73-20

GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF ENERGY, MINES AND RESOURCES

PAPER 73-20

PRECAMBRIAN GEOLOGY OF THE BERENS RIVER MAP-AREA (WEST HALF), MANITOBA (63 A W 1/2)

(Report, 5 figures and Map 2-1973)

I. F. Ermanovics

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Price: $2.00 Catalogue No. M44-73-20

Price subject to change without notice

Information Canada
Ottawa
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Map 2-1973 Geology, Berens River west half	in pocket

ABSTRACT

Quartzofeldspathic layered gneiss underlies 60 per cent of the area, the remainder being intrusive, homogeneous, massive to foliated quartz monzonite and diorite. Metamorphic affects indicate that three separate events of metamorphism have affected rocks in the area. No mineral deposits were found or are known in the area nor are any unusual anomalies displayed on the available aeromagnetic maps.

RÉSUMÉ

Du gneiss quartzofeldspathique lité repose sous 60% de la région; le reste est constitué de monzonite et de diorite quartzifères intrusives, homogènes, parfois foliacées, et parfois massives. Les effets du métamorphisme indiquent que le métamorphisme s'est manifesté en trois étapes distinctes. On n'a trouvé et on ne connaît aucun gisement minéral dans la région et les cartes aéromagnétiques disponibles n'indiquent aucune anomalie particulière.

PRECAMBRIAN GEOLOGY OF THE BERENS RIVER
MAP-AREA (WEST HALF), MANITOBA

INTRODUCTION

General Statement

Berens River map-area (west half) is bounded by latitudes 52-53 degrees north and longitudes 97-98 degrees west (Fig. 1). It adjoins the Berens River - Deer Lake map-area to the east (Ermanovics, 1970b) and most details of rock-types given in that report apply to the present map-area as well.

This report presents the results of remapping a terrain which previously had been known only through broad reconnaissance. The purpose of such work is to provide a lithologic and tectonic basis from which the mineral endowment of the area can be evaluated. Sixty per cent of the map-area is underlain by quartzo-feldspathic, layered gneiss; homogeneous, massive to foliated quartz monzonite and dioritic rocks (40 per cent) intrude the gneisses. Except for local vestiges of meta-volcanic pyroxene-amphibole rocks, no explicit trace of the origin of the gneisses remains; aluminous associations are absent. In the light of such large volumes of 'granitic' rock the area is truly sialic.

The region was mapped in 1972 and, in part, in 1971 during 50 traverses. Twenty helicopter hours were utilized to obtain information from otherwise inaccessible terrain. Both canoes and rubber boats were used, the latter being the safest

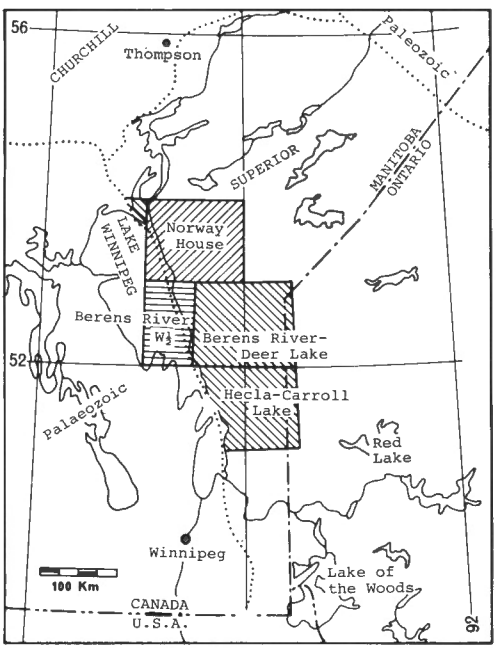

Figure 1. Index map

Original manuscript submitted: February 13, 1973
Final version approved for publication: March 8, 1973

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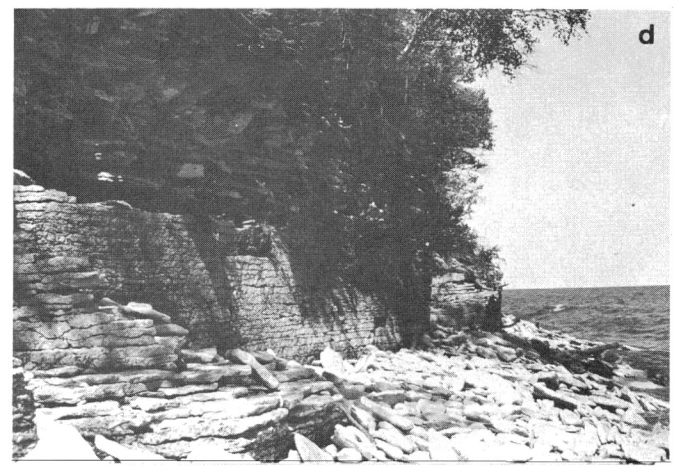
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means of transport on Lake Winnipeg for geological work. One hundred thin sections were studied as a means to estimate the grade and timing of metamorphism of both gneisses and intrusive rocks.

Paleozoic rocks were not studied, and map-units appearing on the accompanying map were taken from the Geological Map of Manitoba (Map 65-1). However, George, Berens, Burton (Fig. 2) and Commissioner Islands were investigated for outcrops of Precambrian rocks; none was found.

Physical Features

The terrain is flat and featureless and 70 per cent of the map-area is underlain by muskeg (Fig. 3). Provided that precipitation in August is not abnormally large, some areas of muskeg can be traversed on foot in late August and early September. Small dense pine is the common wood in muskeg areas (Fig. 3c). Poplar grows in abundance in areas of burned-over pine forest such as at Berens River and Poplar River. Helicopter landings are difficult throughout the area because of dense tree cover.

Outcrops are flat and sparse between Paterson Bay and Big Stone Point. Numerous shoal rocks along the shore of Lake Winnipeg become exposed at low water levels. Much of the shoreline of Lake Winnipeg is a fine clayey sand forming banks 3 to 8 feet high; muskeg appears immediately landward of the banks. Throughout the area clay, varved clay and peat underlie muskeg. Peat deposits in the estuary of Pigeon River (Pigeon Bay) attain thicknesses of 2 to 3 feet.

Gravel and clean sand are everywhere in short supply. The Indian communities of Berens River and Poplar River (Fig. 2) obtain gravel for dry-weather airstrips by barge from the Winnipeg area.

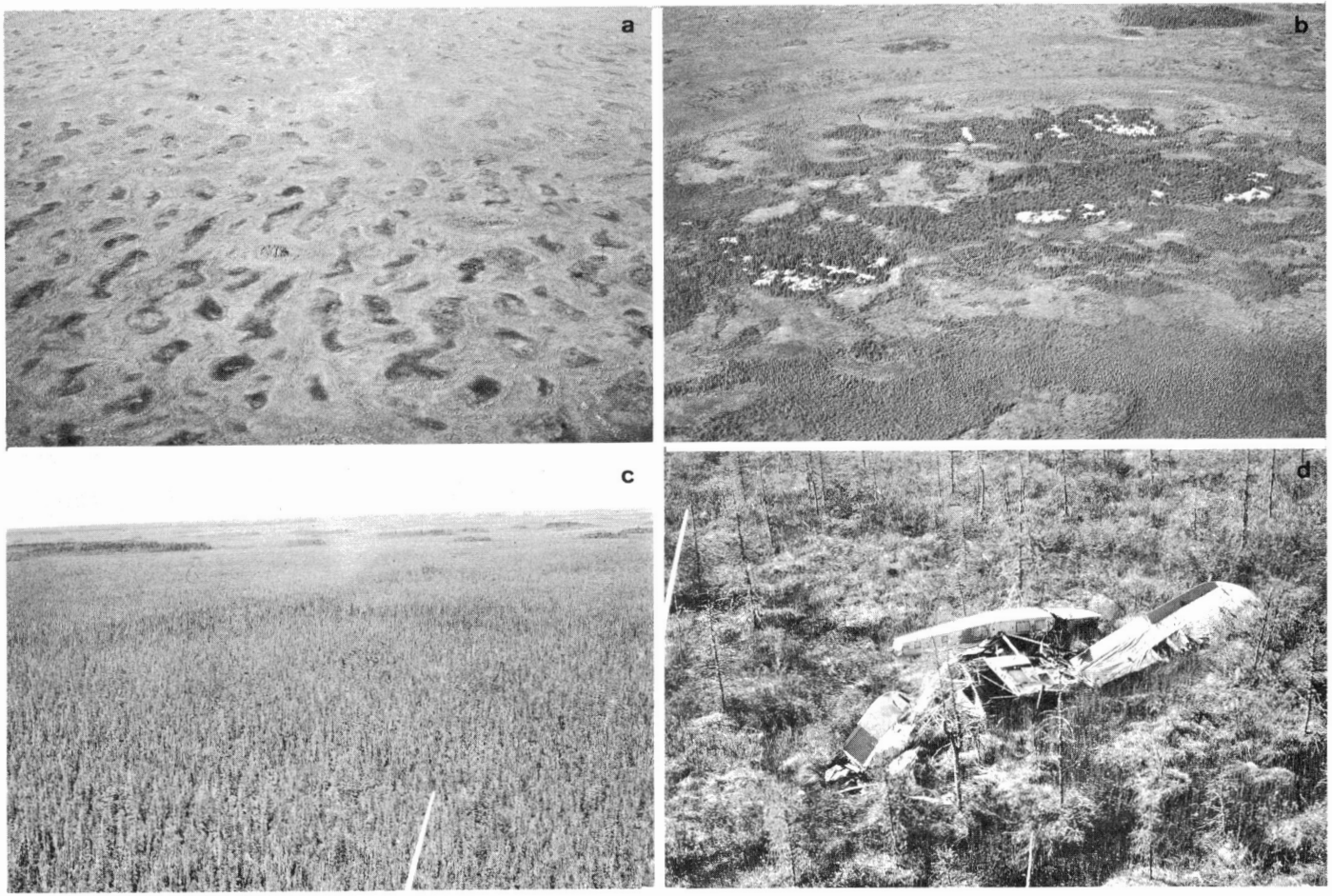
Sorted, flattish limestone-cobble deposits occur on the northeast-facing shoreline of George Island. An 80-foot-high ridge striking southwesterly on Berens Island may be an esker deposit and should be investigated for possible sand and gravel. The Sandy Islands 22 miles west of Poplar Point may contain sizable deposits of clean sand and pebbles.

Previous Work

Detailed descriptions of rock and terrain along the shore of Lake Winnipeg and along rivers flowing into the lake were made by Low, Tyrrell and Dowling, and appear in the Annual Report of the Director of the Geological Survey of Canada (Dowling, 1900). They recognized 'Huronian' schists and sediments, locally enclosed as inclusions in younger 'Laurentian' gneiss. No progress since that time has been made in the time classifications of the rocks, except for fixing the end of the Kenoran orogeny c.f. 2,500 m.y. (K/Ar) and locally establishing the peak of the Kenoran metamorphic episode at 2,700 m.y. (Rb/Sr).

Figure 2. Settlements and limestone of the map-area.

a. Poplar River, view west. (202076-N)
b. Berens River, view east; the ship Lord Selkirk at dock. (160206)
c. Berens River Mission Hospital; view northwest. (160208)
d. Dolomite limestone of the Red River Formation on Burton Island. (160238)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Johnston (1938), dealing with the area in Manitoba extending from 51 to 54 degrees north and from the Manitoba-Ontario boundary west to Lake Winnipeg produced a number of 'lithologic' maps that established the area as a dominantly granitic province. From his maps two batholithic events can be inferred - an early foliated granodiorite-quartz diorite phase and a later, mainly massive, leucocratic quartz diorite to granite phase.

In retracing Johnston's steps since 1968 the author (Ermanovics, 1970a, 1970b, 1972) has not found any new areas of 'greenstones'. The mapping since 1968 has also been 'lithologic' with careful attention, however, paid to the structural and metamorphic fabric of the rocks in the hope of separating broad tectonic styles.

Acknowledgments

For the 1972 field season I thank my assistant Mr. Vincent Vertolli (University of Toronto), members of the Order of the Oblate Fathers at the Berens River Mission and members of the Poplar River Indian Band Community. Permission to map rocks of the Berens River Indian Community was not granted to me by the Band Council probably because of a small diplomatic oversight on my part. However, rocks of the Indian Reserve were mapped from the roads and water, which gave adequate map-coverage. The report contains many of the comments of W. L. Davison who read the manuscript. Finally my thanks to Al Giebmanns in whose memory this report is dedicated. Mr. Giebmanns, helicopter pilot on the project, died a few weeks following the completion of the field work and lies missing somewhere in the area of the estuary of Marchand Creek, south of Poplar River.

GENERAL GEOLOGY

Introduction

The map-area contains 60 per cent layered quartzofeldspathic gneiss and 40 per cent massive and foliated intrusive rock. This percentage of gneiss is greater than in the adjacent (along strike) Berens River-Deer Lake map-area (Ermanovics, 1970b) where the percentage is 50 per cent of gneiss. In such an estimate, the 'granitic' component of layered gneisses is included in the estimate of gneiss because the component may be either allochthonous or autochthonous. It should be noted that with the exception of unit 1 the origin of the gneisses (2, 3) is unknown, although suspected in large part to be feldspathic metasediment, and pre-volcanic.

Figure 3. Physiography of muskeg terrain.

a. String bog in August following 2 days of rain. (202076-J)
b. Area of outcrop, ringed by sorted till, produced when Lake Winnipeg extended eastward. (202076-L)
c. Dense growth of jackpine. (202076-K)
d. Detail of muskeg. Crashed aircraft became visible only latterly after this route had been traversed many times. (202076-M)

Layered Gneiss (1, 2, 3)

Layered gneiss has the following mineralogical components (epidote pervades all groups):

a) quartz-plagioclase-clinopyroxene-hornblende

b) quartz-plagioclase-hornblende

c) biotite-hornblende-quartz-plagioclase

d) biotite-quartz-microcline-plagioclase.

Variations in the relative amounts of minerals present and variation in texture and structure permit further genetic classification. Type (a) is considered volcanogenic; type (b) is amphibolite of unknown origin and together, (a) and (b) constitute unit 1. Type (c) comprises two main textural varieties - one is coarse grained, quartz-dioritic (probably intrusive) and the other is fine to medium grained, granoblastic, leucocratic, and may be sedimentary in origin. Unit 2 thus constitutes small layers of (a) and (b) types in dominantly (c) types. Unit 3 is like unit 2, but contains both fine- and coarse-grained 'quartz monzonitic' component type (d). Some of this granitic component in unit 3 is clearly intrusive into equivalents of unit 2 assemblages producing lit-par-lit gneiss or migmatite. Fine- to medium-grained, granoblastic granitic layers may be sedimentary in origin.

Metavolcanic Gneiss (1)

These rocks are best exposed in the estuary of the Berens River on Lake Winnipeg. They are characterized by their black and grey, fine- to medium-grained, granoblastic laminated fabric, high hornblende and clinopyroxene content, low quartz content and intrafolial folds (Fig. 4). They are, in these respects, similar to the quartz-poor, epidote-hornblende-plagioclase-bearing gneisses associated with basic flow rocks in highly metamorphosed terrain at Horseshoe Lake and Ponask Lake of the western Superior Structural Province in Manitoba.

In outcrops where no 'granitic' material has been added, adjacent laminae of gneiss (Fig. 4a) are as follows:

light lamina: epidote + chlorite (pseudomorphic after plagioclase) + pale-coloured, lepidoblastic amphibole + sphene + calcite.

very light lamina: clinopyroxene + plagioclase + minor quartz and minor hornblende overgrowing clinopyroxene.

darkest lamina: clean, green to brown hornblende + plagioclase (15%).

intermediate dark lamina: clean hornblende + plagioclase + minor quartz.

felsic lamina and clots: pink-weathering, clotted concentrations may be intrusive quartz + plagioclase; fine-grained grey laminae are dominantly quartzose with altered plagioclase and may be greywacke.

Where this mineralogy is recognized the gneisses are in contact with foliated quartz diorite. The contact is conformable, agmatitic (Fig. 5a) and gradational over a distance of 25 feet. Later granitic phases form sharp and discordant contacts and additionally, the effects of intrusion seem to stabilize hornblende + epidote rather than pyroxene.

Rafts of foliated gneiss occur in quartz diorite (4) on the Poplar River estuary and for 20 miles upstream. Volcanogenic gneiss occurs as lenses and blocks throughout the area underlain by gneiss and thus is inferred to have had a wide distribution in gneissose terrain.

Tonalite and Amphibolite Gneiss (2)

Tonalite is here used in the sense of 'quartz dioritic rock'. It is a convenient term to describe both metamorphosed, strongly foliated to gneissose, coarsely grained, diorite and quartz diorite rocks, as well as leucocratic, fine- to medium-grained, granoblastic quartz-plagioclase rocks when these occur mixed in one outcrop. Both coarse- and fine-grained rock-types form compositional and textural layers (Fig. 6) and the distinction of whether they are orthogneiss or paragneiss is problematical. Quartz dioritic phases do form large pods (5 by 20 feet) within gneiss and here they are demonstrably intrusive. However, thin conformable lenses of coarse-grained material in layered gneiss are less amenable to interpretation. Similar gneiss in the Munro Lake area in Manitoba has been interpreted as paragneiss, injected lit-par-lit by tonalitic orthogneiss (Elbers and Gilbert, 1972). According to Elbers and Gilbert, these sediments form the base of a syncline in which rocks grade upwards to basic flow rocks.

Medium-grained, light grey, granoblastic lineated felsic gneiss is a common constituent of unit 2. The following are some characteristics of this component: zoned andesine with amoeboid texture (50 to 65%), microcline (trace amounts to 15%, quartz strings (20 to 30%), strings of hornblende or biotite (5 to 10%), trace amounts of magnetite, sphene, garnet and clear grains of zircon. The normal zoning of andesine grains may be an inherited feature because such zoning is not generally documented in metamorphic rocks. Small, 'matrix' plagioclases may be albite. Layers of fine- to medium-grained amphibolite ranging from a few mm to 15 cm in thickness (Fig. 6a) demonstrate complete recrystallization and have locally developed clinopyroxene. Zircons in these rocks generally appear to be metamict.

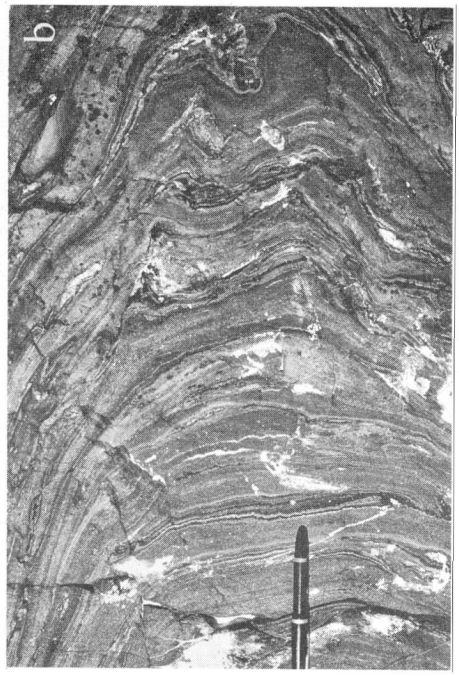
A plagioclase augen-gneiss of quartz dioritic composition, upon microscopic examination was found to comprise quartz and plagioclase aggregates enveloped by poikilitic brown hornblende which is overgrown with biotite. Mineral percentages in the augen-gneiss are as follows: plagioclase, occasionally zoned (60%), microcline (nil to 5%), quartz (10 to 20%), biotite and hornblende (20%); sphene, magnetite, apatite, epidote and zircon are accessory minerals.

Intrusive dioritic intercalations where such can be recognized, are themselves metamorphically differentiated to produce various layers of minerals (Fig. 6c).

Granitic Gneiss and Migmatite (3)

This unit is defined as a granitized portion of unit 2. Granitization is related to the late phase of emplacement of quartz monzonite and proceeded by lit-par-lit injection, filtering of quartz and microcline into tonalite gneiss and by stoping and disruption of gneiss to produce migmatite. Heat and fluids of intrusion during emplacement of the granitic (quartz monzonitic) component of the gneiss caused retrograde metamorphism of pyroxene and hornblende to epidote and biotite.

The quartz monzonitic and granodioritic layers are generally sheared (compressed?) at the edges of thick wedges in gneiss or when they form thin layers in gneiss. Although in these rocks biotite is altered to chlorite, plagioclase is epidotized and quartz is recrystallized, they are not, metamorphosed to the same high grade as the tonalitic and amphibolitic gneiss forming the original template for unit 3. They thus postdate the main metamorphic event.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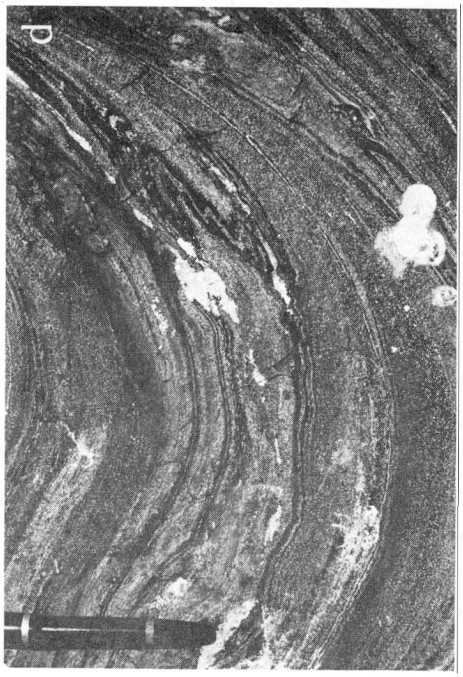
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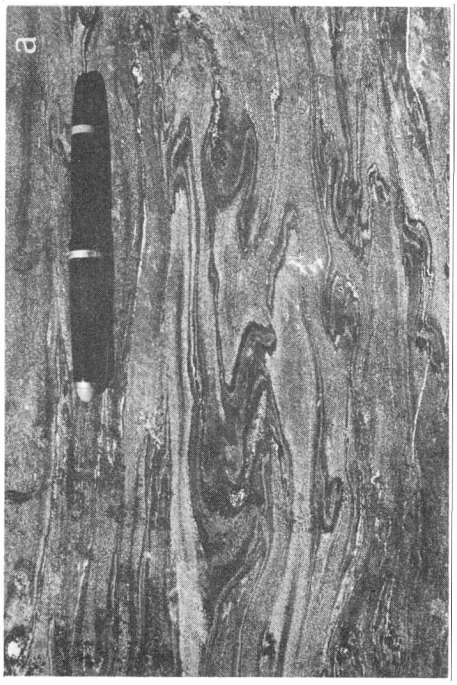
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Intrusive Rocks (4, 5)

Two main intrusive rock-types were mapped; one is dioritic, the other, quartz monzonite. The dioritic rocks are of two types - one is metamorphosed (4a, 4b) the other appears to be an early border phase associated with quartz monzonite intrusion. Of the metamorphosed dioritic rocks, unit 4a signifies additions of microcline and possibly quartz during granodioritization of dioritic rocks. Recognition in the field of massive quartz monzonite is easy, and useful because these intrusions postdate metamorphism throughout the Berens batholithic block (Ermanovics, 1970b), and appear to represent the first large-scale addition of potassium and silica to the crust. Metamorphosed dioritic rocks, on the other hand, are viewed as volcanogenic, and pre-Kenoran (Ermanovics, 1972); some dioritic rocks may be basement to the last cycle of volcanism and sedimentation.

Quartz Diorite, Diorite and Granodiorite (4)

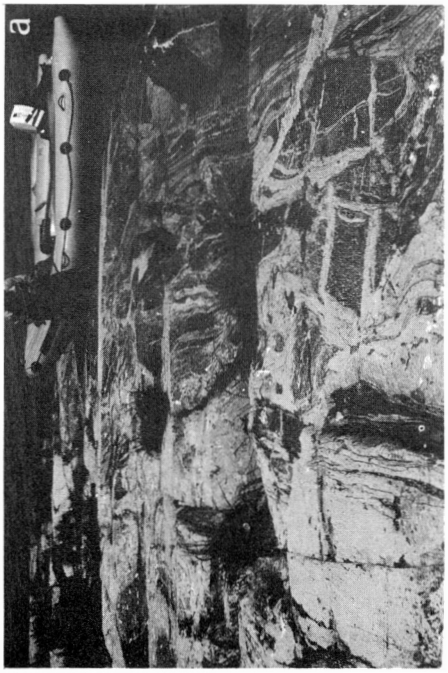
Metamorphosed rocks (4a, 4b). Large areas of epidotized, green-grey intrusive rocks occur north of Poplar River and extend 30 miles farther north into Norway House map-area (Ermanovics, 1972). The rocks vary in composition from quartz diorite to diorite and, where granitized by the addition of microcline and quartz, grade to granodiorite. The rocks are recrystallized, except for central portions of plagioclase grains which still retain zoning inherited from the time of intrusion. Locally the rocks are layered, which is ascribed to metamorphism, giving rise to quartz + plagioclase-rich and mafics + plagioclase-rich layers. Many outcrops show two directions of shear foliation. Compositions and grain size vary over large areas from medium- to coarse-grained to porphyritic which gives rise to the speculation that they are composite, and not necessarily coeval associations.

The plagioclase is sodic andesine, although oligoclase is more common in most rocks where metamorphism has been intense. Poikilitic hornblende grows parallel to the main foliation of the rock, and together with biotite, which overgrows hornblende, can constitute 25 to 30 per cent of the rock. Quartz ranges from 5 to 25 per cent. Epidote, as a second phase of metamorphism, replaces either plagioclase or hornblende; in such cases, biotite is laced with chlorite. Here and there, large enclaves of medium-grained amphibolite and fine- to medium-grained tonalite gneiss occur within bodies of metamorphosed diorite.

Although a few areas show up to 10 per cent interstitial microcline associated with recrystallized quartz, most modal granodiorites (4a) show fresh microcline porphyroblasts (and some quartz) which are interpreted as being introduced into the rock following metamorphism. Some areas are veined, parallel to the foliation, with this granitic component. Microcline porphyroblasts are poikilitic with all components of host metadiorite.

Figure 4. Pyroxene-hornblende-bearing gneisses of unit 1. Black layers are hornblende-rich; light layers are clinopyroxene-rich; intermediate hues of grey reflect various proportions of pyroxene, hornblende, quartz, plagioclase, epidote and calcite.

a. Intrafolial folds. (160232)
b. Mesoscopic combination fold. (202076-H)
c. Detail of (b); combination folds. (160233)
d. Detail of (b); refolded intrafolial folds in nose of parallel fold style; this feature is common near contacts of granitic intrusions; axes of refolded folds tend to be parallel to intrusive contact. (160234)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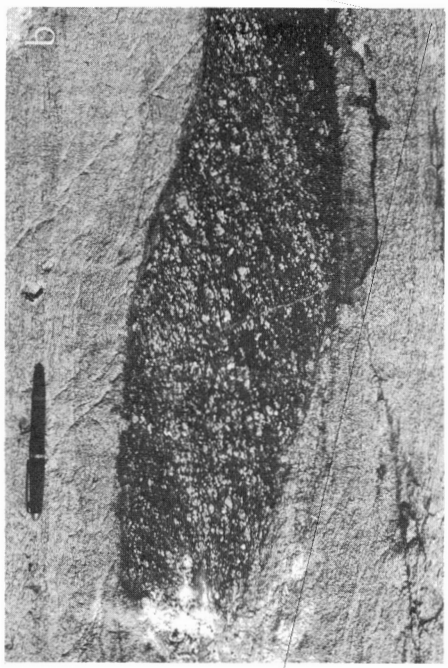
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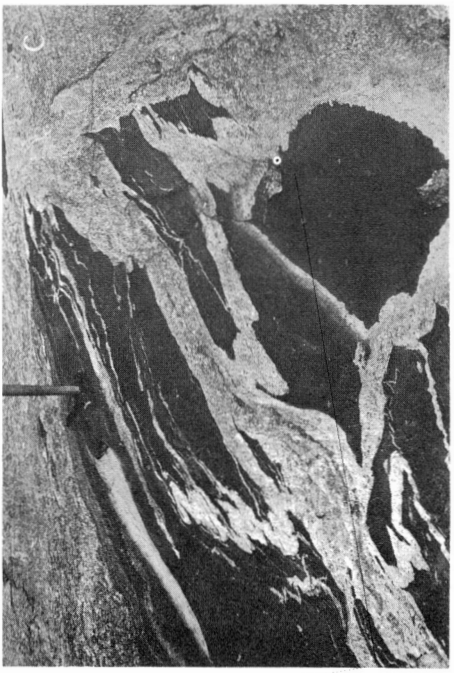
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Shearing comminutes and indurates these rocks. The linear belt of islands and shoals extending across Lake Winnipeg for 20 miles northwestward from Poplar Point attests to such shearing.

Massive quartz diorite. This is a massive to weakly foliated, coarse-grained, grey quartz diorite whose mode is as follows: plagioclase 50 to 70 per cent (andesine-oligoclase, zoned); microcline 0 to 7 per cent (perthite); quartz 15 to 20 per cent; hornblende 2 to 15 per cent; biotite 10 to 15 per cent. Apatite, sphene, magnetite, zircon and epidote are accessory minerals. Where this rock is locally sheared or near a quartz monzonite contact, hornblende is altered to biotite + epidote + magnetite and quartz is recrystallized. Except for bent twin lamellae, plagioclase remains unaffected.

The rock is of interest because, although it belongs to the post-metamorphism regime of rocks and generally appears to be associated as a border phase with quartz monzonite (5), it is nevertheless metamorphosed by and grades into quartz monzonite. Thus these massive quartz diorites vis á vis quartz monzonites are interpreted as cogenetic but not coeval. These relationships are well exposed along the southern shore of Pigeon Bay. The relationship between metamorphosed quartz diorite and tonalite gneiss (2), volcanogenic gneiss (1), and massive quartz diorite can be seen at Berens River.

Quartz Monzonite (5)

The map-area is underlain by the extremities of two quartz monzonite bodies, one centred about Weaver Lake of the Berens River - Deer Lake map-area (Ermanovics , 1970b) and the other lining the shore from the Bloodvein Community of the Hecla-Carroll Lake map-area (Ermanovics, 1970a). The rocks are quartz monzonite, defined as greater than 10 per cent quartz, and microcline in the range of 35 to 65 per cent.

Plagioclase is generally oligoclase but some is zoned, sodic andesine near borders or apophyses of the body, where the composition becomes granodioritic. Microcline is perthitic and the dominant mafic mineral is biotite generally about 5 per cent. Quartz content ranges from 20 to 35 per cent. The rocks are leucocratic with 80 per cent of the modes showing the sum of quartz + microcline + plagioclase equal to or greater than 90 per cent and 40 per cent of the modes showing the sum to be equal or greater than 95 per cent. Where the bodies lack a differentiated border phase, they develop muscovite, and high rubidium (200 ppm) but low strontium (less than 30 ppm) in the rock.

Granodiorites do not form large independent bodies but rather constitute a more basic border phase of quartz monzonite or a transitional facies between quartz monzonite and quartz diorite. In this respect they present the same textural

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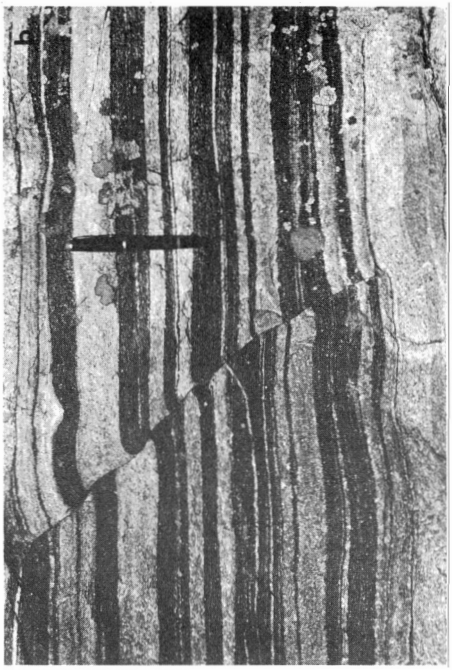
Figure 5. Details of intrusion of early quartz diorite into gneisses of unit 1; all rocks are metamorphosed to hornblende-pyroxene grade.

a. Contact of unit 1 with quartz diorite. (160229)
b. Detail of (a); porphyroblastic amphibolite boudin in light-coloured quartzofeldspathic paragneiss; fabric developed at the same time in both rock types. (160227)
c. Reaction textures of amphibolite with gneissose quartz diorite . (160231)
d. Agmatite developed by quartz diorite intrusion into amphibolite dyke. (160212)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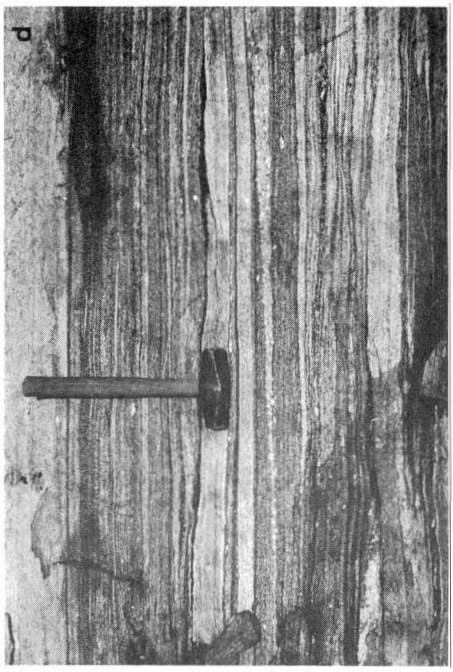
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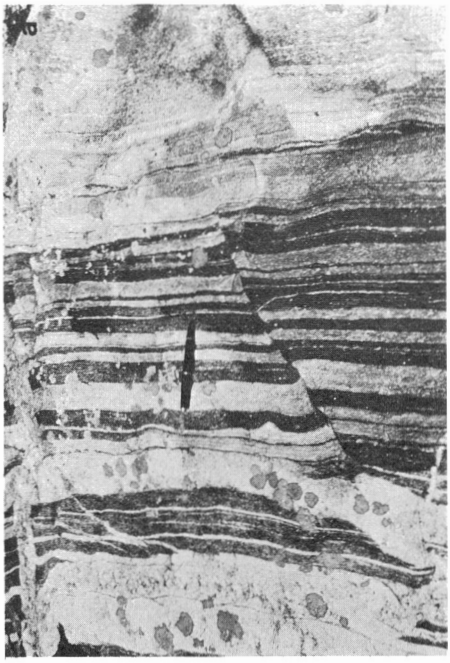
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features as the massive quartz diorites discussed above, because here and there, deuteric alteration due to heat of intrusion of the last granitic phase, affects the already crystalline granodioritic border phase.

METAMORPHIC GRADE

The following contiguous mineral assemblages related to the first metamorphism, obtain throughout the map-area in gneisses (1, 2, 3) and metaquartz diorite (4b), (quartz and calcic oligoclase are additional phases):

1. biotite + garnet + hornblende + microcline (± garnet)
2. biotite + hornblende
3. biotite + hornblende + clinopyroxene (± andesine)
4. hornblende + clinopyroxene (± andesine).

Superimposed metamorphism in areas of younger intrusions (unit 5) and lit-par-lit gneisses (3) has reduced pyroxene to hornblende and hornblende to biotite. Shearing, especially when accompanied by fluids, produces calcite and epidote in large amounts. Pelitic associations were not found and this raises the speculation of whether pelitic rocks were never produced, or were eroded or melted in the catazone to produce granodioritic rocks. Judging from volcanic belts elsewhere in the area, it is likely that pelitic rocks unlike quartzofeldspathic rocks were never very abundant among gneisses now exposed.

Metamorphic effects indicate three separate events of metamorphism have affected rocks in the area. Gneisses and metadiorites with mineral assemblages listed above resulted from an early metamorphic event. Later, acid plutonism modified the mineral assemblages, as already noted. Finally, local metamorphic effects resulted from shearing that occurred after quartz monzonite was emplaced.

STRUCTURE

The trend of layering in the gneisses is east-west in the north and northwesterly at Berens River. The dominant late shearing direction is northwesterly and for this reason it is thought that the northwesterly trend in the Berens block is a superimposed trend on an earlier east-west trend.

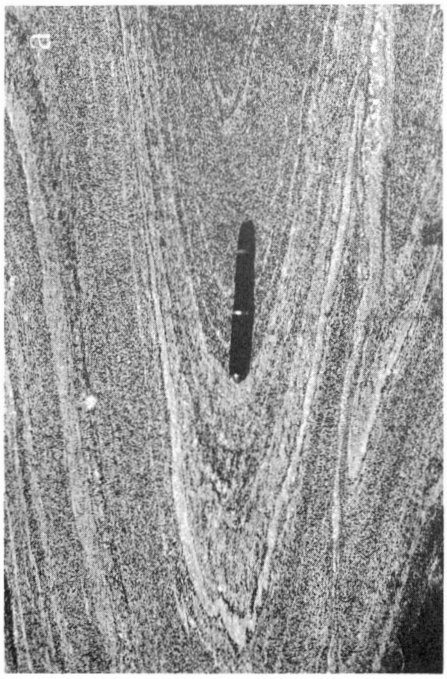
Axial planes of small, intrafolial folds throughout the area strike east-west. Plunges of fold axes within domains of 20 square miles are consistent. Folds are refolded in areas of magmatic intrusion; refolded axes are irregularly oriented about the northwesterly shear direction. In areas of late shearing, a lineation is developed in the plane of layering of the gneissosity.

Figure 6. Layering in rocks of unit 2.

a. General proportion of hornblendic layers and various kinds of quartzofeldspathic layers. (202076-I)
b. Detail of (a). (160251)
c. Diffusely layered gneiss with component of quartz diorite. (160226)
d. Like (c), but with component of greywacke paragneiss. (160225)

b

d


a

c

SUGGESTIONS FOR MINERAL PROSPECTING

No mineral deposits were found or are known in the area. Pyrite occurs ubiquitously as small lenses in volcanogenic gneiss (1). Gneisses of unit 2, in which large lenses of volcanogenic gneiss may be hidden under muskeg areas, should be tested with airborne EM. Present aeromagnetic maps indicate no anomalies in gneiss that are higher than those associated with granitic terrain.

The most urgent present need, however, is for gravel and will be so in the future. Places where these deposits might be found have already been indicated in the section dealing with Physical Features.

SUMMARY

Two plutonic events are separated by a main metamorphic event which attained upper amphibolite-lower granulite grade. The first plutons are quartz dioritic, the second phase is dominantly quartz monzonitic, but ranges from quartz dioritic to quartz monzonitic. A second metamorphism is associated with intrusion of silicic plutons and a third, associated with shearing, postdates them. The gneisses represent formation of rock related to metamorphism and plutonism. The initial template was volcanogenic gneiss (1), and subsequent dioritic intrusions produce unit 2 and final acid plutonism, unit 3.

There is some evidence that the Berens batholith block (defined in Ermanovics, 1972) and small areas surrounding it contain remnants of older rocks, not found in the Uchi and English River gneiss belts to the south. A quartzofeldspathic gneiss at Favourable Lake gave a U-Pb zircon age of 2,950 m.y., compared to 2,750-2,800 m.y. for volcanic and granitic rocks of the Uchi Lake area (Krogh and Davis, 1971). A porphyritic quartz diorite (altered to greenschist) at latitude 51°15' on Lake Winnipeg gave a Pb-U zircon age of 3.05 b.y. and an orthogneiss (?), similar to the one at Favourable Lake (Lorne Ayers, pers. comm.), gave 2.95 b.y. The latest quartz monzonitic and granodioritic intrusions in the old terrain on Lake Winnipeg as well as granoblastic paragneiss and orthogneiss in the English River gneiss belt (at latitude 51°04' on the road south of Manigotagan south of Uchi volcanic belt) gave ages centred about 2.75 b.y. If the Kenoran orogeny (peak of metamorphism) was centred about 2,750 m.y. ago, it remains to be tested whether 2,950 m.y. ago was the time of another orogeny.

Figure 7. Fold styles in rocks of unit 2.

a. Isoclinal folds, plunging 25 degrees in granoblastic gneiss; axial plane cleavage cuts across limbs of folds. (160223)
b. Isoclinal folds in an amphibolite raft in leucocratic gneiss (not shown); folding occurred in both rock-types before dislocation of raft from main amphibolite mass. (160222)
c. Tight infolding and transposition of layers. (160246)
d. Combination of folds, demonstrating varying ductility of layers. (160244)

TABLE I

Rock types in the Berens River (west half) map-area

Rock Description	Map-unit
Quartz monzonite: pink, medium- to coarse-grained, massive; generally less than 10% biotite + sphene + magnetite; foliated near inclusions and contacts, and shear zones.	5
Porphyritic quartz monzonite: microcline phenocrysts, generally near the border of intrusion.	5a
Quartz diorite, diorite and minor granodiorite: grey, medium- to coarse-grained, massive to foliated; generally less than 20% hornblende + biotite + sphene + magnetite; massive portions may belong to the quartz monzonite phase of intrusions.	4
Coarse-grained, foliated and layered, epidotized, and metamorphosed quartz dioritic rocks.	4b
Unit 4b rocks, granitized by addition of quartz and microcline in the form of lenses and porphyroblasts; may include autochthonous segregations.	4a
Granitic gneiss and migmatite: 40% white and grey layered biotite + hornblende + quartz + feldspar gneiss and 60% quartz monzonitic and granodioritic orthogneiss; unit is defined as granitized sequence of unit 2.	3
Tonalite and amphibolite gneiss: layered white, grey and black granoblastic gneiss; biotite + hornblende (± clinopyroxene) + quartz + plagioclase gneiss; rare garnet; contains 40% foliated and layered quartz diorite augen-gneiss.	2
Metavolcanic gneiss fine- to medium-grained, thinly layered, granoblastic, black to grey gneiss; quartz + plagioclase + clinopyroxene (± biotite), clinopyroxene layers, epidote + calcite + altered clinopyroxene, biotite + hornblende; except for injected quartz dioritic layers the quartz content of the black gneisses is generally less than 10% and commonly less than 5%.	1

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