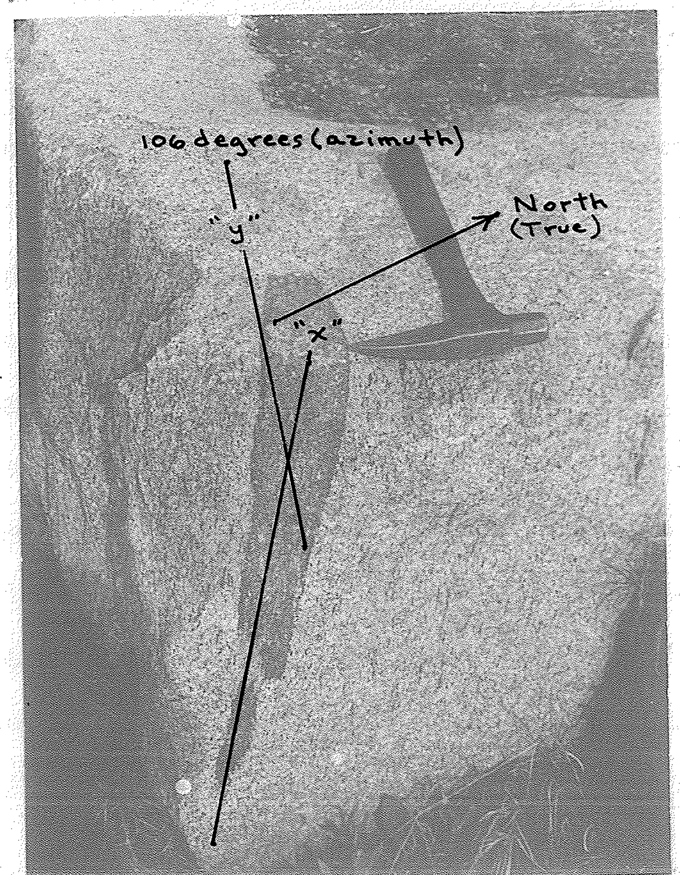
Faults

Lineaments that strike 100 degrees (azimuth) were interpreted as faults by Davies (1965, p. 29). The origin of the lineaments that strike 030 degrees (azimuth) is uncertain, but are presumed by the writer to be of fault origin.

Joints

The most common joint sets strike approximately north-northeast, northeast, and generally east-west. Nearly all of the joint sets





Views looking west showing tabular alignment and vertical elongation of inclusions parallel to the penetrative foliation which passes through the inclusions in the Winnetka Lake stock.

PLATE 12

dip steeply.

Sixty-seven readings on the strike and dip values of the joints were plotted (plate 13). The most common strike direction is centred at azimuth 102 degrees and is nearly vertical. This is nearly parallel to the strike of the foliation maximum (plate 11) and these joint sets are therefore considered to be strike joints. Two secondary joint set strike directions are centred at azimuth 020 degrees and azimuth 049 degrees. Both sets dip close to vertical.

Structural Elements (Microscopic)

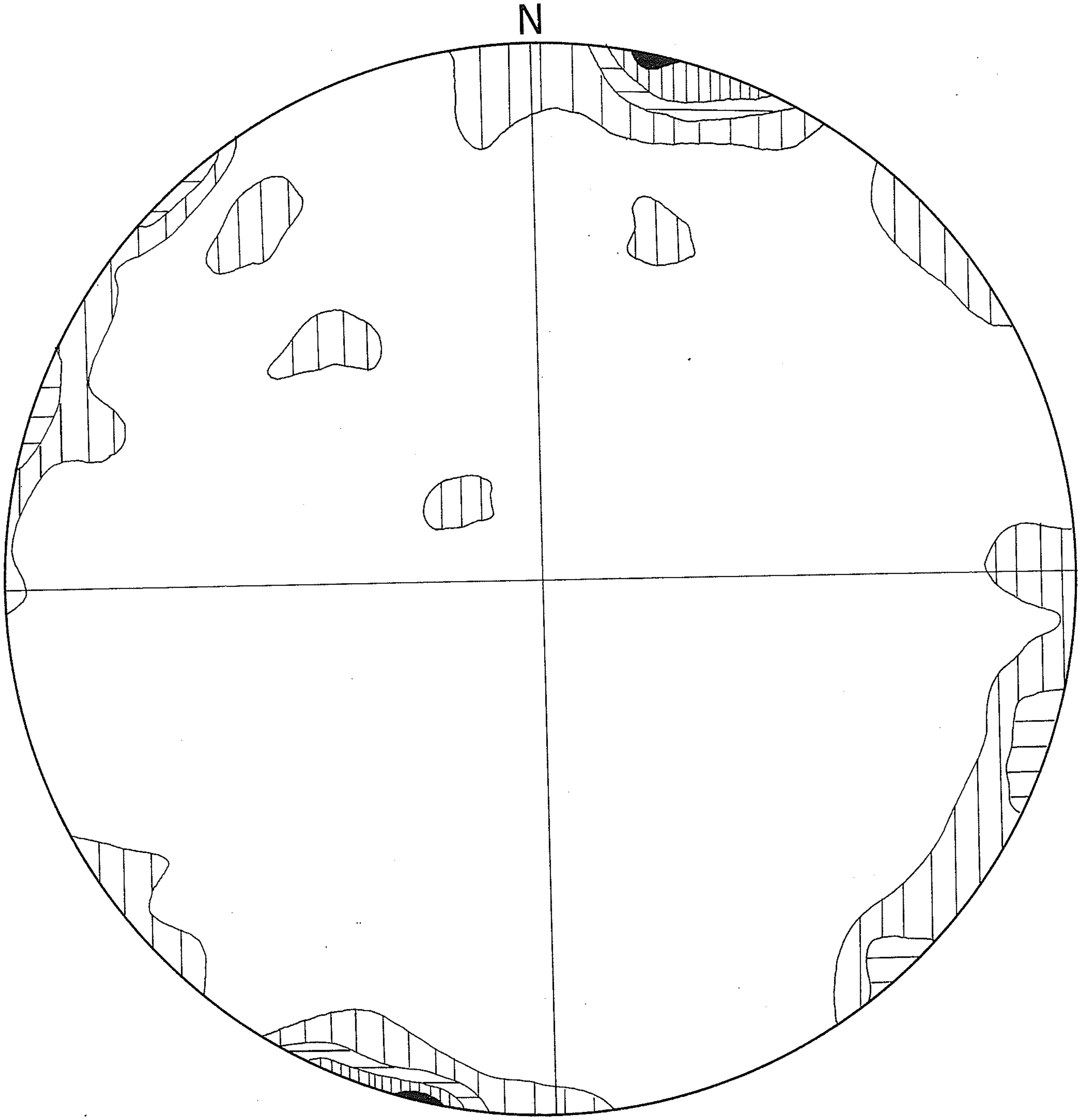
The microtexture of the foliation in the Winnetka Lake stock is characterized by features interpreted to have resulted from what is termed "direct componental movements".[1] Grain boundaries have been partially rounded resulting in unequal grain sizes (A. plate 14). Quartz shows irregular extinction in the well known appearance of strain-shadows. Crystals of plagioclase are commonly bent and some exhibit irregular spaced and discontinuous twinning, which is interpreted to be of secondary origin (B. plate 14).

The microtexture of the foliation in the Winnetka Lake stock indicates that cataclastic metamorphism[2] caused fracturing,

---

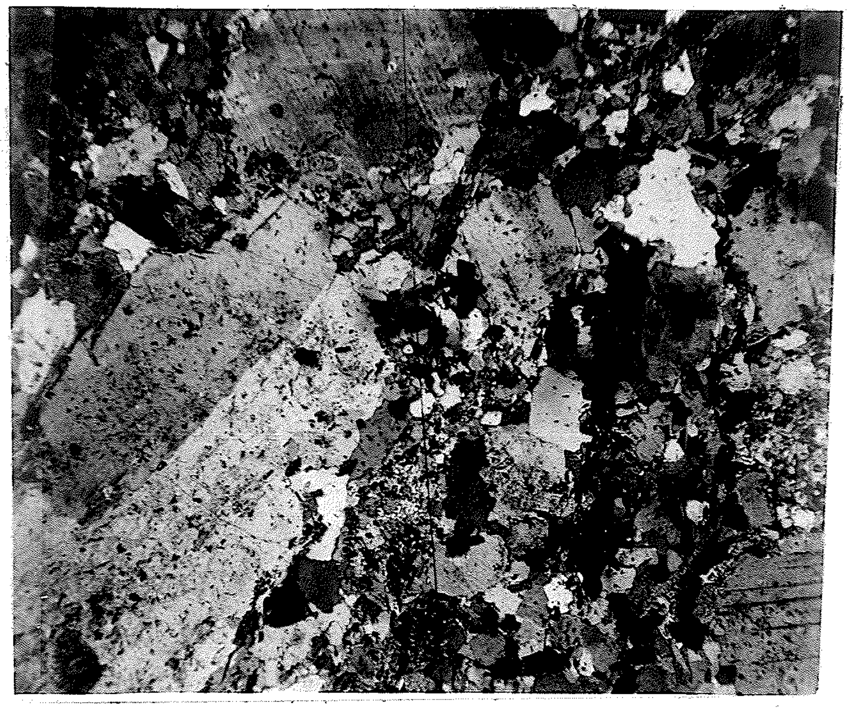
[1] "Direct componental movements", after Sander (1950), involves crystal gliding or relative displacement of grains (Turner and Verhoogen, 1960, p. 612).

[2] Cataclastic metamorphism is defined as the mechanical deformation (plastic flow, rupture) of rocks without recrystallization or chemical reaction (Turner and Verhoogen, 1960, p. 452).



Joint Distribution
Winnetka Lake Stock
Lower Hemisphere Equal Area Projection
(67 poles to joint surfaces)
Contours: 3%, 6%, 9%, and 12%.
Sample points at 1000 foot intervals
along north-south lines 2000 feet apart.

PLATE 13



A. Photomicrograph (x20) (crossed nicols), showing cataclastic texture and unequal grain size in the Winnetka Lake stock.

B. Photomicrograph (x40) (crossed nicols), showing bent feldspar crystals (lower) and discontinuous secondary twinning (upper) in the Winnetka Lake stock.

PLATE 14

crushing and deformation of the mineral grains which produced a cataclastic texture. The breaking down process has not progressed generally to the stage known as "mortar structure", in which there are relatively large very well rounded relicts or original crystals embedded in a matrix of much smaller elements.

Recrystallization of quartz along the partially rounded grain boundaries has occurred. The recrystallization is indicated by the occurrence of non-strained crystals which form a mosaic pattern. Regarding the process of recrystallization in tectonically deformed rocks, Harker (1939, p. 170) states:

> "In particular, we must presume in all cases a certain amount of recrystallization of the more soluble minerals present, proceeding concurrently with the cataclastic process proper."

The aligned mineral grains of hornblende and biotite in the inclusions do not show evidence of cataclasis; the texture suggests recrystallization during the deformation.

Concluding Statements

The Winnetka Lake stock is characterized by steeply dipping penetrative foliation planes that have an average strike of 106 degrees (azimuth) and pass completely through inclusions which occur in the stock. Within the stock itself foliation is defined by the alignment of lenticular mineral grains and plates of biotite. Many of the mineral grains have been rounded and bent by crushing and deformation. The lenticular shape of the grains has resulted from cataclastic metamorphism and is characteristic of tectonically deformed rocks. Harker (1939, p. 167) states:

> "The lenticular shape is retained as being that best adapted to resist further crushing under the given type of stress."

The penetrative foliation is parallel to the two longest dimensional axes of the tabular inclusions contained in the stock and passes completely through them.

This leads to the conclusion that the foliation in the Winnetka Lake stock and the alignment of the inclusions were of tectonic origin. The regional tectonic foliation in the metamorphosed volcanic and sedimentary rocks passes directly into the penetrative tectonic foliation of the Winnetka Lake stock which suggests that the foliation in both rock types is of common origin. Further evidence of a common origin is in the form of the movement direction on the foliation surfaces which in both rocks is close to the dip line of the foliation.

Observations suggest that movement on the steeply dipping tectonic foliation surfaces was accomplished by two processes, each one characteristic of certain rock types. The basic volcanic rocks and the inclusions in the Winnetka Lake stock were foliated tectonically by slip accomplished by the internal rotation and pronounced recrystallization of mineral grains. At the same time the body of the Winnetka Lake stock was tectonically foliated by cataclasis and accompanying weak recrystallization of mineral grains. Although the geometry and direction of strain were persistent in the metamorphosed volcanic and sedimentary rocks and in the Winnetka Lake stock, the strain mechanism appears to have been dependent on rock type.

The generally east-west striking joints may be related to the interpreted faults that strike 110 degrees (azimuth). The origin of the north-northeast and the northeast striking joints is not positively known, however, a possible origin is discussed in chapter VIII.

CHAPTER VI

PETROLOGY AND STRUCTURAL GEOLOGY OF THE GRANITE LAKE PORPHYRY

Introduction

Greer (1930) and Thomson (1937) mapped respectively the southwest and southeast part of the Granite Lake porphyry. The northwest portion of the pluton, lying in the northwest corner of Boys township, was mapped during the present investigation of the eastern extension of the Winnetka Lake stock and the gneissic granodiorite.

The Granite Lake porphyry is bounded by basic volcanic rocks along the west, the northwest and a portion of the northeast contact. Intermediate volcanic rocks lie along the south contact of the Granite Lake porphyry. The Granite Lake porphyry and the main body of the Winnetka Lake stock were not observed to be in contact on the surface; they are separated by an arcuate belt of basic and intermediate volcanic rock.

The Granite Lake porphyry is characterized by east-west striking, generally steeply dipping foliation planes that have a similar appearance to the foliation planes in the Winnetka Lake stock.

Petrology

The Granite Lake porphyry appears to have the same average composition throughout the northwest portion of the body. The average composition of three specimens, based on a visual microscopic estimate of the mineral percentages is: oligoclase-andesine 45 per cent, microcline 20, quartz 20, biotite 8, hornblende 5, and epidote, sphene and apatite comprise about 2 per cent. The mineralogy indicates that this body is granodiorite in composition.

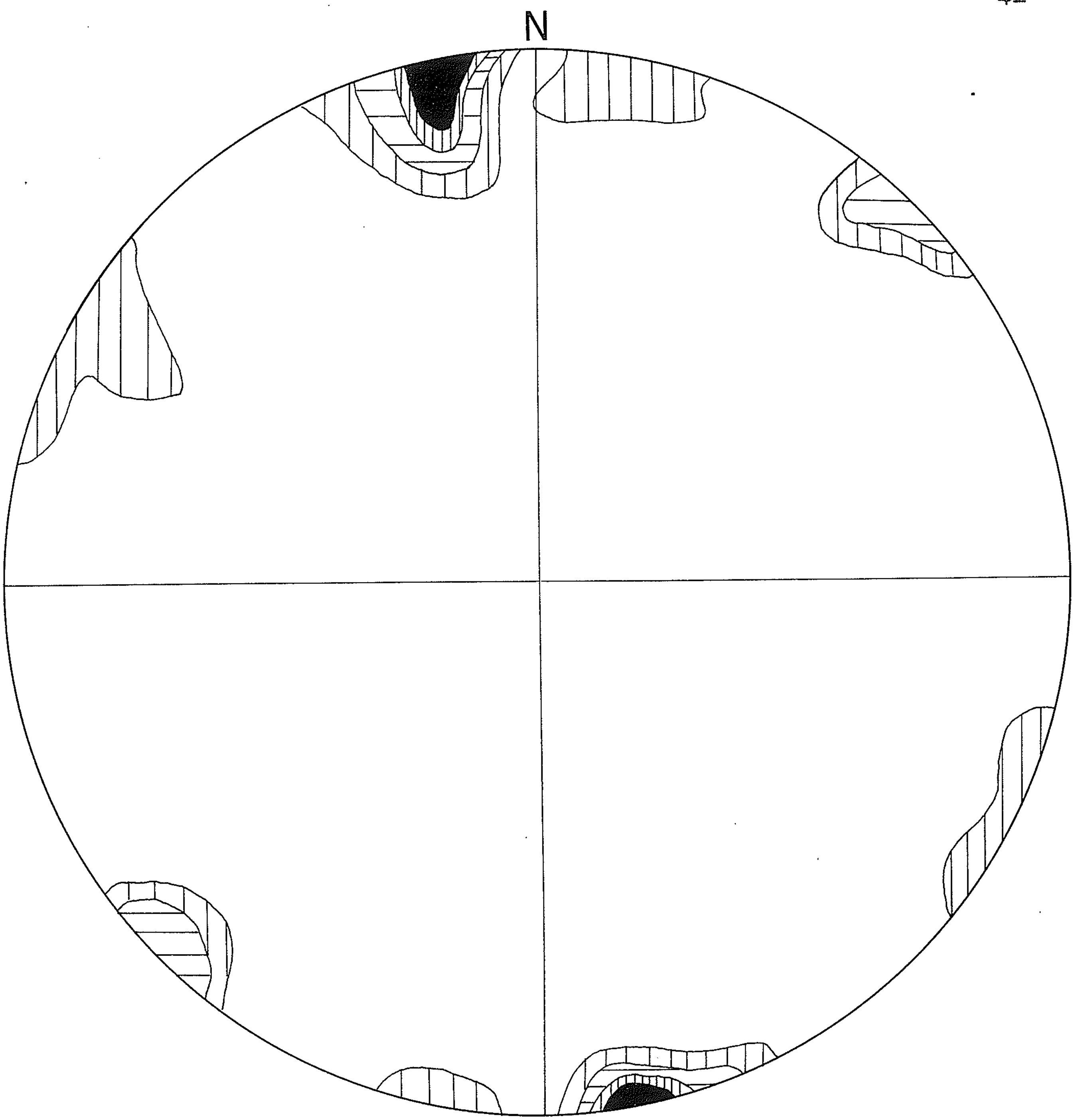
The Granite Lake porphyry is greyish pink in color and has a porphyritic or porphyroblastic texture. The phenocrysts or porphyroblasts are microcline; the origin of these is unknown at present. Sharply defined regular shaped inclusions interpreted to be metamorphic volcanic rock fragments, similar to the inclusions in the Winnetka Lake stock, occur throughout the Granite Lake porphyry. The inclusions comprise about one per cent of the volume of the porphyry.

Structural Elements (Mesoscopic)

Foliation

The Granite Lake porphyry is characterized by a weakly developed penetrative foliation. Sixteen readings on the strike and dip values of the foliation were plotted, but the contour diagram cannot be considered representative of the body as a whole because the frequency of sampling is small and only a relatively small portion of the body lies within the thesis area. Plate 15 indicates that the centre of the maximum concentration of readings is at azimuth 080 degrees. The average dip is near vertical.

The 080 degree (azimuth) penetrative foliation is parallel



Foliation Distribution
Granite Lake Porphyry
Lower Hemisphere Equal Area Projection
(16 poles to foliation surfaces)
Contours: 5%, 10%, 15%, and 20%.
Sample points at 1000 foot intervals
along north-south lines 2000 feet apart.

PLATE 15

to the long and intermediate dimensional axes of the tabular inclusions and passes completely through them. The foliation results from the alignment of individual minerals and lenticular aggregates of quartz and feldspar and plates of biotite. The lenticles exhibit an alignment similar in character to that of the Winnetka Lake stock. They are elongate in a direction close to vertical and are also aligned in the tabular sense.

The foliation pattern is complicated by localized shearing along steeply dipping surfaces which strike northwest and northeast.

Lineations

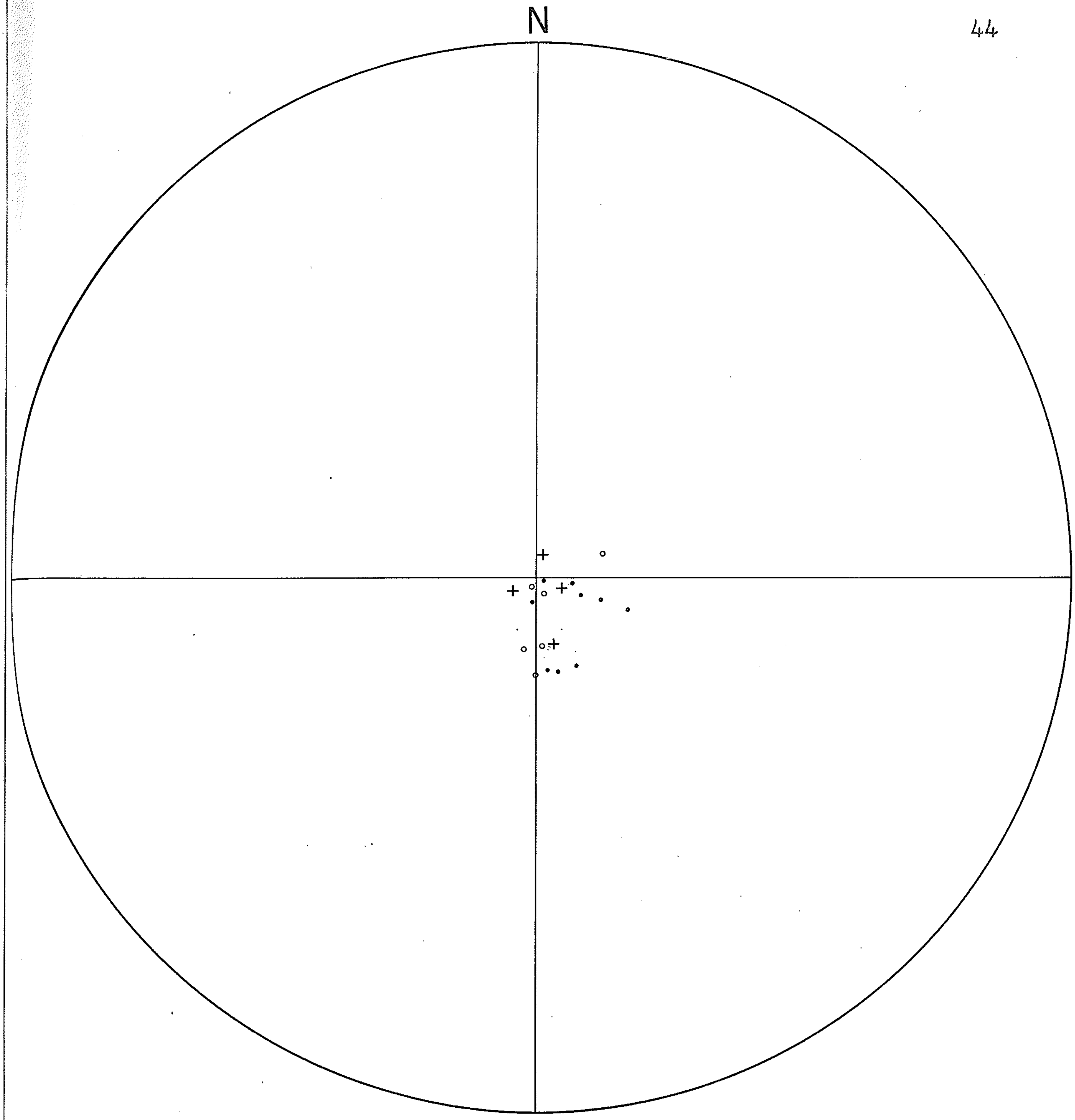
The individual mineral grains, aggregates of mineral grains, and the elongate and tabular inclusions throughout the Granite Lake porphyry, exhibit a well developed near vertical elongation similar to equivalent features in the Winnetka Lake stock (plate 16). Plate 17 is a plot of the plunge of elongate inclusions in the Winnetka Lake stock and the Granite Lake porphyry, as well as the plunge of elongate inclusions in the gneissic granodiorite as discussed later.

Faults

The Granite Lake porphyry is transected by northeast, northwest, and east-west trending lineaments that are very apparent on aerial photographs and have been interpreted to be faults. The frequency of these features suggest that the Granite Lake porphyry has been disturbed by faulting to a greater extent than has the Winnetka Lake stock or the gneissic granodiorite.

View of near vertical face, looking west, showing vertical elongation of inclusions parallel to the penetrative foliation of the Granite Lake porphyry. The photograph was taken immediately north of Lake of the Woods on the Trans-Canada Highway.

PLATE 16



Plunge of Elongate Inclusions

+ Winnetka Lake Stock--Each Symbol Represents Many Readings.
° Granite Lake Prophyry--Each Symbol Represents Many Readings.
• Gneissic Granodiorite--Each Symbol Represents an Individual Reading.

Lower Hemisphere Wulff Net.

PLATE 17

The northeast striking lineaments are parallel to previously described faults which were observed in the basic volcanic rocks along the east contact of the Winnetka Lake stock. Further evidence of faulting is in the form of northwest and east-west shearing which was observed near the southeast and the north central extremities of the Granite Lake porphyry.

Joints

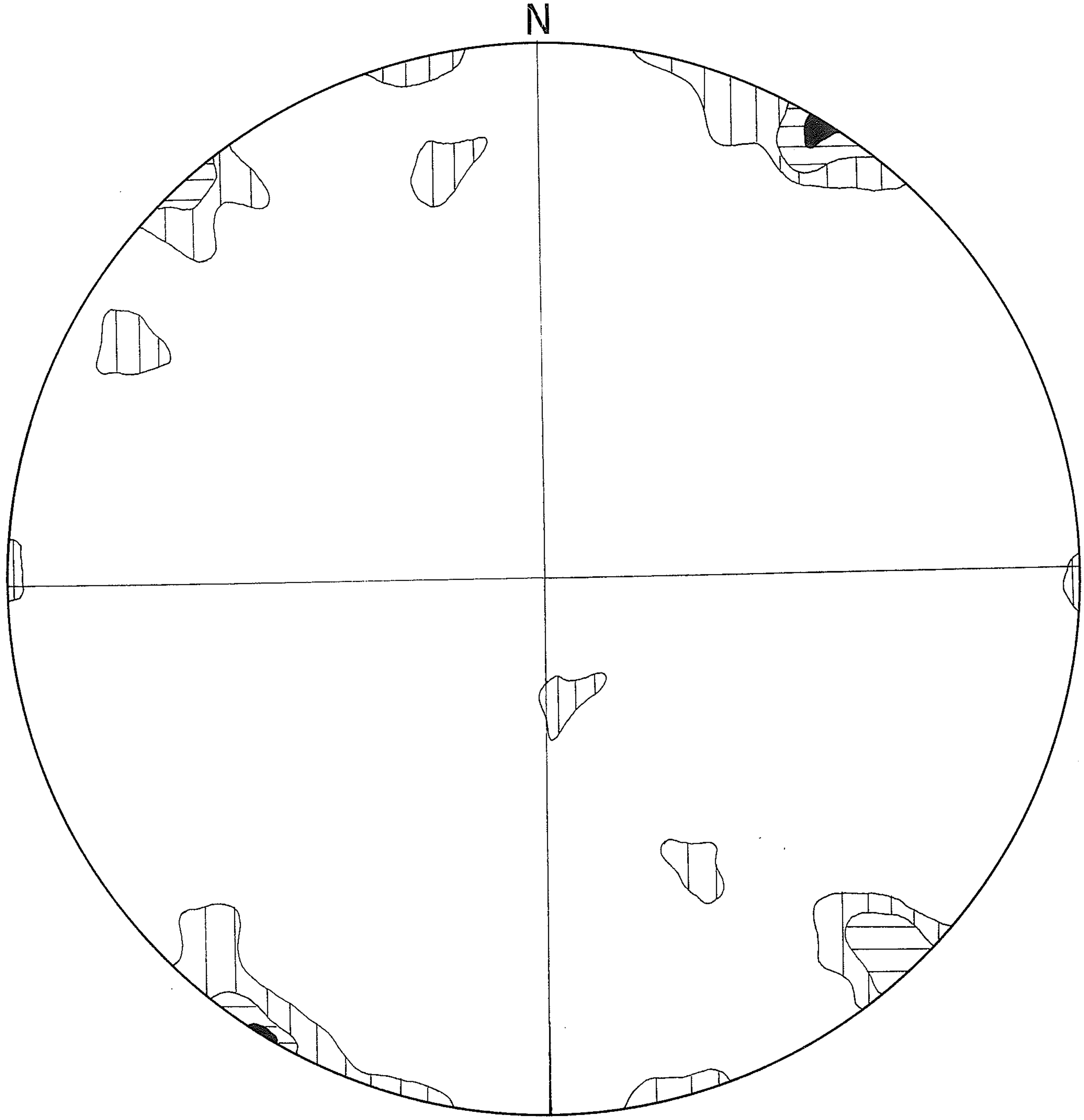
The most common joint sets strike northwest and northeast. Nearly all of the joint sets dip steeply.

Twenty-one readings on the strike and dip values of joints were plotted. Plate 18 indicates that there are two dominant sets centred at azimuth 122 degrees and azimuth 048 degrees.

Structural Elements (Microscopic)

The microtexture of the foliation in the Granite Lake porphyry, like the microtexture of the foliation in the Winnetka Lake stock, is characterized by features which are interpreted to indicate that direct componental movement of grains occurred. Features commonly observed are: rounded mineral grains of unequal size which have fractured and fragmented boundaries, fractured and strained quartz grains, and weak bending of plagioclase laths. These features of the foliation indicate that crushing by mechanical deformation was severe enough to produce a cataclastic texture.

Recrystallization of quartz adjacent to rounded grain boundaries was observed in some thin sections.



Joint Distribution
Granite Lake Porphyry
Lower Hemisphere Equal Area Projection
(21 poles to joint surfaces)
Contours: 5%, 10%, and 15%.
Sample points at 1000 foot intervals
along north-south lines 2000 feet apart.

PLATE 18

Concluding Statements

The Granite Lake porphyry is characterized by a poorly defined penetrative foliation produced by the alignment of lenticular mineral grains and plates of biotite. The 080 degree (azimuth) penetrative foliation is parallel to the two longest dimensional axes of the tabular inclusions and passes completely through them.

The mesoscopic study, and the microscopic study of textures, interpreted to be of cataclastic origin, indicate that the foliation in the Granite Lake porphyry is of tectonic origin. The dominant movement direction or slip direction on the foliation surfaces, as indicated by near vertically elongate individual mineral grains, aggregates of mineral grains, and inclusions, appears to be nearly parallel to the dip line in the foliation surfaces.

The origin of the northwest and northeast striking joints is not definitely known, however, a possible origin is discussed in chapter VIII.

CHAPTER VII

PETROLOGY AND STRUCTURAL GEOLOGY OF THE GNEISSIC GRANODIORITE

Introduction

The gneissic granodiorite was previously classified (Davies 1965, p. 5) as one of the later acid intrusive rock bodies (Table 1).

The gneissic granodiorite examined by the writer (plate 2) lies adjacent to the south contact of a vast area of granitic rocks, most of which has been mapped at a reconnaissance scale only. Contacts between the gneissic granodiorite and the Winnetka Lake stock are not exposed; however, the different structural characteristics in the two rocks implies that the gneissic granodiorite is intrusive into the Winnetka Lake stock. No evidence of a fault contact was observed.

The gneissic granodiorite is characterized by a curviplanar foliation which generally strikes east-west and has steep dips. The foliation planes tend to wrap around inclusions and have a less regular orientation than the foliation described in the two previous chapters.

Petrology

The gneissic granodiorite was previously mapped as intrusive gneissic hornblende-biotite granodiorite, with aplite, pegmatite, and dark inclusions (Davies 1965, p. 18). There has been assimilation by the gneissic granodiorite of the volcanic and sedimentary rocks of the belt that lies along the south contact. This zone of assimilation was previously mapped as a hybrid zone (Davies 1965, and plate 6), and although contacts were not found due to poor outcrop exposure, the occurrence of the hybrid zone is interpreted by the writer to indicate that the gneissic granodiorite has an intrusive relationship to the rocks of the greenstone belt as previously stated.

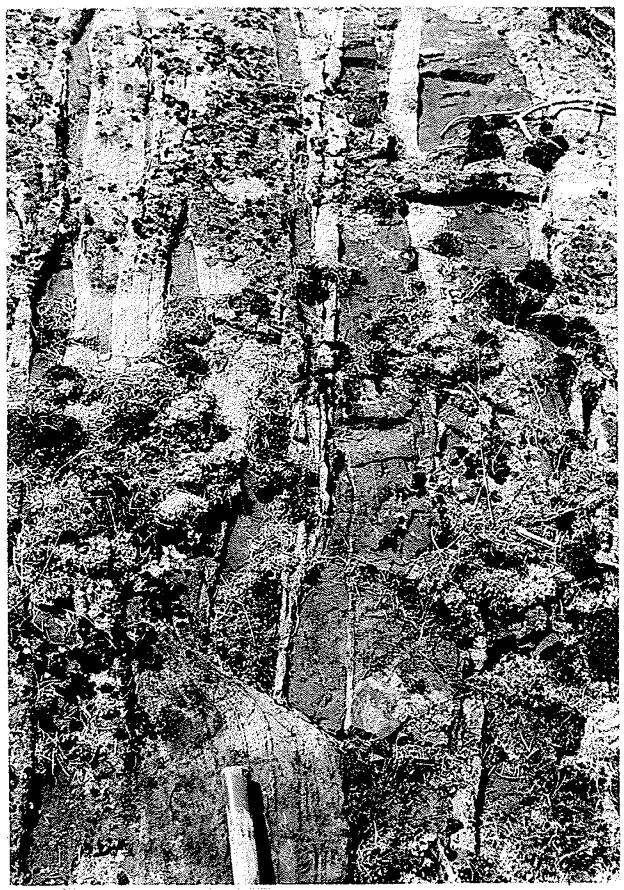
The gneissic granodiorite is grey in color and medium to coarse grained. The gneissic character of the granodiorite is due to compositional layering resulting from laths of feldspar and grains of quartz concentrated along 1/4 inch to 1 inch wide layers that alternate with layers of biotite and hornblende. The light and dark colored layers tend to wrap around inclusions (B. plate 19 and plate 20). Inclusions are usually irregular shaped and have been interpreted to be metamorphosed basic volcanic rock. The inclusions contain numerous small (one millimeter) crystals of feldspar which are probably of metamorphic origin.

The average mineral composition of leucocratic layers in three specimens of gneissic granodiorite west of the Sherwood Lake road, based on a visual microscopic estimate of the mineral percentages, is: oligoclase-andesine 40 per cent, microcline 12, quartz 28, biotite 10, hornblende 5, epidote 2, sphene 1, and apatite and magnetite comprise about 2 per cent. The melanocratic layers consist of approximately 40 percent biotite, 30 per cent hornblende and 30 percent quartz and feldspar.

A. Horizontal exposure showing curviplanar foliation in the gneissic granodiorite. Photograph was taken 1000 feet south of Sherwood Lake.

B. Horizontal exposure showing curviplanar foliation wrapping around inclusion in the gneissic granodiorite. The photograph was taken about 200 feet north of northeast extremity of the Winnetka Lake stock.

PLATE 19



Horizontal exposure showing curviplanar generally east-west striking foliation wrapping around inclusions in the gneissic granodiorite. The photograph was taken about $1\frac{1}{2}$ miles west of Minkaduza Lake.

PLATE 20

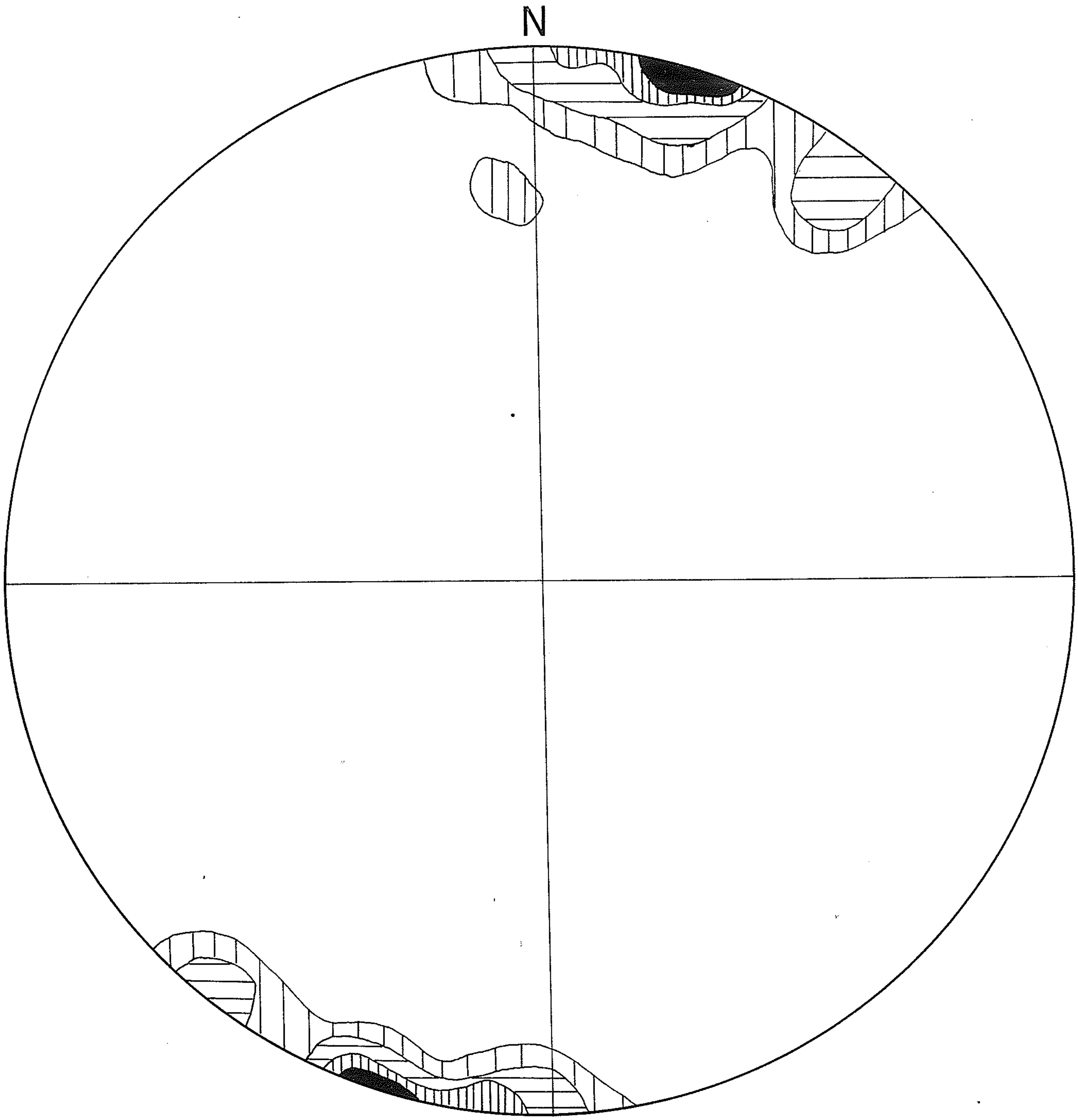
Structural Elements (Mesoscopic)

Foliation

The gneissic granodiorite is characterized by a well developed curviplanar foliation resulting from the alignment of biotite and hornblende in the dark colored layers and the alignment of tabular crystals of feldspar in the light colored layers. The foliation is parallel to the compositional layering (A. plate 19). Twenty-four readings on the strike and dip values of the foliation were plotted and show an average attitude of azimuth 108 degrees in the study area (plate 21). The curviplanar foliation and compositional layering is generally parallel to the east-west striking steeply dipping tectonic foliation in the metamorphosed volcanic and sedimentary rocks, in the Winnetka Lake stock, and in the Granite Lake porphyry. The curviplanar foliation in the gneissic granodiorite, however, is unique in that it does not pass through or penetrate inclusions like the foliation of the Winnetka Lake stock and the Granite Lake porphyry, but instead is distorted around them to form a typical flow foliation. Where typical flow foliation occurs in the gneissic granodiorite, a weak foliation was observed within and parallel to the boundaries of the inclusions. This foliation results from the alignment of mafic mineral grains in the inclusions.

Lineations

The long dimensions (3 to 4 feet) of inclusions in the gneissic granodiorite within 500 feet of the Winnetka Lake stock, are commonly aligned in the near vertical direction. The



Foliation Distribution
Gneissic Granodiorite
Lower Hemisphere Equal Area Projection
(24 poles to foliation surfaces)
Contours: 5%, 10%, 15%, and 20%.
Sample points at 1000 foot intervals
along north-south lines 2000 feet apart.

PLATE 21

alignment may be indicative of near vertical movement near the contact where differential shear produced by emplacement of the intrusive body of gneissic granodiorite would be most pronounced.

In most parts of the gneissic granodiorite the inclusions are similar to those shown in plate 22 which was taken about 1000 feet north of the Winnetka Lake stock. The photograph shows that there is no preferred alignment of the inclusions; however, there is a tendency for hornblende mineral grains within the inclusions to align parallel to the irregular inclusion boundaries. This forms a foliation near the edges of the inclusions and is interpreted to have resulted from rotation and recrystallization caused by reaction with a liquid or semi-liquid melt.

Faults

Faulting in the gneissic granodiorite is revealed only by the numerous east-west and northeast striking lineaments which can be observed on aerial photographs. The lineaments have the same strike as the assumed faults in the Winnetka Lake stock.

Joints

The most common joint sets strike north-northeast and approximately east-west. Nearly all of the joint sets dip steeply.

Forty readings on the strike and dip values of joints

View of vertical surface showing that no vertical alignment of inclusions occurs in the gneissic granodiorite. The photograph was taken on township line 1000 feet north of the northern extremity of the Winnetka Lake stock.

PLATE 22

were plotted. Plate 23 indicates that there are two joint sets which are centred at azimuth 110 degrees and azimuth 025 degrees.

Structural Elements (Microscopic)

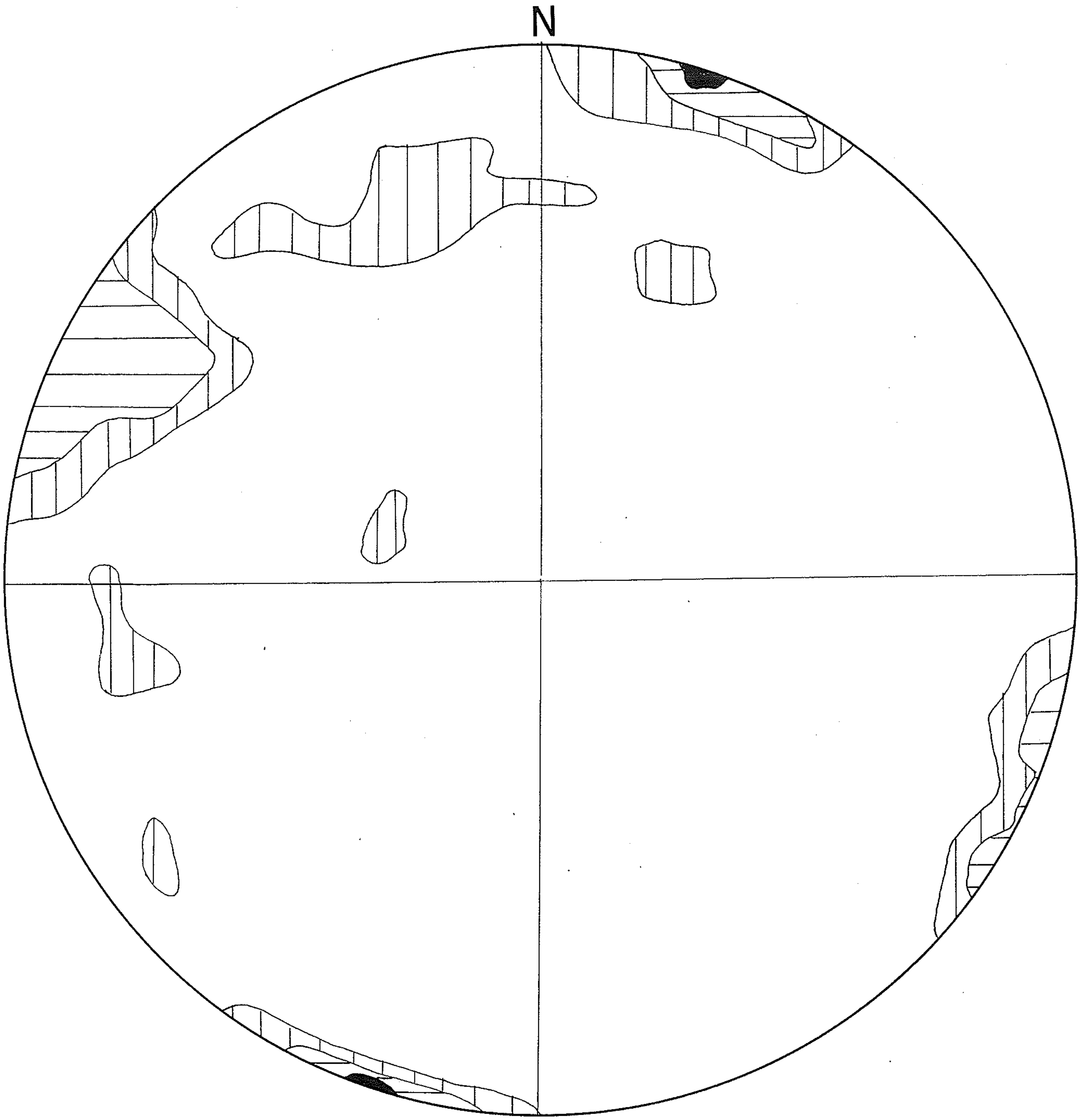
The microtexture of the leucocratic and melanocratic layers in the gneissic granodiorite are characterized by well defined mineral grain boundaries. The relatively large grains of feldspar and quartz in the leucocratic layers are particularly well defined and exhibit an interlocking relationship (plate 24).

Quartz generally does not exhibit fractures and "strain-shadows"; if present, they are only weakly developed. Crystals of feldspar are lath shaped, and, like the interstitial quartz grains, there has been no granulation or rounding at the grain boundaries as observed in the microtexture of the Winnetka Lake stock. Plates of mica and grains of hornblende commonly exhibit parallel alignment.

The microtexture of the gneissic granodiorite is interpreted to be of flow origin. Turner and Verhoogen (1960, p. 590) state:

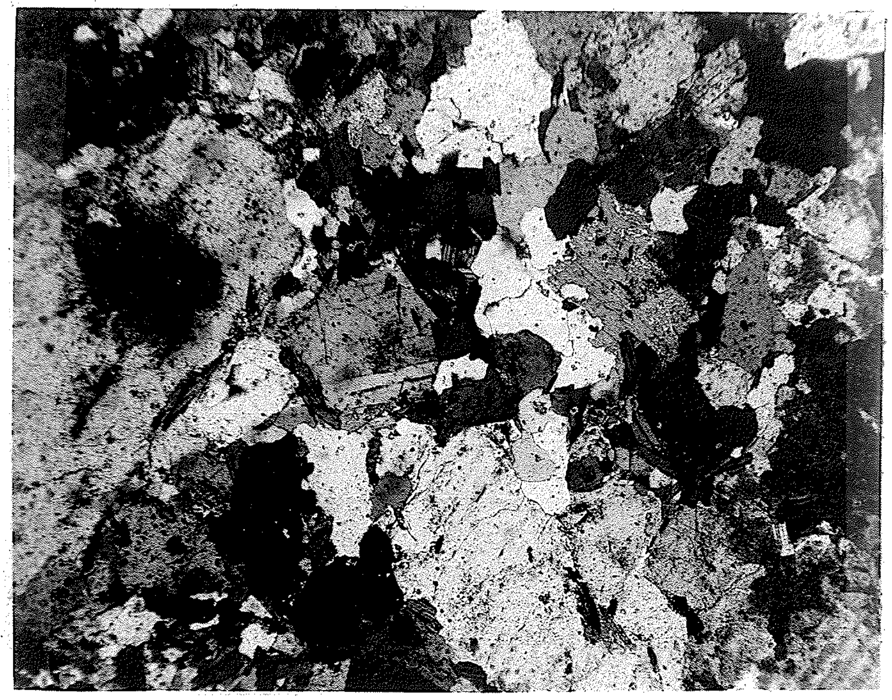
> "In the absence of granulation, undulose extinction, or marked preferred orientation in the crystals of quartz - the mineral most sensitive to deformation - any parallel arrangement of mica flakes or of prisms of hornblende may safely be interpreted as due to magmatic flow."

Weak cataclastic textures resulting from incipient granulation occur locally near the south extremity of the gneissic granodiorite where the vertically aligned inclusions occur. The weak cataclastic textures are interpreted to be a protoclastic effect,



Joint Distribution
Gneissic Granodiorite
Lower Hemisphere Equal Area Projection
(40 poles to joint surfaces)
Contours: 5%, 10%, and 15%.
Sample points at 1000 foot intervals
along north-south lines 2000 feet apart.

PLATE 23



Photomicrographs (x20) showing approximately equigranular minerals with interlocking grain boundaries in the gneissic granodiorite.

PLATE 24

although the possibility of later faulting cannot be discounted. Regarding protoclastic structures Turner and Verhoogen (1960, p. 590) state:

> "The forces which bring about sustained flow of a highly viscous, largely crystalline magma are usually sufficiently powerful to cause rupture and incipient granulation of some of the grains of quartz and feldspar in the last stages of magmatic flow. The result is a protoclastic (nonmetamorphic) structure. More often than not the deforming forces continue to operate after crystallization is complete and consequently then imprint a truly metamorphic fabric upon the quartz and perhaps upon other minerals as well."

Recrystallization of quartz along some grain boundaries occurs, but it is weakly developed similar to that in the Winnetka Lake stock.

Concluding Statements

The gneissic granodiorite is characterized by a curviplanar foliation which is parallel to compositional layering defined by bands of light and dark minerals. The foliation and compositional layering, which is generally parallel to the steep dipping foliation of tectonic origin in the Winnetka Lake stock, the Granite Lake porphyry, and the greenstone, tends to wrap around inclusions rather than to penetrate through inclusions as it does in the other rock bodies.

The mesoscopic and microscopic studies indicate that the foliation in the main body of gneissic granodiorite is of flow origin. The dominant movement or flow direction on the foliation surfaces, as indicated by near vertically aligned inclusions and weak cataclastic textures in portions of the body near the south contact, appears to be approximately parallel to the dip line of the steep dipping flow foliation.

The origin of the north-northeast and generally east-west striking joints is not known, but a possible origin is discussed in chapter VIII.

CHAPTER VIII

INTERPRETATION AND DISCUSSION

Introduction

The results of the field, mesoscopic and microscopic studies presented in previous chapters have indicated that the origin of the foliation in the Winnetka Lake stock and the Granite Lake porphyry was by cataclastic slip caused by tectonic processes. The observed geometry of the foliation and lineations also supports this origin. The principal strain was in the form of movements along foliation surfaces approximately parallel to the dip of the foliation.

The studies have indicated that the origin of the foliation in the gneissic granodiorite was by magmatic flow and this origin is compatible with the observed geometry of the foliation and lineations within this body. The movement during flow was interpreted to be laminar, approximately parallel to the dip of the flow foliation surfaces.

The main purpose of this chapter is to present an interpretation of the historical sequence of intrusion and tectonism based on these results. This interpretation of relative ages of the intrusive bodies is followed by discussions with regard to:

1) Problems relating to the relative age of the Granite Lake porphyry.
2) The significance of the foliation strike change at the east end of the study area.

These discussions are important because they emphasize that there are complications to interpreting a relatively simple age relationship based solely on the origin and geometry of the foliation and the movement direction as indicated by lineations.

The chapter concludes with a discussion of the joint system and faults in the study area.

Relative Ages of the Intrusive Rocks

The geometry of the fabric in each of the intrusive rock bodies is very similar. The maximum concentration of the foliation orientation in the Winnetka Lake stock (plate 11) and in the Granite Lake porphyry (plate 15) is similar to the maximum concentration of the foliation orientation in the gneissic granodiorite as shown by plate 21. The plane of maximum concentration is generally east-west and near vertical in the distribution plots of the three intrusive bodies. Plate 17 shows that the plunges of elongate inclusions in the Winnetka Lake stock, in the Granite Lake porphyry, and near the south contact of the gneissic granodiorite, are oriented in a similar manner. All of these lineations plunge steeply. This similarity in the geometry of the fabric elements in the three intrusive bodies indicates that the strain pattern was the same and that the principal direction of strain was nearly parallel to the direction of dip of the foliation surfaces in each of the intrusive bodies. However, strain in the Winnetka

Lake stock and in the Granite Lake porphyry was interpreted to have been produced by slip accompanied by cataclasis, and strain in the gneissic granodiorite was interpreted to have been produced by magmatic flow. It is evident that, although the strain pattern in all three intrusive bodies is similar, the strain mechanism in the Winnetka Lake stock and the Granite Lake porphyry was different than the strain mechanism in the gneissic granodiorite. The structural evidence indicates that the Winnetka Lake stock and the Granite Lake porphyry were in a semi-solid or solid state at the time of deformation and were emplaced prior to the deformational event that produced the foliation. The time of intrusion of the Winnetka Lake stock relative to the time of intrusion of the Granite Lake porphyry is uncertain; this is referred to in later discussion.

It is consistent with the above to suggest that the gneissic granodiorite was intruded during or following the development of the tectonic foliation in the Winnetka Lake stock and the Granite Lake porphyry. This would indicate a posttectonic or syntectonic origin for the gneissic granodiorite. However, the similarity in the average attitude of the steeply plunging lineations near the south contact of the gneissic granodiorite with the average attitude of lineations in the Winnetka Lake stock and the Granite Lake porphyry (plate 17), suggests that the near vertical emplacement of the large body of intrusive gneissic granodiorite may have imposed the tectonic foliation on the Winnetka Lake stock, the Granite Lake porphyry and the rocks of the greenstone belt. This interpretation envisages the gneissic granodiorite as a relatively mobile magma emplaced by flow in a vertical sense. If this interpretation is correct the emplacement of the gneissic granodiorite and the development of its flow foliation would be contemporaneous with the development of the tectonic foliation in the Winnetka Lake stock and the Granite Lake porphyry. The gneissic granodiorite is interpreted, therefore, to be of syntectonic origin (Table 2).

A Discussion of the Problems Relating to the Relative Age of the Granite Lake Porphyry

A pretectonic origin for the Winnetka Lake stock and a syntectonic origin for the younger gneissic granodiorite seem to be supported by all of the data. On the other hand, the interpreted pretectonic origin of the Granite Lake porphyry is somewhat uncertain. The main reason for this uncertainty is that the tectonic foliation in the host rocks of the greenstone belt was not observed to pass directly into the tectonic foliation in the Granite Lake porphyry due to the lack of good outcrop exposure. The interpreted pretectonic origin for the Granite Lake porphyry was primarily based on studies which suggested that the cataclastic foliation in the Granite Lake porphyry originated at the same time as the cataclastic foliation in the Winnetka Lake stock. This interpretation was supported further by the similarity in the shape of the inclusions and the penetrative nature of the cataclastic foliation through the inclusions in both intrusive bodies.

TABLE 2

TABLE OF FORMATIONS

Age (Archean)	Rocks of the Winnetka Lake Area	Rocks of the High-Shoal Lakes Area	Deformational Events
ALGOMAN?		↑? High Lake grey granodiorite, Indian Reserve granodiorite, Snowshoe Bay granodiorite } relative ages unknown	
	gneissic granodiorite	↓?	Second generation deformation (foliation developed)
TIMISKAMING	↑? Granite Lake porphyry, Winnetka Lake stock } relative ages indefinite ↓?	Late metamorphosed sedimentary rocks of the Kenora-Westhawk Lake greenstone belt (Crowduck Lake group, see Table 1, p.7). Note : Some metamorphosed volcanic rocks may also be included in this group.	↑? First generation deformation ↓?
LAURENTIAN?		High Lake porphyritic granodiorite	
KEEWATIN	Early metamorphosed volcanic and sedimentary rocks of the Kenora-Westhawk Lake greenstone belt.		

A syntectonic or posttectonic origin, as opposed to a pretectonic origin for the Granite Lake porphyry is possible if the Granite Lake porphyry is assumed to have been emplaced in a partially solidified state. The displacement of the basic volcanic rocks and intermediate volcanic rocks, and the accompanying change in the direction of the foliation around the north and south sides of the body of Granite Lake porphyry, caused by a wedge-like emplacement of the body, would be consistent with this assumption. The cataclastic or metamorphic fabric in the Granite Lake porphyry might therefore be considered of protoclastic origin, but it is difficult to provide a satisfactory explanation of the manner in which the inclusions could be preferentially oriented by this fabric origin. If the observed fabric in the body of Granite Lake porphyry was produced by the emplacement of the body itself, when it was in a partially solidified state, the tectonic foliation in the Granite Lake porphyry could have been formed independently of the tectonic foliation in the Winnetka Lake stock and the host rocks of the greenstone belt. Based solely on a protoclastic origin for the metamorphic fabric, then, the Granite Lake porphyry could be of syntectonic or posttectonic origin. However, as it is difficult to envisage how the inclusions could be preferentially aligned throughout the body by protoclastic effects alone, the syntectonic or posttectonic origin is not considered to be as favorable as the interpreted pretectonic origin.

A Discussion of the Significance of the Foliation Strike Changes at the East End of the Study Area.

The east end of the study area is characterized by changes in the strike direction of the foliation from the regional strike direction of 106 degrees (azimuth). These changes are represented by:

1) The foliation strike in the metamorphosed basic volcanic rocks and the metamorphosed intermediate volcanic rocks which strikes northeast and southeast, respectively, around the west boundary of the Granite Lake porphyry (plate 2).

2) The foliation strike at the eastern extremity of the Winnetka Lake stock which strikes 080 degrees (azimuth) (plate 2).

3) The foliation strike within the studied part of the Granite Lake porphyry which has a maximum concentration of foliation orientation at 080 degrees (azimuth) (plate 15).

The purpose of this discussion is to examine possible explanations for these changes.

The northeast and southeast strike of the metamorphosed basic volcanic rocks and the metamorphosed intermediate volcanic rocks around the body of Granite Lake porphyry could have resulted from the wedge-like emplacement of the body when it was in a partially solidified state (see page 66). If the Granite Lake porphyry forced aside the rocks into which it intruded, the change in the strike direction of the foliation at the eastern extremity of the Winnetka Lake stock could also be accounted for. This explanation would require that the Granite Lake porphyry post-dates the Winnetka Lake stock.

Another possible explanation for the change in strike direction in the Winnetka Lake stock is based on the presence of shear zones and faults which occur near the eastern extremity of the stock. In this case, drag along faults or rotation of fault blocks with a pre-existent tectonic foliation could account for the present strike and dip of the foliation in the eastern extremity of the Winnetka Lake stock. There is no good explanation of the 080 degree (azimuth) strike of the maximum concentration of the foliation direction in the northwest part of the Granite Lake porphyry. However, an explanation for this which is in accord with the interpreted pretectonic origin of the Granite Lake porphyry and assumes that the Granite Lake porphyry is approximately the same age as the Winnetka Lake stock is as follows. The Granite Lake porphyry may have been more competent, and although a tectonic foliation developed within it, the body acted as a structural buttress which resulted in a realignment of the forces that produced the generally east-west striking regional tectonic foliation in the Winnetka Lake stock and the host rocks of the greenstone belt. Alternatively, the orientation of the foliation at the east end of the area may have had a much more complex origin involving a later deformational event which post-dated the foliation. This alternative is favored considering there are many intrusive bodies of unknown age which lie within or adjacent to the greenstone belt.

Discussion of Joint Set Distribution and Faults

The intrusive rocks and host rocks of the greenstone belt are characterized by steeply dipping joints which strike generally east-west, north-northeast, northeast and southeast (plates 13, 18 and 23). Many of these joints are at an angle to the strike of the foliation and also cross-cut the foliation in the intrusive rocks and the host rocks.

The origin of the joints is not definitely known, but considering that the joints have generally the same geometry in each of the intrusive bodies, all joint sets may have formed after the development of the tectonic foliation and the flow foliation in the respective intrusive bodies. If this is true all of the joints developed late in the structural history and may be related to the lineaments which have been interpreted as faults. In this case they could represent incipient shear directions.

CHAPTER IX

STRUCTURAL GEOLOGY AND PETROLOGY OF THE INTRUSIVE ROCKS IN THE HIGH-SHOAL LAKES AREA

Introduction

The study of the geometry, character and origin of the foliation in the intrusive rocks of the High-Shoal Lakes area (see Plate 3, in pocket) was of a preliminary nature only. The intrusive rocks to be discussed are the High Lake porphyritic granodiorite, the High Lake grey granodiorite, the Snowshoe Bay granodiorite and the Indian Reserve granodiorite. Each of these bodies was examined to determine the presence or absence of foliation, and if present to obtain data bearing on the origin of the foliation.

Additional petrographic data on each of the above intrusive bodies except the Snowshoe Bay granodiorite may be found in the High Lake-Rush Bay report describing the geology of the Ewart-Forgie area (Davies 1965).

Foliated Intrusive Rocks

High Lake porphyritic granodiorite

The High Lake porphyritic granodiorite was sampled in the southeast trending embayment which projects into the basic volcanic host rocks at the eastern tip of High Lake, and along the northeast shore of the lake. Six thin sections were made.

The High Lake porphyritic granodiorite predominantly consists of subhedral phenocrysts of quartz and plagioclase feldspar in a very fine grained matrix of quartz, feldspars, and sericite. The phenocrysts comprise about 50 percent of the rock.

The High Lake porphyritic granodiorite is characterized mesoscopically by a well developed foliation that strikes east-northeast and dips steeply. The foliation has the same attitude as the foliation in the host metamorphosed basic volcanic rocks where they were examined (plate 3, in pocket).

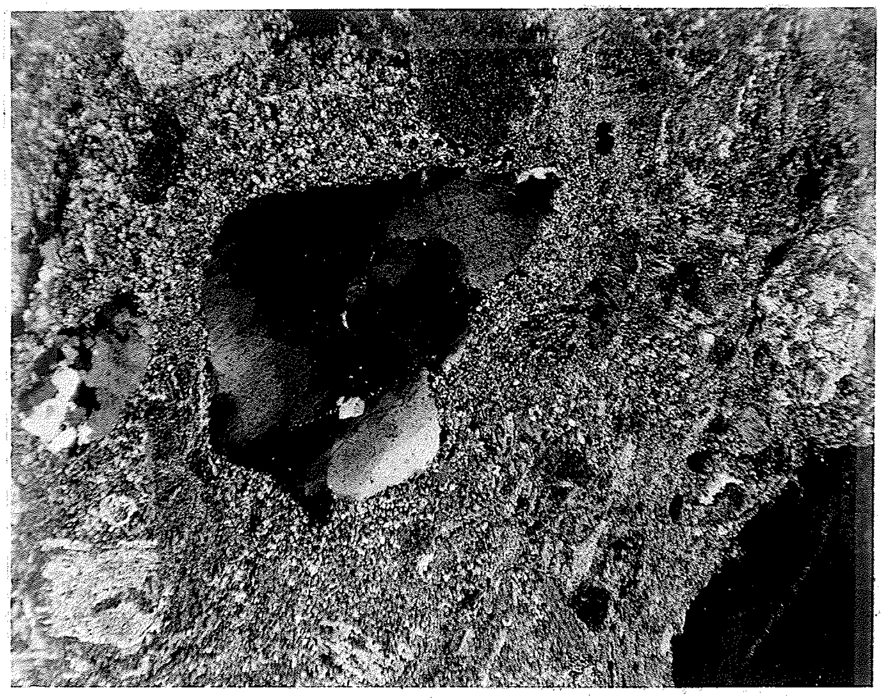
The microtexture is characterized by the occurrence of fractured, strained, and partially rounded phenocrysts of quartz and plagioclase feldspar indicative of cataclastic metamorphism (A. plate 25). The similarity in the geometry of the foliation in the porphyritic granodiorite and the rocks of the greenstone belt, and the presence of a cataclastic texture in the porphyritic granodiorite, suggests that the porphyritic granodiorite was subject to deformation. The High Lake porphyritic granodiorite is interpreted to be of pretectonic origin (Table 2, p. 65).

Non-Foliated Intrusive Rocks

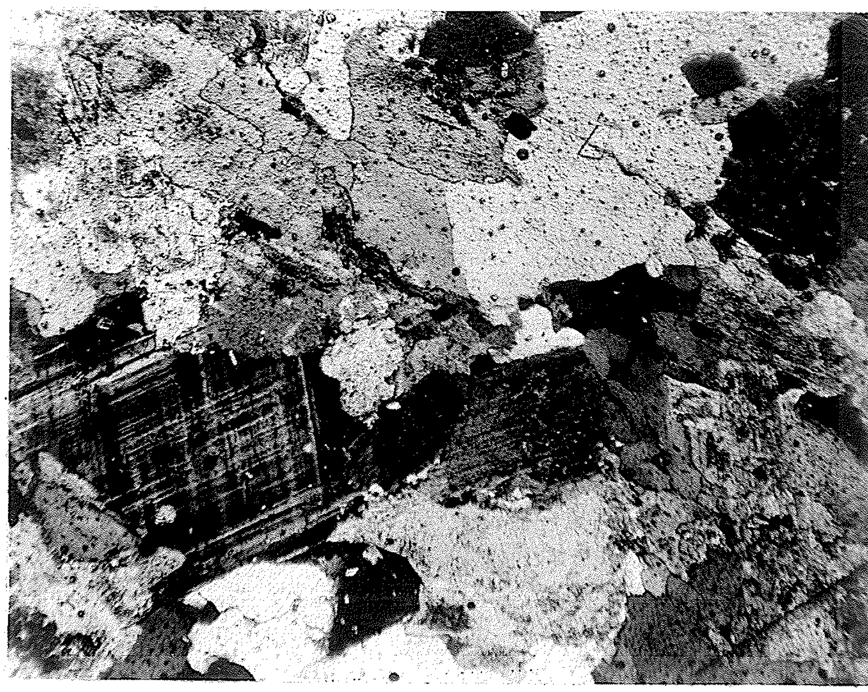
High Lake grey granodiorite

The High Lake grey granodiorite was sampled at the southeast shore of High Lake.

The composition of one specimen based on a visual microscopic estimate of the mineral percentages is: plagioclase 45 per cent, quartz 25, microcline 15, biotite 7, hornblende 3, and epidote,



A. Photomicrograph (x20), showing cataclastic texture with strained and fractured quartz phenocrysts in the High Lake porphyritic granodiorite.



B. Photomicrograph (x40), showing non-cataclastic texture with interlocking grains in the High Lake grey granodiorite.

PLATE 25

sphene and apatite about 5 per cent.

The microtexture is characterized by interlocking mineral grains (B. plate 25). The mineral grains are not strained or broken as they are in the High Lake porphyritic granodiorite and the biotite and hornblende are randomly oriented. The characteristics of the microtexture indicate that the body has not been subjected to penetrative deformation. This leads to the conclusion that the time of emplacement of the body was the same as, or post-dated the deformational event which produced the tectonic foliation. In this sense the High Lake porphyritic granodiorite is identified as syntectonic or posttectonic.

Snowshoe Bay granodiorite

The Snowshoe Bay granodiorite was sampled along a generally north-south trending line parallel to the shoreline at the western edge of Shoal Lake.

The average composition of six specimens based on a visual microscopic estimate of the mineral percentages is: plagioclase 50 per cent, quartz 20, microcline 10, biotite 15, and hornblende 5 per cent.

The microtexture is characterized by interlocking non-fractured mineral grains which are randomly oriented. This indicates that the body was not subjected to penetrative deformation. Some specimens taken near the edge of the stock are characterized by mineral grains that exhibit incipient cataclasis, but this may be due to localized shearing as a result of faulting. The Snowshoe Bay granodiorite is interpreted to be of syntectonic or posttectonic origin on the basis of the non-cataclastic microtexture and on the lack of a penetrative foliation (Table 2, p. 65).

Indian Reserve granodiorite

The Indian Reserve granodiorite was sampled along the east-west trending shoreline at the northwest end of the main part of Shoal Lake.

The average composition of two specimens based on a visual microscopic estimate of the mineral percentages is: plagioclase 45 per cent, quartz 20, microcline 15, biotite 10, hornblende 5, epidote, magnetite, apatite and sericite, 5 per cent.

The microtexture is characterized by interlocking non-fractured mineral grains which are randomly oriented. This indicates that the body was not subjected to penetrative deformation. The Indian Reserve granodiorite is, therefore, also interpreted to be of syntectonic or posttectonic origin (Table 2, p. 65).

Concluding Statements

The preliminary study of the geometry, character, and origin of the penetrative foliation in the High Lake porphyritic granodiorite indicated that this body is of pretectonic origin. A similar study of the High Lake grey granodiorite, the Snowshoe Bay granodiorite and the Indian Reserve granodiorite indicated that these intrusive bodies have no penetrative foliation and were therefore interpreted to be of syntectonic or posttectonic origin.

The pretectonic origin for the High Lake porphyritic granodiorite is in general agreement with previous work. This granodiorite was previously mapped with the earlier acid intrusive rocks of the Ewart-Forgie area, and was considered to be pre-Timiskaming in age because boulders of granodiorite occur in overlying conglomerate (Davies 1965, p. 21 and Table 1).

A syntectonic or posttectonic origin for the High Lake grey granodiorite and the Indian Reserve granodiorite is in general agreement with Davies (1965), who mapped the High Lake grey granodiorite and the Indian Reserve granodiorite with the later acid intrusive rock group.

A syntectonic or posttectonic origin for the Snowshoe Bay granodiorite is in general agreement with previous work by Greer (1931, p. 49), who tentatively assigned all the granites of the Shoal Lake area to the Algoman period.

CHAPTER X

CONCLUSIONS

The intrusive rock bodies in the Kenora-Westhawk Lake greenstone belt are divided into three relative age groups. These groups are primarily distinguished by the geometry, characteristics and origin of their foliation surfaces.

The Winnetka Lake stock, the Granite Lake porphyry, and the High Lake porphyritic granodiorite are characterized by a cataclastic foliation of tectonic origin. These bodies are considered to have been emplaced prior to the regional deformation that produced the east-west striking, steeply dipping tectonic foliation which occurs within them and within the rocks of the greenstone belt.

The large body of gneissic granodiorite situated north of the greenstone belt is characterized by a flow foliation parallel to the tectonic foliation of the nearby Winnetka Lake stock and the Granite Lake porphyry, and on this basis is presumed to be younger than the rock bodies which have the tectonic foliation. The geometry and direction of flow within this gneissic granodiorite is considered to be consistent with a syntectonic origin. The emplacement of this body could be responsible for the development of the tectonic foliation in the rocks which it has intruded.

The High Lake grey granodiorite, the Snowshoe Bay granodiorite and the Indian Reserve granodiorite are non-foliated and each of the bodies is characterized by a microtexture which exhibits interlocking non-fractured mineral grains that clearly have not been subjected to penetrative cataclastic deformation. These intrusive bodies are therefore classified with the younger intrusive bodies situated in the Kenora-Westhawk Lake greenstone belt. Based on the preliminary study, the non-foliated intrusive rock bodies studied in the High-Shoal Lakes area may have been emplaced at the time of, or after the deformational event producing the tectonic foliation.

BIBLIOGRAPHY

Brisbin, W. C., 1965, Shear Folding in Northwestern Ontario, Canada; Paper presented to the Geological Society of America Annual Meeting, Kansas City, Missouri, Nov. 4-6, 1965.

Buckingham, J. G., 1968, An Investigation of the Folding in Forgie Township, Ontario; Unpub. M.Sc. Thesis, University of Manitoba, Winnipeg, Manitoba.

Carey, S. W., 1962, Folding; Journal of Alberta Society of Petroleum Geologists, Vol. 10, No. 3, pp. 95-144.

Davies, J. C., 1965, Geology of High Lake-Rush Bay Area, District of Kenora; Ontario Dept. of Mines, Geological Report No. 41.

Greer, L., 1931, Geology of Shoal Lake (west) Area, District of Kenora; Ontario Dept. of Mines, Vol. XXXIX pt. 3, pp. 42-56.

Harker, A., 1939, Metamorphism; London, Methuen, 362 p.

Hills, E. S., 1963, Elements of Structural Geology; New York, John Wiley & Sons, 483 p.

Lawson, A. C., 1885, Report on the Geology of the Lake of the Woods Region; Geol. Survey of Canada, Vol. I, pt. CC pp. 1-151.

Parsons, A. L., 1911, Goldfields of the Lake of the Woods, Manitou and Dryden; Ontario Bureau of Mines, Vol. XXI, pt. 1, pp. 198-203.

Thomson, J. E., 1937, Geology of the north central part of the Lake of the Woods; Ontario Dept. of Mines, Vol. XLV, 1936, pt. 3, pp. 1-43.

Turner, F. J., and Verhoogen, J., 1960, Igneous and Metamorphic Petrology, New York, McGraw-Hill, 694 p.

BIBLIOGRAPHY

Brisbin, W. C., 1965, Shear Folding in Northwestern Ontario, Canada; Paper presented to the Geological Society of America Annual Meeting, Kansas City, Missouri, Nov. 4-6, 1965.

Buckingham, J. G., 1968, An Investigation of the Folding in Forgie Township, Ontario; Unpub. M.Sc. Thesis, University of Manitoba, Winnipeg, Manitoba.

Carey, S. W., 1962, Folding; Journal of Alberta Society of Petroleum Geologists, Vol. 10, No. 3, pp. 95-144.

Davies, J. C., 1965, Geology of High Lake-Rush Bay Area, District of Kenora; Ontario Dept. of Mines, Geological Report No. 41.

Greer, L., 1931, Geology of Shoal Lake (west) Area, District of Kenora; Ontario Dept. of Mines, Vol. XXXIX pt. 3, pp. 42-56.

Harker, A., 1939, Metamorphism; London, Methuen, 362 p.

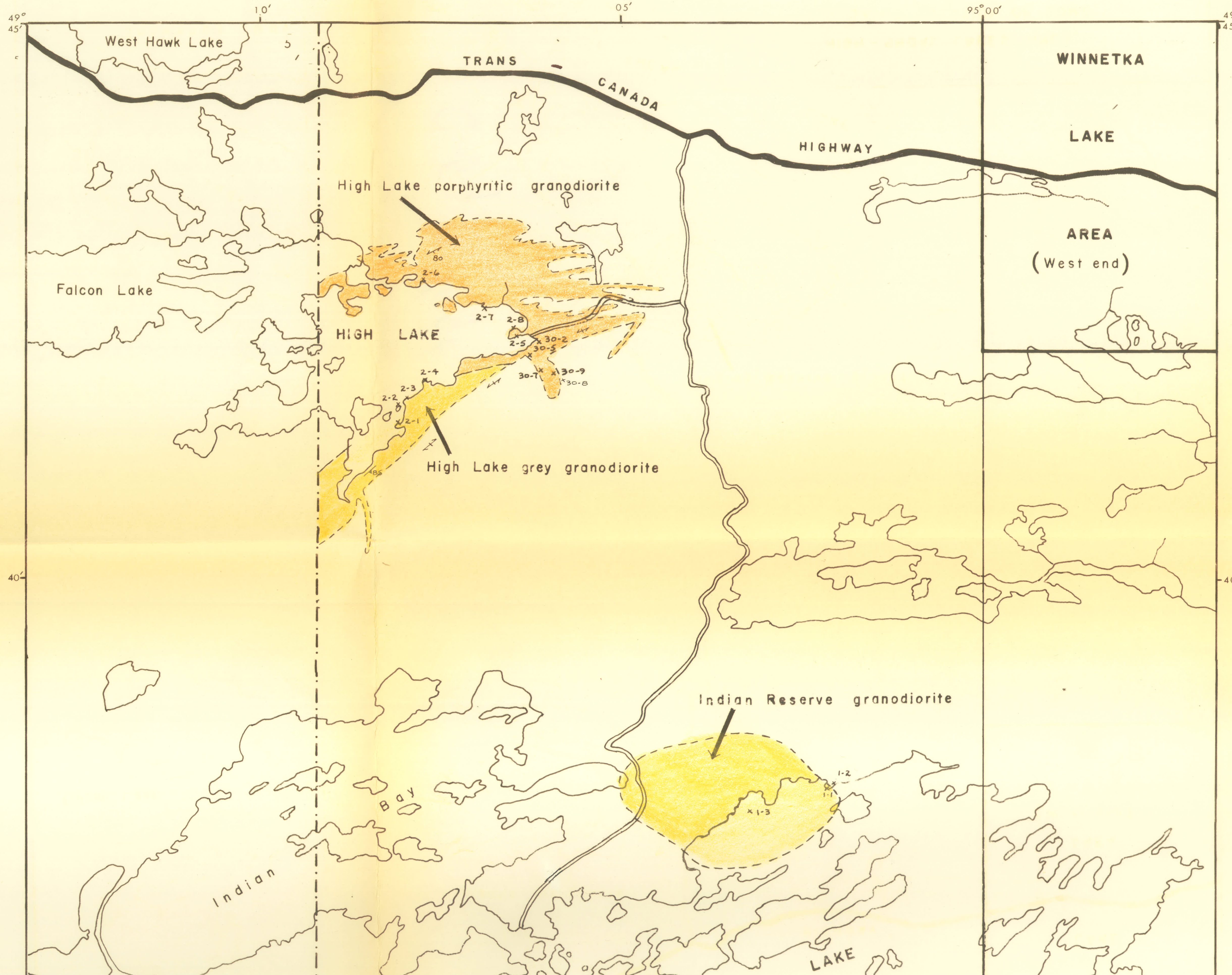
Hills, E. S., 1963, Elements of Structural Geology; New York, John Wiley & Sons, 483 p.

Lawson, A. C., 1885, Report on the Geology of the Lake of the Woods Region; Geol. Survey of Canada, Vol. I, pt. CC pp. 1-151.

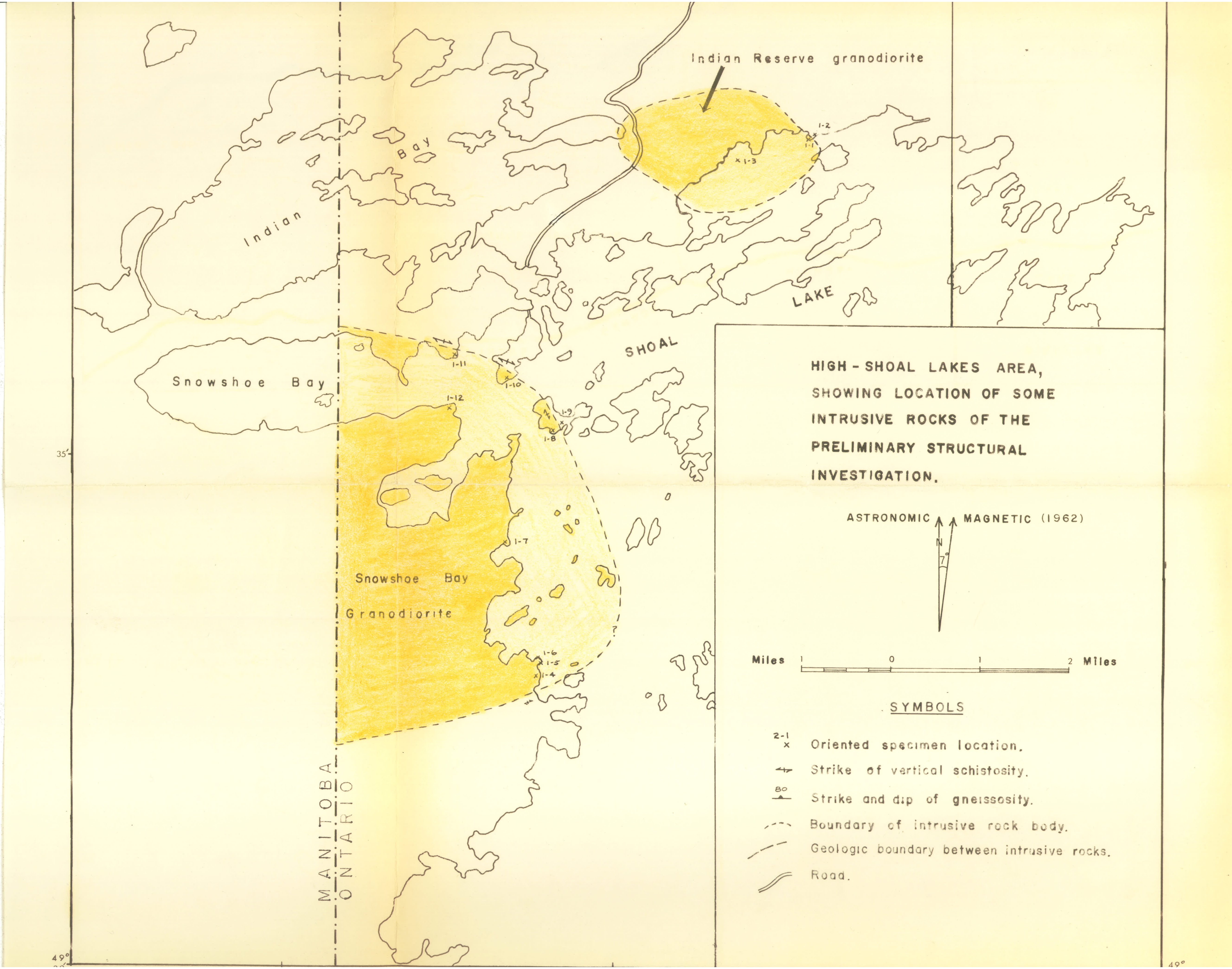
Parsons, A. L., 1911, Goldfields of the Lake of the Woods, Manitou and Dryden; Ontario Bureau of Mines, Vol. XXI, pt. 1, pp. 198-203.

Thomson, J. E., 1937, Geology of the north central part of the Lake of the Woods; Ontario Dept. of Mines, Vol. XLV, 1936, pt. 3, pp. 1-43.

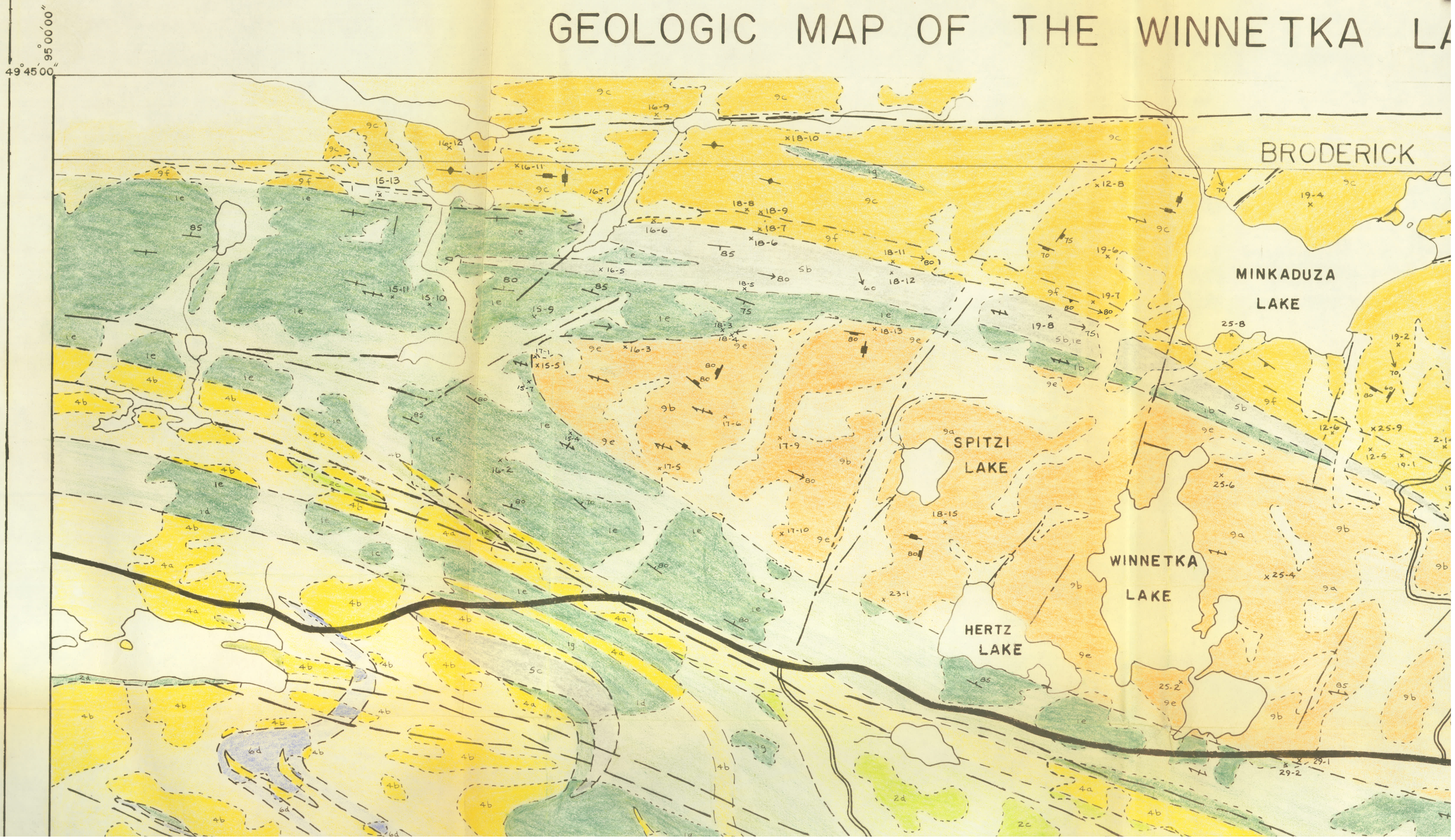
Turner, F. J., and Verhoogen, J., 1960, Igneous and Metamorphic Petrology, New York, McGraw-Hill, 694 p.



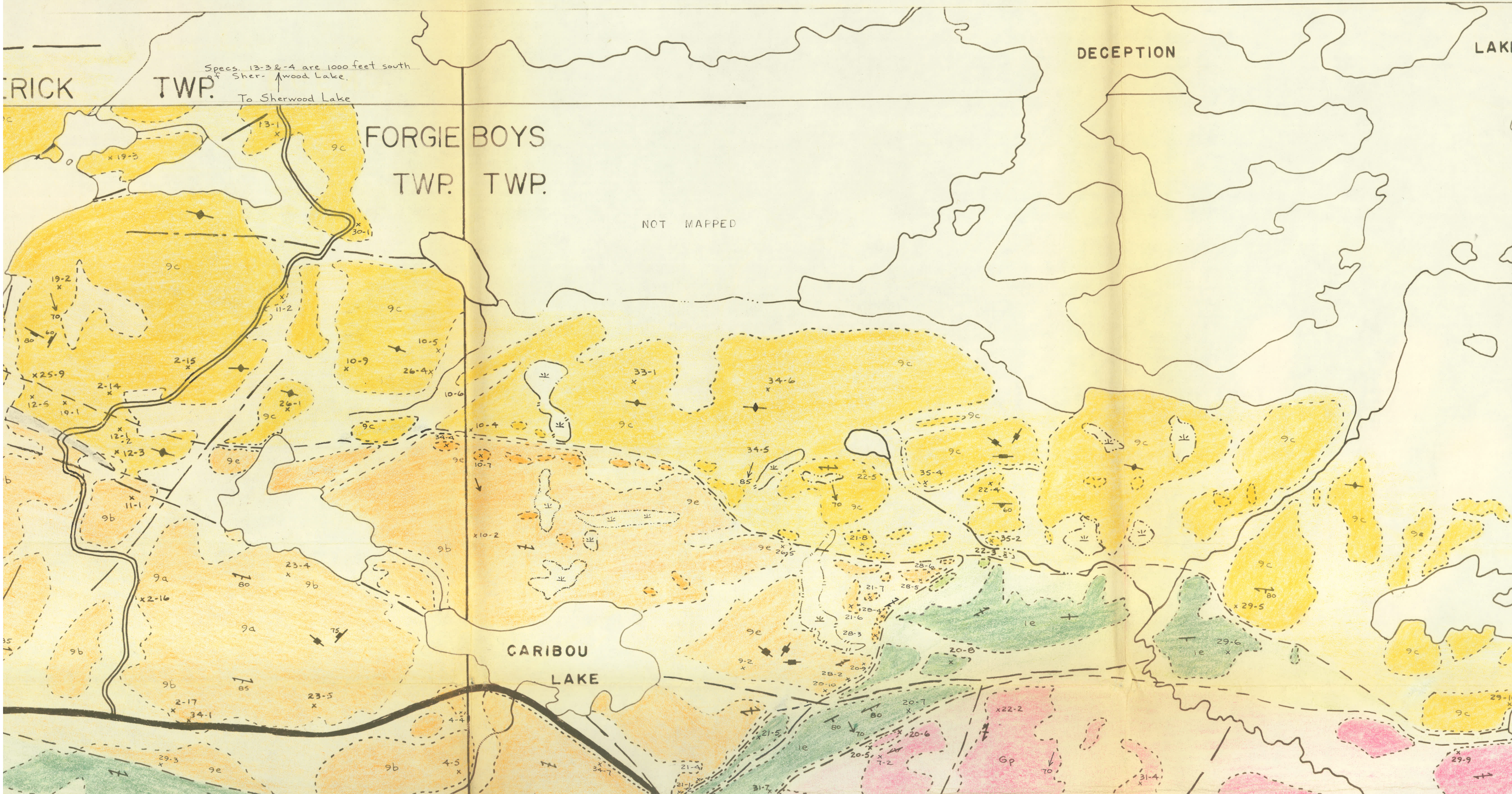
49° 45′
10′
05′
95°00′
49° 45′
West Hawk Lake
TRANS - CANADA
HIGHWAY
WINNETKA
LAKE
AREA
(West end)
High Lake porphyritic granodiorite
Falcon Lake
HIGH LAKE
High Lake grey granodiorite
40′
40′
Indian Reserve granodiorite
Indian
Bay
LAKE


HIGH - SHOAL LAKES AREA,
SHOWING LOCATION OF SOME
INTRUSIVE ROCKS OF THE
PRELIMINARY STRUCTURAL
INVESTIGATION.
ASTRONOMIC
MAGNETIC (1962)
N
7°
Miles
1
0
1
2
Miles
SYMBOLS
2-1 x
Oriented specimen location.
Strike of vertical schistosity.
80
Strike and dip of gneissosity.
Boundary of intrusive rock body.
Geologic boundary between intrusive rocks.
Road.
Indian Reserve granodiorite
Indian
Bay
Snowshoe Bay
Snowshoe Bay
Granodiorite
SHOAL
LAKE
MANITOBA
ONTARIO
1-1
1-2
1-3
1-4
1-5
1-6
1-7
1-8
1-9
1-10
1-11
1-12
35'
49°
49°

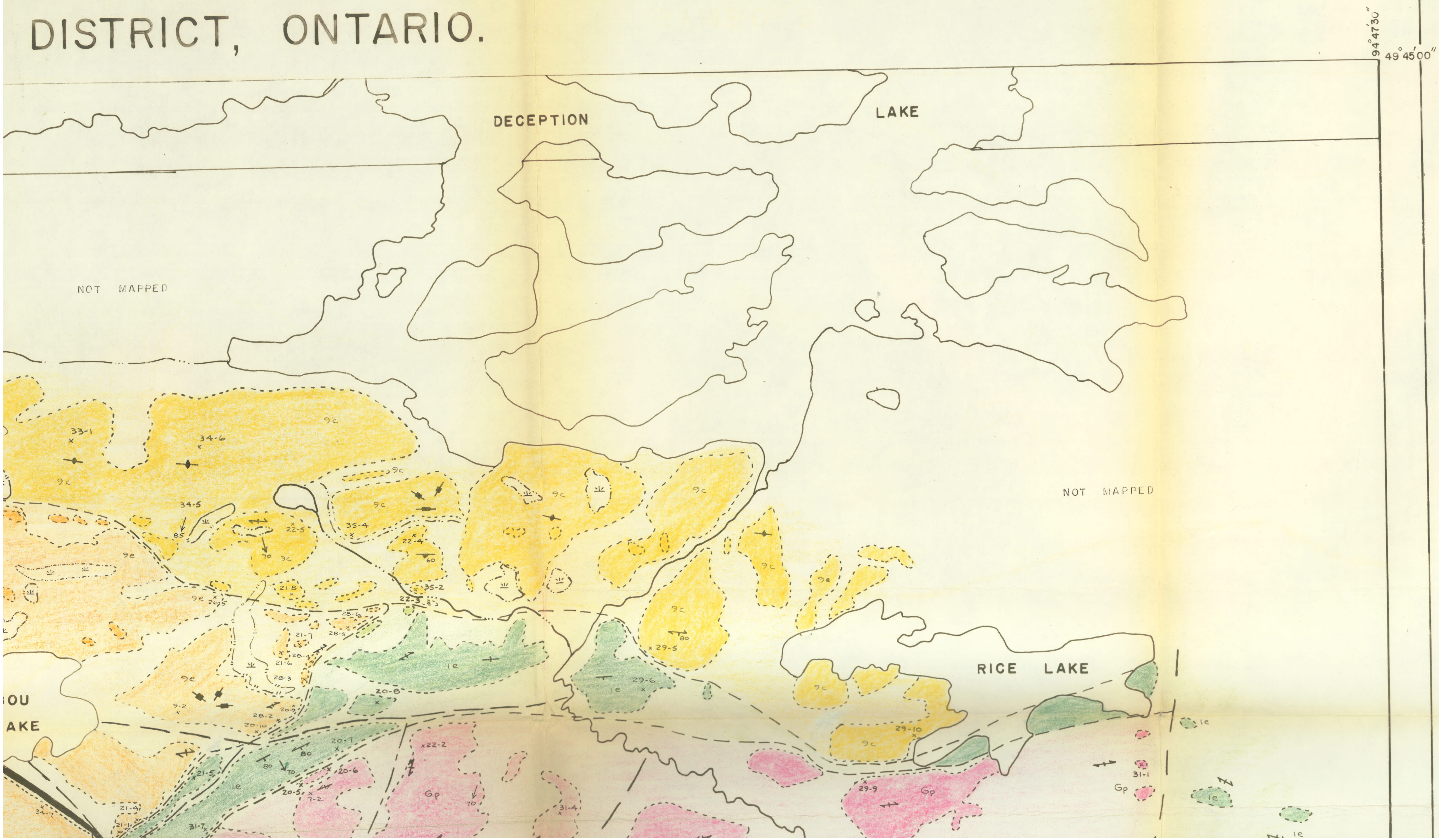
GEOLOGIC MAP OF THE WINNETKA LA



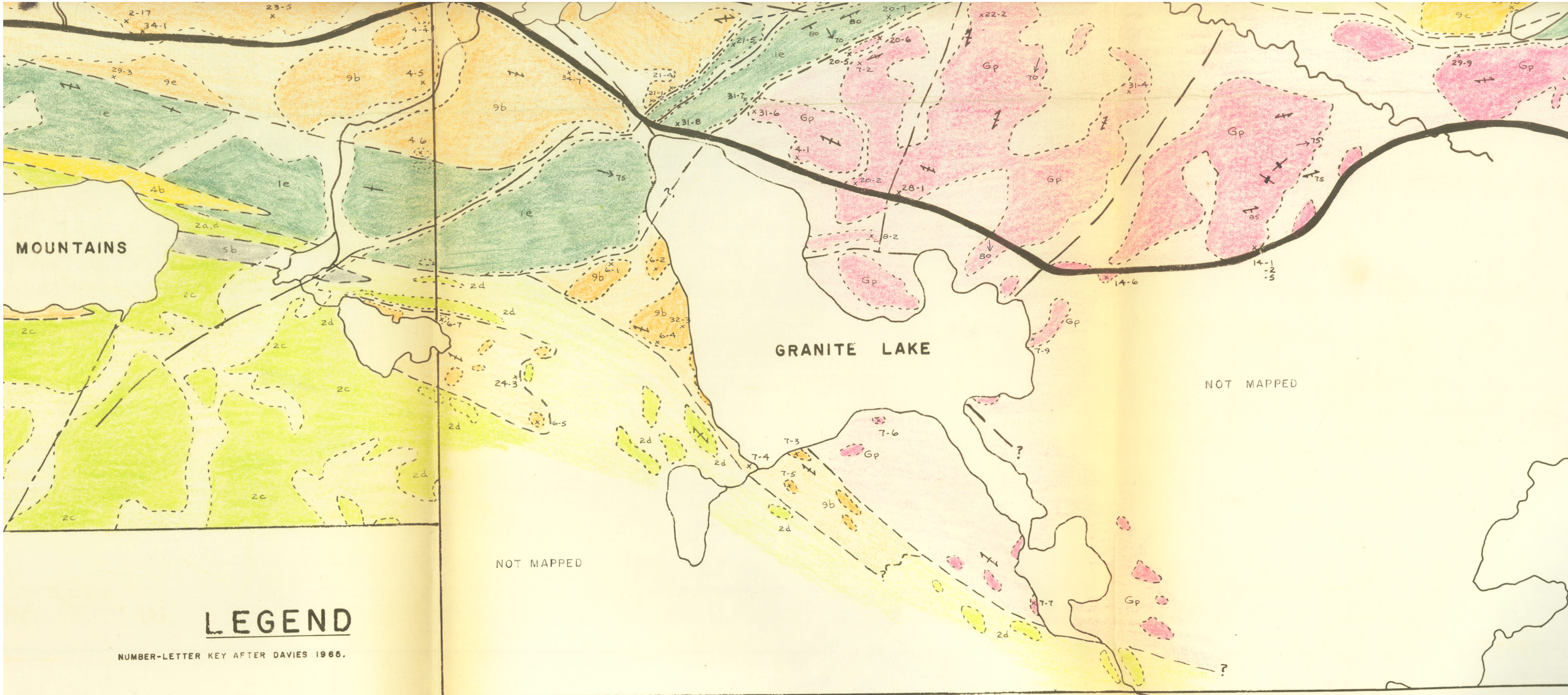
A LAKE AREA, KENORA DISTRICT, ONTARIO.



DISTRICT, ONTARIO.



LAKE OF TWO MOUN
49°42'05"
95°00'00"
ASTRONOMIC
MAGNETIC (1962)
N
7°
Arche
29-1
29-2



LEGEND

NUMBER-LETTER KEY AFTER DAVIES 1965.

Archean

SYNTECTONIC INTRUSIVE ROCKS

- 9c — Gneissic granodiorite.
- 9f — Border phase of hybrid rocks and lit-par-lit gneiss.

INTRUSIVE CONTACT *

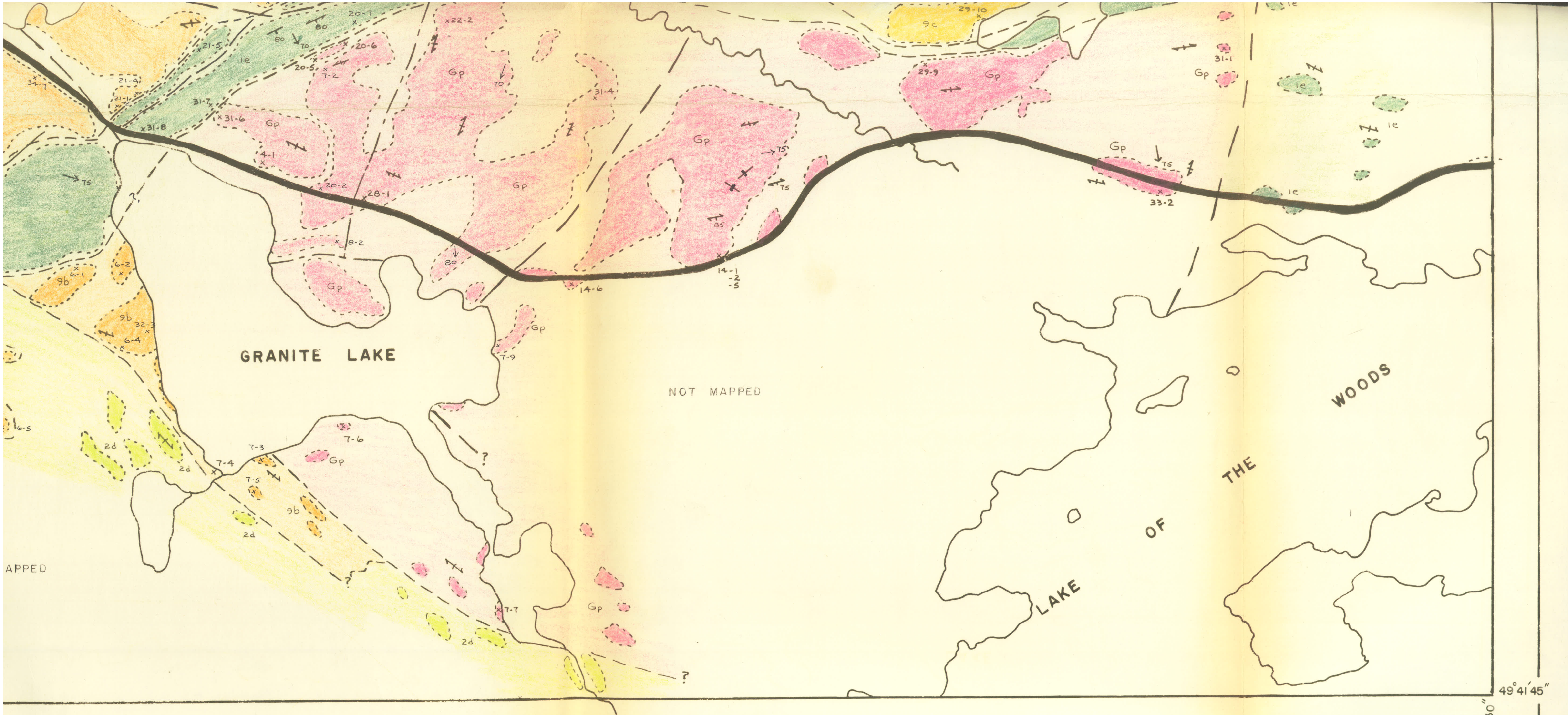
PRETECTONIC INTRUSIVE ROCKS

- Gp — Granite Lake porphyry.
- 9 — Winnetka Lake stock.
  - 9a Quartz monzonite.

* This intrusive contact is inferred by the presence of the border phase rocks and by the difference in the character of the foliation in the intrusive rocks.

SYMBOLS

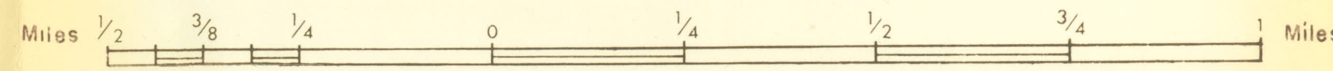
- 14-1 x — Oriented specimen location.
- 80 — Strike and dip, direction of top unknown.
- Strike and vertical dip, direction of top unknown.
- 75 — Strike and dip of schistosity.
- Strike of vertical schistosity.
- 80 — Strike and dip of gneissosity.



SYMBOLS

14-1 ×	Oriented specimen location.
80	Strike and dip, direction of top unknown.
	Strike and vertical dip, direction of top unknown.
75	Strike and dip of schistosity.
	Strike of vertical schistosity.
80	Strike and dip of gneissosity.

* This intrusive contact is inferred by the presence of the border phase rocks and by the difference in the character of the foliation in the intrusive rocks.

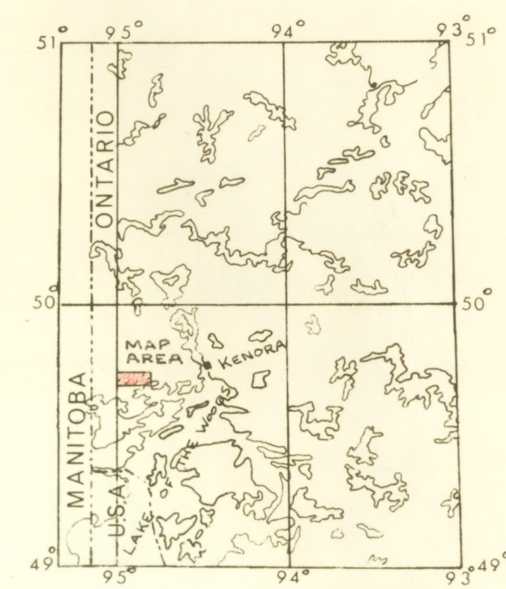


SOURCES OF INFORMATION

Geology of Forgie twp. by J. C. Davies 1961 and 1962.

Geology of Boys twp near Granite Lake by G O Vagt 1967.

Basemap supplied by Department of Lands and Forests, Province of Ontario.



Scale 1 inch to 50 miles.

of the border phase rocks and by the difference
in the character of the foliation in the intrusive rocks.

PRETECTONIC INTRUSIVE ROCKS

- Gp — Granite Lake porphyry.
- 9 — Winnetka Lake stock.
  - 9a Quartz monzonite.
  - 9b Grey granodiorite.
  - 9e Tonalite and Diorite.

INTRUSIVE CONTACT

KEEWATIN GROUP

- 5 — Metamorphosed sedimentary rocks.
  - 5b Greywacke, arkosic greywacke, tuff.
  - 5c Conglomerate, reworked agglomerate.
- 4 — Acid volcanic rocks.
  - 4a Bedded rhyolitic and dacitic tuff, minor flows and agglomerate.
  - 4b Massive fine grained rhyolitic and dacitic tuff.
- 3 —
  - 3a Porphyryitic (quartz) rhyolite flows with minor tuff and agglomerate.
  - 3b Rhyolitic agglomerate.
- 2 — Intermediate volcanic rocks.
  - 2c Andesite dacite agglomerate.
  - 2d Andesite dacite tuff, agglomerate and flows.
- 1 — Basic volcanic rocks.
  - 1c Tuff, lapilli tuff.
  - 1e Interbanded lensy tuff, flows and sediments.
  - 1g Gabbro, coarse grained tuff and flows (possibly gabbro)

NOTE 6d is a gabbro and is not described in the manuscript

Strike and vertical dip, direction of to

75 Strike and dip of schistosity.

Strike of vertical schistosity.

80 Strike and dip of gneissosity.

Strike of vertical gneissosity.

70 Lineation, plunge known.

80 Jointing, inclined.

Jointing, vertical.

Boundary of outcrop area.

Geological boundary.

Fault, indicated or assumed.

Lineaments.

Muskeg or swamp.

Trans-Canada highway.

Other road.

Plate 2

of the border phase rocks and by the difference
in the character of the foliation in the intrusive rocks.

ws and agglomerate.

tuff.

nor tuff and agglomerate.

flows.

nts.

(possibly gabbro)

script

Strike and vertical dip, direction of top unknown.

Strike and dip of schistosity.

Strike of vertical schistosity.

Strike and dip of gneissosity.

Strike of vertical gneissosity.

Lineation, plunge known.

Jointing, inclined.

Jointing, vertical.

Boundary of outcrop area.

Geological boundary.

Fault, indicated or assumed.

Lineaments.

Muskeg or swamp.

Trans-Canada highway.

Other road.