Geological Report GR82-1

Geology of the Lower Nelson River Project Area

By M.T. Corkery

Manitoba
Energy and Mines
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INTRODUCTION

LOCATION AND ACCESS

The Lower Nelson River Project encompasses an area of approximately 4000 square kilometres extending from northwest Split Lake down the Nelson River to Long Spruce Rapids, including "Moose Lake"* (Stephens Lake) and Little Assean Lake. The area includes the Split Lake settlement in the west and the town of Gillam in the east (Fig. 1).

In the National Topographic Series this includes map sheets 64A/1, 64A/8, 54D/4, 54D/5, 54D/6, 54D/7 and parts of 54D/10 and 54D/11.

The Split Lake-Assean Lake area is accessible from Thompson by an all weather road, and Stephens Lake in the east is directly accessible from Gillam. This facilitates boat access to the entire area.

PREVIOUS WORK

Initial geological investigations in the Split Lake area were made by Bell (1880) during a track survey in 1879 along the Nelson River downstream to Clark Lake. The Split Lake area was more extensively mapped in 1939 by A.S. Dawson (1941). J.C. Gill (1951) extended coverage in the area and re-examined and modified Dawson's earlier work. R. Mulligan (1957) incorporated Gill's work in the Geological Survey of Canada Map 10-1956 of the Split Lake Sheet (NTS 64A) at a scale of 1:253 440.

Detailed mapping by Haugh (1969) covered the south and west portions of Split Lake and the Assean Lake area. In this work the cataclastic nature of the rocks in the Split Lake and Assean Lake fault zones was recognized for the first time.

Geological investigations within the Kettle Rapids area (NTS 54D) began with a river survey eastward from Clark Lake conducted in 1906 by McInnes (1913). He reported hornblende gneiss in the Gull Lake area, garnetiferous gneiss and schist in the river channel east of Gull Rapids, and a thin section of fine grained rocks, interpreted as metasedimentary rocks, in the Gull Rapids area.

Quinn and Currie (1961) published a 1:253 440 geological map of the Kettle Rapids Sheet (NTS 54D).

Recent geological work by Elphick, Frohlinger, Haugh and Hubregtse is described in the section on "Present Work and Acknowledgements" (q.v.).

PHYSICAL CHARACTERISTICS

The Nelson River traverses the area from Split Lake eastward to Long Spruce Rapids and provides access to most bedrock exposures in the region. Little Assean Lake and "Moose Lake" are the only other major lakes within the area.

From Split Lake to Gull Rapids, the Nelson River is fast-flowing, with a smooth gradient broken only at Birthday Rapids. Gull Lake consists of a widening of the river and a split into two channels around an island where the rate of flow is reduced but still strong.

Prior to flooding, associated with the Kettle Rapids Hydro development, the river from Gull Rapids to Long Spruce Rapids was dominated by numerous sets of rapids which exposed long stretches of outcrop. Fluctuations in water level and seasonal ice movement kept the exposures clean of lichen.

In the northwestern part of the area, Little Assean Lake forms a narrow body of water 1 to 4 km wide and about 15 km long. It extends southwest through a narrows into Assean Lake. These lakes have a limited catchment basin and are filled by flow into the lakes from the Hunting River up the Assean River in the spring. During the remainder of the year the Assean River drains the lakes.

Completion of hydro-electric dams at Kettle Rapids and Long Spruce Rapids has eliminated upstream rapids along the Nelson River to Gull Rapids.

*Place names in quotations refer to topographic features that are now flooded.

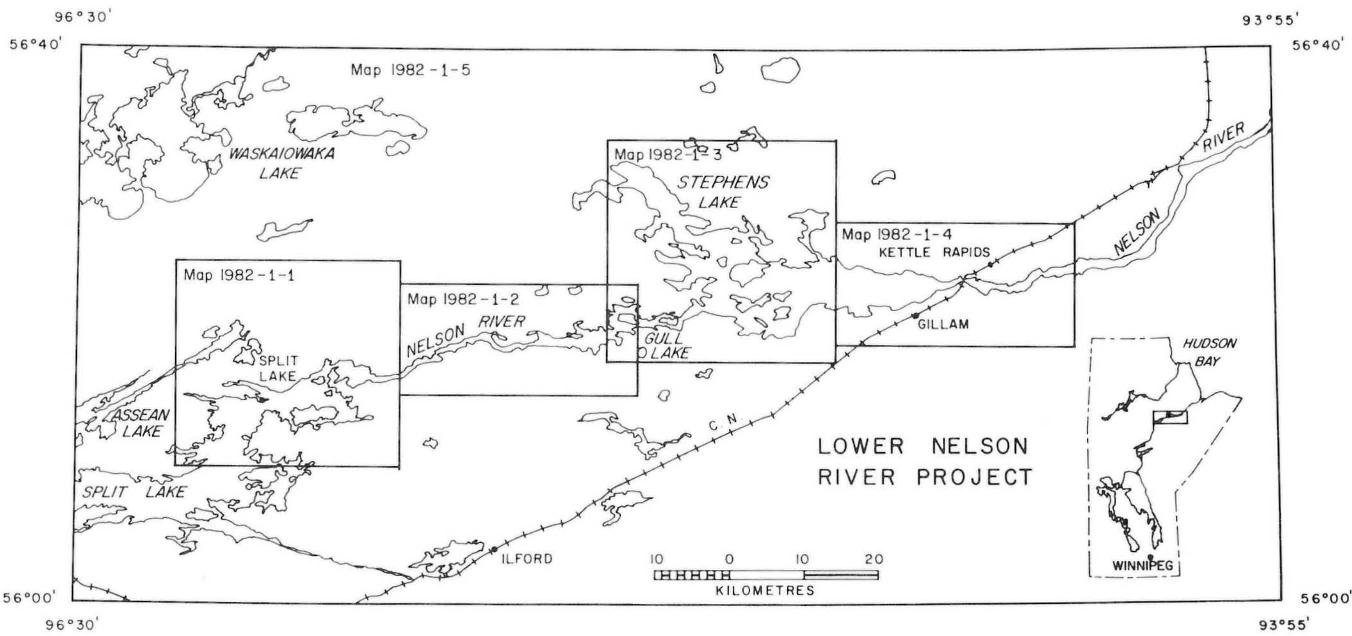


FIGURE 1: *Location map of the Lower Nelson River Project area. Boxed areas indicate geological maps contained in the pocket.*

Inland, the map area is covered by extensive thick Pleistocene glacial and glacial lake deposits. Varved clays are commonly exposed along eroded lake shores. Numerous sand and gravel deposits are found in the Stephens Lake area.

PRESENT WORK AND ACKNOWLEDGEMENTS

This compilation encompasses a series of mapping programs undertaken by several geologists between the spring of 1968 and the close of the 1977 field season. The results of these programs have been compiled and interpreted by the author who is also responsible for the interpretation of previous workers' field data.

These geological mapping programs covered the portion of the Lower Nelson River most affected by Manitoba Hydro's Nelson River hydro-electric projects.

The initial survey, undertaken by I. Haugh during a two-month field season in 1968, was designed to recover maximum geological information prior to extensive flooding of the area by the forebay of the Kettle Rapids dam and generating station in 1971. The area covered in this program extended from Gull Rapids east to the Hydro dam at Kettle Rapids and included mapping of "Moose Lake". The area was subsequently flooded and the forebay, known as Stephens Lake, has inundated most of the shoreline exposures investigated by Haugh and Elphick (1968); inland exposures now accessible by boat include 20 to 30 outcrops in a series of bays on the northeast shore of Stephens Lake and a few scattered outcrops in the former "Moose Lake" area.

In 1974 a three-week geological examination by T.G. Frohlinger was carried out along the Nelson River downstream from Manitoba Hydro's Kettle Rapids generating station to the proposed axis of the Long Spruce Rapids dam site. Outcrops were examined prior to their flooding by the Long Spruce Rapids forebay.

In July of 1975 T.G. Frohlinger and the writer completed mapping the Long Spruce Rapids area and extended mapping downstream to the limit of Precambrian exposure. This lower reach will be flooded in the future following construction of the Limestone Rapids dam.

Further geological mapping was carried out by the writer in 1975 in the section of the Nelson River from Split Lake downstream to Gull Rapids. This area has been affected by increased flow rates resulting from partial diversion of the Churchill River into the Nelson River.

A further three-week field season in 1976 extended the mapping of Haugh (1969) in the Assean Lake area through Little Assean Lake and north to Crying Lake.

Geological mapping of the northeast portion of Split Lake (Corkery, 1977) completed the geological data-gathering program for the Lower Nelson River from Split Lake downstream to Limestone River.

Field mapping programs were carried out predominantly by boat traverses. Where this was not possible, due to rapids or falls, the shoreline was walked or, alternatively, a helicopter was used to gain access to islands and reefs. Within the area, shoreline exposures of bedrock constitute more than 90 per cent of the available outcrop. Where isolated outcrops or groups of outcrops were found away from the shoreline a helicopter was used to gain access.

The author is grateful to I. Haugh and T.G. Frohlinger for invaluable discussions of their data and geological interpretations which have been incorporated, along with several of their photographs, into this report. The helpful assistance of the geological staff of both Manitoba Hydro and Crippen Acres Engineering and the availability of Hydro reports, maps, drill hole data and diamond drill core has significantly broadened the data base in the Kettle Rapids-Long Spruce Rapids area.

Through the various field mapping programs field assistance was rendered to: I. Haugh by senior assistant S.C. Elphick and junior assistants J.R. Taylor, G. Ross and D. Holland (1968); T.G. Frohlinger by G. Smith (1974); M.T. Corkery by R. Dresal (1975), G. Oppenheimer (1976), B. Hunt and F. Wiktorowitz (1977).

AVAILABLE MAPS AND AERIAL PHOTOGRAPHS

The Split Lake map (National Topographic Map 64A) and the Kettle Rapids map (National Topographic Map 54D) include the area mapped at a scale of 1:250 000. Topographic maps at a scale of 1:50 000 which cover the area include Split Lake (64A/1), Little Assean Lake (64A/8), Birthday Rapids (54D/5), Gull Rapids (54D/6), Kettle Rapids (54D/7), Brooks Creek (54D/8) and 54D/10 and 11. These maps are available from the Map Distribution Office, Ottawa, or the Surveys and Mapping Branch of the Manitoba Department of Natural Resources.

Several series of vertical aerial photographs were utilized in the mapping programs; these are available from the National Air Photo Library in Ottawa.

Aeromagnetic maps 2443G, 2444G, 2475G, 2476G, 2483G, 2467G and 2491G, at a scale of 1:63 360, cover the map area and are available from the Geological Survey of Canada and the Province of Manitoba.

INTRODUCTION

Geological investigations between Split Lake and Long Spruce Rapids confirmed the presence of sparsely exposed Precambrian bedrock, overlain unconformably in the extreme east by a thin veneer of Ordovician limestone (Bad Cache Rapids Group).

The Precambrian rocks are subdivided into a) Proterozoic rocks of the Churchill Structural Province, and b) Archean and Proterozoic rocks of the Superior Structural Province (Fig. 2, Table 1). The contact between the two Structural Provinces is marked by cataclastic rocks that were possibly developed as a result of continental collision during the late stages of the Hudsonian orogeny. Gibb and Thomas (1976) indicate that this crustal suture marking the contact between the Superior and Churchill Provinces "extends from the Manitoba nickel belt (Nelson Front) through the Split Lake-Fox River region of Manitoba and the Hudson Bay Lowlands of Northern Ontario to eastern Hudson Bay and then to the Cape Smith Belt and Labrador Trough of Northern Quebec."

The southwest half of the area lies within the Superior Province. The rocks are similar in geologic history and composition to granulites of the Pikwitonei domain; however, extensive retrogressive metamorphism has resulted in widespread recrystallization of granulite assemblages to those characteristic of lowermost amphibolite and middle greenschist grades of metamorphism.

A zone of cataclasis mapped by Haugh (1969) through Assean Lake marks the south side of a broad complex contact zone between rocks of the Superior Province and those of the Churchill Province. This zone of cataclasis can be traced eastward from Little Assean Lake to the limit of outcrop, and thence using aeromagnetic trends (Fig. 3) to the mylonites exposed at Gull Rapids (Haugh and Elphick, 1968).

At Gull Rapids the most continuous section across the contact between the Churchill and Superior Structural Provinces is exposed. However, the contact relationships at Gull Rapids differ markedly from those observed to the southwest and to the east, in that metavolcanic and metasedimentary sequences such as the Ospwagan and Fox River groups are absent.

To the east of this major contact, metasedimentary rocks and derived migmatites are similar to those of the Kisseynew area of the Churchill Province.

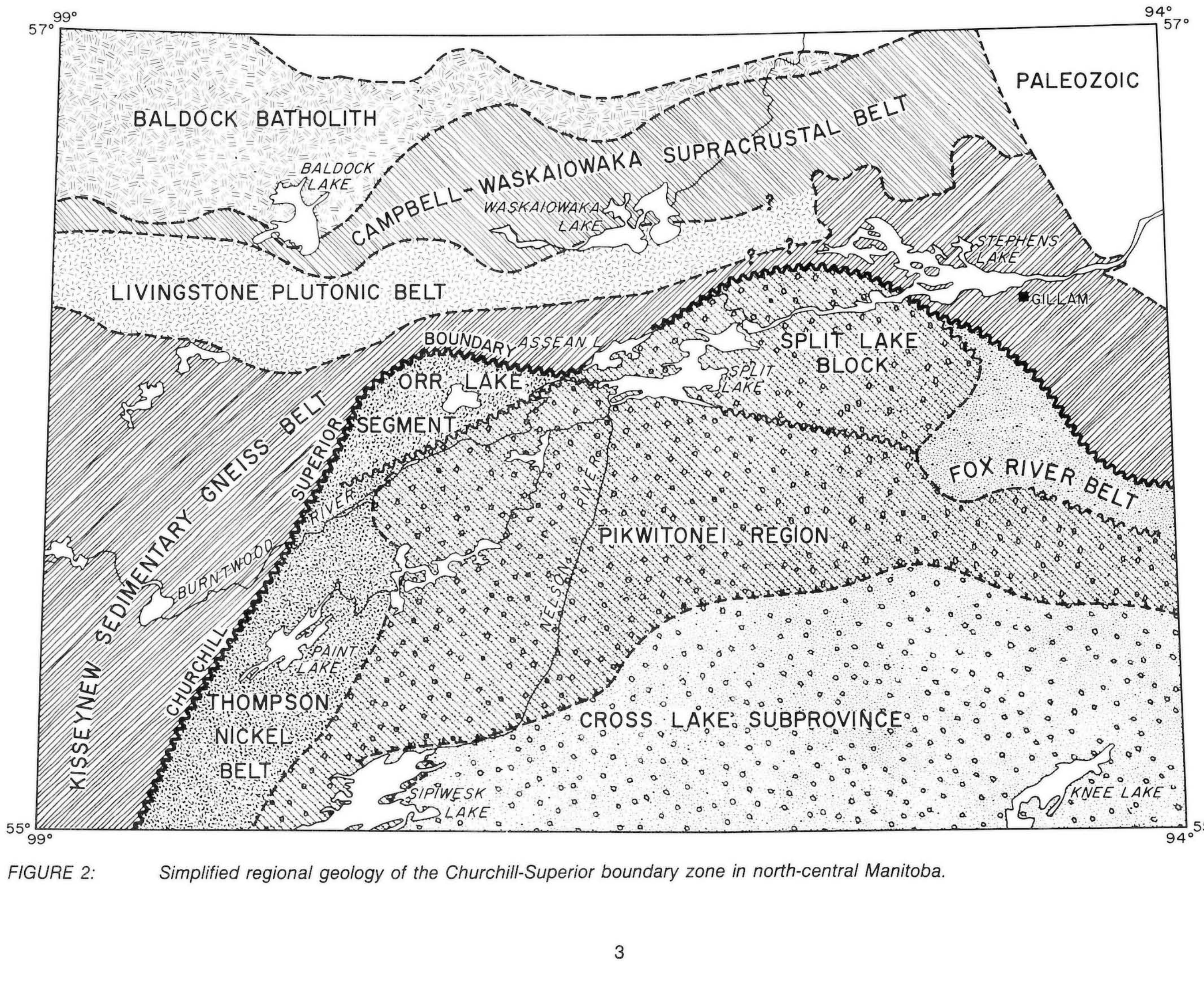


FIGURE 2: Simplified regional geology of the Churchill-Superior boundary zone in north-central Manitoba.

Table 1: Table of Formations for the Lower Nelson River Project area.

Pleistocene and Recent	Sand, Gravel, Clay (Morainic deposits, lacustrine deposits, glaciofluvial (outwash) deposits, marine (near shore) deposits, alluvium)
	Unconformity
Paleozoic	22 Ordovician Bad Cache Rapids Group, Portage Chute Formation
	Unconformity
PRECAMBRIAN	21 Cataclastic rocks and mylonites of the Churchill-Superior Boundary

PRECAMBRIAN		SUPERIOR STRUCTURAL PROVINCE	Age	CHURCHILL STRUCTURAL PROVINCE			Age
PROTEROZOIC	Hudsonian Igneous and Metamorphic Rocks	9 Tectonized migmatites 8 Granite 7 Mafic dykes Molson?	(1) K-Ar 1720 Ma	PROTEROZOIC	Hudsonian Igneous Rocks	20 Mafic dykes 19 Granite 18 Granodiorite/Tonalite	(2) Rb/Sr 1700 ±95 Ma
						INTRUSIVE CONTACT	
					METASEDIMENTARY ROCKS: Sickle Metamorphic Suite	16 Metagreywacke 15 Sillimanite-bearing meta-arkose 14 Feldspathic metagreywacke 13 Hornblende-plagioclase metagreywacke	
					METASEDIMENTARY ROCKS: Burntwood River Metamorphic Suite	12 Transitional metagreywacke 11 Hornblende-diopside para-amphibolite 10a Psammitic metagreywacke 10b Meta-arkose 10c Psammitic/Pelitic metagreywacke 10d Pelitic metagreywacke	
ARCHEAN	Kenoran Igneous and Metamorphic Rocks	6a Granite 6b Granite/Granodiorite	(3) Rb/Sr 2600 ±75 Ma				
		INTRUSIVE CONTACT					
		5 Hornblende-biotite gneiss and migmatites					
		4 Clotted tonalite					
		3 Mafic/Ultramafic dykes					
		INTRUSIVE CONTACT					
		2 Anorthosite complex 1 Amphibolite and metagabbro					

(1) K 7.52%, Ar^{40}/K^{40} 0.1642; radiogenic argon 99% Lowden, (1961, p. 49).

(2) 1.42×10^{-11} yr^{-1} decay constant, initial ratio 0.7014 Clark (1981).

(3) Recalculated with decay constant 1.42×10^{-11} yr^{-1} Clark (1974).

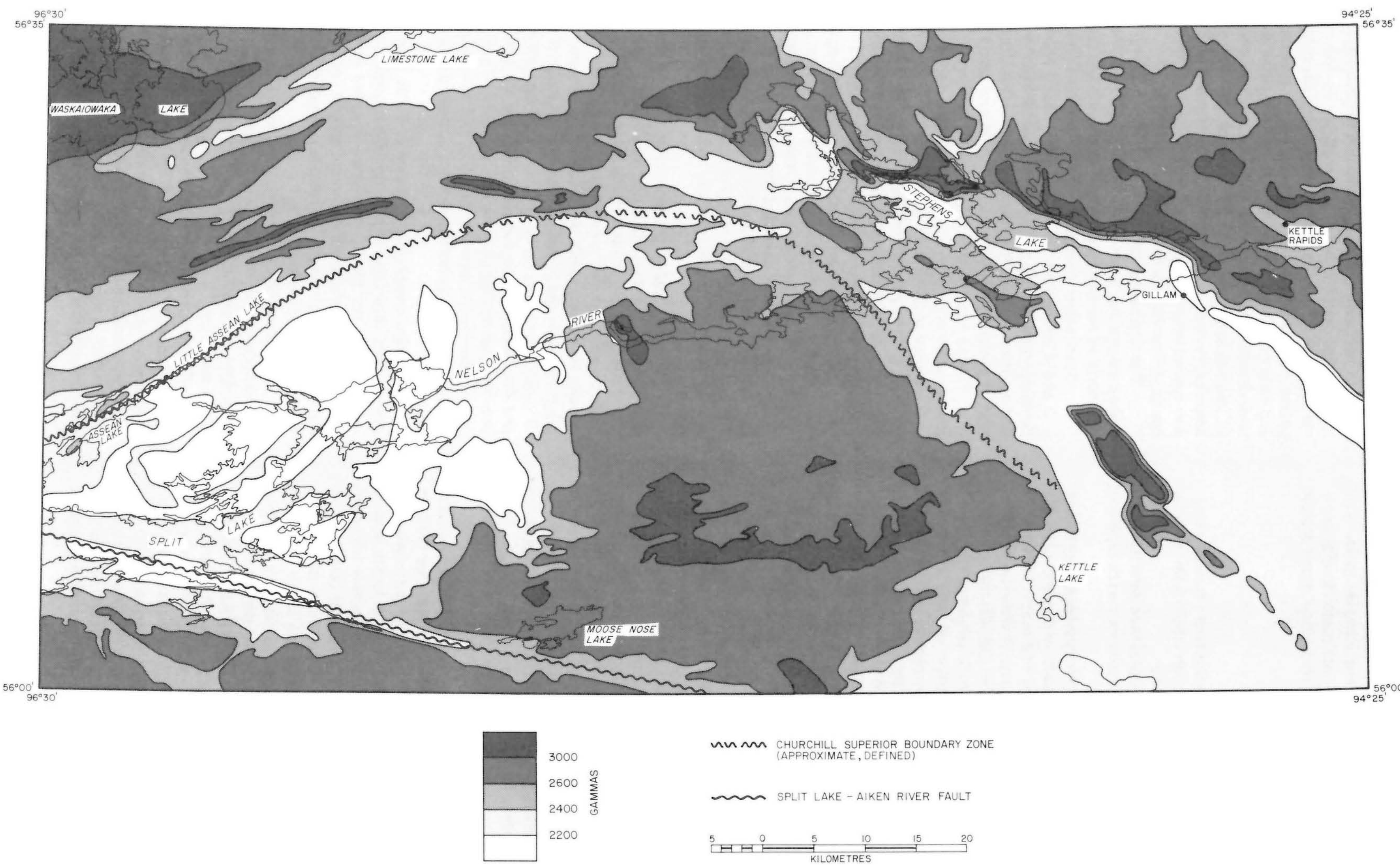


FIGURE 3: Aeromagnetic map of the Lower Nelson River Project area and adjacent regions.

The sequence of geologic events is different for rocks in the Superior and Churchill Structural Provinces and only late cataclastic events (D_4 and D_5) related to the major fault zones are common to both sides. Structural style, metamorphic events and intrusive rocks have no counterparts across the boundary. This is interpreted to indicate a significant spatial and/or temporal separation throughout much of their geological evolution.

SUPERIOR PROVINCE

Rocks in the map area assigned to the Superior Province represent a continuation of those described by Haugh (1969) from the area between the Split and Assean Lake fault zones.

From northeast Split Lake to the Gull Rapids fault zone the rocks have been subdivided into 9 units, which have been modified by repeated tectonism and metamorphism (Table 2).

Unit 1 constitutes a compositionally heterogeneous suite of well layered to massive amphibolites, hornblendite and mafic granulite gneisses of gabbroic composition. In the area of the Split Lake Indian Reserve (IR 171) discrete layers of metagabbro occur within layered gabbroic anorthosite and anorthositic gabbro (unit 2B). On the southeast side of the anorthosite complex (unit 2) a thick sequence of layered metagabbro (unit 1a, b, c) occurs in association with the anorthosite complex. Similar metamorphosed gabbro-pyroxenite-peridotite rocks were observed by Hubregtse (1975) in the Ilford area and potentially correlative gabbro and minor picrite in the Wintering Lake area "exhibit a "skaergaard type" rhythmic primary igneous layering" (Hubregtse, 1977). Elsewhere in the Pikwitonei domain Weber (1978) described mafic granulites and amphibolites associated with iron formation, felsic gneisses and quartz-rich garnet gneiss. These associations "most likely represent supracrustal rocks" (Weber, 1978). It is assumed that the mafic gneisses (unit 1) in the Split Lake block are comparable to those in the Pikwitonei domain; however, the distinctive associated supracrustal rocks have not been documented here.

A northeast-trending belt of amphibolite (unit 1) several kilometres thick, occurs along the Nelson River east of Birthday Rapids. Within this belt granulite facies mineral assemblages and textures are preserved. A domal anorthosite intrusion (unit 2) with layered anorthositic gabbro marginal phases is associated with metagabbro (unit 1) in the Split Lake Indian Reserve (IR 171). Subunits of metagabbro and anorthosite can be traced along the shoreline for several kilometres. Elsewhere, metagabbro and rare anorthosite are recognized as restite in migmatites and rafts in agmatite zones.

An early mafic to ultramafic dyke system (unit 3) intruded the metagabbro (unit 1).

Clotted tonalite (unit 4) forms long narrow intrusive bodies a few metres to 8 km long. Along the north shore of Indian Reserve 171B an agmatite, comprising amphibolite blocks injected by clotted tonalite, occurs at the margin of a major tonalite intrusion. The blocks are layered indicating a period of metamorphism (M_{1a}) prior to tonalite intrusion. Mineral assemblages indicative of M_{1a} metamorphism could not be distinguished. However, relict granoblastic textures in the metagabbro blocks indicate amphibolite or hornblende-granulite facies may have been attained. In the Pikwitonei domain evidence of this early metamorphic event is better preserved indicating that the first Kenoran orogenic event reached hornblende-granulite facies conditions (Hubregtse, 1980).

Early tonalite intrusions(unit 4) typically exhibit relict granoblastic textures. Near Ilford these tonalites contain metamorphic orthopyroxene formed during an early Kenoran granulite grade metamorphic event (M_{1b}). Sporadic migmatites with clotted tonalitic leucosome and relict granoblastic textures were also generated during this event; however, the original extent and nature of these rocks is obscured by extensive reworking during later Kenoran and Hudsonian tectonometamorphic events.

Deformational features attributed to early Kenoran events are distinguished only in the amphibolite belt east of Birthday Rapids. Here compositional layering has been folded, (probably during the D_1 deformation), into a series of large-scale shallow-plunging asymmetrical folds with northwest-trending axial planes.

A second Kenoran tectonic event resulted in the formation of north- to northeast-trending layering in migmatites (unit 5) and upper amphibolite grade mineral assemblages in the amphibolites and metagabbros (unit 1). Extensive migmatitic zones of layered amphibolite gneiss, hornblende-biotite gneiss and biotite gneiss, contain restite layers and rafts of unit 1 amphibolite in varying degrees of assimilation. Extensive mobilization and injection of granitic material (unit 6a) resulted in migmatization and hybridization of pre-existing rock types. In amphibolite-metagabbro restite, granulite grade pyroxene, hornblende and garnet have been pseudomorphed by M_2 green hornblende + quartz or hornblende-biotite aggregates.

The migmatites are characterized by numerous minor folds with a weak axial planar fabric trending north-northeast in the Split Lake area, and north in the Birthday Rapids and Gull Lake area.

Granite and granodiorite dykes and sills (unit 6a) intrude units 1, 2 and 4 throughout the area. Emplacement appears to have been contemporaneous with partial anatexis and *lit* injection in the hornblende and hornblende biotite gneiss (unit 5). In the Gull Lake area two younger granite plutons (unit 6b) intrude unit 1b and unit 5.

Three ages of mafic (Molson?) dykes (unit 7) were intruded in a northeast-trending swarm after the major Kenoran orogenic events.

Linear tectonic belts (unit 9) containing abundant injections of younger granite phases (unit 8) are attributed to a later, Hudsonian, orogenic cycle. These rocks comprise reworked older rocks (derived from units 1 to 7) which have undergone a period of deformation and retrograde metamorphism. These northeast- trending tectonic belts, comprising foliated heterogeneous leucocratic gneisses, extend through the centre of Split Lake into a more northerly trending belt along the Nelson River between Clark Lake and Birthday Rapids. These gneisses contain rafts, and rare, large enclaves of older units. In enclaves of units 1 to 7, greenschist grade retrogression resulted in the development of felted amphibole, biotite, chlorite, muscovite and epidote, and a relict texture.

Within the Split Lake block (Fig. 2) three series of mafic dykes (unit 7) postdate the youngest Kenoran age granites and display typical late, retrograde, M_3 metamorphic assemblages. Deformation of the mafic dykes is retricted to narrow tectonic belts (unit 9). In the Pikwitonei domain Hubregtse (l980) has clearly demonstrated the post-Kenoran, pre-Hudsonian age of mafic dykes which are part of the Molson swarm (Scoates and Macek, 1978). The similar geological setting of unit 7 dykes and the Molson dykes suggests that they are part of the same dyke swarm. However, Haugh (pers. comm.) observed mafic dykes with chilled margins cutting the mylonites (unit 21), indicating at least one late period of mafic dyke activity postdates the cataclasis of the Hudsonian orogenic cycle.

Granite and pegmatite dykes and sills (unit 8a) and one large granite body (Fox Lake pluton, unit 8b) represent the youngest rocks in the Split Lake block. They were intruded during the Hudsonian orogenic event throughout the northeast Split Lake area. Dykes and sills (unit 8a) vary from massive to weakly foliated within the Hudsonian tectonized migmatites (unit 9).

Cataclasis observed along the Churchill-Superior boundary zone and Split Lake fault (Haugh, 1969) occurs throughout the Split Lake block in parallel northeast and east-trending zones, as well as in a late north-south shear set.

The sequence of geological events documented in the Split Lake block is similar to that recorded in the Pikwitonei domain and the Thompson belt (Weber, 1977; Hubregtse, 1978, 1979). However, the geological features indicate significant differences in physical conditions among these areas. Within the Split Lake block M_1 and M_2 textures are extensively overprinted by the later retrograde M_3 metamorphism. In the Moak Lake segment of the Thompson belt hypersthene is locally preserved in the highly deformed and reworked migmatites (Scoates, pers. comm.) indicating a less pervasive retrograde metamorphic event. Granulite grade mineral assemblages are rarely preserved within the

Table 2: Order of geological events, northeast Split Lake block.

$D_{4\text{-}5}$	— intense repeated cataclasis and mylonitization along the Churchill-Superior boundary — associated northeast, east-west and minor north-south faults within the Superior segment of map area		HUDSONIAN OROGENY
D_3	— formation of "tectonized migmatites" (unit 9) in restricted northeast and northwesterly-trending belts; deformation of mafic dykes (unit 7)	M_3 regional retrogession to upper greenschist	HUDSONIAN OROGENY
	— intrusion of granite and pegmatite dykes and sills and the Fox Lake pluton (unit 8) associated with unit 9		HUDSONIAN OROGENY
	— intrusion of mafic dykes (unit 7) type III in east-west orientation		
	— intrusion of mafic dykes (unit 7) types I and II in a northeast orientation		
	— intrusion of Gull Lake granite (unit 6b) and major metasomatism in western portion of the area		KENORAN OROGENY
	— intrusion of tonalite-granodiorite dykes and sills and associated white pegmatite (unit 6a)		KENORAN OROGENY
D_2	— north to northeast-trending isoclinal folding variably developed in migmatites (unit 5) with a weak axial planar foliation — associated larger-scale folding in unit 1 metagabbro — lineation in unit 4 tonalite	M_2 amphibolite grade metamorphism	KENORAN OROGENY
	— formation of migmatites (unit 5) and derivation of minor plagioclase-pyroxene + garnet mobilizates in unit 1 metagabbros		KENORAN OROGENY
	— intrusion of clotted tonalite (enderbite?) (unit 4) with agmatization and *lit-par-lit* injection of unit 1 metagabbros	M_{1b} hornblende granulite facies metamorphism (orthopyroxene altered to garnet)	KENORAN OROGENY
		M_1 granulite and hornblende granite facies metamorphism may represent two periods — M_{1a}, M_{1b}	KENORAN OROGENY
D_1	— formation of metamorphic layering (S_1) boudinage and rotation of unit 3 dykes	M_{1a} granulite facies metamorphism forms plagioclase + 2 pyroxene mobilizate	KENORAN OROGENY
	— intrusion of mafic-ultramafic dykes (unit 3)		
	— emplacement of anorthosite (unit 2)		
	— formation of amphibolite and gabbros (unit 1) — S_o layering		

Split Lake block, and are extensive only in the Ilford area. However, in contrast to the Thompson belt, the Split Lake block has not been affected by pervasive Hudsonian deformation, and does not exhibit the gradational decrease in intensity of Hudsonian metamorphism and deformation recorded in the Pikwitonei region to the south.

CHURCHILL PROVINCE

North and east of the arcuate Churchill-Superior boundary (Fig. 2) the area is underlain by a suite of high grade regionally metamorphosed Proterozoic metasedimentary gneisses, intruded by granitic and granodioritic bodies (Table 1).

The gneisses and derived migmatites constitute two groups: graphitic metagreywackes which correlate with the Burntwood River Metamorphic Suite, and magnetiferous metagreywacke and meta-arkosic rocks which correlate with the Sickle Metamorphic Suite. In most localities these major lithologic units are separated by a thin, relatively continuous amphibolite unit which forms a useful marker for mapping. These sediment-derived gneisses and migmatites have been traced through sporadic outcrops to metaconglomerate and metagreywacke at Apetowachakamasik Lake and to metagreywacke on Assean Lake. The major lithologic units are further correlated with rocks on Pearson Lake-Rock Lake and Strong Lake and into the Harding-Leftrook Lakes area (Corkery and Lenton, 1980). The metasedimentary gneisses of the Harding-Leftrook Lakes area form the northeastern portion of the Kisseynew metasedimentary gneissic belt (McRitchie, 1974). The tenuous physical correlation is strengthened by the similarities of the sequence of metasedimentary units observed in the Gillam-"Moose Lake" area and the Kisseynew metasedimentary gneiss belt. Thus the terminology introduced by Lenton (1981) of Burntwood River Metamorphic Suite for graphitic metagreywacke gneiss and Sickle Metamorphic Suite for magnetiferous metagreywacke and meta-arkosic rocks of the Kisseynew metasedimentary gneiss belt has been used in this report.

The geological units mapped within the metasedimentary gneiss belt, have diagnostic magnetic signatures (see Aeromagnetic Maps 2483/G, 2475G, 2476/G and 2491/G). The Burntwood River Suite underlies an area of broad lows ranging from 2200 to 2500 gammas. Sickle Suite rocks produce a complex series of well defined highs and lows within the 2500 and 4100 gamma range. The consistency of this correlation can be used to delineate the contacts of the major suites through areas of sparse outcrop.

Reliable top indicators were not observed in the map area; however, Elphick (1970) interpreted the rocks included in the Burntwood River Metamorphic Suite as forming the base of the sequence. This is in accord with the stratigraphy reported in numerous studies of the Burntwood River Metamorphic Suite, and Sickle Metamorphic Suite associations to the west in the Kisseynew and Lynn Lake areas (Barry and Gait, 1966; Gilbert et.al., 1980). In this report metasedimentary rocks of the Sickle and Burntwood River Metamorphic Suites, units 10 through 16, are in stratigraphic order; however, subunits within each group may not represent a stratigraphic sequence.

Burntwood River Metamorphic Suite rocks occur as a west to northwest-trending belt paralleling the Churchill-Superior boundary. In the Gull Rapids area, where the boundary zone is exposed, the metasediments have undergone cataclasis and are truncated by a major mylonite zone.

Greywacke-derived paragneisses are highly folded and contain extensive white anatectic granodiorite and granite veins which constitute up to 50 per cent of the outcrop. The grey gneisses contain garnet, biotite, quartz, plagioclase, cordierite and sillimanite, with accessory graphite. Sporadic discontinuous amphibolite layers and calc-silicate lenses occur throughout the sequence.

In the Stephens Lake area the highly irregular northwest-trending contact between the Burntwood River, and Sickle Metamorphic Suites outlines a complex basin and dome interference pattern resulting from two periods of folding.

Sickle Metamorphic Suite rocks formerly outcropped extensively within fold structures along the Nelson River and in less complete sections in the "Moose Lake" area. These gneisses are well layered, buff to grey-brown on weathered surfaces, and contain variable amounts of pink granitic mobilizate and injected *lits*. Their mineralogy is dominantly microcline, plagioclase, quartz and accessory magnetite. Individual units can be discriminated by variations in the mafic minerals; biotite, hornblende-biotite, and biotite-sillimanite-cordierite assemblages typify the major categories.

The general sequence of metasedimentary units observed in the stretch of the Nelson River from the island south of Ferris Bay downstream to Kettle Rapids, is shown in composite stratigraphic columns in Figure 4. Within this area the Burntwood River Suite consists of pelitic gneiss (10d), overlain by a thick sequence of interlayered psammitic and pelitic gneiss (10c), the upper portion of which is a sillimanite *faserkiesel*-rich pelitic gneiss. The top of the Burntwood River Metamorphic Suite (units 10 to 12) comprises well layered to laminated psammitic metasediments (10a, 12) interlayered with arkosic metasediments (10b). An amphibolite occurs within the psammitic metasediments near the contact with the overlying Sickle Suite rocks. This lithological sequence is continuous around fold structures and is interpreted to represent a relict primary stratigraphy. Compositionally, these gneisses correspond to typical geosynclinal greywacke.

The overlying paragneisses of the Sickle Metamorphic Suite (units 13 to 16) represent a considerably more heterogeneous sequence of metasedimentary rocks which are interpreted as metamorphosed equivalents of shallow water deposits, as indicated by the occurrence of arkoses and polymictic conglomerates. Within the major map units rapid changes in composition, across and along strike, probably indicate facies changes in the original sediments. However, major lithologic map units are continuous along strike throughout the large structures in the Nelson River channel. Variations observed in the total thickness of the Sickle Metamorphic Suite, (related to major structures), are interpreted as thinning on limbs and thickening in the hinges of large-scale early folds. Subsequent cross folding has further enhanced and complicated these relationships. The discontinuous nature of the marker amphibolite is probably related to thinning and boudinage on the limbs of major folds.

Sickle Metamorphic Suite paragneisses are well exposed in the synformal structure at Kettle Rapids. Here the succession comprises basal layered hornblende-bearing psammitic metagreywackes (unit 13), passing upward through biotite-bearing psammitic gneisses (unit 14) into overlying sillimanite-bearing meta-arkoses (unit 15). This sequence is consistent throughout the Kettle Rapids-"Moose Lake" area. The highest unit observed in the metasedimentary sequence is restricted in occurrence and consists of a magnetite-rich, garnet-cordierite-sillimanite pelitic gneiss (unit 16).

West of Stephens Lake and north of the Churchill-Superior boundary, isolated outcrops of amphibolite and hornblende-bearing gneiss (unit 12) indicate some westward continuity of the paragneiss belt toward the Apetowachakamasik Lake area. On Apetowachakamasik Lake an extensive belt of polymictic conglomerate and psammitic metasedimentary rocks has been preserved. These can be traced to the Assean Lake area where the Burntwood River Metamorphic Suite-Sickle Metamorphic Suite association has been documented (Corkery and Lenton, 1980).

East of Stephens Lake, and to the north of the metasedimentary gneisses, extensive granitic bodies have been intruded. A large granodiorite pluton (unit 18) underlies the Long Spruce Rapids area and extends downstream to the limit of Precambrian outcrop. Near Ferris Bay the paragneisses are extensively mobilized and intruded by granite. Quinn and Currie (1961) reported outcrops of "biotite-hornblende granite gneiss" and "massive granite, granodiorite, (and) syenite" along Limestone River. Immediately north of "Moose Lake" megacrystic granites are present on the Limestone River. North of the conglomerate-psammite metasedimentary rocks on Apetowachakamasik Lake a late biotite-granite pluton was mapped by Corkery (1976, 1977).

Haugh and Elphick (1968) reported the "injection of discordant dykes of pink pegmatitic granite, commonly trending southwest, parallel

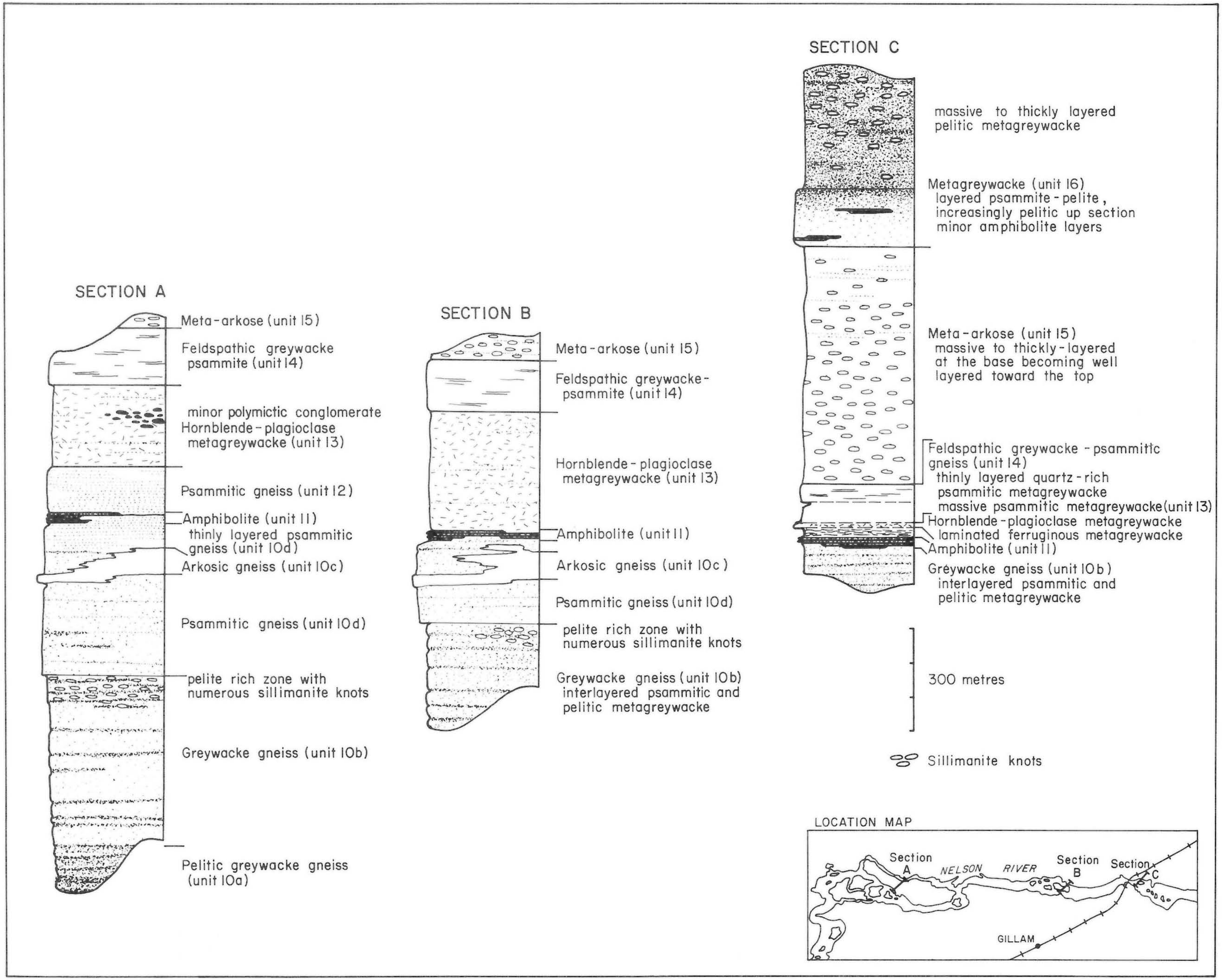


FIGURE 4: Schematic sections of the supracrustal rocks in the Gillam area. Section locations given on geological maps 82-1-5 (in pocket).

to the axial planes of late stage Z-folds throughout the area". They described these as a "later phase, postdating the main folding and metamorphism of the belt".

A single, slightly discordant, northeast-trending mafic dyke intersects all units in the Kettle Rapids area.

PALEOZOIC ROCKS

East of the Long Spruce Rapids generating station, outcrops of Precambrian granodiorite (unit 18) are restricted to reefs and low shoreline exposures within the Nelson River channel. These rocks are unconformably overlain by Ordovician limestones (unit 22) of the Hudson Bay Lowlands which are exposed sporadically in the lower portion of the steep river banks as far as the eastern margin of the map area. The limestones are overlain by a thick succession of Quaternary sediments.

The Ordovician rocks comprise the basal members of the Portage Chute Formation of the Bad Cache Rapids Group. Cumming (1975) has described members 1 and 2 of the Portage Chute Formation at the confluence of Limestone and Churchill Rivers; member 2 is exposed eastward from Long Spruce Rapids. A brief description of these occurrences, from Cumming (1975), follows; GSC stations 189CE to 191CE are shown on map 82-1-5 (in pocket).

Station 189CE: on the east bank of the Nelson River at the uppermost of the Upper Limestone Rapids (98°08'W), 4.3 miles east of Bird railroad station.

Unit	Portage Chute Formation, member 2	Thickness (feet)
1	Limestone, bioclastic, light grey, beds averaging 4 inches thick, containing black chert nodules with white rims, averaging 3 to 4 inches in diameter, but up to 7 inches in maximum diameter. Sparse fragments of *Grewingkia* sp. (GSC loc. 81800).	4.0

Station 190CE: on the southeast bank of Nelson River at 94°06'W, 4.9 miles east of Bird railway station.

Unit	Portage Chute Formation, member 2	Thickness (feet)
1	Limestone, light grey, bioclastic, dominant vertical joint system at 207° parallels river bank. Megafossils include (GSC. loc. 81811): *Receptaculites* sp. *Maclurites* sp. *Hormotoma* sp. *Endoceras* sp.	18.0

Station 191CE: on the north bank of Nelson River at 94°06'W; 56°32'N.

Unit	Portage Chute Formation, member 2	Thickness (feet)
4	Limestone, light grey, mottled, irregular bedding with few pyrite nodules. Mega-fossils include *Orthoceras* sp. up to 4 feet in length, *Receptaculites* sp. and *Halysites* sp. Microfossils include (GSC loc. 80328): *Panderodus* sp.	3.0
3	Limestone, light grey, mottled, pyrite nodules, contains wisps of sandy limestone.	4.0

Unit	Portage Chute Formation, member 1	Thickness (feet)
	Sandstone, light grey, fine grained matrix is greenish grey clay; contains occasional angular black chert fragments up to 1/4 inch in diameter; interbeds of white to grey clay contain smoky quartz clasts up to 1.5 inches in diameter.	4.0

FIGURE 5: Bank of the Nelson River east of Kettle Rapids. Outcrops of granodiorite form the rapids in the river, overlain by a thin section of Ordovician limestone with a thick Quaternary section forming the major portion of the river banks. (Photo courtesy of E. Nielsen).

PLEISTOCENE AND RECENT

The project area is predominantly a low relief landscape within the zone of discontinuous permafrost, and numerous small lakes separated by extensive peat bog and boreal forest cover the region. Beneath the organic cover surficial deposits indicate the previous existence of both glacial lakes and marine waters.

Klassen and Netterville (1980) indicate glacial lakes formed over extensive peat areas in front of the last continental glaciers as they retreated northward about 9,000 to 7,000 years ago. This was followed by a marine inundation which was limited to the extreme eastern portion of the present map area. These authors report that regionally "the area is characterized either by extensive blankets of thick varved clay and silt or by discontinuous patches of fine lacustrine or marine sediments between coarse lag deposits on hills or bare ridges".

Discontinuous esker deposits and outwash deposits with a west-northwest trend occur between Stephens Lake and Gull Lake. In the Gillam area extensive kame deposits have provided sand and gravel for both Manitoba Hydro and the Gillam Local Government District. The northeast shore of Stephens Lake is marked by high banks of silty or sandy deposits, reported by Klassen and Netterville (1980) as ground moraine.

East of Kettle Rapids high river banks with excellent Pleistocene sections (Fig. 5) have been described by Nielsen (1980) as containing the "most complete late Quaternary stratigraphic section uncovered in Manitoba to date". He described a sequence which includes deposits related to Illinoian Glaciation, Sangamonian Interglacial, Wisconsinan Glaciation, Lake Agassiz and the Tyrrell Sea.

SUPERIOR PROVINCE

AMPHIBOLITE AND METAGABBRO (1)

This unit comprises an assemblage of medium grained, dark grey-green to light grey-buff amphibolites, metagabbros and derived mafic gneisses. Three subunits are recognized: melanocratic hornblende + pyroxene amphibolite (1a), garnetiferous amphibolite (1b), and mesocratic to leucocratic quartz-bearing amphibolite (1c). In general the rocks exhibit well defined metamorphic layering and subunits are interlayered in many outcrops. These gneisses show varying degrees of retrogressive alteration and injection by granitic dykes.

Amphibolite occurs as mappable units on the Nelson River about 2 km east of Birthday Rapids, within the Split Lake Indian Reserve (IR 171) and in the narrows between Clark Lake and Split Lake. These areas of amphibolite represent large structural blocks which were not appreciably affected by late Kenoran and Hudsonian deformation and migmatization. In the area of the anorthosite on the Split Lake Indian Reserve (IR 171) the amphibolites form layers within the anorthositic gabbro (unit 2b); also, an extensive area of layered amphibolite (units 1a, 1b, 1c) on the southeast margin of the anorthosite is interpreted as an associated metagabbro. Elsewhere in the Split Lake block direct evidence to indicate an intrusive gabbro relationship is lacking; therefore, this unit is referred to as amphibolite.

Compositional layering ranges from 2 to 5 cm. The most striking layering consists of abrupt changes in the ratio of dark to light minerals, appearing on the weathered surface as multiple grey-toned bands. A more subtle distinction is produced by variation in the amphibole content of adjacent layers. Dominance of hornblende produces grey tones whereas actinolite imparts a green cast to individual layers. A third variation in layering is exemplified by the abundance, presence or absence of garnet within individual layers. The presence of garnet is used to define subunit 1b.

In some localities larger scale layering, ranging from 20 cm to 1 m, is superimposed upon the small-scale layering. In Figure 6 a 50 cm thick mesocratic, banded, garnet-poor layer is flanked by layers which are more mafic and garnet-rich.

The amphibolites typically display a fine- to medium-grained granoblastic polygonal texture comprising a framework of mafic minerals and interstitial plagioclase. This early texture was developed during granulite grade metamorphism. However, subsequent M_2 and M_3 metamorphic events have commonly overprinted the granoblastic textures, producing three distinctive fabrics and associated mineral assemblages.

Where M_1 granulite grade mineral assemblages are preserved, the amphibolites are dark grey to black and weather grey-brown. Mineralogically they comprise a mosaic of clinopyroxene, rare orthopyroxene, brown hornblende and plagioclase (An_{45}-An_{52}). These rocks may contain up to 10 per cent coarse grained plagioclase-pyroxene-garnet-hornblende mobilizate in the form of discontinuous layers or irregular pods. Porphyroblastic garnets up to 1 cm are common in subunit 1b.

In many localities the original granoblastic texture of the amphibolites has been overprinted during the M_2 amphibolite grade metamorphism. The rocks are dark green-grey and weather grey to slightly greenish grey. Original pyroxene, brown hornblende and garnet crystals have been pseudomorphed by green hornblende or hornblende and biotite. Hornblende forms fine-grained multi-crystal pseudomorphs of the original mafics. Plagioclase commonly has albitized rims (An_{25}-An_{35}) and cloudy saussuritized cores.

Greenschist grade metamorphism (M_3) has variably overprinted granulite and amphibolite grade textures. Resulting relict granoblastic textures are less distinct but generally still recognizable. These rocks are distinctly green. Earlier mafics are altered to pale green actinolite-chlorite cores with epidote-chlorite or epidote-quartz rims. Plagioclase is highly altered, has indistinct twinning and contains abundant epidote crystals.

Mineralogy and textures associated with the three metamorphic events are relatively consistent for all rock types in the northeast Split Lake block. More detailed information is provided in the section on metamorphism.

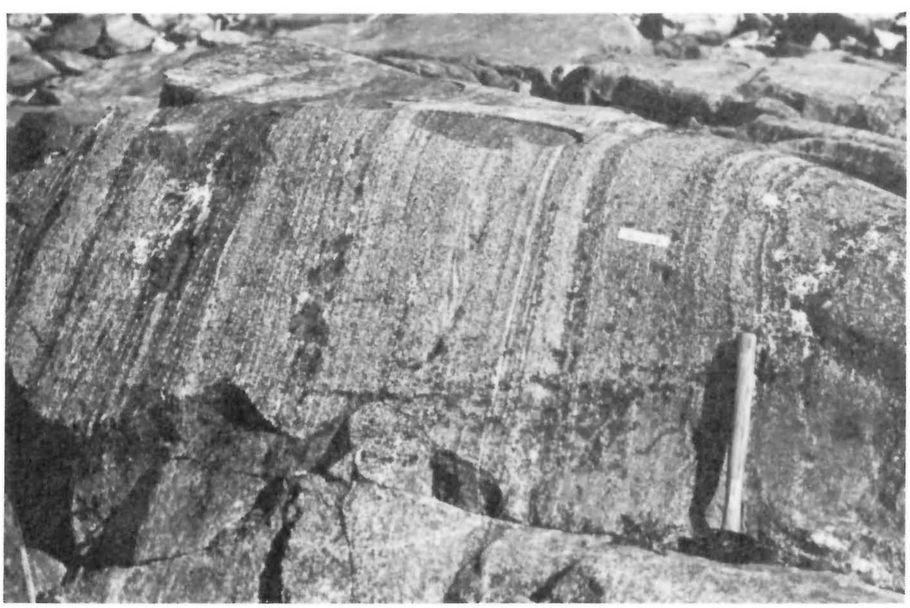


FIGURE 6: Metagabbro (unit 1) with plagioclase, clinopyroxene, garnet mobilizate pods parallel to S_1 layering.

ANORTHOSITE COMPLEX (2)

An anorthosite complex forms a north-northeast-trending body approximately 3 by 10 km which outcrops along the northwest shore of Split Lake within Indian Reserve 171. The main body is a dome with an anorthosite core surrounded by layered gabbroic anorthosite and anorthositic gabbro. Gabbro, and ultramafic inclusions and layers, were also observed in the border facies. In the southwestern portion of the complex, clotted tonalite to granodiorite dykes and apophyses of unit 4 cut the anorthositic rocks. Locally the tonalite becomes abundant enough to produce agmatites of the anorthosite. Diabase dykes and irregular granitic dykes (unit 8a) form late intrusions.

The south end of the complex is truncated by a northeast-trending migmatite belt (unit 9) containing anorthosite inclusions. The inclusions range in size from a few centimetres to tens of metres and decrease in abundance to the northeast. Two several hundred metre exposures of anorthosite were mapped in the Clark Lake area.

Most rocks in the complex were recrystallized during regional metamorphic events. Anorthosite in the core of the complex is massive to weakly foliated (Fig. 7). Non-foliated phases contain well preserved pseudomorphs of original plagioclase megacrysts. As the margins are approached a weak foliation and vague lamination becomes apparent and this grades into layered gabbroic anorthosite and anorthositic gabbro (Fig. 8). This layering is parallel to the margin of the complex. At the contact with the surrounding gneiss, dips are approximately 90°. Towards the massive core of anorthosite the dip becomes increasingly shallow (to about 45°) and within the anorthosite the foliation is very shallow indicating a domal configuration for the complex.

The anorthositic rocks contain plagioclase, amphibole, garnet, chlorite, epidote and rare biotite, calcite and paragonite. They are highly recrystallized and only a few pseudomorphs of the original plagioclase phenocrysts, generally about l by 4 cm, are preserved. Numerous ragged crystals of plagioclase with An_{85-95} comprise the main portion of the rock and may represent original igneous minerals. Twinning is poorly

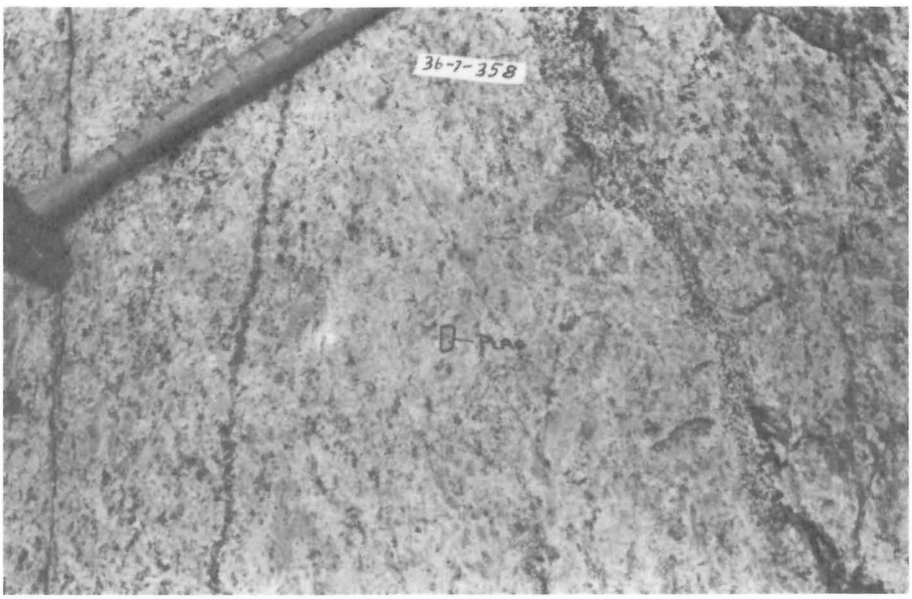


FIGURE 7: Massive anorthosite (unit 2a) intruded by deeply weathered mottled grey tonalite (unit 4).

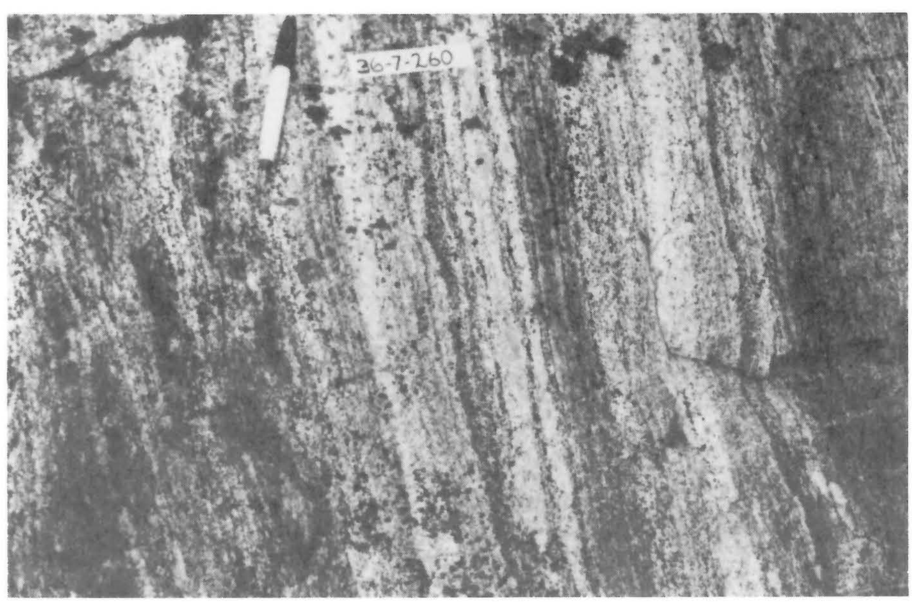


FIGURE 8: Layered anorthositic gabbro (unit 2b).

defined, these crystals are fogged due to alteration to sericite, and included needles of amphibole are present. The plagioclase also shows numerous deformation features, the most common being bent twin lamellae and deformation-induced twinning (Fig. 9). Late plagioclase of An_{40} forms small rounded crystals generally associated with fractures.

Amphibole exists in two forms: pseudomorphs after pyroxene, and as small disc-shaped radiating bundles in the metamorphic fabric. Pseudomorphs after clinopyroxene comprise felted masses of pale green amphibole with minor biotite and numerous quartz inclusions.

Epidote grains up to 2 mm are a common alteration product throughout the anorthosite as well as white mica (paragonite), chlorite and fine green amphibole.

Chemical analyses of the anorthosite and gabbroic anorthosite are presented in Table 3.

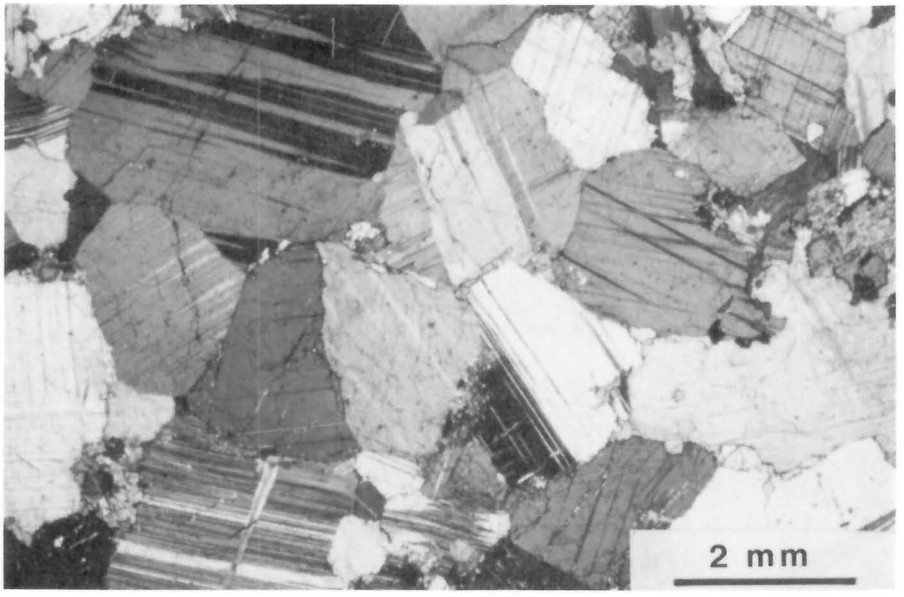
MAFIC TO ULTRAMAFIC DYKES (3)

Field evidence suggests that numerous mafic and altered ultramafic bodies represent an early dyke system. Hornblendite pods with highly irregular intrusive contacts (Fig. 10) were observed in several outcrops of unit 1 amphibolite. Outcrops of younger migmatites and intrusions contain altered mafic and ultramafic inclusions.

En echelon ultramafic pods, in an outcrop of unit 5 migmatites at the entrance to Clark Lake, form a discontinuous chain at a high angle to foliation and layering.

Mafic inclusions in areas of M_2 amphibolite grade metamorphism are almost entirely composed of hornblende. In areas affected by M_3 retrograde greenschist metamorphism they are extensively altered to actinolite containing fine grained magnetite.

FIGURE 9: *Photomicrograph of massive anorthosite with deformation-induced twinning in the plagioclase.*



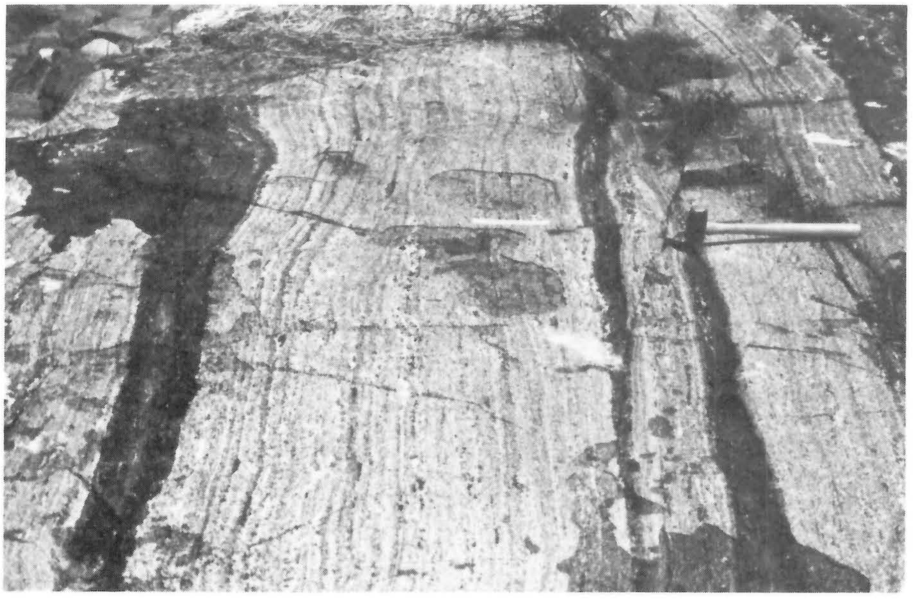


FIGURE 10: *Hornblendite dyke (unit 3) intruding layered metagabbro (unit 1a).*

Table 3: Chemical analyses of anorthosites (unit 2) of the Split Lake block.

Sample Number	36-7-401-1	36-7-368-2	36-7-405-1
	Oxide wt.%	Oxide wt.%	Oxide wt.%
SiO_2	49.65	47.15	45.75
Al_2O_3	29.60	30.00	25.70
Fe_2O_3	1.10	0.75	1.91
FeO	0.20	1.48	2.56
CaO	14.21	14.64	15.61
MgO	0.39	1.15	4.30
Na_2O	3.25	2.06	1.70
K_2O	0.41	1.08	0.39
TiO_2	0.06	0.14	0.20
P_2O_5	0.01	0.01	0.02
MnO	0.02	0.03	0.09
H_2O	0.72	1.44	1.34
S		TRACE	
CO_2	0.02	0.03	0.12
C (graphite)	0.02	0.02	
Other	0.08	0.06	0.08
TOTAL	99.74	100.04	99.77
Total Fe as Fe_2O_3	1.32	2.39	4.75
	ppm	ppm	ppm
Cu	10	8	7
Ni	6	4	63
Pb	16	<3	<3
Zn	14	37	48
Cr	14	16	258
Sr	330	215	150
Ba	340	280	100

36-7-401-1 Massive anorthosite with a few gabbroic layers.
36-7-368-2 Massive anorthosite.
36-7-405-1 Anorthosite layer from layered anorthositic gabbro zone.

Inclusions of altered ultramafic rocks comprise a more complex mineral assemblage, the zonation of which indicates chemical reaction between the inclusion and the surrounding rock during metamorphism. The core of these inclusions consists of pale green sieved actinolite interpreted as altered clinopyroxene and orthopyroxene. This is enclosed within a talc-chlorite layer, an intermediate talc-amphibole layer, and a biotite-rich outer rim. These inclusions are invariably highly rounded and commonly equidimensional.

CLOTTED TONALITE (4)

This unit comprises several lens-shaped intrusive bodies described by Haugh (1969) as clotted granodiorite (unit B3). The mineralogy indicates predominantly tonalitic composition extending to quartz gabbro (Streckeisen, 1976). This unit is widely distributed throughout the Superior Province portion of the map area as the injected phase in Kenoran gneisses. It also forms a series of lens-shaped intrusive bodies ranging from about 100 m to 8 km long. These lenses are generally parallel to northeast structural trends of migmatites in the Split Lake portion of the area but swing into the dominant north-south direction observed from Clark Lake to Gull Lake.

Tonalite (unit 4) intrudes amphibolite and associated gneisses of unit 1. Agmatites and schollen-rich zones are common at the margins of these bodies. Evenly distributed mafic to ultramafic inclusions comprise 10 to 25 per cent of the exposures (Fig. 11). These inclusions show variation in composition and texture similar to the amphibolite from which they are derived. Alteration rims occur around the more mafic inclusions. Various degrees of assimilation and rounding are apparent in less mafic blocks. Gneissic layering within individual blocks is generally parallel to the long dimension; however, it is not uncommon to find inclusions with layers at a high angle to the long dimension of the oriented blocks.

Mafic clots, which average 0.5 cm in diameter and constitute 25 to 35 per cent of the rock, are evenly distributed within a plagioclase-quartz matrix. The clots have a tendency to weather more deeply giving a pitted appearance to outcrops. Mineralogically the mafic clots consist of aggregates of actinolite, quartz, biotite and chlorite and represent

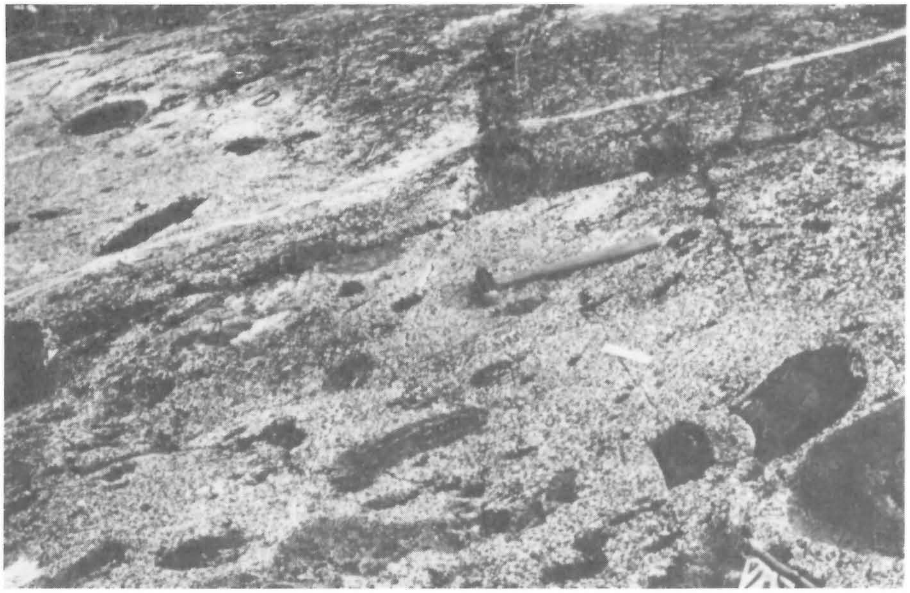


FIGURE 11: *Clotted tonalite (unit 4) with inclusions of metagabbro (unit 1).*

FIGURE 12: *Photomicrograph (plain light) of pseudomorphs of hornblende and pyroxene from a mafic clot in clotted tonalite (unit 4).*

pseudomorphed hornblende or pyroxene. In Figure 12 remnants of brown hornblende, formed during the M_{1b} granulite metamorphism, are surrounded by fine, tabular, oriented actinolite grains and an outer rim of biotite and chlorite. Magnetite and pyrrhotite, commonly associated with the mafic clots, are typically rimmed by radiating biotite crystals. The matrix consists chiefly of plagioclase which is variably saussuritized. In highly altered specimens euhedral epidote crystals are scattered throughout the plagioclase. Calcite occurs near some boundaries with mafic clots. Equant grains of light grey to blue opalescent quartz constitute 5 to 25 per cent of the rock. Sporadic zones of late potassium metasomatism contain microcline-quartz myrmekite in the plagioclase and microcline along fractures.

Haugh (1969) noted that "a weak foliation generally present in this unit, is defined by a preferred orientation of the slightly inequidimensional clots ... This foliation is believed to be a primary foliation, resulting from flow of the material during emplacement, possibly a partially recrystallized 'mush'. In some places the rocks are almost massive, with both clots and inclusions randomly oriented."

HORNBLENDE AND HORNBLENDE-BIOTITE GNEISS (5)

This unit encompasses a diverse suite of medium grained, massive to slightly foliated migmatites derived chiefly from unit 1 amphibolite. It has been distinguished from unit 1 on the basis of having: a) greater than 10 per cent mobilizate, b) a tonalite to granodiorite injection phase, and c) consistent M_2 amphibolite facies mineral assemblages.

Commonly, unit 5 contains discontinuous melanocratic to mesocratic restite layers 1 to 5 centimetres thick. Up to 20 per cent mobilizate occurs as subparallel layers ranging in thickness from a few centimetres up to 10 cm. The amount of mobilizate is dependent to some extent upon the composition of the original rock types, the leuco-

FIGURE 13: Isoclinally folded mesocratic hornblende gneiss (unit 5).

amphibolite (unit 1c) commonly being the most mobilized. *Lit-par-lit* injected granodiorite typically forms the dominant neosome, ranging from a few per cent to 75 per cent. A broad range of structures is observed in the migmatites (Fig. 13) as the unit grades, with increasing mobilizate and granodiorite injection, from amphibolite to granitoid migmatite.

The migmatites, formed during the M_2 event, consist of variable proportions of plagioclase, green hornblende, quartz and biotite with accessory sphene and apatite and minor magnetite, pyrite and pyrrhotite. In zones least influenced by the Hudsonian greenschist metamorphism (M_3), the restite retains relict granoblastic texture, with remnants of brown hornblende, plagioclase and rare clinopyroxene, the latter in part replaced by pseudomorphs of aggregated green hornblende. In these zones M_{1b} garnet is common both in restite and mobilizate layers.

The Hudsonian metamorphic event (M_3) produced a distinctive mineral assemblage of variable extent. Most specimens display some (M_3) alteration. Pale green pleochroic amphibole is the dominant mafic mineral. Straw-yellow to pale brown oriented biotite, chlorite, muscovite and epidote are also common in rocks affected by this metamorphic event.

GRANITE-GRANODIORITE (6a)

The earliest felsic intrusive rocks are represented by irregular dykes and sills of light grey to pink-grey granite-granodiorite and younger white pegmatite which cut the amphibolite-metagabbro (unit 1), anorthosite and anorthositic gabbro (unit 2). Emplacement appears to have been contemporaneous with partial anatexis and *lit* injection in the hornblende and hornblende-biotite gneiss (unit 5). Granite-granodiorite and pegmatite on the northwest shore of Split Lake are cut by mafic dykes of unit 7.

Granite-granodiorite dykes and sills, ranging in width from a few centimetres to 4 metres, are homogeneous and generally massive to slightly foliated. Variable proportions of plagioclase and potassium feldspar constitute 70 to 80 per cent of the rock. Plagioclase is altered with partially sericitized cores. Albitized rims are common especially adjacent to microcline. Quartz makes up 20 to 25 per cent of the rocks, and dark green-grey biotite, muscovite, garnet, sphene and opaques are accessories. Biotite and garnet commonly show some degree of replacement by chlorite with associated epidote aggregates. These alteration mineral assemblages are attributed to M_3 Hudsonian metamorphism.

Southeast of the Gull Rapids cataclastic zone diamond drill core samples of the dykes from three locations give an isochron age of 2600 $\pm$ 75 m.y. and an initial ratio of 0.715 $\pm$ 0.002 (Clark, 1974). Clark states that "the high initial ratio is believed to indicate that this granitic phase is a mobilizate of a lower temperature phase caused by fractional melting of older upper crustal rocks". Field evidence indicates that this period of mobilization and granite injection is synchronous with the formation of hornblende and hornblende-biotite gneiss (unit 5) during a Kenoran metamorphic event.

GULL LAKE GRANITE (6b)

A large granite intrusion underlies the Gull Lake area and a second, smaller body occurs approximately 3 km west on the Nelson River. Hubregtse (1975) in mapping the adjacent map sheets to the south (54D-3, 4) reported increasingly abundant granites east of 95°47'. Field relationships suggest that these rocks represent a zone of granitization of pre-existing migmatites. The granite is intruded by west-trending mafic dykes (unit 7 type 3). Northeast-trending mafic dykes (unit 7 type 1) are observed within the larger migmatite blocks but not within the granite.

The Gull Lake granite (6b) differs from earlier (unit 6a) and later (unit 8) granites in composition and appearance. It contains 50 to 75 per cent large, almost totally assimilated, rafts of earlier migmatites.

Relatively fine-grained hypidiomorphic granular textures are typical. Plagioclase (up to 50 per cent) is generally subhedral; however, the western portion of the body is typified by pervasive braid antiperthite. Anhedral microcline (20 to 25 per cent) increases to 35-40 per cent in antiperthite-rich zones. Quartz and 5 per cent red-brown biotite are also common.

Within the nebulitic rafts, clots of chlorite, actinolite and, in rare instances, pyroxene were noted. The mafic clots display the same textural features as mafic minerals in the older migmatites (unit 5) (Fig. 14).

Two major north-trending zones of mafic gneiss (units 1 and 5) are preserved in the granite. Granite near the contact is nonfoliated but well layered. More leucocratic portions of the gneisses form layered granite gneiss.

Three granitic phases are observed as numerous dykes and irregular bodies caught up within the cataclastic zones at Gull Rapids. However, not enough data are available to distinguish the distribution or abundance of each phase.

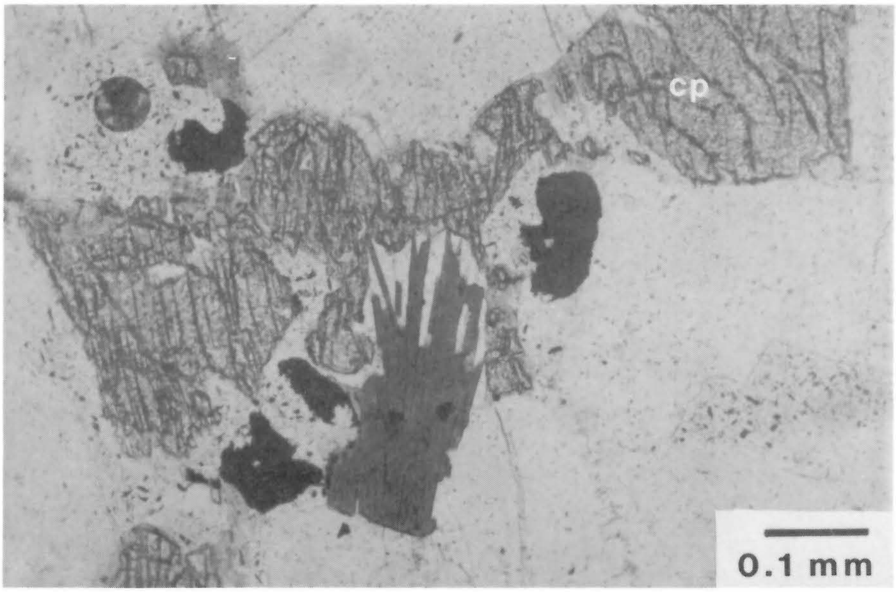


FIGURE 14: Photomicrograph (plain light) of relict clinopyroxene (cp) from nebulitic zone in the Gull Lake granite (unit 6b).

MAFIC DYKES (7)

Mafic dykes ranging in thickness from a few centimetres to 20 metres are abundant throughout the Superior Province rocks. Field relationships indicate three periods of mafic dyke intrusion during the period between the Kenoran and Hudsonian orogenies. The dykes intrude all units in the area with the exception of unit 8 granite and unit 9 migmatite. All dykes have been metamorphosed (probably during the Hudsonian orogeny) and are composed chiefly of fine-grained felted green amphiboles and altered plagioclase. Within Kenoran migmatites the dykes are undeformed but show alteration of the primary igneous mineralogy. Migmatites formed during the Hudsonian event contain mafic dykes which show various degrees of deformation.

The mafic dykes have been subdivided on the basis of cross-cutting relationships, orientation, and, to some extent, compositional differences. The dykes appear to fall into three categories:

(1) early mafic dykes with a relict salt-and-pepper texture; generally northeast-trending; cut by granite dykes (unit 8);
(2) porphyritic, commonly compositionally layered, gabbroic dykes which cross-cut type (1) dykes, but are themselves cut by granitic dykes of unit 8; and
(3) later east-trending dykes which intrude the Gull Lake granite (unit 6b).

The trends of the major dykes in the Superior Province are shown in Figure 15. The area has been divided into four subareas: 1 and 3 represent areas of Kenoran migmatites generally not overprinted by the Hudsonian orogeny, subarea 2 has been significantly reworked during the Hudsonian event, and subarea 4 is extensively intruded by granitic rocks and contains areas of reworked Kenoran migmatites.

Within subarea 1 undeformed dykes (1) are steeply dipping with a consistent northeast strike (Figs. 15 and 16a). A similar slightly more easterly trend is observed in type (1) dykes in subarea 3 (Figs. 15 and 16c).

The type (3) dykes which cross-cut and have chilled margins against type (1) dykes show a consistent easterly trend (Figs. 15 and 16d) where they are undeformed. No preferred orientation can be determined for the small number of type (2) dykes observed (Fig. 16d).

The younger age of type (3) dykes relative to type (2) is inferred from a single cross-cutting relationship in subarea 1.

The majority of dykes in subarea 2 display deformation features ranging from foliated margins, with curved or undulating contacts, to folded and segmented layers within Hudsonian migmatites. In stereographic plots (Fig. 16b) deformed dykes exhibit a wide range in orientation whereas undeformed dykes from less tectonized zones within subarea 2 display a steeply dipping northeast or easterly trend typical for subareas 1 and 3.

Mafic dykes within the Split Lake block are fine- to medium-grained and greenish black. On the weathered surface an equigranular speckled green and white medium grained ophitic texture is common.

The M_3 metamorphic event which produced the regionally persistent assemblage of green amphiboles, epidote, chlorite and biotite has, to some degree, affected all observed mafic dykes. Green amphibole comprises 45 to 70 per cent of the rock with altered plagioclase forming most of the remainder. A more detailed description of the petrology and textures of the mafic dykes is found in Haugh (1969, p. 31, 32).

LATE GRANITIC INTRUSIVE ROCKS (8)

Granitic dykes and sills and one large granite body represent the youngest rocks in the Split Lake Block. Three ages of intrusion have been distinguished in these rocks based upon cross-cutting relationships. All are contemporaneous with, or younger than, the migmatites (unit 9) and are therefore interpreted as Hudsonian. The rocks locally exhibit a cataclastic foliation and contain cataclastic zones associated with the major fault zones in the Assean Lake and Split Lake areas.

A large granite intrusion is centered on Fox Lake and crops out along the north shore of Split Lake in the bay north of the Split Lake settlement. An east- to southeast-trending branch of the Assean Lake fault forms the southern termination of the body. However, a small segment of granite south of the fault and west of the settlement exhibits good intrusive relationships indicating that the granite is younger than the migmatites. Further east the contact is represented by a zone of agmatite with blocks of earlier gneisses and migmatites, up to several hundred metres long, stoped into the granite. The northern margin of the Fox Lake granite becomes increasingly cataclastic towards the major mylonite zone on Little Assean Lake. Clear evidence exists to indicate that significant portions of the leucocratic mylonites on the south shore of Little Assean Lake consist of mylonitized Fox Lake granite.

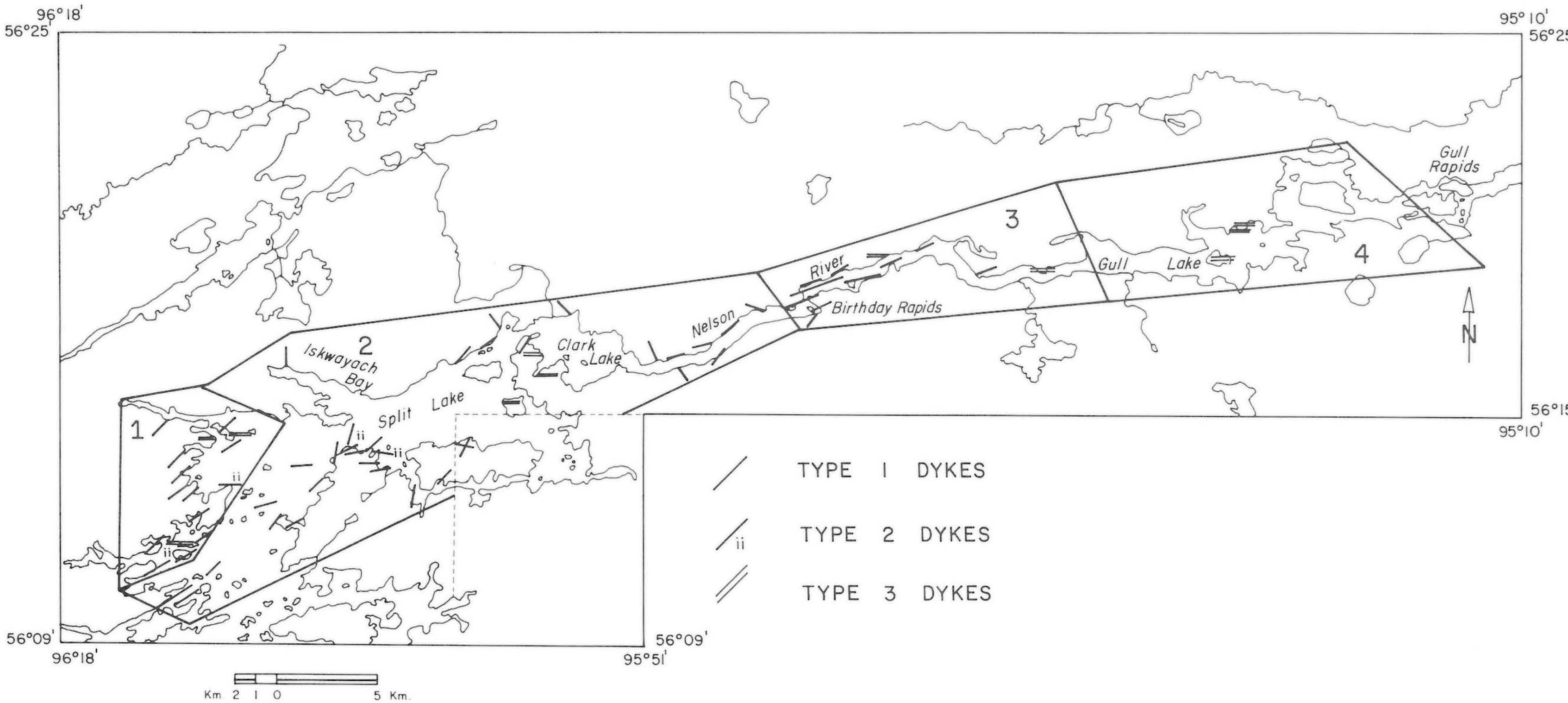


FIGURE 15: Distribution and orientation of diabase dykes in the northeast Split Lake block.

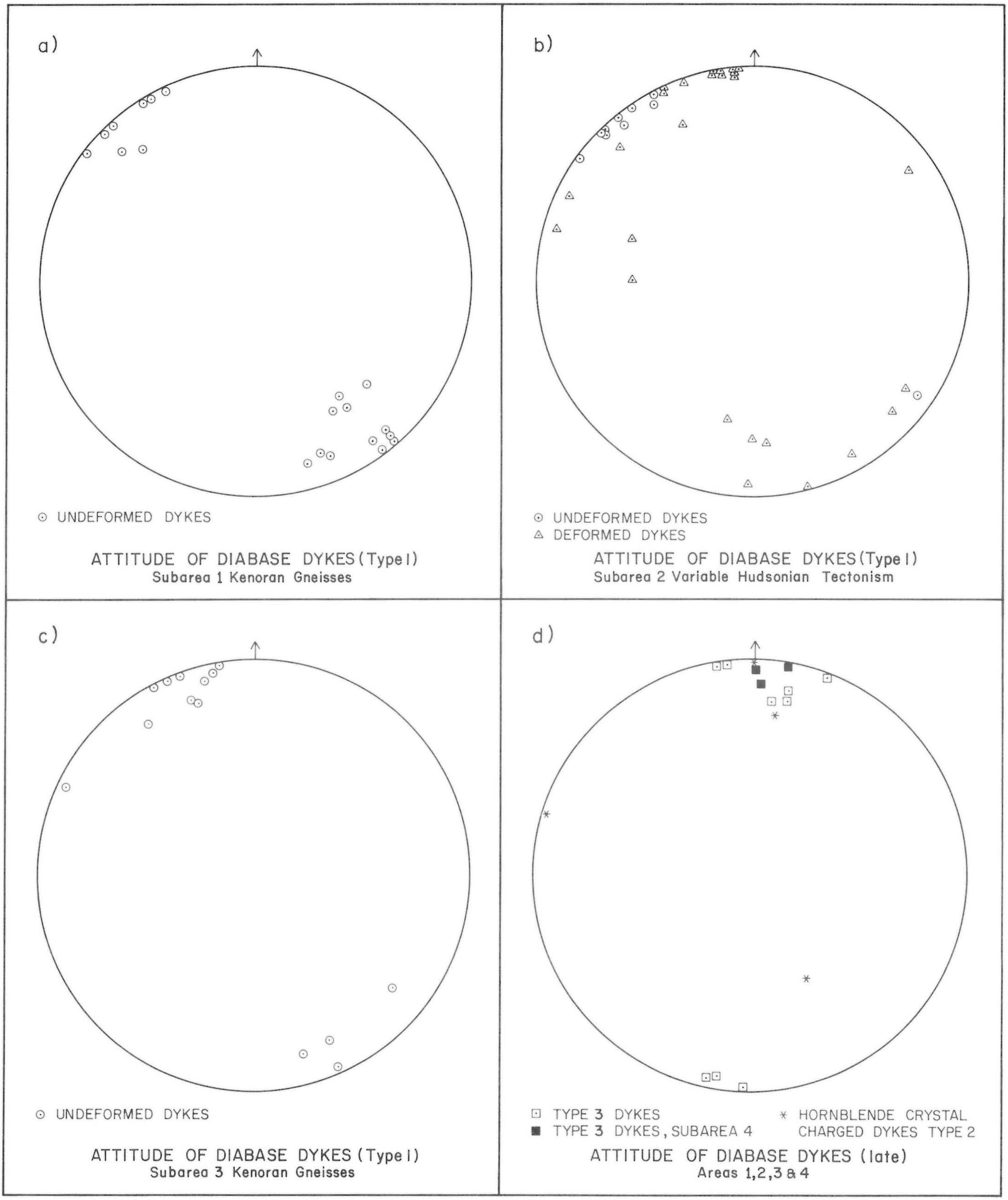


FIGURE 16: Equal angle stereograms of poles of diabase dykes in the northeastern Split Lake block.

Undeformed portions of the Fox Lake pluton are massive to weakly foliated leucocratic pink to pink-grey biotite granite. Along the southeastern intrusive contact a younger light grey granite phase is evident.

Dykes of fine grained granite, which are extremely abundant throughout the Split Lake area, appear to be comagmatic with the Fox Lake granite. These pink and grey granite dykes display the same age relationships as observed in the pluton. The dykes pinch and swell in an irregular fashion and form an irregular stockwork on outcrop surfaces.

Pegmatite dykes postdate the granite dykes and are abundant throughout the Split Lake Block. These late pegmatites are pink, massive and coarse to very coarse-grained. They rarely exceed a metre in thickness and are randomly oriented.

Several outcrops near the anorthosite complex on Split Lake and one outcrop on the Nelson River east of Birthday Rapids contain 1 to 2 m thick feldspar porphyry dykes. These dykes cut all other rock types in the area and can be distinguished by 1-3 mm feldspar phenocrysts within a fine grained to aphanitic grey to pink grey groundmass (see Haugh, 1969, p. 36).

TECTONIC COMPLEX (9)

In several areas the layering of the Kenoran migmatitic gneisses is abruptly truncated by tectonized zones (unit 9) in which much of the earlier fabric is obliterated.

Although many of the earlier paleosome-leucosome relationships may be preserved (despite the pervasive tectonic overprint), the mineralogy is variously altered by associated chlorite, actinolite and biotite retrogression (M_3). Locally the tectonized zones are also characterized by extensive networks of unit 8 granitic injections, and constitute a second generation tectonized migmatites.

Two major belts of unit 9 tectonized migmatites have been recognized in the Split Lake block. The best exposed belt forms a northeasterly-trending zone, 4 km thick, extending from central Split Lake to northeast of the Split Lake settlement. The northeast termination of this zone coincides with the fault south of the Fox Lake pluton; however, rafts of foliated biotite gneiss are observed within the margin of the pluton. A large raft from within the granite gave a K/Ar age of 1720 m.y. (Lowden, 1961) indicating a Hudsonian metamorphic age for these migmatites. The second belt of tectonized migmatite is exposed along the Nelson River east of Clark Lake. This zone is typified by numerous northeast-trending foliated and layered tectonized migmatite zones which obliquely cut large inclusions of older gneisses (Fig. 17). Unlike the tectonic reorientation of older gneisses (units 1 to 5) within the central Split Lake tectonized migmatite zones, the gneiss inclusions in this area retain a north-south to slightly northeast metamorphic layering. This early metamorphic layering accounts for the apparent north-south orientation in unit 9 along the Nelson River (Maps GR82-1-1 and GR82-1-2).

FIGURE 17: Weakly foliated layered migmatites (unit 5) truncated by tectonized migmatite (unit 9).

The "late" tectonic complex is characterized by the following features which serve to distinguish it from the "earlier" Kenoran migmatites of unit 5:

- pervasive foliation defined by alignment of biotite and lensoid quartz aggregates;
- units 1 to 5 occur as inclusions ranging in length from a few centimetres to several hundred metres (Fig. 18);

FIGURE 18: Tectonized migmatite (unit 9); well foliated injection gneiss typical of the late migmatite belts.

Erratum: The photographs for Figures 17 and 18 are transposed

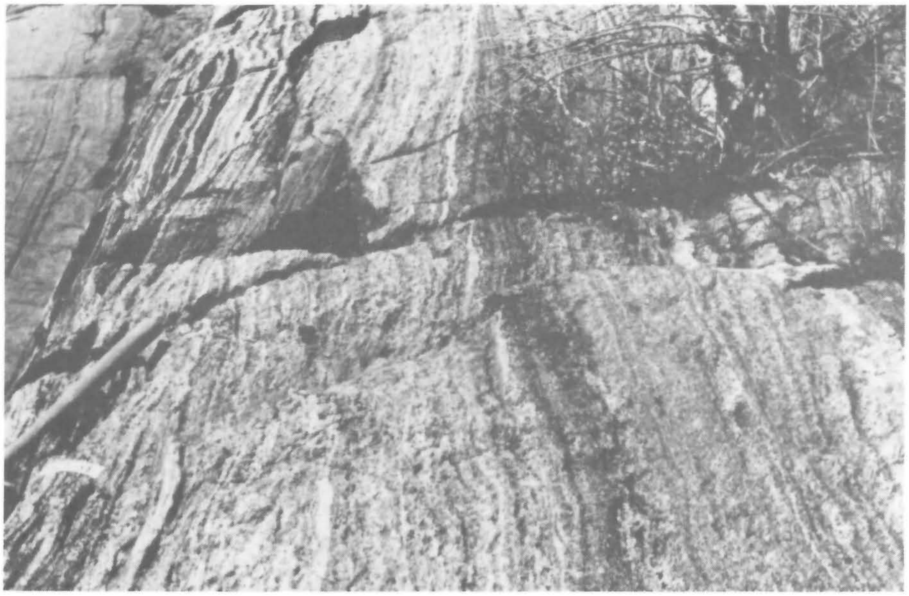


FIGURE 19: Granodiorite gneiss (unit 9a); discontinuously laminated and layered gneiss derived from clotted tonalite (unit 4).

— extensive small-scale deformation including boudinage of amphibolites and minor folds;
— gabbroic inclusion trains composed chiefly of amphibole and plagioclase with relict salt-and-pepper textures represent deformed mafic dykes (unit 7) which have been boudinaged and transposed into the layering direction.

Exposures of unit 9 exhibit a high degree of tectonic reworking during the Hudsonian event. The texture and composition of the paleosome rafts are variable and dependent on the original unit from which they were derived; mafic restites generated from units 1, 3 and 5 are most prominent. They consist chiefly of plagioclase and amphibole and may have gradational contacts with the adjoining gneisses, showing alteration to chlorite, actinolite and biotite.

Leucosome in the tectonized migmatites comprises well foliated discontinuously layered leucocratic biotite gneiss inherited in part from the earlier felsic phases-tonalite-granodiorite (unit 6a) and granodiorite mobilizates from units 4 and 5. A variable content of injected granite (unit 8) is also present.

GRANODIORITE GNEISS (9a)

This distinctive unit is derived through deformation of unit 4 tonalite. It forms a relatively continuous arcuate band extending northeast from the south side of Indian Reserve 171A into a northerly-trending belt underlying Clark Lake.

It consists of 2 to 5 mm thick lenses and discontinuous laminations of coarse grained feldspar and pale blue quartz interlayered with deeply weathered fine grained biotite-chlorite-amphibole schist (Fig. 19). Mafic inclusions, common in unit 4, are for the most part tectonically destroyed; however, a few highly altered mafic bands a few centimetres thick were observed.

The granodiorite gneiss is similar in mineralogical composition to the parent tonalite except for a higher microcline content. Furthermore, the metamorphic assemblage attributed to the Hudsonian orogeny (green amphibole, biotite, chlorite and epidote) displays none of the relict textures observed within undeformed portions of unit 4. Quartz commonly forms lens-shaped aggregates with complex sutured crystal boundaries. Microcline is highly variable in abundance, ranging from a few to 15 per cent of the rock. It occurs as augen or interstitial grains in the mobilizate. Increased microcline content of these rocks over the parent tonalite (unit 4) may be due to incorporation of early granite dykes or metasomatism during tectonism.

CHURCHILL PROVINCE

Introduction

Units 10 through 20 comprise metamorphosed and variably migmatized sedimentary and intrusive rocks of Proterozoic age. The metasedimentary rocks are interpreted as the eastward continuation of the Burntwood River Metamorphic Suite and the Sickle Metamorphic Suite. The terminology for major metasedimentary gneiss and migmatite units (metagreywacke gneiss, hornblende metagreywacke, feldspathic metagreywackes, etc.) as well as the subdivision of psammitic and pelitic metagreywacke used in this report is as defined by Lenton (1981) for rocks in the McKnight-McCallum Lakes area of the Kisseynew metasedimentary gneiss belt.

In the following section mineralogical and textural descriptions have been extensively quoted from a thesis by S. Elphick (1970).

Burntwood River Metamorphic Suite

METAGREYWACKE GNEISS (10, 12)

Greywacke-derived paragneisses form the principal map unit along the Nelson River from Gull Rapids downstream to Kettle Rapids. They occupy a northwest-trending belt oblique to the river channel and appear as outcrops in the "Moose Lake" area to the northeast. These gneisses display a consistent low magnetic expression (2200 to 2500 gammas) permitting extrapolation of the unit through areas of limited exposure from the Nelson River to "Moose Lake". In the Assean Lake-Pearson Lake area (Corkery and Lenton, 1980) extremely poor exposure and complex aeromagnetic expression prevent a similar extrapolation, and link up, with the main sequence observed in the Kisseynew metasedimentary gneiss belt to the west. However, physical characteristics and a preliminary Rb/Sr isochron of 1700 Ma ± 95 (Clark, 1981) support a direct correlation between these metasediments and the Kisseynew metagreywackes.

Unit 10 has been subdivided into four subunits. The subunits have been distinguished by significant compositional and textural variations which form laterally continuous mappable units of paragneiss and metatexites. The stratigraphic sequence of subunits has not been definitely established in some areas and subunits 10a and 10b are typically interlayered near the top of the metagreywacke gneiss sequence. Thus the subunits are labelled 10a to 10d, in general from the top downward, and a strict stratigraphy is not implied. The subunits described comprise:

10a psammitic metagreywacke gneiss
10b arkosic gneiss
10c psammitic and pelitic metagreywacke gneiss
10d pelitic metagreywacke gneiss.

In areas of limited exposure, and where a high degree of migmatization has produced diatexites, subunits have not been differentiated.

Silicate analyses (Table 4) and graphical analysis using the Pettijohn (1957) SiO_2/Al_2O_3 vs. Na_2O/K_2O diagram (Fig. 20) support a greywacke affinity for these rocks. A transition from basinal greywacke sedimentation to shallow water sedimentation may be inferred from the chemical continuity between psammite (10a) and meta-arkoses of unit 10b at the top of the sequence.

Unit 10 is in large part composed of varying amounts of plagioclase, quartz and biotite. The latter has characteristic straw-yellow to red-brown pleochroism. Pink garnet, and graphite are common throughout the sequence and sillimanite occurs in many specimens, commonly with cordierite in the form of lensoid aggregates of acicular crystals within the plane of gneissosity and biotite foliation.

The most complete lithological sequence containing all metasedimentary units is exposed on the islands and river channel west of Gillam. The lithologic units are exposed across strike from the core of an antiformal structure centred on "Wapicho Rapids" flanked by synforms which expose the overlying arkosic units.

The lowest unit of the sequence (10d) is exposed at "Wapicho Rapids" and consists of large blocks of pelitic gneiss in an equigranular white granite. Elphick (1970) described the gneiss as "equigranular, fine grained, with biotite, plagioclase and quartz in a mosaic containing some poikilitic garnet porphyroblasts up to 1/2 cm in diameter".

A regionally extensive and thick sequence of interlayered psammitic and pelitic metagreywacke (10c) overlies the pelitic gneiss (Fig. 21). The metagreywackes comprise variable proportions of fine grained light grey psammitic layers commonly containing 1 to 2 mm garnets and pelitic layers as described in unit 10d. Variable proportions of white granitic *lits* and mobilizate are common and may reach 50 per cent on some exposures.

The top of unit 10c metagreywacke, is marked by a relatively continuous grey pelitic gneiss with poorly defined psammitic layers. In these rocks Elphick (1970) indicates that "Biotite percentages are slightly lower and microcline content slightly higher than in the normal pelite. Several of the outcrops show good development of microcline porphyroblasts, appearing on outcrop as diffuse, light grey patches up to 1 cm diameter, randomly scattered. Present on nearly all outcrops are elongate sillimanite knots".

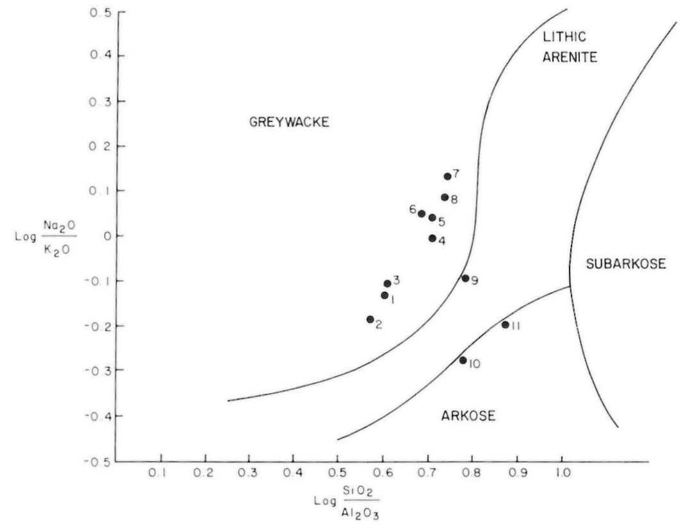


FIGURE 20: Log (SiO_2/Al_2O_3) vs. log (Na_2O/K_2O) diagram (after Pettijohn, 1957) for metasedimentary rocks of the Burntwood River Metamorphic Suite. Data point numbers indicate chemical analyses contained in Table 4.

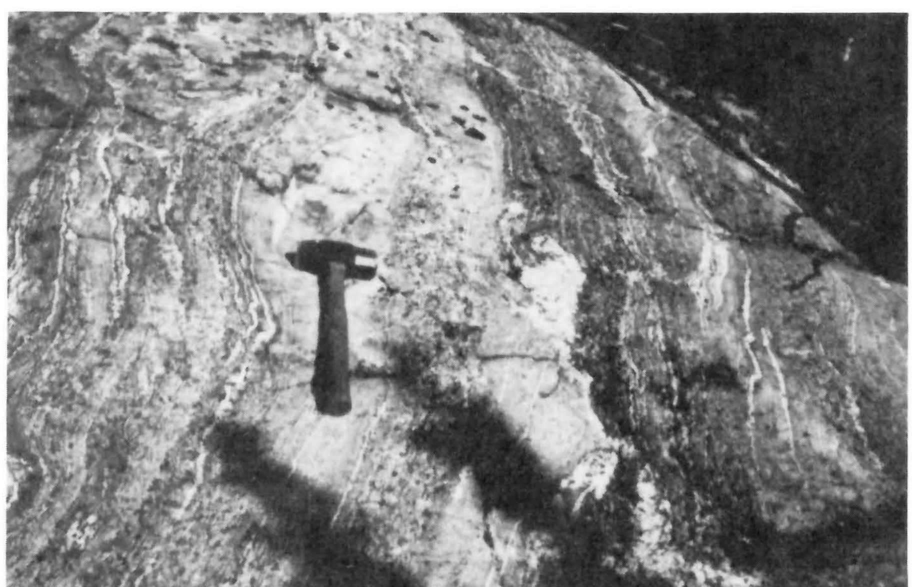


FIGURE 21: Interlayered fine grained psammite and coarsely recrystallized pelite typical of metagreywacke (unit 10b) in least mobilized zones.

Table 4: Chemical analyses of Burntwood River Metamorphic Suite metasedimentary rocks from the Gillam-Moose Lake area.

Sample Number	10c Pelitic gneiss 1	2	3	10c Psammitic gneiss 4	5	6	7	10a Psammitic gneiss 8	9	10	10b Arkosic gneiss 11	11 Amphibolite 12	13
	Oxide wt. %	Oxide wt. %	Oxide wt. %	Oxide wt. %	Oxide wt. %	Oxide wt. %	Oxide wt. %	Oxide wt. %	Oxide wt. %	Oxide wt. %	Oxide wt. %	Oxide wt. %	Oxide wt. %
SiO_2	63.10	61.40	59.35	68.35	69.65	69.05	71.25	72.70	75.70	74.65	79.50	48.40	47.50
Al_2O_3	15.90	16.35	16.65	13.57	13.68	14.81	13.06	13.30	12.90	12.59	10.90	12.60	12.10
Fe_2O_3	0.76	0.78	2.96	0.55	0.49	0.57	0.39	0.91	0.03	0.27	0.10	2.49	1.36
FeO	6.04	5.97	5.50	5.31	4.42	3.84	4.46	2.41	0.89	1.93	1.42	14.28	12.50
CaO	2.32	2.32	3.33	1.59	2.18	2.62	1.95	1.92	1.28	0.83	1.15	9.80	14.80
MgO	2.85	2.93	3.67	2.49	2.19	1.04	1.78	0.67	0.32	0.75	0.30	4.46	3.42
Na_2O_3	2.72	2.83	2.41	2.80	2.64	3.11	2.76	3.85	3.55	2.62	2.29	2.40	2.05
K_2O	3.65	4.33	3.07	2.87	2.38	2.76	2.01	3.10	4.43	4.88	3.50	0.78	1.22
TiO_2	0.73	0.80	0.85	0.52	0.72	0.60	0.61	0.49	0.07	0.38	0.18	1.95	1.77
P_2O_5	0.11	0.23	0.23	0.02	0.14	0.13	0.11	0.06		0.02	0.05	0.28	0.24
MnO	0.08	0.07	0.14	0.07	0.04	0.11	0.07	0.09	0.02	0.02	0.10	0.23	0.31
NiO												0.015	0.015
Cr_2O_3												0.02	0.01
H_2O	1.00	1.16	1.75	1.06	0.90	0.93	0.88	0.64	0.48	0.56	0.40	1.75	1.38
S			Nil	0.15	TRACE	0.07	NIL			NIL	0.01		
CO_2	0.97	0.36	0.03	0.05	0.17	0.16	0.14	0.24	0.22	0.22	0.24	0.38	0.96
C (Graphite)						0.06					NIL		
Other				0.13	0.12	0.02	0.12			0.17	0.16		
TOTAL	100.23	99.53	100.10	99.51	99.76	100.03	99.63	100.38	99.89	99.91	100.30	100.08	99.69
TOTAL Fe in Fe_2O_3			9.07	6.45	5.40	4.84	5.35			2.41	1.68		
Geochemistry			ppm	ppm	ppm	ppm	ppm			ppm	ppm		
Cu			7	39	47	40	6			5	15		
Ni			68	56	24	4	26			8	4		
Pb			12	115	7	11	<3			3	11		
Zn			139	113	104	93	78			71	24		
Cr			120	198	147	26	119			42	30		
Rb			109	248	100		78			112			
Sr			260	110	195	260	245			130	220		
Ba			630	170	330	1330	440			1130	1110		
F				840	670		550			290			

Analyses 1, 2, 8, 9, 12 and 13 are from Elphick (1970).

1 Metapelite, foliated biotite gneiss with abundant garnet porphyroblasts up to 1 cm (95° 7'3'', 56° 26'28'')

2 Metapelite, foliated biotite gneiss with garnet porphyroblasts up to 1 cm (90° 6'57'', 56° 26'24'')

3 Metapelite, foliated biotite-garnet gneiss layer within dominantly psammitic, metagreywacke sequence (95° 14'4'', 56° 28'8'')

4 Psammitic metagreywacke, interlayered with thin discontinuous biotite-rich pelitic layers (95° 11', 56° 20'19'')

5 Semipelitic metagreywacke, biotite gneiss with sillimanite-cordierite knots (94° 53'2'', 56° 22')

6 Psammitic metagreywacke, garnet-biotite gneiss (94° 54'1'', 56° 23')

7 Psammitic metagreywacke, well layered biotite-garnet gneiss with minor associated semipelite layers (94° 55'4'', 56° 22'10'')

8 Psammitic metagreywacke, thinly layered biotite gneiss (94° 57'31'', 56° 19'49'')

9 Psammitic metagreywacke, thinly layered microcline-biotite-garnet gneiss (94° 57'9'', 56° 20')

10 Psammitic metagreywacke, microcline-garnet-biotite gneiss (94° 53'24'', 56° 22'47'')

11 Arkosic gneiss, thinly layered, garnetiferous biotite-poor gneiss (94° 39'35'', 56° 22'49'')

12 Amphibolite, narrow amphibolite layer within metagreywacke (unit 10c) (95° 7'18'', 56° 26'45'')

13 Amphibolite, hornblende-diopside layer from layered amphibolite (unit 11) (95° 16'54'', 56° 29'31'')

Minor discontinuous amphibolite layers occur within and overlying these pelitic gneisses in exposures north of the confluence of the Nelson and Butnau Rivers. A thick section of amphibolite (unit 11) occurs at this stratigraphic location on the south shore of the Nelson River in islands south of Ferris Bay. This amphibolite thins eastward and is not observed elsewhere in the map area at this position in the section.

Throughout most of the area the microcline-bearing pelitic gneisses grade into thick sections of dominantly psammitic metagreywacke (10a, 12) with subordinate semi-pelitic and pelitic layers. These gneisses represent a transitional change from graphitic metagreywackes of Burntwood River Metamorphic Suite affinities to magnetiferous metagreywackes and meta-arkoses of the Sickle Metamorphic Suite.

Typical psammites are well layered on a scale of 1 to 3 cm (Fig. 22). Rocks at the base of the section are light pinkish grey on the weathered surface and grade upward to light buff brown.

The psammites contain quartz, microcline, plagioclase and biotite. A gradational increase in quartz from about 35 per cent at the base to 50 per cent at the top of unit 12, and a decrease in plagioclase from 28 per cent at the base to 10 per cent at the top, is observed in the section on islands south of Ferris Bay. Microcline content consistently averages about 30 per cent and biotite 10 to 12 per cent. Garnet is common throughout the sequence but decreases in abundance upwards. Graphite and magnetite do not coexist; a change in the colour of biotite from red-brown to green straw pleochroism coincides with the change from graphitic to magnetite-bearing gneisses.

Near the top of the microcline-bearing psammites (unit 10a) in the structure on islands south of Ferris Bay a relatively continuous thin amphibolite unit (11) was observed. Elsewhere discontinuous amphibolite layers mark the contact between units 10a and 12.

A white weathering light grey arkose (10b) is interlayered with psammitic gneisses in many outcrops (analysis 11 in Table 4). Mineralogically these rocks resemble the psammitic gneisses (10a) with a slight increase in quartz and an average biotite content of less than 5 per cent.

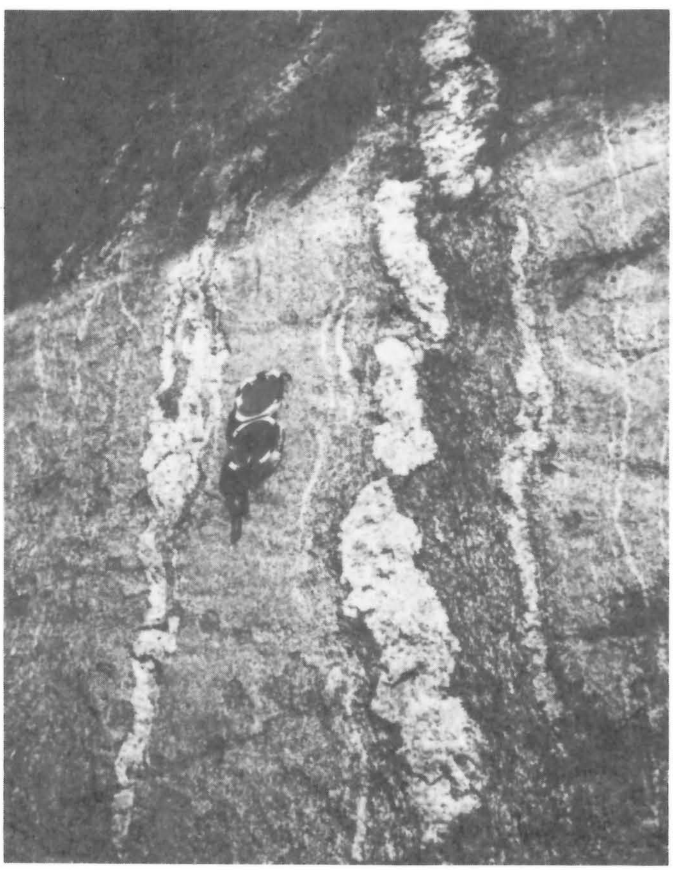


FIGURE 22: Thinly layered psammite metagreywacke (unit 10a).

FIGURE 23: Layered amphibolite (unit 11).

AMPHIBOLITE (11)

The contact between the graphitic metasedimentary rocks of the Burntwood River Metamorphic Suite and the overlying magnetiferous metasedimentary rocks of the Sickle Metamorphic Suite is typically marked by the occurrence of a thin amphibolite. This unit is not observed in all sections and this lack of continuity is interpreted as a result of structural thinning and boudinage on the limbs of early (F_1) large-scale folds.

"Three mineralogical types may be recognized in this amphibolite:

(A) Normal amphibolite
(B) Diopsidic amphibolite
(C) Calcic schlieren

(B) and (C) form distinct layers and schlieren in (A) but with highly gradational contact" (Elphick, 1970). Chemical analyses of two samples from this unit are listed in Table 4.

"Amphibolite (A) is typically dark green-brown in colour, massive, with a salt-and-pepper texture and displays little compositional variation. In thin section the normal amphibolite is a moderately equigranular mosaic of hornblende, plagioclase and quartz, average grain size 0.3 mm. Also present are persistent but minor amounts of iron oxide (magnetite) and sulphide (pyrite)".

Weathered exposures of diopsidic amphibolite (B) commonly exhibit pale green, buff (0.5 to 3.0 cm) diopside-rich layers interlayered with dark green-brown amphibolite layers (Fig. 23) which are mineralogically the same as the massive amphibolites (A) but commonly display compositional layering.

Elphick (1970) reports "the gneiss is a fine grained, moderately equigranular mosaic of hornblende, plagioclase, quartz and diopside, average grain size 0.8 mm. Set in this are elongate porphyroblasts of diopside, up to 1.2 mm long x 0.2 mm wide, with their long axis parallel to the gneissic foliation". Minor opaques are also common to these layered amphibolites.

Calcic schlieren type (C) form boudinaged lenses and layers within type (A) and (B) amphibolites. They consist of "an equigranular mosaic of rounded diopside grains up to 1 mm in diameter, sphene, plagioclase, and quartz" (Elphick, 1970).

Sickle Metamorphic Suite

HORNBLENDE METAGREYWACKE (13)

The basal unit of the Sickle Metamorphic Suite is a hornblende-biotite-magnetite gneiss derived from greywacke (chemical analyses 1, 2 and 3 in Table 5 and Figure 24). This unit is characterized by the assemblage:
hornblende + biotite + magnetite + plagioclase + microcline + quartz. It weathers ochre-dull brown, with a characteristic mottled texture, due to small concentrations of hornblende.

The hornblende metagreywacke is areally extensive at this horizon but highly variable in thickness. In the Kettle Rapids area it is observed as a 1 to 3 m thick unit at the base of the Sickle Metamorphic Suite. To the west along the Nelson River, this unit forms much thicker sections within synformal structures. In one location in the structure south of Ferris Bay a polymictic conglomerate (13a) (Fig. 25) is observed within the hornblende greywackes. The exact position of this conglomerate in the sequence is unknown due to lack of outcrop. However, the occurrence of conglomerate lenses is common in hornblende greywackes of the Sickle Metamorphic Suite mapped elsewhere in the Churchill Province. To the northwest on "Moose Lake" hornblende gneisses are thin or in some locations absent from the section.

Elphick (1970) described the hornblende metagreywacke as "inequigranular, with no preferred orientation of the biotites. The latter have characteristic olive green to straw pleochroism. The more calcic varieties of the gneiss carry layers of stubby diopside crystals, with little or no biotite. These layers are poor in potassium feldspar, this being restricted to thin bands up to 1 cm wide, usually separated by up to 4 to 5 cm."

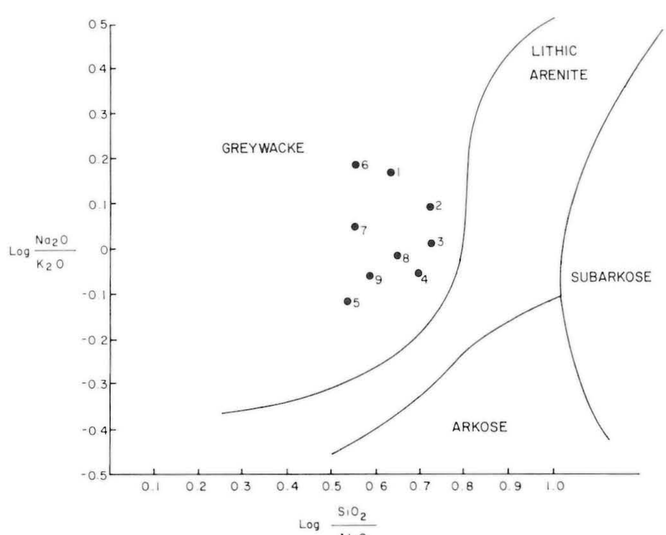


FIGURE 24: *Log (SiO_2/Al_2O_3) vs. log (Na_2O/K_2O) diagram (after Pettijohn, 1957) for metasedimentary rocks of the Sickle Metamorphic Suite. Data point numbers indicate chemical analyses from Table 5.*

FIGURE 25: *Deformed and recrystallized metaconglomerate (unit 12a).*

FELDSPATHIC GREYWACKE-PSAMMITE GNEISS (14)

A well layered biotite-magnetite psammitic gneiss overlies the hornblende greywackes. It was well exposed in the synclinal structure centred on the Kettle Rapids dam site where Elphick (1970) observed that "two distinct lithologies may be recognized in this unit on the west half of the fold, the difference between these due to variation in the biotite and microcline percentages".

"Type A is more mafic than type B and has a higher biotite content but no microcline. It generally has a well formed but poorly defined gneissosity due to slight variations in the biotite content. This unit occurs just above the hornblende-biotite-magnetite gneiss". In outcrops under the railway bridge at Kettle Rapids, this portion of the unit is well layered and laminated, and contains red-brown magnetite-rich basal layers (Fig. 26) overlain by a yellow-white quartz-rich section with a total thickness of 70 m exposed.

"Type B is the typical gneissic variety, with moderately high content of quartz, plagioclase and microcline. On clean outcrop it is ochre to dull yellow, and shows good metamorphic differentiation in some places, being divided into potassium-rich and potassium-poor layers" (Elphick, 1970).

Elphick (1970) indicates that this unit contains "biotite, microcline, plagioclase, quartz and magnetite. The biotite occurs as randomly scattered flakes, with a good subparallel orientation, pleochroic in shades from olive brown to pale straw. These are set in an inequigranular mosaic of plagioclase, quartz and microcline, with numerous scattered grains of magnetite of variable size which have slight interstitial habit."

Table 5: Chemical analyses of the Sickle Metamorphic Suite metasedimentary rocks from the Gillam-Moose Lake area.

SAMPLE NUMBER	Hornblende Psammite 12			Biotite greywacke 13			Sillimanite greywacke 14	Pelite 15	
	1	2	3	4	5	6	7	8	9
	Oxide wt. %	Oxide wt. %	Oxide wt. %	Oxide wt. %	Oxide wt. %	Oxide wt. %	Oxide wt. %	Oxide wt. %	Oxide wt. %
SiO_2	66.30	74.40	63.65	64.2	59.6	59.20	59.40	63.35	60.80
Al_2O_3	14.42	13.95	12.60	12.3	17.3	16.65	16.53	14.24	15.79
Fe_2O_3	0.76	0.24	5.29	5.78	6.23	4.83	4.53	4.28	2.63
FeO	4.38	1.34	3.11	3.89	3.66	4.63	4.61	3.90	5.93
CaO	5.15	1.88	4.15	2.65	2.18	4.32	3.71	2.89	2.72
MgO	2.33	0.48	2.85	2.70	3.00	2.85	2.93	2.89	3.55
Na_2O	2.28	3.55	2.48	2.41	1.87	2.96	2.89	2.29	2.78
K_2O	1.57	2.85	2.40	2.75	2.45	1.91	2.62	2.38	3.16
TiO_2	0.67	0.12	1.18	1.66	0.93	0.88	0.85	1.14	0.99
P_2O_5	0.12	NIL	0.16	0.09	0.15	0.15	0.17	0.22	0.26
MnO	0.07	0.06	0.11	0.08	0.13	0.17	0.13	0.12	0.16
H_2O	1.05		1.43	1.30	1.62	0.86	0.99	1.91	1.17
S	TRACE					0.02	NIL	NIL	TRACE
CO_2	0.37	0.72	0.17	0.14	0.42	0.07	0.05	0.14	0.07
(Graphitic)									0.02
Other	0.10	0.28				0.16	0.15	0.14	0.15
TOTAL	99.62	99.87	99.58	99.95	99.54	99.70	99.61	99.92	100.18
TOTAL Fe as Fe_2O_3	5.63					9.98	9.65	8.61	9.22
	ppm					ppm	ppm	ppm	ppm
Cu	6					7	3	5	103
Ni	22					68	64	46	74
Pb	<3					7	<3	<3	<3
Zn	98					154	130	119	134
Cr	66					127	129	182	136
Rb	67					58	80	63	
Sr	140					200	185	175	130
Ba	450					690	640	600	690
F	750					820	870	600	

Analyses 2, 3, 4 and 5 are from Elphick (1970).

1 Hornblende psammite, well layered quartz, biotite hornblende gneiss (94° 52', 56° 22'7")

2 Hornblende psammite (94° 40'5", 56° 22'26")

3 Hornblende psammite, with hornblende porphyroblasts up to 1 cm in diameter (94° 47'49", 56° 22'13")

4 Biotite metagreywacke, layered magnetiferous biotite gneiss (94° 52'42", 56° 22'24")

5 Biotite metagreywacke (95° 18'44", 56° 31')

6 Sillimanite metagreywacke, massive with sillimanite knots up to 1 cm long (95° 19', 56° 31'05")

7 Sillimanite metagreywacke, highly magnetiferous sillimanite-biotite gneiss (95° 7'20", 56° 26'48")

8 Metapelite, highly magnetiferous garnet-biotite gneiss (95° 6'46", 56° 26'42")

9 Metapelite, highly magnetiferous cordierite-biotite gneiss (95° 7', 56° 27'49")

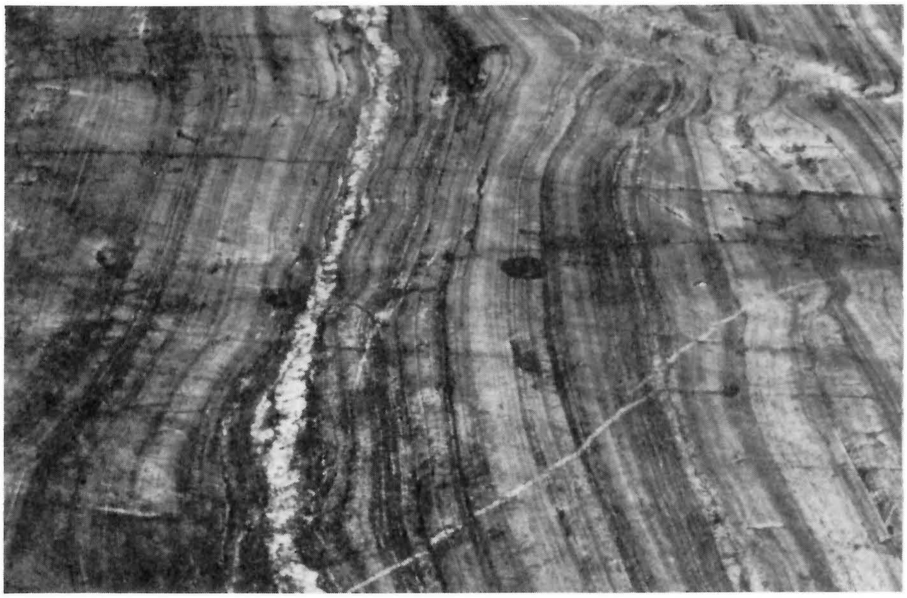


FIGURE 26: *Thinly layered magnetite-rich feldspathic metagreywacke (unit 14).*

SILLIMANITE META-ARKOSE (15)

Near Kettle Rapids, on the north side of the river and on islands in the rapids, the core of a major fold exposes the most continuous cross-section of the Sickle Metamorphic Suite in the region. Here, sillimanite gneiss derived from arkose — observed sporadically by Haugh and Elphick in their 1968 map area — is well exposed overlying the feldspathic greywacke psammite (unit 14).

This unit is similar in texture and mineralogy to unit 14, differing chiefly in consistently lower biotite content (rarely more than 10 per cent) and having up to 8 per cent sillimanite and minor cordierite. The basal 10 to 15 m of this unit contain sillimanite as fine needles parallel to the foliation and gneissosity. Sillimanite content increases upwards and the upper 360 m contain numerous *faserkiesel* (Fig. 27), which are knots of fibrous sillimanite in quartz, generally flattened within the plane of biotite foliation. The upper *faserkiesel*-rich gneiss typically contains remnants of garnet pseudomorphed by cordierite, quartz and biotite.

METAGREYWACKE (16)

This is the highest unit observed in the metasedimentary sequence. At Kettle Rapids a 250 m thick section of metagreywacke is well preserved in a major synclinal structure. Elsewhere exposures are restricted to small outcrop areas within fold closures.

The contact with the underlying sillimanite arkose is marked by a sharp decrease in sillimanite content and the appearance of garnet. Otherwise the lower 100 m of the metagreywacke is transitional. Within this zone biotite increases upward — from less than 5 per cent to an average of 15 per cent. The garnet and magnetite content also increases in abundance upward. Sporadic discontinuous 5 to 10 cm thick amphibolite layers are interlayered with the greywacke gneiss.

The upper I50 m comprise massively layered, dark grey-black pelitic gneiss with numerous *faserkiesel* and subordinate semi-pelite layers. Chemical analyses 8 and 9 in Table 5 are from this unit.

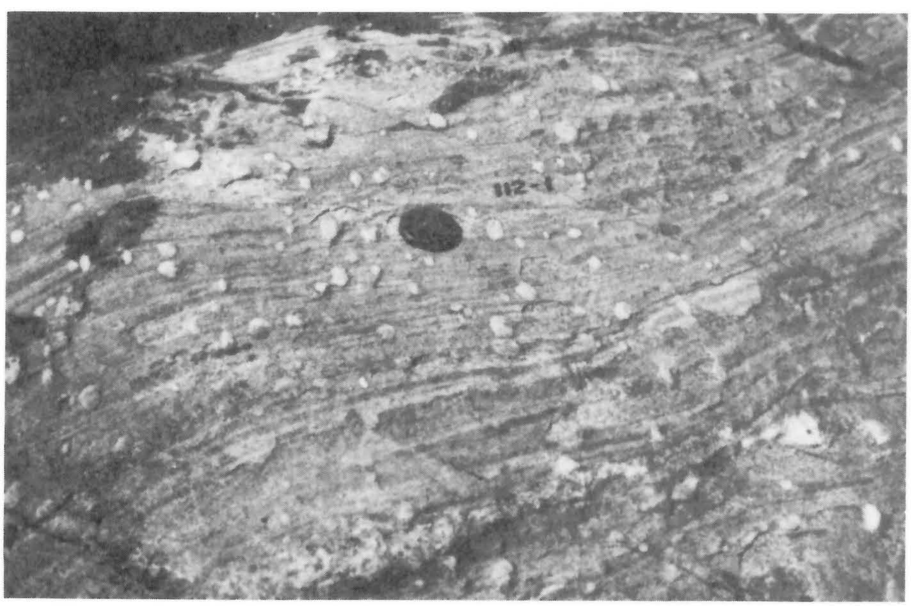


FIGURE 27: Faserkiesel-*bearing sillimanite meta-arkose (unit 15).*

Typically the rock exhibits a fine- to medium-grained groundmass of inequigranular plagioclase and quartz with subordinate microcline. Abundant biotite (averaging 15 per cent) is pleochroic from dark olive brown to pale straw, and forms subparallel bundles or laminations. Cordierite is commonly preserved as knots permeated with acicular sillimanite needles or as alteration around garnet. Magnetite content is higher in this unit than any other and will significantly deflect a compass.

Intrusive Rocks

TONALITE-GRANODIORITE (18a, 18b)

The area east of Long Spruce Rapids downstream to the limit of Archean outcrop is underlain by a large felsic intrusion. The western margin consists of homogeneous, coarse grained, equigranular tonalite (unit 18a) which is well foliated and contains numerous xenoliths of greywacke gneiss (unit 10) in all stages of assimilation. The tonalite grades over several hundred metres into an inclusion-free granodiorite (unit 18b) of similar texture. Irregular pegmatitic zones with gradational contacts occur sporadically in the tonalite.

This unit comprises equigranular plagioclase and quartz with variable amounts of microcline, isolated randomly oriented hornblende crystals, and biotite. It commonly contains magnetite with minor chlorite and epidote.

Elsewhere in the map area grey to white tonalite to granodiorite intrude the Burntwood River Metamorphic Suite as irregular bodies, dykes, and injected *lits*. These range from granitic to pegmatitic in texture and are highly variable in abundance. At "Wapicho Rapids" the pelitic gneisses (10d) are described as "large blocks 'floating' in an inequigranular white granite (tonalite) . . . . None of the blocks and layers appear to be rotated, as shown by the consistency in the foliation readings at the Wapicho Rapids area, many of which were measured in blocks and totally isolated in the granite (tonalite)." (Elphick, 1970). This was interpreted by Elphick (1970) to indicate that intrusion occurred during the peak of metamorphism, and took place slowly, so that various layers were literally floated apart.

A direct relationship between the intrusion at Long Spruce Rapids and the typical intrusive tonalite-granodiorite described above could not be established in the field. They are grouped because of their compositional and textural similarities.

GRANITE, PEGMATITE (19)

Discrete granite bodies and numerous late granite and pegmatite dykes and sills occur throughout the Churchill Province segment of the map area.

Homogeneous massive pink biotite-granite intrudes the conglomerate at Apetowachakamasik Lake north of Little Assean Lake. Several isolated outcrops of magnetiferous pink granite were observed north of the Churchill-Superior boundary between Little Assean Lake and Stephens Lake. Throughout the Stephens Lake-Gillam area numerous granitic dykes and sills were observed and small bodies occur near the confluence of the Butnau and Nelson Rivers and between Kettle and Long Spruce Rapids.

Cross-cutting relationships are observed in late granite dykes and sills; however, sparse outcrop precludes regional comparison. One late granitic phase is consistent and is "always fresh in appearance, crosscuts all other units, and has epidote alteration on joint surfaces". (Elphick, 1970). It is composed chiefly of microcline and quartz with minor plagioclase, biotite and muscovite. Numerous earlier granite and pegmatite dykes and sills are interpreted as anatectic and formed during the major period of regional migmatization.

MAFIC DYKE (20)

One mafic dyke, which postdates the migmatization and granite dyke intrusion, was observed along the north shore of the Nelson River in the Kettle Rapids area. The dyke is exposed in three locations and can be traced over 700 m along strike at a slight angle to the gneissic layering. It is a fine grained, salt-and-pepper textured, black diabase with narrow chilled margins, and contains amphibole and plagioclase.

Table 6: Classification of cataclastic rocks, after Higgins (1971)

Approximate volume per cent porphyroclasts in rocks *with* fluxion structure, OR Approximate volume per cent fragments in rocks *without* fluxion structure.	Rocks *without* primary cohesion	Rocks *with* primary cohesion				Approximate size of *most* porphyroblasts in rocks *with* fluxion structure, OR Approximate size of *most* fragments in rocks *without* fluxion structure
		Cataclasis dominant over neomineralization-recrystallization			Neomineralization-recrystallization dominant over cataclasis	
		Rocks *without* fluxion structure	Rocks *with* fluxion structure		Rocks *with* fluxion structure	
>50	Fault breccia	Microbreccia	Protomylonite		Mylonite gneiss (mylonite schist)	Visible to naked eye
<50 30			Mylonite	Phyllonite (variety)		
>10 <10	Fault gouge	Cataclasite	Ultramylonite		Blastomylonite	> 0.2 mm < 0.2 mm

All rocks are gradational

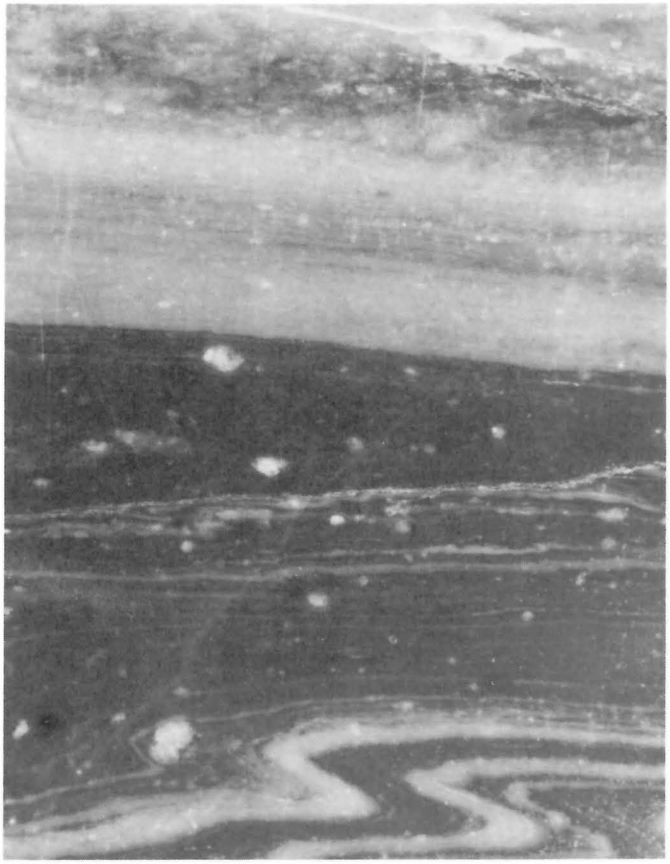


FIGURE 28: *Thinly layered and laminated mylonite (unit 21a), with feldspar porphyroclasts up to 5 mm in diameter.*

Churchill-Superior Boundary Zone (21)

INTRODUCTION

Rocks included in the Churchill-Superior boundary zone are cataclastic rocks and rocks which cannot be directly assigned to the Churchill or Superior Province. On maps GR82-1-1 and GR82-1-3 (in pocket) the extent of the boundary zone is shown by a patterned overlay.

The brittle deformation which produced the megascopically layered mylonites of the Churchill-Superior boundary zone was not restricted to these rocks. Cataclastic textures are recognized in hand specimen and thin section in all samples from Little Assean Lake. In contrast to the mylonites the original rock type can generally be determined. For example, progressively increasing cataclasis of the "Fox Lake Granite" (unit 8b) in the Little Assean Lake area is observed as the mylonite zone is approached. In the Gull Rapids area progressive cataclasis of greywacke metasedimentary rocks (unit 10) was documented by Elphick (1970). Both Superior Province and Churchill Province rock types have been involved in the brittle deformation and the extent of cataclasis into each geological province is used to define the limits of the boundary zone.

Terminology used in this report (Table 6) to describe the cataclastic rocks observed throughout the project area, and more specifically in the boundary zone, is a general classification for cataclastic rocks proposed by Higgins (1971). In the map area these rocks are represented by layered mylonite and mylonite gneiss (unit 21a). Some rock types within the boundary zone are not strictly cataclastic rocks under Higgins' (1971) definition; however, features attributed to brittle deformation predominate. These rocks contain discontinuous fluxion structure, lensing of quartz and augen-shaped porphyroclasts. Crushing is less severe than in the mylonite zone and a progressive increase in the degree of cataclasis occurs as the mylonite zones are approached.

MYLONITES (21a)

Layered and laminated mylonites occur on Little Assean Lake and along the Assean River to the northeast and southwest. As previously indicated, continuity of the fault zone, in an arcuate form, from Little Assean Lake through to the Gull Rapids mylonite, is interpreted from aeromagnetic trends. At Little Assean Lake a major mylonite about 500 m wide occurs continuously along the northwest shore. A subsidiary

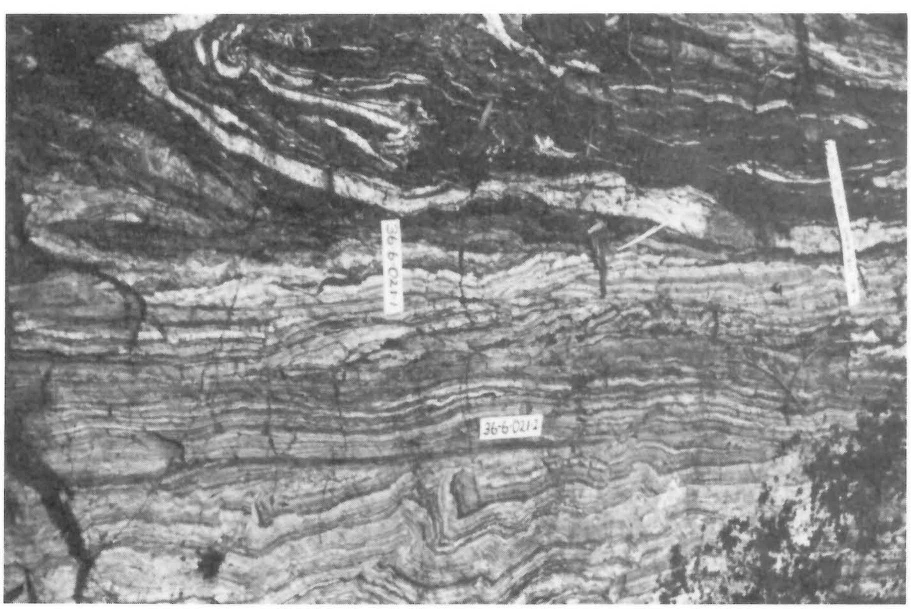


FIGURE 29: *Mylonite (unit 2la): upper portion of the figure consists of mylonite derived from mafic rocks. These are in contact with quartzofeldspathic mylonite.*

mylonite, parallel to the main zone, occurs in a bay to the north. This may represent a continuation of the "Lindal Bay" cataclastic rocks described by Haugh (1969). In the main cataclastic zone immediately downstream of Gull Rapids Elphick (1970) described an 1100 m thick mylonite. Further to the east, at Gull Rapids, subsidiary mylonites were delineated (Corkery, 1975).

The mylonites are highly variable in mineral content, colour and layering characteristics. This variability is due to the diverse nature of the parent rocks as well as the degree of cataclasis. All mylonites observed have well developed fluxion structure grading into millimetre-scale lamination (Fig. 28). A variably developed compositional layering (Fig.29) is interpreted to reflect variations in original rock composition. Particularly good evidence indicating primary compositional layering is observed in outcrops where pegmatites show palimpsest cataclastic texture. Figure 30 shows a sample of cataclastically deformed pegmatite with large crushed feldspars in the upper half. The lower half of the specimen is a mylonite layer derived from the pegmatite. Similarly, black mylonites composed chiefly of green amphibole, chlorite and epidote, derived from amphibolites, occur as layers within quartzofeldspathic mylonites.

The mineralogy is relatively consistent regardless of variations in modal proportions. Mylonites comprise quartz, plagioclase and alkali feldspars with variable content of chlorite, biotite, muscovite and green amphibole. In many specimens epidote and/or calcite and minor sulphides are present.

Textures indicate some recrystallization in conjunction with cataclasis. Thus many cataclastic rocks are classified as mylonite gneiss or blastomylonite (Table 6). However, protomylonites and ultramylonites are dominant. Several examples of mylonitic textures from Little Assean Lake are presented below. Textures can be classified only through microscopic examination.

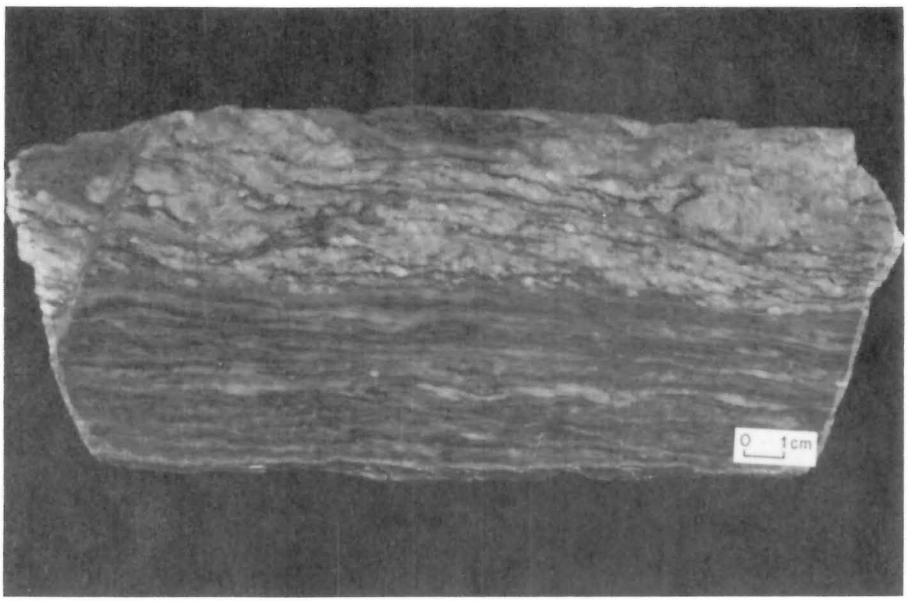


FIGURE 30: Mylonite (unit 21a) derived from pegmatite. Large porphyroclasts of potassium feldspar are the only recognizable remnants of the pegmatite.

FIGURE 31: Photomicrograph (polarized light) of mylonite (unit 21a). Porphyroclasts of quartz and feldspar within an unrecrystallized finely comminuted matrix.

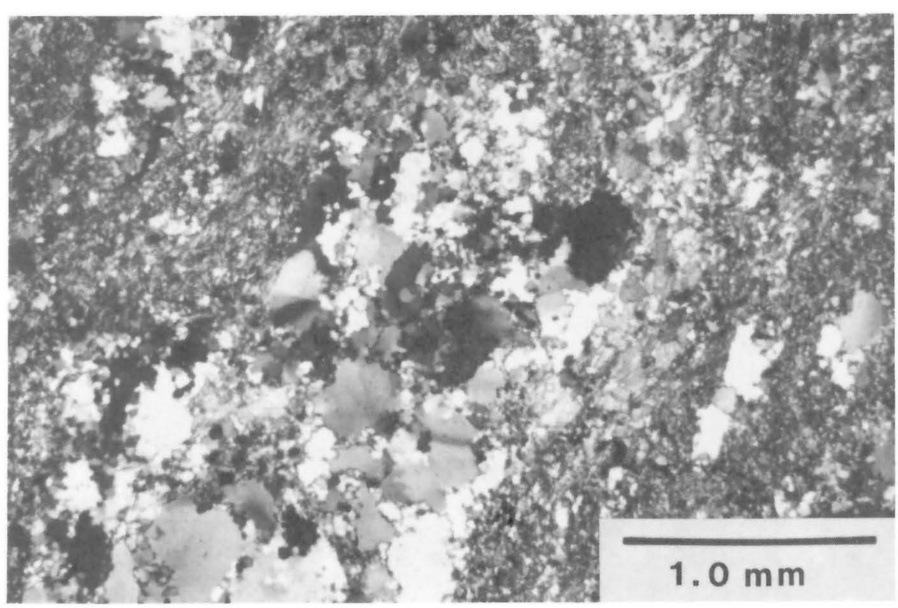


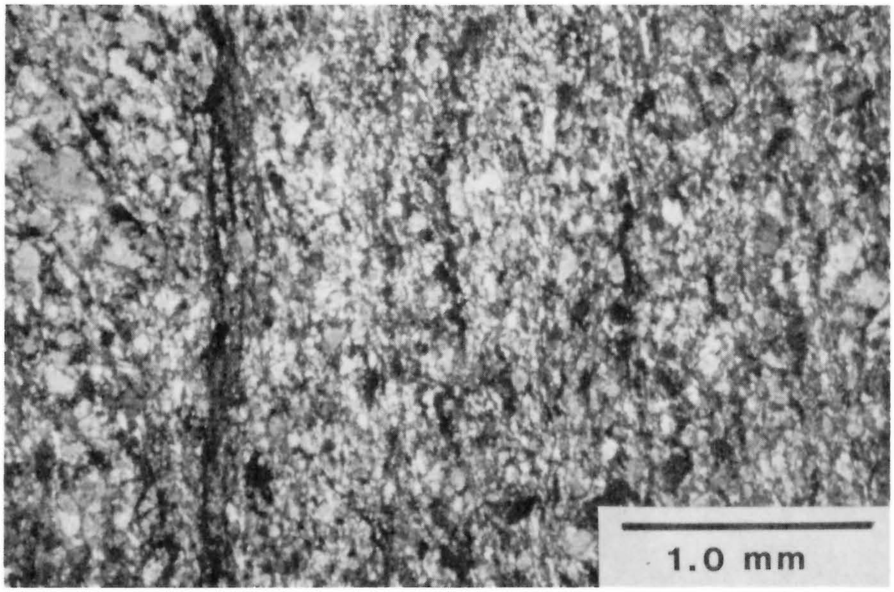
Figure 31 is a photomicrograph of a mafic layer of mylonite, comprising porphyroclasts separated by glide surfaces of finely ground material. Porphyroclasts of quartz and feldspar are internally brecciated with serrated crystal boundaries. Trains of finely ground comminuted crystal fragments occur along some fractures. Typically, quartz is highly strained and feldspar twins are distorted. The fine grained matrix consists of highly strained and comminuted quartz and feldspar as well as fine-grained fluxion structured biotite, chlorite, muscovite and calcite. Segregation lamination between mafic minerals and felsic minerals form a ribbon texture. Fluxion structure is deflected around the porphyroclasts.

An example of ultramylonite consisting of coherent, aphanitic, ultracrushed pressure breccia with fluxion structure is shown in Figure 32. Note that the remaining few porphyroclasts are 0.2 mm or smaller and generally consist of non-recrystallized plagioclase with bent twin lamellae. Brecciated aggregates of quartz are all that remain of quartz porphyroclasts. The very fine grained matrix consists of a mosaic of crystalloblastic quartz and feldspar with wispy muscovite.

In the mylonites it is diagnostic that neither porphyroclasts nor crystalloblastic matrix show extensive recrystallization.

The mylonite gneisses display the same grain size variations as observed in mylonites. Figure 33 is a photomicrograph of mylonite gneiss containing a plagioclase porphyroclast with deformed twin lamellae. Margins of the porphyroclast show comminution of plagioclase, and pressure trails extend parallel to the fluxion structure direction. The fine grained matrix of dominant quartz and plagioclase is recrystallized. Figure 34 shows the nature of recrystallization in the mylonite gneiss.

FIGURE 32: *Photomicrograph (polarized light) of ultramylonite with fluxion structure.*



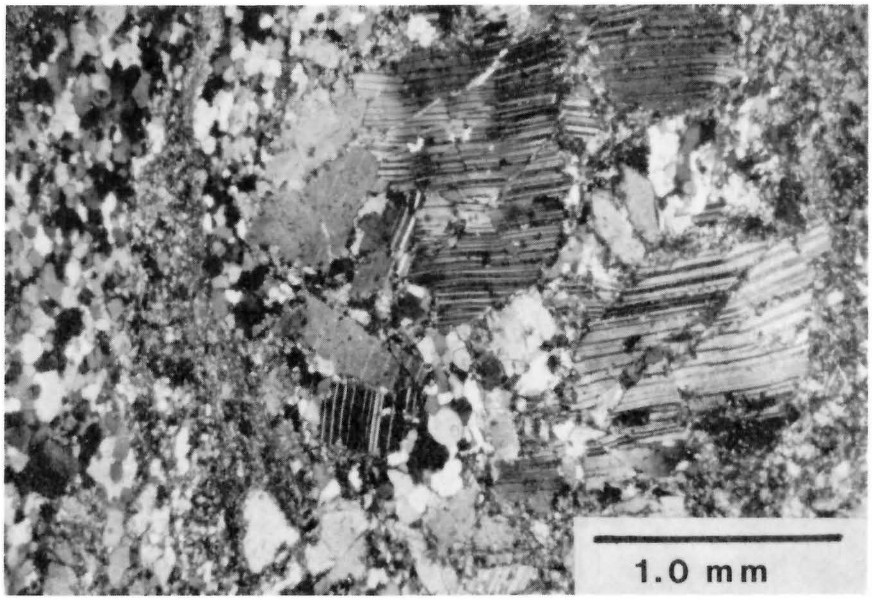


FIGURE 33: *Photomicrograph (polarized light) of mylonite gneiss with severely deformed plagioclase porphyroclasts. Note recrystallized fine grained quartzo-feldspathic matrix.*

Fine grained quartz and feldspars do not appear to be internally strained and grain boundaries are curved rather than serrated. Similarly, quartz porphyroclasts and ribbon quartz have recrystallized to form more coalesced boundaries. Larger plagioclase and quartz porphyroclasts retain their strained and irregular form.

Many outcrops within the mylonite zone show evidence of more than one period of cataclasis. These polycataclastic rocks are generally blastomylonites, and intrafolial folds are common. In Figure 35 irregularly folded porphyroclasts consist of laminated mylonite deformed during a later cataclasis. Euhedral pyrite consistently occurs within the matrix of late mylonite.

A second style of folding commonly observed in the mylonites consists of kink folds along surfaces of décollement (Fig. 36).

CATACLASTIC GRANITIC TO TONALITIC GNEISSES (21b)

As previously noted, rocks from Little Assean Lake and Gull Rapids display variable amounts of cataclasis. Unit 21b rarely displays megascopically recognizable fluxion structure. In thin section, however, incipient development of crush trains and cataclastic foliation is observed. These rocks are all coherent and recrystallization is common. With increasing cataclasis they grade into mylonite gneiss, previously described.

Unit 21b consists of granitic to tonalitic gneisses. Irregular zones contain up to 20 per cent mafic layers, from 5 to 20 cm thick. The least deformed rocks show strained quartz, deformed feldspar twin lamellae and seriate grain boundaries. Three samples described below indicate the nature of the gradational increase in cataclasis as the mylonite zone

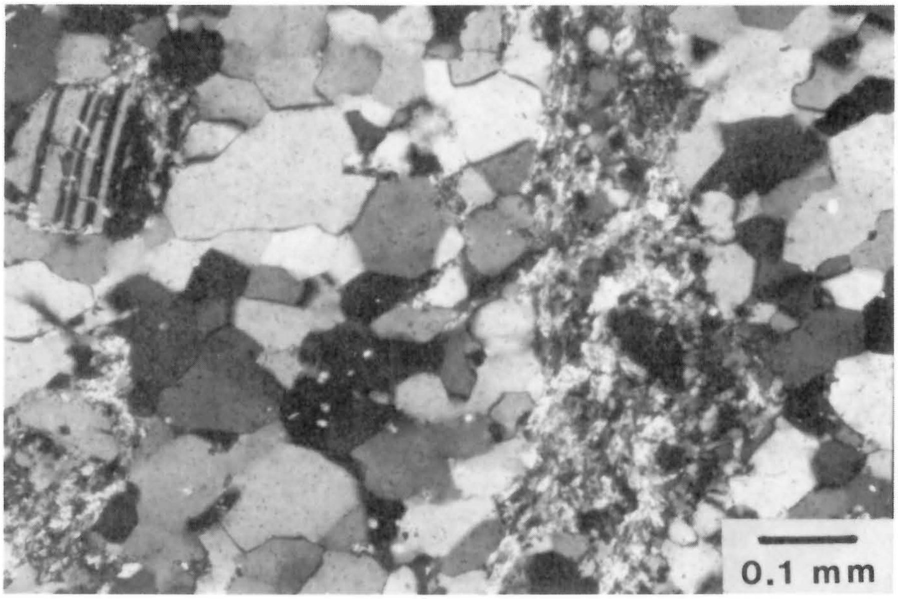


FIGURE 34: Photomicrograph (polarized light) of mylonite gneiss. Note the more rational crystal boundaries.

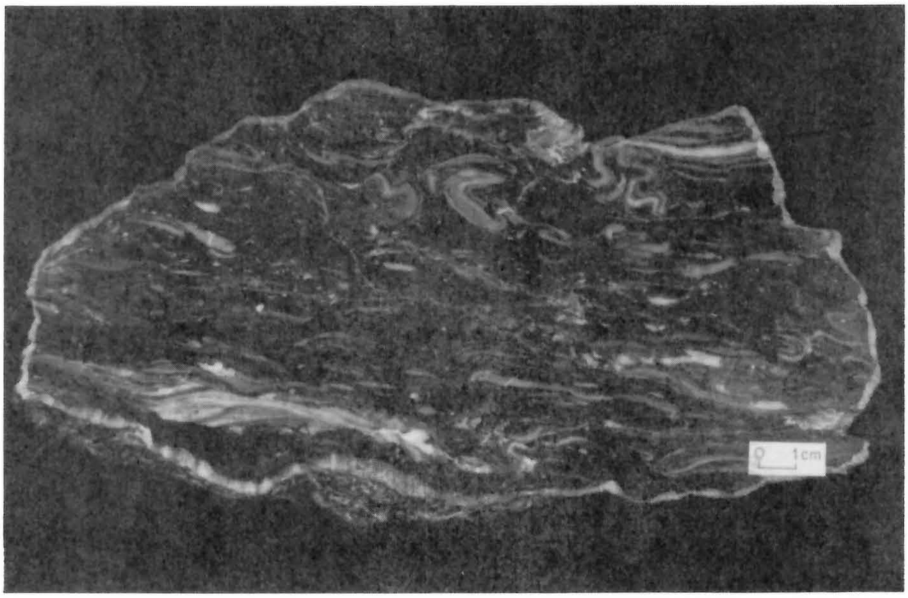


FIGURE 35: Irregularly folded and dismembered fragments of early mylonite with a pyrite-enriched later mylonite.

FIGURE 36: *Kink-folds in laminated mylonite, developed along surfaces of décollement.*

is approached. This progressive cataclasis, also observed by Haugh (1969) in the Split Lake-Assean Lake areas, is a consistent feature of cataclasis associated with the northern segment of the Churchill-Superior boundary zone.

The least deformed zones display only minor granulation along crystal boundaries (Fig. 37). Quartz is typically highly strained with irregular crystal boundaries, and feldspars are variably deformed internally with comminuted margins. The original biotite is finely granulated and interleaved with chlorite and muscovite. These mafic zones are commonly smeared out into fine grained stringers between felsic minerals to form a discontinuous microscopic fluxion texture.

This degree of cataclasis results in only minor changes to the megascopic appearance of the granite gneiss. However, alteration of the mafic minerals lightens the colour of the rock.

Specimens from an outcrop approximately 200 m from the major mylonite zone show an increase in granulation and recrystallization (Fig. 38). The feldspars are deformed and often fractured and rotated with fragments up to 0.4 mm. Quartz up to 2.5 mm is granulated and recrystallized into aggregates of annealed crystals averaging 0.2 mm. In some specimens these aggregates are augen-shaped. Margins of quartz and feldspar grains are reduced to 0.02 to 0.04 mm granules forming a "crush matrix" between the original grains. Mafic minerals, in this specimen biotite, are altered to very fine-grained (0.01 to 0.03 mm) chlorite, muscovite and biotite within finely comminuted quartz and plagioclase. The mafic-rich zones may coalesce with intergranular crush zones to form incipient fluxion structure.

In hand specimen the rocks show a reduction in overall grain size and lensing of quartz grains. Otherwise the character of the granitic gneiss is retained.

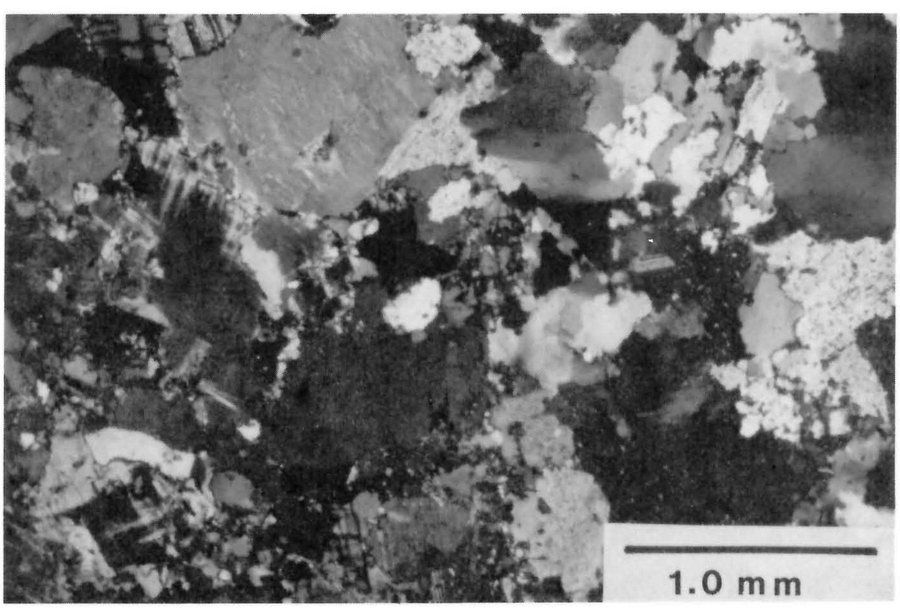
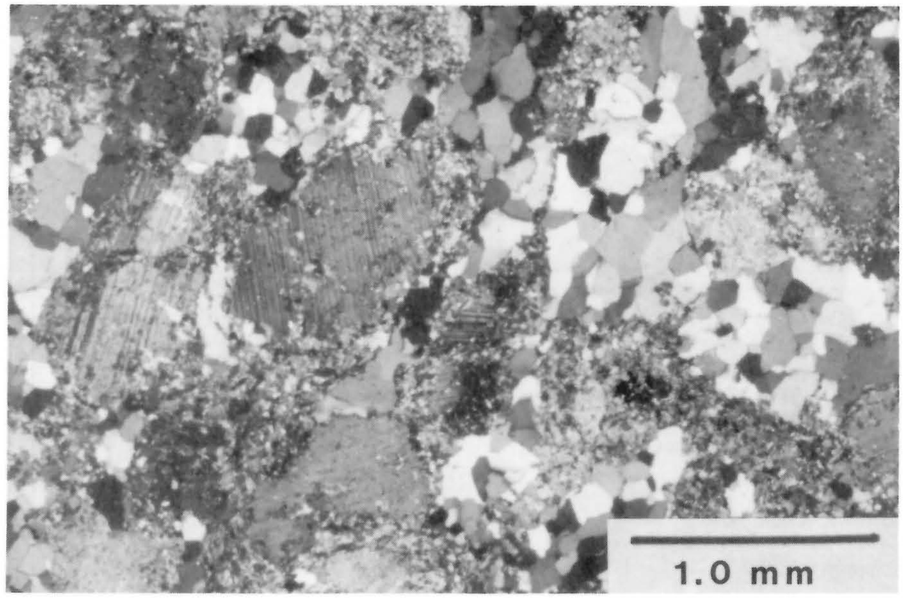


FIGURE 37: *Photomicrograph (polarized light) of a cataclastic granite gneiss (unit 21b) from Little Assean Lake. Quartz is highly strained with irregular crystal boundaries. Feldspars show more strain as the crystal boundary is approached and have granulated zones between the larger crystals.*

FIGURE 38: *Photomicrograph (polarized light) of a cataclastic granite gneiss (unit 21b) from Little Assean Lake.*



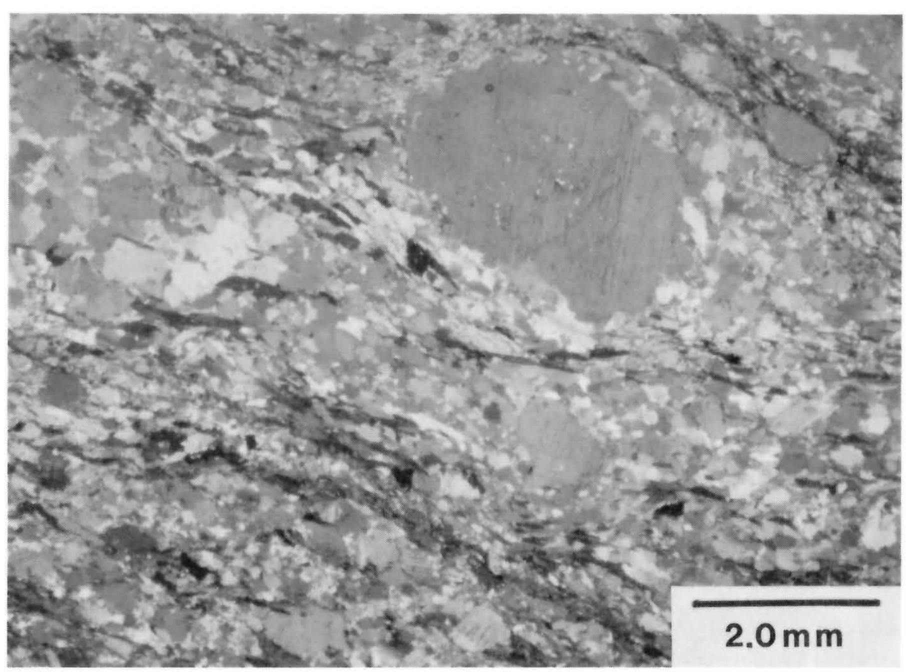
Outcrops bordering the mylonite zones consist of augen-rich rocks verging on protomylonite. These rocks consist of porphyroclasts averaging 3 mm by 1 cm with a few up to 2 to 5 cm. These lenticular fragments are separated by megascopic glide surfaces (Fig. 39) which consist of 0.5 to 1 mm thick zones of finely ground material. Fragments display the characteristic deformational features of previously described rocks. However, mafic minerals within the augen are not severely deformed.

CATACLASTIC AMPHIBOLITE (21c)

Amphibolites within the boundary zone form irregular bodies measuring up to 1 km along strike and fall into two compositional types. The most abundant type consists of hornblende and plagioclase with minor magnetite and sphene. Epidote is a common alteration product of plagioclase. These amphibolites are interpreted as altered and deformed mafic dykes.

The second amphibolite of unknown origin consists of hornblende, plagioclase and quartz with fractured garnets, magnetite and sphene.

FIGURE 39: *Photomicrograph (polarized light) of cataclastic augen gneiss (unit 21b).*



METAMORPHISM

INTRODUCTION

The Superior and Churchill Province segments of the project area experienced significantly different metamorphic histories. Rocks in the Split Lake block contain metamorphic mineral assemblages and textures attributable to both Kenoran and Hudsonian tectonic events — similar to events documented in the Thompson belt. Metamorphic features in metasedimentary rocks of the Gillam-"Moose Lake" area (Churchill Province) are similar to those of the correlative gneisses in the Kisseynew belt to the west.

SUPERIOR PROVINCE

INTRODUCTION

Metamorphic textures and mineral assemblages observed in rocks from the Split Lake block indicate four major metamorphic events:

M_{1a} — amphibolite grade and hornblende granulite grade metamorphism produced metamorphic layering and early migmatites;
M_{1b} — granulite grade metamorphism (Kenoran);
M_2 — middle to upper amphibolite grade metamorphism (Kenoran);
M_3 — greenschist and retrograde greenschist grade metamorphism (Hudsonian).

The distribution of granulite grade in the Split Lake block and, where possible, the amphibolite M_2 and greenschist M_3 grade rocks have been plotted on Figure 40.

Recent mapping in the Pikwitonei region south of Split Lake, has focussed on the nature of the granulite terrain and its relationship to the lower metamorphic grade portions of the Superior Province to the east and the Thompson belt to the west (Fig. 41) (Weber, 1976, Weber and Scoates, 1978, Hubregtse 1977, 1980).

The eastern boundary of the Pikwitonei domain is defined as the orthopyroxene isograd produced as a result of prograde metamorphism in the northwestern Superior Province. A preliminary Rb-Sr whole rock isochron age of 2475 Ma indicates a late-Kenoran granulite facies event along the northwestern margin of the Superior Province in Manitoba (Charbonneau and Brooks, in Hugbretse, 1979).

The western margin of the Pikwitonei domain is defined by the eastern limit of a complex tectonic-metamorphic overprint (Fig. 41). This is defined by Weber (1977) and Hubregtse (1978, 1979) as the limit to which Hudsonian tectonic overprinting of the Thompson belt extended eastward on to the Pikwitonei granulite terrain. Metasomatically altered Archean gneisses of the Thompson belt produced a Rb-Sr whole rock age of 1720 Ma (Charbonneau and Brooks in Hubregtse, 1979). Thus rocks of Archean origin, belonging to the Pikwitonei region of the Superior Province, were reworked and intruded during the Hudsonian orogeny. The Split Lake block represents an isolated portion of the Archean granulite terrain which has undergone variable amounts of reworking during the Hudsonian orogeny.

The extent to which Hudsonian retrograde metamorphic events were able to alter Kenoran granulite and amphibolite grade assemblages within the Split Lake block was dependent upon availability of water and other volatiles and the peak temperature and pressure conditions attained. Thus small areas of rocks with granulite mineral assemblages, surrounded by partially retrograde zones, were preserved where the migration of volatiles had not penetrated prior to the end of the retrogressive metamorphism. Similarly significant areas of M_2 amphibolite grade rocks have been preserved or only suffered partial retrograde metamorphism by the M_3 middle greenschist event. Factors controlling the observed metamorphic assemblages are:

1. The proximity to mobile belts in which unit 9 tectonized migmatites formed during the M_3 metamorphic event.
2. The intrusion of late granitic rocks, unit 8.
3. D_3 cataclasis and mylonitization.

M_{1a} METAMORPHISM

Characteristic features which can be unequivocally attributed to M_{1a} metamorphism are rarely preserved. However, a significant number of features are best explained by an early high grade metamorphic event. Elsewhere in the Pikwitonei region, Hubregtse (1980) has documented an early hornblende granulite (M_1) metamorphism which could be equivalent to M_{1a} in this report.

On Indian Reserve 171B evidence of a metamorphic event (M_{1a}) prior to the pyroxene granulite metamorphism (M_{1b}) is observed. Here tonalite (unit 4) displays relict granoblastic textures typical of M_{1b} metamorphism indicating intrusion before the M_{1b} metamorphic event. Within the tonalite are randomly oriented inclusions of layered amphibolite and gneiss (unit 1). The formation of these gneisses, prior to inclusion within the tonalite, indicates a period of metamorphism (M_{1a}) predated the major M_{1b} granulite metamorphism.

Field relationships in the amphibolite belt east of Birthday Rapids indicate that the M_{1a} event was upper amphibolite to granulite grade. Clinopyroxene-garnet-bearing mobilizate, formed during M_{1b} granulite metamorphism cross-cuts early metamorphic layering in amphibolite (unit 1). M_{1a} granulite facies minerals, only partially re-equilibrated during the M_{1b} metamorphism, were observed in a single amphibolite sample, where the following reaction was indicated:

orthopyroxene + plagioclase = garnet + clinopyroxene + quartz.

M_{1b} GRANULITE GRADE METAMORPHISM

Pyroxene granulite and hornblende granulite facies assemblages of Kenoran age are locally preserved in the map area (Fig. 40). The widespread occurrence of relict granoblastic textures typical of the granulite rocks indicates regional extent. However, M_{1a} and M_{1b} metamorphic assemblages can only rarely be distinguished because they were of similar grade and are typically partially altered by subsequent lower grade metamorphic events. Thus the following description of M_{1b} granulite assemblages may also include those formed during the earlier M_{1a} metamorphism.

Mineral assemblages observed within mafic gneiss, amphibolite and metagabbros consist of:

clinopyroxene + orthopyroxene + plagioclase in the hypersthene granulites; and

clinopyroxene + orthopyroxene + hornblende + plagioclase in the hornblende-bearing granulites.

Plagioclase in these associations is typically An_{45} to An_{52}.

Field relationships indicate later mobilizates containing garnet and clinopyroxene are associated with restites in which the following reaction is observed:

orthopyroxene + plagioclase = garnet + clinopyroxene + quartz.

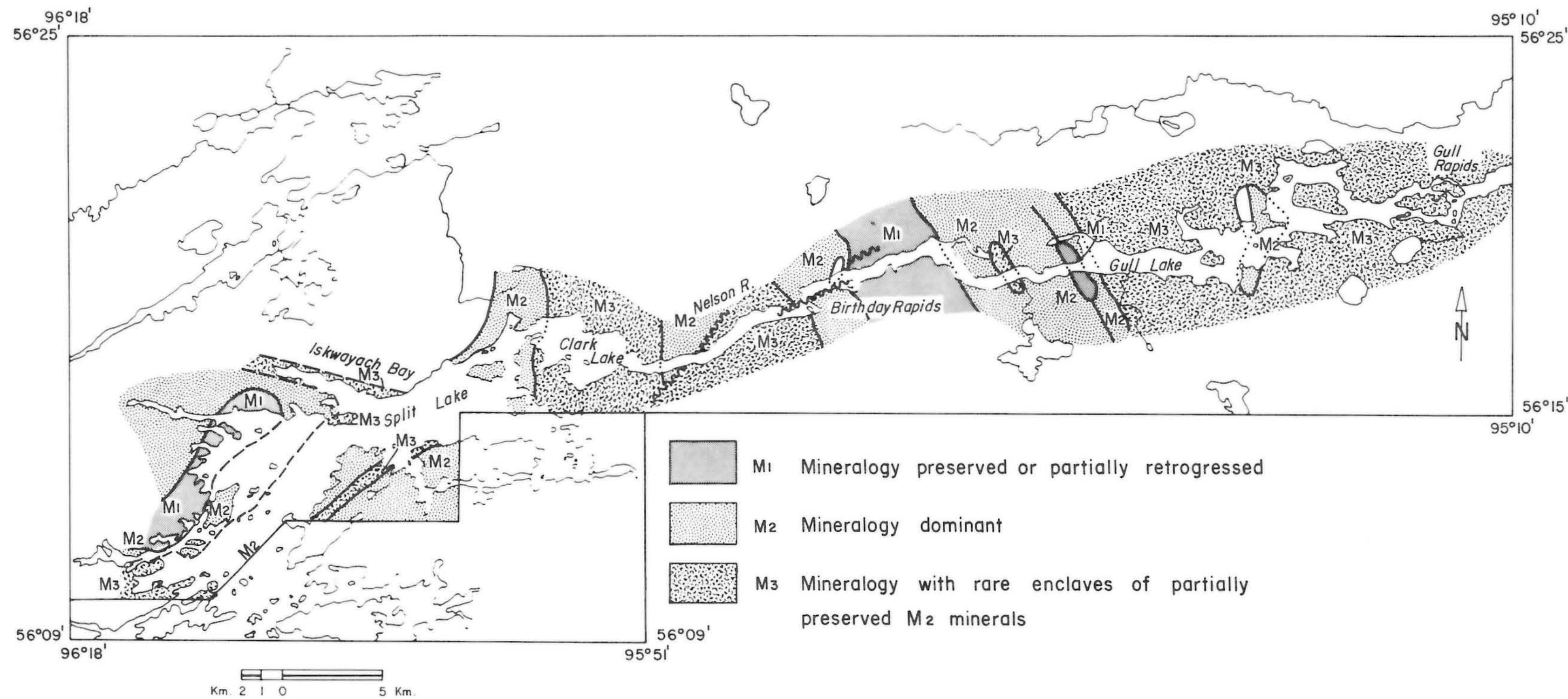


FIGURE 40: Distribution of M_1, M_2 and M_3 metamorphic zones in the northeast Split Lake block.

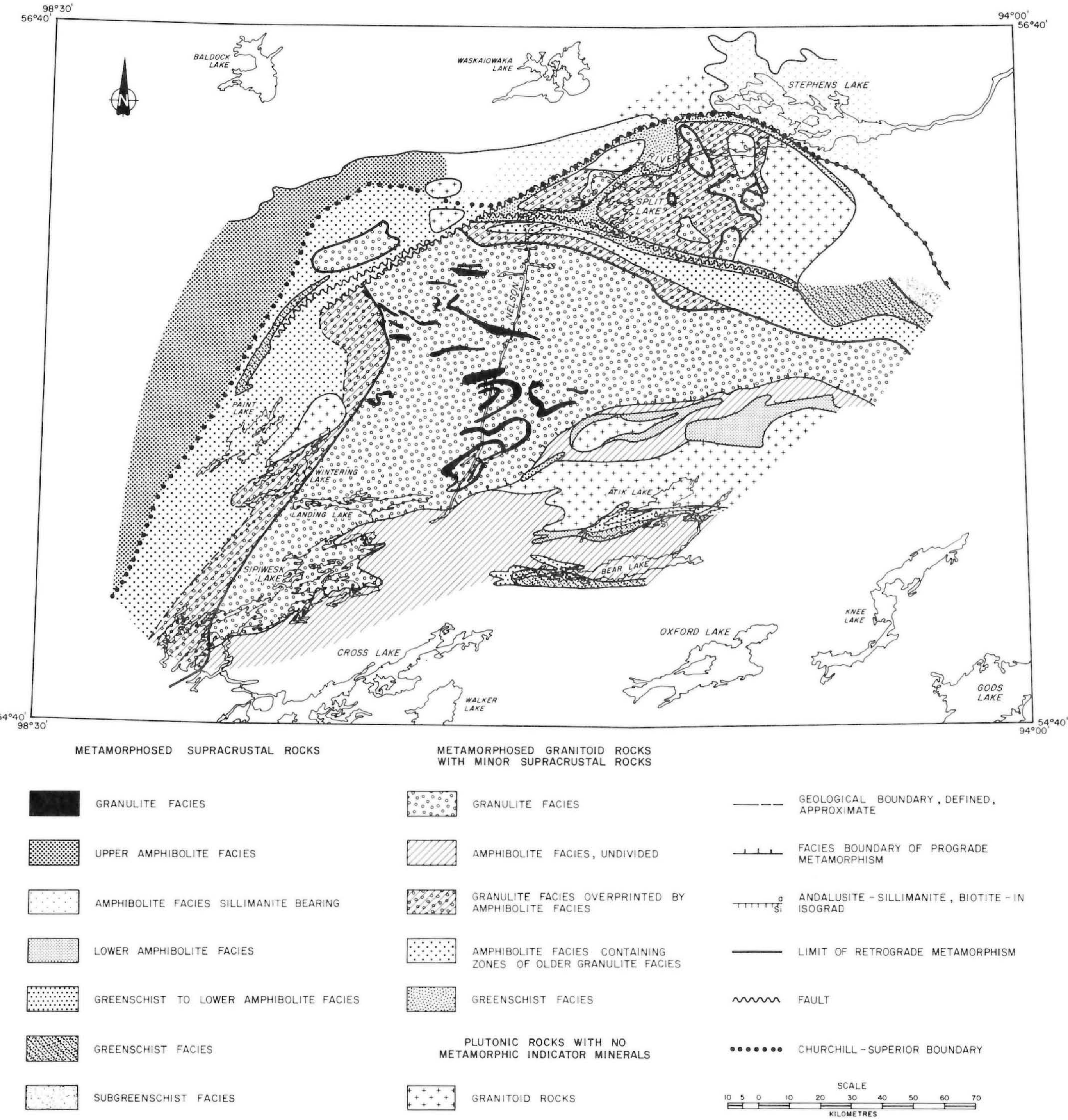


FIGURE 41: *Metamorphic zones in the Churchill-Superior boundary area of northern Manitoba.*

Winkler (1977) equates this reaction to experimental temperatures of 700°C with pressures in the 8 to 10 kb range. These granulites contain the assemblage:

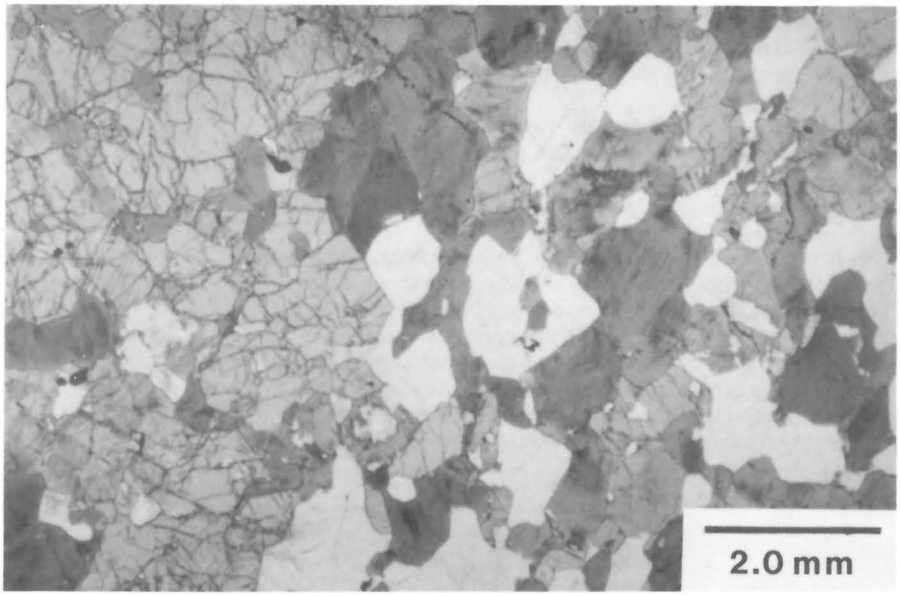
clinopyroxene + garnet + plagioclase + hornblende + orthopyroxene

In hornblende granulites which contained only a few per cent orthopyroxene, all of the orthopyroxene has reacted to form garnet, clinopyroxene and minor quartz (Fig. 42).

These garnet-bearing assemblages and associated mobilizates are interpreted as M_{1b} metamorphic associations which represent a second high grade Kenoran event, probably equivalent to Hubregtse's (1980) M_2 event in the Pikwitonei domain.

Granulite facies assemblages are rarely preserved within rocks of granitic composition. These rocks appear to have been more susceptible to retrogressive metamorphic processes than the mafic rocks.

FIGURE 42: *Photomicrograph (plain light) showing M_{1b} garnet-hornblende-clinopyroxene metamorphic assemblage.*



However, in partially retrograde tonalite (unit 4), the assemblage observed is:

hornblende + clinopyroxene + garnet + biotite.

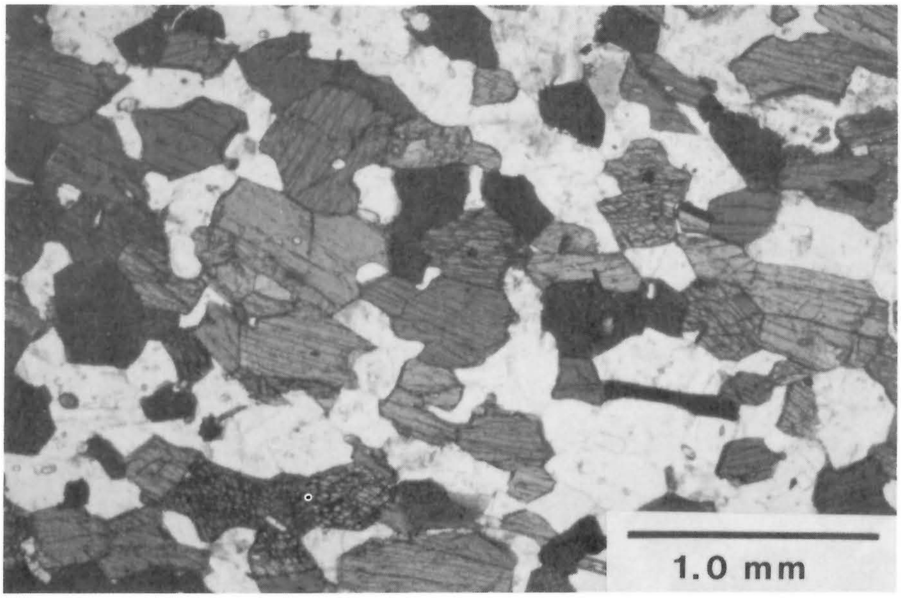
Since these rocks have been subjected to both M_2 amphibolite and M_3 greenschist grade metamorphism, it is uncertain whether the mafic pseudomorphs were originally orthopyroxene. In the same unit in the Ilford area Hubregtse (1975) reported preserved hypersthene-bearing opdalite-enderbite rocks.

Well developed fine grained granoblastic-polygonal fabrics are typical in unit 5 restite and unit 1 metagabbros (Fig. 43); within associated mobilizates porphyroblasts of clinopyroxene and garnet, from 0.5 to 3 cm, are contained within a medium grained feldspar mosaic. Throughout most of the Split Lake block, retrogressive metamorphic events have completely altered the granulite mineral assemblages. This resulted in a characteristic relict granulite fabric which is observed in many locations within units 1 to 5. The occurrence of this widespread relict texture throughout the Split Lake block indicates that granulite grade events were of regional scale. It is, however, impossible to delineate the extent of hornblende and/or hypersthene granulite areas due to the intense recrystallization and reworking during M_2 and M_3 metamorphic events.

M_2 AMPHIBOLITE GRADE METAMORPHISM

M_2 metamorphism was a regional event of amphibolite grade, preserved sporadically throughout most of the northeast Split Lake and in the Gull Lake area (Fig. 40). It is associated with late Kenoran deformation and intrusive events in which unit 5 migmatite belts were formed. The metamorphism is not restricted to the mobile belts and distinctive

FIGURE 43: *Photomicrograph (plain light) of fine grained granoblastic-polygonal texture in hornblende-clinopyroxene metagabbro (unit 1).*



relict granoblastic textures and pseudomorphs replace the early granulites. Later M_3 greenschist metamorphism strongly altered the rocks in many areas, making it difficult to assess the total areal extent of the M_2 metamorphism.

M_2 mineral assemblages associated with non-migmatitic, pseudomorphed M_1 granulite minerals are relatively consistent and comprise:

hornblende + plagioclase (An_{30-35}) + quartz + garnet + epidote + minor biotite.

Garnet occurs only in retrograde granulite rocks which were originally garnetiferous. These appear to be M_{1b} garnets which remained metastable in the amphibolite grade metamorphism. The breakdown of M_{1a} and M_{1b} calcic plagioclase and hornblende resulted in formation of less calcic plagioclase, epidote and green hornblende. The occurrence of biotite in the rocks is restricted to the opdalite-enderbite suite.

The pseudomorphed granulite assemblage is ascribed to the introduction of water into dry granulites which were subjected to amphibolite metamorphism. This is indicated by the replacement of the anhydrous granulite mineral assemblage comprised dominantly of pyroxene, plagioclase and garnet to M_2 amphibolite hydrous minerals, hornblende, biotite and epidote. Resultant relict textures show no obvious preferred mineral alignment.

Mineral assemblages in unit 5 migmatites typically comprise:

hornblende + plagioclase (An_{30} to An_{35}) + biotite + quartz + epidote + microcline.

The addition of M_2 light brown biotite and minor microcline is likely due to increased availability of potassium associated with the granodiorite-granite magmas injected into the migmatites. M_{1b} garnet which was stable in undeformed zones is rarely preserved. Garnet remnants, associated with green hornblende, biotite and quartz (Fig. 44) are found in some specimens from unit 5 migmatites (Fig. 45).

The most common and characteristic M_2 mafic mineral is a highly pleochroic sea-green to pale-yellow, or green-brown to yellow hornblende. These amphiboles define the typical M_2 pseudomorphs and are

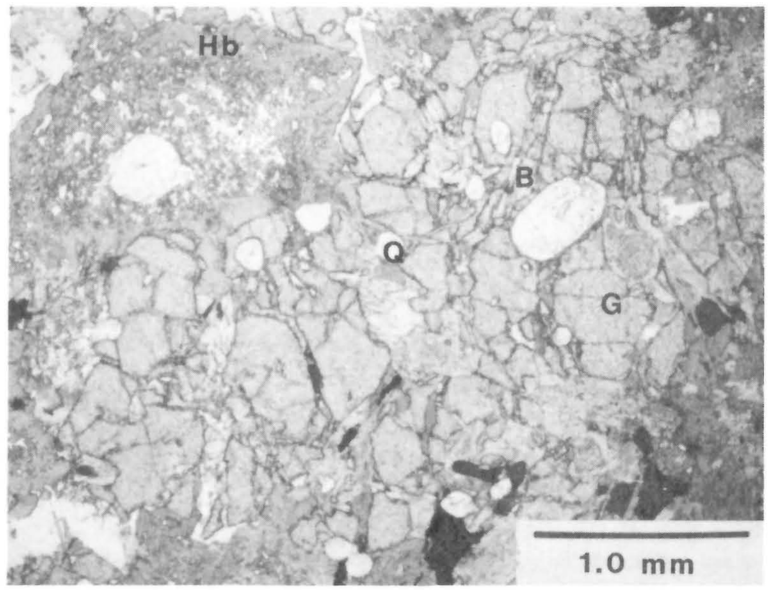


FIGURE 44: Photomicrograph (plain light) of M_{1b} garnet (G) porphyroblasts with M_2 hornblende (Hb), biotite (B) and quartz (Q) along the internal fractures.

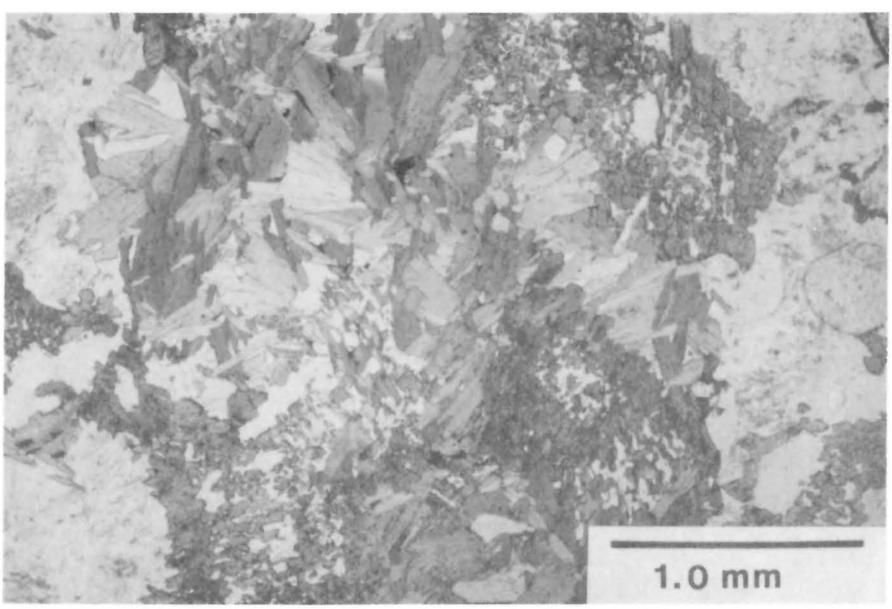


FIGURE 45: Photomicrograph (plain light) of pseudomorph after euhedral M_{1b} garnet.

distinct in colour and habit from the dark brown to olive green hornblendes of hornblende granulite association.

Hornblende associated with M_2 metamorphism occurs in three distinct forms, each being characteristic of the mineral which the hornblende has replaced. Hornblende pseudomorphs after clinopyroxene form poikilitic aggregates of green hornblende and quartz (Fig. 46) or an aggregate of euhedral hornblende grains with interstitial quartz. Orthopyroxene alters to platy aggregates of green hornblende (Fig. 47), whereas M_1 hornblende is replaced by large green hornblende crystals with a distinctive closely spaced cleavage and minute magnetite grains (Fig. 48).

These three hornblende modes are relatively consistent throughout the area. Figure 49 depicts relict M_1 granoblastic textures with M_2 metamorphic overprint.

M_3 GREENSCHIST GRADE METAMORPHISM

The extent of retrograde M_3 assemblages is extremely variable, and areas which are least affected have been described in the previous sections. In most rocks, some greenschist mineral assemblages exist. Areas consisting totally of M_3 greenschist facies assemblages are associated with the tectonized migmatites (unit 9) in central Split Lake and from Clark Lake to Birthday Rapids (Fig. 40). Within these rocks complex intergrowths of fine- grained metamorphic minerals overprint the original M_1 and M_2 textures which are generally still recognizable.

The dominant mineral assemblage attributed to the M_3 metamorphism is:

amphibole (actinolite) + chlorite + plagioclase + epidote + quartz + potassium feldspar

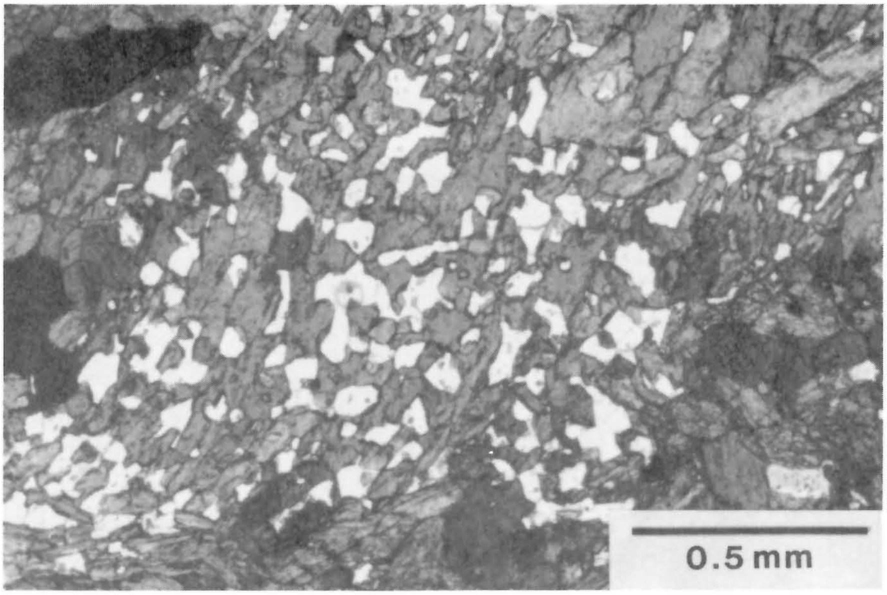


FIGURE 46: *Photomicrograph (plain light) of M_2 hornblende-quartz aggregate pseudomorph after clinopyroxene.*

FIGURE 47: *Photomicrograph (plain light) of platy aggregates of M_2 hornblende after orthopyroxene or clinopyroxene.*

FIGURE 48: Photomicrograph (plain light) of a green M_2 hornblende with dusty magnetite which has pseudomorphed brown M_1 hornblende.

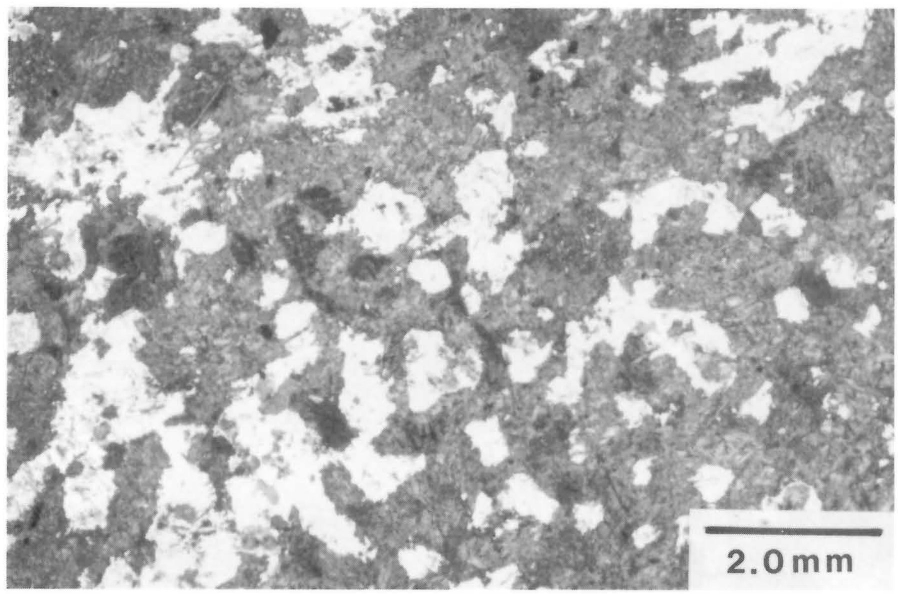


FIGURE 49: Photomicrograph (plain light) of relict M_1 granoblastic textures in M_2 metamorphic zone.

Minor amounts of calcite, muscovite, sphene, magnetite and apatite were also formed by M_3 metamorphic reactions.

The degree of M_3 greenschist grade retrogression, as with M_2, appears to have been controlled by migration of a fluid phase into dry assemblages, at elevated temperatures and pressures. Within the Split Lake block, M_3 metamorphism is most intense near the late-tectonized migmatite zone (unit 9) and along zones of cataclasis. These tectonized migmatites and cataclastic zones are parallel to the northeast trend of the Assean Lake fault as well as the east-west Split Lake-Aiken River fault zone. Numerous fault zones provided channels for movement of fluid phases into the area. In areas of limited faulting and fracturing the M_3 recrystallization was extremely localized, and accordingly, large areas of only partially altered higher grade assemblages were preserved.

Corona formation around early mineral phases is typical of the M_3 event. Multiphase, complex coronas between M_2 hornblende-plagioclase and hornblende-biotite are shown in Figures 50 and 51. Hornblende and plagioclase contacts display a complex chlorite-epidote intergrowth, oriented perpendicular to original grain boundaries. Similarly, coronas of epidote and quartz occur between hornblende and biotite. More extensively metamorphosed specimens exhibit epidote inclusions within plagioclase and the cores of M_2 hornblendes are replaced by a fibrous mat of actinolite and chlorite.

Within altered granulites, multi-layer complex coronas are found on pyroxene and to a lesser extent on M_1 hornblende. Figure 52 illustrates fine grained epidote enclosing pale green fibrous actinolite alteration of a clinopyroxene core. This example also documents the formation of characteristic M_3 relict texture produced from granoblastic granulite rocks.

Rocks totally recrystallized during M_3 display complex fine-grained aggregates of greenschist facies minerals. In cataclastic rocks sutured grain boundaries, deformation-induced twinning and in some cases ribbon textures are observed. At some distance from these discrete

FIGURE 50: Photomicrograph (plain light) of relict M_1 granoblastic textures in M_3 metamorphism. Mafic aggregates—dominantly M_2 hornblende (H)—in contact with plagioclase (P) have a corona of epidote and quartz developed during M_3 metamorphism.

FIGURE 51: Depicts M_3 corona development of epidote (E) quartz (Q) between plagioclase (P) and M_2 hornblende (H) and epidote-chlorite (C) corona development between M_2 hornblende and biotite (B).

shear zones, original granoblastic textures of the earlier metamorphic phases can still be observed despite replacement by multi-phase, multi-crystal greenschist assemblages (Fig. 53). The cores of early minerals have been completely replaced by an aggregate of actinolite + chlorite, and plagioclase forms complex intergrowths with numerous inclusions of euhedral epidote.

CHURCHILL PROVINCE

INTRODUCTION

Four metamorphic events have been identified within the Churchill Province sector of the present study area, each of which has produced distinctive assemblages. The first event, M_1, reached upper amphibolite grade. In the second prograde event (M_2) a somewhat higher grade of metamorphism resulted in anatexis. During this event the variably mobilized and injected migmatites associated with S_2 layering and foliation were formed.

Textures developed during M_1 and M_2 are difficult to distinguish in much of the area, as M_2 has overprinted M_1. However, mineral associations and textures attributed to M_1 are preserved in several locations where M_2 conditions during the peak of metamorphism were below the limits of partial anatexis. In these rocks evidence suggests a period of deformation between M_1 and M_2.

The third event was a considerably lower grade retrogressive metamorphism associated with D_3 deformation. A late greenschist grade event, associated with cataclasis, is dealt with in a subsequent section dealing with metamorphism of the Churchill-Superior boundary zone.

A Rb-Sr whole rock isochron determined from greywacke metasediments from units 9 and 11 gave an age of 1700 ± 95 Ma with an initial ratio of 0.7041 ± 0.0013 (Clark, 1981), suggesting that the mineral assemblages were formed during Hudsonian metamorphism. There is no evidence in the Churchill Province sector of the map area to suggest the existence of earlier Archean metamorphic events similar to those observed in the rocks of the Split Lake block.

M_1 AMPHIBOLITE GRADE METAMORPHISM

Present mineral assemblages are all upper amphibolite grade but remnants of metastable minerals and pseudomorphs indicate lower amphibolite assemblages and reactions transitional into upper amphibolite M_2 assemblages. Primitive assemblages indicated in the psammitic rocks are:

quartz + plagioclase + biotite + garnet + staurolite + muscovite + chlorite,

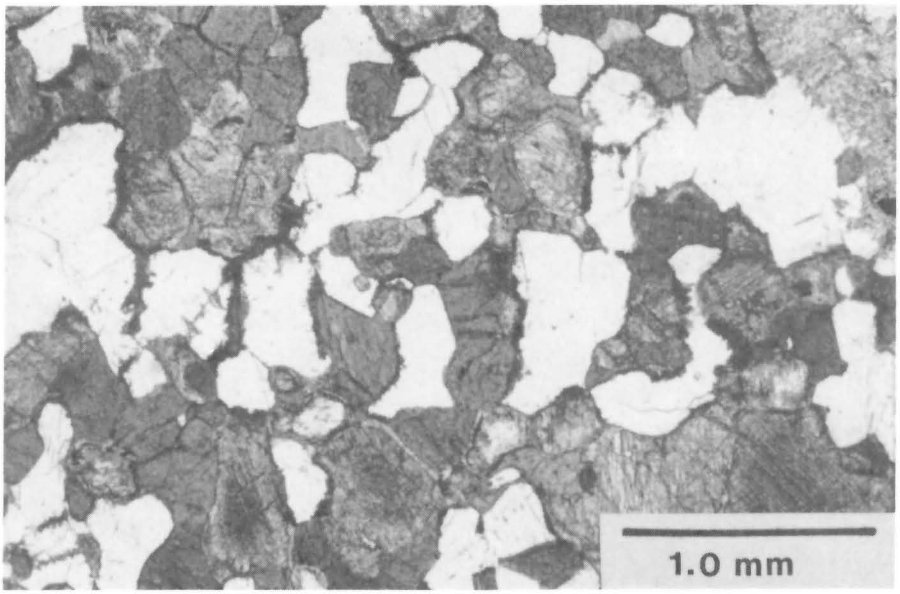


FIGURE 52: Photomicrograph (plain light) of M_3 retrograde metamorphic textures near a fracture (top right) in M_1 granulite grade rocks.

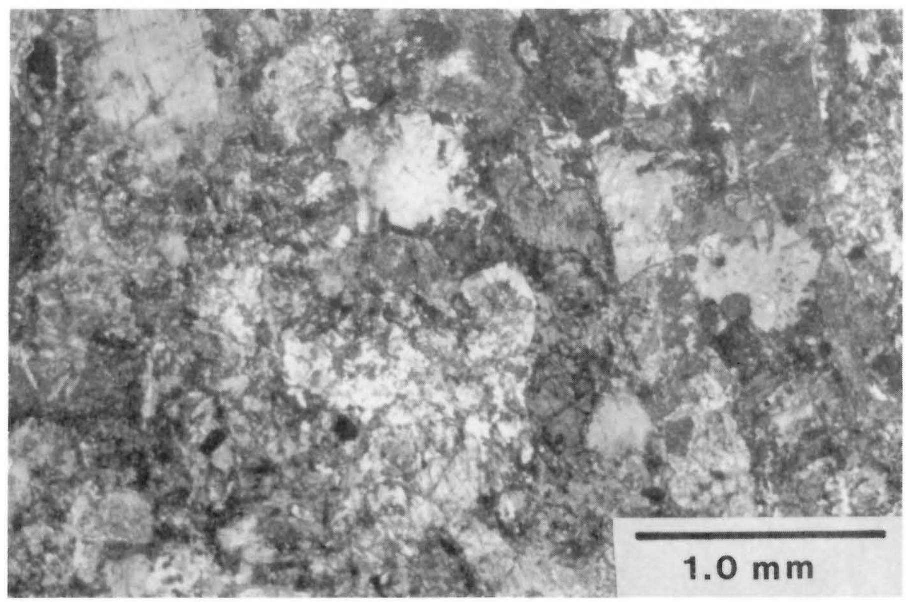


FIGURE 53: Photomicrograph (plain light) of relict M_{1b} granoblastic textures in M_3 metamorphic zone.

and in the pelitic and semi-pelitic rocks:

quartz + plagioclase + biotite + garnet + staurolite + muscovite + chlorite.

In the pelitic rocks the peak of M_1 metamorphism is shown by staurolite breakdown. Two reactions are apparent depending upon the bulk composition of the rock. In muscovite-bearing rocks:

R1 staurolite + muscovite = biotite + sillimanite + garnet.

The textures associated with this reaction are:

- depletion of groundmass muscovite
- formation of sillimanite-quartz knots
- intergrowth of biotite and sillimanite in knots
- growth of anhedral to skeletal garnet surrounding and within the knots. Commonly staurolite remnants remain armoured by plagioclase. This may indicate that muscovite was consumed prior to the depletion of staurolite.

In muscovite-poor rocks staurolite reacted by:

R2 staurolite + quartz = cordierite + sillimanite + garnet.

The associated textures are:

- destruction of staurolite — only rare remnants armoured by quartz or plagioclase remain
- formation of cordierite knots permeated with sillimanite needles (commonly as a staurolite pseudomorph)(Fig. 54)
- overgrowth of inclusion-poor rims of garnet on existing poikiloblastic garnet.

No reaction textures, which could be directly attributed to the M_1 event, were observed in psammitic rocks.

Evidence suggests that muscovite remained stable in the absence of staurolite up to the thermal climax, indicating that M_1 peaked at a temperature below the second sillimanite isograd. It is unlikely that M_1 resulted in partial anatexis.

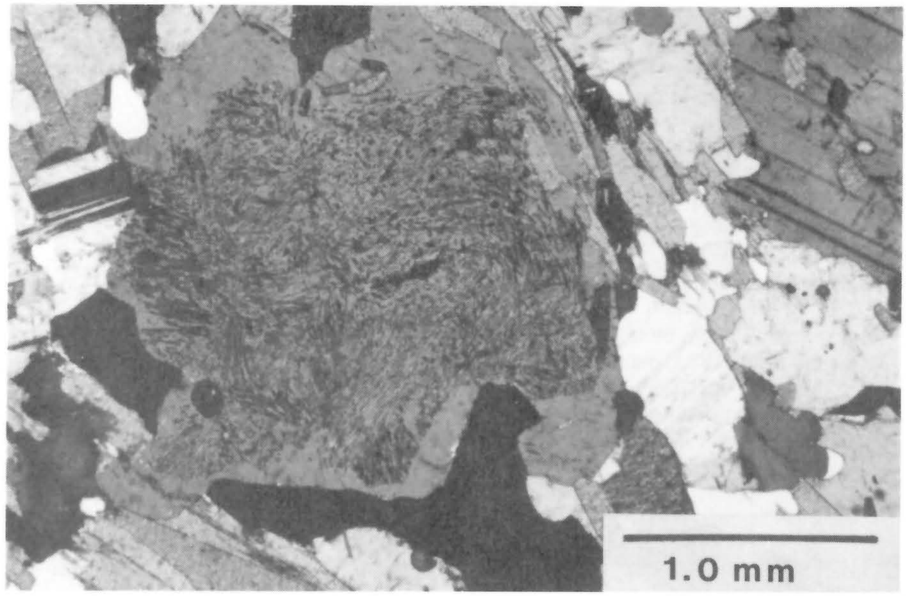


FIGURE 54: *Photomicrograph (polarized light) of cordierite-sillimanite which has pseudomorphed staurolite.*

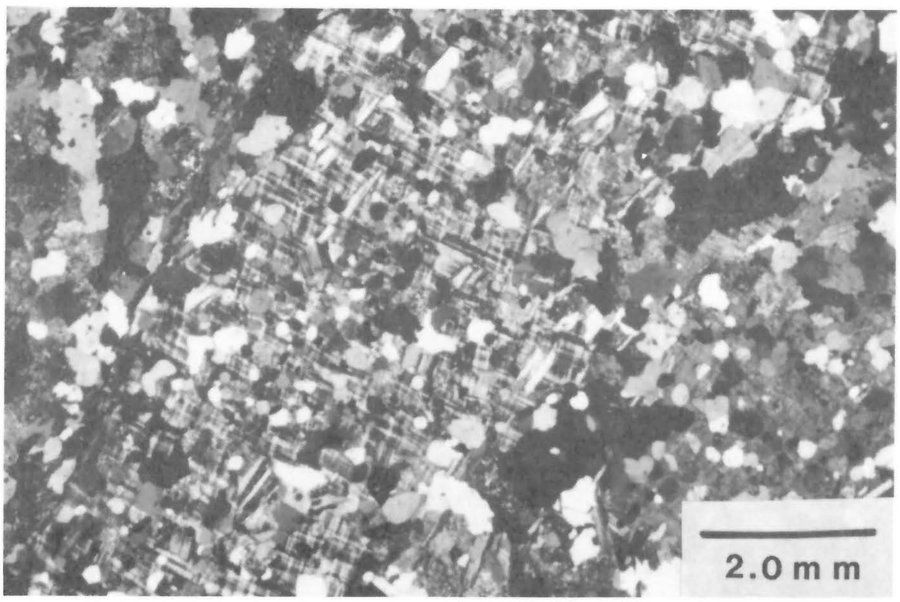


FIGURE 55: *Photomicrograph (polarized light) of poikilitic microcline, within a groundmass of quartz, plagioclase, microcline and biotite.*

Flattening and folding of M_1 sillimanite-cordierite and sillimanite-quartz-garnet knots indicate a deformation event occurred between M_1 blastesis and subsequent M_2 recrystallization.

M_2 AMPHIBOLITE GRADE METAMORPHISM

The M_2 event resulted in mineral assemblages and reactions characteristic of uppermost amphibolite grade. Pressure and temperature conditions at thermal climax range from lowest grade in the Kettle Rapids area where the limit of muscovite stability was exceeded but partial melting did not occur, to regions of extensive partial melting and formation of migmatites in the "Moose Lake"-Gull Rapids areas.

Rocks in the minimum temperature regions display evidence of characteristic reactions involving muscovite instability and incompatability of garnet and microcline. This resulted in the following mineral assemblages in psammitic rocks:

quartz + plagioclase + biotite,
quartz + plagioclase + biotite + microcline,

and in the pelitic and semi-pelitic rocks:

quartz + plagioclase + cordierite + sillimanite + garnet,
quartz + plagioclase + cordierite + sillimanite + microcline.

Reactions and textures characteristic of M_2 are described below.

In the minimum temperature regions, formation of potassium feldspar and sillimanite is controlled by the reaction:

R3 muscovite + plagioclase + quartz = sillimanite + plagioclase + potassium feldspar + H_2O + Na.

This reaction and associated textures have been fully described by Lenton (1981) for equivalent metasediments in the McKnight-McCallum area. In the Gillam-"Moose Lake" area irregularly-shaped light grey poikiloblastic microcline (Fig. 55) forms after albite in association with fibrolite-quartz knots.

Preservation, in lower grade zones, of microcline and sillimanite formed by reaction R3 sets limits to the pressure conditions associated with M_2 metamorphism. Reactions in pelitic metasedimentary rocks from the Gillam-"Moose Lake" area have been plotted on a petrogenetic grid (Fig. 56) adopted from Bailes (1980). In the area of the reaction curve for R3 the lower and upper pressure limits are set by the absence of andalusite, and the absence of partial melt, respectively. The minimum melt reaction is defined by:

R4 plagioclase + potassium feldspar + quartz = H_2O + melt,

resulting in an aggregate reaction:

R5 muscovite + plagioclase + quartz = sillimanite + melt.

Thus reaction R3 can be taken to indicate pressures in the range 2-3 kb for the Churchill M_2 metamorphism.

Apparent instability of garnet in the reaction of garnet and potassium feldspar is described as:

R6 garnet + potassium feldspar = cordierite + biotite + quartz,

R7 garnet + potassium feldspar = biotite + plagioclase + quartz.

Lenton (1981) has described these reactions and the associated textures and indicates that they began at a higher temperature than R3 and continue through the temperature range of partial melt.

Reactions R6 and R7 are dependent upon the availability of microcline. Since metagreywackes are generally deficient in microcline, garnet was not consumed. However, in the islands south of Ferris Bay, microcline-rich psammitic and semi-pelitic rocks (unit 10) contain only rare garnets, preserved as small round inclusions armoured in plagioclase.

In the highest grade regions the limit of sillimanite-biotite coexistence is surpassed and an anatectic component is observed in the rock.

Characteristic assemblages in the psammitic rocks are:

quartz + plagioclase + microcline + biotite,
quartz + plagioclase + biotite + garnet,

and in the pelitic and semi-pelitic rocks:

quartz + plagioclase + biotite + garnet + cordierite,
quartz + plagioclase + biotite + cordierite + microcline,
quartz + plagioclase + biotite + cordierite + garnet + microcline.

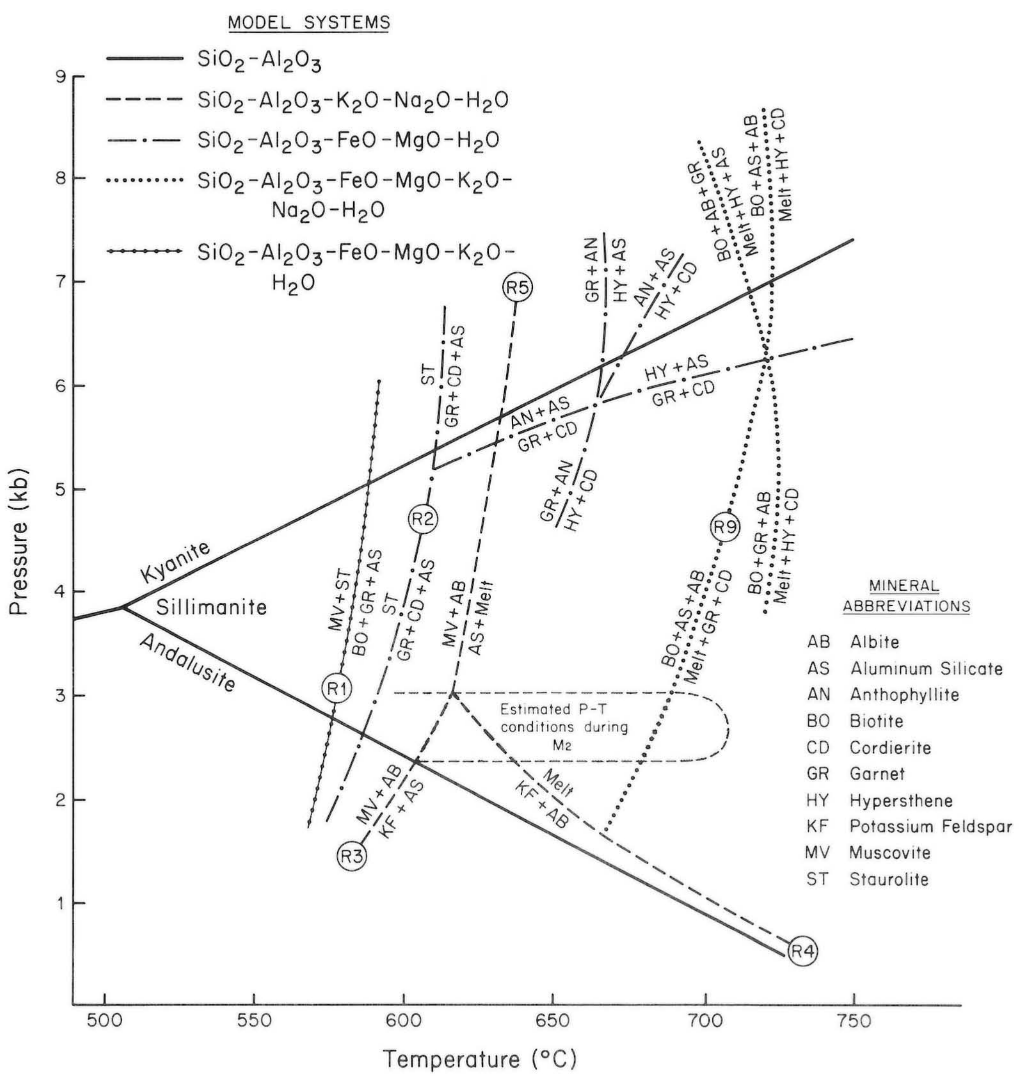


FIGURE 56: Calibrated petrogenetic grid adapted from Bailes (1980) showing metamorphic reactions identified in the pelitic metasediments in the Gillam-"Moose Lake" area.

Granitic mobilizate within metasedimentary rocks in higher grade zones is considered to be anatectic, an inference supported by textures indicating the following reaction in which melt would be formed:

R8 biotite + sillimanite + quartz = cordierite + potassium feldspar + H_2O.

Pelitic rocks from the "Moose Lake" area exhibit reaction R8 in which biotite and sillimanite react to form microcline and associated mobilizates rich in cordierite and microcline.

In zones of pelitic diatexite, east of Gull Rapids, mobilizate containing large euhedral garnets and cordierite may have resulted from the reaction:

R9 biotite + sillimanite + plagioclase + quartz + H_2O = cordierite + garnet + melt

described by Blumel and Shreyer (1977). This would be equivalent to the transition from high grade A to high grade B zones of partial melting described by Bailes and McRitchie (1978) for the Kisseynew sedimentary gneiss belt.

The sequence of reactions described above and shown in Figure 56 for the Gillam-"Moose Lake" area indicates a progressive increase in grade from northeast to southwest. There may also be a similar increase in grade toward the granitic intrusive rocks to the northeast; however, lack of outcrop precludes an interpretation for this area.

M_3 METAMORPHISM

The M_3 metamorphic event documented in rocks from the Gillam-"Moose Lake" area was of considerably lower grade than earlier events. Several distinct mineralogical changes related to the M_3 event have been documented:

- minor sericitization of plagioclase
- local pinitization of cordierite
- biotite-chlorite alteration of garnet
- chlorite-muscovite alteration of biotite in fold noses.

Biotite is stable in this event and a well developed S_3 biotite cross-foliation was produced throughout the area. M_3 garnet-biotite reaction is also associated with the M_3 event. Biotite in the metagreywacke displays a consistent rust brown to pale straw pleochroism throughout the region. However, adjacent to garnet, biotite pleochroism is typically medium green to pale straw. Elphick (1970) interpreted this as an effect of local diffusion of metal ions around the garnets in the pelitic rocks in M_3 metamorphic zones.

CHURCHILL-SUPERIOR BOUNDARY — CATACLASTIC ZONES

A distinct metamorphic event was associated with formation of the cataclastic zones in the Churchill-Superior boundary zone and the adjacent Superior Province and Churchill Province.

In the cataclastic gneiss (unit 21b) on Little Assean Lake significant recrystallization is observed in conjunction with the cataclasis. Within the megascopic cataclastic glide surfaces in these rocks, finely granulated biotite is interleaved with chlorite and muscovite. Associated lenticular fragments of less deformed rock contain unaltered biotite.

Similarly, in the Gull Rapids area, Elphick (1970) indicated that the mylonites consistently contain plagioclase, quartz, muscovite and chlorite. He states that during this event "biotite is unstable and is breaking down to the assemblage microcline and hematite. There is also alteration of biotite to chlorite." Elphick (1970) also describes late potassium mobility along shears as probably the last event, in which microcline was introduced along the shear planes with slight potassium metasomatism around them.

STRUCTURAL GEOLOGY

INTRODUCTION

Two distinct structural domains have been documented in the project area. These major subdivisions correspond to the Split Lake block of the Superior Structural Province and the Gillam-"Moose Lake" area of the Churchill Structural Province. Cataclastic rocks of the Churchill-Superior boundary zone (unit 21), described in the unit descriptions of chapter 3, form an arcuate contact between the structural provinces.

As previously stated, the sequence of geological events is different for rocks in the Superior and Churchill Structural Provinces and only late cataclastic events (D_4 and D_5) related to the major fault zones are common to both sides. Thus, deformational events D_1 to D_3 described below from the Superior Province area are not equivalent to D_1 to D_3 deformational events of the Churchill Province area.

SUPERIOR PROVINCE

INTRODUCTION

Structural fabrics and related metamorphic and intrusive relationships documented in rocks of the Split Lake block have been used to distinguish major deformational events (Table 2). As described in the metamorphic section, varying degrees of preservation of early formed features occur in restricted areas. These inhomogeneities, formed during successive periods of tectonism, assist in recognizing major structural events. The complex nature of reworked migmatite terrains makes a comprehensive deformational history difficult to define — especially in areas of limited outcrop. Thus descriptions of deformation, intrusion and migmatization, which have been defined as a single deformational event, may in fact represent more complex sequences of deformation, which have produced distinctive migmatite suites.

Minor folds and associated planar and linear structures, related to successive migmatite-forming events, define three major structural trends. Early northwest-trending metamorphic layering S_1 with relatively open folds, observed within relict granulite zones and variably preserved within larger reoriented blocks in the younger migmatites, define D_1. The dominant regional fabric was formed during D_2 associated with the development of Kenoran migmatite (unit 5). Trends are northwards in the eastern portion of the area and swing into a south-southwesterly trend in the northeast Split Lake area. The early structures were reoriented and deformed during the Hudsonian D_3 deformation into strongly developed linear belts of northeast-trending tectonized migmatites. D_4 mylonites, cataclasites and discrete shear zones parallel the major northeast- trending Assean Lake cataclastic zone and the east-trending Split Lake-Aiken River cataclastic zone. A late set of north-trending faults formed during D_5.

D_1 DEFORMATION

Early deformational events associated with M_{1a} and M_{1b} metamorphism cannot be distinguished with certainty in most of the Split Lake block due to the intense nature of subsequent tectonic events. However, in granulite and retrograde granulite segments there is at least one set of early folds associated with the M_{1b} granulite grade metamorphism. It is possible that a period of deformation contemporaneous with M_{1a} metamorphism occurred. Amphibolite, metagabbro and associated gneiss (unit 1), which occur as rafts in pre-M_{1b} tonalites (unit 4), exhibit well developed compositional layering (S_0) and contain rare *lits* injected parallel to this layering. Some of the layering may have a tectonic origin but other features of an early deformation are not recognized in this area.

Stereograms of the distribution of S-surfaces in the Clark Lake to Gull Lake segment of the Split Lake block are shown in Figure 57.

In the area of preserved amphibolite (unit 1) east of Birthday Rapids, S_0 layering forms a series of large-scale asymmetrical F_1 folds. In most outcrops the compositional layering is transposed in the steep-dipping northeast-trending axial surface (S_1), of these folds. Where the short limb of the folds is observed, compositional layering, S_0, with a northwest strike and dipping 55° northeast, is cross-cut by enderbitic mobilizate lenses and layers oriented in the S_1 direction. Two large fold hinges plunging northwest at shallow angles (5-° to 10-°), are preserved in this area.

Minor F_1 folds are rare; however, a few tight isoclinal folds in the more highly mobilized portions of unit 1 may have formed during D_1. In the migmatites, which were formed during D_2, rafts of folded unit 1 gneiss were observed in the southern Split Lake area by Haugh (1969).

In northwest Split Lake structural features associated with D_1 were complicated by intrusion of anorthosite. Layering in the marginal phases of the anorthositic gabbro is concordant with the domal configuration of the intrusion. However, the long axis of the intrusion and S_1 layering in anorthositic gabbro have a preferred north-south orientation where they have remained undeformed during the subsequent deformational events. Similar north-south orientations are preserved in unit 1 amphibolite in the extreme northeast of Split Lake.

D_2 DEFORMATION

The most extensive deformation in the Split Lake block was contemporaneous with M_2 amphibolite grade metamorphism.

Migmatitic structures formed during this event are diverse in nature and range from isoclinally folded *lit-par-lit* gneisses (Fig. 58) to schollen gneiss (Fig. 59). The S_2 planar fabric is defined by: (1) *lit* injection, (2) mobilizate layering, (3) weakly developed axial planar foliation in isoclinally folded gneisses, and in schollen gneisses, (4) the long axis of boudinaged and rotated restite layers and rafts within leucocratic injection gneiss.

The orientation of D_2 structures has been significantly modified by later Hudsonian deformation. In Figure 60 major regional trends of S_2 have been delineated. In the eastern segment of the area S_2 and related structures trend consistently to the north. Trends of S_2 in the northeastern portion of the Split Lake area are less consistent; however, a general north trend is observed in areas least affected by Hudsonian deformation. In this area distinctive right lateral deflection of S_2 is observed in association with northeast-trending tectonized migmatite and cataclastic zones.

Major F_2 folds could not be documented due to the disruptive nature of the deformation. The S_0, S_1 layering which was recognized in older gneisses is totally disrupted and large-scale continuity which could be used to define major folding was not observed.

Minor F_2 folds, within more continuously layered gneisses, are predominantly tight to isoclinal with steeply plunging axes within the planar S_2 migmatite layering. Axial planar fabric is generally weakly developed except in more leucocratic biotite gneisses where biotite schistosity and parallel lensoid quartz grains (2 to 5 mm) are observed.

D_3 DEFORMATION

This period of deformation postdates intrusion of most diabase dykes (unit 7) and is attributed to the Hudsonian orogeny. Deformation is contemporaneous with retrograde greenschist metamorphism (D_3) and is responsible for extensive reworking of the Kenoran migmatites

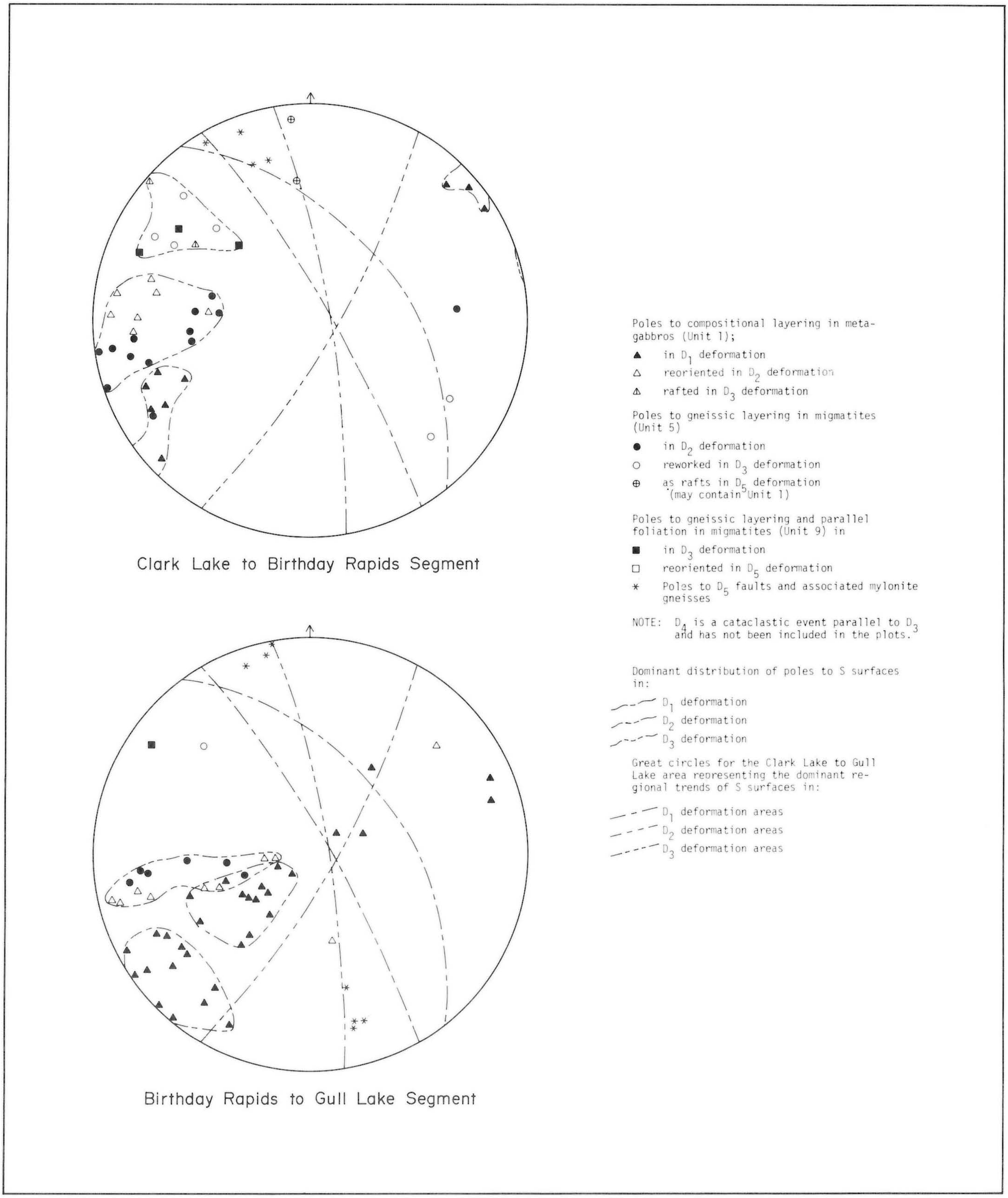


FIGURE 57: Stereograms of the distribution of S-surfaces in the Clark Lake-Gull Lake segment of the Split Lake block.

FIGURE 58: Hornblende gneiss (unit 5) isoclinally folded during D_2 deformation.

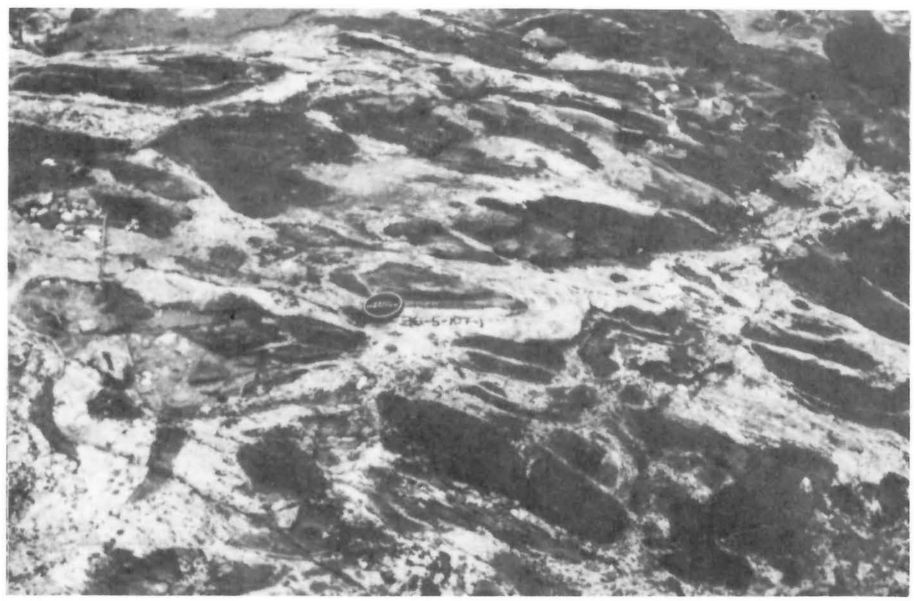


FIGURE 59: Schollen gneiss (unit 5) isoclinally folded during D_2 deformation.

within 2 to 5 km wide northeast-trending belts. On the margins of reworked migmatite belts, earlier planar fabrics (S_0, S_1, S_2) display apparent arcuate right lateral deflections, and numerous inclusions of Kenoran migmatites within reworked D_3 zones are rotated into the steeply dipping S_3 planar fabric, that strikes 060°.

Figure 60 depicts the arcuate Kenoran migmatite belts and their deflection by the major Hudsonian (D_3) tectonized migmatite belts and D_4 cataclastic zones.

Within zones of intense D_3 deformation, heterogeneous highly tectonized migmatites and deformed early intrusive phases are observed. These zones enclose numerous reoriented inclusions of Kenoran rocks up to several hundred metres in size. S, layering is generally transposed parallel to the strongly developed northeast-trending S_3 direction. However, locally the tectonized gneisses (S_3) sharply truncate the earlier Kenoran trend (S_2). Extreme dislocation of the older units is also observed within D_3 tectonic zones. For example, random anorthosite inclusions ranging from a few centimetres to greater than 100 m long are found as variably deformed rafts (Fig. 61) within unit 9 tectonites. Larger inclusions of Kenoran migmatite commonly contain diabase dykes (unit 7) with deformed contacts and schistose margins which retain a pseudomorphed diabase texture in the core. These dykes, where recognized within Hudsonian (D_3) tectonized migmatites, form schistose discontinuous irregular layers in which igneous textures have been destroyed.

A steeply dipping northeast-trending planar fabric is well developed throughout D_3 tectonic zones. This fabric is represented by parallel chlorite-biotite foliation and leucocratic-melanocratic gneissic layering inherited from earlier gneisses as well as further segregation of mafic minerals into discontinuous laminations.

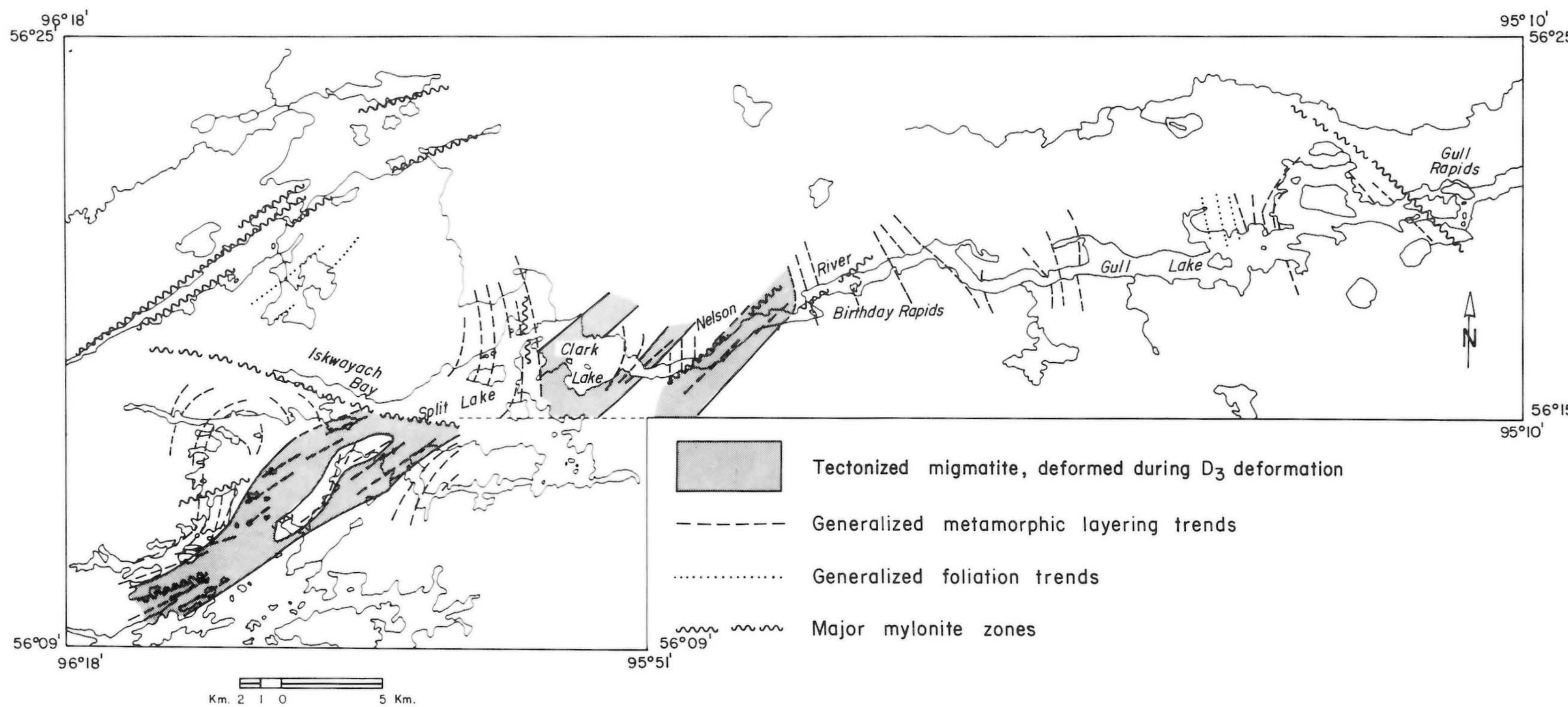


FIGURE 60: *Sketch map of the trends of metamorphic layering and foliation in the northeast Split Lake block. Areas of strong northeast reorientation during the Hudsonian deformation (D_3) are shown in a grey tone.*

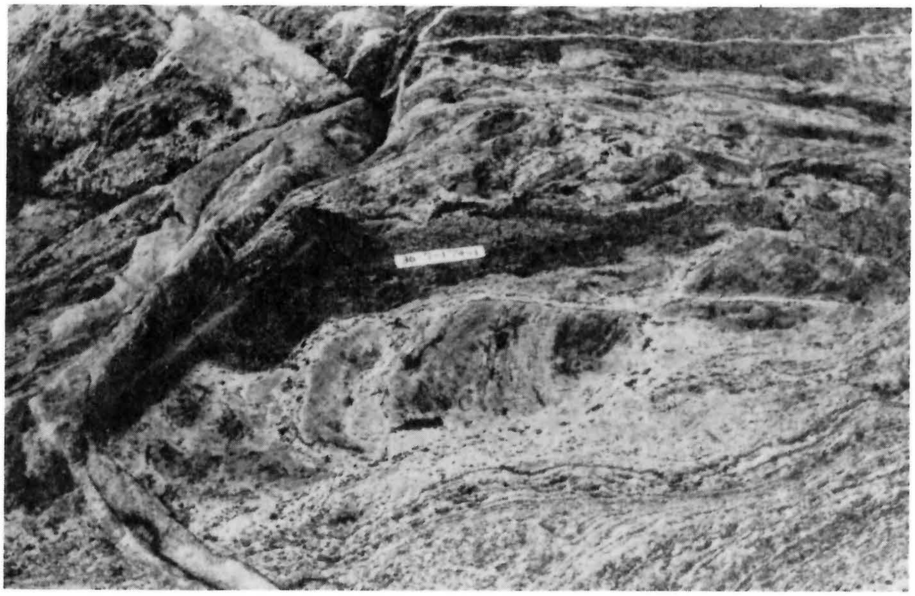


FIGURE 61: *Hudsonian migmatite (unit 9) containing an isolated anorthosite restite inclusion (A).*

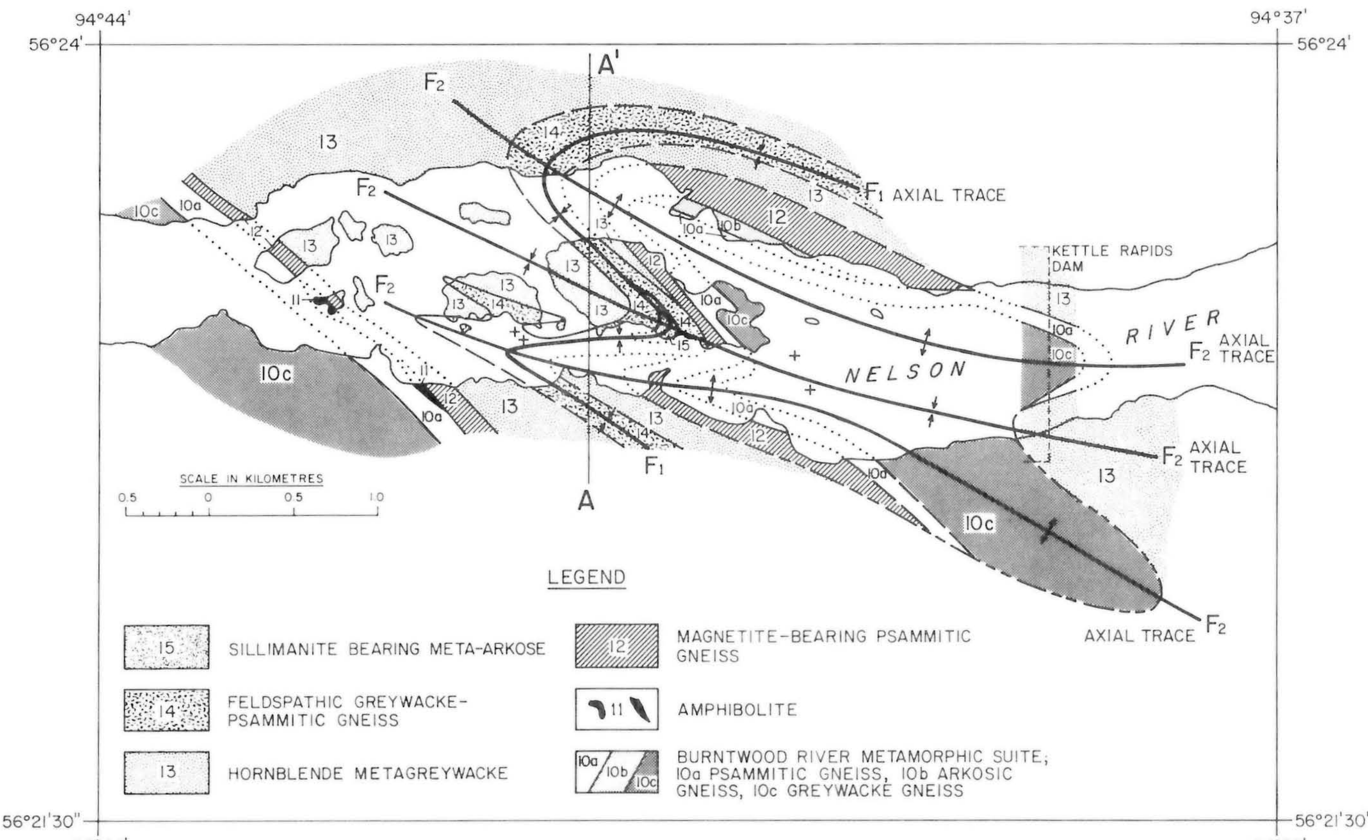


FIGURE 62: *Sketch map of the antiformal dome in the Kettle Rapids structure. A-A' is the section line for Figure 64.*

D_4 CATACLASTIC DEFORMATION

Two sets of faults, represented by narrow mylonite zones, are recognized within the Split Lake block. These faults are parallel to the major Assean Lake and Split Lake cataclastic zones and are considered to be contemporaneous with them. The most extensive zones of mylonite and cataclastic rocks are shown on Figure 60. Data from these zones are insufficient to interpret the extent or sense of movement. However, if truncation of the D_3 migmatite zone in northeast Split Lake is attributed to the east-southeast D_4 fault through Iskwayach Bay, then significant movement is indicated.

D_5 DEFORMATION

The final phase of deformation caused minor north-south faulting. Minor offsets in this direction postdate the major mylonite zones in the Little Assean Lake area.

CHURCHILL PROVINCE

INTRODUCTION

Metasedimentary rocks form an arcuate fold belt with a general west-northwesterly trend in the Gillam area swinging to the west-southwest in the area north of Little Assean Lake. To the south these rocks are bounded by the major cataclastic zone of the Churchill-Superior Province boundary and to the north and east by a dominantly granitic terrain.

Paragneisses in the area have been subdivided into the Burntwood River Metamorphic Suite and the Sickle Metamorphic Suite (Lenton, 1981). As in other areas of the Churchill Province the boundary between these suites is marked by a major change in magnetic susceptibility. The appearance of each suite is distinctive and stratigraphic subdivisions of each suite have considerable lateral extent. Major fold patterns are developed in these units. The folds have been interpreted from shoreline exposures, but are also outlined quite clearly on 1:63,360 scale airborne magnetic maps.

The regional structure is a broad arc described by a steeply north-dipping and north-facing metasedimentary succession of the Burntwood River and Sickle Metamorphic Suites. The arcuate form of the contact is complicated by tight east-trending irregularities which are interpreted to indicate a tightly folded sequence caused by two major periods of deformation. Domal structures expose Burntwood River Suite rocks and basins contain Sickle Suite rocks in an upright sequence.

F_1 folding and F_2 refolding are inferred from the complex disposition of Sickle Suite lithologic units about folded hinge lines in doubly plunging "eyed" folds (Haugh and Elphick, 1968). These structures have been mapped in the Nelson River near the Kettle Dam site and at "Wapicho Rapids". The early structures are commonly obscured by D_2 overprinting which transposed layering and produced a pervasive axial planar schistosity. D_3 is defined by minor Z folds with axial planes generally trending southwest and a persistent weakly developed southwest-trending chlorite-biotite cross foliation.

D_1 DEFORMATION

1) Major folds (F_1) produced during the D_1 deformation have been identified from reversals in the lithologic sequence within Sickle Metamorphic Suite rocks, upstream from the Kettle Rapids Dam site (Fig. 62) and upstream from "Wapicho Rapids". These folds have subsequently been refolded about a steep eastward plunging F_2 axes;
2) Minor F_1 folds in metamorphic layering S_1 are commonly associated with the major folds and have similarly been refolded during D_2.

Structural data from the Kettle Dam area are plotted on Figure 63. Poles to metamorphic layering include a distinct secondary concentration of measurements with shallow northerly dips and variable strike.

D_2 DEFORMATION

Major elongate basin and dome structures were produced during D_2 by superposition of F_2 folds on pre-existing F_1 structures. This interference pattern of folding has been mapped in the "Wapicho Rapids" and Kettle Rapids areas and can also be interpreted from the magnetic signatures of the Sickle and Burntwood Metamorphic Suites on magnetic maps. Refolded minor folds have also been observed on some outcrops.

Near Kettle Rapids (Fig. 62) a tightly folded sequence of Sickle Metamorphic Suite rocks surround Burntwood River Metamorphic Suite metagreywackes in the core of a domal structure. The stratigraphy within the Sickle Metamorphic Suite section indicates the presence of an F_1 isoclinal synform which was refolded during D_2. An idealized cross-section is shown in Figure 64 and a schematic diagram of the entire structure in Figure 65.

Refolded minor folds giving rise to basin and dome interference patterns were also observed on some outcrops. A stereo plot (Fig. 63) for the Kettle Dam area structure shows strongly developed northeast-trending S_2 foliation parallel to the axial planes of minor folds. This S_2 penetrative axial planar foliation was developed and numerous pegmatites were intruded along F_2 axial surfaces. A second concentration of layering directions in the pole girdle is interpreted as a weakly developed S_2 north-trending limb. Intersection of these two planes coincides with the main concentration of fold axes and lineations (Fig. 63). The cross-shaped dispersion of fold axes along these planes may be due in part to transposed F_1 minor fold axes which have been tightened in the subsequent D_2 deformation.

D_3 DEFORMATION

Several features attributed to D_3 deformation were documented by Haugh and Elphick (I968) who noted that "minor Z-folds are ubiquitous and reflect a late stage of deformation in the area. Axial planes, which generally trend southwest, may be sheared, and commonly have dykes of pink pegmatite injected along them." Larger scale Z-folds "were observed at the Kettle Rapids Dam site where such a fold appears to refold an early tight fold" (Haugh and Elphick, 1968). A persistent weakly developed, southwest-trending biotite-chlorite cross foliation, contemporaneous with M_3, defines S_3 surfaces.

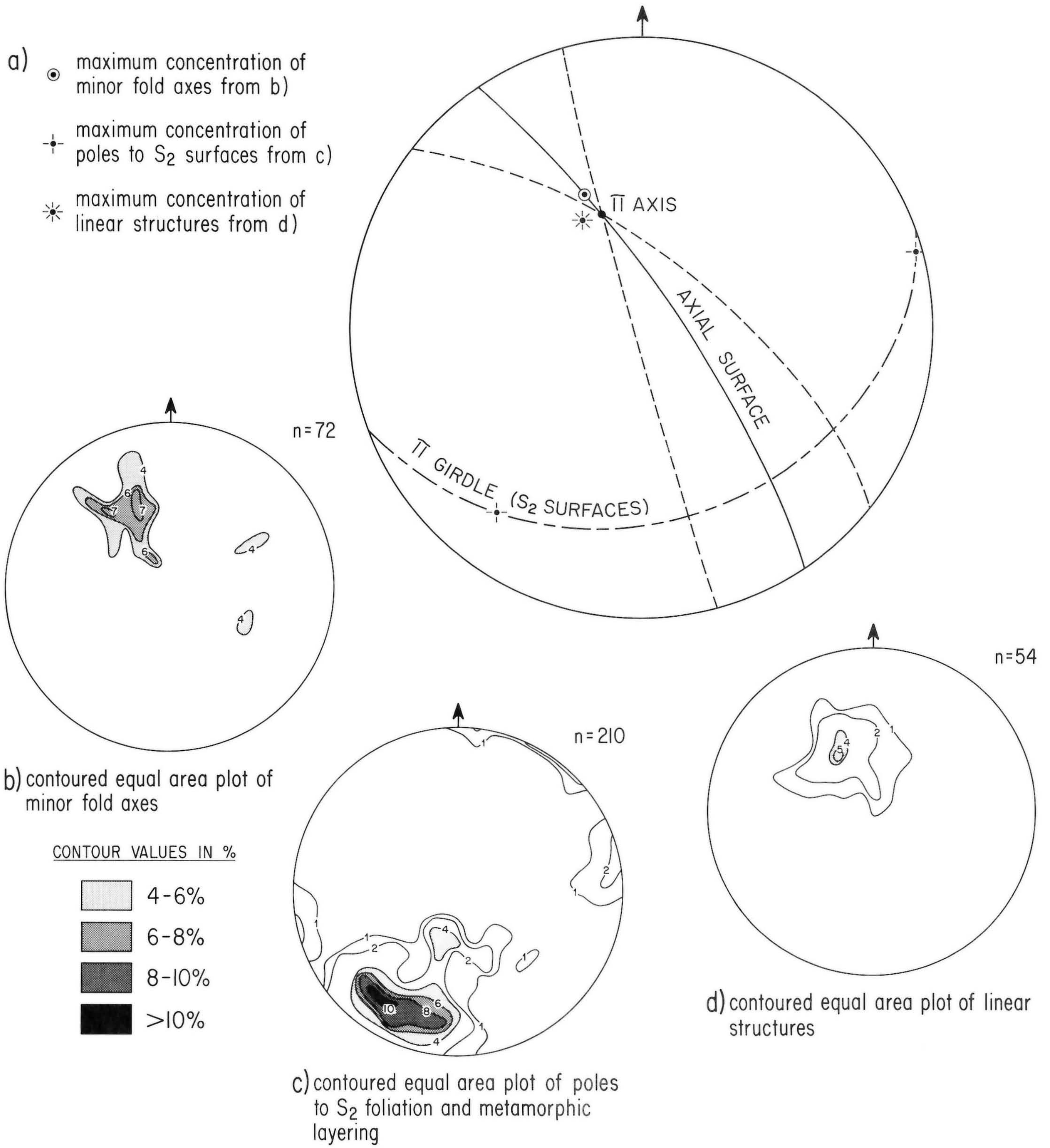


FIGURE 63: Stereographic plots of the structural fabric elements of the Kettle Rapids structure.

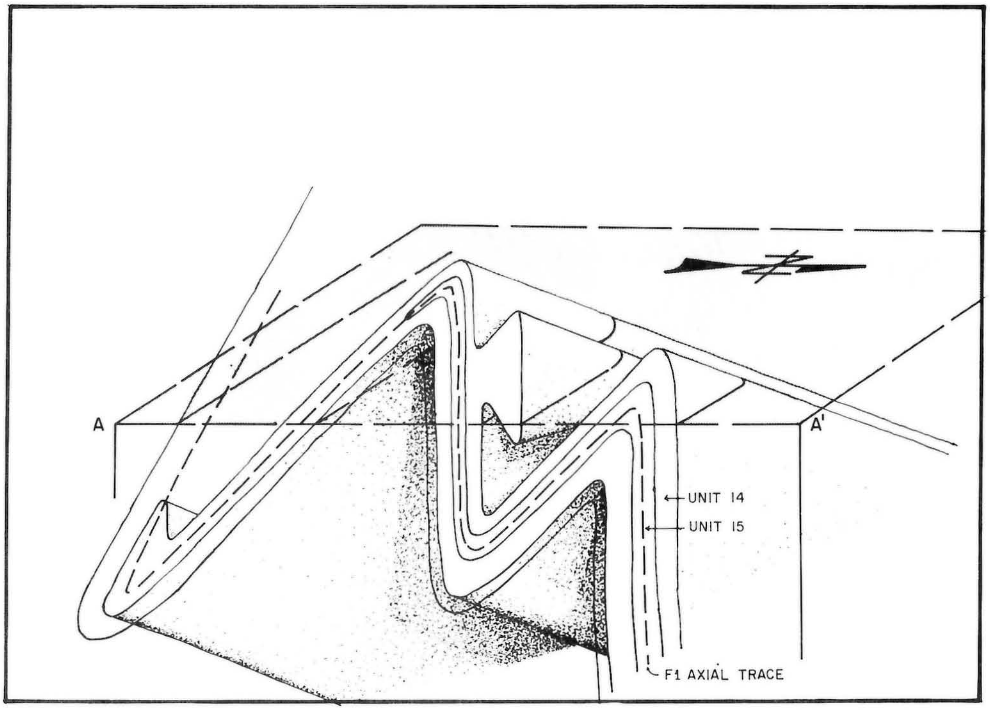


FIGURE 64: *Idealized right cross-section to F_2 folds in the Kettle Rapids structure showing the folded F_1 axial surface within the feldspathic greywacke-psammite gneiss (unit 14) and the meta-arkose (unit 15). Location of the section line AA' is shown on Figures 62 and 65.*

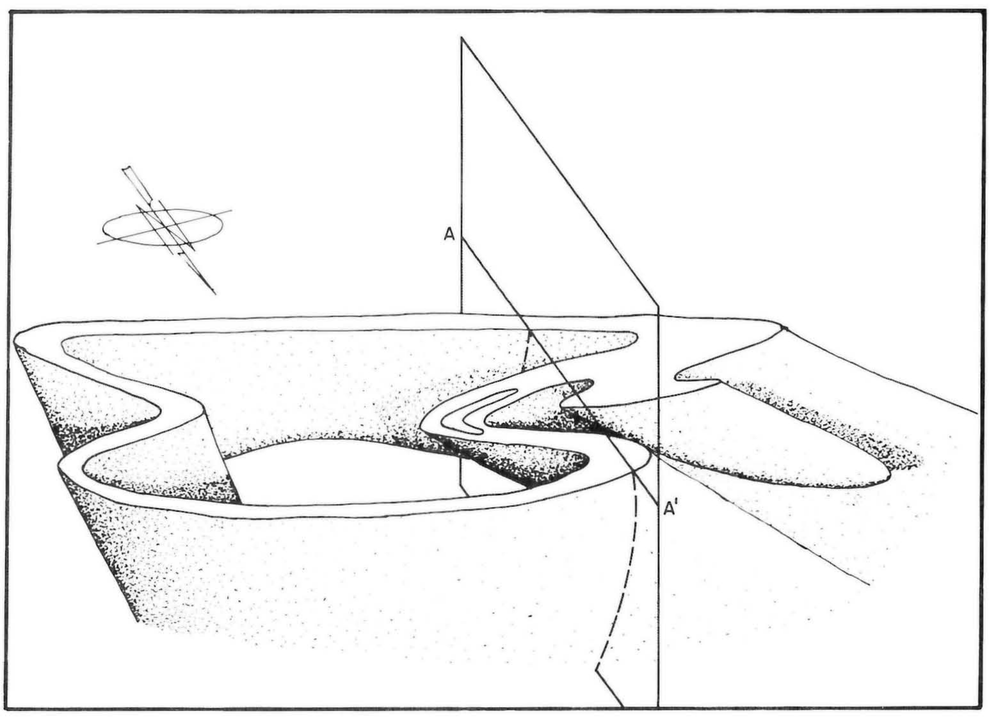


FIGURE 65: *Diagrammatic representation of the Kettle Rapids structure. The folded layer represents the feldspathic greywacke-psammite gneiss (unit 14) of the Sickle Metamorphic Suite. AA' represents the section line in Figures 62 and 64.*

ECONOMIC GEOLOGY

INTRODUCTION

Earliest exploration activity recorded in the area involved prospecting for precious metals in the late 1920's and 1930's. This resulted in the identification of gold prospects in the Assean Lake area; however, no economic deposits were discovered in the region. Subsequent to International Nickel Company's 1956 major nickel discovery in Thompson, exploration interest was again focussed in the region, and as the Thompson Nickel Belt was defined and its consistent relationship with the Churchill-Superior boundary became evident, exploration was extended into the Lower Nelson River area. This activity lasted through the 1960's and has continued sporadically to the present.

SUMMARY OF EXPLORATION ACTIVITY

Most of the following information on mineralization has been obtained from Open File Assessment data submitted to the Manitoba Mineral Resources Division by exploration companies. However, several minor occurrences of sulphides were recorded by Mines Branch geologists during survey mapping programs and the locations of these zones are shown on Figure 66. Results of assessment work are summarized in Table 7 and more detailed summaries from drill core logs are found in Table 8. Figures 67 and 68 show the locations and areal extent of each program documented in the tables.

Extensive airborne surveys were carried out in the area. In general, magnetic and electromagnetic responses were interpreted as resulting from regional variations in conductivity. The scintillometer survey by Atlantic Richfield detected two weak anomalies.

Reports on three diamond drill holes south of Gillam — Try Claims and two further drill holes in the Gull Rapids area: Lac and Ox by Selco — were drilled in Proterozoic metasedimentary rocks of the Churchill Province. Sulphides reported in drill core are generally disseminated with 0.5 to 1 foot (15 to 30 cm) massive zones commonly associated with graphite. Sulphides reported are pyrite and pyrrhotite with minor chalcopyrite and rare sphalerite. Assays from the two drill holes indicate weak copper values and trace nickel with some associated cobalt; however, no significant mineralization was encountered.

Diamond drilling in the Northeast Split Lake-Little Assean Lake area reported no mineralization.

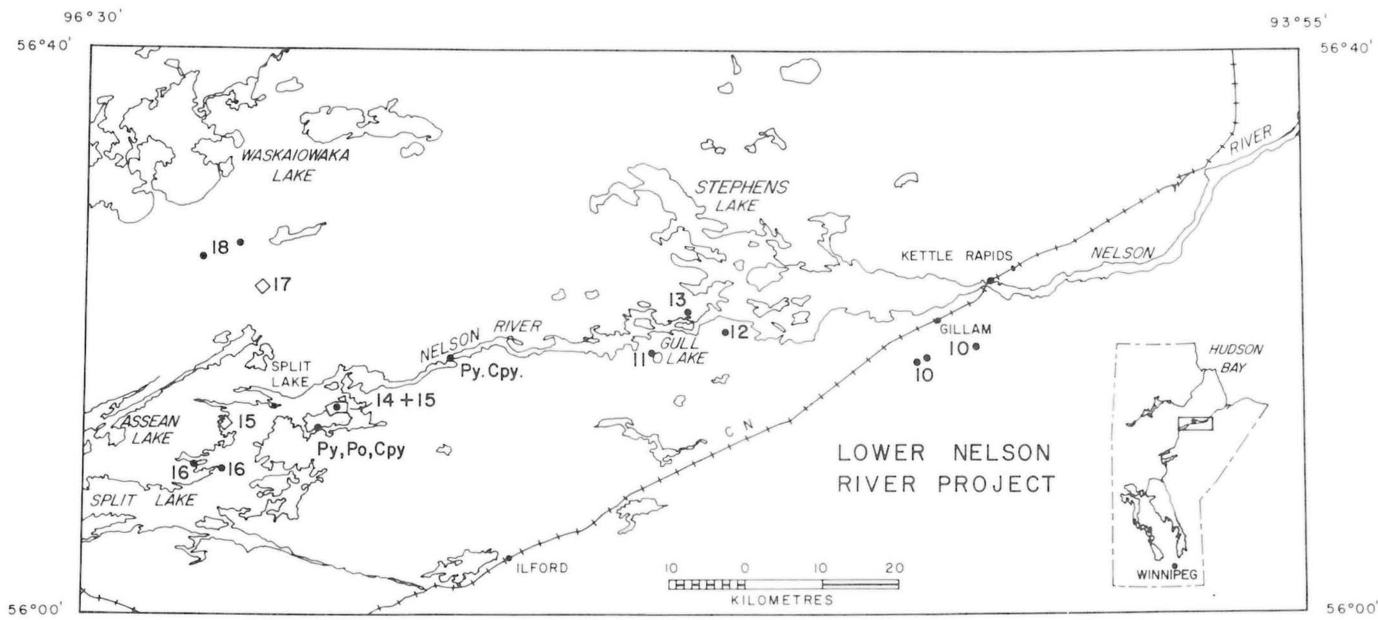


FIGURE 66: Location map for diamond drilling programs described in Tables 7 and 8 and minor mineral occurrences in the Lower Nelson River Project area. Numbers correspond to entries in Table 7.

Table 7: Summary of assessment work from the Lower Nelson River Project area.

No.	Reservation, Airborne Permit number, Claim names	Company Name and Year	Type of Work	Summary of Results	Figure or Table cross-reference
1	Airborne Permit #26	Canadian Nickel Co. 1959	Airborne electromagnetic survey using the International Nickel airborne electromagnetic unit at an altitude of 500' above the ground on ¼ mile line spacing.	Conductivity varies regionally; however, no anomalies with significant response were reported and no ground follow-up resulted.	Figure 67
2	Airborne Permit #28	Kennco Exploration Ltd. 1960	Airborne electromagnetic and magnetic survey was performed by Hunting Survey Corporation. Instrumentation not documented. Flown at 450' on ¼ mile line spacing.	Regional anomalies well represented showing some response to the Churchill-Superior boundary in the southwest. However, no economic responses were indicated and no ground follow-up was done.	Figure 67
3	Airborne Permit #58	Canadian Nickel Co. 1966	Airborne electromagnetic survey using the International Nickel airborne unit at about 500' above the ground. Lines at ¼ mile spacing.	"Conductivity in this area is generally very low".	Figure 67
4	Airborne Permit #60	AMAX Exploration Inc. 1966	AF Mag survey conducted by Hunting Survey Corporation in conjunction with a magnetic survey (using a Varian proton magnetometer model V49379).		Figure 67
5	Airborne Permit #65	Sherritt Gordon Mines Limited 1971	1) Airborne electromagnetic and magnetic survey at 450' above ground. No instrument information available. 2) Reconnaissance geological survey.	No drilling or ground geophysics was performed within the Lower Nelson River project map area; however, in the adjoining area to the south limited drilling was done.	Figure 68
6	Airborne Permit #69	Canadian Nickel Co. 1968	Airborne electromagnetic survey as described in entry #3.	"Conductivity in the Gillam area occurs in a few isolated instances with no major trends indicated".	Figure 68
7	Airborne Permit #72	AMAX Exploration Inc. 1970	Airborne electromagnetic and magnetic survey carried out by McPhar Geophysics using the McPhar F400 AEM system and a Varian V4937 nuclear precession magnetometer. Flight elevation of 450' above ground on ¼ mile spacing.		Figure 68

Table 7: Summary of assessment work from the Lower Nelson River Project area. (continued)

No.	Reservation, Airborne Permit number, Claim names	Company Name and Year	Type of Work	Summary of Results	Figure or Table cross-reference
8	Airborne Permit #74	Atlantic Richfield Company 1968	Airborne scintillometer survey using two SCI radioactive discriminators plus a 5" x 4" sodium iodide (thallium activated) crystal and detector. Lines were flown at 1 mile intervals at an elevation of 135 feet above ground.	Two uranium peak value anomalies (3 cps and 4 cps) were found. These occur over unit 19 granite and unit 13b conglomerate in the Apetowachakamasik Lake area.	Figure 67
9	Airborne Permit #95	Canadian Nickel Co. 1975	Airborne electromagnetic survey as described in entry #3. This survey filled in the earlier survey to close the spacing down to ¼ mile in all areas.		Figure 68
10	Try group	Selco Exploration Company Ltd. 1967	Three diamond drill holes.	A number of conductive zones were drilled and reported as graphitic horizons. Some sulphides were encountered — up to 10% pyrrhotite and some specks of chalcopyrite. No assays were reported.	Figure 66 Table 8
11	Lam 15	Canadian Nickel Co. 1969	Two diamond drill holes.	The first hole was abandoned. Sulphide-bearing zones with a few per cent pyrite and/or pyrrhotite were encountered and 0.007 to 0.013 per cent zinc was reported. One 3.4' sulphide-rich zone with up to 40% pyrite assayed 0.008% zinc.	Figure 66 Table 8
12	Lac 1	Selco Exploration Company Ltd. 1968	One diamond drill hole.	A number of pyrite-pyrrhotite zones containing up to 20% sulphide, usually in massive 1" veins were recorded. Assays show minor amounts of copper, nickel and cobalt.	Figure 66 Table 8
13	Ox 3	Selco Exploration Company Ltd. 1968	One diamond drill hole.	A number of weakly mineralized zones with minor copper in assay.	Figure 66 Table 8
14	"Pit" Claims	W. Bruce Dunlop Ltd. 1965	Ground electromagnetic survey using a Ronka E.M. horizontal loop instrument at a frequency of 2400 cps. Readings were taken at 100' intervals on lines spaced at 400'.	Five conductive zones were located which show a circular pattern interpreted as possible indicators of sulphides around the edge of an olivine peridotite. (Note: an intrusive olivine peridotite crops out on an island NE of the claim block).	Figure 66

Table 7: Summary of assessment work from the Lower Nelson River Project area. (continued)

No.	Reservation, Airborne Permit number, Claim names	Company Name and Year	Type of Work	Summary of Results	Figure or Table cross-reference
15	Row and Ted Groups	Prospectors Airways Co. Ltd. 1961	Ground electromagnetic survey using a crone, wedge-type-junior electromagnetic unit at 1800 cps. Readings were taken at 100' intervals on grid lines 400' apart. In the vicinity of conductors 50' separation of readings on 200' line separation were made. Also, near conductors, a Ronka horizontal coil electromagnetic instrument and a Sharpe A-3 magnetometer were used to further define geophysical anomalies.	Two anomalies were delineated in the Row group. Drilling was recommended but not done.	Figure 66
16	Doug Claims	Rio Canadian Exploration 1960	1) Electromagnetic and magnetometer surveys were carried out on 400' line spacing grids with 100' and 50' station separation. An Electronics Associated EM5 vertical loop unit and an Askania torsion magnetometer were used. 2) Two diamond drill holes were drilled by Canadian Longyear.	Three conductors were located in the geophysical survey. One drill hole was abandoned without intersecting the conductor. The second drill hole intersected the projected anomaly; however, no sulphides are reported.	Figure 66 Table 8
17	For Claims	Falconbridge Nickel Mines Ltd. 1962	A ground magnetometer survey was carried out using a Watts magnetometer with 100' reading intervals on 400' line spacing.	One positive magnetic anomaly was located and an electromagnetic survey was recommended; however, the EM survey was not conducted.	Figure 66
18	Wask 49, 47, 28	Canadian Nickel Co. 1967	Five diamond drill holes were drilled.	No sulphide intersections were reported.	Figure 66 Table 8

Table 8: Summary of diamond drill hole results from the Lower Nelson River Project area.

Claim and DDH No. *	Footage	Rock Types	Reported Mineralized Sections		ASSAYS				
					Sampled Section (feet)	Zn	Cu	Co	Ni
Try Claims DDH #2	209 -282	Quartz-hornblende-biotite gneiss, garnet-hornblende-biotite gneiss	209 -233	finely disseminated py and po less than 2%					
	282 -330	Chloritized-hornblende-biotite gneiss	282 -304	finely disseminated pyrite, less than 2%					
	330 -401	Hornblende-biotite gneiss	330 -350	mineralized quartz stringers 12" to 14" with 3% py and less than 2% po					
			363.8-364.4	8% py - less than 1% cpy					
			373.0-374.2	5% py - less than 1% cpy					
Try Claims DDH #5	220 -298.5	Quartz-muscovite-gneiss	289 -293	5% pyrite					
	298.5-302	Skarn rocks							
	302 -514	Quartz-muscovite-gneiss, quartz Chlorite-graphite schist, garnet-quartz-chlorite-muscovite schist	312 -318	3-5% py and po					
			334.5-335.5	10% py and po					
			398 -401	5% py and po					
			403 -403.5	70% po and py					
			412 -415	Chlorite zone with one 6" zone at 30% py					
	514 -515	Siliceous Rocks	514 -515	15% po					
	515 -648	Quartz-chlorite-epidote gneiss, porphyroblastic quartz-chlorite-epidote-biotite schist	515 -516.5	Chlorite zone at 412-415 with 10% fine po					
Try Claims DDH #6	172 -248	Quartz-muscovite gneiss, quartz chlorite rock	172 -192	1-2% po and py with specs of cpy					
			192 -248	1-2% po and py					
	248 -250	Sulphide zone	248 -248.5	20% po and py plus specs of cpy					
			248.5-249	60% po and py plus specs of cpy					
			249 -250	20% po and py plus specs of cpy					
	250 -291	Quartz-epidote-muscovite gneiss, quartz chlorite rock							
	291 -293	Carbonaceous schist	291 -293	5% po and py					

Table 8: Summary of diamond drill hole results from the Lower Nelson River Project area. (continued)

Claim and DDH No. *	Footage	Rock Types	Reported Mineralized Sections		ASSAYS Sampled Section (feet)	Zn	Cu	Co	Ni
	293 -483.5	Quartz-chlorite rock, quartz-epidote-muscovite gneiss	328.5-334	5% py and po					
			368 -370	10% po					
			394 -395	10% po and py					
			419 -432	Average 15 to 20% po and py with specs of cpy					
	483.5-502	Graphite schist	483.5-502	50% specular graphite					
			494 -495	30% po and py					
	502 -521	Quartzite	504.5-504.8	Graphitic with 10% po					
	521 -523	Graphite schist							
	523 -572	Quartz-epidote-muscovite gneiss, pegmatite							
Lam 15 35222-0	39.0-76.3	Mylonite, iron formation	39.0-40.8	occasional stringers of py - specks of minor sph	39.0-40.8	0.002			
			40.8-44.0	minor graphite	40.8-44.0	0.007			
			53.1-55.0	20% po and py with specks of sph	53.1-55.0	0.007			
			55.0-60.4	minor graphite, 5% py, specks of sph	55.0-60.4	0.008			
					60.4-67.9	0.016			
			67.9-71.3		67.9-71.3	0.008			
	76.3-117.8	Amphibole, biotite schist volcanic,							
	177.8-190.0	Pegmatite, granite							
Lac 1	102 -262	Amphibolite	102 -235	traces of disseminated po and py	109 -113		0.02		Tr
					213 -213.2			0.08	Tr
	260 -262	Pegmatite							
	262 -283	Amphibolite							
	283 -288	Argillite							
	288 -401	Amphibolite	288 -401	po content generally 1% up to 5% from 312' - 314'. Occasional py and cpy. Some graphite bands.	312 -314		0.07		Tr
					382 -382.1			0.09	Tr

Table 8: Summary of diamond drill hole results from the Lower Nelson River Project area. (continued)

Claim and DDH No. *	Footage	Rock Types	Reported Mineralized Sections		ASSAYS Sampled Section (feet)	Zn	Cu	Co	Ni
	401 -413	Argillite	401 -413	some graphite bands					
	413 -416	Granite, pegmatite							
	416 -445	Amphibolite			439.5-444		0.01		Tr
	445 -477	Quartzite, argillite, siltstone	445 -477	7-10% po and py throughout	450 -452		0.01		Tr
					464 -469		0.02		Tr
	477 -516	Granite, amphibolite, siltstone, biotite schist							
	516 -524	Metagreywacke, quartzite	516.5-519	15% Po	516.5-519		0.03		Tr
					522 -524		0.03		Tr
	524 -556	Granite, granite gneiss, hornblendite, hornblende gneiss							
	556 -618	Quartzite	556 -572	minor graphite average 4% Po.					
			572 -618	graphitic with 7% Po	584 -588		0.02		Tr
					603 -606		0.01		Tr
	618 -716	Biotite schist, granite gneiss							
Ox 3 68-1	50 -95	Hornblende gneiss, massive quartz		minor po, py and graphite					
	95 -100.5	Argillite		highly graphitic with veinlets of po and minor py.	95 -100		0.02	Tr	
	100.5-148	Granite, quartz, biotite-muscovite schist	144 -146	60% po	143 -146		0.09		Tr
	148 -237	Amphibolite, argillite, hornblende gneiss	168.5-173	Graphitic with minor po and py	168 -173		0.02		Tr
					183 -188		0.02		Tr
			222 -237	disseminated po throughout some graphite and po bands.	226 -226.3		0.01		Tr
					232 -235		0.02		Tr
	237 -372	Pegmatite, granite							
	372 -411	Metagreywacke, metasiltstone							
	411 -553	Pegmatite granite							

Table 8: Summary of diamond drill hole results from the Lower Nelson River Project area. (continued)

				ASSAYS				
Claim and DDH No. *	Footage	Rock Types	Reported Mineralized Sections	Sampled Section (feet)	Zn	Cu	Co	Ni
Doug Claims 23-1	101 -229	Diorite biotite gneiss, aplite diorite dyke						
	229 -297	Biotite gneiss						
	297 -350	Diorite gneiss, aplite, granite						
Doug Claims 28-7	60 -208	Biotite gneiss, diabase dykes, biotite granite						
Wask 28 31265	124 -165	Iron formation						
	165 -277.6	Gneiss biotite						
	277.6-289.1	Skarn						
	289.1-353.0	Gneiss biotite, gneiss amphibole						
Wask 47 31264	107 -137.2	Skarn						
	137.2-302	Gneiss biotite, schist biotite pegmatite						
Wask 49 31261	71.0-312	Gneiss biotite, pegmatite, gneiss granite						

*Refer back to Table 7.

NOTE: All information is quoted directly from drill logs in the cancelled Assessment files.

List of Abbreviations:

- cpy - chalcopyrite
- py - pyrite
- po - pyrrhotite
- Co - cobalt
- Cu - copper
- Ni - nickel
- Zn - zinc
- Tr - trace

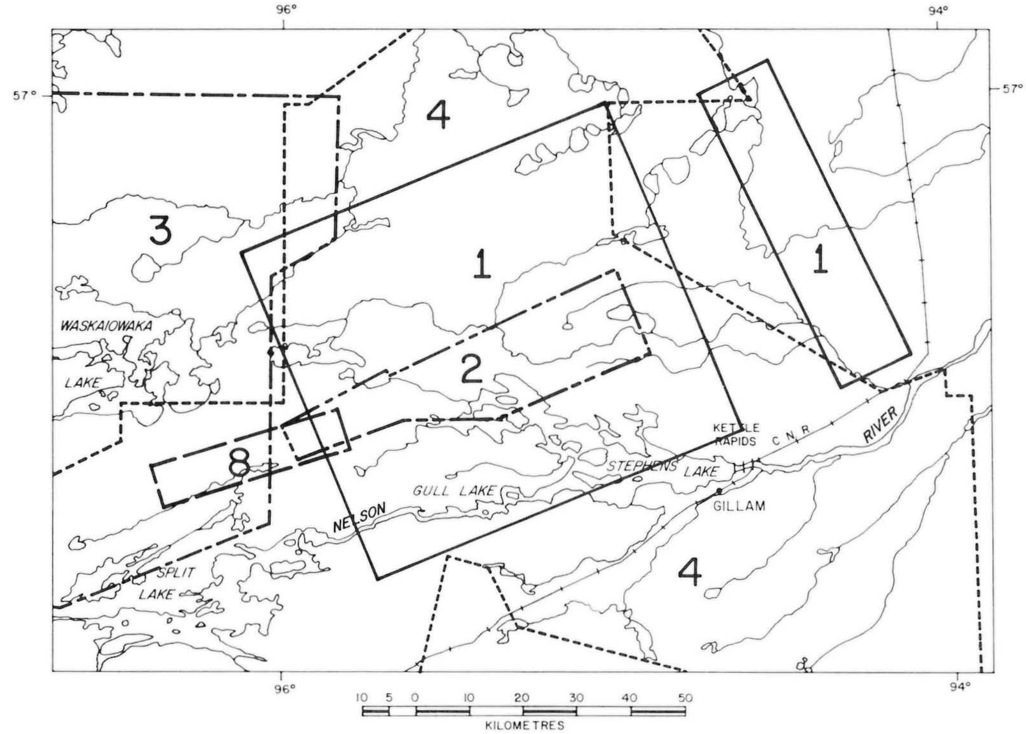


FIGURE 67: *Location and areal extent of airborne geophysical surveys 1, 2, 3, 4 and 8 documented in Table 7. Numbers correspond to entries in Table 7.*

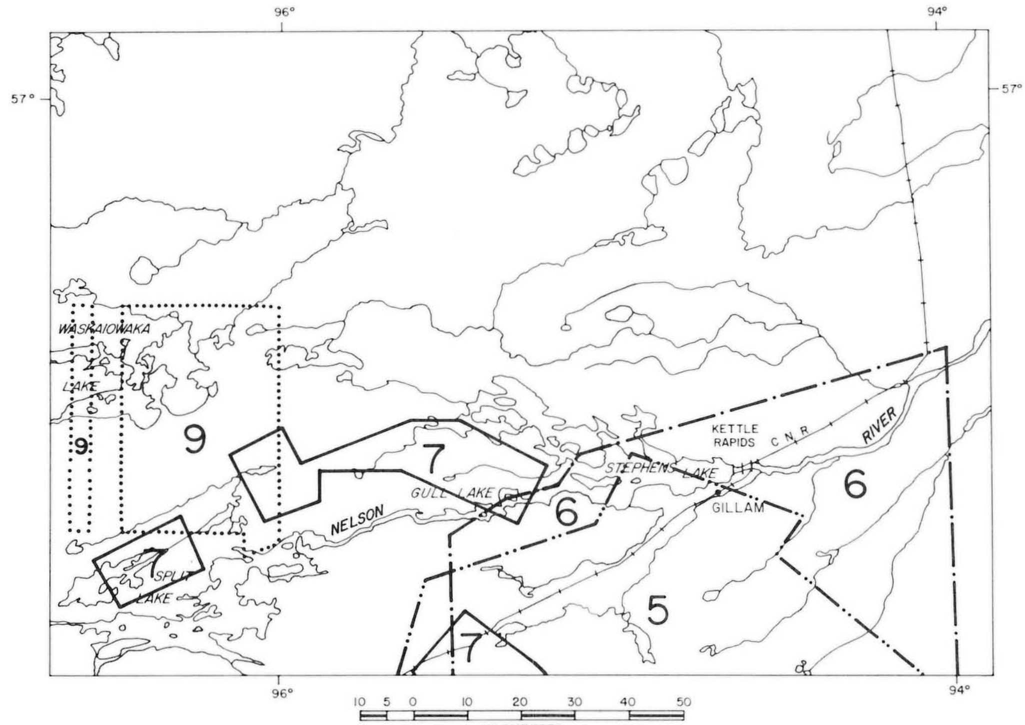


FIGURE 68: *Location and areal extent of airborne geophysical surveys 5, 6, 7 and 9 documented in Table 7. Numbers correspond to entries in Table 7.*

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