Geology of the Daly-Suttle-Middle Foster Lakes Area, Eastern Wollaston Domain (NTS 74A-5, -11, and -12)

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This report presents results of 1:20 000 scale mapping, during the summer of 1998, of nearly 350 km^2 in the east-central Wollaston Domain, extending from west of Daly Lake eastwards to Lower Foster Lake. The map area lies southeast of the Athabasca Basin and about 120 km northwest of Missinipe (Figure 1). It covers part of the Foster Lake (west) map sheet (McMurchy, 1938), as well as parts of the Daly Lake east (Money, 1966), Daly Lake west and Middle Foster Lake (Ray, 1981), Pylypow Lake east (Fuh, 1976), and Pylypow Lake west (Forsythe, 1977) areas, mapped at scales ranging from 1:63,360 to 1:253,440 and part of the 1:31,680 scale Middle Foster Lake map sheet (Mawdsley, 1957). The southern part of the study area was mapped by H. Tran and the northern part by G. Yeo and S. Bradley. This represents the second year of a multi-year project designed to examine the lithostratigraphy and structural geology of the central Wollaston Domain.

1. General Geology

The map area is underlain by generally northeast-trending belts of Paleoproterozoic siliciclastic to calc-silicate metasediments, which unconformably overlie a basement of remobilized Archean felsic gneisses: both are intruded by mafic to felsic plutons. Five main lithological subdivisions are distinguished:

1) an Archean basement complex, comprising the Roper Bay and Pederson Lake inliers (Figure 2), which includes quartz monzocharnockite, quartz monzonite-granodiorite, syenogranite, amphibolite, and a heterogeneous marginal assemblage of various intrusive rocks and subordinate amphibolite and metasedimentary xenoliths;
2) a Paleoproterozoic lower metasedimentary sequence (Figure 3), comprising a basal siliciclastic assemblage of garnet-cordierite-bearing pelites with quartzitic to psammitic interlayers, overlain by arkosic sillimanite-cordierite-bearing pelitic to psammopelitic rocks and biotite wackes, and an overlying transitional heterogeneous siliciclastic to calc-silicate assemblage ranging from biotite wacke to arkose, and including magnetite- and calc-silicate-bearing varieties;
3) an upper dominantly calc-silicate-rich sequence (Figure 3) with subordinate arkose conglomerate;
4) the early syn-tectonic Suttle Lake Intrusive Complex comprising mostly sheet-like bodies, from tens to hundreds of metres wide, ranging compositionally from gabbro-diorite to granodiorite-tonalite, which contain xenolithic screens and inclusions of various metasedimentary rocks; and
5) late syn-tectonic to post-tectonic granites and pegmatites.

Four deformation phases were recognized. D_1 resulted in development of the regional foliation (S_1) and isoclinal folding (F_1). D_2 produced mostly northeast-trending regional F_2 folds and steeply northwest-dipping, S_2 penetrative axial planar foliation. D_3 deformation gave rise to very open, northwest-trending folds and crenulations (F_3), and local subvertical S_3 axial planar fabrics. D_4 produced late, steeply-dipping to subvertical, mostly brittle sinistral fault and shear zones.

The rocks underwent relatively high-temperature, low-pressure high-grade metamorphism, probably to granulite facies. At least two phases of metamorphic mineral growth, broadly coeval with the D_1 and D_2 deformation events, are apparent.

2. Rock Descriptions

a) Basement Complex: Roper Bay and Pederson Lake Inliers

Unit 1: Quartz Monzocharnockite

Charnockitic rocks form mappable bodies in the Pederson Lake and Roper Bay inliers (Figure 2). They also occur sporadically as unmappable bodies and sheets in granitoid rocks of Unit 2. In some outcrops the two rock types are interlayered. Charnockitic rocks are buff to dark greenish or brown, medium to coarse grained, and massive to well foliated. They are distinguished from other rock types by their dark

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colour, commonly dark green or grey K-feldspar and local brown hypersthene megacrysts. They are composed of quartz (10 to 25 percent), K-feldspar (20 to 60 percent), plagioclase (10 to 50 percent), biotite (<1 to 5 percent), hornblende (<1 to 5 percent), hypersthene (trace to 3 percent), and magnetite (trace to 3 percent). Up to 1 percent garnet is found at the eastern margin of the Roper Bay Inlier, near the contact with Unit 5 garnet-cordierite-bearing pelites.

Unit 2: Monzonite to Granodiorite

Most of the basement complex in the Roper Bay and Pederson Lake inliers comprise moderately to strongly foliated granitoid gneisses. These are mostly pink or brick red, medium-to coarse-grained quartz monzonite to monzogranite, but lesser amounts of quartz syenite-syenogranite and granodiorite also occur. They commonly contain quartz (5 to 30 percent), K-feldspar (30 to 50 percent), plagioclase (5 to 40 percent), biotite (trace to 10 percent), hornblende (0 to 2 percent), and magnetite (trace to 5 percent). There are also some fine-grained, well-layered quartzofeldspathic rocks, with alternating mafic-rich/mafic-poor interlayers ranging from <1 to 10 cm. Abundant unmappable, elongated or boudinaged amphibolite bodies, several centimetres to metres wide, derived from either mafic dikes/sills or mafic volcanic rocks (part of Unit 3?) also occur, especially near contacts with Unit 4.

Rocks of this unit are commonly strongly foliated, with planar fabrics well defined by parallel alignment of biotite and/or amphibole and by elongated quartz and feldspar crystals. Zones of more intense deformation are marked by elongate ribboned quartz, rotated K-feldspars and local C/S fabrics (Berthé *et al.*, 1979).

Unit 3: Amphibolite

Amphibolite locally forms mappable bodies at the margin of the Roper Bay Inlier (see separate map). The rocks are dark green, generally fine to medium grained, and contain: hornblende (20 to 60 percent); biotite (10 to 15 percent); plagioclase (20 to 40 percent); quartz (5 to 10 percent); several percent hypersthene, clinopyroxene and biotite; and trace amounts of pyrrhotite and other opaques. Coarser grained, more hornblende-rich variants are typically massive, homogeneous, and intrusive in appearance, whereas less hornblendic, more plagioclase- and quartz-rich members are commonly well foliated and exhibit dark and light banding, up to 50 cm thick, which may represent epiclastic or pyroclastic primary layering. These rocks are tentatively interpreted as mafic intrusive sheets and/or pyroclastic volcanic rocks, formed during basement rifting.

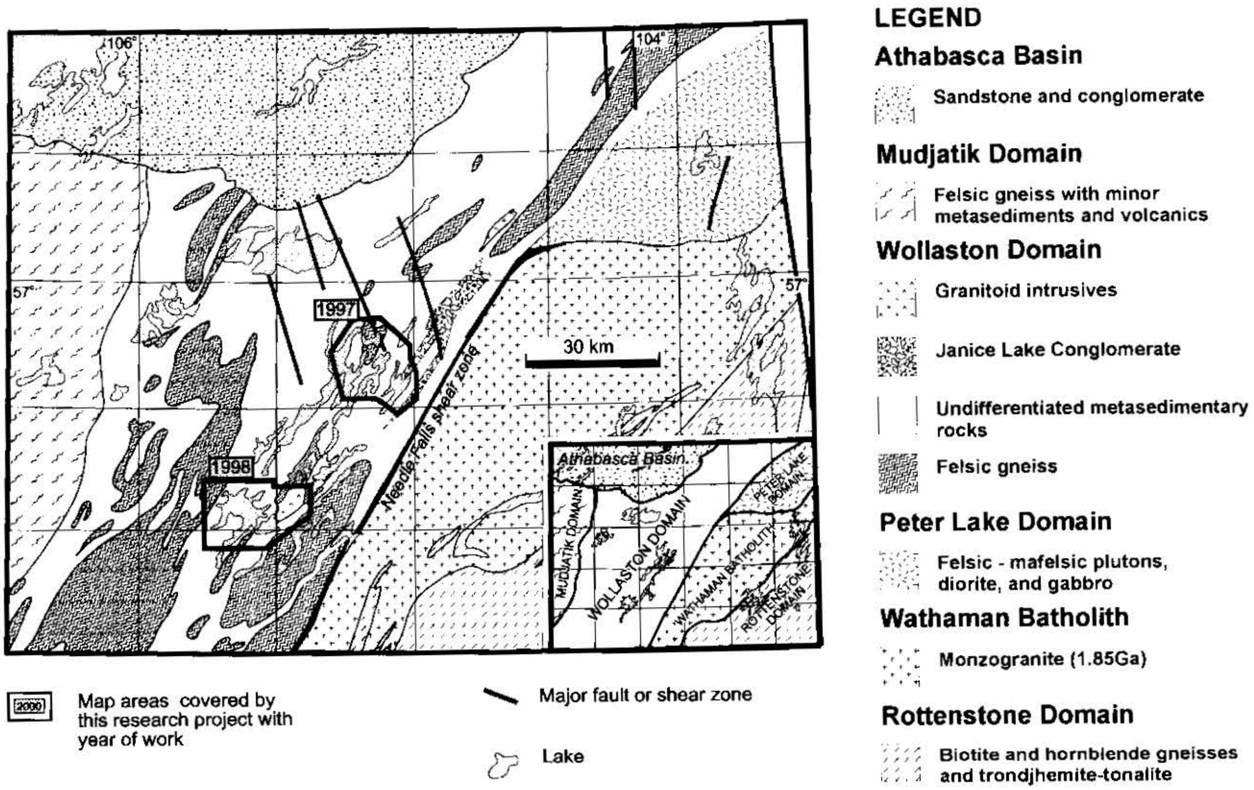

Figure 1 - Location of the Daly-Suttle-Middle Foster lakes area mapped in 1998. The Upper Foster Lake–Burbidge Lake area mapped in 1997 is also shown.

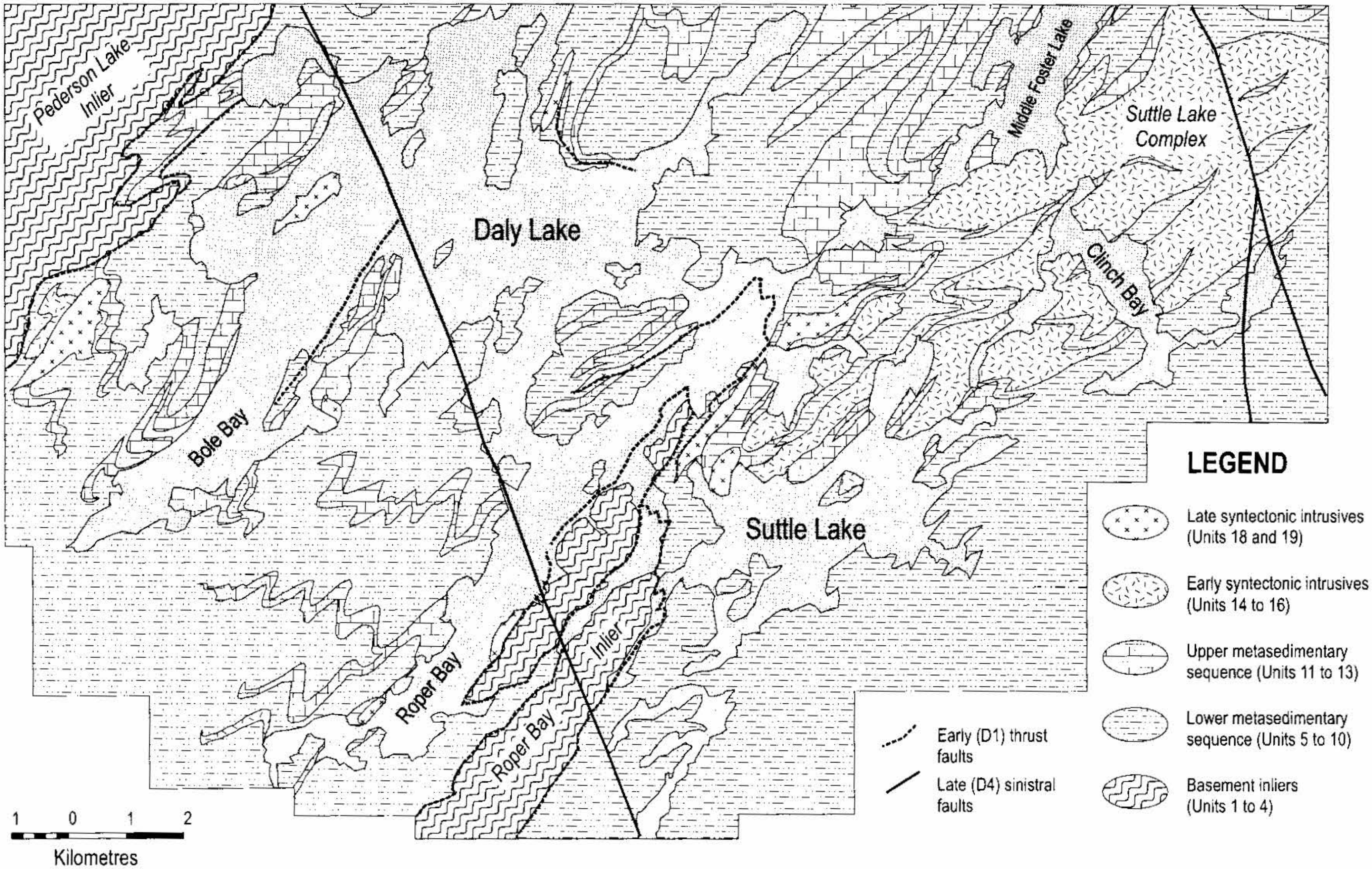

Figure 2 - Geological sketch map of the Daly-Suttle-Middle Foster lakes area.

Unit 4: Marginal Rocks

This heterogeneous assemblage, occurring mostly at the margins of the Roper Bay and Pederson Lake inliers, is dominated by weakly to strongly deformed dioritic to tonalitic rocks similar to those of the Suttle Lake Complex, discussed below, and younger, mostly undeformed aplite and granite pegmatite. Abundant xenoliths of foliated to sheared granitoid rocks (Unit 2), amphibolite (Unit 3), and metasedimentary rocks, including arkose, biotitic psammite, quartzofeldspathic gneisses, and pelites occur in this unit.

The metasedimentary inclusions, with the exception of the pelites, locally include thin (less than 5 to 20 cm), typically boudinaged bands of amphibolite. The contacts between the amphibolites and metasediments are commonly sharp, suggesting that the amphibolites are mafic sheets intruded into the sedimentary rocks.

b) Lower Sedimentary Sequence

Unit 5: Garnet-cordierite (±sillimanite)-bearing Pelite

Grey, medium- to coarse-grained, thinly layered, finely foliated, sparsely sillimanite-bearing garnet-cordierite pelitic rocks, with thin quartzite or biotite psammite interlayers, occur immediately adjacent to the margins of the basement complex, most notably around the Roper Bay Inlier (Figure 2 and separate map). They contain biotite (over 20 percent), cordierite (3 to 20 percent), garnet (trace to 10 percent), and sillimanite (trace to several percent). Quartzite layers, from less than 5 cm to over 1 m thick, occur locally, mainly in the lower part of the unit. The unit also includes unmappable biotite-rich psammopelite to psammite layers up to several metres thick. In places, pelite, quartzite, psammopelite, and biotite psammite are

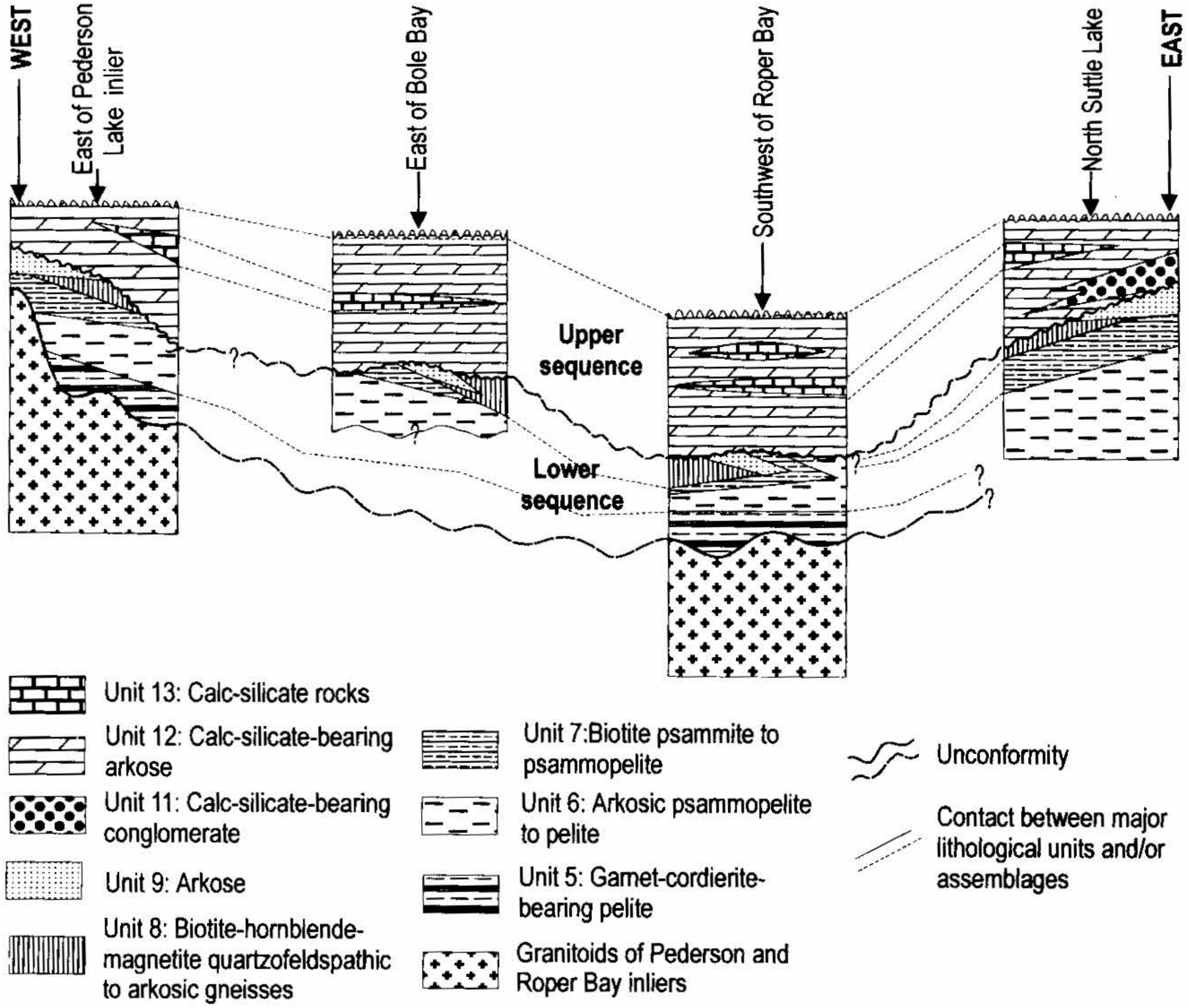

Figure 3 - Idealized, pre-deformation, stratigraphic cross-section from west to east in Daly-Suttle Lake area (not to scale). The thickness of the lithological units is uncertain due to intense multiphase deformation and high-grade metamorphism.

intercalated in very thin bands, ranging from less than 1 to 50 cm (Figure 4). A sequence of garnet-poor cordierite- and biotite-rich rocks, locally containing up to 30 percent cordierite and 20 percent biotite is also included in this unit (sub-unit 5a). In the west, near the Pederson Lake Inlier, garnet-cordierite-bearing pelites include 10 cm to 3 m thick arkosic interlayers. This unit is gradational upwards, via thin biotite-psammite and quartzofeldspathic members, into rocks of Unit 6.

Unit 6: Arkosic Psammopelite to Pelite

This is the most extensive unit in the area. It is typically pinkish grey, coarse to very coarse grained and massive, with cordierite (8 to 10 percent), sillimanite (trace to 3 percent), abundant, augen-like K-feldspar lenses up to 5 cm long, and migmatitic neosome. The neosomal component locally comprises up to 70 percent of the outcrop. The rocks also contain biotite (<15 percent) and magnetite (trace to 5 percent). The unit includes unmappable impure quartzitic and psammitic layers, which locally comprise up to 40 percent of the outcrop. It is separated from Unit 5 by a grey to pinkish, medium- to coarse-grained, poorly layered to massive, biotitic (<10 percent) quartzofeldspathic subunit from 5 to 20 m wide, which locally contains thin bands (<1 to 3 cm) rich in sillimanite flecks. Quartzofeldspathic lenses and pods centimetres to tens of centimetres in length, possibly representing boudinaged layers or metamorphic segregations, are common in this unit. Sillimanite is locally abundant, forming thin bands (<1 mm to several centimetres), most commonly in more biotite-rich layers. The contact with Unit 7 is transitional.

Unit 7: Biotite Psammite to Psammopelite

Grey to rusty, fine- to medium-grained, finely foliated psammite and psammopelite are locally interlayered with thin bands of Unit 6 cordierite-sillimanite-bearing psammopelitic rocks and Unit 8 magnetite-bearing psammite. Beds, ranging from several centimetres to several metres in thickness, are relatively homogeneous and comprise quartz (40 to 60 percent), lesser amounts of K-feldspar and plagioclase, and biotite (15 to 20 percent). Accessory minerals include magnetite, cummingtonite, and sulphides locally. Magnetite-rich (up to 7 percent) psammite layers up to 50 cm thick become more prevalent near the apparently transitional contact with Unit 8.

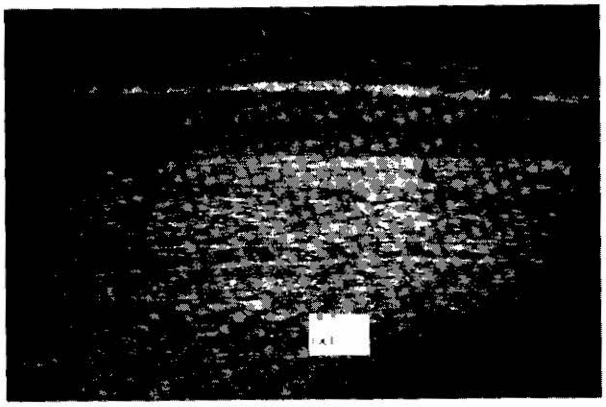

Figure 4 - Thin beds of interlayered, graded pelite with feldspathic melt lenses, psammite (dark grey), and quartzite (light grey) of Unit 5.

Unit 8: Biotite-hornblende-magnetite Quartzofeldspathic to Arkosic Gneisses

Unit 8 is a heterogeneous, thinly interlayered package, including psammopelite, quartzite, subarkose, arkose, and calc-silicate-bearing arkoses. Generally, these rocks are grey to rusty in weathering, fine to medium grained, weakly to strongly foliated, and thinly to thickly bedded (<1 cm to >1 m).

The dominant components are biotite gneisses containing abundant magnetite (<1 to 10 percent) and hornblende (trace to 5 percent), and trace actinolite and diopside. These are commonly well layered. Rare psammopelitic interlayers contain sparse sillimanite faserkiesel. These rocks are either in contact with or transitional into quartzitic, subarkosic, arkosic, or calc-silicate-bearing arkosic members. Quartzite and subarkose layers are commonly less than 10 cm thick, and contain less than 15 percent biotite and subordinate magnetite and hornblende. Weakly- or non-magnetic opaque minerals are tentatively interpreted as spinel or hercynite. Arkosic members are weakly foliated, range from 10 to 50 cm in thickness, and contain biotite (1 to <15 percent), magnetite (trace to 3 percent), and trace diopside and hornblende. More calcareous arkoses contain up to 5 percent each of diopside and hornblende, as well as actinolite (trace to 2 percent), biotite (<10 percent), and opaques (<1 percent). This unit appears to be gradational with Unit 9.

Unit 9: Arkose

Arkosic rocks are pink or pinkish grey on fresh surfaces, and orange to pinkish white on weathered surfaces. They are fine to coarse grained, thin to thick bedded, and foliated to massive. They commonly occur as thin interlayers in rocks of Units 6 and 8 but locally form a thick mappable unit (Figure 2). Typical arkose is medium grained, with abundant K-feldspar (<50 percent locally) and minor biotite (<10 percent). A trace to several percent of magnetite, hornblende, and diopside occur locally. In places, sillimanite faserkiesel up to 3 cm long are aligned oblique to the S_0/S_1 fabric, probably parallel to S_2. Subordinate, 0.5 to 1 m thick quartzite beds are interlayered with the arkose.

Unit 10: Quartzite

Quartzite beds are common throughout the stratigraphic succession, but only form mappable units locally, where they are commonly in contact with or interlayered with massive arkose of Unit 9. Typical quartzite is light grey to white, medium to coarse grained, poorly layered to massive, and generally impure, with quartz (>70 percent), biotite (<10 percent), feldspar (<15 percent), and trace amounts of sulphides, malachite, and magnetite.

c) Upper Sequence

Unit 11: Calc-silicate-bearing Conglomerate

Polymictic conglomerates occur as thin mappable units only on the north shore of Suttle Lake (Figures 2 and 5, and separate map), along the eastern edge of the Suttle Lake Complex. They also occur as inclusions, several centimetres to metres across, within the Suttle Lake Complex. The conglomerates include both clast-supported and matrix-supported types. Clast-supported conglomerate layers, from <1 to 3 m thick, comprise up to 70 percent clasts ranging from angular boulders up to 60 cm (Figure 6) to rounded pebbles, <1 cm diameter. Matrix-supported conglomerate members, ranging from 1 to 5 m in thickness, typically contain less than 50 percent clasts, mostly less than 5 cm in size.

The clasts are poorly to well-sorted and commonly flattened parallel to the main tectonic fabric (S_1). The predominant clasts are white, grey or dark brown, impure quartzite (up to 50 percent locally). Pinkish, medium- to coarse-grained granitoid clasts (15 to 30 percent) consist of K-feldspar (50 to 70 percent), quartz (<20 percent), and minor biotite (<5 percent). Rarely, the granitoid clasts have a weak planar fabric oblique to the main foliation, suggesting derivation from a previously deformed granitoid terrain. Their composition, however, is different from the nearby basement granitoid rocks. Subordinate clasts include: fine- to medium-grained, white to pinkish quartz pebbles, interpreted to be derived from quartz veins or feldspathic quartzite (Ray, 1981); and pink, fine- to medium-grained, leucocratic (<5 percent biotite) and/or calcareous (diopside-, actinolite-, hornblende-, and scapolite-bearing) arkose. Primary internal layering was seen in a few quartzofeldspathic sedimentary clasts.

The conglomerate matrix is a medium- to coarse-grained arkose with up to 10 percent calc-silicate minerals including diopside, actinolite, hornblende, biotite, and traces of calcite. Rare layers contain up to 10 percent coarse to grit-size, dark-blue quartz aggregates in the matrix. In places, remobilization, albitization, and concentration of calc-silicate minerals has produced a very coarse-grained matrix and local 'pseudo-pebbly' appearance on outcrop surfaces. Ray (1981) reported some amphibolite "pebbles" in the conglomerates, but the irregular lenses and pods of actinolite, hornblende, diopside, and calcite up to 20 cm across are likely the products of partial remobilization and concentration of calc-silicate minerals in the matrix during thermotectonism.

The relationship of the conglomerates to other rock units is problematic. Money (1966) considered them to be associated with the meta-arkoses, whereas Ray (1981) interpreted them to young eastward and conformably overlie semipelite and amphibolite which he inferred to rest unconformably on the Suttle Lake Complex. Abundant metasedimentary xenoliths, including conglomerate, within the Suttle Lake Complex, however, are evidence that the latter is younger than the metasediments. Moreover, the younging direction of the conglomerate is probably westward, towards the Suttle Lake Complex. At one location, a 2 m wide layer of mostly angular quartzite boulders to cobbles (Figure 6), grades westwards into 3 m of polymictic pebble conglomerate, which grades in turn into 10 m of pebbly arkose with some conglomerate interlayers less than 1 m thick.

Both contacts of the conglomerate west of the portage between Suttle Lake and Clinch Bay appear transitional to other units (Figure 5). To the east, near the portage, conglomerates grade into calc-silicate-bearing arkoses with thin (<10 cm) interlayers of sillimanite-bearing psammopelitic and calc-silicate-bearing rocks. In the west, conglomerates grade into a 5 m wide pebbly calc-silicate-bearing arkose unit, which is succeeded by a sequence of quartzite and massive arkoses intruded by granodiorite of the Suttle Lake Complex (Figure 5). Thus, although the conglomerates form a mappable unit, their intimate relation to the calcareous arkose suggests that they may have been, in part, deposited contemporaneously with them, as suggested by Money (1966).

Unit 12: Calc-silicate-bearing Arkose

These are light-grey to pinkish, fine-, medium- or coarse-grained, massive to well-layered quartzofeldspathic rocks containing up to 10 percent calc-silicate minerals, mostly diopside, actinolite, and hornblende, along with biotite (up to 10 percent locally), magnetite (trace to 3 percent), and trace hematite and epidote. Colour banding is common, with alternating layers ranging from <1 to 30 cm thick. More quartzofeldspathic layers are white or pink; those rich in diopside, amphibole or biotite are greenish or brown; and those containing magnetite and some hematite are red. This banding is interpreted as transposed primary bedding. In more massive layers, pyroxene and amphibole are commonly concentrated as pods and sweats, up to 20 cm across, either oriented parallel to tectonic foliation or along late fractures.

Near the contact of this unit with the conglomerate (Unit 11), there are 1 to 10 m thick layers of pebbly arkose containing <1 to 10 percent polymictic pebbles. Unmappable calc-silicate (Unit 13) layers and scapolite/diopside-bearing plagioclasite (Unit 18) bodies also occur locally.

This unit is locally in apparent contact with several other lithological units, including Units 6, 7, 8, and 9, which are stratigraphically older. This relationship, and the previously described association of this unit with the conglomerates, suggests that Unit 12 unconformably overlies the older rock units. Hence this contact is a major stratigraphic break between the lower and upper parts of the metasedimentary succession.

Unit 13: Calc-silicate Rocks

White to green, pinkish, massive to layered, medium- to coarse-grained calc-silicate rocks locally form a mappable unit within Unit 12 calcareous arkoses. They are typically quartz-poor and plagioclase (albite) rich,

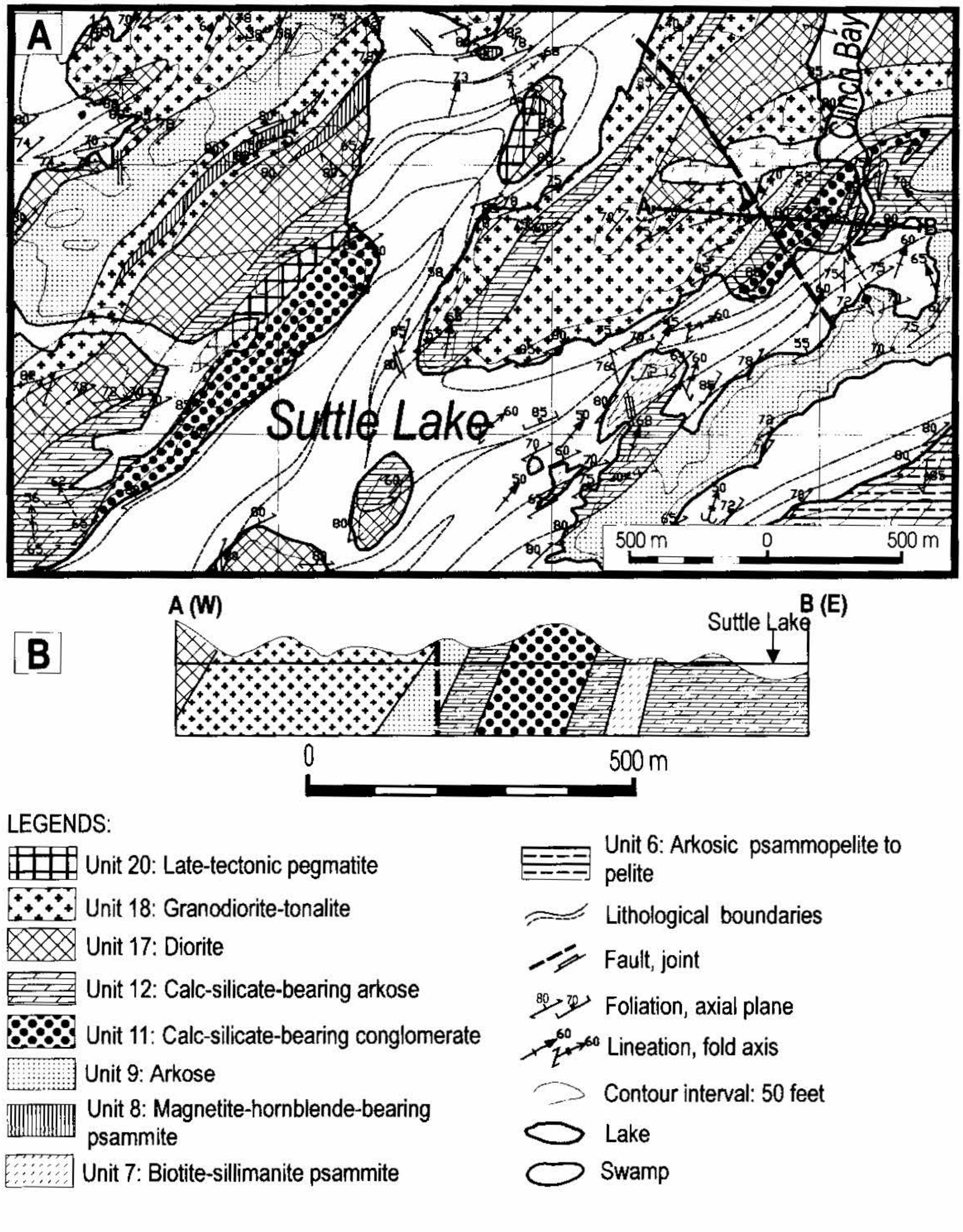

Figure 5 - A) Detailed geological map and B) cross-section of the area between Suttle Lake and Clinch Bay, showing the relationship between Unit 11 calc-silicate-bearing conglomerate and other rock units.

Figure 6 - Flattened quartzite clasts up to 50 cm long in a calcareous matrix from the lower part of the Unit 11 conglomerate, north Suttle Lake. Knife is 9 cm long.

with up to 60 percent calc-silicate minerals including tremolite/actinolite, hornblende, and diopside. They also contain variable amounts of scapolite, calcite, epidote, and traces of sphene and vesuvianite.

Massive, pegmatitic or 'pseudo-ophitic' textured plagioclasite bodies occur locally, but most of the unit possesses distinct lithological/metamorphic layering. Where compositional banding is well developed, green diopside-rich bands, from less than one to several centimetres thick, alternate with white or pinkish, plagioclase-rich layers. This may be transposed primary layering. Thin impure dolomitic marble layers, <5 to 30 cm thick, occur locally.

In places, this unit includes pods or layers up to several metres wide of a distinct brecciated texture of debatable origin. The breccias comprise milky white to pinkish, angular to rounded, unsorted clasts from <1 to 5 cm across, set in a light green matrix rich in tremolite/actinolite and diopside (<30 percent locally). The clasts mostly comprise an equigranular finely granoblastic mosaic of plagioclase (possible albite) crystals. Larger clasts commonly have traces of tremolite/actinolite and quartz (mostly in the core). In many exposures, the clasts appear undeformed; in others they are strongly flattened. Clast boundaries are generally diffuse, but are locally sharp and distinct.

d) Early-syntectonic Intrusives (including the Suttle Lake Complex)

Unit 14: Gabbro

Dark-green, medium- to coarse-grained, massive to weakly-foliated gabbroic rocks are exposed in several places, notably in the southwest and northeast parts of the area. They comprise hornblende (up to 80 percent), plagioclase (10 to 15 percent), pyroxene (trace to 10 percent), minor opaques, and trace calcite.

Unit 15: Diorite, Quartz-diorite, and Monzodiorite (Suttle Lake Complex)

Mawdsley (1957), Money (1966), and Ray (1981) described the Suttle Lake Complex as a large, relatively homogeneous, batholith-like body; however, this study shows that it includes a significant metasedimentary component. Metasedimentary xenoliths including cordierite-sillimanite psammopelites to pelites, conglomerates, arkoses, and calc-silicates, range from several centimetres to tens of metres across. Contacts between the intrusive and metasedimentary rocks are sharp, though locally modified by deformation. Metasomatic alteration zones 10 to 50 cm wide in the metasedimentary rocks were observed locally. Intrusive components of the complex are heterogeneous, consisting mainly of sheet-like bodies of variable mafic to felsic composition. Two principal intrusive units are distinguished, a dioritic one (Unit 15) and a granodioritic one (Unit 16).

Dioritic rocks are black, grey or buff, medium to coarse grained, massive to strongly foliated and form mappable units north of Suttle Lake. Unmappable bodies occur along the margin of the Roper Bay Inlier, where they contain inclusions of basement rocks and garnetiferous metasediments, and as small bodies and sheets within the metasedimentary rocks. Gradational compositional variation from typical diorite to quartz-diorite and monzodiorite occurs locally over distances of several metres. Pyroxene-rich bodies, which are more granodioritic in composition, are also seen locally. The diorites typically contain hornblende (20 to 40 percent), biotite (<5 to 10 percent), quartz (<5 to 20 percent), pyroxene (trace to 1 percent, including augite and hypersthene?), and magnetite (trace to 3 percent). Plagioclase generally accounts for 60 to 90 percent of the felsic mineral component.

Unit 16: Monzogranite to Granodiorite-tonalite (Suttle Lake Complex)

Medium- to coarse-grained, weakly- to well-foliated monzogranite and granodiorite-tonalite form the main intrusive components of the Suttle Lake Complex. They also intrude, and form part of the basement complex (Unit 4) and commonly occur as unmappable sheets in metasedimentary rock units throughout the map area. They are pink or light red, grey, or buff in fresh surface and weather white or light-brown.

These rocks comprise plagioclase (<65 percent), K-feldspar (<5 to 3 percent), biotite (10 to 15 percent), hornblende (trace to 5 percent), magnetite (<1 to 5 percent), and trace garnet. Idioblastic to xenoblastic crystals of hypersthene up to 1 cm across were found locally in the Clinch Bay area.

Unit 17: Chatwin Lake Granodiorite–Quartz Monzodiorite

Only the southwestern edge of the Chatwin Lake Body (Ray, 1981), east of Middle Foster Lake, was mapped.

The marginal rocks are pale grey weathered, grey, medium crystalline (2 to 3 mm) with megacrystic feldspars (<10 mm) locally, and generally are weakly foliated granodiorite to quartz monzodiorite. The rocks contain quartz (10 to 25 percent), plagioclase (50 to 80 percent), K-feldspar (10 to 20 percent), hornblende (0 to 10 percent), biotite (5 to 10 percent), and magnetite (2 to 5 percent) and rare garnet (<1 percent).

An intrusive relationship with the Wollaston metasediments is indicated by chilled marginal contacts, intrusive sheets in the adjacent metasediment, angular xenoliths of biotite and garnet-biotite psammopelite near the contact, generally weak foliation, and compositional and textural similarity with the Suttle Lake Complex. Garnet is interpreted to reflect contamination by sedimentary rock. In contrast with regional basement inliers, which are typically overlain concordantly by Unit 6 garnet- and graphite-bearing metasediments, the Chatwin Lake Body is in discordant contact with pelites and psammopelites, arkose, and calc-silicate-rich rocks (Mawdsley, 1957; Ray, 1981). Previous workers (Mawdsley, 1957; Ray, 1981) also interpreted the Chatwin Lake Body to intrude the metasediments.

Although the Chatwin Lake Body is generally similar in composition to the Suttle Lake Complex, it contains a central mass of hypersthene-bearing diorite and quartz diorite (Ray, 1981). Limited geochemical data (Ray, 1981) also suggest some affinity with the basement rocks.

e) Late Tectonic Intrusives

Unit 18: Plagioclasite

Pinkish to light-green, coarse-grained to pegmatitic, massive to weakly foliated plagioclasite contains mostly plagioclase (50 to 70 percent), diopside (5 to 25 percent), hornblende (5 to 20 percent), and scapolite (trace to 10 percent). Locally it forms mappable bodies, but more commonly occurs as unmappable masses associated with, and probably derived from, calcareous arkoses (Unit 12) and/or calc-silicate rocks (Unit 13). This unit includes small bodies and sheets previously called 'scapolite gabbro or gabbroic pegmatite' (Money, 1966), that occur as dikes and sills, cross-cutting the country rocks. 'Xenoliths' of Units 12 and 13, from less than 10 cm to several metres across, are abundant in this unit and its contacts with the metasediments are commonly irregular.

Unit 19: Late Syntectonic Granite Pegmatite

White to pink, medium-grained to very coarse-grained, massive to weakly foliated granite to quartz pegmatite is widespread and locally forms mappable bodies. It generally forms semi-concordant sheets ranging from veins less than 10 cm thick to bodies hundreds of metres wide. These crosscut primary layering and early tectonic fabric (S_1) but are widely overprinted by the S_2 planar fabric. Sedimentary xenoliths, locally forming up to 40 percent of the outcrop area, are common in such bodies, which locally contain several percent cordierite and sillimanite.

Unit 20: Post-tectonic Pegmatite

Massive, undeformed, pink granite pegmatite veins, dikes and sheets, from <10 cm to several metres wide, which transect all planar tectonic fabrics, occur throughout the area. They mostly comprise K-feldspar (up to 80 percent), subordinate quartz (less than 15 percent), biotite/ muscovite (<2 percent) and minor tourmaline.

3. Structural Geology

At least four deformation events were identified: D_1 to D_3 produced penetrative structures, whereas D_4 is an episode of mostly brittle faulting.

a) First Generation Structures (D_1)

All rocks in the study area (except Units 18, 19, and 20) are affected by the earliest recognizable deformation. D_1 is represented by a well-developed penetrative regional foliation (S_1), paralleled by transposed compositional layering and axial planar to coeval F_1 isoclinal folds. Primary sedimentary layering and pre-tectonic magmatic bodies (dikes and veins) are isoclinally folded and boudinaged, with resultant widespread lithological repetition (Figure 2 and separate map) parallel to the S_1 foliation. The S_0/S_1 foliation is mostly steeply dipping and northeast-southwest-trending, except in hinge zones of second generation major folds. S_1 includes the flattening plane of grain aggregates and rock fragments/pebbles, early anatectic neosome veins and segregations, and preferred crystallographic and/or dimensional orientation of most metamorphic minerals. Early metamorphic minerals, including biotite, sillimanite, K-feldspar, cordierite, amphibole, and pyroxene, were formed and partly deformed during development of S_1, indicating broadly coeval high-grade metamorphism.

S_1 is strongly developed in granitoid rocks of the Pederson Lake and Roper Bay inliers, where it is concordant with the S_1 fabric in the enclosing supracrustal cover rocks. No evidence of an earlier tectonic fabric was identified in the basement. Near the contact between basement and sedimentary cover, the S_1 foliation increases in intensity and becomes protomylonitic to mylonitic in character, locally forming discrete shear zones up to tens of metres wide. This strain gradient is accompanied by an increase in migmatitic neosome. In such zones, supracrustal layers, intrusives and early pegmatites are highly transposed and prominently boudinaged. Mesoscopic shear-sense indicators including: back-rotated layers and swells, rotated boudins, and asymmetric small-scale folds (Hanmer and Passchier, 1991); C/S fabrics (Berthé *et al.*, 1979); and a stretching lineation, are well documented and generally indicate consistent oblique sinistral reverse movement. Such shear zones are commonly refolded by second-generation folds (Figure 7). Several shear zones were identified in the central part of the Roper Bay Inlier, where granitoid basement rocks overlie garnet-cordierite-sillimanite pelites. This relationship implies local D_1 crustal imbrication with overthrusting of sedimentary cover by basement rocks.

A generally well-developed L_1 lineation, lying within S_1 is defined by mineral aggregate elongation, quartz-rodding, and pebble/clast extension. This lineation is reoriented by later folding events and its initial attitude is unknown. Completely isoclinal F_1 minor folds, defined by primary layering (Figure 8), and locally by early quartz-feldspar segregations, are widely preserved.

b) Second Generation Structures (D_2)

First generation fabric elements were strongly deformed during a second deformation event (D_2). S_0/S_1 foliation is extensively refolded by open to very tight, locally isoclinal major and minor second generation folds (F_2) which generally exhibit a near-similar fold profile geometry characteristic of highly flattened flexural folds (Ramsay, 1962, 1967; Ramsay and Huber, 1987). F_2 axial planes are northeast trending and steeply northwest dipping: F_2 fold axes plunge moderately to the northeast (Figure 9). F_2 major folds are common and control the structural grain of the study area. Refolding of F_1 by F_2 folds commonly produced coaxial type-3 fold interference patterns (Ramsay, 1967; Figure 10).

F_2 minor folds are commonly accompanied by a well-developed S_2 axial plane schistosity. This is best developed in F_2 fold hinge zones and is most commonly a strain-slip schistosity. Where F_2 folds are very tight to isoclinal, the S_1 foliation is mostly

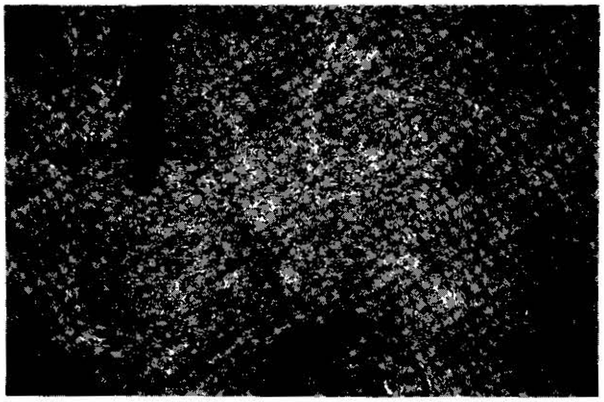

Figure 7 - An early (D_1) mylonite zone developed in Unit 2 granodiorite folded by F_2 folds; from the central Roper Bay Inlier. Pencil is 8 mm wide.

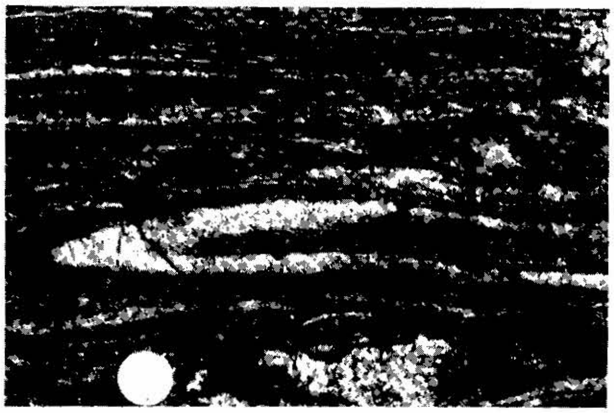

Figure 8 - Isoclinal F_1 fold of a thin quartzite layer in Unit 5 pelitic rocks east of the Roper Bay Inlier. Coin is 28 mm wide.

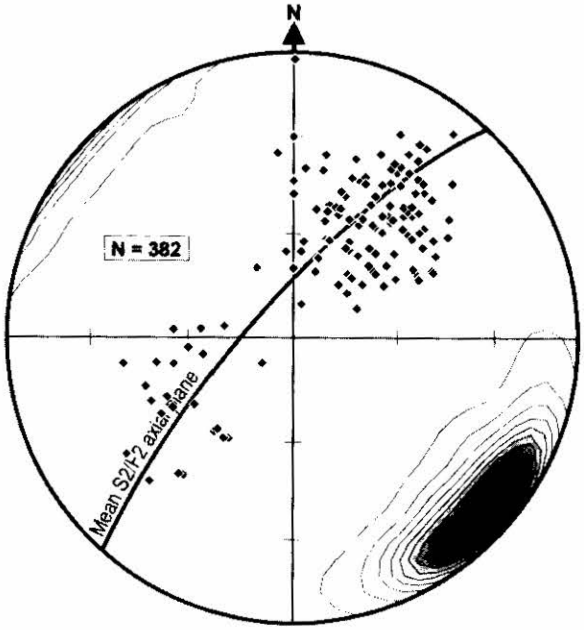

Figure 9 - Lower hemisphere equal-area stereographic projection of poles to S_2 foliation and F_2 axial planes (contours) and F_2 minor fold axes (diamonds). The lowest contour is 1 percent and higher contours are at 5 percent intervals.

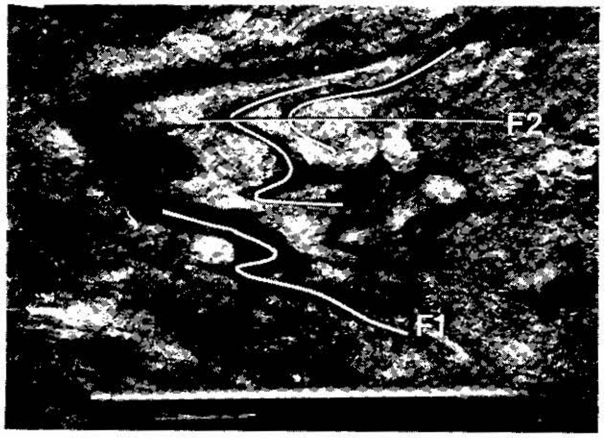

Figure 10 - F_1/F_2 fold interference pattern of a quartzofeldspathic layer in Unit 7, west of Daly Lake. Pencil is 15 cm long.

transposed into S_2 and the distinction between S_1 and S_2 is problematic. The S_2 planar fabric is marked by a planar preferred crystallographic orientation of second-generation metamorphic minerals such as biotite, sillimanite faserkiesel, cordierite, and K-feldspar lenses and of cordierite-K-feldspar (±garnet)-bearing anatectic melt segregations.

c) Third Generation Structures (D_3)

Locally, D_1/D_2 structures are overprinted by third generation minor folds. These are generally very open to open, long-wavelength structures with subvertical northwest-southeast-trending axial surfaces (Figure 11). They refold F_2 folds to form both type-2 and type-3 fold-interference patterns (Figure 12). Late D_2 anatectic veins and sweats are commonly folded by F_3 and locally overprinted by a weak S_3 axial planar fabric.

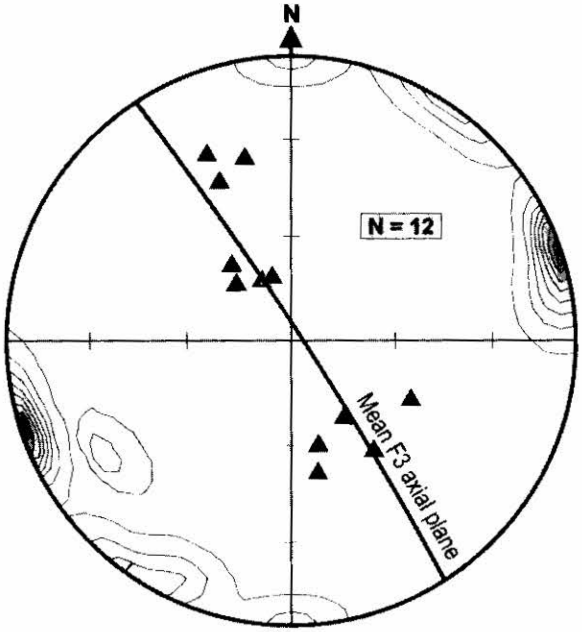

Figure 11 - Lower hemisphere equal-area stereographic projection of poles to S_3 axial planes (contours) and F_3 minor fold axes (dots). The lowest contour is 1 percent and higher contours are at 2 percent intervals.

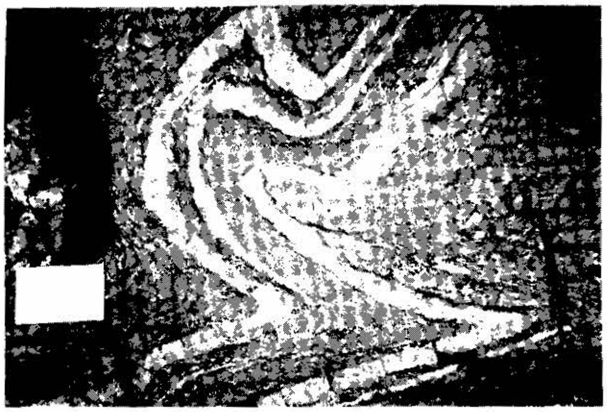

Figure 12 - F_2/F_3 fold interference pattern of quartzite layers in Unit 5, south of Roper Bay.

d) Fourth Generation Structures (D_4)

All other structures are cut by several generally subvertical, mostly north- to northwest-trending brittle and locally brittle-ductile faults. They are identified in the field by: a) cataclastic zones up to several metres wide, b) zones of hematization, c) locally well developed slickensides, d) disruption of lithological units, and e) local small-scale shear/fault zones (Figure 13). Kinematic indicators show that these fault/shear zones have dominantly sinistral displacement.

4. Metamorphism

All rocks, except late pegmatites, have undergone high-grade metamorphism. The highest grade mineral is hypersthene, which is abundant in charnockitic basement rock, and in granodioritic rocks of the Suttle Lake Complex. Clinopyroxene, hornblende, and biotite are common metamorphic minerals in intrusive rocks of both the basement and the Suttle Lake Complex. Calcareous metasediments contain tremolite/actinolite, hornblende, diopside, biotite, scapolite, and calcite/dolomite. The most widespread metamorphic assemblages are those in aluminous, pelitic to psammopelitic metasedimentary rocks, which include biotite, sillimanite, cordierite, garnet, K-feldspar, and magnetite. Anatectic melt components are also widespread in such rocks.

At least two generations of metamorphic mineral growth have been identified, broadly overlapping the first two deformation episodes. Metamorphic conditions are discussed below on the basis of metamorphic mineral relationships seen in pelitic rocks.

a) First Generation Mineral Growth

The earliest documented phase of metamorphic mineral growth in pelitic rocks appears to have

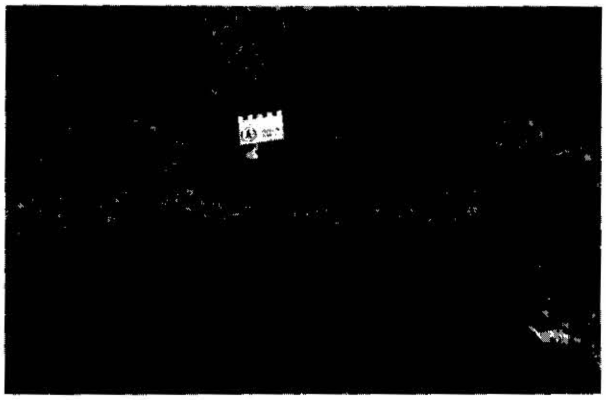

Figure 13 - A small, sinistral, brittle-ductile shear zone (D_4) in psammitic rocks of Unit 7, northeast Suttle Lake.

spanned and outlasted D_1 deformation, as demonstrated by preferred orientation of most metamorphic minerals including biotite, sillimanite, and cordierite. These commonly define the S_1 foliation and are locally deformed by D_1 structures.

Sillimanite faserkiesel are generally preferentially flattened within S_1 and elongated in L_1. Some are folded by F_1 isoclinal microfolds, but most commonly they are refolded by F_2 microfolds and crenulations (Figure 14). Sillimanite also commonly occurs as xenoblastic inclusions in cordierite, garnet, and feldspar, suggesting that the sillimanite has been largely replaced by these minerals during subsequent prograde metamorphism.

Prominent early cordierite, most commonly associated with K-feldspar and locally with sillimanite, includes two varieties: 1) small, highly altered, flattened, brown lenses easily recognized in weathered outcrops, commonly contain cores of felted fibrolitic sillimanite, biotite, and quartz, implying that cordierite may have formed by breakdown of these minerals; and 2) brownish, fine-grained cordierite aggregates that are elongated in the S_1 foliation.

Early, possibly syn-D_1 garnet occurs as fine-grained aggregates, generally less than 5 mm across, which are commonly elongated in the S_1 foliation in pelitic rocks of Unit 5 of the basal assemblage.

First generation metamorphic K-feldspar occurs as lensoid poikiloblastic porphyroblasts up to several centimetres across, commonly rimmed by a biotite-rich, and locally sillimanite-bearing, melanosome. It appears to be associated with the formation of sillimanite and cordierite. K-feldspar growth is coeval with the first appearance of anatectic neosome and also occurs in large, strongly deformed leucosomal sweats, veins, and dikes, which are commonly strongly deformed by D_2.

Early migmatitic neosome occurs throughout the map area, ranging from small patchy sweats to sheets over 1 m wide and locally forming up to 70 percent of the outcrop area. It is commonly boudinaged, transposed into the S_1 fabric, isoclinally folded by F_1, and refolded by second-generation folds.

b) Second Generation Mineral Growth

Second generation mineral growth in pelitic rocks, broadly coeval with and outlasting the D_2 deformation, included garnet, cordierite, and K-feldspar. This event overprinted earlier structural fabric and metamorphic features. Extensive anatectic melt also formed during this metamorphic episode.

Second generation cordierite occurs both as: 1) purple, translucent, subidioblastic to lensoid, porphyroblasts, up to 2 cm across, either rimmed or cored by K-feldspar, and dimensionally oriented parallel to the S_2 fabric; and 2) large unoriented porphyroblastic aggregates up to 10 cm across in leucosomal segregations.

Second-generation garnet, associated with second-generation cordierite and K-feldspar, occurs as large, randomly oriented, and poikiloblastic aggregates, locally up to 5 cm across, with abundant inclusions of sillimanite, biotite, and quartz. This kind of garnet overgrows D_2 fabrics and is undeformed, suggesting late- to post-D_2 growth.

Second generation K-feldspar, occurs as:
1) undeformed lensoid porphyroblasts up to several centimetres across, either rimmed or cored by cordierite and oriented parallel to S_2 fabric (Figure 15), especially in F_2 fold hinge zones; and 2) idioblastic crystals up to several centimetres diameter in weakly deformed neosome and aluminous pegmatitic veins/dikes.

Anatectic melt, developed during the second metamorphic event, forms weakly to undeformed sweats, veins, dikes, and large aluminous pegmatite bodies. These are mostly either axial planar to F_2 folds or randomly crosscut earlier fabrics, but are locally deformed by D_3 folds.

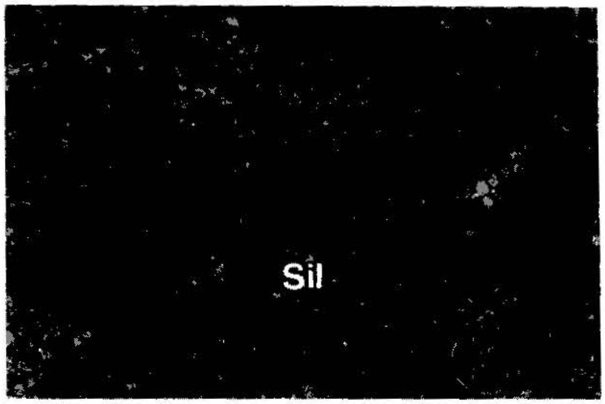

Figure 14 - First-generation sillimanite aggregates elongated in S_1 foliation and refolded by F_2 folds, southwest Suttle Lake.

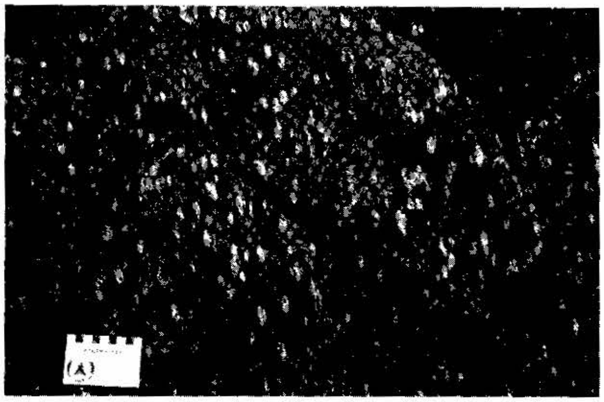

Figure 15 - Second-generation K-feldspar lenses with biotite melanosomes oriented parallel to F_2 fold axial planes in Unit 6 east of Suttle Lake.

c) Conditions of Metamorphism

Metamorphic assemblages clearly indicate upper amphibolite to granulite facies high-grade metamorphic conditions. No metamorphic isograds have been defined. Differences in mineral assemblages among different rock units are interpreted to be largely a function of bulk rock composition rather than changing metamorphic grade.

In pelitic rocks, the absence of muscovite and abundance of sillimanite in association with other high-grade minerals such as cordierite and K-feldspar, and the abundance of anatectic melt, suggest that metamorphic grade was above the second sillimanite isograd. This led to the breakdown of muscovite to form sillimanite, cordierite, and melt, possibly via reaction 1 (Evans, 1965), or, in the presence of phengitic muscovite, reaction 2 (Thompson, 1982), or, assuming the presence of plagioclase, reaction 3 (Evans and Guidotti, 1966).

Muscovite+Quartz→Sillimanite+K-feldspar+H_2O (1)

Phengite+Quartz→Cordierite+K-feldspar+H_2O (2)

Muscovite+Quartz+Plagioclase→K-feldspar+Sillimanite+H_2O (3)

Cordierite porphyroblasts commonly have sillimanite inclusions, which may reflect a breakdown of sillimanite to produce cordierite by one of reactions 4 (Holdaway and Lee, 1977), 5 or 6 (Wickham, 1987).

Biotite+Sillimanite+Quartz→Cordierite+K-feldspar+H_2O (4)

Biotite+Albite+Sillimanite+Quartz→Cordierite+K-feldspar+H_2O (5)

Biotite+Albite+Sillimanite+Quartz+H_2O→Cordierite+Melt (6)

The garnet in Unit 5 may be produced by a number of dehydration reactions such as those in reactions 8 and 9.

Chlorite+Muscovite→Garnet+Biotite+Quartz+H_2O (8)

Sillimanite+Biotite+Quartz→Cordierite+Garnet+K-feldspar+Melt(9)

Reaction 8 (Hsu, 1968) occurs at low grade metamorphic conditions (Bucher and Frey, 1994) and may correspond to growth of first generation garnet during early stages of metamorphic history. Reaction 9 (Grant, 1985) represents transition from upper amphibolite to granulite facies (Bucher and Frey, 1994). This may correspond to the production of the second generation cordierite-garnet-K-feldspar-melt assemblage and may define peak metamorphic conditions in the study area.

No orthopyroxene was found in pelitic rocks, but it has been reported elsewhere near the study area (Harper 1975; Potter, 1980; Ray, 1981). Hypersthene is common in intrusive rocks of the Suttle Lake Complex, where it is clearly of metamorphic origin (see Section 2). It therefore seems that the P-T conditions were high enough for formation of orthopyroxene via breakdown of biotite (Spear, 1993) or cordierite and garnet (Grant, 1985). The absence of orthopyroxene in pelitic rocks may be a function of the rock's bulk composition. Spear (1993) considered that breakdown of biotite to form orthopyroxene could occur only in Al-deficient rocks (e.g. low-Al annite-phlogopite solutions). Bucher and Frey (1994) considered that the cordierite-garnet-orthopyroxene paragenesis formed only in Mg-rich rocks or in the presence of annitic biotite.

Metamorphic mineral assemblages and their relationship to deformational fabrics clearly document two distinct periods of mineral growth. High-grade mineral assemblages formed in part during D_1, but peak metamorphic conditions were not reached until late stages of, or even after, D_2 deformation.

A P-T grid, which includes the mineral reactions described above, and a proposed P-T trajectory for metamorphism in the area is presented in Figure 16. The abundance of anatectic melt components, together with cordierite and sillimanite in pelitic rocks, suggests that metamorphic conditions exceeded the second sillimanite isograd (reaction 1) and the water-saturated solidus (curve 10, Figure 16; Bucher and Frey, 1994). Reaction (1) intersects the water-saturated solidus at 4 kbar and 680°C (point A, Figure 16; Bucher and Frey, 1994). P-T conditions to the right of point A would result in extensive melting and may account for extensive early anatectic neosome production in pelitic rocks of the study area.

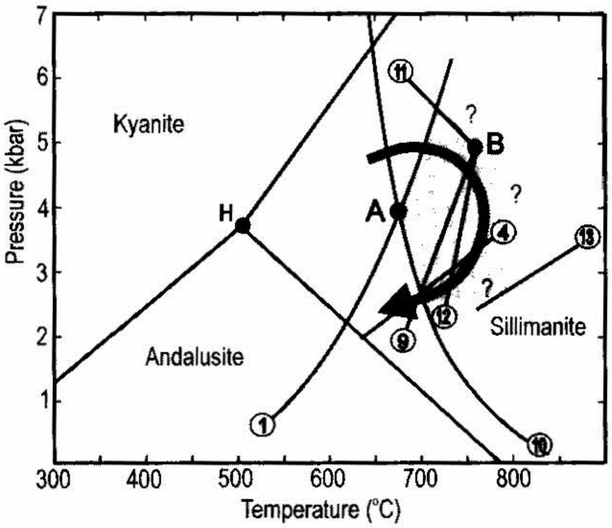

Figure 16 - P-T grid showing a preliminary interpretation of metamorphic conditions in the Daly-Suttle-Middle Foster lakes area on the basis of metamorphic mineral assemblages observed in the field. H is Holdaway's (1971) triple point. The shaded area indicates possible metamorphic conditions in the study area. The number of each invariant curve refers to a reaction discussed in the text. Point A, the intersection of the water-saturated solidus (curve 10) and the second sillimanite isograd (curve 1) indicates the lowest temperature for melting and production of neosome, 680°C. Point B, the intersection of curves for reactions 9, 11, and 12 (see text) represents the maximum conditions attained, about 750°C and 5 kbar.

Peak metamorphic P-T conditions in the area must have reached those required for reaction 9, to produce the widespread garnet-cordierite-K-feldspar assemblage. The univariant intersection of curves 9, 11, and 12 (point B, Figure 16), estimated to occur at about 5 kbar and 750°C (Bucher and Frey, 1994), is the highest P-T that reaction 9 can attain. Reaction 11 marks the breakdown of garnet+cordierite to form sillimanite+orthopyroxene, and reaction 12 involves garnet+biotite breakdown to form cordierite+ orthopyroxene respectively. Although no orthopyroxene was found in pelitic rocks, the presence of orthopyroxene in intrusive rocks of the Suttle Lake Complex, and in semipelitic rocks west of Daly Lake (Ray, 1981), suggests that the absence of orthopyroxene in this area may be a function of rock composition, and that metamorphic temperatures may have exceeded this invariant point. However, no sign of garnet breakdown to form spinel (curve 13, Figure 16) was found, suggesting that maximum metamorphic temperature did not exceed that for garnet breakdown by a reaction such as reaction 13.

$$\text{Almandine+Sillimanite} \rightarrow \text{Spinel+Quartz} \qquad (13)$$

This occurs at a minimum temperature of ~770°C at 2.5 kbar pressure (Bucher and Frey, 1994).

In conclusion, peak metamorphic conditions are interpreted to have been ca. 5 kbar and at temperatures less than 770°C. This P-T range indicates an average geothermal gradient of up to $60°C/km^{-1}$ at metamorphic peak. Such high thermal gradients and the presence of typical mineral assemblages indicate a high T/low P metamorphic regime belonging to the andalusite-sillimanite facies series (Miyashiro, 1973).

5. Economic Geology

Since the 1950s, several radioactive pegmatite bodies have been identified in the vicinity of the study area (Mawdsley, 1957; Ray, 1981), but none were noted in the map area itself. Several claims have been staked in the Daly Lake area (Money, 1966) and some test pits excavated, but nothing of economic significance has been reported. Several minor metallic mineral occurrences are found in the area (see separate map). These include: quartzite- and/or arkose-hosted pyrite, chalcopyrite, pyrrhotite, and malachite; and ilmenite/magnetite-bearing veins in calcareous arkose or calc-silicate rocks. Rocks of Unit 8 locally contain up to 10 percent magnetite.

6. Discussion and Conclusions

a) Basement Inliers

Previous workers (Money, 1966; Ray, 1981) showed that the Pederson Lake Inlier is an Archean basement complex unconformably overlain by Paleoproterozoic supracrustal rocks of the Wollaston Group. The status of the Roper Bay Inlier, although comprising broadly similar rock types, is more controversial. Money (1966) considered the Roper Bay Inlier to be intrusive into metasedimentary rocks, and both Fuh (1976) and Forsythe (1977) made similar interpretations of the southern extension of this complex.

This study confirms that the Roper Bay Inlier is, in fact, a part of the basement complex, essentially identical to the Pederson Lake Inlier, as first suggested by Ray (1981). This is indicated by similarity of rock assemblage, structural style, relationship to the sedimentary cover rocks, and comparison with other inliers in this part of the Wollaston Domain (e.g. Ray, 1977, 1978, 1981).

Ray (1981) considered that the Suttle Lake body might also be part of the basement complex, arguing that it is unconformably overlain by conglomerate. This study has demonstrated, however, that plutonic rocks of the complex contain abundant xenoliths of sedimentary rocks of various compositions including conglomerate, calc-silicate, arkose, and biotite psammite, with clear intrusive relationships. Thus the Suttle Lake Complex clearly postdates the Wollaston Group.

The Chatwin Lake body, or at least its marginal rocks, also intrude the Wollaston sediments.

b) Lithostratigraphy

Money (1966) used the term 'Daly Lake Group' to include all metasedimentary rocks in the area. Ray (1975) included these in the Paleoproterozoic 'Wollaston Group'. This group has a broadly consistent stratigraphy throughout much of the domain: a lower sequence of locally graphitic pelitic and semipelitic rocks, and an upper sequence of dominantly arkosic sediments (Gilboy, 1975; Ray, 1975, 1977, 1978, 1981; Potter, 1977; Sibbald, 1983). They are widely considered to represent a sequence of inboard rift and post-rift passive margin sediments (Coombe, 1979; Ray and Wanless, 1980; Lewry and Sibbald, 1980; Sibbald, 1983) deposited on the western margin of the Rae-Hearne Craton (Lewry and Stauffer, 1990).

In this area, quartzofeldspathic and meta-arkosic sediments of Unit 4, which occur as xenolithic remnants at the margins of the Archean inliers, may be remnants of a pre- or syn-rift sedimentary succession. Abundant amphibolite bodies in this unit, some clearly boudinaged dikes, may represent mantle-derived dikes or mafic volcanics, generated during basement rifting.

The basal part of the overlying succession (Unit 5), comprising mainly pelitic rocks interlayered with quartzite and psammopelite, is similar to the basal metasediments elsewhere in the Wollaston Domain (e.g. Ray, 1977, 1978, 1981; Sibbald, 1983; Tran and Yeo, 1997), except for the absence of graphite in this area. Unit 5 probably lay unconformably on the basement complex originally; however, the irregular spatial distribution of this unit near the basement complexes (Figure 2, and separate map), repeated folding of the cover rocks, and the high-strain regime at or near the basement/cover contact (see Section 3), has obliterated all direct evidence of an *in situ* unconformity. These cover rocks may be allochthonous, with significant tectonic transport from their original depositional position.

The abundance of aluminous minerals in rocks of Units 5 and 6 reflects high original clay content and an extensive source of muddy sediments. The wide extent of this sequence throughout the Wollaston Domain, the interlayering of quartzitic sandstone and psammopelite layers, some with thin graded beds (Figure 6), suggests that they were deposited mainly by suspension in a relatively quiet, low energy environment (e.g. Tucker, 1981), possibly in an offshore shelf setting.

With upward passage to the transitional assemblage (Units 7 and 8), pelitic sediments are progressively replaced by more semipelitic and psammitic rocks, with significant increase in iron and calc-silicate content. This suggests a relative fall in sea level and transition to a near-shore or deltaic marine environment (e.g. Surlyk *et al.*, 1981). The interbedded sand, silt, and mud of Units 7 and 8 may represent delta front deposits.

Units 9 and 10, which consist mostly of thin- to thick-bedded arkose and impure quartzite are typically poorly sorted and poorly bedded. The abundance of arkoses requires a K-feldspar rich source (i.e. K-feldspar-bearing plutons or gneisses), and rapid deposition, possibly in either a fluvial or deltaic/estuaries environment.

Unit 11 conglomerates are intercalated with Unit 12 calcareous arkoses, but occur only in the eastern part of the map area. A polymictic assemblage of granitoid, quartz, quartzite, and arkose clasts indicate a provenance including granitic basement (probably previously deformed) and sedimentary rocks. The presence of poorly-sorted, angular boulders and well-sorted rounded pebbles in different layers, suggests both proximal and distal sources. Variable rounding, sorting and intercalation of clast-supported and matrix-supported and arkosic layers suggests an alluvial fan setting (Nilsen, 1982). These rocks are probably correlative with the Janice Lake Conglomerate in the Burbidge Lake area (Delaney *et al.,* 1996; Tran and Yeo, 1997).

The Unit 12 calcareous arkose is one of the most widespread units in the map area. The presence of abundant calcareous minerals in this unit suggests reduced rates of clastic input (Glover *et al.*, 1995). Although generally separated from the lower part of the succession by Unit 8, in many places it rests directly on Units 6 or 7. It is associated and intercalated with conglomerates in the eastern part of the area. Thus, its base is a major unconformity separating the lower and upper stratigraphic sequences. A similar relationship was documented farther north, in the Upper Foster–Burbidge lakes area (Tran and Yeo, 1997).

The origin of the calc-silicate rocks of Unit 13, which are in part interlayered with Unit 12, is problematic. These rocks are markedly heterogeneous, ranging from quartzofeldspathic sediments to dolomitic marble: most are plagioclase (albite) -rich and they include scapolite-bearing plagioclasites. They probably represent a variety of impure calcareous metasediments, enriched in sodium salts probably by evaporation, as suggested by Weber *et al.* (1975) and Chandler (1978). Some of these rocks were remobilized during later thermotectonism.

Sodium-rich breccias within this unit are particularly controversial. Mawdsley (1957) considered them to be tectonic breccias, formed by forcible igneous intrusion. Ray (1977) suggested that they were either tuffs or calcareous breccias of sedimentary origin. Any interpretation of these rocks must account for the following features: 1) they form thin layers in an overall calc-silicate assemblage, which may in part be of evaporitic origin; 2) they are mostly unsorted and essentially oligomictic, with clasts mostly comprising albitic plagioclase; and 3) geochemically they are sodium rich (Ray, 1981). Ray (1978) suggested that they may represent 'solution collapse breccias'. Dissolution of evaporite commonly leads to collapse and brecciation of overlaying strata (e.g. Tucker, 1991). Dolomitic marble, which occurs locally in this unit, may also be derived from such dissolution. The mineralogy of the breccia clasts suggest that they may be fragments of a salt-impregnated clay (Ray, 1981). This unit therefore, may derive from an evaporitic sequence in a shallow basin.

Similar rock types exist elsewhere in the Wollaston Domain (Mawdsley, 1957; Weber *et al*, 1975; Ray, 1977; Delaney *et al.*, 1996; Tran and Yeo, 1997); thus the occurrence of evaporitic units and solution collapse breccias in the upper part of the Wollaston Group has important implications for the depositional environment. Marine evaporite formation generally requires restricted access to the open ocean (Kendall and Harwood, 1996), with some intermittent barrier so that the water can evaporate to produce high salinities. Periodic replenishment of seawater is also necessary (Tucker, 1981; Kendall and Harwood, 1996).

A possible scenario, which accommodates not only evaporite formation, but also formation of the mid-Wollaston unconformity, conglomerate, and arkose deposition, and the generally calc-silicate-rich character of the upper part of the Wollaston Group, involves proximal uplift to produce a restricted basin. Clast compositions in the conglomerate imply that this uplift included felsic igneous rocks; their poor sorting and angularity suggests the source area was nearby. If the Wollaston basin is a passive margin basin on the southeast edge of the Rae-Hearne craton (Lewry and Sibbald, 1977; Lewry and Stauffer, 1990; Stauffer, 1984), uplift likely occurred to the east. The arrival and subduction of the 1885 to 1875 Ma La Ronge Arc (e.g. Van Schmus *et al.*, 1987) from the southeast might have produced such an uplift. This would have resulted in a transition from passive margin to active margin foreland basin conditions, preceding tectonic inversion of the Wollaston sedimentary basin. The newly formed high-relief terrain would have been a barrier to the open ocean, favouring accumulation of carbonates and evaporites, at the same time as clastics, including conglomerate, were shed westward from the uplifted area to form the uppermost part of the Wollaston succession. Yeo (this volume) suggests an alternative hypothesis in which a crustal bulge, formed in the Wollaston shelf edge as the La Ronge Arc began to collide with the craton, migrated landward, resulting in the regional unconformity.

7. Structure

The Wollaston Group is generally considered to unconformably overlie the Archean basement complexes (e.g. Ray, 1977, 1978, 1981). However, the D_1 deformation involved regional foliation development and extensive isoclinal folding, not only of supracrustal rocks but locally also of the Archean (?) basement. During this deformation, the basement-cover contact was the locus of relatively high strain, with development of pronounced kinematic shear-sense indicators, which indicate sinistral, northwest-southeast transportation. The basal part of the sedimentary succession is highly disrupted, boudinaged, and recumbently folded. Locally, basement rocks structurally overlie the metasediments along a high-strain mylonitic contact, indicating structural imbrication. Such evidence of extreme structural modification of the basement/cover contact suggests that it can no longer simply be regarded as a primary unconformity, at least in this area, as previously suggested (Money, 1966). The earliest documented deformation event, affecting both basement and supracrustal cover, is probably of Proterozoic age; earlier Archean structures in the basement inliers are not documented. Previous lack of recognition of mesoscopic and macroscopic D_1 isoclinal folding led to the suggestion that D_1 deformation in the Wollaston Domain involved essentially subvertical development of basement 'gneiss domes' which were then flattened during D_2 deformation (Lewry and Sibbald, 1980). However, this study has documented extensive lithological repetition related to isoclinal F_1 folding at both mesoscopic and macroscopic scale. This, and other structural features noted above, suggest that the D_1 event involved major horizontal crustal shortening, possibly including formation of a major décollement zone between basement and cover, with local imbrication, and widespread isoclinal folding, leading to relative crustal thickening and generation of the first metamorphic mineral assemblages.

D_2 deformation involved major northwest-southeast crustal shortening, presumably related to a major collisional event during Trans-Hudson orogeny. It was accompanied by peak metamorphic mineral growth. The D_3 event produced post-peak metamorphic, northwest-trending, upright folds locally, possibly accompanied by retrogressive metamorphism and alteration. D_3 was succeeded by late, brittle-ductile faulting (D_4) which is presumed to reflect post-collisional stages of the Trans-Hudson orogeny.

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