AN INVESTIGATION OF THE ORE ZONE
AND OTHER BASIC INTRUSIONS
AT POPULUS LAKE, KENORA, ONTARIO

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ABSTRACT

The Kenbridge ore zone at Populus Lake, Kenora District, Ontario, is a complex of basic intrusive rocks with andesite inclusions and later felsite dikes. The several varieties of basic rocks were intruded separately, but are probably derived from the same magma. The later basic phases cut the earlier ones or occur as the matrix of breccia zones containing fragments of the earlier types. The basic rocks intrude an area which is bounded on either side by faults which are parallel to the regional strike faults. The ore zone is a vertical lens-shaped body with nearly vertical ore shoots that are parallel to the enclosing shear zones. The sulphides, which are of magmatic origin, occur in the last phase of the basic intrusion. The sequence of crystallization of the sulphides is pyrite, pyrrhotite, pentlandite, and chalcopyrite.

The other basic intrusions in the Populus Lake area are composed of several rock types, but do not contain intrusive breccias, nor much sulphide. The rock types are similar to those in the ore zone. The intrusions occur near, but are not controlled by, the old fault zones; later faults cut across them.

The basic intrusions of the Populus Lake area appear to be formed by the crystallization of a basic magma by fractionation. The lighter fractions intrude first in the ore zone; the nickel-copper sulphides are associated with the heavier magnesium and iron-rich fraction.

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CHAPTER I

INTRODUCTION

The ore zone at Populus Lake was chosen as the subject of this thesis because these rocks appear to belong to several intrusions, or to several phases of one intrusion of which only one particular phase has nickel-copper mineralization. Several other basic intrusions occurring in the same area are similar in appearance to those in the ore zone, except that appreciable nickel-copper mineralization is not observed.

PROPERTY

The property of Kenbridge Nickel Mines Limited is situated between the southwest bay of Populus Lake, Betula Lake, and Empire Lake. The mineralized zone outcrops on a hilltop almost in the center of this area. The original property consisted of the following patented mining claims in the District of Kenora, on the Atikwa Sheet: K 4732 to K 4735; K 6634 to K 6638; K 7502; and K 8364 to K 8366 inclusive.

In 1952, Falconbridge Nickel Mines Limited optioned the property from Kenora Nickel Mines Limited. During September 1954, a group of ninety-nine claims was staked to protect the optioned property, and later a new company, Kenbridge Nickel Mines Limited [1], was formed to

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1 - Kenbridge Nickel Mines Limited consists of 24 claims.--- Canadian Mines Handbook, 1959.

develop it.

ACCESS

The property of Kenbridge Nickel Mines Limited at Populus Lake is situated forty-three air miles southeast of Kenora, Ontario. Two non-schedule airlines operate regularly from Kenora and during some summers an aircraft is based at Sioux Narrows, twenty miles west of Populus Lake. Several canoe routes connect Populus Lake to the Kenora-Fort Frances Highway in the west, and to Vermilion Bay in the north on the Kenora-Fort William Highway. When the underground development work started at Kenbridge, the company constructed a winter road and a summer barge and portage system to link the property to existing roads leading to Kenora. Thus, the Kenbridge property is accessible from Kenora by air and water routes except for the break-up and freeze-up periods.

HISTORY

During the 1890's, the region immediately east of the Lake of the Woods attracted prospectors who staked gold claims from Kakagi Lake to the southwest bay of Populus Lake. A decade later, more gold showings were located on the southwestern part of Eagle Lake. As attempts to develop these discoveries into mines failed, prospectors abandoned the Kenora District.

In 1936 and 1937, Findlay MacCallum of Winnipeg staked the showings at Populus Lake. Several trenches across the hilltop exposed the nickel-copper mineralization in the basic intrusive rocks.

In 1937, Coniagas Mines Limited optioned the property. They did about 10,000 feet of drilling which consisted of a series of short inclined holes from the valley on the east side of the hill, from the top of the hill, and from the west edge of the hill. In general, the holes are perpendicular to the strike of the showing and undercut the trenches. The drill logs note some massive sulphides, but mostly scattered, disseminated sulphides are reported throughout the mineralized zone.

Coniagas held controlling interest in Kenora Nickel Mines Limited, which was formed in 1937, until the International Nickel Company of Canada Limited (Inco) optioned the property in 1948.

Inco mapped the property and the surrounding area, and conducted a magnetic survey. From approximately 10,000 feet of drilling they acquired information from greater depth than that explored by Coniagas. The drilling program consisted of inclined holes collared west of the ore zone. The first series of holes, spaced at 100-foot intervals, was intended to cut the favourable rock structure at a depth of 500 feet; the second series spaced at 200-foot intervals to cut the ore zone at a depth of 1000 feet. Inco then dropped the option.

In 1952, Falconbridge Nickel Mines Limited optioned the property, conducted a magnetic survey of the showing and the adjoining area, prepared a generalized geological map of the mineralized area, and completed 5,000 feet of drilling. The program consisted of fifteen, 300-foot, vertical holes on a grid pattern with 100-foot intervals along Inco's baseline.

The 1953 program consisted of deepening eleven of the old holes and drilling eight new holes to 500 feet at intermediate points on the grid pattern. An electromagnetic survey failed to indicate conducting zones beyond the ends of the visible ore zone. In January 1954, Falconbridge deepened certain holes to 1000 feet, and continued drilling to determine the length of the ore zone. The country near Populus Lake was prospected and a geological map prepared in the early summer of 1954; later, drilling was resumed in the ore zone. The writer supervised drilling at Populus Lake from June 1953 to September 1954.

During the fall and winter of 1954-55, four, 2,000-foot, controlled, vertical holes indicated that the attitude of the favourable zone was nearly vertical. Falconbridge formed a new company, Kenbridge Nickel Mines Limited, to develop the property. In June 1955, the shaft was collared and the mineralized zone was cross-cut on the 300-foot level in February 1956. Kenbridge suspended operations in June 1957, after sinking the shaft to 2,000 feet and drifting along the 300-foot and 500-foot horizons.[1]

Because of the heavy staking in the area during the previous fall and winter, the Ontario Department of Mines engaged a geological party to map the Populus Lake area in 1955.

NICKEL OCCURRENCES IN THE DISTRICT OF KENORA

The principal nickel occurrences in the District of Kenora and in the adjacent areas are: the Kenbridge Nickel Mines Limited property at Populus Lake; the Gordon Lake property of Nickel Mining and Smelting Company; the Norpax Nickel Mines Limited property at Tigre Lake; the Maskwa Nickel Chrome Mines Limited properties in the Bird River and Maskwa Lake areas of Manitoba; and the Emo nickel showing in Rainy River District, first optioned by Falconbridge Nickel Mines Limited and later by Stratmat Limited. The accompanying map (Fig.1) shows the location of these properties.

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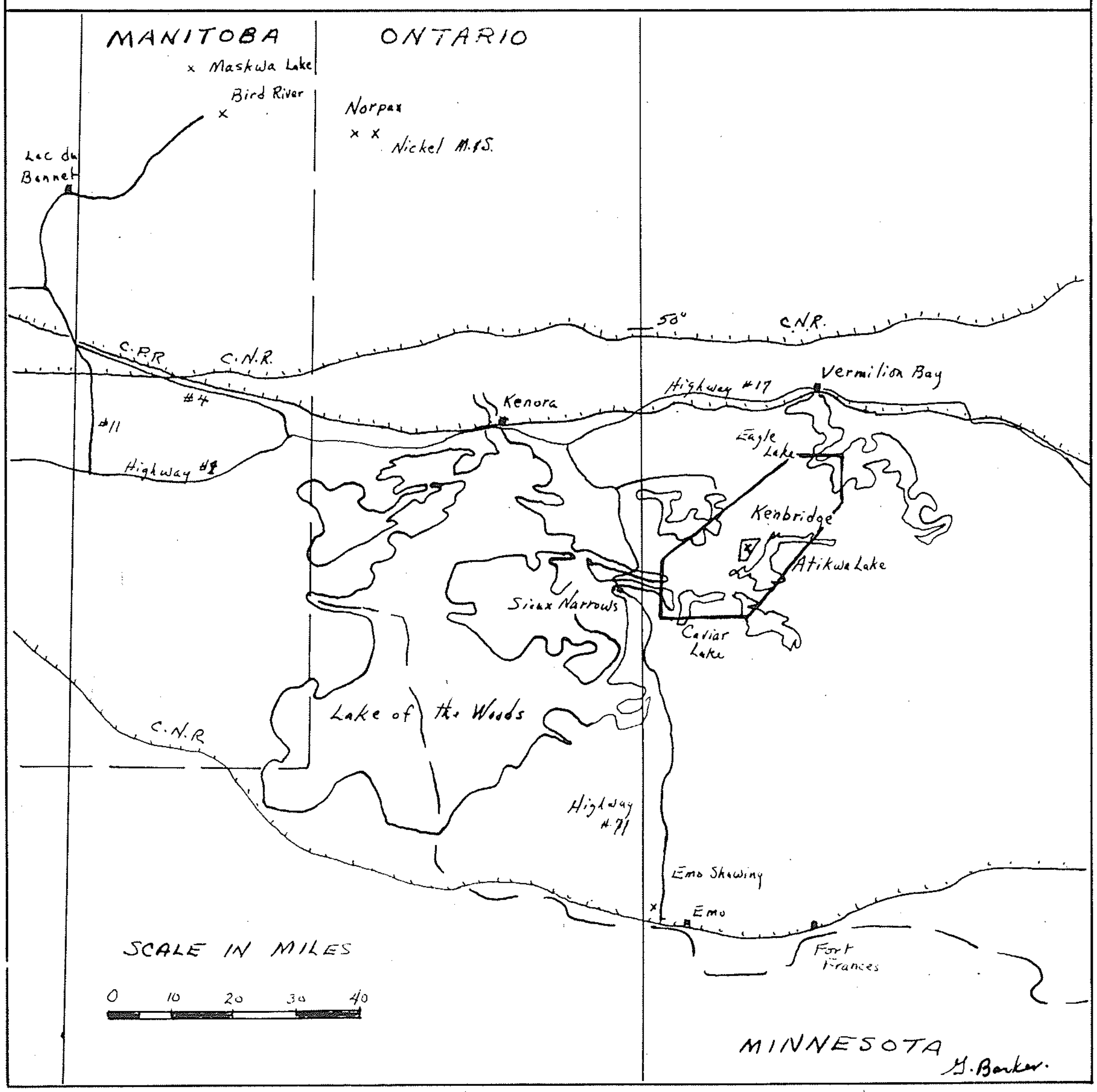
1 - Canadian Mines Handbook, 1959, -- Falconbridge Nickel Mines Ltd., Outside Properties: Kenbridge Nickel Mines Ltd., Surface and underground drilling indicate 794,960 tons averaging 1.14% nickel, 0.58% copper, and 2,707,780 tons averaging 1.04% nickel, 0.54% copper. Ore grade of Falconbridge Mines at Sudbury, is 1.45% nickel, 0.81% copper.

Figure 1

INDEX MAP

SHOWING THE LOCATION OF:
KENBRIDGE NICKEL MINES LTD.
POPULUS LAKE AREA
CAVIAR - EAGLE LAKE AREA
AND
OTHER NICKEL OCCURRENCES



GEOLOGICAL REPORTS AND MAPS

Geological reports and maps of the area consist of one map published by the Geological Survey of Canada and several reports and maps by the Ontario Department of Mines.

The maps and reports include:

"Manitou Lake Sheet", by Wm. McInnes, Geological Survey of Canada, Publication Number 720, 1902.

"Geology of the Kakagi Lake Area", by E.M.Burwash, Ontario Department of Mines, Volume XLII, Part IV, 1933.

"Geology of the Eagle Lake Area", by W. W. Moorhouse, Ontario Department of Mines, Volume XLVIII, Part IV, 1939.

"Geology of the Populus Lake Area", by J.C. Davies and S. N. Watowich, Ontario Department of Mines, Volume LXV, Part IV, 1956.

"Base Metal Exploration in the Kenora Area", by H.D. Carlson, Canadian Mining Journal, April 1955, No. 4, Vol. 77, p.87 (a paper presented at the Prospectors and Developers Association Convention, Toronto, 1956).

ACKNOWLEDGMENTS

The writer would like to thank those who have aided in the preparation of this thesis, in particular, the members of the staff of the Geology Department at the University of Manitoba with their many helpful comments.

Falconbridge Nickel Mines Limited have permitted the use of detailed maps prepared during the 1954 field season and of logs of holes drilled in 1953 and 1954.

The regional geology was discussed with Mr. J. C. Davies and Mr. S. N. Watowich at the University of Manitoba during the winter of 1955-56. They had spent the previous summer mapping the Populus Lake area for the Ontario Department of Mines.

GEOLOGY OF NICKEL AND NICKEL ORE BODIES

This section contains excerpts from the "Geology and Geochemistry of Base Metal Deposits, by H.D.B. Wilson[1], which has data from the Sudbury ore bodies, from other Canadian ore bodies, and from the Norwegian ore bodies.

The nickel-copper ore bodies are of magmatic origin. The characteristics of a nickel ore body are: (1) the amount of nickel in the sulphides, in any particular ore body, is relatively constant in most ore bodies; (2) the grade of nickel in the sulphides generally corresponds to the rock type; (3) the nickel sulphides are associated with specific intrusions, and show a lack of mobility in that they occur within, or alongside, their related intrusion; and (4) the nickel sulphides

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1 - Wilson, H.D.B., "Geology and Geochemistry of Base Metal Deposits", Economic Geology, Vol. 48, 1953, p. 370.

occur at, or near, the base of the intrusion if it has a base. The major control in the emplacement of most nickel-copper ore bodies is the basal contact of a high-magnesium intrusion. Other controls, such as the downward embayments and fault structures, are also important.

RELATION OF NICKEL CONTENT OF SULPHIDE TO ROCK TYPE[1]

Locality	Rock Type	Maximum Percent Nickel in the Sulphides
Canadian and Norwegian Nickel Deposits	Serpentine	10.0
	Peridotite	8.0 - 10.0
	Pyroxenite	4.5 - 5.0
	Norite	2.6 - 6.5
	Diorite	1.0
	Anorthosite	0.5
Kenbridge		9.0

Note: Kenbridge added to table. Assay of massive sulphides was 9 percent nickel, 0.5 percent copper.

1 - Wilson, H.D.B., op. cit.

CHAPTER II

THE GEOLOGY OF THE POPULUS LAKE AREA

INTRODUCTION

The Populus Lake area, for the purpose of this paper, covers the area between southern Populus Lake, southern Betula Lake, Granite Lake, and Empire Lake. (Fig. 2) The Kenbridge ore zone occurs near the center of this area.

The regional geology (Fig. 3) is compiled from reports and maps of the Ontario Department of Mines[1]. The greenstone belt from Caviar Lake to Eagle Lake has many small basic intrusions and a large boss southwest of Eagle Lake. For the most part, these intrusions seem to be elongated bodies parallel to the trend of the greenstone belt; some of them at Empire Lake cut across the formation.

GENERAL GEOLOGY

The geological map of the Populus Lake area (Fig. 2) shows that basic intrusions, granites and felsites invade the greenstone belt. In the north, the greenstone belt appears to be a series of tightly folded synclines and anticlines, whereas the south end is the west facing limb of a broad fold. The larger basic intrusions generally contain several rock types, and the smaller ones a single rock type. The Kenbridge ore

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1 - Burwash, E.M., "Geology of the Kakagi Lake Area", Ont. Department of Mines, Vol. XLII, Pt. IV, 1933.
Davies, J.C. and Watowich, S.N., "Geology of the Populus Lake Area", Ont. Dept. Mines, Vol. LXV, Pt. IV, 1956.
Moorhouse, W.W., "Geology of the Eagle Lake Area", Ont. Dept. Mines, Vol. XLVIII, Pt. IV, 1939.

Figure 2

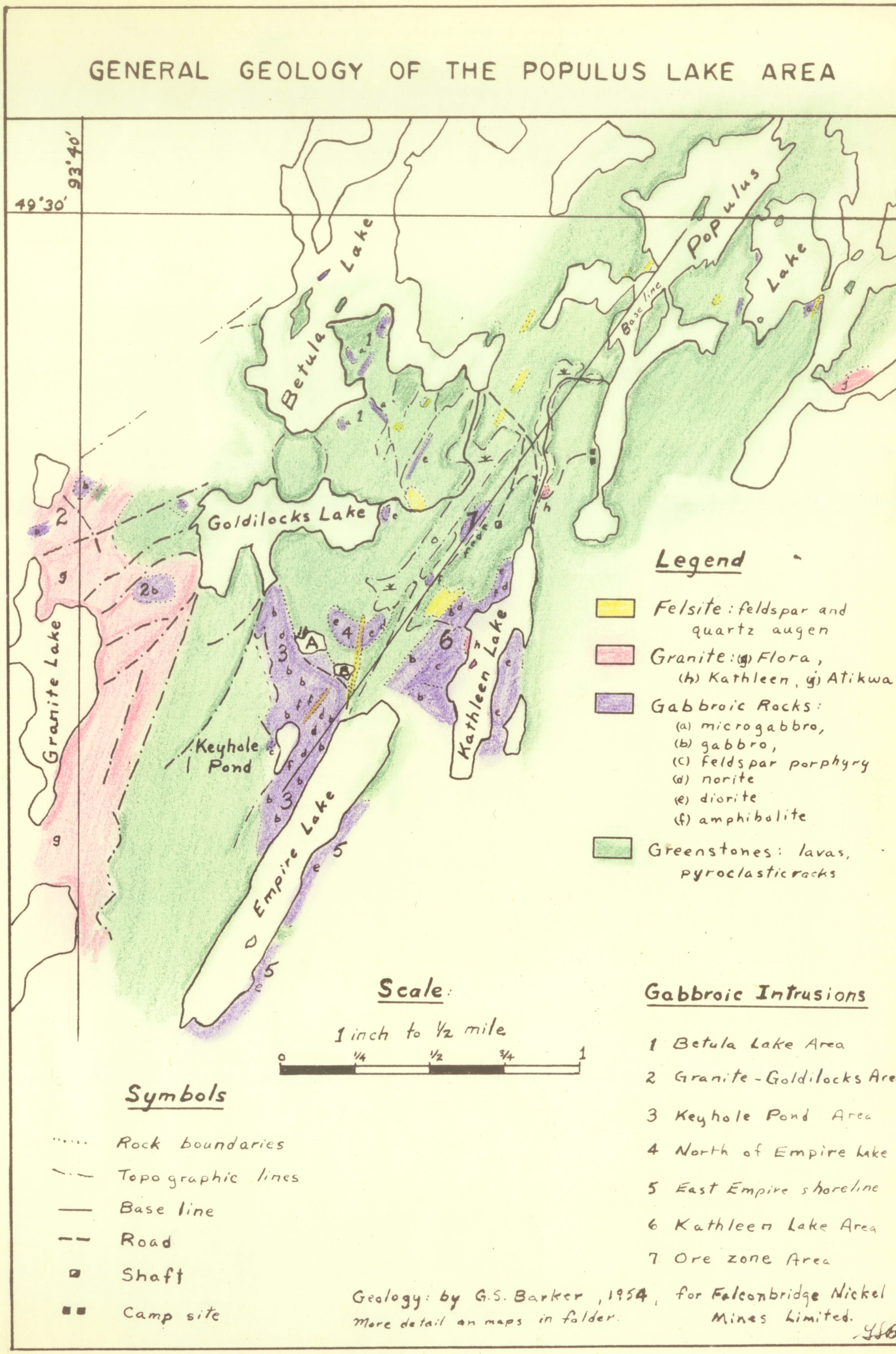
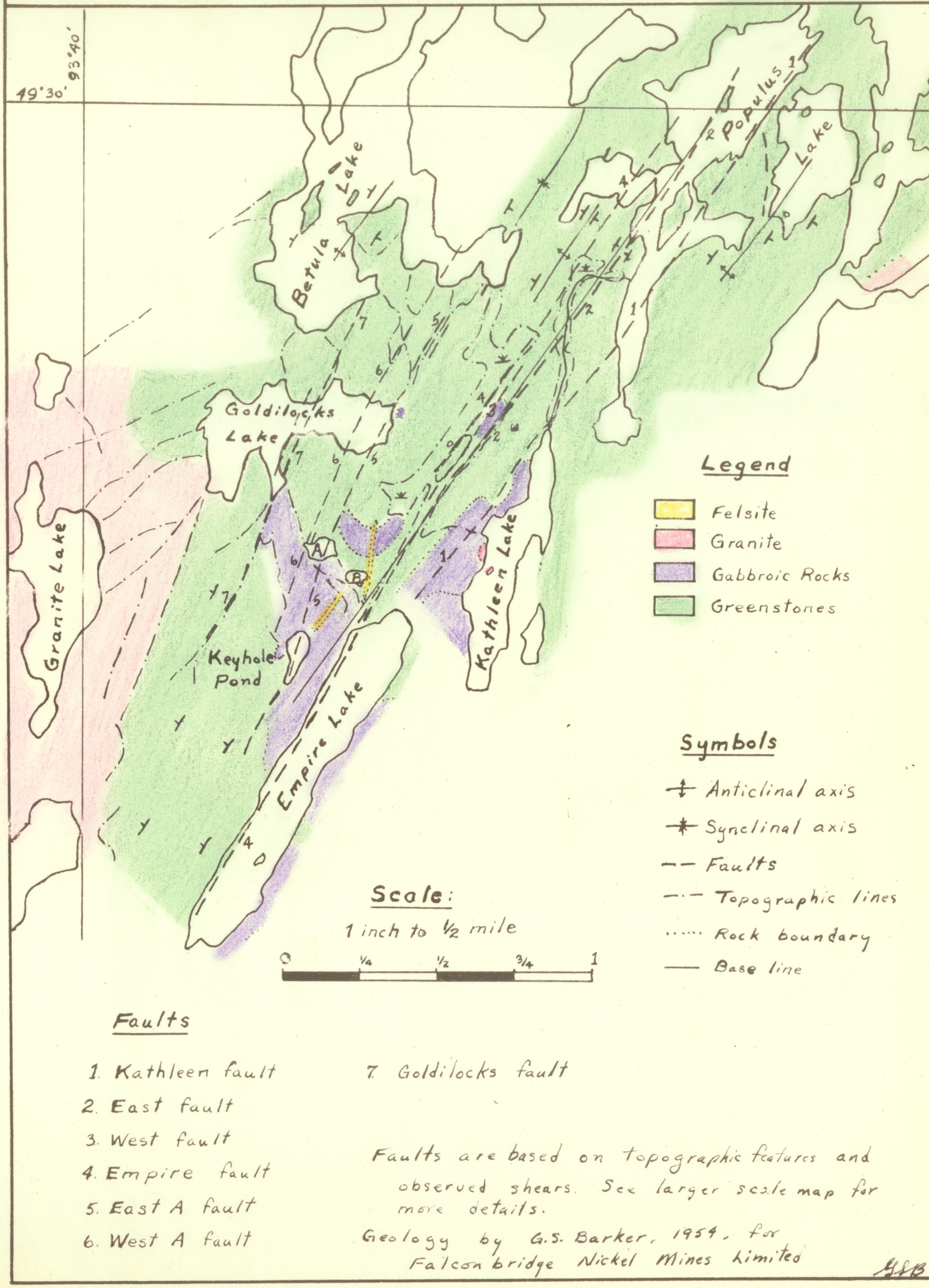

GENERAL GEOLOGY OF THE POPULUS LAKE AREA
49°30'
93°40'
Betula Lake
Populus Lake
Base line
Goldilocks Lake
Granite Lake
Keyhole Pond
Empire Lake
Kathleen Lake
Legend
Felsite: feldspar and quartz augen
Granite: (g) Flora, (h) Kathleen, (j) Atikwa
Gabbroic Rocks:
(a) microgabbro,
(b) gabbro,
(c) feldspar porphyry
(d) norite
(e) diorite
(f) amphibolite
Greenstones: lavas, pyroclastic rocks
Scale:
1 inch to ½ mile
0
¼
½
¾
1
Gabbroic Intrusions
1 Betula Lake Area
2 Granite - Goldilocks Area
3 Keyhole Pond Area
4 North of Empire Lake
5 East Empire shoreline
6 Kathleen Lake Area
7 Ore zone Area
Symbols
Rock boundaries
Topographic lines
Base line
Road
Shaft
Camp site
Geology: by G.S. Barker, 1954, for Falconbridge Nickel Mines Limited.
More detail on maps in folder.

Figure 3

STRUCTURAL GEOLOGY OF THE POPULUS LAKE AREA



body, however, is distinctive in that breccia zones are common and that sulphides are associated with one variety of the basic rocks. Two different granites intrude the greenstone in the map area; one in the east, and the other in the southwest. The felsite dikes cut across both the greenstones and the basic intrusive rocks. An iron formation band occurs in the greenstones in the western part of the map area.

TABLE OF FORMATIONS

QUATERNARY

RECENT:	Lake and stream deposits.
PLEISTOCENE:	Clay, sand, gravel, and boulders.

GREAT UNCONFORMITY

PRECAMBRIAN

FELSITES:	Felsite dikes with feldspar, quartz, or, feldspar and quartz phenocrysts.
GRANITES:	Flora granite boss -- pink, hornblende granite.
	Small granite intrusions at Kathleen Lake -- pink, hornblende granite.
	Atikwa granite -- pink, biotite granite.

INTRUSIVE CONTACTS

BASIC ROCKS: Feldspar porphyry, gabbro, diorite, norite, and amphibolite.

INTRUSIVE CONTACTS

GREENSTONES: Pillow and massive lavas, tuffs, and agglomerates of andesite or basalt. Cherty, magnetic iron formation interbedded with the greenstones.

GREENSTONES

The greenstones of the Populus Lake area consist of massive and pillow lavas, tuffs, and agglomerates of andesite or basalt. The regional strike of the lavas, the pyroclastic rocks and the schistosity is N 35° E. Tops of the flows were determined with difficulty from the elongated pillows in most of the Populus-Betula Lake region, but were determined readily from the bun-shaped pillows on the islands and peninsula in Betula Lake. The tops of the beds cannot be determined in the interbedded pyroclastic rocks.

A band of magnetic, cherty iron formation occurs between bands of north striking, vertical pillow lavas at Goldilocks Lake.

Felsites with feldspar phenocrysts outcrop throughout the greenstone belt at Populus Lake. These occur as short, thick lenses in massive greenstones, or as long, narrow bands in weakly sheared greenstones.

BASIC INTRUSIVE ROCKS

The basic intrusive rocks of the Populus Lake area are feldspar porphyry, gabbro, norite, diorite, and amphibolite; several of these may occur together as a composite intrusion. The various rock types are distinguished by textures; the original plagioclase and pyroxene or amphibole have been saussuritized and uralitized respectively. The feldspar porphyry which is well exposed along a ridge in the Kathleen intrusion consists of white feldspar phenocrysts in a dark fine grained groundmass. The rock can change greatly within a few feet; the size and quantity of the phenocrysts may vary from 2 to 20 mm. in diameter and from 20 to 80 percent in volume. On a cliff face the porphyry is observed to change to a gabbro by a rapid decrease in the quantity of the phenocrysts and by an increase in the grain size of the groundmass. The gabbro is a medium to coarse grained rock composed of dark coloured amphiboles and feldspars. The norite is composed of almost equidimensional grains of a dark green amphibole in a pale groundmass of feldspar; in thin sections, remnants of an orthopyroxene were observed in the amphiboles. The diorite is composed of feldspar laths in a groundmass of dark green amphiboles. The amphibolite in the ore zone is composed of massive amphiboles, blue quartz eyes, and sulphides in a groundmass of fibrous amphiboles; remnants of an orthopyroxene are observed in the amphibole grains. In the other intrusions the amphibolites are composed of fibrous amphiboles which are probably developed by the alteration of earlier amphiboles or pyroxenes. The feldspar porphyry, norite, and diorite are similar in all the intrusions in the Populus Lake area.

The sequence of the basic intrusions in the ore zone is determined from the fragments in the igneous breccia zones; it is feldspar porphyry, diorite, norite, and amphibolite. The diorite and the norite appear to overlap in age since they contain inclusions of each other. In the other intrusions the sequence of the component parts was not recognizable.

The basic intrusions appear to be formed from a magma which fractionated at depth; the various fractions partially crystallized, and then intruded before completing crystallization. In the ore zone the lighter fractions intruded first; and finally the heavier, magnesium and iron-rich fractions with associated sulphides.

Others have suggested a different possibility; the basic intrusions except for the ore zone are part of the lava sequence -- that is, the normal sill intrusions that occur in all volcanic fields. These were then folded and faulted; the ore zone is a later intrusion coming up the fault zone. The host rock of the ore zone breccias may be related to the other basic intrusions and to the fragments in the breccias, or it may be a much later, unrelated intrusion.

The intrusions occur in various locations in the Populus Lake area: these are (1) Betula Lake area, (2) Goldilocks-Granite Lake area, (3) East shore of Empire Lake, (4) North of Empire Lake, (5) Keyhole Pond area, (6) Kathleen Lake area, and (7) Ore Zone area. The basic intrusions are shown in Figure 2, page 11 and in detail on the maps in the folder. Gradational or intrusive contacts occur between various types of the basic rocks. The Kathleen, the Keyhole, and the North Empire intrusions have gradational or fault contacts between various rock types. The ore zone is more complex having intrusive contacts between various rock types; breccia zones are common, but assimilation of the fragments is not observed.

BETULA LAKE AREA: Several small bodies of fine grained gabbro or microgabbro outcrop near Betula Lake. Sulphides, mainly pyrrhotite with some chalcopyrite, are weakly disseminated locally in the gabbro.

GOLDILOCKS-GRANITE LAKE AREA: On the west shore of Goldilocks Lake, coarse grained gabbros are cut by dikes of pink granite. Large inclusions of very coarse grained gabbros occur in the pink, hornblende granite near Granite Lake. Sulphides are not observed in these gabbros.

EAST SHORE OF EMPIRE LAKE: A massive diorite-gabbro, having a coarse diabasic texture of 1 x 2 mm. laths of a dark green mineral in a pale green groundmass, occurs along the east shore of Empire Lake and along part of the east shore of Kathleen Lake. Burwash[1] considers the diorite-gabbro to be part of the border phase of the Atikwa granite. As the writer did not traverse this area, he was unable to verify this relationship.

NORTH OF EMPIRE LAKE: A crescent-shaped body of medium to coarse grained diorite outcrops on a prominent hill north of Empire Lake. The diorite has 30 to 50 percent dark green amphiboles, 2 to 3 mm. in diameter, in a pale green to white groundmass of feldspar. A narrow margin of norite occurs on the eastern edge of the diorite mass. The diorite intrudes massive greenstones, and in turn, dikes of pale grey felsite with quartz phenocrysts cut across the diorite and greenstone.

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1 - Burwash, E. M., op. cit.

A similar, medium grained diorite outcrops at the east end of Goldilocks Lake. A narrow dike of fine grained diorite strikes parallel to the regional schistosity in the pillow lavas at the copper-gold showing on a prominent hill west of the ore zone. The dike is traced southward through small outcrops to a spruce swamp, and is thought to be continuous with the diorite at the east end of Goldilocks Lake.

KEYHOLE POND AREA: The Keyhole intrusion, the largest basic intrusion in the Populus Lake area, extends from a bay on Goldilocks Lake to the west shore of Empire Lake. Several different basic rocks occur in this intrusion. The portion between Goldilocks and Pond A is mostly a medium grained norite, but is partly fine grained. Hand specimens of the medium grained norite contain 40 to 60 percent dark green amphiboles, 1 to 2 mm. in diameter, in a dark groundmass of feldspar. Some specks of sulphides occur in the norite near Goldilocks Lake.

The area between Pond A, Keyhole Pond, and Empire Lake is mostly fine to medium grained gabbros. An amphibolite with very weakly disseminated pyrrhotite-chalcopyrite occurs near Keyhole Pond. A medium to coarse grained norite outcrops on the hilltop parallel to the Empire shoreline. The gabbro is strongly sheared and altered on the cliffs and steep hill sides along the west shore of Empire Lake. An outcrop of feldspar porphyry, gabbro, and pillow greenstone occurs on the hill west of Keyhole Pond.

The massive greenstone outcrops within the Keyhole intrusion are either large inclusions or roof pendants. Several felsite dikes cut the basic rocks. A prominent dike in the amphibolite on the ridge between Keyhole Pond and Pond B extends for several hundreds of feet parallel to the schistosity.

Two thin sections of norite from the Keyhole intrusion were examined. Their average composition is 45 percent clinozoisite and plagioclase, 53 percent amphiboles, and 2 percent black opaque minerals. The minerals of this norite are similar to those of the norite from the ore zone.

KATHLEEN LAKE AREA: The various basic intrusive rocks compose distinct parts of the Kathleen intrusion. The fine grained diorite-gabbro on the east shore is similar to the diorite-gabbro on the east shore of Empire Lake. The northern part along the west shore of Kathleen Lake consists of a fine grained diorite on the west, and a medium to coarse grained norite on the east. A small amount of amphibolite occurs along a shear zone near the diorite-greenstone contact.

The southern part consists of mixed fine grained gabbros and medium grained norites in the west; feldspar porphyry in the center, on a ridge extending from Kathleen Lake to Empire Lake; and fine to medium grained gabbros in the east along the west shore of Kathleen Lake. On the east side of the ridge, the gabbro grades to a feldspar porphyry within a few feet. On the west, the porphyry is separated from the gabbro by a sharp valley which probably is the trace of a fault. Volcanic rocks occur along the west, north, and east contacts of the Kathleen intrusion; the south contact was not mapped.

A small mass of granite outcrops on the west shore and on the island in Kathleen Lake; contacts were not observed between the granite and basic rocks. A small outcrop of greenstone occurs north of the granite.

Three thin sections of Kathleen norite were examined. Their average composition is 58 percent clinozoisite and plagioclase, 35 percent amphiboles, 5 percent quartz, and 2 percent black opaque minerals; remnants of orthopyroxene occur in the amphiboles. The minerals are similar to those in the norite from the ore zone.

ORE ZONE AREA: The ore zone is a lens shaped complex of intrusive rocks, bound on either side by strong fault zones. The results of a detailed study are given in the following chapter.

Another mass of strongly sheared and altered amphibolite occurs about 700 feet south of the ore zone; a cedar swamp lies in the long narrow valley between them. This mass is bound on either side by the East and the West Faults of the ore zone.

GRANITES

The granites of the Populus Lake area include the Flora granite boss, the small intrusions at Kathleen Lake, and the Atikwa granite (fig. 2, page 11).

FLORA GRANITE: The Flora granite boss intrudes the greenstone belt west of Empire Lake. The northeastern part of the boss, at Granite Lake, is in the Populus Lake area; the entire boss is outlined on the map showing the regional geology (fig. 3, page 12).

The rock is a coarse grained, pink, hornblende granite. The granite-greenstone contact on the east is sharp with small dikes of granite a few hundred feet away from the granite mass. At the north-eastern part of the boss, inclusions of greenstones and gabbros are common in the granite; and the granite dikes occur farther away from the boss.

SMALL INTRUSIONS AT KATHLEEN LAKE: A medium grained, pink, hornblende granite outcrops on the island and on the west shore of Kathleen Lake. Outcrops of feldspar porphyry, gabbro, and greenstone occur nearby, but contacts with the granite are not observed. Quartz veins are prominent in the granite on the island.

A small mass of white granite outcrops near the bridge on Kathleen Creek.

ATIKWA GRANITE: The large granite mass at Atikwa Lake extends to the eastern part of Populus Lake. The rock is a coarse grained, pink, biotite granite. The contact is marked by abundant pink granite dikes in the greenstone.

The relative ages of the granites are unknown. The Flora and the Kathleen granites are similar in appearance; both are pink, hornblende granites. The Flora and the Atikwa granites have different mineral compositions, the latter is a pink, biotite granite; both intrude the greenstone, and are massive in the map area.

FELSITES

The felsites are leucocratic rocks that may contain feldspar phenocrysts, quartz phenocrysts, or both quartz and feldspar phenocrysts, with or without chlorite in the groundmass.

The felsites can be divided into three groups. The first consists of long, narrow, massive dikes that cut across the greenstones and the basic intrusions. The second consists of long, sill-like masses in sheared greenstones, or as short, thick pods in massive greenstones. Very few intrusive contacts are observed between the second group and the greenstones. The third group consists of small masses of felsites that intrude into the greenstones; they are usually equidimensional in outcrop.

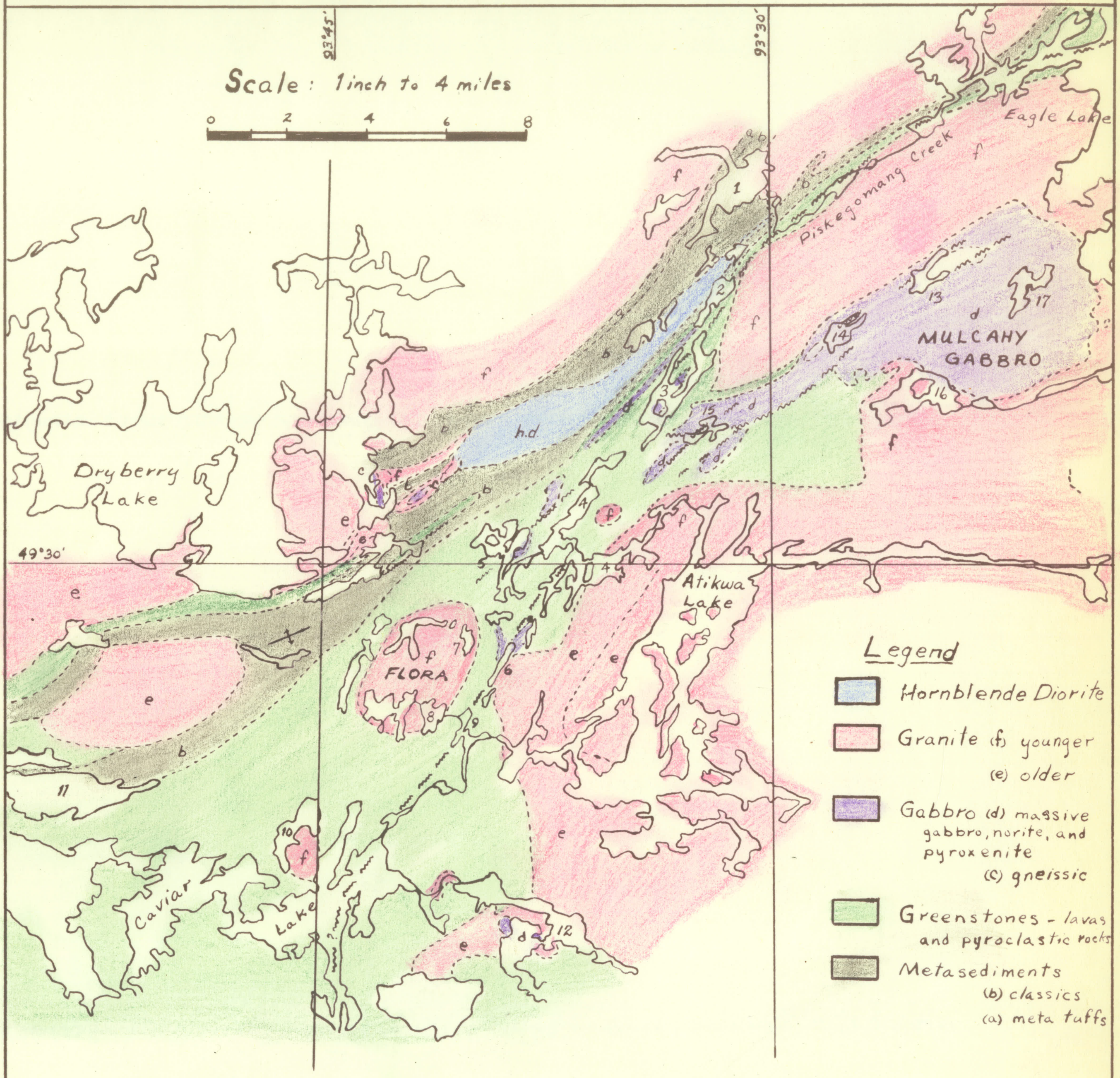
STRUCTURAL GEOLOGY

The basic intrusive rocks, granites and felsite dikes intrude the greenstone belt in the Populus Lake area (fig. 6, page 31). The greenstones are deformed so that several tight synclines and anticlines appear in the north, and a thick limb of a fold appears in the south. In general, the beds, the schistosity, the trace of the fold axes, and the trace of the faults have a strike of N 35° E. The beds and the schistosity dip vertically, or nearly vertically.

A series of small anticlines and synclines occur at Populus and

Figure 4

STRUCTURAL GEOLOGY OF THE CAVIAR - EAGLE LAKE AREA



Lakes

1. Hawkcliff
2. Stoat
3. Fisher
4. Populus
5. Betula
6. Empire
7. Granite
8. Flora
9. Waterfall
10. Hope
11. Lobstick Bay, Lake of the Woods
12. Denmark
13. Alford
14. Easter Chicken
15. Lava
16. Beaverhouse
17. Mulcahy

Geology from Ont. Dept of Mines' geological maps. Faults presumed.

Topography from the Dryden Topography sheet.

GLB

at Betula Lakes. These folds are based on tops determined from pillow lavas; however, in many places, tops are difficult to determine from elongated pillows. Tops were not observed in the interbedded pyroclastic rocks. A thick series of west-facing pillow lavas occur west of Empire Lake; these lavas are part of the east limb of a large syncline or the west limb of an anticline. The writer interprets the evidence of folding in the greenstone to indicate a limb of a large syncline or simple synclinorium west of Empire Lake and several small synclines and anticlines on a limb of a synclinorium in the Populus-Betula Lake area.

Many faults and numerous shear zones were mapped in the Populus Lake area. Several faults cross the Keyhole intrusion causing a left-hand separation of the gabbro-greenstone contact on the north, and a right-hand separation on the south. The presence of most of the faults is based on such topographic features as sharp draws and cliffs. Small shear zones occur in outcrops throughout the area.

The distinctive faults in the Populus Lake area have been named; they are Empire Fault, West Fault, East Fault, Kathleen Fault, East A Fault, West A Fault, and Goldilocks Fault.

The Empire Fault, the most prominent fault in the Populus Lake area, is marked by the high cliffs on the west shore of Empire Lake and by the cliffs of sheared andesite west of the ore zone. The Empire Fault can be extended north through some small shear zones to Populus Lake, and south by topographic features, such as sharp valleys, to Caviar Lake.

The West Fault is a series of parallel shears along the west margin of the ore zone and in the adjacent greenstones, with the Empire Fault being the most westerly of this series. South of the ore zone, a narrow ridge of massive greenstone separates the Empire Fault from the West Fault, which occurs along the west side of a narrow swamp.

The East Fault, which occurs in the draw that separates the ore zone from the greenstone ridge on the east, continues south along the east side of the narrow swamp. The East and the West Faults extend south to Empire Lake where they join the Empire Fault to form a single fault zone. The north end of the East Fault is drift covered, but it may extend far enough north to be represented by a small inlet and a shear zone on an island in Populus Lake.

The Kathleen Fault extends northward from Empire Lake along the draw that separates the feldspar porphyry from the gabbro in the Kathleen intrusion, through an observed fault contact of norite and greenstone at the north end of the Kathleen intrusion, and through a shear zone in the greenstones along the southwest bay of Populus Lake.

The East A Fault is recognized by the draws that extend north and south from Keyhole Pond. This fault may be extended northward through Goldilocks Lake and along a cliff near the copper-gold showing. The gabbro-greenstone contact has a right hand separation south of Keyhole Pond, and a left hand separation at Pond A.

The West A Fault, at the northwest bay of Pond A, has three observed fault contacts: greenstone against greenstone, greenstone against gabbro, and gabbro against gabbro. The gabbro-greenstone contact has a left-hand separation. The fault is extended northward by topographic features and a shear zone to Betula Lake, and southward across the gabbro mass. The south contact has a right-hand separation.

The Goldilocks Fault separates the gabbro from the greenstone south of Goldilocks Lake and extends southward along a sharp valley. The fault forms a cliff along a prominent hill on the north shore of Goldilocks Lake. A second, smaller fault on the north shore has a left-hand separation.

CHAPTER III

THE GEOLOGY OF THE ORE ZONE

INTRODUCTION

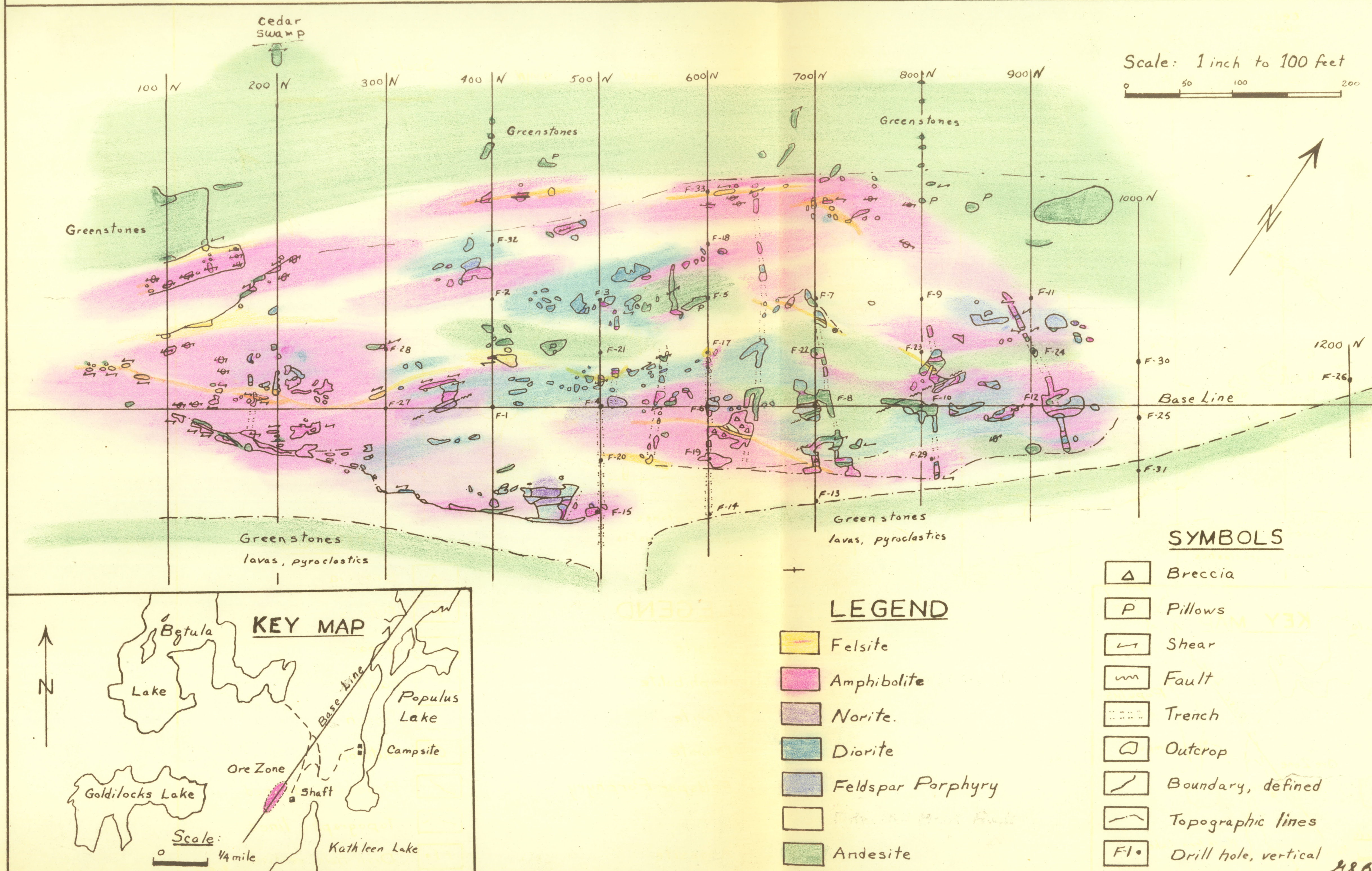
The ore zone outcrops on a hilltop approximately one quarter of a mile west of the southwest bay of Populus Lake. On the east, a draw separates the ore zone from the greenstone ridge where the shaft is located; on the west, a series of cliffs and ledges of sheared greenstones mark the boundary. The north end of the ore zone is covered by drift, and the south end by a cedar swamp.

The ore zone is a lens shaped complex of several basic intrusions, andesite, and felsite dikes. The maximum area of outcrop is 300 by 1,000 feet, and much of this area has a light covering of glacial drift. In 1937, the prospect was examined by a series of trenches. Since then extensive drilling programs have explored the ore zone from surface and underground. The ore zone is vertical to the explored depth of 2000 feet.

During the summer of 1954 the writer prepared a geological map of the ore zone, but did not complete the western part of it. This map in the folder (figure 7) illustrates the complex nature of the ore zone with the intermingling of various rock types. Locally, the intrusive rocks and the inclusions are mixed too intimately to be

figure 6

THE GEOLOGY OF THE ORE ZONE AT POPULUS LAKE



separated on the map.

ROCK TYPES IN THE ORE ZONE

The rocks are divided into the following units for mapping: feldspar, porphyry, diorite, norite, amphibolite, andesite, and felsite. Several additional rocks observed in the core are quartz diorite, mineralized diorite, and mottled norite.

FELDSPAR PORPHYRY

MEGASCOPIC: The feldspar porphyry ranges from one rock composed of a few "feldspar phenocrysts" in a fine grained, dioritic groundmass, to another composed of many large "phenocrysts" in a dark green, aphanitic groundmass. Generally, in the ore zone, the large occurrences of the porphyry have 10 to 30 percent "phenocrysts" ranging from 2 to 4 mm. in diameter, and the breccia fragments and smaller occurrences have 20 to 60 percent "phenocrysts", 2 to 20 mm. in diameter. The drill core shows a similar relation of quantity and size of "feldspar phenocrysts" to the length of intersection.

MICROSCOPIC: Two specimens of feldspar porphyry with 20 percent "phenocrysts", 10 mm. in diameter, were examined. The "phenocrysts" are metacrysts composed of large clinozoisite grains with interstitial low-calcic plagioclase, apparently pseudomorphic after calcic plagioclase. The groundmass consists of large amphibole grains and clusters of clinozoisite grains in a finer grained groundmass of chlorite and low-calcic plagioclase. The minor constituents are quartz, black opaque minerals, and apatite. The amphiboles are hornblende, tremolite-actinolite, hornblende with a rim of tremolite-actinolite, or tremolite-actinolite with a rim of hornblende. Two of these amphiboles may appear in the same section.

DIORITE GROUP

MEGASCOPIC: The diorite group consists of various rocks in which the feldspar has definite crystal form. A medium grained diorite contains laths of white feldspar, 1 mm. long, in a green amphibole groundmass. Small feldspar "phenocrysts" occur in some diorites. The diorite grades to a feldspar porphyry, or to a rock in which neither the feldspar nor the amphibole has distinct form.

Several relationships were observed between the diorite and the other rocks in the ore zone. Diorite intrudes the andesite. Small tongues of amphibolite occur in the large exposures of medium grained diorite, and angular fragments of diorite occur in the amphibolite breccia. Diorite breccias have angular fragments of norite. In one outcrop, the diorite intrudes the norite; but, in less than one hundred feet, fragments of diorite occur in the norite breccia.

MICROSCOPIC: Thin sections from eight specimens of medium grained diorite in the ore zone were examined. The average composition of these diorites is 50 percent clinozoisite and low-calcic plagioclase, 45 percent amphiboles, 5 percent quartz, and minor quantities of black opaque minerals, carbonate, and apatite. The white laths or former plagioclase crystals are clusters of small clinozoisite grains in a groundmass of low-calcic plagioclase. The amphiboles are hornblende with an actinolite-tremolite rim, hornblende, actinolite-tremolite with a hornblende rim, or actinolite-tremolite; two of these amphiboles may be present together. The groundmass may consist of secondary tremolite. Either large strained quartz grains, or small quartz granules fill the interstitial spaces between the original plagioclase and amphibole. Quartz granules, chlorite, carbonate, and biotite occur in small shear zones in the diorite sections.

The fine grained diorite has a similar composition in thin sections; the amphiboles and the clinozoisite-plagioclase units are smaller, and the quartz more difficult to recognize as the grain size diminishes.

NORITE GROUP

MEGASCOPIC: The norite group consists of norite, mottled norite and a finer grained variety. Margins of mottled norite on norite core intersections are common; in places, margins of norite occur on mottled norite. The norite is composed of 30 to 60 percent dark green amphiboles in a green to white groundmass of feldspar. The amphiboles are nearly equidimensional grains about 2 mm. in diameter. The mottled norite has a similar proportion of amphibole to feldspar, but the amphiboles are not as large nor as uniform in size and shape as those in the norite. The minerals form a distinct pattern of predominantly green and predominantly white areas. The fine grained variety consists of small grains of amphibole and feldspar. The criteria for determining the rock type are the size and shape of the amphiboles in the hand specimen.

The norite occurs in a few small masses, in three large masses in different parts of the ore zone, and as angular fragments in the amphibolite breccia. The amphibolite intrudes the norite. A small norite breccia zone with fragments of diorite and feldspar porphyry is adjacent to a large exposure of norite.

MICROSCOPIC: Five thin sections of norite from the ore zone were examined. The average composition of the norite is 55 percent clinozoisite and low-calcic plagioclase, 35 percent amphiboles, and 10 percent quartz. The amphiboles may be a rim of actinolite around tremolite with disseminated iron oxides, actinolite, or a hornblende rim around actinolite. A few remnants of orthopyroxene occur in the amphibole grains. Some of the tremolite-actinolite may alter to chlorite. The groundmass consists of clusters of clinozoisite grains surrounded by low-calcic plagioclase, and a small quantity of tremolite-actinolite. An intermediate plagioclase occurs when the clinozoisite does not appear in the groundmass. In some sections, strained quartz grains fill the interstitial spaces between the plagioclase grains. Small black opaque minerals with an alteration product occur in most sections.

Four thin sections of mottled norite were examined; these were cut from a core section in which the rock grades from a fine grained rock to mottled norite to norite. The average composition of the mottled norite is 45 percent clinozoisite and low-calcic plagioclase; 50 percent tremolite-actinolite with varying amounts of alteration to chlorite; 5 percent quartz; and some black opaque minerals with an alteration product.

The green patches are small tremolite-actinolite grains with a few small clinozoisite grains. The white patches are low-calcic plagioclase with small clinozoisite grains and some amphibole grains. Quartz fills the interstitial spaces between the original minerals.

The fine grained variety of the norite is composed of small grains of tremolite-actinolite and clusters of minute clinozoisite grains in a low-calcic plagioclase groundmass. Quartz was not observed. The fine grained rock of the norite group and that of the diorite group cannot be separated.

QUARTZ DIORITE

MEGASCOPIC: The quartz diorite does not outcrop, but occurs in two adjacent drill holes. The core indicates a quartz diorite body with an amphibolite mantle; the contacts are gradational.

The medium to coarse grained quartz diorite has 45 percent white feldspar, 45 percent amphiboles, and 10 percent quartz. The rock grades to an amphibolite by a decrease in the amount of feldspar and in the grain size of the amphibole.

The amphibolite has amphiboles 1 mm. in diameter, some blue quartz eyes, and some feldspar. The sheared amphibolite has orientated amphibole grains in a chlorite groundmass. When the shearing becomes more intense, the amphibolite alters to soapstone.

MICROSCOPIC: The composition of the quartz diorite in two thin sections is 10 to 20 percent large strained quartz grains filling the interstitial spaces; 30 to 35 percent clusters of clinozoisite grains surrounded by low-calcic plagioclase; and 45 to 60 percent tremolite-actinolite grains with some hornblende rims. Some of the amphibole is altered to chlorite.

The composition of the amphibolite in four thin sections is 15 to 25 percent large strained quartz grains filling the interstitial spaces; up to 10 percent low-calcic plagioclase and clinozoisite; 35 to 75 percent tremolite-actinolite with rims of green actinolite and interiors of clear tremolite with disseminated iron oxides, or actinolite with hornblende rims; 5 to 25 percent biotite; variable amounts of carbonate; and minor apatite. The tremolite-actinolite may be altered to chlorite.

The composition of the sheared amphibolite in one section is 20 percent tremolite grains; 2 percent black opaque minerals; and the remainder a mesh of chlorite, secondary white micas, and milled quartz grains.

MINERALIZED DIORITE

MEGASCOPIC: The mineralized diorite is a fine to medium grained rock that has blebs of pyrrhotite-pentlandite-chalcopyrite, a few feldspar phenocrysts, and small angular inclusions of greenstone. The mineralized diorite is the only rock containing sulphides other than the amphibolite; however, it does not approach ore grade unless it is intruded by the amphibolite.

The mineralized diorite occurs in three adjacent drill holes and in a small outcrop near hole F-7.

MICROSCOPIC: Thin sections from three specimens of mineralized diorite and two specimens of adjacent fine grained diorite were examined.

The average composition of the mineralized diorite is 40 percent clinozoisite and low-calcic plagioclase, 40 percent amphiboles, 15 percent quartz, 5 percent sulphides and other black opaque minerals, and minor apatite.

The average composition of the fine grained diorite is 33 percent clinozoisite and low-calcic plagioclase, 42 percent amphiboles, 20 percent quartz, 5 percent pyrite and other black opaque minerals, and minor apatite.

The minerals of the mineralized diorite and the fine grained diorite occur in about the same proportion as the minerals in the diorite (page 33), except that the quartz and the black opaque minerals have increased in quantity. The amphiboles are similar, with hornblende, tremolite-actinolite, and rims of one on the other; however, an orthopyroxene remnant was observed in an actinolite grain in a mineralized diorite section.

AMPHIBOLITE

MEGASCOPIC: The amphibolite has massive amphiboles in a fibrous amphibole groundmass. Blue quartz eyes may or may not be present. The rock may contain disseminated blebs of pyrrhotite-chalcopyrite-pentlandite. The size of the blebs remains relatively constant, although the amount of sulphides may range from negligible to massive.

In weal shear zones, the slippage occurred between the fibrous amphiboles in the amphibolite. In strong shear zones, the massive amphiboles have beeen milled out and the fibrous amphiboles altered to talc so that the rock becomes a soapstone. All gradations of shear zones exist between these extremities with a corresponding change in the amphibolite.

The amphibolite occurs in the ore zone as large masses, as the matrix in breccia zones, or as small tongues intruding the other rocks. The breccia contains angular fragments of feldspar porphyry, norite, and diorite. The fragments have angular, sharp edges; assimilation is not evident. Apparently, the intruding magma has carried the fragments up from greater depths, and then solidified. The amphibolite intrudes all other rock types except the later felsite dikes. The ore zone may be a large breccia zone with large fragments of other basic intrusive rocks and volcanic rocks suspended in a matrix of the amphibolite.

MICROSCOPIC: The average composition of four thin sections of amphibolite is 20 percent large amphibole grains; and the remainder a groundmass of small tremolite grains with variable amounts of quartz, sulphides, and apatite. The amphibole may be hornblende, actinolite with a hornblende rim, hornblende with a tremolite rim, or hornblende with a rim of tremolite and an interior of tremolite with disseminated iron oxides. In places, remnants of orthopyroxene were observed in the amphiboles.

Adjacent to shear zones, the exterior of the amphibole alters to tremolite, chlorite replaces the tremolite groundmass, and the quartz grains have been milled out.

The soapstones in the strong shear zones was not examined microscopically.

ANDESITE

MEGASCOPIC: The andesite is green, aphanitic, massive or pillow lava. Disseminated pyrite occurs in core sections of the andesite.

The basic rocks and the felsite dikes intrude the andesite.

MICROSCOPIC: The andesite was not examined under the microscope.

FELSITE

MEGASCOPIC: The felsites may have feldspar, quartz, or feldspar and quartz phenocrysts, with or without chlorite, in a pale green to grey, aphanitic groundmass.

The felsite dikes cut across the ore zone almost parallel to its length.

MICROSCOPIC: Four thin sections of the felsite were examined. The quartz "phenocrysts" consist of several strained quartz grains. The altered feldspar "phenocrysts" are composed of small clinozoisite grains in a low-calcic plagioclase groundmass. White mica may be developed in some feldspar "phenocrysts". The chlorite is an aggregate of small grains. The groundmass consists of low-calcic plagioclase and quartz with shreds of chlorite, small clinozoisite grains, and carbonate grains. Several slides were stained for potash, but potassium was not indicated; therefore, all the feldspar is plagioclase.

RELATIVE AGES

The ore zone is a complex of basic intrusive rocks, andesites, and felsite dikes; the andesites are remnants of the country rock, and the felsite dikes have cut across the complex. Several different basic intrusive rocks are present; their order of intrusion, determined from the fragments in the breccia zones, is feldspar porphyry, diorite, norite, and amphibolite. The feldspar porphyry of the ore zone appears in several separate masses, and with diminishing quantity of feldspar phenocrysts grades to a diorite. The porphyry was not observed as a host rock in any of the numerous breccia zones. The diorite and norite appear to be closely related in their time of intrusion, because each has breccias containing fragments of the other, and of feldspar porphyry. The amphibolite breccia zones are very common and contain fragments of feldspar porphyry, diorite, and norite. In different parts of the ore zone the norite, the diorite, and the amphibolite intrude the andesite. The other basic rocks do not show any age relationships, other than that they are younger than the amphibolite. All of the basic rocks may have been derived from the same magma.

METAMORPHIC FACIES

The rocks in the ore zone are in the epidote-amphibolite facies, except those rocks adjacent to shear zones which are in the chlorite facies.

The original suite of minerals in the basic rocks was pyroxene or amphibole, intermediate- to high-calcic plagioclase, and quartz. The pyroxene or amphibole, and the plagioclase are uralitized and saussuritized, respectively.

During uralitization, the pyroxene or amphibole altered to tremolite with disseminated iron oxides. As the temperature increased, the tremolite absorbed some iron and changed to actinolite, the actinolite reacted to form hornblende. Near the shear zones a new metamorphism altered the hornblende to tremolite. The reactions may not be complete and parts of the old mineral remain in the new one; two or three amphiboles in one mineral grain are common. Some remnants of orthorhombic pyroxene occur in the amphiboles in the norite and in the amphibolite.

During saussuritization, the plagioclase broke down to clinozoisite and a low-calcic plagioclase. The composition of the plagioclase is controlled by the temperature; as the temperature increased some clinozoisite reacted with the low-calcic plagioclase to form a higher calcic plagioclase.

The minerals in the felsite dikes are in the epidote-amphibolite facies. Clinozoisite and low-calcic plagioclase replace the former plagioclase phenocrysts.

A new low grade of metamorphism occurs adjacent to shear zones; other amphiboles alter to tremolite, and tremolite to chlorite.

THE ORE

MINERALIZATION: In the upper part of the ore zone the ore consists of disseminated sulphide blebs containing pyrrhotite, pentlandite and chalcopyrite in the amphibolite. The quantity of sulphides ranges from negligible to massive. The grade depends on the frequency of distribution, not on the size of the blebs which remain relatively constant at approximately one-eighth of an inch in diameter. The sulphide bleb is a crystallized droplet of sulphide liquid which separated from the silicate liquid.

The mineralized diorite has small disseminated blebs of pyrrhotite-pentlandite-chalcopyrite; but this rock never approaches ore grade unless the amphibolite intrudes it.

Different types of mineralization are known in two places. First, in the deeper parts of drill hole F-21, the sulphides, pyrrhotite-pentlandite, have a greater than normal proportion of pentlandite and occur in one-quarter inch diameter blebs in the amphibolite. Second, the massive sulphides, which occur with the felsite from 357 to 368 feet in drill hole F-24, appear to have been mobilized during a period of faulting and then injected into the fractures in the felsite.

The mineralization is independent of zones of weakness within the rock. The amphibolite and the mineralized diorite were the agents that carried the sulphides into the ore zone.

ORE SHOOTS: The ore shoots which lie within the ore zone consist of well mineralized amphibolite breccia zones with small barren inclusions. The sulphides form more than 10 percent of the rock by volume. Some ore shoots also consist of massive sulphide or sulphide stringers in fracture zones.

The nickel-copper ratio, about 2:1, is fairly uniform throughout the ore shoots; however, the amount of chalcopyrite tends to decrease, relative to the pyrrhotite-pentlandite, as the total amount of the sulphides increases. In the massive sulphides, pentlandite occurs as grains and as rims on the pyrrhotite grains. Some short intersections contain as much as 9 percent nickel, with 0.5 percent copper.

ORE MINERALS: The writer did not collect any specimens of ore to make polished sections.

In the spring of 1956, six polished sections were available in The Economic Geology Laboratory at the University of Manitoba. Three specimens of ore were obtained from a cross-cut on the 300 foot level at Kenbridge Nickel Mine. The polished sections are labelled; E-71-1A, -1B, -2A, -2B, -3A, and -3B.

Polished section E-71-2A is composed of pyrrhotite, pentlandite, chalcopyrite, pyrite, magnetite, and amphiboles. Pyrrhotite, the dominant mineral, forms independent grains. Pentlandite occurs as blebs along the rim of the pyrrhotite grains, as rims about the pyrrhotite grains, or as large grains with octahedral cleavage. Minor chalcopyrite occurs between the pyrrhotite grains. The pyrite grains are corroded by pentlandite, pyrrhotite, and chalcopyrite. Magnetite is concentrated locally in parts of the amphibole grains. The non-metallic grains in the section are amphiboles.

The other sections are similar; a greater amount of amphiboles occur in E-71-1A and -1B.

The sequence of the crystallization of the sulphide droplet is: pyrite, pyrrhotite, pentlandite, and chalcopyrite.

STRUCTURAL GEOLOGY

The ore zone is a lens shaped complex bound on either side by faults. (fig. 5, page 30) The East Fault is a rolling fault plane that separates the intrusive rocks from the greenstones on the east. It appears as a ten-foot wide shear zone in the inclined drill holes. The West Fault is a series of parallel shear zones along the west margin of the intrusion and in the adjacent greenstones. At the south end of the ore zone, the East and West Faults converge to form a wide shear zone. At the north end the faults disappear under drift. Several shear zones occur in the ore zone between the East and West Faults; even though drill holes have cut through these zones, the position of the shears is difficult to determine.

The felsite dikes cut across the ore zone nearly parallel to its length, but the dikes cannot be traced any appreciable distance due to overburden. At the south end of the ore zone, the felsite has irregular contacts with the amphibolite breccia and in the east-central part, has straight contacts with a similar rock. Many of the felsite dikes are very narrow though some may be fifteen feet wide. The chlorite in the felsite is aligned parallel to the walls of the dike; thus, the thickness of the felsite dikes can be determined from the inclination of the chlorite to the core axis.

Several distinct intrusions can be determined in the ore zone; these consist of diorite, norite, quartz diorite, mineralized diorite, or amphibolite. A large diorite mass occurs in the west-central part of the ore zone. In the east-central part, a large mass of norite outcrops and is cut in two adjacent drill holes. The mineralized diorite forms one distinct intrusion that is cut in three adjacent drill holes. The quartz diorite is cut in two adjacent drill holes. The amphibolite breccia zone with small fragments occurs as large units on surface and in many drill holes.

The great number of short core intersections of various basic intrusive rocks or of andesite with amphibolite between them probably indicate a large scale breccia zone. Blocks of andesite up to a hundred feet in one dimension occur in the ore zone.

Later information from underground workings and drilling shows that the ore zone is a lens-shaped, vertical dipping body and that the ore shoots are continuous along strike and have an almost vertical dip, i.e., parallel to the fault plane.

CHAPTER IV

CONCLUSIONS

The Kenbridge ore zone and the other basic intrusions at Populus Lake are investigated in this paper. The geology of the ore zone and that of the Populus Lake area are described. The similarities and the differences between the ore zone and the other basic intrusions are given.

The Populus Lake area consists of a greenstone belt with intrusions of basic rocks, granites, and felsite dikes. The greenstones are interbedded pillow and massive lavas, and pyroclastics. In the northern part of the area, these are deformed to form a series of tightly folded synclines and anticlines, and in the southern part to form one limb of a large fold. The larger basic intrusions occur near a major fault zone which has a trend parallel to the trace of the fold axes. The Kenbridge ore zone occurs between two branches of this fault zone. Later faults and shear zones cut across the basic intrusions. The granites occur in three parts of the area: one of these is the margin of a large batholith, the second is a stock in the greenstone belt, and the third is a group of small outcrops at Kathleen Lake. The granite stock is younger than some of the basic intrusions. The felsite dikes cut across the basic intrusions and the greenstones.

The Kenbridge ore zone is a complex of basic intrusive rocks, greenstone fragments, and felsite dikes. The ore zone is a vertical, elongated lens-shaped body cut by several parallel faults, and bound on the west by a series of parallel faults and on the east by a shear zone along an old fault.

The original basic intrusive rocks ranged from one predominantly plagioclase to another predominantly pyroxene with associated nickel-copper sulphides; all gradations exist between these two extremes. Metamorphism has saussuritized and uralitized the plagioclase and the pyroxene, respectively. These rocks appear to be derived from the same magma. The magma fractionated and the fractions probably intruded as a crystal mush. The lighter fractions intruded first and the heavier ones later. Later fractions picked up fragments of slightly older, crystallized fractions and carried these upwards to form the breccia zones.

The ore consists of pyrrhotite-pentlandite-chalcopyrite blebs which range in distribution from a light dissemination to massive. The order of crystallization of the sulphides is pyrite, pyrrhotite, pentlandite, and chalcopyrite. The sulphides in the ore zone have settled against fragments in the amphibolite breccia zones. The ore shoots appear to be continuous along strike and to have a steep dip parallel to the fault planes.

The other basic intrusions in the Populus Lake area are not as complex as the Kenbridge ore zone. They are larger units, usually composed of several rock types. Greenstone inclusions occur in the Keyhole intrusion, felsite dikes cut across several of the intrusions, but breccia zones are not observed. Older fault zones do not control the intrusions although the zones are adjacent to the Empire Fault. Later shear zones and faults cross the intrusions.

The rock types of the basic intrusions are similar to those in the ore zone. These have been compared in hand specimens and in a few thin sections. The plagioclase and the pyroxenes are saussuritized and uralitized, respectively. Only a very light dissemination of sulphides was observed in the amphibolite in the Keyhole intrusion.

The basic intrusions of the Populus Lake area may have occurred at the same time and have been derived from similar magmas, or the same magma. All of the basic rocks appear to have crystallized from definite fractions. The ore zone is unique in its manner of intrusion with its breccia zones; this is the only intrusion which has surface exposures of the heavier fraction with extensive nickel-copper mineralization.

THE GEOLOGY OF THE ORE ZON

SCALE : 1 INCH = 40 FEET

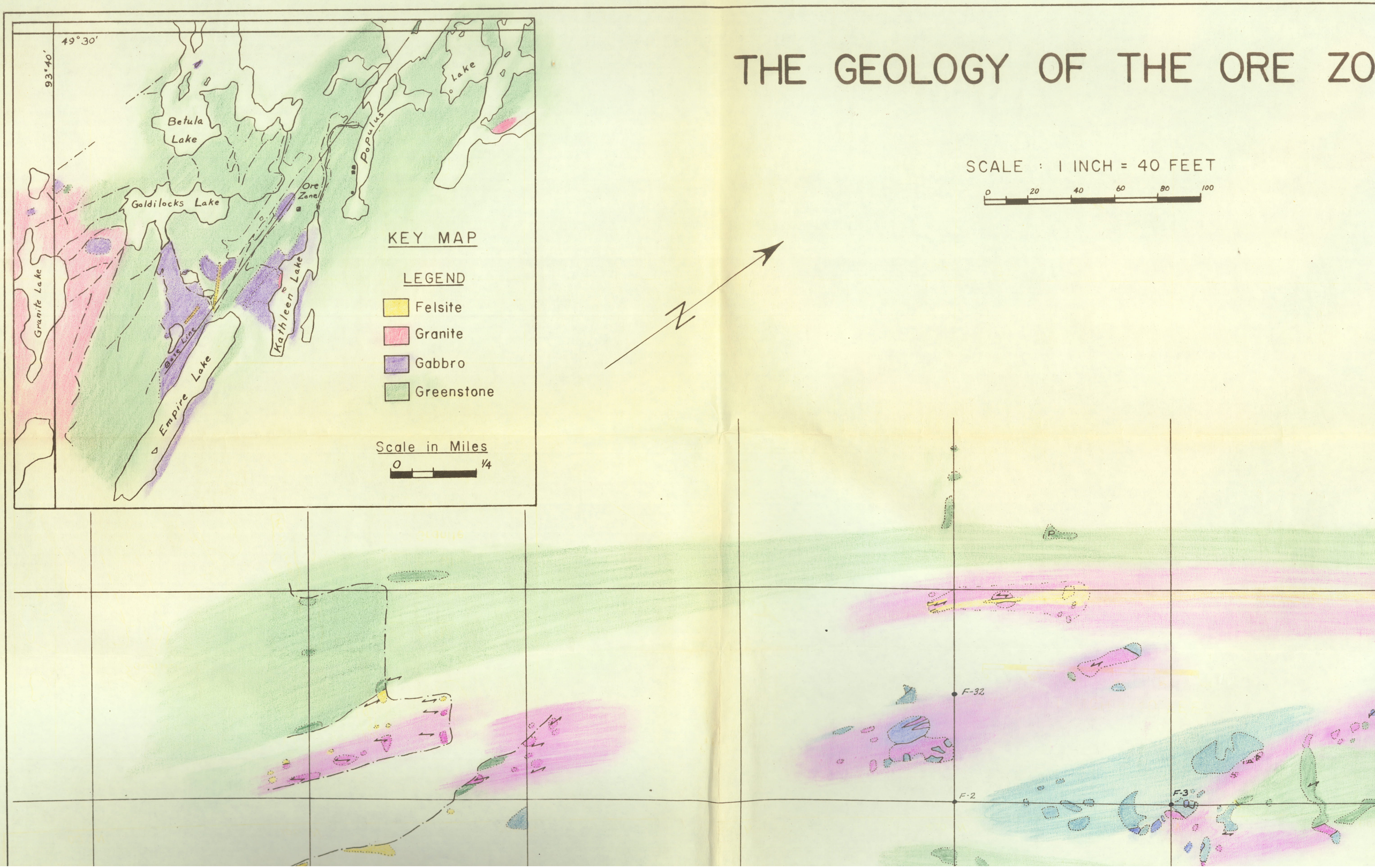
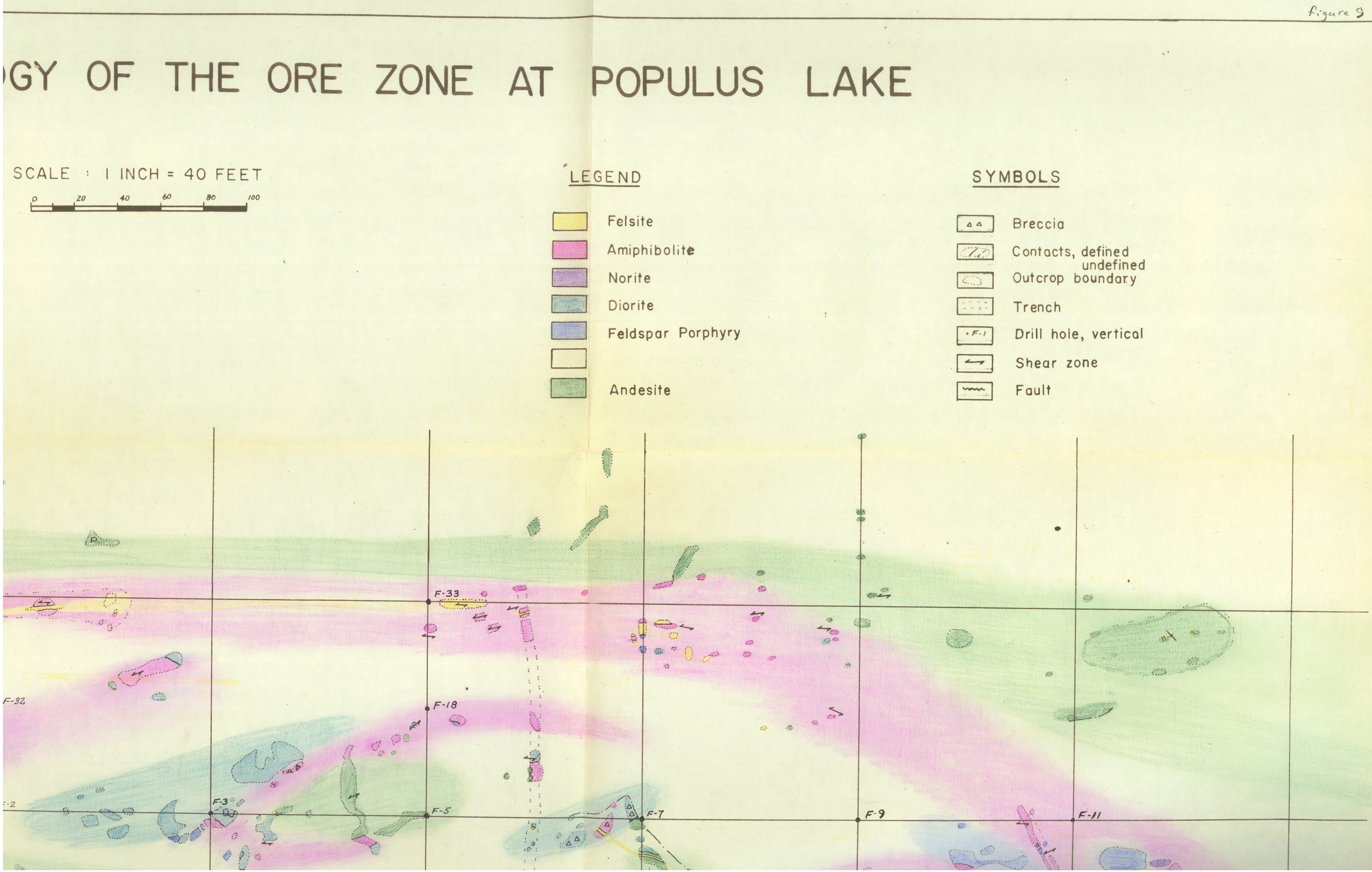
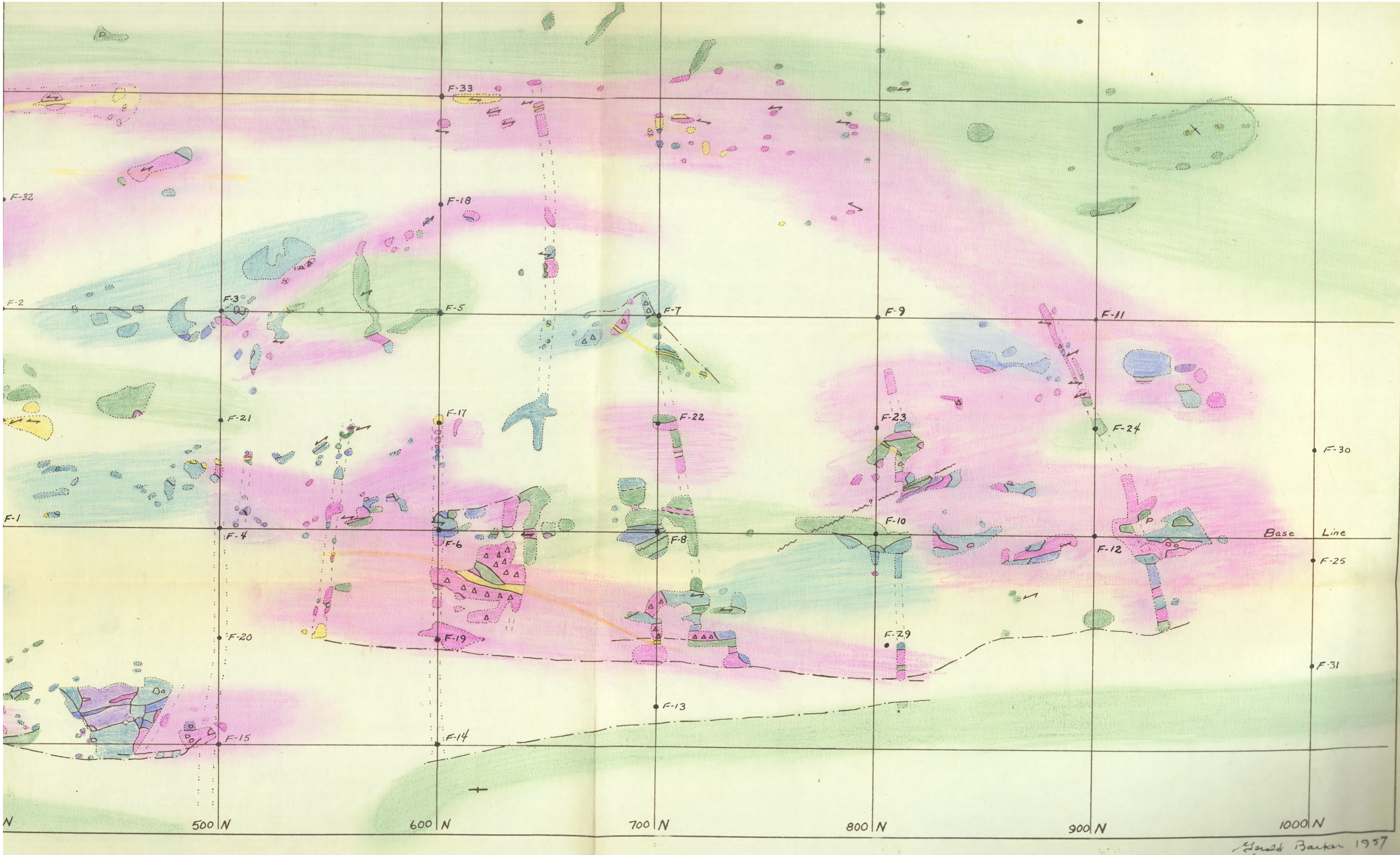


figure 9


GY OF THE ORE ZONE AT POPULUS LAKE
SCALE : 1 INCH = 40 FEET
0 20 40 60 80 100
LEGEND
Felsite
Amiphibolite
Norite
Diorite
Feldspar Porphyry
Andesite
SYMBOLS
Breccia
Contacts, defined
undefined
Outcrop boundary
Trench
Drill hole, vertical
Shear zone
Fault
F-1
F-33
F-32
F-18
F-3
F-5
F-7
F-9
F-11
P



F-33
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F-18
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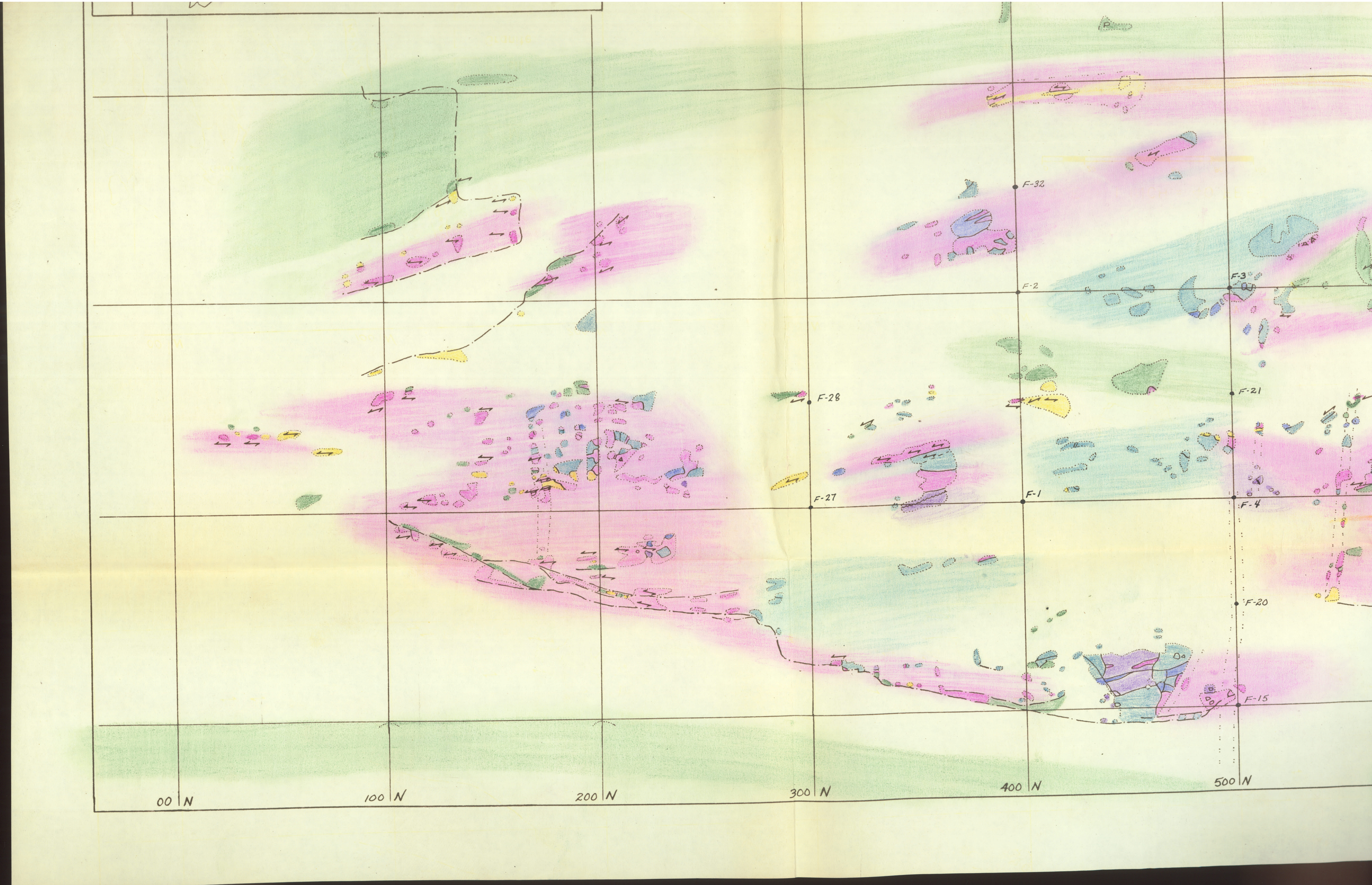
F-24
F-30
F-1
F-4
F-6
F-8
F-10
F-12
Base Line
F-25
F-19
F-20
F-29
F-31
F-13
F-14
F-15
500 N
600 N
700 N
800 N
900 N
1000 N
Gerald Barker 1957


F-32
F-2
F-3
F-21
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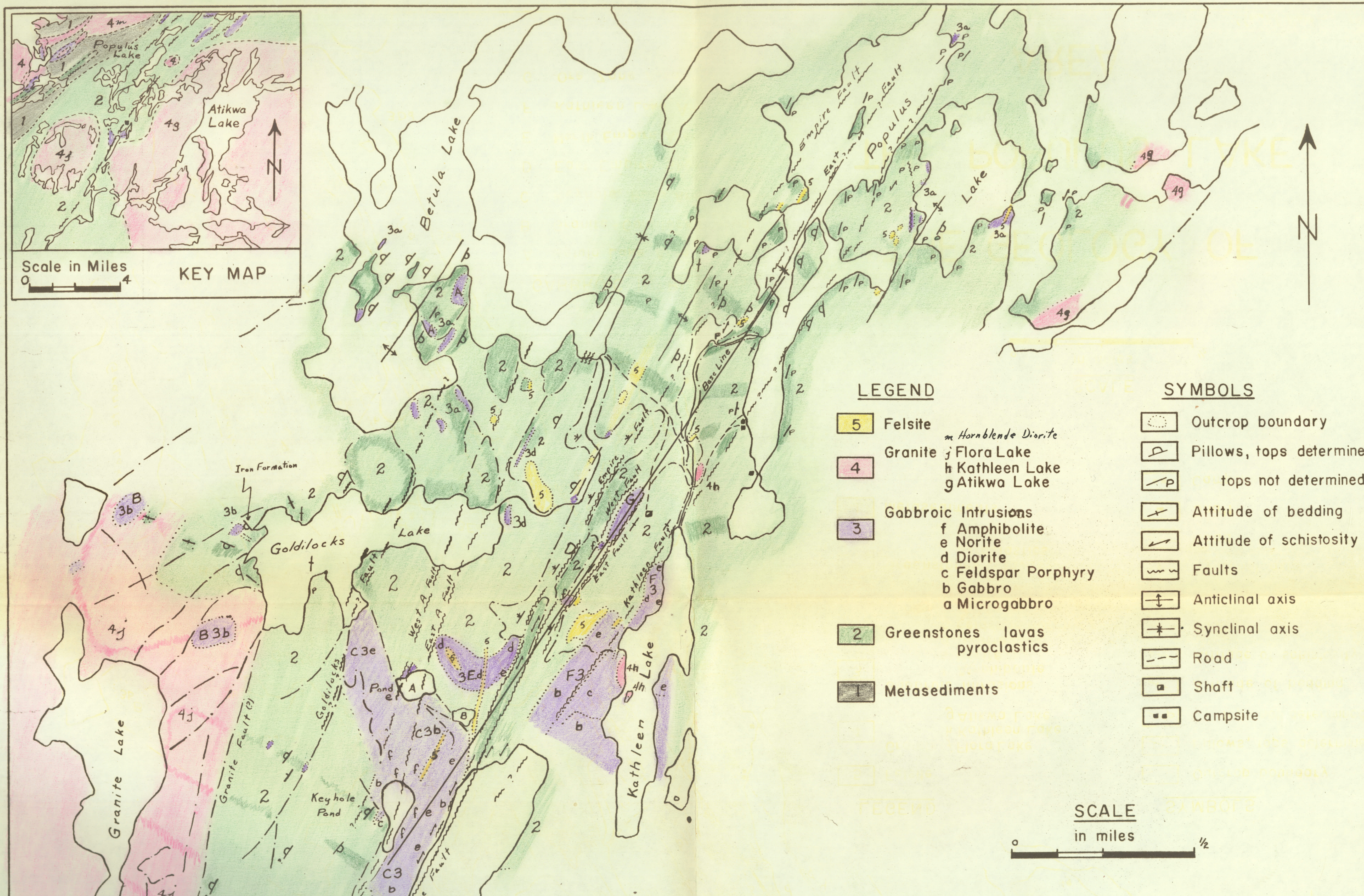
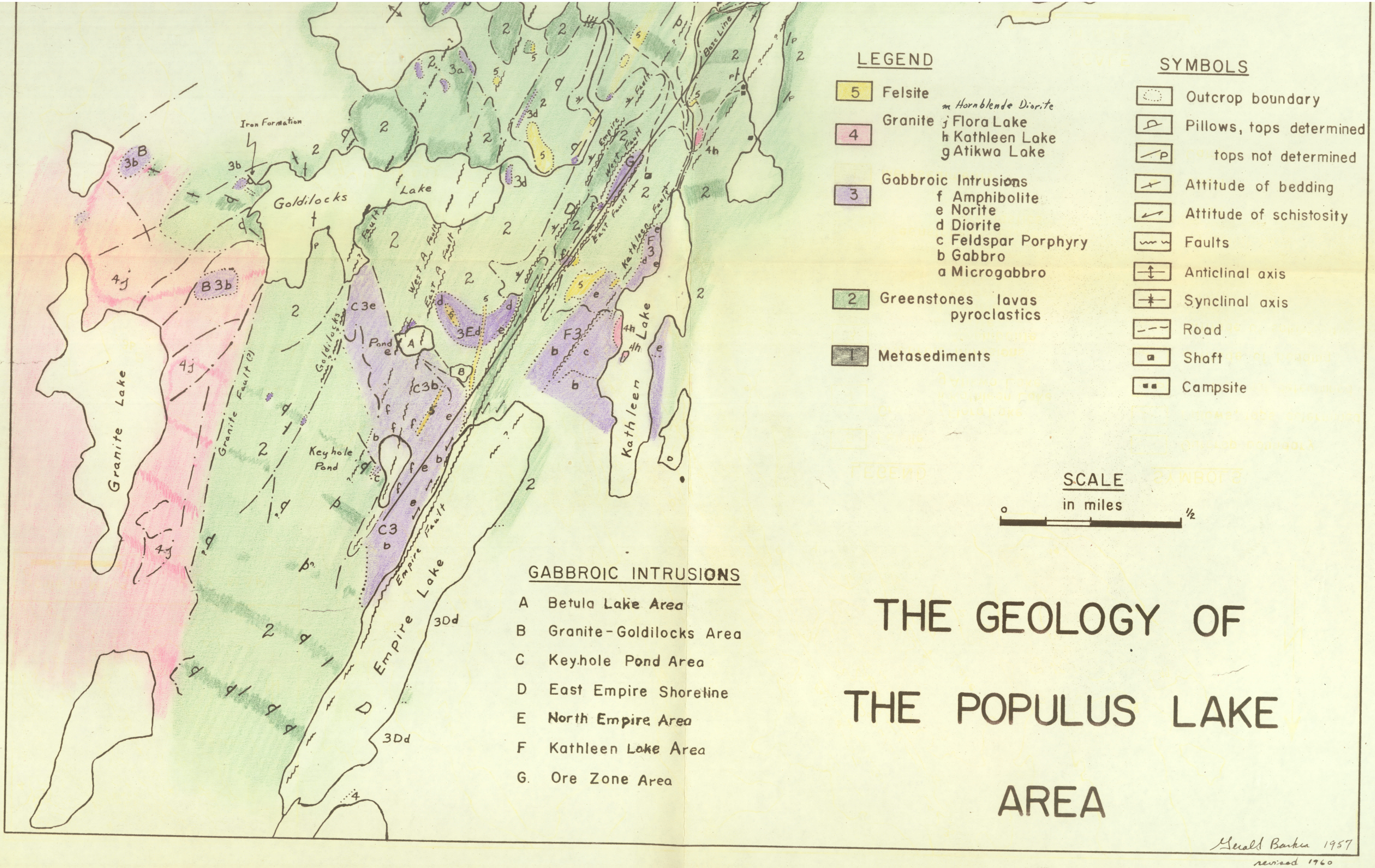
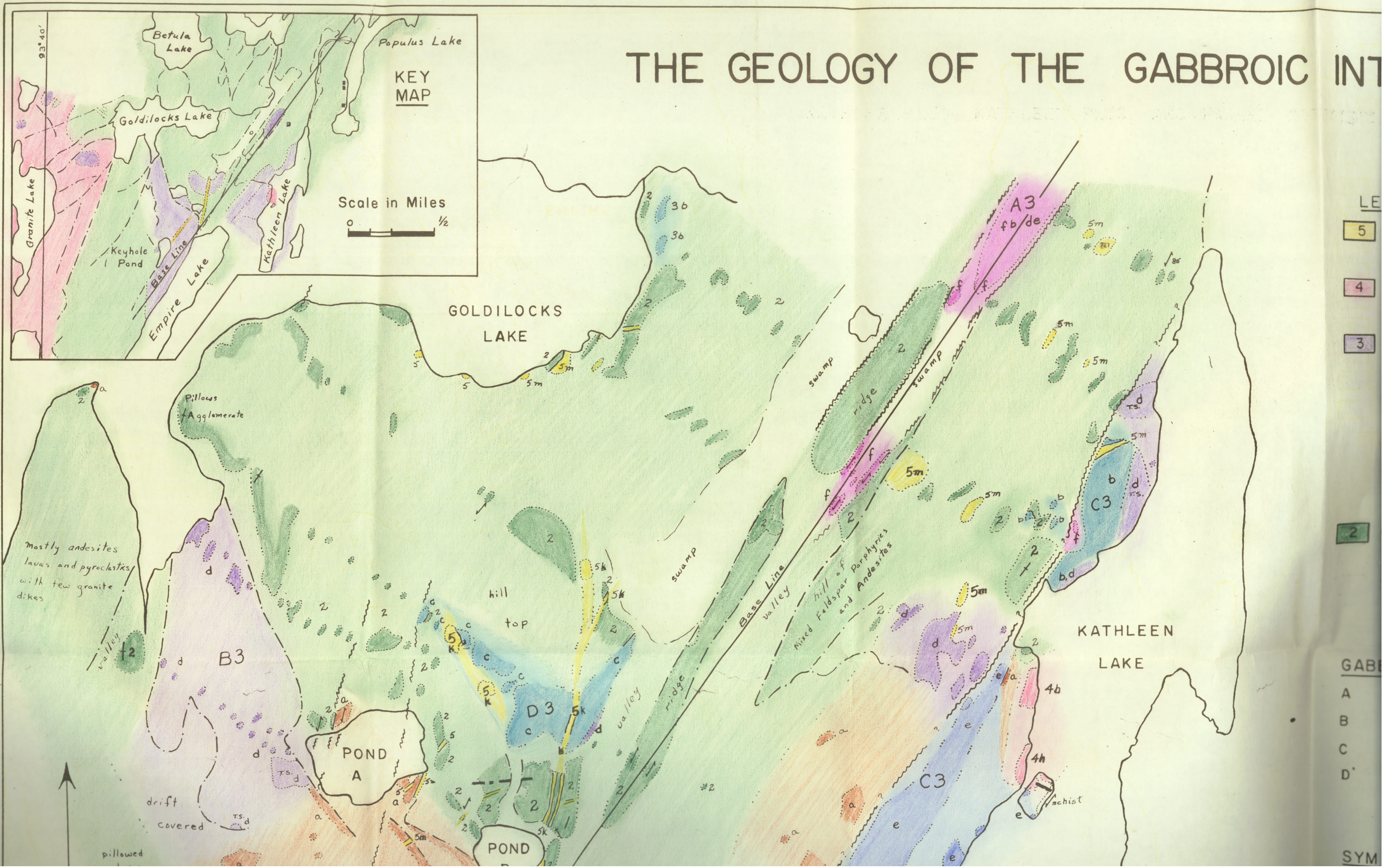
F-15
00 N
100 N
200 N
300 N
400 N
500 N

figure 7

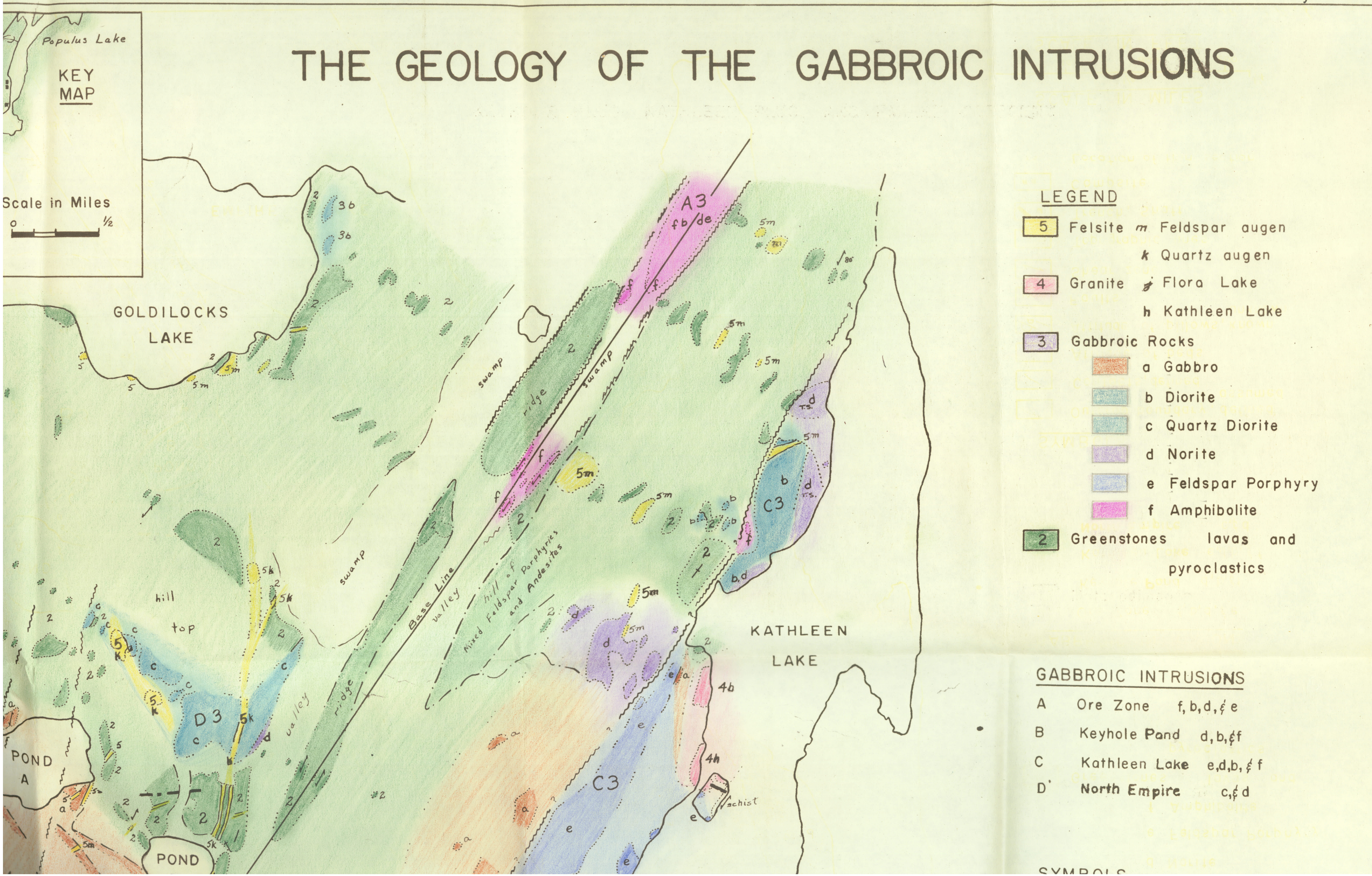


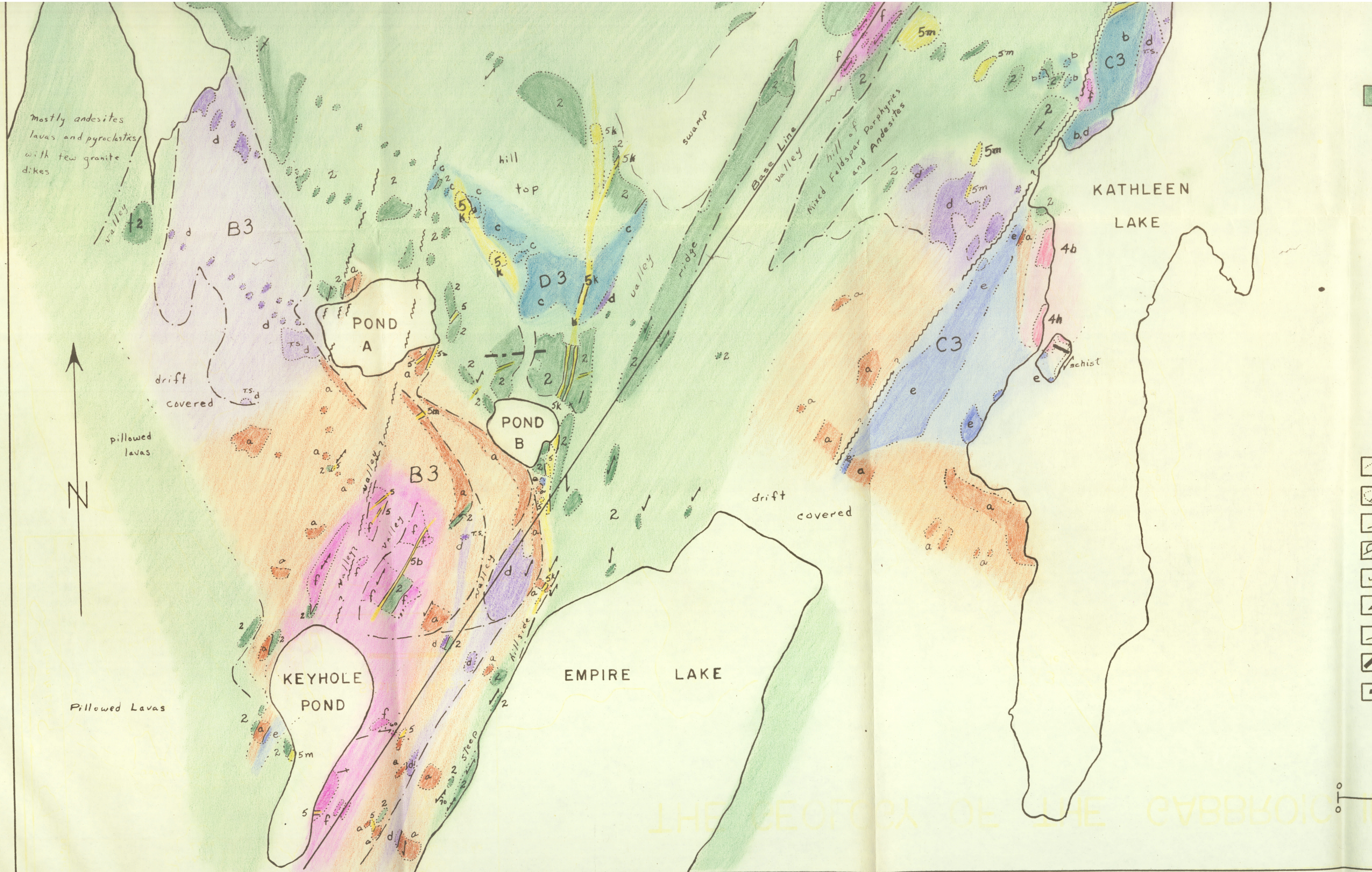
GABBROIC INTRUSIONS


LEGEND
5 Felsite
Granite m Hornblende Diorite
4 j Flora Lake
h Kathleen Lake
g Atikwa Lake
3 Gabbroic Intrusions
f Amphibolite
e Norite
d Diorite
c Feldspar Porphyry
b Gabbro
a Microgabbro
2 Greenstones lavas pyroclastics
1 Metasediments
SYMBOLS
Outcrop boundary
Pillows, tops determined
tops not determined
Attitude of bedding
Attitude of schistosity
Faults
Anticlinal axis
Synclinal axis
Road
Shaft
Campsite
SCALE
in miles
0
½
GABBROIC INTRUSIONS
A Betula Lake Area
B Granite-Goldilocks Area
C Keyhole Pond Area
D East Empire Shoreline
E North Empire Area
F Kathleen Lake Area
G. Ore Zone Area
Granite Lake
Goldilocks Lake
Iron Formation
Keyhole Pond
Empire Lake
Kathleen Lake
Granite Fault (?)
Goldilocks Fault
West A Fault
East A Fault
Empire Fault
West Fault
East Fault
Kathleen Fault
Base Line
THE GEOLOGY OF THE POPULUS LAKE AREA
Gerald Barker 1957
revised 1960

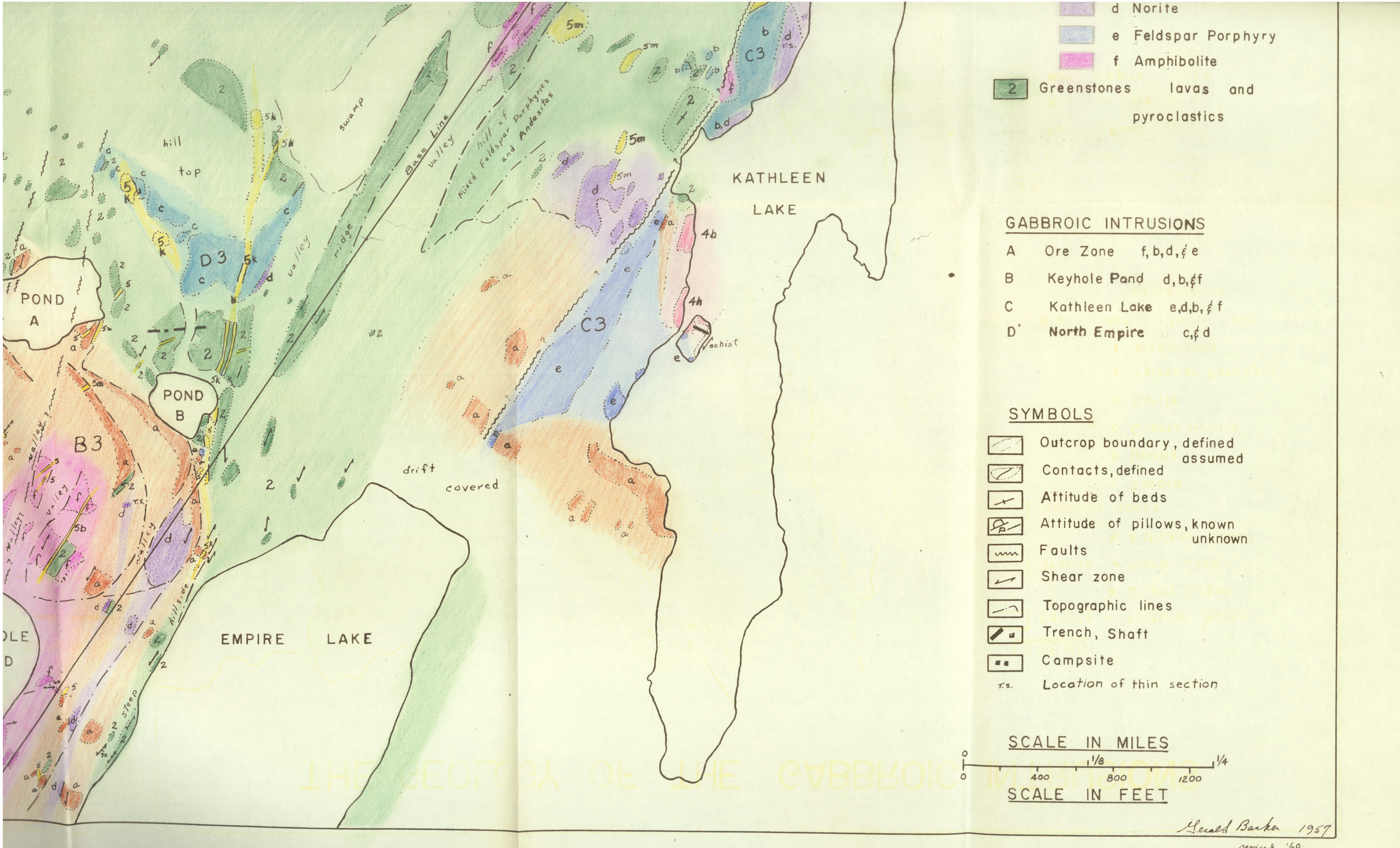

THE GEOLOGY OF THE GABBROIC INT
KEY MAP
Betula Lake
Populus Lake
Goldilocks Lake
93° 40'
Granite Lake
Keyhole Pond
Base Line
Empire Lake
Kathleen Lake
Scale in Miles
0
1/2
GOLDILOCKS LAKE
KATHLEEN LAKE
Pillows
Agglomerate
mostly andesites lavas and pyroclastics with few granite dikes
valley
B3
drift covered
pillowed
POND A
POND
hill top
D3
swamp
ridge
Base Line
valley
hill of Mixed Feldspar Porphyries and Andesites
A3
fb/de
C3
schist
LE
5
4
3
2
GABB
A
B
C
D'
SYM

THE GEOLOGY OF THE GABBROIC INTRUSIONS





mostly andesites lavas and pyroclastics with few granite dikes
valley
B3
hill
top
swamp
Base Line
valley
ridge
hill of Mixed Feldspar Porphyries and Andesites
D3
POND A
POND B
drift covered
pillowed lavas
KATHLEEN LAKE
C3
schist
N
drift covered
EMPIRE LAKE
KEYHOLE POND
Pillowed Lavas
steep hillside


d Norite
e Feldspar Porphyry
f Amphibolite
2 Greenstones lavas and pyroclastics
GABBROIC INTRUSIONS
A Ore Zone f, b, d, & e
B Keyhole Pond d, b, & f
C Kathleen Lake e, d, b, & f
D North Empire c, & d
SYMBOLS
Outcrop boundary, defined assumed
Contacts, defined
Attitude of beds
Attitude of pillows, known unknown
Faults
Shear zone
Topographic lines
Trench, Shaft
Campsite
T.S. Location of thin section
SCALE IN MILES
0
1/8
1/4
0
400
800
1200
SCALE IN FEET
Gerald Barker 1957
revised '60
KATHLEEN LAKE
EMPIRE LAKE
POND A
POND B
B3
C3
D3
Base Line
swamp
hill top
valley
ridge
hill of Mixed Feldspar Porphyries and Andesites
drift covered
schist
hillside
steep