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GEOLOGY OF BERENS RIVER — DEER LAKE MAP-AREA, MANITOBA AND ONTARIO AND A PRELIMINARY ANALYSIS OF TECTONIC VARIATIONS IN THE AREA

(Report, 6 figures and Map 11-1970)

I. F. Ermanovics

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I. F. Ermanovics

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ABSTRACT

The Berens River-Deer Lake map-area is underlain by massive and layered quartz monzonite and granodiorite which also constitute the dominant rock types in the northern part of the adjacent Hecla-Carroll Lake map-area to the south. Gneissose and layered quartz monzonite and granodiorite underlie 46 per cent of the area, massive granodiorite 32 per cent and leuco-quartz monzonite 19 per cent; metadacite and metasedimentary gneiss constitute 3 per cent. Tectonic variation in both map-areas is synthesized to three domains: metavolcanic-sedimentary rocks (domain I); an adjacent, hybrid mobile zone containing high-grade gneisses and basic plutonic rocks (domain II), and a sialic nucleus comprising massive and layered siliceous plutonic rocks (domain III). Domains I and II constitute a down-faulted remnant of the total volcanic-sedimentary tectogene, originally deposited on the sialic nucleus of domain III.

"Nur erst, wenn die Form klar ist, wird dir der Geist klar werden"

- R. Schuhmann, quoted by
E. H. Kranck, 1957

GEOLOGY OF BERENS RIVER — DEER LAKE MAP-AREA, MANITOBA AND ONTARIO

INTRODUCTION

General Statement

The Berens River-Deer Lake map-area, Manitoba-Ontario is underlain by weakly foliated to stratiform gneiss ranging in composition from quartz monzonite to granodiorite (51 per cent of the area), massive plutonic rocks of similar composition (46 per cent), and metavolcanic-sedimentary rocks present as small remnants (3 per cent).

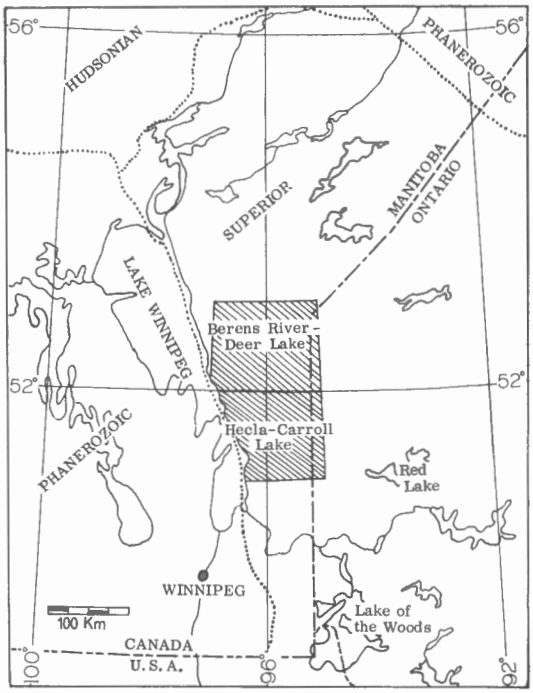

Figure 1. Index map and structural provinces.

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This report presents the results of remapping a terrain which previously had been known only through gross reconnaissance. Similar work by the author in 1968 in the adjacent Hecla-Carroll Lake map-area to the south (Ermanovics, 1969) demonstrated that this region of the Superior Province of southeastern Manitoba, comprising dominantly 'granitic' terrain, required petrologic and structural analysis if the total variation was to be understood. To do this, areas previously selected after airphoto and aeromagnetic interpretation were traversed by three mapping teams using pace and compass methods during three months. In addition, a helicopter was used for twenty days to cover systematically the terrain along flight lines spaced at 2- to 3 1/2-mile intervals. Excellent map coverage was obtained by this method of combined ground and helicopter traversing.

Two hundred thin sections were examined. Modes of a number of them were determined by point-counting to substantiate quartz monzonite plutons which were mapped as separate bodies. At the end of this report a preliminary analysis of the structural geometry of the map-area and the northern half of the Hecla-Carroll Lake area to the south is presented thus providing information that could be integrated with more detailed work being done south of 51 degrees north by members of the Manitoba Mines Branch. When this work is completed new information will be available for a cross-section of the Superior Province in Manitoba including the Wabigoon, English River, and Cat Lake belts (Stockwell, 1964). Additional work between latitude 53 and 54 degrees, on a scale similar to the present work will include the Cross Lake belt, adding information available for the proposed subprovince as defined by C.K. Bell (Wekukso Lake map-area, Manitoba, and the Superior-Pikwiton-Churchill Boundary, in preparation).

Physical Features

Berens River on Lake Winnipeg lies 715 feet above sea level and the terrain rises gradually eastward to 1,150 feet. Outcrop is abundant throughout the area even in the flat eastern portion, 40 per cent of which is covered with muskeg. Most of the area is wooded with birch and small pine. Berens River and Little Grand Rapids are dominantly Indian communities accessible in winter by tractor roads. Eardley Lake is a gas depot station for tractor trains. Berens River is served by boat in summer from Winnipeg. The area is poorly drained. All rivers flow westward into Lake Winnipeg except for the waters in the northeast of the area (notably Elliot and Charron Lakes), which drain towards the northeast.

Previous Work

The first detailed rock descriptions were made by A. P. Low in 1886, Tyrrell in 1890, 1891, Dowling in 1895 and compiled by Dowling in 1898 (Tyrrell, 1898). Schists and sediments were recognized by Tyrrell as the oldest rocks and he extended the term Huronian to apply to such rocks along Lake Winnipeg. Exploring the Poplar, Etomami (north and south branches) Berens and Pigeon Rivers he mapped massive granitoid bodies which locally graded to 'granitite' gneiss. Here and there he refers to such irregularly foliated gneisses as 'typical Laurentian gneisses' and he recognized in them inclusions of Huronian rock.

Johnston (1936 a-f), dealing with the area in Manitoba extending from 51 to 54 degrees north and from the Manitoba-Ontario boundary west to Lake Winnipeg, postulated a sequence of plutonic intrusions and hybrid gneisses. He mapped the earliest intrusions as granodiorite and quartz diorite followed by a granite phase. This event was followed by an undifferentiated phase of granite, granodiorite and quartz diorite intrusion. His gneisses were of two types: predominantly paragneiss and predominantly orthogneiss containing greenstone inclusions.

An age of 2,600 m.y. was obtained by the K-Ar method from biotite taken from a specimen of paragneiss (oligoclase, quartz, biotite, epidote and accessory apatite and magnetite) which occurs as an inclusion in granodiorite (Lowdon, 1961, p. 51).

Acknowledgments

For making the field component of this work a success, I wish to thank my field assistants: R. K. Anderson (University of Manitoba), W. D. Corstorphine (University of Waterloo), J. D. Hill (Acadia University), A. T. Lytviak (University of Alberta, Calgary Campus) and R. D. Thomas (Queen's University). To Drs. W. D. McRitchie, A. Turek, W. Weber, members of the Manitoba Mines Branch, Geological Division, I express my thanks for courtesies and help extended to me during the preparation of this report. Professor J.M. Moore, Carleton University, helped in the preparations of the section of the text dealing with 'Tectonic Variations'. I thank Dr. A. Davidson for adding clarity to the manuscript.

GENERAL GEOLOGY

Introduction

Aside from metavolcanic-sedimentary rocks (1, 2)[1], and probable hybridized gneiss variants (3) of units 1 and 2, the area comprises 97 per cent plutonic and gneissose rock. The massive to weakly foliated plutonic rocks[2] are divided into quartz monzonite (unit 7, Fig. 2) and rocks ranging in composition from quartz monzonitic granodiorite to granodiorite (dominant rock-type) with minor amounts of quartz diorite (6); wherever possible separate letter designations were used to differentiate these compositions. The reason for the compositional spread of unit 6 lies not in the lack of mapping resolution alone but is based largely on the fact that contacts of these compositional variants are gradational over many miles so that any number of mixed rock compositions are possible. Petrographic detail dealing with amount and kind of mafic minerals, percentages of feldspars, and various chemical fractionation indices might help to resolve the problem of whether these plutons (6) are complex or composite intrusions; the onerous job of

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[1] Numbers in parentheses refer to map-units of geological map accompanying this report.

[2] The classification used is that of I.C. Brown, 1967 and is similar to that of Bateman, et al., 1963.

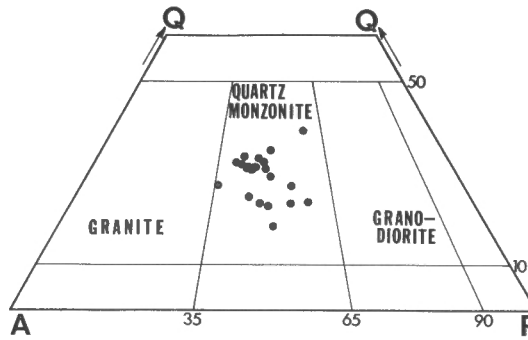

Figure 2. Range of rock compositions (20 modes) mapped as quartz monzonite in Hecla-Carroll Lake and Berens River-Deer Lake map-areas (Fig. 4). Classification after Bateman et al., 1963; Q, quartz, A, alkali feldspar, P, plagioclase (An_{24} to An_{35}); 80% of the modes show $\Sigma(Q + A + P) \geq 90\%$; 40% of the modes show $\Sigma(Q + A + P) \geq 95\%$.

mapping such a magmatic mélange, of course, remains. One answer for resolving this problem may lie in carefully designed randomized sampling schemes in which chemical analyses, statistically treated, may provide rock groupings which could then be related to the geology or tectonics of the region.

Foliated rocks (4 and 5), representing 46 per cent of the area presently exposed, range from foliated augen-gneiss to layered, stratiform gneiss. Except where they include thin, discontinuous wedges of layered amphibolite, their gross mineralogical composition differs little from their massive equivalents (6 and 7) with the possible exception that on the whole they tend to be more granodioritic than quartz monzonitic. In this report a distinction is made between granodiorite gneiss (4) and quartz monzonite gneiss (5). The distinction is a useful and important one, especially for determining synformal or antiformal structures (Ermanovics, 1970b, and 1969). For example, a common gneiss association in keels of relict folds is an 'axial' distribution of granodiorite gneiss (4) bounded on either side by quartz monzonite gneiss. Layered amphibolite and grey gneiss (3) in turn are bounded by granodiorite gneiss (4). A model, therefore, comprising a continuum of gneiss formation with addition of magmatic material with each successive intrusion of adjacent magma to an original template of protogneiss (original structural framework) seems irresistable. Alternatively, if the gneisses, which are siliceous, are predominantly paragneiss then any hypothesis that proposes transforming sediments to quartz monzonite gneiss must also include provenance and depositional areas.

Metavolcanic-Sedimentary Rocks (1, 2)

Gneisses, schists and massive 'hornfelsed' rocks recognized as being metavolcanic and metasedimentary occur at Horseshoe Lake (Johnston, 1936d) and north and southeast of Mackay Lake (Kirwan, 1958). The volcanic

rocks of Mackay Lake comprise diaphthoretic greenschists and form the distal arm of the Cherrington Lake assemblage extending from Ontario, just east of the present map-area. Metasediments at both localities consist of amphibolitic and aluminous varieties and are best exposed at Horseshoe Lake. Metavolcanic rocks at Horseshoe Lake are 'hornfelsed' dacite. Those at Mackay Lake are dominantly greenschists bearing chlorite, epidote, plagioclase and hornblende.

Metasedimentary Rocks (1)

A layer (.5 miles thick, 10 miles long) of varicoloured gneiss and schist occurs at the edge of the southern arm of the Horseshoe Lake metavolcanics. The layer persists .9 miles northwestward beyond the volcanic rocks into hybrid granodiorite. North and southeast of Mackay Lake, thin beds of grey-green schists containing garnet occur discontinuously within amphibolitic greenschists.

The following are some compositional variations of these rocks.

Varicoloured gneiss: biotite + quartz + garnet + plagioclase; biotite + garnet + quartz; quartz + biotite + tremolite/actinolite; chlorite + quartz + plagioclase + green to pale brown hornblende (30 to 70%).

Green-grey diaphthoretic schists: quartz + chlorite + biotite + tremolite; quartz + plagioclase + epidote + hornblende.

Black, conchoidally fracturing, spotted traps: quartz + plagioclase + hornblende (75%, idioblastic)

Volcanic fragmental rocks: altered 'dacite inclusions' in a matrix of epidote and hornblende.

Diopside is present in 'spotted trap' rocks at Horseshoe Lake comprising quartz, plagioclase and abundant idioblastic hornblende; the fresh diopside occurs in a light-coloured inclusion, bearing quartz and plagioclase. Poikiloblastic diopside also occurs in a layered amphibolite gneiss in rocks near the mouths of Berens River and Poplar River. The metasediments are intercalated with metadacite and fragmental volcanic rocks locally form zones as thick as 600 feet adjacent to metasediments; such zones are difficult to distinguish from metadacite and have been included in unit 2. Elsewhere metadacite occurs in transition zones comprising alternating layers of agglomerate, mafic schists, banded amphibolite, and quartz diorite. Locally quartz diorite occurs as inclusions in metadacite or metadacite in quartz diorite. At Mackay Lake in addition to biotite, garnet and tremolite/actinolite, the gneisses contain abundant epidote and chlorite related to pervading shear deformation; relict staurolite in schists is masked by chlorite and epidote.

Metasediments and light-coloured layers of greywacke in fragmental volcanic rocks at Horseshoe Lake dip 40 to 60 degrees northeast and therefore structurally underlie metadacite. However, as no tops were found the stratigraphic relationship between metasediments and metadacite is not known. Lineations on major foliation planes plunge variably to the east.

Metavolcanic Rocks (2)

The dominant volcanic rock at Horseshoe Lake is grey, massive, fine-grained, dense metadacite, porphyritic metadacite, and metadacite agglomerate (fragmental metadacite), whose texture is best described as hornfelsic. The rocks are locally pervaded by narrow shear zones. The minerals most readily discernible in hand specimens are plagioclase (An_{45}) and blue quartz. Metamorphism has produced idiomorphic, poikiloblastic hornblende and biotite. Plagioclase phenocrysts overgrown by muscovite, biotite and hornblende, show relict idiomorphic outlines and are absorbed into a recrystallized, granoblastic matrix of hornblende, biotite, feldspar, quartz and carbonate. Small amounts of felsic rock, presumably metaquartz latite (2a), show porphyroblastic muscovite and biotite in a granoblastic matrix of feldspar and quartz. Here and there inclusions of metadacite were found in metaquartz latite. In several places in metadacite light-coloured, grey, well-layered gneiss units 3 to 15 feet thick and 9 to 60 feet long, were found to consist of quartz and feldspar relicts in a matrix rich in muscovite, biotite and hornblende.

The metavolcanic rocks at Horseshoe Lake lie in a basin measuring 4.3 by 8 miles. The centre of the structure is intruded by muscovite-bearing leucoquartz monzonite (7) which stopes but little alters the lava wall-rocks. Peripheral to the basin, especially along the southwestern contact, lies a migmatitic rock composed of mafic granodiorite that here and there includes aluminous schlieren containing biotite + muscovite + sillimanite. Along the northeastern side of the basin, metadacite is sheared against grey granodiorite gneiss. Metadacite and porphyritic metadacite are gradationally altered to medium-grained grey granodiorite and quartz diorite (6) on Family Lake due to contact metamorphism by later siliceous intrusions. On the channel south of Flour Channel on Berens River a vuggy ultramafic sill (?) occupies the contact between lavas and grey granodiorite.

The greenschists north and southeast of Mackay Lake are dominantly fine-grained, brittle, green to black, layered, quartz- and plagioclase-rich amphibolites bearing 5 to 15 per cent epidote and chlorite; they are locally veined with granodiorite. Peripheral, hybrid hornblende granodiorite is cut by later intrusions.

Gneissic Rocks (3, 4 and 5)

Distinction between these rocks is based upon gross compositional differences. Gneissosity is pronounced where amphibolite layers are present, but is also well developed in quartzofeldspathic gneisses, a feature that is, however, only displayed clearly in burned-over or water-washed outcrops, and is elsewhere obscured by lichens. The planar fabric varies from thinly layered augen-gneiss to broadly stratiform rock. Mylonite or shear deformation locally contribute planar fabric, accentuating original fabric, and in some places produce mylonite gneiss indistinguishable from original gneiss. Where both types of foliation are present, mylonite foliation occurs at a small angle to the gneiss belts. Gneissic rocks are intruded by and occur as inclusions in, later quartz monzonite and granodiorite.

Layered Amphibolites and Grey Gneiss (3)

These rocks are dominantly banded amphibolites with intervening layers of gneissic quartz monzonite or granodiorite. They are commonly bounded by a mélange of hybrid magmatic rock or grey granular mica-bearing granodiorite gneiss. This assemblage is similar to that found in the migmatite rim peripheral to the lavas at Horseshoe Lake. These remnants of presumably once larger rock exposures and now eroded occur as thin wedges and are best exposed at Gilchrist Lake and north of Family Lake where they presumably represent recrystallized volcanic rock.

Granodiorite Gneiss (4)

The rocks have a mineral composition similar to massive granodiorite (6) except that they contain muscovite locally and hornblende commonly. Their chemical variation with respect to the magmatic rock is not known. Fresh biotite, calcic oligoclase and 20 to 30 per cent quartz are the dominant minerals. Mafic bands in these gneisses at Carr-Harris Lake, Poplar River and Berens River produce prominent stratiform layering. Here and there, pyroxene-bearing gabbroic and amphibolite schlieren, enclosed by coarsely grained, mafic granodiorite, are reminiscent of the gneisses of unit 3. Plagioclase in these rocks varies from An_{50} to An_{28}, depending on the degree of granitization, and some may be fragmented dykes as for example the gabbroic lenses just south of Sturgeon Falls on the Berens River.

Small shear folds lie in the plane of the foliation. Dips are generally steep (70 to 90 degrees), becoming shallower (45 degrees) where rocks are well layered. Separately or combined with gneiss of unit 5, these gneisses delineate long bifurcating, arcuate belts which are uniformly distributed throughout the area.

Quartz Monzonite-Granodiorite Gneiss (5)

These gneisses include rocks of unit 4 but are dominantly quartz monzonite in composition. Their occurrence and relationship to rocks of unit 4 and quartz monzonite (7) is best demonstrated on Fishing and Elliot Lakes.

On Fishing Lake, the rocks grade southwards towards the falls at Little Grand Rapids from massive quartz monzonite (7) to granodiorite gneiss with quartz monzonite layers (5) to granodiorite gneiss with mafic layers (the rocks are included in unit 5). It appears that here, as perhaps elsewhere in the area, unit 5 has developed from lit-par-lit injections of adjacent quartz monzonite into granodiorite gneiss (4). Elsewhere, however (e. g. Elliot Lake), banded quartz monzonite gneiss outcrops without notable granodiorite gneiss.

Granodiorite, Quartz Monzonitic Granodiorite (6)

These rocks are massive, white to grey, and coarse grained. Plagioclase (commonly zoned) ranges from An_{25} to An_{32}. Quartz content varies

from 15 to 30 per cent and microcline from 0 to 25 per cent. Colour index ranges from 5 to 20. All mineralogical indicators vary locally and it is a dilemma of this type of terrain that these mineralogical variants may represent complex or multiple intrusions of either coeval or cogenetic origin.

There are four main rock types within this group, none of which is easily mapped as a separate entity:

1. Alkali-feldspar free, calcic oligoclase rock but whose An content is too low for the rock to be quartz diorite.
2. Small, dome-like masses (e.g. Lewis Lake, see geological map) whose mafic content (biotite + hornblende + magnetite) makes them aeromagnetically dominant but which have abundant, small, mafic-rich quartz monzonite concentrations.
3. Very coarse grained, white, plagioclase rock (An_{30}) with fresh biotite concentrations; this rock type is confined to the northern boundary of the map-area.
4. Rocks whose compositions range from quartz monzonite to granodiorite. The erratic alkali content may be an indication of addition of alkalis from later quartz monzonite intrusions. They form the dominant group within map-unit 6.

Rocks that have a high mafic mineral content correlate with aeromagnetically 'high' areas. Gneisses of apparent similar compositions or mylonite zones traversing granodiorite invariably produce patterns of low aeromagnetic intensity.

Quartz Monzonite (7)

Massive, medium- to coarse-grained, leucocratic monzonite is the most readily recognized rock-type of all the plutonites in the area and is mapped separately even though here and there granodiorite associated with quartz monzonite and placed in unit 6 may be of the quartz monzonite kindred (7). The rocks form elongate plutons and lenses and intrude gneisses and granodiorite. Colour index is generally less than 10; plagioclase varies from 24 to 32 per cent, anorthite and quartz content ranges from 20 to 35 per cent (Fig. 2). Quartz monzonite at Horseshoe Lake contains 3 to 6 per cent muscovite and no mafic minerals.

Porphyritic varieties (7a), sporadically developed in quartz monzonite, pass with reduction of the proportion of alkali feldspar phenocrysts into granodiorite containing 5 to 10 per cent alkali feldspar. In the southern part of Family Lake, a sheet-like body of porphyry has been shown to grade downwards into mafic granodiorite (Ermanovics, 1970b).

The relationship to other rocks of the medium-grained, pink, gneissic leucocratic quartz monzonite (7b) that forms a large mass near Mackay and Meandrine Lakes, is uncertain. This body is bounded on all sides by gneiss (4, 5) but as it is intruded by granodiorite (6), it must belong to the gneiss kindred (4 and 5).

Here and there, associated with massive and gneissic granodiorite, are coarse-grained, brownish quartz monzonite rocks that contain recrystallized domains of perthitic microcline + quartz, and biotite + antiperthitic oligoclase; oligoclase and microcline are in the ratio 2 to 1. Their origin is not known, although like 7b, they may be related to the early granodiorites.

Migmatite (8)

This unit constitutes a chemical and mechanical mixture of recognizable rock-types belonging to units 4 to 7. Various medium- to coarse-grained magmatic rocks (dominantly granodioritic) grade subtly into one another, forming large transitional areas between massive and homogeneous rocks. South of Weaver Lake migmatite includes irregular masses of medium-grained, buff-pink, granular granodiorite. Migmatite, mapped around the Horseshoe Lake metavolcanic-sedimentary rocks, includes metadacites recrystallized and granitized to hornblende-rich quartz diorite, and granodiorite; sporadic gneiss schlieren range in composition from banded amphibolite to sillimanite-muscovite-biotite gneiss. Migmatite (8) shown between quartz monzonite (7) and metadacite (2) at Horseshoe Lake constitutes large metadacite enclaves in quartz monzonite and demonstrates stoping of brittle cover rocks for the intrusion there. In some places more detailed mapping could separate this mixture but in most occurrences it could not.

METAMORPHIC GRADE

The following contiguous mineral assemblages from Horseshoe Lake indicate middle amphibolite grade of metamorphism (quartz, calcic oligoclase to sodic andesine and epidote are additional phases):

1. biotite + muscovite
2. biotite + garnet
3. biotite + sillimanite + muscovite
4. tremolite/actinolite + biotite
5. hornblende + biotite
6. diopside + hornblende

Cell edge (11.545 A) and refractive index (1.810) measurements on three garnets indicated almandine-rich compositions; inclusions in garnet excluded specific gravity determinations. Assemblages 3 and 6 occur in or near coarse-grained magmatic rock. Garnet and diopside are also present in the stratiform gneisses (4) on Poplar River. Except in localized shear zones and in schists intercalated with paragneiss, there is little evidence of retrogressive metamorphism at Horseshoe Lake.

STRUCTURAL GEOLOGY

The structural trend changes from northwest in the south to east-west in the north and west. Gneiss belts arc and bifurcate about plutonic rocks much like volcanic-sedimentary rocks in greenstone belts. The patchy density of foliation symbols in gneiss units of the accompanying map is, of course, a function of the density of the number of measurements at any particular locality. However, in the absence of appropriate marker beds the 'streaming' effect produced by the foliation symbols demonstrates some variation in local structures. For example, 12 miles east of Carr-Harris Lake a northwesterly foliation trend associated with mylonite cuts across an east-west foliation trend. Consequently, if the northwesterly shear zone trend (general in the area) is considered secondary, then the primary trend is east-west as discovered, for example, by the easterly plunging lineations at

Horseshoe Lake and by the east-west trend of gneisses in the northern part of the area. Single shear zones, pervading all rock-types, can be traced for 37 1/2 miles. They vary in thickness and intensity of shearing, and in many places contain cataclastic gneiss and mylonite.

Local Structures

Elliot Lake

Elliot Lake is underlain by east-trending quartz monzonite gneiss. Shown particularly well on shoals and islands of the lake are southeasterly plunging lineations, formed by intersection of gneissosity and a northeast-striking cross foliation. Although no large or single structure was discernible, the plunge of lineations is consistent over a much broader region (Fig. 4).

Lewis Lake

Lewis Lake is circular and is centred over a dome structure of biotite-hornblende granodiorite which here and there includes microcline phenocrysts. Crescent-shaped quartz monzonite bodies are emplaced in the dome and the structure has a strong aeromagnetic expression. It is bounded in part by granodiorite gneiss and in part by a converging lineament and shear zone. Here and there oriented gneiss inclusions outline closure of foliation about the dome (Figs. 3 and 4)

Moar Lake

Moar Lake, which extends into the Hecla-Carroll Lake map-area, is underlain by massive and gneissic granodiorite and seems to be a fold or basin showing closure both in the northwest and south (Ermanovics, 1970a). Foliation is not well developed and, as at Lewis Lake, it is manifest mainly in the form of oriented relict gneiss inclusions. An assemblage of quartz monzonite and granodiorite gneiss with mafic layers occurs immediately west of Moar Lake and extends to the Horseshoe Lake structure.

Horseshoe Lake

Metadacite at Horseshoe Lake is distributed in the shape of a horseshoe that closes to the northwest. Lineations, small folds and axes of granite boudins in gneiss plunge east, although northeast and southeast plunges

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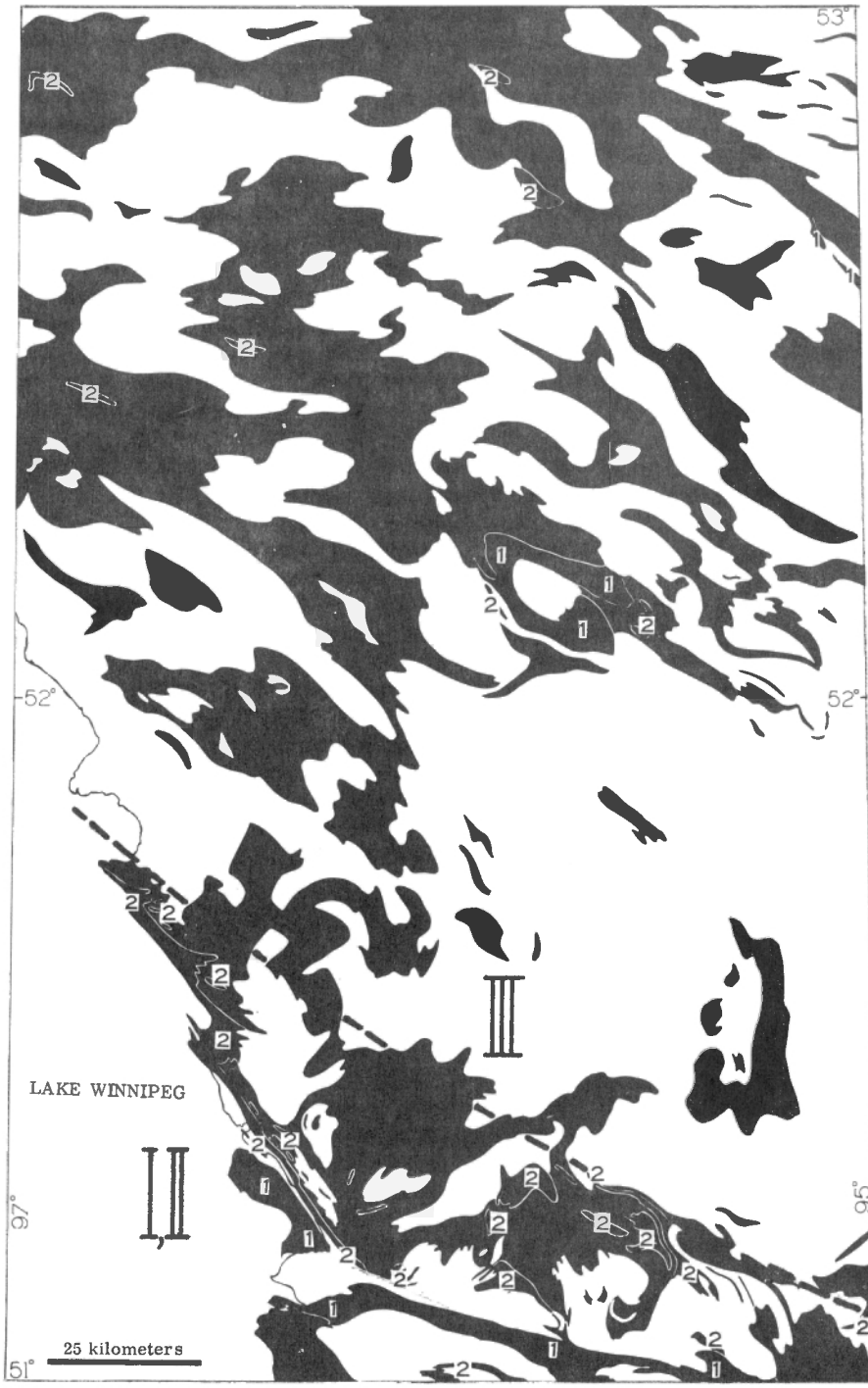
Figure 3. Distribution of metavolcanic-sedimentary rocks (1), banded paragneiss and amphibolite (2), and quartz monzonitic to granodioritic gneiss (black shading, unnumbered) of unknown origin in Hecla-Carroll Lake and Berens River- Deer Lake map-areas. Unshaded areas are quartz monzonite and granodiorite of domain III and quartz diorite and granodiorite of domain I and II, separated by heavy dashed line A-B.


53°
52°
52°
97°
95°
51°
LAKE WINNIPEG
25 kilometers

exist. Foliation, parallel to the shear zone in the northern arm of the structure, strikes northwest; the central quartz monzonite is not foliated. In the absence of marker horizons more structural observations from this area are required to determine the nature of the structure. Sparse evidence for closure of the northwestern 'nose' of metadacite exists in granodiorite just beyond the volcanic rock boundary.

Charron Lake

Charron Lake, underlain by massive and gneissic granodiorite (6), is circular and bounded by lineaments whose rocks are slickensided. A shear zone, tangential to the north-northeastern part of the lake, contains mylonite zones whose foliation is in part cut by 'pseudotachylite' (Fig. 5). Cataclastic rock-types include phyllonite (brittle, paper-thin schist) ultramylonite and cataclastic granodiorite (Fig. 6). The 'pseudotachylite' seems to be chiefly an opaque rock paste[1], forced into fractures in cataclastic granodiorite. Visible fragments of plagioclase and quartz constitute 10 to 30 per cent of the volume of the veins. In 8 measurements made of the optically 'aphanitic' and inclusion-free material weak X-ray patterns show quartz, plagioclase and rarely magnetite. In several veins dominantly opaque layers are interspersed with fine (light coloured) rock flour (Fig. 6c). Portions of some veins show 'flow' structures (Fig. 5b) but whether this represents flow as a liquid or as rock paste is not known.

Basic Dykes

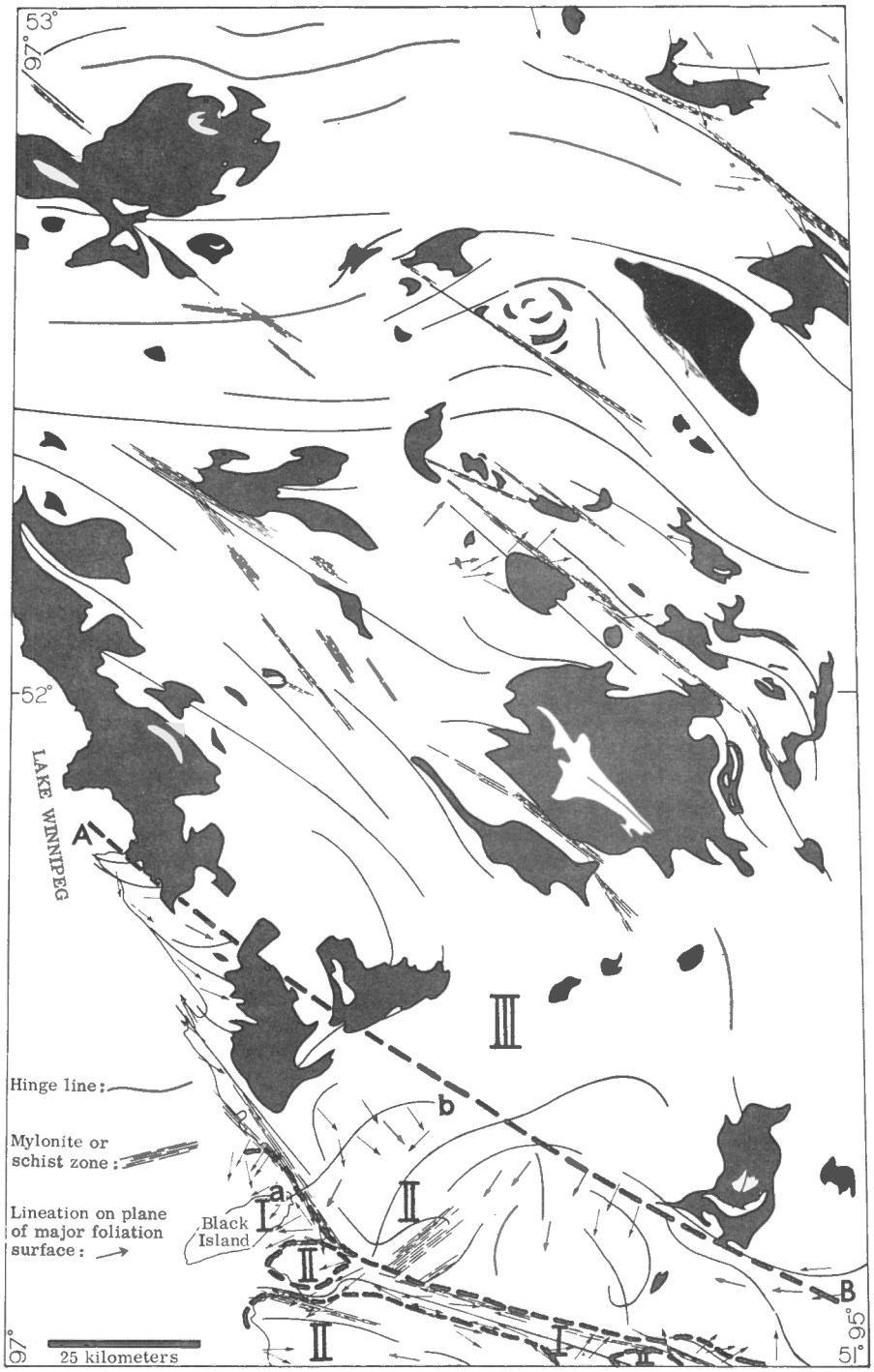
No 'diabase' dykes are present in the granitic terrain but lenses of gabbroic rocks and amphibolites bearing quartz, hornblende, plagioclase (An_{50}) and pyroxene occur on Berens and Poplar Rivers. A zone of basic inclusions in granodiorite extends from Vickers Lake (Hecla-Carroll Lake map-area) to Round Lake along Pigeon River. This lineament if extended northwest from Round Lake intersects Berens River at Sturgeon Falls and at the river's mouth; both of these localities contain large lenses of gabbro and basic amphibolites. This lineament, 50 miles long and striking northwest, may represent a relict dyke system that has been broken and 'granitized' by later intrusions.

SUGGESTIONS FOR MINERAL PROSPECTING

No mineral prospects in the area are known to the author. Quartz veins several feet thick at Horseshoe Lake and pegmatite bodies on the east

[1] "Flinty crush-rock" may be the preferred term applied to these structures.

Figure 4. Structural elements and disposition of quartz monzonite (black shading, compositions shown in Fig. 2) in Hecla-Carroll Lake and Berens River-Deer Lake map-areas. Roman numerals refer to structural domains discussed in text. Boundary A-B coincides with position of seismic discontinuity discussed in text; hinge line a-b is the Black Island-Shallow Lake fold axis discussed in text.


53°
97°
52°
LAKE WINNIPEG
A
B
III
b
a
I
II
Black Island
Hinge line:
Mylonite or schist zone:
Lineation on plane of major foliation surface:
97°
25 kilometers
95°
51°

side of Elliot Lake are barren. However, pyrite is consistently present at localities where quartz monzonite and sheared rock come in contact. Thus, for example, mineralization may occur west of Moar Lake where hybrid granodiorite to quartz monzonite gneiss were sheared and then intruded by quartz monzonite. Examination of similar shear zones near quartz monzonite ('granite') might uncover mineral deposits in the following localities:

1. the area between Carr-Harris and Natchi Lakes; possibly also 1 mile northward along the river draining Carr-Harris Lake;
2. the south and southeast shore of Lynx Lake (south of Lewis Lake) near the quartz monzonite;
3. Round Lake;
4. just north of where Palsen River flows into the southwestern arm of Elliot Lake;
5. in the region centred about the portage between Fishing and Assiniki Lakes.

Mafic quartz monzonite may be a more favourable source of ore-forming solutions because the high activity of water related to the formation of mafic minerals may also give rise to hydrothermal solutions. All of the areas listed are readily accessible by small aircraft. Additionally, the following rivers, underlain by foliated and banded gneisses, although less important prospecting ground, should be explored at periods of low water when more rock is exposed along the river banks.

1. Poplar River, from its mouth to 18 miles up river.
2. Pigeon River, from its mouth to Windigo Lake.

SUMMARY

The area is underlain by massive and gneissic granodiorite and quartz monzonite, and minor amounts of metavolcanic-sedimentary rocks in the following proportions:

Quartz monzonite + granodiorite gneiss (4, 5)	46%
Granodiorite + quartz monzonite granodiorite (6)	32%
Quartz monzonite (7)	19%
Amphibolite + metavolcanic - sedimentary rocks (1, 2, 3)	3%
	100%

Some quartz monzonite intrudes granodiorite and both intrude all rock types belonging to units 1 to 5. Rocks of unit 6 have a wide range in composition including minor amounts of quartz diorite. Rocks included in unit 7 are readily mapped and comprise leucocratic quartz monzonite (Fig. 2). Gneisses (4, 5, of unknown origin) vary in structure and composition but their regional geometry indicates an east-west trend in the north and west and a northwesterly trend in the south and east. Shear and mylonite zones (schist zones) trend northwesterly. East-west gneissosity in nonsheared areas suggests that the northwesterly foliation is the later. The highest aeromagnetic intensity is produced by massive granodiorite and, locally by quartz monzonite. With minor exceptions, shear zones and gneiss have low aeromagnetic

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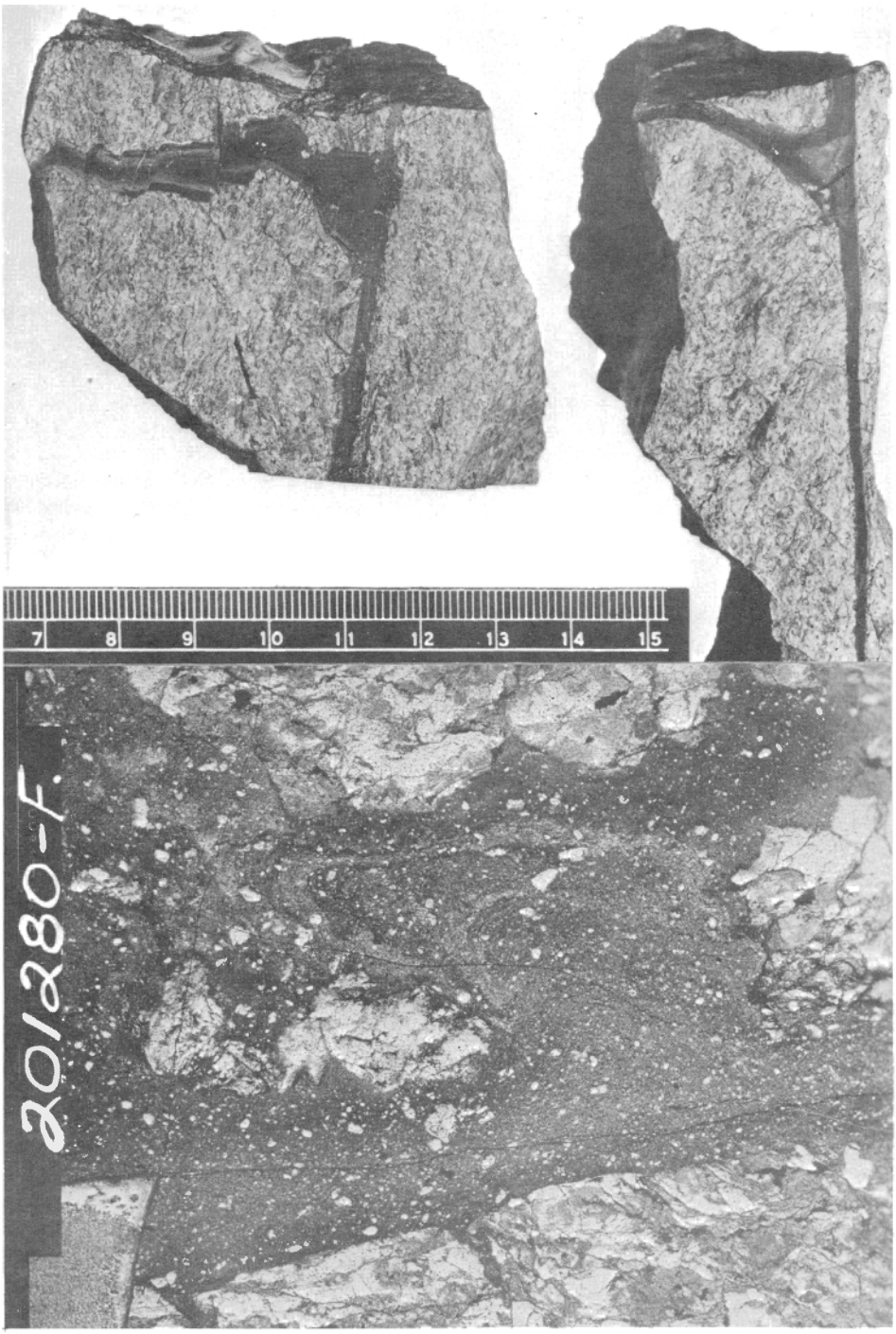
Figure 5. 'Pseudotachylite' fabric

a) Zoned, 'pseudotachylite' in sheared granodiorite parallel and perpendicular to foliation. 201265-B.

b) 'Flow' texture in 'pseudotachylite'; light-coloured portions and fragments are quartz and plagioclase. Plane light. 201280-F.


7 8 9 10 11 12 13 14 15
201280-F.

expression. Metamorphism has reached middle amphibolite grade and locally near igneous rocks has attained upper amphibolite grade.

Compared to igneous rocks near the major greenstone belt in the southern part of Hecla-Carroll Lake map-area, those in this area and northern part of Hecla-Carroll Lake map-area are siliceous and are considered to be part of a sialic nucleus with respect to the greenstone belt and its adjacent hybrid zone of the English River belt in Manitoba. This idea is formulated below.

A PRELIMINARY ANALYSIS OF TECTONIC VARIATIONS BETWEEN LATITUDES 51-53 DEGREES NORTH

Introduction

The area under discussion, located east of Lake Winnipeg (Fig. 1) is bounded by 51-53 degrees north and 95-97 degrees west. Field work in 1968 (Hecla-Carroll Lake map-area) and in 1969 (Berens River-Deer Lake map-area) included remapping of 12,000 square miles by the author utilizing three mapping teams for six months and 160 helicopter hours in 40 calendar days. Helicopter traverse-lines were spaced 2 to 3 1/2 mile intervals and the entire area was thus traversed systematically. The first of these reports is now published (Geol. Surv. Can., Paper 69-42) and Table I attempts to match rock types of both areas.

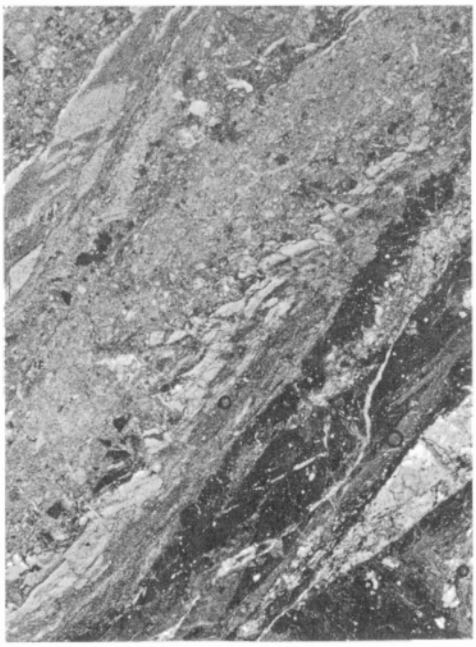
Unfortunately, because many mapping projects are not geared to handle large areas of complex 'granitic terrain', rocks other than metavolcanic-sedimentary rocks or recognizable paragneiss have been mapped in the past as 'granites' even though few or none exist (Fig. 2). However, in this and other parts of the Canadian Shield containing large areas of granitic terrain any evaluation of tectonic variation must include a compositional and structural analysis of these rocks.

Tectonic Domains: A Three-Fold Division

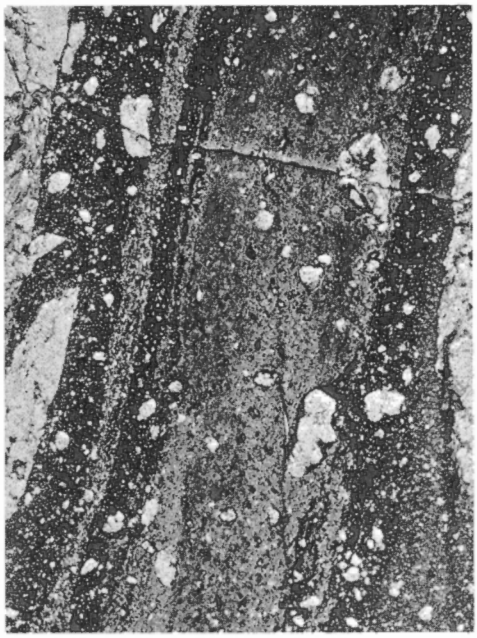
Structurally, Superior Structural Province, which includes the present area, has been divided by Goodwin (1968) into "a framework comprising a predominantly granitic nucleus or craton (Cat River belt, Stockwell, 1964)

Figure 6. Microfabric of host rock and pseudotachylite
- a) Phyllonite (brittle, granodiorite schist) located 1.5 metres from 'pseudotachylite' veins. Plane light. 201280-J.
- b) Brecciated, brittle schist with broken pieces of pseudotachylite (opaque matrix). Plane light. 201280-E.
- c) Zoned vein of 'pseudotachylite'; light-coloured portions are dominantly rock flour of enclosing cataclastic granodiorite. Plane light. 201280-H.
- d) Relatively uniform opaqueness of 'pseudotachylite' filled with quartz and plagioclase fragments; enclosing rock is cataclastic granodiorite. Plane light. 201280-I.

a



b



c

d

with an adjoining annular belt or orogen" - the Uchi volcanic belt (English River belt, Stockwell, 1964). The northernmost portion of the 'granitic nucleus' is rimmed by the Windigo volcanic belt (Goodwin, 1968), termed by Stockwell (1964) the Cross Lake belt but is not discussed here because pertinent information about its geology and structure in Manitoba is not available.

A three-fold division of the area based on the total aspect of the rocks consists of: metavolcanic-sedimentary rocks (Rice Lake Group, domain I), a mobile zone comprising paragneiss and basic igneous rocks (domain II) and an area comprising massive and gneissic quartz monzonite and granodiorite (sialic nucleus, domain III) (Fig. 3).

Domain I: Greenstones

The Rice Lake metavolcanic-sedimentary rocks lie in a schist zone in which in the present area, middle amphibolite facies assemblages (staurolite, garnet, hornblende ± sillimanite ± oligoclase) have been downgraded to greenschist facies, with production of mica, epidote (imparting much of the green colour to the rock), chlorite, and talc. The grade of metamorphism tends to increase toward the edges of the belt. Structures are obliterated and mylonite is developed in competent rocks; lineations are commonly small crenulations caused by cleavage cutting across the main foliation planes.

Quartz diorite, dioritic gabbros, minor gabbros and ultrabasic rocks are closely associated with volcanism. At Horseshoe Lake, for example, dacite, porphyritic dacite, and quartz diorite are locally gradational. Quartz monzonites small and few in number, however, occur later and seem to post-date the main period of tectonism. They are thus received into a cooled suprastructure as small 'high-level' stocks that have stoped and shouldered aside adjacent cover rocks, although porous sediments may have been granitized. Inclusions in these rocks are little altered and were already gneisses at the time of intrusion of a main period of metamorphism; adjacent wall-rocks are only slightly hornfelsed.

Domain II: Mobile Zone

Diapiric quartz diorite intrusions, paragneiss, amphibolite and migmatite characterize this zone. An important member is granodioritic paragneiss with migmatite, containing mica, garnet and, locally, cordierite and sillimanite. These gneisses show refolding, absorption into granodioritic magma and finally faulting. Rocks of the mobile zone represent hybridized 'infrastructure' underlying the 'supracrustal' greenstones and are responsible for the present involuted and bifurcated disposition of the greenstones. The proportion of gneiss to magmatic rocks, 1:1, is similar to that found in domain III except that in the latter both gneiss and plutonic rocks have a more limited range of quartz monzonite to granodiorite composition.

Granodioritic to quartz dioritic, diapiric plutons dominate domain II and intrude and enclose rocks of the greenstone domain. They are marginally foliated parallel to the foliation of adjacent gneisses and are locally characterized by abundant mafic inclusions. The plutons become homogeneous and massive toward their centres, resembling in this respect, mantled gneiss domes. Characteristic petrographic features are: oscillatory zoning in

andesine; colour index 15 to 25 (some mafic varieties contain 25 to 50 per cent biotite and hornblende as, for example north of Wallace and east of English Lakes); quartz content 20 to 30 per cent; microcline variation of 0 to 15 per cent. Large bodies of leuco-quartz monzonite are rare although this rock type occurs abundantly in dykes and vein-networks in hybrid rock areas and more rarely in porphyritic zones; large bodies have a highly variable texture and chemical composition.

Domain III: Sialic Nucleus

Constituting 50 per cent of the area underlain by rocks of domain III are foliated and stratiform gneisses of quartz monzonite and granodiorite composition (Fig. 3). Their widespread occurrence brings into perspective the importance of attempting an insight into the origin of these rocks. The gneisses exhibit an east-west trend in the north and a northwest trend in the south; these trends also control the disposition of leuco-quartz monzonite (Fig. 4). Mineralogically they differ little from their massive counterparts - the plutonic rocks; their chemical variation is not known. Weak cross-foliation in the form of crenulation of mica schlieren in weakly foliated gneiss, produces lineations whose plunges are consistent over large regions (Fig. 4). Stratiform gneisses, positioned higher in structural sections, commonly lack well-defined linear elements and comprise sporadic amphibolitic and aluminous (mica and garnet) interbands similar to those found abundantly in domain II. In summary, the gneisses represent a hybrid assemblage of para- and orthogneiss and lit-par-lit injections arising in part from subjacent, later intrusions. Their total composition is such that they could be the transformed products of sediments rather than of volcanic rocks; at the very least, such gneisses may be metamorphically transformed products of older igneous rocks. In any case these rocks demonstrate a process of either sedimentation or metamorphism whose style and magnitude are not fully represented by domains I and II.

Leuco-quartz monzonite (Fig. 2), and granodiorite constitute the bulk of the igneous rocks in this domain. Compared to domains I and II these plutonic rocks are the most siliceous, have elongated, structurally controlled forms, and except for their margins where they are weakly foliated, are massive. Leuco-quartz monzonite (Fig. 4), most easily recognized during regional mapping, forms bodies of all sizes. The rocks generally contain less than 10 per cent mafic minerals (biotite, sphene, epidote, magnetite, ± muscovite) and commonly equal amounts of zoned oligoclase and microcline; the average quartz content ranges from 20 to 35 per cent.

Porphyritic quartz monzonite, consisting of microcline phenocrysts (25 x 15 mm) aligned in a granodioritic matrix, constitutes the major portion of the pluton near Family Lake (95° 25'W, 51° 50'N). The porphyry is a sheet-like body grading downwards into porphyritic and then mafic granodiorite (Ermanovics, 1970b). Elsewhere, as north of Bloodvein Bay (96°45'W, 51°50'N) where the topographic relief is low, porphyritic quartz monzonite encloses 'windows' of porphyritic granodiorite.

Because of their mixed occurrence the remaining igneous intrusive rocks, ranging from quartz monzonitic granodiorite to small amounts of quartz diorite, are less easily distinguished as separate entities. Foliated portions of these rocks are found in quartz monzonite. In turn, mafic and

foliated granodiorites of domain II are readily recognized as inclusions in granodiorites of domain III. The total content of biotite, hornblende and sphene plus magnetite, has an average range of 12 to 18 per cent and this mineral content probably accounts for the large, uniform 'blue areas' (greater than + 200 gammas) seen on the Magnetic Anomaly Map of Canada (Geol. Surv. Can. Map 1255A) which characterize terrain underlain by these rocks.

Contacts Between Domains

The contact between the mobile zone (domain II) and the greenstones of domain I is sheared and mylonitized, and is expressed in some places by faults with a predominantly horizontal component of displacement (e. g. Wallace Lake, W. D. McRitchie, personal communication). That domain II represents a deeper level than I is demonstrated by the northeast-striking, synformal Black Island-Shallow Lake axis (hinge line a-b, Fig. 4). Black Island consists of a syncline overturned to the northwest, plunging southwest (b-lineations) and contains schistose, pillowed lavas, slates, phyllites and metagreywacke. The closure of the Shallow Lake synform (Ermanovics, 1969), about 15 miles to the northeast lies on the same axial trace and is thus deeper in the section. It is overturned to the northwest also but all linear elements plunge southeasterly. The rocks here, inferred to represent the lower section of the fold, comprise stratiform granodioritic and quartz monzonitic gneiss with biotite + hornblende layers (Ermanovics, 1969). This axis is intersected by a 2-mile wide, northwest-trending schist zone that masks the boundary between domains I and II. Coarse-grained igneous rocks on Black Island are quartz gabbro and quartz diorite, whereas those of Shallow Lake range from quartz diorite to quartz monzonite with granodiorite predominating.

The geological contact between domains II and III, although less well defined, nevertheless can be established where aluminous and mafic gneisses and granular and mafic granodiorites cease to be abundant. Locally, this boundary is a topographic lineament marked by abundant inclusions of mafic gneiss and foliated granodiorite of domain II in granodiorite of domain III. The boundary extends from the mouth of the Bloodvein River on Lake Winnipeg to the south shores of Aikens and Carroll Lakes (Fig. 4, boundary A-B). Extending northwest and southeast from Bloodvein Bay on Lake Winnipeg the boundary is coincident with an aeromagnetic lineament whose size and extent suggests a large-scale structure (L. J. Kornik, personal communication). Preliminary seismic data provide another clue to the nature of this major structural discontinuity: "... on the Bloodvein River fault... we have determined a 4 1/2 mile displacement on the intermediate (Conrad) discontinuity. The south side is displaced downwards. The 'Moho' appears to have a slight warp of perhaps one or two kilometres with the vertical displacement in the opposite direction from that of the 'Conrad'" (H. D. B. Wilson, written communication). This would seem to indicate a thinner 'Unterbau' beneath the mobile zone.

Summary and Discussion

The last radiometric (K/Ar) rejuvenation in all three domains occurred around 2,450 m.y. and is expressed by shearing and retrograde deformation in domain I, and emplacement of small quartz monzonite plutons at structural discontinuities (mylonite zones, domain boundaries. e.g. Leyond and Aikens Lakes). The presence of quartzofeldspathic materials in sediments of the greenstone belt and the fact that adjacent terrain comprises a compositionally suitable provenance (domain III) for such materials strongly suggests that the volcanic-sedimentary rocks were deposited upon a 'granitic' and sialic basement, even though no unconformity has been found. Indeed most evidence shows that adjacent plutonic rocks intrude the greenstones. One feature which may be important is that aeromagnetic patterns, recognized by some workers as only partly delineating greenstone belts (e.g. Ayres et al., 1969, McGrath and Hall, 1969), include the hybrid zone (domain III) which is faulted against the 'sialic nucleus' (domain III). Thus the mobile zone (domain II) comprising a mélange of para- and orthogneiss and diapiric plutons, is really a deeper part of an actively folded volcanic-sedimentary basin, hybridized by intermediate to basic plutonic rocks related to the extruding lavas of adjacent volcanic belts. Actual basement rocks for domains I and II if such exist, may therefore occur in the compositionally simple, monotonously banded gneisses of domain III. Such sialic nuclei (protonucleus, Goodwin, 1968), consistent with preliminary seismic data, are displaced upwards and thus expose basement rock at the same level as supracrustal rocks of domains I and II. Structural breaks, such as the 'Bloodvein River fault' between domains II and III, may be annealed by later intrusions and as in the case of the present boundary leave little surface expression.

Work in Precambrian terrains by Anhaeusser et al. (1969), Martin (1969), Kranck (1957) and others has produced models in which the relationship between sialic nuclei and greenstone belts may be a response to gravitational adjustment during upwelling of 'granite' and the concomitant sinking of the greenstone belts. Thickening of the sialic nucleus comes about by continuous addition of sialic matter and metamorphic differentiation, in older material to form layered gneiss. Infiltration of material on all scales causes volumetric increase in the rocks during folding. In domain III the characteristic rock type formed by refusion and flow deformation either in the solid or fluid state is gneiss. Consequently, the regional geometric form of the gneiss formations is the key to an understanding of the granitic terrain, although necessarily on a broad scale because small-scale structures are too few to permit generalization. The massive plutonic rocks are controlled by and intrude these gneisses and are not batholiths in the strict sense but rather represent differentiated rocks of mobilized infrastructure pushed upwards. They are thus 'derivatives' and 'residues' of rocks of the sialic crust.

The Cross Lake map-area (Bell, 1962, 54-55 degrees north, 96-98 degrees west) shows dominantly diapiric granodiorite and more basic plutonic rocks plus layered gneisses (domain II-type) constituting terrain between systematically spaced greenstone belts. Continuing the present cross-section northward, the northern contact of the sialic nucleus in Manitoba must be somewhere in the Norway House map-area (53-53° N, 96-98° W) mapped by Johnston (1936 a-f) as being dominantly 'granite'.

Table I

Equivalent rock types and map-units of Hecla-Carroll Lake and Berens River-Deer Lake map-areas

Rock Description	Map Units	
	Berens River-Dear Lake	Hecla-Carroll Lake
Undifferentiated rocks, migmatitic and hybrid rocks	8	16
Quartz monzonite, porphyritic quartz monzonite, fine-grained, leucocratic quartz monzonite	7, 7a	17, 17a, 14 14a, 14b
Medium-grained, gneissic quartz monzonite; leucocratic and coarse-grained brownish varieties	7b	14
Granodiorite and minor amounts of quartz diorite; locally, weakly foliated augen facies	6, 6a	12, 12b, 13 15
Quartz monzonite to granodiorite; locally foliated	6a	13a, 13b
Quartz monzonite to granodiorite gneiss; local stratiform layering	5	9
Granodiorite gneiss; local stratiform layering and amphibolite gneiss	4	8
Layered amphibolite and biotite-hornblende gneiss	3	7b
Metavolcanic rocks and schists	2	2, 1
Metasedimentary rocks; schists and gneiss	1	4

The following map-units, chiefly confined to an area adjacent to the Rice Lake Group of metasedimentary-volcanic rocks (Fig. 3, domain II) in the Hecla-Carroll Lake map-area are absent in the Berens River-Deer Lake map-area: stratiform granitoid (aluminous) gneisses (units 7a and 7c); mafic granodiorite to gabbro (units 10 and 11). Additionally, basic volcanic and coarse sedimentary rocks, and magnetite formation (units 3, 5 and 6) are confined to rocks of the Rice Lake Group (Hecla-Carroll Lake map-area) in the area.

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