GEOLOGICAL SURVEY OF CANADA
COMMISSION GÉOLOGIQUE DU CANADA

PAPER 80-26

GEOLOGY OF THE MANIGOTAGAN AREA, MANITOBA

I.F. ERMANOVICS

Canada

1981

GEOLOGICAL SURVEY
PAPER 80-26

GEOLOGY OF THE MANIGOTAGAN AREA, MANITOBA

I.F. ERMANOVICS

1981

Available in Canada through

authorized bookstore agents
and other bookstores

or by mail from

Canadian Government Publishing Centre
Supply and Services Canada
Hull, Québec, Canada K1A 0S9

and from

Geological Survey of Canada
601 Booth Street
Ottawa, Canada K1A 0E8

A deposit copy of this publication is also available
for reference in public libraries across Canada

Cat. No. M44-80/26E	Canada: $4.00
ISBN 0-660-10882-8	Other countries: $4.80

Price subject to change without notice

Critical Readers

A.V. Okulitch
W.F. Fahrig
W.L. Davison

Original manuscript submitted: 1975-10-02
Approved for publication: 1980-07-04

CONTENTS

Tables

Figures

GEOLOGY OF THE MANIGOTAGAN AREA, MANITOBA

Abstract

Arkoses that lie stratigraphically above rhyodacite (U-Pb zircon age 2732 Ma) of the Black Island succession unconformably overlie metatonalite (U-Pb zircon age 2999 Ma) at Hole River. Metagreywackes and aluminous schists at Manigotagan were metasomatized during intrusion of later tonalite and granodiorite about 2690 Ma ago but the contact with early metatonalite, thought to be unconformable, is not exposed. Hole River arkose and Manigotagan metasediments were derived from a granitic source and are correlated with the San Antonio Formation at Bissett, Manitoba.

Metavolcanic rocks, hornblende gneiss and layered tonalite gneiss may predate the 2999 Ma old metatonalite. Mafic schists, metagabbro, and serpentinized ultramafic rocks occur as small bodies in metatonalite.

Manigotagan metasediments were metamorphosed to lower amphibolite facies and retrogressed to greenschist facies in localized shear zones. Early metavolcanics and tonalites record at least two periods of regional metamorphism in the amphibolite facies and retrogression to greenschist in shear zones.

Résumé

Les arkoses qui recouvrent stratigraphiquement les rhyodacites (2732 millions d'années selon le rapport U-Pb dans le zircon) de la succession de Black Island ont été déposées en discordance sur les métatonalites (2999 millions d'années selon le rapport U-Pb dans le sircon) à Hole River. Il y a eu métasomatose des métagrauwackes et des schistes alumineux lors de l'intrusion, il y a environ 2690 millions d'années, de tonalites et de granodiorites plus récentes, mais le contact avec la métatonalite ancienne, vraisemblablement une discordance, n'est pas exposé. Les arkoses de Hole river et les métasédiments de Manigotagan proviennent d'une source granitique et ont été associées avec la formation de San Antonio à Bisset (Manitoba).

Des roches métavolcaniques, des gneiss à hornblende et des gneiss rubanés à tonalite ont peut-être été déposés avant la métatonalite qui date de 2999 millions d'années. Des schistes ferromagnésiens, des métagabbros et des roches ultramafiques serpentinisées se retrouvent sous forme de petites masses dans la métatonalite.

Les sédiments de Manigotagan ont été métamorphisés dans le faciès amphibolite inférieure et ont rétrogradé dans le faciès schistes verts, dans les zones de cisaillement séparées. Les roches métavolcaniques et les tonalites anciennes ont enregistré au moins deux périodes de métamorphisme régional dans le faciès amphibolite et ont rétrogradé vers le faciès schistes verts dans les zones de cisaillement.

INTRODUCTION

This report reviews and adds information to work by Davies (1950, 1951) and Russell (1949) in the Manigotagan-English Brook area and extends work by Brown (in preparation) in the Black Island area (Fig. 1). Emphasis is given to the grade of metamorphism, the extreme complexity of age relationships of the many varieties of rocks of tonalitic compositions, and the relationship of the tonalitic rocks to gneissic bodies and metasediments. It is suggested that some of the granitic gneiss and meta-igneous rocks, such as those of map unit 2 and 3, are older than the metasedimentary rocks (4,5)[1]. Furthermore, there may be unconformities between supracrustal units, for example, between mafic volcanic rocks (1) and metasediments (4), which are difficult to see because of a strong penetrative fabric developed during the last deformation.

The San Antonio Formation overlies tonalite unconformably at Rice Lake 38 km east of the area and McRitchie (1971b, p. 33) reported that a conglomerate containing trondhjemitic clasts forms the basal part of a supracrustal succession at Wallace Lake 64 km to the east. Within the map area, early tonalites are not observed to intrude metasediments of units 4 and 5 and rocks of unit 5 in contact with tonalite do not display any effects of contact metamorphism.

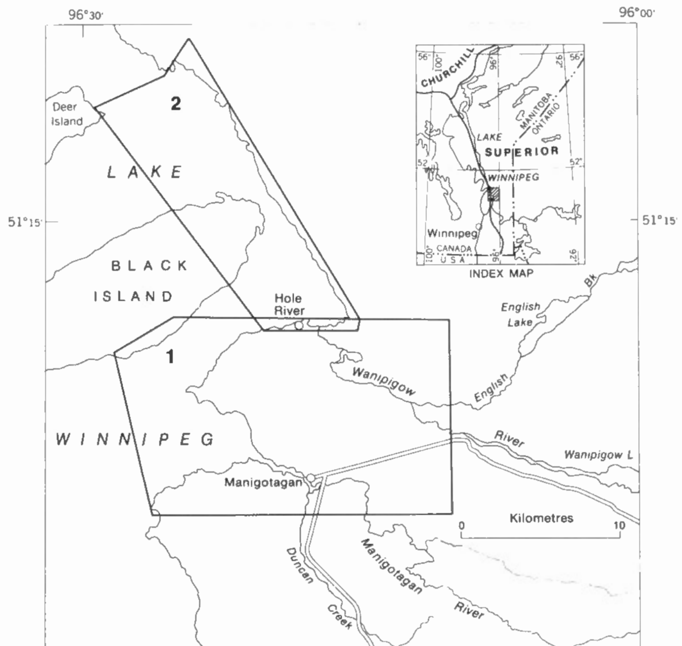


Figure 1. Index map to Manigotagan map area (1) and Black Island map area (2), Brown in preparation.

[1] Numbers in parentheses refer to map units on Figure 8.

Table 1. Chemical analyses (weight per cent) of ultramafic rocks (2U, Clangula Lake area) and mafic schists (1a, Virrs Point)

	Ultramafic Rocks (2U)			Mafic Schists (1a)			
	325	327	412	410	411	326	387
SiO_2	42.4	40.8	40.5	45.5	46.9	46.6	49.1
Al_2O_3	0.76	1.5	2.4	13.0	13.2	8.5	10.7
TiO_2	0.01	0.05	0.12	0.85	0.70	0.37	0.73
Fe_2O_3	1.2	2.7	4.7	3.4	3.0	4.4	3.6
FeO	3.4	5.3	5.4	8.0	11.2	9.3	7.0
MnO	0.11	0.25	0.12	0.19	0.22	0.20	0.20
MgO	40.0	38.1	34.6	9.1	9.6	7.5	11.9
CaO	0.2	0.16	0.08	12.0	8.9	8.6	10.2
Na_2O	0.02	0.01	0.02	1.4	1.6	0.91	1.3
K_2O	0.01	0.01	0.01	0.57	0.31	1.4	1.6
P_2O_5	0.03	0.01	0.02	0.08	0.08	0.07	0.34
CO_2	0.01	nf	nf	2.1	0.06	6.5	0.03
H_2OT	12.0	10.8	11.4	3.6	3.3	5.6	2.2
S	0.04	0.23	0.02	0.01	0.07	0.02	0.02
CrO_3	0.44	0.36	0.57	0.09	0.02	0.03	0.12

Mafic schists are tholeiitic basalt (normative classification of Irvine and Baragar, 1971).

Previous and Present Work

Studies before 1951, including those of Russell (1949) and Davies (1950, 1951) have been reviewed by Ermanovics (1970). McRitchie (1971c) compiled the geology of the Wanipigow-Winnipeg rivers area and separated metasediments in Manigotagan Bay (on Lake Winnipeg) from similar rocks west of Wanipigow Lake. Lying between these areas is his unit 7b, lower amphibolite facies paragneiss. The present report, based on four weeks of investigation during 1972 of outcrops mapped by Russell and Davies, shows that the Manigotagan metasediments (4) from Manigotagan Bay eastward to Wanipigow Lake are similar in composition and metamorphic grade.

Outcrop in the map area is sparse, especially in critical areas. However, interpretation of the geological history of these rocks is attempted because U-Pb radiometric studies (Krogh et al., 1974) suggest the presence of very old zircons in tonalite of unit 2 (3.0×10^9 years old) and in tonalitic gneiss of unit 3 (2.9×10^9 years old).

Nomenclature

Hole River and Manigotagan metasediments are given informal names because neither tops nor bottoms are exposed. Rocks are named according to the recommendations of the IUGS Subcommission on the Systematics of Igneous Rocks.

All isotopic age calculations are based on 25th IGC constants (^{87}Rb decay constant = $1.42 \times 10^{-11} a^{-1}$). Chemical analyses were perfomed by staff of the Analytical Chemistry Section of the Geological Survey of Canada. Analysis was by XRF (not fused) 'rapid methods' extant in 1974.

GENERAL GEOLOGY

Metavolcanic Rocks and Hornblende Gneiss (1)

Intermediate to basic volcanic rocks comprise greenschist and amygdaloidal to porphyritic greenstone. Only three areas of outcrop of this unit were found in the map area and these occur at Virrs Point on the northwest side of the Manigotagan metasediments. Elsewhere, highly schistose lenses of probable volcanic origin (1b,1a) occur on the southeast side of the Manigotagan metasediments (4) in the southeastern part of the map area. The rocks consist of quartz, epidote, calcite, chlorite, albite and colourless to green cummingtonite and hornblende. 'Porphyries' are aggregates of epidotized albite, and 'amygdules' are calcite and quartz. Norms (Table 1) show that the schists have compositions of tholeiitic basalt.

No felsic volcanic rocks were recognized, although they were reported by Russell (1949). On the basis of mylonitic fabric and its occurrence in shear zones Russell's (1949) rhyolitic rock is interpreted as a sheared quartzofeldspathic rock (4b). Rhyodacite, however, occurs in the upper Black Island succession in areas to the east and north, as described by Davies (1950) and Brown (in preparation).

TABLE OF MAP UNITS

unit 6: Late tonalite and granodiorite; undivided; metamorphosed, coarse grained, generally leucocratic, gneisses, mixed with alkali mobilizate and gneissose rocks of unit 3; 6a, massive granite to oligoclase granodiorite.

Not in contact with unit 5, but unit 6a intrudes all other rock types. May be intrusive into units 1, 2 and 3.

unit 5: Hole River metasediments; arkosic sediments correlative with San Antonio Formation; this is map unit 47 in Black Island area (Brown, in preparation).

Not in contact with unit 4 but may be correlative with it. Contact with unit 2 is not exposed, but arkoses probably lie unconformably on metatonalite of unit 2.

unit 4: Manigotagan metasediments; undivided, fine grained, pelitic spotted mica schist and grey, thin bedded, micaceous quartzofeldspathic rocks and rare interlaminated quartzite (85% quartz). 4a: chlorite-garnet-muscovite-biotite schist (quartz + albite); staurolite-chlorite-garnet-biotite-muscovite schist (quartz + albite/oligoclase) 4b: dominantly quartzofeldspathic rocks (mica + garnet) with a common range of 40% to 60% quartz.

Contact remobilized but probably unconformable

unit 3: Tonalitic and trondhjemitic gneiss; subdivided in Brown (in preparation) as "layered tonalite"; medium grained, granoblastic, locally layered, feldspathic gneiss, and coarse grained biotite-hornblende gneiss; locally intruded by up to 35% late tonalite (unit 6) and pink granitic mobilizate (unit 6a); may be intruded by tonalite of unit 2.

Contact partly intrusive and partly gradational

unit 2: Early metatonalite, metagabbro, and meta-ultramafic rocks; subdivided in Brown (in preparation) as "tonalite"; undivided, metamorphosed, porphyroblastic tonalite and mafic tonalite of dacitic and andesitic composition; locally intruded by possibly late tonalite (unit 6) and pink granitic mobilizate 6a, 2U, serpentinized dunite and pyroxenite.

Contact not exposed, but may be intrusive

unit 1: Metavolcanic rocks and hornblende gneiss; undivided metamorphosed volcanic rocks and gneiss of intermediate to basic composition. 1a: greenschist, amygdaloidal greenstone and intercalated fine- to medium-grained metagabbro; probably younger than 1b. 1b: hybrid, granoblastic hornblende-oligoclase gneiss, amphibolite and small lenses of 1a; becomes dominantly gabbroic east of map area.

The origin of lineated, medium- to coarse-grained, layered hornblende-oligoclase gneiss (1b) presents a problem. It generally shows a higher grade of metamorphism (oligoclase-hornblende with a secondary overprint of albite-chlorite-biotite-epidote) than do other rocks in the area but occupies a stratigraphic level similar to volcanic rocks of unit 1a (i.e. basal). It is commonly separated from overlying rocks by amphibolitic or granitic material. Russell (1949) interpreted such gneiss (1b) as a metamorphosed equivalent of the Rice Lake supracrustal rocks and recognized them as far north as English Lake (5 km northeast of map area). Ermanovics (1970) removed this gneiss from the supracrustal sequence because its derivation from nearby supracrustal rocks is not obvious and it is rarely in contact with them. Hornblende-bearing gneiss (1b) occurs as discontinuous remnants along the northern contact of tonalite (6) in the southeast corner of the map area. Here it appears to be intercalated with volcanic schist (1b,1a) and quartzofeldspathic metasediments (4b) and grades through a zone of shearing into tonalite. It forms granitized inclusions in tonalite (6) and discernible layers in tonalitic gneiss (3).

As these rocks lack volcanic textures and have suffered metamorphism of higher grade than volcanic rocks (1a) it is suggested that unit 1b is older than the volcanic rocks.

Metatonalite, Metagabbro and Meta-ultramafic Rocks (2)

This unit is an early tonalite, distinguished from younger tonalites in the area by its pervasive cataclastic texture (Fig. 2c), metamorphic mineralogy and association with gabbroic and ultramafic rocks. The rock is most commonly porphyroblastic (6 to 25 mm elongated aggregates of epidotized albite and quartz) with a schistose matrix consisting of about 10 to 20 per cent chlorite, epidote, calcite and pale green hornblende. Recrystallized quartz appears as blue quartz eyes and constitutes 25 to 35 per cent of the rock and is locally oriented and folded into micro-chevron and kink folds with dark, platy matrix. Locally, the rock is layered (25 to 75 mm wide), which may be the result of metamorphic differentiation. At Clangula Lake and locally east of the Wanipigow River, it is less sheared and may represent a younger suite of intrusions. The relationship between gabbroic phases, serpentinized ultramafic rocks (2U) and tonalite could not be ascertained; it is likely, however, that they are comagmatic. Although mostly serpentinized, and distinctly schistose, some ultramafic rocks show skeletal orthopyroxene and serpentine pseudomorphs after olivine. Work has suggested that these small bodies are lenticular steeply plunging syntectonic pipes (Scoates, 1971) and that some are concentrated along faults, in particular along the westward extension of the Wallace Lake Fault (McRitchie, 1971c; Scoates, 1971). Another hypothesis to consider, however, is that they are remnants of early, extensive Mg-rich sheets stoped and disrupted by later dioritic intrusion. Scoates (1971) favoured an allochthonous origin, including the hypothesis of an intrusive event related to the evolutionary cycle of the lower greenstone succession. Ultramafic rocks are most common on the north side of the Rice Lake volcanic belt in early metatonalitic rocks and re-mapping of these rocks north of the Rice Lake volcanic belt from Wanipigow Lake to Clements Point on Lake Winnipeg, as well as the east side of English Lake, should reveal other ultramafic bodies.

The contact between metatonalite (2) and Hole River Formation (5) although not exposed, is probably abrupt and most likely displaced by tight vertical fold movements (Brown, in preparation). No contact metamorphism is evident and within the tonalite near the contact, small slices of metasedimentary rocks with primary textures show no thermal effects greater than those produced elsewhere by regional metamorphism within the Hole River metasediments (5). This suggests an unconformable relationship. The inclusions were structurally interleaved with tonalite in a zone of cataclastic shear (Brown, in preparation).

The origin of this metatonalite is uncertain because it has undergone such severe metamorphism and cataclasis that all primary igneous textures have been erased. The rocks have an 'andesitic' composition and less commonly a 'dacitic' composition; gabbroic phases are 'basaltic' (Fig. 4, Ermanovics et al., 1979).

Tonalitic and Trondhjemitic Gneiss (3)

Two main textural phases of intimately mixed leucocratic tonalitic gneiss are included in this group of rocks. One is a medium grained, granoblastic, lineated quartz-oligoclase gneiss (Fig. 2b) with biotite and hornblende streaks comprising up to 10 per cent; these streaks may have been derived from sedimentary rocks. The other is a coarse grained augen (quartz + oligoclase) gneiss in which biotite, epidote and relict poikilitic hornblende (Fig. 2d) are wrapped around the augen; this may be orthogneiss, but the origin of the gneissic phases remains uncertain. Both types were intruded by late kinematic granitic material but their original composition was similar to metatonalite of unit 2 (Fig. 4. Ermanovics et al., 1979). The tonalitic and trondhjemitic gneisses of unit 3 are in contact with Manigotagan metasediments (4b) in Manigotagan Bay. The rocks are interfolded but no intrusive relationship was demonstrated. Both units are intruded by massive granite and oligoclase granodiorite (6a). The contact between tonalite (2) and gneiss (3) is not exposed in the map area; however, Brown (in preparation) reports them to be intercalated in the Black Island area.

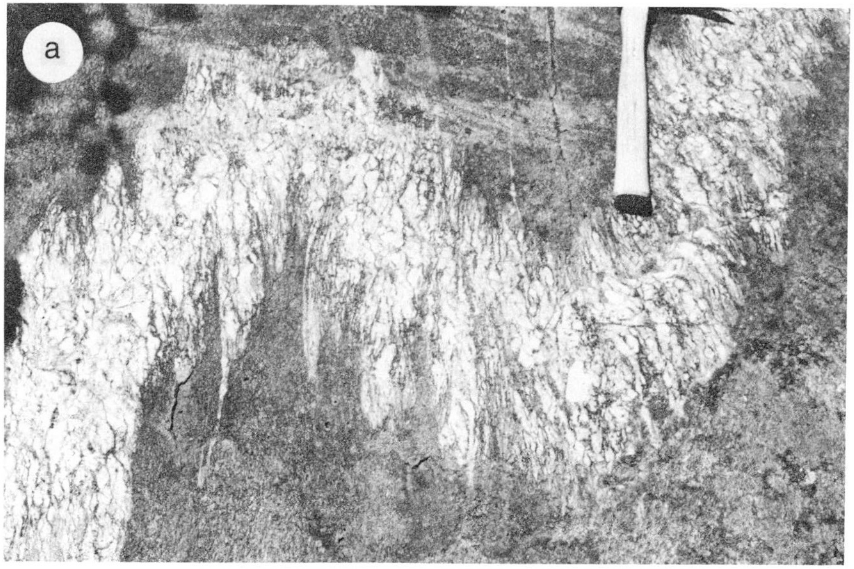
Manigotagan Metasediments (4)

Within the map area these fine grained rocks constitute a well defined unit of grey to silver, garnetiferous, spotted mica schist (4a) and a quartzofeldspathic, garnetiferous, mica greywacke sandstone (4b). Quartzite, reported by Russell (1949), was found as thin dark grey laminae. Beds are regular, eastward-thickening laminae of greywacke sandstone in schist (Fig. 3). Thin beds consisting of epidote (55%), alibite and quartz, are found in schist in a few localities; these may have been tuff of dacitic composition. Such rocks are more plentiful east of the map area.

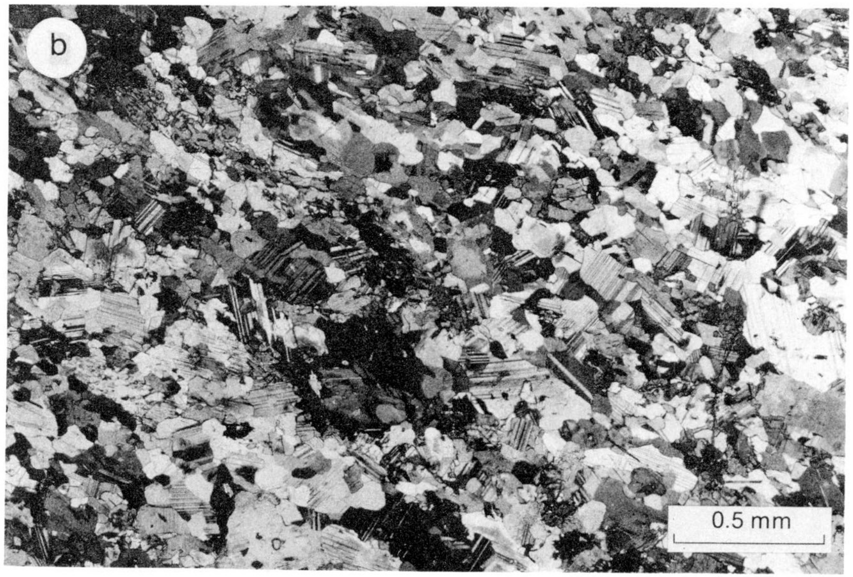
Members containing an average of 80 per cent quartz plus albite appear to have been derived from a siliceous terrane. Thus the Manigotagan (4) and Hole River (5) metasediments may be correlative with the San Antonio Formation (38 km east of the map area).

Albite forms small poikilitic idioblastic grains (Fig. 4); poikilitic biotite forms black spots in hand specimens of silvery spotted mica schist; garnet is usually visible only in thin section. Muscovite idioblasts tend to lie at an angle to the main foliation. Staurolite forms large poikiloblastic crystals but is rare. The idioblasts appear to be synkinematic (Fig. 5) and grow in a layered fibroblastic matte variously comprising mica + chlorite, and quartz + albite. The grade of metamorphism is estimated to be lower amphibolite facies (staurolite zone, Fig. 7). Manigotagan metasediments observed in broad folds are estimated to have a minimum thickness of 900 m.

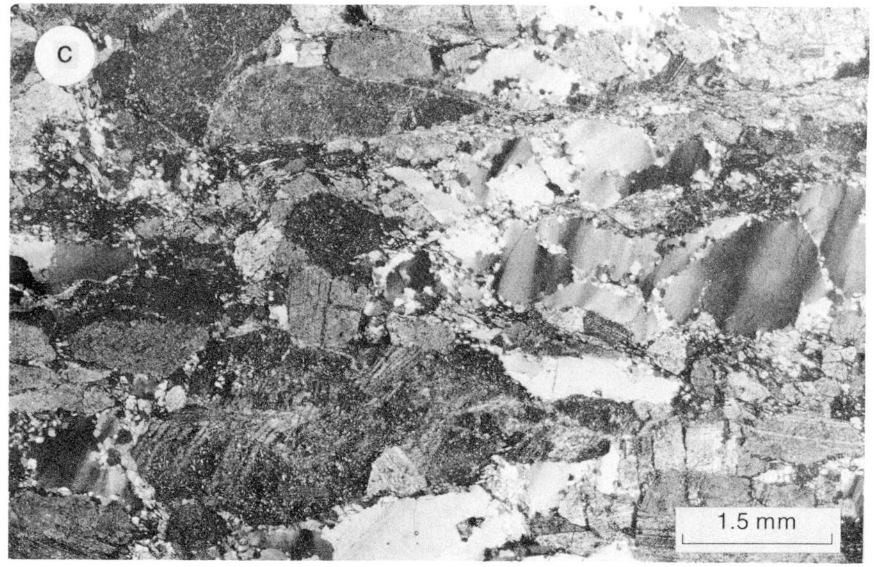
No primary sedimentary features remain except for bedding, and rare granitic lenses that might be stretched pebbles, which occur in quartzofeldspathic metasediments (4b). Graded bedding is recognizable but is an unreliable criterion for 'tops' because at this grade of metamorphism originally fine grained material is coarsely crystalline.



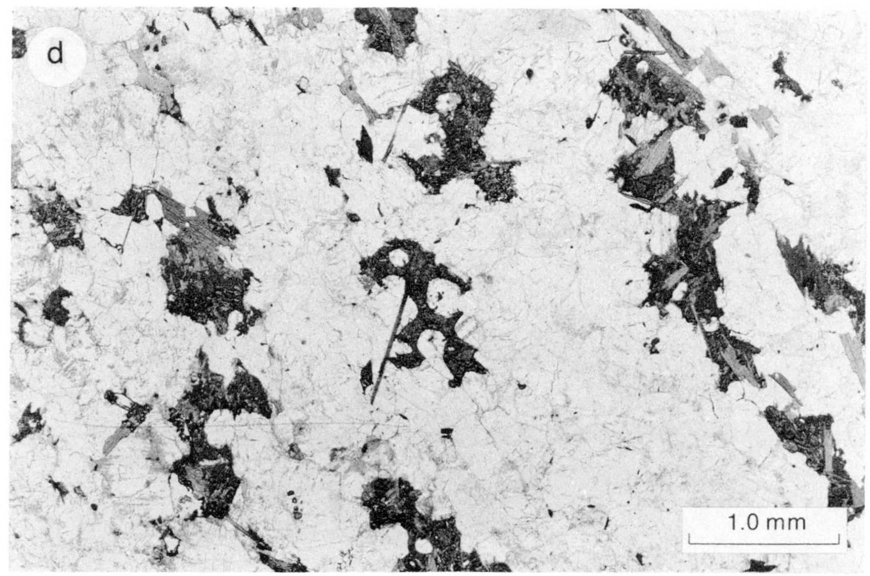
a. *Folded feldspar pegmatite in trondhjemitic gneiss of unit 3 that predates M_2 metamorphism. GSC 160218*



b. *Layer of recrystallized, twinned oligoclase (original feldspar was probably andesine) in a matrix of chlorite + muscovite + biotite + epidote + incompletely recrystallized plagioclase, in trondhjemitic gneiss (3). Crossed nicol. GSC 202288-G*

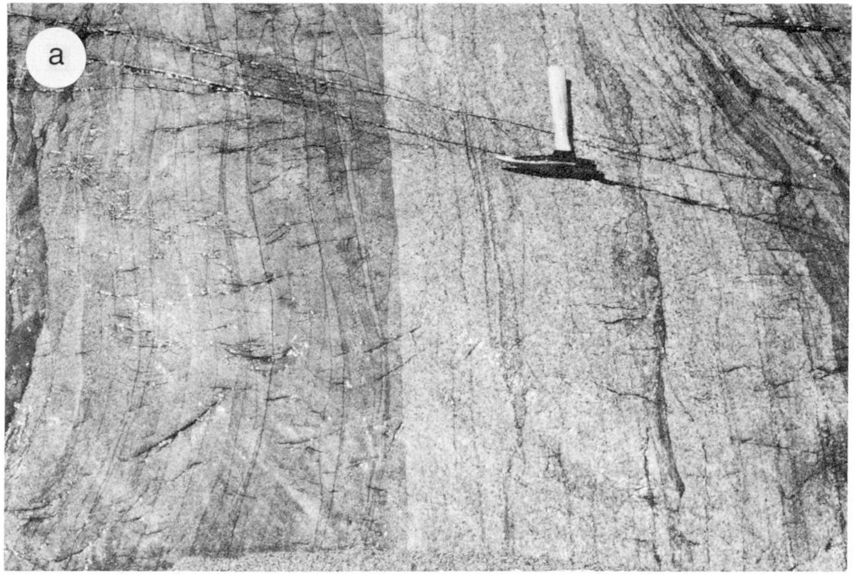


c. *Pervasive cataclastic texture in tonalite of unit 2. Recrystallized, strained quartz and sausseritized albite. Crossed nicol. GSC 202288-C*

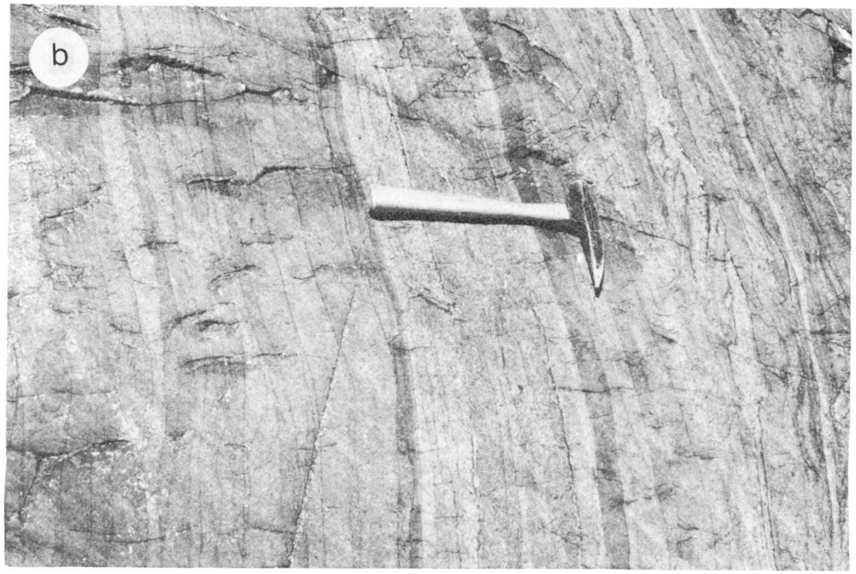


d. *Metamorphic, poikilitic hornblende (M_1) overgrown by late biotite and chlorite (M_2) in orthogneiss of unit 3. Plane light. GSC 202509-S*

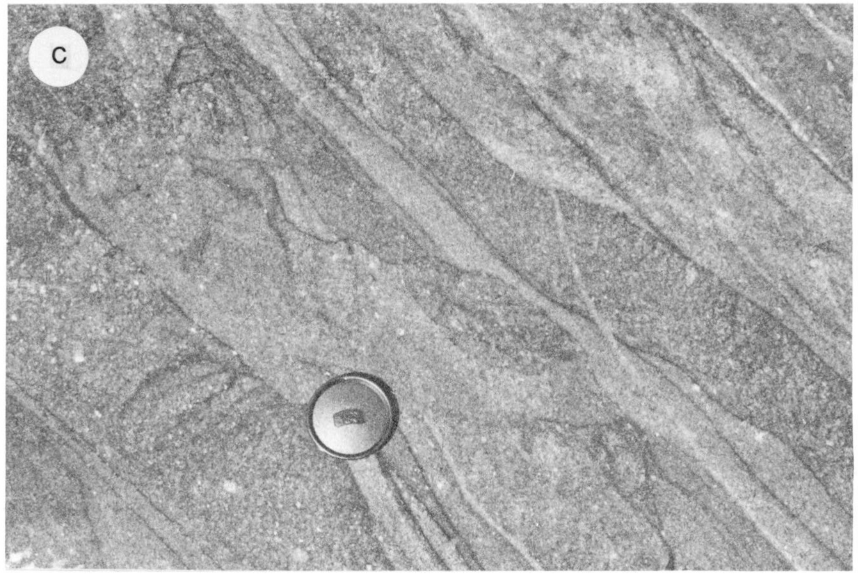
Figure 2. *Metamorphosed plutonic rocks.*



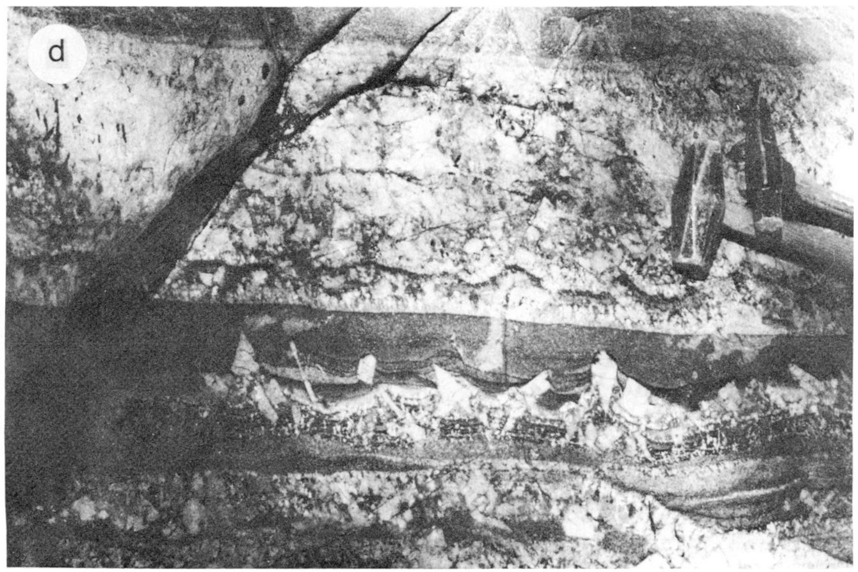
a. Laminae of pelitic schist (dark, left half) truncated by quartzofeldspathic metasediment (right half). GSC 160215-B



b. Layered metasediment. Darkest laminae here and in Figure 3a are quartz rich. GSC 160215-A

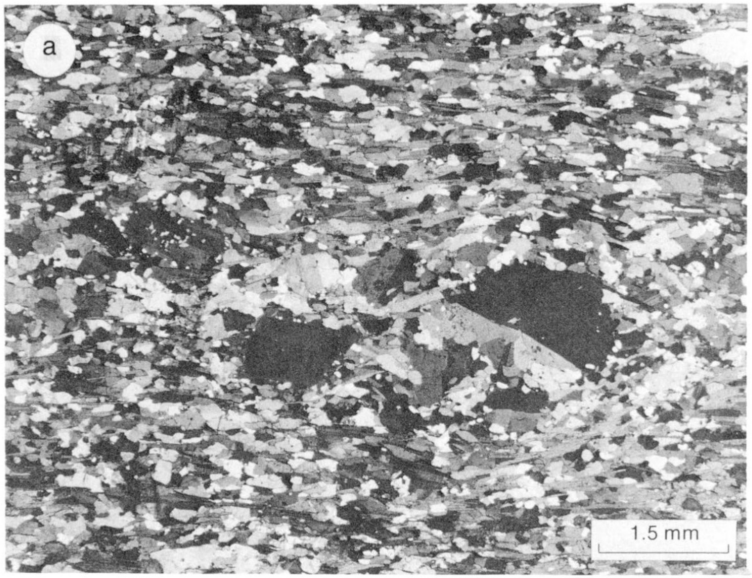


c. Quartzofeldspathic metasediment possibly exhibiting scoured or truncated crossbeds. Although most dark laminae are biotite rich, some are tourmaline layers associated with adjacent granitic mobilizate in this outcrop. GSC 160216

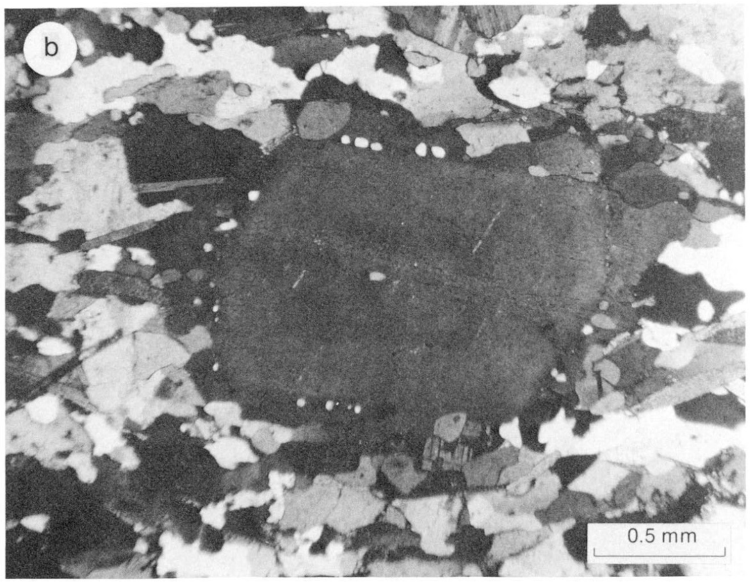


d. Dents-de-cheval texture of microcline perthite in layered metasediment at contact with trondhjemitic gneiss (3). GSC 160218-A

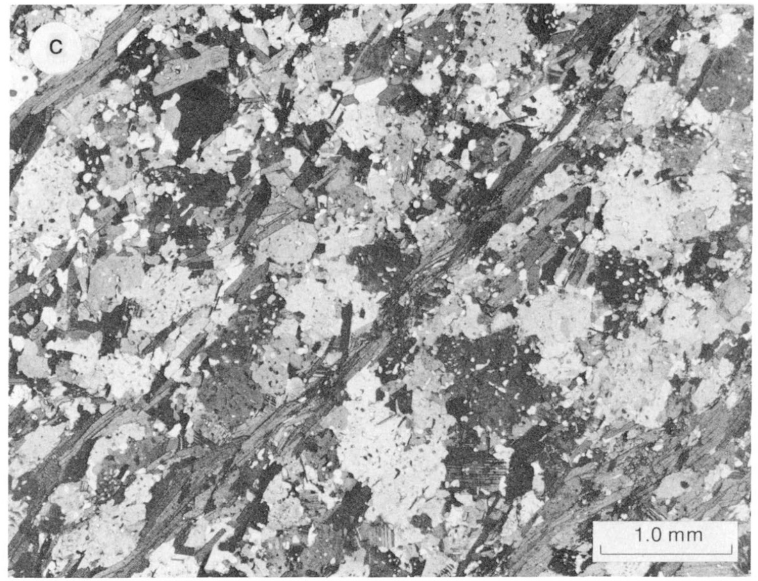
Figure 3. *Manigotagan metasediments (4) at their most westerly occurrence on Lake Winnipeg.*



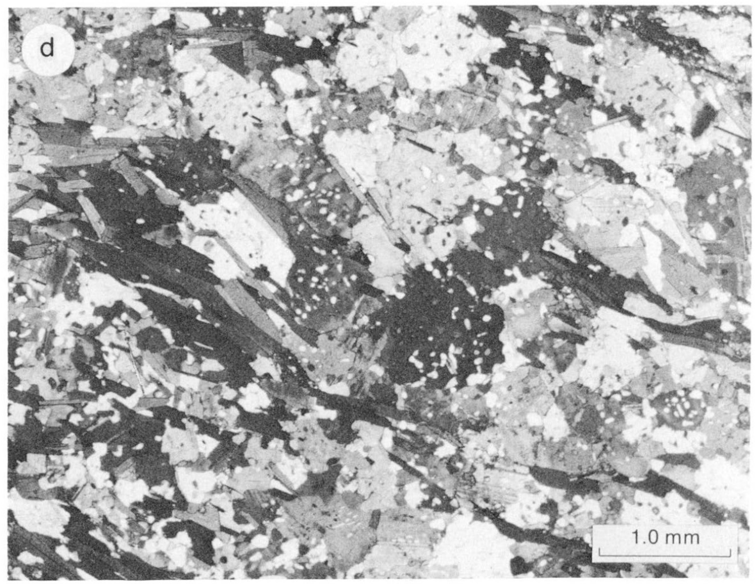
a. Zoned porphyroblastic grains of albite-oligoclase in biotite-bearing metasediment. Crossed nicol. GSC 202288-K



b. Detail of zoned albite-oligoclase (lower left grain of Fig. 4a) poikilitic with quartz at grain boundary. Multiple zones are probably due to metasomatism caused by the intrusion of a small quartz monzonite body 3 m from this sample. Crossed nicol. GSC 202288-M

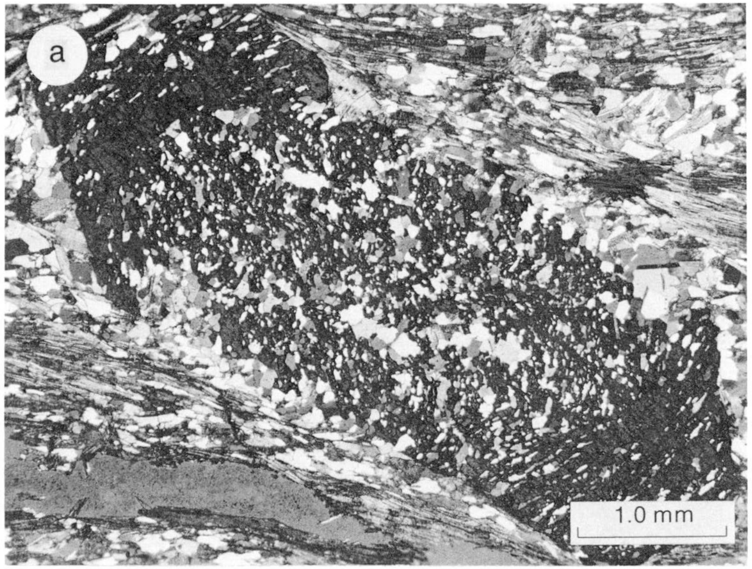


c. Highly poikilitic (with quartz) granoblastic albite bounded by epidote-biotite interlayers. Crossed nicol. GSC 202288-L

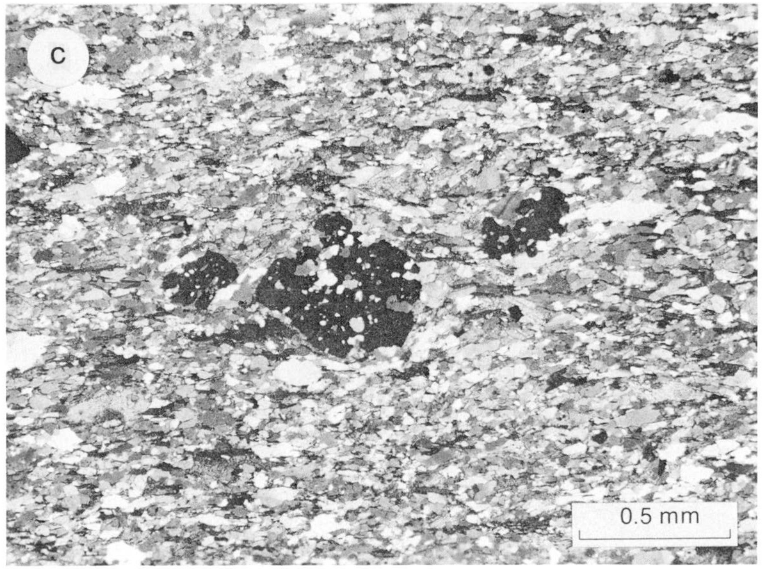


d. Detail of Figure 4c. Compare Figures 4c and 4d to gneiss of Figures 2b, which is infolded with metasediments but is interpreted as an older gneiss (3) probably of plutonic origin. Crossed nicol. GSC 202311-I

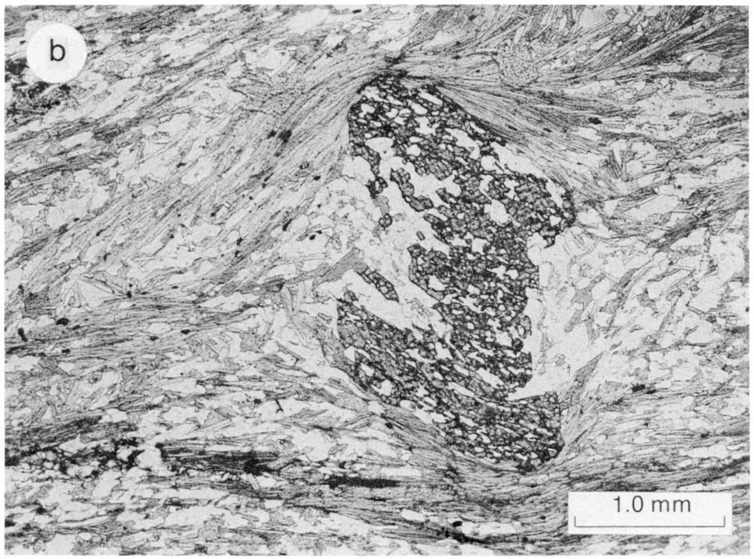
Figure 4. *Manigotagan quartzofeldspathic metasediments (4b).*



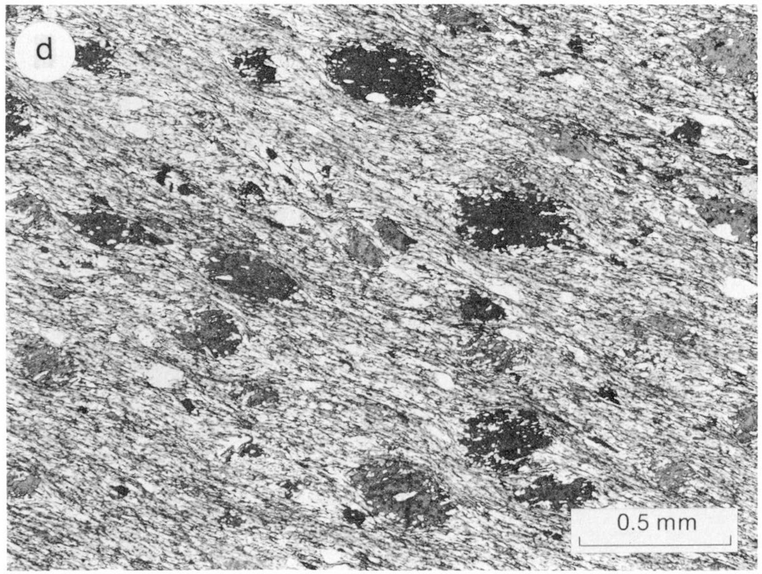
a. *Poikiloblastic staurolite from a silvery grey, knotted staurolite biotite-muscovite schist (4a). Crossed nicol. GSC 200273*



c. *Poikiloblastic garnet from quartzofeldspathic laminae (muscovite + biotite + albite ± chlorite) interlayered with staurolite schist of Figures 5a and 5b. Crossed nicol. GSC 201280-V*

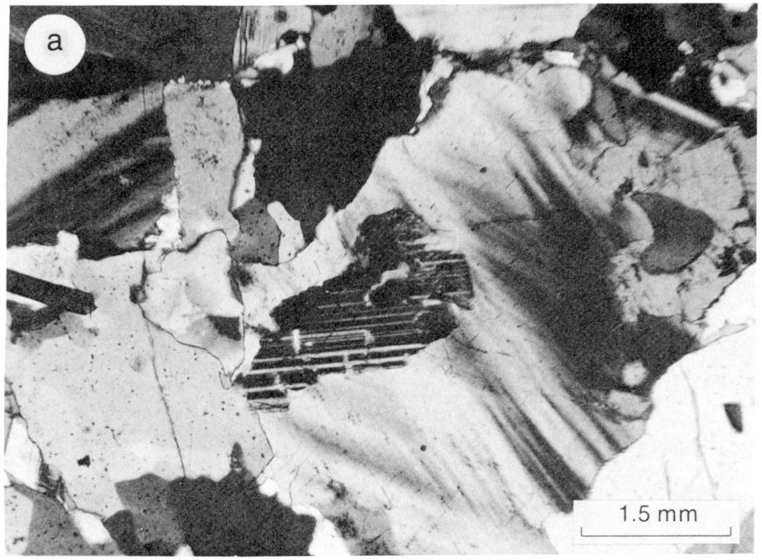


b. *Poikiloblastic staurolite from knotted staurolite, biotite-muscovite schist (4a). Plane light. GSC 201280-W*

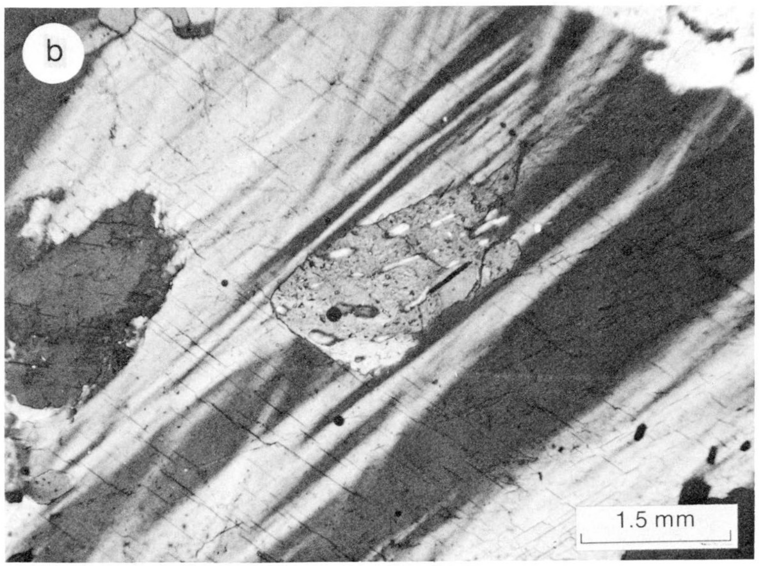


d. *Poikiloblastic biotite from silvery, muscovite bearing, knotted biotite schist of unit 4a. Plane light. GSC 202509-R*

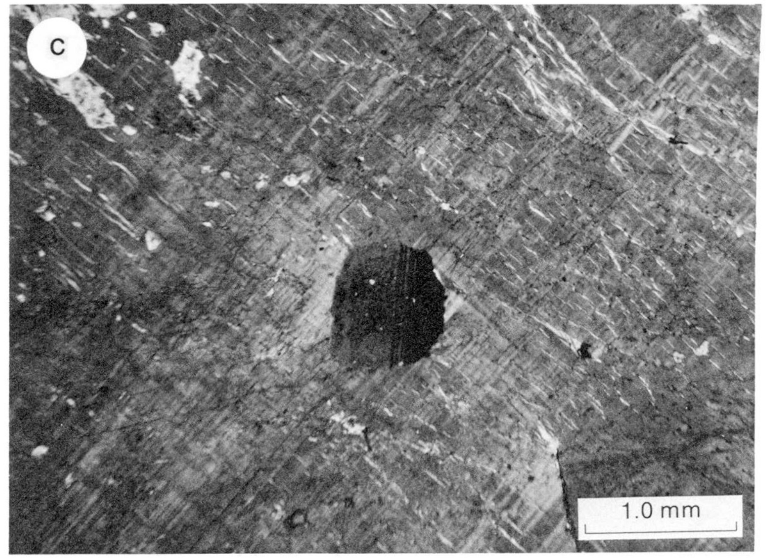
Figure 5. *Synkinematic M_2 metamorphic textures in Manigotagan metasediments (4).*



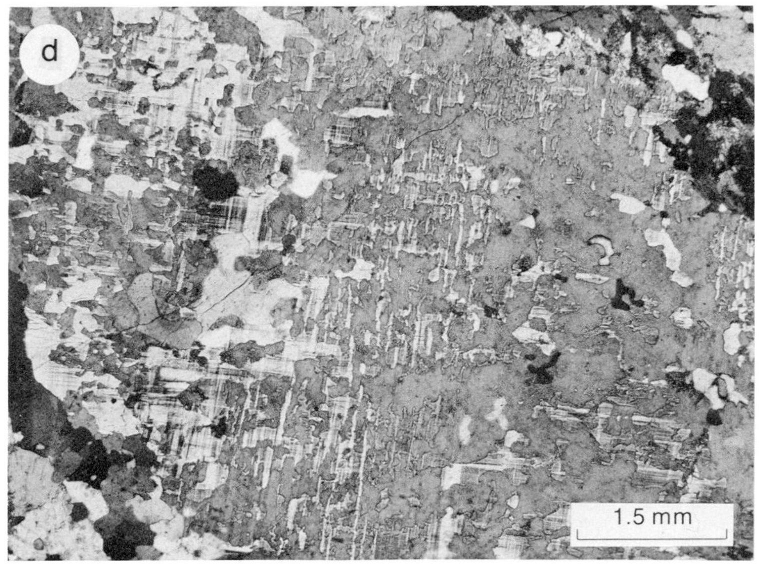
a. *Poikilitic twinned albite in microcline. Crossed nicol. GSC 200273-V*



b. *Poikilitic (with quartz) sausseritized albite in microcline. Crossed nicol. GSC 200273-P*



c. *Sausseritized, twinned albite in perthite. Crossed nicol. GSC 200273-Z*



d. *Mesoperthite in trondhjemitic gneiss (3) with quartz inclusions. GSC 201280-U*

Figure 6. *Late metasomatic alkali-feldspar mobilizate in metasediment (4) and trondhjemitic gneiss (3).*

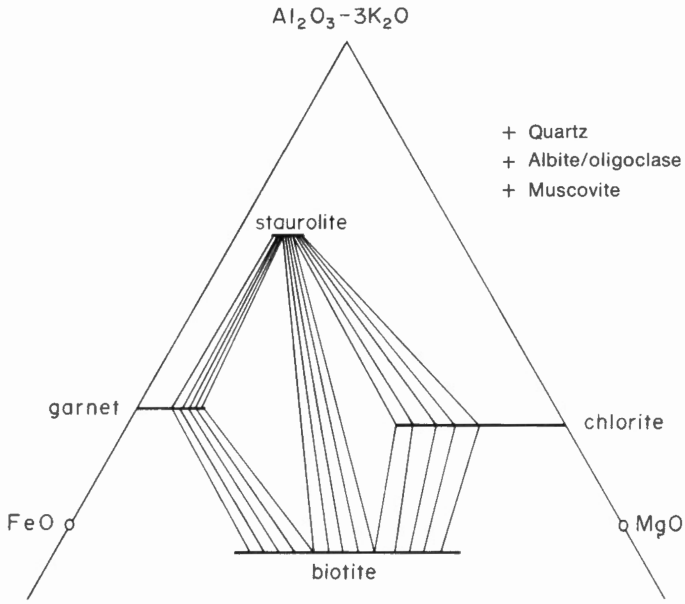


Figure 7. *Schematic presentation of mineral assemblages (coexisting with quartz, plagioclase and muscovite) of the Manigotagan metasediments (4) in the system SiO_2-Al_2O_3-MgO-FeO-K_2O-H_2O. The assemblage is interpreted to be lower amphibolite facies and M_2 metamorphism for the area.*

Three top determinations based on cross-bedding, and graded bedding in Manigotagan Bay indicate overturning of northerly dipping beds toward the south (Fig. 8). The attitude of bedding in the area surrounding Wood Falls suggests that the structure is a synclinorium.

The contact of metasediments with volcanic rocks (1a) is not exposed, but it is likely that the volcanic rocks lie beneath. Similarly, the relationship between quartzofeldspathic metasediments (4b) and hornblende-bearing gneiss (1b) could not be determined. Unit 1b exhibits a higher grade of metamorphism and is thought to be older and to lie beneath the metasediments. The contact between metasediments (4) and tonalite (2) is not exposed, but again on metamorphic criteria, the relationship is thought to be disconformable. However, Manigotagan metasediments (4) appear to be interfolded with tonalite and trondhjemite gneiss (3) along the southern contact on lake Winnipeg. Here, granitic mobilizate (albite-oligoclase) has pervaded metasediments to produce dents-de-cheval and strings of tourmaline crystals parallel to bedding (Fig. 3c, 3d). Unstrained albite, microcline, and perthite enclose poikiloblastic albite grains (Fig. 6). The granitic component is not strained and therefore postdates the metamorphism of the Manigotagan metasediments.

Chemical compositions of schists (4a) and quartzofeldspathic members (4b) overlap (Table 2). Schists (pelitic facies, Table 2) are unusually rich in K_2O (5.0 to 8.5%) in the range 17 to 23 per cent Al_2O_3. These values are compatible with a derivation of the schists from illite- and montmorillonite-rich argillites (Fig. 8.4, Garrels and Mackenzie, 1971). High Al_2O_3 (18 to 23%) and K_2O (5.0 to 6.5%) have been reported by Guitard (1970) from schists in sillimanite zone of the eastern Pyrenees. Although Guitard discussed evidence for potassium metasomatism in sillimanite zone his observations are confined to the schist–intrusive granite contact. Alkali metasomatism (Fig. 3d, 6) in Manigotagan area is confined to the quartzofeldspathic facies along the southern contact. Thus the composition of the schists is probably original.

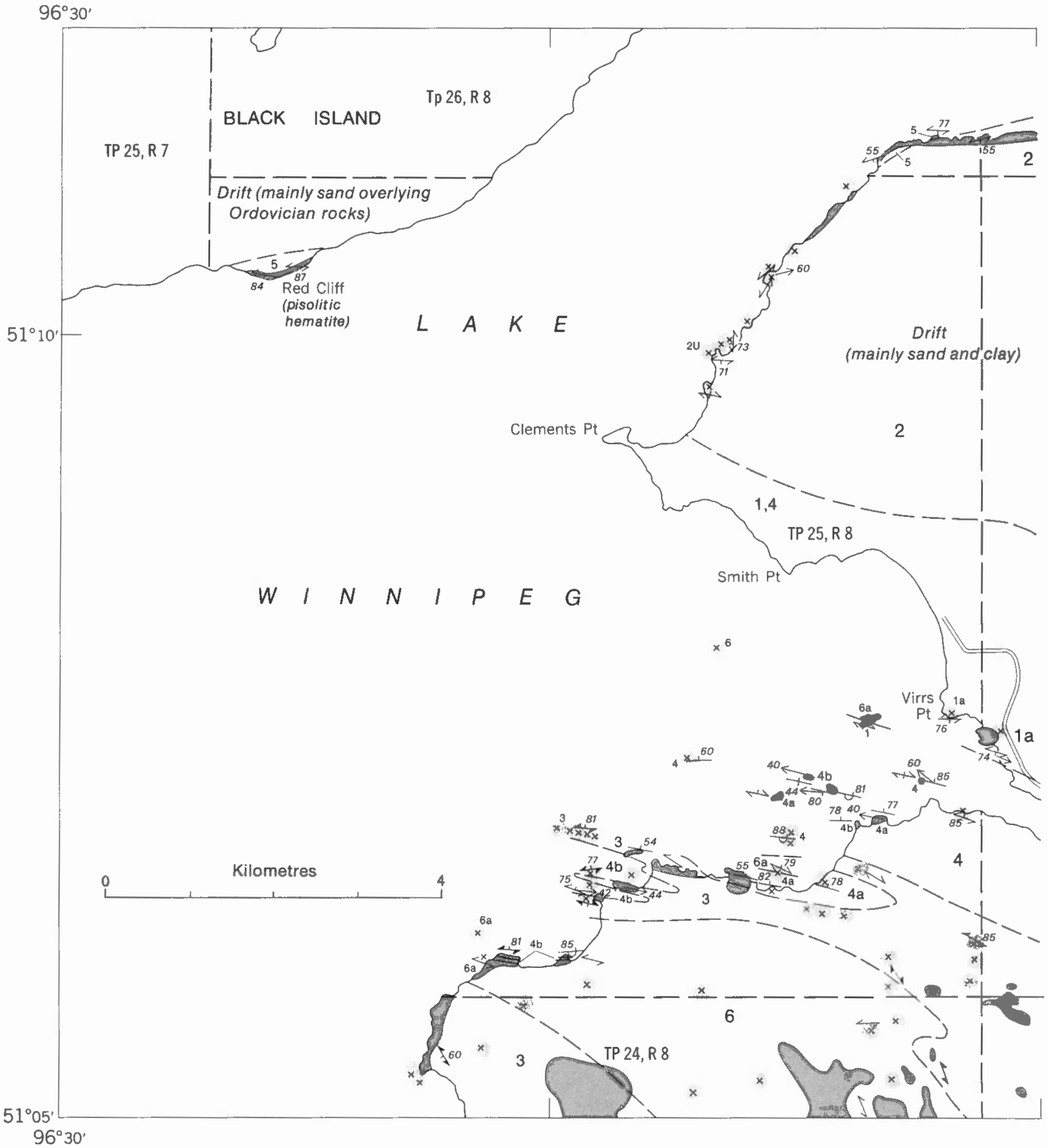
Table 2. Chemical analyses (weight per cent) of Manigotagan metasediments from the area around Wood Falls and Lake Winnipeg. Analyses are arranged with decreasing Al_2O_3 from left to right.

	Pelitic facies							Psammitic facies								San Antonia Formation arkosic facies[1]
	391	381	389	395	382	385	393	396	380	384	383	392	388	386	394	
SiO_2	54.6	54.2	54.3	58.8	58.9	63.4	61.1	66.8	62.5	64.9	67.5	65.1	67.6	68.8	68.5	76.6
Al_2O_3	22.6	20.7	20.2	18.9	18.4	17.9	17.1	15.7	15.6	15.0	15.0	14.7	14.7	14.3	13.3	11.6
TiO_2	0.67	0.69	0.66	0.45	0.66	0.62	0.70	0.56	0.73	0.61	0.53	0.59	0.57	0.44	0.54	0.28
Fe_2O_3	1.3	2.2	2.0	1.7	1.8	1.3	1.0	1.1	1.6	0.80	0.54	2.0	0.82	0.54	0.97	Fe(T)
FeO	3.8	5.9	5.8	3.7	5.4	3.1	5.2	3.7	4.9	4.5	4.2	3.7	3.7	3.0	3.4	1.9
MnO	0.05	0.07	0.07	0.07	0.07	0.05	0.08	0.6	0.10	0.08	0.09	0.09	0.07	0.07	0.06	0.03
MgO	3.3	4.5	4.1	3.8	3.8	2.8	3.3	2.4	3.5	2.8	2.5	3.3	2.5	2.6	3.2	0.8
CaO	0.20	0.57	0.17	0.64	0.79	0.33	0.70	1.5	1.8	2.2	2.4	2.5	2.4	2.7	2.5	0.6
Na_2O	0.26	0.68	0.20	0.58	1.1	0.57	1.2	2.7	2.4	3.9	3.3	3.5	3.6	3.6	3.3	1.9
K_2O	8.5	5.7	7.2	7.4	5.0	5.7	5.8	3.3	4.0	2.8	2.6	2.4	2.4	2.4	2.4	2.9
P_2O_5	0.16	0.17	0.14	0.18	0.16	0.17	0.16	0.18	0.15	0.18	0.16	0.17	0.16	0.13	0.14	0.04
CO_2	nf	nf	nf	nf	nf	nf	nf	nf	nf	nf	nf	nf	nf	0.04	nf	-
H_2	3.9	4.2	4.1	3.2	3.2	3.0	2.6	1.9	1.9	1.0	1.3	1.4	0.90	0.80	1.1	-

[1]average of 16 handspecimen, 8 analyses, from two stations; arkosic grits.

H_2OT = total water; Fe(T) total iron calculated as Fe_2O_3.

nf = not found



6 Late Tonalite and Granodiorite: undivided; metamorphosed, generally leucocratic, coarse grained gneiss of unit 3; 6a, massive granite and oligoclase granodiorite

5 Hole River Metasediments: arkosic sandstone, locally calcareous and locally containing minor greenstone, granite and quartzite pebbles and granules

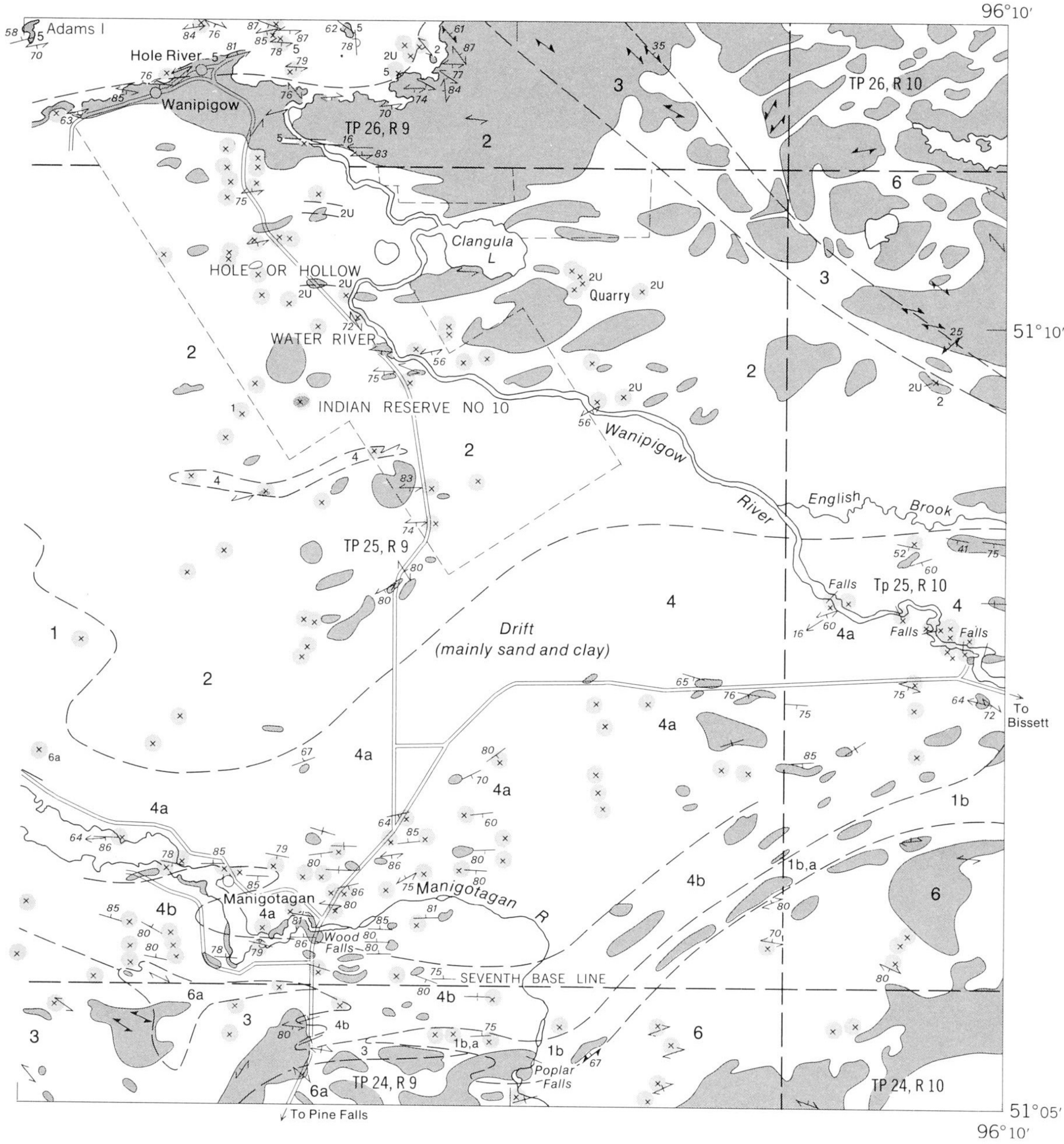
4 Manigotagan Metasediments: undivided, fine grained, pelitic, spotted mica schists and grey, thinly bedded, micaceous quartzofeldspathic rocks and rare interlaminated quartzite; 4a, chlorite-garnet-muscovite-biotite schist (quartz + albite/oligoclase); 4b, dominantly quartzofeldspathic rocks (mica + garnet) with 40 to 60 per cent quartz

3 Tonalitic and Trondhjemitic Gneiss: medium grained, granoblastic, locally layered, feldspathic gneiss and coarse grained biotite-hornblende gneiss; locally intruded by 6 and includes up to 35 per cent 6a

2 Early Metatonalite, Metagabbro and Meta-ultramafic rocks: undivided metamorphosed porphyroblastic tonalite and mafic tonalite of dacitic and andesitic composition; locally intruded by 6 and 6a
2U: serpentinized dunite and pyroxenite

1 Metavolcanic Rocks and Hornblende Gneiss: undivided metamorphosed volcanic rocks and gneiss of intermediate to basic composition; 1a, greenschist, amygdaloidal greenstone and intercalated fine- to medium- grained metagabbro; probably younger than 1b; 1b, hybrid, granoblastic hornblende-oligoclase gneiss, amphibolite and small lenses of 1a

Figure 8. *Geological map.*



Geological boundary (approximate and assumed) ....

Bedding (vertical, inclined, tops unknown except where indicated as overturned) ....

Foliation (vertical, inclined, dip unknown) ....

Layering (vertical, inclined, dip unknown) ....

Lineation in major plane of foliation (may be combined with bedding or foliation symbol) ....

Area of outcrop ....

Single outcrop ....

All weather road (position approximate) ....

Geology by G.A. Russell (English Brook Area in 1948), J.F. Davies (Manigotagan-Rice River Area in 1950), I.F. Ermanovics (Hecla-Carroll Lake map area in 1968), and A. Brown and I.F. Ermanovics in 1972. Compilation and interpretation by I.F. Ermanovics and A. Brown 1973-74

***Figure 8** (cont.)*

Chemical compositions of quartzofeldspathic members (psammitic facies, Table 2) are similar to the 'average of 20 Archean greywackes' of Yellowknife Supergroup (Table 5, Henderson, 1975). East of Wood Falls beds become thicker and micaceous schists have lower K_2O content.

Hole River Metasediments (5)

This group of rocks is fully described by Brown (in preparation) and in the Manigotagan map area lies in contact with metatonalite (2). Hole River metasediments are locally calcareous arkosic sandstones which locally contain minor quantities of greenstone, granite, and quartzite pebbles and granules. Metamorphism has produced chlorite, muscovite and recrystallized quartz-albite mosaics. These rocks resemble the San Antonio Formation which unconformably overlies volcanic rocks and tonalite at Bissett 38 km to the east (Stockwell, 1938). The chemical composition of arkose at Bissett is given in Table 2.

Compositions of Hole River arkose, San Antonio arkose and Manigotagan metasediments suggest that these rocks were derived mainly from a granitic source. Manigotagan metasediments may be a mudstone facies equivalent of the arkoses. Sporadic clasts of microcline have survived metamorphism both in Hole River metasediments and San Antonio Formation and may be represented by muscovite at the higher metamorphic grade in Manigotagan metasediments.

Late Tonalite and Granodiorite (6)

This is a group of undivided, dominantly igneous rocks that are light grey, coarse grained, generally leucocratic gneisses. Oligoclase is the dominant feldspar; biotite or hornblende and epidote constitute 10 to 15 per cent of the rock; locally, chlorite attains 5 per cent. The rocks are mixed with hybrid gneiss of unit 3 and with amphibolite. They are pervaded by small bodies and segregations of massive granite and granodiorite (6a). The primary composition of these plutonic rocks was probably tonalite but invasion by alkali material has altered the bulk composition to an undetermined extent.

In the area south of the Rice Lake volcanic belt McRitchie and Weber (1971) have suggested that the intrusive material was anatectically derived from rocks of upper amphibolite facies.

METAMORPHISM

Metamorphism ranges from middle amphibolite to lower greenschist facies. Greenschist metamorphism in rocks thought to be older or to be underlying Manigotagan and Hole River metasediments is retrograde.

Minerals in the Manigotagan metasediments define M_2 metamorphism (Fig. 7) and the following synkinematic mineral associations are present:

1. staurolite + biotite + muscovite + tourmaline
2. garnet + biotite + muscovite
3. garnet + biotite + muscovite + chlorite
4. garnet + staurolite + biotite + muscovite + chlorite + tourmaline

Quartz and albite/oligoclase are always present, and these assemblages, indicative of lower amphibolite facies, are uniformly distributed within the Manigotagan metasediments. The rocks show no retrogression except along localized shear zones.

Hole River metasediments represent a slightly lower grade (lower to upper greenschist?) than the Manigotagan metasediments. Neither staurolite nor garnet was found, primary features are still preserved, and the grain size is smaller. Chlorite, biotite, muscovite, albite and quartz are present as 'matrix'.

The tonalitic rocks of unit 2 show two periods of metamorphism. M_2 metamorphism is synkinematic (Fig. 2c) and is indicated by chlorite and muscovite with quartz and highly epidotized albite and calcite; locally, pale green amphibole has developed. These minerals developed together with kink and chevron folds in rocks that had already been metamorphosed, probably to amphibolite facies. The earlier M_1 metamorphism is evident in tonalite which has escaped severe cataclasis generally associated with M_2 metamorphism. Such rocks show relicts of zoned epidotized obigoclase and aligned altered poikilitic hornblende. The imprint of M_2 metamorphism is characterized by epidotized rims of albite about more calcic feldspar centres overgrown by muscovite, development of clean epidote, and by alteration of metamorphic hornblende to biotite and chlorite. The grade of M_2 metamorphism in tonalite (2) is similar to that affecting Hole River metasediments. A similar sequence of metamorphism is shown by tonalitic gneiss (Fig. 2d) except that where gneiss is intercalated with metasediments, M_2 metamorphism of gneiss is comparable in grade to that of the Manigotagan metasediments (Fig. 2b).

The evidence for M_1 metamorphism for the volcanic rocks is meagre because only three areas of outcrops (at Virrs Point) are available for study. The evidence rests on what is interpreted as M_1 plagioclase and hornblende porphyroblasts breaking down into M_2 mattes of epidote, chlorite and pale green amphibole. Just east of the map area amphibolitized gabbroic rocks associated with mafic volcanics also show similar evidence of M_2 retrogression.

Late tonalite and granodiorite (6) show only M_2 metamorphism, although this is not certain owing to the hybrid nature of the rocks in the map area. Foliation in these rocks is produced by recrystallized quartz, muscovite and chlorite folia and altered hornblende. Zones of abundant muscovite and tourmaline in tonalite (6) are associated with contact metasomatism in areas of alkali mobilizate (Fig. 6). Coarse grained muscovite, tourmaline and zoned oligoclase (Fig. 4a, and 4b) are developed in paragneiss (3) or metasediment (4) adjacent to massive granite (6a).

The M_2 metamorphism described here is correlated with the M_2 of McRitchie and Weber (1971) in the Rice Lake region. M_1 metamorphism is also likely correlative except that in this report the evidence rests on early M_1 poikiloblastic hornblende, whereas McRitchie and Weber's evidence relies on "inclusion trails in M_1 porphyroblasts" (op. cit., p. 239).

In summary, it appears that the Hole River and Manigotagan metasediments (5 and 4) and the late granitoids (6), show no evidence for M_1 metamorphism, whereas units considered older show both M_1 and M_2. It is therefore suggested that the metasediments lie unconformably on volcanic rocks (1), tonalite (2) and tonalitic gneiss (3) and that the late granitoids (6) are related to late or synkinematic M_2 metamorphism. Absolute ages of these metamorphic events are not known.

GEOCHRONOLOGY

Two plutono-volcanic episodes separated by about 300 Ma have been established in the area (Krogh et al., 1974, Ermanovics and Wanless, in preparation). A sample of porphyroclastic tonalite (2) collected 3 km west of Hole River settlement yielded a U-Pb zircon age of 2999 ± 10 Ma.

Opposite Black Island this tonalite intrudes (?) or is in gradational contact with layered, leucocratic tonalite gneiss (3) whose U-Pb zircon age of 2900 ± 10 Ma is interpreted to reflect a time of metamorphism (Krogh et al., 1974). Together, these ages were used by Stockwell (in preparation) to define the Wanipigowan Orogeny. It was suggested earlier that metatonalite and volcanic rocks (2) may be comagmatic and thus may represent a plutono-volcanic event at 3.0 Ga.

Three U-Pb zircon ages of late granitoid rocks, two of which cut tonalite gneiss (3) opposite Black Island, are in the range 2715-2737 Ma. Together with a 2732 ± 10 Ma old U-Pb zircon age from rhyodacite (Brown, in preparation) at Black Island, these represent the youngest primary ages of igneous rocks in the area. Hole River arkose overlies the 2732 Ma old rhyodacite and the age of arkose is thus bracketed by this age and a minimum age of ca. 2670 Ma obtained from the San Antonio arkose at Bissett (Turek and Peterman, 1971). Metamorphism following the igneous activity is indicated by a Rb-Sr whole rock isochron age of 2674 ± 136 Ma (GSC Project 121) in layered tonalite gneiss (3) at Rice River and by a U-Pb zircon age of 2690 ± 10 Ma (Krogh et al., 1974) obtained from a granitized paragneiss (4b) collected 1.2 km south of Wood Falls. This plutono-volcanic episode represents Laurentian Orogeny (Stockwell, in preparation). Argon-loss blocking temperatures in biotites were attained ca. 2430 Ma ago in the area (GSC 61-128 and 61-129, Lowdon et al., 1963) and this age probably represents the time of complete cratonization and crustal stability nearly 300 Ma after Laurentian Orogeny and about 600 Ma after Wanipigowan Orogeny.

SUMMARY

M_2 metamorphism is prograde for the Manigotagan and Hole River metasediments (4 and 5) and possibly late tonalite (6), and it is retrograde for volcanic rocks (1), tonalite (2) and tonalite gneiss (3). Hole River and Manigotagan metasediments (4,5) show no pervasive retrogression and therefore record only M_2 metamorphism. The metasediments represent detritus derived in part from a granitic landmass. These facts make it highly likely that the metasediments are significantly younger than mafic greywacke and volcanic rocks of Rice Lake volcanic belt.

The Hole River metasediments and the San Antonio Formation are very similar in lithology and metamorphic grade. Manigotagan metasediments, particularly and pelitic schist (4a), could represent a deeper water facies of the San Antonio Formation. The beds of the Manigotagan metasediments thicken considerably, from laminations centimetres thick in the west to several metres eastward in the direction of the San Antonio Formation, which is a proximal facies comprising thickly bedded coarse arenites (Stockwell, 1938, p. 19; Davies, 1950, p. 17).

The crystalline terrane is described as highly complex by Davies (1950), Russell (1949) and Ermanovics (1970, 1971). The complexity resulted from an involved sequence of plutonism which produced widespread metasomatism and anatexis in the metamorphic terrane (McRitchie, 1971a; McRitchie and Weber, 1971; Ermanovics, 1971). At the southern contact of the Rice Lake belt, the rocks appear to have been progressively melted and mobilized. This produced discrete igneous bodies as well as gneiss units which make up English River subprovince. Thus any evident of 'basement', 'craton' or 'older rocks' that might have existed is oblitered and must be inferred from isotope ages. In the Manigotagan area, however, metamorphism has not produced melts in sediments although post-M_2 mobilizate in adjacent granitic rocks was hot enough to produce limited contact metamorphism in relatively cooler host rocks. Therefore the disconformable relationships described above can still be inferred.

It is concluded that igneous and metamorphic activity took place 3000 Ma (Wanipigowan) and 2700 Ma (Laurentian) ago in the map areas (Ermanovics and Wanless, in preparation). A period of widespread metamorphism and possibly local granite intrusion ca. 2500 Ma ago (Kenoran Orogeny?) affected rocks of the eastern Rice Lake greenstone belt (Turek and Peterman, 1971) and may have also affected rocks in the map area.

ACKNOWLEDGMENTS

I am indebted to A.V. Okulitch and W.L. Davison for reviewing the manuscript.

REFERENCES

Brown, Anton
Geology of the Hole River – Black Island – Rice River area; Geological Survey of Canada, Paper (in preparation).

Davies, J.F.
1950: Geology of the Wanipigow River Area; Manitoba Mines Branch, Publication 49-3.

1951: Geology of the Manigotagan-Rice River Area; Manitoba Mines Branch, Publication 50-2.

Ermanovics, I.F.
1970: Precambrian geology of Hecla-Caroll Lake map-area Manitoba-Ontario; Geological Survey of Canada, Paper 69-42.

1971: 'Granites', 'granite gneiss' and tectonic variation of the Superior Province in Southeastern Manitoba; in Geological Association of Canada, Special Paper No. 9, p. 77.

Ermanovics, I.F., McRitchie, W.D., and Houston, W.N.
1979: Petrochemistry and tectonic setting of plutonic rocks of the Superior Province in Manitoba; in Trondhjemites, Dacites and Related Rocks (ed. F. Barker), Elsevier, p. 323-362.

Ermanovics, I.F. and Wanless, R.K.
Isotopic age studies and tectonic interpretation of Superior Province in Manitoba; Geological Survey of Canada, Paper (in preparation).

Garrels, R.M. and Mackenzie, F.T.
1971: Evolution of Sedimentary Rocks; W.W. Norton and Company Inc., New York, 397 p.

Guitard, G.
1970: Le métamorphisme hercynien mésozonal et les gneiss oeillés du massif du Carigou (Pyrenées orientales); Bureau de Recherches Géologiques et Minières, Mémoires 63, 317 p.

Henderson, J.B.
1975: Sedimentology of the Archean Yellowknife Supergroup at Yellowknife, District of Mackenzie; Geological Survey of Canada, Bulletin. 246, 62 p.

Irvine, T.N. and Baragar, W.R.A.
1971: A guide to the chemical classification of the common volcanic rocks; Canadian Journal of Earth Sciences, v. 8, p. 523-548.

Krogh, T.E., Ermanovics, I.F. Davies, J.T.
1974: Two episodes of metamorphism and deformation in the Archean rocks of the Canadian Shield; Annual Report, Geophysical Laboratory Year Book 73.

Lowdon, J.A., Stockwell, C.H., Tipper, H.W., and Wanless, R.K.
1963: Age determinations and geological studies, Geological Survey of Canada, Paper 62-17.

McRitchie, W.D.
1971a: Petrology and environment of the acidic plutonic rocks of the Wanipigow-Winnipeg Rivers region, Southeastern Manitoba; in Manitoba Mines Branch, Publication 71-1, p. 7.

1971b: Geology of the Wallace Lake-Siderock Lake area: a reappraisal; in Manitoba Mines Branch, Publication 71-1, p. 107.

1971c: Geology of the Wanipigow-Winnipeg Rivers Region SE Manitoba; Manitoba Mines Branch, Map 71-1/1 in Manitoba Mines Branch, Publication 71-1.

McRitchie, W.D. and Weber, W.
1971: Metamorphism and deformation of the Manigotagan gneissic belt, Southeastern Manitoba; in Manitoba Mines Branch, Publication 71-1, p. 235.

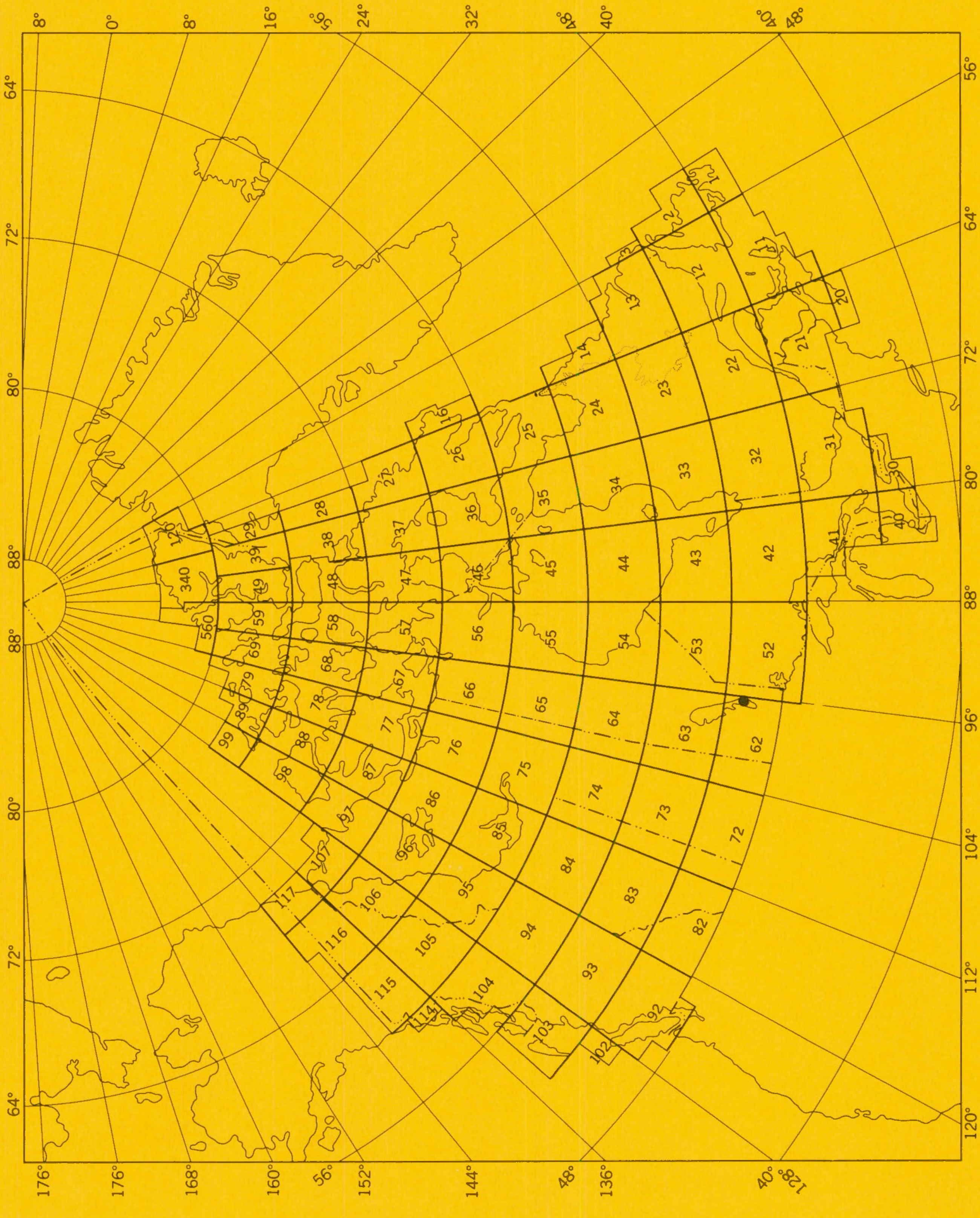
Russell, G.A.
1949: Geology of the English Brook Area; Manitoba Mines Branch, Publication 48-3.

Scoates, R.F.J.
1971: Ultramafic rocks of the Rice Lake greenstone belt; in Manitoba Mines Branch, Publication 71-1, p. 189.

Stockwell, C.H.
1938: Rice Lake-Gold Lake area, Southeastern Manitoba; Geological Survey of Canada, Memoir 210.

Time classification of Precambrian rocks and events of Canada and adjacent Shield areas of the United States: Geological Survey of Canada Paper (in preparation).

Turek, Andrew and Peterman, Zell, E.
1971: Advances in the Geochronology of the Rice Lake-Beresford Lake area, Southeastern Manitoba; Canadian Journal of Earth Sciences, Vol. 8, p. 572-579.



Energy, Mines and Resources Canada
Énergie, Mines et Ressources Canada