MANITOBA
DEPARTMENT OF MINES, RESOURCES AND
ENVIRONMENTAL MANAGEMENT

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# GEOLOGY

OF THE

# RAT LAKE AREA

BY
D. C. P. SCHLEDEWITZ

1972

PROVINCE OF MANITOBA
DEPARTMENT OF MINES, RESOURCES AND
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PUBLICATION 71-2B

# GEOLOGY
OF THE
# RAT LAKE AREA

(N.T.S. Map 64B/4 and part of 64B/5W)

THE PAS MINING DISTRICT

BY
D. C. P. SCHLEDEWITZ

WINNIPEG 1972

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# INTRODUCTION

## LOCATION AND ACCESS

The Rat Lake map-area lies between latitudes 56°00′ and 56°15′ north and longitudes 99°20′ and 100°00′ west (Figure 1). It is approximately 75 miles from both Thompson and Lynn Lake and is readily accessible by air from these centres. A well travelled water route connects Rat Lake to the settlement of Nelson House, approximately 50 miles to the southeast.

## PREVIOUS WORK

The Rat Lake area was mapped on a reconnaissance scale of four miles to the inch by Wright (1953). The areas adjoining the Rat Lake area to the west, north and east were previously mapped for the Manitoba Mines Branch at one inch to one mile by Barry and Gait (1966), Pearse (1964), Milligan (1964), and Carlson (1962).

## AVAILABLE MAPS AND AERIAL PHOTOGRAPHS

The Uhlman Lake map (National Topographic Series 64B) covers this area at a scale of 1:250,000 and is available from the Map Distribution Office, Ottawa or from the Surveys Branch of the Manitoba Department of Mines, Resources and Environmental Management.

Federal-Provincial aeromagnetic maps 2387G, 2388G, 2395G and 2396G at one mile to the inch cover the Rat Lake and Pemichigamau Lake areas. An airborne magnetic and INPUT electromagnetic survey of a major part of the Southern Indian Lake project area, including Rat Lake, was flown for the Manitoba Mines Branch by Questor Surveys Limited in 1968. The results of this survey were released in June, 1969 (Manitoba Mines Branch, 1969).

Vertical aerial photographs of the area were taken in the fall of 1969 at a scale of 1320 feet to the inch. The centres of these photographs are shown on Geological Maps 71-2-2 and 71-2-3, and 71-2-6. Vertical photographs at one mile to the inch are also available for this area. Both scales of photographs can be purchased from the National Air Photo Library, Ottawa.

## PRESENT WORK AND ACKNOWLEDGEMENTS

The present work forms part of the Southern Indian Lake project (Figure 1). Mapping was carried out at a scale of one-half mile to the inch, using base maps enlarged from 1:40,000 Advance Information Prints supplied by the Department of Energy, Mines and Resources in Ottawa. The final geological maps (Maps 71-2-2, 71-2-3, 71-2-6 and 71-2-7) which accompany this report are published at a scale of 1:50,000. Adjoining areas were mapped by Campbell (1972a and b), Elphick (1972), Steeves and Lamb (1972), and Kendrick (1972).

All outcrops on the shores of Rat Lake and the Rat River were examined in detail. Inland exposures were mapped by conventional pace and compass traverses, laid out on the basis of air photo and aeromagnetic map interpretations. Excellent correlation was found between aeromagnetic data and bedrock geology. In areas of complex aeromagnetic patterns, traverses were spaced at one-quarter of a mile or less, but elsewhere traverse intervals were greater. Station locations were plotted directly on vertical aerial photographs and transferred to transparent mylar base maps.

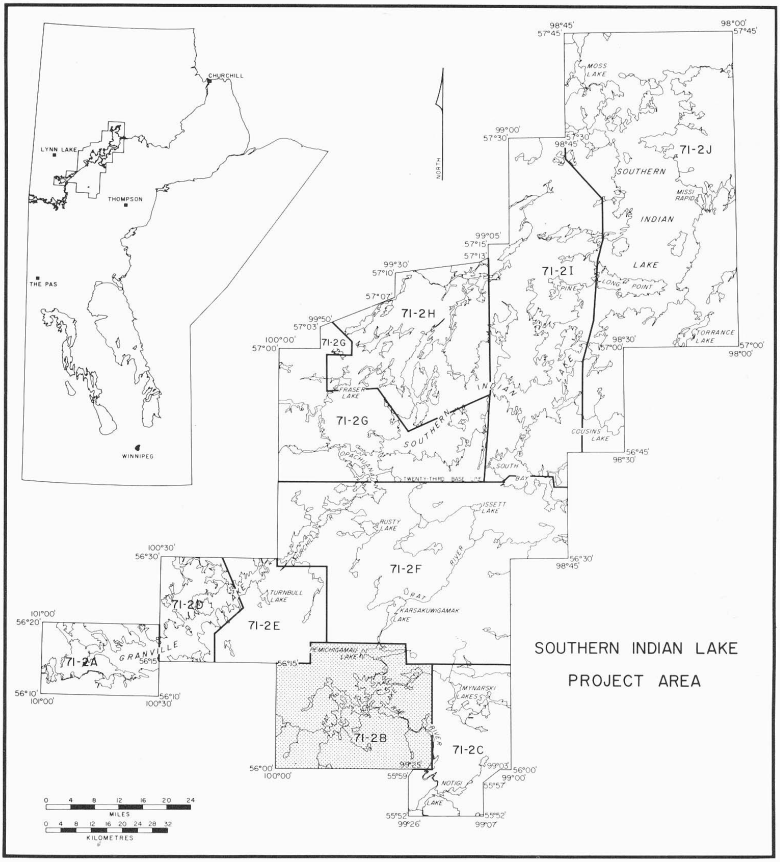



*Figure 1:* Location of map-area: Southern Indian Lake project.

The author acknowledges the enthusiastic and valuable assistance rendered in the field mapping by senior assistant D. Baldwin during the 1969 and 1970 field seasons, and by junior assistants H. Smith, G. Wallace, K. Kravec, B. Skinner, G. Daniels and K. Hunt, all of whom performed their duties in a capable and efficient manner.

## GLACIATION

Glacial striae and ice polished outcrop surfaces were observed in all parts of the area. Widespread glacial erratics range from volcanic rocks to dolomitic limestones. The general direction of ice movement was southwest (240 to 225)

A large ridge of glacial drift, approximately 1 mile in length, occurs at latitude 56°09'N and longitude 99°56'W and trends 222. Fluvial and or lacustrine clays form large deposits in the Suwannee River area and where the river enters Rat Lake. Clay ridges 40 to 50 feet thick are common. Isolated clay ridges and knolls are also present around the northern segment of Rat Lake.

## GENERAL PHYSICAL FEATURES AND RESOURCES

The main topographic feature of the area is Rat Lake, an irregular body of water comprising a complex pattern of linear bays and promontories, which reflect the underlying bedrock lithology and structure. The Rat River flows through the lake, entering from the north and discharging to the east. The Suwannee and Reading Rivers also flow into Rat Lake. Two major canoe routes pass through the lake, one linking Nelson House to the Churchill River via the Suwannee River, and the other linking Nelson House to the settlement at South Indian Lake. Other streams in the area are only partially navigable, as they are shallow and obstructed by numerous rapids and fallen trees.

Outcrop in the map-area is generally good, and approximately 40 per cent of the bedrock in the area is exposed. The paragneisses and granitic rocks form large ridges, some with relief of 150 to 200 feet above swamp-filled valleys. South of Pemichigamau Lake, the ridges become more numerous and the terrain more rugged. The Suwannee River valley and the southwest corner of the map-area have lower relief and fewer outcrops, while clay ridges and flats are common.

Approximately half of the area has been burnt over by forest fires. The northwest and southeast portions of the map-area are the most heavily fire damaged. Outcrops in these areas are excellent, but access is hampered by fallen trees and low scrub growth. Aerial photographs of burnt areas give a false impression of open treeless ridges, whereas almost all ridges have low jack pine growth or patchy clusters of burned trees. Most of the swamp-filled valleys have thick growths of black spruce and jack pine. The southwest and south-central portions of the map-area have good stands of poplar and white spruce. Some of the trees have diameters of eighteen inches at the butt.

Rat Lake is the site of a small commercial fishing operation. A clean, well maintained ice-house on the north part of Rat Lake is used to prepare pickerel, whitefish, tullibee and northern pike for shipment to Thompson.

## TABLE 1. TABLE OF FORMATIONS

| | | |
|---|---|---|
| PLEISTOCENE and RECENT | | Sand, gravel, till and clay deposits |
| | | **GREAT UNCONFORMITY** |
| PRECAMBRIAN | **INTRUSIVE ROCKS** | |
| | 19 | Diabase** |
| | 18 | Microcline pegmatite |
| | 17 | Microcline granite |
| | 16b | Granodiorite** |
| | (16a, *15a*)* | Quartz monzonite to granodiorite |
| | 15 | Hornblende syenite |
| | 14c | Altered ultramafic rock |
| | 14b | Meta-gabbro |
| | 14a | Olivine gabbro and hornblende gabbro |
| | 13 | Pyroxene diorite |
| | 12 | Tonalite |
| | 11 | White pegmatitic granodiorite |
| | (10, *12*)* | Magnetiferous quartz diorite |
| | 9 | Meta-quartz diorite |
| | **SICKLE GROUP** | |
| | *8c** | Arkose-derived gneisses and migmatite |
| | *8b** | Impure arkose, minor quartzite |
| | 8 | Quartzo-feldspathic biotite (hornblende) gneiss |
| | 7 | Hornblende-diopside gneiss |
| | 6 | Hornblende-biotite-magnetite gneiss |
| | 5b, c | Biotite-magnetite gneiss (5c restricted to Mynarski Lakes area) |
| | 5a | Weakly magnetiferous quartzo-feldspathic gneiss |
| | **GNEISSES OF UNKNOWN AFFINITY** | |
| | 4 | Cordierite-sillimanite-anthophyllite-biotite gneiss |
| | 3a, b | Quartzo-feldspathic gneiss and migmatite |
| | **WASEKWAN AND/OR SICKLE GROUP** | |
| | 2e | Hypersthene-garnet-hornblende gneiss and associated cordierite gneiss** |
| | 2d | Gneissic meta-diorite** |
| | 2c | Hornblende-biotite-magnetite gneiss |
| | 2b | Amphibolite (with thin calc-silicate and/or carbonate layers) |
| | 2a | Amphibolite |
| | **WASEKWAN GROUP** | |
| | 1 | Pelitic gneiss |

*Note: The map-area covers portions of four map-sheets (Rat Lake, Map 71-2-2; Mynarski Lakes, Map 71-2-3; Pemichigamau Lake, Map 71-2-6; Earp Lake, Map 71-2-7). Map-units which occur in the Rat-Mynarski Lakes area are identified by upright numbers; italicized numbers refer to those units which occur in the Pemichigamau-Earp Lakes area.

**Occurs only in the Mynarski-Notigi Lakes map-area (Elphick, 1972).

# GENERAL GEOLOGY

## INTRODUCTION

Precambrian sediments in the Rat Lake area have undergone polyphase deformation and metamorphism, and have been intruded by a broad range of igneous rocks. The resulting paragneisses and amphibolites (Table 1) are considered to be the equivalents of Wasekwan and Sickle Group rocks in the Suwannee Lake map-area (Barry and Gait, 1966; Campbell, 1972a). This correlation is based on the similarity of the lithologic sequences and the assumed continuity of lithologies from one area to the other, based on aeromagnetic data. The Wasekwan Group is represented by pelitic gneiss (biotite-plagioclase-quartz gneiss) containing variable amounts of garnet, sillimanite and cordierite, and probably derived from metagreywacke. Magnetiferous quartzo-feldspathic paragneisses, containing variable amounts of hornblende, have been correlated with the Sickle Group. Both these major paragneiss sequences display variable degrees of anatexis. Lying between them is a zone of amphibolite and interlayered biotite-hornblende-plagioclase-quartz gneisses.

The paragneisses have undergone regional metamorphism to the amphibolite facies. The cordierite-amphibolite facies of Abukuma-type metamorphism is the most evident. The paragneisses were intruded by large batholithic masses of quartz monzonite to granodiorite, and smaller stock-like bodies of quartz diorite and minor basic to ultrabasic intrusions. Initial folding about east-west axial planes caused overturning of the Wasekwan Sickle Group sequence. This inversion persists into the Mynarski Lakes map-area (Map 71-2-3). Subsequent folding was in part synchronous with the emplacement of the batholithic masses of quartz monzonite-granodiorite (16a, *15a*) and was itself followed by shearing, and a final phase of open folding. Intersection of the present day erosion surface with the resulting structures has produced a complex distribution of rock types.

## WASEKWAN GROUP

### PELITIC GNEISS (1)

Pelitic gneiss is common in the southern part of the map-area and forms the principal map-unit in the southwest (Figure 2). It is correlated with Wasekwan-derived paragneisses of the Suwannee Lake area (Barry and Gait, 1966, unit 7). These gneisses extend into the Rat Lake area and have a similarly low magnetic expression (2200 to 2600 gammas). The pelitic gneiss is spatially continuous with rocks of a similar appearance and magnetic intensity in the Mynarski Lakes area (Elphick, 1972).

The gneiss (1) is well layered and consists of variable proportions of pale grey, fine-grained, weakly schistose layers (mainly plagioclase, quartz, biotite and garnet) alternating with massive, white, quartzo-feldspathic *lits* (Plate 1A). Graphite is a common constituent, and occurs as clots in the granitic *lits*, or interleaved with the biotite in the fine-grained layers. Variations in the biotite content gives rise to a weak compositional layering in the fine-grained portion of the rock. Granitic *lits*, which stand out on weathered surfaces, consist mainly of coarse white plagioclase and quartz, but are locally pale pink where microcline is present. Biotite is coarser grained where the *lits* are abundant, and forms selvages along their margins. Layered gneiss (1) grades locally into strongly veined gneiss and white pegmatitic granite with mafic schlieren.

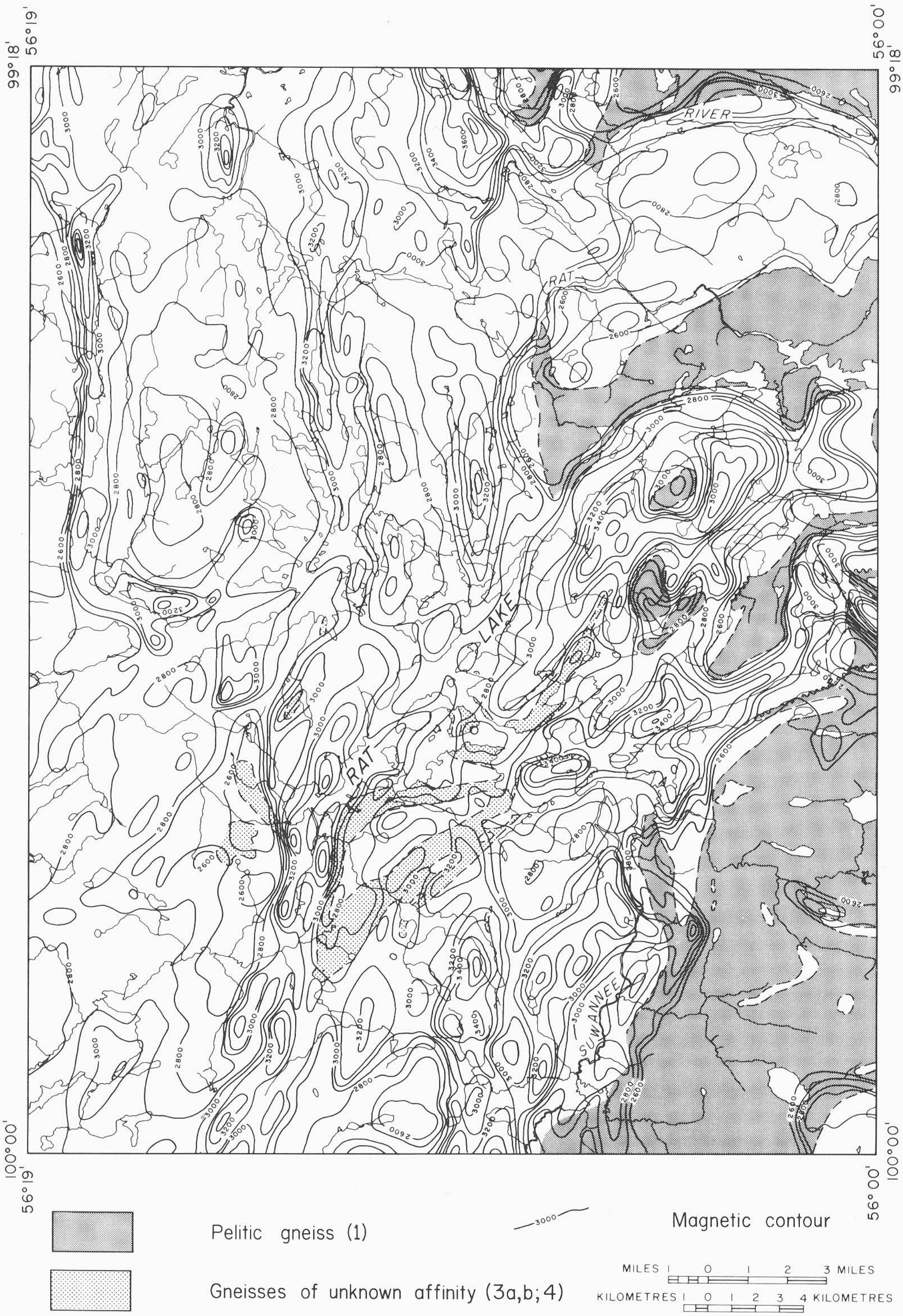



*Figure 2:* Distribution of Wasekwan-derived gneisses (1) and gneisses of unknown affinity (3a, b; 4), superimposed on simplified aeromagnetic map.

The typical mineralogical composition of the pelitic gneiss, based on thin section examination, is: plagioclase (40%), quartz (30%); biotite (20-25%); microcline (sporadic), garnet (5%), and minor cordierite, sillimanite, muscovite and graphite. Quartz and plagioclase form a granoblastic mosaic containing porphyroblasts of mauve to red garnet. The reddish brown biotite shows preferred orientation parallel to both the main layering, and to a secondary cross-foliation. The secondary cross-fabric is usually parallel to the axial planes of microcrenulations. Minor muscovite and graphite are associated with the biotite. Graphite also occurs as thin seams of very fine grains parallel to the layering. Microcline varies from small interstitial grains to slightly elongate idioblastic porphyroblasts. The latter are highly sieved with abundant grains of quartz, biotite and plagioclase. These spongy porphyroblasts have overgrown the main biotite fabric, although in places they also contain the second biotite cross-fabric. Cordierite occurs sporadically as coarse grains and porphyroblasts. It commonly includes fine needles of sillimanite which also may occur in porphyroblastic clusters.

## WASEKWAN AND/OR SICKLE GROUP AMPHIBOLITES AND BASIC GNEISSES (2)

### AMPHIBOLITE (2a)

A well layered amphibolite (2a) (Plate 1B) occurs at or near the major lithologic break between the pelitic gneiss (1) (Wasekwan Group) and the suite of quartzofeldspathic gneisses (Sickle Group). The amphibolite occurs either as a fairly continuous marker zone at this sharply defined break in lithology, or in places it occurs as discontinuous layers in the pelitic gneiss (1) up to one kilometre or more from the Wasekwan-Sickle contact. These layers range in thickness from 30 to 500 feet (9-150 m) and become more numerous towards the contact.

The amphibolite (2a) may be either volcanic or sedimentary in origin. It is black to greenish black with thin, pale olive green layers. In places, lensoid patches of greenish brown granular plagioclase impart a streaky appearance to the dark hornblendic layers. Sulphides (mainly pyrrhotite with minor chalcopyrite) are sporadically disseminated throughout the amphibolite. The dark layers are fine grained equigranular and granoblastic. They contain 60 to 65 per cent stubby hornblende (pleochroic to greenish brown); 30 to 35 per cent plagioclase (andesine-labradorite); and 5 per cent quartz. The pale green layers are equigranular with fine-grained diopside and tremolite (20 to 25%) evenly distributed throughout a medium-grained mosaic of andesine-labradorite. The latter shows partial alteration to sericite, epidote and calcite.

Hypersthene-bearing phases occur sporadically within the amphibolite as greenish brown, fine-grained, equigranular lensoid zones from 10 to 20 feet (3-6 m) in length. Their composition is 50 per cent andesine-labradorite, 30 per cent hornblende; 6 per cent quartz; 5 per cent diopside, 3 to 50 per cent hypersthene, 3 to 5 per cent biotite, 2 per cent tremolite and minor disseminated pyrrhotite. Both hornblende (strongly pleochroic to dark greenish brown) and hypersthene form stubby rounded grains. Examples of this rock type occur at stations 24-0-1517 (lat. 99°55′10″; long. 56°03′42″), and 24-0-1896 (Lat. 56°00′15″; long. 99°51′55″) in the southwest corner of Map 71-2-2. The fine-grained granoblastic texture and the presence of hypersthene may be indicative of metamorphism to the hypersthene granulite facies. However, it is uncertain whether the hypersthene-bearing lenses represent basic intrusions into the amphibolite prior to metamorphism, or whether they are local developments or relics of a hypersthene granulite facies.

## CALC-SILICATE ROCK (2b)

This rock is of minor extent in the map-area, but because of its distinctive character, it has been treated as a separate subunit. It outcrops at three localities in the map-area: one mile south of the mouth of the Suwannee River (Map 71-2-2); seven miles southeast of the above location (Map 71-2-2); and 8 miles (13 km) north of Misinagu Lake (Map 71-2-3).

The rock comprises alternating calcite-rich layers and layers rich in hornblende and diopside. The layering is particularly prominent on outcrop surfaces owing to the differential weathering of the calcite-rich layers. The latter are predominantly white, but contain prominent dark, honey brown crystals of diopside and scattered amber coloured granules of sphene. Tremolite, epidote, and shimmer aggregate after plagioclase are visible in thin sections. Lenses and thin discontinuous layers of quartz and microcline (4 to 6 mm thick), within the calcitic layers, impart a ribbed appearance to the weathered surface; thin sections show the microcline to be fine grained while the quartz is considerably coarser and has strong strain extinction.

Dark layers (5 to 15 cm thick) rich in hornblende and diopside, are much more resistant to weathering than the calcite-rich layers. They weather with a spotted buff colour, but fresh surfaces are pale green to dark grey-green. The hornblende is greenish brown and plagioclase is highly altered to sericite and calcite. Minor iron sulphides and sphene are also present; the latter is evenly distributed throughout the rock as euhedral to anhedral grains (up to 3%). Thin layers of quartz, altered plagioclase and calcite also occur in the dark layers; quartz is commonly drawn out into lenses which define a cataclastic foliation parallel to the layering.

A white acidic granitoid rock (1 to 4 m thick), is sporadically interlayered with the calc-silicate rock. It consists of quartz (65%), microcline (33%), biotite (1%), and disseminated pyrrhotite and pyrite (1-2%).

The calc-silicate rock occurs as part of the transitional sequence between the Wasekwan and Sickle-derived gneisses, forming discontinuous layers in the biotite and hornblende-bearing gneisses (units 5b and 6) of the Sickle Group. The rocks on either side of the calc-silicate rock are generally sheared and heavily intruded by microcline pegmatite. The calc-silicate unit itself may have been derived from the amphibolite of unit 2a by shearing and metasomatism, which produced a secondary layering defined by the calcitic and quartz-microcline layers.

## HORNBLENDE-BIOTITE-MAGNETITE-QUARTZ GNEISS (2c)

This rock type is also of limited occurrence and has been mapped in only two places: (i) on the shore of Rat Lake, 1 mile (0.6 km) south of the mouth of the Suwannee River (Map 71-2-2), where it is interlayered with the calc-silicate rock (2b); and (ii) 5½ miles (8 km) east of the most southerly tip of Rat Lake (Map 71-2-2), where it occurs as a layer 100 feet (30 m) thick, interlayered with the amphibolite (2a).

The gneiss is well layered but weathers with an even surface. Layering is defined by variations in the proportions of biotite and hornblende which vary inversely with one another across strike. The more hornblende-rich portions of the gneiss comprise grey and pale greenish pink layers, consisting of hornblende (10-15%), biotite (8%), plagioclase and microcline (60%), quartz (20%), and magnetite (1%). The biotitic portions of the gneiss comprise 15-20 per cent biotite, 3-5 per cent hornblende, and 3 per cent magnetite. Widely spaced pale pink microcline-rich layers alternate with the dark grey and weakly schistose biotitic layers.

## GNEISSES OF UNKNOWN AFFINITY (3a, b; 4)

These gneisses, which occur mainly west and northwest of Rat Lake (Map 71-2-2) comprise a belt of highly granitized paragneisses intruded by quartz monzonite (16a) and granite (17). Because of the absence of the amphibolite (2a) in this area and the high degree of migmatization, recrystallization and potash metasomatism which these rocks have undergone, neither of the two suites of rocks can be readily placed in the Wasekwan-Sickle lithologic sequence. Unit 4 may represent a highly altered pelitic gneiss (1) of the Wasekwan Group, in contact with an arkose-derived gneiss of the Sickle Group (5a). Alternatively, both units (3) and (4) may belong to the Sickle Group. Either interpretation can be accommodated in the structural interpretation.

### QUARTZO-FELDSPATHIC BIOTITE GNEISS (3a) AND MIGMATITE (3b)

The gneiss is generally white, with a smoothly weathered pale buff surface. It splits easily along thin biotite partings, spaced 2 to 5 cm apart. In places, these biotite seams reach a thickness of 8 mm. The rock is fine to medium grained and consists of oligoclase-andesine (45-50%), quartz (30%), microcline (10-15%), and biotite (5-10%). The microcline occurs either in distinct layers or irregular patches in the gneiss; inequigranular quartz and plagioclase form a mosaic for the disseminated biotite. The biotite is olive brown and displays a good preferred orientation parallel to the parting direction. Unit 3b is compositionally similar to unit 3a but the biotite partings are more widely spaced and microcline-plagioclase-quartz *lits* are an integral part of the layering.

### CORDIERITE-SILLIMANITE-ANTHOPHYLLITE-BIOTITE GNEISS (4)

This highly variable unit extends intermittently southeast across the centre of the map-area for at least 15 miles (24 km). It occurs in a deformed zone that has undergone plutonic intrusion and potash metasomatism; the gneiss itself was derived from a pelitic or semi-pelitic paragneiss through partial anatexis and granitization.

Outcrops are buff coloured and have a ribbed appearance due to differential weathering. The principal rock type consists of an inequigranular quartzo-feldspathic mosaic (75%) with oriented brown biotite (15-20%) and variable amounts of cordierite (0-6%), sillimanite (0-5%), and garnet (3%). The feldspar (50-55%) consists of variable proportions of plagioclase and microcline. Other minerals, found as local segregations and alteration products include anthophyllite, tremolite, magnetite, chlorite and muscovite. The following mineral assemblages form discontinuous layers and thin lenses:

a) biotite-plagioclase-microcline-quartz with variable garnet, cordierite and sillimanite, grey to buff.
b) cordierite-garnet-anthophyllite, grey-green.
c) biotite-cordierite-quartz-plagioclase, dark grey.
d) tremolite-bearing amphibolite, grey brown, associated with (b).

In general, the gneiss is heavily veined by plagioclase-microcline-quartz *lit* and is folded into tight to isoclinal asymmetric folds with an axial planar foliation. An early generation of sillimanite is folded with the layering and a second generation of sillimanite is axial planar to these folds. The habit of the sillimanite of both ages is very similar; in general both occur as elongate porphyroblasts in a quartzo-feldspathic mosaic. The sillimanite also occurs as smeared out sheets in shear planes which are parallel to the axial planes and limbs of the tight to isoclinal folds. The shearing sppears to be later than the generation of the axial planar sillimanite and involved some recrystallization of the sillimanite. Muscovite formed during the later stages of the shearing as felty sericite and large idioblastic grains. Cordierite occurs as fine to medium sized grains in folded quartz-rich lenses and thin layers, 5 mm to 2 cm thick; and as elongate porphyroblasts parallel to the axial planes of the tight to isoclinal folds. The cordierite porphyroblasts commonly contain inclusions of swirled and microfolded fibrolite. The elongation of the porphyroblasts and the folding of cordierite-quartz layers both indicate a phase of deformation post-dating crystallization of the cordierite. Garnet occurs as clear porphyroblasts, some with idioblastic rims. Two distinct ages of garnet growth are represented, the idioblastic rims corresponding to a period of metamorphism under static conditions.

Three compositionally distinct types of layers also occur sporadically in unit 4, and are best exposed on the shores of Rat Lake. These layers are tightly folded, with boudins developed on the fold limbs:

(i) medium-grained amphibolite, forming discontinuous layers which are complexly folded with the cordierite gneiss;

(ii) black equigranular fine-grained amphibolite, containing red pin-head garnets. This amphibolite, appears to form a folded and boudined layer, 0.6 to 1.5 m thick, along the west shore of Rat Lake;

(iii) dark grey magnetite-garnet-biotite granulite (textural granulite), forming a layer 15 to 30 cm thick, with a maximum observed strike length of 60 m. The granulite is buff on the weathered surface, highly resistant to weathering, and is composed of magnetite (3-4%), garnet (3%), biotite (15%), plagioclase (50-55%), and quartz (25%). The texture is fine grained granoblastic with a weak biotite foliation.

## SICKLE GROUP

### INTRODUCTION

Sickle Group rocks comprise a sequence of quartzo-feldspathic gneisses which stratigraphically overlie the Wasekwan-derived pelitic gneiss (1). The division of the Sickle Group into units is based on the variable content of magnetite, biotite, hornblende and diopside. The weakly magnetiferous quartzo-feldspathic gneiss (5a) is light grey and contains up to 10 per cent biotite and 1 per cent magnetite, whereas the dark grey biotite magnetite gneiss (5b) contains 20-25 per cent biotite and 3 per cent magnetite. The hornblende biotite magnetite gneiss (6) contains 10 per cent hornblende and 3 per cent magnetite. The presence of diopside as well as hornblende, and a pronounced pink and grey colour banding, distinguish the hornblende-diopside gneiss (7). A pronounced orange-brown colour, laminated structure, and minor amounts of biotite and hornblende characterize the quartzo-feldspathic biotite-hornblende gneiss (8). In many localities, rapid variations in biotite content, on outcrop scale, make the definition of the boundary between gneisses 5a and 5b difficult. Equal difficulty is encountered in defining the boundary between gneisses 5b and 6 due to similarly rapid variations in the hornblende content. The transitional nature of units 5a and 5b and units 5b and 6, may reflect original sedimentary facies changes. On a larger scale, the stratigraphic position of the gneisses of the Sickle Group varies such that the quartzo-feldspathic gneiss which is in contact with the Wasekwan pelitic gneiss (1) may be either unit 5a, 5b, or 6. For the most part however, the weakly magnetiferous quartzo-feldspathic gneiss (5a) forms the basal unit of the Sickle Group.

## WEAKLY MAGNETIFEROUS QUARTZO-FELDSPATHIC GNEISS (5a)

This unit occupies a large area in the southeast and extends intermittently northwest across the map-area (Map 71-2-2). Other sizeable bodies occur along the Reading and Rat Rivers (Maps 71-2-2 and 71-2-3). In the extreme southeast corner of the map-area (Map 71-2-3), a large mass of quartz monzonite (16a) is separated from pelitic gneiss (1) by persistent belts (commonly about one-quarter mile wide) of unit 5a.

Outcrops are smooth, and weather buff to pale grey; they show granular quartz and feldspar, and about 1 per cent disseminated magnetite. Biotite is uniformly distributed throughout the rock and also forms thin layers or partings with highly variable spacing. The main constituents of the gneiss are microcline, plagioclase and quartz, with olive green to dark brown biotite (5-10%). Stained slabs show compositional layering defined by variable proportions of microcline and plagioclase. Grain size is fine to medium and the texture is inequigranular-granoblastic with a weak preferred orientation of the biotite. Small amounts of sillimanite occur locally and form elongate porphyroblasts.

Two types of granitic mobilizate occur within the gneiss: pale, flesh pink, medium-grained *lits*; and deep red, pegmatitic, microcline granite which occurs as *lits*, dykes and larger irregular bodies which cut the earlier pink *lits*. The red pegmatitic granite contains large irregular clots of magnetite, and the only observed occurrence of cordierite in unit 5a forms small anhedral dark blue crystals in this pegmatite. Green to reddish calcium-rich lenses up to 0.5 × 1.0 m occur sporadically within the gneiss (5a). These lenses are contained within the layering in the gneiss and are composed of plagioclase and quartz. The plagioclase is almost completely altered to epidote, zoisite and clinozoisite.

## BIOTITE-MAGNETITE GNEISS (5b)

This unit occurs in the southern part of the map-area, and in many places it is in direct contact with the pelitic gneiss (1) of the Wasekwan Group. The actual contact relationship, however, is obscured by intense shearing, intrusions of microcline granite-pegmatite and quartz veins. Outcrops of unit 5b are dark grey and weather evenly. The rock is moderately schistose and thin discontinuous layers of plagioclase and quartz impart a weak layering. Thin sections and stained slabs show fine to medium-grained oligoclase-andesine (40-45%), quartz (28%), variable amounts of microcline (1-20%) and biotite (20-25%), the latter showing a preferred orientation. Magnetite (3%) is uniformly disseminated. The texture is inequigranular granoblastic with local cross-orientation of biotite. A variable spotted appearance is caused by the presence of 1-10 per cent plagioclase-quartz knots with cores of magnetite.

## HORNBLENDE-BIOTITE-MAGNETITE GNEISS (6)

The hornblende-biotite-magnetite gneiss occurs in contact with units 5a and 5b in the southern part of the map-area. In the southeast portion of the Rat Lake area (Map 71-2-2), the gneiss (6) is tightly folded and occurs in the cores of antiformal structures, separated from the Wasekwan Group pelitic gneiss (1) by unit 5a. The same relationship is present in the southwest corner of the Mynarski Lakes area (Map 71-2-3), where the hornblende-biotite-magnetite gneiss flanks a stock-like body of quartz monzonite (16a). On the basis of this relationship and the inferred structural inversion of the sequence, the hornblende-biotite-magnetite gneiss (6) has been placed within the Sickle Group, stratigraphically above the quartzo-feldspathic gneiss (5a). In the Suwannee River region, however, (Map 71-2-2) unit 6 lies between the pelitic gneiss (1) and the quartzo-feldspathic gneiss (5a). It is uncertain whether this variation in the stratigraphic sequence is due to faulting or to a sedimentary facies change. Unit 6 also occurs on the northwest arm of Rat Lake, and in the western part of the Mynarski Lakes area. In both localities it is in contact with the weakly magnetiferous quartzo-feldspathic gneiss (5a).

The gneiss (6) varies from a well layered rock containing only 10 to 15 per cent pegmatite layers, to a highly mobilized diatexite in which only sporadic rafts and schlieren of the layered gneiss remain. The well layered gneiss consists of alternating grey-pink and grey weathering layers. The grey-pink layers are fine to medium grained and consist of variable proportions of microcline and plagioclase (together comprising 50-60% of the rock), quartz (26%), bright green hornblende (10%), olive brown biotite (5%), magnetite (3%), and apatite (1%). The grey layers are fine grained and granoblastic with a moderately preferred orientation of the biotite, parallel to the layering. The grey layers are composed of quartz (22%), biotite (15-20%), bright green hornblende (10%), magnetite (3%), apatite (1.5%), and sphene (0.5%). In general, the hornblende forms stubby crystals in both the grey and pink layers but is poikiloblastic when it occurs in the granitic veins and *lits*. Magnetite is very fine grained and evenly disseminated throughout the pink and grey layers.

**HORNBLENDE-DIOPSIDE GNEISS (7)**

Outcrops of this unit were found only in the vicinity of Mismagu Lake (Map 71-2-3). The gneiss is associated with units 5a and 6, into which it shows a lateral gradation. The thickness varies from 15 m on the Rat River to 300 m at the north end of Mismagu Lake. Alternating pale pink and pale green discontinuous layers (2.5 to 7.5 cm wide) impart a pronounced colour banding on the weathered surface. The mineralogical composition of these layers is shown in Table 2.

TABLE 2. MINERALOGICAL COMPOSITION OF CONTRASTING LAYERS IN UNIT 7

| | Green layer | Pink layer |
|---|---|---|
| Plagioclase | 40% | 25% |
| Microcline | 16% | 40% |
| Quartz | 20% | 28% |
| Hornblende | 20% | 3% |
| Biotite | | 4% |
| Diopside | 3% | |
| Magnetite | | 2% |
| Accessories | sphene, apatite, calcite | chlorite |

Inequigranular feldspar forms a granoblastic, polygonal mosaic for stubby equigranular crystals of bright green hornblende, diopside and olive brown biotite. The biotite shows a preferred orientation parallel to the layering. Calcite and chlorite are alteration products of the hornblende, diopside and plagioclase.

## QUARTZO-FELDSPATHIC BIOTITE-HORNBLENDE GNEISS (8)

The main occurrence of this rock type is in the southwest corner of the Mynarski Lakes area (Map 71-2-3), where it occurs along the eastern margin of the quartz monzonite stock (16a). A single outcrop of the gneiss was also found at the end of the northwesternmost arm of Rat Lake (Map 71-2-2) where it is associated with units 10 and 6. The nature of the contact relationships with these units at this locality is uncertain. Unit 8 is regarded as the uppermost unit in the Sickle paragneiss sequence.

Outcrops weather evenly to a distinctive orange-brown surface showing rounded quartz grains. Hornblende is a minor variable constituent and forms small aggregates. Mafic layers (¼ to 1 inch, 0.6 to 2.5 cm) containing 15 per cent biotite and 3 per cent magnetite weather as pronounced troughs compared with the more feldspathic layers. Minor folds and basin and dome interference patterns are common in this rock unit. The mineralogical composition is estimated from thin sections and stained slabs as 57 per cent feldspar (variable proportions of microcline and plagioclase), 30 per cent quartz, 8 per cent biotite and muscovite, 1-3 per cent bright green stubby crystals of hornblende and 2 per cent magnetite.

## IMPURE ARKOSE; MINOR QUARTZITE *(8b)**, ARKOSE-DERIVED GNEISSES AND MIGMATITE *(8c)**

These metasediments and derived gneisses form a broad easterly trending belt through Pemichigamau Lake. They appear to constitute a large roof pendant in the extensive batholithic complex of quartz monzonite and granodiorite which is continuous to the south into the Rat Lake area (16a, *15a*).

Unit *8b* consists of a metasedimentary sequence comprising interlayered impure arkose or subgreywacke, arkose and minor quartzite. The layer thickness varies from 50 feet (15 m) down to 15 to 30 cm. The meta-arkose and quartzite are confined mainly to the northern shore and the central islands of the lake. Crossbedding and load casts are preserved in these rocks but in insufficient number for meaningful top determinations to be made. The meta-arkose grades northward into impure arkose or subgreywacke inland from the shore of the lake. Impure arkose also outcrops along the south shore. Further to the north and south, the impure arkose grades, with increasing amounts of granitic *lits* and degree of recrystallization, into the derived gneisses and migmatites *(8c)*.

Weathered surfaces of the meta-arkose are smooth and pink to grey in colour. Pale pink granitic *lit* constitute 10 per cent of the rock.

The meta-arkose comprises a fine-grained equigranular quartzo-feldspathic mosaic consisting of microcline with low 2V (40-45°), plagioclase (10%), olive green biotite (5%), accessory magnetite (2%), sphene (1%), and apatite (1%). The preferred orientation of the biotite imparts a weak schistosity to the rock.

The impure meta-arkose or subgreywacke weathers with an uneven surface and comprises alternating pink quartzo-feldspathic layers, grey biotitic layers and intermittent green hornblende-bearing layers. Pale pink granitic *lit* constitute 10-15 per cent of the rock.

The mineralogical composition of the impure meta-arkose is 55-60 per cent microcline and plagioclase in highly variable proportions, 20-25 per cent quartz, 10 per cent hornblende and 8-10 per cent biotite. The quartz and feldspar form a fine

*See footnote page 4

to medium-grained mosaic for the hornblende and biotite. The hornblende crystals are medium grained, stubby and highly poikiloblastic. Both the hornblende and biotite show a preferred orientation, defining the schistosity which is parallel to the layering. Accessory minerals are magnetite (2–3%), sphene (1%), and apatite (1%), all of which occur as very fine disseminated grains.

The derived gneisses and migmatite (*8c*) occur between the impure meta-arkose (*8b*) and the quartz monzonite - granodiorite (16a, *15a*) along the north and south shores of the lake, and constitute the main rock unit at the west and east ends of the lake. The contact between units *8b* and *8c* is gradational, the proportion of granitic *lits* increases from 10 per cent in unit *8b*, to 30 to 40 per cent in the paragneisses of unit *8c* and more than 60 per cent in the migmatite. The derived gneisses and migmatite are pale pink to cream coloured. Medium to coarse-grained potassium feldspar and plagioclase together comprise 45–50 per cent of the rock in variable proportions. Biotite (10–15%), and hornblende (0–10%) show a preferred orientation parallel to the layering. Accessory minerals are magnetite (2%) and minor sphene.

The arkosic rocks on Pemichigamau Lake were considered by Milligan (1964) to be part of the Sickle Group. These rocks strongly resemble the quartzo-feldspathic suite of gneisses of the Sickle Group on Rat Lake. The impure meta-arkose or subgreywacke of unit *8b* is similar to the least migmatized portions of units 6 and 7, while the meta-arkose component of unit *8b* resembles the quartzo-feldspathic gneisses of unit 5a or unit 8.

# INTRUSIVE ROCKS

## META-QUARTZ DIORITE (9)

Several bodies of the metamorphosed quartz diorite (9) have been mapped in the northern half of the Rat Lake area. They range in size from small stocks, up to 3 km in diameter, down to smaller lens shaped bodies less than 1 km in length and 0.25 km in width. These bodies occur as intrusions into the quartzo-feldspathic gneisses or form partially or completely included bodies within the quartz monzonite (16a, *15a*) and microcline granite (17). The smaller bodies of quartz diorite in the quartz monzonite (16a, *15a*) have locally undergone partial anatexis, resulting in the formation of white pegmatite (plagioclase and quartz) containing hornblende crystals up to 1.5 cm in length. The typical outcrops of the quartz diorite are smoothly rounded and weather white, with prominent clots of stubby green hornblende crystals.

The average mineralogical composition (Table 3) for six samples (Figure 3) is 68 per cent anhedral andesine-labradorite, 23 per cent olive green hornblende, 5 per cent quartz and 2 per cent interstitial biotite, with accessory magnetite and sphene. The texture is hypidiomorphic inequigranular comprising a fine-grained plagioclase mosaic in which the medium-grained mafic constituents form lenses up to 30 cm in length and 6 mm wide. These lenses have a preferred orientation which gives the rock a crude gneissosity.

## MAGNETIFEROUS QUARTZ DIORITE (10, *12*)*

This rock type is distinguished from the meta-quartz diorite (9) by its higher magnetite content. The magnetiferous quartz diorite occurs as (i) lens-shaped bodies, several kilometres long, lying between units 5a or *8b* and *8c* of the Sickle. These bodies are one-quarter to four miles (0.5–6.6 km) in length; (ii) sheet-like

*See footnote page 3

TABLE 3 MODAL ANALYSES OF QUARTZ DIORITE (9)

| Sample number | 24-9-3041 | 24-0-3800A | 24-0-3803 | 24-0-3841-1A | 24-0-3844A | 24-9-471 | Average composition |
|---|---|---|---|---|---|---|---|
| Location shown in Figure 3 | 9-1<br>56°11'07"<br>99°35'13" | 9-2<br>56°08'19"<br>99°41'00" | 9-3<br>56°08'05"<br>99°56'46" | 9-4<br>56°08'07"<br>99°42'06" | 9-5<br>56°07'35"<br>99°41'31" | 9-6<br>56°10'44"<br>99°35'00" | |
| Quartz | 3.5 | 6.3 | 5.0 | 6.2 | 7.3 | 3.0 | 5.2 |
| K-feldspar | | | 0.5 | | | | 0.1 |
| Plagioclase | 64.4 | 67.6 | 72.3 | 69.6 | 74.0 | 61.7 | 68.3 |
| Biotite | 2.2 | 0.6 | 1.0 | 1.0 | | 6.6 | 2.3 |
| Hornblende | 29.4 | 24.5 | 21.5 | 23.3 | 17.6 | 28.2 | 23.1 |
| Magnetite | 1.0 | 0.8 | 0.5 | | 0.4 | 0.5 | 0.6 |

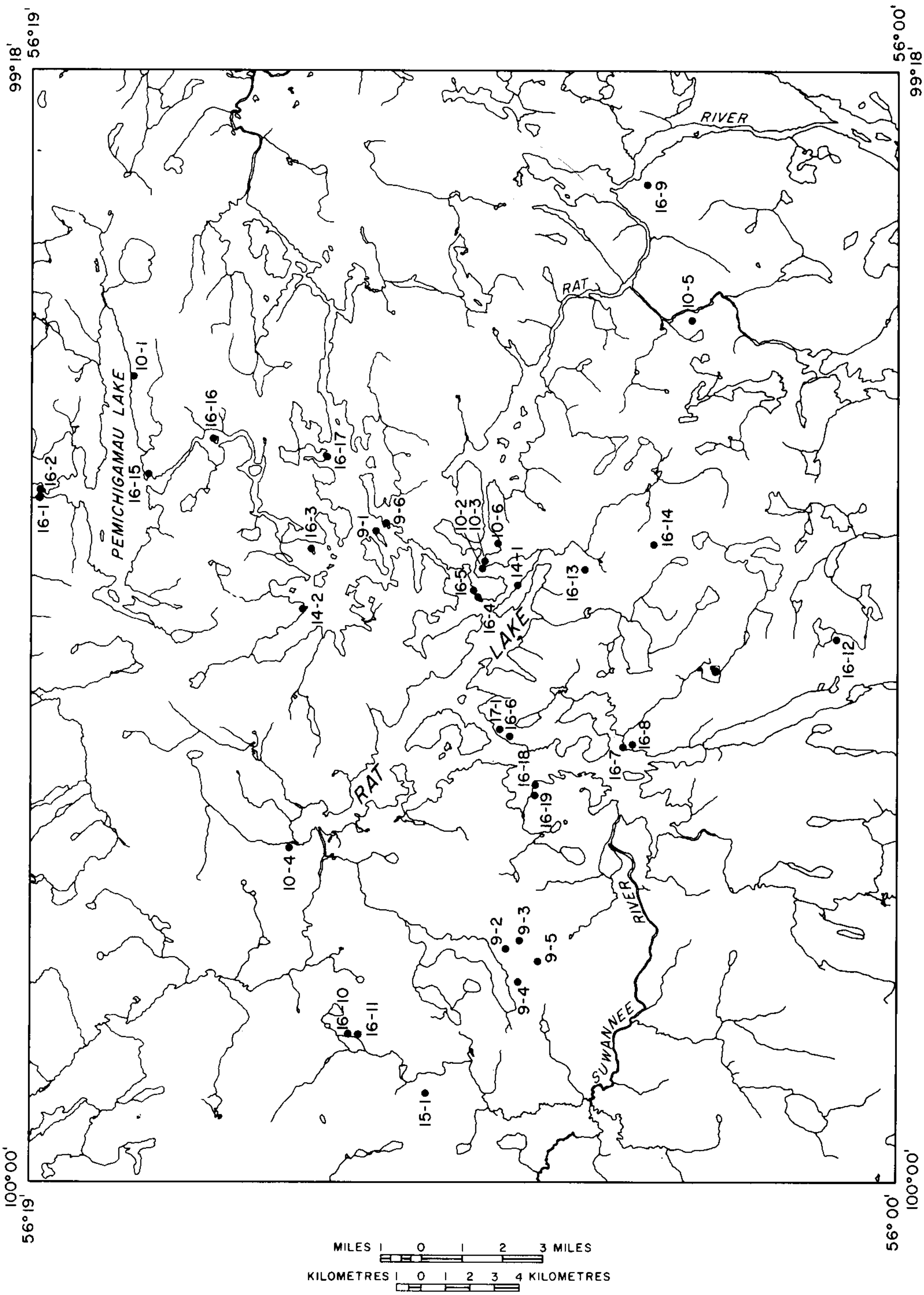



*Figure 3:* Location of samples from map-units 9, 10 *(12)*, 14c, 15, 16a *(15a)*, and 17.

bodies, several kilometres long, lying between units 5a or 8b and 8c of the Sickle Group and the quartz monzonite (16a, *15a*) or microcline granite (17) e.g. on Pemichigamau Lake (Map 71-2-6) and on the northern arm of Rat Lake (Map 71-2-2); (iii) large inclusions within the quartz monzonite (16a, *15a*) and the microcline granite (17). The foliation in the quartz diorite in all three modes of occurrence is parallel to that in the host rocks. The larger bodies of magnetiferous quartz diorite (10) can be distinguished on the Federal-Provincial aeromagnetic maps of the area (Maps 2387G, 2388G, 2395G, and 2396G), by their relatively high magnetic intensity (3300 to 4000 gammas).

The magnetiferous quartz diorite (10) is predominantly a well foliated (commonly schistose) mafic rock, which weathers with a dark grey pitted surface. Magnetite, with buff quartzo-feldspathic coronas, forms coarse-grained spheroids which give the rock a spotted appearance (Plate 2A). A less common leucocratic variety, which may comprise as much as 80 per cent of some outcrops, has a considerably lower mafic content and is only weakly to moderately foliated. This leucocratic variety forms irregularly shaped zones which grade into the more mafic rock.

The mafic variety comprises a fine to medium-grained mosaic of quartz and plagioclase (andesine), containing brown to olive brown biotite and medium-grained olive green poikiloblastic hornblende. The schistosity of the rock is defined by the preferred orientation of the biotite and hornblende. Medium to coarse-grained microcline is a variable constituent (1-10%). Magnetite occurs as coarse-grained spheroids and as disseminated medium-sized grains. Other minor constituents are sphene (as rims on magnetite or as disseminated euhedral grains) and apatite which typically occurs as inclusions in biotite and hornblende. Allanite, epidote, calcite and sericite occur in minor amounts as alteration products. Modal analyses of this rock are listed in Table 4.

The leucocratic variety of the quartz diorite weathers with a smooth pink to light grey surface. It differs from the mafic variety mainly in its lower hornblende content (Table 4, sample 667). The hornblende comprises only 1 to 3 per cent of the rock, and forms very fine-grained green stubby crystals. Disseminated olive green to brown biotite constitutes 15 to 20 per cent of the rock. The preferred orientation of the biotite gives the rock its weak to moderate foliation. Microcline is a minor interstitial constituent in the fine to medium-grained quartz and plagioclase (andesine) mosaic which makes up the bulk of the rock. Sphene, apatite and allanite are accessory minerals. The allanite displays a zoned structure.

Pearse (1964) suggested that this unit in the Pemichigamau Lake area was derived from Sickle sediments by contact metamorphism and metasomatic alteration, caused by emplacement of the adjoining quartz monzonite (unit *15a* in this report). In this area the magnetiferous quartz diorite occurs as sheet-like bodies between the Sickle Group and the quartz monzonite. As noted above, it occurs in a similar environment in the Rat-Mynarski Lakes area (Map 71-2-2). In the latter area, however, it also forms lens-shaped bodies completely within the Sickle Group gneisses, which completely precludes its formation by contact metamorphism.

Modal and chemical analyses of sample 24-9-135, from a sheet-like body on the south shore of Pemichigamau Lake (Figure 3), and sample 24-0-2040B from one of the lens-shaped bodies in the Mynarski Lakes area, are given in Tables 4 and 5. These samples are similar in composition and in physical appearance suggesting that they had a similar origin. Based on the chemical and modal analyses, this unit has been interpreted as a quartz diorite which was intruded as sills into the Sickle Group rocks.

TABLE 4. MODAL ANALYSES OF MAGNETIFEROUS QUARTZ DIORITE (10,12)

| Sample number | 24 9 135 Mafic variety | 24 9 653 Mafic variety | 24 9 656 Mafic variety | 24 0 1257 Mafic variety | 24 0 2040B Mafic variety | 24 9 667 Leucocratic variety |
|---|---|---|---|---|---|---|
| Location shown in Figure 3 | 10 1<br>56°16′25″<br>99°29′26″ | 10 2<br>56°08′45″<br>99°37′42″ | 10 3<br>56°08′41″<br>99°37′25″ | 10 4<br>56°12′38″<br>99°47′10″ | 10 5<br>56°14′21″<br>99°26′55″ | 10 6<br>56°08′23″<br>99°35′44″ |
| Quartz | 16.6 | 25.2 | 18.0 | 23.2 | 15.0 | 25.6 |
| Plagioclase | 38.6 | 38.8 | 40.3 | 30.8 | 43.7 | 51.5 |
| K-feldspar | 1.4 | 10.0 | | 1.0 | 1.6 | 1.0 |
| Biotite | 19.7 | 22.0 | 18.0 | 36.6 | 21.5 | 16.6 |
| Hornblende | 10.2 | 10.0 | 12.6 | | 6.0 | 1.0 |
| Epidote | 1.0 | | | | 1.0 | |
| Chlorite | 2.2 | | | | 2.0 | |
| Apatite | 2.0 | 1.6 | 3.0 | 1.4 | 2.1 | 1.0 |
| Sphene | 2.5 | 1.8 | 3.5 | 2.1 | 3.0 | 1.5 |
| Magnetite | 5.5 | 4.5 | 5.4 | 4.2 | 4.5 | 2.0 |

TABLE 5. CHEMICAL ANALYSES OF MAGNETIFEROUS QUARTZ DIORITE (10, 12)

| | | |
|---|---|---|
| Sample number | 24-9-135 | 24-0-2040B |
| Location shown in Figure 3 | 10-1<br>56°16'25"<br>99°29'26" | 10-5<br>56°04'21"<br>99°26'58" |
| $SiO_2$ | 56.6 | 53.83 |
| $Al_2O_3$ | 17.3 | 15.20 |
| $TiO_2$ | 1.68 | 2.33 |
| $Fe_2O_3$ | 3.61 | 4.86 |
| FeO | 5.26 | 6.19 |
| MnO | 0.16 | 0.17 |
| MgO | 2.21 | 3.25 |
| CaO | 4.95 | 5.30 |
| $Na_2O$ | 3.10 | 3.03 |
| $K_2O$ | 2.69 | 2.55 |
| $P_2O_5$ | 0.56 | 2.66 |
| $H_2O$ | 1.02 | 1.29 |
| $CO_2$ | 0.26 | 0.11 |
| Total | 99.4% | 99.2% |
| Total Fe as $Fe_2O_3$ | 9.4 | 11.67 |

## WHITE PEGMATITIC GRANODIORITE (11)

The grey to white granodiorite is a massive to weakly foliated, medium-grained to pegmatitic rock derived by anatexis from the pelitic gneiss (1). It forms small irregular bodies in the pelitic gneiss (1) and amphibolite (2a) ranging in size from thin *lit* and discontinuous lenses, comprising 15 per cent of an outcrop, up to larger mappable bodies in which the pelitic gneiss (1) occurs as isolated inclusions.

The rock comprises albite-oligoclase (45-50%), microcline (20-25%), quartz (20-25%) as interstitial grains and in myrmekitic and micrographic intergrowths with the feldspar; red brown biotite (5-8%), garnet (0-2%), cordierite (0-2%), and graphite (0-1%).

## TONALITE (12)

Two small bodies of tonalite occur in the extreme south-central part of the map-area where they are in contact with the quartz monzonite (16a), granite (17), and granitized paragneisses (3a, 5a). The contact relationships with the paragneisses are indeterminate owing to lack of outcrop; the contacts with units 17 and 16a are gradational. The rock possesses a moderate foliation defined by the preferred orientation of biotite and hornblende.

Outcrops weather evenly to a buff colour. The overall texture is fine to medium grained, hypidiomorphic granular. The rock consists of 15 per cent olive green, anhedral hornblende and 10 per cent olive brown biotite, evenly distributed in a mosaic of oligoclase-andesine (50%) and quartz (25%).

## PYROXENE DIORITE (13)

This rock type was found only in the pelitic gneiss southwest of Rat Lake (Map 71-2-2), where it occurs as a narrow L-shaped body, approximately 3.5 km long, and a smaller ovoid body 800 m long. In the immediate vicinity of the smaller body there are unmappable, discontinuous dykes, that cut the gneiss (1) and are sheared with the host rock.

The diorite weathers distinctively to a buff-brown colour and is flecked with dark olive brown clots of diopside and minor tremolite, up to 1 to 5 cm across. Pale greenish diopside and minor hypersthene are finely disseminated throughout the rock. The hypersthene (1-2%) displays various degrees of alteration to magnetite and serpentine. It forms intergrowths with the diopside or occurs as discrete fine grains. Diopside comprises up to 10 per cent of the rock. Brown biotite (8-10%) exhibits a weak preferred orientation. The equigranular, hypidiomorphic groundmass consists of quartz (14%) and andesine-labradorite (65%) showing albite-Carlsbad twinning.

## OLIVINE GABBRO; HORNBLENDE GABBRO (14a)

This rock type was found only in the west central part of the area where it occupies an area of 0.6 × 1.8 miles (1 km × 3 km).

The age relationships of unit 14a and the meta-quartz diorite (9) are indeterminate owing to lack of exposure. These two basic units may be related so as to form a basic igneous complex, or they may represent two separate intrusive events. Unit 14a has been intruded by the microcline granite (17a) as shown by the presence of dykes of 17a in unit 14a and inclusions of 14a in the granite (17a).

Outcrops of olivine gabbro display alternating grey and black layers. The layers vary in thickness from 15 to 30 cm. The layering is most pronounced near the southern boundary of the unit but gives way to a homogeneous black, weakly to non-foliated rock towards the northern contact. The grey layers are olivine gabbro consisting of olivine (5-8%), hypersthene (5-8%), and bytownite-anorthite (50-55%). The black layers and the weakly foliated homogeneous portion of the body are hornblende gabbro composed of medium-grained hornblende (40-45%) and bytownite (55-60%).

Both the olivine gabbro and hornblende gabbro have an idiomorphic to hypidiomorphic texture. The olivine and hypersthene in the olivine gabbro posses augite rims, which in many cases are themselves rimmed by hornblende. Augite also occurs as pale medium-grained crystals with hourglass zoning. The plagioclase forms medium-sized anhedral grains which display Carlsbad-albite twinning, and commonly contain minute green inclusions (possibly hornblende). Where the inclusions are abundant, the twinning in the plagioclase is absent.

## META-GABBRO (14b)

Small bodies of highly altered meta-gabbro (14b) were found along the west shore of Rat Lake, in the quartz monzonite (16a), and along the contact between the cordierite gneiss (4) and the quartzo-feldspathic magnetite gneiss (5a). The rock is black, and in places reddish black where microcline has been introduced. Examination of thin sections and stained slabs confirm that the potash metasomatism was accompanied by sericitization, chloritization and an increase in the amount of magnetite present. The latter forms irregular aggregates and fine disseminated grains. The main constituents of the gabbro are stubby olive green hornblende (50–70%) and labradorite (20–40%). The hornblende displays varying degrees of alteration to chlorite; the plagioclase is altered to sericite and chlorite. Minor constituents of the rock are interstitial quartz (5–8%) and fine to medium-grained microcline (0–10%) occurring either as small interstitial grains or as larger irregular crystals.

**ALTERED ULTRAMAFIC ROCK** (14c)

Two minor bodies of this unit outcrop in the map-area. One of these occurs on a small island in the Rat River where it exits from the east side of Rat Lake (Map 71–2–2, Figure 3, Location 14–1). At this location the ultramafic body lies within amphibolite (2a) and pelitic gneiss (1). The other body is exposed in a single outcrop on the most northerly arm of Rat Lake, where it occurs within quartz monzonite (16a). (Map 71–2–2, Figure 3, Location 14–2). The Rat River body weathers greenish black whereas the Rat Lake occurrence is greenish grey; both exposures have a pitted surface. The rock has a fibrous appearance on fresh surface.

The Rat River body consists of cummingtonite (60–65%), hypersthene (10–15%), olivine (5%), diopside (5%), serpentine (5%), hercynite (5%), magnetite (3–5%), and calcite (2%). The rock is transected by discrete shear planes and serpentinization of hypersthene and olivine has occurred along these shears. The shears trend 315 and dip 60 degrees to the northeast. The long axes of the cummingtonite generally lie within the plane of shearing. Hercynite is disseminated as very fine grains which are oriented within the shear planes, some of them forming short continuous mineral trains.

The Rat Lake body is composed of labradorite (20–25%), amphibole (cummingtonite-tremolite, 40–45%), diopside (5–8%), magnetite (8–10%), brown biotite (5–8%), and light green hornblende (2%). The rock is foliated and has an inequigranular texture. Medium-sized grains of plagioclase, with a moderate preferred orientation of their c-axes, lie within a fine-grained groundmass of cummingtonite and tremolite, the latter similarly showing a strong preferred orientation of their long axes. This amphibole schistosity is deflected around the plagioclase crystals. Irregular lenses of medium-grained magnetite are oriented within the foliation planes.

**HORNBLENDE SYENITE** (15)

A pear-shaped body of hornblende syenite occurs near the western boundary of the map-area, north of the Suwannee River. The body is clearly defined on the aeromagnetic map (Federal-Provincial Aeromagnetic Map 2387G) as an area of intermediate magnetic intensity ranging from 2700 to less than 2600 gammas. The body appears to be bounded along its western margin by a fault, as indicated by a strong north-trending topographic lineament, and an abrupt aeromagnetic gradient. The syenite is surrounded by quartz monzonite (16a) and granite (17) but the contacts are not exposed. The position of the southern contact has been interpreted from the aeromagnetic map. The foliation in the surrounding rocks is conformable with the margin of the syenite body.

Weathered surfaces of the syenite show a pink feldspathic groundmass, distinctively spotted with greenish black hornblende, and cut by fine-grained microcline-quartz veins and dykes. Thin sections and stained slabs show an irregular feldspathic mosaic of microcline (57%) and plagioclase (25–30%) with fine-grained interstitial quartz (5%) (Table 6 and Figure 4). Hornblende occurs as irregular olive green grains and as smaller bright green crystals.

## QUARTZ MONZONITE-GRANODIORITE (16a, *15a*)*

This rock type, together with microcline granite (17), forms a large batholithic mass in the northern part of the map-area. This batholith extends north into the Pemichigamau-Earp Lakes area (Kendrick, 1972; Steeves and Lamb, 1972) and east into the Mynarski Lakes area (Elphick, 1972). Within the map-area, the batholith for the most part is in contact with arkose-derived gneisses of the Sickle Group, and in the northwest corner, with microcline granite. Unit 16a also forms smaller elongate bodies in the paragneisses in the southern half of the map-area. In the southwest corner of the Mynarski Lakes map-area (Map 71-2-3) it forms a stock-like protuberance, the Misinagu Lake stock, which extends south from the main batholith. The batholith is generally weakly foliated; some areas possess a penetrative schistosity while others are massive. It contains large relict masses of paragneiss (5a, *8c*)* and quartz diorite (9, 10), particularly in the area around the most northeasterly bay of Rat Lake (Map 71-2-2), and also around Pemichigamau Lake (Map 71-2-6). The quartz monzonite-granodiorite is cut by aplite and red pegmatite dykes which have been folded passively in areas where the quartz monzonite-granodiorite possesses a well developed schistosity. These deformed dykes are themselves cut by red microcline granite dykes which show no deformation.

Microcline porphyroblasts, some 4 cm in length, occur sporadically, and are best developed in areas where the rock is well foliated. A good example of this is seen where the Rat River enters Pemichigamau Lake (Map 71-2-6). Here the quartz monzonite-granodiorite has been altered to a muscovite-microcline-quartz schist within narrow discrete shear zones oriented at 340°/15° NE and 300°/15° NE. Microcline porphyroblasts are present as far away as 100 feet (30 m) from these shear zones. Elsewhere, in the map-area microcline porphyroblasts occur where small irregular diffuse patches of microcline granite (17) are present in the quartz monzonite-granodiorite, particularly where the latter is well foliated. Conversely, the porphyroblasts are also present in unit 16a where it forms irregular shaped bodies within larger bodies of the microcline granite (17), for example, in the area southwest of the northwesternmost arm of Rat Lake.

The smaller bodies of unit 16a that occur in the gneisses in the southeastern part of the map-area, generally possess a more well defined foliation than the main batholith. This foliation and the elongation direction of the bodies is parallel to the regional foliation in the host paragneisses.

The body in the extreme southwest corner of the map-area (Map 71-2-2) trends north-south and has deflected the foliation in the host pelitic gneisses (1) parallel to its contact. However, the main foliation in unit 16a trends north-northeast, and Barry and Gait (1966) who mapped the western extension of this body in the Suwannee Lake area, suggest that the intrusive body appears to have been subjected to a phase of deformation after emplacement.

The quartz monzonite-granodiorite generally weathers with a smooth pale grey surface, but is pink or red where hematite is present. The schistosity is defined by the preferred orientation of biotite and coarse lenticular aggregates of quartz grains. The latter stand out on weathered surfaces. Thin section and stained slab examination (Table 6) show that the rock consists mainly of medium-grained anhedral oligoclase-andesine (35-55%), subhedral microcline (1-16%), and quartz (25-38%). The ferromagnesian minerals, also medium grained, are brown to olive green biotite (5-11%), olive green hornblende (0-5%), and magnetite (0.5 to 2.5%) as finely

*See footnote page 4

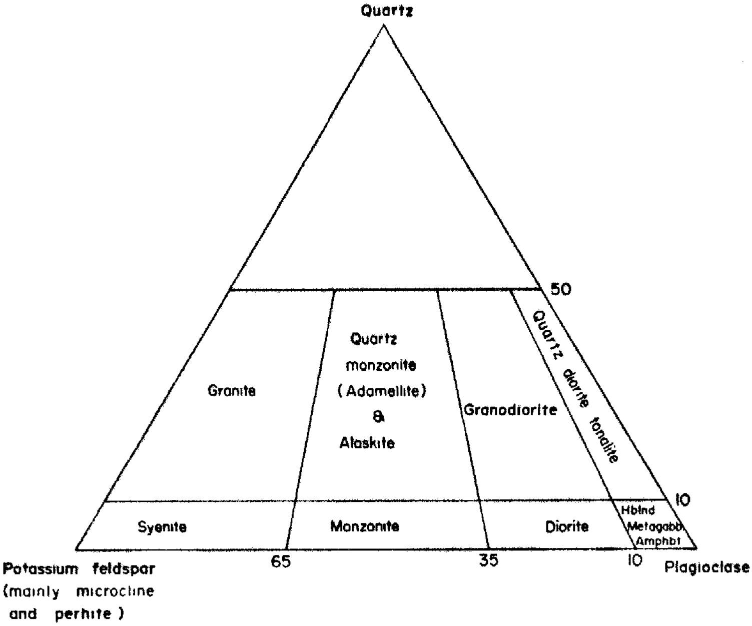
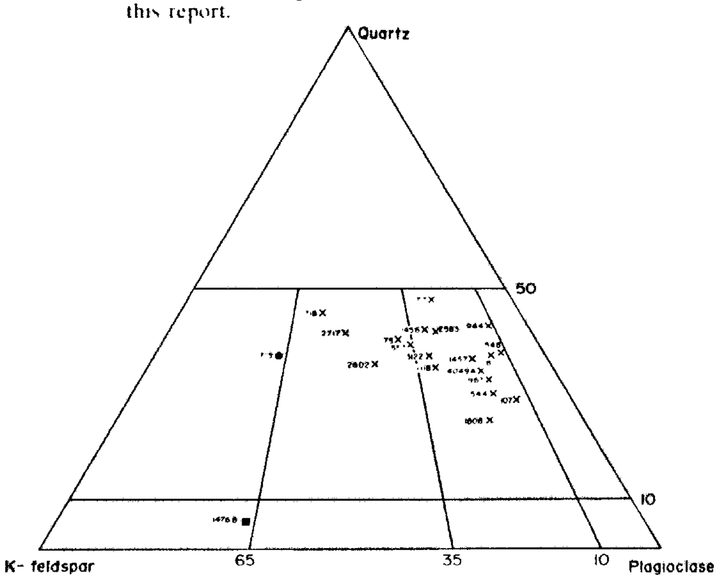



*Figure 4:* (a) Classification of granitic rocks (after Bateman, 1961) used in this report.




(b) Ternary plot showing modal composition (quartz, plagioclase, K-feldspar) for units 15, 16a *(15a)*, and 17

TABLE 6. MODAL ANALYSES OF MAP-UNITS 15; 16a, *15a*; 17

| Sample number | 24 0 1476B | 24 9 75 | 24 9 77 | 24 9 107 | 24 9 544 | 24 9 548 | 24 9 718* |
|---|---|---|---|---|---|---|---|
| Location shown in Figure 3 | 15 1<br>56°09'58"<br>99°56'25" | 16 1<br>56°18'17"<br>99°34'53" | 16 2<br>56°18'10"<br>99°34'45" | 16 3<br>56°12'25"<br>99°35'56" | 16 4<br>56°08'58"<br>99°37'47" | 16 5<br>56°09'04"<br>99°37'33" | 16 6<br>56°08'16"<br>99°43'05" |
| Map-unit | 15 | 16a, *15a* | 16a, *15a* | 16a, *15a* | 16a, *15a* | 16a, *15a* | 16a, *15a* |
| Quartz | 5.1 | 37.0 | 45.0 | 25.0 | 26.0 | 34.0 | 42.0 |
| K-feldspar | 56.3 | 12.0 | 13.0 | 9.0 | 12.0 | 7.0 | 31.0 |
| Plagioclase | 25.2 | 35.0 | 38.0 | 58.0 | 54.0 | 52.0 | 22.0 |
| Biotite | 2.0 | 7.0 | 4.0 | 3.0 | 6.0 | 5.5 | 3.0 |
| Hornblende | 7.7 | | | 4.0 | 2.0 | | |
| Magnetite | 0.5 | | 1.0 | 1.0 | 1.0 | 0.7 | 2.0 |

*Quartz monzonite occurs along with the microcline granite at this location. Microcline granite is the main rock type as shown on Map 71-2-2

TABLE 6 (Cont'd)

| Sample number | 24-9-964 | 24-9-967 | 24-9-1118 | 24-0-1456 | 24-0-1457 | 24-0-1557 | 24-0-1808 |
|---|---|---|---|---|---|---|---|
| Location shown in Figure 3 | 16-7<br>56°05′55″<br>99°43′25″ | 16-8<br>56°05′42″<br>99°43′15″ | 16-9<br>56°05′17″<br>99°21′48″ | 16-10<br>56°11′38″<br>99°54′22″ | 16-11<br>56°11′33″<br>99°54′20″ | 16-12<br>56°01′22″<br>99°39′15″ | 16-13<br>56°06′48″<br>99°36′48″ |
| Map-unit | 16a, *15a* | 16a, *15a* | 16a, *15a* | 16a, *15a* | 16a, *15a* | 16a, *15a* | 16a, *15a* |
| Quartz | 37.0 | 29.2 | 32.0 | 37.5 | 33.0 | 34.5 | 22.8 |
| K-feldspar | 6.8 | 10.1 | 17.0 | 16.5 | 12.0 | 18.5 | 12.8 |
| Plagioclase | 47.0 | 52.6 | 42.6 | 37.5 | 49.0 | 36.1 | 54.0 |
| Biotite | | 6.4 | 7.4 | 6.8 | 4.0 | 9.2 | 9.0 |
| Hornblende | 9.0 | | | | | | |
| Magnetite | 1.0 | 1.6 | 1.0 | 1.5 | 1.0 | 1.5 | 1.4 |

TABLE 6 (Cont'd)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Sample number | 24-0-1827 | 24-9-2583 | 24-9-2602 | 24-9-2717 | 24-0-3122 | 24-0-4049A | 24-9-713 |
| Location shown in Figure 3 | 16-14<br>56°05'16"<br>99°35'53" | 16-15<br>56°15'52"<br>99°33'07" | 16-16<br>56°14'30"<br>99°31'41" | 16-17<br>56°12'08"<br>99°32'28" | 16-18<br>56°07'44"<br>99°44'43" | 16-19<br>56°07'42"<br>99°45'11" | 17-1<br>56°08'31"<br>99°42'53" |
| Map-unit | 16a, *15a* | 16a, *15a* | 16a, *15a* | 16a, *15a* | 16a, *15a* | 16a, *15a* | 17 |
| Quartz | 32.1 | 35.0 | 34.3 | 30.7 | 33.2 | 30.7 | 35.0 |
| K-feldspar | 8.0 | 17.2 | 11.3 | 11.4 | 17.0 | 11.0 | 40.5 |
| Plagioclase | 48.9 | 43.5 | 48.2 | 55.0 | 41.0 | 49.8 | 19.7 |
| Biotite | 9.0 | 4.0 | 6.2 | 2.1 | 6.4 | 7.6 | 3.0 |
| Hornblende | | | | | | | |
| Magnetite | 1.8 | 1.0 | 08 | 0.4 | 2.4 | 1.2 | 1.7 |

disseminated grains or coarse lenticular aggregates. The latter are oriented within the plane of the foliation. Modal analyses of unit 16a, when plotted on a ternary diagram of quartz, potassium feldspar and plagioclase (Figure 4) fall in the quartz monzonite-granodiorite field.

### MICROCLINE GRANITE (17)

The microcline granite forms high prominent ridges with sparse tree growth. It occupies much of the northwestern corner of the map-area and forms smaller elongate bodies in the southeasterly trending zone of quartzo-feldspathic paragneiss which extends diagonally across the map-area. The main mass of granite in the northwestern part of the map-area contains inclusions of paragneiss (3, 4) and the magnetiferous quartz diorite (10). Its relationship with the quartz monzonite-granodiorite batholith (16a) is not clearly defined owing to the lack of outcrops in the contact region. The presence of red microcline granite dykes in the granodiorite is indicative of a younger age for unit 17 with respect to unit 16a, and as mentioned previously in the discussion of unit 16a, the microcline granite (17) contains large inclusions of unit 16a (100 × 500 m). However, the granite also occurs as small patches up to 9 m square, within unit 16a. Where these patches are numerous they commonly impinge on each other, giving the whole outcrop surface a web-like appearance. The contacts between the two rock types are gradational in these areas, and the generation of the microcline granite (17) may thus be due in part to recrystallization and potassium metasomatism of unit 16a. In thin section this potassium enrichment can be observed as the growth of poikiloblastic grains of microcline, and as very fine to fine-grained microcline as rims on grains of plagioclase.

In places where unit 17 intrudes the quartzo-feldspathic paragneiss, it contains abundant inclusions of the paragneiss. For example, to the north of the Suwannee River, where unit 17 almost rings the quartz diorite body (9), the granite contains large angular blocks, 60 m by 20 m, of unit 5a, constituting a large scale agmatite. In the northwest corner of the map-area the granite forms a complex with unit 5a, 8c within the batholitic mass of unit 16a. The contacts between unit 5a, 8c and the microcline granite (17) are gradational and the relative proportions of these two units are difficult to determine. Approximately 60 per cent of the complex consists of microcline granite, which occurs as distinct intrusions and also appears to have formed by in situ granitization of arkosic paragneisses.

Outcrops weather distinctively with interstitial medium to coarse-grained quartz standing out above the pink microcline groundmass. The quartz surrounds each microcline crystal giving the weathered surface a "brick and mortar" texture. In general the granite is weakly to moderately foliated with the preferred orientation of biotite defining the foliation. The microcline crystals also show a weak preferred orientation. In a few places the foliated granite grades into pegmatitic areas which are massive. The foliation also becomes very weak and difficult to measure in areas where the biotite content is less than 5 per cent. The modal analysis of a typical sample of the microcline granite is given in Table 6 and Figure 4.

### PINK PEGMATITE (18)

Pegmatite (18) is almost entirely restricted to the Sickle Group paragnesses and quartz monzonite (16a). A single large dyke of pegmatite (18) occurs in the pelitic gneiss in the southwestern portion of the map-area (Map 71-2-2), and was traced south-southwest for one and one-half miles (2.5 km) to the southern map-boundary. The dyke has a thickness of less than 450 m, and shows as a magnetic high on the aeromagnetic map. It contains inclusions of a magnetite-bearing gneiss which resembles unit 5b.

In general, the pegmatites in the area are deep pink in colour, and contain microcline and quartz, with minor perthite, muscovite and biotite.

# METAMORPHISM

## INTRODUCTION

The metamorphic history of the area has been based on the identification and correlation of certain index minerals and critical mineral assemblages (Table 7 and Figure 5).

Two main regional metamorphic events have been recognized and these have been related to the deformation of the area (Table 9). The conditions of the first phase of regional metamorphism ($M_1$) were intermediate to high pressure and high temperature, characteristic of the Barrovian type of metamorphism. The second, and dominant episode of regional metamorphism ($M_2$) was to the upper amphibolite facies of Abukuma-type metamorphism, under conditions of low to intermediate pressure (3-5 kb) and high temperature.

Overlap between Abukuma-type metamorphism and conditions of contact metamorphism are indicated by the presence of the hornblende-cordierite-anthophyllite assemblage (6a) which is indicative of conditions of the orthoamphibole subfacies of the potassium feldspar-cordierite hornfels facies (Winkler, 1967). The contact metamorphism ($M_{2b}$, Table 9) is related to the emplacement of the quartz monzonite (16a, *15a*).

Retrograde metamorphism ($M_3$) which resulted in the formation of muscovite, biotite and chlorite, is restricted to discrete shears.

In the following section of the report, the critical mineral assemblages in Table 7 are discussed in detail and related to the metamorphic and structural history of the area.

TABLE 7. CRITICAL MINERAL ASSEMBLAGES AND INDEX MINERALS IN THE RAT LAKE AREA

| | Critical assemblages | Index minerals |
|---|---|---|
| 1 | garnet-hornblende-plagioclase | hypersthene |
| 2a | hypersthene-garnet-sillimanite + cordierite | anthophyllite |
| 2b | anthophyllite-orthopyroxene | garnet |
| 2c | anthophyllite-cordierite-hercynite | |
| 2d | garnet-sillimanite-hercynite-cordierite | sillimanite |
| 3 | sillimanite-orthoclase-garnet-biotite | cordierite |
| 4 | sillimanite-cordierite-garnet-microcline | orthoclase |
| 5 | hercynite-magnetite-cordierite-garnet + sillimanite | andalusite |
| | | muscovite |
| 6a | cordierite-anthophyllite-hornblende | chlorite |
| 6b | hornblende-tremolite + diopside | tremolite |
| 7 | muscovite + chlorite-microcline-sillimanite-magnetite | |
| 8 | andalusite-chlorite-muscovite | |

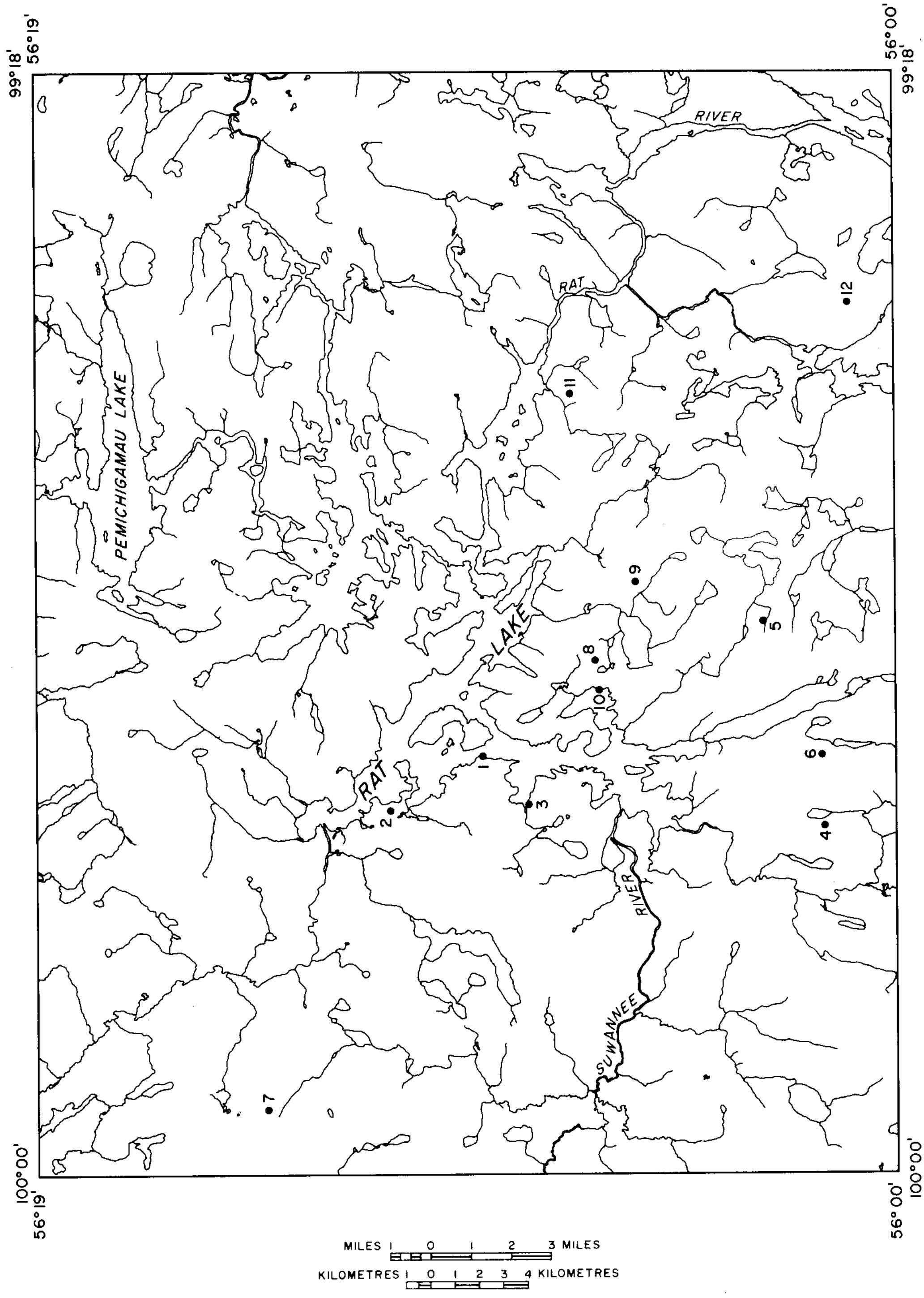



*Figure 5:* Location map for metamorphic mineral assemblages.

# DISCUSSION OF MINERAL ASSEMBLAGES

## ASSEMBLAGE 1: GARNET-HORNBLENDE-PLAGIOCLASE

This assemblage occurs in an amphibolite which outcrops along the western shore of Rat Lake (Figure 5, Locations 1 and 2). The amphibolite occurs as discontinuous boudined layers 2 to 5 feet (0.6–1.5 m) thick within the paragneiss (4). The amphibolite is equigranular and medium grained.

This assemblage is significant in that it is indicative of high pressure and high temperature Barrovian metamorphism (Table 8). In the Barrovian type metamorphism the almandine-hornblende tie line (Figure 6a) is established during lower amphibolite metamorphism and persists to the highest subfacies of the amphibolite facies. Under lower pressure conditions of Abukuma-type metamorphism, however, the persistence of the tie line plagioclase-anthophyllite, cummingtonite through the amphibolite facies (Figure 6b), precludes the coexistence of hornblende and almandine.

The conditions of metamorphism suggested by Winkler (1967) for this assemblage are pressures of 8 to 9 kilobars and temperatures ranging from 650 to 700°C.

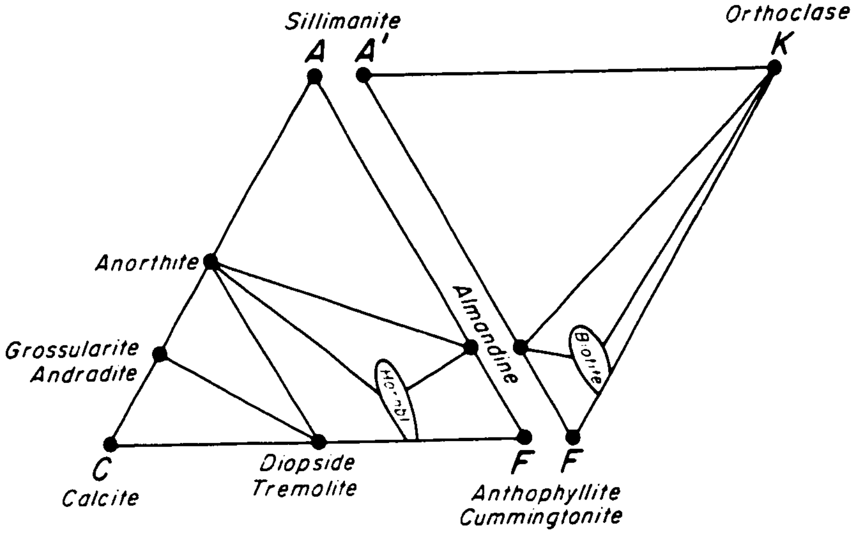
The restriction of this assemblage to only two localities is admittedly scant evidence for a distinct regional $M_1$ metamorphism. However evidence for the $M_1$ metamorphism elsewhere in the map-area is assumed to have been largely obliterated by the overprinting of the subsequent $M_2$ regional event.

## ASSEMBLAGE 2a: HYPERSTHENE-GARNET-SILLIMANITE + CORDIERITE
## ASSEMBLAGE 2b: ANTHOPHYLLITE-ORTHOPYROXENE
## ASSEMBLAGE 2c: ANTHOPHYLLITE-CORDIERITE-HERCYNITE
## ASSEMBLAGE 2d: GARNET-SILLIMANITE-HERCYNITE-CORDIERITE

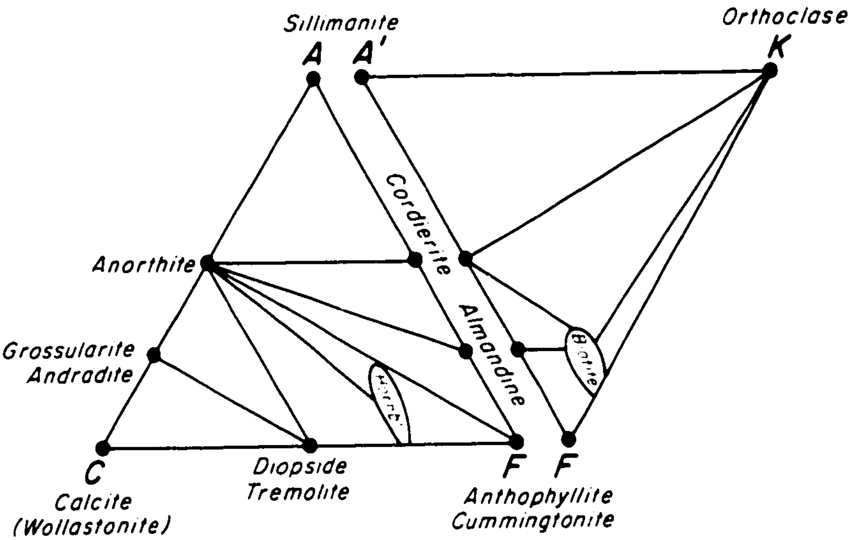
These four unique assemblages occur at only one locality in the map-area, on the western shore of Rat Lake 3.25 miles (5.2 km) directly north of the mouth of the Suwannee River (Figure 5, Location 3). The rocks containing these four assemblages outcrop within an area of approximately 1,000 square feet. They have been assigned to unit 4, but have no counterparts in the rest of the map-area. The outcrop comprises (Figure 7).

a) a lens of massive magnetite 60 feet (18 m) long and 3–5 feet (1–1.5 m) thick;
b) a porphyroblastic anthophyllite schist, containing variable amounts of porphyroblastic garnet, cordierite and magnetite;
c) layers of grey quartzite with biotite laminations and variable but minor amounts of anthophyllite, garnet and magnetite;
d) cordierite-garnet-potassium feldspar pegmatite.

The porphyroblastic anthophyllite schist (b) contains the four critical assemblages 2a, b, c, and d. Baldwin (1971) has subdivided this unit on the basis of textures and variations in mineralogical composition; these subunits have been combined in this report to simplify the discussion. The porphyroblastic anthophyllite schist is also the most striking rock on the outcrop because of its topographic relief and textures. On one part of the outcrop (Figure 7) it forms a knoll whose crown stands several feet above the rest of the outcrop. The dark green to black anthophyllite schist consists of radiating acicular crystals of anthophyllite and contains abundant porphyroblasts of garnet, cordierite, and magnetite. These porphyroblasts range from one-half inch (1.3 cm) to 3 inches (5 cm) in diameter. The grey-blue porphyroblasts of cordierite contain granoblastic hercynite and some of the grey-blue cordierites contain cores of garnet. The magnetite spheroids in one place on the outcrop have a thin outer layer of garnet (Plate 3A). Variably sized garnets also form continuous veins which have filled fractures in the anthophyllite schist (Plate 2B).




(a) Sillimanite-almandine-orthoclase subfacies of the almandine-amphibolite facies.




(b) Sillimanite-cordierite-orthoclase-almandine subfacies of the cordierite-amphibolite facies. Biotite may co-exist with sillimanite.

*Figure 6:* Comparison of mineral parageneses for Abukuma-type and Barrovian facies series: upper amphibolite facies (after Winkler, 1967).

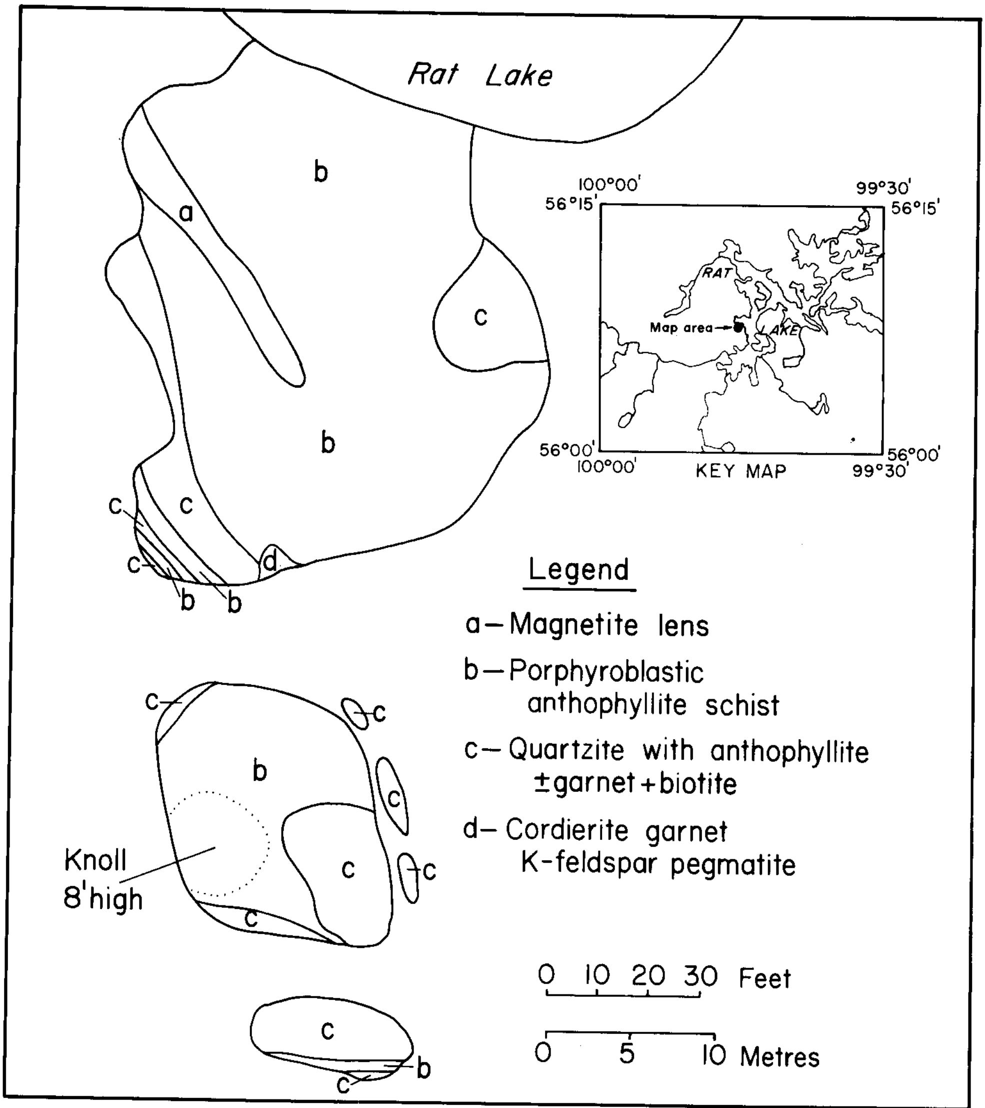



*Figure 7:* Simplified outcrop map (after Baldwin, 1971) showing distribution of main rock types; garnet-cordierite-anthophyllite rocks, west shore of Rat Lake.

The cordierite-feldspar pegmatite is an equally spectacular rock. It forms a small lens 10 feet (3.3 m) by 15 feet (5 m) and consists of pegmatitic microcline, quartz, and cordierite. The cordierite occurs as clear, deep blue massive clots and more rarely as euhedral hexagonal crystals. Garnet is rare, occurring as small irregular grains within the cordierite.

Baldwin (1971) has proposed that the four critical mineral assemblages in the porphyroblastic anthophyllite schist are indicative of two phases of metamorphism. The assemblage hypersthene-garnet-sillimanite ± cordierite (assemblage 2a) is indicative of granulite grade metamorphism and was produced by the first phase of metamorphism. The coexistence of cordierite, in this case a high magnesium cordierite, and hypersthene has been attributed by Baldwin (op. cit.) to the unusual bulk chemistry of the rock. The rock is high in alumina, magnesia and iron, and low in

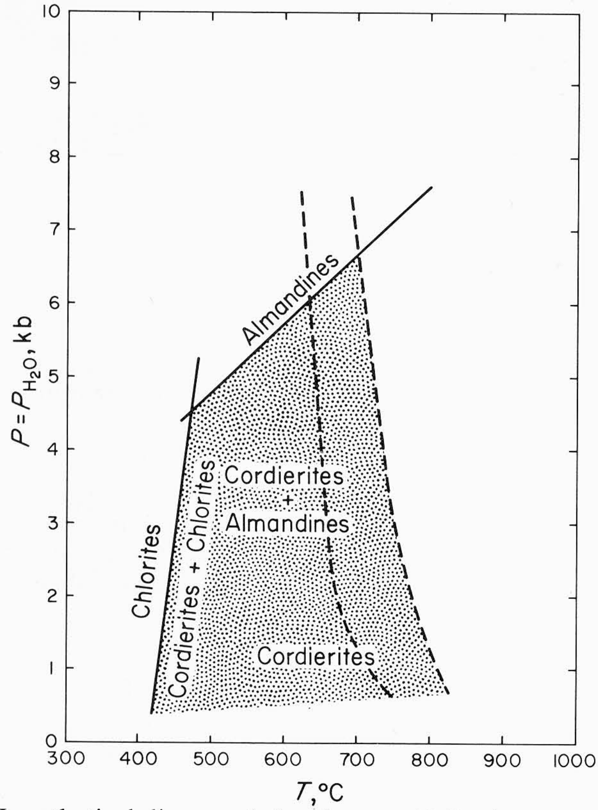



*Figure 8:* Hypothetical diagram (after Turner, 1968) showing shape of the stability field of cordierites (stippled) as inferred from geologic data.

Microcline occurs as interstitial grains in the quartz-feldspar mosaic of this rock, and as larger ovoid porphyroblasts which contain abundant inclusions of plagioclase, quartz, biotite and graphite. The porphyroblasts overprinted the S layering and biotite schistosity and are therefore considered to be further products of the $M_2$ metamorphism, specifically resulting from the partial anatexis which also produced the quartz-microcline-cordierite pegmatites.

**ASSEMBLAGE 5: HERCYNITE-MAGNETITE-CORDIERITE-GARNET ± SILLIMANITE**

This assemblage was found in the pelitic gneiss at only one locality in the map-area, three miles (5 km) directly south of the most southerly point of Rat Lake (Figure 5, Location 6). The pelitic gneiss at this location possesses a crude layering defined by concentrations of cordierite and garnet porphyroblasts in one-half to 1 inch layers (1.3–2.5 cm) alternating with quartzo-feldspathic layers 1 inch to several inches thick and containing only scattered porphyroblasts of garnet and cordierite. The porphyroblasts are highly elongated parallel to the compositional layering ($S_1$). Five distinct types of porphyroblasts occur: (i) garnet; (ii) garnet-cordierite intergrowths or garnet with rims of cordierite; (iii) garnet with rims of cordierite, quartz and magnetite; (iv) cordierite with fibrolite inclusions; (v) cordierite with magnetite and minor hercynite inclusions.

As in assemblage 4, the coexistence of potassium feldspar and sillimanite and the presence of garnet are indicative of the upper amphibolite facies. It is also evident that Abukuma-type metamorphism ($M_2$) causing replacement of garnet by cordierite, succeeded an earlier ($M_1$) phase of metamorphism during which the silica and very low in calcium. The other three assemblages, 2b, 2c, and 2d, were formed during the second phase of metamorphism and are indicative of the cordierite-amphibolite facies. These are retrograde assemblages relative to 2a. Textural evidence shows that the following reactions occurred during this second phase of metamorphism:

(i) garnet + sillimanite ⟶ cordierite + hercynite
(ii) orthopyroxene + $SiO_2$ + $H_2O$ ⟶ anthophyllite
(iii) anthophyllite + hercynite ⟶ cordierite

**ASSEMBLAGE 3: SILLIMANITE-ORTHOCLASE-GARNET-BIOTITE**

This assemblage was found only in the pelitic gneiss (1) four miles (6.5 km) directly south of the mouth of the Suwannee River (Figure 5, Location 4).

Two phases of upper amphibolite grade metamorphism can be inferred from this assemblage based on:

(a) the coexistence of potassium feldspar with sillimanite and the absence of muscovite; and
(b) the texture of the mineral assemblage.

The rock is strongly foliated. Sillimanite knots and needles, and porphyroblasts of both garnet and microcline are elongated parallel to the biotite schistosity. The garnets commonly contain swirled fibrolite. Microcline and plagioclase form an inequigranular mosaic. Small grains of orthoclase were identified (using the universal stage) in the microcline-plagioclase mosaic.

The assemblage is indicative of the sillimanite-almandine-orthoclase subfacies of the upper amphibolite facies (Winkler, 1967). Subsequent metamorphism caused inversion of the orthoclase to microcline but under P-T conditions above the stability field of muscovite. Both periods of metamorphism are therefore assumed to have taken place under conditions of the upper amphibolite facies.

**ASSEMBLAGE 4: SILLIMANITE-CORDIERITE-GARNET-MICROCLINE**

This assemblage is common in the pelitic gneiss (1) in the southeast quadrant of the map-area. The specific example of this assemblage discussed here occurs three miles (5 km) southeast of the most southerly tip of Rat Lake (Figure 5, Location 5).

The coexistence of cordierite with the other minerals in this assemblage is indicative of Abukuma-type metamorphism (Winkler, 1967). The assemblage itself is representative of the upper amphibolite facies (sillimanite-cordierite-orthoclase-almandine subfacies) as shown by the absence of muscovite and the coexistence of potassium fedlspar and sillimanite.

The cordierite occurs in three distinct associations: (i) as very coarse grains in quartz-microcline-cordierite pegmatites which form irregular lenses (2.5–5 cm thick) and cross-cutting veins; (ii) as discrete grains and porphyroblasts arranged in layers parallel to the metamorphic layering ($S_1$); and (iii) as rims on garnet. The quartz-microcline-cordierite pegmatites are indicative of partial anatexis. These irregular-shaped bodies cut across the metamorphic layering ($S_1$) and are therefore, considered to be products of $M_2$ metamorphism. The garnets rimmed by cordierite are interpreted to be $M_1$ garnets which have been subsequently altered to cordierite during $M_2$. However, the cordierite overgrowths and details of the relationships were not studied. "In *natural pelitic* assemblages (Chinner, 1959) cordierite plays a role that is inversely complimentary to that of almandine", (Turner, 1968). Cordierite when compared to almandine is common in low pressure to intermediate pressure high temperature assemblages and is not as widely distributed as almandine at higher pressures and comparable temperatures (Figure 8).

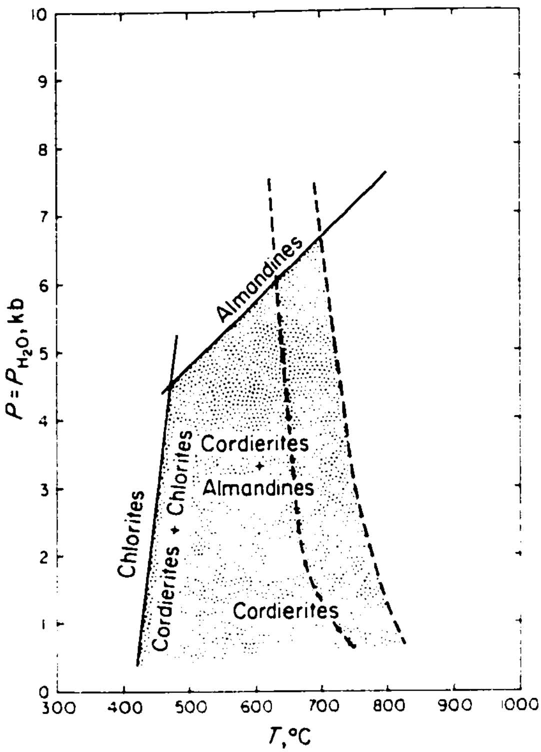



*Figure 8:* Hypothetical diagram (after Turner, 1968) showing shape of the stability field of cordierites (stippled) as inferred from geologic data.

Microcline occurs as interstitial grains in the quartz-feldspar mosaic of this rock, and as larger ovoid porphyroblasts which contain abundant inclusions of plagioclase, quartz, biotite and graphite. The porphyroblasts overprinted the S layering and biotite schistosity and are therefore considered to be further products of the $M_2$ metamorphism, specifically resulting from the partial anatexis which also produced the quartz-microcline-cordierite pegmatites.

## ASSEMBLAGE 5: HERCYNITE-MAGNETITE-CORDIERITE-GARNET + SILLIMANITE

This assemblage was found in the pelitic gneiss at only one locality in the map-area, three miles (5 km) directly south of the most southerly point of Rat Lake (Figure 5, Location 6). The pelitic gneiss at this location possesses a crude layering defined by concentrations of cordierite and garnet porphyroblasts in one-half to 1 inch layers (1.3-2.5 cm) alternating with quartzo-feldspathic layers 1 inch to several inches thick and containing only scattered porphyroblasts of garnet and cordierite. The porphyroblasts are highly elongated parallel to the compositional layering ($S_1$). Five distinct types of porphyroblasts occur: (i) garnet; (ii) garnet-cordierite intergrowths or garnet with rims of cordierite; (iii) garnet with rims of cordierite, quartz and magnetite; (iv) cordierite with fibrolite inclusions; (v) cordierite with magnetite and minor hercynite inclusions.

As in assemblage 4, the coexistence of potassium feldspar and sillimanite and the presence of garnet are indicative of the upper amphibolite facies. It is also evident that Abukuma-type metamorphism ($M_2$) causing replacement of garnet by cordierite, succeeded an earlier ($M_1$) phase of metamorphism during which the garnet porphyroblasts and sillimanite were generated (sillimanite-orthoclase-almandine subfacies).

The complex porphyroblasts of garnet with cordierite + magnetite + quartz rims and of cordierite with hercynite inclusions implies the following reactions:

*Step 1:*

$$\text{almandine} \xrightarrow[\text{decreasing } P_{total}]{\text{increasing } P_{O_2}} \text{magnetite + hercynite + quartz + fluid}$$

*Step 2:*

$$\text{magnetite + hercynite + quartz + fluid} \xrightarrow[\substack{\text{low pressure} \\ \text{high temperature}}]{\text{high } P_{O_2}} \text{Fe-cordierite + hercynite}$$

The final reaction (step 2) would require a temperature of approximately 900°C. These qualitative reactions are based on phase studies related to garnet equilibria by Hsu (1968). The temperature and partial pressure of oxygen during these reactions increased while the total pressure decreased. As this assemblage was found in the pelitic gneiss at one locality only, these conditions may have been localized within this one area.

## ASSEMBLAGE 6a: CORDIERITE-ANTHOPHYLLITE-HORNBLENDE
## ASSEMBLAGE 6b: HORNBLENDE-TREMOLITE + DIOPSIDE

These assemblages were found in the cordierite-sillimanite-anthophyllite gneiss (unit 4) at Locations 7, 8, and 9 (Figure 5). Assemblage 6a forms thin discontinuous layers up to 6 mm in width, interlayered with quartzo-feldspathic layers and massive cordierite-quartz layers at Locations 7, 8, and 9. The hornblende-tremolite assemblage (6b) forms distinct layers 30 cm to 1 m thick, which are interlayered with the paragneiss (4) at Locations 7 and 8.

The two mineral assemblages 6a and 6b have been interpreted together as belonging to the orthoamphibole subfacies of the potassium feldspar-cordierite hornfels facies (Winkler, 1967) of contact metamorphism (Figure 9), which overprinted an upper amphibolite assemblage. The contact metamorphism was produced by emplacement of the quartz monzonite (16a, *15a*).

The absence of garnet in the cordierite-anthophyllite assemblage is indicative of contact metamorphism at high temperatures and pressures (Winkler, 1967). The absence of primary muscovite and the coexistence of potassium feldspar and sillimanite in the quartzo-feldspathic layers in unit 4, indicate that the temperature and pressure remained above the stability field of muscovite during the contact metamorphism ($M_{3b}$). Therefore the minimum conditions of the contact metamorphism would be in the range of 640–660°C and 2 to 2.5 kb.

## ASSEMBLAGE 7: MUSCOVITE + CHLORITE-MICROCLINE-SILLIMANITE-MAGNETITE

This is a common mineral assemblage in the weakly magnetiferous quartzo-feldspathic gneiss (5a) of the Sickle Group (Figure 5, Location 10).

Muscovite is present in these rocks but only as secondary ragged poikiloblastic grains enclosing sillimanite, or as shimmer aggregates. Chlorite has been formed by the alteration of biotite. Both the muscovite and chlorite occur in discrete zones of cataclasis ($S_4$). The assemblage is interpreted as a retrograde upper amphibolite facies assemblage (sillimanite-orthoclase-almandine subfacies). The muscovite and

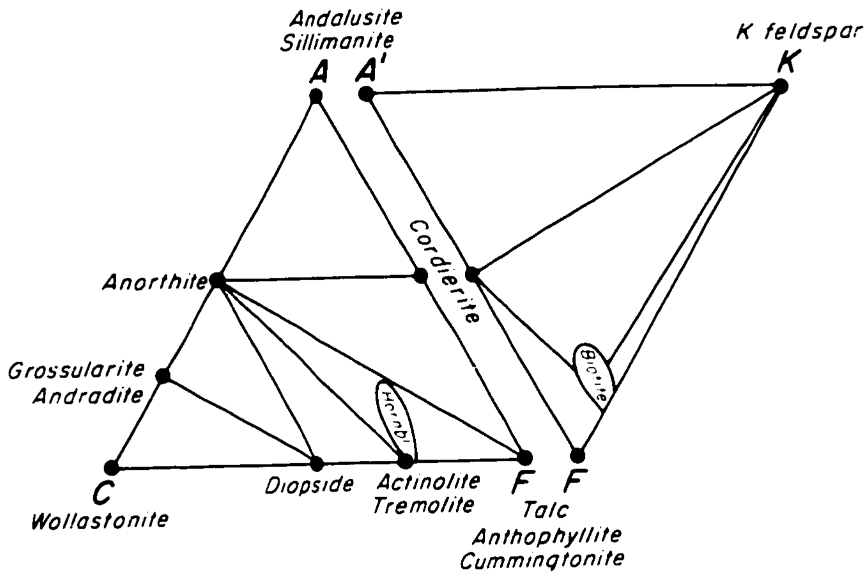



*Figure 9:* Orthoamphibole subfacies of the potassium-feldspar-cordierite-hornfels facies (after Winkler, 1967).

chlorite were produced by later retrograde metamorphism ($M_3$) associated with the ($D_3$) cataclasis (Table 9).

**ASSEMBLAGE 8: ANDALUSITE-CHLORITE-MUSCOVITE**

This is a retrograde assemblage, which occurs in conjunction with the normal high grade pelitic gneiss assemblage of garnet-sillimanite-cordierite-biotite. The total mineral assemblage, which clearly is indicative of disequilibrium, was observed at only two localities (Figure 5, Locations 11 and 12). The high grade minerals are highly altered and the characteristics of the alteration are very similar at both localities. Cordierite is altered along fractures and commonly is completely rimmed by pinite. Biotite is partially or completely altered to chlorite, and muscovite, which is sporadic in its occurrence, occurs as one of the alteration products of cordierite. The muscovite forms irregular-shaped patches in the cordierite and also occurs as irregular poikiloblastic grains. Andalusite forms fine grains, enclosed in muscovite, in the most intensely altered portions of the rock. Its development appears to have been related to the formation of the muscovite, rather than being the result of inversion of sillimanite.

## SUMMARY OF METAMORPHIC EVENTS

The critical mineral assemblages have been presented in order of decreasing metamorphic grade:

(i) assemblages 1, 2a and 3 (Table 8) are indicative of Barrovian upper amphibolite facies metamorphism ($M_1$). Localized granulite facies metamorphism (assemblage 2a) was controlled by the unusual bulk chemistry of the rocks;

## TABLE 8. CONDITIONS OF METAMORPHISM

| Metamorphic event | Assemblage | Pressure | Temperature | Type of metamorphism |
|---|---|---|---|---|
| $M_1$ | 1 | 8-9 kb | 650-700(+)°C | Regional, Barrovian, upper amphibolite facies |
| $M_1$ | 2a | 6-8 kb; $P_{H_2O}$<2 kb | 650-700(+)°C | Relict assemblage indicating local granulite facies |
| $M_1$ | 3 | - | 650-700(+)°C | Regional, Barrovian, upper amphibolite facies |
| $M_{2a}$ | 2b, 2c, 2d | 3-3.5 kb | 600-650°C | Regional, Abukuma, upper amphibolite facies |
| $M_{2a}$ | 4 | 3-3.5 kb; | 670-680°C | Regional, Abukuma, upper amphibolite facies |
| $M_{2a}$ | 5 | 2-4 kb; high $P_{O_2}$ | 800-900°C | Local (?), upper amphibolite facies |
| $M_{2b}$ | 6a, 6b | 2-2.5 kb | 640-660°C | Contact, orthoamphibole subfacies K-feldspar-cordierite hornfels facies |
| $M_3$ | 7 | 2-4 kb | 490-550°C | Regional, upper greenschist to lower amphibolite facies |
| $M_3$ | 8 | 2-2.5 kb | 490-505°C | Local, upper greenschist facies |

(ii) assemblages 2b, 2c, 2d, 4 and 5 (Table 8) are indicative of Abukuma-type upper amphibolite facies metamorphism ($M_{2a}$). The temperature range indicated by assemblage 5 is high compared with that for the other assemblages of the $M_{2a}$ metamorphism, and the oxygen partial pressure required to account for the complex breakdown of garnet is anomalous. These appear to be localized conditions but they cannot be explained on the basis of the present study;

(iii) assemblages 6a and 6b are indicative of the orthamphibole subfacies of the potassium feldspar-cordierite hornfels facies of contact metamorphism (Table 8, $M_{2b}$);

(iv) assemblages 7 and 8 are indicative of lower amphibolite or upper greenschist facies of metamorphism (Table 8). These assemblages were produced by retrogressive metamorphism ($M_3$) which overlapped in time the local effects of the contact metamorphism ($M_{2b}$), and was related to $D_3$ cataclasis and $D_4$ folding.

These metamorphic events and their relationship to the structural and plutonic history of the area, are summarized in Table 9.

# STRUCTURAL GEOLOGY

## INTRODUCTION

The map-area lies on the north side of a major easterly trending Precambrian sedimentary basin which is bounded to the south by the Flin Flon-Snow Lake greenstone belt (Bailes, 1971).

The paragneisses in the map-area are the high grade metamorphic derivatives of the Wasekwan and Sickle Group sediments (see page 5). The contact between these groups has been mapped from Lynn Lake to Granville Lake (Milligan, 1960; Campbell, 1972a) and into the Suwannee Lake area (Barry and Gait, 1966). Lack of outcrop prevents precise location of the contact or determination of its attitude in most of the region between Suwannee Lake and the south end of Rat Lake. However, the foliation and metamorphic layering in the gneisses of the map-area generally parallel the contacts of the major units. Thus, from the attitude of these planar structures in the gneisses closest to the inferred Sickle-Wasekwan contact, the contact west of Rat Lake appears to dip to the north so that the Sickle Group gneisses appear to overlie the Wasekwan pelitic gneiss. The sequence is therefore overturned. Similarly in the southeastern part of the Rat Lake area (Map 71-2-2) the structure has been interpreted as representing a complete inversion of the sequence, such that the Wasekwan pelitic gneiss (1) appears in structural basins surrounded by Sickle Group gneisses.

Recognition of the Wasekwan-Sickle contact, the disposition of the major lithologic units, and the apparent inversion of the stratigraphic sequence in the map-area are the principal factors which form the basis for interpretation of the earlier structural events. The intensity of later deformations has made recognition of mesascopic structures associated with earlier episodes of folding very difficult to identify. The main structural and related metamorphic and plutonic events in the Rat Lake area are summarized in Table 9.

### $D_1$ DEFORMATION

It is assumed that the apparent inversion of the stratigraphic sequence was caused by an early ($D_1$) phase of deformation. Although no corresponding $F_1$ folds have been recognized, all the major folds identified in the area deform an already inverted sequence and, therefore, were not themselves responsible for the inversion. Furthermore, the earliest recognized folds in the area (designated $F_2$) deform a pre-existing metamorphic layering $S_1$, which is assumed to have been produced by an earlier metamorphism $M_1$, approximately contemporaneous with the early folding ($F_1$). This layering is parallel to the main lithologic contacts, indicating that the $F_1$ folds were isoclinal. It can also be postulated that the large recumbent isoclinal $F_1$ folds trended east-west, parallel to the axis of the main sedimentary trough which lay to the south.

The deformed $S_1$ metamorphic layering is a gneissic layering, defined by the alternation of quartzo-feldspathic layers and layers containing variable proportions of mafic minerals. The tabular and platy mafic minerals have a preferred orientation parallel to the layering.

## $D_2$ DEFORMATION

The $S_1$ metamorphic layering was deformed during the $D_2$ deformation into tight upright isoclinal folds ($F_{2a}$) about easterly trending axial planes (Figure 10). The $F_{2a}$ folds have been locally modified by $D_2$ cross-folding ($F_{2b}$) at right angles to the $F_{2a}$ folds, and by the emplacement of the quartz monzonite (16a, *15a*), specifically the Misinagu Lake stock (Figure 12). The latter appears to have been emplaced contemporaneously with the cross-folding, although precise cause and effect relationships have not been determined.

The $F_2$ structures were subsequently modified by a third deformation ($D_3$) which caused extensive cataclasis and faulting, and specifically appears to have produced a major structural break, referred to here as the "Rat Lake fault"* which cuts diagonally across the map area (Figure 10). The fault, which has an arcuate trace and dips to the east, effectively separates the area into two distinct structural subareas (subareas A and B, Figure 10).

### SUBAREA A

The $F_{2a}$ longitudinal folds are preserved in the northern half of this subarea (Figure 10). The folds have vertical or steep northerly dipping axial planes and plunge at moderate angles to the east (Figure 11). North to northwest-trending cross-folds ($F_{2b}$) in this subarea are assumed to have formed contemporaneously with the longitudinal folds ($F_{2a}$) largely because refolding relationships between the two fold sets are lacking.

The Misinagu Lake stock forms the core of one of the northerly trending $F_{2b}$ antiformal cross-folds and is flanked to the west by a second northwesterly trending antiform (Figures 10 and 12).

### SUBAREA B

West of the "Rat Lake fault" structures interpreted as $F_2$ folds trend obliquely to their counterparts in subarea A (Figure 10). One possible explanation of this is that the $D_3$ deformation produced an apparent clockwise rotation of the structures of subarea B relative to subarea A** accompanying the left lateral displacement on the "Rat Lake fault" (see below). Thus, the axial traces of the $F_{2a}$ and $F_{2b}$ folds in subarea B now trend southeast and northeast respectively.

From inspection of Figure 10 and Map 71-2-2, the metamorphic layering $S_1$ in the Sickle-Wasekwan Group gneisses immediately to the west of the fault, has been deformed into an interference pattern of small domes and basins apparently resulting from the interaction of the $F_{2a}$ and $F_{2b}$ folds. The longitudinal axial planes ($F_{2a}$) of the basins dip steeply to the northeast; those of the cross-folds appear to be nearly vertical. The basins are occupied by Wasekwan pelitic gneiss (1) and amphibolite (2a), both of which normally have a low magnetic expression. However, the Federal-Provincial Aeromagnetic Map 2387C, shows only a moderate depression of the magnetic intensity over these structures, suggesting that the Wasekwan rocks are underlain by more highly magnetic Sickle Group rocks, and the sequence is therefore inverted.

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*Note This fault, which is only partially shown on Geological Map 71-2-2, follows the contact between the Wasekwan and Sickle gneisses in the extreme eastern part of the Rat Lake map-sheet

**Note This rotation could also be explained by regional $D_3$ folding about a northeast-trending axial plane. However this would require that the "Rat Lake fault" continued to act as a major structural discontinuity, in order to explain the non-continuity of such $D_3$ folding into subarea A

# TABLE 9. SUMMARY OF STRUCTURAL, METAMORPHIC AND PLUTONIC EVENTS

| Deformation | Folding | Planar fabric | Metamorphism | Structure | Metamorphism | Plutonism |
|---|---|---|---|---|---|---|
| $D_1$ | $F_1$ | $S_1$ | $M_1$ | Formation of recumbent isoclinal folds about easterly striking axial planes $S_1$ mainly parallel to $S_0$ (bedding) | Regional metamorphism Barrovian, upper amphibolite facies (sillimanite-almandine-orthoclase subfacies) | |
| $D_2$ | $F_{2a}$ | $S_2$ | $M_{2a}$ | Formation of tight to isoclinal upright longitudinal folds ($F_{2a}$) about easterly trending axial planes. Weak $S_2$ axial planar schistosity | Regional metamorphism Abukuma-type upper amphibolite facies (sillimanite-cordierite-orthoclase-almandine subfacies). The peak of this metamorphism may have been reached at the same time as the main $F_{2a}$ folding | |
| | $F_{2b}$ | | $M_{2b}$ | Localized cross-folding at right angles to the $F_{2a}$ folds producing a basin and dome interference pattern | K-feldspar cordierite hornfels contact metamorphism produced by emplacement of quartz monzonite-granodiorite (16a, *15a*) | Emplacement of quartz monzonite-granodiorite (16a, *15a*) batholith along the main $F_{2a}$ easterly fold trend and the Misinagu Lake stock along the $F_{2b}$ cross-fold trend |
| $D_3$ | | $S_3$ | $M_3$ | Ductile shearing and cataclasis along primary shear directions oriented north and northwest. $S_3$ foliation comprises planes of discrete shear. Formation of the "Rat Lake fault" late in the $D_3$ stage of deformation | Recrystallization of minerals in $S_3$. The degree of alteration of the rock depends on the spacing of the shear planes. Initially $M_3$ metamorphism produced amphibolite facies assemblages but decreased in grade as deformation continued and produced upper greenschist facies assemblages in the final stages of $M_3$ | Small bodies of microcline granite (17) emplaced in the late stages of $D_3$ |
| $D_4$ | $F_4$ | $S_4$ | ($M_3$ continued) | Folding about steep to vertical northeast-trending axial planes. Fold axes plunge 30° to 35° to the northeast. Weak axial planar schistosity | | |
| $D_5$ | | | ($M_3$ continued) | Faulting mostly oriented north-south. Some reactivation of $D_3$ shears and faults. Local retrograde metamorphism associated with the faults | | |

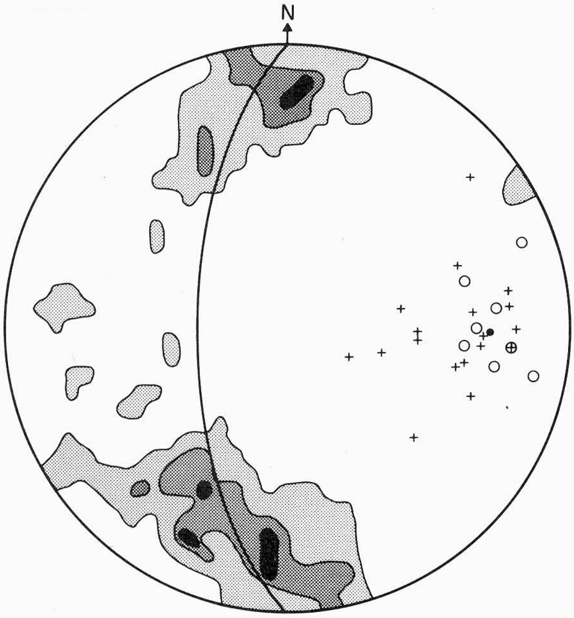


*Figure 11:* Equal-area projections of poles to foliation planes minor fold axes and linear structures, subarea 1.

Southwest of the interference folds, the $F_{2b}$ cross-folds appear to die out and only the longitudinal $F_{2a}$ folds are developed (Figure 10). The latter are tight overturned folds with axial planes which dip to the northeast, parallel to the longitudinal axial planes of the basins and domes. A weak axial plane schistosity, $S_2$, is developed in the $F_{2a}$ folds.

## $D_3$ DEFORMATION

The third phase of deformation, $D_3$, caused fairly intense cataclasis and shearing, particularly in a 12 km wide zone which extends southeast from Rat Lake to the southern edge of the map-area. All rock units within this zone, with the exception of the microcline granite (17), are affected by the cataclasis; the microcline granite displays only minor shearing and is considered to have been emplaced during the waning stages of the $D_3$ deformation. The northeastern edge of the zone of cataclasis is marked by the "Rat Lake fault" (Figure 10) which follows an arcuate southeasterly to southerly trend across the area. Although the actual fault is not exposed, an inspection of the cataclastic foliation planes ($S_3$) in its vicinity indicate that the fault plane dips northeast to east at between 60 and 80 degrees. Subsidiary discrete zones of cataclasis in the rocks to the southwest of the fault show approximately the same orientation as the fault.

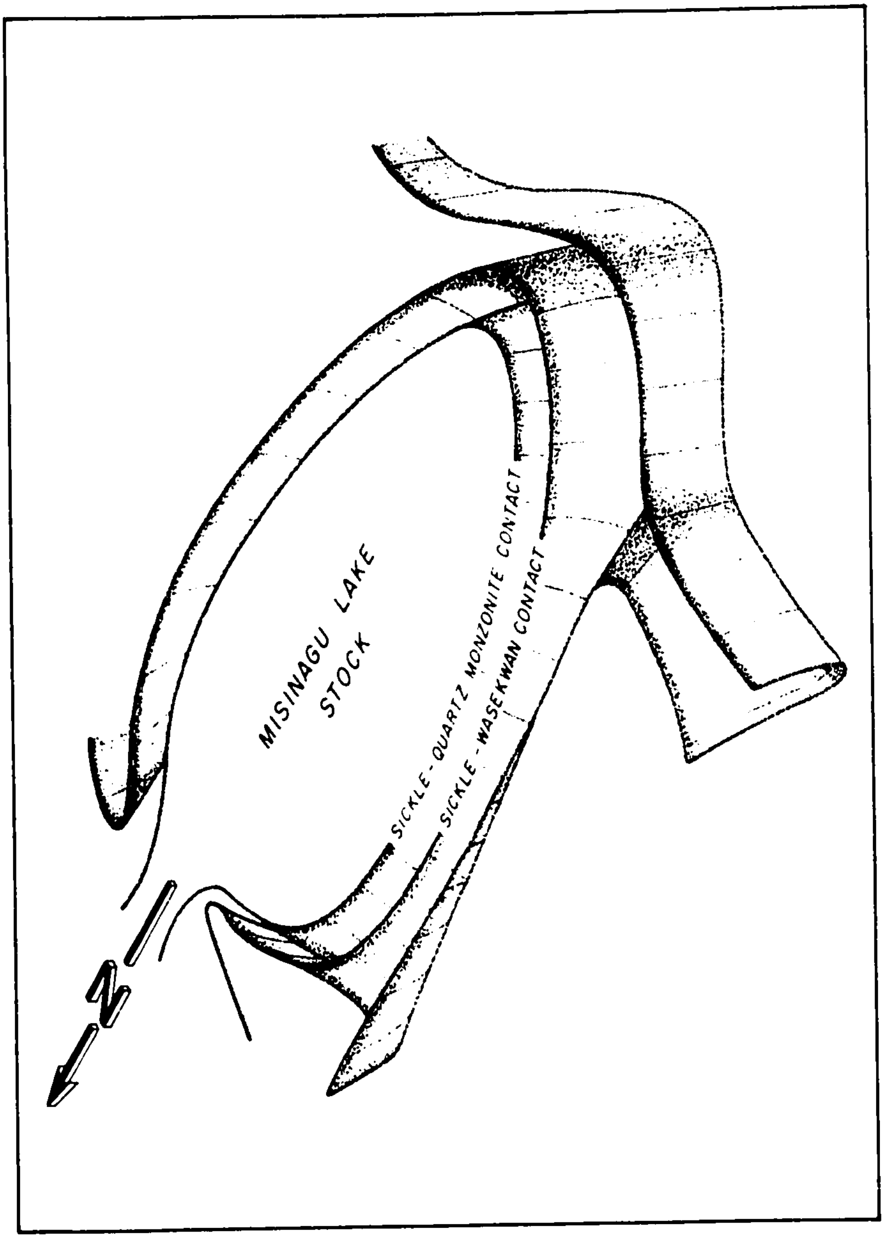


*Figure 12:* Diagrammatic representation of the Misinagu Lake stock showing its relationship to the $F_2$ folds.

The apparent horizontal displacement of the "Rat Lake fault" may be interpreted as left lateral, as shown by the 11 km displacement of the Wasekwan-Sickle contact (A-A' in Figure 10)*. As noted above, this strike slip movement appears to have been accompanied by clockwise rotation of subarea B relative to subarea A. In subarea A (Figure 10), the trace of the fault is parallel or subparallel to the structural trend of the $F_{2b}$ cross-folds, but truncates the $F_{2a}$ longitudinal folds. Immediately southwest of the fault (subarea B), the axial traces of the $F_{2a}$ folds have been rotated into parallelism with the trace of the "Rat Lake fault", and the $F_2$ folds are transected by the $S_3$ foliation. This tendency towards parallelism of the $F_2$ structures with the trace of the fault decreases towards the southwest.

The $S_3$ schistosity comprises discrete shear planes along which the $S_1$ layering has been transposed (Plate 3B). Augen schists and gneisses containing microcline porphyroclasts, have been produced along linear zones of cataclasis in some of the paragneisses and granitic intrusive rocks. Elsewhere in the Sickle and Wasekwan paragneisses and metatexites, cordierite porphyroblasts and sheets of sillimanite are present in the shear zones. As the grade of metamorphism decreased however, chlorite was produced by degradation of biotite, and muscovite crystallized as felted masses, shimmer aggregate and sieved porphyroblasts.

## $D_4$ DEFORMATION

$F_4$ folds occur only in subarea B. They are large wave length, moderate amplitude folds, with steep or vertical axial planes striking northeast, and axes plunging moderately to the northeast (30-35°). The $F_4$ fold in the southernmost part of the map-area (Figure 10) has refolded the $F_{2a}$ folds about a northeasterly trending axial plane. Poles to foliation planes ($S_1$ and $S_3$) from subarea 2 (Figure 10) fall on a great circle whose axis plunges to the northeast at 30 to 35 degrees (Figure 13), parallel to the $D_4$ linear structures and minor folds.

The $F_4$ folds possess a moderately developed axial plane schistosity ($S_4$) defined by the preferred orientation of biotite and hornblende, particularly in units 10, 12, and 16. The $S_4$ schistosity is more poorly defined in the paragneisses (units 5a, 6) as a weak strain slip cleavage. In these rocks it intersects the pre-existing $S_1$ and $S_3$ layering and foliation to produce a lineation, best described as a rodding of quartz and biotite aggregates.

## $D_5$ DEFORMATION

The final phase of deformation caused faulting and shearing. North-trending faults cut across the pre-existing structures, and localized silicification and retrograde metamorphism to lower or middle greenschist facies is associated with them. Some of the north-trending lineaments indicated in Figure 10 have been interpreted as late faults.

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*Note The apparent displacement could also be interpreted as right lateral based on the 14 km displacement of this same contact A-A11 in Figure 10. Such a sense of movement however would require a more complex model than the one postulated above, in order to accommodate the movement in relationship to the development of the other structures in the area. Considerably more work is required to resolve this problem.

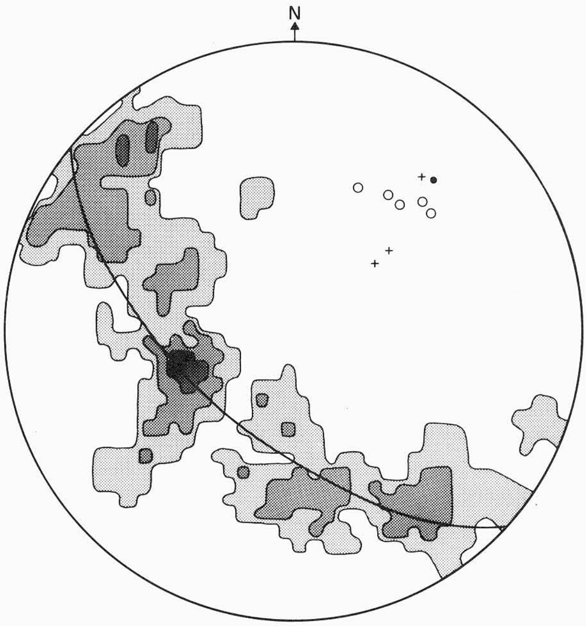



*Figure 13:* Equal-area projections of poles to foliation planes, minor fold axes and linear structures, subarea 2.

## TECTONIC SYNTHESIS

The structural pattern in the Rat Lake area has been interpreted as resulting from the refolding of early recumbent folds, followed by a phase of shearing and faulting, and a final phase of folding (Table 9). The early recumbent folds ($F_1$) proposed for the Rat Lake area, were formed by tectonic transport in a northeasterly direction, from a geosynclinal trough located between Rat Lake and the Snow Lake area to the south. Stocks and sills of quartz diorite (9) and sills of magnetiferous quartz diorite (10) were emplaced after the early folding.

A second phase of folding $F_2$, resulting from north-south compression, refolded the recumbent folds into a series of upright isoclinal folds. Cross-folds, oriented about north-south axial planes and of local extent, appear to have been related to the period of east-west isoclinal folding. The cross-folding produced an interference pattern of basins and domes in the southeast portion of the map-area. The local extent of the cross-folding suggests that it was not a regional event, but rather may have been just a local "wrinkling", about north-south vertical axial planes, of the main east-west isoclinal folds.

At this point in the history of the area, large intrusions of quartz monzonite (16a, *15a*) were emplaced along the main east-west fold trend, and a smaller stock was intruded along one of the north-south cross-folds. The intrusions were not entirely passive, but exerted lateral and vertical pressure during their emplacement, causing enhancement of the antiformal structures and attenuation of the synforms.

A major phase of shearing and faulting, $D_3$, together with intrusions of microcline granite post-date the intrusion of the quartz monzonite (16a, *15a*). A major northeasterly dipping structural break, the "Rat Lake fault", was produced at this time. The sense of movement on this fault appears to have been left lateral. The area east of the fault was only weakly deformed by shearing, whereas the zone to the west was intensely sheared. The shearing caused transposition of the layering in the gneisses, and the presence of cordierite and sillimanite in the transposed layers indicates that pressures and temperatures during the shearing were initially high enough to allow the recrystallization of these minerals.

The orientation of the shearing and faulting may have been controlled by the large bodies of quartz monzonite (16a, *15a*), which acted rigidly because of their more massive character. The paragneisses and migmatites, with well developed foliations, offered the easiest path for stress release.

The final phase of folding $F_4$, about northeasterly trending axial planes, was restricted to the area west of the "Rat Lake fault". The folds appear to be of regional extent, however, as they continue into the map-areas south of the Rat Lake area.

Faulting with associated retrograde metamorphism and silicification comprised the final phase of deformation ($D_5$) in the map-area. The faults trend predominantly north-south while some of them are parallel to the older $D_3$ trends.

# ECONOMIC GEOLOGY

The number and the varying ages of claim posts observed in the Rat Lake area, indicates that considerable exploration activity has taken place over a number of years. However, there is no record of cancelled assessment work, done prior to 1969, on open file at the Mines Branch in Winnipeg. Interest in the area was revived with the release of the results of the Manitoba Government airborne INPUT electromagnetic survey in June, 1969 (Manitoba Mines Branch, 1969), and a number of claims were staked in the area at this time.

The most persistent zones of mineralization in the map-area are the amphibolite (2a) and the calc-silicate layers in unit 2b (see Table 10 and Figure 14). The mineralization consists mainly of sparse but widespread disseminations of pyrrhotite and minor chalcopyrite. The sulphides tend to show a greater concentration in zones affected by tectonic and metamorphic processes. For example, where shears intersect the amphibolite (2a) or where the amphibolite is intensely folded and sheared, gossans and concentrations of visible pyrrhotite occur. Furthermore, the hypersthene-bearing lenses in the amphibolite (see page ) show a higher concentration of disseminated pyrrhotite than the amphibolite itself.

Local occurrences of molybdenite and sphalerite were also found in the map-area. The molybdenite was observed in zones of silicification at three locations (see Table 10 and Figure 14). At Location 1, the host rock is microcline granite (17). The molybdenite forms large spectacular clots of very limited extent within quartz veins. Similar local occurrences of molybdenite clots occur at Location 2 and Location 3, where the silicified host rocks are hornblende-biotite-magnetite gneiss (6) and quartzo-feldspathic gneiss and migmatite (3) respectively. The molybdenite mineralization in all cases appears to have been a late stage event, accompanied by local retrograde metamorphism along the quartz veins. The coarseness of the molybdenite suggests that it crystallized from late magmatic fluids.

Sphalerite occurs on the northeast arm of Rat Lake at Location 4 (Table 10 and Figure 14), as clots and veins in steeply dipping joints, oriented at 240 degrees and 290 degrees, in a leucocratic quartz diorite. The leuco-quartz diorite, which forms a narrow contact phase between the quartz diorite (9) and quartz monzonite (16a), is altered alongside the sphalerite veins and clots. Plagioclase is altered to epidote and calcite, and chlorite forms veinlets which are most pronounced close to the sphalerite-quartz diorite contact, but become thinner and die out within a distance of a few centimetres. An INPUT electromagnetic anomaly, and corresponding magnetic anomaly, were recorded off-shore from this occurrence of sphalerite.

In evaluating the INPUT electromagnetic anomalies in the Rat Lake area, priority should be given to anomalies lying in or near the amphibolite (2a), the associated quartz norite and the calc-silicate rocks (2b); and also to anomalies such as that accompanying the sphalerite occurrence. The latter type of anomaly does not fit any apparent pattern of stratigraphic or structural control. Another anomaly of this type occurs in the area of microcline granite (17) and granitized paragneiss (5a) in the extreme northwest corner of the map-area (lat. 56°14'30", long. 99°55'30"). Ground follow-up was inconclusive owing to lack of outcrop.

Anomalies in the pelitic gneiss (1) are considered least significant as they are commonly caused by graphite. The anomalies are numerous and the conductors are parallel to the foliation. Sulphide conductors, if present, are obscured by the graphite but the presence or absence of an aeromagnetic anomaly may be a means of distinguishing anomalies of interest. The only sulphide mineralization observed in the pelitic gneiss occurs in microclinized shear zones which contain thin layers of pyrrhotite and minor chalcopyrite, together with graphite. The mineralization was observed in drill core stored on the shore of a lake which lies 7 miles (11 km) southeast of the mouth of the Suwannee River (Figure 14, Location 15). The only information available on the location of the drill hole is that the core comes from an area within a 6-mile radius of the core storage location (personal communication).

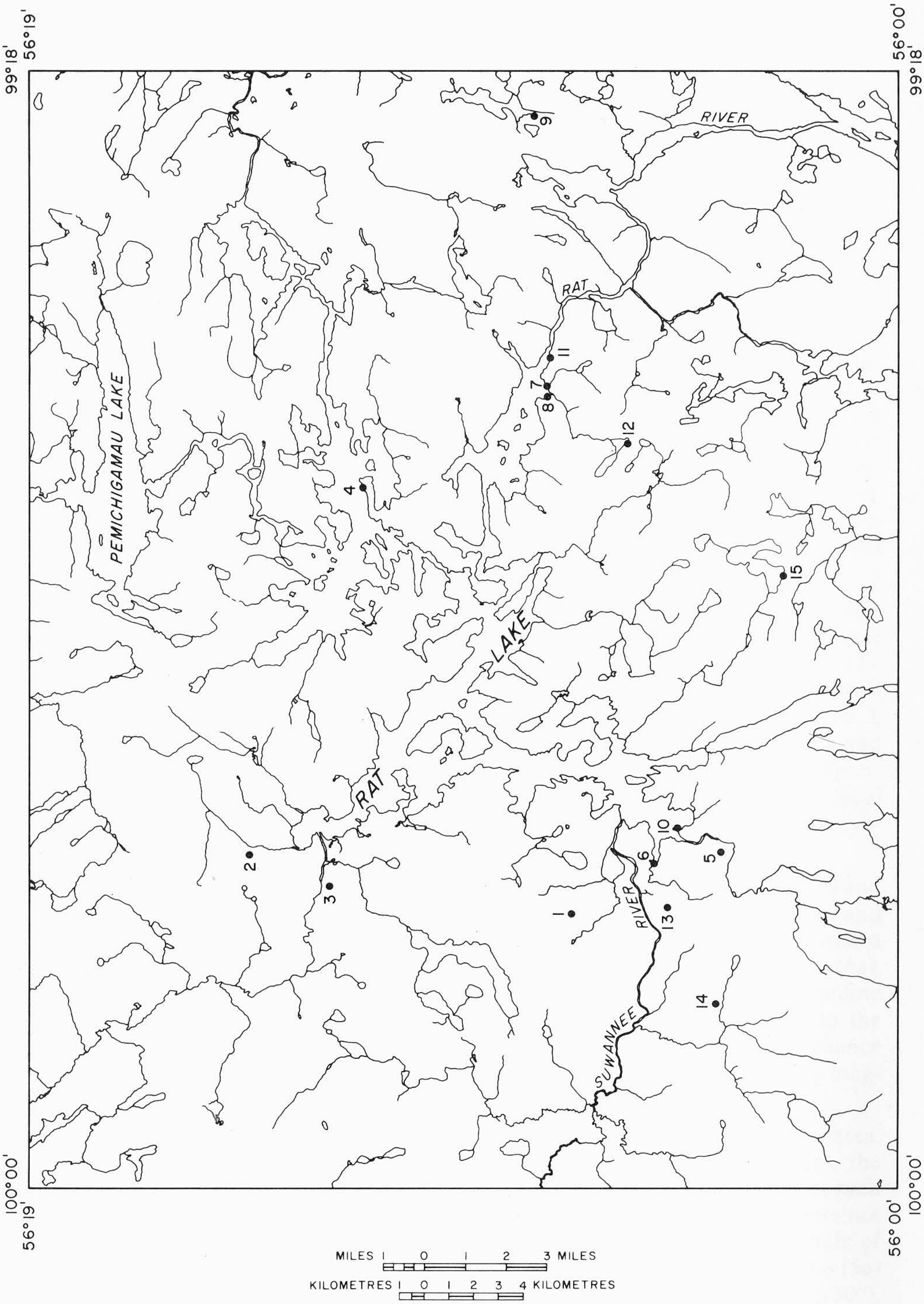



*Figure 14:* Location of sulphide occurrences.

## TABLE 10. SULPHIDE OCCURENCES AND RELATED GEOPHYSICAL ANOMALIES

| Location shown in Figure 14 | Latitude and longitude | Type of Mineralization | Rock type | Associated INPUT electromagnetic anomaly and magnetic correlation* |
|---|---|---|---|---|
| 1 | 56°07′00″; 99°44′40″ | molybdenite | Microcline granite (17) with abundant inclusions of the weakly magnetiferous quartzo-feldspathic gneiss (5a) | None |
| 2 | 56°13′48″; 99°47′15″ | molybdenite | Quartzo-feldspathic gneiss and migmatite (3) | None |
| 3 | 56°12′30″; 99°48′30″ | molybdenite | Hornblende-biotite-magnetite gneiss (6) | None |
| 4 | 56°11′32″; 99°33′29″ | sphalerite | Leuco-quartz diorite contact phase between quartz monzonite (16a) and quartz diorite (9) | 5-channel, offshore; direct magnetic correlation |
| 5 | 56°03′50″; 99°47′20″ | pyrrhotite (disseminated) | Amphibolite (2a) | 3-channel; direct magnetic correlation |
| 6 | 56°05′10″; 99°47′45″ | pyrrhotite (disseminated) | Quartz-microcline layers in calc-silicate rock (2b) | 3-channel |
| 7 | 56°07′25″; 99°29′30″ | pyrrhotite (disseminated) | Amphibolite (2a); sheared | None |
| 8 | 56°07′25″; 99°30′10″ | pyrrhotite (disseminated), graphite | Amphibolite (2a) and pelitic gneiss (1); both sheared | 4-channel; direct magnetic correlation |
| 9 | 56°07′43″; 99°19′25″ | pyrrhotite (disseminated) | Lensesof amphibolite (2a) within pelitic gneiss (1) intersected by fault zone | 3-channel (large clusters of anomalies directly to the east and south of this sulphide occurence) |
| 10 | 56°04′45″; 99°46′25″ | chalcopyrite (minor small blebs) | Pelitic gneiss (1); silicified and sheared | None |
| 11 | 56°07′20″; 99°28′25″ | pyrrhotite (disseminated) | Amphibolite (2a) and pelitic gneiss (1); sheared | 2-channel |
| 12 | 56°05′42″; 99°31′55″ | pyrrhotite (disseminated) | Quartz microcline layers (similar to those interlayered with the calc-silicate rock (2b) within pelitic gneiss (1) | 4-channel; direct magnetic correlation |
| 13 | 56°05′00″; 99°49′25″ | pyrrhotite (disseminated), minor chalcopyrite | Amphibolite (2a) | 4 and 6-channel |
| 14 | 56°03′55″; 99°53′00″ | Minor disseminated pyrrhotite | Amphibolite (2a); folded and sheared | 5-channel. Immediately to the south of this occurrence is a string of 5 and 6-channel anomalies with direct magnetic correlation, corresponding to a linear topographic depression |

*Data from airborne INPUT electromagnetic survey and aeromagnetic survey, flown by Questor Surveys Limited in 1968 for the Manitoba Department of Mines and Natural Resources (Manitoba Mines Branch, 1969).

# REFERENCES


Bailes, A.H.
1971: Preliminary Compilation of the Geology of the Snow Lake-Flin Flon-Sherridon area: *Man. Mines Br.*, Geol. Paper 1/71.

Baldwin, D.A.
1971: Garnet-cordierite-anthophyllite rocks of Rat Lake, Manitoba: unpublished M.Sc. Thesis, University of Manitoba.

Barry, G.S., and Gait, R.I.
1966: Geology of the Suwannee Lake Area: *Man. Mines Br.*, Publ. 64-2.

Bateman, P.C.
1961: Granitic formations in the East-Central Sierra Nevada near Bishop, California: *Bull. Geol. Soc. Amer.*, 72: 1521-1538.

Campbell, F.H.A.
1972a: Stratigraphic and structural studies in the Granville Lake-Lynn Lake region: *Man. Mines Br.*, Publ. 71-2A.

1972b: Geology of the Turnbull Lake (West half) Area: *Man. Mines Br.*, Publ. 71-2D.

Carlson, H.D.
1962: Geology of the Mynarski Lakes Area: *Man. Mines Br.*, Publ. 62-3.

Elphick, S.C.
1972: Geology of the Mynarski-Notigi Lakes Area: *Man. Mines Br.*, Publ. 71-2C.

Hsu, L.C.
1968: Selected phase relationships in the system Al-Mn-Fe-Si-O-H: A Model for Garnet Equilibria: *J. Petrol.*, 9: 40-83.

Kendrick, G.
1972: Geology of the Turnbull Lake (East half) and Pemichigamau Lake (West half) Areas: *Man. Mines Br.*, Publ. 71-2E.

Manitoba Mines Branch
1969: Southern Indian Lake Project: Questor Surveys Limited Airborne Mark V INPUT electromagnetic survey: Maps 12, 13.

Milligan, G.C.
1960: Geology of the Lynn Lake District: *Man. Mines Br.*, Publ. 57-1.

1964: Geology of the Earp Lake Area (West Half): *Man. Mines Br.*, Publ. 61-2.

Pearse, G.
1964: Geology of the Pemichigamau Lake Area (East Half): *Man. Mines Br.*, Publ. 61-3.

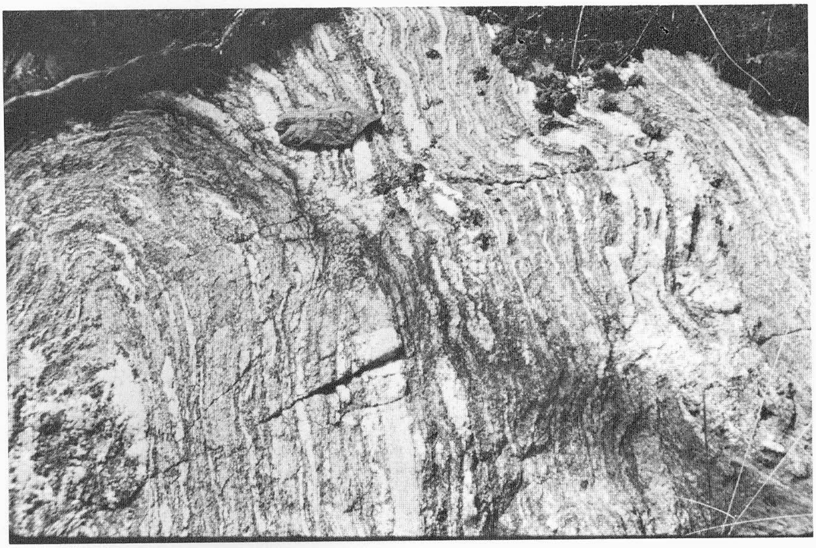
Steeves, M.A., and Lamb, C.F.
1972: Geology of the Issett-Opachuanau-Pemichigamau-Earp Lakes Area: *Man. Mines Br.*, Publ. 71-2F.

Turner, F.J.
1968: Metamorphic Petrology: *McGraw-Hill Book Co.*, New York.

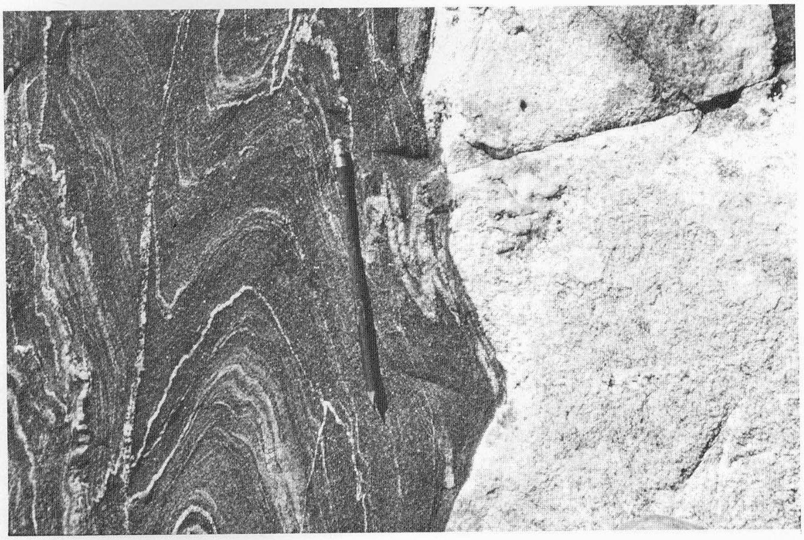
Winkler, H.G.F.
1967: Petrogenesis of Metamorphic Rocks (Second edition): *Springer-Verlag*, New York.

Wright, G.M.
1953: Uhlman Lake Map-area, Manitoba: *Geol. Surv. Can.*, Paper 53-12.

# PLATE 1



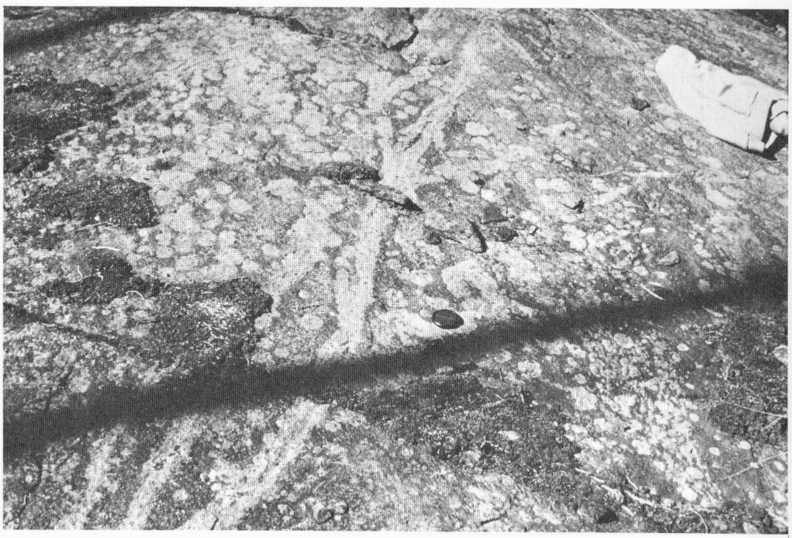
A Typical pelitic gneiss (1), station 24-0-1617, 3.5 miles (5.6 km) southeast of the most southerly tip of Rat Lake.



B Amphibolite (2a) showing metamorphic layering (S) intruded by white pegmatitic granodiorite (11), station 24-9-3176, 4 miles (6.4 km) east of the most southerly tip of Rat Lake.

PLATE 2

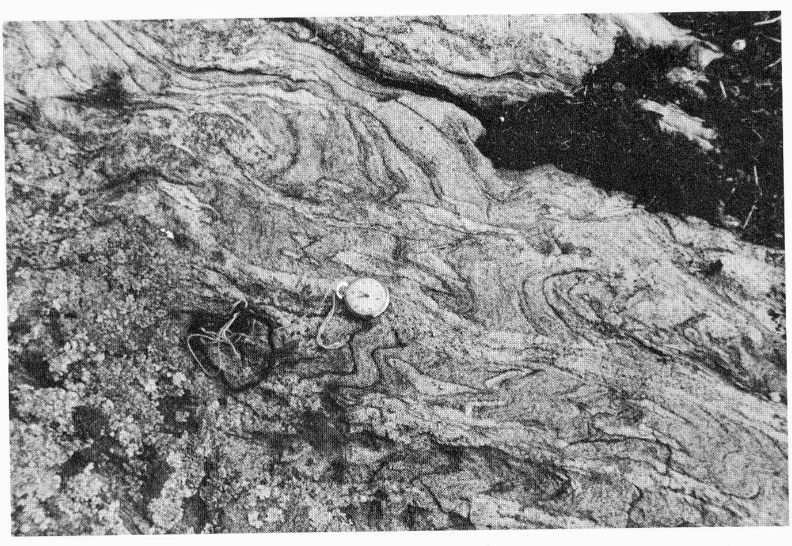

A. Magnetiferous quartz diorite (10) showing quartzo-feldspathic coronas around magnetite grains, station 24 0 1862, 7 miles (11 km) southeast of the most southerly tip of Rat Lake



B. Anthophyllite schist (4) with garnet porphyroblasts and veins, west side of Rat Lake (Figure 5, location 3), station 24 0 1021 (*Photo J. Haugh*)

# PLATE 3

A. Overgrowths of garnet on magnetite porphyroblasts in anthophyllite schist (4), west side of Rat Lake (Figure 8, location 3), station 24-9-1021.



B. S metamorphic layering in unit 4, transposed along S foliation planes, station 24-9-1013, 2.7 miles (4.4 km) north of the mouth of the Suwannee River.