



**MANITOBA
DEPARTMENT OF ENERGY AND MINES**

MINERAL RESOURCES DIVISION

GEOLOGICAL REPORT 78—1

GEOLOGY OF THE FILE LAKE AREA

By
A.H. Bailes
1980



MANITOBA
DEPARTMENT OF ENERGY AND MINES

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Winnipeg, 1980

PREFACE

The File Lake area straddles the boundary between the early Proterozoic Flin Flon volcanic-sedimentary belt and the Kiseynew sedimentary gneiss belt of the Churchill Structural Province in northern Manitoba. This investigation indicates that the Flin Flon and the Kiseynew belts developed contemporaneously and that their boundary is gradational and characterized by a lateral change from volcanism in the Flin Flon belt to volcanoclastic sedimentation in the Kiseynew belt. Their boundary is also marked by a steep metamorphic gradient which increases into the Kiseynew belt where rocks are coarsely recrystallized and partially melted. No evidence for a major fault along the contact between the two belts was found in the File Lake area.

ERRATUM

p. 99 Column 2, Paragraph 2, Line 6 - "Baly" should read "Bay".

Figure 94
(in pocket)

Chemical analyses (sample sites 47-50) of altered unit 2 strata underlying Dickstone No. 1 orebody are shown on map but not listed in index. These analyses are given in Table 20.

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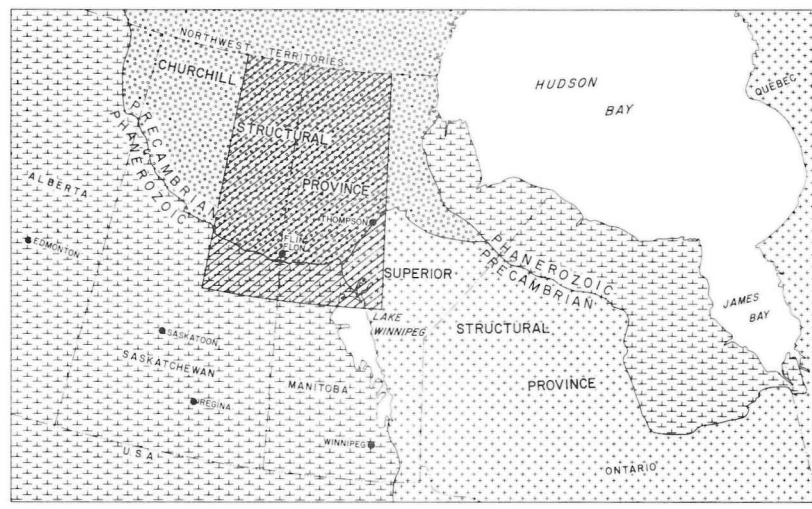
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MAP

Map 78-1-1: Geology of the File Lake area	(in pocket)
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(a)



(b)

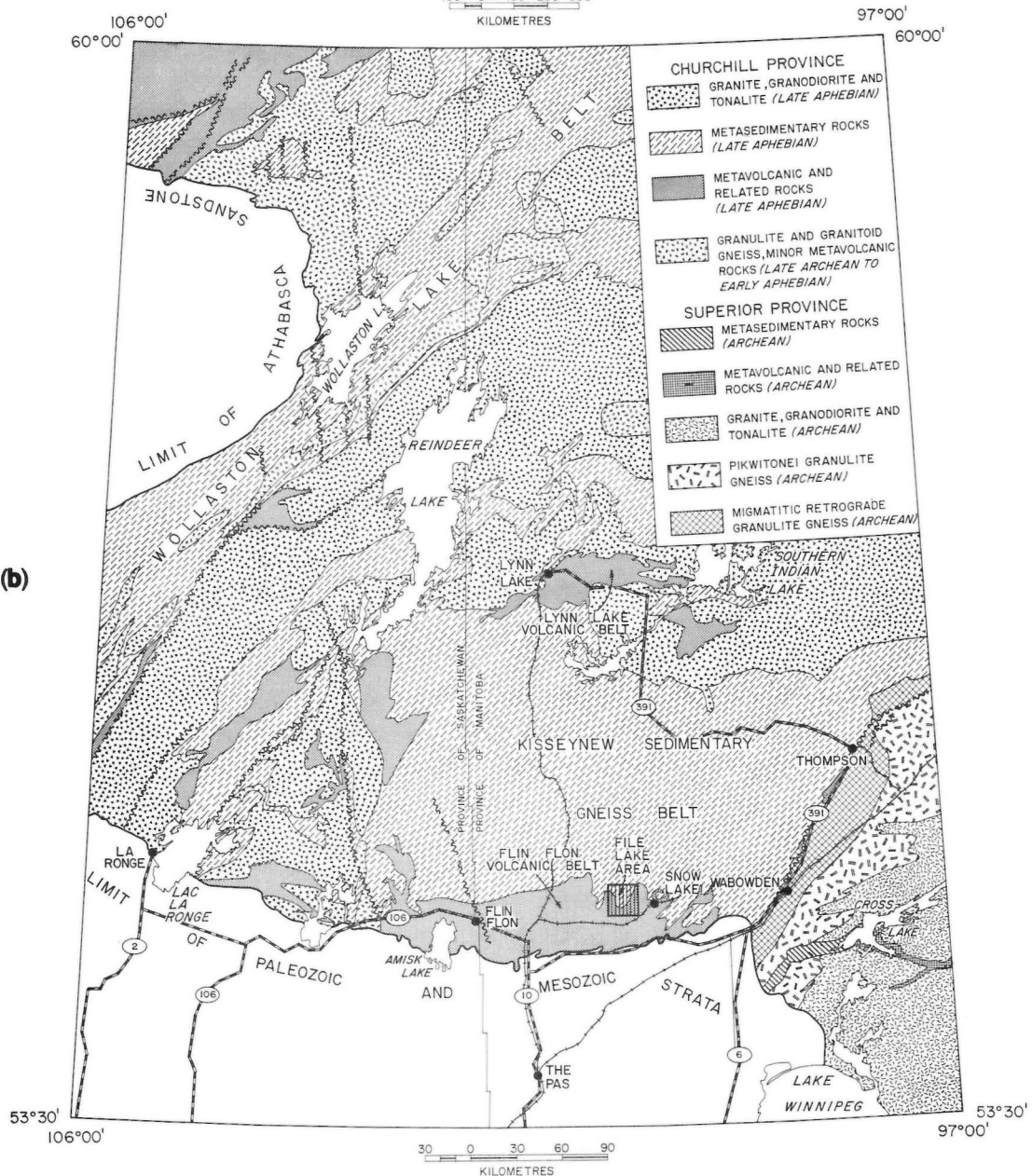


FIGURE 1: Main geological provinces in central Canada (a) and location of the File Lake area on a generalized geological map of the Churchill Province in western Manitoba and eastern Saskatchewan (b).

INTRODUCTION

LOCATION AND ACCESS

The File Lake area is 260 km² and is bounded by latitudes 54°47.5' and 54°58' north and longitudes 100°12.5' and 100°31' west. It is 130 km northeast of The Pas and 20 km west of Snow Lake (Fig. 1).

There is no road access, but there are water and portage routes from Reed Lake, on Highway 391. The most convenient method of access is by float-equipped aircraft based at The Pas, Flin Flon or Wabowden. There is also rail access to Woosey Lake on CNR trains hauling ore from the Snow Lake mining area to the Hudson Bay Mining and Smelting Co. Ltd. refinery complex in Flin Flon.

PREVIOUS WORK

The File Lake area has been mapped several times. It was mapped originally by Alcock (1920) and later by Stockwell (1935) at 1:126 720. Harrison (1949) mapped most of it at 1:63 360 and McGlynn (1959) mapped a small strip along the western edge that was not covered by Harrison. Currie (1947) has described the progressive regional metamorphism of mafic volcanic rocks of the File Lake area. Harrison (1949), Froese and Gasparrini (1975), Bailes and McRitchie (1978), Bailes (1979) and Froese and Moore (1980) have described many aspects of the metamorphic paragenesis of metasedimentary rocks. Discussions of the origin and significance of Amisk Group sedimentary rocks have been reported previously by the author (Bailes, 1979 and 1980).

PRESENT WORK AND ACKNOWLEDGEMENTS

The File Lake area was mapped in 7 months of field work, during the summers of 1970, 1971 and 1972. The mapping was conducted by standard pace and compass traverses, spaced every 150 to 300 m. Vertical aerial photographs at a scale of 1:15 840 were used to navigate.

P. Whiteway assisted with mapping in the summer of 1972 and covered most of the area between Morton and Woosey Lakes and between Folster Bay and the northeast arm of File Lake. H. Ambach, B. McCarrol, K. Mysk, P. Reynolds and K. Schmidt provided field assistance. Radio contact and expediting during the field program were provided by C. Wishart and W. Medd of the Department of Renewable Resources.

Sample preparations and chemical analyses were provided by laboratories of the Manitoba Mineral Resources Division, under the direction of A. Asham and J. Gregorchuk. Maps and figures were prepared by the cartography section, under the direction of R. Sales. The meticulous work of P. Buonpensiere, U. Fraser, D. McShane and D. Kleinholz of the cartography section is particularly appreciated. The

manuscripts were patiently and accurately typed by B. Thakrar. Photographs were prepared by J. Malyon.

Hudson Bay Mining and Smelting Co. Ltd. provided accommodation at the Dickstone mine site, during part of the summer of 1971. This greatly facilitated the mapping program and gave the author an opportunity to examine the Dickstone mine in more detail than would otherwise have been possible. P. Walford provided the author with several surface and underground geological tours of the Dickstone mine.

The author is grateful for the assistance of colleagues at the Manitoba Mineral Resources Division, in particular W.D. McRitchie, R.F.J. Scoates and H. Zwanzig. W.D. McRitchie read the manuscript and suggested many constructive modifications. L. Ayres, W.C. Brisbin, E. Froese and A.C. Turnock read and made constructive changes to those parts of the report which were incorporated from a Ph.D. thesis by the author to the University of Manitoba. I. Haugh and W.D. McRitchie are thanked for their patience and support during all phases of this project.

PHYSIOGRAPHY AND SURFICIAL DEPOSITS

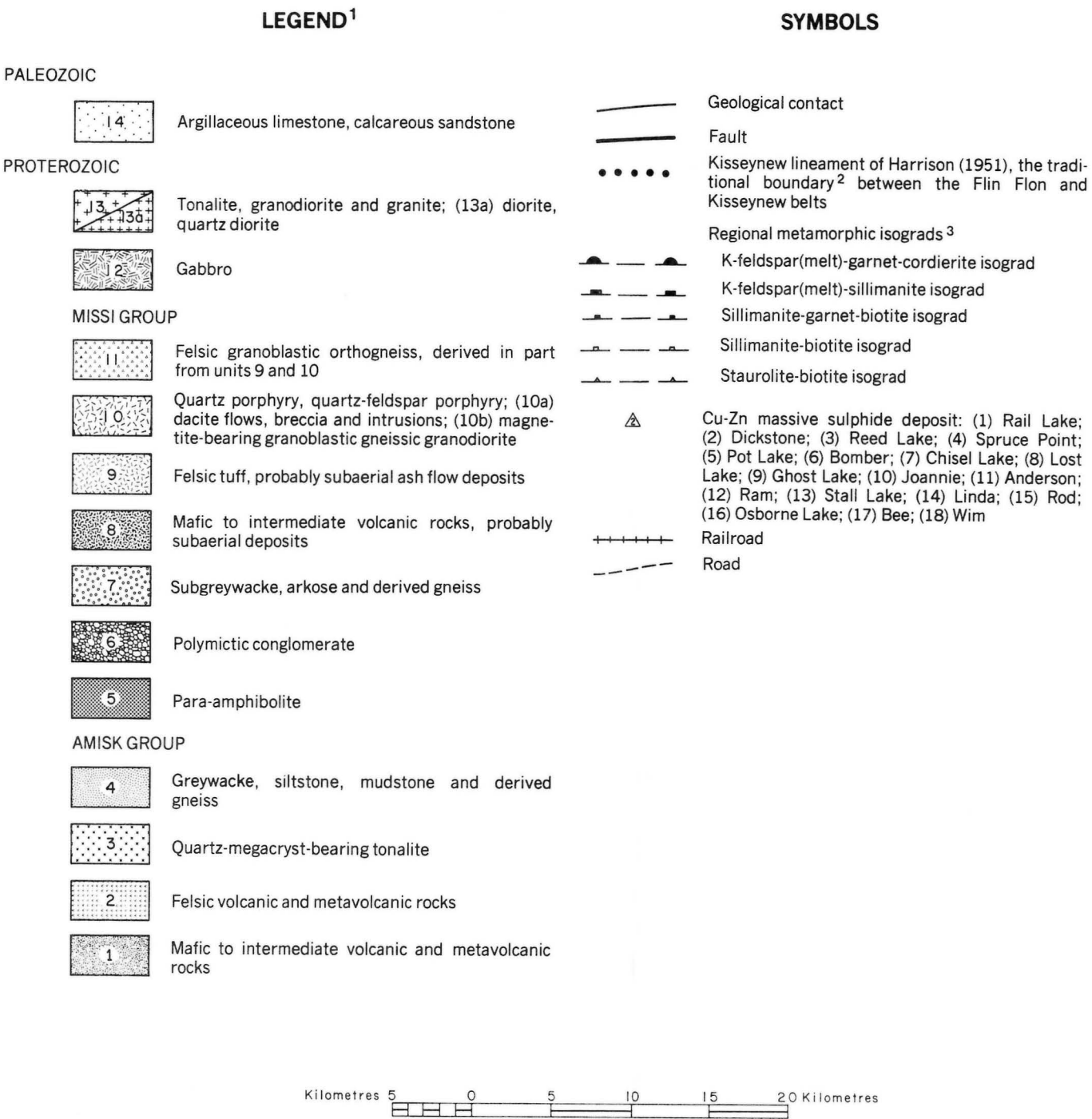
The File Lake area is dotted by small muskegs, swamps and lakes, typical of the Canadian Shield. The File River drains to the north into the Burntwood River. Woosey Lake drains to the south into the Grass River.

Outcrop exposure is excellent. Outcrops are ice sculptured and polished, and locally protrude up to 50 m above surficial deposits and areas of muskeg.

Pleistocene surficial deposits comprise sand, silt and clay. Shallow discontinuous sand planes occur south and east of Morton Lake, south of File Lake and northeast of Ellice Bay (Fig. 108, in pocket). Areas of muskeg are generally underlain by silt and clay deposits.

The surficial deposits are most likely beach and lacustrine deposits of Glacial Lake Agassiz. They occur below and are outlined by the 295 m contour. This is consistent with an estimate by Elson (1966) that the maximum limit of the basin of Glacial Lake Agassiz is defined by the 305 m contour in the region defined by the watersheds of the Burntwood and Grass Rivers.

Southwest of the map-area Harrison (1949) mapped a broad, flat sand plain, east of Morgan Lake, which he interpreted to be a raised beach or spit. South of the map-area three raised beaches, at elevations of 291 m, 297 m and 301 m, were recognized by Alcock (reported in Johnston, 1946) on a sand plain followed by the portage between Reed and Morton Lakes. The latter roughly correlate, according to their elevation, with the The Pas beach of Glacial Lake Agassiz (Johnston, 1946). The water plain, represented by the The Pas beach, is approximately 8000 years old (Elson, 1966).



¹Geology compiled from: Bailes (this report); Froese and Moore (1980); Shanks and Bailes (1977); Bailes (1975); Kornik (1968); McGlynn (1959); Robertson (1953); Harrison (1949); Frarey (1948), Armstrong (1941); Stockwell (1937).

²Bailes (1979) and Froese and Moore (1980) have demonstrated that the Kisseynew lineament does not exist, and that the boundary between the two belts is gradational and marked by a facies change from volcanism to sedimentation and by a steep increase in grade of regional metamorphism.

³The position of metamorphic isograds are from Bailes (this report) and Froese and Moore (1980).

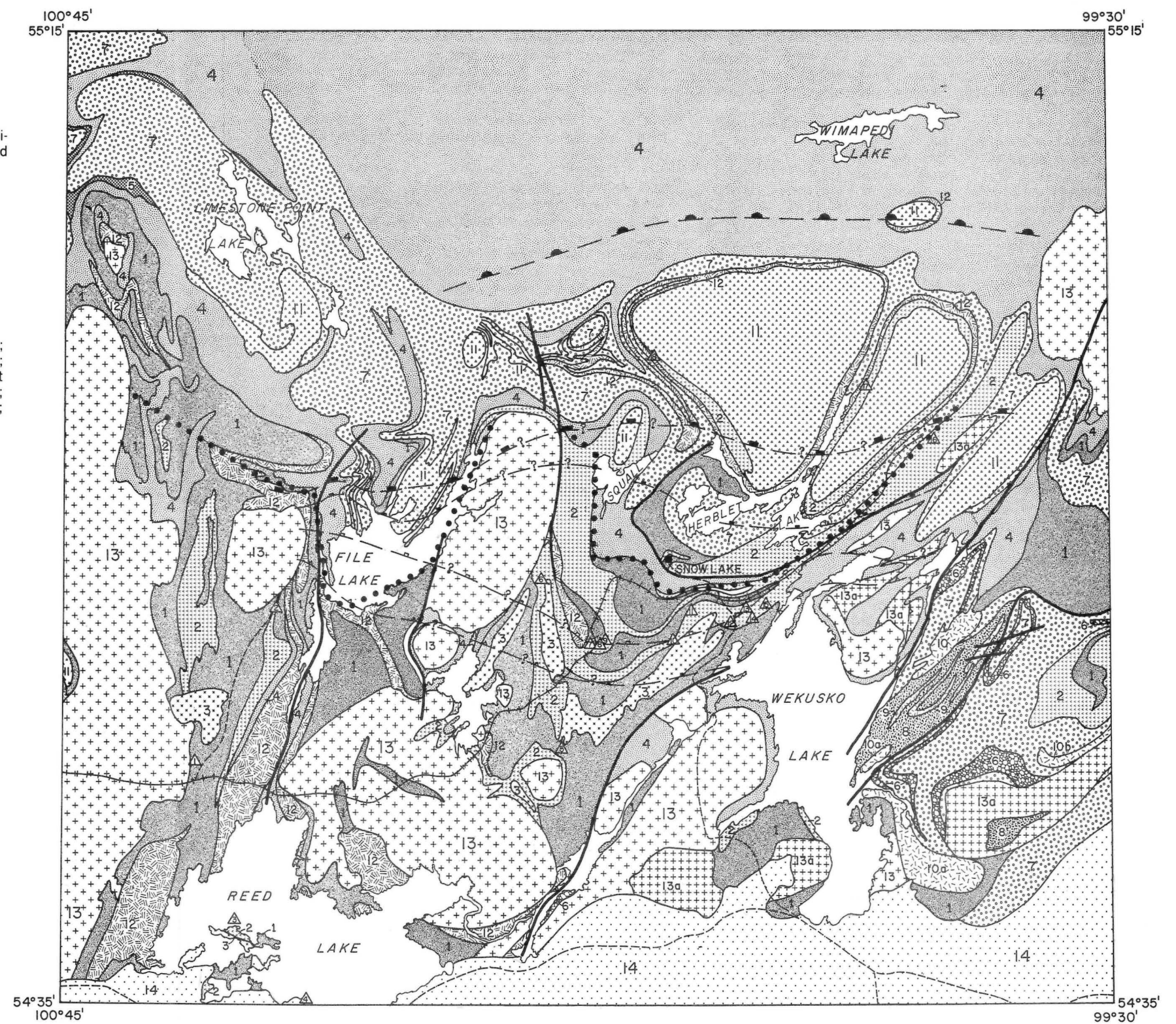


FIGURE 2: Simplified geological map of the File Lake-Snow Lake area.

GEOLOGIC SETTING

The File Lake area is in the Churchill Structural Province of the Canadian Shield and straddles the boundary between the Flin Flon volcanic-sedimentary belt and the Kiseynew sedimentary gneiss belt (Figures 1 and 2). The supracrustal and intrusive rocks of both belts have been dated by a variety of radiometric techniques (Sangster, 1978) and are between 1800 and 1900 Ma old, and were deformed and metamorphosed before 1750 Ma.

The Flin Flon volcanic-sedimentary belt comprises four main lithologic subdivisions. They are:

- Intrusive rocks
- Missi Group metasedimentary and metavolcanic rocks
- Amisk Group metasedimentary rocks
- Amisk Group metavolcanic and intrusive rocks

The Amisk Group metavolcanic rocks are up to 5000 m thick (Byers and Dahlstrom, 1954). They comprise subalkaline basalt to rhyolite flows and fragmental rocks. Mafic flow rocks, which form most of the Amisk Group, are generally pillowed and were extruded subaqueously, but subaerial extrusion occurred locally toward the top of the group (Ayres, 1978). Felsic volcanic rocks compose less than 20 percent of the Amisk Group. They occur throughout the Amisk succession, but are most abundant in the upper part as small isolated edifices. The volcanic rocks are locally intruded by epizonal, probably subvolcanic plugs, stocks, sills and dykes ranging in composition from diorite to granodiorite.

Metasedimentary rocks predominate in the upper part of the Amisk Group. They comprise up to 1000 m of volcanoclastic greywacke, siltstone and mudstone turbidites and related debris flow deposits (Bailes, 1979 and 1980). These deposits form the upper part of the largely volcanic Amisk Group. In the File Lake area, and probably elsewhere, they are composed of immature felsic to intermediate volcanic debris. Bailes (1979 and 1980) has interpreted them to be submarine fan deposits and has suggested that they were fed by unconsolidated debris shed off contemporaneous pyroclastic volcanoes of the Flin Flon belt.

The Amisk Group is overlain disconformably by 1300 to 3000 m of Missi Group fluvial-alluvial arkose, subgreywacke and conglomerate (Byers and Dahlstrom, 1954; Mukherjee, 1971; Stauffer, 1974; Shanks and Bailes, 1977). East of Wekusko Lake, the Missi Group sedimentary strata are overlain by volcanic rocks which include subaerial felsic ash flows (Shanks and Bailes, 1977). The Missi Group is postdated by a suite of intrusive rocks which includes large tabular sheets of gabbro and large plutons of granitic rocks. Several large pre-Missi plutons of 'quartz-eye' tonalite and granodiorite have also been recognized.

The Kiseynew sedimentary gneiss belt consists of two main supracrustal successions: a lower sequence of migmatitic greywacke-siltstone- and mudstone-derived gneisses; and an overlying succession of migmatitic subgreywacke- and arkose-derived gneisses. At present no unified system of stratigraphic nomenclature exists for these rocks, but similarity of these strata throughout the belt suggests that broad regional correlations may be possible (Harrison, 1951; Sangster, 1972; McRitchie, personal communication, 1979). On the south flank of the Kiseynew belt, these strata generally have been referred to, respectively, as the Nokomis and Sherridon Groups (Robertson, 1953; Pollock, 1964 & 1965; Kornik, 1968). More recently, in the Snow Lake and File Lake areas, Moore and Froese (1972), Froese and Moore (1980) and Bailes (1975 and 1979) have correlated Nokomis and Sherridon Group paragneisses to sedimentary rocks of the Amisk and Missi Groups, respectively, of the Flin Flon belt. This correlation has led these authors to apply the terms Amisk and Missi to strata of the Kiseynew belt, a break from the traditional use of these names only for rocks of the Flin Flon belt.

GENERAL FEATURES OF MAP-AREA

In the File Lake area, the boundary between the Flin Flon and Kiseynew belts traditionally has been placed along the west, south and east shores of File Lake (Figure 2). Harrison (1949 and 1951) considered the contact to be a major fault, which he termed the Kiseynew lineament. According to this study, the contact is not a fault and strata can be traced across the boundary. There is a rapid increase in metamorphic grade from the Flin Flon belt into the Kiseynew belt, but the increase is gradual and metamorphic isograds cut across the contact between the two belts and are not displaced. The same nomenclature is used for strata of both the Flin Flon and Kiseynew belts (Table 1; Map 78-1-1).

STRATIGRAPHIC FRAMEWORK

Four major lithostratigraphic groups have been recognized (Table 1; Map 78-1-1): Amisk Group metavolcanic and related intrusive rocks; Amisk Group metasedimentary rocks; Missi Group metasedimentary rocks; and post-Missi intrusive and metamorphic rocks. Several schematic stratigraphic sections of supracrustal rocks of the File Lake map-area are shown in Figure 3.

The Amisk Group metavolcanic rocks (units 1 to 8) are the oldest strata. They comprise a 2000 m thick sequence of subalkaline mafic to felsic subaqueous flows and fragmental rocks. Pillowed and massive tholeiitic mafic volcanic flows comprise 80 percent of the exposed succession. Felsic tholeiitic and calc-alkaline flows and fragmental rocks, which occur in small edifices and isolated narrow layers, comprise the remainder. The volcanic rocks outcrop predominantly in the south half of the map-area, in the Flin Flon volcanic-sedimentary belt. The volcanic rocks have been arbitrarily subdivided into three geographic subgroups: Storozuk-Morton Lakes area; Butler-Fussey Lakes area; and Woosey Lake area. In all three areas, the metavolcanic rocks are overlain by Amisk Group metasedimentary rocks (Figure 3).

The Amisk Group volcanic rocks are locally intruded by small plugs, stocks, sills and dykes of diorite and quartz-feldspar tonalite porphyry (units 9 and 10). These intrusions are epizonal, fine grained and possible feeders for Amisk volcanism. None of them intrude Amisk Group metasedimentary or younger rocks.

The Amisk Group metasedimentary rocks (units 11 to 15) comprise a 1000 m thick sequence of pebbly greywacke, greywacke, siltstone and mudstone that were deposited by turbidity currents and related subaqueous sediment gravity flows. They overlie Amisk volcanic rocks and outcrop in the south and north half of the map-area, in both the Flin Flon and Kiseynew belts. On Morton Lake, they contain middle to upper greenschist facies mineral assemblages and have well preserved primary sedimentary structures and textures. On File Lake and Woosey Lake, they contain lower to upper almandine-amphibolite facies mineral assemblages and are strongly recrystallized and, locally, partially melted. They consist mainly of felsic to intermediate volcanic detritus.

The Missi Group (units 16 and 17) is a 1300 m thick sequence of quartz-feldspathic magnetite-bearing paragneisses derived from thick-bedded subgreywacke and arkose. It disconformably overlies Amisk Group strata and outcrops only in the north half of the map-area, in the Kiseynew sedimentary gneiss belt. The Missi Group rocks are completely recrystallized and contain middle to upper almandine-amphibolite facies mineral assemblages. They locally contain close-spaced parallel laminations, rare pebbles and small-scale current laminations. They are probably shallow-marine or continental deposits.

The post-Missi igneous rocks intrude volcanic-sedimentary strata belonging to both the Flin Flon and Kiseynew belts, but are more abundant in the Flin Flon belt. Three main groups of intrusions have

TABLE 1: Table of Formations, File Lake area

PLEISTOCENE AND RECENT		Surficial Deposits of Gravel, Sand and Clay				
UNCONFORMITY						
PRECAMBRIAN PROTEROZOIC APHEBIAN	Post-kinematic	28 Felsic pegmatite dykes				
	INTRUSIVE AND METAMORPHIC ROCKS Syn- to late kinematic	INTRUSIVE CONTACT				
		24	Barron Lake Pluton: Granite and leucogranite	Metamorphic and anatectic rocks {	27	Loonhead Lake Intrusions: Gneissic, pegmatitic granodiorite and monzogranite
		23	Norris Lake Pluton: Plagioclase-rich leucotonalite		26	Nelson Bay Gneiss Dome [units 25-26]: Granoblastic oligoclase-quartz-microcline gneiss
		22	Reed Lake Pluton: Plagioclase-rich leucotonalite and quartz leucodiorite		25	Granoblastic oligoclase-quartz gneiss
		21	Ham Lake Pluton: Granodiorite, leucotonalite and tonalite, in part gneissic			
		20	Woosey Lake Pluton: Gneissic quartz-rich leucotonalite and granodiorite			
		INTRUSIVE CONTACT				
	Pre- to early kinematic	18 & JOSLAND LAKE GABBRO: Gabbro and metagabbro				
		19				
	INTRUSIVE CONTACT					
	MISSI GROUP	16 & Metasubgreywacke and meta-arkose				
		17				
	DISCONFORMITY					
	Metasedimentary Rocks	FILE LAKE FORMATION [units 13-15]:				
		15	Corley Lake Member: Mudstone			
		14	Mafic and felsic volcanic rocks			
		13	Lithic greywacke, feldspathic greywacke, siltstone and mudstone			
12		YAKYMIW FORMATION: Laminated mudstone, siltstone and sandstone interbedded with pebbly volcaniclastic sandstone				
	11	PARISIAN FORMATION: Polymictic volcaniclastic conglomerate				
? DISCONFORMITY ?						
AMISK GROUP Intrusive Rocks	10 Quartz-and feldspar-phyric tonalite					
	Intrusive Contact					
	9	Diorite				
INTRUSIVE CONTACT						
Metavolcanic Rocks	Storozuk-Morton Lakes area		Butler-Fussey Lakes area	Woosey Lake area		
	4	Dacite flows	6 Dacite fragmental	8 Felsic volcanic rocks		
	3	STOROZUK FORMATION: Basalt and andesite flows and breccia; minor dacite and rhyolite flows and tuff	5 Basalt and andesite flows	7 Mafic fragmental rocks		
	2	DICKSTONE FORMATION: Rhyolite and dacite flows, breccia and tuff				
	1	PREASTON FORMATION: Basalt and andesite flows				

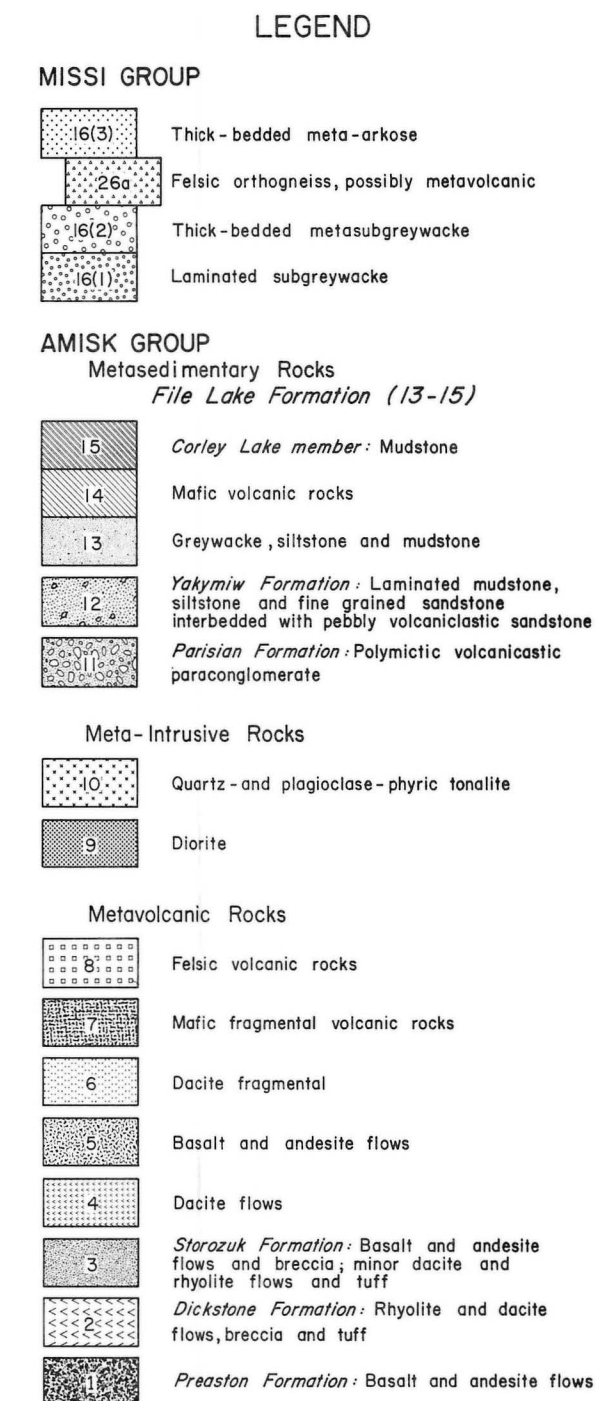
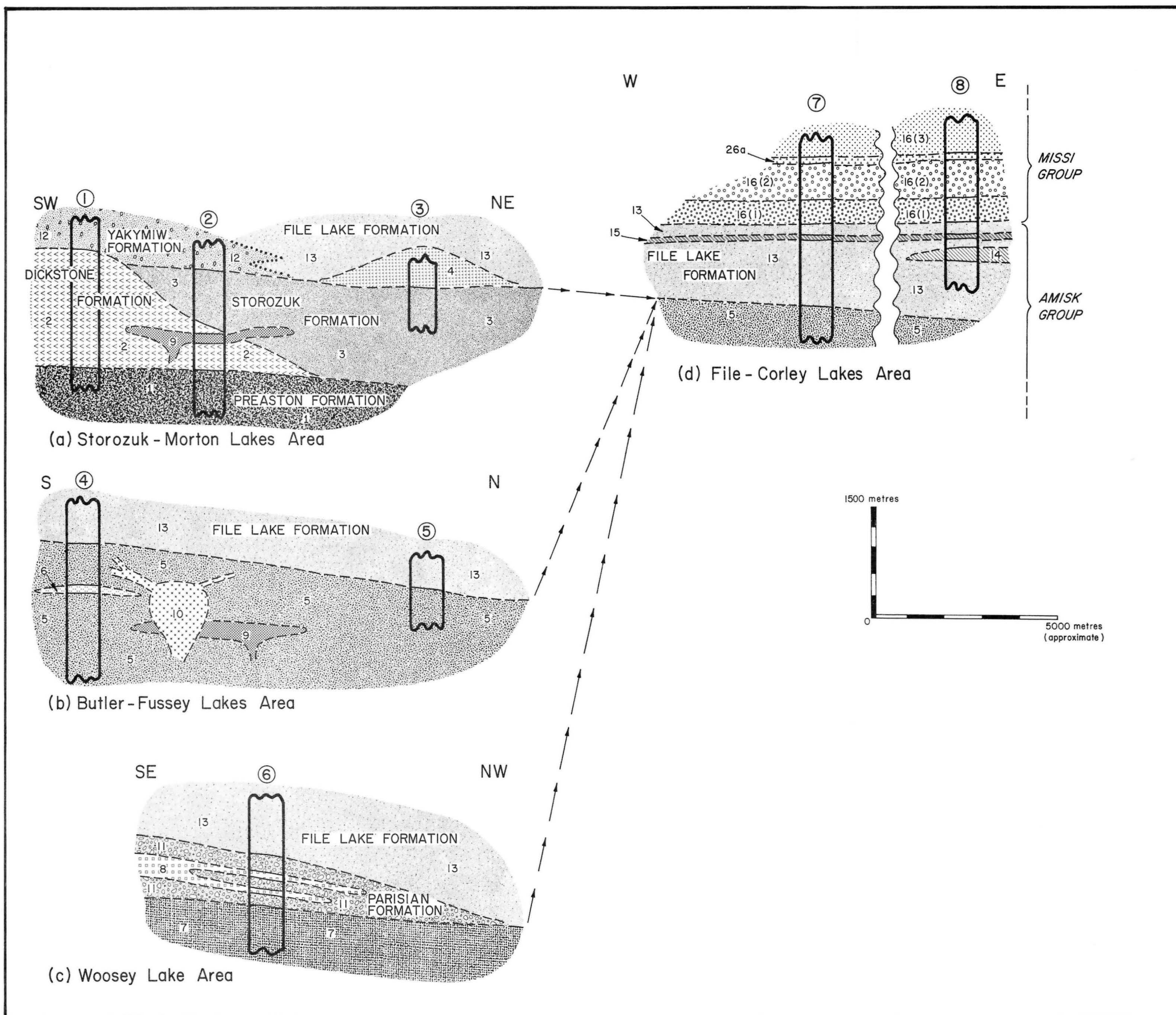


FIGURE 3: Schematic restored stratigraphic sections of supracrustal rocks, File Lake area. Section locations given on Figure 95 (in pocket).

been recognized: *early kinematic*, differentiated concordant bodies of tholeiitic gabbro (unit 18) and derived amphibolite (unit 19); *syn- to late-kinematic* calcalkaline felsic plutons (units 20 to 24); and *post-kinematic*, small dykes of felsic pegmatite (unit 28).

Metamorphic rocks, formed during a syn- to late-kinematic episode of high grade regional metamorphism, include a large domal complex of recrystallized orthogneisses (units 25 and 26) and a suite of anatectic granodiorite and tonalite (unit 27). The latter was formed by partial melting of Amisk Group mudstones. The origin of the felsic orthogneisses is uncertain but they may belong to the supracrustal succession, as shown in Figure 3, and may be a coarsely recrystallized and partially remobilized Missi Group felsic metavolcanic unit.

The vertical distribution of lithologies in the volcanic-sedimentary succession of the File Lake map-area (Figure 3) indicates an upsection change from subaqueous volcanism (Amisk Group metavolcanic rocks), to deep water sedimentation by mass sediment gravity flows (Amisk Group metasedimentary rocks) to shallow marine or continental sedimentation (Missi Group). The lateral distribution of volcanic and sedimentary lithologies is less clearly defined, but two observations suggest a north dipping paleoslope and a lateral downslope change from volcanism to sedimentation. The first is the concentration of volcanic strata to the south and sedimentary strata to the north of the map-area. This could be, and probably is, partly due to exposure of higher stratigraphic levels, to the north, but if this were the only control then volcanic rocks should occur throughout the northern Kiseynew belt in the cores of large antiformal structures. Since volcanic rocks do not occur in this manner, the south to north change, from volcanic to sedimentary strata in the File Lake area, is considered to be, at least in part, due to a lateral facies change. A second observation which supports a south to north change from volcanism to sedimentation, and indicates a north dipping paleoslope, is the volcanoclastic character of Amisk Group sedimentary rocks. Bailes (1979 and 1980) has demonstrated that Amisk Group sedimentary rocks of the File Lake area are composed almost entirely of texturally immature volcanic detritus and are most logically interpreted to be the deposits of subaqueous mass sediment gravity flows shed from the flanks of major unconsolidated, pyroclastic, felsic to intermediate Amisk volcanoes.

DEFORMATION AND METAMORPHISM

Four episodes of deformation and three episodes of regional metamorphic recrystallization occurred in the File Lake area. All are post-Missi. In addition, contact metamorphic aureoles surround many of the larger granitic plutons. The main features of the deformational and regional metamorphic events are summarized in Table 17 on page 70 of this report.

The earliest deformational event formed large recumbent folds and caused major inversions and repetitions of the stratigraphic succession. Subsequent deformational events were largely coincident with high grade regional metamorphism and many of their fold structures are geometrically disharmonious and some appear to have involved upward, gravity-induced movement of light ductile rock units.

Only one of the three episodes of regional metamorphism in the File Lake area, that coincident with the main episode of deformation, has had widespread effects. It formed a prominent zonation of metamorphic minerals from middle greenschist facies, in the south, to upper almandine-amphibolite facies, in the north. It has completely and coarsely recrystallized supracrustal rocks in the northern third of the map-area, and has partially melted some the Amisk Group mudstones.

Similar deformational and regional metamorphic episodes have been observed throughout the Flin Flon and Kiseynew belts (Moore and Froese, 1972; Bailes, 1975; Bailes and McRitchie, 1978).

GEOCHRONOLOGY

Five Rb/Sr whole rock isochron ages have been obtained from units in the File Lake area (Josse, 1974). Four of these date the time of regional metamorphism and range from 1715 ± 83 Ma to 1760 ± 43 Ma. The other, 1860 ± 112 Ma., is interpreted as the time of emplacement of the syn-kinematic Ham Lake pluton. These ages are in accord with those of other geochronological studies by Mukherjee (1971), Sangster (1972, 1978), Anderson (1974) and MacQuarrie (1978). Initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratios on the four metamorphically updated rocks are low and indicate that they had a short crustal history prior to metamorphism.

AMISK GROUP METAVOLCANIC AND INTRUSIVE ROCKS

The Amisk Group metavolcanic and intrusive rocks are the oldest rocks and outcrop in the south half of the map-area, in the Flin Flon volcanic-sedimentary belt. They consist mainly of massive and pillowed mafic flows, with local small felsic volcanic edifices and small epizonal, probably subvolcanic, plugs, dykes and stocks of diorite and quartz- and plagioclase-phyric tonalite. Approximately 2 km of Amisk Group metavolcanic and intrusive rocks are exposed in the File Lake area; no base is exposed.

DESCRIPTION OF METAVOLCANIC ROCKS

Amisk Group metavolcanic rocks have been arbitrarily subdivided into three geographic subgroups (Table 1, p. 4; Map 78-1-1, in pocket): Storozuk-Morton Lakes area; Butler-Fussey Lakes area; and Woosey Lakes area. This subdivision was made because the volcanic units could not be reliably correlated between these areas, due to lack of marker units, lensy stratigraphy and complicated deformation. The Storozuk-Morton Lakes area includes all volcanic strata between the west boundary of the map-area and the fault zone along the east shore of Morton Lake. The Butler-Fussey Lakes area comprises volcanic strata between this fault zone and the fault zone along the west shore of Woosey Lake. The Woosey Lake area is located east of the Butler-Fussey Lakes area. Typical stratigraphic successions in these subareas are shown in Figure 3.

The main features of Amisk Group metavolcanic rocks are summarized in Table A-1.

STOROZUK-MORTON LAKES AREA

Four major volcanic formations are recognized in the Storozuk-Morton Lakes area:

Dacite flows (unit 4):	0-600 m thick
Storozuk Formation (unit 3):	0-1200 m thick
Dickstone Formation (unit 2):	0-1500 m thick
Preston Formation (unit 1):	500 m thick

The total thickness of this volcanic succession is over 2 km.

South of Storozuk Lake the volcanic rocks are only slightly recrystallized, contain middle to upper greenschist facies mineral assemblages and have well preserved macroscopic primary textures and structures. North of Storozuk Lake the volcanic rocks are poorly exposed, invaded by numerous sills of the Josland Lake gabbro (unit 18), and contain almandine-amphibolite facies mineral assemblages formed during regional metamorphism and by contact metamorphism during intrusion of the Norris Lake pluton (unit 23).

The best exposed volcanic section in the Storozuk-Morton Lakes area is west of Yakymiw Lake. It comprises 2000 m of almost continuous section which tops to the east, dips steeply and includes the upper part of unit 1 and complete sections across units 2 and 3. It is conformably overlain to the east by volcanoclastic sediments of the Yakymiw Formation (unit 12). The upper part of this volcanic section (unit 3) is repeated in an antiformal structure southeast of Josland and is conformably overlain, along the west shore of Morton Lake, by greywacke, siltstone and mudstone turbidites of the File Lake Formation (unit 13).

Dacite flows (unit 4), exposed on Elmes Island, have uncertain stratigraphic relations with the other rocks of the Storozuk-Morton Lakes area, but are interpreted to be part of a small dacite dome that was deposited on top of the basalt and andesite flows of unit 3.

PRESTON FORMATION (1, 1a)

The Preston Formation comprises subaqueous basalt and andesite flows (unit 1) and layered garnetiferous mafic and

intermediate metavolcanic gneiss (unit 1a). Most of the Preston Formation outcrops west of the map-area, where it is estimated to be over 2 km thick (no base is exposed). Only the upper 500 m is exposed in the map-area. It is overlain, to the east, by felsic flows and pyroclastic rocks (unit 2) of the Dickstone Formation. The main features of units 1 and 1a are summarized in Table A-1.

Dark green basalt and andesite flows of unit 1 outcrop southwest of Storozuk Lake. They are recrystallized to a fine grained granoblastic mixture of middle- to upper-greenschist facies mineral assemblages. They are generally massive and structureless, but locally contain pillows, phenocrysts of plagioclase, and thin layers of breccia. Southwest of Storozuk Lake, unit 1 exhibits a gradational eastward change in composition from basalt to andesite. Narrow layers of felsic volcanic rocks and mafic fragmental volcanic rocks are common towards the top of the exposed section.

The mafic to intermediate metavolcanic gneisses of unit 1a outcrop northwest of Storozuk Lake. They are garnetiferous and are composed of fine-to medium-grained, lower to middle almandine-amphibolite facies mineral assemblages. Discontinuous, diffuse layering is common and is defined by alternating centimetre thick bands of mafic and intermediate composition. The layering is considered primary, although a metamorphic or tectonic origin cannot be discounted. The strong recrystallization of rocks of unit 1a is due to thermal metamorphism by the Norris Lake pluton (unit 23).

The Preston Formation is interpreted to be a subaqueous deposit as flows are locally pillowed. Rare felsic bombs and minor interbeds of felsic volcanic strata, in the upper portions of the Preston Formation, suggest that there was some overlap of its deposition with that of the overlying felsic volcanic Dickstone Formation.

DICKSTONE FORMATION (2, 2a, 2b)

The Dickstone Formation is a mixture of dacite and rhyolite flows and fragmental rocks (unit 2). Strata composed mainly of flow material (unit 2a) occur widely south of Yakymiw Lake and those with a high proportion of fragmental material (unit 2b) outcrop on the islands and shoreline of Storozuk Lake (Fig. 4). There is a complete gradation between rocks of units 2, 2a and 2b. Their main features are summarized in Table A-1.

The Dickstone Formation is exposed in the map-area in cross-section and comprises a steep-dipping, homoclinal, east-facing succession. South of Yakymiw Lake it reaches a maximum thickness of 1500 m and thins to zero thickness to the north and south. It has a strike length of 15 km (Fig. 2, p. 2) but only the northern 6 km are exposed in the map-area. Harrison (1949) originally mapped the Dickstone Formation as intrusive quartz porphyry and quartz-feldspar porphyry. South of the map-area it was mapped as an intrusive porphyry of rhyolite composition by McGlynn (1959) and as a silicified and sheared tonalite by Rousell (1970).

The degree of recrystallization of rocks of the Dickstone Formation increases to the north, largely through contact metamorphism by the Norris Lake pluton (unit 23) and, to a lesser degree, by regional metamorphism (the latter increases in grade from south to north). South of Yakymiw Lake rocks of the Dickstone Formation are relatively unrecrystallized and contain lower to middle greenschist facies minerals, such as small grains of chlorite and muscovite. From Yakymiw Lake to the north shore of Storozuk Lake they are slightly more recrystallized and contain upper greenschist facies mineral assemblages, including porphyroblasts of almandine garnet, biotite, tremolite-actinolite, hornblende, epidote, zoisite, chlorite and muscovite. North of Storozuk Lake, in particular north of the Dickstone mine-area, they are completely recrystallized to

orthogneisses containing lower almandine-amphibolite facies mineral assemblages, including minerals such as almandine garnet, hornblende, biotite, epidote, muscovite, chlorite, cummingtonite, tourmaline, and rare staurolite and diopside.

Rocks of the Dickstone Formation are not prominently deformed. A few outcrop scale north-trending, steep, south-plunging isoclinal folds occur in the vicinity of Storozuk Lake. A broad flexing of the Dickstone Formation, about a steep east plunging open fold with a steep-dipping east-northeast-trending axial plane, occurs west of Yakymiw Lake. Fragments within the Dickstone Formation are generally flattened in a northerly direction and are vertically elongated up to 5 times their maximum horizontal dimension. The deformed clasts plunge steeply to the south.

The Dickstone Formation south of Yakymiw Lake consists of white to light blue-green weathering flow rocks (unit 2a) characterized by subhedral to euhedral translucent blue quartz phenocrysts, 0.5 mm to 1.0 mm in size. Twinned and untwinned subhedral to euhedral phenocrysts of plagioclase (now albite, An₂₋₉) are also common. The matrix is a fine grained mixture of quartz and plagioclase with small porphyroblasts of chlorite, muscovite and rare biotite. The flows are massive, with rare quartz filled amygdaloids. Scoriaceous margins (Fig. 5) and contorted flow banding (Fig. 6) are present in some flow units.

Fragmental rocks are prominent in two localities, north of the south end of Storozuk Lake and 4 km south-southwest of Yakymiw Lake (Fig. 4). The fragmental rocks are typically monolithologic and vary from chaotic coarse breccias to crudely layered and locally size-sorted tuff, lapilli-tuff and tuff breccia. The matrix is a light rust-brown to light- to medium-grey weathering felsic tuff and lapilli tuff. The coarse chaotic breccias outcrop 4 km south-southwest of Yakymiw Lake and on the south shore of Storozuk Lake. The stratified fragmental rocks outcrop on the islands in Storozuk Lake and to the north of Storozuk Lake. The coarsest breccias are locally associated with pods (Fig. 7) and irregular bodies (Figs. 8 and 9) of massive white rhyolite. The rhyolite bodies typically have dark altered rims (Figs. 7 and 9) and are lobate in shape (Fig. 9). The fragmental rocks and associated irregular rhyolite bodies resemble the hyaloclastite, microbreccia and lava lobes and tongues of subaqueous rhyolite flows described by Dimroth and Rocheleau (1979) at Rouyn-Noranda, Quebec. Thus, at least some, and probably most of the fragmental rocks were derived by autobrecciation of subaqueous rhyolite flows.

The Dickstone Formation is interpreted to be the rapidly deposited product of a short-lived felsic volcano, which was constructed on a platform of mafic flows of the Preston Formation. The volcano was submarine because the underlying and overlying formations are subaqueous deposits and because the flows locally contain lava forms and structures characteristic of subaqueous deposition. The volcano deposited mainly massive flows at its crest and autoclastic and, perhaps, epiclastic fragmental rocks on its flanks. Basalt and andesite flows (unit 3) of the Storozuk Formation overlapped the flanks but did not cover the central crest of the Dickstone volcano. The Dickstone and Storozuk Formation were subsequently covered by immature volcanoclastic sediments (unit 12) of the Yakymiw Formation.

STOROZUK FORMATION (3, 3a-3d)

The Storozuk Formation is a subaqueous sequence of basalt and andesite flows (unit 3), basalt and andesite breccia (unit 3a) and felsic tuff and flows (unit 3b). Metamorphic derivatives include mafic metavolcanic gneiss (unit 3c) and felsic metavolcanic gneiss (unit 3d). The Storozuk Formation is exposed in a north-trending zone which extends from Yakymiw Lake to Loonhead Lake. Rocks of the Storozuk Formation exhibit a gradual northerly increase in grade of metamorphism and degree of recrystallization. Southeast of Storozuk Lake they are fine grained and contain upper greenschist facies mineral assemblages, whereas on Loonhead Lake they are completely recrystallized orthogneisses which contain middle to upper almandine-amphibolite facies mineral assemblages. The main features of rocks of units 3, 3a, 3b, 3c and 3d are summarized in Table A-1.

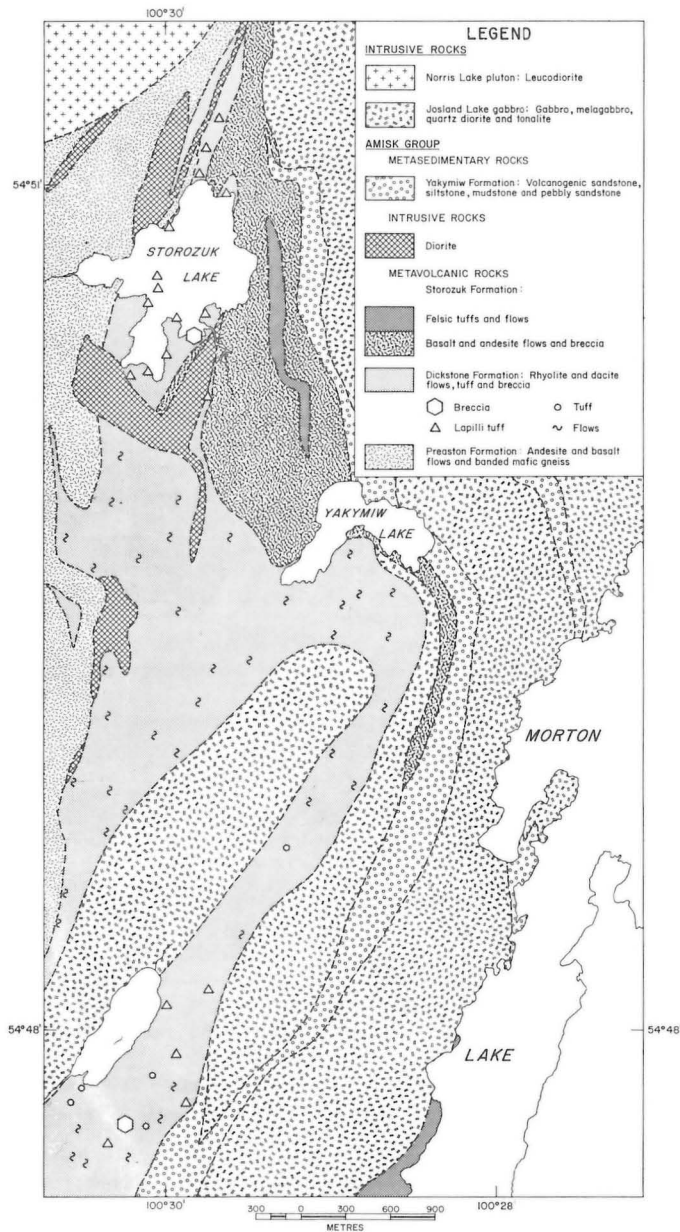


FIGURE 4: Distribution of flow and fragmental rocks in the Dickstone Formation.

The type-section of the Storozuk Formation is southeast of Storozuk Lake. It is a homoclinal, steep-dipping, east-facing 1200 m thick succession, which is overlain by volcanoclastic sediments of the Yakymiw Formation (unit 12). It becomes gradually less mafic upsection and is composed mainly of subaqueous basalt and andesite flows (unit 3). The flows are prominently pillowed (Fig. 10), particularly those stratigraphically below the felsic tuff layer of unit 3b. Vesicles and amygdaloids are common, typically concentrated within centres of pillows, adjacent to their selvages, or both. The centres of pillows commonly contain irregular alteration patches, recrystallized to

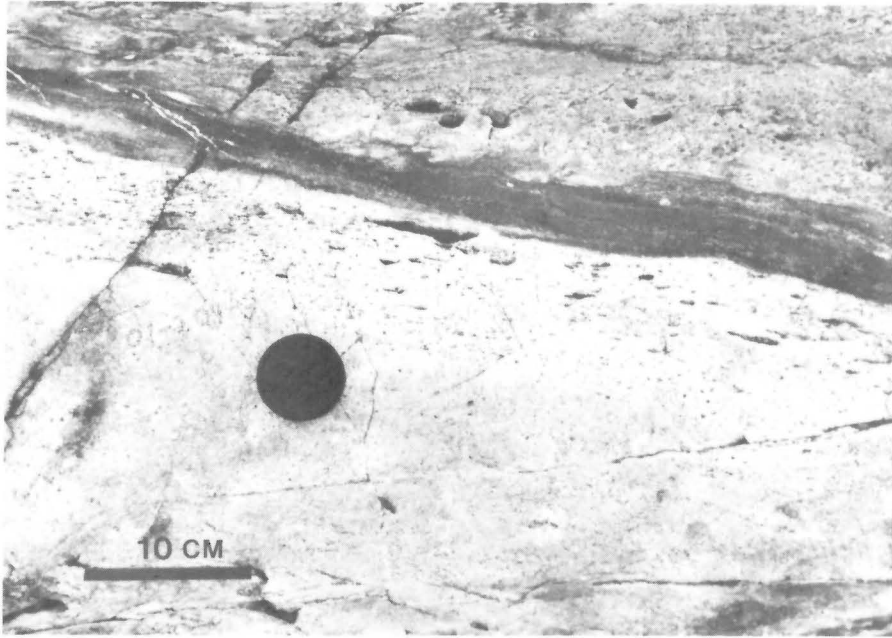


FIGURE 5: Felsic flows (unit 2a), Dickstone Formation, 2.8 km southwest of Yakymiw Lake. Note vesiculated top of light coloured flow unit and flow lines at base of overlying flow.

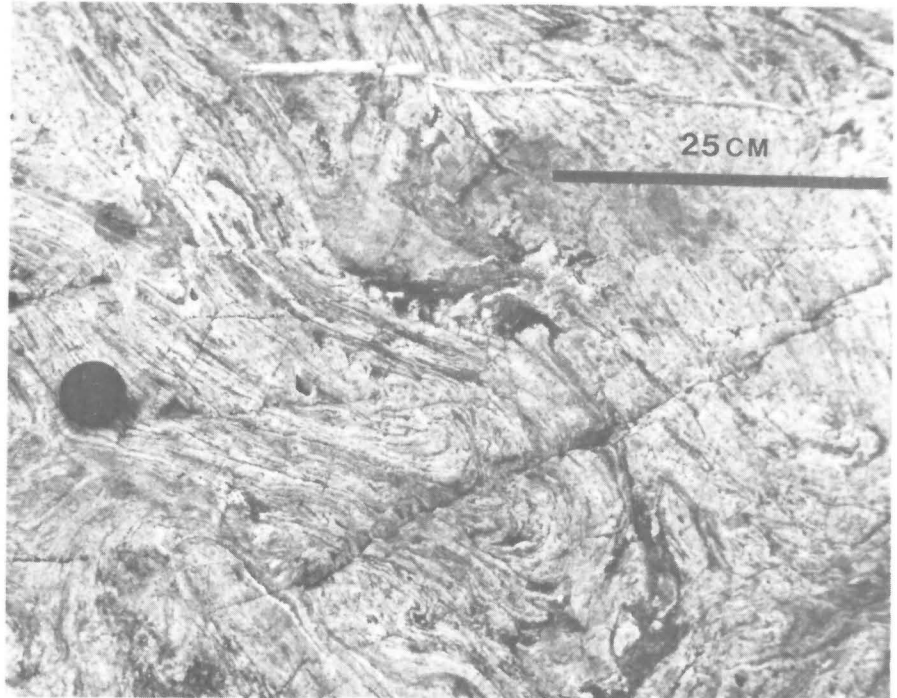


FIGURE 6: Contorted flow layering in felsic flow (unit 2a), Dickstone Formation, 1.4 km southwest of Yakymiw Lake.

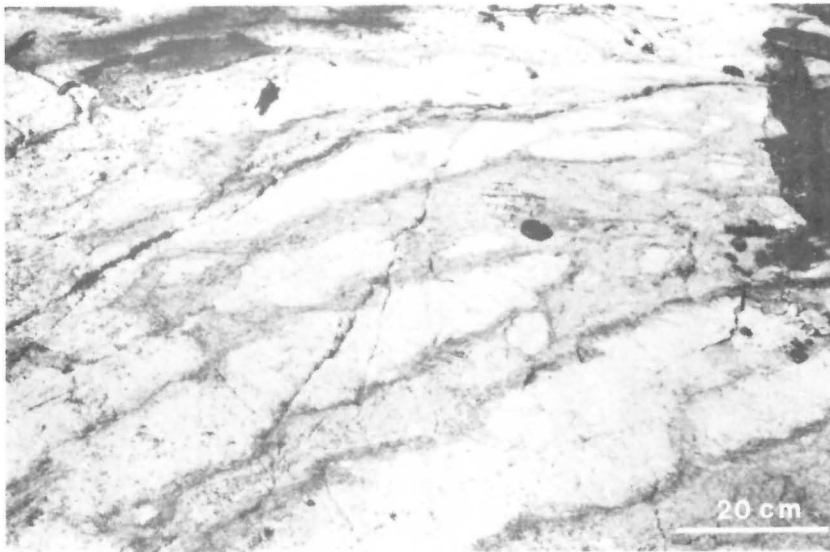


FIGURE 7: Pods of massive white rhyolite in rust-brown to light grey tuff (unit 2b), Dickstone Formation, 4 km south-southwest of Yakymiw Lake. Note dark altered rims on rhyolite pods.



FIGURE 8: Irregular bodies and blocks of white rhyolite in a matrix of light grey tuff and lapilli-tuff (unit 2b), Dickstone Formation, southwest shore of Storozuk Lake.



FIGURE 9: Irregular lobe of white rhyolite in a matrix of grey tuff (unit 2b), Dickstone Formation, south shore of Storozuk Lake.

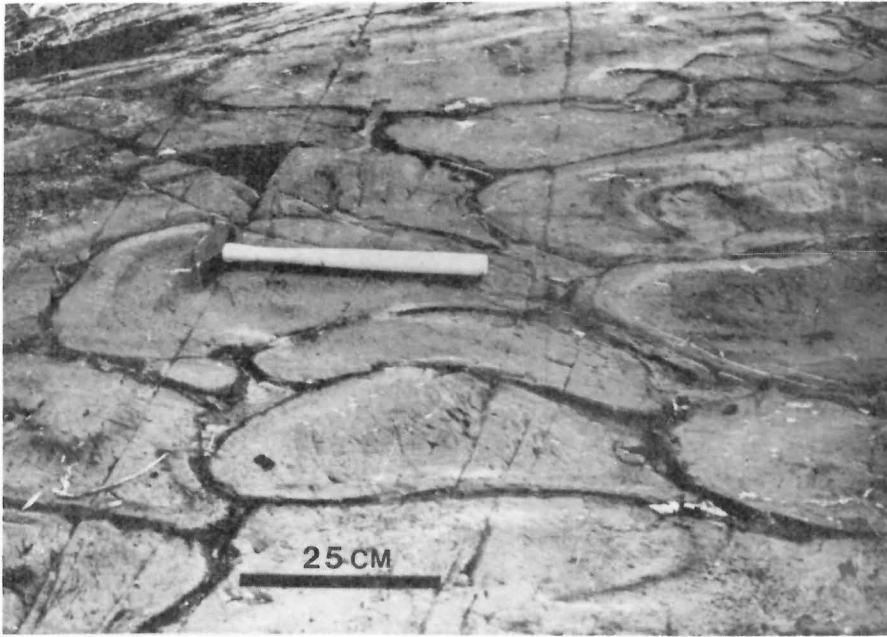


FIGURE 10: Pillow basalt (unit 3), Storozuk Formation, southeast shore of Storozuk Lake.



FIGURE 11: Irregular carbonate-epidote-bearing alteration patches in pillow basalt (unit 3), Storozuk Formation, 150 m east of Storozuk Lake.

yellow-green mixtures of epidote and carbonate (Fig. 11). The pillow flow units rarely contain narrow layers of isolated pillow breccia (Figs. 12 and 13). North of Yakymiw Lake, a 50 m thick layer of heterolithologic fragmental andesite (unit 3a), with rare felsic clasts, outcrops near the top of the Storozuk Formation. To the north this layer is strongly gossaned. A 100 m thick unit of fine grained, generally massive, white weathering felsic volcanic rocks (unit 3b) occurs near the top of the Storozuk Formation, southeast of Storozuk Lake. This unit is distinctly layered at its base, with rare graded beds. The relationship of this layer of felsic rocks to the host mafic volcanic flows is uncertain.

Southeast of Josland Lake, the Storozuk Formation is exposed in a major antiformal structure. This section, like the type-section,

contains mainly mafic pillowed flows (unit 3). However, it differs somewhat as it contains a higher percentage of porphyritic monolithologic pyroclastic rocks (unit 3a) and because it is intruded by numerous epizonal intrusions of diorite (unit 9) and large sills of the Josland Lake Gabbro (unit 18). Adjacent to the gabbro intrusions large portions of units 3 and 3a have pseudo-gabbroic textures due to ubiquitous amphibole porphyroblasts. Two narrow units of felsic volcanic rocks (unit 3b) occur in the Storozuk Formation southeast of Josland Lake. One outcrops along the east shore of Josland Lake and comprises white weathering, locally pillowed, intermediate to felsic rocks containing phenocrysts of andesine and porphyroblasts of tremolite-actinolite. It is commonly carbonate-bearing and strongly gossaned. The second layer is a felsic tuff which outcrops northwest of

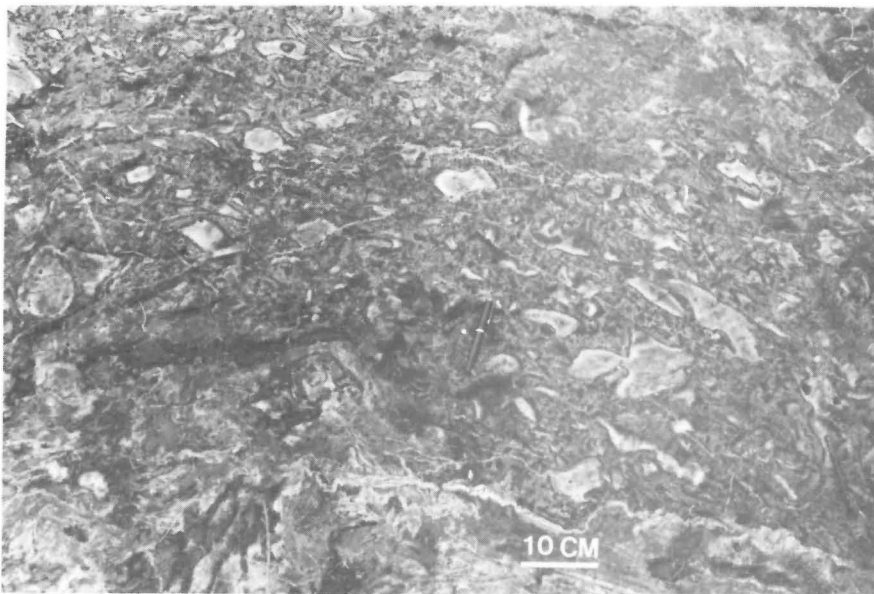


FIGURE 12: Isolated pillow-breccia at top of pillowed basalt flow (unit 3), Storozuk Formation, 600 m southeast of Storozuk Lake.

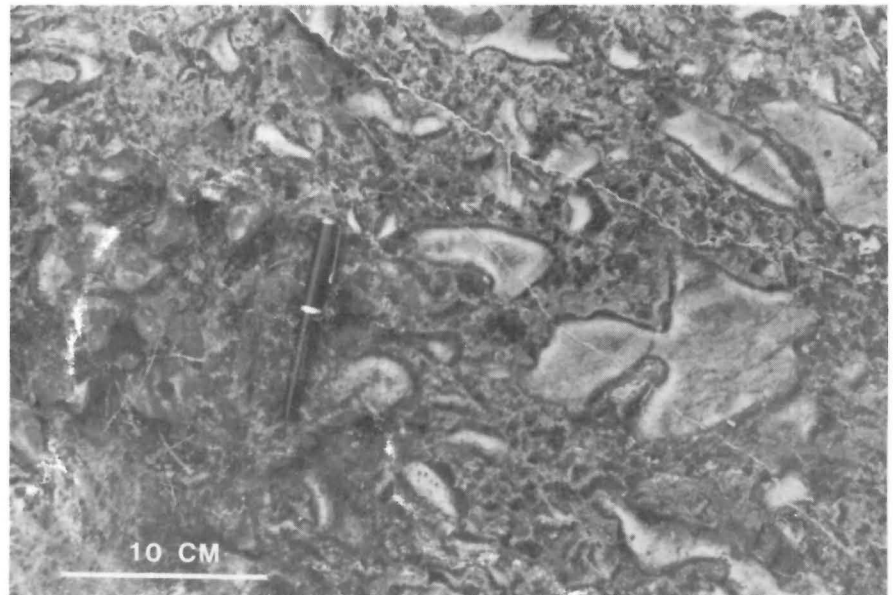


FIGURE 13: Close-up of isolated pillow-breccia in Figure 12. Note miniature amoeboid pillows and dark pillow-selvage fragments.

Morton Lake between sills of the Josland Lake Gabbro. This tuff generally has a baked, bleached hornfelsed appearance and locally contains disseminated sulphide minerals and is weakly gossaned.

Between Ducharme Bay and Loonhead Lake rocks of the Storozuk Formation are strongly recrystallized and comprise mafic metavolcanic gneiss (unit 3c) and minor amounts of felsic metavolcanic gneiss (unit 3d). The mafic metavolcanic gneisses of unit 3c are featureless dark green equigranular melanocratic granoblastic mixtures of hornblende, plagioclase and biotite. The felsic metavolcanic gneiss outcrops in three small lenses at the top of the Storozuk Formation, just below paragneisses of unit 13c of the File Lake Formation. The lens exposed southwest of Corley Lake comprises weakly porphyritic massive leucocratic light grey to pale buff weathering intermediate to felsic orthogneisses. In contrast the lenses of unit 3d due east of Corley Lake and on the east shore of Loonhead

Lake are non-porphyritic, fine grained, equigranular and very siliceous.

The Storozuk Formation represents a discrete, dominantly mafic volcanic episode that is probably unrelated to the mafic volcanism of the underlying Preston Formation. The subaqueous flows of the Storozuk Formation have covered the flanks of the Dickstone volcano. The relationship of these flows to the dacite flows of unit 4 and to the basalt and andesite flows of unit 5 is uncertain. However, an interpretation of major fold structures west of Morton Lake (see sections C-C' and D-D', Figure 95) suggests that the dacite flows of unit 4 lie above the Storozuk Formation and that the basalt and andesite flows of unit 5 are, in part, stratigraphic equivalents of the basalt and andesite flows (unit 3) of the Storozuk Formation. The fine grained intrusions of diorite (unit 9), common in rocks of the Storozuk Formation, are likely synvolcanic.

DACITE FLOWS (4) AND METADACITE (4a)

Unit 4 comprises massive homogeneous dacite flows and unit 4a consists of metadacite characterized by 1 to 3 mm porphyroblasts of actinolite. The lateral extent and stratigraphic position of the units is uncertain as they outcrop only on Elmes Island, Morton Lake, and are not observed in contact with other rock formations. The units probably overlie the mafic flows of the Storozuk Formation and are likely overlain by turbidite greywacke, siltstone and mudstone of the File Lake Formation. Their thickness, assuming the succession on Elmes Island is homoclinal, is over 600 m. They have been intersected in drill holes by Hudson Bay Exploration and Development Co. Limited up to 1.5 km south of Elmes Island and, consequently, their lateral extent is over 2.5 km. Their general features are summarized in Table A-1.

The dacite flows of unit 4 are white to light grey weathering, massive, and aphanitic to fine grained. They are generally featureless, but locally contain autoclastic monolithologic breccias, rare pillows, rare quartz phenocrysts and scattered quartz-filled amygdaloids. Two types of autoclastic breccias are recognized: flow-top breccias with angular fragments; and monolithologic breccias with rounded fragments containing curving bifurcating fractures. The rounded fragments, which resemble shattered porcelain are enclosed in a green, fine grained matrix. The clasts in both types of breccia are tectonically deformed with steep south-plunging long axes.

Rocks of unit 4a outcrop along the northeast shore of Elmes Island and on a small island to the north. They are white to light green weathering, felsic, and contain up to 15 to 20 percent randomly oriented acicular porphyroblasts of actinolite. The actinolite porphyroblasts impart a pseudo-igneous texture to the metadacites, which were originally mapped as a diorite by Harrison (1949). The actinolite porphyroblasts were probably formed by contact metamorphism by the sill of gabbro (unit 18) exposed on the east shore of Morton Lake.

The rocks of units 4 and 4a were probably part of a small local subaqueous dacite dome which extruded quietly above the mafic flows (unit 3) of the Storozuk Formation. Their relationship to the felsic volcanic rocks (units 3b and 3d) of the Storozuk Formation is not known; however, they may, in part, be stratigraphic equivalents.

BUTLER-FUSSEY LAKES AREA

The Butler-Fussey Lakes area, located between Morton and Woosey Lakes, contains a thick monotonous sequence of mafic volcanic flows (unit 5) and a 200 m wide and 1 km long lens of dacite fragmental rocks (unit 6). The volcanic succession is complexly deformed and a major north-trending steep-plunging fold is defined, north of Butler Lake, by top determinations on pillowed flow units. The total thickness of the Butler-Fussey Lakes volcanic sequence is not known, but is estimated to be over 2 km with no base exposed.

The volcanic rocks of the Butler-Fussey Lakes area are only slightly recrystallized and generally contain greenschist facies mineral assemblages. In their most southerly and northerly exposures, they are more strongly recrystallized and contain lower almandine-amphibolite facies mineral assemblages. In the south this is due to contact metamorphism and in the north to an increase in the grade of regional metamorphism.

The volcanic rocks of the Butler-Fussey Lakes area underlie sedimentary rocks of the File Lake Formation and probably correlate, at least in part, with mafic volcanic rocks of the Preston Formation (unit 1) and the Storozuk Formation (unit 3) according to structural cross sections C-C' and D-D' on Figure 95 (in pocket).

BASALT AND ANDESITE FLOWS AND RELATED ROCKS (5, 5a, 5b, 5c)

Basalt and andesite flows of unit 5 are the dominant rock type of the Butler-Fussey Lakes volcanic succession. Also present are some labradorite-phyric basalt and andesite flows (unit 5a), which outcrop around the Reed Lake pluton, and some basalt and andesite breccia (unit 5b), which outcrop in a narrow north-trending layer 1 km west of

Butler Lake. At the north end of Ducharme Bay rocks of unit 5 are strongly recrystallized to mafic orthogneisses (unit 5c).

Unit 5 comprises equal amounts of massive and pillowed mafic flows. The flows locally contain small lenses of pillow breccia and isolated pillow breccia. They contain no intermixed pyroclastic debris, except rare metre-wide layers of mafic ash. The proportion of hyaloclastic breccias is uncertain as many volcanic rocks with rough, rubbly weathered surfaces, considered in the field to be flow rocks with closely spaced fractures, when examined more closely in cut, etched samples, are monolithologic hyaloclastic and pillow-fragment breccias cemented by carbonate. Locally, rocks of unit 5 contain amygdaloids and vesicles, and pillowed varieties commonly contain irregular alteration patches, recrystallized to yellow-green mixtures of epidote and carbonate. Most of the rocks of unit 5 are fine grained equigranular mixtures of upper greenschist facies mineral assemblages, mainly plagioclase and dark green amphibole, with small amounts of biotite, chlorite and epidote. Adjacent to the Reed Lake pluton and along the south shore of File Lake rocks of unit 5 are foliated and slightly coarser grained. Along the south shore of File Lake and the west shore of Woosey Lake they are locally strongly sheared. West of Butler Lake, in a homoclinal steep-dipping west-facing succession, a gradual upwards change to slightly less mafic flows occurs as the layer of fragmental dacite (unit 6) and pyroclastic andesite-basalt breccia (unit 5b) is approached.

Unit 5a is a plagioclase-phyric metabasalt to meta-andesite which crops out southeast of Butler Lake, adjacent to the Reed Lake pluton. It is characterized by up to 30 percent lath-shaped phenocrysts of strongly twinned labradorite (Fig. 14). The labradorite phenocrysts are typically planar aligned, possibly a primary flow alignment, and commonly have delicate well formed igneous zoning. Microlites of lath-shaped plagioclase are also common in the groundmass of these rocks. Carbonate and quartz-filled vesicles, up to 1 cm in diameter, are present locally. The groundmass of rocks of unit 5a has been contact metamorphosed by the Reed Lake pluton to a mixture of green hornblende, brown biotite, plagioclase, epidote and iron oxide minerals; metamorphic adgrowths of anorthite have been developed on the labradorite phenocrysts. Carbonate-filled vesicles reacted with the host silicate minerals during the contact metamorphism and are now zoned from core to rim, as follows: calcite—calcium garnet—diopside—mixture of epidote, plagioclase and sphene.

Unit 5b comprises mafic to intermediate volcanic breccia which occurs intermixed with flow rocks of unit 5 in a narrow north-trending zone west of Butler Lake. These rocks are on strike with a small lens of fragmental dacite (unit 6). The breccias of unit 5b are slightly heterolithologic and probably pyroclastic. Most of the fragments are mafic to intermediate in composition, but they include some felsic varieties. Many of the flows and pyroclastic rocks of unit 5b are porphyritic. They are overlain, to the west, by mafic flows of unit 5.

Unit 5c comprises strongly recrystallized regionally metamorphosed mafic orthogneisses which crop out at the north end of Ducharme Bay. They are fine grained, foliated and consist of middle almandine-amphibolite facies mineral assemblages. They locally contain poorly preserved pillows and are lithologically identical to the mafic metavolcanic gneisses of unit 3c. They are separated from the latter rocks by a fault zone, which has arbitrarily been chosen as the division between the Storozuk-Morton Lakes and Butler-Fussey Lakes area.

The mafic volcanic rocks of units 5, 5a, 5b and 5c comprise a subaqueous succession which may have been erupted from more than one vent. They correlate, at least in part, with mafic volcanic rocks of the Preston and Storozuk Formations of the Storozuk-Morton Lakes area.

DACITE FRAGMENTAL (6)

Unit 6 comprises a white to light green weathering fragmental dacite which outcrops in a north-trending 150 m wide and 600 m long zone located 1 km west of Butler Lake. The fragments in this unit vary in composition from felsic to intermediate. Unit 6 is intermixed with

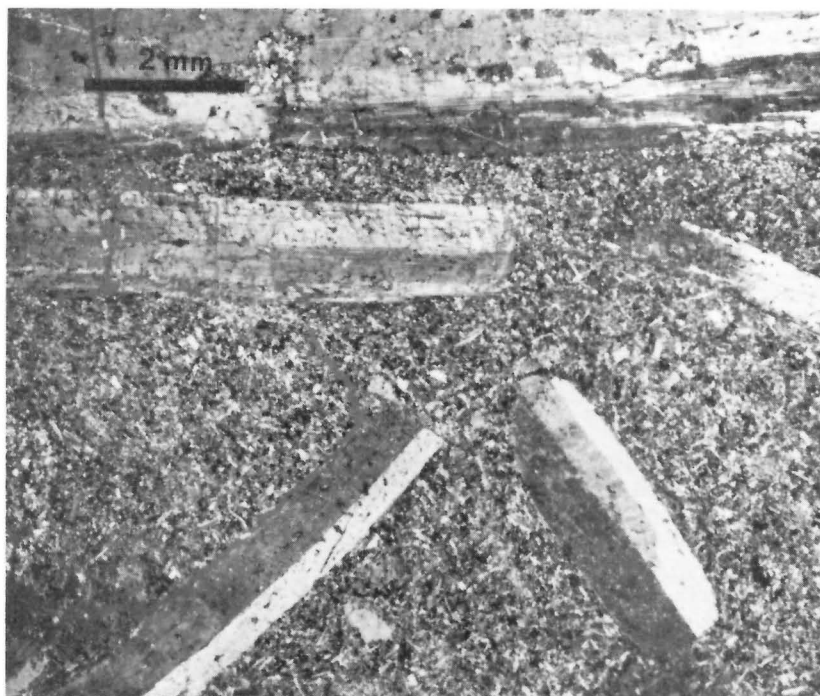


FIGURE 14: Photograph (polarized light) of plagioclase-phyric basalt (unit 5a). Note plagioclase microlites in groundmass.

intermediate to mafic flows and breccias of units 5 and 5b. The boundaries of rocks of unit 6 with those of units 5 and 5b are completely gradational.

WOOSEY LAKE AREA

A small section of metavolcanic strata occurs on the east shore of Woosey Lake. It comprises the upper part of a thick volcanic succession, which outcrops east of the map-area in the Snow Lake area (Harrison, 1949; Froese and Moore, 1980). The following units crop out on Woosey Lake:

Felsic metavolcanic gneiss (unit 8):	0-100m thick
Fragmental mafic metavolcanic gneiss (unit 7):	500 m thick

Outcrops of the volcanic rocks on Woosey Lake are poorly exposed, except those on the lakeshore, due to heavy overgrowth of lichen and moss. All the rocks contain lower almandine-amphibolite facies mineral assemblages and have been strongly recrystallized to orthogneisses by contact metamorphism associated with emplacement of the Woosey, Reed and Ham Lake plutons.

The volcanic rocks of the Woosey Lake area directly underlie Amisk metasedimentary rocks and, in this respect, occupy a similar stratigraphic position to the volcanic sequences exposed in the Butler-Fussey Lakes and Storozuk-Morton Lakes areas (Fig. 3, p. 5). A major difference is that felsic metavolcanic rocks of unit 8 occur as discrete layers within Amisk metasedimentary rocks of the Parisian Formation (unit 11), indicating overlap of the Amisk volcanism and sedimentation.

MAFIC FRAGMENTAL METAVOLCANIC GNEISS (7) AND MAFIC METAVOLCANIC GNEISS (7a)

The oldest volcanic rocks exposed in the Woosey Lakes area are mafic volcanic gneisses of units 7 and 7a. Unit 7 is a plagioclase-phyric fragmental mafic metavolcanic gneiss and unit 7a is a massive non-porphyritic and non-fragmental mafic metavolcanic gneiss. Their contact is gradational. They top to the west with rocks of unit 7a underlying those of unit 7. Their combined thickness is approximately 500 m. Their main features are summarized in Table A-1.

Rocks of unit 7 are heterolithic mafic breccias characterized by prominent plagioclase phenocrysts in both matrix and fragments.

The fragments are typically more felsic than their matrix and vary from mafic to felsic in composition. Felsic fragments are most common near the top, or west contact, of unit 7. The fragments average 2 to 6 cm in largest horizontal dimension. Locally, unit 7 includes flow rocks, some pillowed. All rocks of unit 7 are strongly recrystallized and comprise fine grained garnetiferous hornblende-plagioclase gneisses.

Rocks of unit 7a are massive homogeneous garnetiferous hornblende-plagioclase gneisses. They outcrop adjacent to the Woosey Lake pluton. They were probably massive structureless basalt to andesite flows prior to recrystallization.

The environment of deposition of rocks of units 7 and 7a is submarine, as they locally contain pillowed flow units. The heterolithic fragmental rocks of unit 7 could be pyroclastic but their wide variety of fragments suggests that they have been transported, perhaps as lahars or debris flows.

FELSIC METAVOLCANIC GNEISS (8)

Rocks of unit 8 are grey garnet- biotite-bearing gneisses derived from felsic volcanic strata. They are exposed in two small 100 m thick layers on islands in the central bay of Woosey Lake and are contained within polymictic volcanogenic conglomerates of unit 11. Their origin is difficult to discern due to destruction of most of their primary textures and structures by recrystallization during lower almandine-amphibolite facies metamorphism. However, although they are generally massive and structureless, they locally contain plagioclase phenocrysts, close packed monolithic fragments and layering with diffuse boundaries. The fragments vary in size from a few millimetres to several centimetres. The layering and monolithic clast compositions suggest that fragmental varieties of this unit were probably pyroclastic in origin.

DESCRIPTION OF INTRUSIVE ROCKS

Intrusive rocks of the Amisk Group comprise small pre-kinematic stocks, plugs, sills and dykes of diorite (unit 9) and quartz-feldspar tonalite porphyry (unit 10). They are fine grained, epizonal and possibly subvolcanic. They are hosted by Amisk Group volcanic rocks and do not intrude, and probably predate, other supracrustal rocks. They are cross-cut by small gabbro dykes that probably originate from

sills of the Josland Lake Gabbro (unit 18). They vary from weakly to moderately recrystallized and contain mineral assemblages comparable to those of their host rocks. Their main features are summarized in Tables A-2a and A-2b.

DIORITE (9)

Unit 9 is a dark green, massive, fine- to medium-grained diorite. It outcrops most prominently on Storozuk Lake and southeast of Josland Lake, where it forms irregular-shaped intrusions in volcanic rocks of the Preston, Dickstone and Storozuk Formations. It also occurs east of Morton Lake in small dykes and sills in mafic volcanic strata of unit 5. Northeast of Ducharme Bay it includes a body of gabbroic rocks, of uncertain affinity. Intrusions of unit 9, east of Morton Lake, are cross-cut by dykes of quartz-feldspar tonalite porphyry (unit 10) and those west of Morton Lake, at the Dickstone minesite, are cut by small east-trending, steep dipping, mafic dykes which are probably offshoots from a nearby sill of the Josland Lake Gabbro (unit 18).

On Storozuk Lake, diorites of unit 9 are fine grained, massive, structureless rocks. Those southeast of Josland Lake are similar except they commonly have prominent polygonal thermal contraction fractures and their contacts with the surrounding volcanic rocks are not as sharply defined nor as obviously intrusive. Some of the intrusions southeast of Josland Lake have transitional boundaries with pillowed mafic volcanic rocks of the Storozuk Formation and could be thick massive extrusive mafic flows.

East of Morton Lake, diorites of unit 9 are generally coarser grained than those west of Morton Lake. Many of them are similar to the gabbro of unit 18(1). The intrusion of unit 9 northeast of Ducharme Bay comprises a complex mixture of lithologies, ranging from rocks similar to the diorites of unit 9 to rocks resembling the gabbro and ferrogabbro of units 18(1) and 18(2).

West of Morton Lake, intrusions of unit 9 are interpreted to be subvolcanic and to have been possible feeders for volcanism of the Storozuk Formation. Those east of Morton Lake also probably include subvolcanic intrusions but, in addition, may include younger intrusive rocks related to the Josland Lake Gabbro (unit 18).

QUARTZ-FELDSPAR TONALITE PORPHYRY (10)

Unit 10 is a leucocratic white weathering quartz-feldspar-phyric tonalite. It outcrops east of Morton Lake in small plugs and irregular dykes intruding basalt and andesite flows of unit 5. Many dykes, too small to represent on the geological map, occur in the volcanic rocks east of Morton Lake. The size and abundance of the dykes generally decrease away from the major mappable intrusions. No dykes were found outside the area bounded by Morton Lake, Wotton Lake, latitude 54 °50' and the Reed Lake pluton. Intrusions of unit 10 cross-cut diorites of unit 9 and are cross-cut by small mafic dykes of uncertain genesis, but which may emanate from sills of the Josland Lake Gabbro (unit 18).

The tonalites of unit 10 are characterized by large 2-10 mm phenocrysts of quartz and plagioclase. The quartz phenocrysts are translucent, rounded crystals, with resorbed embayed boundaries (Fig. 15). Plagioclase phenocrysts are anorthitic and locally have a weak igneous zoning. The matrix is a fine grained mixture of recrystallized quartz and plagioclase with minor amounts of red-brown biotite, green amphibole, rare almandine garnet and accessory minerals formed by upper greenschist facies metamorphism. A weak to moderately strong foliation defined by biotite and slightly flattened phenocrysts of quartz and plagioclase is present locally.

The fine grain size of the matrix of the tonalites and the irregular shape and small size of their intrusions suggest they are epizonal. They may be coeval, subvolcanic intrusions, as they do not intrude any rocks younger than the volcanic succession of the Amisk Group.

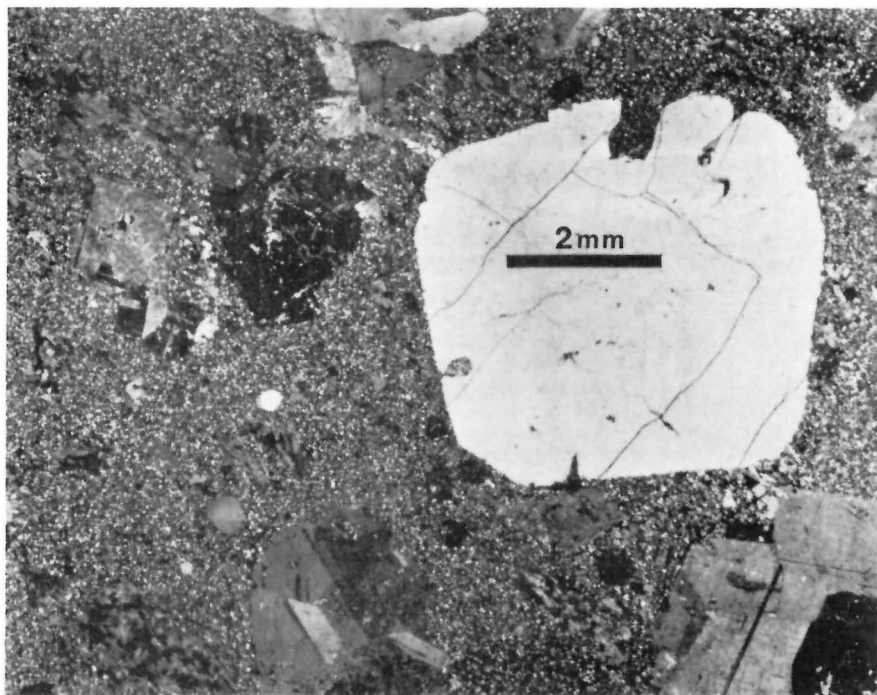


FIGURE 15: Photomicrograph (polarized light) of quartz- and plagioclase-phyric tonalite (unit 10). Note crystal faces and resorbed margins on quartz phenocryst.

GEOCHEMISTRY

Twenty-two Amisk Group extrusive and two Amisk Group intrusive rocks have been analyzed for major elements (Tables 2 & 3). The samples are from localities scattered throughout the map-area and include all rock units of the Amisk Group extrusive and intrusive suite, except unit 6. The analyses indicate that the Amisk Group extrusive and intrusive suite is subalkaline and includes both tholeiitic and calc-alkaline varieties. Alteration of samples, particularly alkali metasomatism and oxidation, is common.

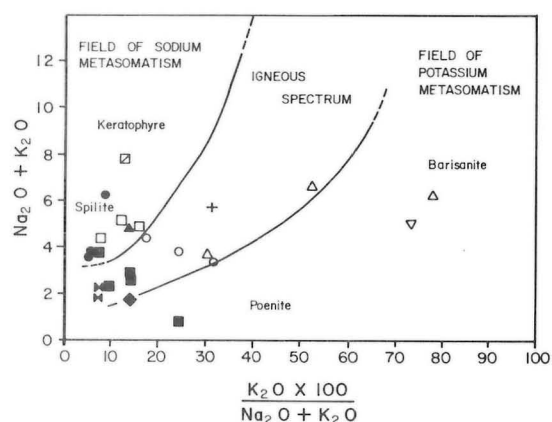
ALTERATION

Over half of the analyses of Amisk extrusive and intrusive rocks have abnormal sodium and potassium ratios, as can be seen in Figure 16a which shows samples plotted on the *igneous spectrum* diagram of Hughes (1973). The abnormal alkali ratios are interpreted to be due to alkali ion exchange alteration reactions rather than atypical primary

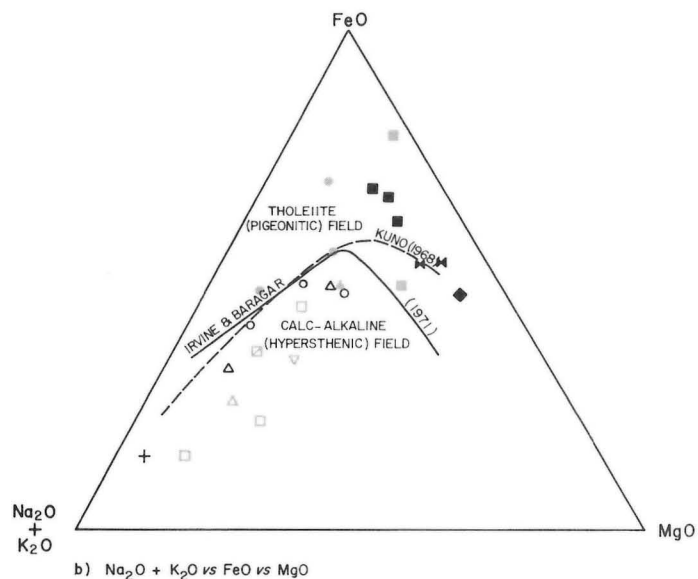
magmatic ratios. This is inferred because groups of analyses from individual units, for example units 2 and 3, are distributed across the *igneous spectrum* field rather than in small clusters or in groups which trend parallel to the field boundaries, as would be expected if they were primary igneous ratios. Another reason is that most of the alteration involves addition of sodium (or albitization), which is a common type of alteration, forming spilites and keratophyres, in submarine volcanic environments.

Several analyses of Amisk extrusive and intrusive rocks have abnormal ferric to ferrous iron ratios, either more Fe_2O_3 than FeO or more Fe_2O_3 than $\text{TiO}_2 + 1.5$, and according to Irvine and Baragar (1971) this strongly suggests oxidation. This alteration has most prominently effected metabasalts of units 3 and 3c as three of their five analyses have abnormal ferric to ferrous iron ratios.

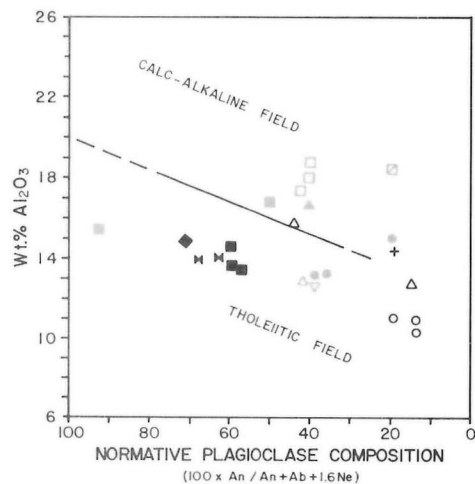
The widespread alkali metasomatism of extrusive Amisk Group rocks means that most standard chemical variation diagrams are of dubious value for classifying the volcanic rocks of the File Lake area.



a) IGNEOUS SPECTRUM DIAGRAM (AFTER HUGHES, 1973)



b) $\text{Na}_2\text{O} + \text{K}_2\text{O}$ vs FeO vs MgO



c) NORMATIVE PLAGIOCLASE vs Al_2O_3 (AFTER IRVINE AND BARAGAR, 1971)

AMISK GROUP EXTRUSIVE AND INTRUSIVE ROCKS

ALKALI-METASOMATISED ACCORDING TO IGNEOUS SPECTRUM DIAGRAM

- METABASALT AND META-ANDESITE (UNITS 1 & 1a), PREASTON FORMATION
- METARHYOLITE AND METADACITE (UNIT 2), DICKSTONE FORMATION
- METABASALT AND META-ANDESITE (UNITS 3 & 3c), STOROZUK FORMATION
- ◻ FELSIC QUARTZO-FELDSPATHIC ORTHOGNEISS (UNIT 3d), STOROZUK FORMATION
- ◻ METADACITE (UNITS 4 & 4a)
- ✕ METABASALT (UNIT 5)
- ▲ PLAGIOCLASE-PHYRIC HETEROLITHOLOGIC META-ANDESITE BRECCIA (UNIT 7)
- △ METADACITE AND METARHYOLITE TUFF AND TUFF-BRECCIA (UNIT 8)
- ▽ QUARTZ PORPHYRITIC FELSIC ORTHOGNEISS (UNIT 14a)
- ◆ METADIORITE (UNIT 9)
- ⊕ QUARTZ- AND PLAGIOCLASE-PHYRIC METATONALITE (UNIT 10)

FIGURE 16: Chemical and variation diagrams, Amisk Group extrusive and intrusive rocks (units 1 to 10).

TABLE 2: Whole rock chemical analyses^{1,2} and C.I.P.W. norms³ of mafic to intermediate Amisk Group extrusive and intrusive rocks, File Lake area.

UNIT NO.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	1		1a		3			3c	5		7	9
SiO ₂	64.9	65.1	60.25	47.0	50.0	51.8	58.35	49.75	48.2	52.85	57.95	49.8
Al ₂ O ₃	13.05	14.6	13.25	14.4	16.85	15.25	13.5	13.5	14.0	13.8	16.6	15.8
Fe ₂ O ₃	1.52	1.68	2.74	2.31	2.20	6.46	2.69	3.16	1.21	1.36	1.46	2.52
FeO	6.89	5.67	10.45	14.17	8.82	4.84	10.27	11.26	8.80	9.84	7.19	7.18
MgO	5.15	1.33	1.94	5.62	7.03	2.22	3.53	6.00	6.56	7.95	3.79	8.96
CaO	2.68	3.00	5.75	10.35	9.02	14.68	6.98	9.85	14.0	10.70	6.40	12.24
Na ₂ O	3.53	5.80	3.40	2.20	3.50	0.39	2.10	2.20	1.95	1.63	4.20	1.42
K ₂ O	0.20	0.52	0.18	0.35	0.27	0.12	0.22	0.38	0.16	0.12	0.69	0.21
TiO ₂	1.32	1.00	1.17	1.13	0.50	0.83	0.93	0.86	0.91	0.84	0.41	0.45
P ₂ O ₅	0.14	0.37	0.31	0.18	0.09	0.10	0.12	0.08	0.08	0.07	0.13	0.08
MnO	0.16	0.11	0.23	0.24	0.18	0.15	0.22	0.26	0.18	0.18	0.15	0.02
H ₂ O [±]	0.91	0.90	0.79	1.55	1.42	1.48	1.09	1.40	1.26	1.18	0.81	1.44
CO ₂	0.10	0.05	0.15	0.80	Nil	1.33	0.08	0.70	2.20	0.15	0.20	0.18
S	0.01	0.02	0.05	0.12	0.20			0.02	0.10	0.01	0.04	0.02
less S=O				(0.05)					(0.04)			
Cu(ppm)	Nil		50		Nil					100		
Zn(ppm)	0.010		300		100					100		
Cr(ppm)				34		34		Nil	154			34
Ni(ppm)				118		Nil			Nil	118		157
TOTAL	100.6	100.2	100.70	100.4	100.1	99.7	100.1	99.4	99.7	100.2	100.0	100.4
Total Fe as Fe ₂ O ₃	9.10	7.92	14.2	17.9	11.9	11.78	13.98	15.55	10.89	12.2	9.37	10.42
QUARTZ	24.58	18.77	19.04	0.0	0.0	20.64	19.31	2.68	0.0	5.22	7.53	1.6
CORUNDUM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ORTHOCLASE	1.22	3.12	1.11	2.17	1.62	0.77	1.37	2.36	0.09	0.73	4.13	1.25
ALBITE	32.57	52.73	31.70	20.67	31.78	3.80	19.77	20.77	18.38	15.00	38.13	12.95
ANORTHITE	19.71	12.43	21.15	29.94	29.81	42.89	28.07	27.19	30.42	30.73	24.68	36.64
WOLLASTONITE	0.0	0.0	0.0	0.0	0.0	5.30	0.0	0.0	0.0	0.0	0.0	0.0
ENSTATITE	6.53	3.69	4.82	7.41	6.35	0.0	8.95	12.36	6.57	16.72	9.22	17.93
FERROSILITE	7.06	6.39	11.62	9.05	3.83	0.0	12.02	10.75	4.20	10.19	8.56	6.55
FORSTERITE	0.0	0.0	0.0	3.54	7.18	0.0	0.0	0.0	1.66	0.0	0.0	0.0
FAYALITE	0.0	0.0	0.0	4.32	4.33	0.0	0.0	0.0	1.06	0.0	0.0	0.0
DIOPSIDE	2.16	0.06	1.49	8.21	7.41	13.30	2.54	10.12	20.46	11.53	2.72	14.32
HEDENBERGITE	2.33	0.10	3.60	10.03	4.47	4.47	3.41	8.81	13.09	7.02	2.53	5.23
MAGNETITE	1.63	1.78	2.98	2.53	2.33	7.33	2.95	3.47	1.33	1.48	1.54	2.62
HEMATITE	0.0	0.0	0.0	0.0	0.0	0.01	0.0	0.0	0.0	0.0	0.0	0.0
CHROMITE				0.01		0.0		Nil	0.5			0.02
ILMENITE	1.89	1.41	1.69	1.65	0.70	1.26	1.36	1.26	1.33	1.20	0.58	0.64
APATITE	0.30	0.78	0.67	0.39	0.19	0.23	0.26	0.18	0.18	0.15	0.31	0.17
PYRITE	0.03	0.05	0.14	0.33	0.0			0.06	0.27	0.3	0.11	0.5
Thornton and Tuttle Diff. Index	58.36	73.31	51.84	22.83	33.39	25.21	40.45	53.47	19.37	20.94	49.78	15.79
Normative Colour Index	21.60	13.42	26.20	46.72	36.61	26.36	31.22	25.81	49.70	48.15	25.15	47.23

- | | |
|---|--|
| (1) Plagioclase-phyric metadacite breccia (F07-1657-1) 1600 m south-southwest of Storozuk Lake. | (7) Meta-andesite (F07-130-1) from massive lavas 750 m west of Morton Lake. |
| (2) Sodium metasomatized metadacite (F07-1585-1) 60 m stratigraphically below Dickstone No. 1 orebody. | (8) Mafic fine grained hornblende-plagioclase orthogneiss (F07-2281-1), north shore of large island in Loonhead Lake. |
| (3) Strongly recrystallized garnetiferous meta-andesite tuff (F07-1671-1) 450 m north-northwest of Dickstone minesite. | (9) Metabasalt (F07-5404-1) from massive lavas, 1000 m south of southwest corner of File Lake. |
| (4) Metabasalt (F07-77-1) from massive lavas on west shore of Morton Lake, southwest of Elmes Island. | (10) Metabasalt (F07-6259-1) from massive lavas on southeast shore of File Lake. |
| (5) Metabasalt (F07-1548-1) from pillowed lavas 150 m above stratigraphic base of Storozuk Formation and 300 m west of north end of Yakymiw Lake. | (11) Plagioclase-porphyrritic amygdaloidal heterolithic meta-andesite breccia (F07-3247-1), small island 900 m east of north end of Biebrick Island on Woosley Lake. |
| (6) Metabasalt (F07-118-2) from altered pillowed lavas 180 m above stratigraphic base of Storozuk Formation and 150 m due east of Storozuk Lake. | (12) Fine grained massive equigranular metadiorite (F07-1616-1), 375 m south of Storozuk Lake. |

1 Analysts - D. Brown and J. Gregorchuk, Manitoba Mineral Resources Division.

2 Sample sites are located on Fig. 94 (in pocket).

3 C.I.P.W. norms calculated volatile-free and summed to 100 percent. Analyzed ferric and ferrous iron values were used in calculation of norm.

TABLE 3: Whole rock chemical analyses^{1,2} and C.I.P.W. norms³ of felsic to intermediate Amisk Group extrusive and intrusive rocks, File Lake area.

UNIT NO.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
		2		3d		4	4a		8		14a	10
SiO ₂	73.65	73.65	75.6	58.1	65.85	66.55	60.45	67.05	73.25	73.3	72.9	74.6
Al ₂ O ₃	10.3	10.81	10.9	18.25	17.95	18.55	17.25	15.75	12.75	12.8	12.4	14.2
Fe ₂ O ₃	0.89	2.65	0.83	1.22	0.42	0.21	0.38	0.83	0.23	1.30	0.55	0.57
FeO	4.94	3.24	3.15	4.90	1.44	0.88	5.81	5.21	2.61	2.72	3.56	0.59
MgO	2.96	1.80	1.01	2.44	1.73	0.85	2.32	2.62	1.61	1.40	2.53	0.38
CaO	0.72	0.86	1.70	5.37	5.30	5.65	5.90	3.90	2.02	1.22	1.67	1.57
Na ₂ O	2.35	2.92	3.72	7.0	4.10	4.45	4.16	2.75	1.50	3.25	1.36	3.98
K ₂ O	1.08	0.91	0.76	0.94	0.34	0.62	0.77	0.89	4.79	3.42	3.56	1.78
TiO ₂	0.30	0.29	0.24	0.69	0.40	0.40	0.75	0.32	0.16	0.14	0.31	0.12
P ₂ O ₅	0.06	0.03	0.05	0.41	0.49	0.39	0.33	0.14	0.04	0.08	0.05	Nil
MnO	0.10	0.10	0.56	0.12	0.13	0.01	0.07	0.10	0.07	0.06	0.05	0.02
H ₂ O [±]	2.04	1.20	0.93	0.88	1.07	0.65	0.98	0.85	0.83	0.47	1.20	0.77
CO	0.08	0.34	0.35	0.15	0.08	0.15	0.56	0.10	0.10	0.20	0.08	0.87
S	0.17	1.55			0.03	0.12		0.07	Nil	Nil	Nil	
less S=O								(0.03)				
TOTAL	99.54	100.35	99.8	100.5	99.3	99.48	99.23	100.55	99.96	100.4	100.2	99.5
Total Fe as Fe ₂ O ₃	6.32	6.21	4.30	6.66	2.00	1.18	6.77	6.56	3.10	4.29	4.11	1.16
QUARTZ	45.37	46.41	41.79	0.0	25.87	24.10	13.38	30.23	35.93	33.13	39.93	38.71
CORUNDUM	4.73	3.97	1.12	0.0	2.64	1.35	0.0	3.91	1.71	1.92	3.85	3.24
ORTHOCASE	6.75	5.55	4.67	5.47	2.05	3.70	4.65	5.38	29.29	20.62	21.88	10.87
ALBITE	22.29	27.02	34.70	61.82	37.50	40.34	38.17	25.21	13.92	29.74	12.69	36.88
ANORTHITE	3.36	4.20	8.43	15.35	23.53	25.73	26.70	18.23	10.09	5.64	8.27	8.04
WOLLASTONITE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ENSTATITE	8.63	5.12	2.90	1.76	4.87	2.37	6.36	7.39	4.60	3.94	7.26	1.08
FERROSILITE	6.84	0.24	5.04	1.56	1.39	0.47	7.75	7.23	3.90	3.27	5.11	0.39
FORSTERITE	0.0	0.0	0.0	2.34	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FAYALITE	0.0	0.0	0.0	2.08	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DIOPSIDE	0.0	0.0	0.0	3.49	0.0	0.0	0.36	0.0	0.0	0.0	0.0	0.0
HEDENBERGITE	0.0	0.0	0.0	3.09	0.0	0.0	0.44	0.0	0.0	0.0	0.0	0.0
MAGNETITE	0.98	2.86	0.90	1.26	0.45	0.22	0.41	0.89	0.25	1.39	0.60	0.62
HEMATITE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ILMENITE	0.44	0.42	0.35	0.95	0.57	0.56	1.07	0.46	0.23	0.20	0.30	0.17
APATITE	0.13	0.07	0.11	0.84	1.05	0.82	0.71	0.30	0.09	0.17	0.11	0.0
PYRITE	0.36	4.16			0.08	0.32		0.19	0.0	0.0	0.0	0.0
Thornton and Tuttle Diff. Index	74.41	78.97	81.17	67.29	65.43	68.14	56.20	60.82	79.14	83.48	74.50	86.46
Normative Colour Index	16.90	8.64	9.18	16.15	7.27	3.63	16.39	15.96	8.97	8.79	13.27	2.26

- (1) Quartz- and plagioclase-phyric sodic metarhyolite (F07-1636-1) 450 m south of Storozuk Lake.
- (2) Quartz- and plagioclase-phyric sodic metarhyolite (F07-1619-1) 800 m south of Storozuk Lake.
- (3) Quartz- and plagioclase-porphyrritic sodic metarhyolite (F07-309-1) 90 m south of the southwest corner of Yakymiv Lake.
- (4) Felsic fine grained hornblende-bearing quartz-feldspathic orthogneiss (F07-1796-1) 2250 m north of Ducharme Bay.
- (5) Sodic metadacite (F07-3702-1), south tip of Elmes Island, Morton Lake.
- (6) Sodic metadacite (F07-103-4), south tip of Elmes Island, Morton Lake.
- (7) Hornblende-porphyroblastic sodic metadacite (F07-603-1), northeast shore of Elmes Island, Morton Lake.

- (8) Gneissic garnet- and biotite-bearing heterogeneous metadacite tuff-breccia (F07-3227-1), small island 1250 m northeast of Biebrick Island, Woosey Lake.
- (9) Gneissic biotite-bearing metarhyolite (F07-3219-1), west shore of island located 110 m north-northeast of Biebrick Island, Woosey Lake.
- (10) Gneissic biotite-bearing plagioclase-porphritic metarhyolite (F07-3209-1), northeast shore of island located 110 m north-northeast of Biebrick Island, Woosey Lake.
- (11) Strongly recrystallized quartz phenocryst-bearing felsic orthogneiss (F07-5880-A), small island 1250 m south-southwest of hydro line on northeast arm of File Lake.
- (12) Fine grained quartz-porphyrritic tonalite (F07-5239-1) from small intrusion 375 m east of central Morton Lake.

¹ Analyst - D. Brown and J. Gregorchuk, Manitoba Mineral Resources Division.

² Sample sites are located on Figure 94 (in pocket).

³ C.I.P.W. norms calculated volatile-free and summed to 100 percent. Analyzed ferric and ferrous iron values were used in calculation of norm.

MAFIC TO INTERMEDIATE EXTRUSIVE AND INTRUSIVE ROCKS

The mafic to intermediate extrusive and intrusive rocks have subalkaline geochemistry, including normative quartz and orthopyroxene and low total alkalis (Table 2). They are considered to be predominantly tholeiitic because they are characterized by low Al_2O_3 contents ($< 16\%$), low K_2O/Na_2O ratios, and absence of plagioclase phenocrysts. They also plot in the tholeiitic field on the $Na_2O + K_2O$ vs FeO vs MgO and the Al_2O_3 vs normative plagioclase composition diagrams (Figs. 16b & 16c). They have a wide scatter on the $Na_2O + K_2O$ vs FeO vs MgO variation diagram (Fig. 16b) which probably reflects alkali metasomatism (spilitization), but could also reflect the widely separated sample sites and a consequent varied sampling of magma-types.

Basalt samples (columns 4 to 6 and 8 to 10, Table 2) are characterized by low TiO_2 contents, which average 0.86% and range from 0.50 to 1.13%, and by low P_2O_5 contents, which average 0.10% and range from 0.07 to 0.18%. These low TiO_2 and P_2O_5 values suggest that the parent magmas were not strongly fractionally crystallized, because TiO_2 and P_2O_5 are selectively concentrated in fractionated magmas. In oceanic volcanic islands and on stable cratons, subvolcanic magma chambers are typical and consequently their magmas are usually fractionated and have high TiO_2 and P_2O_5 contents. In volcanic arcs, magmas are commonly extruded directly from an unfractionated primitive deep source and typically have low TiO_2 and P_2O_5 values. Thus, the low TiO_2 and P_2O_5 values of the File Lake basalts may indicate that they were extruded in a tectonically unstable environment where the magma was tapped directly from a deep unfractionated source.

The metadiorite of unit 9 (column 12, Table 2) has a similar chemistry to basalts of unit 3, with the exception that it has slightly higher Al_2O_3 and CaO . The high Al_2O_3 and CaO contents could reflect

accumulation of calcic plagioclase in the residual magma of the intrusion chamber.

FELSIC TO INTERMEDIATE EXTRUSIVE AND INTRUSIVE ROCKS

Felsic to intermediate extrusive and intrusive rocks have subalkaline geochemistry, including normative quartz and orthopyroxene and low total alkalis (Table 3). With the exception of unit 2, they appear to have calc-alkaline geochemistry, although this is not certain because most samples have suffered alkali metasomatism.

Rocks of unit 2 are rhyolites in composition. They have low Al_2O_3 , CaO and total alkali contents (Table 3). They plot in the calc-alkaline field on the $Na_2O + K_2O$ vs FeO vs MgO diagram (Fig. 16b) and in the tholeiite field on the Al_2O_3 vs normative plagioclase composition diagram (Fig. 16c). They are considered to be tholeiitic because of their extremely low Al_2O_3 contents.

Rocks of units 3d, 4 and 4a are dacites to andesites in composition. They are characterized by high Al_2O_3 , Na_2O , TiO_2 and P_2O_5 (Table 3). The high Al_2O_3 , CaO and Na_2O contents indicate that these rocks are plagioclase-rich. They are considered to be calc-alkaline despite their low K_2O/Na_2O ratios; as the latter are likely due to post-depositional sodium metasomatism. High TiO_2 and P_2O_5 contents characterize this suite and strongly suggest that unit 3d is genetically related to unit 4. None of the other felsic volcanic strata have high TiO_2 and P_2O_5 values.

Rocks of units 8 and 14a are rhyolites to dacites in composition. They are characterized by high Al_2O_3 and K_2O contents and are considered to be calc-alkaline. Both units have similar chemistry and both occur as thin layers within the Amisk Group metasedimentary sequence.

The quartz- and plagioclase-phyric tonalites of unit 10 have calc-alkaline geochemistry. Unlike the diorites of unit 9, there are no extrusive rocks with comparable geochemistry.

TABLE 4: Primary structures and textures of Amisk Group
metavolcanic rocks, File Lake area

Primary structure or texture	Preston Formation	Dickstone Formation	Storozuk Formation	Unit 4	Unit 5	Unit 6	Unit 7	Unit 8
Pillows	XX	R	XXX	R	XXX	...	X	...
Pillow fragment breccia and hyaloclastite	...	XX	XX	...	XX	...	...	...
Flow breccia	...	...	...	XX	X	...	...	...
Amygdales	XX	XX	XX	R	XX	...	...	...
Mafic pyroclastic breccia	X	...	XX	...	...	...	XX	...
Felsic pyroclastic breccia	...	...	...	...	...	XX	...	XXX

XXX - abundant

XX - common

X - present, but not widespread

R - rare

... - not observed

SUMMARY

All the volcanic rocks are subalkaline. The mafic volcanic rocks are predominantly tholeiitic and the felsic volcanic strata are largely calcalkaline. There is no indication of mafic to felsic volcanic cycles. Rather the felsic volcanoes appear to be short-lived and rapidly deposited, each having a distinctive and unique chemistry which is unrelated to the underlying mafic succession.

The basaltic rocks are geochemically primitive and appear to have been tapped from a deep unfractionated source. Chemically they are similar to the low-K tholeiites of island arc systems, a feature noted previously for Amisk Group mafic volcanic rocks at Flin Flon by Stauffer *et al.* (1975).

Both mafic and felsic volcanic rocks have suffered extensive alkali metasomatism. This alteration is consistent with their subaqueous deposition since it occurs commonly in modern submarine environments, forming spilites from mafic volcanic rocks and keratophyres from felsic varieties.

DEPOSITIONAL ENVIRONMENT

Primary structures and textures in Amisk Group metavolcanic rocks of the File Lake area indicate that the lavas were probably extruded in a shallow water depositional environment, generally less

than 500 m deep, but with local slightly greater depth (see Ayres, 1969, for a discussion of depth criteria). The shallow water environment persisted during deposition of a 2000 m thick section and this suggests that there was subsidence during the volcanism. Subaerial volcanism is likely to have occurred in this environment as any major pyroclastic edifice constructed on such a shallow water platform would have had to have been built up above sea level.

The volcanic succession in the File Lake area is geochemically diverse and probably is a composite of deposits extruded from more than one volcano or eruptive centre. Mafic volcanic flows predominate and include both massive and pillowed flows. They may be either subaqueous fissure eruptions or parts of major subaqueous shield volcanoes. The felsic volcanic sequences comprise small domes of very local extent, and thin discontinuous lenses in the otherwise dominantly mafic flow accumulations.

In summary, mafic Amisk volcanism in the File Lake area was extruded in a shallow water environment from either fissure eruptions or from major shield volcanoes, forming an extensive platform. Periodically, more felsic material was extruded in small domes, some of which may locally have been constructed above water level. Subsidence accompanied the volcanism and, in general, maintained a shallow water subaqueous environment despite the continued thickening of the volcanic pile.

AMISK GROUP METASEDIMENTARY ROCKS

The Amisk Group metasedimentary rocks are a 1 km thick resedimented greywacke, siltstone, mudstone and pebbly greywacke sequence deposited by subaqueous gravity flows, mainly turbidity currents. They conformably overlie Amisk Group volcanic strata, but are composed of detritus which was derived from contemporaneous up-slope Amisk stratavolcanoes.

The Amisk Group sedimentary rocks comprise three formations (Map 78-1-1, in pocket; Table 1, p. 4): the Parisian Formation (unit 11); the Yakymiw Formation (unit 12); and the File Lake Formation (units 13 to 15). Their main features are summarized in Table A-3.

The three formations vary in thickness and comprise a succession with lateral and vertical facies variations (Fig. 3, p. 5; Map 78-1-1, in pocket). The Parisian and Yakymiw Formations are restricted to the south half of the map-area, to the Flin Flon belt, and occur locally. The File Lake Formation is a widespread thick unit which extends from the south to the north margin of the map-area, and from the Flin Flon belt into the Kisseynew belt.

PARISIAN FORMATION (11)

The Parisian Formation (unit 11) is a 0 to 600 m thick, wedge-shaped deposit of polymictic paraconglomerate. It outcrops on the west side of Woosey Lake and is not present elsewhere in the map-area. It overlies a heterolithic fragmental mafic metavolcanic formation (unit 7) of the Amisk Group, and contains two 100 to 200 m thick lensoid felsic fragmental metavolcanic layers (unit 8). It is overlain conformably by metagreywacke, metasiltstone and metamudstone of the File Lake Formation (unit 13b). Metamorphic grade is lower to middle almandine-amphibolite facies and primary textures and structures are generally poorly preserved. Garnet porphyroblasts and a biotite foliation are common. The main features of the Parisian Formation are summarized in Table A-3.

The paraconglomerate is a chaotic unsorted deposit that consists of 20 to 80 percent pebble-sized clasts in a completely recrystallized matrix. The matrix is a fine grained granoblastic mixture of quartz and plagioclase, with up to 20 percent combined red-brown biotite, green hornblende and mauve garnet. It was probably a siltstone or very fine grained greywacke. Bedding in the paraconglomerate is rare and has diffuse contacts. Contacts are defined by variations in clast size populations, clast type populations, clast to matrix ratios and in rounding of clasts.

Most clasts in the paraconglomerates are 1 to 3 cm in size, but some are up to 20 cm. They vary from subangular to rounded.

The following clast types, in order of decreasing abundance, have been identified in cut and etched rock slabs and in thin sections from an outcrop on the south shore of the large island 1 km north-northeast of Biebrick Island:

- fine grained felsic, probably volcanic fragments;
- quartz and plagioclase-phyric felsic volcanic fragments;
- plagioclase cleavage fragments;
- single crystal quartz grains;
- medium grained granophyric tonalite;
- vein quartz;
- chert fragments rich in disseminated graphite and pyrite; and
- mafic hornblende-rich fragments of uncertain origin.

Felsic fragments greatly predominate and indicate a felsic volcanic provenance. The individual plagioclase and quartz grains are likely to have been derived from phenocrysts in the felsic volcanic sequence. The granophyric tonalite fragments could have been derived from subvolcanic intrusions or from extrusive spines or domes.

The paraconglomerates were most likely deposited by debris flows. An intimate association with volcanism is indicated by local layers of felsic volcanic rocks (unit 8) and by framework clasts that are

almost entirely of volcanic derivation. Several features suggest a subaerial source terrain:

- 1) the wide variety of clast lithologies indicates a level of mixing that requires subaerial transport;
- 2) the thickness of the paraconglomerate sequence (600 m) is consistent with subaerial build-up, because such an extensive coarse epiclastic unit is not likely to have been derived from a subaqueous source;
- 3) the partial rounding of pebbles suggests subaerial transport or beach abrasion, although this rounding could also occur during shallow-water wave agitation, in the vent, or during avalanching down submarine slopes; and
- 4) granophyric tonalite clasts indicate that there may have been unroofing of subvolcanic intrusions.

The paraconglomerate consists of a pebble- and cobble-sized coarse fraction and a recrystallized fine fraction; it contains no intermediate, medium- to coarse-sand fraction. Similar deposits in modern submarine fan systems have been interpreted to form by rapid deposition of sand and gravel on top of unstable water-logged muds (Crowell, 1957). The loading of the muds creates an excess pore pressure because interstitial water cannot escape. The consequent reduction in shear strength leads to slump failure and debris flows. The Parisian Formation paraconglomerates could have been formed by this mechanism, for example by covering a subaqueous mud deposit with loose gravel and pyroclastic debris transported from a subaerial environment by a flash flood. However, this origin requires a pre-existing subaqueous mud deposit and this is inconsistent with the lack of interbeds of mudstone, siltstone and fine sandstone in the Parisian Formation. However, if the mud was diagenetic, formed in the volcanic environment from volcanic glass of sand-size, then a flash flood or slumping of this detritus could lead directly to a debris flow deposit of the type observed in the Parisian Formation.

Debris flows have a cohesive matrix and a tendency for rapid deposition once the angle of the slope they are traversing is reduced. For this reason, the Parisian Formation is probably close to its source and close to the margin of the Amisk sedimentary basin. The restricted extent and wedge shape of the Parisian Formation most likely represent confinement of this deposit by the pre-existing topography of the underlying Amisk volcanic terrane.

YAKYMIW FORMATION (12)

The Yakymiw Formation (unit 12) outcrops west of Morton Lake and occupies the core of a tight syncline which has been disrupted by intrusion of an axial planar sheet of gabbro (unit 18). The formation is composed of sequences of laminated mudstone, siltstone and very fine grained sandstone that are interlayered with sequences of thick-bedded matrix-supported pebbly volcanoclastic greywacke. It overlies, with apparent structural conformity, felsic subaqueous flows (unit 2) of the Dickstone Formation and mafic subaqueous flows (unit 3) of the Storozuk Formation. The maximum exposed thickness of the Yakymiw Formation is 330 m; no top is exposed.

Yakymiw Formation rocks are weakly recrystallized and contain middle to upper greenschist facies mineral assemblages, except near the Norris Lake pluton (unit 23) where they are more strongly recrystallized and contain lower to middle almandine-amphibolite facies mineral assemblages. Primary sedimentary textures and structures are generally well preserved.

The sequence of laminated mudstone, siltstone and very fine sandstone are typically a few metres thick, but locally are tens of

metres thick. Their bedding is continuous, parallel-sided, repetitive and varies from a fraction to three centimetres thick. Primary textures are not preserved due to recrystallization. Bedding, rare graded bedding and syn-depositional slump structures (Fig. 17) are the only primary structures preserved.

The pebbly greywacke beds are lensey and range in thickness from a few centimetres to 3 m, averaging 1 m. Pebble content is variable from bed to bed and ranges from 0 to 70 percent. In some beds, pebble content varies erratically, changing laterally over a few centimetres from 70 percent to less than 10 percent and fluctuating in amount across the bed. The pebbles locally form stratum, but these layers are rarely continuous. The pebbles, which range in size from 0.5 to 3 cm, vary from subangular to rounded and are wholly supported in a greywacke matrix. In many beds the pebbles are all aphyric felsic volcanic clasts that are uniform in composition, roundness and size. Such beds commonly contain large fragmental cobbles and pebbles, consisting of aggregates of aphyric felsic volcanic clasts that are identical in composition, size and shape, to the discrete clasts in the same bed (Fig. 18). The pebble types are, in order of decreasing abundance:

- felsic aphyric volcanic fragments;
- quartz- and plagioclase-phyric felsic volcanic fragments;
- single crystal quartz grains, which locally have embayed margins and adhering fine grained felsic material;
- plagioclase (now albite) crystals; and
- microcline crystals.

The greywacke matrix is a fine sand to siltstone, and contains recrystallized plagioclase, quartz and 20 to 40 percent biotite. In many beds, the distinction between matrix and pebbles, which is well defined in hand specimen, is diffuse in thin sections and is defined solely by the higher biotite content of the matrix.

Primary sedimentary structures, other than bedding, are not common in the pebbly greywacke beds. Graded bedding is present locally. Several varieties were observed: gradual size grading in thick pebbly beds (Fig. 19); concentration of large pebbles at the base of thick massive sand-sized greywacke beds; irregular poorly defined grading in thin, poorly sorted, lensey greywacke beds; and coarse-tail grading, of the kind described by Middleton (1967), in beds which have internal Bouma zonation of sedimentary structures (Fig. 20). Beds with internal Bouma zonation were only observed in a



FIGURE 17: Sequence of laminated mudstone and siltstone between two thick coarse greywacke beds (unit 12), Yakymiw Formation, north shore of Yakymiw Lake. Bottom of laminated mudstone and siltstone sequence has penecontemporaneous slump folds. A series of close-spaced faults transects bedding in upper part of photograph.

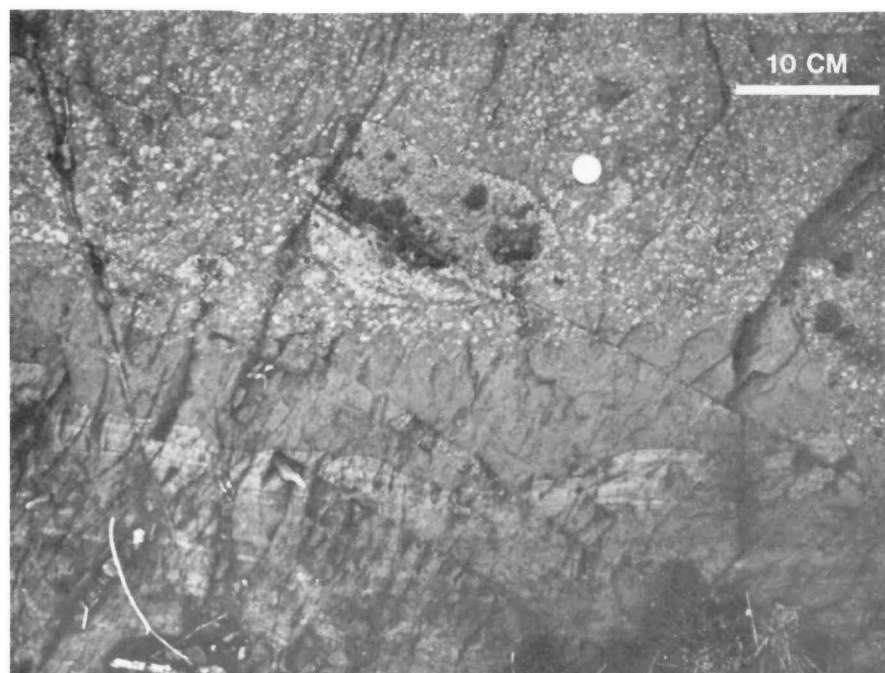


FIGURE 18: Laminated mudstone, siltstone and fine sandstone (bottom) overlain by a bed of massive greywacke that grades upward into pebbly greywacke (unit 12), Yakymiw Formation, 750 m northeast of Yakymiw Lake. Upper bed has a small scour at its base and its pebbly portion contains a large fragmental cobble which consists of felsic fragments that are similar in size, shape and composition to smaller discrete clasts in same bed. The felsic pebbles were probably pumice fragments.

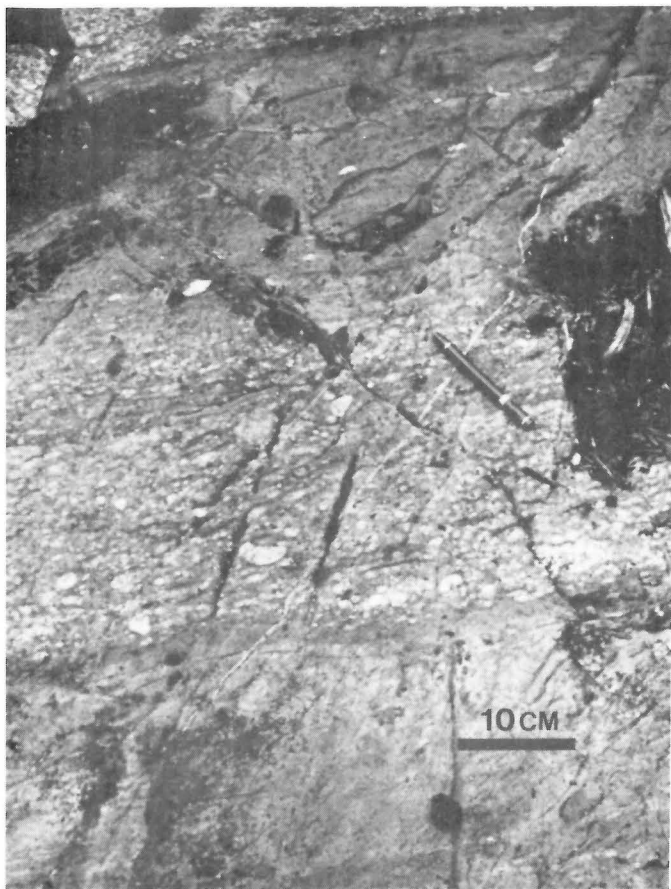


FIGURE 19: Sequence of laminated mudstone and siltstone (bottom) overlain by a normally graded metre-thick pebbly greywacke bed (unit 12), Yakymiw Formation, 700 m northeast of Yakymiw Lake. The bottom few centimetres of a thick, pebble-rich greywacke bed is exposed at top of photograph.

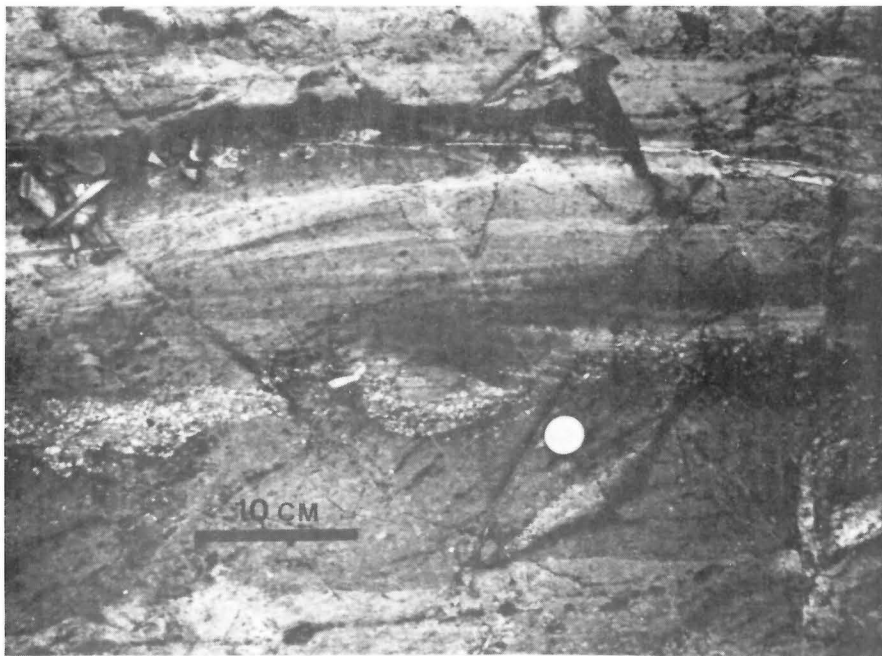


FIGURE 20: Series of greywacke and pebbly greywacke beds (unit 12), Yakymiw Formation, 700 m northeast of Yakymiw Lake. Bed above coin has scour channels at base that are filled by coarse pebbly greywacke. This bed grades upward into trough cross-stratified medium sand and subsequently into parallel laminated fine sand.

sequence of thick greywacke beds 700 m north of Yakymiw Lake. At this locality, scour channels (Fig. 20), intraformational rip-up clasts, convolute laminations, current laminations (Fig. 20) and flame structures are present. These primary structures indicate that the beds were deposited by mass-flow subaqueous density currents. Felsic volcanic pebbles occur in the upper parts of these beds (Fig. 18) and this is important because it indicates that the pebbles had a low primary density and were probably pumaceous.

The mudstone, siltstone and very fine grained sandstone sequences are interpreted to have been deposited by normal subaqueous settling of finely comminuted material, combined with weak turbidity current activity that formed rare, thin, graded beds. These strata are probably composed of volcanic detritus, but this could not be determined because of their fine grain size. The pebbly volcanoclastic greywacke beds are interpreted to have been deposited by subaqueous mass-flow density currents, which periodically entered the sedimentary basin. These subaqueous density currents could have been initiated by: slumping of volcanic detritus which collected on the margin of the sedimentary basin; subaqueous pyroclastic flows; or subaerial or subaqueous slumping of pyroclastic detritus from the flank of a volcano. The extreme immaturity of detritus, which includes microcline and plagioclase phenocrysts, embayed quartz grains, weakly cemented fragmental clasts and, perhaps pumice, indicates that there was limited reworking of detritus and is consistent with direct input of detritus into the sedimentary basin from the volcanic terrain, either as subaqueous pyroclastic flows or as debris flows. The limited heterogeneity of clast-types also indicates absence of reworking and is consistent with this origin. The rounding of detritus (Figs. 18 and 19) and the presence of lithified fragmental fragments (Fig. 18) is more consistent with an origin by slumping of partly consolidated pyroclastic flows. The rounding of detritus in the pebbly greywacke beds, given the extreme immaturity of these deposits, indicates that the detritus was probably extremely susceptible to both mechanical and chemical abrasion and was probably composed largely of volcanic glass.

The Yakymiw Formation occurs at about the same stratigraphic position as the File Lake Formation and is most likely a facies equivalent, as shown in Figure 3, p. 5. The sedimentation which produced the mudstone, siltstone and very fine grained sandstones should be widespread and may be equivalent to similar fine grained sandstone, siltstone and mudstone sequences that form unit 13a and

occur locally in units 13 and 13b of the File Lake Formation. The coarser grained, thicker beds in the two formations are quite different. In the Yakymiw Formation they are subaqueous debris flow deposits of extremely immature volcanic detritus whereas in the File Lake Formation they are turbidity current and fluidized sediment flow deposits of more mature, slightly reworked, more heterolithic volcanic debris. This difference could be due to a combination of factors, including: different sediment sources; a local topographic division of the sedimentary basin; and channelization of the turbidity currents such that only overbank turbidites and hemipelagic sedimentary deposits could occur in both formations. The Yakymiw Formation is most likely a very local sedimentary facies that was derived from a small local felsic volcanic edifice. It was probably isolated topographically from the more regional turbidity current sedimentation pattern, represented by the File Lake Formation.

FILE LAKE FORMATION (13-15)

GENERAL STATEMENT AND STRATIGRAPHY

The File Lake Formation is a 1000 m thick succession composed mainly of interbedded greywacke, siltstone and mudstone (units 13 and 13a) and derived paragneiss and migmatitic gneiss (units 13b and 13c). Near the top of the formation there is a locally developed 200 to 300 m thick metavolcanic layer (units 14 and 14a) and a more widespread 50 m thick unit of metamudstone, named the Corley Lake member (unit 15). The File Lake Formation outcrops widely in the File Lake area, in both the Flin Flon and Kisseynew belts, and extends east of the study area, at least as far as Snow Lake and Wekusko Lake (Fig. 2). To the north it can be traced directly into the widespread Nokomis Group paragneisses of the Kisseynew belt.

In most of the area, the File Lake Formation directly overlies, with apparent structural conformity, Amisk Group metavolcanic rocks, but at Woosey Lake, it overlies the Parisian Formation. Nowhere is it in direct contact with the Yakymiw Formation. At File Lake, it is overlain, possibly disconformably, by subgreywacke- and arkose-derived gneiss (unit 16) of the Missi Group.

The type exposures of the File Lake Formation are due west of Elmes Island, Morton Lake, and at the north tip of the peninsula at the south end of Morton Lake. At these localities, the top of the formation is missing but the rocks are only weakly recrystallized, with greenschist facies mineral assemblages. A complete section of the File Lake Formation is exposed along the northwest shore of File Lake, but it is folded and strongly recrystallized to biotite-, garnet-, staurolite-, sillimanite- and anthophyllite-bearing paragneisses (units 13b and 15). Similar high grade metamorphic derivatives, formed by contact metamorphism associated with syn- to late-kinematic felsic plutons, are present in the formation at Woosey Lake.

At Morton Lake, there is an increase in the sandstone to mudstone ratio and bed thickness from north to south and, in the north part of Morton Lake, from bottom to top of the exposed section. On the northwest shore of File Lake, however, the opposite relationship is observed with the sandstone to mudstone ratio and bed thickness decreasing upward. In general, the section at Morton Lake is more sandy and thicker bedded than that at File Lake, but comparisons are difficult because of the stronger metamorphic recrystallization and deformation of the File Lake section.

The stratigraphy and sedimentology of the File Lake Formation is important and is emphasized in this report because it is the only sedimentary formation which can be traced directly into the Kisseynew belt from the Flin Flon belt.

DESCRIPTION OF UNITS

GREYWACKE, SILTSTONE, MUDSTONE AND DERIVED PARAGNEISS (13, 13a, 13b, 13c)

Unit 13 is exposed in a major north-trending synclinal structure along Morton Lake. It consists of weakly recrystallized and repetitively

interbedded lithic greywacke, feldspathic greywacke, siltstone and mudstone. They contain well preserved primary sedimentary structures and textures (see pp. 26 to 35) which indicate that they were deposited by subaqueous mass-sediment gravity flows, mainly turbidity currents. The intensity of metamorphic recrystallization increases to the north. At south Morton Lake, they are relatively unrecrystallized and contain lower to middle greenschist facies mineral assemblages. At north Morton Lake, the rocks are slightly to moderately recrystallized and contain upper greenschist facies mineral assemblages. The greywacke and siltstone are light to medium grey and are composed almost entirely of volcanic detritus, mainly felsic in composition (see pp. 37 to 40). Mudstone layers are dark grey with a weak iron oxide stain on weathered surfaces.

Unit 13a outcrops on the northwest shore of Morton Lake and comprises metasiltstone, and minor metamudstone. These strata underlie and may also be lateral facies equivalent of rocks of unit 13. They occur at the base of the File Lake Formation. The rocks are massive, except for local, poorly defined thin bedding and some rare felsic volcanic pebbles. They are recrystallized, contain upper greenschist facies mineral assemblages, and comprise fine grained aggregates of plagioclase, quartz, red-brown biotite and bright green actinolite. At the north end of Morton Lake they locally contain porphyroblasts of cumingtonite and almandine. Porphyroblasts of actinolite are ubiquitous, acicular, randomly oriented and are characteristic of this unit.

Unit 13b consists of garnet-, biotite-, staurolite-, sillimanite-, and anthophyllite-bearing paragneisses derived by metamorphic recrystallization of isoclinally folded greywacke, siltstone and mudstone. They are the more highly recrystallized equivalents of unit 13 and outcrop on File Lake and on Woosey Lake.

On File Lake, unit 13b varies from moderately recrystallized garnetiferous metagreywacke, metasiltstone and metamudstone, on southwest File Lake, to strongly recrystallized garnet-, staurolite- and sillimanite-bearing paragneisses, on the south shore of Corley Lake. This is part of a regional northerly increase in metamorphic grade described in detail on pages 72 to 88 of this report. Isograd reaction surfaces for muscovite-bearing rocks are shown on the geological map (Map 78-1-1, in pocket). On southwest and south File Lake, unit 13b locally contains well preserved primary sedimentary structures identical to those in unit 13 on Morton Lake. With the exception of graded bedding and scour marks, these structures have been destroyed in more strongly recrystallized varieties to the north. The paragneisses of unit 13b, northwest of File Lake, are the only complete stratigraphic section of the File Lake Formation. They are isoclinally folded and are estimated to have a pre-folding thickness of 1050 m. The bottom quarter of the section is dominated by anthophyllite-bearing garnetiferous metagreywacke. These rocks are also exposed on the islands on southwest File Lake and the peninsula east of Ducharme Bay. There is a gradual up-formation increase in the proportion of metamudstone on northwest File Lake, with the upper third of the formation averaging 30 to 50 percent. The metamudstone beds are conspicuous as they have preferentially developed abundant and large porphyroblasts of staurolite and nodules of fibrous sillimanite. Exposures of unit 13b between Ellice and Folster Bays are strongly recrystallized paragneisses in which there are no primary structures, except bedding. They contain garnet porphyroblasts, nodules of fibrolitic sillimanite and rare staurolite porphyroblasts. They are generally more uniform in composition and lack the distinct alteration of mudstone and greywacke beds that is typical of the upper part of unit 13b on the northwest shore of File Lake.

On Woosey Lake, unit 13b comprises fine- to medium-grained garnet-, biotite-, staurolite- and chlorite-bearing paragneisses. They directly overlie polymictic paraconglomerates (unit 11) of the Parisian Formation. Adjacent to the Ham Lake, Woosey Lake and Reed Lake plutons, they are more strongly recrystallized, partially altered, and locally contain porphyroblasts of sillimanite. Andalusite occurs locally and is generally replaced by a mixture of muscovite, quartz and plagioclase. Contact metamorphism of rocks of unit 13b by the Reed Lake pluton is prominent and is described on pages 71 to 72. Strongly

flattened and elongated calcareous concretions are a characteristic feature of the paragneisses on Woosey Lake. They are strongly recrystallized and stand up in relief on weathered shoreline outcrops.

Unit 13c consists of medium grained garnetiferous paragneisses characterized by narrow sills and veins of white gneissic granodiorite and monzogranite. It outcrops north of Corley Lake, northeast of Ellice Bay on File Lake, and at the north end of the northeast arm of File Lake. It is the high grade metamorphic equivalent of paragneisses of unit 13b. The paragneisses contain granoblastic aggregates of quartz, andesine, brown biotite, pyralispite garnet and local clots of fibrolitic sillimanite. The granitic mobilizate phase locally forms discrete plugs and sheet complexes (unit 27). The appearance of the granitic mobilizate, and the discrete plugs of unit 27, is interpreted to be due to a granite melt reaction initiated by the breakdown of muscovite in the presence of quartz and plagioclase (see p. 81).

MAFIC AND FELSIC METAVOLCANIC GNEISS (14, 14a)

The File Lake Formation contains a 200 to 300 m thick layer of mafic metavolcanic rocks (unit 14) and felsic metavolcanic rocks (unit 14a) which occur 50 to 100 m below the Corley Lake member (unit 15). The mafic metavolcanic rocks (unit 14) outcrop between Ellice and Folster Bays on File Lake. The felsic metavolcanic rocks (unit 14a) occur at the same stratigraphic position but outcrop on islands along the northeast arm of File Lake. The felsic metavolcanic rocks can be traced to the west into a thick succession of Amisk Group metavolcanic rocks of the Snow Lake area (Fig. 2, p. 2).

The mafic metavolcanic rocks (unit 14) comprise fine- to medium-grained granoblastic aggregates of hornblende and plagioclase. They contain no primary structures or textures, with the exception of some strongly flattened and tectonized pillow structures, in one locality only, and widespread layering of uncertain genesis. Oxidation of disseminated pyrite and pyrrhotite, which results in rusty staining on weathered surfaces, is particularly prevalent towards the stratigraphic top of unit 14, east of Ellice Bay; it coincides with local occurrences of felsic metavolcanic rocks.

The felsic metavolcanic rocks (unit 14a) comprise white to light grey, fine- to medium-grained granoblastic plagioclase-quartz-microcline-biotite gneisses. They are indistinctly bedded and locally contain small layers of hornblende-plagioclase gneiss. Porphyroblasts of pyralispite garnet and poikilitic green amphibole are common, as are megacrysts of quartz. The latter are annealed monomineralic aggregates believed to be recrystallized phenocrysts. Rocks of unit 14a were previously mapped by Harrison (1949) as garnetiferous paragneisses derived from greywacke. However, the paucity of distinctive bedding, the presence of quartz megacrysts and their occurrence at the same stratigraphic position in the File Lake Formation as the mafic metavolcanic rocks of unit 14 supports a metavolcanic origin. Similar quartz-megacryst-bearing felsic metavolcanic gneisses occur in the Amisk Group east of the Ham Lake pluton on Squall Lake (Froese and Moore, 1980).

The layers of metavolcanic gneisses in the File Lake Formation indicate that volcanism was contemporaneous with deposition of the main metagreywacke, metasiltstone and metamudstone succession. This, combined with the volcanoclastic nature of the sedimentary rocks of the File Lake Formation (see pp. 37 to 40), suggests that the transition, in the Amisk Group, from volcanism up the sequence into sedimentation, although seemingly abrupt in the map-area, elsewhere was probably gradational and may have involved interfingering of the volcanic and sedimentary facies.

CORLEY LAKE MEMBER (15)

The Corley Lake member is a 50 m thick layer of medium- to dark-grey metamudstone (unit 15) which occurs 200 m below the upper contact of the File Lake Formation. It is exposed almost continuously for 2.5 km along strike between the northeast shore of File Lake and the south shore of Corley Lake. Small exposures are also located north of Corley Lake, on the east shore of Ellice Bay and on

several small islands on the northeast arm of File Lake. It is estimated to have a strike length of 35 km in the map-area, but most of it is covered by the waters of File Lake. North of Squall Lake, 20 km east of the map-area, it occurs along the contact of Amisk and Missi strata (Harrison, 1949; Bailes, 1975; Froese and Moore, 1980). Similar rocks, at the same stratigraphic position have been observed by the author 60 km east of the map-area on Crowduck Bay and Robertson Lake.

Rocks of unit 15 are characterized by numerous distinctive 5 to 10 mm subhedral to euhedral porphyroblasts of deep mauve to purple pyralispite garnet and by delicate 2 to 4 cm thick layering. The unit is homogeneous in composition, both across and along strike. However, there are textural and mineralogical variations along strike which reflect changes in grade of regional metamorphism. Northwest of File Lake this is reflected by gradual coarsening of the unit, and by growth of cordierite porphyroblasts. North of Corley Lake it is reflected by growth of fibrolitic sillimanite nodules.

The metamudstones of the Corley Lake member differ from those of units 13, 13b and 13c in several ways. For example, they form a distinctive homogeneous unit whereas those of units 13, 13b and 13c form cappings to greywacke beds or occur in sequences of beds alternating with sequences of beds of greywacke and siltstone. They also have distinctive garnet porphyroblasts that are volumetrically greater and several times larger in size than those in metamudstones of units 13b and 13c. The Corley Lake mudstones also have a slightly different chemistry and as a consequence lack muscovite at a metamorphic grade where metamudstones of unit 13b contain abundant muscovite. The absence of muscovite in metamudstones of unit 15 has had two important consequences. One is that metamudstones of the Corley Lake member have responded differently to metamorphism and as a consequence have significantly different mineral assemblages than those of unit 13b (see pp. 72 to 81). Secondly, the metamudstones of unit 15 do not have a granitic mobilizate phase at metamorphic grades where those of unit 13c are strongly veined by a granitic mobilizate. This is because the granitic mobilizate phase in unit 13c was formed by the breakdown of muscovite, and the absence of muscovite in unit 15 precluded formation of such a melt.

The rocks of unit 15 pose a stratigraphic problem as they occur 250 m below the top of the File Lake Formation in the File Lake area and at its top at Squall Lake, 15 km east of the map-area (Harrison, 1949; Bailes, 1975; Froese and Moore, 1980). Bailes (1975) interpreted this to mean that the Missi Group unconformably overlies, at a shallow angle, strata of the Amisk Group, with more of the Amisk succession eroded from the Squall Lake area than from the File Lake area. This is consistent with the different environments of sedimentation of Amisk and Missi Group rocks, which suggests a hiatus between the two groups. An alternative interpretation is that there were topographic variations in the sedimentary basin and that parts of the File Lake Formation that are present in the File Lake area were not deposited in the Squall Lake area.

The metamudstones of unit 15 are probably hemipelagic deposits and, as such, represent a dramatic, but short-lived, change from the pattern of sedimentation represented by the turbidite and fluidized sediment flow deposits of units 13, 13b and 13c. The nature of the change in sedimentation pattern which caused deposition of the Corley Lake member is not known. However, a temporary change in either the sediment dispersal system or the character of the source area seem most likely. For example, a temporary blockage of the main feeder channel into the sedimentary basin, perhaps by a major volcanic flow, could starve the basin of coarse detritus and allow build-up of a hemipelagic mudstone deposit. Alternatively, eruption of a fine grained easily weathered ash deposit in the source area could provide a temporary influx and deposition of finely laminated mud and silt. The widespread occurrence of the Corley Lake member, up to 60 km from the map-area, and its rather unique composition (see pp. 41 to 42) is more consistent with derivation from an ash deposit than temporary blockage of coarse detritus to the basin.

PRIMARY SEDIMENTARY STRUCTURES

Primary sedimentary structures are abundant and well preserved at Morton Lake in weakly recrystallized greywacke, siltstone and mudstone strata of unit 13. Three interbedded bed types have been identified by their internal sequence of sedimentary structures. Using the terminology of Bouma (1962), the bed types are: 1) *ABCD(E)* greywacke, siltstone and mudstone beds; 2) *AE* greywacke and pebbly greywacke beds; 3) and *DE(?)* sequences of laminated mudstone, siltstone and fine sandstone, which locally include thin (<5 cm) *A*→*E* beds of the type described by Walker (1967). At File Lake and Woosey Lake, the internal sedimentary structures by which *ABCD(E)* and *AE* beds are identified have been destroyed by coarse recrystallization.

DESCRIPTION OF BED TYPES

ABCD(E) beds, which form about 70 percent of the beds at Morton Lake, include both base and/or top truncated sequences, for example *BCD(E)*, *ABC* and *BC* beds. They range in thickness from 5 cm to 2.35 m; average thickness is 30 cm. They are composed of silt to granules, but normally consist of fine to medium sand. All the features normally attributed to turbidity current deposits occur in these beds, including: 1) the Bouma zonation of internal primary structures (Figs. 21 and 22), which is the consequence of slowing of a turbidity current according to Harmes and Fahnestock (1965), Walker (1965) and Middleton and Hampton (1975); 2) intraformational erosion features such as scour marks (Fig. 22) and intraformational mudstone clasts

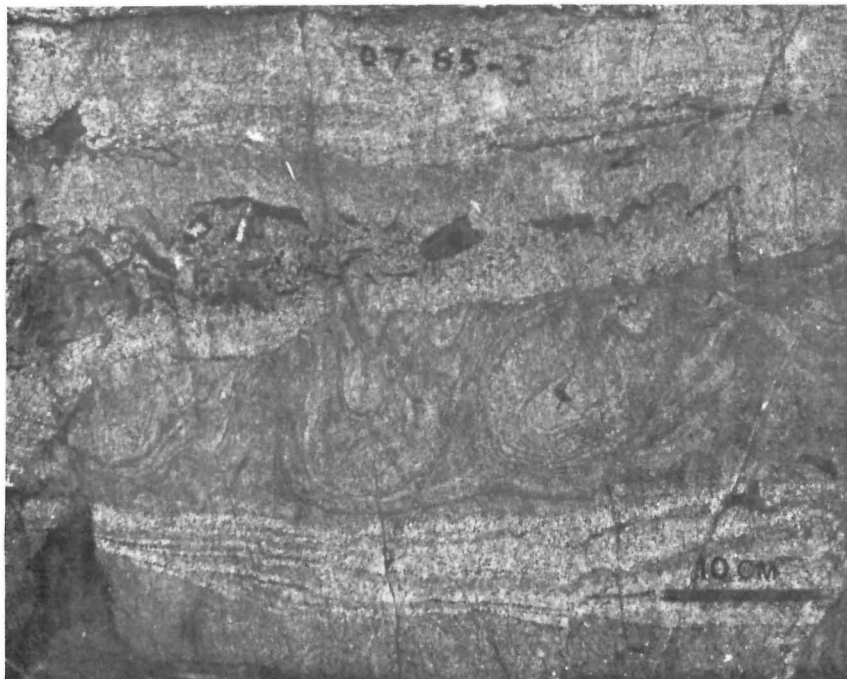
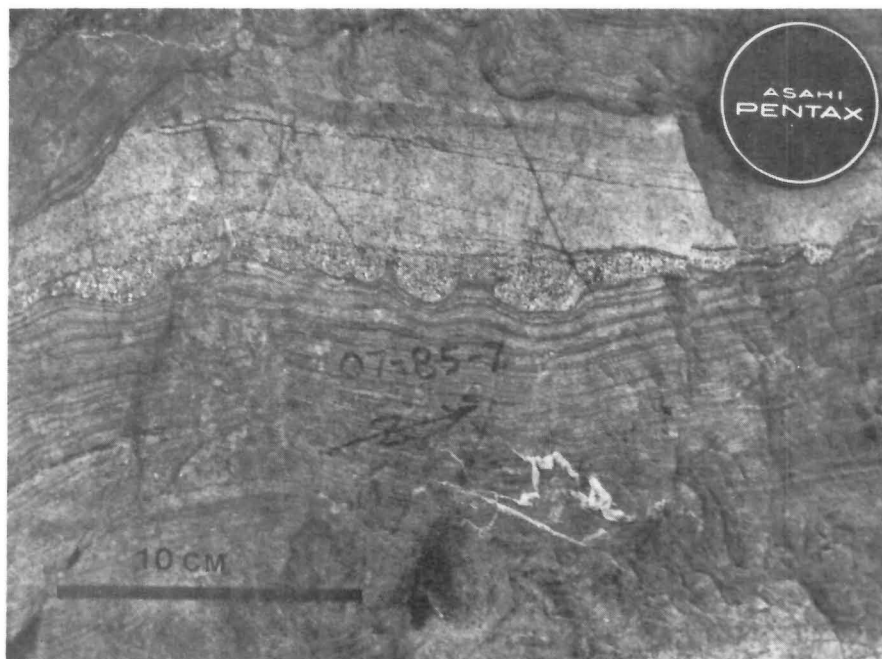


FIGURE 21: Series of *ABCD(E)* greywacke beds (unit 13), File Lake Formation, west shore of Morton Lake, opposite Elmes Island. Bottom bed consists of a massive *A* division, a parallel laminated *B* division and a convolute laminated *C* division with bulbous synclines and sharp-crested anticlines. The overlying bed truncates the convolute laminations and contains a zone of angular slabby intraformational mudstone fragments.

FIGURE 22: Parts of three *ABCD(E)* beds, File Lake Formation, west shore of Morton Lake, opposite Elmes Island. Lower bed shows *B* division; middle bed shows *A* and *B* divisions; and upper bed shows *B* division. Note loaded scour marks filled by coarse greywacke at base of middle bed and large scour mark at base of upper bed.

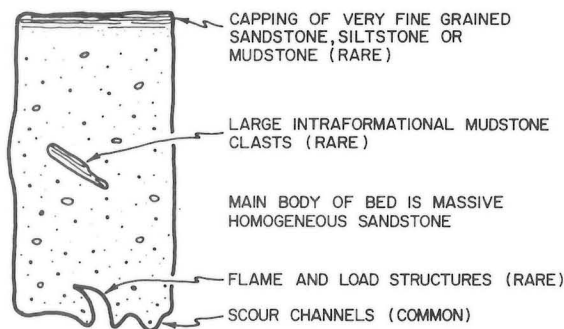


(Fig. 21) that were formed by scouring and erosion of underlying beds by the head of the turbidity flow; and 3) soft-sediment, penecontemporaneous deformation structures that were caused by instantaneous burial, loading and current induced shearing of water-saturated strata.

AE beds form about 20 percent of the beds at Morton Lake, and include both massive and graded varieties (Fig. 23). They range in thickness from 5 cm to 11.4 m; average thickness is 90 cm. They are thickest and coarsest at south Morton Lake where they form more than two-thirds of the beds, average 185 cm in thickness, are composed of medium to coarse sand, and locally contain pebbles at the base. The AE beds are intercalated with and contain many features in common with ABCD(E) beds, including intraformational scour marks and erosional features (Figs. 23 and 24), grain gradation (Fig 23), large suspended intraformational mudstone and siltstone clasts (Figs. 23 and 25), and cappings of mudstone and siltstone (Fig. 23). The main difference is that the AE beds lack traction features, such as parallel laminations and current ripple laminations, that are characteristic of the ABCD(E) turbidite beds. Several authors, most notably Middleton (1970) and Middleton and Hampton (1975), have suggested that traction features are suppressed in subaqueous, mass-sediment flows that have high grain concentrations because there is rapid restriction of grain movement and rapid deposition when the flow loses velocity. Thus, the AE beds may simply represent deposits from mass-sediment flows of higher density and higher concentration that were similar to turbidity currents in many respects, but which deposited their load instantaneously rather than by progressive deposition during a waning turbidity current as in ABCD(E) beds. The common occurrence of rapid grain gradation in the bottom few centimetres of both bed types attests to the high grain concentration of flows depositing these beds (Middleton, 1967).

Sequences of laminated mudstone, siltstone and fine grained sandstone form 10 percent of the beds at Morton Lake, except at the base of the File Lake Formation of north Morton Lake, where they predominate in the lower 200 m. They were probably deposited by settling of finely comminuted material between episodes of deposition of coarser ABCD(E) and AE beds. They include some thin, less than 5 cm thick, A→E beds (Fig. 26) of the types described by Walker (1967). Walker (1967) interpreted A→E beds to be the deposits of slow, almost stagnant turbidity currents.

a) MASSIVE AE BED



b) GRADED AE BED

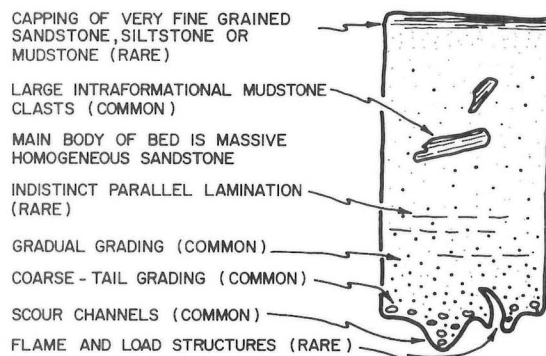


FIGURE 23: Schematic representation of sedimentary structures in typical AE beds, File Lake Formation.

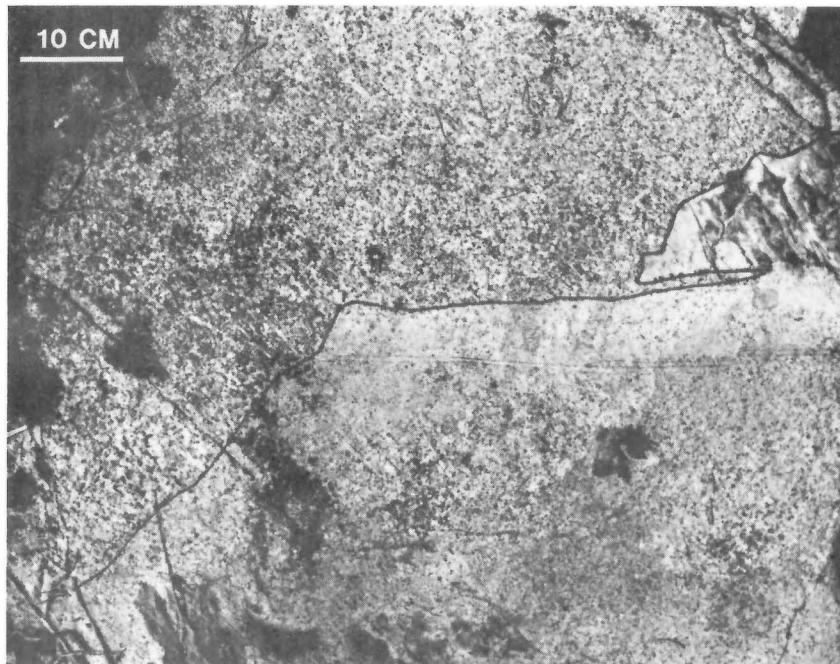


FIGURE 24: Part of large scour channel, outlined on outcrop in black, at base of thick coarse graded AE bed (unit 13), File Lake Formation, southeast Morton Lake. Underlying bed is an AE bed with a fine grained sandstone top.

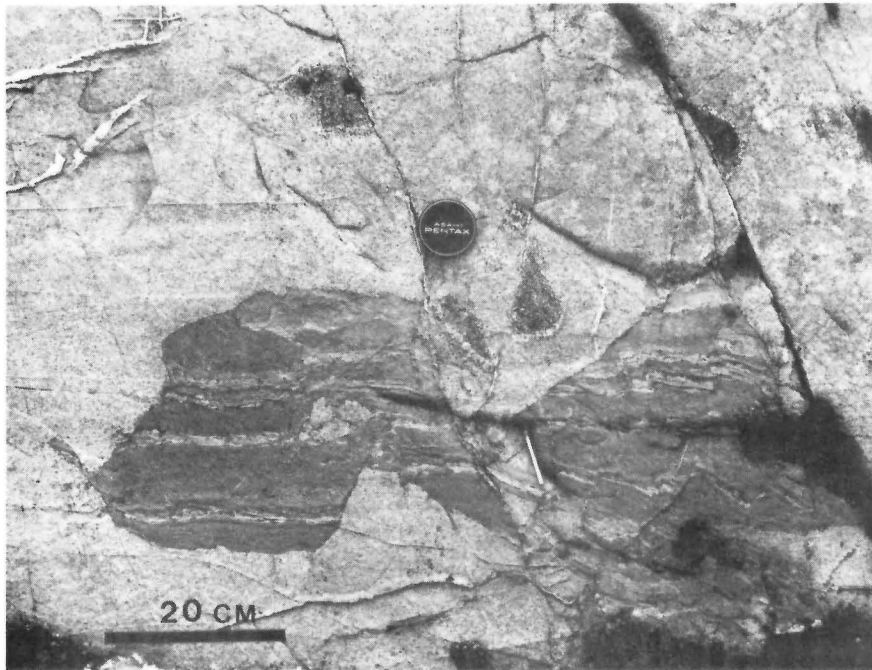


FIGURE 25: Part of thick massive coarse AE sandstone bed (unit 13), File Lake Formation, southeast Morton Lake. Note large intraformational siltstone rip-up fragment and small, dark, amphibole-rich, metamorphosed calcareous concretions.

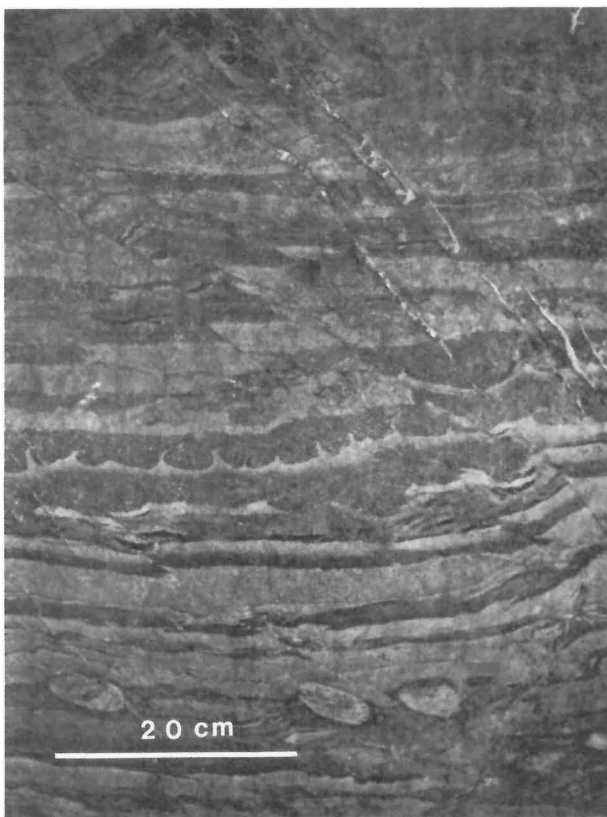


FIGURE 26: Series of A → E beds (unit 13), File Lake Formation, west shore of Morton Lake, opposite Elmes Island. Note delicate load casts on top of evenly graded, small A → E bed (in centre of photograph). Shale protrusions on loaded bed are overturned to north and indicate that this was probably the paleoslope direction. Also note ellipsoidal concretions near bottom of photograph.

DESCRIPTION OF PRIMARY SEDIMENTARY STRUCTURES

Primary sedimentary structures have been examined carefully in all exposures at Morton Lake and, in addition, their size and distribution have been recorded systematically in several representative stratigraphic sections (Fig. 27; Table 5, p. 36). Parts of two sections, one dominated by AE and the other by ABCD(E) bed-types are shown in Figure 28.

Bedding contacts

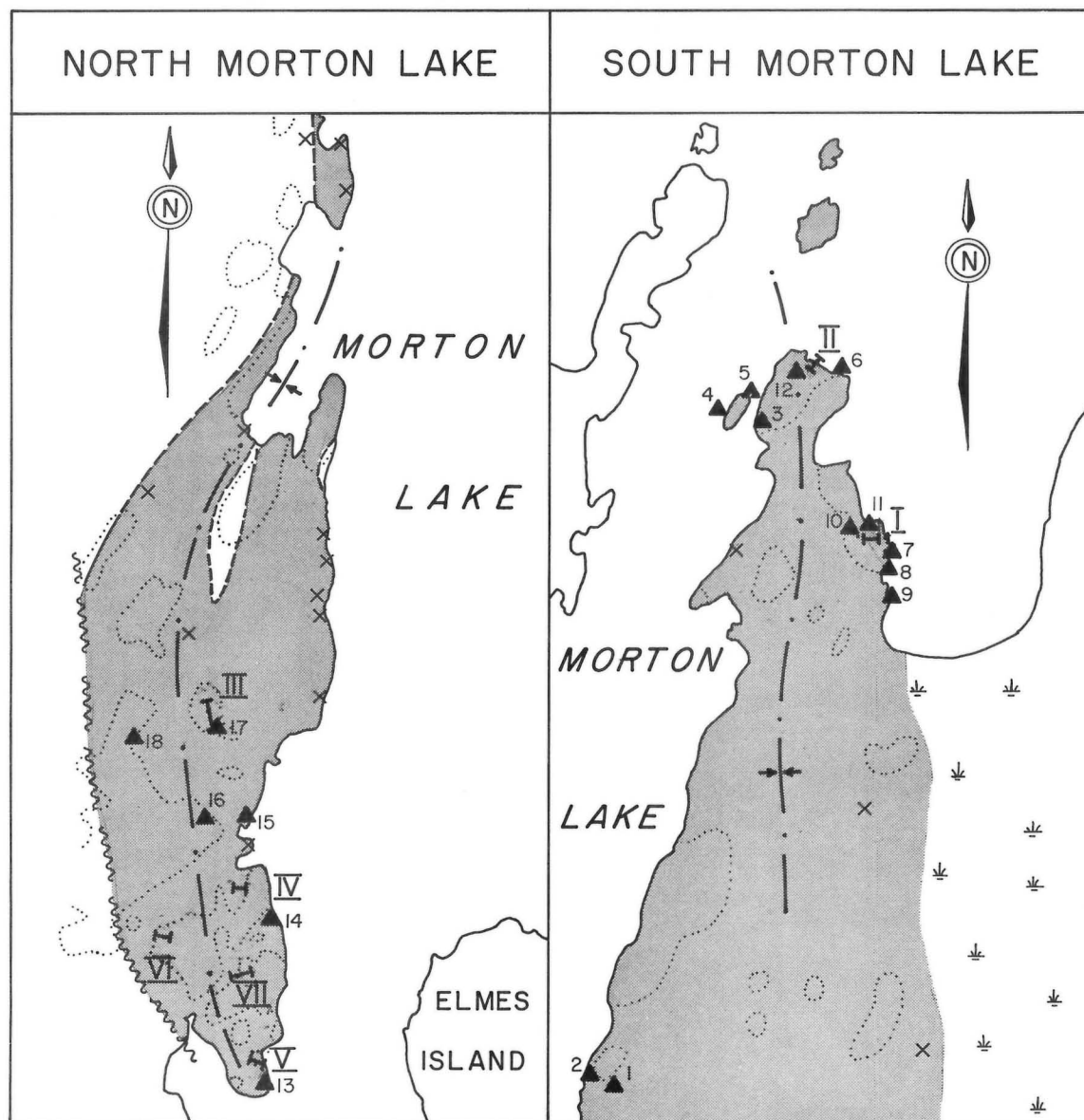
Bed contacts of ABCD(E) and AE beds are sharp. They are coarsest at their base and generally grade upwards into finer material (Fig. 22), with the base of the next bed defined by an abrupt coarsening of grain size. Mudstone and siltstone cappings sharply delineate the tops of many ABCD(E) and AE beds. Bed contacts in sequences of mudstone, siltstone and fine sandstone are well defined, regular and laterally continuous.

Bed contacts vary from flat to highly irregular, with irregularities due to a combination of intraformational erosion and soft-sediment deformation. Scour marks (Fig. 22) are abundant on the top of beds and range in depth from 0.5 to 80 cm, and average 1 to 2 cm. In general, the size of the scour marks is in direct proportion to the thickness of the overlying bed. Mudstone beds overlain by coarse thick greywacke beds have locally been ripped up, leaving irregular truncations (Fig. 27), and producing fragments within the greywacke beds (Figs. 22, 34 and 36).

Internal structures of ABCD(E) beds

ABCD(E) beds may contain all five Bouma divisions, but generally one or more of the upper divisions, lower divisions, or both are missing. Middle divisions are rarely absent.

The graded division (A) is present in 70 percent of the ABCD(E) beds. The grain size is generally coarse at the base and medium to fine sand at the top. The grain gradation, which characterizes this division, is variable. In many beds it begins as a rapid grain gradation (the coarse-tail grading of Middleton, 1967) in the bottom few centimetres, followed upward by more subtle and gradual grain gradation (the distribution grading of Middleton, 1967) or by ungraded medium to fine sand. Also common are A divisions with distribution grading throughout. In a few thick beds, reverse grading is present under large intraformational mudstone clasts, within otherwise normally



- Distribution of the unit 13 of the File Lake Formation
- Outcrop area; small outcrop
- Fault
- Measured stratigraphic section (see Table 5)
- Modal analysis of greywacke (see Table 6)
- Syncline

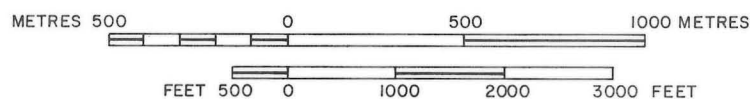


FIGURE 27: Location of measured stratigraphic sections and modally analyzed greywacke and siltstone samples (unit 13), File Lake Formation.

graded beds. Beds beginning with the A division are generally thicker than beds beginning with other divisions and are most abundant in sections containing many AE beds (Table 5, p. 36).

The lower parallel laminated division (B) is present in 90 percent of the ABCD(E) beds and typically consists of medium to fine sand. It generally overlaps or is gradational with the underlying A division. The laminations vary from diffuse and locally discontinuous to well defined and regular (Figs. 21 and 22). B divisions are poorly developed and locally missing in thick coarse beds with thick A divisions. Such beds are most common on south Morton Lake associated with AE beds.

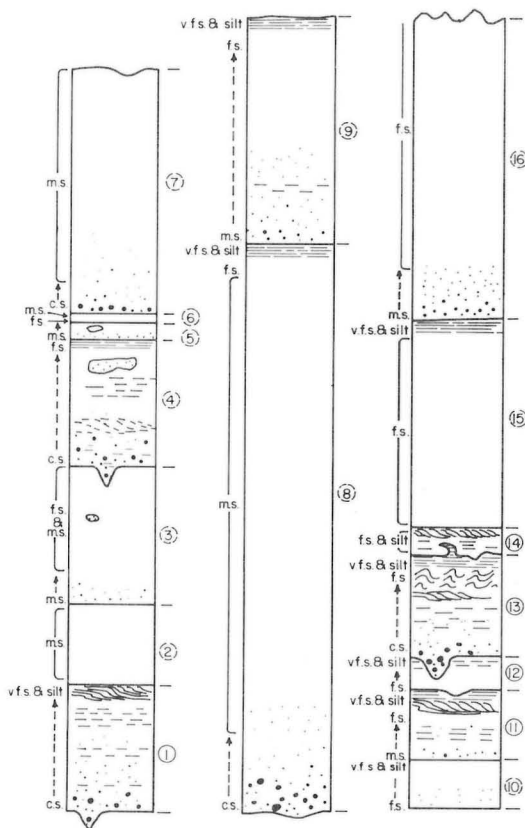
The current ripple laminated or convolute laminated division (C) is present in 70 percent of the ABCD(E) beds and typically consists of fine sand to silt. It is most prominently developed in beds of moderate thickness which either have a thin A division or begin with the B division. It is generally weak or missing in thick beds with thick A divisions. Beds with convolute laminations (Plate 21) are four times as common as those with current ripple laminations. The convolutions comprise a complex series of broad bulbous synclines and sharp crested anticlines. The upper and lower surfaces of the convoluted units are undeformed and this, in conjunction with the presence of current ripple laminations in some convoluted units (Fig. 29), indicates that the convolutions were formed by or during action of the current depositing the beds.

The upper parallel laminated division (D) and the pelitic division (E) comprise dark grey to black siltstone and mudstone. They are gradational and generally could not be subdivided. One or both of these divisions is present in 65 percent of the ABCD(E) beds.

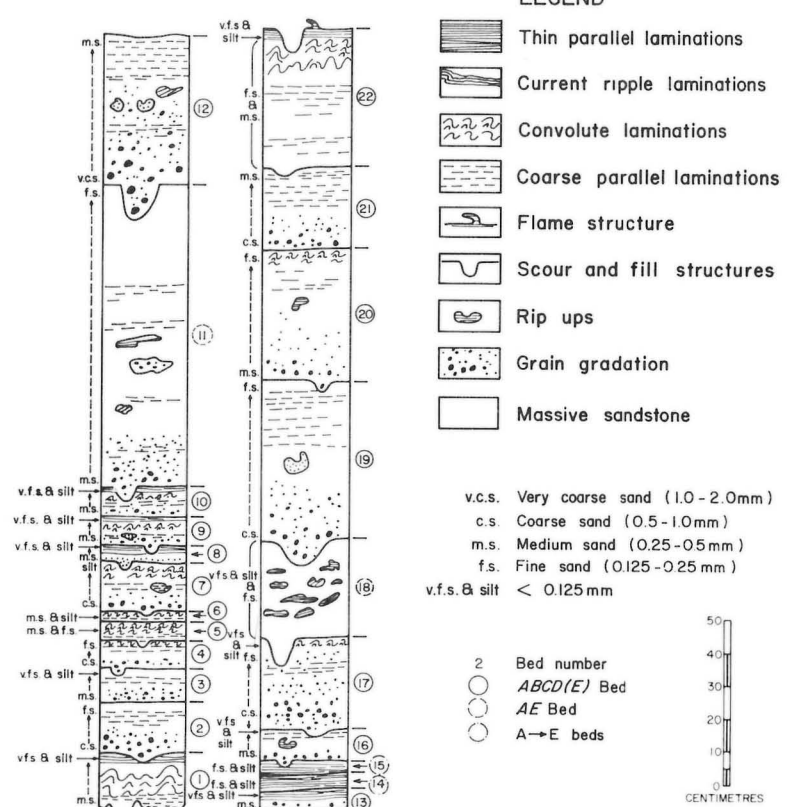
Some beds, generally less than 5 cm thick, have a narrow graded fine sand division that passes directly into massive poorly laminated, silty to clayey DE divisions (Fig. 26). These beds are similar to the A → E beds that Walker (1967) considered to be deposits of almost stagnant turbidity currents and, therefore, to be closely related to turbidite DE beds.

Internal structures of AE beds.

Both massive and graded AE beds (Fig. 23) contain scour marks, scour channels (Fig. 24), load and flame structures (Fig. 30) and intraformational mudstone and siltstone clasts (Fig. 25), but do not contain traction features, such as parallel laminations and current ripple laminations. The most characteristic feature of these bed-types, in particular the massive varieties, is their homogeneity and lack of internal structures. Grading, where present, typically comprises a basal coarse fraction, which is overlain by either massive sandstone or gradually graded sandstone that passes upward into massive sandstone. The graded beds rarely contain poorly developed coarse



a) Bottom 16 beds of section II, which is composed dominantly of AE beds.



b) Bottom 22 beds of section III, which is composed dominantly of ABCD(E) beds.

FIGURE 28: Schematic representation of measured stratigraphic sections II and III, File Lake Formation. See Figure 27 for location of sections.

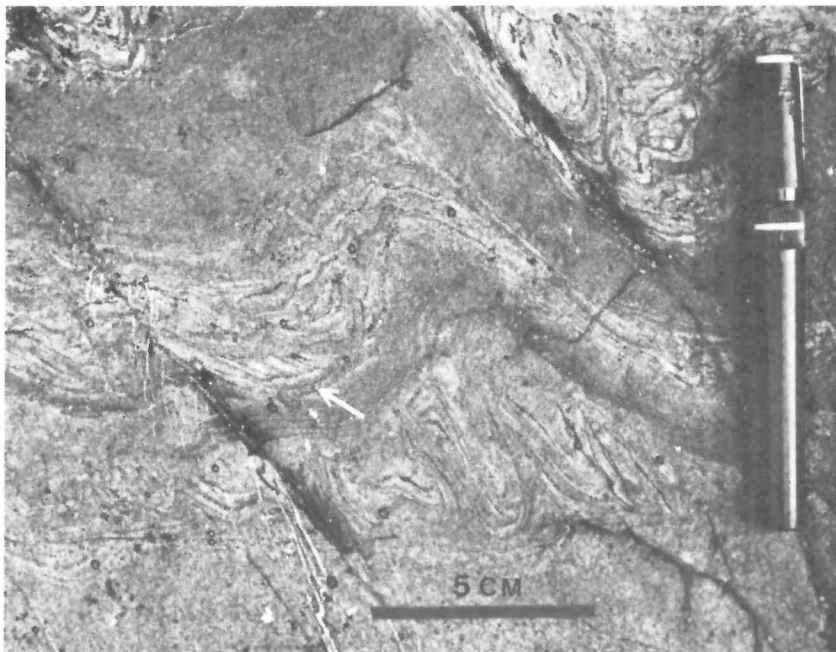
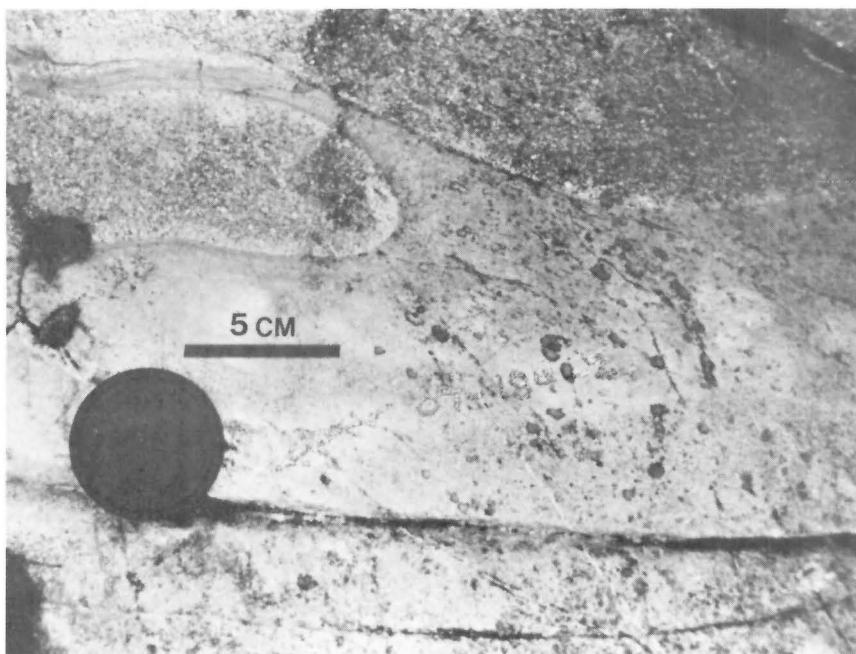


FIGURE 29: Combined current ripple laminations and convoluted laminations (see arrow) in C division of ABCD(E) bed (unit 13), File Lake Formation, 600 m northwest of Elmes Island on west shore of Morton Lake.

FIGURE 30: Two AE beds (unit 13), File Lake Formation, southeast Morton Lake. Lower bed has fine sand to silt top. Upper bed is massive, coarse sand with large flame structure at base. The flame structure is overturned to north, down the interpreted paleoslope.



parallel laminations, like those of the Bouma B division. They locally have reverse grading in the bottom 1 to 3 cm of some thick beds.

In graded beds the thickness of the graded basal zone relative to the bed thickness is variable. Where it is thin, the graded beds are very similar to massive beds. For this reason, it is likely that there is no real break between the two bed types and they are part of a continuum. To some extent, there is also a continuum between graded AE beds, that contain discontinuous parallel laminations and a capping of fine siltstone, and coarse thick turbidite ABCD(E) beds which have a thick A division but lack the C division. However, beds that are difficult to classify as either AE or ABCD(E) are extremely rare. Generally any bed of this type which contained relatively continuous coarse parallel

laminations, restricted to a definable zone, was classified as an ABCD(E) type.

Penecontemporaneous deformation structures

Both ABCD(E) and AE beds contain deformation structures that formed during or immediately after deposition, while the sediment was still soft. These include: gravity induced features such as load structures; gravity movement structures such as slump faults and folds; and liquefaction structures such as sandstone intrusions.

Load structures, that formed when heavier sand sank into lighter fine sand, silt and mud of the underlying bed, are common. They include bulbous sand protrusions into underlying mud or silt beds and

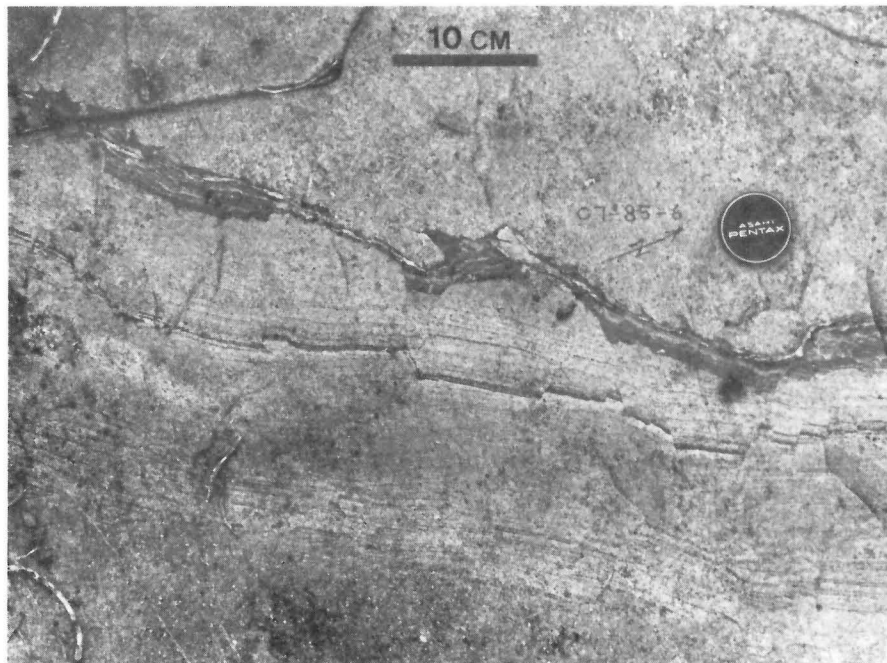
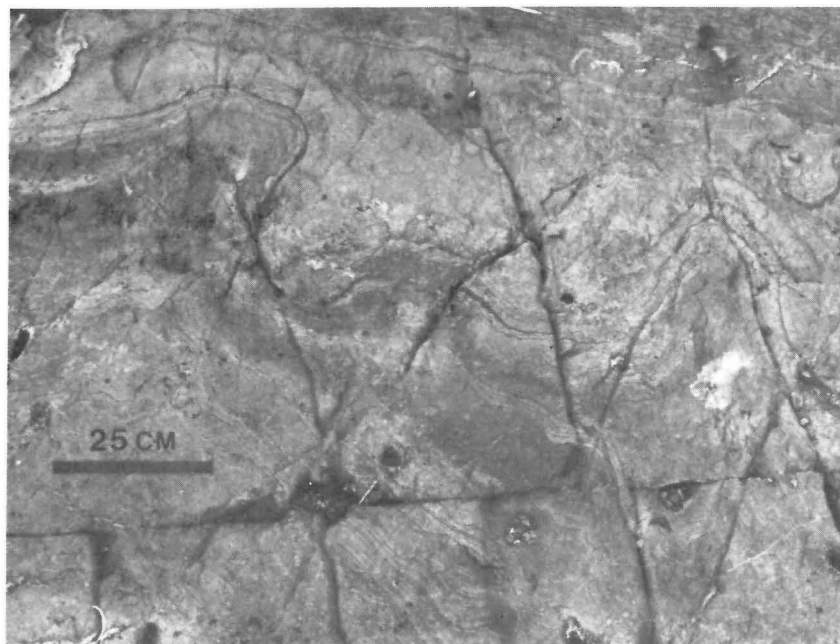


FIGURE 31: Two ABCD(E) beds with intervening layer of black mudstone (unit 13), File Lake Formation, west shore of Morton Lake, opposite Elmes Island. Lower bed comprises massive part of A division and a well-laminated B division. Penecontemporaneous soft-sediment gravity slump faults are conspicuous in laminated B division under mudstone bed. The faults which bound down-dropped sections are concave upwards. Note also the load structures on top of dark mudstone bed.

FIGURE 32: Large bulbous concentric slump folds (unit 13), File Lake Formation, west shore of Morton Lake opposite Elmes Island. Fold amplitude is approximately 50 cm, at centre of photograph, and decreases downwards. Folds affect several beds. Note undeformed overlying siltstone beds and black, recrystallized carbonate concretions (in bottom part of photograph).



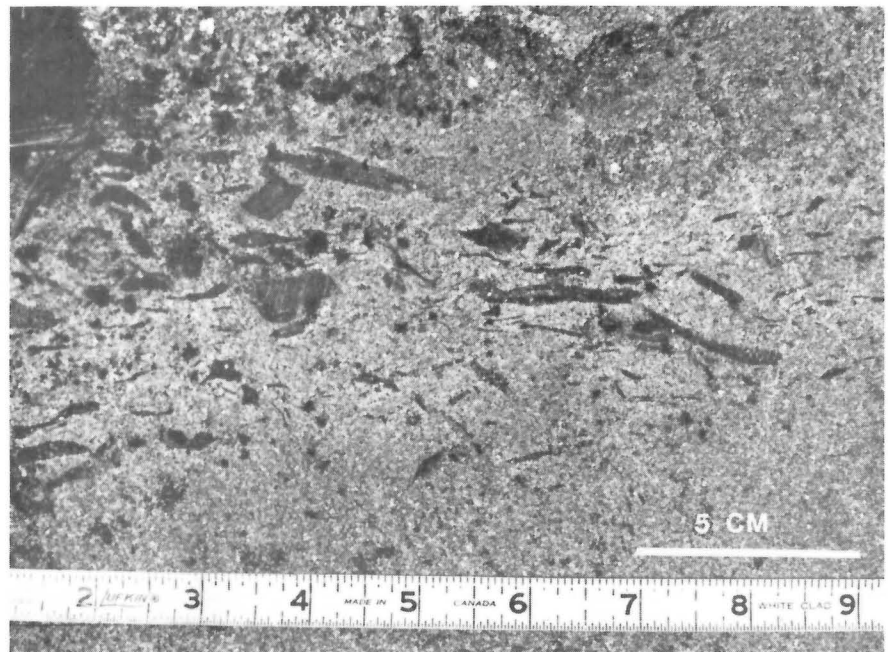
narrow flames composed of mud or silt between the sand protrusions (Figs. 22 and 26). Rarely the sand protrusions are detached and form sandstone balls. Many of the load structures were probably initiated by scour marks (Fig. 22). Downslope creep of the beds, after formation of the load structures, has bent the tops of many of the flames (Figs. 26 and 30). This is one of the few paleoslope criteria in the File Lake Formation, and the overturning suggests a north-dipping paleoslope.

Slump structures include some discontinuous gravity-induced faults (Fig. 31) and some rare large irregular folds (Fig. 32). The faults are rarely continuous for more than 10 cm, die out gradually, and generally come in pairs that are concave upwards with a down-dropped bed in between. Their penecontemporaneous formation is indicated by undeformed overlying strata. The slump folds are also overlain by undeformed strata. They differ from convolute laminations in that they



FIGURE 33: Irregular intrusions of coarse sand into A → E silt and mudstone beds (unit 13), File Lake Formation, 1.5 km northwest of Elmes Island. Note rotation and brecciation of A → E beds by the sand intrusions.

FIGURE 34: Angular and tabular dark intraformational mudstone fragments in massive AE sandstone bed (unit 13), File Lake Formation, southeast Morton Lake.



have bulbous anticlines as well as synclines and generally involve several beds (Fig. 32). The slump folds in Figure 32 are concentric and die out at depth.

Sand intrusions are rare and include both upward and downward protrusions of sand into thinly laminated mudstone and siltstone layers. They have locally brecciated the intruded beds (Fig. 33). They probably formed by escape of water from compacting of sand beds buried beneath cohesive, relatively impermeable clay-rich sediments.

Other Structures

Dark coloured, angular to tabular massive to laminated intraformational mudstone fragments (Fig. 34) are common in AE beds and in the A division of ABCD(E) beds. Siltstone and rare sandstone clasts are also present. Most of the fragments are 1 to 3 cm in size, but in thick AE sandstone beds they are locally more than 20 cm (Fig. 25). The fragments occur in about one-third of the beds and generally, but not always, form trains concentrated along a single horizon in the bed

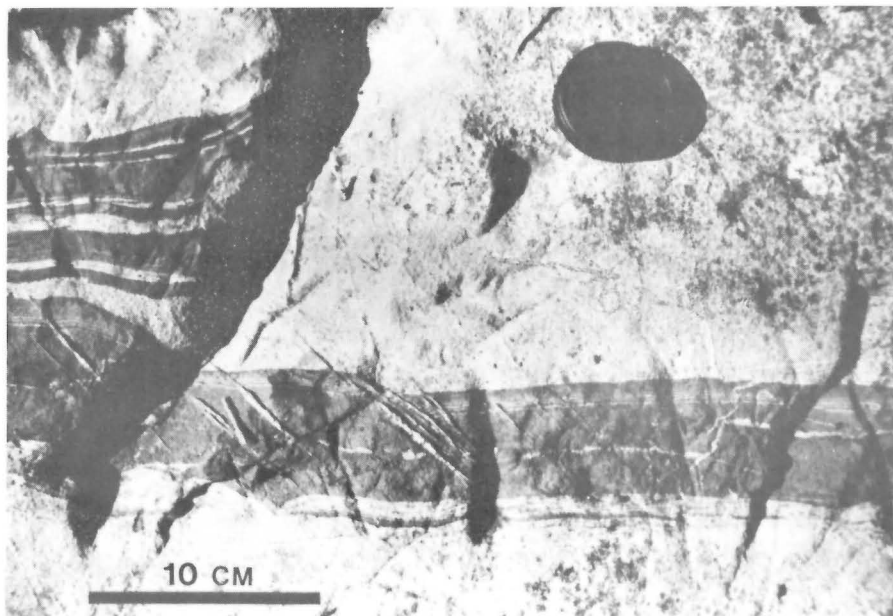
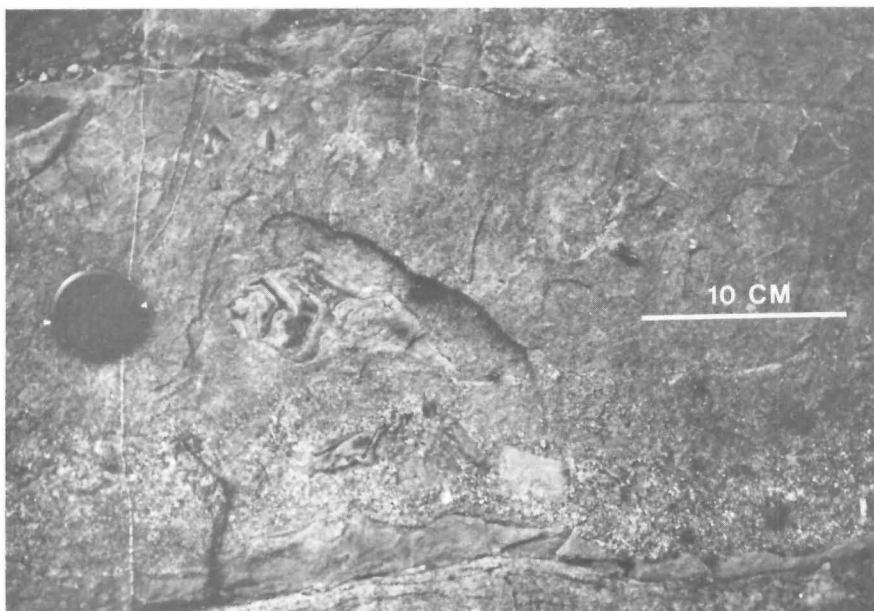


FIGURE 35: Truncated beds of mudstone at base of thick coarse massive AE bed (unit 13), File Lake Formation, southeast Morton Lake.

FIGURE 36: Coarse-tail graded AE bed with numerous intraformational mudstone clasts (unit 13), File Lake Formation, 1 km northwest of Elmes Island. Note angular intraformational clast of folded mudstone.



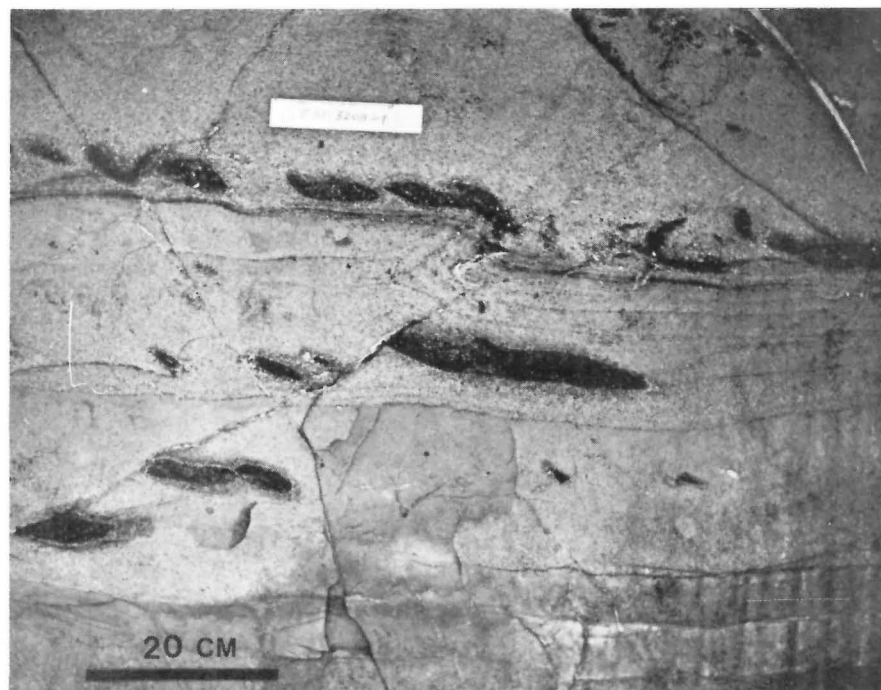


FIGURE 37: Series of four graded AE beds containing elongate carbonate concretions (unit 13), File Lake Formation, 600 m west-northwest of Elmes Island. In top bed, the concretions occur at a single horizon, in the coarsest sand, at the base of the bed.

(Fig. 21). The position of these trains of fragments varies from bed to bed; in *ABCD(E)* beds they are common at the top of the A division, but in *AE* beds they have no preferential position. The fragments probably originated by intraformational erosion and/or slumping. Truncated mudstone beds (Fig. 35) are evidence that subsequent subaqueous sediment flows have ripped up parts of partially consolidated mudstone beds and transported them deeper into the sedimentary basin. Rare angular fragments of folded mudstone (Fig. 36) suggest that erosion also occurred during slump folding and slump failure higher on the sedimentary slope.

Ellipsoidal 10 to 20 cm long carbonate concretions are common in the coarse parts of thick sandstone beds. They generally occur selectively along a single horizon in a bed (Fig. 37), but locally occur randomly. They are white to dark green and typically weather in positive relief. Bedding planes pass through some of the concretions, indicating that they formed after deposition of the sediment. This is also indicated by the presence of clastic grains, in the carbonate cement of the concretions. During regional metamorphism the carbonate in the concretions has reacted with silicate material, within and adjacent to the concretions, to form calc-silicate mineral assemblages. Acicular green actinolite porphyroblasts are abundant in the concretions at Morton Lake and give them a pseudogabbroic texture (Fig. 25). In more highly metamorphosed greywacke, on File and Woosey Lakes, the concretions are composed of a mixture of calcic plagioclase, diopside, sphene, epidote, calcic garnet, green hornblende and calcite, and are concentrically zoned.

DISTRIBUTION AND CHARACTERISTICS OF BED TYPES IN MEASURED SECTIONS

The frequency of bed types and primary structures have been recorded systematically from seven representative stratigraphic

sections at Morton Lake (Fig. 27). The percentage of *AE* and *ABCD(E)* beds, the latter subdivided by its lowermost division, is given for each section in Table 5.

Sections I and II are from the peninsula at the south end of Morton Lake (Fig. 27). The position of these sections relative to the unexposed base of the File Lake Formation is not known. These sections are characterized by an abundance of *AE* beds, extreme thickness of beds, coarseness of detritus, and scarcity of *ABCD(E)* beds which begin with B and C divisions. The *AE* beds vary widely in thickness, ranging from 5 to 1140 cm (Table 5). A common feature of the *ABCD(E)* beds in these sections is the absence of a C division. The P_1 index, modified from Walker (1967), for sections I and II is high (Table 5) and indicates that deposition of most beds was initiated under high flow velocities.

Sections III to VIII are from north Morton Lake and are in stratigraphic order. In this area a fault, not shown on the geological map (Map 78-1-1, in pocket), has locally removed the lower part of the formation (Fig. 27). Section III is 200 to 300 m above the unfaulted base of the formation and Section VII is at the top of the exposed section, 700 to 800 m above its base. The measured data represents about 30 percent of the central 500 m of the formation. Strata underlying Section III are thin-bedded mudstone, siltstone and fine grained sandstone in which bed thickness is typically less than 5 cm and commonly less than 2 cm. With the exception of Section IV, grain size and bed thickness increase upward (Table 1). An upward increase in abundance of *AE* beds and in the P_1 index (Table 1) indicates that deposition of beds higher in the section was generally initiated from flows with higher concentration and higher velocity.

TABLE 5: Frequency of bed-types and their thickness and grain size in measured sections of File Lake Formation, Morton Lake

Section No ¹	Thickness of Section (in m)	Bed Nos.	Bed Types(Percent)						Modified P ₁ Index ³
			AE beds		ABCD(E) beds beginning with division:			A → E beds	
			Massive	Graded	A ²	B	C		
I	26.900	1-14	0	78	22	0	0	0	100
II	23.300	1-26	8	38	35	8	0	11	85
III	65.723	1-25	4	12	40	32	8	4	72
		26-50	4	20	52	12	8	4	82
		51-75	0	0	52	28	8	12	66
		76-100	0	0	30	30	40	0	45
		101-125	0	16	56	16	0	12	80
		126-150	0	4	64	16	0	16	76
		150-178	4	4	21	4	3	64	31
IV	11.330	1-25	4	0	60	28	4	4	78
		26-50	0	0	44	40	8	8	64
		51-75	0	0	36	32	12	20	52
V	35.752	1-25	0	8	80	12	0	0	94
		26-53	4	4	61	14	17	0	76
VI	23.360	1-29	0	59	38	0	0	3	97
		30-58	10	28	62	0	0	0	100
VIII	18.040	1-31	6	62	23	0	3	6	91
I-VII	204.405	435	2.6	19.6	45.6	16	6.5	9.6	76

Section No ¹	Bed Thickness (in cm)								Average of coarsest grain size of beds (in mm)
	AE beds				ABCD(E) beds.				
	Mean	Log Normalized Mean	Thinnest bed	Thickness bed	Mean	Log Normalized Mean	Thinnest bed	Thickest bed	
I	229.0	62.4	5	1140	55.3	54.1	40.0	66	—
II	141.1	87.4	5	425	48.0	32.6	9.0	126	.51
III	44.0	35.5	14.5	88	16.8	12.5	3.0	45	.56
	25.3	18.5	11.5	55	35.0	28.5	8.0	80	.50
					30.1	18.5	3.0	105	.37
					16.0	10.5	1.1	38	.54
	23.0	21.5	11.0	28	29.3	16.3	0.5	99	.65
					40.7	26.4	8.0	138	.40
	23.0	21.9	16.0	30	26.6	22.6	10.0	70	.31
IV					14.1	11.4	5.4	58	.36
					13.2	10.8	3.0	33	.45
					15.4	12.6	3.0	38	.56
V	392.0	270.4	109.0	675	31.4	22.7	7.0	124	.67
	520.0	280.0	82.0	958	35.0	17.3	1.2	210	.53
VI	29.4	25.2	8.0	68	61.0	41.3	13	211	1.23
	28.8	20.0	5.5	68	44.5	36.9	11	113	.77
VIII	44.3	37.3	17.0	105	112.5	90.9	25	235	1.28
I-VII	90.2	39.1	5	1140	30.6	19.0	0.5	235	.61

Note:

- 1 Location of section is given on Figure 27.
- 2 Does not include A → E beds which are classified separately.
- 3 The P₁ index in this table is calculated as follows:

$$P_1 = \%(\text{AB ... beds}) + \% \text{AE beds} + \frac{1}{2}\%(\text{BC ... beds}).$$
This differs from the P₁ index of Walker (1967) which was

calculated as follows:

$$P_1 = \%(\text{AB ... beds}) - \%(\text{A} \rightarrow \text{E beds}) + \frac{1}{2}\%(\text{BC ... beds}).$$
This difference is because Walker (1967) either did not have or did not distinguish between AB ... and AE beds and because his beds beginning with the A division included A → E beds whereas in this tabulation AB ... beds do not include A → E beds.

PETROGRAPHY

GREYWACKE AND SILTSTONE PETROGRAPHY

Greywacke and coarse siltstone (unit 13) from Morton Lake are composed dominantly of felsic volcanic rock fragments and volcanic quartz and plagioclase crystal fragments (Table 6). They include both lithic and feldspathic varieties (Fig. 38). Fragments of intermediate to mafic volcanic rocks, chert, translucent microcrystalline material, opaque and semi-opaque amorphous material (probably colophane), felsic granophyric tonalite and angular intraformational mudstone are present in small amounts (Table 6). The framework grains are surrounded by and commonly supported by a matrix of silt- and

clay-sized particles that are largely the same composition as the framework grains. The framework grains and matrix are described in Table 7.

The greywacke and siltstone are mineralogically, compositionally, and texturally immature. This is evident from the abundance of unstable volcanic rock fragments and the abundance of plagioclase relative to more stable quartz grains. Except for chert and felsic granophyric fragments, the framework clasts are generally angular to subrounded and poorly sorted (Fig. 39), and this in conjunction with the volcanic shapes of quartz and plagioclase grains (Table 7; Figs. 39, 40 and 41) indicate limited mechanical abrasion. The better rounding of the chert and felsic granophyre fragments indicates more abrasion and transport, and possibly a more distant source.

TABLE 6: Detrital modes¹ of metagreywacke and metasiltstone, File Lake Formation, Morton Lake

Column No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Sample No.	F07-179-1	F07-179-2	F07-184-1	F07-185-3	F07-185-4	F07-187-1	F07-189-2B	F07-189-C	F07-190-1A	F07-751-1	F07-751-3	F07-3745-1B	F07-85-2	F07-89-5	F07-90-1	F07-90-1	F07-93-1	F07-402-B
Monocrystalline quartz	0.9	3.1	2.4	6.0	1.5	1.5	5.5	3.9	2.2	6.5	8.5	1.7	2.3	1.4	2.3	1.8	3.5	2.6
Polycrystalline quartz		1.7		2.1			0.2	1.5	0.7	1.0	3.5		0.8		1.3	0.5	4.6	4.3
Plagioclase	18.0	24.2	22.0	9.5	10.8	15.7	13.4	3.9	12.3	6.7	5.3	12.4	1.2	0.4	1.5	2.0	0.9	0.6
Quartz- and plagioclase-phyric felsic volcanic rock fragments	1.3	5.8	4.1	4.2	26.7	0.5	9.1	21.6	5.5	23.0	6.3		5.8		0.3	1.3		
Aphyric felsic volcanic rock fragments	6.7	4.4	12.7	14.5	11.7	3.2	8.9	15.7	23.3	16.4	16.4	5.9	29.5	12.8	20.3	16.8	14.9	13.7
Mafic and intermediate volcanic rock fragments	0.3	1.3	1.2	0.7	2.2		3.6	9.0	0.1	3.6	0.8		4.3		0.1	1.4	6.4	
Chert rock fragments		3.5	1.4	6.1	2.4		2.5	6.8	8.8	8.4	8.1	0.1	4.1	0.4	3.3	2.6	7.4	5.4
Translucent microcrystalline rock fragments		0.2	0.1	0.5		0.1					0.5							0.5
Opaque and semi-opaque amorphous rock fragments				1.3	0.5		0.4	0.3		1.0								
Felsic granophyre fragments		3.3						8.8	1.1	2.5	8.0		0.8		0.5			0.2
Mudstone fragments					8.9		5.9	1.8		0.4				5.6				1.2
Total framework	27.2	47.5	43.9	45.5	64.7	21.0	50.5	73.3	54.0	69.5	57.9	20.1	48.8	20.6	29.6	26.4	37.7	31.2
Plagioclase, quartz and rock fragments less than 0.06 mm	57.4	42.3	46.1	42.0	32.3	55.4	38.5	20.5	31.6	22.1	31.9	67.4	32.3	36.9	43.8	53.0	43.0	53.0
Biotite ²		9.0		1.4	3.0	12.0	12.0			6.5	5.9	11.7	16.9	32.6	24.8	20.5	17.9	15.7
Actinolite ²			8.1	0.1				6.0	13.0	1.2	3.9		0.3					
Chlorite ²	15.1	0.2	0.3			11.6				0.1	0.4		1.7		1.4			
Sericite ²	0.3	0.2															0.5	
Calcite		0.8	1.3	11.5					1.4	0.6		0.5						
Opaque minerals			0.3	0.5				0.2				0.3		0.2	0.4	0.1	0.9	0.1
An content plagioclase	38,38,39	37	41	31	34	23,30,32	34,35,36,37,38		40,42,45			37						
Coarsest size fraction	1 mm	3-4 mm	1-2 mm	1-2 mm	3-5 mm	1 mm	3-8 mm	3-5 mm	5-7 mm	3-4 mm	2-3 mm	1-2 mm	1-2 mm	1 mm	1-2 mm	1-2 mm	1-2 mm	2-3 mm

Note: 1 Based on an average of 680 points per thin section. Points were 1 mm apart along traverses 1 mm apart. Minimum points counted was 473. Main detrital components are described in Table 7. Sample locations are given on Figure 27.

2 Biotite, tremolite, chlorite and sericite are metamorphically generated from fine grained clay-rich matrix.

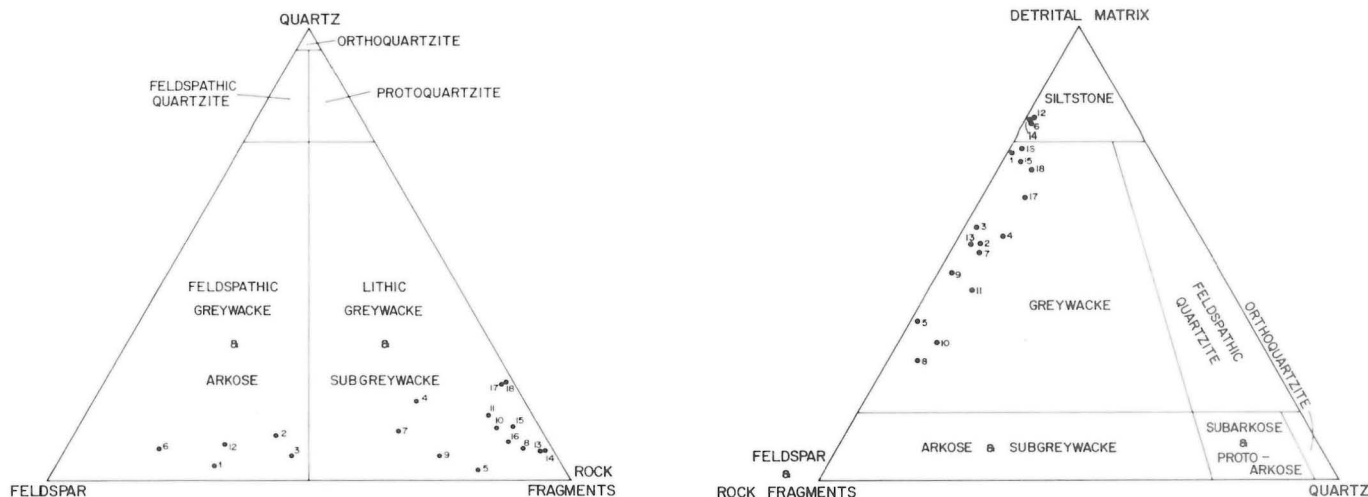


FIGURE 38: Ternary diagrams (after Pettijohn, 1957) showing detrital modes of greywackes and siltstones (unit 13), File Lake Formation.

TABLE 7: Description of detrital components in metagreywacke and metasiltstone (unit 13), File Lake Formation

Monocrystalline quartz:	Large (0.5 to 3 mm) clear single unit grains; generally round in shape, locally with embayed margins and partial sheaths of microcrystalline felsic material; some have crystal faces; grains typically have undulose extinction due to post-depositional deformation; the shape and local sheaths of microcrystalline felsic material indicate that some, and possibly all, of the grains were originally volcanic phenocrysts.	Mafic and intermediate volcanic rock fragments:	Lenticular, wispy clasts, 0.5 to 1 mm long; comprise recrystallized mixtures of actinolite, biotite, chlorite and lesser amounts of plagioclase and quartz; clasts vary in percentage of mafic minerals; more felsic varieties generally less recrystallized, less flattened, and locally plagioclase-phyric.
Polycrystalline quartz:	Large (1 to 3 mm) clear multiple unit grains; generally round in shape, but include subangular varieties; rounded grains locally have embayed margins; internal grain size varies from 0.3 to 1 mm; clasts have undulose extinction and internal contacts between units in grains are typically lobate-sutured, probably due to post-sedimentation deformation; polycrystalline quartz similar to that forming framework grains is also present in felsic granophyre rock fragments; embayed margins suggest that some grains were originally volcanic phenocrysts whereas similarity to quartz in felsic granophyre clasts suggest that others were derived from felsic granophyre intrusions.	Chert Fragments:	Fine grained (0.03 to 0.2 mm) granoblastic-polygonal aggregates of quartz; clast size is variable, but generally in between 0.5 and 1 mm; grain contacts are straight and not sutured, clasts are subangular to rounded, but generally are subrounded.
Plagioclase:	Large (0.3 to 1 mm) clear subhedral to euhedral crystal fragments ranging from An ₂₃ to An ₄₅ and averaging An ₃₅ ; generally well-twinned with abundant albite and Carlsbad twins and rare pericline twins; locally have oscillatory zoning; high temperature structure present in some grains; identical in size, shape, twinning and composition to plagioclase phenocrysts in felsic and intermediate volcanic rock fragments; the shape, zoning and high temperature structure also indicate that at least some, and probably most, of the grains were originally volcanic phenocrysts; the An contents of the plagioclase crystal fragments suggest a dacitic to andesitic source.	Translucent microcrystalline rock fragments:	Microcrystalline (<0.03 mm) mixture of colourless to pale yellow chlorite, colourless zoisite and minor quartz and opaque minerals; clasts are subangular and 0.5 to 1 mm in size; possibly altered vitric volcanic fragments.
Porphyritic felsic volcanic rock fragments:	Angular to subrounded, but generally subangular clasts; 2 to 8 mm in size; plagioclase- and quartz-phyric; phenocrysts range from 0.3 to 2 mm in size; groundmass is slightly recrystallized, very fine grained (< 0.03 mm) mixture of quartz, plagioclase and 2 to 10 percent tiny secondary crystals of biotite and muscovite; quartz phenocrysts locally have embayed margins; clasts within this group have variable matrix grain size, phenocrysts size and abundance, and groundmass mica content.	Opaque and semi-opaque rock fragments:	Clasts are angular and 0.5 to 1.5 mm in size; include pyrite clasts but most are black, do not reflect light and are amorphous; X-ray and chemical analysis indicated presence of apatite and suggests clasts are collophane; amorphous clasts contain crystals of plagioclase; several intermediate volcanic clasts with plagioclase-bearing black amorphous margins were observed; most clasts appear to be altered volcanic clasts, with alteration having occurred either in the volcanic environment or during diagenesis.
Aphyric felsic volcanic rock fragments:	Very fine grained (<0.03 mm) clasts which vary in size from 0.5 to 5 mm; vary from angular to subrounded, but are generally subangular; clasts are composed of recrystallized mixture of plagioclase and quartz with 2 to 10 percent secondary biotite and muscovite; grain size and mica content vary from clast to clast; clasts are interpreted to be largely volcanic because they are identical to the groundmass of the porphyritic felsic volcanic rock fragments.	Felsic granophyre fragments:	Fine- to medium-grained (0.5 to 2 mm) tonalite with graphically intergrown quartz and plagioclase; no mafic or micaceous minerals; vary from subangular to rounded; but generally are subrounded; range from 1 to 4 mm in size; source of clasts probably an unroofed epizonal intrusion, but it could also have been the centre of a felsic dome or ejected from a vent.
		Mudstone fragments:	Angular, massive, homogeneous intraformational mudstone and siltstone fragments; 0.5 to 8 mm in size; comprise silt-sized grains of quartz, plagioclase and rock fragments, 10 to 25 percent biotite and minor amounts of chlorite, sericite, actinolite and opaque minerals; layering present in some fragments; fragments vary widely in composition, most notably in their biotite contents; angularity of fragments and similarity to formational mudstone layers indicates they are probably intraformational rip-up clasts.
		Detrital matrix:	Fine grained interstitial material generally less than 0.3 mm but up to 0.06 mm in grain size; dominantly quartz and plagioclase plus some small rock fragments; includes approximately 20 percent biotite and 5 percent combined actinolite, chlorite, sericite, calcite and oxide minerals; biotite, actinolite and more rarely, chlorite and muscovite form small porphyroblasts 0.1 to 1 mm in size.

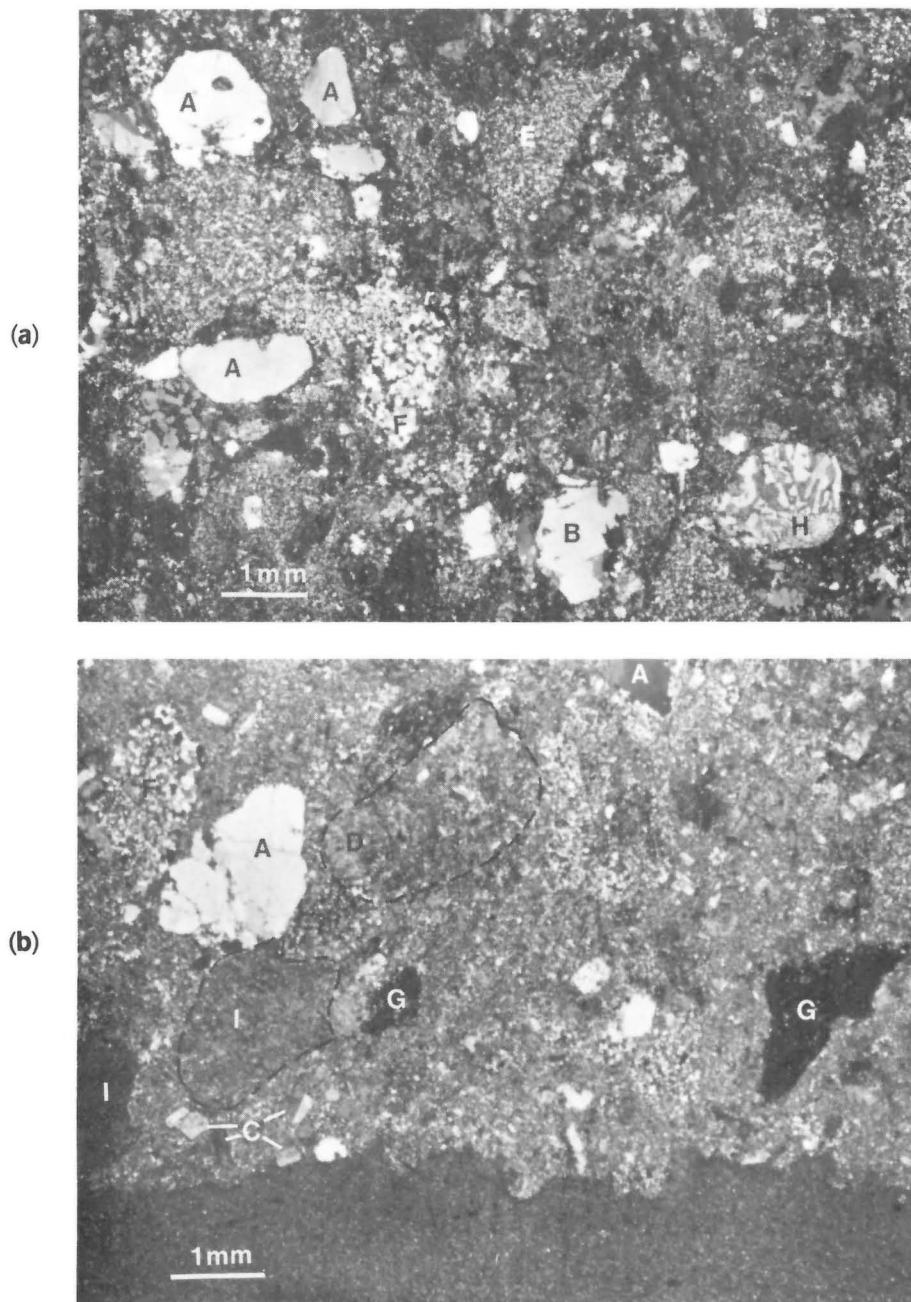


FIGURE 39: Photomicrographs (polarized light) of lithic greywacke (unit 13), File Lake Formation, south Morton Lake, showing wide variety of fragment types including: A monocrystalline quartz; B polycrystalline quartz; C plagioclase; D plagioclase-phyric felsic volcanic rock fragments; E aphyric felsic volcanic rock fragments; F fine grained chert rock fragments; G opaque and semi-opaque amorphous fragments; H felsic granophyre fragments; and I mudstone fragments. Note embayed margins on monocrystalline quartz grains in (a) and the load structures at the base of the greywacke bed in (b).

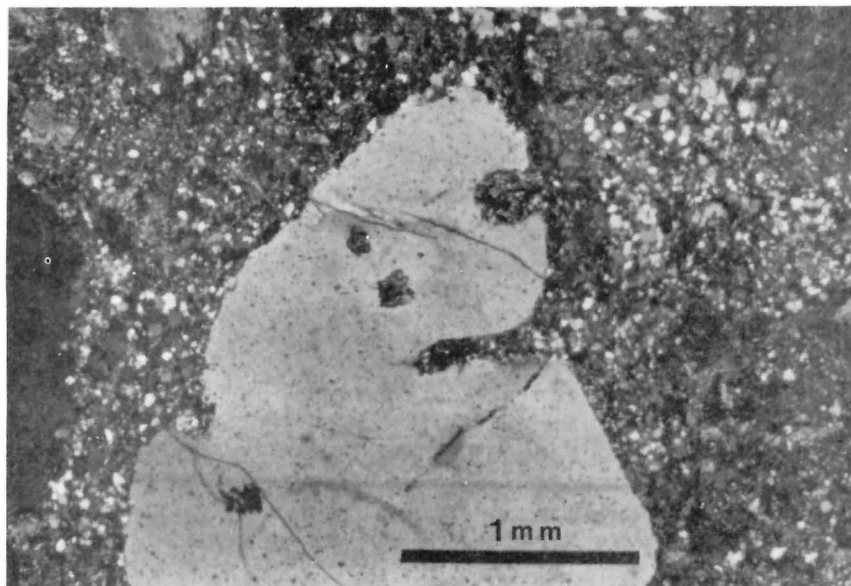
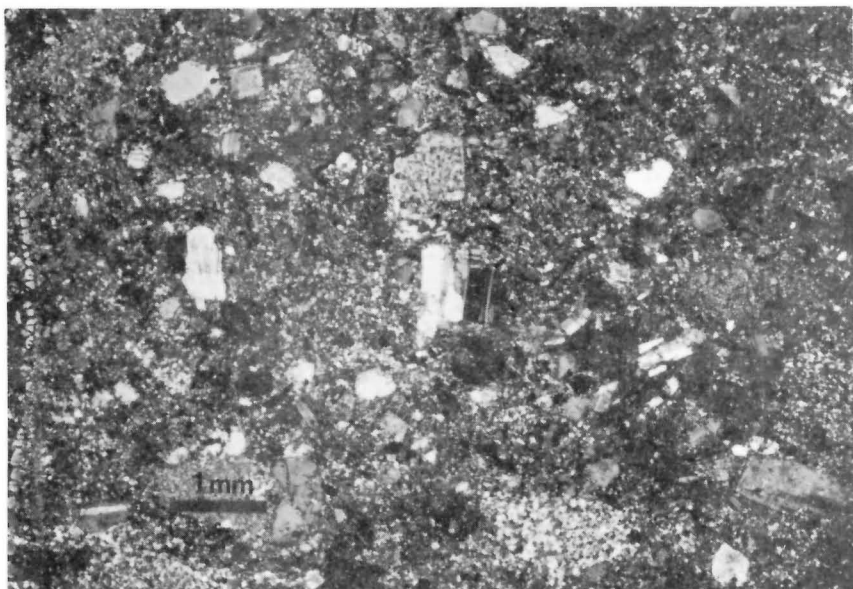


FIGURE 40: Photomicrograph (polarized light) of embayed quartz grain in lithic greywacke (unit 13), File Lake Formation, south Morton Lake.

FIGURE 41: Photomicrograph (polarized light) of feldspathic greywacke (unit 13), File Lake Formation, south Morton Lake. Note abundant fragments of well-twinned plagioclase (An_{41}).



With the exception of intraformational mudstone, the framework clasts (Table 6) are either obviously volcanic or can be interpreted to be volcanic in derivation. No metamorphic or obviously deep-seated plutonic fragments were noted in the File Lake Formation at Morton Lake.

MUDSTONE PETROGRAPHY

Mudstones (unit 13) have a grain size less than 0.06 mm and

contain detrital felsic rock fragments, quartz and plagioclase, and small porphyroblasts of biotite, sericite, muscovite, chlorite and actinolite. The porphyroblasts probably were derived from clay minerals and carbonate cement. The detrital composition of the mudstones could not be accurately determined but probably is similar to that of the associated siltstones and greywackes, except for a higher content of mica and mafic minerals.

MAJOR ELEMENT GEOCHEMISTRY

GREYWACKE, SILTSTONE, MUDSTONE AND DERIVED PARAGNEISS (UNITS 13 and 13b)

Major element analyses for nine greywacke samples and fourteen mudstone samples are listed in Tables 8 and 9. They include relatively unrecrystallized rocks (unit 13) from Morton Lake, and strongly recrystallized rocks (unit 13b) from File and Woosley Lakes. No significant chemical differences appear to exist between the highly recrystallized samples and weakly recrystallized equivalents. The apparent difference in chemistry of highly and weakly recrystallized mudstones in Table 9 is probable due to higher silt contents in the higher grade samples.

The greywackes (Table 8) have typical greywacke major element chemistry, including excess Na_2O over K_2O (Fig. 42) and, relative to other sandstones, high Al_2O_3 , MgO and total iron contents. They plot in the greywacke field on a log-log plot of $\text{SiO}_2/\text{Al}_2\text{O}_3$ versus $\text{Na}_2\text{O}/\text{K}_2\text{O}$ (Fig. 43). They show a wide range in composition, which largely reflects variation in plagioclase to rock fragment ratio and in abundance of clay minerals.

The mudstones (Table 9) have typical mudstone chemistry, including $\text{K}_2\text{O} > \text{Na}_2\text{O}$ (Fig. 42). Relative to greywackes, they have lower SiO_2 , CaO and Na_2O and higher Al_2O_3 , total iron, MgO , TiO_2 and K_2O

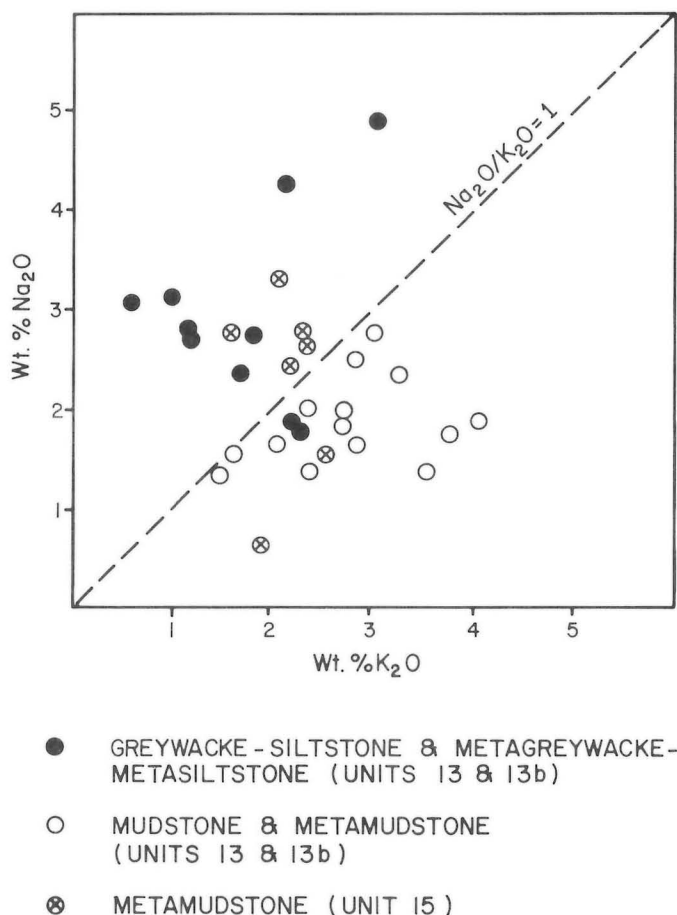


FIGURE 42: K_2O versus Na_2O (after Pettijohn, 1963) for metasedimentary rocks of the File Lake Formation.

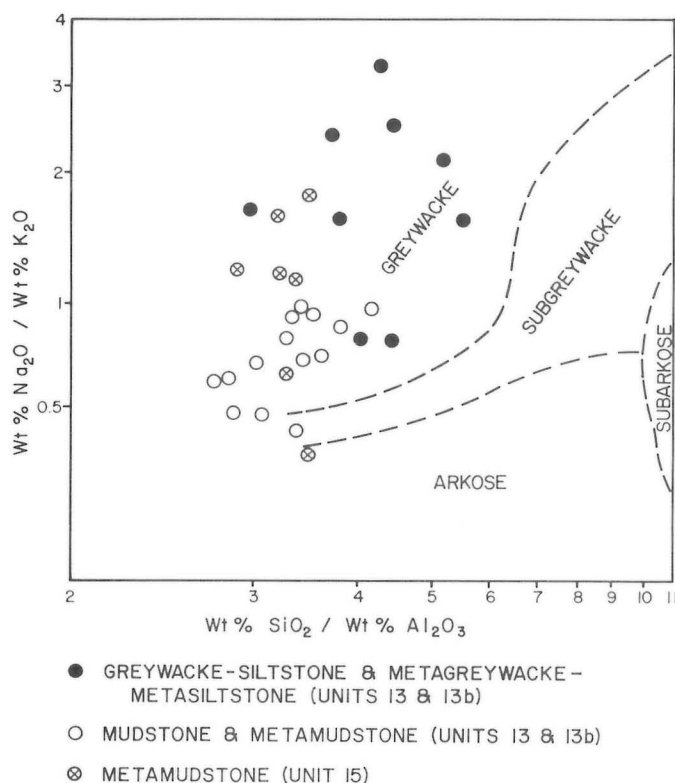


FIGURE 43: $\log (\text{SiO}_2/\text{Al}_2\text{O}_3)$ vs $\log (\text{Na}_2\text{O}/\text{K}_2\text{O})$ diagram (after Pettijohn et al., 1972) for metasedimentary rocks of the File Lake Formation.

contents. This probably reflects lower quartz and plagioclase and higher clay contents in the mudstone.

The average composition of greywackes and mudstones, along with analyses of other early Precambrian and Phanerozoic varieties, is given in Table 10. The File Lake Formation greywackes and mudstones are very similar to other suites of early Precambrian greywackes and mudstones, but they differ slightly from the average of Phanerozoic analyses due to higher grade metamorphism and more restricted provenance.

The early Precambrian greywackes and mudstones have lower H_2O contents and $\text{Fe}_2\text{O}_3/\text{FeO}$ ratios than do most analyzed Phanerozoic varieties, due to higher grade metamorphism and consequent loss of water from clay minerals and reduction of Fe_2O_3 to FeO . In addition, the early Precambrian mudstones have lower CO_2 and CaO contents than do fossiliferous Phanerozoic varieties (Table 10). Precambrian and Phanerozoic analyses that are calculated volatile- and carbonate-free (bracketed analyses, Table 10), with the FeO and Fe_2O_3 values recalculated as FeO , indicate the early Precambrian greywackes and mudstones to have lower SiO_2 contents and higher Al_2O_3 , total iron, MgO , CaO and Na_2O contents than averages of Phanerozoic counterparts. These differences likely reflect the immaturity, rapid deposition and volcanic provenance of the Precambrian sediments. For example, their lower SiO_2 and higher Al_2O_3 , Na_2O , MgO , FeO and CaO contents (CaO in calcite excluded) are probably due to abundant discrete volcanic plagioclase, abundant MgO - and FeO -rich volcanic fragments and low quartz content.

CORLEY LAKE MEMBER (unit 15)

Seven metamudstones from the Corley Lake member of the File Lake Formation have been analyzed for major elements (Table 11). The analyses are similar to those of metamudstones of unit 13 and

TABLE 8: Chemical analysis^{1,2} of metagreywacke and siltstone (units 13 and 13b) File Lake Formation

UNIT NO.	1	2	3	4	5	6	7	8	9
	13		13b						
SiO ₂	63.3	63.4	62.6	62.95	64.85	67.0	67.55	68.15	71.35
Al ₂ O ₃	14.25	15.5	17.0	16.8	15.5	16.65	15.55	13.35	13.10
Fe ₂ O ₃	1.83	0.62	0.30	1.04	1.08	1.07	1.11	0.82	0.53
FeO	6.96	5.40	7.00	6.10	5.97	5.30	4.29	6.71	5.23
MgO	4.17	2.98	3.21	2.82	2.61	2.04	2.35	1.90	1.86
CaO	1.98	4.02	3.58	3.20	3.57	1.25	3.20	0.40	2.39
Na ₂ O	1.78	3.06	2.77	2.78	3.15	1.78	2.80	4.27	2.49
K ₂ O	2.29	0.54	1.15	1.80	0.98	2.24	1.14	2.05	1.65
TiO ₂	0.85	0.51	0.56	0.54	0.48	0.48	0.32	0.41	0.42
P ₂ O ₅	0.13	0.31	0.15	0.18	0.18	0.14	0.15	0.09	0.16
MnO	0.08	0.08	0.07	0.08	0.13	0.07	0.07	0.12	0.05
H ₂ O [±]	2.56	2.62	1.39	1.72	1.30	1.66	1.66	0.60	0.99
CO ₂	0.17	0.75	0.27	0.20	0.34	0.40	0.05	0.34	0.11
TOTAL	100.4	99.8	100.1	100.2	100.1	100.1	100.24	99.21	100.33
Total Fe as Fe ₂ O ₃	9.49	6.56	8.00	7.65	7.75	6.90	5.83	8.20	6.28

1 Weakly recrystallized silt-rich lithic metagreywacke (F07-90-1), see Table 6, column 15, for modal analysis.

2 Weakly recrystallized feldspathic metagreywacke (F07-184-1; see Table 6, column 3, for modal analysis).

3 Biotite-garnet-bearing fine grained metagreywacke (F07-30-2).

4 Garnet-biotite-bearing metagreywacke (F07-08-1).

5 Garnet-hornblende-biotite-bearing fine grained metagreywacke (F07-01-2).

6 Garnet-muscovite-sillimanite-staurolite-bearing interlayered metasilstone and metagreywacke (F07-762-1).

7 Garnet-chlorite-biotite-bearing medium grained metagreywacke (F07-738-1).

8 Garnet-biotite-bearing metagreywacke (F07-1798-1).

9 Garnet-biotite-bearing medium- to coarse-grained metagreywacke (F07-705-2).

¹ Chemical analyses by Analytical Laboratory of Manitoba Mineral Resources Division.

² Sample sites are located on Figure 94 (in pocket).

13b, with the exception that they have higher total iron, higher TiO₂, lower SiO₂, lower Al₂O₃, and a K₂O/Na₂O ratio less than one.

The high total iron and TiO₂ content is due to disseminated ilmenite, which varies in concentration from layer to layer. The ilmenite is probably a primary detrital component. The low K₂O/Na₂O ratio probably reflects a low clay and high plagioclase content in the original sediment. A low clay and high plagioclase content could be produced if the mudstones were derived from a weakly weathered source.

PROVENANCE

Almost all greywacke framework clasts are volcanic and more than two-thirds are either felsic volcanic rock fragments or quartz and plagioclase grains that were most likely derived from felsic eruptions. Thus the most probable source area for the File Lake Formation was a felsic volcanic terrain. The lack of metamorphic, plutonic and

sedimentary rock fragments, except for intraformational mudstone clasts and minor chert and felsic granophyre clasts, suggests that cratonized land was absent in the source area.

The greywackes are poorly sorted and texturally immature. This is, in part, a consequence of their deposition by turbidity currents. However, the poor rounding of both rock and crystal fragments, and the chemical immaturity of the greywackes, shown by their low SiO₂/Al₂O₃ ratios, indicate that the detritus had undergone only limited chemical decomposition, mechanical abrasion, transportation and sorting before resedimentation by turbidity currents. These features indicate that the source area was probably relatively close to the sedimentary basin and was undergoing active and rapid erosion. They also suggest that the greywackes were derived from largely unconsolidated pyroclastic deposits rather than by dissection of an older volcanic terrane which would require stream erosion and consequent abrasion of clasts. The large volume of sediment, the

TABLE 9: Chemical analysis of metamudstone
(units 13 and 13b), File Lake Formation

UNIT NO.	1	2	3	4	5	6	7
	13					13b	
SiO ₂	57.3	58.5	59.6	60.9	58.5	59.35	59.1
Al ₂ O ₃	17.1	17.5	17.4	16.0	20.4	21.1	19.6
Fe ₂ O ₃	2.10	1.30	1.15	1.36	2.64	2.65	2.73
FeO	7.99	6.94	6.79	7.32	4.74	4.58	4.06
MgO	4.22	3.79	3.66	3.85	2.86	2.69	2.89
CaO	0.95	1.55	1.43	2.37	1.40	1.20	1.95
Na ₂ O ₃	1.39	2.45	2.23	1.97	1.75	1.68	1.83
K ₂ O	3.57	2.78	3.28	2.34	3.72	2.87	2.73
TiO ₂	0.77	0.77	0.82	0.82	0.54	0.58	0.58
P ₂ O ₅	0.18	0.09	0.09	0.70	0.14	0.15	0.22
MnO	0.05	0.05	0.05	0.05	0.05	0.06	0.06
H ₂ O [±]	3.89	2.92	2.45	2.40	2.25	2.05	2.36
CO ₂	0.18	0.13	0.15	0.38	0.10	0.08	0.2
S		0.25	0.17		0.05	0.03	
GRAPHITIC CARBON ³		0.25	0.25		*	*	*
TOTAL	99.7	99.3	99.5	100.5	99.1	99.1	98.3
Total Fe as Fe ₂ O ₃	10.89	9.01	9.70	9.41	7.85	7.68	7.20

UNIT NO	8	9	10	11	12	13	14
				13b			
SiO ₂	63.1	63.95	64.6	65.4	58.55	64.63	58.90
Al ₂ O ₃	17.8	19.55	17.95	15.75	18.95	19.00	21.70
Fe ₂ O ₃	1.15	0.98	1.12	1.07	0.51	1.56	1.20
FeO	4.53	4.40	4.88	4.27	5.16	3.63	5.10
MgO	2.55	2.32	2.65	2.22	2.70	2.49	2.63
CaO	2.17	1.27	1.50	6.03	2.70	3.48	1.54
Na ₂ O	2.72	1.65	1.93	1.39	1.85	1.54	1.39
K ₂ O	3.02	2.06	2.72	1.50	4.07	1.60	2.41
TiO ₂	0.49	0.80	0.54	0.43	0.53	0.42	0.63
P ₂ O ₅	0.18	0.12	0.18	0.18	0.17	0.21	0.50
MnO	0.05	0.03	0.04	0.09			
H ₂ O [±]	2.02	1.71	1.86	1.35	1.60	1.12	1.78
CO ₂	0.15	0.3	0.40	0.20	0.60	tr	0.00
GRAPHITIC CARBON ³		*			2.58	0.64	1.56
TOTAL	99.9	99.1	100.4	99.9	99.97	100.32	99.34
Total Fe as Fe ₂ O ₃	6.13	5.82	6.49	5.77	6.57	5.55	6.81

1	Weakly recrystallized metamudstone (F07-89-5) with scattered sand-sized lithic particles (see Table 6, column 14, for modal analysis).	7	Garnet-muscovite-staurolite-biotite-bearing metamudstone (F07-30-1).
2	Weakly recrystallized metamudstone (04-74-M2, unpublished analysis from W.D. McRitchie).	8	Staurolite-muscovite-garnet-biotite-bearing metamudstone (F07-31-1).
3	Weakly recrystallized metamudstone (07-74-M1, unpublished analysis from W.D. McRitchie).	9	Sillimanite-staurolite-biotite-bearing metamudstone (F07-632-1).
4	Weakly recrystallized metamudstone (F07-89-3).	10	Sillimanite-staurolite-muscovite-biotite-bearing metamudstone (F07-757-1).
5	Staurolite-muscovite-biotite-bearing laminated metamudstone (F07-3278-1) (contains pseudomorphs of andalusite replaced by muscovite hornfels (F07-3379-1)).	11	Garnet-hornblende-biotite-bearing metamudstone (F07-943-2).
6	Sillimanite-andalusite-staurolite-muscovite-biotite-bearing mudstone hornfels (F07-3379-1).	12	Garnetiferous argillite (Harrison, 1949, I, p.26).
		13	Staurolite schist (Harrison, 1949, II, p. 26).
		14	Sillimanite-staurolite schist (Harrison, 1949, III, p. 26).

¹ Chemical analyses by Analytical Laboratory of Manitoba Mineral Resources Division.

² Sample sites are located on Figure 94 (in pocket).

³ Samples with asterisk have graphitic carbon in undissolved residue.

TABLE 10: Comparison of chemical composition¹ of average metagreywacke and metamudstone of the File Lake Formation with early Precambrian and Phanerozoic greywackes and mudstones.

	GREYWACKE				MUDSTONE				
	1	2	3	4	5	6	7	8	9
SiO ₂	65.7(67.2)	67.47	63.66(67.31)	66.7(70.7)	60.9 (62.66)	58.45 (59.77)	57.80 (60.13)	56.2 (66.0)	53.4 (62.9)
Al ₂ O ₃	15.3 (15.6)	15.76	14.85 (15.70)	13.5 (14.3)	18.6 (19.13)	18.04 (18.44)	18.37 (19.1)	15.1 (17.7)	16.4 (19.3)
Fe ₂ O ₃	0.93 (6.86)	6.10	1.01 (6.00)	1.6 (5.4)	1.54 (7.39)	1.44 (9.88)	1.67 (8.19)	3.4 (6.8)	3.4 (7.4)
FeO	5.78		4.67	3.5	5.64	8.22	6.21	2.3	2.8
MgO	2.66(2.72)	1.70	2.99 (3.16)	2.1 (2.2)	3.06(3.15)	3.14 (3.21)	3.93 (4.08)	2.1 (2.5)	2.4 (2.8)
CaO	2.62 (2.38)	1.98	2.63 (1.20)	2.5 (1.4)	2.11 (1.96)	2.27 (2.25)	1.89 (1.79)	4.4 (1.4)	5.8 (1.8)
Na ₂ O	2.92 (2.99)	3.20	3.14 (3.32)	2.9 (3.1)	1.84 (1.89)	2.24 (2.29)	2.19 (2.28)	1.1 (1.3)	1.1 (1.3)
K ₂ O	1.54 (1.57)	2.59	2.30 (2.43)	2.0 (2.1)	2.76 (2.84)	2.12 (2.16)	3.26 (3.40)	2.6 (3.0)	2.7 (3.2)
TiO ₂	0.51 (0.52)	0.49	0.57 (0.60)	0.6 (0.6)	0.66 (0.68)	1.39 (1.42)	0.70 (0.72)	0.8 (0.9)	0.7 (0.8)
P ₂ O ₅	0.19 (0.19)		0.14 (0.15)	0.2 (0.2)	0.22 (0.23)	0.12 (0.12)	0.19 (0.20)	0.1 (0.1)	0.2 (0.2)
MnO	0.08 (0.08)	0.09	0.11 (0.12)	0.1 (0.1)	0.05 (0.05)	0.04 (0.04)	0.09 (0.09)	0.1 (0.1)	0.1 (0.1)
H ₂ O [±]	1.61		2.17	3.0	2.09	1.64	3.11	5.0	4.5
CO ₂	0.29		1.49	1.2	0.20	0.07	0.17	3.3	4.3
SO ₃				0.3		0.02		0.8	0.8
C				0.1 (0.1)		0.41 (0.42)		0.2 (0.2)	0.2 (0.2)
TOTAL:	100.1	99.38	99.73	100.3	99.67	99.61	99.58	97.5	98.8

1. Average of 9 greywackes, File Lake Formation

2. Average of 7 early Precambrian volcanoclastic greywackes (Shegelski, 1976)

3. Average of 20 early Precambrian greywackes (Henderson, 1975)

4. Average of 61 analyses of greywacke (mainly Phanerozoic, but includes 13 early Precambrian greywackes) (Pettijohn, 1963)

5. Average of 14 mudstones, File Lake Formation

6. Average of 7 mudstones, Corley Lake Member

7. Average of 20 early Precambrian slates (Henderson, 1975)

8. Average of 4030 Mesozoic and Cenozoic mudrocks (290 analyses) from Russian platform (Ronov *et al.*, 1966)

9. Average of 11,151 mudrocks (455 analyses) from the Great Caucasus geosyncline (Ronov *et al.*, 1966).

¹ Chemical compositions in brackets have been recalculated volatile-free to 100 percent after CaO equivalent to the weight percent of CO₂ has been removed. This has been done to delete the effects of volatiles and carbonate (cement or organic fossil remains).

general coarseness of detritus and its deposition by mass-sediment gravity flows all indicate that the volcanic source terrane was largely subaerial because these quantities of detritus could not be derived from a subaqueous source. A subaerial source is also indicated by the wide variety of volcanic clast lithologies, because such mixtures of detritus generally form only through subaerial transport (Ayres, 1978, pers. comm., 1979). Slight rounding of the detritus and scattered, more rounded clasts of felsic granophyre of probably subvolcanic origin also suggest stream transportation and a subaerial rather than a subaqueous source.

Paleocurrent and paleoslope data are virtually absent in the File Lake Formation because basal sole marks are concealed by metamorphic welding of bed contacts. At Morton Lake, bent flame

structures and current ripple laminations indicate a north-dipping paleoslope and paleocurrent direction. However, this is just an approximation because these structures are only exposed in two dimensions.

DEPOSITIONAL ENVIRONMENT OF AMISK GROUP METASEDIMENTARY ROCKS

The Amisk Group metasedimentary rocks were deposited upon a thick platform of moderate- to shallow-water, predominantly mafic, flows. The sediments were derived by rapid subaerial erosion of unconsolidated to weakly consolidated pyroclastic detritus from a predominantly felsic volcanic source. The detritus of the Parisian and

TABLE 11: Chemical analyses^{1,2} of metamudstones of the Corley Lake member (unit 15) of the File Lake Formation

	1	2	3	4	5	6	7
SiO ₂	53.3	57.2	57.3	58.8	59.05	59.45	64.05
Al ₂ O ₃	18.7	17.9	18.1	18.2	17.05	17.85	18.5
FeO	1.45	1.04	0.86	3.38	0.53	1.96	0.83
Fe ₂ O	10.77	9.44	7.64	6.13	9.36	7.16	7.07
MgO	3.62	3.38	2.98	3.17	3.09	3.25	2.51
CaO	2.45	3.09	3.07	1.40	2.96	2.25	0.68
Na ₂ O	2.70	2.58	3.25	1.50	2.73	2.35	0.58
K ₂ O	2.30	2.30	2.09	2.53	1.55	2.16	1.90
TiO ₂	1.77	1.20	1.65	1.35	1.22	1.36	1.20
P ₂ O ₅	0.08	0.12	0.11	0.11	0.17	0.12	0.11
MnO	0.08	0.07	0.05	0.08	0.08	0.05	0.05
H ₂ O [±]	1.71	1.18	1.51	2.39	1.29	1.70	1.71
CO ₂	0.10	tr.	0.05	0.05	0.2	tr.	0.10
S	0.02	0.01	0.01	0.05		0.04	0.03
Graphitic carbon ³		0.57	0.66	0.42	*	*	
TOTAL	99.0	100.1	99.3	99.6	99.3	99.7	99.3
Total Fe as Fe ₂ O ₃	13.3	11.42	9.26	10.12	10.83	9.84	8.61

1. Coarsely porphyroblastic sillimanite-, garnet-, and biotite-bearing metamudstone (F07-2798-1).
2. Coarsely porphyroblastic sillimanite-, cordierite-, garnet- and biotite-bearing metamudstone (F07-2376-2).
3. Coarsely porphyroblastic cordierite-, garnet- and biotite-bearing metamudstone (F07-3776-1).
4. Coarsely porphyroblastic garnet-, staurolite-, sillimanite- and biotite-bearing metamudstone (F07-3776-4).

5. Coarsely porphyroblastic garnet-, chlorite- and biotite-bearing metamudstone (F07-39-1).
6. Coarsely porphyroblastic garnet-, staurolite- and biotite-bearing metamudstone (F07-3776-9).
7. Coarsely porphyroblastic cordierite-, sillimanite-, garnet- and biotite-bearing metamudstone (F07-2422-1).

¹ Chemical analyses by Analytical Laboratory of Manitoba Mineral Resources Division.

² Sample sites are located on Figure 94 (in pocket).

³ Samples with asterisk have graphitic carbon in undissolved residue.

File Lake Formations was probably moved in subaerial transportation systems, such as streams, to the Amisk sedimentary basin, and then moved deeper into the basin by catastrophic subaqueous downslope movement of sediment-charged density currents. The detritus of the Yakymiw Formation was probably moved into the sedimentary basin by debris flows or by pyroclastic flows directly from the source volcano. The excellent preservation of sedimentary structures in the Yakymiw and File Lake Formations indicates that these sediments were not reworked by strong bottom currents and were probably deposited in deep water below storm wave base.

The debris flow deposits of the Parisian and Yakymiw Formations are restricted to the volcanic terrane of the Flin Flon belt and were probably deposited close to the margin of the Amisk sedimentary basin. The mass-flow deposits, mainly turbidites, of the File Lake

Formation are widespread and contain bed types and distribution of bed types which indicate that they are part of a subaqueous fan system that was transporting detritus from the Flin Flon belt into the Kiseynew belt. Features which suggest that the File Lake Formation is a subaqueous fan deposit are:

- (1) The *ABCD(E)* beds and the *AE* beds, and their distribution, thickness and grain sizes, are comparable to those identified on modern submarine fans by Nelson and Kulm (1973), Walker and Mutti (1973) and Walker (1976). For example, the *AE* beds at south Morton Lake are similar to Holocene and late Pleistocene strata described by Nelson and Kulm (1973) from the Cascadia channel of the Astoria fan, Oregon.

- (2) The upward increase in grain size bed thicknesses, percentage of *AE* beds, and P_1 index at north Morton Lake (p. 36) is comparable to changes that have been demonstrated to be a typical feature of aggrading submarine fans (Walker, 1976). These changes are a consequence of construction of the fan into its depositional basin such that coarse grained, thick-bedded, proximal mid-fan deposits cover earlier, finer grained, thinner bedded distal outer fan deposits.

Several features indicate that the Amisk Group sedimentary rocks were derived from contemporaneous upslope Amisk volcanoes rather than an older dissected volcanic terrane. These include direct input of the pebbly greywacke of the Yakymiw Formation from their volcanic source without any evidence of reworking; intercalation of thin layers of volcanic rocks in the Parisian and File Lake Formations; absence of plutonic or metamorphic rocks which would be expected from a deeply dissected volcanic terrane; and only slight rounding of detritus which favours derivation from largely unconsolidated pyroclastic deposits rather than stream dissection of an older volcanic terrane with consequent abrasion of clasts.

The wide variety of volcanic clast lithologies in the Parisian and File Lake Formations indicates a subaerial source area because such mixtures of detritus generally form only through subaerial transport. Slight rounding of the detritus and scattered clasts of epizonal, probably subvolcanic intrusions also indicate a subaerial source. The thickness and large lateral extent of Amisk sedimentary deposits also imply subaerial derivation, because large quantities of detritus are

unlikely to have been derived from a subaqueous source.

The predominance of immature felsic volcanic detritus in the Amisk sediments and the subaerial derivation of this detritus from contemporaneous unconsolidated Amisk pyroclastic deposits suggest that at least one major emergent felsic stratovolcano was constructed south of the map-area late in the evolution of the Flin Flon belt. Subaerial stratovolcanoes are inherently susceptible to rapid erosion because they are dominantly fragmental, and because newly erupted material near their top causes unstable slopes (Ayres, 1978). Thus, subaerial debris flows, rain, stream activity and shoreline wave erosion probably transported the detritus from the stratovolcano and deposited a surrounding subaqueous epiclastic apron. The Amisk metasedimentary rocks of the File Lake area are interpreted to have been deposited by downslope subaqueous mass-sediment density flows transporting detritus from this epiclastic apron towards the Kisseynew belt.

The Amisk Group sedimentary rocks represent a type of sedimentation that has been recognized in both ancient (Ayres, 1978; Dimroth and Rocheleau, 1979; Tasse *et al.*, 1978) and modern (Dickinson, 1968, 1974; Mitchell, 1970; Ballance, 1974; Keunzi *et al.*, 1979) volcanic environments. It is suggested that this type of sedimentation is a natural consequence of build-up of volcanic successions into shallow water to subaerial environments, combined with gradual increase in quantities of felsic volcanism. This is because both these features lead to increased pyroclastic activity and to the construction of easily eroded subaerial stratovolcanoes that shed large quantities of volcanoclastic detritus into adjacent sedimentary basins.

MISSI GROUP METASEDIMENTARY ROCKS

INTRODUCTION

The Missi Group is a 1.3 km thick sequence of quartzo-feldspathic paragneisses derived from subgreywacke and arkose. It disconformably overlies Amisk Group rocks and outcrops north of File Lake in the Kisseynew belt.

The bottom 300 m of the Missi Group is laminated and locally cross-laminated metasubgreywacke (unit 16(1)); the laminations are defined by concentrations of biotite and magnetite. The next 700 m is massive, thick-bedded, generally unlaminated metasubgreywacke (unit 16(2)). Massive, thick-bedded, unlaminated meta-arkose (unit 16(3)) forms the upper 300 m; the top of this unit is not exposed. A 100 m thick layer of pink granoblastic gneiss (unit 26a), located along the contact between units 16(2) and 16(3), may be a conformable metavolcanic unit and, as such, belong to the Missi Group. However, this layer traces directly into a gneiss dome diapir (units 25 and 26), and along with these rocks has been arbitrarily included as a metamorphic unit. Features distinguishing units 16(1), 16(2) and 16(3) are subtle and for a large part of the map-area these units have not been differentiated and are combined as unit 16. Strongly recrystallized, massive, granoblastic felsic gneisses (unit 17) occur locally and appear to have formed by coarse recrystallization and metasomatism of paragneisses of units 16, 16(1), 16(2) and 16(3). The main features of Missi Group metasedimentary rocks are summarized in Table A-4.

The Missi Group of the File Lake area differs from the Missi Group in its type localities at Amisk Lake, Saskatchewan, and at Flin Flon, Manitoba, as follows: it is more strongly recrystallized; it lacks conglomerate layers which are abundant in the type localities; and it disconformably overlies deep-water turbidites rather than unconformably overlying subaerially weathered volcanic rocks as it does in type localities.

The Missi Group rocks of the File Lake area were classified by Harrison (1949) as the upper unit of his Snow Group. They can be traced to the north directly into arenaceous paragneisses of the Sherridon Group of the Kisseynew belt.

DESCRIPTION OF UNITS

METASUBGREYWACKE AND

META-ARKOSE (16, 16(1), 16(2), 16(3))

Unit 16(1) is a light grey to white weathering quartz-rich leucocratic metasubgreywacke with local interbeds of darker grey silt-rich layers. It forms a 200 to 300 m thick unit which directly overlies the File Lake Formation between File and Corley Lakes and outcrops in a few exposures as a thin veneer along the west shore of Ellice Bay. It consists of felsic quartz-feldspar-biotite paragneisses, which locally contain 0.5 to 1 cm diameter aggregates of fibrolitic sillimanite and porphyroblasts of garnet, and rare porphyroblasts of staurolite. It locally contains thin, green calc-silicate layers and rarely includes small isolated rounded pebbles of vein quartz, quartzite and several varieties of lithic felsic fragments (Fig. 44). Beds are thick, parallel-sided and defined by subtle changes in mineralogy, texture, colour and composition. Close-spaced partings or laminations (Fig. 45), marked by concentrations of biotite, magnetite, or both, are characteristic. Ripple current laminations (Fig. 45) occur locally; they are extremely rare in overlying units. Siltstone layers, parallel laminations and porphyroblasts of garnet, staurolite and sillimanite decrease upward in unit 16(1). The contact with the overlying paragneisses of unit 16(2) is gradational.

Unit 16(2) is a monotonous, homogeneous succession of white weathering plagioclase-rich leucocratic metasubgreywacke. It contains thick massive beds, rare parallel laminations, rare garnet and sillimanite porphyroblasts, and small amounts of microcline. It is exposed in a 700 m thick layer between File and Corley Lakes and along the west shore of Ellice Bay. Small magnetite porphyroblasts stand up in relief on weathered outcrop surfaces.

Unit 16(3) is a buff coloured, microcline-bearing meta-arkose which outcrops in the core of a large isoclinal synform between File and Corley Lakes. It is massive, homogeneous and indistinctly layered. It is locally pink coloured and granoblastic, and grades into gneisses of unit 17.

Unit 16 consists of undivided metasubgreywacke and meta-arkose and has many of the features described previously for units

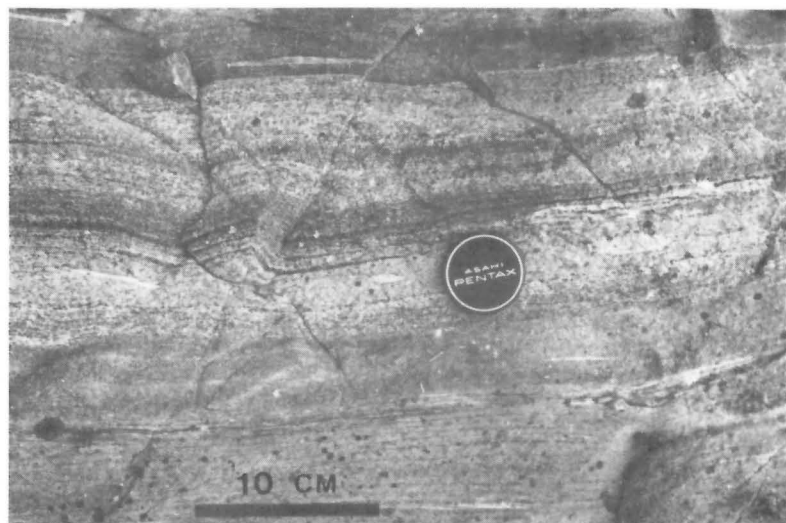


FIGURE 44: Calc-silicate layers (white) in laminated metasubgreywacke (unit 16(1)), Missi Group, northwest shore of File Lake. Isolated pebbles are present in subgreywacke and in calc-silicate layers.

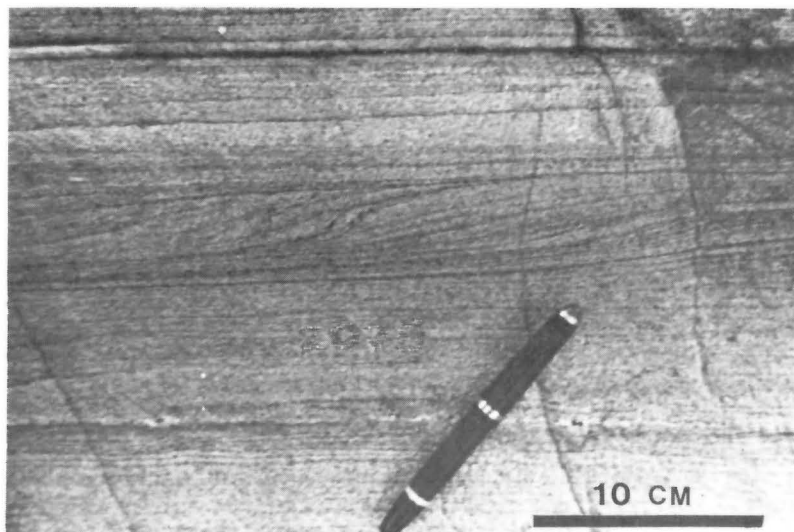
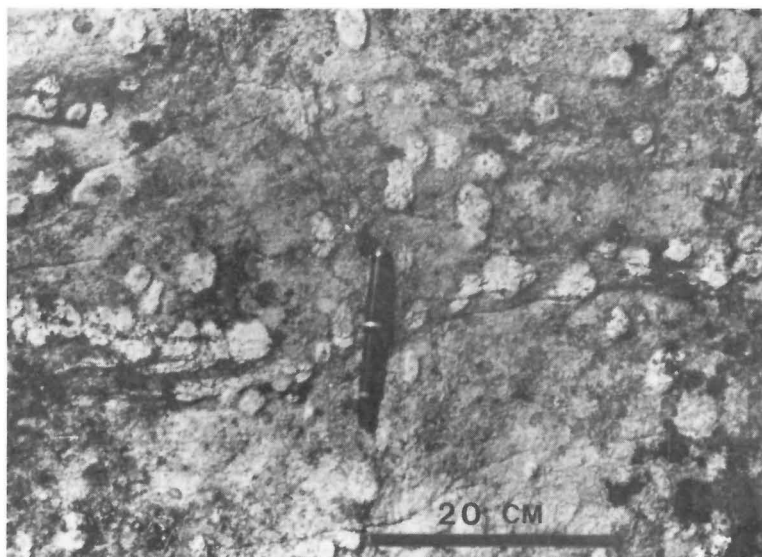


FIGURE 45: Horizontal and ripple cross laminations in metasubgreywacke (unit 16(1)), Missi Group, 0.3 km south of Corley Lake.

FIGURE 46: Nodular metamorphic aggregates of quartz and sillimanite in meta-subgreywacke (unit 16), Missi Group, 0.5 km southwest of File River on hydro line.



16(1), 16(2) and 16(3). It outcrops northeast of Corley Lake and along the west shore of the northeast arm of File Lake. Northeast of Corley Lake, it consists of light grey to buff, granoblastic, homogeneous gneisses that are locally gradational into unit 17. Aggregates of quartz and fibrous sillimanite (*faserkiesel*), up to 3 cm in diameter, are common (Fig. 46). In one exposure, located 800 m southwest of the File River on the hydro line to the Dickstone minesite, the quartz and fibrous sillimanite aggregates occur both as nodules and as thin layers. Exposures along the west shore of the northeast arm of File Lake typically consist of light grey to white, well bedded paragneisses. They locally contain some rusty weathering, slightly darker coloured, massive gneisses which contain small amounts of disseminated pyrite and pyrrhotite. These rocks occur in a 50 to 100 m thick stratigraphic layer which outcrops west of Titley Island along the shore of File Lake, and west of the second amphibolite layer (unit 19) along the hydro line at the north end of File Lake.

GRANOBLASTIC FELSIC PARAGNEISS (17)

Granoblastic felsic gneisses of unit 17 outcrop northeast of Corley Lake, on strike with paragneisses of unit 16(3), and northeast of Harry Lake. They are white, light grey and pink, fine- to medium-grained, gneissic, exhibit an indistinct layering, and consist of oligoclase, quartz and microcline, lesser amounts of biotite, green hornblende, magnetite and garnet, and traces of apatite and sphene. Northeast of Harry Lake, they are characterized by small porphyroblasts of green hornblende and by rusty staining on weathered surfaces. Harrison (1949) considered these rocks to be paragneisses soaked by granitic fluids from the Nelson Bay Gneiss Dome (units 25 and 26), which he interpreted to be an intrusive granite. However, the Nelson Bay Gneiss Dome is not an intrusive granite and it is more likely that the granoblastic gneisses of unit 17 are formed by coarse recrystallization and local alkali metasomatism of rocks of units 16, 16(1), 16(2) and 16(3) during high grade regional metamorphism.

MAJOR ELEMENT GEOCHEMISTRY

Four analyses of Missi Group paragneisses are given in Table 12. They include one of unit 16(1), two of unit 16 and one of unit 17. The samples of unit 16 are from exposures on strike with strata of unit 16(2) and are likely to be representative of the latter unit.

The analyses plot in the greywacke and arkose fields on Figure 47. They have higher $\text{SiO}_2/\text{Al}_2\text{O}_3$ ratios and, with the exception of one sample of unit 16, they have lower $\text{Na}_2\text{O}/\text{K}_2\text{O}$ ratios than greywackes and siltstones of the File Lake Formation (compare Figs. 43 and 47). These features reflect the higher quartz content and higher microcline/plagioclase ratio of the Missi paragneisses.

DISCUSSION

There are no reliable indicators of depositional environment in the Missi Group of the File Lake area. Elsewhere Byers (1953), Byers and Dahlstrom (1954), Mukherjee (1971), Staufer (1974) and Shanks and Bailes (1977) have interpreted the Missi Group to be fluvial-alluvial deposits.

The origin and significance of the 100 m thick layer of pink fine grained granoblastic gneiss (unit 26a), located between units 16(2) and 16(3), is uncertain. However, there are several features which suggest it may be a strongly recrystallized, subaerial felsic metavolcanic rock: 1) it has an igneous chemistry (p. 66, this report); 2) it contains poorly preserved primary features typical of a welded ash flow deposit (p. 66, this report); and it is very similar to and occurs at a similar stratigraphic position as do felsic welded ash flow layers observed by Shanks and Bailes (1977) in volcanic rocks overlying Missi Group sedimentary rocks east of Wekusko Lake. If unit 26a is a

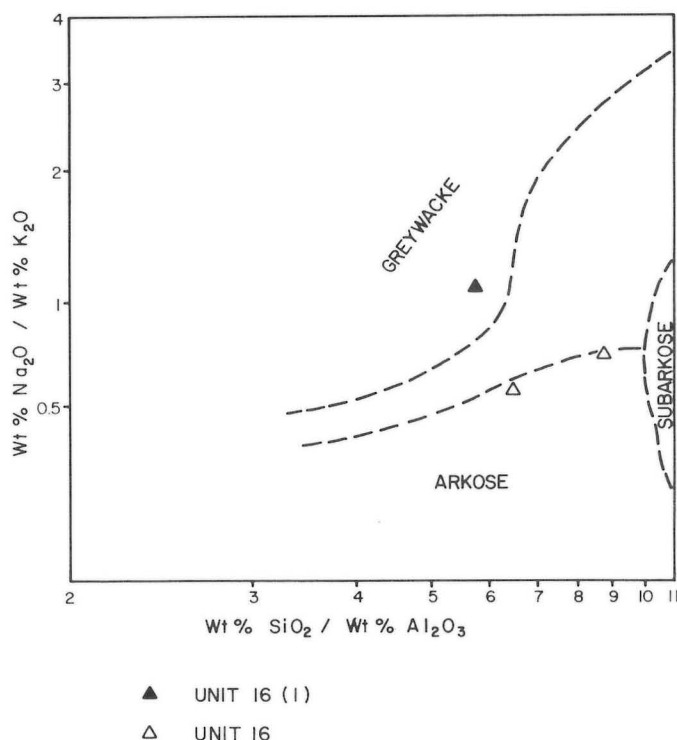


FIGURE 47: Log ($\text{SiO}_2/\text{Al}_2\text{O}_3$) vs log ($\text{Na}_2\text{O}/\text{K}_2\text{O}$) diagram (after Pettijohn et al., 1972) for metasedimentary rocks of the Missi Group.

TABLE 12: Chemical analyses^{1,2} of metasubgreywacke and meta-arkose of units 16(1), 16 and 17 of the Missi Group

UNIT NO.	1 16(1)	2 16	3 16	4 17
SiO_2	79.65	72.4	74.4	82.55
Al_2O_3	9.4	12.8	11.7	8.35
Fe_2O_3	0.27	2.19	1.95	1.43
FeO	4.10	1.84	2.14	0.75
MgO	1.37	1.41	1.00	0.42
CaO	2.70	1.90	1.40	0.67
Na_2O	0.68	2.42	1.82	1.16
K_2O	0.96	2.25	3.25	3.65
TiO_2	0.32	0.49	0.51	0.32
P_2O_5	0.08	0.10	0.10	0.01
MnO	0.08	0.05	0.05	0.03
H_2O^\pm	0.50	1.36	1.06	0.17
CO_2	0.23	0.25	0.25	0.15
TOTAL	100.2	99.5	99.6	99.66
Total Fe as Fe_2O_3	4.78	4.21	4.30	2.26

1. Metasubgreywacke (F07-629-1) from 150 m above base of Missi Group. Sample comprises granoblastic mixture of quartz, plagioclase, biotite and garnet with traces of magnetite and chlorite.

2. Meta-arkose (F07-714-1). Sample comprises granoblastic mixture of quartz, plagioclase, microcline, biotite and muscovite. Muscovite occurs as nodular metamorphic aggregates.

3. Meta-arkose (F07-714-2). Sample comprises granoblastic mixture of quartz, plagioclase, microcline, biotite, muscovite, sillimanite and accessory magnetite and apatite. Sillimanite occurs with quartz in nodular metamorphic aggregates (faserkiesel).

4. Pink granitoid paragneiss (F07-714-3) composed of quartz, microcline, plagioclase and biotite, with traces of magnetite, sillimanite, zircon and chlorite.

1 Chemical analyses by Analytical Laboratory of Manitoba Mineral Resources Division

2 Sample sites are located on Figure 94 (in pocket).

metamorphosed felsic welded ash flow deposit then it is likely that the Missi Group at File Lake was locally deposited under subaerial conditions.

The contact of the Missi Group with underlying turbidity current deposits of the File Lake Formation, although never observed directly, has been delineated to within a few metres at several localities and is structurally conformable. However, strata below and above the contact were probably deposited in very different and

mutually exclusive environments, deep water and subaerial to shallow marine, respectively. This abrupt change in character of the sedimentation suggests either rapid fluctuation in water level or a hiatus in sedimentation and perhaps a disconformity. A disconformity of very low relief may exist because the Corley Lake member (unit 15) occurs 250 m below the top of the File Lake Formation in the map-area, whereas east of the map-area, on Squall Lake, it occurs at the top and is locally missing (Harrison, 1949; Bailes, 1975; Froese and Moore, 1980).

POST-MISSI INTRUSIVE AND METAMORPHIC ROCKS

Four main groups of post-Missi intrusive and metamorphic rocks are recognized (Map 78-1-1; Table 1, p. 4):

- Post-kinematic intrusions
- Metamorphic and anatectic rocks
- Syn- to late-kinematic intrusions
- Early kinematic intrusions

Their ages relative to major metamorphic and tectonic events are indicated in Table 17 (p. 70). The igneous rocks are named according to a nomenclature system proposed by the IUGS Subcommittee on Systematics of Igneous Rocks (Streckeisen, 1976).

The early kinematic intrusions are concordant bodies of tholeiitic gabbro (unit 18) and derived metagabbro and amphibolite (unit 19). The syn- to late-kinematic intrusions are calc-alkaline felsic plutons (units 20 to 24), some of batholithic dimensions. The metamorphic and anatectic rocks comprise domal complexes of coarsely recrystallized felsic orthogneiss (units 25 and 26) and intrusions of anatectic granodiorite and tonalite (unit 27). The felsic orthogneisses of units 25 and 26 were mobilized during tectonism that accompanied regional metamorphism and have locally penetrated overlying strata. For this reason, they are included with the igneous and metamorphically derived rocks, rather than with the Missi Group in which they appear to be rooted (see pp. 94 to 97). The post-kinematic intrusions comprise small, late dykes of felsic pegmatite (unit 28).

EARLY KINEMATIC INTRUSIVE ROCKS

The early kinematic intrusive rocks comprise a group of strongly differentiated, concordant, layered intrusions of tholeiitic gabbro (unit 18), collectively known as the Josland Lake Gabbro, and a series of metagabbro and amphibolite layers (unit 19); the latter are interpreted to be, at least in part, strongly recrystallized equivalents of the Josland Lake gabbro. Two ages of intrusions of the Josland Lake Gabbro are recognized (Table 17, p. 70).

A summary of the general characteristics and features of early kinematic intrusive rocks is given in Tables A-5a and A-5b.

JOSLAND LAKE GABBRO (18)

GEOLOGIC SETTING, AGE AND GENERAL FEATURES

Concordant intrusions of the Josland Lake Gabbro occur throughout the map-area, but are most abundant in the west half of the map-area and in the Flin Flon belt. They average 500 to 700 m in thickness and typically occur along geological discontinuities, for example along the interface between Amisk Group volcanic and sedimentary rocks and along the axial surfaces of early recumbent fold structures. The intrusions are likely hypabyssal, but no extrusive volcanic equivalents outcrop in the map-area. The intrusions cross-cut Amisk Group volcanic and sedimentary rocks and thus cannot have been feeders for Amisk volcanism. They may have been feeders for late Missi to post-Missi volcanism, which has been recognized east of the map-area at Wekusko Lake (Stockwell, 1937; Shanks and Bailes, 1977).

Concordant intrusions of the Josland Lake Gabbro are differentiated and zoned bodies. They consist of three major stratigraphic zones or units (Map 78-1-1). Their lower two zones comprise gabbro (unit 18(1)) and ferrogabbro (unit 18(2)), respectively. Their upper zone consists of granophyric and porphyritic quartz diorite and tonalite (unit 18(3)). Gabbros of the lower two zones contain cumulate textures and rhythmic layering, features which indicate that the intrusions solidified by fractionation combined with current activity; the latter could be related to convective overturn in the intrusions. Intrusions of the Josland Lake Gabbro are strongly tholeiitic and late phase differentiates are strongly enriched in iron.

The Josland Lake Gabbro comprises two suites of intrusions. Both are lithologically similar, but they exhibit different age relationships. One suite was emplaced prior to an early phase of recumbent folding, F_1 , and the other was emplaced after and along the axial planes of the early F_1 folds. Features which result from and are evidence for the two ages of intrusions are:

- 1) juxtaposition of unfolded and tightly folded intrusions northwest of Morton Lake;
- 2) juxtaposition of intrusions with opposite facing directions, indicated by mafic and felsic differentiation trends, northwest and west of Morton Lake; and
- 3) pre- F_1 (i.e. folded) intrusions west of Morton Lake always top the same direction as their host volcanic host strata.

The two suites of intrusions have been identified, where possible, in structural cross sections on Figure 95 (in pocket).

Intrusions of the Josland Lake Gabbro are cross-cut by syn- to late-kinematic felsic plutons (units 20 to 24), are deformed by many fold structures and were strongly recrystallized during high grade regional metamorphism. They are best preserved and least recrystallized in the south half of the map-area where they consist of lower greenschist facies mineral assemblages and commonly contain relicts of primary mineral assemblages. The degree of recrystallization increases to the north; at the north boundary of the map-area the intrusions are completely recrystallized and contain upper almandine-amphibolite facies mineral assemblages.

Large concordant intrusions of gabbro are common throughout the Flin Flon volcanic-sedimentary belt. It is likely that many, and possibly most, of these intrusions are equivalent to those of the Josland Lake Gabbro. These intrusions, like the Josland Lake Gabbro, are commonly differentiated (Buckham, 1944); they rarely contain ultramafic phases (Williams, 1966), a feature not observed in intrusions of the map-area.

STRATIGRAPHY AND PETROGRAPHY OF LAYERED INTRUSIONS

Individual units in differentiated intrusions of the Josland Lake Gabbro vary from one intrusion to another, and vary with degree of recrystallization. However, these variations are slight, and are commonly predictable, particularly those that relate to metamorphic recrystallization (see p. 56 and pp. 86 to 87). The main features of individual rock units in intrusions of the Josland Lake Gabbro are summarized in Tables A-5a and A-5b.

Josland Lake Intrusion

The main features of a post- F_1 intrusion which outcrops south of Josland Lake are described in this section. The stratigraphy and zoning of this intrusion are similar, and in some cases identical, to that of other intrusions, so that much of the description of the Josland Lake intrusion, which follows, can be applied equally well to other intrusions.

The intrusion south of Josland Lake is geometrically conformable with the enclosing sedimentary rocks of the Yakymiw Formation and occupies the axial plane of an early recumbent fold. It is approximately 750 m thick and uniform in width, and is over 10 km in length, and extends an undetermined distance south of the map-area. At its north end it is intruded and terminated by the Norris Lake pluton (unit 23). Its eastern contact (stratigraphic base) is sharp and locally chilled. Its western contact (stratigraphic top) is gradational over a few metres and shows signs of roof melting and hybridization. The degree of metamorphism of the intrusion increases, south to north, from middle greenschist to lower almandine-amphibolite facies. Most rocks are

completely altered to secondary minerals, but primary minerals can generally be identified from local remnant grains and remnant textures.

The three major stratigraphic units or zones, that characterize intrusions of unit 18, are present in the intrusion south of Josland Lake. They are:

Granophyre Zone :	Quartz diorite (unit 18(3)b)) Tonalite (unit 18(3)c)	150 m thick
Ferrogabbro Zone:	Ferrogabbro (unit 18(2))	250 m thick
Gabbro Zone :	Gabbro, leucogabbro (unit 18(1))	350 m thick

Contacts between the individual zones are well defined and gradational over 2 to 3 m. The contact between units 18(3)b and 18(3)c is gradational over 30 m.

The Gabbro Zone consists of olive-green to white, medium grained gabbro and leucogabbro (unit 18(1)). It is homogeneous, but locally exhibits some weak rhythmic layering (particularly near its top). It locally contains some patchy aggregates of light and dark minerals (Fig. 48) and some widely spaced centimetre thick veinlets of secondary carbonate and zoisite. The primary minerals of the gabbro and leucogabbro, now largely altered, were clinopyroxene (augite), labradorite and ilmenite; the ilmenite is a minor component and characteristically occurs as skeletal grains. Both the clinopyroxene and

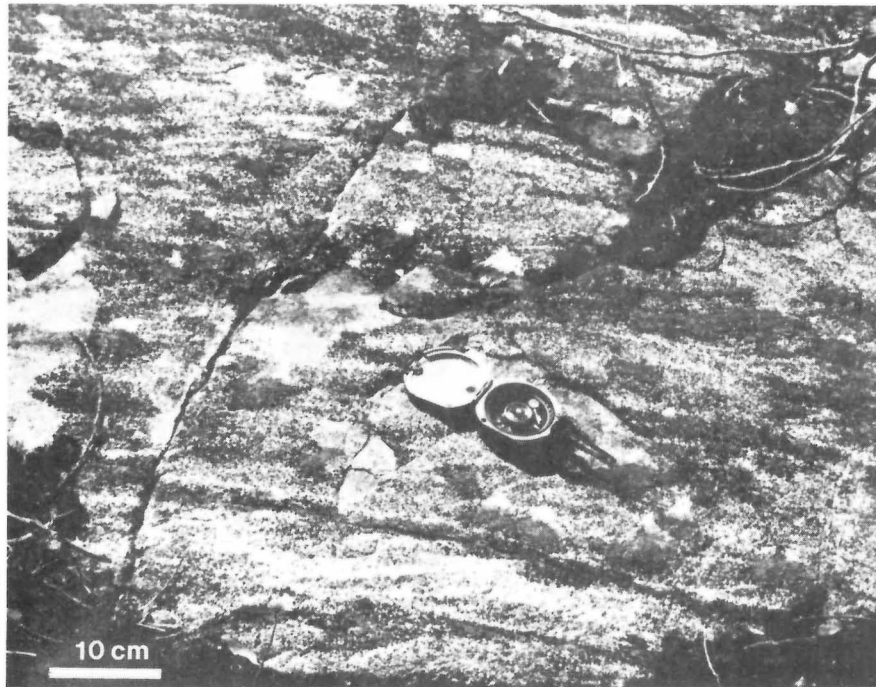


FIGURE 48: Mottled leucogabbro (unit 18(1)), 700 m east of Storozuk Lake.

FIGURE 49: Photomicrograph (plain light) of gabbro (unit 18(1)) containing zoisite-replaced cumulus plagioclase (PG) and tremolite-replaced intracumulus clinopyroxene (CP), Josland Lake intrusion.

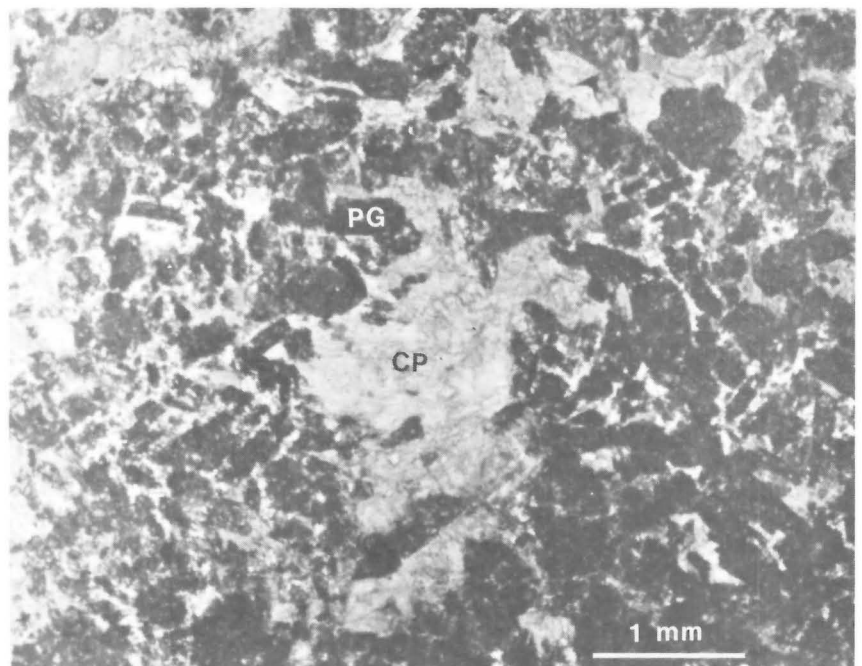
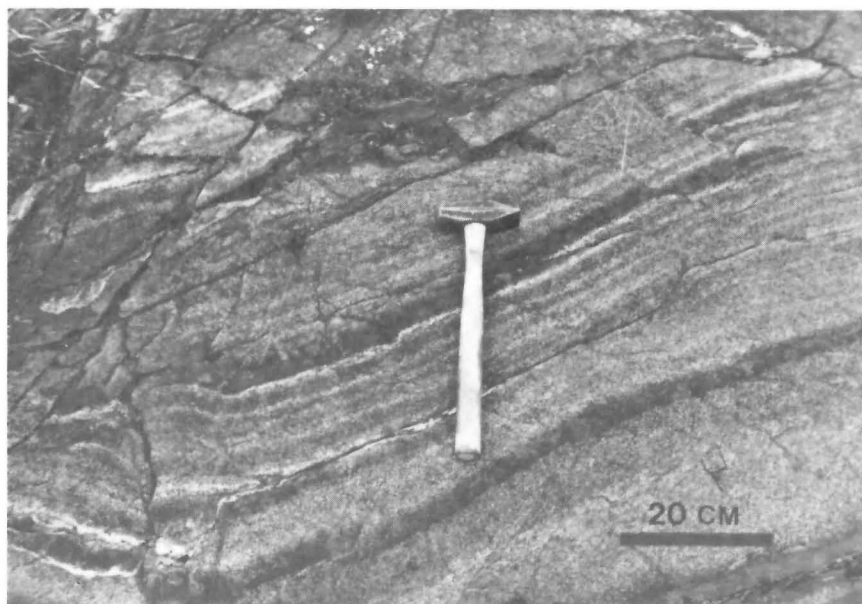




FIGURE 50: Rhythmic layering in ferrogabbro (unit 18(2)), 330 m northeast of Yakymiw Lake. Note dark mafic-rich base and light plagioclase-rich top to many layers.

FIGURE 51: Rhythmic layering in ferrogabbro (unit 18(2)), same locality as Figure 50.



labradorite are cumulus and, to a lesser extent, intracumulus phases (Fig. 49). During lower to middle greenschist facies metamorphism, tremolite and minor phlogopitic biotite replaced clinopyroxene, zoisite, and calcite replaced labradorite, and sphene replaced ilmenite. With increase in grade of metamorphism, to upper greenschist facies, the tremolite changes to actinolite and becomes more granoblastic. The average content of mafic minerals in these rocks is 40 to 50 percent.

The Ferrogabbro Zone comprises dark green to black ferrogabbro (unit 18(2)). Its contact with the lower Gabbro Zone is gradational over a few metres. Immediately above the contact, rocks of unit 18(2) are characterized by strong rhythmic layering (Figs. 50 and 51) which continues, less distinctly, throughout this unit. The ferrogabbro consists of blue-green amphibole (secondary), plagioclase and ilmenite, with mafic minerals averaging 60 to 70 percent. The primary mafic mineral of unit 18(2) is not preserved; the plagioclase is

recrystallized and partially altered to zoisite and calcite; and the ilmenite, which commonly is skeletal, is partly replaced and rimmed by sphene. Indistinct pseudomorphs of clinopyroxene occur rarely within some of the secondary amphibole grains, but it is not known if clinopyroxene was a major primary mineral.

The Granophyre Zone comprises white to light green quartz diorite (unit 18(3)b) and tonalite (unit 18(3)c). Its contact with the underlying Ferrogabbro Zone is gradational over a few metres. The quartz diorite directly overlies the ferrogabbro and is overlain in turn by the tonalite. The contact between the quartz diorite and tonalite is completely gradational. A steady decrease in mafic minerals, from 40 to 5 percent, from base to top, with a comparable increase in quartz, is exhibited by rocks of the Granophyre Zone. The upper contact of this zone is rapidly gradational, with partial melting and assimilation of the overlying sediments of the Yakymiw Formation (unit 12).

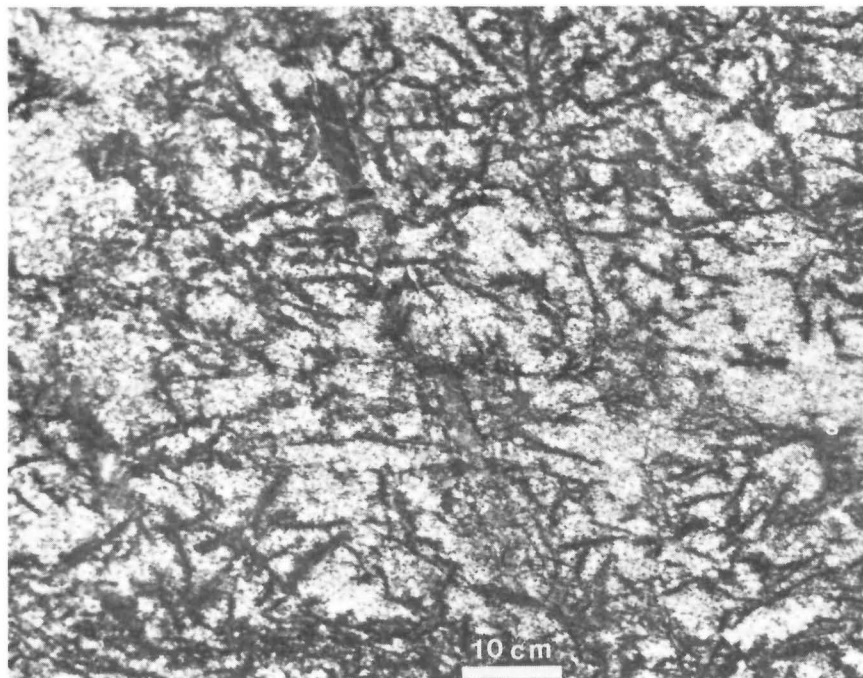
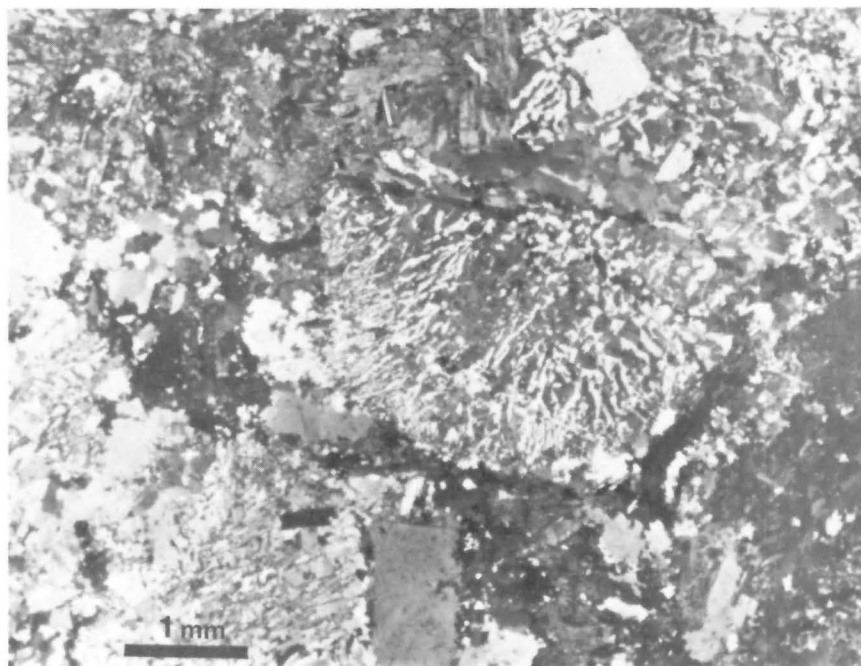


FIGURE 52: Synneusitic radiating clusters of actinolite crystals in quartz diorite (unit 18(3)b), 120 m north of Yakymiw Lake.

FIGURE 53: Photomicrograph (polarized light) of granophyric tonalite (unit 18(3)c), Josland Lake intrusion.



The quartz diorite (unit 18(3)b) comprises equal proportions of albite, quartz and dark blue-green amphibole (secondary), and contains accessory ilmenite and apatite. The albite and quartz are, in part, micrographically intergrown. Blue quartz phenocrysts and synneusitic clusters of lath-shaped amphibole crystals (Fig. 52) are common. The tonalite (unit 18(3)c) is a micrographic rock (Fig. 53) composed largely of quartz and albite, with 5 to 25 percent dark blue-green amphibole (secondary), minor green-brown biotite (secondary) and accessory ilmenite. Minor orthoclase is also present locally. The quartz and albite occur as prominent phenocrysts, as constituents of the fine grained groundmass, and as granophyric

intergrowths. In northern exposures, rocks of units 18(3)b and 18(3)c are more strongly recrystallized, more granoblastic and contain small porphyroblasts of mauve pyralispite garnet.

Other Intrusions

Other intrusions, both pre- and post- F_1 , are similar to the post- F_1 Josland Lake intrusion. However, there are some slight differences between the pre- and post- F_1 intrusions and between large and small intrusions.

The only large pre- F_1 intrusion is that exposed in a series of

antiformal domes, along the west shore of File Lake and to the north and south of Podruski Lake. This intrusion is tightly folded, averages 600 m in thickness, and has a lateral extent of over 20 km. It follows the contact between Amisk volcanic and sedimentary rocks for much of its length, except northwest of Morton Lake, and like the post-F₁ Josland Lake intrusion it has uniform thickness and well defined zones. It differs from the Josland Lake intrusion in several ways. For example, it has: a narrower Ferrogabbro Zone; a wider Granophyre Zone; a more porphyritic and less micrographic Granophyre Zone; no obvious subdivision of its Granophyre Zone; and a Gabbro Zone which is darker and characterized by 50 to 60 percent mafic minerals, compared to 40 to 50 percent in the Josland Lake intrusion. These differences are slight, and could be due to slight changes in the conditions of crystallization or in the degree of contamination and hybridization of the magma.

The large intrusions have uniform thickness, large lateral extent and well defined zones; however, many of the smaller intrusions have irregular shapes, bifurcated extremities, large lateral changes in thickness along strike, and local absence of upper zones. These differences probably reflect the way in which the present erosion surface intersects the individual intrusions. For example, if the intrusions are pancake-shaped in three dimensions, cross-sections across their centre produce continuous bodies such as that south of Josland Lake or that south and west of File Lake. Cross-sections across the edge of a pancake-shaped intrusion, on the other hand, would produce an irregular, laterally discontinuous, and poorly zoned intrusion of the kind observed at various locations along the west shore of Morton Lake.

DESCRIPTION OF UNLAYERED INTRUSIONS

Most intrusions of the Josland Lake Gabbro are layered and differentiated. Three exceptions are a plug of gabbro southwest of Yakymiw Lake, a concordant intrusion of porphyritic leucogabbro (unit 18(1)b) north of Norris Lake, and a concordant intrusion of gneissic tonalite west of the File River. None of these intrusions are layered or differentiated.

The gabbro southwest of Yakymiw Lake, which Harrison (1949) previously termed a serpentinized peridotite, has a primary

composition of 60 to 70 percent clinopyroxene (augite) and 30 to 40 percent labradorite. The clinopyroxene has been largely replaced by colourless to pale tremolite and the labradorite by zoisite and calcite. Original textures, which are pseudomorphed by the secondary minerals, indicate that the clinopyroxene and labradorite were mainly cumulus grains (Fig. 54). Weathered surfaces of the gabbro are pistachio green. Fresh surfaces are soft and resinous, with pale apple-green tremolite and white mixtures of zoisite and carbonate. The gabbro is resilient and difficult to break with a hammer.

The porphyritic leucogabbro (unit 18(1)b) north of Norris Lake, which Harrison (1949) previously termed a diabasic anorthositic gabbro, intrudes an F₁ folded gabbro and therefore is post-F₁. It is coarse grained and is composed of 60 to 70 percent phenocrysts of andesine, 25 to 35 percent dark green hornblende, 0 to 5 percent red-brown biotite and accessory amounts of apatite, ilmenite and sphene. The andesine phenocrysts are lath-shaped, 0.5 to 1.5 cm long, strongly twinned, in part delicately igneous zoned, and partly strained and crushed (Fig. 55). The hornblende is metamorphic and forms both large poikiloblasts (0.2 to 5mm) and fine grained granoblastic aggregates. Biotite overgrows the hornblende locally. Apatite and ilmenite comprise small discrete grains (0.5 to 1.0 mm). Sphene occurs as rims on ilmenite grains.

The sill of gneissic tonalite east of the File River is 500 m wide, approximately 2 km long, and intrudes Amisk Group paragneisses. It is a white, fine-to medium-grained rock with ubiquitous 1 to 3 mm phenocrysts of andesine. The matrix is composed of andesine, brown biotite, green amphibole and accessory sphene, apatite and calcite. The biotite is aligned and defines a prominent foliation. The intrusion, which locally contains xenoliths of host rocks, is included with the Josland Lake Gabbro suite because it is pre-metamorphic, early kinematic, and lithologically similar to rocks of unit 18(3). It is also possible that this intrusion is unrelated to the Josland Lake Gabbro and is a separate intrusive phase.

The undifferentiated intrusions are similar to other intrusions of the Josland Lake Gabbro, with the exception that they are unzoned. The intrusion of gabbro south of Yakymiw Lake and the intrusion of porphyritic leucogabbro north of Norris Lake are both cumulate rocks, like other rocks of unit 18(1). The intrusion of gneissic tonalite

FIGURE 54: Photomicrograph (plain light) of gabbro (unit 18(1)) containing zoisite-replaced cumulus plagioclase (PG) and tremolite-replaced intracumulus clinopyroxene (CP), undifferentiated plug south-southwest of Yakymiw Lake.

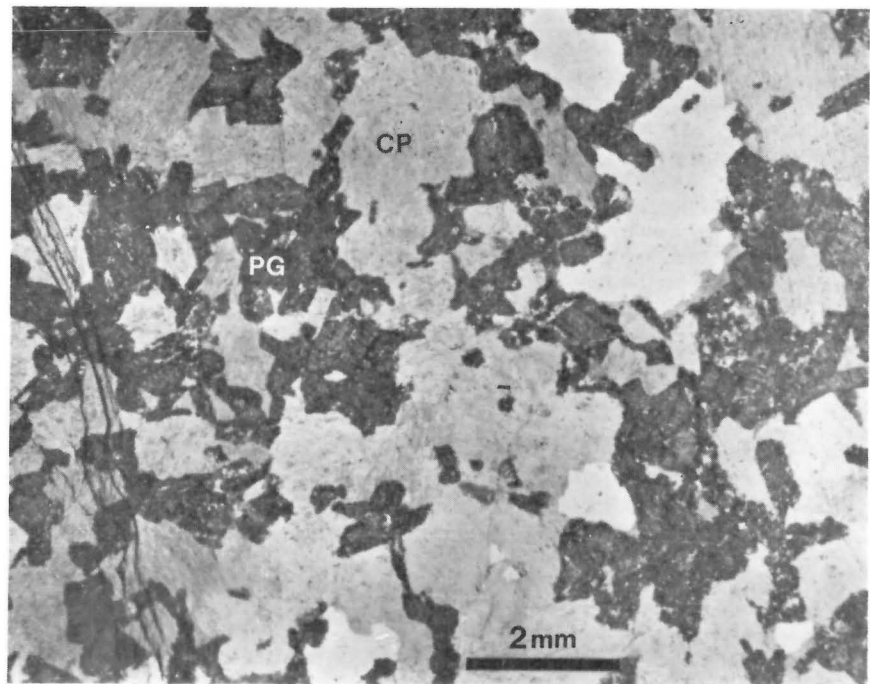




FIGURE 55: Photomicrograph (polarized light) of porphyritic leucogabbro (unit 18(1)b). Note serrated, recrystallized margins of plagioclase phenocrysts (PG) and recrystallized margins of hornblende crystals (HB).

east of the File River is similar to the metatonalite (unit 18(3)a) in the intrusion south of File Lake. It could be a late phase differentiate that moved from its parent magma chamber.

METAMORPHIC RECRYSTALLIZATION

Intrusions of the Josland Lake Gabbro are strongly recrystallized and their primary mineral assemblages are replaced by secondary minerals. The recrystallization occurred during an episode of regional metamorphism, M₂ (see Table 17 and pages 86 to 87). The grade of regional metamorphism and degree of granoblastic recrystallization of the intrusions increase rapidly to the north. This is particularly evident in north-trending intrusions west of Morton and File Lakes. Southern exposures of these intrusions comprise moderately recrystallized rocks (units 18(1), 18(2) and 18(3) which contain lower greenschist facies mineral assemblages and relicts of primary minerals and textures. Northern exposures comprise strongly recrystallized granoblastic orthogneisses (units 18(1)a, 18(2)a and 18(3)a) which contain upper almandine-amphibolite facies mineral assemblages.

Rocks of the Gabbro Zone vary dramatically with increasing metamorphic grade. South of Yakymiw Lake, they comprise gabbro and leucogabbro (unit 18(1)) composed of clear to pale green tremolite which has pseudomorphically replaced primary augite, zoisite which has replaced primary calcic labradorite, sphene rimming primary ilmenite, and small rare crystals of biotite. North of Ducharme Bay the Gabbro Zone consists of metagabbro (unit 18(1)a) in which tremolite has been completely and pseudomorphically replaced by dark green hornblende, zoisite has been completely replaced by sodic labradorite, and metamorphic clinopyroxene (diopside) has recrystallized in many specimens. Similar metagabbros occur on Loonhead Lake and, except for slightly more granoblastic textures, are identical to those north of Ducharme Bay.

Rocks of the Ferrogabbro Zone do not change dramatically with increasing metamorphic grade. Both low and high grade varieties, units 18(2) and 18(2)a, respectively, contain dark blue-green secondary hornblende. The only difference is that aggregates of hornblende are more granoblastic in unit 18(2)a.

Rocks of the Granophyre Zone change considerably during metamorphic recrystallization. South of Yakymiw Lake, they comprise granophyric quartz diorite and tonalite (units 18(3)b and 18(3)c). North of Ducharme Bay, they consist of quartz-plagioclase-hornblende-biotite-microcline orthogneisses (unit 18(3)a) which locally contain small porphyroblasts of pyralisite garnet.

One of the main criteria for distinguishing between rocks of unit 18(1) and unit 18(2) is the difference in colour of their amphibole

minerals. In weakly recrystallized bodies of gabbro, the amphibole in unit 18(1) is a colourless to pale green tremolite, whereas in unit 18(2) it is a dark blue-green hornblende. At higher metamorphic grade the amphibole in unit 18(1) is modified to a dark blue-green hornblende and the differences between the orthogneisses of units 18(1)a and 18(2)a are less obvious than in their low grade equivalents. Consequently, in small, highly metamorphosed intrusions, it is not always possible to delineate the original igneous zoning.

METAGABBRO AND AMPHIBOLITE (19)

Narrow layers of dark green to black, medium to coarse grained hornblende-plagioclase gneisses (unit 19) are common in Amisk and Missi Group paragneisses. Most of these layers are probably thin recrystallized gabbro intrusions genetically related to the Josland Lake Gabbro. They may also include some layers that are recrystallized mafic extrusive rocks and, less likely, some that are para-amphibolites.

Rocks of unit 19 are granoblastic mixtures of hornblende and plagioclase, with variable, but minor, amounts of brown biotite, quartz, diopside and garnet. Ilmenite, sphene and apatite are typical accessory minerals.

Thick bodies of unit 19 locally exhibit stratigraphic zoning similar to that of intrusions of the Josland Lake Gabbro. For example, a 150 m wide body on the peninsula at the north end of the northeast arm of File Lake displays three well defined zones which become more felsic to the west. The 300 m wide body which outcrops between File and Corley Lakes is also zoned, although weakly, with more felsic gneisses located on its western side. Other bodies of unit 19 are not obviously zoned and many are monolithologic.

The gneisses of unit 19 are similar, both mineralogically and texturally, to those which occur in highly metamorphosed intrusions of the Josland Lake Gabbro.

MAJOR ELEMENT GEOCHEMISTRY

Twenty-two rocks from the Josland Lake Gabbro (unit 18) and one from an amphibolite layer (unit 19) have been analyzed for major elements (Table 13). Sixteen of the analyses are from the differentiated intrusion south of Josland Lake, and ten of these are from a representative series of samples collected across this intrusion 700 m north of Yakymiw Lake.

CHEMICAL VARIATION

Chemical analyses indicate that intrusions of the Josland Lake Gabbro are subalkaline (Fig. 56a) and tholeiitic (Figs. 56b and 56c),

TABLE 13: Chemical analyses^{1, 2} and CIPW norms of early kinematic intrusive rocks (units 18 and 19), File Lake area.

	JOSLAND LAKE INTRUSION										OTHER INTRUSIONS											
	SERIAL SAMPLES										MISCELLANEOUS SAMPLES						MISCELLANEOUS SAMPLES					
COLUMN NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
UNIT NO.	18(1)				18(2)		18(3)b		18(3)c		chilled base	18(1)	18(2)		18(3)b	18(3)c	18(1)		18(3)c	18(3)		19
SiO ₂	49.25	48.15	48.35	48.6	44.65	47.75	46.95	55.45	64.75	64.1	46.4	47.85	46.8	49.7	59.8	71.8	46.4	47.4	68.45	67.8	68.25	51.3
Al ₂ O ₃	15.4	17.4	16.00	16.6	14.85	13.6	13.0	10.65	11.45	12.05	14.2	18.45	11.65	13.95	11.5	11.45	12.5	16.5	10.85	15.6	12.4	17.15
Fe ₂ O ₃	0.90	1.10	0.79	0.95	3.98	2.88	3.04	5.22	1.94	3.94	2.20	2.12	3.50	3.71	3.07	1.09	1.10	1.25	2.32	0.85	0.30	1.00
FeO	8.06	6.17	6.49	6.21	11.02	13.47	14.15	14.89	10.60	8.24	12.50	7.02	15.76	10.99	12.32	5.69	5.30	7.33	6.59	3.12	1.93	8.51
MgO	10.75	9.2	8.85	8.7	7.75	6.85	7.05	0.83	1.27	0.85	8.30	7.0	4.26	6.95	1.27	0.65	15.0	9.70	1.10	1.18	0.74	7.10
CaO	9.25	13.4	13.5	12.4	13.1	10.15	10.2	7.35	3.55	3.82	9.75	12.3	9.31	9.62	5.55	2.82	12.3	13.55	5.02	1.88	5.20	11.90
Na ₂ O	2.25	1.65	1.72	2.10	1.27	1.85	1.90	1.75	4.20	4.07	2.05	2.06	2.41	1.98	2.52	4.13	0.79	1.53	2.77	6.95	4.00	0.77
K ₂ O	0.67	0.25	0.25	0.65	0.19	0.27	0.25	0.32	0.36	0.37	0.72	0.38	0.31	0.21	0.34	0.30	0.30	0.46	0.21	0.50	1.30	0.22
TiO ₂	0.54	0.46	0.35	0.33	1.14	1.65	1.64	1.43	0.73	1.09	0.80	0.05	3.04	0.94	1.65	0.39	0.19	0.40	0.67	0.37	0.67	0.84
P ₂ O ₅	0.06	0.06	0.05	0.05	0.03	0.05	0.05	0.41	0.18	0.23	0.06	0.12	0.11	0.08	0.32	0.06	0.12	0.09	0.17	0.08	0.18	0.20
MnO	0.14	0.15	0.15	0.15	0.21	0.21	0.31	0.37	0.18	0.21	0.26	0.15	0.28	0.21	0.33	0.18	0.12	0.15	0.15	0.05	0.05	0.22
H ₂ O ⁺	2.15	1.28	1.66	1.54	1.54	1.18	1.39	0.91	0.98	0.69	2.10	2.35	1.01	1.54	0.84	0.77	3.61	1.01	0.87	0.80	0.91	0.85
CO ₂	0.20	0.60	1.70	1.80	0.50	0.34	0.20	0.80	0.25	0.3	tr	0.20	1.06	0.14	0.23	0.09	2.36	0.27	0.43	0.25	3.05	0.39
S	Nil	0.04	0.02	0.01	0.08	0.04	0.05	0.09	Nil	Nil	0.04	0.05	0.23	0.05	Nil	Nil	0.13	0.65	0.27	0.05	0.10	0.08
Less S=O					(0.03)			(0.04)									(0.05)	(0.26)				
Cr (ppm)	1095	958	308	68	Nil	Nil	Nil				411	68	Nil	Nil			1711	684				205
Ni (ppm)	196	157	118	79	118	39	79				196	118	79	Nil			354	196				tr
Cu (ppm)			Nil	40	480	240	440	Nil	Nil	Nil												
Zn (ppm)			40	40	80	120	120	120	80	80												
TOTAL	99.8	100.1	99.5	100.1	100.35	100.3	100.3	100.45	100.45	100.0	99.5	100.1	99.7	100.1	99.7	99.4	100.5	100.2	99.9	99.5	99.1	100.6
Total Fe as Fe ₂ O ₃	9.77	7.89	7.93	7.78	16.1	17.7	18.6	21.6	13.6	13.00	15.95	9.84	20.84	15.80	16.62	7.35	6.93	8.58	9.57	4.28	2.42	10.36
QUARTZ	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.67	22.48	25.51	0.0	0.0	1.48	3.31	23.93	34.66	0.0	0.0	36.29	16.60	29.54	7.11
CORUNDUM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.44	0.0	0.0
ORTHOCLASE	4.01	1.49	1.52	3.39	1.17	1.66	1.54	2.06	2.22	2.29	4.42	2.30	1.96	1.29	2.15	1.85	1.83	2.71	1.31	2.96	8.11	1.33
ALBITE	20.44	14.95	15.87	19.26	11.85	17.28	17.80	17.1	39.25	38.28	19.11	18.92	23.18	18.47	24.21	38.59	7.32	13.70	26.21	62.49	38.13	7.07
ANORTHITE	30.75	39.71	36.19	34.69	35.62	29.15	27.35	22.06	11.80	14.17	28.48	40.91	21.49	29.67	20.40	12.30	30.62	36.70	17.45	8.82	12.79	43.64
ENSTATITE	12.57	8.17	8.10	4.36	6.20	14.44	11.53	1.82	3.25	2.11	5.39	7.14	8.25	15.36	3.24	1.73	16.13	4.28	2.32	3.26	0.0	16.15
FERROSILITE	4.71	2.62	3.04	1.58	3.74	12.85	10.62	14.22	13.21	7.95	4.00	3.50	12.51	10.71	14.01	7.51	2.66	1.42	5.66	3.72	0.0	9.46
FORSTERITE	9.67	6.96	5.71	9.91	6.09	0.29	2.66	0.0	0.0	0.0	10.12	5.30	0.0	0.0	0.0	0.0	11.82	10.12	0.0	0.0	0.0	0.0
FAYALITE	3.63	2.23	2.14	3.27	3.68	0.26	2.45	0.0	0.0	0.0	7.51	2.60	0.0	0.0	0.0	0.0	1.95	3.37	0.0	0.0	0.0	0.0
DIOPSIDE	9.16	16.36	18.8	16.34	15.84	9.70	9.89	1.34	0.84	0.69	9.81	11.13	8.67	9.13	1.03	0.28	21.65	17.86	1.77	0.0	4.34	7.75
HEDENBERGITE	3.44	5.24	7.06	5.93	9.56	8.63	9.64	10.44	3.42	2.60	7.28	5.46	13.11	6.37	4.43	1.20	3.57	5.95	4.33	0.0	3.72	4.54
MAGNETITE	0.95	1.16	0.85	1.02	4.33	3.13	3.32	5.94	2.11	4.32	2.39	2.26	3.92	4.03	3.43	1.19	1.19	1.30	2.56	0.89	0.33	1.07
CHROMITE	0.18	0.16	0.46	0.01	0.0	0.0	0.0				0.07	0.01	0.0	0.0			0.29	0.11			0.0	0.03
ILMENITE	0.75	0.65	0.50	0.47	1.65	2.39	2.38	2.17	1.06	1.59	1.16	0.07	4.54	1.36	2.46	0.57	0.27	0.56	0.98	0.52	0.99	1.20
APATITE	0.13	0.13	0.11	0.11	0.07	0.11	0.11	0.93	0.39	0.50	0.13	0.26	0.25	0.17	0.72	0.13	0.26	0.19	0.38	0.17	0.40	0.43
PYRITE	0.0	0.105	0.05	0.03	0.22	0.11	0.14	0.26	0.0	0.0	0.11	0.13	0.64	0.14	0.0	0.0	0.35	1.69	0.74	0.13	0.28	0.21
Thornton & Tuttle Diff. Index	24.46	16.45	17.39	23.19	13.02	18.94	19.34	40.83	63.95	66.07	23.54	21.22	26.62	23.06	50.29	75.10	9.15	16.41	63.81	82.05	75.84	15.50
Normative Colour Index	44.87	43.40	46.20	41.97	51.08	51.69	53.06	35.93	23.87	19.26	47.66	37.47	51.01	46.95	28.60	12.47	59.24	44.86	17.62	8.39	9.38	40.17

Serial Samples from Josland Lake Intrusion					Miscellaneous Samples from Josland Lake Intrusion					Miscellaneous Samples from Other Intrusions									
1	Gabbro (F07-7006-1) from base of intrusion. Contains equal proportions of cumulate plagioclase and augite (latter completely replaced by tremolite).				7	Foliated ferrogabbro (F07-7006-10) from 532 m above base of intrusion and 3 m below top of ferrogabbro zone. Contains 40/60 proportion of plagioclase and secondary blue-green hornblende. Opaque oxide phase (probably titaniferous magnetite) comprises 5% of rock.				11	Fine grained chilled gabbro (F07-551-1) from base of intrusion, west shore of Morton Lake, 4 km north of south edge of map-area.				17	Melagabbro (F07-282-1) from 1 km south of southwest corner of Yakymiw Lake. Contains 30/70 proportion of interstitial plagioclase (completely replaced by zoisite) and cumulus augite (completely replaced by tremolite).			
2	Leucogabbro (F07-7006-2) from 60 m above base of intrusion. Contains 60/40 proportion of cumulate plagioclase (An ₆₀) and augite (latter completely replaced by tremolite).				8	Granophytic ferrodiorite (F07-7006-11) from 547 m above base of intrusion and 12 m above base of granophyre zone. Contains 60% secondary blue-green hornblende, 20% albite (An ₃), 12% quartz (commonly intergrown graphically with albite), 5% garnet porphyroblasts and 3% opaque oxide phase (probably titaniferous magnetite).				12	Gabbro (F07-239-1) from near base of intrusion, west shore of Morton Lake, 2.5 km north of south edge of map-area. Contains 50/50 proportion of plagioclase and augite (latter completely replaced by tremolite).				18	Gabbro (F07-470-1) from 600 m east of north end of Josland Lake. Contains 40/60 proportion of cumulus plagioclase (An ₇₇) and augite (latter completely replaced by tremolite).			
3	Leucogabbro (F07-7006-3) from 120 m above base of intrusion. Contains 60/40 proportion of cumulate plagioclase (An ₃₈) and augite (latter completely replaced by tremolite).				9	Granophytic tonalite (F07-7006-12) from 600 m above base of intrusion. Contains 29% secondary blue-green hornblende (partially overgrown by anthophyllite), 50% albite (An ₄), 20% quartz (both as individual grains and intergrown with albite) and 1% opaque oxide phase (probably titaniferous magnetite).				13	Ferrogabbro (F07-239-1) from 850 m southeast of Yakymiw Lake. Contains 25/75 proportion of plagioclase and secondary blue-green hornblende. Opaque oxide phase (probably titaniferous magnetite) comprises 8% of rock.				19	Granophytic tonalite (F07-249-1) from small intrusion 2 km south of Yakymiw Lake. Contains 25% acicular secondary blue-green hornblende, 55% albite (An ₃) (as phenocrysts and graphically intergrown with quartz), 19% quartz (as individual grains and intergrown with albite) and 1% opaque oxide component (probably titaniferous magnetite).			
4	Gabbro (F07-7006-5) from 240 m above base of intrusion. Contains equal proportions of cumulate plagioclase (An ₄₆) and augite (latter completely replaced by tremolite and, to a lesser degree, by biotite).				10	Granophytic tonalite (F07-7006-13) from 660 m above base and within 9 m of top of intrusion. Contains 22% secondary blue-green hornblende (as large interlocking acicular plates), 50% albite (An ₄) (as both phenocrysts and graphically intergrown with quartz), 20% quartz (as individual crystals and graphically intergrown with albite), 5% garnet porphyroblasts and 3% opaque oxide phase (probably titaniferous magnetite).				14	Ferrogabbro (F07-342-1) from 360 m east of Yakymiw Lake.				20	Quartz-and plagioclase-porphyritic tonalite (F07-5450-1) from southwest shore of File Lake. Plagioclase is an albite (An ₁₁).			
5	Ferrogabbro (F07-7006-6) from 300 m above base of intrusion and 30 m above base of ferrogabbro zone. Contains 40/60 proportion of plagioclase and secondary blue-green hornblende. Opaque oxide phase (probably titaniferous magnetite) comprises 5% of rock.									15	Granophytic quartz diorite (F07-391-2) from 1350 m north of Yakymiw Lake. Contains 35% secondary blue-green hornblende (as large elongate plates), 40% albite (An ₇) (as both phenocrysts and granophyrically intergrown with quartz), 15% quartz (intergrown graphically with albite), 5% garnet porphyroblasts and 5% opaque oxide phase (probably titaniferous magnetite).				21	Quartz- and plagioclase-porphyritic (F07-5468-1) from southwest shore of File Lake.			
6	Foliated ferrogabbro (F07-7006-8) from 420 m above base of intrusion. Contains 25/75 proportion of plagioclase and secondary blue-green hornblende. Opaque oxide phase (probably titaniferous magnetite) comprises 5% of rock.									16	Granophytic tonalite (F07-391-1) from 1350 m north of Yakymiw Lake. Contains 15% secondary blue-green hornblende, 50% albite (An ₇), 30% quartz (as individual grains and graphically intergrown with albite), 3% garnet porphyroblasts and 2% opaque oxide phase (probably titaniferous magnetite).				22	Amphibolite (F07-42-1) from small horizon along contact between Amisk and Missi Group paragneisses on northwest shore of File Lake.			

¹ Chemical analyses by Analytical Laboratory of Manitoba Mineral Resources Division.

² Sample sites are located on Figure 94 (in pocket).

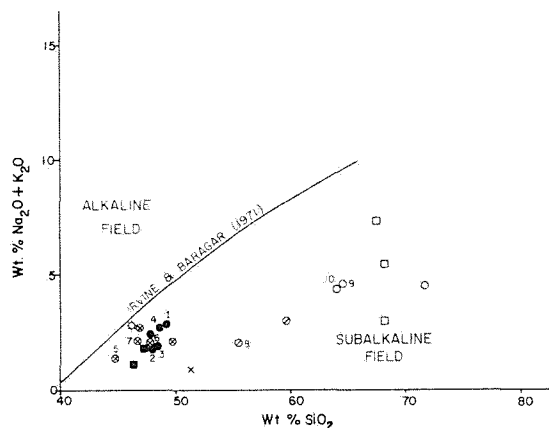
with extreme iron enrichment in middle to late stage differentiates. The iron enrichment trend on the $\text{Na}_2\text{O} + \text{K}_2\text{O}$ vs FeO vs MgO diagram (Fig. 56c) is more pronounced than that of the Skaergaard intrusion.

A series of samples collected across the intrusion south of Josland Lake exhibit typical chemical variations. Figure 57 is a plot of weight percent oxides against distance from base of this intrusion. Chemical variations evident from this figure are:

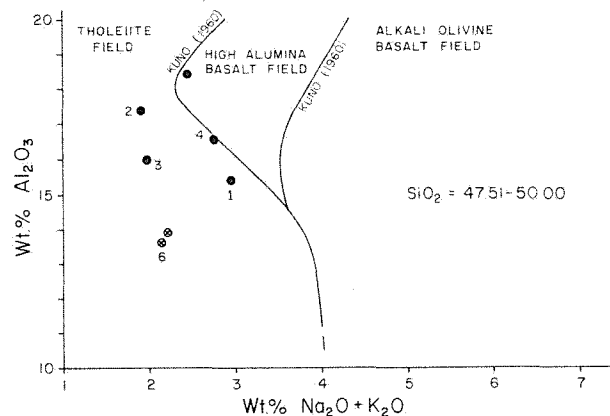
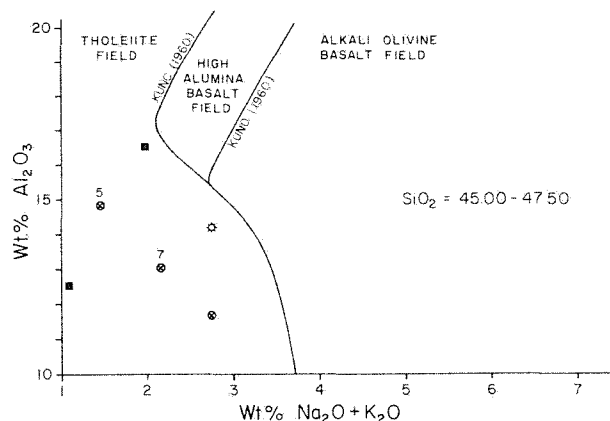
- 1) a decrease in SiO_2 in the middle stage differentiates followed by a rapid rise in late stage differentiates;
- 2) an extreme rise in total iron and TiO_2 in middle stage differentiates;

- 3) a gradual decrease in Al_2O_3 , MgO and CaO during differentiation, with an abrupt decrease in late stage differentiates;
- 4) an abrupt increase in Na_2O in the late stage differentiates;
- 5) a constant low content of K_2O ; and
- 6) a rapid decrease in Cr_2O_3 and a more gradual decrease in NiO from base to top of sill.

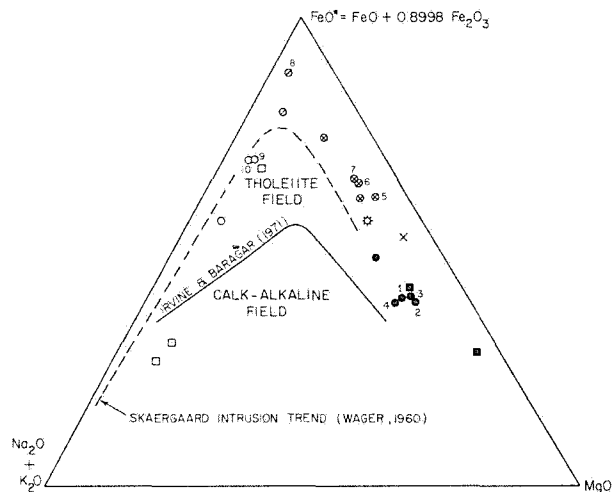
These chemical variations are typical for a strongly differentiated mafic intrusion, and are very similar to those shown by the Skaergaard intrusion. One of the most interesting features is the restricted



a) SiO_2 vs $\text{Na}_2\text{O} + \text{K}_2\text{O}$ DIAGRAM



b) $\text{Na}_2\text{O} + \text{K}_2\text{O}$ vs Al_2O_3 DIAGRAM



c) $\text{Na}_2\text{O} + \text{K}_2\text{O}$ vs FeO vs MgO DIAGRAM

EARLY KINEMATIC INTRUSIVE ROCKS

- ■ GABBRO ZONE: GABBRO AND LEUCOGABBRO (UNIT 18 (1))
- FERROGABBRO ZONE: FERROGABBRO (UNIT 18 (2))
- ○ GRANOPHYRE ZONE: QUARTZ DIORITE (UNIT 18 (3)b)
- ○ GRANOPHYRE ZONE: TONALITE (UNITS 18 (3)c and 18 (3))
- ✱ CHILLED BORDER GABBRO
- ✱ MISCELLANEOUS INTRUSIONS
- INTRUSION SOUTH OF JOSLAND LAKE
- 1,2,3,..... SERIAL SAMPLES (TABLE 13) ACROSS INTRUSION SOUTH OF JOSLAND LAKE
- x METAGABBRO (UNIT 19)

FIGURE 56: Chemical variation diagrams comparing early kinematic intrusive rocks (units 18 and 19) with compositional fields of established magma series.

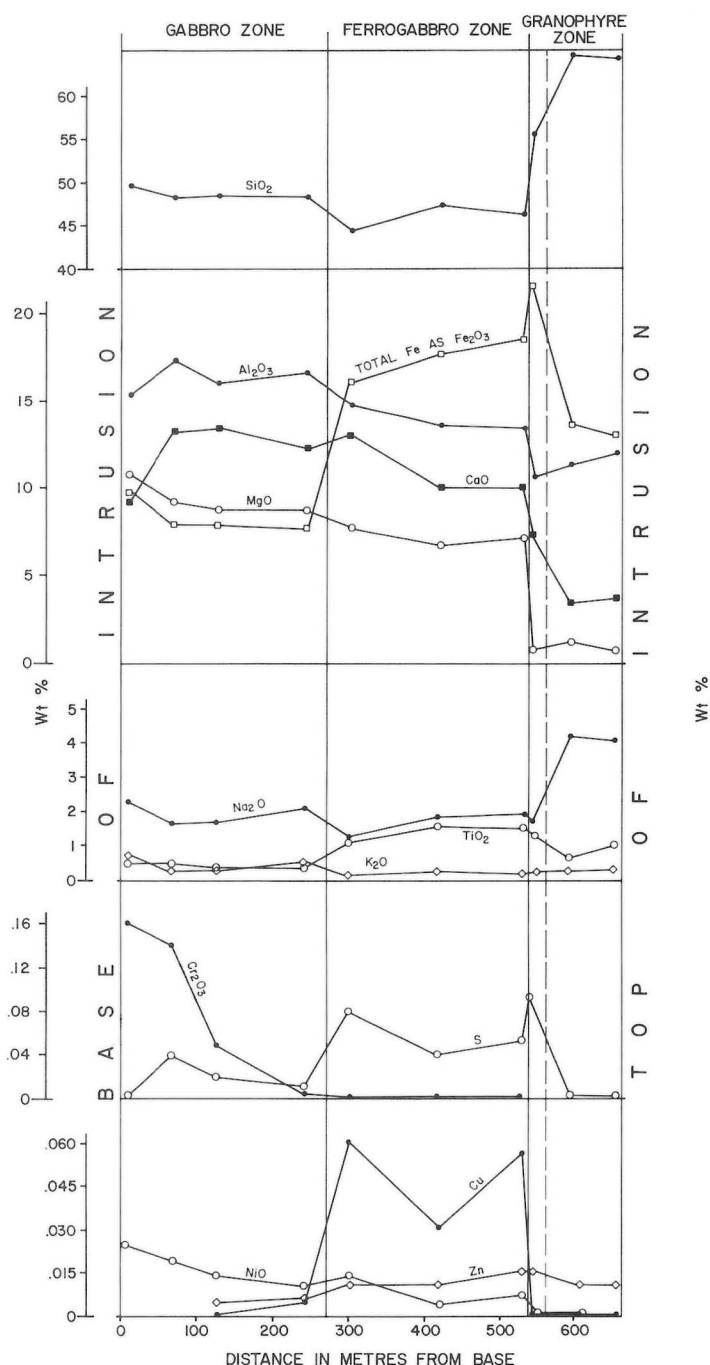


FIGURE 57: Variation of major elements across a representative section of the Josland Lake intrusion.

composition of rocks in individual zones in the intrusion and the abrupt changes in composition from one zone to the next. This is evident in many of the variation diagrams, particularly in the $\text{Na}_2\text{O} + \text{K}_2\text{O}$ vs FeO vs MgO plot (Fig. 56c), from the clusters formed by rocks from individual zones, followed by gaps between zones. This probably reflects abrupt exit of old cumulate phases, or entry of new cumulate phases or both. This could have been caused by changing composition of the residual magma, or a drop in temperature during recrystallization, or both.

Mineralogical variations responsible for the observed chemical variations are difficult to identify due to metamorphic recrystallization of the analyzed samples. However, based on limited petrographic data, CIPW norms (Table 13), and typical mineral compositions of equivalent rocks in the Skaergaard intrusion, some inferences have been made as to the primary mineralogy of the rocks of the individual zones. Rocks of the Gabbro Zone are inferred to have been composed of 60 percent cumulate labradorite and 40 percent cumulate magnesian augite, accounting for the high Al_2O_3 , CaO and MgO contents of these rocks. Rocks of the Ferrogabbro Zone are inferred to have been composed of reduced quantities of cumulate labradorite (35 percent of rock), 60 percent cumulate ferroaugite and 5 percent titaniferous magnetite, accounting for the sharp drop in SiO_2 and Al_2O_3 and parallel increase in total iron and TiO_2 in these rocks relative to those of the underlying Gabbro Zone. This change in mineralogy probably resulted from the decrease of SiO_2 and Al_2O_3 and the increase in total iron and TiO_2 in the residual magma during precipitation of labradorite and magnesian augite in the underlying Gabbro Zone. Rocks of the Granophyre Zone contain quartz, albitic plagioclase and reduced quantities of mafic and oxide minerals. This is reflected by the sharp increase in SiO_2 and Na_2O and the parallel decrease in total iron, Al_2O_3 and CaO in these rocks relative to those of the underlying Ferrogabbro Zone.

PARENT MAGMA

A chilled sample from the base of the intrusion south of Josland Lake (column 1, Table 14) is inferred to approximate the parental magma for this intrusion, and for other intrusions of the Josland Lake Gabbro suite. This analysis is considered to be a reliable approximation of the parent magma because the computed average composition of this intrusion (column 2, Table 14), calculated by determining average composition of different zones, from analyses 2 to 10 in Table 13, and adding them in proportion to their percentage of the intrusion, is almost identical. The similarity of composition of the chilled border phase and the computed average composition of the intrusion suggest that it was emplaced as a single sheet, with chemical variation in the intrusion reflecting *in situ* differentiation.

The parent magma of the Josland Lake Gabbro suite is very similar to Amisk Group basalts (column 3, Table 14), extruded in the File Lake area, and to younger Missi Group basalts (column 4, Table 14), extruded in the Saw Lake area 60 km east of the map-area. This indicates that a similar basaltic magma source was tapped by these intrusive rocks. Considering the wide variation in age of these rocks, this suggests that their magma source must have been very large and long-lived or, alternatively, that similar magma was generated under analogous tectonic conditions.

COMPARISON TO THE SKAERGAARD INTRUSION

One of the striking features of intrusions of the Josland Lake Gabbro suite is the similarity of their chemical variation to that of the Skaergaard intrusion. The similarities include:

- 1) both have tholeiitic basalt parent magmas (Table 14), with the exception that the Skaergaard magma was more aluminous and lower in iron content;
- 2) both have extreme iron enrichment trends in $\text{Na}_2\text{O} + \text{K}_2\text{O}$ vs FeO vs MgO diagrams (Fig. 56c);
- 3) both exhibit a decrease in SiO_2 in middle differentiates followed by a sharp increase in late granophyric differentiates;

TABLE 14: Parental magma of Josland Lake Gabbro suite compared to Amisk and Missi Group basalts and to chilled border gabbro of the Skaergaard intrusion

	1	2	3	4	5
SiO ₂	46.4	49.69	49.6	50.89	49.69
Al ₂ O ₃	14.2	14.50	14.6	14.24	13.21
Fe ₂ O ₃	2.20	2.50	2.05	2.08	1.69
FeO	12.50	10.05	10.6	10.45	11.24
MgO	8.30	6.77	6.63	6.45	6.61
CaO	9.75	10.93	10.78	10.30	10.18
Na ₂ O	2.05	1.96	2.30	1.83	2.37
K ₂ O	0.72	0.32	0.26	0.15	0.56
TiO ₂	0.80	0.98	0.85	1.39	2.66
P ₂ O ₅	0.06	0.10	0.10	0.14	0.22
MnO	0.26	0.21	0.24	0.21	0.22
H ₂ O [±]	2.10	1.33	1.36	1.69	n.d.
CO ₂	tr.	0.79	0.77	0.42	
S	0.04	0.04	0.09	0.00	
Cr (ppm)	411	171	128	216	
Ni (ppm)	196	63	102	100	
TOTAL	99.4	100.2	100.2	100.24	98.65

- 1 Chilled base of intrusion south of Josland Lake, File Lake area
- 2 Computed average composition of intrusion south of Josland Lake, File Lake area
- 3 Average of 5 analyses of Amisk Group basalt, File Lake area

- 4 Average of 4 analyses of Missi Group basalt, Saw Lake area (unpublished analyses by author)
- 5 Chilled sample of marginal gabbro of Skaergaard intrusion (Hoover, 1978, analysis KT-39)

- 4) both have similar zoning, with the exception that the intrusions of the Josland Lake Gabbro have no equivalent to the Hidden Zone or to the Upper Layered Zone of the Skaergaard intrusion.

The absence of an equivalent to the Hidden Zone in intrusions of the Josland Lake Gabbro is likely related to the absence of an equivalent to the Upper Layered Zone. This is because precipitation of calcic plagioclase in the Hidden Zone of the Skaergaard intrusion probably caused enrichment of Na₂O in the residual magma such that a shift to more sodic plagioclase (andesine) overlapped precipitation of ferroaugite and titaniferous magnetite to form ferrodiorites of the Upper Layered Zone. Intrusions of the Josland Lake Gabbro have no equivalent to the Hidden Zone and consequently their residual magma probably did not become significantly enriched in Na₂O and form sodic plagioclase until after precipitation of ferroaugite and titaniferous magnetite. This may explain why the Josland Lake Gabbro has a thicker ferrogabbro zone than the Skaergaard intrusion and why it does not form ferrodiorites. The more extreme iron enrichment trend in Na₂O + K₂O vs FeO vs MgO plots of the Josland Lake Gabbro is probably because their iron enrichment is not accompanied by increasing alkali content (mainly Na₂O in plagioclase) as is the case in the Skaergaard intrusion.

SYN- TO LATE-KINEMATIC INTRUSIVE ROCKS

The syn- to late-kinematic intrusive rocks comprise large calcalkaline felsic stocks, plutons and batholiths composed of medium-to coarse-grained, massive to gneissic quartz diorite, tonalite,

granodiorite and granite (Fig. 58). The intrusions have sharp contacts, xenolithic margins and prominent thermal contact aureoles. They postdate intrusions of the Josland Lake Gabbro and range in age from older to younger than the regional metamorphism of rocks of the map-area (Table 17, p. 80).

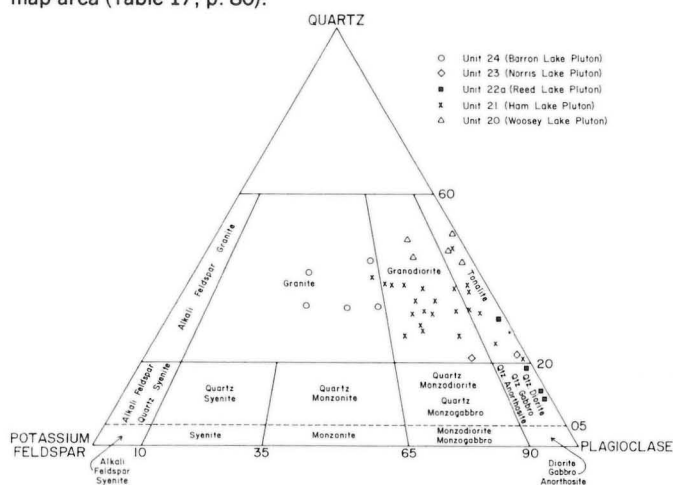


FIGURE 58: Ternary plot of quartz vs plagioclase vs potassium feldspar (after Streckeisen, 1976) showing modal composition of syn- to late-kinematic intrusive rocks (units 20 to 24). Modal analyses are based on a minimum of 500 points per sample.

Five syn- to late-kinematic felsic plutons are exposed in the File Lake area. Each is texturally and lithologically distinct, but all are felsic in composition, plutonic in shape and texture, and broadly similar in age of emplacement. The plutons, listed in order of estimated age, are:

Woosey Lake pluton (units 20, 20a);
Ham Lake pluton (unit 21);
Reed Lake pluton (units 22a, 22b, 22c);
Norris Lake pluton (unit 23); and
Barron Lake pluton (unit 24).

The relative age of the plutons was estimated from their degree of recrystallization and deformation, with the most tectonized considered to be oldest and the least tectonized considered to be youngest. The main features of syn- to late-kinematic intrusive rocks are summarized in Tables A-6a and A-6b.

DESCRIPTION

WOOSEY LAKE PLUTON (20, 20a)

The Woosey Lake pluton, located on the east shore of the central bay in Woosey Lake, is the most strongly recrystallized and gneissic of the syn- to late-kinematic intrusions and, therefore, is considered to be the oldest. It is a north-northeast-trending intrusion, 6 km long and 1.5 km wide, of pale pink to buff gneissic quartz-rich leucotonalite and granodiorite (unit 20). Locally, it has a marginal hybrid zone, up to 50 m wide, of agmatite and metasomatized gneiss (unit 20a).

The leucotonalite and granodiorite of unit 20 is fine-to medium-grained, strongly recrystallized, gneissic and, in part, garnetiferous. It is also porphyritic, with 1 to 3 mm annealed and recrystallized phenocrysts of quartz and plagioclase.

The contact of the Woosey Lake pluton with surrounding rocks varies from sharp to gradational. Locally the surrounding rocks are metasomatized and converted to agmatites. Mappable zones of the latter rocks (unit 20a) have been delineated, where possible, on the geological map (Map 78-1-1).

Harrison (1949) considered the Woosey Lake pluton to be the southern appendage of the Ham Lake pluton. However, the Woosey Lake pluton is distinctly more quartz-rich than the Ham Lake pluton (Fig. 58) and it is finer grained, porphyritic and much more

recrystallized and gneissic. In some respects the Woosey Lake pluton resembles the descriptions given by Harrison (1949) and Williams (1966) of a rock termed by them a "quartz-eye granite" and "quartz-eye gneiss", respectively. This latter rock forms a large folded sill-shaped body east of the map-area which has been described variously as an early granite (Harrison, 1949; Froese and Moore, 1980; Walford, pers. comm., 1979), as a sedimentary rock (Russell, 1957) and as a felsic volcanic rock (Williams, 1966). This rock is closely associated, spatially, with major copper-zinc sulphide deposits in the Snow Lake mining district, east of the map-area.

HAM LAKE PLUTON (21)

The Ham Lake pluton, located east of File Lake, is a 18 km long and 6.5 km wide, north-northeast-trending batholith composed of massive to gneissic, white to creamy-pink granodiorite, leucotonalite and tonalite (unit 21). It postdates major F_1 folds and cross-cuts intrusions of the Josland Lake Gabbro.

The intrusion occupies the core of a major north-northeast-trending F_2 anticline and may have contributed to formation of this fold by forcibly shouldering aside supracrustal rocks during its emplacement. However, the F_2 folding episode outlasted crystallization of the intrusion because rocks north of Weech Lake have been flattened, annealed and foliated by this folding (Fig. 59). The foliation formed by this folding is north-northeast-trending and is defined by flattened and aligned grains of quartz, plagioclase and biotite. The foliation cuts across the east-trending northern margin of the pluton and therefore was definitely imposed by external tectonic forces rather than by internal deformation within the pluton during its forceful emplacement.

The Ham Lake pluton predated the main episode of regional metamorphism, M_2 . This is evident from the absence of deformation of east-trending M_2 isograds by the pluton (Fig. 2, p. 2) and from local metamorphic recrystallization of rocks of the pluton north of Vickers Lake. The metamorphic recrystallization of the pluton is not pronounced.

The granodiorite, leucotonalite and tonalite (unit 21) are medium-coarse-grained (2-7 mm) and vary from massive to gneissic. Gneissic varieties occur only along the western margin and in the northern half of the pluton. Primary minerals are, in order of abundance, andesine, quartz, microcline, green to brown biotite and green hornblende.

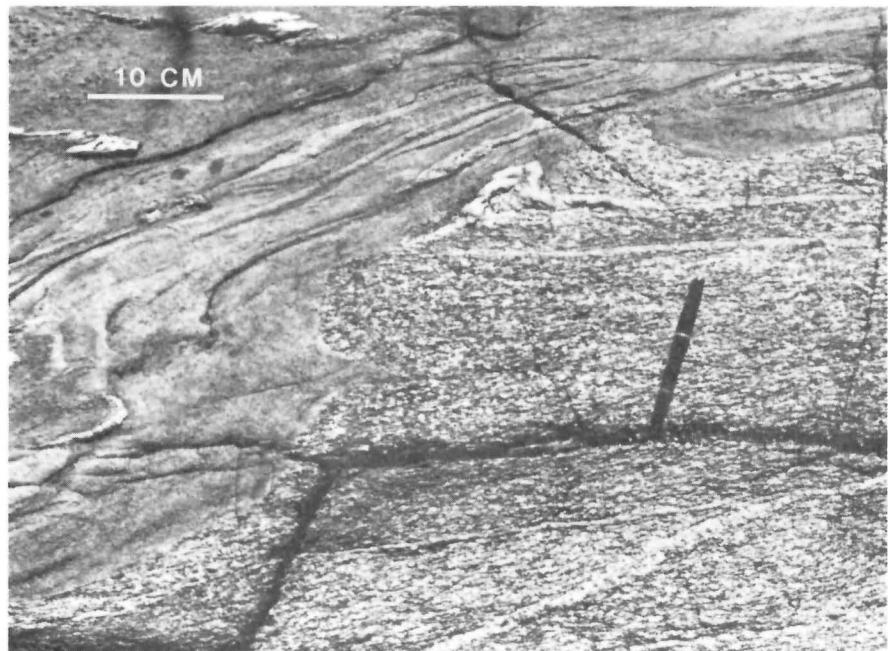


FIGURE 59: Contact between S_1 - and S_2 -foliated paragneiss (unit 13c) and gneissic S_2 -foliated granodiorite of the Ham Lake pluton (unit 21), northeast shore of File Lake.

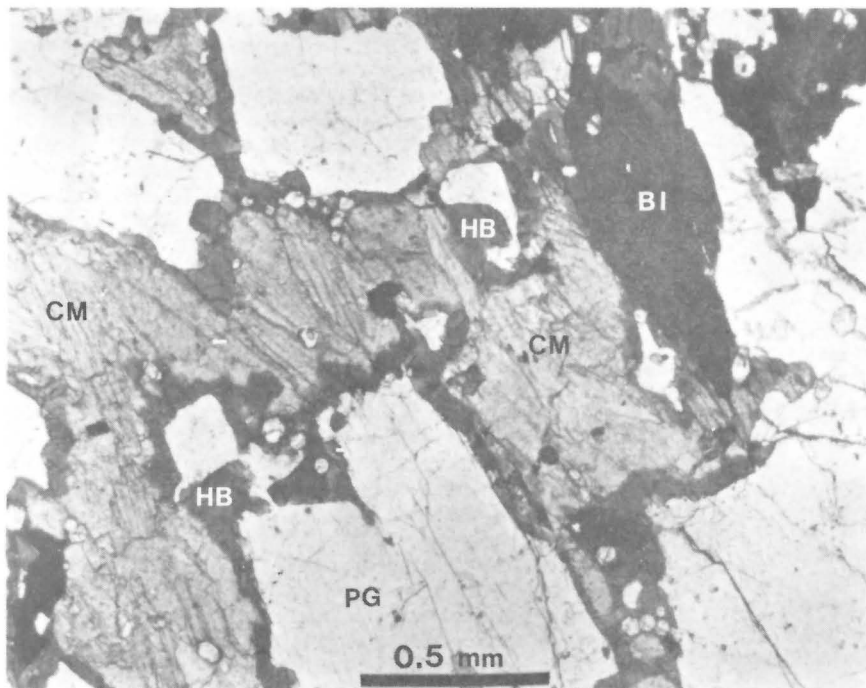


FIGURE 60: Photomicrograph (plain light) of corona development on mafic minerals, quartz leucodiorite (unit 22a), Reed Lake pluton. A central core of cummingtonite (CM) is rimmed by hornblende (HB) that is overprinted by biotite (BI).

Secondary minerals, which are not prominent, include muscovite, red-brown biotite, chlorite, epidote, zoisite and, in northern exposures, pyralisite garnet and sillimanite. Pyralisite garnet porphyroblasts are common north of Vickers Lake. A metamorphic aggregate of sillimanite and quartz was noted in one locality on the northeast shore of File Lake.

REED LAKE PLUTON (22a, 22b, 22c)

The Reed Lake pluton is an elliptical batholith, 16 km wide, from south to north, and 22 km long, from east to west. It is located south of the map-area and north of Reed Lake. Its northern tip is exposed along the southern edge of the map-area. Two features indicate that the top of the intrusion was just above the present erosion surface: i) south of the map-area it contains numerous curvilinear zones or remnants of the overlying volcanic rocks (Harrison, 1949); and ii) it has a prominent well developed aureole of contact metamorphic rocks, considered to result from upward migration and concentration of heat and vapours over the pluton.

The Reed Lake pluton comprises two distinct rock types, a grey quartz leucodiorite (unit 22a) and a white leucotonalite (unit 22b). In addition, it has a prominent marginal agmatite zone (unit 22c), consisting of melted and altered host rocks, xenoliths of country rocks and a network of intrusions of units 22a and 22b.

Rocks of unit 22a comprise a zone along the northern contact of the Reed Lake pluton. They are grey, medium grained hypidiomorphic granular quartz leucodiorites, composed of 60 to 70 percent plagioclase, 10 to 20 percent quartz, 10 to 20 percent combined hornblende and biotite, and to 1 to 5 percent combined potassium feldspar, ilmenite, sphene and epidote. They are locally garnetiferous. The most striking feature of rocks of unit 22a are metamorphic coronas on primary minerals. The coronas are most prominent on mafic minerals (Fig. 60). A sketch of typical corona development of mafic minerals is shown on Figure 61. Most coronas are incomplete, many composed of only hornblende and biotite. Hypersthene is likely the primary mafic mineral of rocks of unit 22a as it forms the cores of many of the coronas. Thus, unit 22a is possibly a retrogressed hypersthene-bearing plagioclase-rich charnockite. Other minerals in unit 22a are also zoned. For example, plagioclase consists of a core of primary labradorite ($\sim \text{An}_{52}$), commonly with igneous zoning, rimmed

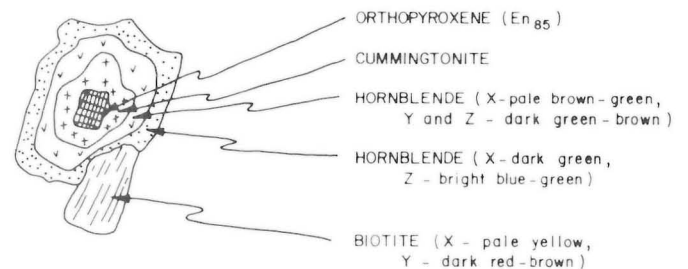


FIGURE 61: Sketch of typical corona development on mafic minerals, quartz leucodiorite (unit 22a), Reed Lake pluton.

by an irregular zone of secondary andesine ($\sim \text{An}_{34}$). Similarly ilmenite is rimmed by sphene. The metamorphic coronas on minerals of rocks of unit 22a may possibly be due to subsequent heating by the second phase, unit 22b, of the Reed Lake pluton.

Rocks of unit 22b are white weathering fine-to medium-grained equigranular plagioclase-rich leucotonalites. They do not outcrop widely in the map-area, but are the major rock type of the Reed Lake pluton south of the map-area, according to Harrison (1949).

The Reed Lake pluton has a narrow contact zone, up to 300 m thick, of agmatite (unit 22c). The agmatite zone is most prominently developed in two localities. One is south of Fussey lake, where the Reed Lake pluton intrudes Amisk Group mafic volcanic rocks, and the second is south of Woosey Lake, where it intrudes Amisk Group greywacke, siltstone and mudstone. The nature of the agmatite zone is different at these two localities.

In the volcanic rocks, south of Fussey Lake, the agmatite zone comprises: mafic volcanic xenoliths of variable size and degree of assimilation; irregular intrusions of unit 22, aplites and, to a lesser extent, unit 22b; and a fine grained grey garnetiferous hornblende-bearing leucocratic gneiss. The leucocratic gneiss is the major component of unit 22c south of Fussey Lake and is an intrusive



FIGURE 62: Xenolithic margin of Norris Lake pluton (unit 23), 900 m north-northeast of Dickstone mine.

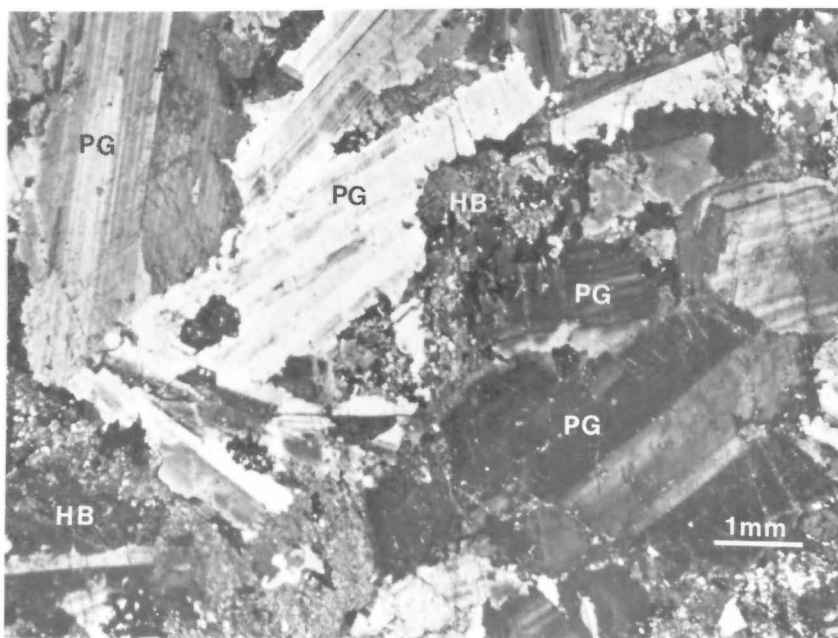


FIGURE 63: Photomicrograph (polarized light) of plagioclase-rich hornblende leucotonalite (unit 23), Norris Lake pluton. Note serrated recrystallized margins on plagioclase grains (PG) and granular recrystallized hornblende (HB).

rock of uncertain origin. It may be a chilled contaminated variety of unit 22a or a melted portion of the host volcanic rocks. Metamorphic minerals in mafic volcanic xenoliths in unit 22c include granular clinopyroxene (diopside), porphyroblasts of pyroxene garnet, and small grains of biotite and epidote.

In the greywacke, siltstone and mudstone sequence, south of Woosey Lake, the agmatite zone comprises xenoliths, of variable size and degree of assimilation, and a grey medium grained garnet-, staurolite-, biotite-, and hornblende-bearing leucocratic gneiss. The latter is a coarsely recrystallized, altered and remobilized sedimentary gneiss. This rock has gradational contacts with the quartz leucodiorite (unit 22a), of the Reed Lake pluton, and with the surrounding metamorphosed greywacke, siltstone and mudstone (unit 13b), of the File Lake Formation. It contains numerous, small, poorly-formed poikiloblastic crystals of garnet and staurolite.

NORRIS LAKE PLUTON (23)

The Norris Lake pluton, which outcrops on Norris Lake, is a slightly flattened, 8 km long and 6.5 km wide stock of homogeneous,

white weathering, medium grained, equigranular, plagioclase-rich leucotonalite (unit 23). It intrudes and shoulders aside Amisk Group volcanic rocks and intrusions of the Josland Lake Gabbro. Like the Ham Lake pluton, it is emplaced along the axial trace of a major north-trending F_2 fold. Unlike the Ham Lake pluton, the Norris Lake pluton is massive and unfoliated, except along its contact.

The Norris Lake pluton is texturally and compositionally homogeneous, and is characterized by sharp, well defined contacts, with no indication of significant assimilation of country rocks. Along its contact, and in small dykes, rocks of unit 23 are characterized by numerous angular xenoliths (Fig. 62). Internally the pluton is cut by aplite dykes and by rare quartz-feldspar porphyry dykes, both likely late-stage products of crystallization.

Unit 23 is porphyritic, with small prominent phenocrysts of andesine (Fig. 63). The andesine commonly has oscillatory igneous zoning and irregular metamorphic rims of oligoclase. The primary mafic mineral is brown hornblende which is partially or wholly altered to green hornblende and red-brown biotite. The oligoclase, green hornblende and red-brown biotite probably formed during the M_2 episode of regional metamorphism (Table 17, p. 70).

BARRON LAKE PLUTON (24)

The Barron Lake pluton, located on Woosey Lake, is a circular 4 km diameter stock of white to light-pink coarse grained porphyritic granite and leucogranite (unit 24). Its main mechanism of intrusion was stoping, and surrounding metasedimentary rocks of the Amisk Group have not been shouldered aside. It intrudes the southern margin of the Ham Lake pluton.

The granite and leucogranite of the Barron Lake pluton are texturally and compositionally homogeneous. They are massive, unfoliated and contain large 1 to 2 cm poikilitic phenocrysts of microcline. The microcline phenocrysts are typically intergrown graphically with quartz. In chilled zones, near margins of the pluton, microcline, quartz and plagioclase all form phenocrysts and the groundmass is fine grained.

The Barron Lake pluton is undeformed and unaltered, relative to other syn- to late-kinematic felsic plutons and, therefore, is considered to be the youngest of this suite of rocks.

GEOCHEMISTRY

Six rocks of the syn- to late-kinematic intrusive suite have been analyzed for major elements (Table 15). There are two samples from the Ham Lake pluton, one from the quartz leucodiorite of the Reed Lake pluton, one from the Norris Lake pluton and two from the Barron Lake pluton. The analyses indicate that the intrusions are subalkaline and, except for the quartz leucodiorite of the Reed Lake pluton, calc-alkaline (Fig. 64).

Felsic plutons, similar in composition, size and age to the syn- to late-kinematic intrusions of the map-area, occur along the entire length of the Flin Flon volcanic belt. These intrusions are also subalkaline and calcalkaline in composition. They are generally restricted to the Flin Flon volcanic belt and rarely occur in rocks of the adjacent Kiseynew sedimentary gneiss belt. This suggests that there was some tectonic control on their formation and on their sites of intrusion.

The calc-alkaline geochemistry of the felsic plutonic rocks suggests that they are a distinct magmatic suite, separate from the earlier tholeiitic magmatism of the Josland Lake Gabbro. A low initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratio of 0.7019 ± 0.0005 on the Ham Lake pluton (Josse, 1974) suggests the source of the magma was geochemically primitive, perhaps derived from the mantle, and did not involve assimilation or melting of old crustal material.

METAMORPHIC AND ANATECTIC ROCKS

Following and , in part, overlapping the episode of syn- to late-kinematic felsic plutonism, an episode of high grade regional metamorphism, M_2 , effected rocks of the map-area. In the northern third, where the highest grade metamorphism took place, partial anatexis and metasomatism of metasedimentary and some metavolcanic rocks occurred locally. Two groups of rocks, of distinct metamorphic affinity, were formed at this time: granitoid oligoclase-quartz-microcline gneisses (units 25 & 26) of the Nelson Bay gneiss dome; and gneissic to pegmatitic granodiorite and monzogranite (unit 27) of the Loonhead Lake intrusions.

NELSON BAY GNEISS DOME (25, 26)

Rocks of the Nelson Bay gneiss dome are exposed in the core of a north-northeast-trending doubly-plunging antiform. The gneiss dome comprises granoblastic gneisses (units 25 and 26), which Harrison (1949) previously mapped as a foliated granite, and which are interpreted here to be composed predominantly of coarsely recrystallized metavolcanic orthogneisses. The granoblastic gneisses of unit 26 can be traced into a narrow layer of finer grained orthogneisses (unit 26a) which occur in the Missi Group metasedimentary succession, and which originally may have been a felsic ash flow. The gneiss dome, itself, was probably a syn-metamorphic diapir. It is identical to larger and lithologically more variable diapiric gneiss domes which the author mapped to the

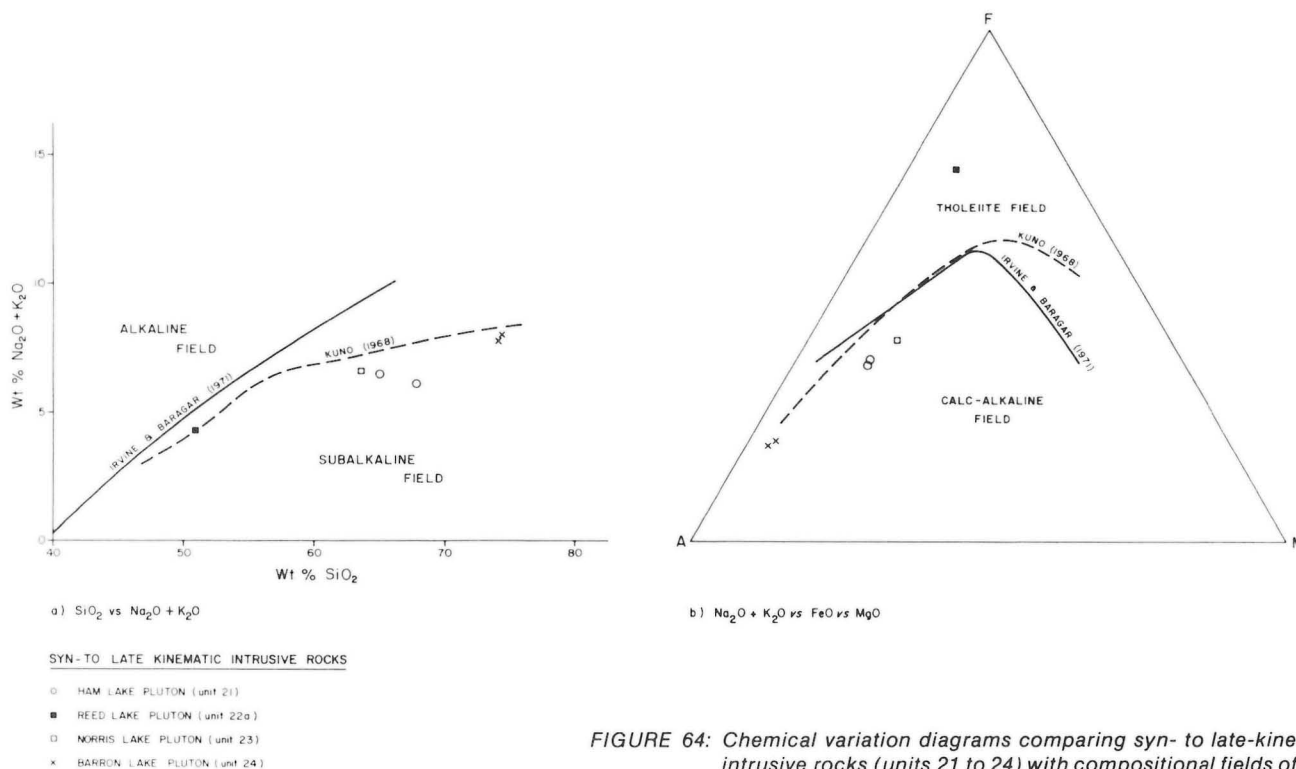


FIGURE 64: Chemical variation diagrams comparing syn- to late-kinematic intrusive rocks (units 21 to 24) with compositional fields of established magma series.

TABLE 15: Chemical analyses and C.I.P.W. norms of syn- to late-kinematic intrusive rocks (units 21 to 24).

UNIT NO.	1	2	3	4	5	6
	21		22a	23		24
SiO ₂	65.3	67.9	51.0	63.65	74.25	74.35
Al ₂ O ₃	16.2	15.95	14.7	15.2	13.3	13.25
Fe ₂ O ₃	0.83	0.60	3.06	1.30	0.46	0.41
FeO	3.58	3.46	13.35	4.50	1.61	1.57
MgO	1.55	1.43	1.83	2.15	0.44	0.38
CaO	3.50	2.90	7.05	4.35	1.15	1.17
Na ₂ O	3.82	3.35	2.95	3.65	3.10	3.25
K ₂ O	2.62	2.65	1.30	2.87	4.70	4.65
TiO ₂	0.50	0.55	1.75	0.77	0.13	0.10
P ₂ O ₅	0.16	0.14	0.63	0.19	0.02	0.01
MnO	0.06	0.05	0.23	0.09	0.04	0.04
H ₂ O [±]	0.91	0.92	1.29	0.65	0.59	0.55
CO ₂	0.10	0.05	0.08	0.08	0.15	0.08
S	0.01	0.01	0.01	0.01	0.04	0.01
TOTAL	99.1	100.0	99.2	99.5	100.0	99.8
Total Fe as Fe ₂ O ₃	4.76	4.41	17.85	6.25	2.23	2.14
QUARTZ	20.24	26.53	5.53	16.53	32.23	31.65
CORUNDUM	1.23	2.93	0.0	0.0	1.19	0.85
ORTHOCLASE	15.87	16.00	8.18	17.33	28.38	28.07
ALBITE	35.13	30.69	28.16	33.46	28.42	29.78
ANORTHITE	16.72	13.75	24.50	16.82	5.69	5.86
ENSTATITE	4.38	4.03	4.59	5.24	1.24	1.07
FERROSILITE	4.45	4.25	14.95	4.52	2.03	2.10
DIOPSIDE	0.0	0.0	1.56	1.64	1.64	0.0
HEDENBERGITE	0.0	0.0	5.09	1.41	0.0	0.0
MAGNETITE	0.84	0.64	3.40	1.39	0.49	0.44
ILMENITE	0.71	0.78	2.59	1.10	0.19	0.14
APATITE	0.34	0.30	1.40	0.41	0.04	0.02
PYRITE	0.03	0.03	0.03	0.03	0.11	0.02

- 1 Biotite tonalite (F07-1030-3), Ham Lake pluton, from southeast shore of Vickers Lake.
- 2 Biotite granodiorite (F07-1032-2), Ham Lake pluton, from southeast shore of Vickers Lake.
- 3 Diorite (F07-3408-1), Reed Lake pluton, from south shore of Woosey Lake.

- 4 Hornblende-biotite granodiorite (F07-523-1), Norris Lake pluton, from 600 metres (2000 feet) north of Josland Lake.
- 5 Microcline porphyritic granite (F07-6292-1), Barron Lake pluton, from 960 metres (3500 feet) west of Barron Lake.
- 6 Microcline porphyritic granite (F07-3272-1), Barron Lake pluton, 510 metres (1700 feet) southeast of Barron Lake.

northeast in the Guay-Wimapedi Lakes area (Bailes, 1975). The latter gneiss domes were, at one time, considered by the author (Bailes, 1971) to be remobilized basement gneisses, but rooting of the Nelson Bay gneiss dome to the layer of unit 26a in the Missi Group supracrustal succession is inconsistent with this interpretation.

The main gneiss dome structure, north of Nelson Bay, is 3 km wide and 6 km long. On its west, east and south margins, strata dip

outwards, moderately to steeply. The dome only partially closes to the north. In its centre, foliations dip shallowly. The contact of unit 26 with Missi Group strata on the east side of the dome is rapidly gradational over a few metres. The western contact with rocks of the File Lake Formation is not exposed, but appears to be tectonic. Harrison (1949) mapped it as a fault, but the author found no direct evidence of faulting, and interprets it to be an intrusive contact formed during syn-metamorphic diapiric mobilization of rocks of the gneiss dome.

PETROGRAPHY

The Nelson Bay gneiss dome consists of granoblastic oligoclase-quartz-biotite gneiss (unit 25) and granoblastic oligoclase-quartz-microcline biotite gneiss (unit 26). Unit 26a comprises finer grained less recrystallized equivalents of gneisses of unit 26. They occur in a narrow layer within the Missi Group metasedimentary succession. The main features of rocks of the Nelson Bay gneiss dome are summarized in Tables A-7.

Gneisses of unit 25 occur in the main gneiss dome structure north of Gates Lake. They appear to structurally underlie rocks of unit 26. They are white weathering, medium grained, granoblastic and composed of oligoclase, quartz and lesser amounts of microcline, biotite, green amphibole and magnetite. They are tonalitic in composition. The magnetite crystals typically stand up in relief on weathered outcrop surfaces. The parent rocks of these gneisses were probably sedimentary as they locally contain relic bedding, and narrow layers and concretions of calc-silicate rocks.

Gneisses of unit 26 form the main body of the gneiss dome north of Nelson Bay. They are bright pink on both fresh and weathered surfaces, fine-to medium-grained, granoblastic and composed of oligoclase, quartz, microcline and lesser amounts of muscovite, green-brown biotite, green amphibole and magnetite. They are granodioritic in composition. They locally contain porphyroblasts of microcline and plagioclase and typically have magnetite crystals which stand in relief on weathered outcrop surfaces. They are characterized by strong gneissic foliation that is typically lensey or stringy in appearance and which resembles a recrystallized cataclastic fabric. The rocks are generally homogeneous, but locally exhibit faint layering. Small lensoid pods of quartz, a few centimetres long, are common. The pseudocataclastic fabric of rocks of unit 26 is interpreted, for reasons which follow, to be a recrystallized fluidal or eutaxitic layering.

Rocks of unit 26a are identical to rocks of unit 26 except that they are finer grained and less thoroughly recrystallized. Unit 26a outcrops in a 75 m wide layer which is conformable with host Missi Group metasedimentary rocks. Northwest of File Lake rocks of this unit become progressively more recrystallized and granoblastic to the north. Their least recrystallized exposures, located on the westerly horizon on the northwest shore of File Lake and on the two islands in the centre of File Lake, locally contain poorly preserved primary features. Those observed include small euhedral igneous phenocrysts of plagioclase, small flattened fragments which resemble collapsed pumice fragments, and streaky foliation and layering which resembles the fluidal and eutaxitic structures of ash flows.

GEOCHEMISTRY

Three samples of unit 26 and two of unit 26a have been analyzed for major elements (columns 1-5, Table 16). These analyses, and three from identical rocks from the Guay-Wimapedi Lakes area (columns 6-8, Table 16), have distinctly igneous chemistry. They range in composition from dacite to rhyolite, but are distinctly more potassic than the dacite and rhyolite of the underlying Amisk Group. They plot within the igneous spectrum (Fig. 65a) of Hughes (1973), are subalkaline (Fig. 65b), and are calc-alkaline (Figs. 65c and 65d). They are characterized by high $\text{Fe}_2\text{O}_3/\text{FeO}$ ratios, compared to Amisk volcanic rocks, and have high normative magnetite contents.

Rocks of units 26 and 26a are similar in composition to a sample of Missi Group rhyolite (column 9, Table 16) from the east shore of Wekusko Lake, and are remarkably similar to analyses of Pleistocene rhyolite flows and ignimbrites (columns 10 and 11, Table 16) from the Taupo volcanic zone, New Zealand. The Taupo zone ignimbrites (column 11) have Fe_2O_3 in excess of FeO , probably due to their subaerial deposition from an oxygen-rich gaseous flow. The high $\text{Fe}_2\text{O}_3/\text{FeO}$ ratios of samples of the Nelson Bay gneiss dome suggests that their parent dacites and rhyolites may also have been deposited by subaerial ash flows.

Several of the gneiss domes in the File Lake-Snow Lake area, including the Nelson Bay gneiss dome, have been dated by Rb-Sr

whole rock isochron techniques (Josse, 1974; Bell *et al.*, 1975). The dates, which are probably metamorphic, vary from 1851 to 1780 Ma (using $\lambda = 1.39 \times 10^{-11} \text{ yr}^{-1}$) and have low initial ratios which vary from 0.7014 to .7038. The low $^{87}\text{Sr}/^{86}\text{Sr}$ ratios suggest that these rocks have not had an extensive crustal history, and according to Bell *et al.* (1975), are most simply interpreted as magnetic rocks erupted just before the onset of extensive deformation and metamorphism.

DISCUSSION

Rocks equivalent to those of units 26 and 26a occur widely throughout the eastern end of the Flin Flon belt and the adjacent parts of the Kiseynew belt. They occur most prominently within large syn-metamorphic gneiss dome diapir complexes. They also occur as a narrow layer or, perhaps, layers in Missi Group metasedimentary rocks of the File Lake and Guay-Wimapedi Lakes area. Narrow layers of lithologically identical, but less recrystallized rocks, occur in a succession of volcanic rocks which overlie Missi Group sedimentary rocks east of Wekusko Lake (Shanks and Bailes, 1977). The latter rocks are rhyolites and dacites which contain igneous phenocrysts, collapsed pumice fragments and fluidal and eutaxitic layering of the type preserved locally in rocks of unit 26a on File Lake.

The igneous composition of rocks of units 26 and 26a, local preservation within them of primary features of ash flow deposits, and widespread occurrence of these rocks, and their equivalents, all point to an origin by violent pyroclastic extrusion, probably as subaerial ash flows. These ash flows probably formed an extensive blanket deposit which, during later deformation and high grade metamorphism, was locally remobilized and, being lighter, locally concentrated in the cores of large syn-metamorphic diapirs.

LOONHEAD LAKE INTRUSIONS (27)

The Loonhead Lake intrusions are small syntectonic bodies of a white, coarse grained, locally pegmatitic, granodiorite and monzogranite (unit 27) which outcrops south and northeast of Loonhead Lake. Rocks of unit 27 also comprise the mobilize phase of migmatitic paragneisses of unit 13c. The main features of rocks of unit 27 are summarized in Tables A-6a and A-6b.

Intrusions of unit 27 occur only in unit 13c, are folded by shallow east-plunging F3 folds, and have diffuse gradational contacts with host metagreywacke, metasiltstone and metamudstone strata of unit 13c. They contain numerous inclusions of unit 13c and commonly contain numerous xenoblasts of pyralisite garnet.

The Loonhead Lake intrusions are interpreted to have been formed by partial anatexis, during M_2 regional metamorphism, of metagreywacke, metasiltstone and metamudstone strata of unit 13. This is based on their occurrence only in rocks of unit 13c and their compositional and textural similarity to the granitic mobilize phase of the migmatites of unit 13c. The granite mobilize phase of unit 13c is shown later in this report (p. 81) to have been formed by a granitic melt reaction related to the breakdown of muscovite. This reaction is shown as an isograd surface on the geological map (Map 78-1-1). It defines the boundary between paragneisses of unit 13b and migmatitic equivalents of unit 13c.

The granodiorite and monzogranite are composed of oligoclase, quartz, microcline, red-brown biotite and muscovite. The quartz and oligoclase commonly form myrmekitic intergrowths. Pyralisite garnet xenoblasts are common. The biotite typically defines a foliation.

Bodies of white granodiorite and monzogranite, equivalent to those of the Loonhead Lake intrusions, are characteristic of highly metamorphosed metagreywacke, metasiltstone and metamudstone strata of the Kiseynew belt. They range from centimetre-wide sills to sheeted sill and dykes complexes many kilometres in extent. These intrusions are characterized by their intimate intermixing with paragneisses and by large garnet and, at highest grades, cordierite xenoblasts. All of these intrusions are interpreted to be products of anatexis of their host metagreywacke, metasiltstone and metamudstone strata (Bailes and McRitchie, 1978).

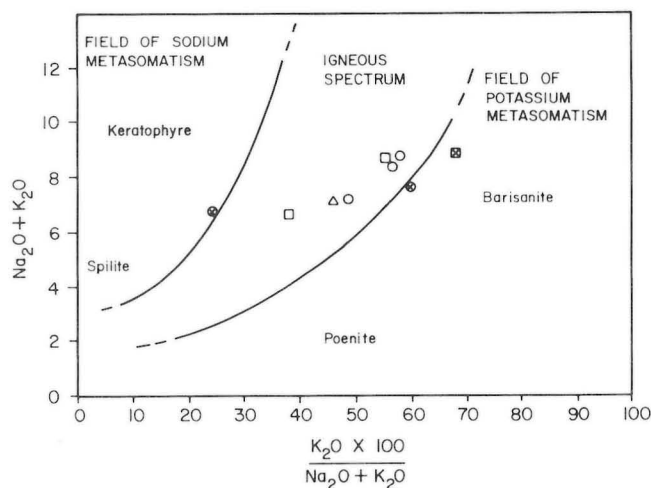
TABLE 16: Chemical analyses^{1,2} and C.I.P.W. norms of rocks from the Nelson Bay Gneiss Dome

UNIT NO.	NELSON BAY GNEISS DOME					ANALYSES FOR COMPARISON					
	1	2 26	3	4	5 26a	6	7	8	9	10	11
SiO ₂	64.04	71.0	71.8	65.0	67.45	70.8	74.6	68.9	74.7	74.22	73.85
Al ₂ O ₃	15.2	14.1	13.8	15.05	13.95	14.75	12.95	14.3	15.9	13.27	13.55
Fe ₂ O ₃	2.31	1.55	1.27	3.30	2.42	1.38	1.23	1.52	0.1	0.88	1.25
FeO	3.56	1.93	1.50	1.79	1.93	1.36	1.06	1.98	1.9	0.92	0.60
MgO	1.67	0.41	0.36	1.01	0.81	0.48	0.45	0.86	0.2	0.28	0.30
CaO	3.15	1.41	1.13	3.36	2.44	1.63	1.65	1.74	0.6	1.59	1.53
Na ₂ O	3.80	3.55	3.50	5.19	2.90	3.55	4.05	2.60	4.0	4.24	3.71
K ₂ O	3.67	4.80	5.10	1.64	4.42	4.80	2.57	5.95	3.5	3.18	3.60
TiO ₂	0.78	0.34	0.28	0.74	0.50	0.22	0.09	0.35	0.13	0.28	0.23
P ₂ O ₅	0.27	0.07	0.05	0.25	0.15	0.04	0.00	0.11	0.02	0.05	0.05
MnO	0.09	0.06	0.13	0.10	0.08	0.05	0.05	0.06	0.02	0.05	0.05
H ₂ O	0.73	0.61	0.50	0.76	1.05	0.46	0.54	0.83	0.6	1.03	0.97
CO ₂	0.54	0.20	.10	1.47	2.03	0.21	1.48	0.75	0.2		
TOTAL	99.8	100.0	99.5	99.7	100.13	99.73	100.7	99.73	101.8	99.99	99.69
Total Fe as Fe ₂ O ₃	6.26	3.69	2.91	5.29	4.56	2.60	2.17	3.35	1.99	1.71	2.62
QUARTZ	16.95	26.16	26.88	20.02	26.45	25.62	34.73	24.26	32.31	31.51	33.11
CORUNDUM	0.0	0.74	0.65	0.0	0.36	0.94	0.56	0.76	4.88	0.09	0.99
ORTHOCLASE	22.22	28.94	30.82	10.00	27.41	28.90	15.58	36.27	20.62	19.17	21.81
ALBITE	34.92	32.50	32.10	47.99	27.30	32.44	37.26	24.06	35.77	38.79	34.12
ANORTHITE	13.89	6.67	5.39	13.31	11.66	7.97	8.39	8.16	2.84	7.71	7.44
ENSTATITE	4.65	1.15	1.02	2.00	2.34	1.35	1.27	2.45	0.55	0.79	0.85
FERROSILITE	2.98	1.56	1.28	0.0	0.77	0.93	0.76	1.66	2.71	0.58	0.0
DIOPSIDE	0.14	0.0	0.0	1.74	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HEDENBERGITE	0.09	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MAGNETITE	2.47	1.65	1.36	2.93	2.65	1.47	1.32	1.64	0.10	0.94	1.06
HEMATITE	0.0	0.0	0.0	0.41	0.0		0.0	0.0	0.0	0.0	0.19
ILMENITE	1.11	0.48	0.40	1.06	0.73	0.31	0.13	0.50	0.24	0.33	0.33
APATITE	0.58	0.15	0.11	0.54	0.33	0.09	0.0	0.24	0.04	0.11	0.11

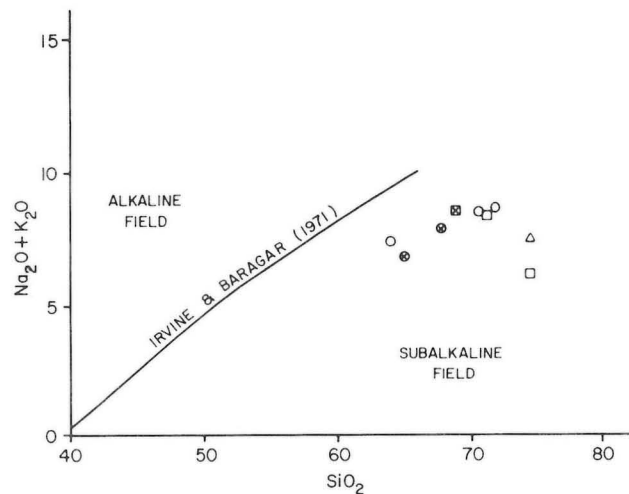
1, 2 & 3	Granoblastic medium grained magnetite-bearing oligoclase-quartz-microcline-biotite gneiss (F07-955-1, F07-953-1 & F07-958-2) northwest shore of Nelson Bay.	8	Granoblastic fine grained magnetite-bearing oligoclase-quartz microcline gneiss (07-373-1) from Guay-Wimapedi Lakes area. Equivalent to unit 26a of File Lake area.
4 & 5	Granoblastic fine grained magnetite-bearing oligoclase-quartz-microcline-biotite gneiss (F07-136-1 & F07-140-1) northwest shore of File Lake.	9	Rhyolite, Missi Group volcanic rocks, near Herb Lake Settlement, Wekusko Lake (Moore, 1978).
6 & 7	Granoblastic medium grained magnetite-bearing oligoclase-quartz-microcline-biotite gneiss (07-2309-1 & 07-2308-1) from Guay-Wimapedi Lakes area (Bailes, 1975). Equivalent to unit 26 of File Lake area.	10 & 11	Average rhyolite lava and ignimbrite, respectively, Taupo volcanic zone, New Zealand (Ewart and Stipp, 1968).

¹ Chemical analyses (1 to 7) by Analytical Laboratory of Manitoba Mineral Resources Division.

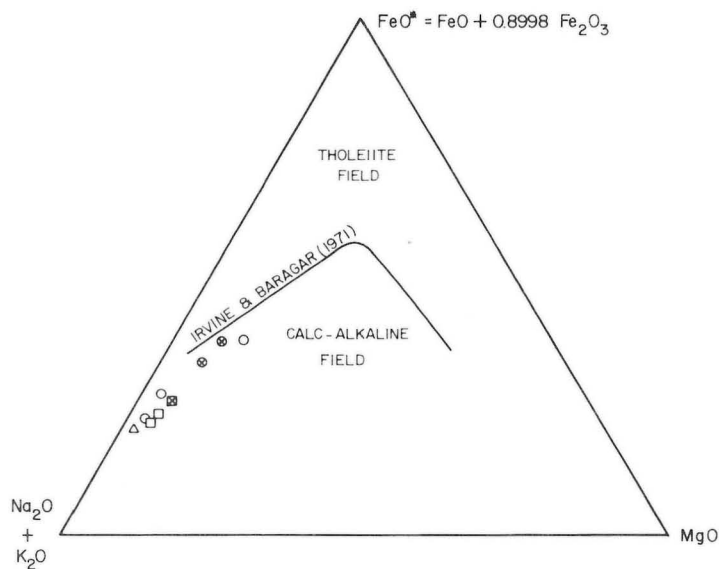
² Sample sites are located on Figure 94 (in pocket).



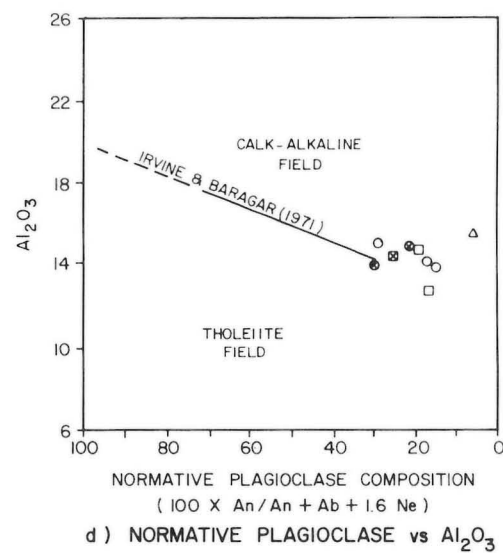
a) IGNEOUS SPECTRUM DIAGRAM
(AFTER HUGHES, 1973)



b) SiO vs Na₂O + K₂O DIAGRAM



c) Na₂O + K₂O vs FeO vs MgO

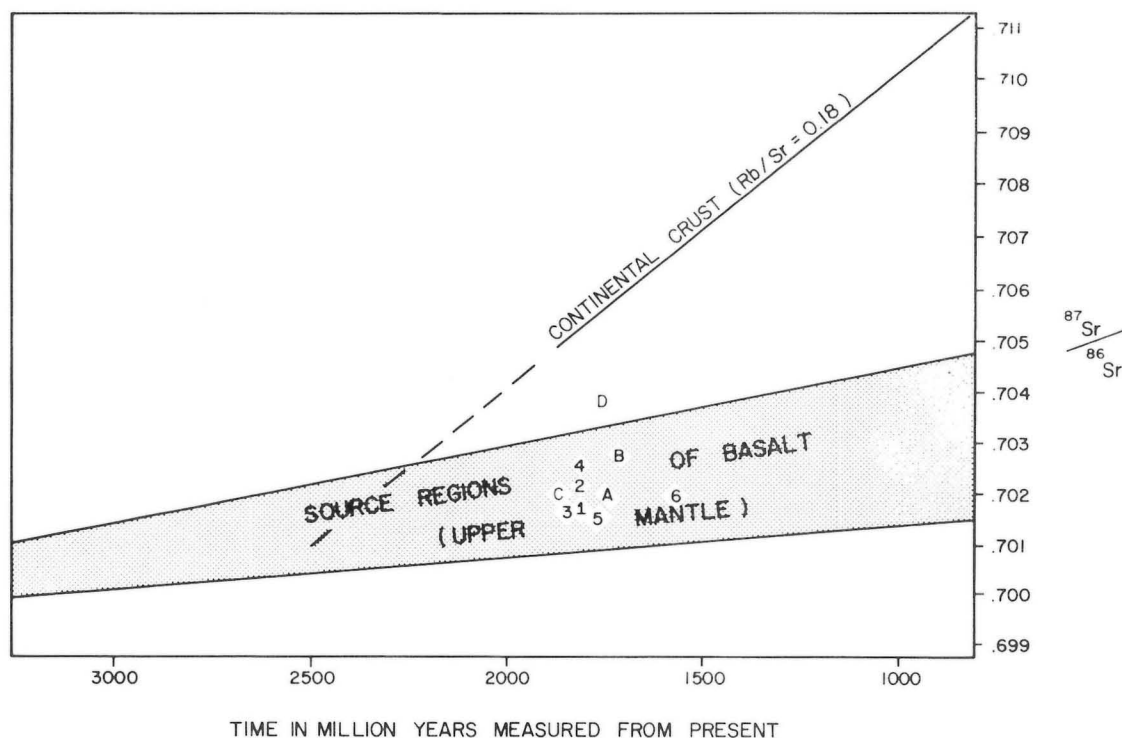


d) NORMATIVE PLAGIOCLASE vs Al₂O₃

ROCKS OF THE NELSON BAY GNEISS DOME AND THEIR EQUIVALENTS

○	OLIGOCASE - QUARTZ - MICROCLINE - BIOTITE GNEISS, unit 26, FILE LAKE AREA
●	" " " " " unit 26a, FILE LAKE AREA
□	" " " " " unit C3, GUAY - WIMAPEDI LAKES AREA (BAILES, 1975)
■	" " " " " unit 5, GUAY - WIMAPEDI LAKES AREA (BAILES 1975)
△	FELSIC METAVOLCANIC ROCK, MISSI GROUP, WEKUSKO LAKE AREA (MOORE, 1977)

FIGURE 65: Chemical variation diagrams comparing rocks of the Nelson Bay Gneiss Dome with compositional fields of established magma series.



ROCK UNIT	AGE ($\lambda = 1.39 \times 10^{-11} \text{Yr}^{-1}$)	INITIAL $^{87}\text{Sr}/^{86}\text{Sr}$ Ratio (2 σ error range)
File Lake area (Josse, 1974)		
A Amisk Group volcanic rocks (unit 4)	1737 \pm 257 Ma	0.7020 \pm 0.0004
B Amisk Group intrusive rocks (unit 10)	1715 \pm 83 Ma	0.7027 \pm 0.0002
C Ham Lake pluton (unit 21)	1860 \pm 112 Ma	0.7019 \pm 0.0010
D Nelson Bay gneiss dome (unit 26)	1760 \pm 43 Ma	0.7038 \pm 0.0016
Snow Lake area (Bell <i>et al.</i> , 1975)		
(1) Amisk Group volcanic rocks	1819 \pm 48 Ma	0.7020 \pm 0.0005
(2) Amisk Group volcanic rocks	1819 \pm 42 Ma	0.7017 \pm 0.0007
(3) Triangle Dome ¹	1851 \pm 74 Ma	0.7017 \pm 0.0010
(4) East Dome ¹	1819 \pm 116 Ma	0.7024 \pm 0.0018
(5) Squall Dome ¹	1787 \pm 63 Ma	0.7014 \pm 0.0009
(6) 'Quartz-Eye' dacite	1570 \pm 116 Ma	0.7019 \pm 0.0006

¹Rocks of the Triangle, East and Squall Domes are equivalent to unit 26 of the File lake area

FIGURE 66: Sr isotope evolution diagram adapted from Faure and Powell (1972) and Josse (1974), showing $^{87}\text{Sr}/^{86}\text{Sr}$ ratios of igneous rocks from the File Lake and Snow Lake areas.

POST-KINEMATIC INTRUSIONS

FELSIC PEGMATITE (28)

Unit 28 comprises small dykes of pink and white felsic pegmatite. The pegmatite dykes are unfoliated, undeformed and postdate all recognized structural fabrics and kinematic events. They occur only in the northern third of the map-area. They are particularly abundant along the northeast arm of File Lake. Most of the dykes are too small to represent on the geological map. A large intrusion of unit 28 occurs north of the map-area, north of the northeast arm of File Lake. Harrison (1949) incorrectly included this intrusion as an apophysis on the northwest tip of the Ham Lake pluton.

The pegmatites are typically granites. They contain large phenocrysts of plagioclase and microcline that are commonly intergrown graphically with quartz. Green-brown biotite is present in small amounts. Colour of the pegmatites varies with their host rock. Those in rocks of the Missi Group, Nelson Bay gneiss dome and Ham

Lake pluton are pink. Those in rocks of the Amisk Group and the Josland Lake Gabbro are white.

ISOTOPE CHEMISTRY OF IGNEOUS ROCKS

Several of the post-Missi intrusive and earlier extrusive rocks of the File Lake and adjacent Snow Lake areas have been dated by Rb-Sr whole rock isochron techniques by Josse (1974) and Bell *et al.* (1975). Initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratios on all the igneous rocks, both intrusive and extrusive, are low (Fig. 66) and suggest, according to both Josse (1974) and Bell *et al.* (1975), that these rocks were derived from a primitive source region, such as the upper mantle, that was depleted in rubidium relative to strontium. The implication is that both Amisk and Missi volcanism and subsequent intrusive activity did not involve magmas that were formed by melting or assimilation of crustal material and, in fact, that there may not have been older crustal material available in this region during their generation.

METAMORPHISM

Three episodes of regional metamorphic recrystallization and several zones of igneous contact metamorphism have effected strata in the File Lake area. All are considered to be late Aphebian to, perhaps, early Paleohelikian in age. Their main features and chronology, relative to deformational and intrusive events, are given in Table 17. All regional metamorphic and deformational events are post-Missi.

Similar regional metamorphic episodes and deformational events have been observed in the adjacent Snow Lake area (Moore and Froese, 1980), in the nearby Guay-Wimapedi Lakes area (Bailes, 1975) and in the centre of the Kisseynew Sedimentary Gneiss Belt (Schledewitz, 1972; McRitchie, pers. comm., 1979).

CONTACT METAMORPHISM

The Reed Lake pluton, the Norris Lake pluton and intrusions of the Josland Lake Gabbro have significant contact metamorphic thermal aureoles. Other intrusions also have contact metamorphic aureoles but they are generally very limited or are obscured by later regional metamorphic recrystallization.

CONTACT METAMORPHISM BY INTRUSIONS OF THE JOSLAND GABBRO

Greywacke, siltstone, mudstone and felsic volcanic strata are generally baked and bleached adjacent to intrusions of the Josland Lake Gabbro. Typical contact metamorphic minerals include tourmaline, sphene, epidote, chlorite, actinolite and, rare, garnet. Mafic volcanic rocks are relatively unaffected by intrusions of the Josland Lake Gabbro.

The contact metamorphic effects of intrusions of the Josland Lake Gabbro are surprisingly limited considering their large size and basaltic composition; the sills average 700 m in width and their basaltic magmas probably crystallized at 1100 to 1200°C. It is estimated, using data from Jaeger (1957), that a 700 m wide gabbro sill intruded into 100°C country rocks, should generate temperatures of 625 to 675°C and form upper almandine-amphibolite facies mineral assemblages 70 m from its contact. These temperatures were not reached adjacent to sheets of the Josland Lake Gabbro. Two potential reasons for this are:

- 1) the magma was introduced in pulses; or
- 2) the gabbro intrusions were shallow and their heat was dissipated rapidly by convection of circulating ground water.

TABLE 17: Summary of Major Metamorphic, Deformational and Intrusive Events, File Lake Area

DEFORMATION	METAMORPHISM	INTRUSIVE ROCKS
D ₄ : Late fractures and north-trending shear zones	M ₃ : Local retrograde low grade (greenschist facies) metamorphism, largely restricted to D ₄ structures	Intrusion of small dykes of felsic pegmatite (unit 28)
D ₃ : East-trending upright flexural folds (F ₃) of S ₁ and S ₀ surfaces. F ₃ folds locally have an axial planar biotite schistosity (S ₃)	M ₂ : Strong regional metamorphic event which increases in intensity from south to north from greenschist facies to upper almandine-amphibolite facies	Intrusion of anatectic granodiorite and monzogranite (unit 27) Emplacement of Nelson Bay Gneiss Dome (units 25 and 26)
D ₂ : Major north-northeast-trending open folds (F ₂) of S ₁ and S ₀ surfaces. Some flattening of F ₁ folds was likely during D ₂ . In the Snow Lake area, F ₂ folds have an axial planar biotite foliation (S ₂); F ₂ folds in the File Lake area do not have an S ₂ foliation		Intrusion of large felsic plutons (units 20 to 24) Barron Lake pluton (may be post-M ₂) Norris Lake pluton (prominent thermal contact aureole) Reed Lake pluton (prominent thermal contact aureole) Ham Lake pluton Woosley Lake pluton
D ₁ : Large isoclinal folds (F ₁) of primary layering (S ₀). F ₁ folds have an axial planar schistosity (S ₁). Deformed fragments are flattened in S ₁ and elongated parallel to F ₁ fold axes. F ₁ folds are interpreted to have been recumbent structures	M ₁ : Muscovite, chlorite and biotite define S ₁ . They were largely recrystallized and annealed during M ₂	Intrusion of post-F ₁ Josland Lake Gabbro sheets (unit 18) and albite-epidote hornfels facies contact metamorphism of adjacent strata Intrusion of pre-F ₁ Josland Lake Gabbro sills (unit 18) and albite-epidote hornfels facies contact metamorphism of adjacent strata

The former is unlikely as the geochemistry of the Josland Lake Gabbro sheets suggests only one main pulse of magma (p. 59).

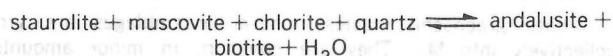
Metasomatic alteration of country rocks is negligible at the base of intrusions but it is locally strong at their tops, particularly where overlying rocks are felsic. Partial digestion and assimilation of Yakymiw Formation greywackes, siltstones and mudstones is common above the large intrusion north of Yakymiw Lake.

CONTACT METAMORPHISM BY THE REED LAKE PLUTON

The Reed Lake pluton has a strong prominent thermal contact aureole. Greywacke, siltstone and mudstone strata adjacent to it, at Woosey Lake, are strongly recrystallized and contain middle to upper almandine-amphibolite facies mineral assemblages. Mafic volcanic rocks up to 1 km north of Pethybridge Lake are granoblastically recrystallized and coarsened. A contact zone of partially melted, coarsely recrystallized agmatitic rocks (unit 22c) also occurs adjacent to the Reed Lake pluton.

The Reed Lake pluton contains many curvilinear zones or remnants of the overlying volcanic rocks (Harrison, 1949) and, for this reason, it is considered to be barely unroofed. The prominent thermal contact aureole on the Reed Lake pluton may have been caused by upward migration and concentration of heat and vapours over the pluton and subsequent intersection of the highly metamorphosed roof zones and upper marginal zones by the present erosion surface.

The effects of thermal metamorphism are most prominent in greywacke, siltstone and mudstone strata at Woosey Lake. They have been strongly recrystallized and contain staurolite, garnet, biotite, muscovite, andalusite and, close to the Reed Lake pluton, sillimanite. Their characteristic mineral assemblage is andalusite + biotite + staurolite + muscovite + chlorite + quartz + andesine (An_{31-40}). This assemblage indicates that the reaction

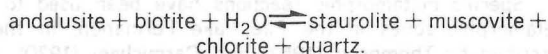


was exceeded. Within 1 km of the pluton sillimanite has replaced andalusite and this indicates that the reaction

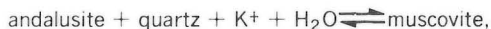


was exceeded. Kyanite was observed in one specimen from the agmatite zone (unit 22c).

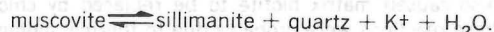
In most metagreywacke, metasiltstone and metamudstone strata at Woosey Lake, andalusite has been replaced by mixtures of other minerals. Close to the Reed Lake pluton a prograde mixture of muscovite and staurolite has replaced andalusite. Further away from the Reed Lake pluton, particularly close to the Barron Lake pluton, a retrograde mixture of plagioclase, muscovite and staurolite has replaced the andalusite. Textures in these rocks indicate that both the prograde and retrograde replacement of andalusite occurred by cation exchange processes of the kind discussed by Carmichael (1969). The prograde replacement textures are interpreted to be due to cation exchange processes related to the prograde conversion of andalusite to sillimanite. The retrograde replacement textures are interpreted to be due to cation exchange processes related to retrograde reaction



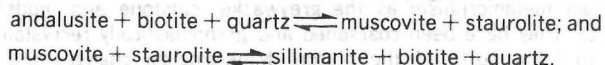
A series of complimentary cation exchange reactions in which Al^{+++} remains immobile, explains most of the textures that formed during prograde conversion of andalusite to sillimanite. The simplest set of complimentary cation exchange reactions for the andalusite to sillimanite conversion (Fig. 67a) is one where andalusite breaks down to muscovite, as follows,



and the muscovite (usually not the same muscovite) breaks down to sillimanite, as follows,

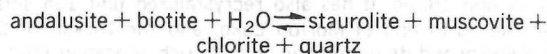


The net reaction is andalusite \rightleftharpoons sillimanite. A slightly more complicated set of complimentary cation exchange reactions for the prograde andalusite to sillimanite conversion (Fig. 67b) is:



The latter reactions have caused replacement of andalusite and adjacent biotite by muscovite and staurolite and the complimentary replacement, elsewhere, of muscovite and staurolite by sillimanite and biotite. Again, the net reaction is andalusite \rightleftharpoons sillimanite. A more traditional interpretation of these textures (i.e. not considering cation exchange processes) would be that there was an episode of metamorphism to form the andalusite, another to form the overprinting muscovite and another to form the later sillimanite.

Cation exchange reactions responsible for the retrograde reaction



are more complicated than those related to the prograde andalusite to sillimanite conversion. One set of complimentary cation exchange reactions which is consistent with observed textures is:

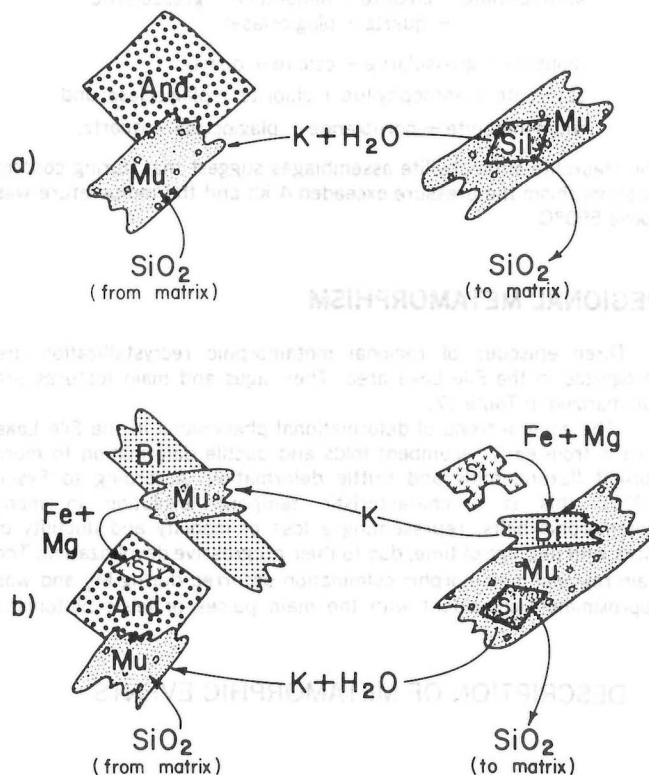
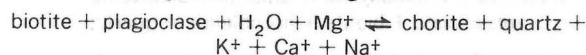
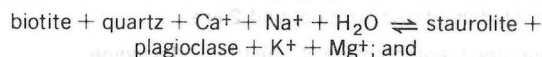
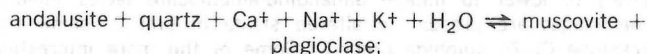


FIGURE 67: Prograde conversion of andalusite to sillimanite through cation exchange involving intermediate phases: a) muscovite and b) muscovite, biotite and staurolite.

The first two reactions have caused andalusite and adjacent biotite to be replaced by plagioclase, muscovite and staurolite. The third reaction also caused matrix biotite to be replaced by chlorite plus quartz. These reactions were probably due to thermal metamorphism by the Barron Lake pluton and, perhaps, other plutons and may, in part, be driven by an influx of H₂O from these plutons.

Mafic volcanic strata were not as profoundly effected by thermal contact metamorphism as the greywacke, siltstone and mudstone strata. They have been coarsened and granoblastically recrystallized up to 1 km north of the pluton. Mineralogical changes are not prominent. Diopside, garnet and sphene have been formed locally in rocks close to the pluton.

CONTACT METAMORPHISM BY THE NORRIS LAKE PLUTON

South of Josland Lake, the Norris Lake pluton has a prominent thermal contact aureole. North of Josland Lake, the contact aureole has been largely overprinted and obscured by subsequent M₂ regional metamorphism. The contact metamorphism has most strongly effected the felsic volcanic strata, of unit 2, and the quartz diorites and tonalites, of unit 18(3)c. It has also recrystallized unit 13a siltstone strata, at the north end of Morton Lake, and the Dickstone Cu-Zn sulphide orebody and its underlying chlorite-rich alteration zone.

Strata of units 2 and 18(3)c are progressively more granoblastic and coarsely recrystallized as the Norris Lake pluton is approached. They contain garnet porphyroblasts north of Yakymiw Lake. A wide variety of lower to middle almandine-amphibolite facies mineral assemblages are present in altered strata of unit 2, below the Dickstone Cu-Zn sulphide orebody. Some of the more interesting assemblages noted in altered strata of unit 2 are:

staurolite + anthophyllite + chlorite + almandine
+ grossularite + biotite + hornblende + quartz;

anthophyllite + chlorite + almandine + grossularite
+ quartz + plagioclase;

diopside + grossularite + calcite + quartz;

staurolite + anthophyllite + chlorite + plagioclase; and

cummingtonite + hornblende + plagioclase + quartz.

The staurolite-anthophyllite assemblages suggest that during contact metamorphism the pressure exceeded 4 kb and the temperature was above 550°C.

REGIONAL METAMORPHISM

Three episodes of regional metamorphic recrystallization are recognized in the File Lake area. Their ages and main features are summarized in Table 17.

The general trend of deformational phenomena in the File Lake area is from early recumbent folds and ductile deformation to more upright flexural folds and brittle deformation. According to Fyson (1971), this is a characteristic temporal evolution in many metamorphic belts, representing a loss of mobility and ductility of rocks with passage of time, due to their progressive devolatilization. The main regional metamorphic culmination occurred during M₂ and was approximately coincident with the main pulses of felsic plutonism.

DESCRIPTION OF METAMORPHIC EVENTS

M₁: GENERATION OF PHYLLOSILICATE MINERALS

M₁ occurred during and following recumbent folding of the D₁ deformational event and generated greenschist facies mineral assemblages. Phyllosilicate minerals (chlorite, muscovite, biotite, etc.) formed during M₁ define a prominent regional schistosity, S₁, axial planar to F₁ folds. This schistosity remains well developed in all rocks despite subsequent recrystallization and annealing during M₂.

M₂: THERMAL CLIMAX

M₂ is the highest grade and most prominent metamorphic episode affecting rocks of the File Lake area. It produced mineral assemblages ranging from middle greenschist facies, south of File Lake, to upper almandine-amphibolite facies, north of Corley Lake. The northerly increase in metamorphic grade is part of a regional rise in metamorphic grade from margin to centre of the Kisseynew sedimentary gneiss belt (Bailes and McRitchie, 1978). Several east-trending M₂ isograd reaction surfaces have been delineated in the File Lake area in muscovite-bearing aluminous sedimentary gneisses of units 13b and 13c (Fig. 68).

The age of M₂ metamorphism, relative to other intrusive and deformational events, is given in Table 17. Some of the features which help to delineate M₂ age relationships are:

- 1) overprinting of S₁ foliations by M₂ porphyroblasts;
- 2) cross-cutting of major F₁ and F₂ fold axial traces by undeformed M₂ isograd reaction surfaces;
- 3) slight M₂ metamorphic recrystallization of both the Ham Lake and Norris lake plutons;
- 4) flattening and folding of M₂ sillimanite nodules and crushing and rotation of M₂ garnet porphyroblasts in F₃ fold domains; and
- 5) F₃ folding and boudinaging of M₂ generated granitic mobilizate in paragneisses of unit 13c.

The main M₂ metamorphic features in the Amisk Group sedimentary rocks and in mafic volcanic and intrusive rocks are summarized later in this chapter.

One of the important features of the File Lake area is that relatively unrecrystallized Amisk Group volcanic and sedimentary strata, south of File Lake, can be traced into orthogneisses and paragneisses, north and northwest of Corley Lake, that are typical of the Kisseynew sedimentary gneiss belt.

M₃: LOW GRADE RETROGRESSIVE METAMORPHISM

Late greenschist facies mineral assemblages are grouped collectively into M₃. They are common, in minor amounts, as retrogressive phases in many rocks of the map-area. They are most prominent in and adjacent to D₄ fractures, faults and shears. Minerals formed during M₃ include chlorite, muscovite (mainly sericite), hematite, zoisite, leucoxene, talc and carbonate.

M₂ METAMORPHIC PARAGENESIS OF METASEDIMENTARY ROCKS OF THE FILE LAKE FORMATION

Metasedimentary rocks of the File Lake Formation are well exposed and strike perpendicular to the M₂ metamorphic gradient. They grade from weakly recrystallized greywacke, siltstone and mudstone with greenschist facies mineral assemblages, southwest of File Lake, to completely recrystallized and partially melted paragneisses with upper almandine-amphibolite facies mineral assemblages, north of Corley Lake.

METAMORPHIC ZONES AND ISOGRAD REACTIONS

Specific metamorphic reactions have been used to delineate metamorphic zones in the File Lake Formation, in the manner described by Thompson (1957) and Carmichael (1970), and used previously, in the adjacent Snow Lake area, by Froese and Gasparrini (1975). Four discontinuous reactions and two continuous reactions have been identified for muscovite-bearing rocks; and six discontinuous and two continuous reactions have been identified for muscovite-free rocks (Table 18). Discontinuous reactions in muscovite-bearing rocks were used to define five metamorphic zones in the File Lake Formation (Fig. 68). Each zone is named after its most characteristic assemblage:

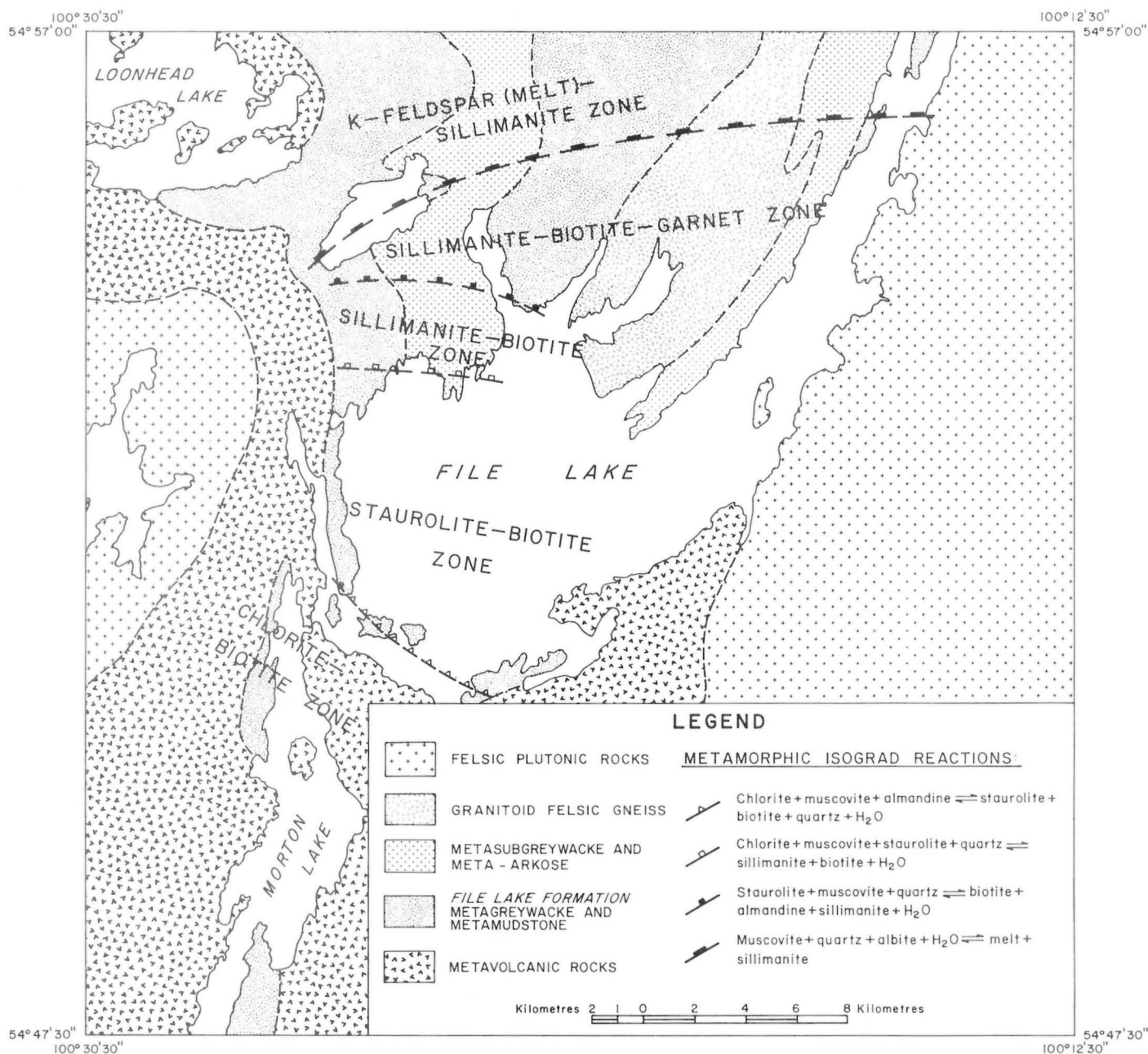


FIGURE 68: Disposition of M_2 metamorphic isograd reactions and zones in the File Lake Formation, File Lake area.

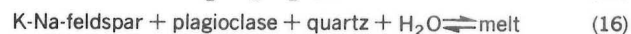
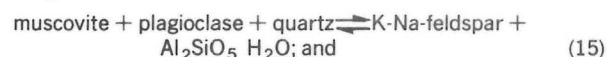
- 1) chlorite-biotite zone;
- 2) staurolite-biotite zone;
- 3) sillimanite-biotite zone;
- 4) sillimanite-garnet-biotite zone; and
- 5) K-feldspar (melt)-sillimanite zone.

The discontinuous reactions which define the zone boundaries are isograd surfaces; they have been named as follows:

- staurolite-biotite isograd (reaction (2))
- sillimanite-biotite isograd (reaction (6))
- sillimanite-garnet-biotite isograd (reaction (12))
- K-feldspar (melt)-sillimanite isograd (reaction (14))

These reactions are typical of the transition from greenschist to upper

almandine-amphibolite facies grade in many metamorphic belts (Guidotti, 1970, 1974; Carmichael, 1970). The first three isograd reactions, (2), (6) and (12), control, respectively, the first appearance of staurolite, the first appearance of sillimanite, and the decomposition of the staurolite in muscovite-bearing rocks. The K-feldspar (melt)-sillimanite isograd reaction (14) is a combination of the following two reactions:



It leads to partial melting and migmatization of pelitic and semi-pelitic rocks (see Winkler, 1976, p. 84 and p. 309).

TABLE 18: Discontinuous and continuous metamorphic reactions¹ identified in File Lake Formation, File Lake area

(1)	chlorite + plagioclase + quartz \rightleftharpoons hornblende + garnet + H ₂ O	D ²
(2)	chlorite + muscovite + garnet \rightleftharpoons staurolite + biotite + quartz + H ₂ O	DM
(3)	chlorite + muscovite \rightleftharpoons staurolite + biotite + quartz + H ₂ O	CM
(4)	chlorite + garnet + hornblende + quartz \rightleftharpoons cummingtonite + plagioclase + H ₂ O	D
(5)	chlorite + garnet + cummingtonite \rightleftharpoons anthophyllite + quartz + H ₂ O	D ³
(6)	chlorite + muscovite + staurolite + quartz \rightleftharpoons sillimanite + biotite + H ₂ O	DM
(7)	chlorite + sillimanite + quartz \rightleftharpoons staurolite + cordierite + H ₂ O	D
(8)	chlorite + staurolite + quartz \rightleftharpoons cordierite + garnet + H ₂ O	D
(9)	muscovite + staurolite + quartz \rightleftharpoons sillimanite + biotite + H ₂ O	CM
(10)	chlorite + staurolite + quartz \rightleftharpoons cordierite + H ₂ O	C
(11)	staurolite + quartz \rightleftharpoons cordierite + garnet + H ₂ O	C
(12)	muscovite + staurolite + quartz \rightleftharpoons sillimanite + garnet + biotite + H ₂ O	DM
(13)	staurolite + quartz \rightleftharpoons cordierite + garnet + sillimanite + H ₂ O	D
(14)	muscovite + plagioclase + quartz + H ₂ O \rightleftharpoons melt + sillimanite	DM

Note: ¹ Reactions listed in order from lowest to highest grade. They are based on observed mineral assemblage changes and were delineated by method introduced by Thompson (1957).

² Letters indicate type of reaction, as follows:

D - discontinuous, muscovite-free rocks

C - continuous, muscovite-free rocks

DM - discontinuous, muscovite-bearing rocks

CM - continuous, muscovite bearing rocks

³ Position of this reaction based on mineral assemblages observed in the adjacent Snow Lake area by Froese and Moore (1980) Mineral assemblages defining this reaction were not observed in the File Lake area until higher metamorphic grade due to lack of rocks of appropriate composition.

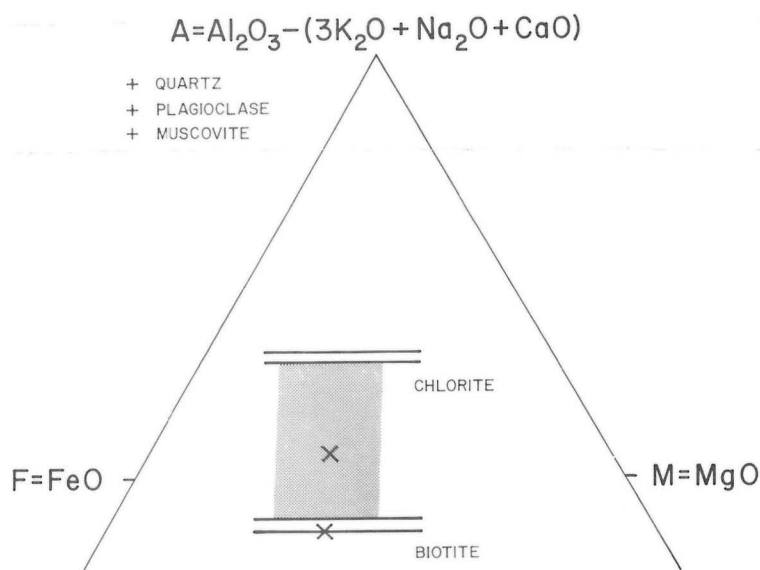


FIGURE 69: Schematic Thompson AFM projection through muscovite, quartz and plagioclase of constant composition of observed muscovite-bearing assemblages (shown by X) in the chlorite-biotite zone.

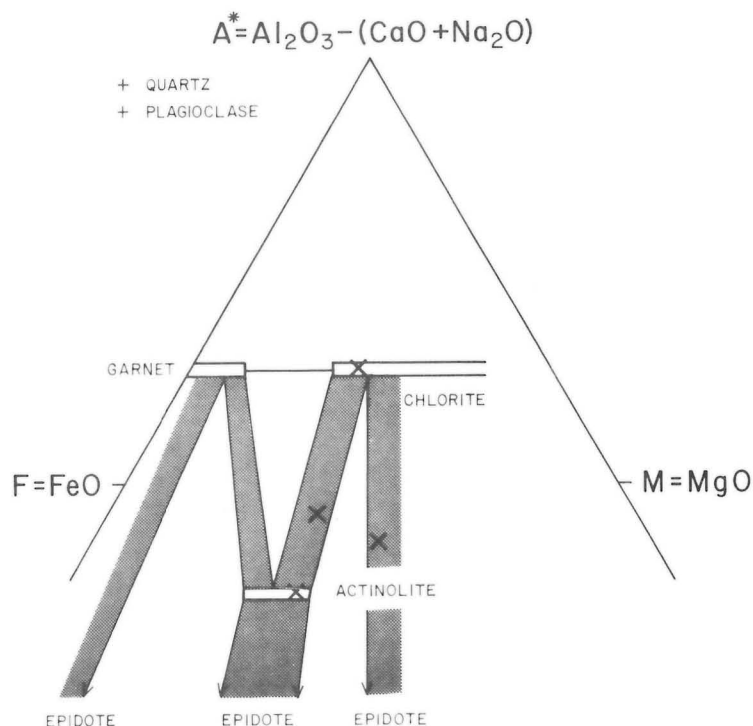


FIGURE 70: Schematic A*FM projection through quartz and plagioclase of constant composition (after Froese, 1969) of observed muscovite-free assemblages (shown by X) in the lower chlorite-biotite zone. Biotite is present in observed assemblages.

Chlorite-biotite zone

Rocks of the chlorite-biotite zone are weakly recrystallized and contain middle to upper greenschist facies metamorphic mineral assemblages. Primary sedimentary structures and textures are well preserved and have been discussed previously.

Typical mineral assemblages in K₂O-rich, muscovite-bearing rocks are shown on Figure 69, a modified Thompson AFM projection

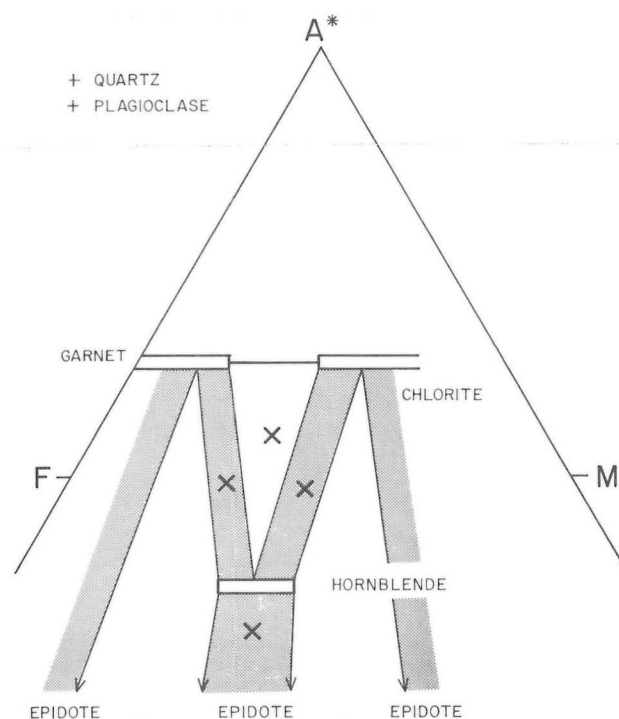
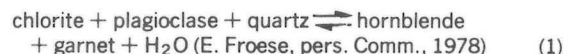


FIGURE 71: Schematic A*FM projection of observed muscovite-free assemblages (shown by X) in the upper chlorite-biotite zone. Biotite is present in observed assemblages.

through muscovite, quartz and plagioclase of constant composition. Typical mineral assemblages of K₂O-poor muscovite-free rocks are shown on Figure 70, an A*FM projection after Froese (1969) through quartz and plagioclase of constant composition. In K₂O-poor rocks, biotite is the only K₂O-bearing mineral and it is compatible with all mineral assemblages shown in A*FM projections.

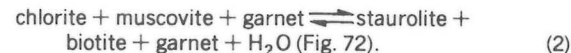
Near the upper boundary of the chlorite-biotite zone, muscovite-free rocks contain garnet (Fig. 71). This is probably due to the discontinuous reaction



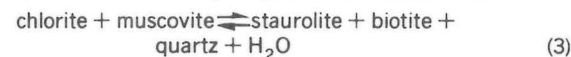
which shifts the chlorite-hornblende-garnet mineral compatibility triangle to more magnesian compositions. Garnet was not observed in muscovite-bearing assemblages in the upper part of the chlorite-biotite zone, probably because of a lack of muscovite-bearing rocks of appropriate composition.

Staurolite-biotite zone

The staurolite-biotite zone is separated from the chlorite-biotite zone by the discontinuous staurolite-biotite isograd reaction



This reaction, rather than the higher grade continuous reaction



is considered to control the appearance of staurolite, since garnet co-exists with staurolite in most rocks of the lower staurolite-biotite zone. Assemblages which indicate that reaction (2) has been exceeded are: garnet-muscovite-staurolite-biotite-quartz (Fig. 73); and garnet-chlorite-muscovite-staurolite-biotite-quartz (Fig. 74).

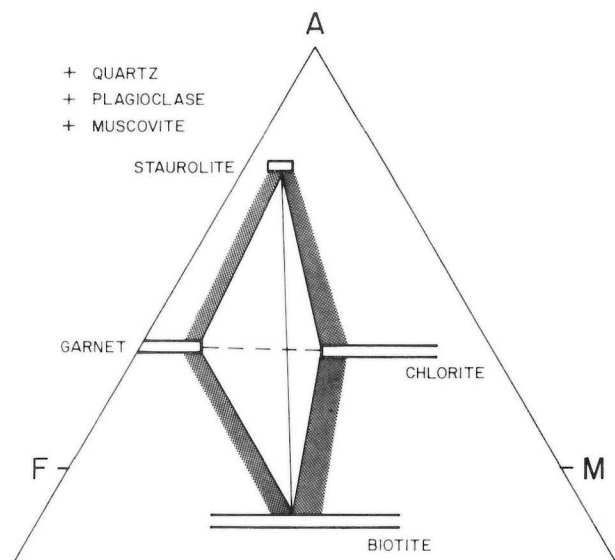


FIGURE 72: The discontinuous reaction at the staurolite-biotite isograd, represented on a schematic Thompson AFM projection. Dashed tie line is broken by staurolite-biotite isograd reaction, represented by solid line.

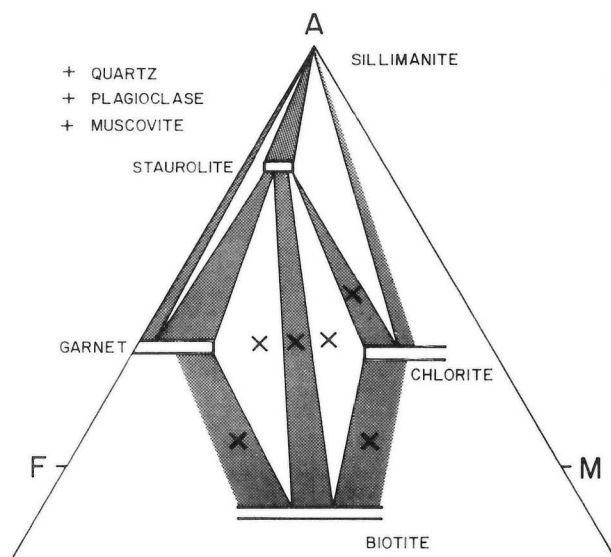


FIGURE 73: Schematic Thompson AFM projection of observed muscovite-bearing assemblages (shown by X) in the staurolite-biotite zone.

Within the staurolite-biotite zone the following changes are observed with increase in metamorphic grade:

- 1) an increase in the abundance and grain size of staurolite, which changes from small poikiloblastic crystals to large inclusion-free idioblastic euhedral crystals (Fig. 75); and
- 2) an increase in range of rock compositions which contain staurolite. In the low grade part of the staurolite-biotite zone, staurolite occurs only in metamudstone, but at higher grades it also occurs in metasiltstone and metagreywacke.

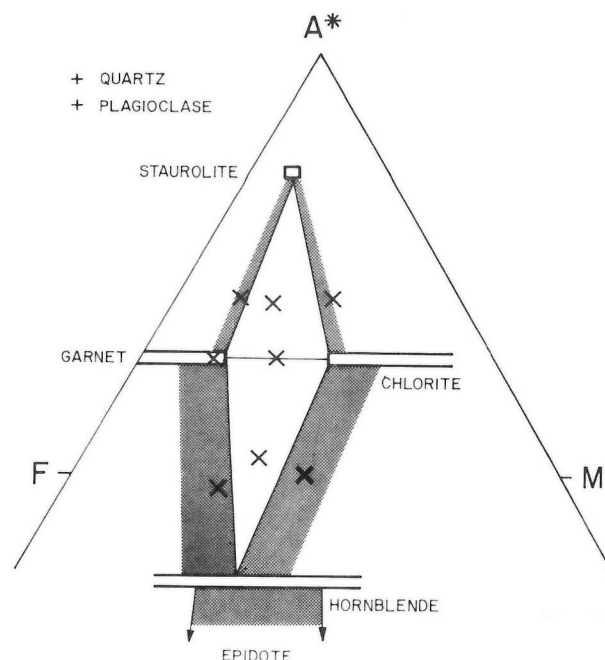
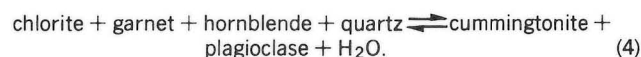


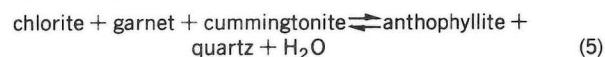
FIGURE 74: Schematic A*FM projection of observed muscovite-free assemblages (shown by X) in the lower staurolite-biotite zone. Biotite is present in observed assemblages.

These two features are probably due to continuous reaction (3) which, as pointed out by Carmichael (1970), causes the staurolite-biotite-chlorite mineral compatibility triangle to migrate towards more magnesian compositions. This reaction forms staurolite and biotite at the expense of chlorite and muscovite, and causes depletion of the bank of tie lines between chlorite and staurolite and between chlorite and biotite while increasing those between staurolite and biotite (compare Figs. 72 and 73). Thus the compositional field of staurolite-bearing rocks is enlarged.

In muscovite-free rocks the following discontinuous reaction probably occurred about midway between the lower and upper boundaries of the staurolite-biotite zone:



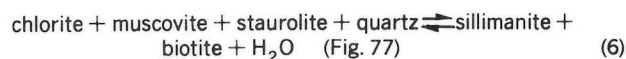
Mineral assemblages in muscovite-free rocks below this discontinuous reaction are shown in Fig. 74. The topology of the reaction, and the assemblages occurring above it, are shown in Figure 76. Based on data from the Snow Lake area (Froese and Moore, 1980), the discontinuous reaction



probably occurred in the staurolite-biotite zone. However, anthophyllite-bearing assemblages are not observed in the File Lake Formation until much higher grade, because of absence of rocks of appropriate composition in the lower grade areas.

Sillimanite-biotite zone

The lower boundary of the sillimanite-biotite zone is defined by the discontinuous sillimanite-biotite isograd reaction



Assemblages which indicate that this reaction has been exceeded are muscovite-sillimanite-biotite-quartz and staurolite-muscovite-sillimanite-biotite-quartz (Fig. 78). The muscovite-free assemblage

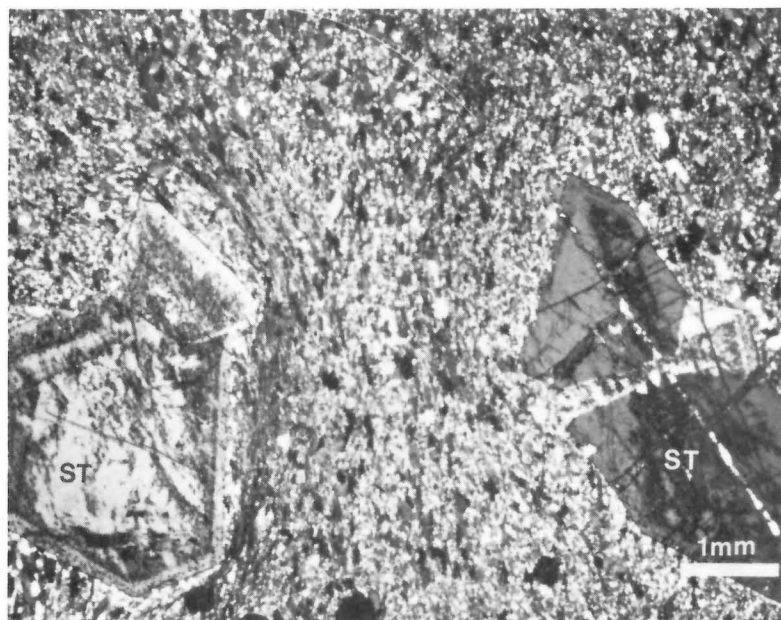
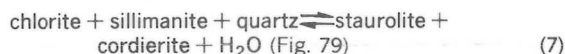


FIGURE 75: Photomicrograph (polarized light) of large euhedral staurolite porphyroblasts (ST) in muscovite-bearing pelitic schist (unit 13b), upper part of staurolite-biotite zone.

staurolite-chlorite-sillimanite-biotite-quartz should ideally occur in rocks above reaction (6), but it was not observed. The absence of this assemblage is probably due to consumption of chlorite or sillimanite by the discontinuous reaction



which is indicated to have occurred just above the sillimanite-biotite isograd by the muscovite-free assemblage staurolite-cordierite-chlorite-biotite-quartz (Fig. 79). At slightly higher grades, but still in the lower part of the sillimanite-biotite zone, the discontinuous reaction

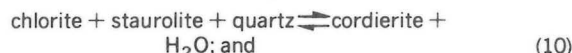
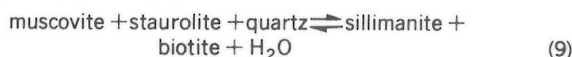


is inferred to have occurred in muscovite free rocks by the assemblage staurolite-garnet-cordierite-chlorite-biotite-quartz (Fig. 80). It is possible that garnet could have been stabilized as an extra phase in this assemblage by either MnO or CaO, in which case it would not indicate that reaction (8) went to completion. However, an electron microprobe analysis of garnet in this assemblage (FO7-3776-10A, Table 19) indicates that the garnet is neither MnO or CaO stabilized; the presence of plagioclase also indicates the garnet is not CaO stabilized. Reaction (8) is particularly significant because it indicates a slightly lower pressure path of metamorphism in the File Lake area than in the adjacent Snow Lake area where Froese and Moore (1980) have documented somewhat higher pressure reactions involving anthophyllite (see Fig. 93, p.87).

Within the sillimanite-biotite zone the following changes are observed with increasing metamorphic grade:

- 1) gradual depletion of staurolite and its progressive replacement by other minerals;
- 2) gradual increase of sillimanite, which occurs as fibrolitic knots, and a coincident loss of staurolite, chlorite and groundmass muscovite; and
- 3) gradual increase in cordierite in very aluminous but muscovite-free rocks.

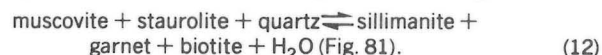
The following three continuous reactions are inferred to be responsible for these features:



Reaction (9) follows the discontinuous sillimanite-biotite isograd reaction (6) and, as pointed out by Carmichael (1970), causes the staurolite-sillimanite-biotite mineral compatibility triangle to shift to more iron-rich compositions (compare Figs. 77 and 78). Reaction (10) causes the staurolite-chlorite-cordierite mineral compatibility triangle to move towards more iron-rich compositions (compare Figs. 79 and 80), decreases the bank of tie lines between staurolite and chlorite, and eventually leads to discontinuous reaction (8), when the last staurolite-chlorite tie line is broken (Fig. 79). Reaction (11) follows discontinuous reaction (8) and ultimately leads to discontinuous reaction (12) in the sillimanite-garnet-biotite zone.

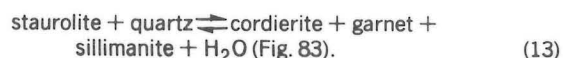
Sillimanite-garnet-biotite zone

The lower boundary of the sillimanite-garnet-biotite zone is defined by the discontinuous sillimanite-garnet-biotite isograd reaction



Assemblages which indicate that this reaction has been exceeded are muscovite-sillimanite-biotite-garnet-quartz (Fig. 81) and staurolite-sillimanite-biotite-garnet-quartz (Fig. 82).

In muscovite-free rocks staurolite persists about 0.5 km beyond the sillimanite-garnet-biotite isograd until it is decomposed by the discontinuous reaction



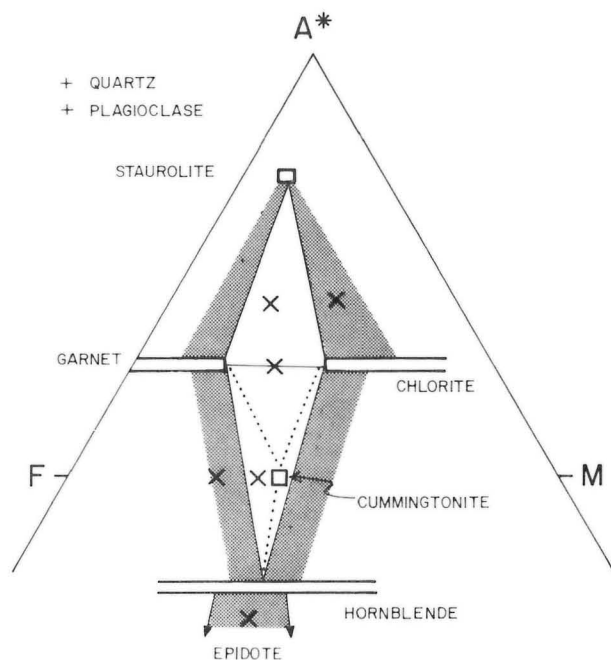


FIGURE 76: Schematic A*FM projection depicting discontinuous reaction responsible for the first appearance of cummingtonite in muscovite-free rocks of the staurolite-biotite zone. Observed assemblages stable above reaction are shown by X. Biotite is present in observed assemblages. Dotted lines are new tie lines established by discontinuous reaction forming cummingtonite.

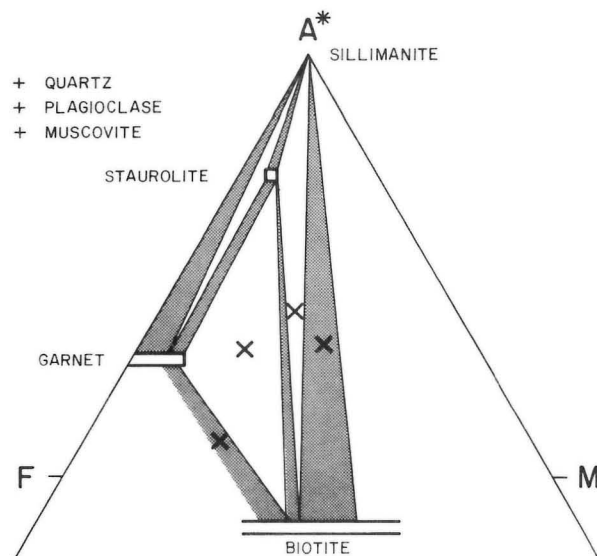


FIGURE 78: Schematic Thompson AFM projection of observed muscovite-bearing assemblages (shown by X) in the sillimanite-biotite zone.

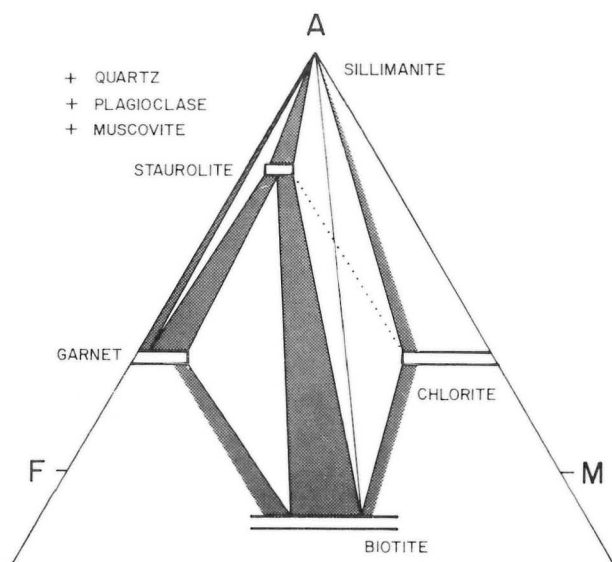


FIGURE 77: The discontinuous reaction at the sillimanite-biotite isograd, represented on a schematic Thompson AFM projection. Dotted tie line is broken by sillimanite-biotite isograd reaction, represented by solid line.

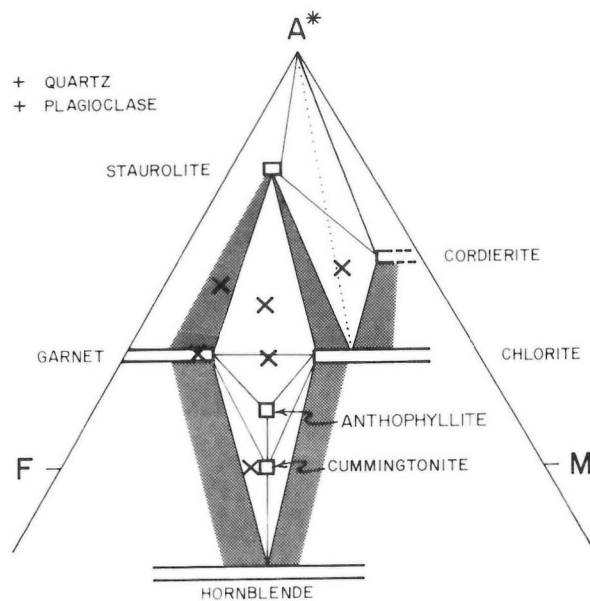


FIGURE 79: Schematic A*FM projection depicting discontinuous reaction inferred to be responsible for first appearance of staurolite + cordierite assemblages in muscovite-free rocks of the lower sillimanite-biotite zone. All observed assemblages stable above reaction (shown by X) contain biotite. Dotted tie line is broken by discontinuous reaction forming staurolite + cordierite assemblages.

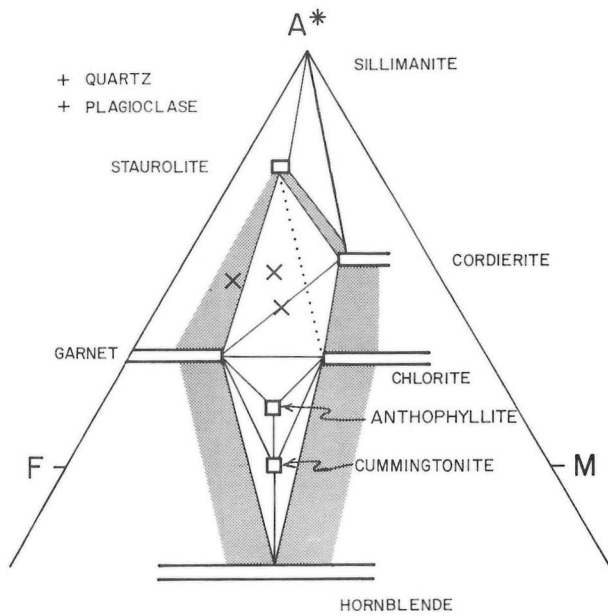


FIGURE 80: Schematic A*FM projection depicting discontinuous reaction responsible for first appearance of cordierite + garnet assemblages in muscovite-free rocks of the lower sillimanite-biotite zone. All observed assemblages stable above reaction (shown by X) contain biotite. Dotted tie line is broken by discontinuous reaction forming cordierite + garnet assemblages.

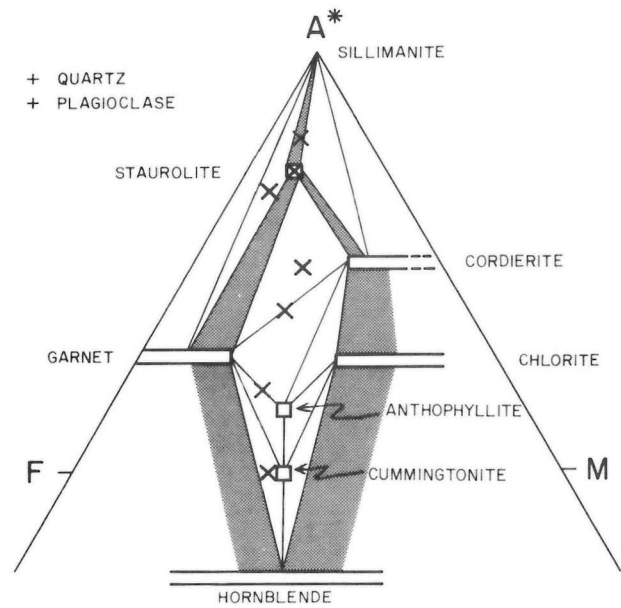


FIGURE 82: Schematic A*FM projection of observed muscovite-free assemblages (shown by X) in the lower sillimanite-garnet-biotite zone. All observed assemblages contain biotite.

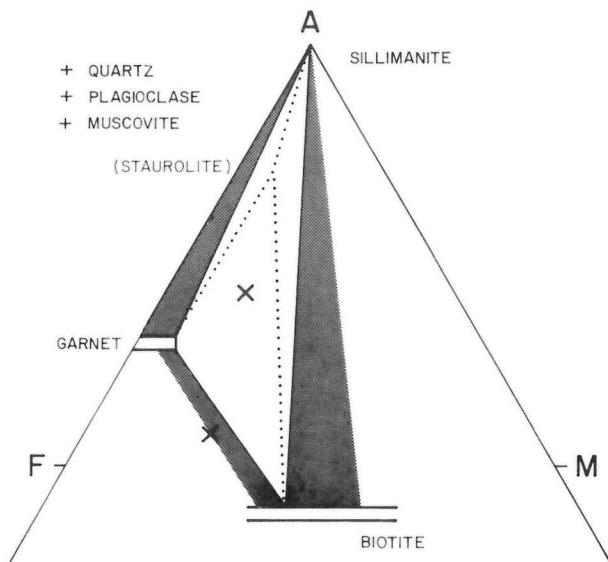


FIGURE 81: Discontinuous reaction at the sillimanite-garnet-biotite isograd, represented on a schematic Thompson AFM projection. Observed assemblages above reaction shown by X. Dotted tie lines are broken by sillimanite-garnet-biotite isograd reaction.

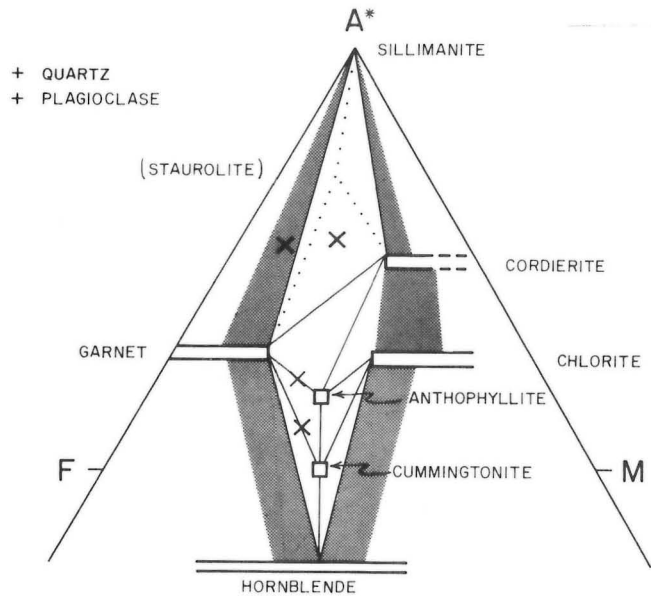


FIGURE 83: Schematic A*FM projection depicting discontinuous reaction responsible for breakdown of staurolite in muscovite-free rocks. All observed assemblages stable above reaction shown by X. Biotite is present in observed assemblages. Dotted lines are tie lines broken by discontinuous reaction decomposing staurolite.

TABLE 19: Chemical composition^{1,2} of garnet in assemblage defining reaction (8) compared to MnO-stabilized garnet. Both are from sillimanite-biotite zone, File Lake area.

	SiO ₂	TiO ₂	Al ₂ O ₃	Cr ₂ O ₃	FeO	MnO	MgO	CaO	Na ₂ O
Garnet in assemblage defining reaction (8) ³	37.45	0.04	20.45	0.06	35.60	0.36	4.29	1.63	0.20
(centre)									
(edge)	37.15	0.07	20.47	0.09	36.17	0.21	3.95	1.33	0.00
MnO stabilized garnet ⁴	36.86	0.04	20.49	0.06	35.87	2.83	2.65	1.35	0.04

1 Analyses by George Plant, G.S.C., Ottawa using a Kevex Lithium-drifted solid state detector for energy dispersive analysis attached to a MAC electron microprobe. Operating conditions were: 20 kv accelerating voltage, specimen current 0.01 nano amps measured on biotite, 40 seconds counting time, focused beam.

2 Analyses are average of three to four grains of mineral in each rock specimen.

3 Sample number F07-3776-10A, a garnet-, staurolite-, cordierite-, biotite-, quartz-, plagioclase-, ilmenite-bearing paragneiss.

4 Sample number F07-2086-1B, a garnet (MnO stabilized)-staurolite-, muscovite-, biotite-, quartz-, plagioclase-, chlorite (retrograde)-bearing paragneiss.

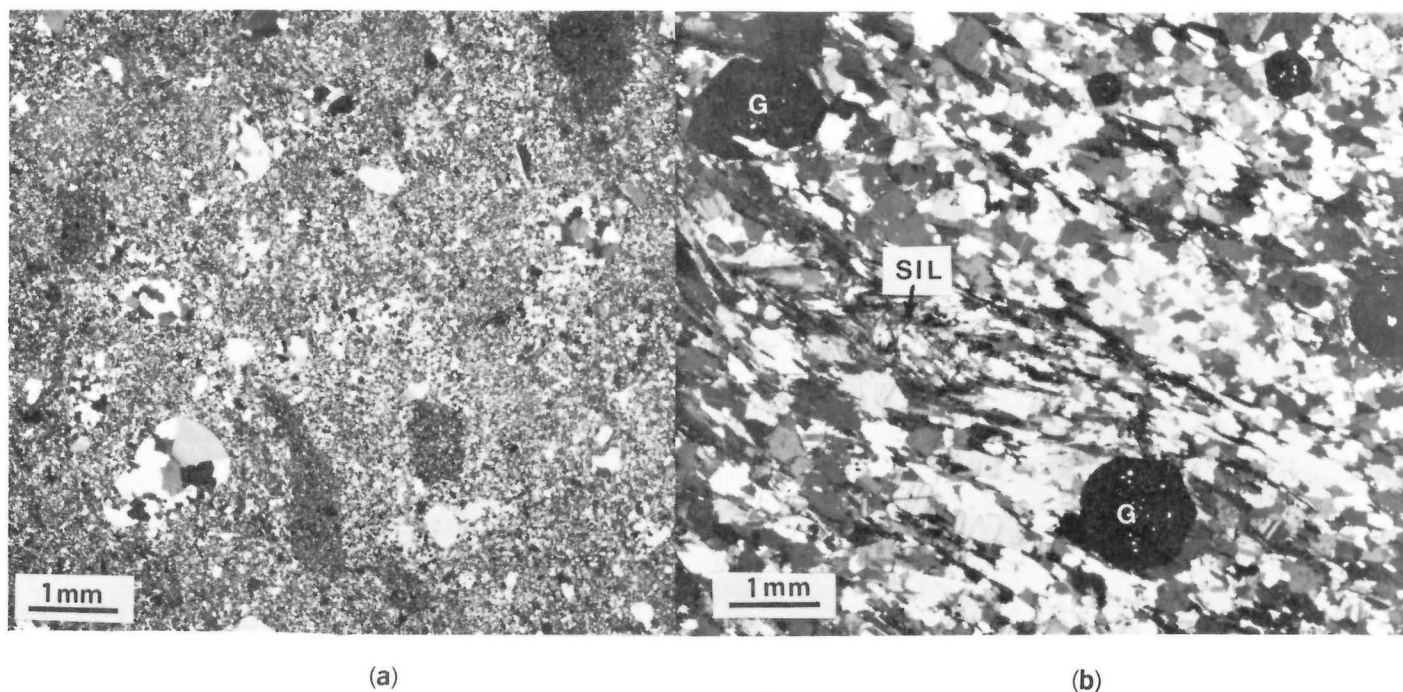


FIGURE 84: Photomicrographs (polarized light) comparing grain size of (a) weakly recrystallized lithic greywacke (unit 13) from the chlorite-biotite zone and (b) coarsely recrystallized metagreywackes (unit 13c) from the K-feldspar (melt)-sillimanite zone. Note trails of fribrolitic sillimanite (SIL) and garnet porphyroblasts (G) in coarsely recrystallized metagreywacke.

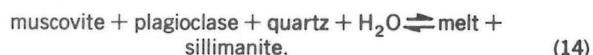
Sillimanite was formed for the first time in many muscovite-free pelitic and semi-pelitic rocks due to breaking of tie lines from staurolite to cordierite and staurolite to garnet by reaction (13).

Anthophyllite-bearing assemblages are present in muscovite-free rocks of the sillimanite-garnet-biotite zone (Figs. 82 and 83). Anthophyllite was not found in lower grade rocks, where it should be stable, due to absence of rocks of appropriate composition.

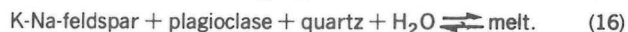
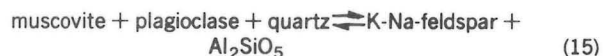
K-feldspar (melt)-sillimanite zone

Rocks of the K-feldspar (melt)-sillimanite zone are characterized by disappearance of muscovite, prominent veining by white tonalite and granodiorite, decrease in sillimanite content, and coarse recrystallization (0.1 to 1.0 mm grain size compared to 0.01 to 0.02 mm in the chlorite-biotite zone, Fig. 84).

The disappearance of muscovite and the coincident appearance of small sills and veins of tonalite and granodiorite suggest that the lower boundary of this zone is defined by the reaction



According to Winkler (1976) this reaction only occurs in rocks under conditions of moderate to high pressure and is a combination of the muscovite decomposition reaction (15) and the granite melting reaction (16):



The observed depletion of sillimanite, however, is at odds with reaction (14) which predicts that sillimanite should be produced rather than depleted. This could have been caused by parallel consumption of alumina by other, as yet undetermined, reactions, possibly involving Fe and Mg and producing aluminous minerals such as biotite or garnet, both of which are common in the tonalite and granodiorite.

An anatectic derivation for the tonalite and granodiorite is strongly suggested by its occurrence only in sedimentary rocks of the File Lake Formation and only in those above the K-feldspar (melt)-sillimanite isograd. This holds for both small veins and sills, that occur ubiquitously, and large sheeted sill and dyke complexes, shown as unit 27 on the geological map (Map 78-1-1, in pocket). Melting did not occur at lower grades because the sedimentary rocks of the File Lake Formation contain no potassium-feldspar and it is the potassium-feldspar-producing muscovite decomposition reaction (15) which permits the granite melting reaction (16) to occur.

METAMORPHIC TEXTURES

One of the problems with isograd reactions based on discontinuities in topology of Thompson AFM projections is that microscopic textures do not always agree with the topologically deduced reactions (Turner and Verhoogen, 1960, p. 460; Chinner, 1961; Carmichael, 1969). In the pelitic gneisses of the sillimanite-biotite zone at File Lake there are many textures that do not agree with predicted reactions, for example:

- 1) replacement of staurolite by prograde muscovite (Fig. 85a);
- 2) replacement of staurolite by prograde plagioclase (Figs. 85b and 86);
- 3) the occurrence of sillimanite in fibrolitic knots isolated from other aluminous minerals (Figs. 87 and 88); and
- 4) garnet porphyroblasts with rims of quartz.

These textures can be shown to be consistent with the topologically determined reactions, discussed previously, but their reaction mechanism is more complicated than a simple direct transformation from reactants to products. The textures appear to be

the result of diffusion-controlled cation exchange reactions (see Carmichael, 1969; Foster, 1977).

Description

Prograde muscovite rimming and replacing staurolite first occurs in muscovite-bearing rocks just above the sillimanite-biotite isograd and occurs in these rocks throughout the sillimanite-biotite zone until staurolite is finally consumed at the sillimanite-garnet-biotite isograd. The replacement of staurolite by muscovite is generally accompanied by the formation of large crystals of biotite, coarse plagioclase aggregates and, in one sample, sillimanite (Fig. 85a). The muscovite content of the rock actually decreases with increasing temperature because matrix muscovite is consumed by production of sillimanite and biotite faster than the formation of new prograde muscovite replacing staurolite. The new muscovite is not a retrograde mineral overprinting staurolite because its first appearance coincides with the sillimanite-biotite isograd and no overprinting of staurolite by muscovite was observed below this isograd. Similar replacement of staurolite by prograde muscovite has been described by Guidotti (1968).

Prograde aggregates of plagioclase rimming and replacing staurolite first occur just above, and appear to be related to, the sillimanite-biotite isograd. This phenomenon occurs in both muscovite-bearing rocks (Figs. 85b and 88) and muscovite-free rocks (Fig. 86), throughout the sillimanite-biotite zone, and into the sillimanite-garnet-biotite zone in muscovite-free rocks, until staurolite is consumed. It is most pronounced in muscovite-free rocks, particularly those containing cordierite. It begins as a minor corrosion of the periphery of the staurolite grains (Fig. 86) and ends as complete replacement of staurolite. In muscovite-bearing rocks, the plagioclase is generally accompanied by both muscovite and biotite, and in muscovite-free rocks, it occurs alone (Fig. 86) or with biotite.

Sillimanite nodules, 3 to 7 mm in size, are characteristic of muscovite- and staurolite-bearing pelitic gneisses of the sillimanite-biotite zone. They comprise aggregates of fibrolitic sillimanite, enveloped by quartz-rich domains, and are isolated from other aluminous minerals (Figs. 85b, 87 and 88).

Garnet porphyroblasts with narrow rims of quartz occur in muscovite-free rocks in high grade parts of the sillimanite-biotite zone. They are most prominent in rocks with large porphyroblasts of cordierite and corroded crystals of staurolite.

Interpretation

Carmichael (1969) suggested that prograde reactions in metamorphosed pelitic rocks proceed by local cation exchange reactions. He assumed that aluminum remained immobile and demonstrated that a set of cation exchange reactions, when summed over a thin section, can yield a net reaction which is equivalent to a topological change of an AFM diagram. The textures in pelitic rocks of the sillimanite-biotite zone of the File Lake area support this cation exchange mechanism, although they indicate that aluminum diffuses over very short distances and thus is not entirely immobile as assumed by Carmichael (1969).

Textures resulting from cation exchange reactions have been and are probably still being misinterpreted by many geologists. Two of the most common misinterpretations, pointed out by Carmichael (1969), are:

- 1) the misinterpretation that many replacement phenomena, such as muscovite and/or plagioclase overgrowing staurolite, are retrogressive features whereas, in fact, they are caused by prograde cation exchange reactions; and
- 2) the misinterpretation that textures caused by cation exchange were produced by a complicated series of metamorphic events, rather than a single event.

Recognition of textures resulting from cation exchange processes was important for correct identification of metamorphic reactions and metamorphic events in the File Lake area.

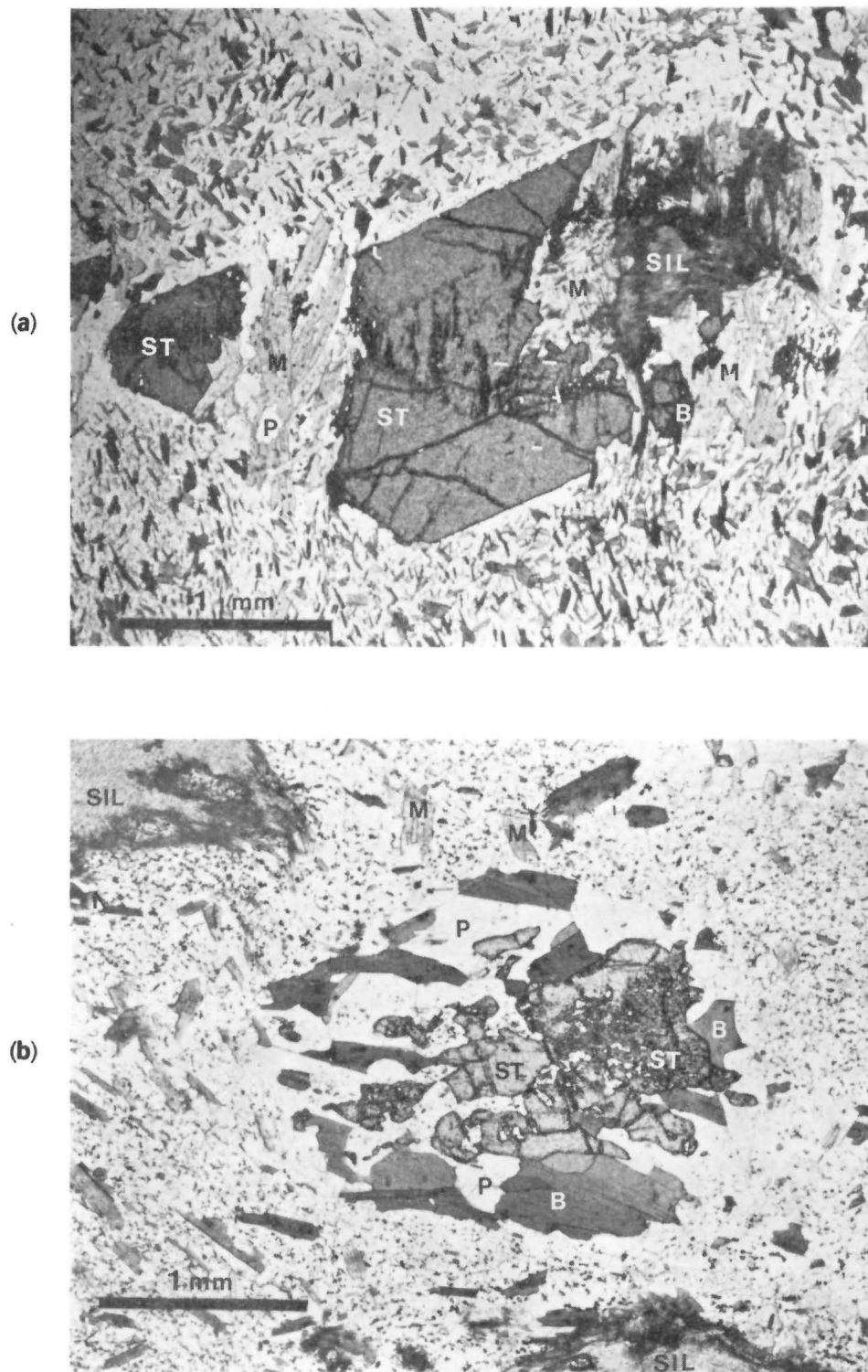


FIGURE 85: Photomicrographs (plain light) of corroded porphyroblasts of staurolite (ST) in muscovite-bearing pelitic gneiss (unit 13b), sillimanite-biotite zone. In (a) staurolite is partially replaced by a mixture of muscovite (M), fibrolitic sillimanite (SIL), plagioclase (P), and minor biotite (B). In (b) staurolite is partially replaced by a mixture of plagioclase (P) and biotite (B).

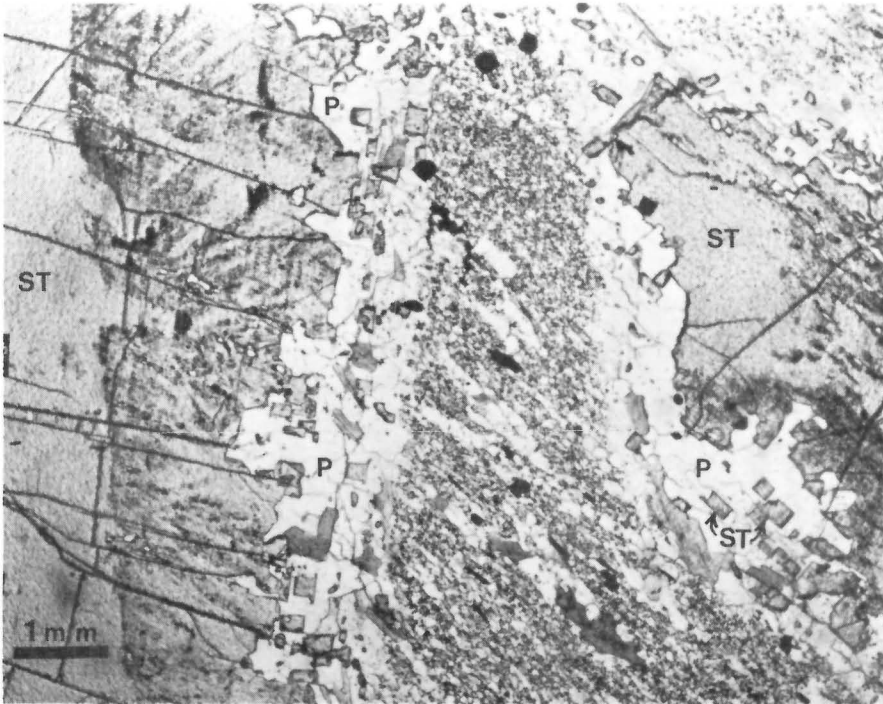
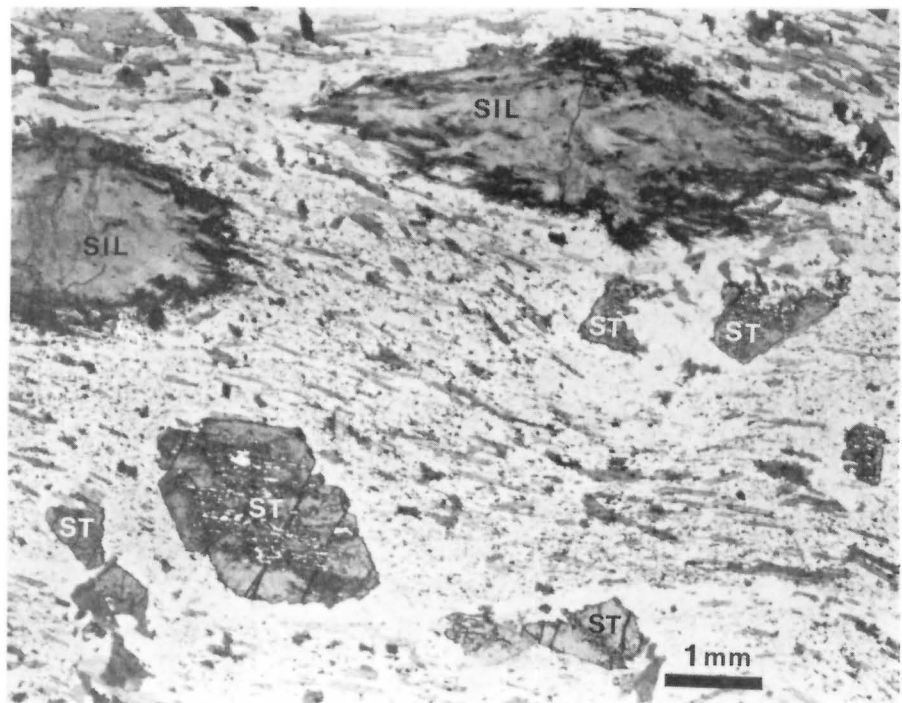


FIGURE 86: Photomicrograph (plain light) of staurolite porphyroblasts (ST) partially replaced by plagioclase (P) in a muscovite-free pelitic gneiss (unit 15), sillimanite-biotite zone.

FIGURE 87: Photomicrograph (plain light) of nodular aggregates of sillimanite (SIL) and corroded porphyroblasts of staurolite (ST) in muscovite-bearing pelitic gneiss (unit 13b), sillimanite-biotite zone. Sillimanite nodules are surrounded by a rim of disseminated magnetite (dark material).



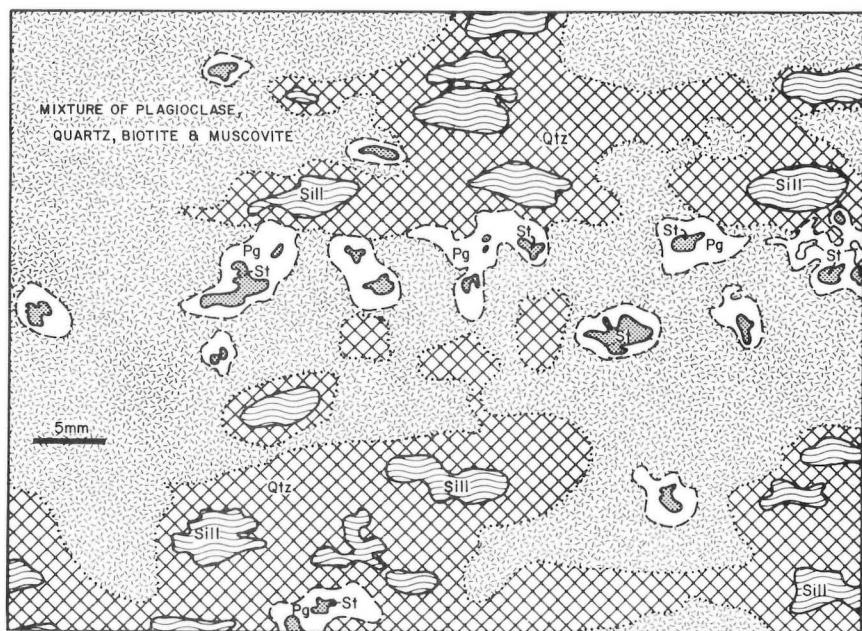
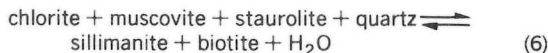


FIGURE 88: Nodules of fibrolitic sillimanite (Sill) surrounded by quartz-rich domains (Qtz) and corroded porphyroblasts of staurolite (St) surrounded by plagioclase-rich domains (Pg). Muscovite-bearing meta-mudstone (unit 13b), sillimanite-biotite zone.

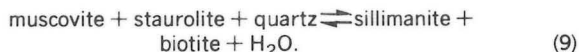
Muscovite-bearing rocks

Typical textures and mineral assemblages of a muscovite-bearing pelitic gneiss from below and above the sillimanite-biotite isograd are compared in Figure 89. Below the isograd, staurolite occurs as well-formed euhedral porphyroblasts (Fig. 75). Above the isograd, the staurolite porphyroblasts are corroded and replaced by a mixture of plagioclase, biotite and muscovite; and aggregates of sillimanite, enveloped by a quartz-rich zone, occur where previously there was a mixture of plagioclase, quartz, biotite, muscovite, and chlorite (Figs. 85b, 87 and 88). Less obvious, but also important, is the absence of chlorite and the reduced amount of muscovite in pelitic gneisses above the sillimanite-biotite isograd.

The textures depicted in Figure 89b are due to cation exchanges which occurred during the sillimanite-biotite isograd reaction



and the subsequent continuous reaction



The main cation exchanges for reactions (6) and (9) are depicted in Figure 90. They allow staurolite to break down to sillimanite without being in physical contact and without the need for transporting relatively immobile aluminum between the two. For the sillimanite domain, this is accomplished by the cation exchange reaction

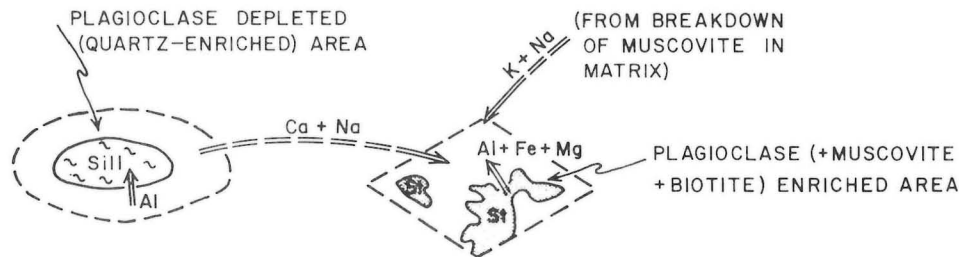
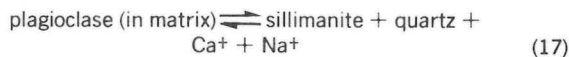
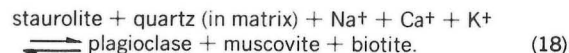


FIGURE 90: Main cation exchanges forming plagioclase-depleted areas around sillimanite knots and plagioclase-enriched areas around, and replacing, staurolite in a muscovite-bearing pelitic gneiss (unit 13b) of the sillimanite-biotite zone (see Figure 89).

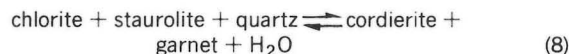
whereby aluminum necessary for sillimanite is derived by breakdown of matrix plagioclase, followed by slight migration of the aluminum into a concentrated core of sillimanite surrounded by a quartz-enriched (or plagioclase-depleted) domain (Fig. 89 and 90). The $\text{Na}^{+} + \text{Ca}^{2+}$ released by reaction (17), along with K^{+} and Na^{+} cations released by breakdown of matrix muscovite, migrate to the staurolite domain where they contribute to the following cation exchange reaction



Reaction (18) permits plagioclase, muscovite and biotite to absorb aluminum, magnesium, iron and silica released by the breakdown of staurolite, plus Ca^{2+} and Na^{+} cations released from the sillimanite domain, K^{+} and Na^{+} cations released from matrix muscovite, and SiO_2 released from surrounding grains of matrix quartz.

Muscovite-free rocks

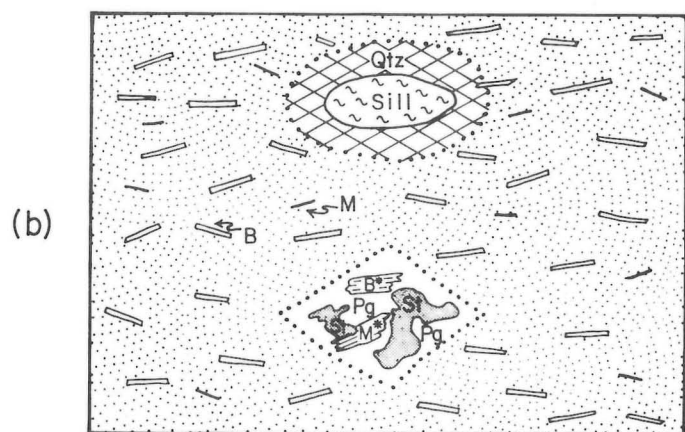
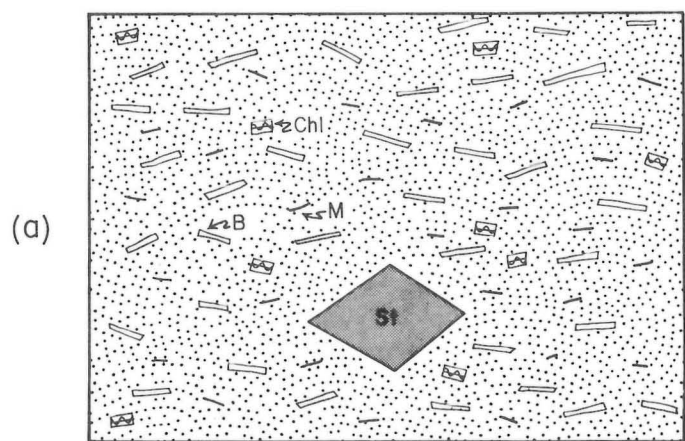
Typical textures and mineral assemblages of muscovite-free pelitic gneiss from below and above the discontinuous reaction



are compared in Figure 91. Reaction (8) occurs near the bottom of the sillimanite-biotite zone and is responsible, along with the related continuous reaction



for most of the decomposition of staurolite in muscovite-free rocks of the sillimanite-biotite zone. Below reaction (8), staurolite occurs as

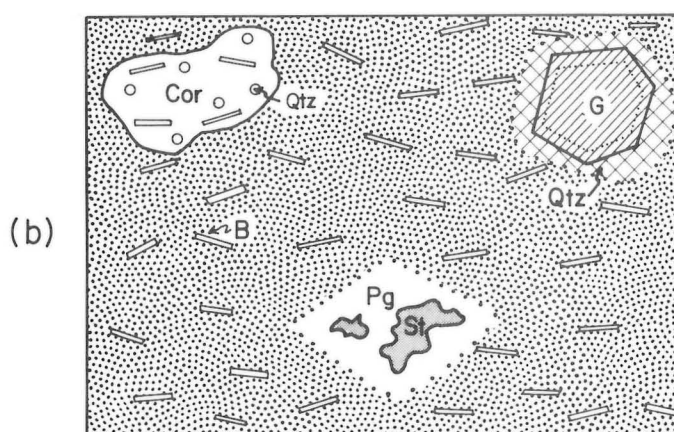
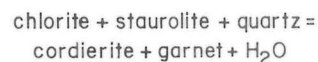
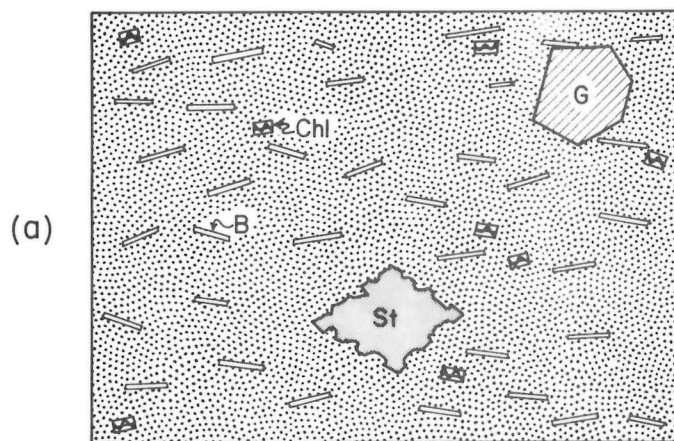
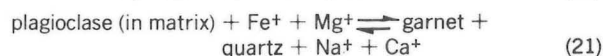
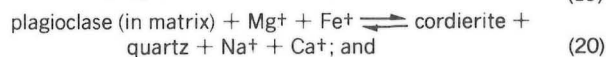
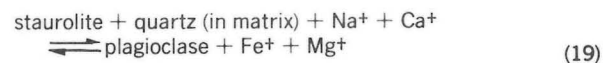


M = muscovite in matrix
M* = new muscovite plates
B = biotite in matrix
B* = new biotite plates
Chl = chlorite
Pg = plagioclase
St = staurolite
Sill = sillimanite
Dotted area = mixture of quartz + plagioclase
Qtz = quartz

FIGURE 89: Typical textures and mineralogy of a muscovite-bearing pelitic gneiss (unit 13b) (a) below and (b) above the sillimanite-biotite isograd reaction.

well-formed, slightly corroded euhedral porphyroblasts. Above reaction (8), the staurolite porphyroblasts are corroded and replaced by plagioclase (Fig. 86); large sieved porphyroblasts of cordierite, containing numerous inclusions of quartz and biotite, occur where previously there was a mixture of matrix plagioclase, quartz, biotite and chlorite; and garnet porphyroblasts have rims of granular quartz.

The textures depicted in Figure 91 are due to cation exchanges which occurred during reactions (8) and (11). The main cation exchanges for the staurolite, cordierite and garnet domains, respectively, are (Fig. 92):



B = biotite in matrix
Chl = chlorite
Pg = plagioclase
Cor = cordierite
G = garnet
St = staurolite
Qtz = quartz
Dotted area = mixture of quartz + plagioclase

FIGURE 91: Typical textures and mineralogy of a muscovite-free pelitic gneiss (unit 15) (a) below and (b) above discontinuous reaction (8), sillimanite-biotite zone.

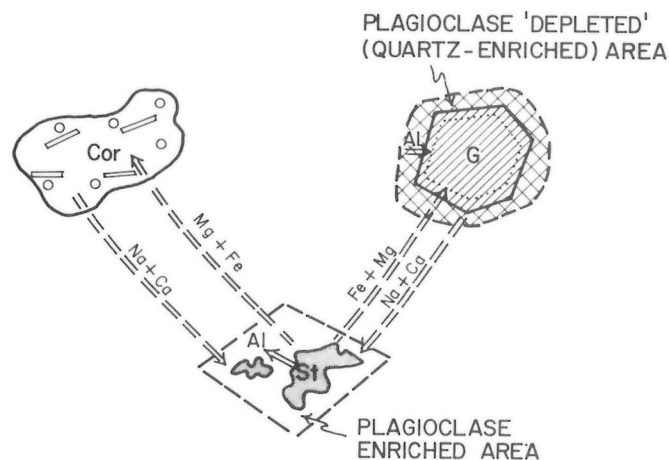


FIGURE 92: Main cation exchanges in a muscovite-free pelitic gneiss (unit 15), sillimanite-biotite zone.

Like the cation exchange reactions (17) and (18) in muscovite-bearing rocks, these reactions allow aluminum to remain relatively immobile and use matrix plagioclase and matrix quartz, respectively, as a source and a sink for needed and unneeded aluminum.

M₂ PARAGENESIS OF MISSI GROUP METASEDIMENTARY ROCKS

Metasubgreywacke and meta-arkose of the Missi Group generally have a simple mineralogy which does not change significantly with metamorphic grade. Their typical mineral assemblages are:

- quartz + andesine + biotite + muscovite + magnetite;
- quartz + andesine + biotite + magnetite; and
- quartz + andesine + microcline + muscovite + biotite + magnetite.

Greywackes at the base of unit 16(1) locally contain mineral assemblages comparable to those of unit 13b of the underlying File Lake Formation. Garnet, fibrolitic sillimanite and rare staurolite occur in these greywackes. Metamorphic aggregates of fibrolitic sillimanite plus quartz (*faserkiesel*) are prominent in unit 16 northeast of Corley Lake and at the northern end of the northeast arm of File Lake. Their first appearance coincides approximately with the K-feldspar (melt)-sillimanite isograd noted in strata of the File Lake Formation.

Metasedimentary rocks of the Missi Group do not partially melt and form migmatites above the K-feldspar (melt)-sillimanite isograd, and do not melt at much higher metamorphic grades than are present in the File Lake area. The Missi Group paragneisses contain ample muscovite, quartz, plagioclase and microcline to have melted by reaction (16) (p. 73). The absence of partial melting may mean that these rocks were fairly dry and, consequently, could not melt until higher grades than their "wet" greywacke, siltstone and mudstone counterparts in the File Lake Formation. The formation of sillimanite-quartz metamorphic nodules in Missi Group metasedimentary rocks above the K-feldspar (melt)-sillimanite isograd may be due to the breakdown of muscovite in the presence of plagioclase and quartz, to sillimanite plus K-feldspar (reaction (15), p. 73). Although this seems to be a feasible explanation for the formation of these nodules, muscovite appears to remain stable above the K-feldspar (melt)-sillimanite isograd in many rocks of the Missi Group.

M₂ METAMORPHIC PARAGENESIS OF MAFIC ROCKS

Mafic extrusive and intrusive rocks of the File Lake area strike perpendicular to the M₂ metamorphic gradient. They grade from partially recrystallized rocks with greenschist facies mineral assemblages, south of File Lake and west of Morton Lake, to completely recrystallized rocks with upper almandine-amphibolite facies mineral assemblages, north of central File Lake and northwest of Corley Lake.

M₂ metamorphic mineral assemblages of mafic Amisk Group volcanic rocks and of concordant bodies of the Josland Lake Gabbro are briefly discussed in this section. These rocks do not show marked mineralogical and textural changes, with increasing metamorphic grade, as do Amisk Group metasedimentary rocks.

MAFIC METAVOLCANIC ROCKS

The metamorphic petrography of Amisk Group mafic metavolcanic rocks, south of File Lake, north of central File Lake and northwest of Corley Lake, is summarized here from a detailed description given by Currie (1947). Several samples of mafic volcanic rocks, for each of the areas described by Currie, were examined by the author; their assemblages are compatible with those identified by Currie.

Typical M₂ mineral assemblages of mafic metavolcanic rocks in unit 5, south of File Lake, are:

- actinolite + andesine + epidote; and
- green hornblende + andesine + epidote.

Clinopyroxene-bearing assemblages were also noted by Currie (1947), but it is likely that they are not M₂ assemblages and are from the thermal contact aureole adjacent to the Reed Lake pluton.

Typical M₂ mineral assemblages of mafic metavolcanic rocks of unit 14, north of Central File Lake are:

- actinolite amphibole + andesine + garnet;
- green hornblende + andesine; and
- blue-green hornblende + andesine + garnet + clinopyroxene (diopside).

Garnet is conspicuously absent in these rocks. They are granoblastic and fine grained.

The main changes in mafic Amisk volcanic rocks from the low grade terrane, south of File Lake, to the higher grade terrane, north of File Lake and northwest of Corley Lake, are, according to Currie (1947):

- 1) a deepening of colour, from green to deep blue-green, in the Z vibration direction of hornblende;
- 2) a slight increase in the An content of plagioclase from 26-30 to 36-42;
- 3) the addition of garnet (pyralspite variety) and clinopyroxene (diopside) to M₂ assemblages; and
- 4) granoblastic recrystallization accompanied by a slight coarsening.

JOSLAND LAKE GABBRO

West of File Lake, intrusions of the Josland Lake Gabbro strike perpendicular to the M₂ metamorphic isograds. The effects of M₂ metamorphism of the rocks of these intrusions is more pronounced than for the Amisk Group mafic metavolcanic rocks. A description of their variation with increasing metamorphic grade is given on p. 56 of this report.

Some of the typical changes that occur in rocks of the Josland Lake Gabbro with increasing M₂-metamorphic grade are:

- 1) a deepening of the colour in the Z vibration direction of tremolite-actinolite in rocks of unit 18(1) and its eventual replacement by dark-green hornblende;
- 2) the addition of garnet to rocks of units 18(1) and 18(3) and the addition of clinopyroxene to rocks of unit 18(1);
- 3) an increase in new M₂ plagioclase and coincident decrease in zoisite in rocks of unit 18(1); and
- 4) an increase in granoblastic recrystallization.

One of the interesting features of these rocks is that the An content of their M₂ plagioclase and the colour and composition of their M₂ amphiboles is controlled more by rock composition than it is by metamorphic grade. Another interesting feature is the retention of gabbroic textures in metamorphic derivatives. The latter occurs because metamorphic amphiboles pseudomorphically duplicate the grain size and orientation of the primary clinopyroxenes they replace. For example, with increasing metamorphic grade there was a grain by grain replacement of primary augite by tremolite in unit 18(1), followed by grain by grain replacement of tremolite by actinolitic amphibole and, finally, grain replacement of actinolitic amphibole by dark green hornblende. The implications of the aforementioned observations are:

- 1) plagioclase An content cannot be used to estimate grade of metamorphism of mafic orthogneisses;
- 2) amphibole type and colour can be used as an estimate of grade of metamorphism only in mafic rocks of identical composition; and

- 3) metagabbroic and metabasaltic orthogneisses can be identified in many metamorphic terranes as their primary textures are likely to be retained in metamorphic derivatives (unless recrystallization is accompanied by strong directed stresses). This means that under medium to upper almandine-amphibolite facies conditions of metamorphism a gabbroic textured amphibolite is not likely to be derived from a fine grained basalt (or vice versa).

INFERRED P-T CONDITIONS OF M₂ METAMORPHISM

Considerable data is available today on metamorphic reactions and the chemical composition of metamorphic minerals in pelitic schists. This information makes it possible to establish

chemographic relations and construct petrogenetic grids using techniques developed by Schreinemaker (1965) and summarized by Zen (1966). A calibrated petrogenetic grid has been constructed by Carmichael (pers. comm., 1978) using a combination of experimental and field data. The discontinuous metamorphic reactions observed in the File Lake Formation on the erosion surfaces of the File Lake area (this study) and in the Snow Lake area (Froese and Moore, 1980) are shown on a slightly modified version of Carmichael's petrogenetic grid (Fig. 93). Reactions involving hornblende and cummingtonite are not shown.

The metamorphic reactions on the File Lake erosion surface indicate metamorphic temperatures ranged from 400 to 500°C in the chlorite-biotite zone to about 625 to 675°C in the K-feldspar (melt)-sillimanite zone. The pressure, based on formation of sillimanite by the reaction

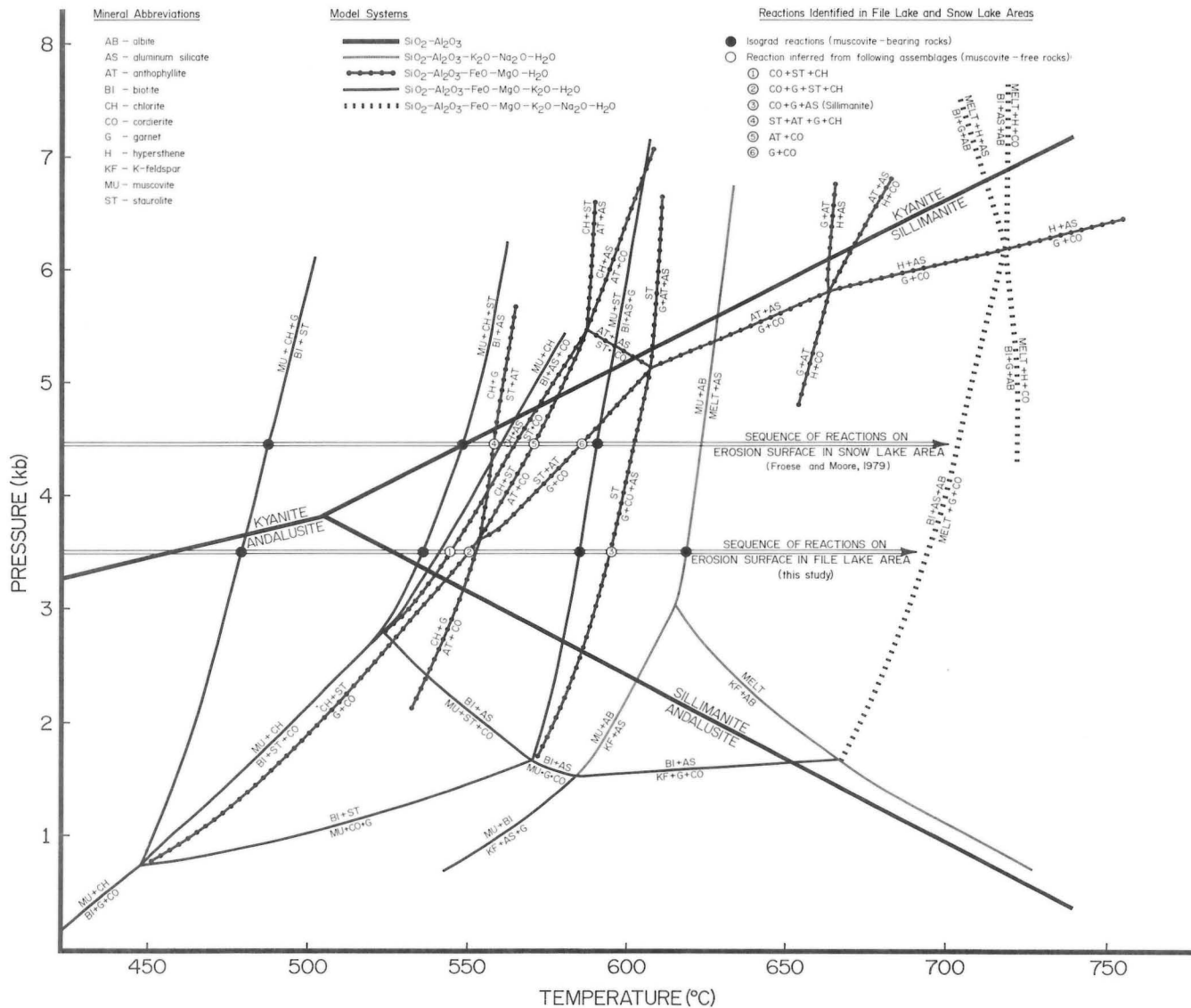
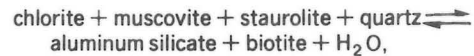
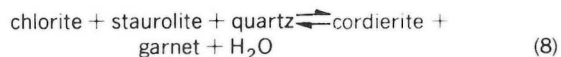


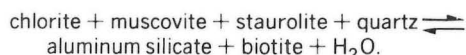
FIGURE 93: Calibrated petrogenetic grid from Hess (1969) and Carmichael (pers. comm., 1978) showing metamorphic reactions identified in Amisk Group metasedimentary rocks of the File Lake and Snow Lake areas.

is inferred to have been above 3.3 kb, but below 3.7 kb because the reaction



is intersected. These pressure and temperature values are only approximate because the locations of the reaction curves in Figure 93 are not known precisely and are effected by such parameters as $\mu\text{H}_2\text{O}$, μO and mineral compositions, in addition to P and T.

The sequence of reactions identified in the Snow Lake area (Froese and Moore, 1980) indicates that slightly higher pressures prevailed than in the File Lake area. The pressure was probably close to 4.5 kb because both kyanite and sillimanite were formed by the reaction



Metamorphic pressure estimated from sphalerite compositions in Snow Lake ore deposits (Bristol, 1974; Scott, 1976) are in the 6 to 8.5 kb range. However, these pressures may be due to low temperature re-equilibration of sphalerite during conversion of adjacent hexagonal pyrrhotite to monoclinic pyrrhotite; this feature has been observed in sphalerites from the Ruttan Lake Mine (Bristol, 1979).

The 3.5 kb and 4.5 kb pressures at the sillimanite-biotite-isograd (550°C) in the File Lake and Snow Lake areas indicate depths of burial of 12.25 km and 15.75 km, respectively, assuming an average rock density of 2.85 (3.5 km = 1 kb). The vertical geothermal gradients indicated by these depths of burial are 45°C/km at File Lake and 35°C/km at Snow Lake.

The temperature increase on the erosion surface in the File Lake area is 150°C from the staurolite-biotite to the K-feldspar (melt)-sillimanite isograd, a distance of 7 km. This is a horizontal gradient of 21°C/km.

METAMORPHIC CHARACTER OF THE BOUNDARY BETWEEN THE FLIN FLON AND KISSEYNEW BELTS

The M_2 metamorphic isograd reactions and zones identified in the File Lake Formation are part of a steep metamorphic gradient which is regionally coincident with the boundary between the Flin Flon and Kisseynew belts. In detail, however, the metamorphic gradient locally cuts across the boundary and was imposed late in the tectonic history of the Flin Flon and Kisseynew belts.

The metamorphic gradient could reflect late updoming of more deeply buried and hence highly metamorphosed strata in the Kisseynew belt. However, such extensive updoming is unlikely because the metamorphic gradient of 21°C/km in the File Lake area is too steep. If it is due solely to differences in depth of burial, strata in the central part of the File Lake area would have to be tilted about 45° to the south, and this amount of uplift is not consistent with the structural history of the area.

The metamorphic gradient could reflect higher heat flow in the Kisseynew belt than in the Flin Flon belt. The different geothermal gradients in the File Lake and Snow Lake areas, 45°C/km and 34°C/km, respectively, indicate that significant heat flow differences did exist, favouring this interpretation.

Higher heat flow in the Kisseynew belt than in the Flin Flon belt could have resulted from several mechanisms: 1) concentration of lithophile and radiogenic elements in the Kisseynew belt and higher heat flow from their radioactive decay; 2) rising flow in a mantle convection cell under the Kisseynew belt; or 3) higher thermal conductivity of sedimentary rocks relative to volcanic rocks. Differences in ability of sedimentary and volcanic rocks to conduct heat could have occurred if heat consumed by metamorphic reactions was greater in volcanic than in sedimentary rocks (L. Ayres, pers. comm., 1978). Lower ability to conduct heat would mean that volcanic rocks of the Flin Flon belt could have acted as an insulator preventing upward movement of heat. This mechanism could explain why Precambrian volcanic belts are invariably much lower grade than associated sedimentary belts, without the need to involve special tectonic conditions.

The supracrustal rocks of the File Lake area have been effected by several episodes of deformation and have been shouldered aside during the emplacement of large plutons of tonalite, granodiorite and granite. The most intense deformation occurred during high grade M_2 regional metamorphism and the overlapping episode of felsic plutonism. Many fold structures are geometrically disharmonious and some appear to have involved gravity reversal phenomena whereby low density rocks have diapirically intruded overlying higher density strata. Complex interference fold structures are common.

Four episodes of deformation have been recognized. Their main features are summarized and correlated with major metamorphic events in Table 17. All the recognized deformational events postdate Missi Group strata and are considered to be late Apebian to, perhaps, early Paleohelikian in age. The distribution of major folds, and their relative ages, are shown on Figure 94 (in pocket). Structural cross-sections of some of the major fold structures are shown on Figure 95 (in pocket).

One of the most important conclusions of this structural analysis of the File Lake area is that there was an early episode of recumbent folding which locally caused major inversions and repetitions of the stratigraphic succession. These early recumbent folds have been previously recognized or postulated to occur elsewhere in the Kiseynew belt by Pollock (1965, p. 31), Schledewitz (1972, p. 39), Elphick (1972) and Lenton (pers. comm., 1978). Lenton has demonstrated that these structures are probably very large as sedimentary facies on the upright and overturned limbs of a fold in the McCallum-McKnight area are very different. This study demonstrates that equivalent fold structures in the File Lake area were recumbent, and not simply isoclinal.

DESCRIPTION OF DEFORMATIONAL EVENTS

D_1 : RECUMBENT FOLDS

Tight isoclinal folds (Figs. 96 and 97) are the oldest recognized structures. They fold the primary sedimentary layering, S_0 , and have an axial planar schistosity, S_1 , which is generally parallel to S_0 on fold limbs. S_1 cross-cuts the layering in the nose of minor F_1 folds (Fig. 98), and this also occurs on large-scale folds, for example in the hinge area of the F_1 Hyde Island syncline (Fig. 94) on southwest File Lake. It is not known whether the S_1 schistosity was imposed during the F_1 folding or whether it was imposed later, perhaps during subsequent flattening of the folds.

The S_1 surface is a plane of flattening as well as a schistosity, and in it the long axes of deformed fragments and clasts parallel the F_1 fold axes. The schistosity is defined by M_1 greenschist facies phyllosilicate minerals, indicating that low temperature prevailed during D_1 deformation. The phyllosilicate minerals are much more strongly aligned in the vertical than in the horizontal directions. S_1 is the most prominent anisotropy in rocks of the File Lake area. It records and controls all subsequent deformational events.

Major F_1 folds are recognized in sedimentary rocks of the File Lake Formation by reversals in top facing directions. However, a scarcity of both major and minor F_1 fold closures prevents positive identification of these folds as either antiformal or synformal. For example, in the case of an F_1 anticline, if the plunge of the fold axis or the direction of convergence of its limbs cannot be identified, it is not possible to determine whether the fold is an antiformal anticline or a synformal anticline. Steep south plunging fold axes have been

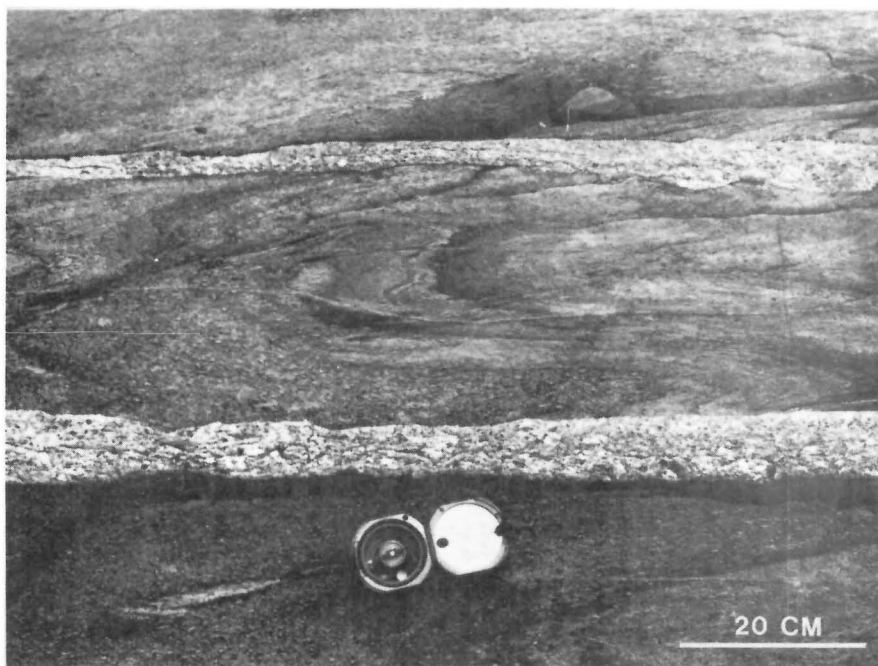


FIGURE 96: Tight isoclinal similar F_1 -folds, with axial planar veins of granodiorite, in File Lake Formation rocks at north end of northeast arm of File Lake.

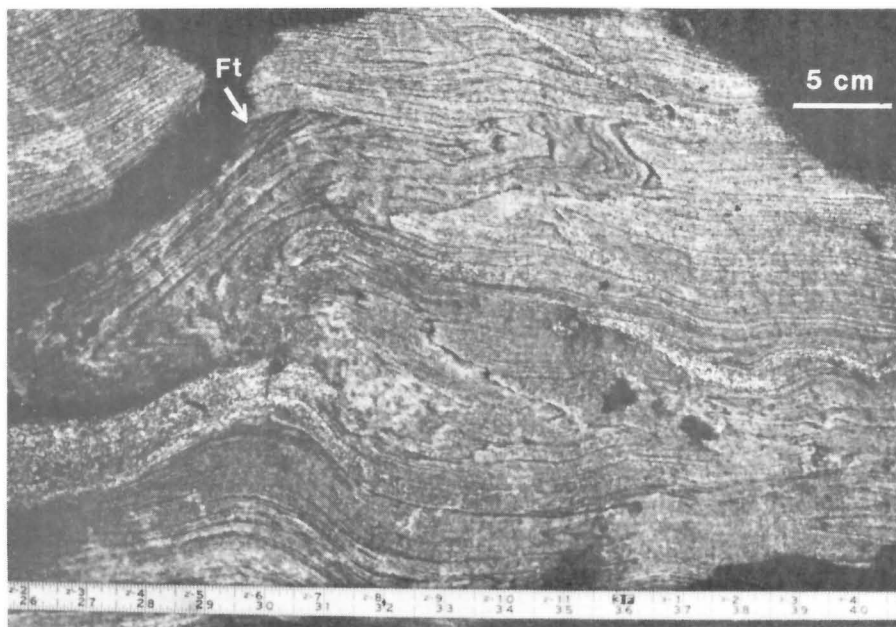
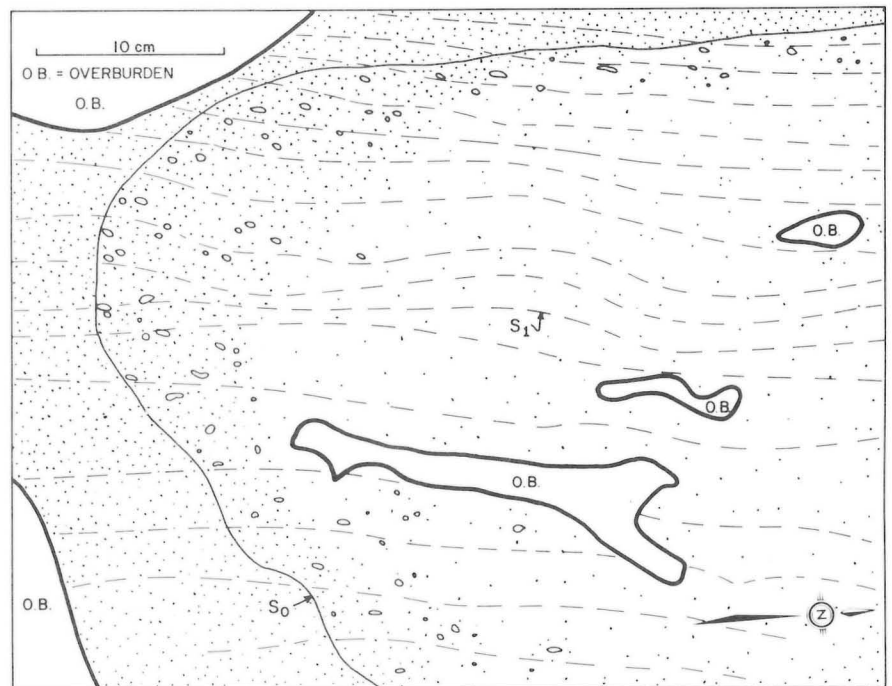


FIGURE 97: Tight isoclinal F_1 -folds in Missi Group rocks west of Ellice Bay, File Lake. Note axial planar fault (Ft).

FIGURE 98: Sketch of F_1 fold-hinge showing traces of axial planar S_1 schistosity.



identified on the F_1 Hyde Island syncline, on southwest File Lake, and on the F_1 Morton Lake syncline, on north Morton Lake. The refolded Podruski Lake anticline (Figs. 94 and 95, in pocket) appears to have a subhorizontal fold axis.

The F_1 folds deform Missi Group rocks (Fig. 97) and early intrusions of the Josland Lake Gabbro. They are postdated by a second group of intrusions of the Josland Lake Gabbro. The latter intrusions are axial planar to the F_1 folds (Fig. 95) and are fractionally differentiated, suggesting that the F_1 folds were recumbent during emplacement and crystallization of these intrusions. Felsic plutons of units 20 to 24 cut across major F_1 fold structures and contain numerous S_1 foliated inclusions. The S_1 schistosity was annealed

during M_2 recrystallization and has been statically overprinted by M_2 porphyroblasts. M_2 isograd reaction surfaces cut across major F_1 folds.

D₂: NNE-TRENDING OPEN FOLDS

North-northeast-trending open fold structures, F_2 , are common in the adjacent Snow Lake area (Froese and Moore, 1980) and to the northeast in the Guay-Wimapedi Lakes area (Bailes, 1975). In the File Lake area, this folding event is represented by the File Lake synform, a structure which buckles the contact between the largely

metavolcanic rocks of the Flin Flon belt and the metasedimentary rocks of the Kiseynew belt (Fig. 94, in pocket).

The File Lake synform is a large open flexural fold, 6 km from its east to west limb. On the south shore of File Lake, it is overturned and plunges steeply to the south. North of File Lake, it is a steep-sided triangular synformal basin.

The File Lake synform folds intrusions of the Josland Lake Gabbro and major F_1 folds, such as the Hyde Island syncline (Fig. 94). M_2 isograd reaction surfaces and porphyroblasts are undeformed by and, therefore, postdate the File Lake synform. Emplacement of the large felsic plutons of units 20 to 24 appears to have been syn- to late- D_2 . Two of them, the Ham Lake and Norris Lake plutons, intrude along F_2 antiforms. The forceful emplacement of these intrusions may have contributed to formation of the F_2 folds. However, in the case of the Ham Lake pluton, the folding apparently outlasted crystallization of the pluton, which has been F_2 flattened and S_2 foliated. The S_2 foliation is defined by flattened, crushed and annealed grains of quartz and plagioclase. On Corley Lake, the west limb of the File Lake synform is cross-folded by east-trending F_3 folds.

The File Lake fold is considered to be equivalent in age to the Threehouse synform of the adjacent Snow Lake area. According to Froese and Moore (1980), the Threehouse synform is coaxial with earlier isoclinal F_1 folds. The F_1 Hyde Island syncline and the F_2 File Lake synform are coaxial on the southwest shore of File Lake.

D_3 : E-TRENDING FLEXURAL FOLDS

East-trending flexural, commonly chevron-shaped folds, F_3 , occur prominently in the northwest corner of the map-area (Figs. 99 and 100). They plunge at shallow to moderate angles to the east. They contort S_1 schistosity surfaces and kink the west limb of the F_2 File

Lake synform. They have a steep-dipping axial planar schistosity, S_3 , defined by large plates of biotite. The S_3 biotite commonly co-exists with M_2 minerals and this suggests that the F_3 folding may have overlapped the waning stage of the M_2 metamorphic recrystallization event. However, a post- M_2 age for the F_3 folds is indicated by axial planar flattening of M_2 quartz-sillimanite nodules in F_3 fold structures east of Corley Lake; the long axes of the deformed nodules are parallel to the F_3 fold axes. A post- M_2 age for F_3 folds is also indicated by F_3 folding of M_2 -generated veins of granitic mobilizate north of Corley Lake.

F_3 folds change from south to north. In the south half of the map-area, they are brittle, relatively insignificant structures, such as the Yakymiw Lake synform and antiform (Fig. 94). These folds are kink- and chevron-shaped and typically have an axial planar strain slip cleavage. In the north half of the map-area, F_3 folds are larger, flexural to quasi-flexural and have an axial planar biotite foliation, S_3 . The S_3 biotite foliation is most pronounced in the folds east of Corley Lake. To the south of Corley Lake, this foliation decreases in intensity and, like the axial planes of minor F_3 folds, it trends northeast.

The northerly increase in intensity and ductility of F_3 folding, noted in the File Lake area, continues to the north. In the Guay-Wimapedi Lakes area and in other areas to the north, the F_3 folds define a prominent east-trending structural grain (Bailes, 1975). In the Guay-Wimapedi Lakes area, many of the F_3 antiforms are invaded by syn- M_2 masses of granitic mobilizate. Bailes (1975) has suggested that the northerly change in the style of D_3 deformation is because this deformational event occurred as the M_2 metamorphic episode was on the wane and after its high grade thermal front had receded to the north of the File Lake map-area.

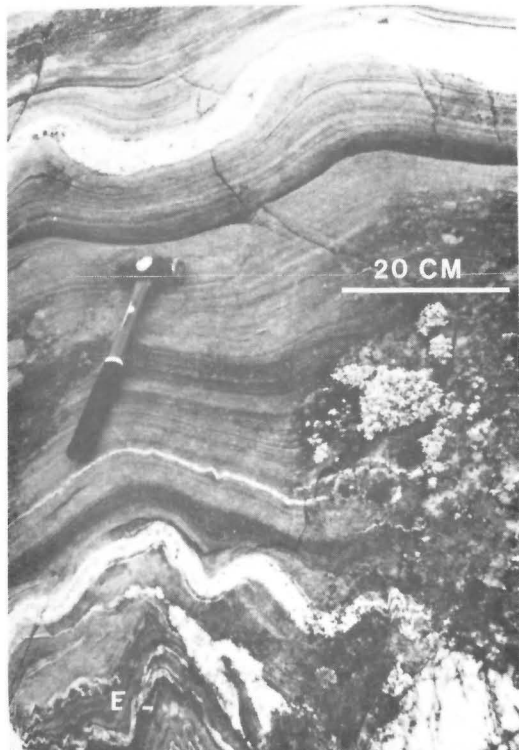


FIGURE 99: Concentric, open, flexural F_3 -folds in Missi Group rocks south of Corley Lake.

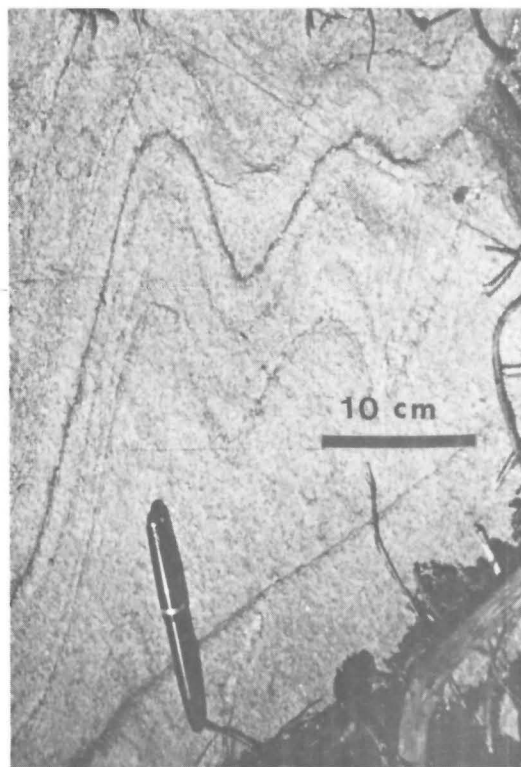


FIGURE 100: F_3 -folds defined by biotite-rich layers in Missi Group rocks, west shore of Ellice Bay. Biotite is aligned axial planar to F_3 -folds.

D₄: LATE FRACTURES, FAULTS AND SHEAR ZONES

Late fractures, faults and shear zones, which contain M₃ greenschist facies mineral assemblages, comprise the fourth deformational event, D₄. The D₄ structures cut across and, hence, postdate all other structural elements and rock units, except pegmatites of unit 28 which are intruded along D₄ structures.

The joint pattern in the Barron Lake pluton (unit 24) is considered to be typical of rocks of the File Lake area. Two main joint sets are recognized (Fig. 101a). Both sets dip vertically. One set strikes at 50° and the other at 315°. These sets of joints are identical to joint sets from a much larger sampling of joints measured in rocks of the adjacent Guay-Wimapedi Lakes area (Fig. 101b).

Two major north-trending D₄ fault and shear zone structures occur in the File Lake area. One follows the northeast shore of Morton Lake, extends north of Ducharme Bay and then swings to the northeast to the north edge of the map-area. A second D₄ fault zone follows the west shore of Woosey Lake and extends an undetermined distance to the north. Both fault structures have minor left lateral offsets. The fault along the east shore of Morton Lake cross-cuts and offsets F₃ fold structures north of Corley Lake. The Woosey Lake fault structure offsets the Reed Lake pluton and cataclastically crushes rocks on the southeast margin of the Barron Lake pluton. Two small east-trending D₄ cataclastic fault structures cut the Josland Lake Gabbro northeast of Storozuk Lake.

Many of the rocks along the south shore of File Lake and along the west shore of Ducharme Bay are strongly sheared. Low grade greenschist facies mineral assemblages are localized in these shear zones. Harrison (1949, 1951) interpreted this shearing to be related to a major fault structure, the Kisseynew lineament, which he considered to regionally follow the contact between the Flin Flon and Kisseynew belts. However, there is no evidence, in the File Lake area, to suggest that there is a major structural discontinuity, along the

south shore of File Lake. Rather, the shearing appears to be due to local adjustments, possibly during D₄, between the more competent volcanic-intrusive rocks and the adjacent less competent metasedimentary rocks.

DESCRIPTION OF SELECTED STRUCTURES

In the previous section some of the general features of each of the deformational events have been summarized. In this section, some of the specific features of individual structures are more fully documented and discussed.

HYDE ISLAND SYNCLINE

The Hyde Island syncline is an isoclinal F₁ fold which is broadly folded by the F₂ File Lake synform. Poles to S₀ surfaces (bedding), poles to average S₁ schistosity surfaces, S₁/S₀ intersections, minor F₁ fold axes and axial surfaces, and long axes of deformed detrital clasts are plotted from four structural subareas, H1, H2, H3 and H4, on Figure 102. In each subarea, the Hyde Island syncline is relatively unmodified by subsequent folding events and, therefore, the orientation of S surfaces and other structural fabrics in them are presumed to be largely the consequence of the F₁ (D₁) deformation.

On southwest File Lake, in subareas H1 and H2, the nose of the Hyde Island syncline is exposed and partially defined by S₀ bedding surfaces. In this area, axial planar S₁ schistositities cut across the S₀ surfaces. A statistical measure of the F₁ fold axis is given by intersections of the S₁ and S₀ surfaces (S₁/S₀), from individual localities, and by intersections of S₀ surfaces (β points) (Figs. 102a and 102b). They indicate that the Hyde Island synform plunges steeply to the south. Measured axes of minor folds also plunge steeply to the south.

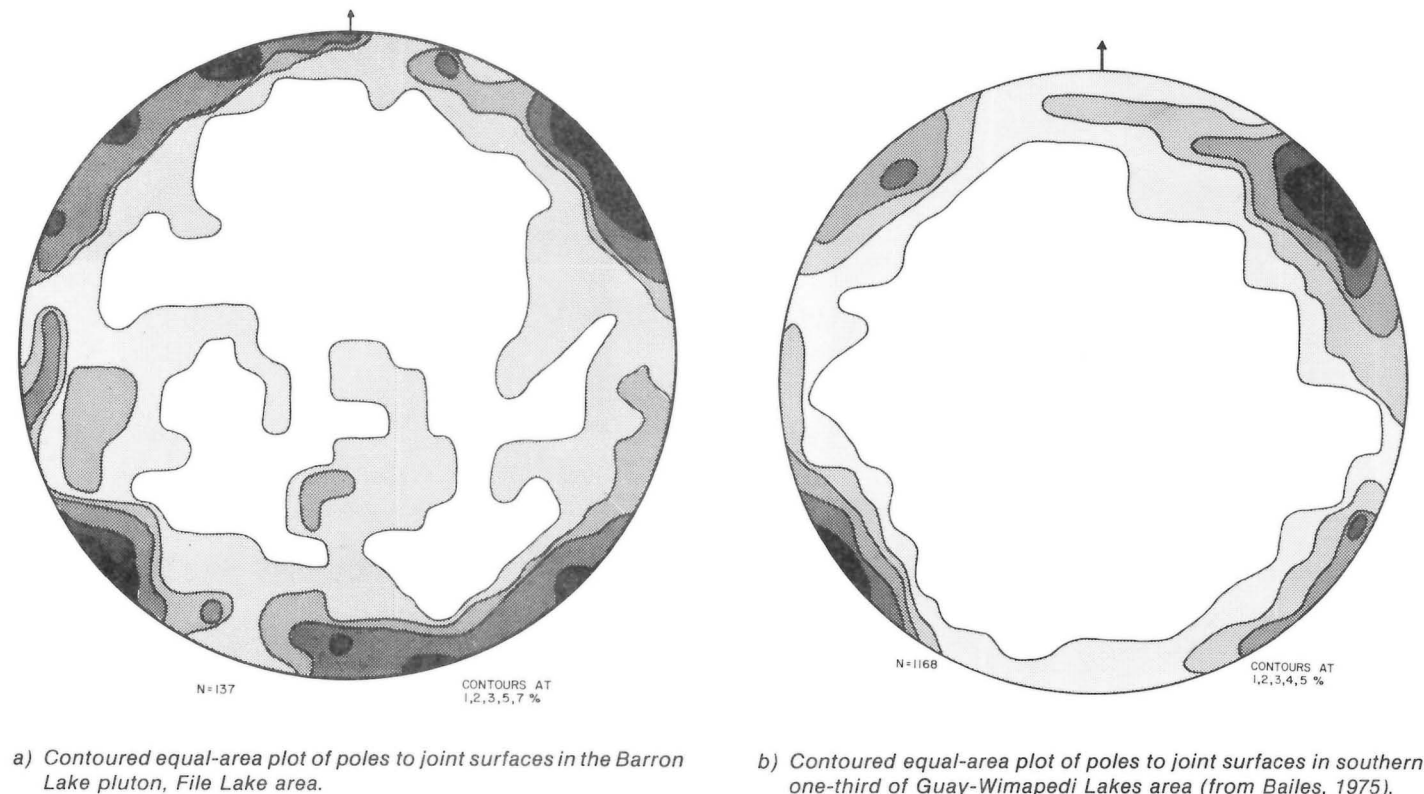
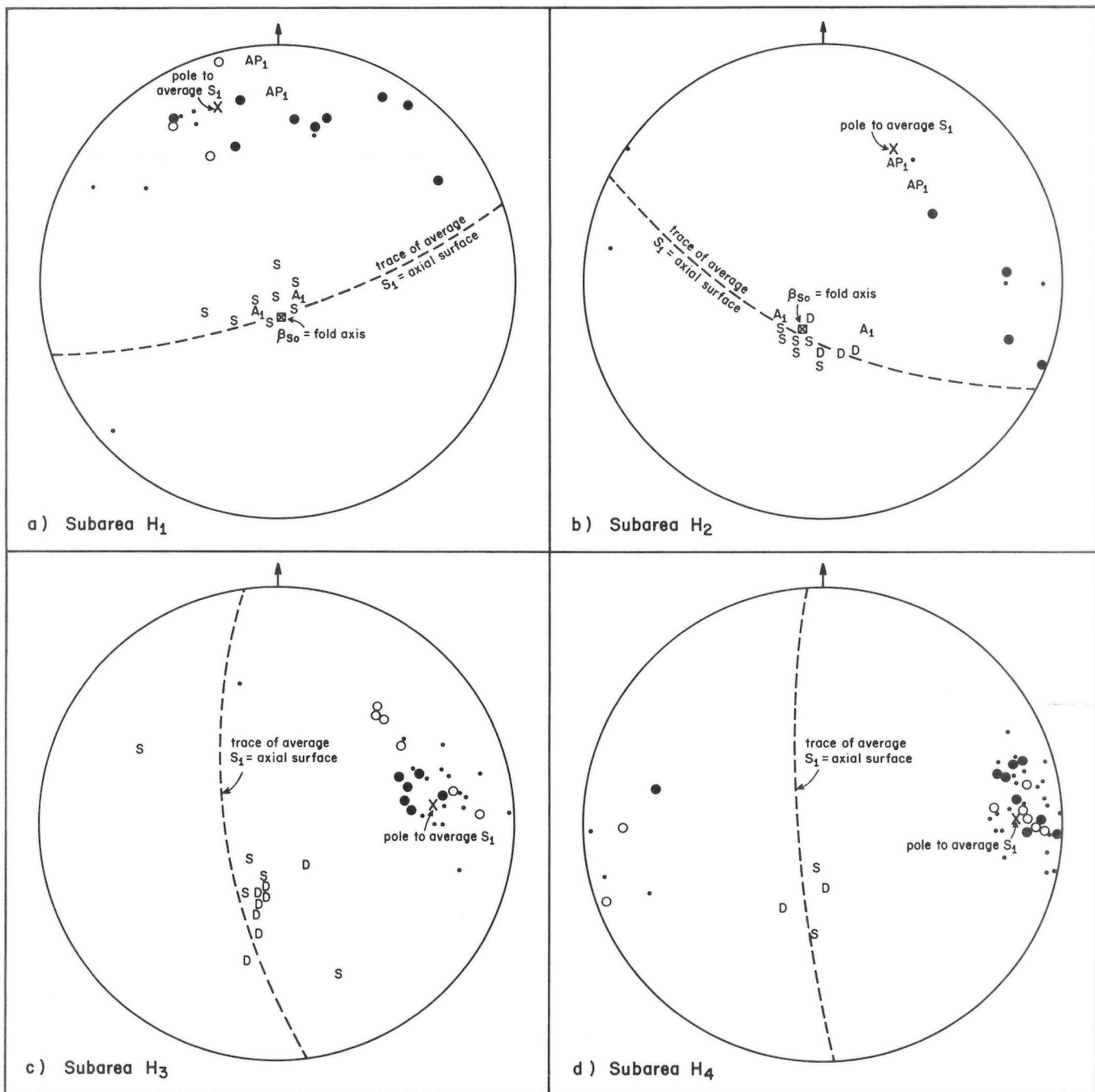


FIGURE 101: Lower hemisphere stereographic plot of D₄ joint surfaces in Barron Lake pluton compared to plot of joint surfaces from adjacent Guay-Wimapedi Lakes area.



- pole to S₀ surface (facing indeterminate)
- pole to upright S₀ surface
- pole to overturned S₀ surface

- S S₁/S₀ intersection
- D long axis of deformed clast
- AP₁ pole to F₁ axial surface
- A₁ F₁ fold axis

FIGURE 102: Lower hemisphere stereographic plots of structural fabric elements of the F₁ Hyde Island Syncline (subareas H1, H2, H3 and H4).

West and northwest of File Lake, in subareas H3 and H4, no F_1 hinge zones are exposed and S_0 and S_1 surfaces are parallel. The absence of F_1 hinge zones and the parallelism of the S_0 and S_1 surfaces suggest that, in these areas, the fold axis of the Hyde Island syncline may be subhorizontal. In these subareas there is insufficient data to determine whether the syncline is synformal or antiformal. This is because poles to S_0 bedding surfaces, both upright and overturned, all plot in a single cluster in lower hemisphere stereoplots (Fig. 102d). This is a consequence of the very tight isoclinal character of the syncline, a fact corroborated by the parallelism of S_0 and S_1 surfaces. There is a slight angle between poles to overturned and upright bedding surfaces in subarea H3 (Fig. 102c), with steeper dips recorded on overturned beds. This suggests that the syncline may be synformal.

The long axes of deformed detrital clasts in subarea H2 are parallel to F_1 fold axes and are slightly flattened in S_1 . However, they also parallel the F_2 axes of the File Lake synform (Fig. 102b), so it is not known if this deformation is a D_1 or D_2 phenomenon. It is possible that it is due to a combination of both events. Mica minerals are more strongly aligned vertically than they are horizontally, a feature which may be linked to the strong vertical elongation of deformed clasts in S_1 surfaces.

Microscopically, S_1 surfaces in the Hyde Lake syncline are defined by small plates of biotite. Large randomly oriented M_2 porphyroblasts of garnet, staurolite, biotite and actinolite overprint the S_1 schistosity and show that the M_2 metamorphism is post- D_1 and has been statically imposed on D_1 structures. Megascopically, this same relationship is evident from the regional overprint of the Hyde Island syncline by cross-cutting and unfolded east-trending M_2 isograd reaction surfaces.

MORTON LAKE SYNCLINE

The Morton Lake syncline is an open north-trending F_1 fold which is well defined by S_0 bedding surfaces in turbidite greywacke, siltstone and mudstone strata of unit 13. Small-scale structural fabrics from subareas M1 and M2 (Fig. 94), that include poles to S_0 bedding surfaces, poles to S_1 schistosity surfaces, π axes to S_0 surfaces (i.e. F_1 fold axes), minor F_3 fold axes and axial surfaces, poles to S_3 strain slip cleavages, and long axes of deformed detrital clasts, are plotted on Figure 103. At north Morton Lake, in subarea M1, the Morton Lake syncline is a steep south-plunging open synform (Fig. 103a) which is broadly cross-folded west of Elmes Island by the north-east-trending F_3 Yakymiw Lake synform and antiform pair (Figure 94). On south Morton Lake, in subarea M2, it is a tight fold with strata on its west limb facing and dipping steeply to the east and those on its east limb facing and dipping steeply to the west (Fig. 103b).

In subarea M1, the poles to S_0 bedding surfaces define a great circle (π girdle). The axis of this great circle (π axis) is a statistical measure of the fold axis. S_1 schistosity surfaces are axial planar, but they are not as prominent nor as well developed as in the F_1 Hyde Island syncline. The S_1 foliations are north-trending with steep, but variable dips. Intersections of the S_1 and S_0 surfaces (S_1/S_0 intersections), like the π axis of S_0 surfaces, indicate that the syncline plunges steeply to the south. Deformed clasts are slightly flattened in S_1 and are strongly elongated parallel to the F_1 axis, a feature the Morton Lake syncline has in common with other F_1 folds. In addition, the mica minerals defining S_1 are only weakly aligned on horizontal surfaces whereas they are strongly aligned on vertical surfaces.

The Morton Lake syncline is deformed by east-trending F_3 folds into major basin and col structures. Small-scale east-trending flexural F_3 folds, S_3 strain slip cleavages and S_3 biotite schistosity surfaces, related to the major F_3 folds, are shown on Figure 103c. North facing S_0 bedding surfaces in the southern part of subarea M1 are a consequence of the F_3 folding and indicate that the F_1 fold axis is tightly folded and plunges steeply to the north in the southern part of subarea M1.

PODRUSKI LAKE AND DUCHARME BAY ANTICLINES

The Podruski Lake and Ducharme Bay folds are tight F_1 structures. Megascopic fabrics, such as S_0 bedding surfaces, S_1 schistosity surfaces and minor fold axes, are not abundant in either structure and do not provide enough data to define the geometry of the folds. However, it is likely that both are anticlinal because they are separated by the F_1 Morton Lake syncline (see previous section). The anticlinal character of these folds is supported by facing directions in fractionally differentiated gabbro intrusions (unit 18) that they deform; the late fractionates (unit 18(3)a) of these intrusions occur on the outside of the fold structures. Limited facing directions in host volcanic and sedimentary rocks are also consistent with these folds being anticlines. The gabbro units, which the Podruski Lake and Ducharme Bay anticlines fold, are considered to be part of a single large pre- F_1 gabbro sill (see cross-sections A-A' and B-B' in Fig. 95). The thin unit of 18(1) on the top of both sills is unique to these bodies and supports this correlation.

The Podruski Lake anticline is intruded by a post- F_1 gabbro intrusion (unit 18(1)b) north of Norris Lake and its east and west limbs have also been intruded by post- F_1 gabbros of unit 18; all the post- F_1 intrusions face west and are unfolded. The Podruski Lake anticline and the post- F_1 gabbro bodies are intruded by the Norris Lake pluton (unit 23). Domal interference structures occur on both the Podruski Lake and Ducharme Bay fold structures and are probably related to cross-folding by east-trending F_3 fold structures. Visible megascopic expressions of the east-trending F_3 folds are absent from the host volcanic and sedimentary strata.

FILE LAKE SYNFORM ON SOUTHWEST FILE LAKE

The File Lake synform is a major north-northeast-trending F_2 structure which broadly folds the metavolcanic and metasedimentary strata at File Lake. At the southwest shore of File Lake, its fold axis is overturned so that it locally becomes antiformal.

The main features of the overturned southern part of the File Lake synform are evident from plots of S_0 bedding surfaces, S_1 schistosity surfaces, F_1 fold axes, and long axes of deformed clasts from subareas H1, H2, H3 and H4 (Fig. 104). Poles to S_0 and S_1 surfaces at southwest File Lake (Figs. 104a and 104b) plot on a great circle (π circle) and indicate that the fold has an open cylindrical shape. The π axis to poles to S_1 surfaces plunges steeply to the south-southwest and is a statistical measurement of the F_2 fold axis. The F_2 π axis in subareas H1 and H2 is approximately coincident with minor F_1 fold axes and with statistical measurements (β_{S_0} axes and S_1/S_0 intersections) of the F_1 fold axis (Fig. 104c). Thus, the F_1 and F_2 fold axes are colinear in subareas H1 and H2. The long axes of deformed clasts are coincident with the F_1 and F_2 fold axes in subareas H1 and H2.

The colinearity of F_1 and F_2 fold axes is a feature which may be regionally significant because Froese and Moore (1980) have also noted colinearity of axes of F_1 and F_2 folds in the Snow Lake area, 15 km east of File Lake. In the File Lake area, the implications of this are important. For example, the F_1 Ducharme Bay anticline plunges steeply, south of Hyde Island, whereas it is a doubly-plunging inverted canoe-shaped structure, northwest of File Lake, and must have a subhorizontal fold axis. This implies that the axis of the F_2 File Lake synform should also be subhorizontal north of File Lake.

NELSON BAY ANTIFORM

The Nelson Bay antiform is a doubly-plunging open antiform cored by granitoid quartzo-feldspathic orthogneisses of units 25 and 26 (Fig. 94). The age of the fold is uncertain, but it may be an F_2 structure modified by syn- M_2 gravity-induced upward movement of the low density orthogneisses of unit 26 (see pages 97 to 99).

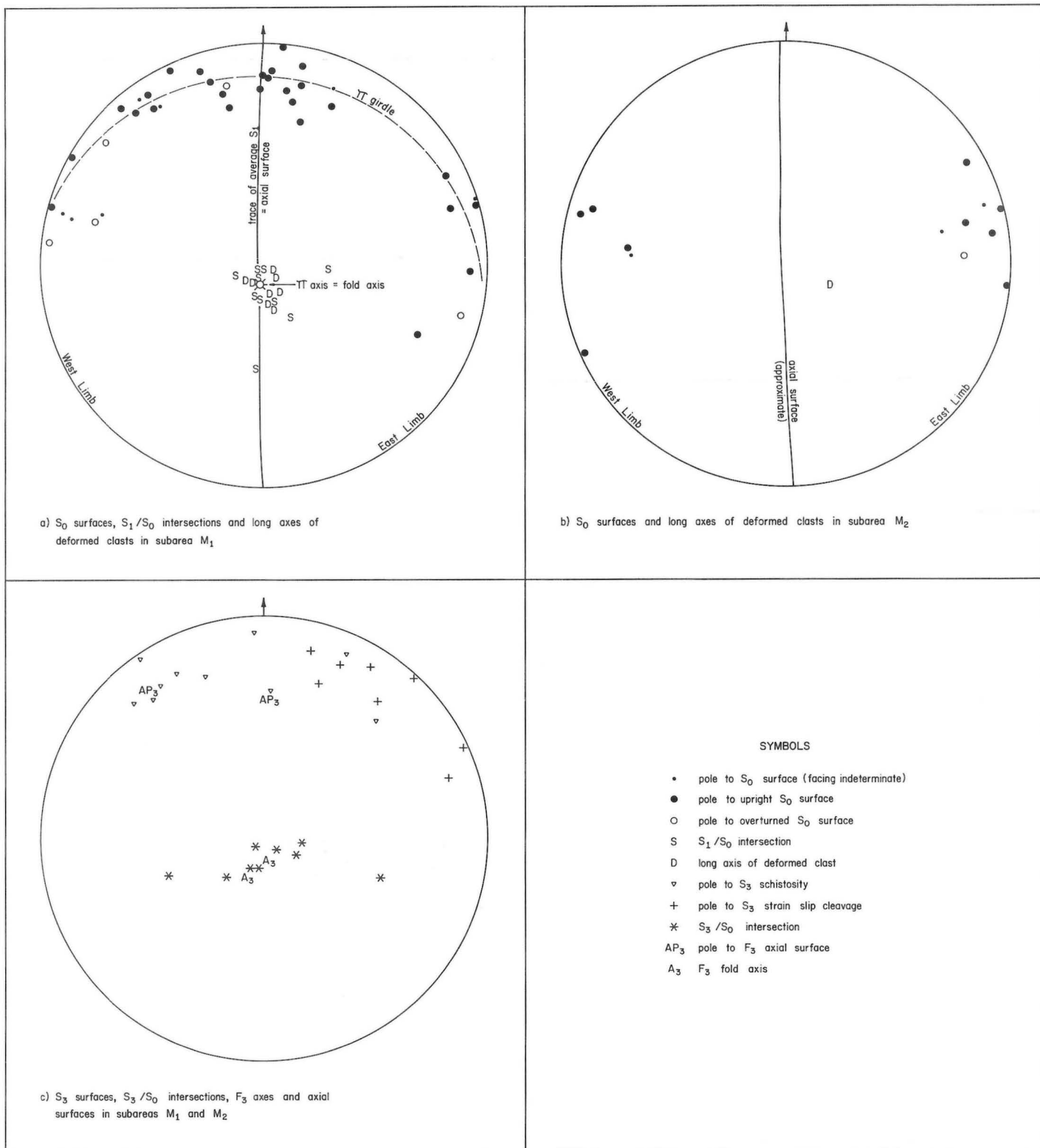


FIGURE 103: Lower hemisphere stereographic plots of structural fabric elements of the F_1 Morton Lake Syncline (subareas M_1 and M_2).

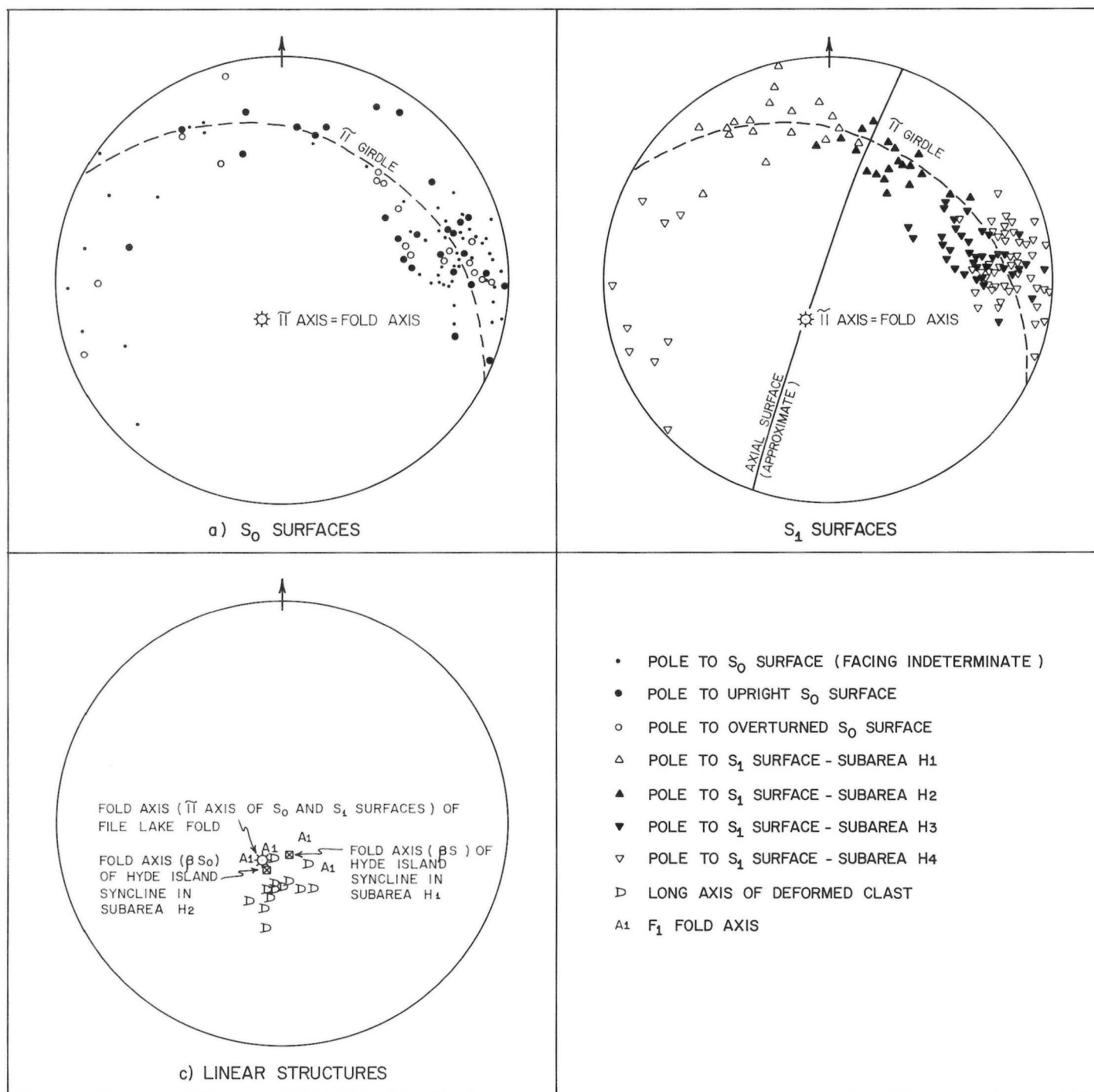


FIGURE 104: Lower hemisphere stereographic plots of structural fabric elements of the F_2 File Lake Synform (combined data from subareas H1, H2, H3 and H4).

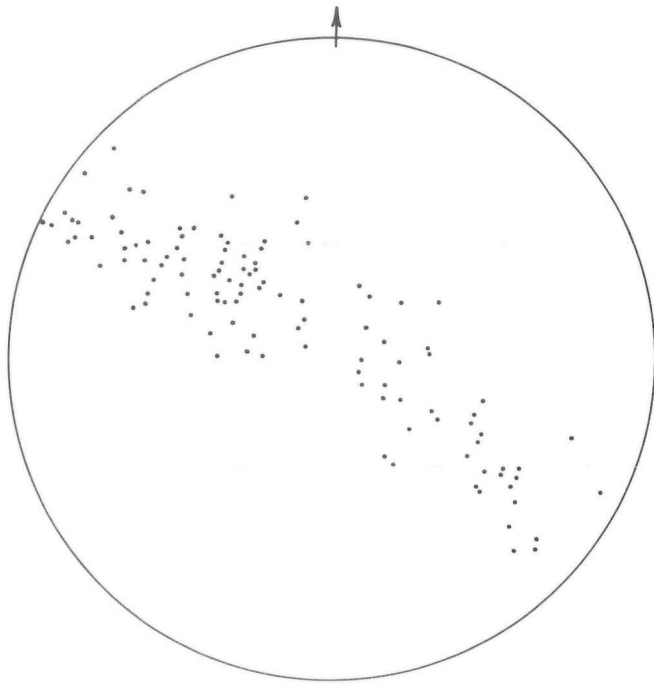


FIGURE 105: Lower hemisphere stereographic plot of poles to foliation (in units 25 and 26) for the Nelson Bay Antiform (subarea N).

A gneissic foliation is the main structural fabric in rocks of unit 26. This gneissic foliation defines the shape of the File Lake antiform. Poles to the gneissic foliation are shown in the lower hemisphere stereographic projection in Figure 105. Airphoto lineaments (Fig. 106) are prominent in rocks of unit 26 and are parallel to the gneissic foliation recorded in individual outcrop exposures. Microscopically the gneissic foliation is defined by aligned flattened grains of quartz and feldspar, and by aligned crystals of biotite. The gneissosity resembles a recrystallized cataclastic foliation. It is possible that this 'pseudo-cataclastic' fabric is a recrystallized fluidal layering, since rocks of unit 26 may be recrystallized ash flows (see pages 64 to 66). Thus the gneissosity may be recrystallized original layering and need not be an imposed fabric, such as an S_1 surface.

The significance of the interference structure between rocks of units 25 and 26 north of Gates Lake is uncertain. It may be caused by an early east-northeast-trending fold structure which has been folded by the Nelson Bay antiform.

The southern end of the Nelson Bay antiform is obscured by File Lake. It is not known whether the Nelson Bay antiform continues to the south as a significant structure or whether it dies out.

ELLICE BAY, CORLEY LAKE AND MACHUCA LAKE FOLDS

The Ellice Bay synform, Corley Lake antiform and Machuca Lake synform are major east-trending F_3 folds. They have near-vertical axial surfaces and plunge moderately to the east. They have an axial planar biotite schistosity, S_3 , and have numerous related minor folds (Fig. 100). The F_3 folds contort the original S_0 layering and S_1 biotite schistosity. M_2 porphyroblasts of garnet are rotated and crushed in F_3 structures, and M_2 metamorphic aggregates of quartz and sillimanite (*faserkiesel*) are flattened in the axial surface of minor F_3 folds and elongated parallel to their fold axes. M_2 generated veins of anatectic mobilizate are folded by F_3 folds (Fig. 99).



FIGURE 106: Aerial view of Nelson Bay Gneiss Dome. Airphoto lineaments are parallel to gneissic fabric of dome.

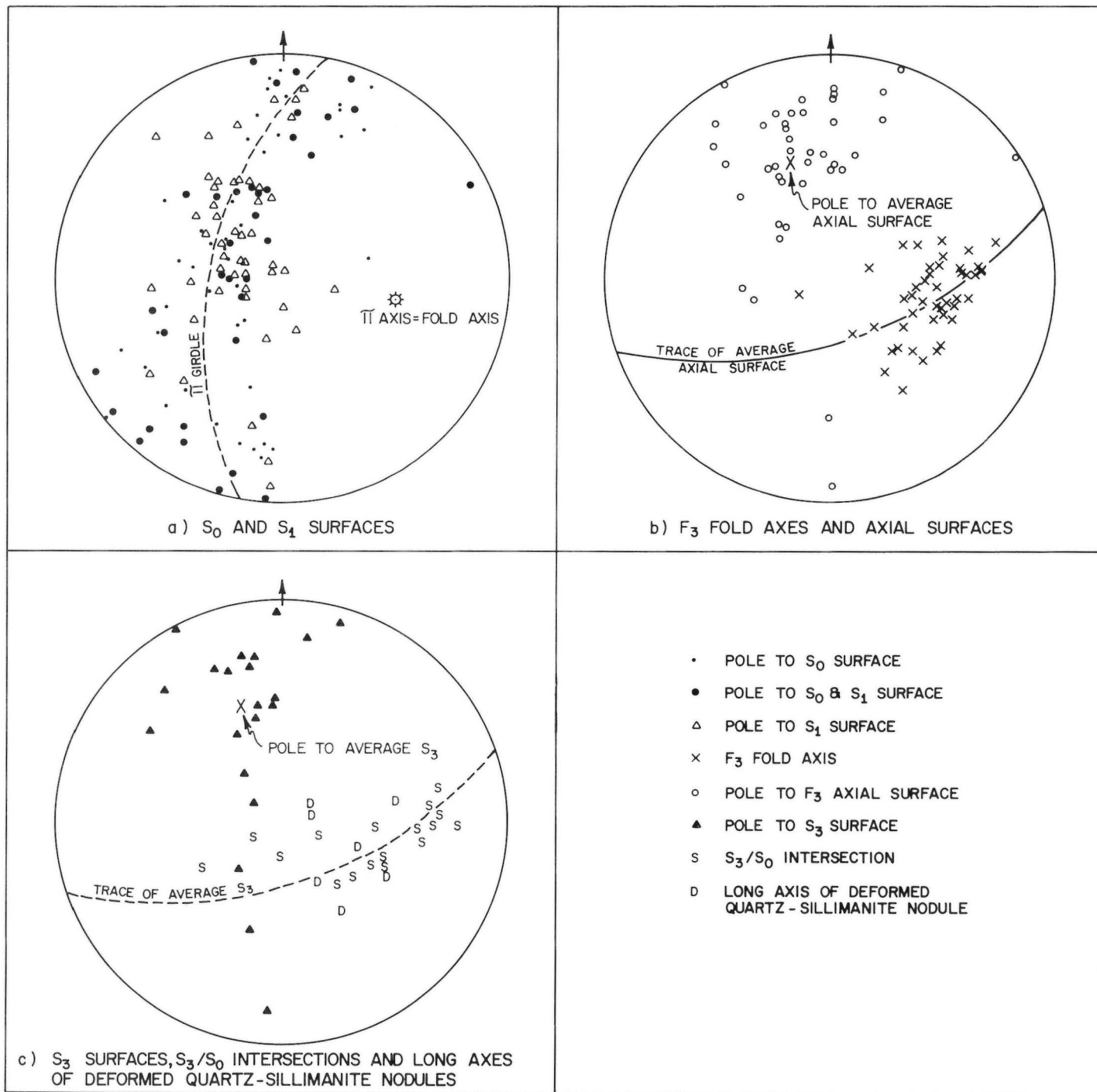


FIGURE 107: Lower hemisphere stereographic plots of structural fabric elements of the Ellice, Corley and Machuca F_3 fold structures (subarea C).

Minor F_3 folds are generally open, with 45° to 90° closures. They vary in style from similar to concentric. Some minor F_3 folds have chevron and kink shapes.

Small-scale structural fabrics from subarea C (Fig. 94), including poles to S_0 bedding surfaces, poles to S_1 schistosity surfaces, poles to S_0 schistosity surfaces, poles to F_3 axial surfaces, F_3 fold axes, S_3/S_0 intersections, and long axes of deformed quartz-sillimanite nodules, are shown in lower hemisphere stereographic projections in Figure 107. The poles to S_0 bedding surfaces and to S_1 schistosity surfaces define a great circle (π circle), the axis of which (π axis) is a statistical measure of the F_3 fold axis (Fig. 107a). Minor F_3 fold axes (Fig. 107b), S_3/S_0 intersections (S_3 is axial planar to F_3 folds) and long axes of deformed quartz-sillimanite nodules (Fig. 107c) indicate that the major F_3 folds east of Corley Lake have an average fold axis with an azimuth of 100° and a plunge of 36°. Poles to S_3 axial planar schistositities (Fig. 107c) and to minor fold axial surfaces (Fig. 107b) indicate that the major F_3 folds east of Corley Lake have an average axial surface with a strike of 70° and a dip of 58° to the southeast.

SYN-M₂ GRAVITY INDUCED DEFORMATION

During M_2 regional metamorphism, temperatures between 550°C and 650°C are estimated to have been reached in the northern one-third of the File Lake area (pp. 87 to 88). According to Fletcher (1972), these temperatures, combined with syn-kinematic recrystallization and a small amount of partial melting, are sufficient to increase gravity instabilities by a factor of one hundred or more, and are sufficient to allow significant gravity reversal structures to form where there are specific gravity differences as low as 0.1 g/cm³.

There are two structures in the File Lake area which probably owe their present geometry to gravity reversal of strata that were mobilized during M_2 metamorphism. They are the steep-sided bulbous triangular basin on the File Lake synform, north of Folster Bay, and the adjacent doubly-plunging Nelson Bay antiform. The basinal structure is cored by medium density grewacke-, siltstone-, and mudstone-derived gneisses of units 13b and 13c. This structure is interpreted to have sunk during M_2 . The Nelson Bay antiform is cored by low density felsic granitoid gneisses of unit 26 and is interpreted to have risen diapirically during M_2 . A number of conditions are considered to have existed during M_2 metamorphism which aided formation of these gravity reversal structures. They are:

- 1) large areas of lower density felsic paragneisses (units 16 and 26) buried beneath higher density intermediate paragneisses (units 13b and 13c) - the burial occurred during the recumbent F_1 folding;

- 2) high temperature, synkinematic recrystallization and partial melting of paragneisses during M_2 , which substantially increased ability of rocks to deform by flow;
- 3) structures that were particularly susceptible to gravity instability during M_2 , for example dome and basin interference fold structures; and
- 4) emplacement of synkinematic tonalite, granodiorite and granite plutons (units 20 to 24), which may have triggered gravity instabilities.

The features which indicate that the synformal basin on the File Lake synform is a gravity reversal structure are: its bulbous shape; its core of slightly higher density strata of units 13b and 13c; the lack of continuity through it of major fold structures; and a structural separation (not a fault) between it and the adjacent domal gneiss complex (unit 26) that cores the Nelson Bay antiform. In addition, the geometry of this basin cannot be explained in terms of structural interference of major fold structures.

The features which suggest that the Nelson Bay antiform is a diapir structure are its domal shape, which cannot be explained in terms of fold interference patterns, the movement (i.e. penetration) along its west contact with strata of unit 13c, and the coring of the Nelson Bay antiform by low density felsic granitoid gneisses of units 25 and 26. However, perhaps the most convincing evidence for this structure being a diapir comes from the adjacent Snow Lake area where several bulbous domal structures, all cored by gneisses identical to those which core the Nelson Bay antiform, have been mapped by Bailes (1975) and Froese and Moore (1980). Bailes (1975, p. 82-85) cites the following evidence for these structures being diapirs:

- 1) They contain complex internal lobes and parasitic folds which are, according to O'Brien (1968), common morphological features of diapir structures;
- 2) they are mantled by various rock formations and, as such, they are most logically interpreted to have penetrated their host gneisses;
- 3) specific gravities of gneisses in the domes are 0.1 to 0.2 g/cm³ lower than those of the mantling greywacke-, siltstone-, and mudstone- derived paragneisses - the latter rocks are equivalent to those of units 13b and 13c of the File Lake area; and
- 4) the gneisses coring the domes are relatively mobile as more competent amphibolite layers in them are intensely boudinaged.

SUMMARY OF EXPLORATION ACTIVITY

The File Lake area has been actively explored for mineral deposits for over 50 years. In the late 1920's and early 1930's it was explored for gold mineralization. Since 1955, it has been explored, mainly by Hudson Bay Exploration and Development Co. Ltd., for massive Cu-Zn sulphide deposits. Only one mine, the Dickstone Cu-Zn massive sulphide deposit (1970-1975), has been operated in the File Lake map-area.

Exploration for gold mineralization, in the 1930's and 1940's was largely confined to the area west of and north of Morton Lake. Three types of gold mineralization were found:

- 1) gold in quartz veins;
- 2) gold in silicified, arsenopyrite-bearing sheared rocks, particularly in association with tonalites of unit 18(3); and
- 3) gold in sulphide deposits.

No significant gold deposits have ever been reported to occur in the File Lake map-area. Most of the gold prospects were examined by the author during mapping of the File Lake area; however, they are poorly exposed and nothing of importance was observed that has not already been reported by Wright (1930, p. 66c to 68c), Stockwell (1935, p. 60-61 and p. 70-71) and Harrison (1949, p. 53-67). The reader is directed to the aforementioned references for information on the gold occurrences.

Exploration for massive sulphide deposits in the File Lake has been carried on in earnest since 1955, using modern airborne and ground geophysical techniques followed up by diamond drilling of anomalous conductive zones. A large number of sulphide zones have been discovered using these techniques; however, with the exception of the Dickstone No. 2 orebody, no economic sulphide deposits were discovered - the Dickstone No. 1 orebody was outlined in 1936 and 1937 by diamond drilling a surface showing.

The results of exploration work, on claims that have been allowed to lapse, are contained in open assessment files of the Manitoba Mineral Resources Division. The location of airborne and ground electromagnetic anomalies, from surveys in cancelled assessment files, are given on Figure 108 (in pocket). The location of diamond drill holes,

trenches, gossan zones and mineral occurrences are also shown on Figure 108. Information on conductive zones and sulphide occurrences intersected by diamond drill holes are summarized in Appendix B. Most of the exploration work has been carried out west and north of Morton Lake. The most intensely explored area is north and south of Storozuk Lake, on strike with the Dickstone mine; however, the results of these exploration operations are still largely confidential.

DESCRIPTION OF SULPHIDE DEPOSITS

DICKSTONE CU-ZN SULPHIDE DEPOSIT

INTRODUCTION AND HISTORY

The Dickstone Cu-Zn mine (Figs. 109 and 110) has two separate sulphide lenses, both contained in felsic volcanic strata of the Dickstone Formation (unit 2). The largest sulphide lens, the No. 1 orebody, is mainly Cu-bearing and is located 250 m north of Storozuk Lake. The second sulphide lens, the No. 2 orebody, is Cu- and Zn-bearing and is located 500 m north-northeast of the No. 1 orebody. Shafts have been sunk to 350 m (1150 feet) on both sulphide lenses and their underground workings are joined by a haulage drift on the 350 (1150 foot) level.

During operation of the Dickstone mine, from 1970 to 1975, 775,210 tonnes of ore grading 2.4% Cu, 3.12% Zn, 12.469 g Ag/tonne and 0.582 g Au/tonne were mined. The mine was closed in August 1975, because of low metal prices. According to McIntosh and Cranstone (1977), 307,988 tonnes of ore, grading 2.3% Cu, 4.1% Zn, 10.619 g Ag/tonne and 0.342 g Au/tonne, remain below the 350 m (1150 foot) level.

The first significant exploration on the Dickstone property was carried out in 1936 and 1937 when Sherritt Gordon Mines Ltd. surface trenched and diamond drilled what is now the No. 1 orebody. Their investigation delineated a stratiform sulphide zone containing approximately 200,000 tonnes of ore averaging 3.13% Cu. It indicated the ore zone to be 3 m wide, 225 m long, 105 m deep and open at depth (Harrison, 1949). The property passed to Dickstone Copper Mines Ltd. in 1937 and no further exploration activity was undertaken until 1965 when an option agreement was entered with Hudson Bay Mining

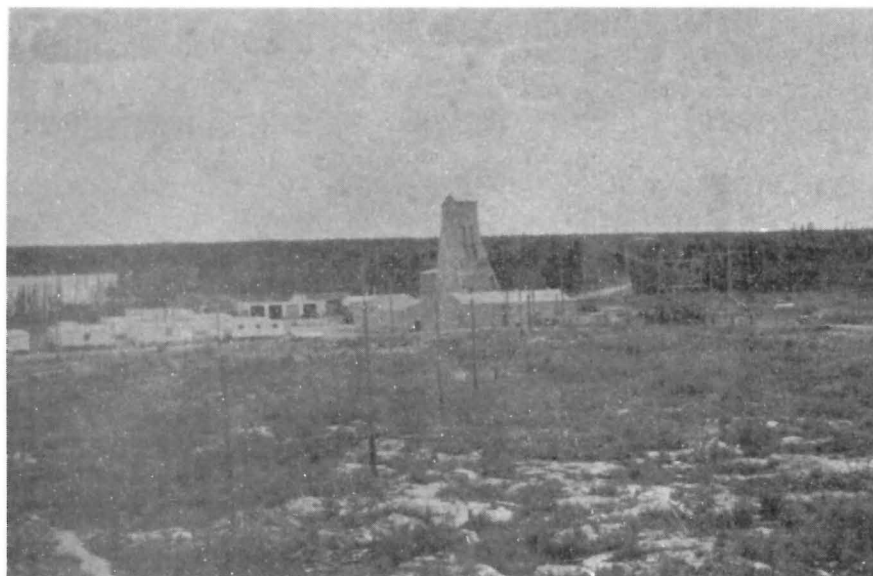


FIGURE 109: Dickstone mine-site, June, 1971, viewed from the No. 2 shaft.

and Smelting Co. Ltd.. Hudson Bay Mining and Smelting Co. Ltd. carried out 3050 m of diamond drilling and proved out additional ore on the original Cu-bearing No. 1 orebody and located the No. 2 Cu-Zn-bearing orebody by drilling an adjacent geophysical anomaly. In November 1966 Hudson Bay Mining and Smelting Co. Ltd. exercised their option with Dickstone Copper Mines Ltd. and an agreement was reached whereby Hudson Bay Mining and Smelting Co. Ltd. would finance and mine both sulphide deposits and return 25% of the net profit to Dickstone Copper Mines Ltd..

A shaft was started on the No. 1 orebody in 1967 and a second shaft was sunk on the No. 2 orebody in 1969. Ore from underground lateral development work was stockpiled on surface until the official start of production from the mine on November 2, 1970. The ore, which was produced at a rate of 600 tonnes per day in 1970, was transported by truck, 16 km to the south, to the CNR railway line and, from there, to the Hudson Bay Mining and Smelting Co. Ltd.'s mill and smelter in Flin Flon.

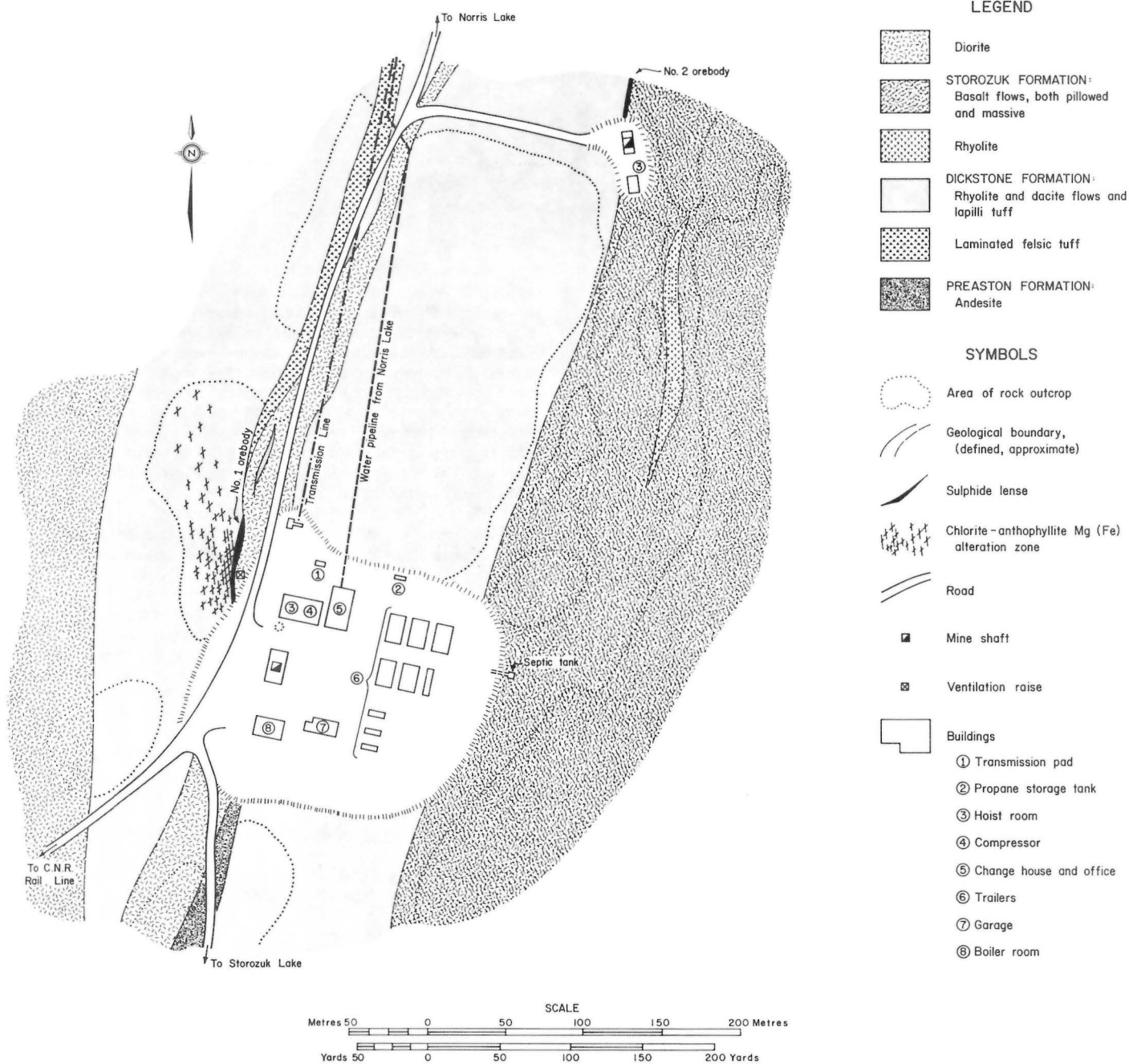


FIGURE 110: Geology of Dickstone mine-area.

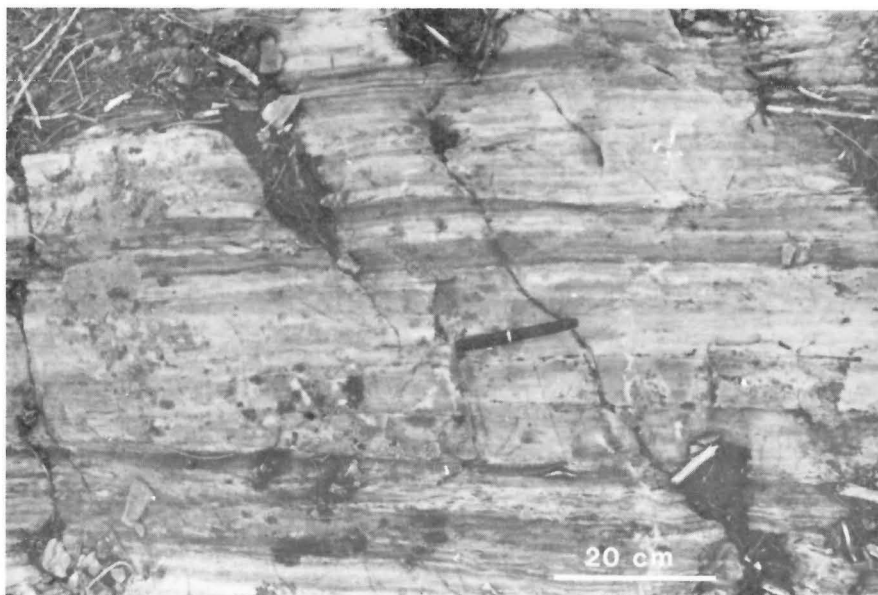


FIGURE 111: Laminated felsic tuffs that overlie Dickstone No. 1 ore-zone.

The Dickstone No. 1 orebody was initially mined by shrinkage but the pyrrhotite in this deposit oxidized in ore stopes and, consequently, in 1972, the mining method for this ore zone was switched to long hole.

DESCRIPTION OF OREBODIES

Hudson Bay Mining and Smelting Co. Ltd. provided the author with accommodation at the Dickstone mine site, during mapping of the Storozuk Lake area in 1971, and allowed the author access to underground mine workings. P. Walford of Hudson Bay Exploration and Development Co. Ltd. guided the author on underground and surface tours of the mine site. Many of the salient features of the geological setting of the ore deposits and most of the data on their geometry and mineralogy were provided by Mr. Walford.

Geologic setting

The Dickstone mine is located on the north flank of a large east-facing steeply-dipping felsic volcanic edifice. The felsic volcanic strata (unit 2) of this edifice have been termed the Dickstone Formation. They are mainly massive flows south of Yakymiw Lake and become progressively more fragmental and, possibly, epically reworked north of Yakymiw Lake (Fig. 4, p.8). North of Storozuk Lake the Dickstone Formation is less than 230 m wide and 800 m to the north it dies out completely.

Both ore zones of the Dickstone mine are hosted by felsic volcanic strata of unit 2. The No. 1 orebody is located about 75 m from the stratigraphic bottom of the Dickstone Formation and is locally overlain by a thin horizon of mafic volcanic strata belonging to unit 1. The No. 2 orebody is located at the top of the Dickstone Formation, along its contact with the overlying pillowed mafic volcanic rocks of unit 3.

A sketch of the geology of the Dickstone mine site is given in Figure 110. This figure is not to be treated as a detailed map, for the geological contacts and outcrops are from rough field notes and field sketches. The location of mine roads and surface buildings are accurately delineated; they are from surface mine plans contained in files of the Mining Engineering Branch, Manitoba Mineral Resources Division.

Dickstone No. 1 orebody

The surface expression of the Dickstone No. 1 orebody is a moderate to strong gossan zone which can be traced approximately 400 m north of the No. 1 shaft. The original discovery of the No. 1 orebody was made on this gossan zone at a point 30 m north of the No. 1 shaft and directly adjacent to the ventilation raise (Fig. 110). The gossan zone

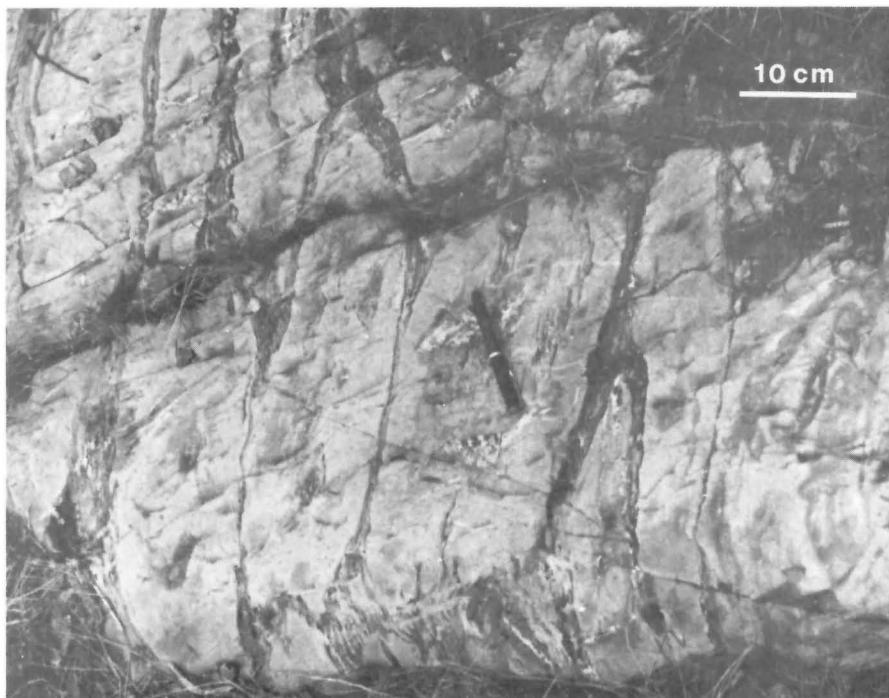
gradually dies out to the north. A swampy terrain covers the southern extension of the ore horizon. The ore horizon is overlain to the east by several metres of distinctive, finely laminated felsic tuffs (Fig. 111). The felsic tuffs continue to the north, beyond the extent of the ore zone. A diorite sill has intruded subparallel to the orebody. It cross-cuts the felsic tuffs and may cross-cut the orebody, although this is difficult to discern because of local mobilization of the sulphides during the post-diorite tectonism and metamorphism. Small late relatively undeformed and non-foliated porphyritic diorite dykes locally cross-cut strata of the minesite and, according to P. Walford (pers. comm., 1971), locally cross-cut the ore zones.

The No. 1 orebody is 2.5 m wide (an average), 245 m long, 350 m deep and open at depth. It is stratiform and consists of a series of thicker zones which plunge steeply to the south. At its extremities, the orebody thins to less than a metre in thickness, Cu values drop and pyrite increases; this subeconomic sulphide mineralization continues a considerable distance laterally away from the orebody.

The sulphide minerals in the No. 1 orebody are pyrrhotite, pyrite, chalcopyrite and, more rarely, sphalerite. Pyrite concretions are fairly common, particularly at the extremities of the orebody or where the ore zone locally thins. Layering is rare in the No. 1 orebody. Strong coarse recrystallization of the sulphide minerals is common, probably due to contact metamorphism by the Norris Lake pluton. The sulphide ore has locally been kneaded, by post-ore tectonism and this has resulted in its local remobilization. It is quite common, for example, for pyrrhotite-rich ore to be remobilized and to pick up fragments of foliated wall rock, post-ore diorite dykes, and other sulphide mineralization (chalcopyrite and pyrite-rich sulphides are common as inclusions). It is also quite common for tectonically remobilized sulphides to locally intrude fractures in host volcanic strata.

Some minor stringer chalcopyrite mineralization occurs below, to the west of, the No. 1 ore zone. This mineralization occurs in anthophyllite-rich and chlorite-rich rocks. The stringer mineralization extends only a few metres below the ore zone but the anthophyllite- and chlorite-rich rocks extend a considerable distance below the ore zone. According to P. Walford (pers. comm., 1971), these rocks have been observed, in drill core, to change gradationally to normal felsic volcanic strata away from the orebody. In surface exposures, a zone of anomalous chlorite-bearing felsic volcanic rocks has been traced over 100 m north of the No. 1 orebody (Fig. 110). The chlorite is irregular and patchy in its distribution (Fig. 112) and decreases in abundance away from the orebody, giving way to normal felsic volcanic strata. This anomalous zone of chlorite-bearing rocks is probably a volcanogenic Mg(Fe) alteration pipe of the kind described by Sangster

FIGURE 112: Chloritic alteration (dark) defining pillow-like features in rhyolite, Dickstone Formation, 100 m west-southwest of shaft on Dickstone No. 1 orebody.



(1972) for other Cu-Zn sulphide orebodies of the Flin Flon volcanic belt. The chlorite bearing rocks have, like other rocks at the Dickstone mine site, been recrystallized through contact metamorphism by the Norris Lake pluton. Metamorphically generated minerals in the altered zone include anthophyllite, staurolite, almandine and cummingtonite. Anthophyllite is particularly abundant, almost to the exclusion of chlorite, in the most intensely altered rocks directly below the orebody. The alteration must also have involved some addition of Ca, as diopside, grossularite and epidote are locally present as metamorphic porphyroblasts in the altered rocks.

Whole rock chemical analysis of the altered rocks, from below the Dickstone No. 1 orebody, are given in Table 20. They are listed in order from least to most altered.

Dickstone No. 2 orebody

The No. 2 orebody, which was found by drilling a geophysical anomaly, has no surface expression. It is located at the contact between felsic volcanic rocks of unit 2 and overlying pillowed mafic volcanic rocks of unit 3.

Morrice (1974) contains a brief description of the No. 2 ore zone. His main emphasis was the sulphide mineralogy of the deposit and the presence in the ore zone of tin-bearing minerals, most notably cassiterite. Much of the description which follows has been summarized from Morrice (1974), with some additional material from P. Walford (pers. comm., 1971).

The No. 2 orebody is 1.2 m thick (an average - it varies from 0.3 to 3 m), 180 m long, 350 m deep and open at depth. It is stratiform, dips near vertical and plunges steeply to the south. The ore is composed primarily of a granoblastic mosaic of pyrite, sphalerite, chalcopyrite and pyrrhotite. Accessory minerals include arsenopyrite and, more rarely, calcite, scapolite and anhydrite. The scapolite commonly occurs along the west margin of the sulphide zone (P. Walford, pers. comm., 1971). The sulphide ore is locally banded and the banding appears to have been imposed by plastic flow during deformation. Inclusions of foliated footwall and hanging wall rocks and intrusion of the sulphides into fractures in the country rock are probably caused by remobilization of the sulphide ore during post-ore deformational and metamorphic events.

The ore reserve for the No. 2 orebody, as of January 1, 1972, was 250,000 tonnes grading 2.04% Cu and 7.9% Zn (Morrice, 1974). According to Morris (1974), the No. 2 orebody contains 0.8% tin, largely in cassiterite, and he considers that this tin could be profitably extracted from the ore if the sulphide deposit was larger and if the ore was not mixed with ore from other mines prior to being milled in Flin Flon.

No alteration was noted in the stratigraphic footwall of the No. 2 orebody.

GENESIS OF MINERALIZATION

The Dickstone No. 1 and No. 2 ore zones are similar to other Cu- and Zn-sulphide deposits of the Flin Flon volcanic belt. Like the others, they are massive, stratiform and stratabound and they are closely associated with felsic volcanism. Also, the No. 1 orebody has an Mg(Fe) alteration zone in its stratigraphic footwall, a common feature for many of the Flin Flon belt massive sulphide Cu-Zn deposits (Sangster, 1972).

Sangster (1972) considered the massive Cu-Zn sulphide deposit of the Flin Flon belt to be good examples of volcanogenic deposits because of their volcanic host rocks, internal metal zoning, stratiform and stratabound character, and footwall stringer ore and Mg(Fe) alteration. He considered this kind of deposit to be formed largely as a subaqueous sulphide sediment over, or close to, a volcanic fumarole exhaling metal-rich brine. This origin is widely accepted for the massive Cu-Zn sulphide ore deposits of the Flin Flon volcanic belt. It is the most satisfactory explanation of the features observed in the Dickstone ore zones.

According to the volcanogenic theory for deposition of massive Cu-Zn massive sulphide deposits, as outlined by Sangster (1972), the Dickstone orebodies represent two separate, but closely related, mineralization events. The first mineralization episode occurred early in the deposition of the Dickstone Formation (unit 2) and involved Cu-rich exhalations which deposited the No. 1 ore zone and formed the chloritic Mg(Fe) alteration below this orebody. The second mineralization episode occurred at the close of deposition of the Dickstone Formation (unit 2) and involved Cu- and Zn-rich exhalations

TABLE 20: Whole rock chemical analyses of altered rocks underlying Dickstone No. 1 orebody

	1	2	3	4	5
SiO ₂	74.3	68.95	66.8	60.75	30.2
Al ₂ O ₃	10.7	13.3	12.6	13.65	18.6
Fe ₂ O ₃	1.46	1.09	2.19	2.71	6.85
FeO	3.78	4.23	11.10	7.81	17.87
MgO	1.92	1.23	1.85	1.95	14.65
CaO	1.09	4.09	0.60	7.20	1.10
Na ₂ O	3.00	4.85	0.12	3.15	0.94
K ₂ O	0.92	0.12	1.80	0.15	Nil
TiO ₂	0.28	0.86	0.84	1.14	1.52
P ₂ O ₅	0.05	0.34	0.31	0.37	0.35
MnO	0.25	0.13	0.06	0.25	0.27
H ₂ O±	1.39	0.61	1.19	1.00	7.69
CO ₂	0.26	0.42	Nil	0.15	Nil
S	0.57	0.01	0.03	0.07	0.34
less S=O				(0.03)	(0.14)
Cu (ppm)		Nil	Nil	Nil	160
Zn (ppm)		120	120	120	803
TOTAL	100.0	100.2	99.5	100.33	100.3
Total Fe as Fe ₂ O ₃	5.61	5.74	14.40	11.30	26.5

1. Unaltered quartz- and plagioclase- porphyritic sodic metarhyolite (unit 2), average of three analyses.
2. Tremolite-rich hornblende-bearing slightly altered quartz- and plagioclase-porphyritic metarhyolite (DICK-28) from 46 m stratigraphically below Dickstone No. 1 orebody.
3. Zoisite, biotite and garnet-rich altered rock (DICK-26) from 30 m stratigraphically below Dickstone No. 1 orebody.
4. Epidote- and hornblende-rich altered rock (DICK-29) from 30 m stratigraphically below Dickstone No. 1 orebody.
5. Chlorite schist with local porphyroblasts of anthophyllite and staurolite from altered stratigraphic footwall of Dickstone No. 1 orebody. Sample collected adjacent to orebody on 76 m (250 ft.) level, due west of mine shaft.

which deposited the Cu- and Zn- bearing No. 2 orebody. Since these mineralization events appear to be related to the volcano which deposited the Dickstone Formation, the rocks of unit 2 are considered to have good potential for other base metal sulphide deposits, with the lower part of the unit having potential for Cu-rich deposits and the upper part of the unit potential for Cu- and Zn-rich deposits.

It is interesting, and perhaps significant, that Gale and Koo (1977) have identified two main horizons of sulphide mineralization in the Snow Lake area; a lower Cu-rich sulphide zone and an upper Zn- and Cu-rich sulphide zone. Both mineralized horizons in the Snow Lake area are related to a major phase of felsic volcanism and the upper Zn- and Cu-bearing sulphide zone occurs at the upper contact of the felsic volcanic sequence and is overlain by mafic volcanic strata. The sequence and geologic setting of the mineralization events in the Dickstone mine are remarkable similar to those observed by Gale and Koo (1977) in the Snow Lake area, except that at the Dickstone mine the associated felsic volcanic edifice is smaller and stratigraphic interval between the two mineralization episodes is also smaller.

OTHER SULPHIDE DEPOSITS

Other sulphide deposits in the File Lake map-area are generally barren of significant base metal concentrations. Some of the sulphide deposits are exposed at surface and were examined during

the mapping program but most of them were located by mining exploration companies during diamond drilling of zones of anomalous electromagnetic conductivity. The core from these diamond drill holes was not available for examination and the author has used and, in some instances, reinterpreted drill logs of these holes to compile descriptions of sulphide deposits from selected areas (see Appendix B).

STOROZUK-YAKYMIW LAKES AREA

There is almost no information available in cancelled assessment files of the Manitoba Mineral Resources Division on the northern part of the Storozuk-Yakymiw Lakes area because this ground is close to the Dickstone mine and most if it has been held in good standing since the original exploration was done. The ground between the south shore of Storozuk Lake and the south shore of Yakymiw Lake was actively explored by Falconbridge Nickel Mines Ltd. from 1967 to 1969. No economic mineralization was found and the claims on this ground were allowed to lapse in 1979. The location of ground geophysical EM anomalies and diamond drill holes from this area are shown on Figure 108 (in pocket).

Strata of unit 2 are an obvious target for exploration for Cu-Zn sulphide deposits because the Dickstone orebodies indicate that conditions appropriate for development of this type of mineralization

occurred during deposition of these strata. However, airborne geophysical surveys conducted in 1955 by Aeromagnetic Surveys Ltd., in 1972 by Questor Surveys Ltd. and in 1977 by Aerodat Surveys Ltd. indicate that there is an absence of significant airborne electromagnetic conductors in strata of unit 2. Although this is not particularly encouraging to further exploration of these strata, it is possible that deeper penetrating ground geophysical surveys could turn up anomalies caused by small sulphide lenses that are too short or too deeply buried to be detected by airborne equipment. The airborne geophysical surveys were conducted for Hudson Bay Exploration and Development Co. Ltd., Noranda Exploration Co. Ltd. and Falconbridge Nickel Co. Ltd., respectively.

Strata of unit 3 contain two zones which are strongly gossaned and appear to have associated sulphide mineralization. The first is a thin, weakly gossaned horizon of felsic volcanic strata (unit 3b), located 200 m east of Storozuk Lake. The second is a narrow zone of heterolithic fragmental mafic volcanic rocks (unit 3a) located 300 m east of Storozuk Lake. A strong gossan zone and a short strong airborne electromagnetic conductor (Fig. 108) are associated with unit 3a strata east of Storozuk Lake. Ground and airborne electromagnetic conductors (Fig. 108), which occur north of Yakymiw Lake and north of Storozuk Lake, may be along strike equivalents of these two zones.

JOSLAND (GORDON) LAKE AREA

Three long, closely spaced north-trending ground electromagnetic conductors follow the east shore of Josland Lake (Fig. 108). Sulphide mineralization has been found, by surface trenching and diamond drilling, in several localities along these conductive zones.

Sulphide occurrences on western conductive zone

The western EM anomaly is by far the strongest (Fig. 108). It appears to be a formational sulphide zone composed mainly of pyrrhotite and, lesser amounts of, pyrite. South of Josland Lake it coincides with a strong 1 km long gossan zone, over which the soil is bright ochre-red. The anomaly and gossan zone occur in massive homogeneous diorite of unit 9. To the south, the gossan zone and EM anomaly are terminated by an east-trending fault and, to the south, the gossan zone and EM anomaly gradually die out, perhaps cut off by the gabbro intrusion of unit 18. The electromagnetic anomaly is shown in Figure 108 to correlate with an anomaly north of Josland Lake; however, north of Josland Lake, the rock lithologies and sulphide mineralization, on the conductive zone, are more similar to those encountered on the more easterly conductive zones.

In 1929, a 15 m deep exploration shaft was sunk on the western conductive zone 150 m south of Josland Lake. Several surface trenches were also made on this zone from 1929 to 1934. In 1971, both the exploration shaft and surface trenches were caved in, heavily oxidized and filled with water, consequently nothing of importance was observed that had not already been reported by Wright (1930) and Stockwell (1935). According to Wright (1930):

"The shaft is sunk in a zone of chloritic schist about 4 feet wide. Some of the schist on the dump contains abundant light coloured pyrrhotite, specks of chalcopryite, quartz veinlets and iron carbonate."

Numerous inclusions of host rocks and vein quartz are present in pyrrhotite samples collected by the author around the exploration shaft. The inclusions are probably due to kneading of the sulphide zone during regional metamorphism and deformation, and do not indicate an intrusive origin for the sulphides. A small trench on the same zone, just east of the south end of Josland Lake, is described by Stockwell (1935) as comprising:

"40 feet of iron-stained schist carrying disseminated pyrite, concretionary balls of pyrite, and a few small lenses of vein quartz."

In 1956 and 1957, Hudson Bay Exploration and Development Co. Ltd. conducted a diamond drill hole program to test the geophysical EM anomalies on Josland Lake. The drilling indicated that the western

anomaly was formed by several closely associated narrow 1 to 2 m zones of massive pyrrhotite (plus pyrite) mineralization in rocks which they termed hornblende diorite or massive andesite. The continuity and strength of the western EM anomaly suggests that the pyrrhotite-rich sulphide zones encountered in drill holes and surface trenches are continuous and probably formational.

The relationship of the sulphide zone to the diorite of unit 9 is uncertain. It may be genetically related to unit 9 but more likely it was simply intruded by the diorite and remained as an undigested remnant.

Sulphide occurrences on eastern conductive zones

The two eastern anomalies, in particular the more easterly, are weak and, in some parts, discontinuous (Fig. 108). The eastern anomaly coincides with a horizon of rusty weathering felsic volcanic rocks (unit 3b). The other conductive zone is poorly exposed, but according to drill hole data, it is also associated with a narrow horizon of felsic volcanic rocks that were not observed during surface mapping. The more westerly of the two EM anomalies is terminated to the south by an east-trending fault. The eastern anomaly is highly discontinuous but it may correlate to the south with the strong conductive zone cored by drill holes 83, 84 and 85 (Fig. 108, in pocket).

Drill holes on the more easterly of the two conductive zones indicate it to comprise a felsic volcanic horizon mineralized with disseminated and, more rarely, massive pyrrhotite and pyrite. Locally, the sulphide mineralization includes traces of chalcopryite and sphalerite. In some drill holes, such as 85 (Fig. 108), the mineralized felsic volcanic horizon appears to have been broken up into segments by intrusions of diorite (probably unit 9). A 20 foot thick sulphide-bearing graphite zone was intersected on this anomaly in drill hole 83, and this may account for the increase in conductivity on the southern part of this EM anomaly.

Drill holes on the more westerly of the two conductive zones indicate it to comprise disseminated and, rarely, massive pyrrhotite and pyrite mineralization associated with very narrow horizon(s) of felsic volcanics. No sphalerite and only trace amounts of chalcopryite were intersected by drill holes on this anomaly.

PODRUSKI LAKE SULPHIDE ZONE

A 6 km electromagnetic conductor, outlined by ground geophysical surveys by Hudson Bay Exploration and Development Co. Ltd., follows the eastern margin of the large folded sill of gabbro (unit 18) east of Podruski Lake. Surface trenches on this zone, examined in 1971, and logs of drill holes by Hudson Bay Exploration and Development Co. Ltd. indicate that the anomaly is due to disseminated, more rarely, massive pyrrhotite. This sulphide zone also includes some pyrite and, rare, specks of chalcopryite. It is hosted by metavolcanic rocks adjacent to the gabbro sill.

The sulphide zone is thought to be genetically related to the gabbro sill, in particular the narrow horizon of unit 18(1), because it occurs within 20 m of the margin of the sill and because the conductive zone appears to cross-cut the stratigraphy of the host volcanic rocks.

A similar electromagnetic anomaly follows the east side of the folded gabbro sill that occurs northeast of Ducharme Bay. It also is associated with a narrow horizon of unit 18(1). No surface exposures or drill hole data were available for this conductive zone.

NORTH MORTON LAKE AREA

Several small pyrrhotite and pyrite-bearing sulphide showings, originally prospected for gold and more recently for base metals, are located north of Morton Lake and on its northwest shore. They contain traces of gold and specks of chalcopryite, but no significant economic mineralization has been reported.

Two of the sulphide showings are located on the west shore of Morton Lake in a small bay 1.4 km from the north end of the lake. On the west shore of the bay one of the showings is exposed in a small trench. The trench is composed of heavily rusted light green coloured fine grained felsic quartz porphyry which contains 10 to 15 percent

disseminated pyrrhotite. This rock unit, which is not shown on the geological map, intrudes the gabbro of unit 18(1). This same rock is also exposed west of a trench on the second showing at the south end of the bay. The latter showing, termed the White Star No. 1 by Stockwell (1935), consists of dark coloured siliceous pyrrhotite-bearing sedimentary rocks. The latter showing also contains some interbedded siltstones and mudstones that are criss-crossed by an irregular network of pyrrhotite- and pyrite-filled fractures. According to Stockwell, the owner of the White Star No. 1 property reported that samples from it carried about 0.05 ounces of gold per ton.

Stockwell (1935) and Harrison (1949) contain descriptions of a small sulphide showing, called the White Star No. 2, located 700 m south of the north end of Morton Lake and 30 m from the western shoreline. This deposit was not located during this study. Stockwell (1935) described it, as follows:

"The deposit is exposed in a trench ... 6 feet deep and crosses about 28 feet of grey, biotite gneiss cut by a few stringers of white quartz and rhyolite. The quartz carries blebs of chalcopyrite and is said to assay high in gold, but the quartz constitutes a very small part of the material in the trench and the veinlets are widely spaced. The gneiss, across the full length of the trench carries disseminated grains and veinlets of chalcopyrite. Chalcopyrite is abundant across a zone of 3 or 4 feet within the middle of the trench. A specimen of the mineralized gneiss is said to have assayed 0.07 ounces of gold per ton."

A third sulphide showing, the Copper Valley sulphide deposit of Wright (1930), is located 1 km north of the northwest corner of Morton Lake. It is located on the north end of a 2 km long north-northeast-trending electromagnetic conductor (Fig. 108). A surface trench on this showing was examined in 1971. It contains heavy pyrrhotite mineralization, which has abundant inclusions of host rocks and irregular stringers of chalcopyrite; the chalcopyrite is commonly localized in extension fractures in silicate inclusions. This showing is associated with a small post-gabbro intrusion of a blue-green pyrrhotite-bearing felsic quartz porphyry. The quartz porphyry intrusion is identical to that associated with the showings in the bay 1.4 km from the north end of Morton Lake. According to Harrison (1949), this showing has two other trenches on it, one near the trench already described and one 120 m to the west on the other side of a long north-trending linear swamp. According to Harrison (1949) all the showings are in sheared, silicified and carbonatized mafic volcanic rocks and all have heavy pyrrhotite mineralization. He indicates that pyrite is common in parts of the showings and that in some places it occurs as concretion-like blebs. The long linear EM anomaly associated with these showings extends 2 km to the south and follows a narrow horizon of felsic tuffs and flows (unit 3b). These rocks are commonly gossaned and locally contain disseminated pyrrhotite and pyrite. They are also commonly impregnated by intrusions of felsic quartz porphyry. Several drill holes have been cored on this EM anomaly by Hudson Exploration and Development Co. Ltd. (Fig. 108). Logs of drill holes 57 and 59 encountered, respectively, 4 m of 50 percent pyrrhotite and pyrite, and 6 m of graphite schist well mineralized with pyrrhotite (Appendix B). In both drill holes the sulphide mineralization was associated with felsic to intermediate volcanic rocks sandwiched between gabbroic rocks. To the south the felsic volcanic horizon of unit 3b lenses out and the associated electromagnetic conductors also die out. To the north the felsic volcanic rocks and the electromagnetic conductors appear to be terminated by the Morton-Machuca Lakes fault zone.

ELMES ISLAND AND SOUTH MORTON LAKE

Elmes Island comprises massive white weathering dacite flows and, more rarely, flow breccias (units 4 and 4a). On the northeast shore of Elmes Island, several small trenches have been opened on a zone of earthy pyrite-bearing fine grained black siliceous sediments. The pyrite comprises up to 50 percent of these sediments

and occurs in three forms:

- 1) finely disseminated submicroscopic grains;
- 2) scattered subhedral 0.5 to 1.0 mm cubes; and
- 3) narrow cross-cutting veinlets or stringers.

Most of the pyrite occurs as submicroscopic disseminated grains and it is this which imparts the black colour to the sediments. These pyritic sediments vary from hard massive varieties to schistose (probably sericitic) varieties. They are, in part, graphitic.

A drill hole (No. 122, Fig. 108), 0.5 km south of the surface trenches on Elmes Island, appears to intersect the same sulphide zone as that encountered in the trenches. The sediments were logged as argillaceous, schistose and graphitic, and reported to contain pyrite and pyrrhotite disseminated in fine bands. The drill hole was stopped after 10 m of the argillaceous sulphide-bearing sediments had been intersected. The drill hole also encountered 30 m of felsic volcanic rocks, containing disseminated pyrrhotite and pyrite, to the west of the sulphide zone and, in addition, intersected approximately 30 m of soft talc-sericite schist. It is possible that the latter rock is part of a Mg(Fe) alteration zone.

The lateral extent, beneath Morton Lake, of the dacitic volcanic rocks of unit 4, and the attendant sulphide-bearing sediments, is uncertain. According to a cancelled assessment file report submitted in 1974 by Noranda Exploration Co. Ltd., three diamond drill holes by Hudson Bay Exploration and Development Co. Ltd. had cored equivalent dacitic volcanic rocks up to 1.5 km south of Elmes Island. The drill holes by Hudson Bay Exploration and Development Co. Ltd. encountered pyrite and pyrrhotite-bearing graphitic dacite tuffs on a long linear conductive zone which has been traced 4 km south of Elmes Island by a combination of airborne and ground electromagnetic surveys (see Fig. 108). It is possible that this electromagnetic conductor may correlate with the sulphide showings on Elmes Island.

DUCHARME (DUMMY) BAY AREA

Harrison (1949) reported several sulphide showings, rich in pyrrhotite and pyrite, on the west side of File Lake, north of Ducharme Bay. These showings were examined by the author in 1971 and 1972. They all occur in strongly schistose, heavily gossaned and silicified mafic volcanic rocks. These rocks outcrop, up to 1 km north of Ducharme Bay, in low exposures adjacent to the east and west margins of a narrow north-trending swampy area. Many of these outcrops have been trenched; however, most of the trenches were caved in, filled with water and strongly weathered when examined in 1971 and 1972. Some new surface trenches, opened in 1972 by Noranda Exploration Co. Ltd., were in good shape.

In 1965, Hudson Bay Exploration and Development Co. Ltd. outlined a strong ground electromagnetic conductor north of Ducharme Bay (Fig. 108). This conductor was 200 m wide, 1 km north of Ducharme Bay. To the north it died out completely and to the south it divided into two narrow relatively weak conductors. The more westerly of these conductors was traced 2 km to the south along the west shore of Ducharme Bay. In 1967, Hudson Bay Exploration and Development Co. Ltd. tested the conductive zone, north of Ducharme Bay, with 4 drill holes (Nos. 35, 36, 38 and 39, Fig. 108). This drilling indicated that the conductor is due to wide sections of strongly graphitic silicified rocks containing 5 to 30 percent pyrite and pyrrhotite. No indication of economic sulphide mineralization was found and no further drilling was undertaken. In 1972, Noranda Exploration Co. Ltd. opened several trenches on this zone. Apparently, they also found nothing of interest as this property was subsequently dropped.

Showings observed by the author north of Ducharme Bay comprise alternating mafic volcanic and more schistose silicified gneisses. Disseminated graphite, pyrite and, more rarely, pyrrhotite are common in the felsic gneisses. Shearing and faulting of rocks north of Ducharme Bay is common and the sulphide mineralization has obviously been concentrated along dislocation zones and in areas of intense shearing. However, the concentration of graphite in the sulphide showings and the termination of the sulphide mineralization and electromagnetic anomaly 1 km north of Ducharme Bay, despite

continuation of the fault, suggests that the sulphide mineralization is probably formational rather than directly related to the faulting.

LOONHEAD AND PELOQUIN LAKES AREA

Ground geophysical surveys by Hudson Bay Exploration and Development Co. Ltd. have delineated numerous small strong electromagnetic conductors in the metagabbroic rocks of unit 18 east and southeast of Peloquin Lake (Fig. 108). Many of these conductive zones have been drilled by Hudson Bay Exploration and Development Co. Ltd.. Logs of drill holes, in cancelled assessment files, indicate that the conductive zones consist of a series of narrow seams of pyrrhotite and pyrite. The individual sulphide seams, which are generally under a centimetre thick, vary from heavily mineralized to massive. The relationship of the sulphide seams to the hosting gabbro is not known.

Surface trenches and diamond drill holes on electromagnetic conductors in metavolcanic rocks between Peloquin and Loonhead Lakes have located minor disseminated pyrite and pyrrhotite zones in siliceous gneisses. No significant sulphide zones and no traces of base metal-bearing sulphides were encountered.

Economically, the most interesting locality in the Peloquin Lake area is the blunt point on the west shore of Peloquin Lake. Most of this point is a post-gabbro intrusion of fine grained white felsic quartz porphyry; this unit is not shown on the geological map (Map 78-1-1). Several very old trenches on this quartz porphyry were examined. Samples of felsic quartz porphyry, from the trenches, contained disseminated magnetite and sulphides. The sulphides were, in general, highly weathered. Malachite was present locally as a weathering product of the sulphides.

OTHER AREAS

In addition to the areas previously discussed, there are several others where sulphide zones have been intersected during diamond drilling of electromagnetic anomalies or where sulphide-bearing gossan zones were observed during mapping. The most notable of these are located between Ellice and Folster Bays; on south File Lake and near Fussey Lake; and on Woosey Lake.

Between Ellice and Folster Bays, on File Lake, the 1972 Questor airborne survey for Noranda identified two long strong electromagnetic conductors (Fig. 108). Although there is no exploration activity recorded on these zones, in claims assessment files, there are old geophysical grids, drill roads, and one drill hole collar (Fig. 108), which indicate they have been examined. In addition, approximately 900 m of drill core, which appears to consist mainly of unit 14 strata, are stored 750 m south of the eighteen base line on the east shore of Ellice Bay. During the field mapping program, disseminated pyrrhotite and pyrite were observed associated with gossaned siliceous metavolcanic gneisses on the west side (stratigraphic top) of the band of unit 14 which follows the east shore of Ellice Bay.

On south File Lake and in the vicinity of Fussey Lake, Hudson Bay Exploration and Development Co. Ltd. has drilled several electromagnetic conductors. The conductive zones are due to pyrite-bearing graphitic schists, which are, with minor exceptions, all contained at the contact of mafic volcanic rocks of unit 5 with gabbroic rocks of unit 18(1) or near the contact of the mafic volcanic rocks with garnet and biotite-bearing metasedimentary rocks of unit 13b. The pyrite-bearing graphitic schists are probably formational. Their association with the basal contact of unit 18(1), in the vicinity of Fussey Lake, is coincidental and they are not thought to be genetically linked with the gabbro sills.

On Woosey Lake, Hudson Bay Exploration and Development Co. Ltd. and Granges Exploration AB have drilled several conductive zones. Most of these conductive zones were identified as horizons of graphitic schists. Only one drill hole (No. 151, Fig. 108) intersected interesting mineralization (0.41% Zn across 7.5 m). A strongly gossaned area on the north shore of Woosey Lake (north-northeast of Biebrick Island) was noted during mapping. One small trench was noted on this gossan zone. It exposed schistose quartz-rich gneisses containing minor disseminated pyrite.

RECOMMENDATIONS FOR FURTHER EXPLORATION

Exploration in the File Lake area, first by prospectors and then by large mining companies, the latter using modern geophysical techniques followed by diamond drilling of anomalous conductive zones, has delineated only one economic mineral deposit, the Dickstone Cu-Zn mine. The exploration programs have, on the whole, been very thorough and for most areas further exploration is not recommended, unless it involves new deeper penetration and more sensitive geophysical equipment.

Geological units in the File Lake map-area which have the highest potential for base metal sulphide mineralization and which should be the focus for future exploration programs in the map-area are:

- 1) felsic volcanic strata of unit 2;
- 2) felsic volcanic strata of unit 3b;
- 3) felsic volcanic strata of units 4 and 6;
- 4) volcanic strata of units 14 and 14a; and
- 5) differentiated gabbro sills of unit 18.

The felsic volcanic of unit 2 host the Dickstone No. 1 and No. 2 orebodies and, if these deposits are volcanogenic, as interpreted, unit 2 strata have proven potential for further Cu-Zn sulphide mineralization. This does not mean that additional deposits were formed but it does mean that the mineralization processes were operational during deposition of unit 2 strata and were capable of producing additional deposits. Furthermore, since the Dickstone orebodies occur at different stratigraphic levels, this means that there were two episodes of mineralization, an early Cu-rich episode (No. 1 orebody) and a later Cu- and Zn-rich episode (No. 2 orebody).

The felsic volcanic strata of unit 3b are commonly gossaned and diamond drilling of associated conductive zones has shown them to be locally sulphide-rich. The sulphides are usually pyrrhotite and pyrite, but locally, for example southeast of Josland Lake, they include traces of chalcopyrite and sphalerite. The presence of sulphides, in particular chalcopyrite and sphalerite, suggests that this unit may be a potential host for base metal sulphide mineralization.

The felsic volcanic strata of units 4 and 6 do not appear to have been explored adequately. Unit 4 is the second largest accumulation of felsic volcanic strata in the map-area and, based on the close association of base metal sulphide mineralization to felsic volcanism elsewhere in the Flin Flon volcanic belt, unit 4 deserves further attention. Unit 6 is a very small horizon of felsic volcanic strata but it is possible that it could correlate with unit 2 strata and, as such, may have a potential for Cu-Zn mineralization. Gossan zones were noted on unit 6 strata and on fragmental mafic volcanic rocks of unit 5b on strike with rocks of unit 6.

Volcanic rocks of units 14 and 14a occur near the top of the Amisk Group sedimentary package and appear to be removed from the main phase of Amisk Group volcanism. However, felsic metavolcanic strata of unit 14a, on the northeast arm of File Lake, are identical to and appear to correlate with felsic metavolcanic strata mapped by Froese and Moore (1980) east of the Ham Lake pluton. The felsic metavolcanic rocks, east of the Ham Lake pluton, correlate to the south with Amisk Group volcanic rocks which host the Cu-Zn sulphide deposits of the Snow Lake area. Therefore, the felsic metavolcanic rocks of unit 14a and, perhaps, the mafic metavolcanic rocks of unit 14, may have potential for base metal mineralization. No exploration of unit 14a strata, using modern geophysical techniques, has been undertaken to date, making these strata a high priority target for any future exploration in the File Lake area.

The gabbro intrusions of unit 18 are strongly differentiated and, as such, might have potential for Ni or Cr mineralization. However, on the other hand, the geochemistry of these gabbro sills (pp. 56 to 60) does not indicate significant potential for either Ni or Cr mineralization. This is because the parent magma for the sills (see columns 1 and 2, Table 14, p. 60) is a basalt and has low primary Ni and Cr values, and because the fractional crystallization of these intrusions did not produce ultramafic phases, with which Ni and Cr mineralization is usually linked.

SUMMARY AND REGIONAL CONSIDERATIONS

In the File Lake area, the Amisk Group volcanic strata of the Flin Flon belt are a heterogeneous sequence of mafic and felsic flows and fragmental rocks that were deposited in shallow to moderately deep water. They are morphologically similar to volcanic deposits occurring in modern volcanic arcs.

The Amisk Group volcanic rocks are overlain by and locally intercalated with pebbly greywacke, greywacke, siltstone and mudstone that is composed mainly of texturally immature felsic volcanic detritus. These strata also belong to the Amisk Group. They were deposited by subaqueous mass-sediment gravity flows, including turbidity currents, fluidized sediment flows and debris flows, and have facies relationships that are, in terms of a modern analogue, similar to those shown by recent submarine fans. Their detritus is texturally and compositionally immature and this suggests that they were derived from contemporaneous Amisk volcanoes. An absence of plutonic, metamorphic or sedimentary clasts in them indicates that there was no contribution from an older cratonic terrane or from an older deeply dissected volcanic belt. Slight rounding of some detritus, rare fragments of hypabyssal intrusions and the coarseness and thickness of the deposits indicates that their source area was, at least in part, subaerial.

The File Lake Formation of the Amisk Group has been traced across a steep metamorphic gradient into highly recrystallized and partially melted paragneisses belonging to the Nokomis Group of the Kiseynew belt. The Nokomis Group paragneisses are a widespread and significant component of the Kiseynew belt. The implication of the correlation of these two groups of rocks is that the Nokomis Group paragneisses, like their lower grade equivalents, comprise detritus derived from the Flin Flon belt, and that they were deposited by subaqueous mass-sediment gravity flows, mainly turbidity currents. Furthermore, since the Amisk Group sediments are composed mainly of felsic volcanic detritus, this implies that a significant proportion of felsic volcanic material was transported from the Flin Flon belt and redeposited in the Kiseynew belt. It is suggested that the detritus was derived from major felsic subaerial stratovolcanoes of the Flin Flon belt and that it was dumped into the Kiseynew sedimentary basin in a subaqueous-fan sediment-dispersal system. Thus the boundary between the two belts, during Amisk-Nokomis time, is interpreted to have been marked by change from deposition by volcanic processes to deposition in a deep marine basin by subaqueous mass-sediment gravity flows of unconsolidated and, in some instances, slightly reworked volcanic detritus.

Amisk Group sedimentary rocks are overlain by subgreywacke and arkose of the Missi Group. These strata are strongly recrystallized in the File Lake area. They are thick-bedded, locally cross-bedded and rarely contain pebbles. They correlate directly with Sherridon Group paragneisses of the Kiseynew belt. Their environment of deposition cannot be interpreted from their highly recrystallized exposures in the File Lake area but elsewhere they have been interpreted to be alluvial fan deposits (Mukherjee, 1971; Stauffer, 1974; Shanks and Bailes, 1977). If the Missi strata of the File Lake area are also subaerial deposits this implies a shift from deep water Amisk sedimentation to subaerial conditions and, therefore, an uplift of the strata of the File Lake area or a lowering of sea level prior to deposition of the Missi Group.

The Amisk and Missi Group strata of the File Lake area have been affected by a series of post-Missi intrusive, deformational and metamorphic events. The first post-Missi event comprised intrusion of a large differentiated iron-rich tholeiitic gabbro sill along the contact between Amisk volcanic and sedimentary rocks. This was followed by an episode of large-scale recumbent folding (F_1) which inverted large segments of the volcanic and sedimentary rocks. A low grade episode of metamorphism (M_1) either accompanied or followed shortly after this episode of deformation. A second pulse of differentiated iron-rich tholeiitic gabbro intrusions were emplaced along the axial planes of the F_1 folds. This was followed by a series of closely related intrusive, metamorphic and deformational events which included emplacement of large synkinematic felsic plutons, F_2 folding about vertical north-northeast-trending axial surfaces, medium to high grade regional metamorphism (M_2), syn- M_2 gravity reversal structures in the northern third of the map-area, and quasi-flexural F_3 folding about vertical east-trending axial surfaces. The youngest deformational event recognized comprises northeast-and northwest-trending D_4 fractures and north-trending vertical faults. The D_4 fractures are locally intruded by felsic pegmatite dykes and have low grade retrograde M_4 mineral assemblages associated with them.

The most important conclusion of this study is that the Flin Flon and Kiseynew belts developed contemporaneously, with volcanism localized in the Flin Flon belt and sedimentation localized in the Kiseynew belt. It is suggested that volcanism in the Flin Flon belt built up a thick succession which supplied detritus to the adjacent Kiseynew belt. This detritus, which now comprise Amisk Group sedimentary rocks, and equivalent higher grade Nokomis Group paragneisses, is inferred to have been transported into the Kiseynew belt by subaqueous mass-sediment gravity flows, mainly turbidity currents; a delivery system, akin to that observed in present-day submarine fans, is envisaged. The preponderance of felsic volcanic detritus in the Amisk sedimentary rocks of the File Lake area infers that late stages of Amisk volcanism probably consisted of large subaerial edifices of felsic volcanic strata that were largely eroded and redeposited in the Amisk-Nokomis sedimentary strata of the Kiseynew belt. It is possible that the felsic volcanic edifices, which are now largely removed from the Flin Flon belt volcanic succession, were the precursors of the felsic plutonic masses which subsequently intruded the Flin Flon belt. These felsic plutons may also have caused an uplift of the Flin Flon belt, and adjacent parts of the Kiseynew belt, and caused the shift from deep marine Amisk sedimentation to the subsequent continental alluvial Missi sedimentation. Granitic cobbles in Missi conglomerates, which are otherwise composed mainly of volcanic fragments, suggest at least some of the plutons were unroofed during the uplift that led to Missi sedimentation. The post-Missi intrusive, deformational and regional metamorphic events recognized in the File Lake area are interpreted to be due to an orogenic collapse of the Kiseynew sedimentary basin and the Flin Flon volcanic belt. The orogeny began with an episode of recumbent folding and reached a climax during which syntectonic felsic plutons were emplaced, high grade regional metamorphism occurred and upright folds were formed.

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APPENDIX A: SUMMARY OF ROCK DESCRIPTION, FILE LAKE AREA

TABLE A-1: MAIN FEATURES OF AMISK VOLCANIC ROCKS (UNITS 1 to 8)¹

Unit No.	Rock type	Weathering characteristics	Colour of fresh surface	Primary structures and textures	Grain size and fabric	Mineralogy	Comments
1	basalt and andesite flows, minor dacite	dark green; large outcrops with low relief	dark green	mainly massive flows; pillows present but not common; aphyric to locally porphyritic; locally contains monolithic fragmental rocks	fine grained; massive, except northern exposures which are weakly foliated	rocks recrystallized, minerals metamorphic; mixture of plagioclase and light green amphibole, plus minor oxide and accessory minerals	grade of metamorphism increases towards the north and towards the Norris pluton, consequently rocks from northern exposures are most intensely recrystallized
1a	mafic metavolcanic gneiss	dark to medium green, with light green layers with rusty tinges	dark to light green	irregular layering, probably primary but may be tectonic or metamorphic	fine grained; moderately to strongly foliated	rocks recrystallized, minerals metamorphic; mixture of plagioclase and medium to dark green amphibole; pyralisite garnet porphyroblasts common; colourless amphibole (cummingtonite?) and red-brown biotite common	may be a recrystallized layered mafic volcanic ash deposit or, alternatively, may be derived from rocks of unit 1 by metamorphic and tectonic processes
2. 2a 2b	rhyolite and dacite flows, tuff and breccia	flows are white to light blue-green; tuffs are light grey to rusty grey; outcrops are large with moderate relief; blue quartz phenocrysts stand up in relief on weathered surfaces	light grey to light blue green	layering ubiquitous, defined by individual flows and by tuffaceous units; phenocrysts of quartz and plagioclase common; monolithic fragments common, particularly in rocks exposed on Storozuk Lake; vesicles and amygdalae moderately common; margins of some flows strongly scoriaceous; pillows observed at one locality (Dickstone minesite); rhyolite lobes and tongues in hyaloclastite and breccia occur on southwest Storozuk Lake	fine grained; rocks from southern exposures are massive while those further north typically are strongly foliated; fragments, amygdalae, and vesicles are tectonically deformed with steep-plunging long axes	rocks recrystallized, mainly composed of metamorphic minerals; consist mainly of mixture of quartz and plagioclase (An ₂₋₉) common in rocks from southern exposures; pyralisite garnet, pale green amphibole and biotite common as porphyroblasts in rocks north of Yakymiw Lake (caused by contact metamorphism by Norris Lake pluton)	rocks of unit 2 comprise a dome shaped deposit with up 1500 metres of original relief; rocks from most northerly exposures are more intensely recrystallized
3	basalt and andesite flows	dark green; large outcrops with low relief	dark green	mainly massive and pillowed flows; pillows have thin selvages and are often zoned internally; epidotized cores to pillows are common; pillows breccias occur locally	fine grained; rocks from southern exposures are massive while those further north are strongly foliated	rocks recrystallized, minerals metamorphic; mixture of light to medium green amphibole and plagioclase, plus minor oxide and accessory minerals	in section east of Storozuk, Lake rocks become slightly less mafic stratigraphically upwards (from west to east); many of the rocks east-southeast of Josland Lake contain numerous large stubby porphyroblasts of green amphibole giving them pseudo-gabbroic textures
3a	basalt and andesite breccia	dark green	dark green	includes both monolithic and heterolithic breccias; most breccias are monolithic; heterolithic breccias include rare felsic fragments; plagioclase phenocrysts common	fine grained; fragments are tectonically deformed with steep-plunging long axes	as above	many of the rocks east-southeast of Storozuk Lake contain prominent stubby porphyroblasts of green amphibole giving them pseudo-gabbroic textures

¹ Units 14 and 14a not included. See Table A-3.

Unit No	Rock type	Weathering characteristics	Colour of fresh surface	Primary structures and textures	Grain size and fabric	Mineralogy	Comments
3b	felsic tuff and flows	white to light green, locally with rusty discolouration	white to light green	mainly tuffaceous; pillows rare but present; plagioclase (andesine) phenocrysts common in horizon on east shore of Josland Lake, layering well developed in tuffaceous varieties	fine grained; moderately foliated; between gabbro sills west of Ducharme Bay rocks have bleached, baked appearance	rocks recrystallized, minerals metamorphic; mixture of plagioclase, quartz, green amphibole and red-brown biotite; rocks in layer on east shore of Josland Lake are rich in calcite and may be calcareous tuffs	stratigraphic affinity of thin layers of this rock unit not known, they may be genetically related to large masses of felsic volcanic strata, such as those exposed on Storozuk Lake or on Elmes Island
3c	mafic metavolcanic gneiss	dark green	dark green	pillows present, but rare and poorly preserved	fine grained, approaching medium grain size; moderately foliated (gneissic); characterized by sugary granular texture	rocks recrystallized, minerals metamorphic; mixture of plagioclase, dark green amphibole and accessory oxide minerals; diopside and garnet present rarely	high grade metamorphic derivatives of rocks of unit 3; lack of garnet in these mafic metavolcanic gneisses is believed to be due to composition of parent volcanic strata
3d	felsic metavolcanic gneiss	light grey with buff and orange hues; large outcrops with moderate relief	light grey	massive, homogeneous, non-laminated; portions porphyritic	fine grained; weakly foliated (gneissic)	rocks recrystallized, minerals metamorphic; mixture of plagioclase, quartz, green amphibole, biotite and rare garnet	parent rock probably dacitic and andesitic in composition
4, 4a	dacite flows (4); metadacite (4a)	white, large outcrops with moderate relief	light grey	mainly massive flows; autoclastic (explosion) breccias present locally; quartz and plagioclase phenocrysts present, but not prominent; amygdalae present locally; pillows noted at two localities	very fine grained; massive; fragments tectonically deformed with steep-plunging long axes	mixture of very fine-grained plagioclase and quartz, which also occur rarely as phenocrysts; biotite, chlorite, muscovite and disseminated sulphides and graphite present in small amounts; rocks from north-eastern shore of island (unit 4a) characterized by numerous large (1-3 mm) porphyroblasts of green amphibole	autoclastic breccias with a 'shattered porcelain' appearance occur at several localities, they are believed to be caused by internal gas explosions after flows solidified
5, 5b	basalt and andesite flows (5); basalt and andesite breccia (5b)	dark green; large outcrops with low relief	dark green	mainly massive and pillowed flows; pillows have thin selvages, many have epidotized cores; pillow breccias common as interlayers in flow sequences; heterolithic breccias common in unit 5b; plagioclase phenocrysts common in rocks of unit 5b; narrow ash horizons present rarely; columnar cooling joints present in some massive flows	fine grained; massive to moderately foliated; strongly foliated on west shore of Woosey Lake and south shore of File Lake	rock recrystallized, minerals metamorphic; consist mainly of mixture of plagioclase and green amphibole; accessory minerals include iron oxides, biotite, chlorite and epidote; rocks within 0.3 km of the Reed Lake pluton show significant increases in grain size and degree of recrystallization	during field mapping many exposures between Butler and Fussey Lakes were noted to have very rubbly weathering surfaces, samples from many of these outcrops subsequently have been identified as hyaloclastic breccias; rocks of unit 5 and 5b on strike with fragmental dacites of unit 6 tend to be porphyritic, typically fragmental and generally slightly less mafic than normal

Unit No.	Rock type	Weathering characteristics	Colour of fresh surface	Primary structures and textures	Grain size and fabric	Mineralogy	Comments
5a	porphyritic basalt and andesite flows	light to medium green	light to medium green	massive; contain prominent flow aligned laths of plagioclase; some plagioclase crystals exhibit excellent igneous zonation; carbonate and quartz filled vesicles	fine grained groundmass with 2-25 mm phenocrysts of plagioclase; plagioclase microlites common in groundmass	rocks recrystallized (some very strongly) by Reed Lake pluton, minerals metamorphic except for plagioclase phenocrysts (An ₄₈₋₆₂); groundmass is mixture of plagioclase, brown biotite, green hornblende and minor epidote; carbonate vesicles recrystallized with following mineralogy typical from core to rim: calcite → calcium garnet → diopside → mixture of epidote, plagioclase and sphene	unit draped around and recrystallized by Reed Lake pluton (unit 22)
5c	mafic metavolcanic gneiss	dark green; large outcrops with moderate to high relief	dark green	massive, homogeneous; pillows present, but rare and poorly preserved	fine grained, approaching medium grain size; moderately foliated (gneissic); characterized by sugary granular texture	rocks recrystallized, minerals metamorphic; mixture of plagioclase, dark green amphibole and accessory oxide minerals; diopside and garnet present rarely	high grade metamorphic derivatives of rocks of unit 5; lack of garnet in these mafic metavolcanic rocks is believed to be due to composition of parent volcanic rocks; rocks of unit 5c identical to and, possibly, stratigraphically equivalent to rocks of unit 3c
6	dacite breccia	white to light green, locally with slight rusty staining		heterolithic breccias common; plagioclase present as phenocrysts	fine grained; weakly to moderately foliated		boundaries of this unit difficult to define because of intermixing of a wide variety of lithologies, including mafic flows
7, 7a	garnetiferous fragmental porphyritic mafic metavolcanic gneiss (7); garnetiferous mafic metavolcanic gneiss (7a)	dark green, large outcrops with low relief	dark green	heterolithic breccias ubiquitous in unit 7, fragments vary from andesite to rhyolite, generally less mafic than matrix, average size of fragments is 2-6 cm (in horizontal plane); both fragments and host rocks are strongly porphyritic; pillows and amygdalae occur rarely	fine grained; massive to weakly foliated	rocks recrystallized, minerals metamorphic; composed chiefly of plagioclase and green amphibole, with lesser amounts of quartz and red-brown biotite; pyralisite garnet porphyroblasts common; oxide minerals, chlorite and zoisite occur in small amounts	rocks of unit 7a generally are non-porphyritic and non-fragmental; this may be due to destruction of these textures by metamorphism adjacent to the Woossey pluton but more likely it is due to lack of them in the parent volcanic rock
8	garnetiferous felsic metavolcanic gneiss	light grey to greyish white, locally with slight rusty staining; outcrops small and poorly exposed	light grey	generally massive, but locally contains diffuse fragments and poorly defined layering; feldspar phenocrysts common	fine grained; weakly to moderately foliated	rocks recrystallized, minerals metamorphic; composed chiefly of quartz and plagioclase, with lesser amounts of acicular pale green amphibole, green biotite and disseminated pyrite; pyralisite garnet present as porphyroblasts	

TABLE A-2a: GENERAL CHARACTERISTICS AND MEGASOCPIC FEATURES OF AMISK INTRUSIVE ROCKS (UNITS 9 and 10)

Unit No.	Rock type	Style of intrusion	Contacts	Homogeneity	Assimilation	Inclusions	Megacrysts	Weathering characteristics	Colour of fresh surface	Comments
9	diorite	pre-kinematic; irregular bodies; likely epizonal, possibly sub-volcanic	intrusive, sharp	homogeneous	absent	absent	absent	dark green, iron oxide staining common; outcrops large with moderate relief	dark green	columnar cooling joints only primary structure noted, east of Morton Lake, some intrusions mapped as unit 9 may comprise rocks of unit 18(1)
10	quartz feldspar tonalite porphyry	pre-kinematic; irregular stocks and dykes; likely epizonal, possibly sub-volcanic	intrusive, sharp	homogeneous	absent	absent	abundant phenocrysts of quartz and plagioclase	white, with minor iron staining; outcrops large with moderate relief	light grey	quartz phenocrysts are a translucent blue colour

TABLE A-2b: MICROSCOPIC FEATURES OF AMISK INTRUSIVE ROCKS (UNITS 9 and 10)

Unit No.	Rock type	Texture		Total mafic mineral content	Mafic materials		Felsic minerals			Accessory minerals	An content plagioclase
		Primary	Secondary		Primary	Secondary	Quartz	Potassium feldspar	Plagioclase		
9	diorite	fine to medium grained	fine to medium grained granoblastic polygonal; portions weakly foliated	40-60%		poikilitic blue-green amphibole	absent	absent	40-60%; occurs as very fine grained recrystallized granoblastic polygonal masses, locally including small amounts of zoizite	sphene, iron-titanium oxide minerals, chlorite, zoizite and calcite	
10	quartz-feldspar tonalite porphyry	strongly porphyritic; very fine grained groundmass; phenocrysts 2-10 mm in size	variable, generally minor recrystallization; portions weakly foliated	10%		1-5% red-brown biotite, defines weak foliation in places	in matrix and as phenocrysts, the latter have strongly embayed boundaries; phenocrysts typically strained, fractured and, in northern exposures, recrystallized	absent	50-60%; occurs in matrix as subhedral phenocrysts; some phenocrysts are: i) weakly zoned; ii) strained, fractured and, in northern exposures, recrystallized; and iii) partially replaced by zoizite	pyrite, apatite, and sphene; muscovite, epidote, tourmaline, paraspate garnet present in minor amounts as small porphyroblasts	38-41

TABLE A-3: MAIN FEATURES OF AMISK SEDIMENTARY ROCKS (UNITS 11 to 15)¹

Unit No.	Rock type	Weathering characteristics	Colour of fresh surface	Grain size and fabric	Mineralogy	Character of bedding	Primary structures and textures	Comments
11	polymictic volcaniclastic paraconglomerate	light to medium grey; outcrops on shore of Woosey Lake show strong differential weathering with fragments showing positive relief	light grey	fine grained; weakly to moderately foliated; fragments are tectonically deformed with steep plunging long axes	rocks recrystallized; minerals metamorphic; composed chiefly of quartz and plagioclase with lesser amounts of red-brown biotite, garnet and green amphibole	lacks layering at all scales except for some rare, thick diffuse 'beds' defined by slight variation in clast sizes and clast to matrix ratios	conglomeratic throughout with fragments which vary widely in composition, size and degree of roundness (most are felsic volcanic, subangular to sub-round, and pebble-sized)	composed of volcanic detritus; probably deposited by sub-aqueous debris flows
12	laminated sandstone, siltstone and mudstone interbedded with pebbly volcaniclastic sandstone	light to dark grey, weak iron staining common; small outcrops with low relief	light to medium grey	variable depending upon bed and degree of metamorphism; generally weakly foliated siltstones; local pebble-bearing horizons	not significantly recrystallized, small porphyroblasts of acicular pale green amphibole common	bedding in tuffaceous sandstone, siltstone and mudstones is thin, continuous and parallel sided; bedding in pebbly sandstone beds is thick, lensoid, commonly irregular and graded	except for bedding, all other structures and textures are rare; the following have been observed in pebbly sandstone beds: -scour and fill channels -intraformational 'rip-up' fragments -flame structures -current laminations -graded bedding -convolute laminations Slump structures and ironstone concretions have been observed in laminated sandstone, siltstone and mudstone sequences	extremely immature sediments with strong volcanic affinities; pebbly volcanic sandstone beds were probably deposited by gravity-driven sub-aqueous mass-sediment flows; type exposures located 750 m north-west of Yakymiw Lake
13	lithic greywacke, feldspathic greywacke, siltstone and mudstone	light to dark grey, mudstones have weak iron staining; moderate to large outcrops with low relief	light to dark grey	variable, depending upon bed and degree of metamorphism; generally weakly foliated sandstone sized material	not significantly recrystallized, small metamorphic crystals of chlorite, sericite and biotite present in detrital matrix	bedding is repetitive, generally parallel-sided and varies from thin to thick; graded bedding and scouring common; Bouma zonation of internal primary sedimentary structures is common	primary structural features of turbidity current deposits ubiquitous, these include (in order of abundance): -graded bedding -internal parallel laminations -scour and fill channels -intraformation 'rip-up' fragments -convolute laminations -load casts -flame structures -calcareous concretions -current laminations	-three main bed types observed in unit 13: 1) <i>ABCD(E)</i> beds with turbidite zonation of primary sedimentary structures; 2) <i>AE</i> beds of massive sandstone and graded massive sandstone; and 3) <i>DE</i> beds of thin-bedded siltstone and mudstone; -type exposure of sequence dominated by <i>ABCD(E)</i> beds is located on west shore of Morton Lake opposite Elmes Island; -type exposure of sequence dominated by <i>AE</i> beds is located on peninsula at south end of Morton Lake.
13a	metasiltstone	light to medium grey; small outcrops with low relief	light to medium grey	fine grained; massive to weakly foliated	recrystallized and characterized by prominent acicular porphyroblasts of green amphibole and small crystals of brown biotite	indistinct, poorly defined, many exposures massive	none, except for bedding and, in one locality, graded bedding and delicate current laminations	relationship to strata of unit 13 uncertain, may be either basal to strata of unit 13 and/or a lateral facies equivalent

¹Includes metavolcanic rocks of units 14 and 14a

Unit No	Rock type	Weathering characteristics	Colour of fresh surface	Grain size and fabric	Mineralogy	Character of bedding	Primary structures and textures	Comments
13b	<u>File Lake area</u> garnet biotite gneiss ± staurolite ± sillimanite ± anthophyllite	light to medium grey; moderate to large outcrops with very low relief	light to medium grey	fine grained; granoblastic polygonal; prominent porphyroblasts of aluminosilicate minerals; moderately to strongly foliated (schistose)	completely recrystallized, minerals metamorphic; mixture of garnet + biotite + quartz + andesine ± staurolite ± sillimanite ± anthophyllite; sillimanite restricted to rocks north of File Lake	same as unit 13	same as unit 13, but rarely preserved (except in outcrops on south shore of File Lake); graded bedding common, even in highly metamorphosed rocks	zonal distribution of staurolite and sillimanite porphyroblasts define south to north increase in regional metamorphic grade; strata of unit 13b are high grade metamorphic derivatives of rocks of units 13
13b	<u>Woosey Lake area</u> garnet biotite gneiss ± staurolite ± chlorite	light to medium grey; moderate to large outcrops with very low relief	light to medium grey	fine grained; granoblastic polygonal; prominent porphyroblasts of aluminosilicate minerals; weakly to moderately foliated (schistose)	completely recrystallized, minerals metamorphic; mixture of garnet + biotite + quartz + andesine ± staurolite; sillimanite present but restricted to rocks directly adjacent to the Reed Lake pluton; andalusite present but almost always replaced by mixture of sericite, staurolite and quartz	same as unit 13	graded bedding and calcareous nodules common	metamorphic minerals probably a combination of regional metamorphism and of contact metamorphism by felsic plutons (in particular by the Reed Lake pluton)
13c	garnet biotite <i>lit-par-lit</i> gneiss	light to medium grey, locally with a brown hue; medium sized outcrops with low relief	light to medium grey	same as unit 13b except slightly coarser grained and foliation becomes gneissic; characterized by sills or white granitic mobilize	same as unit 13b except staurolite and muscovite no longer present (above their limit of stability); sillimanite, although stable, not as prominent as in rocks of unit 13b	common, but only most pronounced bedding preserved	none, except for bedding	granitic mobilize which occurs in rocks of unit 13c in interpreted to be a product of partial anatexis of the paragneiss
14	mafic meta-volcanic gneiss	dark green, strong iron staining locally; medium sized outcrops with moderate relief	dark green	fine- to medium-grained; granoblastic polygonal; moderately to strongly foliated (gneissic)	completely recrystallized, minerals metamorphic; mixture of plagioclase and green poikilitic hornblende; porphyroblasts of diopside and garnet	layering common, but may be metamorphic	strongly tectonized pillow structures(?) observed on one locality	some felsic gneisses, in very minor amounts occur near top of unit
14a	felsic meta-volcanic gneiss	white to light grey	white to light grey	fine- to medium-grained; granoblastic polygonal; commonly contains megacrysts of quartz (phenocrysts?); strongly foliated (gneissic)	completely recrystallized, mineral metamorphic; mixture of plagioclase, quartz, microcline, minor red-brown biotite and trace amounts of oxide minerals, sphene and apatite; porphyroblasts of pyralispite garnet	indistinct layering present locally, many exposures massive	megacrysts of quartz may be phenocrysts	parent rock for these gneisses uncertain; probably felsic volcanic strata, but may also be related to the meta-tonalities of unit 18(3)a, which they resemble; includes some 'interlayered' mafic gneisses
15	metapelite large garnet porphyroblasts	medium to dark grey; outcrops form long linear ridges with moderate relief	medium to dark grey	fine- to medium-grained; granoblastic polygonal; characterized by numerous euhedral 5-10 mm porphyroblasts of deep purple pyralispite garnet; strongly foliated (schistose)	completely recrystallized, minerals metamorphic; mixture of plagioclase, quartz and red-brown biotite, the latter defines a foliation; large porphyroblasts of garnet, poikilitic cordierite and red-brown biotite common; fibrolitic sillimanite clots common in rocks exposed north of Corley Lake; staurolite porphyroblasts present, but not particularly common (do not occur in rocks north of Corley Lake)	delicately laminated; beds very thin compared to those of strata of unit 13b		contact of rocks of units 15 and 13b are rapidly gradational; unit 15 characterized by its homogeneity and distinctive porphyroblasts of garnet and, in thin section, of cordierite; first appearance of sillimanite is 2 km north of its first appearance in rocks of unit 13b

TABLE A-4 : MAIN FEATURES OF MISSI SEDIMENTARY ROCKS (UNITS 16 and 17)

Unit ¹ No.	Rock type	Weathering characteristics	Colour of fresh surface	Grain size and fabric	Mineralogy	Character of bedding	Primary structures and textures	Comments
16(1)	quartz- plagioclase biotite paragneiss ± garnet ± sillimanite	light grey to white; large outcrops with moderate relief	light grey	fine- to medium- grained; grano- blastic polygonal; strongly foliated	completely recrystal- lized, minerals meta- morphitic; mainly quartz and andesine, plus minor amounts of red-brown biotite and muscovite; por- phyroblasts of pyr- alpite garnet and small clots of fibrolitic sillimanite common; rare staurolite; mag- netite and apatite common accessory minerals	parallel-sided, defin- ed by subtle changes in mineralogy, texture, colour and/ or composition; finely laminated, the lami- nations defined by concentrations of biotite and, more rarely, magnetite	parallel lamination and cross lamination	rocks, particularly at base of unit, highly variable and include some varieties which con- tain staurolite porphyroblasts; rocks of unit 16(1) tend to be more quartz-rich than those of either 16(2) or 16(3); locally contain pebbles and narrow, green calcisilicate layers.
16(2)	plagioclase- quartz-biotite paragneiss ± microcline	white to light grey; large out- crops with moderate relief	light grey	as above	completely recrystal- lized mixture of ande- sine, quartz, red- brown biotite and, in small amounts, mic- rocline and muscovite quartz-sillimanite no- dules common in rocks east of Corley Lake; magnetite and apatite common ac- cessory minerals	as above, except rocks not generally finely laminated	rare cross lamina- tion	
16(3)	plagioclase- quartz- microcline- biotite paragneiss	buff to light grey, pink hues common; large outcrops with moderate relief	buff to light grey	as above, portions with a granitoid texture	as above, except microcline a promi- nent component	bedding rarely well preserved, generally thick homogeneous	rare cross lamina- tion	many rocks of this are gradational into those of unit 17
17	granoblastic microcline-rich paragneiss	buff to pink; large outcrops with moderate relief	buff	fine- to medium- grained; grano- blastic polygonal (granitoid); gneissic	as above, except microcline very prominent	bedding rarely pre- served		rocks of unit 17 east of Gates Lake have strong iron staining and contain green amphibole porphyro- blasts; portions of unit 17 closely re- semble rocks of unit 26

¹ In places unit 16 is more strongly recrystallized and cannot be subdivided into 16(1), 16(2) and 16(3). Unsubdivided 16(1) contains a combination of features described for the various subunits.

TABLE A-5a: GENERAL CHARACTERISTICS AND MEGASCOPIC FEATURES OF EARLY KINEMATIC INTRUSIVE ROCKS (UNITS 18 and 19)

Unit No	Rock type	Style of intrusion ¹	Contacts	Homogeneity	Assimilation	Inclusions	Megacrysts	Weathering Characteristics	Colour of fresh surface	Grain size and fabric	Comments
18(1)	gabbro, leucogabbro	basal zone to differentiated mafic sills and sill-like bodies	base sharp, chilled, top (i.e. with unit 18(2)) rapidly gradational over a few metres to, rarely, a few tens of metres	homogeneous (in detail some compositional layering)	absent	absent	absent	white (with green hue) to medium olive-green; large outcrops with moderate to high relief	light to medium olive green	medium grained; massive to weakly foliated	unit 18(1) tends to be slightly more melanocratic (and mafic?) in 2nd generation intrusions; the plug-shaped body of unit 18(1) southwest of Yakymiw Lake is more pyroxene-rich than normal varieties of unit 18(1)
18(1)a	plagioclase-hornblende gneiss	as above	as above	as above	absent	absent	absent	as above	medium to dark green	medium grained; moderately to strongly foliated (gneissic)	rocks of unit 18(1)a are darker coloured than those of unit 18(1) because the secondary amphibole in them is a darker green
18(1)b	porphyritic leucogabbro			homogeneous	absent	absent	large 5-20 mm phenocrysts of euhedral plagioclase	light to medium green; medium sized outcrops with moderate relief	light to medium green	medium- to coarse-grained; massive to weakly foliated (plagioclase laths are aligned in foliation)	xenoliths of unit 18(1)b are common along the northern and eastern edges of the Norris Lake pluton (units 23)
18(2), 18(2)a	ferrogabbro; melanocratic hornblende-plagioclase gneiss	central zone in differentiated mafic sills and sill-like bodies	upper and lower contacts both rapidly gradational over a few metres to, rarely, a few tens of metres; interlayered with rocks of adjacent zones along both upper and lower contacts	homogeneous, but does contain prominent small scale rhythmic igneous layering	absent	absent	absent	dark green to black; large outcrops with moderate to high relief	dark green to black	fine- to medium-grained; massive to weakly foliated in unit 18(2) and moderately to strongly foliated, in unit 18(2)a	rhythmic igneous layering, generally less than a metre thick, is characteristic of this zone; layering is defined by variation in proportion of amphibole to plagioclase across individual layers and between layers.
18(3)	quartz diorite and tonalite	upper zone in differentiated mafic sills and sill-like bodies	basal contact rapidly gradational over a few metres to, rarely, a few tens of metres; upper contact sharp to rapidly gradational	inhomogeneous, generally more leucocratic towards top	active locally	rare	translucent blue quartz phenocrysts common; plagioclase phenocrysts common, particularly in exposures on southwest shore of File Lake	white, sometimes with pale green hue; outcrops moderate in size and relief	light grey	fine- to coarse-grained; moderate to strongly foliated (gneissic)	rocks of this unit most prominent in 1st generation intrusions; strongly sheared in exposures along east shore of Morton Lake and southwest shore of File Lake; plagioclase phenocrysts prominent feature of exposures of this unit on southwest shore of File Lake
18(3)a	plagioclase-quartz hornblende-biotite-gneiss ± microcline ± garnet	as above	as above	as above	as above	as above	garnet porphyroblasts common; quartz and plagioclase phenocrysts rarely preserved	as above	as above	as above	horizon of unit 18(3)a west of the File River is atypical as it has no related mafic phases and it is strongly porphyritic

Unit No	Rock type	Style of intrusion ¹	Contacts	Homogeneity	Assimilation	Inclusions	Megacrysts	Weathering Characteristics	Colour of fresh surface	Grain size and fabric	Comments
18(3)b	syneusitic quartz diorite and tonalite	lower part of upper zone in differentiated mafic sills and sill-like bodies	basal contact rapidly gradational over a few metres to, rarely, a few tens of metres; upper contact very gradational	inhomogeneous, generally more leucocratic towards top	absent	rare	syneusitic clusters of lath shaped green amphiboles prominent; small phenocrysts of quartz and plagioclase common; garnet porphyroblasts common in exposures north of Storozuk Lake	mottled white and black, rarely with buff hues; outcrops moderate in size and relief	mottled white and dark green	medium- to coarse-grained with large syneusitic growths of green amphibole; massive to moderately strongly foliated	rocks of this unit characteristic of lower part of the uppermost zone in the second generation sills; exposures north of Yakymiv Lake are progressively more recrystallized towards Josland Lake
18(3)c	granophyric tonalite	upper part of upper zone in differentiated mafic sills and sill-like bodies	basal contact completely gradational; upper contact diffuse, rapidly gradational with some assimilation of overlying rocks	inhomogeneous, generally more leucocratic towards top	active locally		quartz and, more rarely, plagioclase phenocrysts; garnet porphyroblasts common in exposures north of Storozuk Lake	white, portions with buff hues; outcrops moderate in size and relief	white to light grey	medium- to coarse-grained; massive to moderately strongly foliated	rocks of this unit characteristic of upper part of uppermost zone in second generation intrusions; exposures north of Yakymiv Lake are progressively more recrystallized towards Josland Lake
19	meta-gabbro, amphibolite	sill-like bodies	sharp	homogeneous				dark green to black	dark green to black	medium grained; strongly foliated (gneissic)	mainly metagabbro, but may include minor amounts of metavolcanic rocks and para-amphibolites

¹ Intrusions of the Josland Lake Gabbro are pre- to early kinematic differentiated mafic sills and sill-like bodies. Two ages (or generations) of intrusions are recognized. One is pre kinematic. The other post-dates an early phase of recumbent folds and intrudes parallel to their axial planes

TABLE A5b: MICROSCOPIC FEATURES OF EARLY KINEMATIC
INTRUSIVE ROCKS (UNITS 18 and 19)

Unit No	Rock type	Texture		Total mafics	Mafic minerals		Felsic minerals			Accessory minerals	An content plagioclase ¹
		Primary	Secondary		Primary	Secondary	Quartz	Potassium feldspar	Plagioclase		
18(1)	gabbro, leucogabbro	cumulate textures prominent; plagioclase and augite both occur as cumulate phases; many ilmenite grains are skeletal; grain size is 1-2 mm	secondary minerals; generally relict the primary textures	40-60%, generally less than 50%	augite main primary mafic mineral; green-brown hornblende present rarely	augite almost completely replaced by pale green tremolite and, in small amounts, by phlogopitic biotite; tremolite is darker green and more granoblastic in highly metamorphosed varieties	absent	absent	grains vary from well twinned primary crystals, either as cumulate or inter-cumulate phase, to granoblastic polygonal recrystallized aggregates; zoizite may partially or completely replace plagioclase	ilmenite and sphene prominent accessory minerals; chlorite and calcite common as retrogressive phases	42-80, averages 50-55
18(1)a	plagioclase hornblende gneiss		medium grained; granoblastic polygonal; moderate to strongly foliated	40-60% generally less than 50%		green to blue-green poikilitic sub-hedral amphibole; small amounts of red-brown biotite and granular aggregates of diopside	absent	absent	granoblastic polygonal aggregates of well twinned clear secondary grains	ilmenite and sphene	plagioclase (metamorphic) has similar range in composition as the primary plagioclase above (i.e. An content in these rocks controlled by composition not by grade of metamorphism)
18(1)b	porphyritic leucogabbro	prominent lath shaped phenocrysts of plagioclase up to 2 cm long	mafic minerals recrystallized to granoblastic polygonal aggregates	30-40%	green to blue-green poikilitic sub-hedral amphibole; minor amounts of red-brown biotite	absent	absent		lath shaped euhedral well twinned plagioclase phenocrysts, rarely have oscillatory zoning	ilmenite, sphene and apatite	38-47, averages 43
18(2)	ferrogabbro	rare sub-ophitic textures	fine- to medium-grained granoblastic polygonal aggregates; massive to weakly foliated	50-80%, generally between 60-70%		dark green to dark blue-green sub-hedral amphibole	in very small amounts near the top of zone	absent	generally recrystallized and partially replaced by zoizite	skelital grains of ilmenite	
18(2)a	hornblende-plagioclase gneiss		as above, but strongly foliated (gneissic)	as above		as above; may include minor amounts of diopside	as above	absent	clear, well twinned secondary grains	ilmenite rimmed by sphene	
18(3)	quartz diorite and tonalite	phenocrysts of quartz and plagioclase common; weak granophyric intergrowths of quartz and plagioclase occur rarely	fine- to medium-grained; granoblastic polygonal; moderate to strongly foliated	5-40%, generally between 10-15%		dark blue-green to dark green poikilitic subhedral amphibole and red-brown biotite	increases in amount towards top of unit; prominent as phenocrysts (generally recrystallized)	rare microcline	common, both in ground mass and as phenocrysts; phenocrysts generally well twinned, some with oscillatory zoning	ilmenite, apatite and sphene; garnet common as porphyroblasts in exposures on south shore of File Lake	albite in leucocratic varieties; andesine in mesocratic varieties
18(3)a	plagioclase-quartz-hornblende-biotite gneiss ± microcline ± garnet	as above, but rarely observed	as above	as above		as above	as recrystallized grains in granoblastic polygonal mozaics with plagioclase	rare microcline	recrystallized grains in granoblastic polygonal mozaics with quartz	as above; porphyroblasts of garnet ubiquitous and prominent	

Unit No	Rock type	Texture		Total mafics	Mafic minerals		Felsic minerals			Accessory minerals	An content plagioclase ¹
		Primary	Secondary		Primary	Secondary	Quartz	Potassium feldspar	Plagioclase		
18(3)b	syneustic quartz diorite and tonalite	prominent syneustic clusters of lath shaped green amphibole; granophyric intergrowths of quartz and plagioclase ubiquitous; phenocrysts of quartz and plagioclase common	in part recrystallized to granoblastic polygonal aggregates, massive to moderately strongly foliated	20-50%		dark blue-green to dark green poikilitic sub-hedral amphibole	10-20% as phenocrysts, as graphic intergrowths with plagioclase and as grains in ground mass; strongly recrystallized in northern exposures	absent	40-60% as phenocrysts, as graphic intergrowths with quartz and as grains in ground mass; strongly recrystallized in northern exposures	ilmenite and apatite; garnet occurs as porphyroblasts in rocks from most northerly exposures	3-7
18(3)c	granophyric tonalite	granophyric intergrowths of quartz and plagioclase ubiquitous and prominent; phenocrysts of quartz and plagioclase common	in part recrystallized to granoblastic polygonal aggregates; massive to moderately strongly foliated	5-25%		dark blue-green to dark green poikilitic sub-hedral amphibole and, more rarely, green-brown biotite	15-35%, occurs as above	rare orthoclase (?)	40-70%, occurs as above	as above	3-7
19	metagabbro, amphibolite		medium grained, granoblastic polygonal, strongly foliated (igneissic)	30-70%		dark blue-green poikilitic sub-hedral amphibole; small amounts of dark brown biotite	rare, but locally up to 30%; clear	absent	clear, well twinned sub-euhedral grains	ilmenite, sphene and apatite	andesine (metamorphic)

¹ Plagioclase is primary unless otherwise indicated

TABLE A-6a: GENERAL CHARACTERISTICS AND MEGASCOPIC FEATURES OF SYN- TO POST-KINEMATIC FELSIC INTRUSIVE ROCKS (UNITS 20 TO 24, 27 and 28)

Unit No. ¹	Rock type ²	Style of intrusions ³	Contacts	Homogeneity	Assimilation	Inclusions	Megacrysts	Weathering characteristics	Colour of fresh surface	Grain size and fabric	Comments
20	quartz-rich leucotonalite and granodiorite	early kinematic stock	variable, sharp to gradational	homogeneous	active locally		poorly formed phenocrysts of quartz and plagioclase; porphyroblasts of pyralispite garnet common	creamy pink to buff, rarely white, large outcrops with moderate relief	creamy pink to buff, light grey, rarely, light and dark coloured minerals occur in clusters giving rock a mottled appearance	fine- to medium-grained ground mass; poorly formed phenocrysts of quartz and plagioclase; moderately to strongly foliated (gneissic)	rocks of Woosey Lake pluton are strongly deformed, recrystallized and metamorphosed
21	granodiorite leucotonalite and tonalite	early to syn-kinematic batholith	sharp	homogeneous	absent	abundant adjacent to outer contact, inclusions angular in shape		white to creamy pink, large outcrops with high relief	white to creamy pink	medium- to coarse-grained; hypidiomorphic granular; massive to moderately strongly foliated (gneissic)	exposures along margin of batholith and at its north end are most strongly foliated; foliation defined by flattened (partially crushed and annealed) quartz and plagioclase grains
22a	quartz leucodiorite	part of an early to syn-kinematic batholith	gradational into rocks of surrounding agmatite zone (unit 22c)	homogeneous	active locally	common adjacent to outer contact, inclusions irregular in shape		grey, medium sized outcrops with low relief	greenish-grey to grey	massive, medium grained; hypidiomorphic granular	rocks of unit 22a are metamorphosed, possibly by those of unit 22a cut rocks of the marginal agmatite zone (unit 22c)
22b	plagioclase-rich leucotonalite	part of an early to syn-kinematic batholith		homogeneous				white, medium sized outcrops with low relief	white to light grey	medium grained; hypidiomorphic granular to weakly foliated	the Reed Lake pluton has a prominent thermal contact aureole
23	plagioclase-rich leucotonalite	syn- to late-kinematic stock	sharp	homogeneous	absent	abundant adjacent to outer contact; inclusions angular in shape		white to light grey, large outcrops with moderate relief	light grey	medium grained; hypidiomorphic granular	the Norris Lake pluton has a prominent thermal contact aureole
24	granite and leucogranite	syn- to late-kinematic stock	sharp	homogeneous	absent	rare	microcline (1-2 cm)	white to light pink, large outcrops with high relief	white to light grey, commonly with pink hues	coarse grained; hypidiomorphic granular; prominent phenocrysts of microcline	rocks of intrusion are massive and undeformed; outline of stock is circular; adjacent to margins groundmass of rocks, fine grained with phenocrysts of quartz and plagioclase, in addition to those of microcline

Unit No. ¹	Rock type ²	Style of intrusions ³	Contacts	Homogeneity	Assimilation	Inclusions	Megacrysts	Weathering characteristics	Colour of fresh surface	Grain size and fabric	Comments
27	monzo-granite gran-diorite	syn-kinematic sheets, <i>lit</i> and irregular masses	variable, sharp to completely gradational	heterogeneous	locally very prominent	abundant throughout; inclusions generally have smooth outlines and are partially assimilated	microcline and garnet occur locally as megacrysts	white to, rarely, light pink	white	coarse grained, commonly pegmatitic, massive to strongly foliated (gneissic)	occurs as mobilized phase of <i>lit par lit</i> gneisses of unit 13c; rocks of unit 27 are believed to be produced by partial anatexis of greywacke and mudstone strata of the Amisk Group
28	felsic pegmatite	post-kinematic dykes	sharp	homogeneous	absent	rare		white to pink (varies according to host rock)	white to pink (varies according to host rock)	pegmatitic	cross cuts all other rock units and their contained fabrics

¹ Rocks of units 20a and 22c are agmatite zones adjacent to the Woosey Lake and Reed Lake plutons, respectively. Their general characteristics are not summarized in this table.

² The intrusive rocks are classified according to system of nomenclature proposed by the I.U.G.S. Subcommittee on the Systematics of Igneous Rocks (Streckeisen, 1976).

³ The terms early-, syn- and late-kinematic are used to indicate age of the plutonic rocks related to those deformational events which occurred during the main episode of high grade regional metamorphism. They are not precise terms as several pulses of deformation intervene between and overlap the intrusive episodes (see Table 17).

TABLE A-6b: MICROSCOPIC FEATURES OF SYN- TO POST KINEMATIC FELSIC
INTRUSIVE ROCKS (UNITS 20 to 24, 27 and 28)

Unit No	Rock type	Texture		Total mafics	Mafic minerals		Felsic minerals			Accessory minerals	An content plagioclase
		Primary	Secondary		Primary	Secondary	Quartz	Potassium feldspar	Plagioclase		
20	quartz rich leucotonalite and granodiorite	phenocrysts of plagioclase and quartz common, but poorly preserved; ground mass fine grained	fine- to medium-grained; granoblastic polygonal; moderate to strongly foliated (gneissic)	2-10%		dark green poikilitic subhedral amphibole; dark green biotite; chlorite in small amounts	clear grains, commonly strained and annealed; occurs both in matrix and as large annealed aggregates (phenocrysts?)	microcline in small amounts	cloudy well twinned grains; common as phenocrysts	epidote muscovite and rare magnetite	albite-oligoclase
21	granodiorite, leucotonalite and tonalite	medium to coarse grained; hypidiomorphic	portions gneissic, foliation in part cataclastic; quartz and plagioclase strained and, sometimes, crushed and annealed	2-13%, average 5%	hornblende X-yellow green, Y-olive green, Z-dark green; biotite (greenish-brown to red-brown)	red-brown biotite present rarely	clear grains; strongly strained and, locally, crushed and annealed	microcline common; myrmekitic intergrowths with quartz common	generally clear, strongly twinned grains; rarely has weak igneous zoning	muscovite common in small amounts; epidote, zoisite chlorite and sericite present as retrogressive phases; garnet porphyroblasts present in rocks from northern exposures	28-36, averages 31
22a	quartz leucodiorite	medium grained; hypidiomorphic granular	portions partially recrystallized; prominent metamorphic coronas on mafic minerals	10-20%	orthopyroxene (bronzite)	cummingtonite, green-brown hornblende, blue-green hornblende and red-brown biotite form coronas (zoned as above) around orthopyroxene grains	clear interstitial grains; generally weakly strained and fractured	absent	clear subhedral to euhedral grains; some poor igneous zoning and also metamorphic rims; many grains strained	ilmenite, apatite and sphene common; sphene occurs as rims on ilmenite; pyralisite garnet porphyroblasts present locally	40-51 (32-36 in metamorphic rims)
22b	plagioclase rich leucotonalite	medium grained; hypidiomorphic granular		2-10%	biotite (pale straw-yellow to dark red-brown) plus minor amounts of hornblende (X yellow green, Y dark olive-green, Z dark blue-green)		clear weakly strained grains	microcline is present in small amounts	clear, weakly strained, well twinned subhedral grains	apatite and muscovite	26
23	plagioclase rich leucotonalite	medium grained; hypidiomorphic granular	partial recrystallization and alteration of primary minerals	5-15%	brown hornblende	green poikilitic hornblende and red-brown biotite	15-25% as clear interstitial grains; weakly strained	orthoclase in small amounts	subhedral well twinned crystals; oscillatory zoning common; many grains have irregular metamorphic overgrowths	ilmenite, sphene and apatite	41-43; (26-31 in metamorphic rims)
24	granite and leucogranite	coarse grained; hypidiomorphic granular; prominent phenocrysts of microcline		1-7%	green biotite	chlorite partially replaces biotite	30-40% as clear weakly strained and fractured grains	20-40% as large poikilitic phenocrysts (1-2 cm in size)	25-40% as well twinned subhedral crystals	magnetite, apatite and pyrite present in trace amounts; muscovite, epidote, chlorite and calcite present as retrogressive phases	6-13

Unit No	Rock type	Texture		Total mafics	Mafic minerals		Felsic minerals			Accessory minerals	An content plagioclase
		Primary	Secondary		Primary	Secondary	Quartz	Potassium feldspar	Plagioclase		
27	monzo granite and grano-diorite	pheno-crysts(?) of microcline occur locally, mymekitic intergrowths of quartz and plagioclase common		0-15%	red-brown biotite		clear grains	microcline prominent as large poikilitic grains	subhedral grains	muscovite common	albite oligoclase
28	felsic pegmatite	phenocrysts of microcline common, graphic intergrowths of quartz with microcline and plagioclase common		< 10%	green-brown biotite		as individual grains and as graphic intergrowths in microcline and plagioclase	perthitic microcline	as individual grains and, rarely, as phenocrysts		

TABLE A-7: MAIN FEATURES OF ROCKS OF NELSON BAY GNEISS DOME (UNITS 25 and 26)

Unit No.	Rock type	Contacts	Weathering characteristics	Colour of fresh surface	Grain size and fabric	Mineralogy	Comments
25	granitoid oligoclase-quartz gneiss	rapidly gradational over a few metres with rocks of unit 26	white; large outcrops with moderate relief	white to light grey	fine- to medium-grained; granoblastic polygonal; moderately to strongly foliated (gneissic)	rocks are completely recrystallized gneisses composed of oligoclase (albite), quartz and lesser amounts of microcline, biotite, green amphibole and magnetite	magnetite crystals stand up in relief on weathered surfaces; nebulous layering common
26	granitoid oligoclase-quartz-microcline gneiss	contacts with rocks of both units 25 and 16 are gradational over a few metres	salmon pink; large outcrops with high relief	salmon pink to light pink	fine- to medium-grained; granoblastic polygonal locally with porphyroblasts of microcline, plagioclase, or both; moderately to strongly foliated (gneissic)	rocks are completely recrystallized gneisses composed of oligoclase (albite), quartz, microcline and lesser amounts of green-brown biotite, muscovite, green amphibole and magnetite	magnetite crystals stand up in relief on weathered surfaces; small segregations of quartz common; nebulous layering common
26a	oligoclase-quartz-microcline	gradational over a few metres	salmon pink; outcrops in long linear ridges of moderate relief	salmon pink to light pink	as above, except finer grained and foliation often has 'pseudo-cataclastic' stringy appearance; locally contains small shard-like fragments	as above, except amphibole not generally present	shows features above; outcrops as narrow horizons in Missi gneisses; possibly a recrystallized sub-aerial ash flow deposit

APPENDIX B: SUMMARY OF DIAMOND DRILLING ASSESSMENT WORK
[OPEN FILE, APRIL 1979], FILE LAKE AREA

Reference No. (Figure 108)	Company Reference No.	Depth of DDH in Metres	Date Completed	Name of Company	Claim No.	Accession No.	Significant Results
1	H19	89	10/1/58	HBED	HED69	90489	1 m and 3 m wide zones of sulphide-rich siliceous rock in metagabbro
2	H1	94	24/9/57	HBED	HED59	90489	Several small zones of nearly solid pyrrhotite and pyrite in hornblende-biotite gneiss
3	H3	96	29/9/57	HBED	HED59	90489	Hornblende-biotite gneiss with 7 m zone containing abundant pyrrhotite and minor pyrite
4	H2	234	29/9/57	HBED	HED72	90489	Several narrow seams of graphite in quartz-hornblende-biotite gneiss
5	H6	185	10/10/57	HBED	HED58	90489	Three 1 m and one 3 m wide zones containing abundant to near solid pyrite plus pyrrhotite in hornblende gneiss
6	H8	115	16/11/57	HBED	HED58	90489	Three 1 m and one ½ m wide zones containing abundant to near solid pyrite plus pyrrhotite in hornblende gneiss
7	COR23	94	10/3/67	HBED	COR12	91962	Several small pyrrhotite-rich zones in andesite
8	H4	102	3/10/57	HBED	HED60	90489	Several narrow zones of near solid pyrite and pyrrhotite in hornblende-biotite gneiss
9	H5	192	6/10/57	HBED	HED60	90489	1 m, 2 m and 3 m wide zones of near solid pyrite and pyrrhotite in hornblende gneiss and quartz-hornblende gneiss
10	H7	93	11/10/57	HBED	HED60	90489	Three 1 m zones containing abundant to near solid pyrite and pyrrhotite in hornblende gneiss
11	RED38	188	19/10/57	HBED	RED172	90495	Several narrow zones containing abundant to near solid pyrite and pyrrhotite in quartz-hornblende gneiss and quartz-sericite schist and gneiss
12	COR21	155	7/3/67	HBED	COR13	91962	Several narrow pyrrhotite-rich zones in andesite
13	RED39	117	23/10/57	HBED	RED168	90495	Several narrow zones in gabbro which contain abundant to near solid pyrrhotite and slight pyrite
14	RED41			HBED		90495	
15	RED40			HBED		90495	
16	RED42			HBED		90495	
17	RED43			HBED		90495	
18	RED44			HBED		90495	
19	COR18			HBED		91962	
20	COR20			HBED		91962	
21	COR19	115	1/3/67	HBED	COR22	91962	9 m of pyrrhotite- and pyrite-bearing rhyolite in sequence of coarse grained andesite
22	COR15	130	23/2/67	HBED	COR22	91962	60 m of quartz-hornblende-biotite gneiss containing numerous zones with 5 to 20% disseminated pyrrhotite
23	COR17	63	24/2/67	HBED	COR22	91962	10 m altered pyrrhotite- and pyrite-bearing rhyolite in sequence of coarse grained andesite
24	COR16			HBED		91962	
25	COR22			HBED		91962	
26	ELLIOT 8	24	16/8/52	ELLIOT SYNDICATE	ELLIOT 1	91846	17 m of dark grey, hornblende schist
27	ELLIOT 1	91	30/7/52	ELLIOT SYNDICATE	ELLIOT 1	91846	Siliceous schist with several narrow zones containing abundant pyrrhotite. Minor chalcopyrite reported.
28	ELLIOT 2-7	90 (Total)	1-9/8/52	ELLIOT SYNDICATE	ELLIOT 1	91846	Quartz stringers, containing minor arsenopyrite, pyrite and chalcopyrite, in gabbro
29	COR14			HBED		91962	

Reference No. (Figure 108)	Company Reference No.	Depth of DDH in Metres	Date Completed	Name of Company	Claim No.	Accession No.	Significant Results
30	COR2			HBED		91962	
31	COR1			HBED		91962	
32	COR12			HBED		91962	
33	COR13			HBED		91962	
34	COR10	100	11/2/67	HBED	COR47	91962	36 m of quartz-hornblende gneiss containing numerous zones of disseminated pyrite, pyrrhotite and graphite
35	COR4	95	25/1/67	HBED	COR62	91962	Altered rhyolite with numerous zones rich in graphite, pyrite and pyrrhotite
36	COR8	102	4/12/67	HBED	COR62	91962	Altered rhyolite with numerous zones rich in disseminated graphite, pyrite and pyrrhotite
37	COR6	117	30/1/67	HBED	COR62 & 63	91962	6 m of rhyolite with local pyrrhotite-rich zones
38	COR5	120	28/1/67	HBED	COR67	91962	Altered rhyolite and andesite with disseminated pyrrhotite, pyrite and graphite throughout
39	COR3	121	23/1/67	HBED	COR67	91962	52 m zone of altered rhyolite with numerous pyrite-bearing graphite zones
40	RED20	87	14/9/56	HBED	RED2	90489	2 m zone of rhyolite which contains abundant to near solid pyrrhotite and pyrite
41	RED19	147	9/9/56	HBED	RED11	90489	6 m zone of near solid pyrrhotite with minor pyrite at contact between andesite and quartz-biotite garnet gneiss
42	BILL2	74	3/2/57	NORTHERN CANADA MINES LTD.		90202	Three 1 m wide zones containing 5 to 15% pyrrhotite and minor pyrite in greywacke and 7 m of chlorite schist with 15% pyrrhotite and pyrite with a few specks of chalcopyrite
43	TOM18			HBED		90056	
44	COR11	137	11/2/67	HBED	COR9	91962	134 m of diorite with local narrow zones containing 1 to 3% pyrrhotite and pyrite
45	TOM16			HBED		90056	
46	TOM8			HBED		90056	
47	TOM12			HBED		90056	
48	TOM4	74	24/7/56	HBED	TOM18	90056	1.5 m zone containing abundant to near solid pyrrhotite, pyrite and graphite in siliceous highly altered gabbro
49	TOM14			HBED		90056	
50	TOM10			HBED		90056	
51	RED25	128	26/9/56	HBED	RED4	90489	One 1 m and two 4 m wide zones of pyrite-bearing graphitic schist, and a 26 m wide zone of graphitic rock with stringers of pyrite. Host rock is quartz-mica schist.
52	RED27	82	29/9/56	HBED	RED8	90489	Several narrow pyrite-rich zones in sheared andesite. Bottom 15 m of hole intersected quartz-biotite-staurolite-garnet gneiss
53	BILL 4	136	12/2/57	NORTHERN CANADA MINES LTD.		90202	9 m of argillaceous, locally graphitic metasedimentary rocks containing disseminated pyrrhotite and pyrite
54	RED22	139	20/9/56	HBED	RED10	90489	One 1 m and two 5 m zones of pyrite-bearing graphite schist in altered argillite and greywacke
55	BILL1	107	3/2/57	NORTHERN CANADA MINES LTD.		90202	Greywacke with several narrow zones containing minor pyrite and pyrrhotite
56	BILL3	77	6/2/57	NORTHERN CANADA MINES LTD.		90202	Mica schist with several narrow zones containing minor pyrite and pyrrhotite
57	COR9	65	6/2/67	HBED	COR5	91962	4 m of 50% pyrrhotite and pyrite, with traces of chalcopyrite. Host rock is a 30 m wide zone of rhyolite sandwiched between gabbro and diorite
58	TOM29			HBED		90056	

Reference No. (Figure 108)	Company Reference No.	Depth of DDH in Metres	Date Completed	Name of Company	Claim No.	Accession No.	Significant Results
59	TOM5	226	25/7/56	HBED	TOM4	90056	Hornblende gabbro with 0.5 m, 1 m and 5 m wide zones containing abundant to near solid pyrrhotite and pyrite. An 11 m zone of siliceous andesite, tuff beds and altered flows contains a 6 m wide layer of pyrrhotite- and pyrite-rich graphite schist
60	COR7	65	2/2/67	HBED	COR1	91962	Fine grained gabbro with numerous narrow zones containing 5 to 30% graphite, pyrite and pyrrhotite
61	TOM3			HBED		90056	
62	TOM2			HBED		90056	
63	TOM28			HBED		90056	
64	TOM31			HBED		90056	
65	COPPER5	23	19/7/52	THOMPSON BROS.	COPPER1	90036	3 m of pyrite, pyrrhotite and chalcopyrite in carbonate rock at contact between andesite and feldspar porphyry
66	TOM32			HBED		90056	
67	TOM1			HBED		90056	
68	RED34	191	28/10/56	HBED	RED60	90489	Several narrow zones of pyrite-bearing schist in greywacke, argillite and quartzite
69	RED30	85	16/10/56	HBED	RED29	90489	3 m of abundant to near solid pyrite and pyrrhotite, with traces of chalcopyrite, in andesite and 1 m of abundant pyrite and pyrrhotite with traces of chalcopyrite, in rhyolite
70	T-3	87	14/2/53	THOMPSON BROS.	TOM1	90057	Three 1 m wide zones of pyrite- and pyrrhotite-rich chloritic-mica schist in chloritic andesite that contains disseminated pyrrhotite and pyrite
71	T-2	51	9/2/53	THOMPSON BROS.	TOM5	90057	Two 4 m wide zones of pyrite- and pyrrhotite-rich chloritic schist in siliceous chloritic andesite
72	TOM26	98	6/10/56	HBED	TOM6	90056	1 m of near solid to solid pyrrhotite and pyrite, with traces of chalcopyrite, in sequence of andesitic flows of tuff
73	T-4	168	3/3/53	THOMPSON BROS.	TOM14	90057	2 m of abundant pyrrhotite in chloritic-mica schist
74	TOM33	96		HBED	TOM16	90056	4 m of abundant pyrrhotite and pyrite, with traces of chalcopyrite, in rhyolite. 2 m of pyrrhotite and pyrite, with traces of chalcopyrite, in siliceous andesite
75	TOM24	195		HBED	TOM16	90056	5 m of near solid pyrrhotite, minor pyrite and traces of chalcopyrite in rhyolite. Several other pyrrhotite- and pyrite-rich zones, also hosted by rhyolite
76	TOM23			HBED			
77	TOM35	244	3/12/56	HBED	TOM 16 & 14	90056	Andesite with numerous narrow layers of pyrrhotite- and pyrite-rich rhyolite, one 1.5 m wide zone of near solid pyrrhotite and pyrite. 10 m of pyrite- and pyrrhotite-rich andesite near bottom of drill hole
78	LUCKY21			HBED		90041	
79	LUCKY17			HBED		90041	
80	RED15	190	27/8/56	HBED	RED56	90489	Sequence of andesite and rhyolite. Rhyolite layers contain numerous zones with abundant to near solid pyrrhotite and pyrite, with traces of chalcopyrite and sphalerite. One 4 m wide zone of massive pyrrhotite and pyrite, with traces of chalcopyrite and sphalerite
81	RED7	124	4/8/56	HBED	RED57	90489	Rhyolite and quartz porphyry with two 1 m zones of near solid pyrrhotite and pyrite, with traces of chalcopyrite and sphalerite
82	RED6	132	31/7/56	HBED	RED58	90489	Siliceous rock with a 1 m and 3 m wide zones containing abundant pyrrhotite and pyrite, and traces of chalcopyrite
83	RED13	125	20/8/56	HBED	RED70	90489	6.5 m of pyrrhotite- and pyrite-bearing graphitic schist in altered flows of unspecified composition. Several layers of pyrrhotite- and pyrite-rich rhyolite

Reference No. (Figure 108)	Company Reference No.	Depth of DDH in Metres	Date Completed	Name of Company	Claim No.	Accession No.	Significant Results
84	RED11	129	15/8/56	HBED	RED74	90489	15 m of rhyolite containing abundant to near solid pyrrhotite and pyrite, and traces of chalcopyrite. Andesite occurs above and below rhyolite layer
85	RED9	101	10/8/56	HBED	RED85	90489	16 m of pyrite-rich rhyolite, locally chloritized, that is intruded by gabbro
86	RED36	119	24/7/57	HBED	RED91	90489	Argillaceous sediments that are locally graphitic
87	RED37	38	30/7/57	HBED	RED92	90489	7 m of argillaceous graphitic sediments
88	RED34A	107	12/7/57	HBED	RED91	90489	Several narrow layers of pyrrhotite- and pyrite-bearing graphite
89	RED35	92	17/7/57	HBED	RED92	90489	Argillaceous graphite-bearing sediments
90	M6	84	11/3/69	FALCONBRIDGE NICKEL MINES LTD.	CA1	98795	Basic tuff, acid tuff and granite
91	M15	78	11/3/69	FALCONBRIDGE NICKEL MINES LTD.	MOR68	98795	Andesite and diorite
92	M17	77	6/3/69	FALCONBRIDGE NICKEL MINES LTD.	MOR63	98795	Andesite and acid volcanics
93	M5	91	23/10/67	FALCONBRIDGE NICKEL MINES LTD.	MOR58	92111	Basic volcanics. No mineralization reported
94	M3	92	20/10/67	FALCONBRIDGE NICKEL MINES LTD.	MOR56	92111	Basic volcanics
95	M9	77	17/1/69	FALCONBRIDGE NICKEL MINES LTD.	MOR56	98795	Diorite, acid volcanics and andesite
96	M22	77	28/1/69	FALCONBRIDGE NICKEL MINES LTD.	MOR58	98795	Andesite, amphibolite and garnet-biotite schist
97	M19	79	31/1/69	FALCONBRIDGE NICKEL MINES LTD.	MOR57	98795	Quartz-feldspar-biotite gneiss, amphibolite and biotite-garnet-amphibole gneiss
98	M20	77	3/2/69	FALCONBRIDGE NICKEL MINES LTD.	MOR57	98795	Interlayered basic and acid volcanics
99	M21	77	7/2/69	FALCONBRIDGE NICKEL MINES LTD.	MOR57	98795	Acid and basic volcanics
100	M23	78	24/2/69	FALCONBRIDGE NICKEL MINES LTD.	MOR57	98795	Acid volcanic and amphibolite
101	M24	78	28/2/69	FALCONBRIDGE NICKEL MINES LTD.	MOR57	98795	Acid pyroclastics and acid tuff
102	M10	92	27/3/69	FALCONBRIDGE NICKEL MINES LTD.	MOR52	98795	Biotite chlorite schist and acid pyroclastics and tuff
103	M11	79	20/2/69	FALCONBRIDGE NICKEL MINES LTD.	MOR52	98795	Acid volcanics and andesite
104	M14	92	18/2/69	FALCONBRIDGE NICKEL MINES LTD.	MOR51	98795	Amphibolite
105	M25	86	3/3/69	FALCONBRIDGE NICKEL MINES LTD.	MOR44	98795	Andesite
106	M4	98	29/10/67	FALCONBRIDGE NICKEL MINES LTD.	MOR44	92111	Basic volcanics, rhyolite and argillite-greywacke
107	M12	93	10/2/69	FALCONBRIDGE NICKEL MINES LTD.	MOR51	98795	Weakly mineralized basic volcanics
108	M13	92	12/2/69	FALCONBRIDGE NICKEL MINES LTD.	MOR51	98795	Quartz-biotite schist and amphibole-biotite-chlorite
109	M26	91	14/2/69	FALCONBRIDGE NICKEL MINES LTD.	MOR50	98795	Intermediate volcanics and andesite

Reference No. (Figure 108)	Company Reference No.	Depth of DDH in Metres	Date Completed	Name of Company	Claim No.	Accession No.	Significant Results
110	RED50	108	11/1/59	HBED	RED104	90489	Hornblende diorite
111	RED48	25	28/12/58	HBED	RED128	90489	Hole abandoned before it reached bedrock
112	RED49	73	1/1/65	HBED	RED128	90495	Argillite with pyrite- and graphite-rich sections
113	JOAN1	43	15/2/57	NORTHERN CANADA MINES LTD.	JOAN3	90054	Hole abandoned in overburden
114	JOAN2	243	24/2/57	NORTHERN CANADA MINES LTD.	JOAN7	90054	1 m zone of chlorite schist at contact between body of gabbro and sequence of greywacke and argillite
115	NORANDA	63	1975	NORANDA EXPLORA- TION CO.	CB6692	91505	Hole abandoned in oberburden
116	H21	40	23/8/57	HBED	HEN581	90250	Hole abandoned in overburden
117	H22	94	27/8/57	HBED	HEN581	90250	13 m of siliceous pyrite-bearing graphite schist in sequence of conglomeratic greywacke
118	T3	74	24/12/58	HBED	TOE78	90495	3 m of earthy pyrite and graphite in argillaceous sediments
119	275		1975	HBED		91505	Dacite flows and tuff, graphitic tuffs and andesite
120	268		1975	HBED		91505	
121	266		1975	HBED		91505	
122	BLACK2088	154	26/2/51	INTERNATIONAL NICKEL CO. LTD.	BLACK4	90197	Hole intersected 63 m of rhyolite, 13 m of talc-chlorite schist, 62 m of altered micaceous rhyolite with disseminated pyrrhotite and pyrite, 3 m of argillaceous sediments with layers of graphite and disseminated pyrite and pyrrhotite, and 9 m of argillaceous sediments
123	PEN28	69	8/3/65	HBED	PEN270	90201	1 m of 60-70% graphite and 20-30% pyrite in quartz-biotite gneiss
124	PEN29	77	12/3/65	HBED	PEN372	90201	10 m of 50-60% graphite and 5% pyrite at contact between garnet-quartz -staurolite-biotite gneiss and hornblende-carbonate gneiss
125	PEN27	60	3/3/65	HBED	PEN293	90201	3 m of 50-60% graphite and 10-30% pyrite in quartz-biotite gneiss. Chlorite alteration noted in quartz-biotite gneiss adjacent to graphite- pyrite layer
126	PEN24	24	16/2/65	HBED	PEN297	90201	Hole abandoned in overburden
127	PEN25	69	22/2/65	HBED	PEN297	90201	18 m of earthy graphite (60-90%)- pyrite (10-40%) followed by mafic gneiss
128	PEN22	61	6/2/65	HBED	PEN307	90201	2 m of 20-30% pyrrhotite and 5% pyrite in mafic altered sediment
129	PEN26	96	27/2/65	HBED	PEN298	90201	Five layers (1 m, 4 m, 13 m, 13 m and 24 m) of 70-80% graphite and 10-20% pyrite in white sandstone and quartz-biotite gneiss, and 0.5 m of 20-30% arsenopyrite in quartz veins in metadiorite
130	BOB2089	30		INTERNATIONAL NICKEL CO. LTD.	BOB2	91897	Hole lost in grey gneiss
131	BOB2098	44		INTERNATIONAL NICKEL CO. LTD.	BOB2	91897	Hole abandoned in overburden
132	BOB2099	53		INTERNATIONAL NICKEL CO. LTD.	BOB2	91897	Hole lost
133	BOB2100	140		INTERNATIONAL NICKEL CO. LTD.	BOB2	91897	11 m of pyrite- and pyrrhotite-bearing sediments with 50% graphite in irregular layers
134	PEN17	34	20/1/65	HBED	PEN298	90201	Hole abandoned in 1 m wide zone of 90-95% graphite and 5% pyrite
135	PEN19	77	27/1/65	HBED	PEN300	90201	45 m of 60-80% graphite and 20-30% earthy pyrite between quartz- garnet-biotite gneisses and sequence of andesite
136	PEN18	20	24/1/65	HBED	PEN300	90201	Metadiorite
137	PEN21	76	3/2/65	HBED	PEN301	90201	1 m of 60-70% pyrrhotite and 20-30% pyrite in metadiorite
138	PEN20	88	30/1/65	HBED	PEN283	90201	Several narrow pyrite- and pyrrhotite-rich zones in metadiorite
139	PEN23	48	10/2/65	HBED	PEN343	90201	3 m of biotite gneiss containing 10-20% graphite and 5-10% pyrite

Reference No. (Figure 108)	Company Reference No.	Depth of DDH in Metres	Date Completed	Name of Company	Claim No.	Accession No.	Significant Results
140	T2	51	17/12/58	HBED	TOE38	90196	14 m of banded siliceous graphitic shear zone with disseminated pyrite and pyrrhotite
141	T1	100	12/12/58	HBED	TOE64	90196	16 m of dark tuff, with siliceous bands and very minor pyrite and pyrrhotite in andesite sequence
142	T5	10		HBED	TOE109	90196	Hole abandoned in overburied
143	T6	74	4/2/59	HBED	TOE109	90196	3 m of graphitic grey schist with slight pyrite and near solid pyrrhotite in andesite sequence
144	T4	73	20/1/59	HBED	TAC1	90196	21 m of sheared basic rocks, probably fault zone, in andesite sequence
145	PEN32	77	16/3/65	HBED	PEN148	90201	1 m of 50-60% graphite and 5-10% pyrite and 5 m of 5-10% graphite and 5-10% pyrite in quartz-biotite-garnet-staurolite gneiss
146	PEN33	75	21/3/65	HBED	PEN140	90201	31 m of garnet-quartz-graphite gneiss containing 40-80% graphite and 5% pyrite
147	PEN35	87	24/3/65	HBED	PEN141	90201	2 m, 3 m and 6 m wide zones of 40-60% graphite and 10-20% pyrite in sequence of altered basic sediments
148	PEN36			HBED		90201	
149	C8	75	14/1/75	GRANGES EXPLORATION AB	CBM826	91847	
150	C6	57	10/1/75	GRANGES EXPLORATION AB	CB4571E	91847	1 m of near solid graphite in quartz-biotite-hornblende gneiss
151	C7	60	11/1/75	GRANGES EXPLORATION AB	CB5617	91847	26 m of altered mineralized hornblende gabbro with 7.5 m of 0.41% Zn
152	POINT-4	33 (Total)	14/7/57	A.L. JOHNSON	POINT 2	90061	Arkose, greywacke and argillite containing minor pyrite and traces of chalcopyrite
153	POINT5-6	21 (Total)	14/7/57	A.L. JOHNSON	POINT5	90061	Hornblende gabbro containing 2 m wide zone with visible pyrite and sphalerite