

# Geology of the Wunehikun Bay (Mirond Lake) Area, Northwestern Flin Flon Domain, and Jones Lake Area, Southwestern Kisseynew Domain (parts of NTS 63M/01, /02, /07, and /08)

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## Abstract

*As part of the Flin Flon Targeted Geoscience Initiative 3 project, geological bedrock mapping of two areas east of Pelican Narrows was carried out at 1:20 000 scale. This work builds on mapping completed in the Kakinagimak Lake area in 2007, and represents a northward continuation of mapping carried out by the Saskatchewan Geological Survey between 1991 and 1996. The project is integrated with an airborne radiometric and magnetic survey that was flown over a 3141 km<sup>2</sup> area in late August and early September of 2007.*

*Upper amphibolite facies supracrustal and plutonic rocks of the Wunehikun Bay (Mirond Lake) area represent a continuation of the Amisk Collage in the Flin Flon Domain, exposed 40 km to the southeast. Due to their proximity to the Pelican Thrust Zone to the west, units are strongly transposed and primary features are not preserved. Rocks include a succession of complexly folded mafic to intermediate volcanic rocks and intervening psammitic to pelitic sedimentary rocks, speculated to be of synvolcanic origin. Supracrustal rocks are intruded by granodioritic to quartz dioritic plutons inferred to have been emplaced at circa 1860 Ma. Most rock types have been affected by partial melting, which has resulted in widespread leucogranite and discrete bodies of diatexite.*

*Rocks in the Jones Lake area are situated in the southwestern Kisseynew Domain, close to its transition into the volcanoplutonic Flin Flon Domain. That area is underlain by younger metasedimentary rocks of the graphite-bearing Burntwood and magnetite-bearing Missi groups, all of which have been affected by partial melting. Inliers of granodioritic to dioritic rocks are minor components. Homogeneous varieties of diorite and granodiorite also cut Missi and Burntwood groups.*

*Both areas were affected by at least five ductile deformation events. Primary features are not preserved in the sedimentary or volcanic rocks, but the latter contain some evidence of metamorphosed hydrothermal alteration zones, now preserved as garnet-anthophyllite assemblages, particularly in the Wunehikun Bay area. Minor amounts of chalcopyrite and Fe-sulphides were encountered in several outcrops.*

**Keywords:** *Pelican Narrows, Paleoproterozoic, Flin Flon Domain, Kisseynew Domain, garnet-anthophyllite.*

## 1. Introduction

Bedrock mapping east of Pelican Narrows represents a continuation of work that began in 2007. Approximately 290 km<sup>2</sup> were mapped at 1:20 000 scale in two areas, one located in the northwestern part of the Flin Flon Domain and the other in the southwestern flank of the Kisseynew Domain (Figure 1). The Pelican Narrows project, forms part of the Targeted Geoscience Initiative 3 project (TGI-3) centred in the Flin Flon area, a joint federal-provincial geoscience initiative that strives to use geoscience as a tool “to help sustain the reserves of base metals in vulnerable established mining communities in Canada” (<http://ess.nrcan.gc.ca/tgi/>). To complement bedrock mapping, an airborne radiometric and magnetic survey was flown over an approximately 80 km x 40 km area between the Tabernor Fault and the Saskatchewan-Manitoba border in the fall of 2007 (dashed line in Figure 1).

On a broader scale, the Pelican Narrows project represents a continuation of previous lithotectonic and structural studies (*e.g.*, Ashton and Leclair, 1991a; Lewry *et al.*, 1991; Ashton *et al.*, 1993c, 1995b; Lewry, 1993) carried out by the Saskatchewan Geological Survey (Table 1). One final objective of the current study will be to compile all

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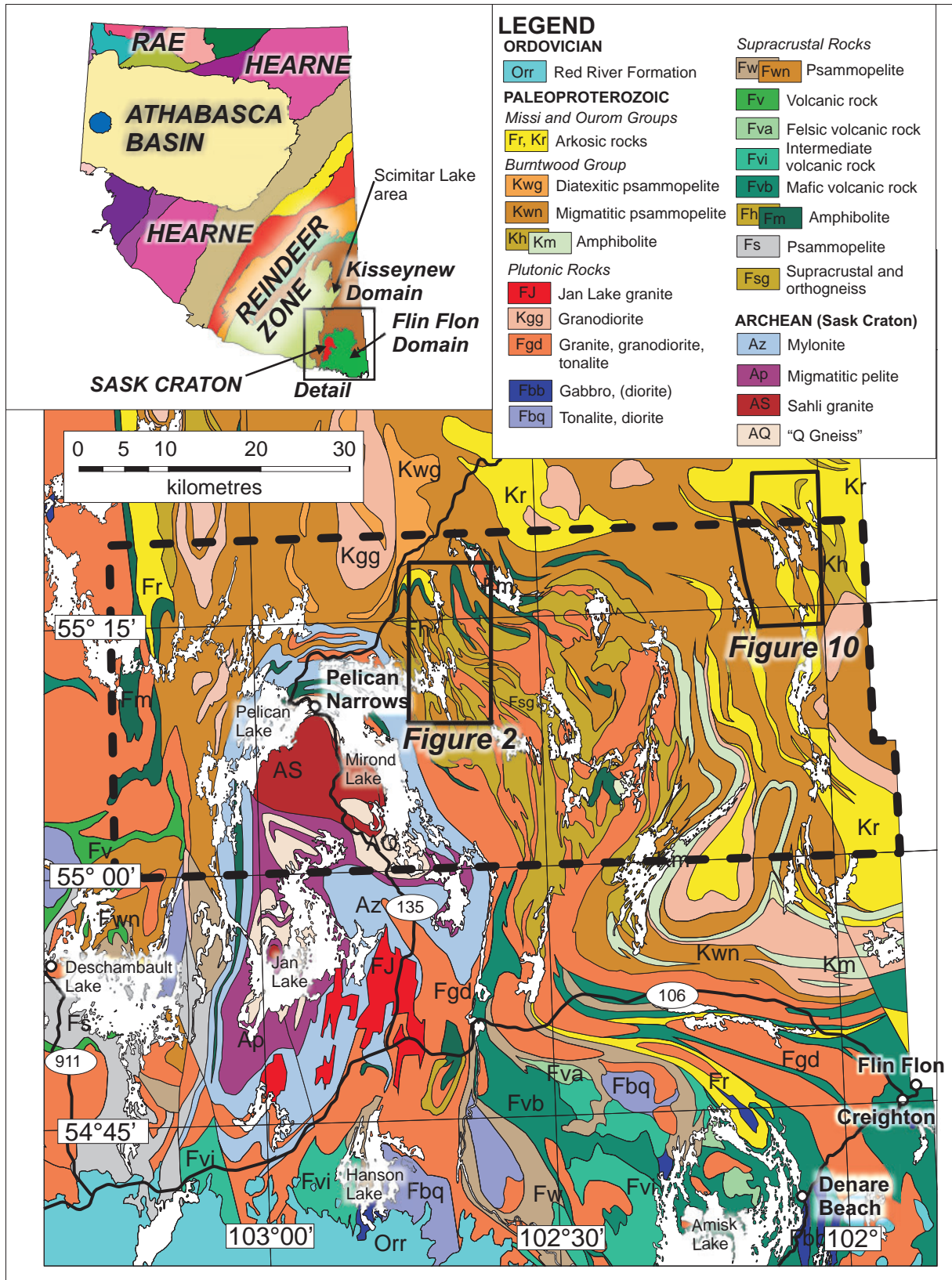


Figure 1 - Location map showing outlines of the Wunehikun Bay (Figure 2) and Jones Lake (Figure 10) map areas (solid lines) and the airborne geophysical survey (dashed line).

**Table 1 - Previous mapping in the larger Pelican Narrows area (with hyperlinks).**

Authors and Links to Reports	Year	NTS sheet 1:250 000 scale	NTS sheet 1:50 000 scale	Report Title	Scale	Map No. and Link
McInnes, W.	1914			The Basins of the Nelson and Churchill Rivers		
Bruce, E.L.	1918			Amisk-Athapapuskow Lake District		105 (GSC)
<a href="#">Byers, A.R. and Dahlstrom, C.D.A.</a>	1954	63L/	13, 16	Geology and Mineral Deposits of the Amisk-Wildnest Lakes Area	1:63,360	14a
<a href="#">Cheesman, R.L.</a>	1956	63M/	01-E	The Geology of the Mari Lake Area, Northern Saskatchewan	1:63,360	23a
<a href="#">Kirkland, S.J.T.</a>	1957	63M/	06-N	The Geology of the Manawan Lake Area	1:63,360	27a
<a href="#">Pyke, M.W.</a>	1961	63M/	01-W	The Geology of the Attitti Lake Area	1:63,360	54a
<a href="#">Pyke, M.W.</a>	1965	63M/	08-E	The Geology of the Nemei Lake Area	1:63,360	97a
<a href="#">Pyke, M.W.</a>	1966	63M/	02-E	The Geology of the Pelican Narrows and Birch Portage Areas	1:63,360	93a
<a href="#">Ashton, K.E., Wilcox, K.J., Wheatley, K.J., Paul, D., and de Tombe, J.</a>	1987	63L/	15, 16	The Boundary Zone Between the Flin Flon Domain, Kisseynew Gneisses and Hanson Lake Block, Northern Saskatchewan	1:50 000	<a href="#">87-4</a>
<a href="#">Ashton, K.E. and Leclair, A.D.</a>	1991	63M/	01, 02	Revision Bedrock Geological Mapping, Wildnest-Attitti Lakes Area (parts of NTS 63M-1 and -2)	1:20 000	<a href="#">91-4</a>
<a href="#">Ashton, K.E., Drake, A.J., and Lewry, J.F.</a>	1993	63M/	01, 02	The Wildnest-Tabbemor Transect: Attitti-Mirond Lakes Area (parts of NTS 63M-1 and -2)	1:20 000	<a href="#">93-4-Sheet 1</a> <a href="#">93-4-Sheet 2</a>
<a href="#">Ashton K.E. and Shi, R.</a>	1994	63M/	02, 03	Wildnest-Tabbemor Transect: Mirond-Pelican Lakes Area (Part of NTS 63M-2 and -3)	1:20 000	<a href="#">94-4-(4.1)</a> <a href="#">94-4-(4.2)</a>
<a href="#">Ashton, K.E. and Balzer, S.S.</a>	1995	63M/	3	Wildnest-Tabbemor Transect: Pelican Lake-Tabbemor Fault Area (part of 63M-3)	1:20 000	<a href="#">95-4-(1.1)</a>
<a href="#">Ashton, K.E., Balzer, S.S., and Tran, H.</a>	1995	63M/	01, 02	Geology of the Galbraith-Attitti Lakes Area, Attitti Block (part of 63M-1 and -2)	1:20 000	<a href="#">95-4-(1.2)</a>
<a href="#">Hartlaub, R.P., Ashton, K.E., and Lewry, J.F.</a>	1996	63M/	01, 02, 07, 08	Geology of the Attitti Block - Kisseynew Domain Contact, Belcher Lake	1:20 000	<a href="#">96-4-(3)</a>

**Note:** Map No. refers to the appropriate Saskatchewan Ministry of Energy and Resources or Geological Survey of Canada (GSC) publications.

recent bedrock maps within the 3200 km<sup>2</sup> area of the geophysical survey at 1:50 000 scale and publish them with marginal notes.

In 2008, two areas were mapped at 1:20 000 scale, the first being 150 km<sup>2</sup> of Wunehikun Bay on Mirond Lake. The map area is centered about 18 km east, and within cell phone range, of Pelican Narrows and is accessible by boat from the town, which can be reached via the Hanson Lake Road (Highway 106) and Highway 135 (Figure 1). The second area, measuring about 140 km<sup>2</sup>, is located along the Saskatchewan-Manitoba border within the southwestern flank of the Kisseynew Domain. It is centered on Jones Lake, located about 60 km east-northeast of Pelican Narrows and 60 km north-northwest of Flin Flon. Jones Lake can be accessed via float-equipped aircraft from Pelican Narrows or Flin Flon.

Field work in both areas was carried out from base camps located on small islands in the centre of Wunehikun Bay and on Jones Lake. Topographic elevation varies from low-lying areas along the Manitoba border with a lake level of about 295 m above sea level (asl) on Kipahigan Lake, gradually rising to about 315 m asl on Mirond Lake. The highest ridges are found bordering Harvey Lake, north of Wunehikun Bay, where elevations between 390 and 410 m were recorded in an area where abundant leucogranodiorite, pegmatite, and diatexite have intruded migmatitic psammopelitic gneisses.

Bedrock mapping was carried out between the beginning of June and the end of August via inflatable boats for shoreline mapping, and GPS-assisted compass traverses inland. Magnetic susceptibility measurements were collected at all outcrops, whereas ground gamma-ray spectrometric measurements were only taken on shoreline outcrops and some selected traverses.

The Mirond Lake forest fire, which was started by lightning on June 21, 2008 began to burn out of control towards the end of the month as a result of hot and windy weather conditions. It forced a camp evacuation on June 30 and continued to burn until about July 7, eventually burning most of the forest within the Wunehikun Bay map area. We returned to the original base camp for two weeks in August, after having mapped the Jones Lake area between July 11 and August 7, 2008.

## 2. Previous Work and Regional Geology

Earlier geological investigations of the larger Pelican Narrows area were summarized by Maxeiner (2007); previous mapping in the area is summarized in Table 1. New geochronological results from samples collected in 2007 are published in a companion paper (Rayner and Maxeiner, this volume).

The Wunehikun Bay area is located in the northwestern, high-grade extension of the Flin Flon Domain, structurally above mylonitic rocks of the Pelican Thrust Zone. It contains Paleoproterozoic volcanoplutonic and intervening sedimentary rocks of the 'Amisk Collage' (Lucas *et al.*, 1996, 1999). Younger supracrustal rocks, correlative with the Missi and Burntwood groups, were not identified. The Jones Lake area lies along the southwestern edge of the Kisseynew Domain, structurally above the volcano-plutonic panel of the Amisk Collage, and is made up predominantly of highly metamorphosed supracrustal rocks of the Burntwood and Missi groups, with only minor infolded panels of older granodioritic rocks.

## 3. Description of Main Units<sup>2</sup>

A 'metamorphic colour index', based on the percentage of mafic minerals in a metamorphosed rock, was used in the field to distinguish between mafic (>35), intermediate (35 to 15), and felsic (<15) variants. In general, primary features other than compositional layering have not been preserved in either of the two areas due mainly to the strong structural transposition of units and to a lesser degree the upper amphibolite facies metamorphic overprint. Comprehensive unit characteristics are presented in table format (Table 2) and the descriptions below will therefore only highlight important lithological characteristics or relationships.

### a) Geology of the Wunehikun Bay (Mirond Lake) Area

The map area borders recent maps by Ashton *et al.* (1993c) and Hartlaub *et al.* (1996) to the south and northeast, respectively. In order to minimize discrepancies across individual map-boundaries, lithological units established during that recent mapping were used within the present area.

#### 'Amisk Collage' (~1.87 to 1.90 Ga)

Supracrustal rocks in the Wunehikun Bay area (Figure 2) are interpreted to represent high-grade equivalents of mafic to intermediate volcanic and sedimentary rocks of the >1.87 Ga Amisk Collage of the Flin Flon area. This interpretation is based on the age of cross-cutting 1.85 Ga granodiorites (Heaman *et al.*, 1993; Ashton *et al.*, 1999), continuity of units from the Amisk–Flin Flon area on a regional scale, and a 1.87 Ga age determination on a rhyodacitic rock from the Scimitar Lake area (Ashton *et al.*, 2005). Due to strong structural transposition, combined with disaggregation by granitoid intrusions, the thickness of lithological units is rarely more than 100 m and commonly variable on a decametre scale.

#### *Volcanic and Associated Rocks*

Volcanic rocks underlie a significant portion of the Wunehikun Bay area and are of variable composition. Mafic rocks generally do not show any signs of partial melting, whereas pelitic intercalations within the volcanic rocks are generally migmatitic. Intermediate to felsic volcanic rocks may contain from 0 to 15% percent tonalitic to granodioritic leucosome.

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<sup>2</sup> Only selected units and important observations and relationships are described in detail in this paper. For comprehensive and systematic descriptions of all units, the reader is referred to the legends on the accompanying maps. Description of rock units follows the IUGS classification of igneous rocks (Streckeisen, 1976) and an 'in-house'<sup>7</sup> classification of metamorphosed clastic sedimentary rocks (Maxeiner *et al.*, 1999).

**Table 2 - Comprehensive table of characteristics for lithological units in the Wunehikun Bay and Jones Lake areas; mineral abbreviations: *amph*, amphibole; *ap*, apatite; *bi*, biotite; *carb*, carbonate; *cpx*, clinopyroxene; *diop*, diopside; *ep*, epidote; *gnt*, garnet; *gp*, graphite; *hbl*, hornblende; *Ksp*, K-feldspar; *mt*, magnetite; *musc*, muscovite; *po*, pyrrhotite; *py*, pyrite; *pxy*, pyroxene; *qtz*, quartz; *sill*, sillimanite; *sul*, sulphides; and *ti*, titanite.**

Neumonic Code	Lithology	Colour	Grain Size	Distinctive Mineralogy (%)	Mafic Mineral Index	Magnetic Susceptibility
<b>UNITS COMMON TO BOTH AREAS</b>						
<i>Lgd</i>	leucogranodiorite, leucogranite	light pink to pinkish grey	fine to coarse	bi, <i>sgrt</i> , <i>asp</i>	5	generally low (<0.2); rarely higher
<i>Dl</i>	diorite, microdiorite	salt and pepper	fine to medium	hbl	15 to 35	low (0.3 to 0.4)
<i>Gdf</i>	quartz diorite, diorite and diorite gneiss	grey, salt and pepper	medium to coarse	qtz (5 to 15), hbl (15 to 25) > bi, <i>mt</i> , <i>sill</i> , <i>tanite</i>	15 to 20	0.1 to 0.4
<i>Gdg</i>	gneissic to migmatitic granodiorite-tonalite	light grey to light pinkish grey	medium to coarse	qtz (20 to 30), hbl (0 to 15), bi (0 to 15), <i>mt</i> , <i>sgrt</i>	5 to 20	variable (0.1 to 0.50)
<i>Am</i>	layered amphibolite	dark green to grey	fine	hbl, <i>cpx</i> , <i>gnt</i> , bi	20 to 50	low (0.3 to 0.7)
<b>UNITS EXPOSED ONLY IN THE JONES LAKE AREA</b>						
<b>Plutonic Rocks</b>						
<i>Lgs</i>	sillimanite-rich leucogranite	buff, beige to light grey	medium	bi (2 to 5), <i>sill</i> (2 to 5), <i>gnt</i> (2)	5	very low (0.1)
<i>Dx</i>	pelitic diatexite	light grey to light pinkish grey	medium to coarse	bi (5), <i>gnt</i> (5), <i>gp</i> , <i>sill</i>	20 to 30	0.05 to 0.3
<i>Gd</i>	homogeneous massive granodiorite	grey to pinkish grey	medium to coarse	hbl (0 to 10), bi (0 to 10), <i>sgrt</i> , <i>mt</i>	10 to 15	generally low (0.1 to 0.3)
<i>Dlm</i>	magnetite-rich diorite and diorite gneiss	salt and pepper	medium	hbl (20 to 30), bi (5 to 10), qtz (5 to 10), <i>mt</i>	25 to 35	very high (1 to 70)
<b>Missi Group</b>						
<i>MZ</i>	aluminous feldspathic quartzite	brownish grey to orange brown	fine to medium	qtz (70 to 90), sill (5 to 10), bi (5), <i>mt</i> (3), <i>gnt</i> (0 to 2)	5 to 10	very high (9 to 32)
<i>MPa</i>	migmatitic aluminous psammopelite	light grey, buff to pinkish grey	fine	bi (5 to 10), sill (5), <i>mt</i> (2 to 5), <i>gnt</i> (0 to 3), <i>amusc</i>	10 to 20	very high (9 to 37)
<i>MPS</i>	migmatitic potassic psammite	light pink, pinkish grey, grey, buff	fine	qtz (30 to 50), <i>Ksp</i> (10 to 20), bi (5 to 10), <i>mt</i> (2 to 5), <i>sgrt</i> , <i>sill</i>	5 to 10	very high (11 to 43)
<i>MPC</i>	migmatitic calcic psammite-psammopelite	light grey, light greenish grey to pinkish grey	fine	bi (5 to 10), hbl (5), <i>mt</i> (1 to 3), <i>gnt</i> (0 to 5), <i>diop</i> (0 to 5), <i>ep</i> (0 to 3)	15	very high (5 to 28)
<i>MCg</i>	migmatitic polymictic conglomerate	white to light grey	matrix: fine to medium; clasts: pebble to cobble	hbl (5 to 15), bi (5), <i>gnt</i> (3 to 5), <i>mt</i> (2), <i>ep</i> (0 to 2)	10 to 15	very high (10 to 50)
<b>Burntwood Group</b>						
<i>BQZ</i>	feldspathic quartzite, quartzite, impure quartzite	light grey to yellowish brown	fine	qtz (70), <i>gnt</i> (5 to 15), bi, <i>sgp</i>	1 to 10	0.1 to 0.2
<i>BFP</i>	migmatitic aluminous psammopelite to pelite	grey to brownish grey	fine to medium	bi (10 to 15), <i>gnt</i> (5 to 10), sill (3 to 5), <i>gp</i> (1)	15 to 30	0.1 to 0.3
<i>BFPp</i>	migmatitic psammopelite (-pelite)	light grey, grey, light pinkish grey	fine to medium	bi (10 to 15), <i>gnt</i> (5 to 10), <i>gp</i> (1), <i>sill</i>	10 to 25	0.1 to 0.4
<i>BFS</i>	migmatitic psammite	light grey to grey	fine	bi (5 to 10), <i>gnt</i> (0 to 2), <i>gp</i> , <i>sill</i>	10	0.1 to 0.2
<b>Older Rocks</b>						
<i>I/g</i>	garnet-rich diorite	salt and pepper, grey to brownish grey	fine to medium	hbl, bi, <i>gnt</i> (5 to 20), <i>py</i>	30 to 35	low (0.3 to 0.4)
<b>UNITS EXPOSED ONLY IN THE WUNEHIKUN BAY AREA</b>						
<b>Plutonic Rocks</b>						
<i>P</i>	granite pegmatite		coarse to pegmatitic	bi, <i>sgrt</i>	5	0.1
<i>Gg</i>	granitic gneiss	pink to pinkish grey	medium to coarse	hbl (5 to 10)	10	variable (0.1 to 50)
<i>Gdx</i>	inclusion-rich granodiorite-quartz diorite	light grey to light pinkish grey	medium to coarse	hbl (10 to 30)	10 to 30	high (2 to 25)
<i>Gdm</i>	migmatitic granodiorite-quartz diorite	pink to grey	medium to coarse	generally hbl>bi	10 to 20	0.3 to 50
<i>Ga</i>	gabro, microgabro	mottled black and white, greenish black	medium to coarse	hbl (50 to 60), <i>cpx</i>	50 to 60	0.6 to 0.7
<i>Up</i>	ultramafic rock (pyroxenite)	blackish green	fine to coarse	<i>amph</i> , <i>pxy</i>	90	0.4 to 2
<b>'Amisk Collage' Sedimentary Rocks</b>						
<i>Dxt</i>	pelitic diatexite	grey to brownish grey	medium to coarse	bi (5 to 25), <i>gnt</i> (5 to 15), <i>gp</i> (0 to 2)	15 to 30	0.2 to 0.4
<i>Pp</i>	migmatitic pelite (-psammopelite) and derived diatexite	grey, brown, brownish grey	fine to medium	<i>gnt</i> (10 to 15), bi (10 to 15), <i>gp</i> (2 to 5), sill (0 to 10%), <i>asp</i>	>25	0.2 to 0.3
<i>Psp</i>	migmatitic psammopelite (-pelite)	grey to brown	fine to medium	bi (10 to 15), <i>gnt</i> (5 to 10), <i>gp</i> (2 to 5), <i>sill</i> , <i>asp</i> , <i>accum</i> , <i>gnt</i> , <i>omtie</i>	10 to 25	0.2 to 0.3
<i>Ps</i>	migmatitic psammite	grey to brownish grey	fine	bi (5 to 15), <i>gnt</i> (0 to 5), <i>gp</i> (0 to 1), <i>sill</i>	5 to 15	0.2 to 0.3
<i>Ch</i>	feruginous 'cherty' rock	greenish grey to brown	very fine	qtz, <i>diop</i> , <i>pxy</i> , <i>po</i>	5 to 15	1 to 2
<i>Pf</i>	feruginous psammite	brownish grey to rusty brown	fine	<i>po</i> (1 to 5), hbl (0 to 5), <i>gp</i>	5 to 15	0.5 to 1.0
<i>Pc</i>	migmatitic calcic psammopelite	grey, greenish grey, brownish grey	fine to medium	hbl (5 to 15%), bi (5 to 10%), <i>gnt</i> (5 to 10), <i>gp</i> , <i>adiop</i> , <i>scarb</i> , <i>sti</i>	10 to 25	0.2 to 0.6
<i>As</i>	mixed calcic sedimentary rock, felsic calc-silicate and intermediate mafic volcanic rock	white, grey, brownish grey, greenish grey	fine	hbl (5 to 20), <i>gnt</i> (5 to 10), qtz (5 to 10), bi (5 to 15), <i>gp</i> , <i>adiop</i> , <i>scarb</i> , <i>sti</i> , <i>spy</i> , <i>apo</i>	15 to 25	0.2 to 0.5
<b>'Amisk Collage' Volcanic Rocks</b>						
<i>Fv</i>	felsic volcanic rock	buff to light grey	very fine to fine	bi (5 to 10), hbl (1 to 5), <i>gnt</i> (0 to 5), <i>sul</i>	5 to 15	0.1 to 0.5
<i>Fvg</i>	altered felsic volcanic rock	buff to light grey	fine to coarse	<i>gnt</i> (10 to 15), <i>sill</i>		
<i>Iv</i>	intermediate volcanic and volcanoclastic rocks	light grey to brownish grey, salt and pepper	fine	hbl (15 to 35), bi (0 to 10), <i>sgrt</i> , <i>cpx</i> , <i>sul</i>	15 to 35	0.2 to 0.5
<i>Ch</i>	mafic calc-silicate rock	light greenish grey, dusky green, greenish black	fine, locally medium	hbl (40 to 60), <i>diop</i> (5 to 20), <i>sgrt</i> , <i>scarb</i> , <i>asp</i>	40 to 60	0.5 to 0.7
<i>Mv</i>	mafic volcanic and volcanoclastic rocks	dark green to greenish black, dark grey	fine	hbl (40 to 60); <i>gnt</i> (0 to 10), <i>cpx</i> , <i>abi</i> , <i>sul</i> , <i>mt</i>	50 to 60	0.4 to 0.85

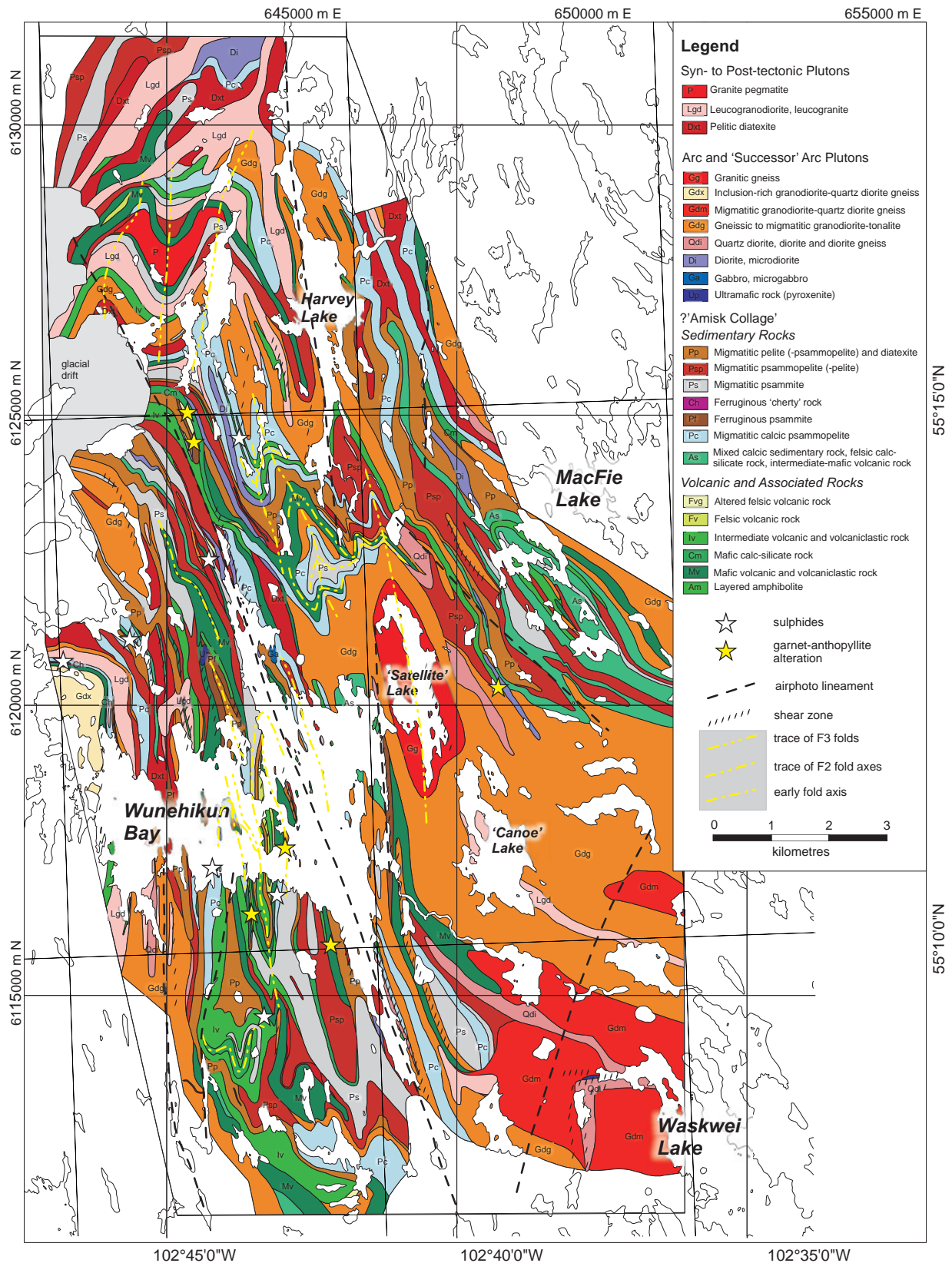


Figure 2 - Simplified bedrock geology of the Wunehikun Bay (Mirond Lake) area.

**Mafic volcanic rocks** (Mv) are found throughout the area and are cut by hornblende-bearing granodiorite on a map scale. These rocks are typically amphibolites and garnet amphibolites, generally characterized by a fine-grained, greenish black appearance and about equal proportions of hornblende and plagioclase, with local accumulations of garnet and/or diopside and trace amounts of sulphides (see Table 2 for details). Layering on decimetre- to metre-scale is common and is defined by changes in colour index and the amount of garnet and or diopside (Figure 3).

A few widely scattered units of **mafic calc-silicate rocks** (Cm) are closely related to the mafic volcanic rocks. They too have roughly equal proportions of plagioclase and mafic minerals, but contain abundant diopside as well as hornblende and variable amounts of quartz. These rocks likely represent quartz-epidote altered mafic volcanic rocks.

**Intermediate volcanic rocks** (Iv), having a mafic mineral content of 15 to 35%, are less widespread than the mafic volcanic rocks, but are closely associated with them, both on outcrop- and map-scale (Figures 2 and 4). Mafic and intermediate volcanic rocks are interlayered on centimetre- to decimetre-scale in some areas and cannot be subdivided; a composite unit of **layered amphibolite** (Am) was consequently created. These may represent volcanic rocks of tuffaceous origin with intercalated epiclastic material, or primary volcanic rocks intruded by later sills.



*Figure 3 - Mafic volcanic rock with boudinaged calc-silicate layers; station RM08-13-ST06 southeast of Wunehikun Bay at UTM<sup>3</sup> 649472 m E, 6116327 m N.*



*Figure 4 - Tight symmetric folds in intermediate to mafic volcanic rocks; hornblende is axial planar to these F<sub>2</sub> folds (not visible at scale of photograph). Folded partial melt layers are contained within the intermediate layer; whereas mafic layers are unaffected by partial melting; station RM08-17-ST12 on small island in centre of Wunehikun Bay at UTM 646720 m E, 6118189 m N.*

Most units of mafic to intermediate volcanic rocks, mafic calc-silicate rocks and layered amphibolite contain minor, 1 to 10 m-thick, pelite and ferruginous psammite layers, diorite to granodiorite sheets, and transposed granitic pegmatite dykes.

In contrast to the Kakinagimak Lake area (Maxeiner, 2007), **felsic volcanic rocks** (Fv) are rare with only a few thin (10 to 30 m) exposures on the largest island in the middle of Wunehikun Bay and a few more exposures on the mainland immediately to the north. These highly siliceous, light grey- to buff-weathering, fine-grained quartzofeldspathic rocks are typically strongly foliated to sheared. Magnetic susceptibilities are low, sulphides are locally present, and garnet (locally up to 15%) is ubiquitous and generally of irregular distribution. In some cases, the observed mineral assemblages suggest derivation from hydrothermally altered felsic volcanic protoliths. In one instance, a 50 m thick unit of felsic volcanic rock containing garnet-anthophyllite alteration is sandwiched between units of ferruginous psammite and mafic calc-silicate rock.

#### *Sedimentary Rocks*

In contrast to the volcanogenic rocks, epiclastic rocks of the Wunehikun Bay area contain considerable amounts of tonalitic (white) to granitic (pink) partial melt. The proportion of partial melt ranges from 10% in psammitic variants to >70% in the pelitic rocks, which have locally undergone near-complete anatexis and formation of diatexite.

A rather voluminous unit of **mixed calcic sedimentary rock, calc-silicate, and intermediate-mafic volcanic rock** (unit As) was mapped northeast of 'Satellite Lake'<sup>4</sup>, where it is intercalated with migmatitic psammopelite and intermediate to mafic volcanic rocks.

<sup>3</sup> All UTM coordinates in this paper are in NAD83, Zone 13 unless otherwise stated.

<sup>4</sup> Unofficial lake names are set in single quotation marks when first used; these marks are omitted from later references to the same lake.

It contains a mixture of well-foliated and well-layered, hornblende-graphite-bearing psammopelite, interlayered on a decimetre- to metre-scale with laminated rocks of intermediate to mafic composition (Figure 5). Minor components include 10 to 50 cm-thick layers of aluminous pelite, diopside- and graphite-bearing calc-silicate rock, and pyrrhotite-bearing ferruginous psammite. The unit is interpreted as a predominantly epiclastic succession of volcanic provenance with intercalated intermediate to mafic tuffs.

**Migmatitic calcic psammopelite (Pc)** is a rather widespread unit, generally 200 to 300 m thick, and closely associated and intercalated with migmatitic psammopelite and pelite. Its layered nature together with ubiquitous hornblende, garnet, biotite, and graphite suggest a sedimentary precursor, likely deposited in a marine setting proximal to volcanic arcs. Partial melt within the calcic psammopelite accounts for 20 to 30% of the rock and is generally of tonalitic composition and locally hornblende bearing.

**Migmatitic psammite (Ps)** forms prominent units up to 300 m thick south and north of Wunehikun Bay. They comprise poorly layered, fine-grained quartzofeldspathic rocks containing about 10% biotite and minor garnet ± graphite. Psammopelitic layers up to 1 m thick can account for up to 10% of this psammitic unit. Leucosome, generally of tonalitic to granodioritic composition, may constitute up to 10% and increases in proportion within the psammopelitic layers.

**Ferruginous psammite (Pf)** occurs just north and east of Wunehikun Bay, where it is intercalated on a map scale with migmatitic pelite and calcic psammopelite. On outcrop scale, ferruginous psammite is well layered and interbedded with minor psammite, calcic psammite, psammopelite, and intermediate volcanic rocks. They are easily identified and distinguished from other psammitic rocks by their brown to rusty brown weathering appearance caused by the presence of trace amounts of pyrrhotite and/or pyrite.

**Ferruginous ‘cherty’ rock (Ch)** outcrops north of Wunehikun Bay at the western extent of the map area, where a discontinuous unit is sandwiched between a mafic volcanic rock and a calcic psammopelite. Another exposure occurs 800 m to the northeast, between migmatitic pelite and mixed calcic sedimentary rocks. These units are only 4 m thick, very hard, siliceous, and, other than quartz, contain only minor amounts of diopside and sulphides. The unit likely originated as an exhalative layer during periods of reduced detrital input or volcanic quiescence.

**Migmatitic psammopelite (-pelite) gneiss (Psp)** represents one of the most voluminous units and is characterized by abundant biotite, garnet and graphite and by pervasive tonalitic to granodioritic leucosome. The psammopelitic gneisses (~70%) commonly grade into pelitic (~20%), and psammitic layers (~10%). Sillimanite is found locally within granitic leucosome and also in association with minor amounts of K-feldspar and retrograde muscovite in the paleosome. **Migmatitic pelite (-psammopelite) gneiss (Pp)** is texturally and compositionally very similar to the migmatitic psammopelite (Table 2), but contains more garnet and sillimanite (Figure 6), partial melt, and reversed proportions of psammopelitic (~30%) and pelitic (70%) components. Apple green apatite, up to several millimetres in diameter, was observed in a number of outcrops within the leucosome of the psammopelitic and pelitic gneisses. Where the partial melt component reaches 90%, such as on the north side of Wunehikun Bay, and northwest and east of Harvey Lake, units of **pelitic diatexite (Dxt)** have been distinguished (Figure 7). Diatexites are usually recognizable by their homogeneous, massive to weakly foliated outcrop appearance and presence of abundant



*Figure 5 - Layered succession of partially sulphide-bearing (note brown weathering in one layer) migmatitic calcic psammopelite; station RM08-01-ST06 on small island in northeast corner of Wunehikun Bay at UTM 648313 m E, 6119820 m N.*



*Figure 6 - Close up of migmatitic pelite with abundant garnet and sillimanite (arrow); station RM08-08-ST11-PH3 on south shore of Wunehikun Bay at UTM 645676 m E, 6116919 m N.*

feldspar neoblasts, biotite, garnet, and graphite.

Most of the hornblende-bearing (units As, Pc, and Pf) and other 'dirty' sedimentary rocks (units Pf and Ch) are tentatively considered synvolcanic and correlative with the Welsh Lake assemblage of the Amisk Lake area to the southeast (Reilly *et al.*, 1995). The synvolcanic interpretation of those rocks was based on a 1.87 Ga youngest detrital zircon age, which inferred deposition prior to emplacement of the widespread 1.88 to 1.83 Ga 'successor arc' plutons (Heaman *et al.*, 1993; Ansdell and Stern, 1997). The more aluminous quartzofeldspathic sedimentary successions (units Pp, Psp, and Ps) might also represent synvolcanic detritus, but some of these components could also belong to the <1.85 Ga Burntwood Group (*e.g.*, Zwanzig, 1990; David *et al.*, 1996), a deep-water facies equivalent of the Missi Group comprising much of the central Kiseynew Domain in Manitoba.

### Arc and 'Successor' Arc Plutons (?1.88 to 1.83 Ga)

A tonalitic gneiss collected 4 km northeast of Pelican Narrows yielded an upper intercept age of  $1856 \pm 3$  Ma, which was interpreted as the time of pluton emplacement (Ashton *et al.*, 1999). A number of other granitoid rocks from the area also fall within the 1850 to 1860 Ma age bracket (Ashton *et al.*, 2005 and refs. therein) and have been interpreted as successor arc plutons (Syme *et al.*, 1998).

As in the Kakinagimak Lake area (Maxeiner, 2007), one of the most prominent rock types at Wunehikun Bay is partially melted granitoid gneiss, likely belonging to the successor arc suite. The largest exposure of **gneissic to migmatitic granodiorite-tonalite** (Gdg) occurs east of Wunehikun Bay, where it forms a 5 km x 5 km body that intrudes the volcanic and sedimentary rocks described above. The unit is characteristically heterogeneous in outcrop appearance with medium to coarse-grained tonalitic to granodioritic rocks being cut by, and locally grading into, coarse-grained layers of transposed granitic material, some of which is locally derived and some of which has been injected (Figure 8). Fine-grained, generally hornblende-bearing, decimetre-scale supracrustal inclusions are commonly encountered (Figure 9) and locally difficult to differentiate from boudinaged mafic dykes. Weakly to moderately foliated, late granitic pegmatite sheets are also abundant within the pluton. Variable amounts of hornblende and biotite generally characterize the unit and together make up 5 to 20% of the rock. Magnetite is ubiquitous. Many smaller units of gneissic to migmatitic granodiorite-tonalite occur as highly transposed, strongly foliated to mylonitic sheets within the supracrustal succession.

Several variants of granitoid gneisses have been separated based on: i) composition, as in the case of the **granitic gneiss** units (Gg) exposed around Satellite Lake and west of Harvey Lake; ii) a combination of composition and texture, as in the case of the **migmatitic granodiorite-quartz diorite** unit (Gdm) southeast of Wunehikun Bay; and iii) texture, as in the



*Figure 7 - Diatextite containing dismembered and unmelted psammitic restite (arrow); dark spots in upper right-hand quadrant of photo are organic in nature, not a constituent of the rock; station RM08-40-ST16 northwest of Harvey Lake; at UTM 647023 m E, 6131126 m N.*



*Figure 8 - Close up of migmatitic granodiorite with granitic leucosome; station RM08-12-ST02 southeast of Wunehikun Bay at UTM 651835 m E, 6115644 m N.*



*Figure 9 - Boudinaged amphibolitic layers in granodiorite gneiss; station Mo08-11-St10 east shore of 'Canoe Lake' at UTM 651117 m E, 6117579 m N.*

case of the **inclusion-rich granodiorite-quartz diorite** unit (Gdx) towards the western end of Wunehikun Bay. Contacts between all of these plutonic rocks are generally gradational. The unit designations and contact boundary positions for these granitoid rocks on the accompanying map separates are somewhat arbitrary given their compositional and textural variability.

**Quartz diorite, diorite, and diorite gneiss** (Qdi) are closely associated with the granitoid pluton described above and are separated based on an increased hornblende content and overall lower concentrations of quartz and magnetite. The rock also contains a larger proportion of fine-grained mafic layers and inclusions, and is heterogeneous with moderate amounts of later granitic material.

**Diorite to microdiorite** (Di), is generally fine to medium grained and widespread. It occurs as 20 to 100 m-thick bodies that intrude the supracrustal succession, particularly in the area between Wunehikun Bay and Harvey Lake. These rocks are generally equigranular and relatively homogeneous; feldspar-phyric variants were previously observed in the Kakinagimak Lake area (Maxeiner, 2007). A feldspar-phyric intermediate rock from the Kakinagimak Lake area, interpreted as a sill intruding the Gifford Bay volcanic succession, yielded an imprecise U/Pb zircon crystallization age of  $1841 \pm 15$  Ma (Rayner and Maxeiner, this volume), and is believed to be correlative with these dioritic rocks. Based on the similar age, they may represent feeders to Missi Group volcanic rocks. A few small intrusive plugs of **gabbro** (Ga) and **ultramafic rock** (Up) in the supracrustal succession at the north end of Wunehikun Bay are of unknown age and correlation.

### Syn- to Post-tectonic Plutons

A relatively extensive suite of white to pink **leucogranodiorite to leucogranite** (Lgd) underlies much of the area northwest of Harvey Lake and also comprises up to 20% of most gneissic granodiorite outcrops (unit Gdg) east of Wunehikun Bay. Based on the overall homogeneous nature of the leucogranodiorite, the generally weakly developed foliation, and their low colour index, they were previously interpreted as syntectonic anatectic melt sheets (Maxeiner, 2007), possibly similar in age to sheared pegmatites to the south of the present study area dated at  $1806 \pm 2$  Ma (Ashton *et al.*, 1992). This assumption is generally supported by recent geochronological results, which constrained zircon overgrowths in an anatectic leucogranodiorite to  $1807 \pm 8$  Ma (Rayner and Maxeiner, this volume), although the detailed story is more complicated, with another two episodes of zircon growth recorded. West of Harvey Lake, abundant leucogranodiorite dykes crosscut large units of diatexite (Dxt), which were derived from the migmatitic pelite and psammopelite.

Weakly deformed to massive, pink **granite pegmatite** (P) forms concordant sheets and small irregular masses is particularly prevalent to the west and southwest of Harvey Lake, where it crosscuts diatexite (unit Dxt) and leucogranodiorite (Lgd) on outcrop scale. It also occurs throughout the area as numerous conformable and transposed, 1 m-thick dykes, which typically contain large books of biotite and local garnet. These pegmatites are likely part of the circa 1770 Ma (*e.g.*, Bickford *et al.*, 1987) Jan Lake Granite Suite (Macdonald and MacQuarrie, 1978).

### b) Geology of the Jones Lake Area

The Jones Lake map area (Figure 10), covering an area of approximately 17 km x 9 km, is predominantly underlain by metasedimentary rocks of the Burntwood and Missi groups and is located at the transition between the Flin Flon Domain in the southwest and the Kisseynew Domain to the northeast. This area was unaffected by the 2008 Mirond Lake forest fire and is covered by old growth forest with poor bedrock exposures; a small portion of the northwest part of the map area was burned by a forest fire some 15 years ago.

### Pre- and Post-Missi Group Plutons, Minor Volcanic Rocks (?1.88 to 1.83 Ga)

A 6 km-long, 500 m-thick unit of **granodiorite gneiss** (Gdg), located southeast of Jones Lake, is similar in appearance to granodiorites mapped in the Wunehikun Bay (see above) and Kakinagimak Lake (Maxeiner, 2007) areas and is interpreted as an inlier of 'basement' to the Missi and Burntwood groups. These granodioritic rocks are characterized by a strong gneissosity, granitic leucosome layers, and amphibolitic inclusions; they contain up to 15% hornblende, with minor amounts of biotite, epidote and magnetite. They differ, however, from those at Wunehikun Bay in that the magnetite content is generally very high, resulting in average magnetic susceptibility readings that tend to be at the upper end of the spectrum reported for the unit in Table 2. Along its western extent, the unit is strongly foliated to mylonitic and is in contact with a heterogeneous quartzofeldspathic rock, interpreted here as a strongly deformed and recrystallized conglomerate (unit MCg, described below) that likely represents a basal unit of the Missi Group. **Quartz diorite gneiss** (Qdi), exposed on the large island on the east side of Jones Lake, also likely represents a tectonic inlier of the circa 1.86 Ga plutons that outcrop within the younger sedimentary strata.

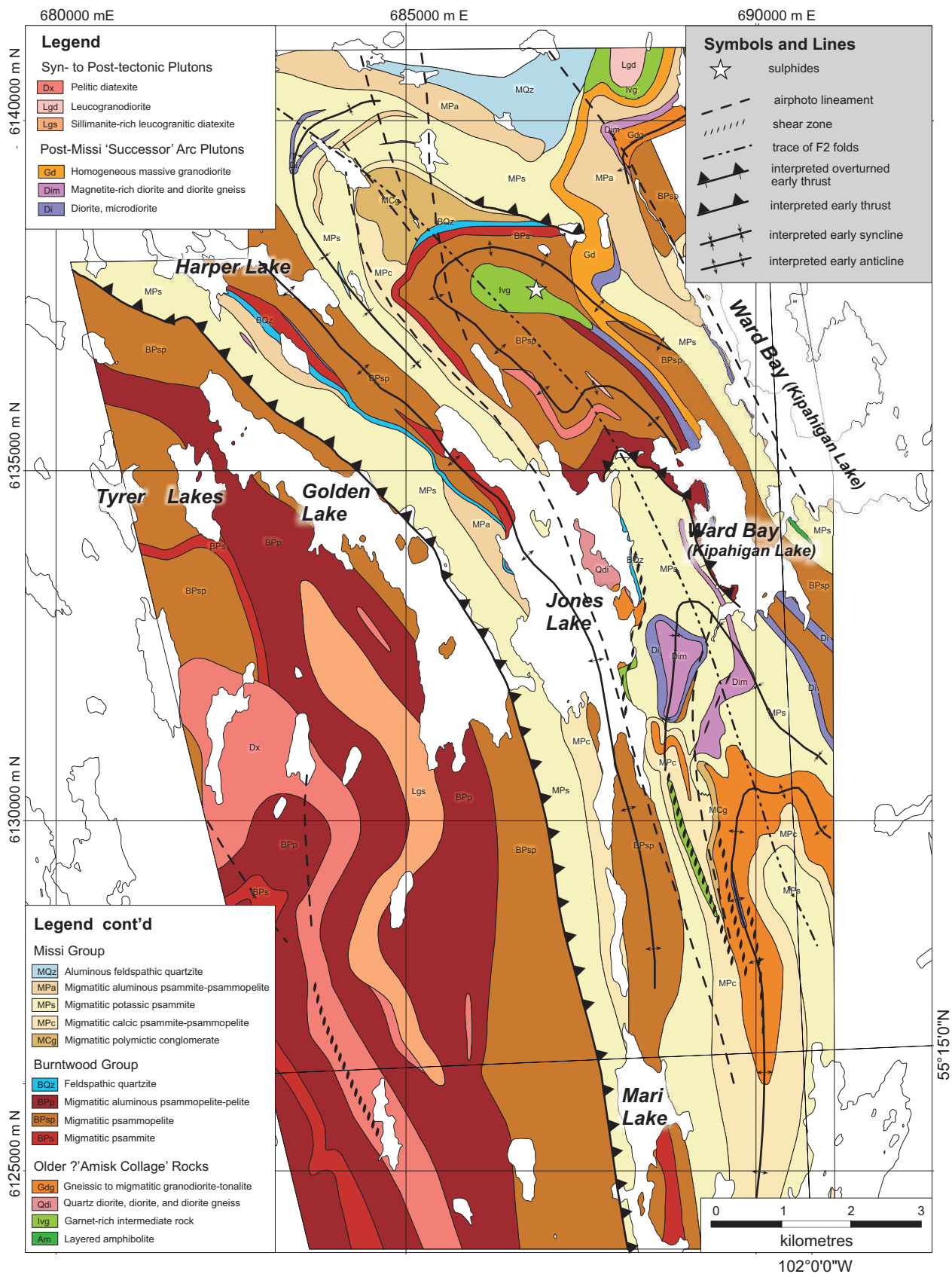


Figure 10 - Simplified bedrock geology of the Jones Lake area.

**Intermediate rocks** (Iv) form a number of small bodies, predominantly within rocks of the Missi Group and less so within Burntwood Group rocks and gneissic to migmatitic granodiorite-tonalite. As all are transposed and of variable fine to medium grain size, it is difficult to determine whether they are intrusive or extrusive in origin or whether they pre- or postdate the Burntwood Group. Several exposures of highly **garnetiferous, fine- to medium-grained intermediate rocks** (Ivg) were encountered. One particularly notable unit north of Jones Lake is slightly more extensive and surrounded by graphitic psammopelite of the Burntwood Group. These hornblende-bearing rocks are easily distinguished from other intermediate rocks, as they contain up to 20%, medium to coarse, purplish red garnet porphyroblasts and local disseminated sulphide (Figure 11). The most garnet-rich varieties also contain tonalitic partial-melt blebs. Based on the overall fine grain size, high garnet content, and presence of minor sulphides, this unit is interpreted as an altered volcanic rock, but it is unclear whether it represents Amisk Collage volcanic rocks exposed in a tectonic window or an example of younger Burntwood Group volcanism possibly related to the boundary intrusions.

**Diorite** (Di), similar to that encountered at Wunehikun Bay (Table 2), forms a number of long, conformable bodies within the Burntwood and Missi groups, but is interpreted to postdate them and likely correlative with the 1841 ±15 Ma (Rayner and Maxeiner, this volume) feldspar-phyric intermediate rock cutting the Gifford Bay volcanic rocks of Kakinagimak Lake. A **magnetic diorite** (Dim), containing up to 3% magnetite, is closely associated with the dioritic rocks east of Jones Lake. A homogeneous, massive **granodiorite** (Gd), containing variable amounts of hornblende and biotite that together account for 15% of the rock, cuts units of Missi and Burntwood groups northwest of Ward Bay.

### Burntwood Group (1.85 to 1.84 Ga)

Pelitic to psammitic migmatites (units Pp, Psp, and Ps) in the Jones Lake area are likely correlative with the 1.85 to 1.84 Ga Burntwood Group (Zwanzig, 1990; David *et al.*, 1996). Distinction between Missi and Burntwood groups in this area is based solely on the presence or absence of magnetite versus graphite, respectively. Other than transposed compositional layering and one conglomerate unit, no primary depositional features were preserved in the migmatitic sedimentary succession.

**Migmatitic psammite** (BPs) represents a minor component, generally occurring in units up to 200 m thick and intercalated with pelitic and psammopelitic counterparts. It differs from the psammitic rocks mapped in the Wunehikun Bay area by being relatively quartz rich (40%) and containing pinhead-sized garnets, which are pale red to purple in colour.

**Migmatitic psammopelite** (BPsp) is much more widespread than the psammitic rocks, underlying large parts of the Golden Lake area and an area between Jones Lake and Kipahigan Lake. It contains more biotite, garnet, and graphite than the psammitic rocks and up to 30% tonalitic leucosome (Figure 12). Garnet forms larger porphyroblasts, approaching 5 mm in diameter and is pale purple in colour. **Migmatitic aluminous psammopelite-pelite** (BPP) makes up most of the Burntwood Group succession on the southwest side of Golden Lake and in a smaller unit between Jones Lake and Kipahigan Lake. The aluminous psammopelite is intercalated and intricately associated with the psammopelitic rocks (unit Psp) on a map scale. It is set apart from them by its abundant sillimanite content, in addition to garnet and biotite, and by having an *in situ* leucosome component of granodioritic to granitic composition.

Four thin units of **quartzitic rocks** (BQz) are exposed along the east and west shores, and 3 km to the north of Jones Lake. They are <50 m thick, but apparently continuous for several kilometres, following the contact

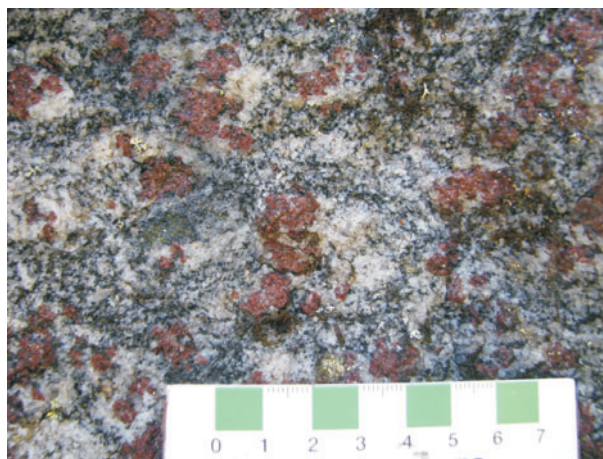


Figure 11 - Garnetiferous intermediate volcanic rock; station RM08-21-ST11-Ph1; north of Jones Lake at UTM 686835 m E, 6137584 m N.



Figure 12 - Layers of tonalitic leucosome in migmatitic psammopelite; station MC08-31-ST15 northwest of Golden Lake at UTM 681586 m E, 6136396 m N.

between the Burntwood and Missi groups in all cases. They comprise feldspathic quartzite, impure quartzite, and up to 10 cm thick 'true' quartzite layers, as well as minor, locally graphitic psammitic and psammopelitic intercalations. Being generally devoid of magnetite and locally intercalated with graphitic sedimentary rocks, they have been grouped along with the Burntwood Group in this report. Regardless of the stratigraphic affiliation of this quartzitic unit, it appears to mark a transition from sedimentation in a predominantly deep-water environment to one of more shallow-water conditions. It also suggests an apparent depositional continuity rather than structural juxtaposition of the two groups, a conclusion also reached by Hartlaub *et al.* (1996) based on their work in the Belcher Lake area.

### Missi Group (~<1.85 Ga)

In the Flin Flon area, deposition of the Missi Group has been bracketed between 1847 Ma (Ansdell, 1993) and 1842 Ma (Heaman *et al.*, 1992). Potential high-grade Missi Group equivalents are exposed in the Kakinagimak Lake area (Maxeiner, 2007) and the Galbraith Lake area (Ashton *et al.*, 1995b) to the southwest, and are abundant in the Mari Lake area to the south (Ashton and Wheatley, 1986).

In the Jones Lake area, the Missi Group is represented by a magnetite-bearing quartzofeldspathic succession of predominantly psammitic to psammopelitic rocks, generally containing granodioritic to granitic leucosome. The rocks are widespread in a >5 km-wide belt extending from the west shore of Jones Lake to the south shore of Kipahigan Lake and continuing further east into Manitoba.

Five units with Missi Group affinity have been distinguished in the Jones Lake area. Two kilometres east of Harper Lake, a 2 km x 1 km exposure of **migmatitic polymictic conglomerate (MCg)** was mapped in the hinge of a northeast-dipping, northwest-plunging, isoclinal, map-scale antiform. It lies structurally, and likely stratigraphically, over the migmatitic psammite of the Burntwood Group to the south. The conglomerate is characterized by a very heterogeneous outcrop appearance, with crude, metre-scale layering dominated by calcic psammite and calcic psammopelite of strongly varying composition, with local irregular layering and lensoid weathering character. The rock tends to be strongly foliated, but less-strained lozenges allow recognition of elongated pebbles and cobbles of epidotized mafic rock, granitoid rocks, vein quartz, and rare garnetite in a hornblende-bearing, fine-grained quartzofeldspathic matrix (Figure 13). Granitic leucosome is prevalent, though locally dismembered, making recognition of original granitic clasts difficult.

In another exposure of polymictic conglomerate located southeast of Jones Lake, a 50 to 100 m-thick unit was traced for an approximate strike length of 2 km, structurally below and along the western margin of highly strained granodiorite gneiss. Distinction between granodiorite gneiss, conglomerate, and a structurally underlying unit of calcic psammite-psammopelite is not straightforward because all three units are strongly deformed, highly magnetic, hornblende-bearing migmatitic gneisses with abundant transposed granitic leucosome. In better exposed examples, however, the conglomerate is characterized by lensoid heterogeneous weathered surfaces (Figure 14), with clasts of epidotized mafic rocks and granitoid rocks within a garnet- and hornblende-bearing quartzofeldspathic matrix. Both of these conglomeratic units could represent basal unconformities of the Missi Group,



Figure 13 - Polymictic conglomerate with pebble- to cobble-sized clasts of epidotized mafic rock, granitoid rock, and vein quartz; note the decimetre-scale calcic psammite layer underneath hammer at bottom of picture; station RM08-26-ST20 north of Jones Lake at UTM 685123 m E, 6139181 m N.

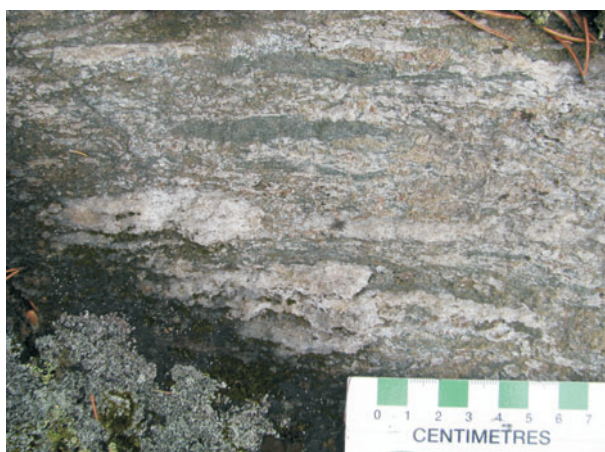


Figure 14 - Polymictic conglomerate with lensoid heterogeneous weathered surfaces, resembling strongly flattened pebble- to cobble-sized clasts of felsic and mafic rocks; station RM08-31-ST07 southeast of Jones Lake at UTM 672828 m E, 6109595 m N.

overlying Burntwood Group in the northern occurrence and granodiorite gneiss in the southern one.

Both conglomeratic units appear to laterally grade into units of **calcic psammite-psammopelite** (MPc), similar in bulk composition to the polymictic conglomerate. This calcic psammite-psammopelite is highly magnetic, consistent with its assignment to the Missi Group. It contains up to 15% mafic minerals, predominantly biotite and hornblende, with lesser garnet, diopside, and epidote. Layering is preserved on centimetre- to metre-scale, locally comprising distinct calc-silicate layers and boudins, as well as granitic layers. It is possible that parts of this unit might be more deformed equivalents of the polymictic conglomerate having lost their textural integrity due to intense transposition along  $F_2$  fold limbs.

**Migmatitic potassic psammite** (MPs) represents one of the most voluminous units of the Missi Group, being particularly prevalent east of Golden Lake. These distinctly pinkish rocks are well layered on the 2 to 20 cm scale, with minor feldspathic quartzite and up to 5 cm-thick, rare calc-silicate layers. Leucosome is of granitic to granodioritic composition and generally accounts for 20% of the rock. The localized presence of amphibolitic layers and boudins likely represent dismembered mafic dykes or sills. Magnetite tends to be concentrated in thin, millimetre-scale laminae, traceable for 10 to 20 cm, that likely represent heavy mineral layers.

**Migmatitic aluminous psammite-psammopelite** (MPa) is concentrated in the northern half of the map area, between Golden Lake and Ward Bay of Kipahigan Lake. It is interlayered on the metre-scale with feldspathic quartzite and impure quartzite and contains 5% round to elongate, white sillimanite-quartz nodules up to 5 cm in diameter (Figure 15). It typically contains biotite and muscovite and, locally, garnet. The migmatitic aluminous psammite-psammopelite unit is generally gradational into, and interlayered with, units of potassic psammite (unit MPs). In several locations, it separates the latter from Burntwood Group rocks, but at the north end of the map area, it is in gradational contact with an **aluminous feldspathic quartzite** unit (MQz), which stretches along strike for an estimated 3 km and bulges in the hinge of a northeast-plunging  $F_3$  synform. The quartzite has a characteristic brownish grey to orange-brown-weathering colour (Figure 16), contains between 70 to 90% quartz and 5 to 10% sillimanite, ubiquitous magnetite and minor biotite and garnet.

### Syn- to Post-tectonic Plutons

**Sillimanite-rich leucogranite** (Lgs), mapped to the southwest of Golden Lake, weathers buff to light grey (Figure 17), is medium grained, massive to weakly foliated, and contains minor amounts of biotite, pinhead-sized garnet, and sillimanite; the latter occurring as 5 cm-wide white flattened discs parallel to the weakly developed foliation. Because of its grain size, homogeneity, and massive texture, it is interpreted



Figure 15 - Flattened, golf ball sized nodules of sillimanite and quartz in migmatitic aluminous psammite-psammopelite; station MC08-21-ST04 north of Jones Lake at UTM 683727 m E, 6139206 m N.



Figure 16 - Close-up view of orange-weathering, sillimanite-bearing quartzite; station RM08-37-ST14 near north end of map area at UTM 686916 m E, 6140483 m N.



Figure 17 - Sillimanite sheets in leucogranite; station RM08-27-ST02 southwest of Golden Lake of Jones Lake at UTM 685121 m E, 6130640 m N.

as intrusive in origin, likely representing a mobilized, low-percentage partial melt derived from the melting of Burntwood Group sedimentary rocks. Within the migmatitic aluminous psammopelite-pelite unit (B<sub>Pp</sub>), paralleling unit Lgs 500 m to the southwest, another massive and homogeneous rock of more granodioritic composition and with a higher colour index (20 to 30) exists. It contains garnet, biotite, and minor sillimanite and was interpreted as a **diatexite** (unit D<sub>x</sub>) that was derived from unit B<sub>Pp</sub> via ‘high-percentage’ partial melting and appears to not have been mobilized to any large extent. The rock is locally grading into and cut by leucogranodiorite and sillimanite-rich leucogranite.

#### 4. Metamorphism

Based on fieldwork by Ashton *et al.* (1995b) and P-T studies conducted by Ashton and Digel (1992) to the south of the present map area, metamorphism in the region reached estimated pressures of 6.6 to 7.9 kbar and temperatures of 630° to 725°C indicative of upper amphibolite facies conditions. A U-Pb zircon age of 1807 +3/-2 Ma (Heaman *et al.*, 1992) obtained from a felsic volcanic rock from the Attitti Lake area, was interpreted as metamorphic and coincides with the age of a syntectonic granitic pegmatite dyke dated at 1806 ±2 Ma (Ashton *et al.*, 1992). This is coeval with the peak of metamorphism in the Hanson Lake and Snow Lake areas, generally constrained between 1804 and 1812 Ma (*e.g.*, Heaman *et al.*, 1994; David *et al.*, 1996; Syme *et al.*, 1998). In the Kakinagimak Lake area (Maxeiner, 2007), widespread partial melting in the granodiorite-tonalite complex (Gd), pelitic to psammopelitic rocks, feldspathic psammites and, to a lesser extent, within the felsic volcanic rocks, together with the absence of orthopyroxene, also suggests upper amphibolite facies metamorphic conditions. Granulite facies conditions have been reported for the centre of the Pelican Window and towards the central part of the Kiseynew Domain, north of Wunehikun Bay and Jones Lake (Ashton *et al.*, 2005).

Both at Wunehikun Bay and at Jones Lake, evidence for partial melting is widespread in psammitic to pelitic sedimentary successions, as well as in the granodiorite-tonalite gneisses. Within calcic psammopelite and hornblende-bearing granodiorite, amphibole remains stable in the presence of garnet, diopside, and plagioclase. Within aluminous sedimentary rocks, sillimanite is the stable Al<sub>2</sub>SiO<sub>5</sub> polymorph and coexists with newly formed K-feldspar, whereas muscovite is retrograde, suggesting that the second sillimanite isograd was exceeded (*i.e.*, temperatures around 700°C).

#### 5. Structural Geology

The structural framework for the Pelican Narrows–Attitti Lake area was set out in papers by Lewry *et al.* (1990), Ashton and Leclair (1991a), and Ashton *et al.* (1999, 2005). The findings of these studies were largely confirmed by work in the Kakinagimak Lake area (Maxeiner, 2007). The structural nomenclature used in this paper largely follows that set out by Ashton *et al.* (2005).

In the Wunehikun Bay area, because of its close proximity to the Pelican Thrust Zone (PTZ), mylonitic fabrics are widespread and structural transposition is extreme, thus hindering development of a detailed structural chronology. On outcrop-scale, earliest structures are defined by compositional layering, attenuation of units, a well-developed biotite and/or hornblende foliation, and gneissic layering (S<sub>1</sub>). These planar features are deformed by abundant isoclinal to close folds (F<sub>2-early</sub>) with generally east-dipping axial planes and variably plunging fold axes (Figure 18), likely initiated during the initial stages of thrusting related to the PTZ (Ashton *et al.*, 2005). Locally, the presence of sheared F<sub>2</sub> fold limbs (Figures 18 and 19), indicates that shearing continued late during D<sub>2-late</sub> deformation. A northeast-plunging lineation, generally defined by quartz, hornblende, and feldspar porphyroclasts, is locally well developed. Within discrete mylonitic zones, a collinear stretching lineation is also developed. Both are likely related to D<sub>2</sub> shearing during the development of the PTZ, with coincident northeast over southwest reverse shear (Ashton *et al.*, 2005). Mylonitic fabrics generally overprint leucosome within granitic gneisses and pelitic to psammopelitic rocks, suggesting partial melt formation began prior to or early during D<sub>2</sub>. Emplacement of large masses of diatexitic material



**Figure 18 - Isoclinal F<sub>2</sub> fold in mafic gneisses with mylonitic fabric on fold limb; fold likely developed during initial stages of mylonitization, while the limb was ‘sheared-off’ during later stages; ribboned quartz defines an axial planar mylonitic fabric in nose of fold (not visible at scale of photo; station RM08-44-ST11 west of Wunehikun Bay; at UTM 644917 m E, 6120877 m N).**



**Figure 19 - Late  $D_2$  shear zone on  $F_2$  fold limb in granodiorite gneiss; station Mo8-11-St11 on lakeshore of 'Trout Lake'; at UTM 651126 m E, 6117086 m N.**

kilometres (Lewry *et al.*, 1990). In the study area,  $F_4$  is expressed by broad gentle warping of units east of Wunehikun Bay.

In the Jones Lake area, outcrop-scale folds are rare, but where present they are generally shallowly northeast-dipping, northeast-plunging, tight folds that are interpreted as  $F_2$  structures. Map-scale  $F_2$  folds appear to be defined by isoclinal folding of Burntwood and Missi strata north of Jones Lake and by isoclinal folding of a granodiorite gneiss unit southeast of Jones Lake. Based on the assumption that the Burntwood Group is slightly older than the Missi Group, which was substantiated in the Jones Lake area by identification of a basal Missi Group conglomerate, a number of highly speculative early syncline-anticline isoclinal fold pairs were constructed. A number of early interpreted thrusts are also illustrated on the map and mostly follow the contact between the Burntwood and Missi groups. As this contact and the interpreted thrust are overturned east of Jones Lake and apparently refolded by the  $F_2$  structures, thrusting was likely coeval with formation of the early folds. North-trending, map-scale  $F_3$  folds as defined by Ashton *et al.* (2005) were not directly identified in the Jones Lake area. Fold interference, likely between  $F_2$  and  $F_3$  folds, is implied by two basin and dome structures cored by intermediate rocks, including a garnet-rich intermediate volcanic north of Jones Lake and a magnetite-rich diorite east of the lake, although the latter could also be an intrusive feature.

## 6. Economic Geology

No mineral occurrences have previously been described in the Wunehikun Bay or Jones Lake areas. During the present field work, a number of minor sulphide occurrences characterized by disseminated pyrrhotite, pyrite, and traces of chalcopyrite were recorded. Most were in the Wunehikun Bay area, where garnet-anthophyllite assemblages, similar to those described by Maxeiner (2007) and Ashton and Leclair (1991a) were also encountered. Such rocks develop during the high-grade metamorphism of chloritic alteration of the type commonly associated with volcanogenic massive sulphide deposits, although the alteration does not necessarily imply economic mineralization, and the extreme transposition of units, coupled with the high metamorphic grade, may have mobilized any large original concentrations of *in situ* mineralization. The age and depositional environment of the clastic successions, coupled with the presence of ferruginous units, also present interesting similarities to Broken Hill-type mineralization, although no indication of the presence of Pb or Zn have been identified in the Pelican Narrows area.

The Jones Lake area is predominantly underlain by younger sedimentary successions. Only one sulphide occurrence with minor pyrite and chalcopyrite was encountered in a unit of strongly garnetiferous intermediate volcanic rock north of Jones Lake.

(units Dx and Lgd), however, outlasted formation of  $F_2$  folds and, in part, might have been coeval with the development of north-trending  $F_3$ -folds, as suggested by their emplacement parallel to  $F_3$  fold axes in the Kakinagimak Lake area (Maxeiner, 2007) and by their generally weak, east to northeast-dipping foliation.

Map-scale early fold closures in the Wunehikun Bay area are defined by systematic repetition of units, locally defining potential  $F_1$  isoclinal folds. In the central part of the map area, units define a series of tight north-to northwest-trending,  $F_2$ -folds with east-dipping axial planes that refold the early isoclinal folds. This suggests that the original orientation of the  $S_1$  fabric was broadly east-west. Fold interference between  $F_1$  and  $F_2$  folds locally produces map-scale (Figure 2, halfway between Harvey Lake and Wunehikun Bay) mushroom-shape, Type 2 fold interference. West of Harvey Lake, a series of moderately to steeply east-dipping, north-trending close folds are related to  $D_3$ . The latest sets of folds in the Pelican Narrows area are open, upright northeast-trending  $F_4$ -folds with wavelengths of tens of

## 7. Conclusions

Fieldwork in the Wunehikun Bay and Jones Lake areas has led to the following conclusions:

- 1) The Wunehikun Bay area, centred 15 km east of Pelican Narrows, is dominated by highly transposed and complexly folded mafic to intermediate volcanic rocks and intervening psammitic to pelitic, possibly synvolcanic, sedimentary rocks. These supracrustal rocks are intruded by granodioritic to quartz dioritic plutons. Most rock types have been partially melted during upper amphibolite facies metamorphism, with local generation of diatexite.
- 2) The Jones Lake area, along the Saskatchewan-Manitoba border 60 km north of Flin Flon, is underlain by younger sedimentary rocks of the graphitic Burntwood and magnetite-bearing Missi groups, all of which have been affected by partial melting. Older granodioritic to dioritic rocks are minor and are infolded with the sedimentary rocks.
- 3) A unit containing several thin quartzitic layers in the Jones Lake area marks the contact between the Burntwood and Missi groups and may mark a transition from sedimentation in a predominantly deep-water environment to more shallow-water conditions. It also suggests depositional continuity between the two groups, with potential facies variations from a fluvial Missi Group environment, through a shallow-water, near-shore environment (quartzitic rocks), to graphitic deep-water deposits of the Burntwood Group. Interpreted thrusts developed during generation of  $F_1$  folds later disrupted some of the stratigraphic relationships. An unrelated quartzite, containing abundant magnetite and sillimanite, was recognized within the Missi Group and likely represents a facies equivalent of potassic aluminous psammite.
- 4) Distinction between synvolcanic and successor arc sedimentary successions in the larger Pelican Narrows area is difficult, if not impossible, because original stratigraphic relationships, facing directions, and depositional environments cannot be ascertained due to the strong structural transposition and reorganization, complex fold interference, and intense metamorphic overprint. However, the graphitic pelitic to psammitic succession at Wunehikun Bay, because of its close association with hornblende-bearing calcic psammopelite and intercalated volcanic components, was very likely deposited during or shortly after the main period of volcanism. In the Jones Lake area, the graphitic sedimentary succession is strongly aluminous with more abundant sillimanite and purplish-coloured garnets, whereas psammitic rocks are rare and clastic sedimentary units with abundant calc-silicate phases are absent. This graphitic succession is closely associated and infolded with magnetite-rich rocks of the Missi Group and therefore interpreted as Burntwood Group equivalents. Thus, the implied stratigraphic break between syn-volcanic (Welsh Lake Assemblage) and successor psammopelitic to pelitic (Burntwood Group) sedimentary rocks has not been identified in the areas mapped.
- 5) The Wunehikun Bay–Kakinagimak Lake (Maxeiner, 2007)–Jones Lake area, despite its high-grade metamorphic overprint and strong structural transposition, contains sydepositional hydrothermal alteration assemblages and occurrences of disseminated sulphides, both potentially indicative of volcanogenic massive sulphide mineralization. The age and environment of formation of the clastic successions of the area, coupled with the presence of ferruginous units, also present interesting similarities to Broken Hill–type mineralization, although no indication of the presence of Pb or Zn have been identified in the Pelican Narrows area.

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