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Report 261

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Cover: Cross-bedded igneous layering (formed near the bottom of a magma chamber, where increased fluid shear stress (a function of velocity and pressure in the magma chamber) within the intrusion causes rhythmically layered dunes and scours. The interior of the pluton is to the top of the picture. Another world-class example of primary layering, rivaling those seen in the 'cross-bedded belt' of the Skaergaard Intrusion (Irvine *et al.*, 1998); west side of a small bay north of Patterson Island; Station 28-8-2 (UTM 642166 m E, 6398924 m N).

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Abstract

The Peter Lake Domain PGE project (Figure A-01), completed between 2002 and 2005, was a joint provincial-federal multidisciplinary initiative with the objective of delineating the geological framework of the Peter Lake Domain and the context of its platinum-group element (PGE) occurrences. The project encompassed bedrock and surficial geological mapping, a multiparameter geophysical survey, and geochronological, geochemical, and metallogenic studies.

The net result of this project is an improved understanding of the geological framework of the Peter Lake Domain with important implications for its platinum-group element potential. The oldest identified rocks are >2630 Ma tonalitic to granodioritic basement rocks and minor associated supracrustal rocks. These basement rocks are cross-cut by widespread 2580 to 2566 Ma granitic rocks of the Lueaza River granitoid suite, and gabbroic rocks of the 2562 Ma Swan River Complex. Geochemical characteristics combined with the lithotectonic setting of the Swan River Complex suggest that these magmas were emplaced within a continental rift. The earliest known high-grade thermotectonic event overprinted the domain between 2550 to 2530 Ma and was accompanied by 2540 Ma monzonitic intrusions. Deposition of a conglomerate-feldspathic arenite-amphibolite succession (Campbell River Group, Sequence 1) is interpreted as coeval with the Courtenay Lake Group of the Wollaston Supergroup and with the onset of 2075 Ma rifting along the Hearne Craton margin. Deposition of a younger carbonaceous argillite-feldspathic wacke succession (Campbell River Group, Sequence 2) postdated a second regional high-grade metamorphic event and is speculated to be contemporaneous with or slightly predate emplacement of the 1917 to 1913 Ma monzonitic to leucogabbroic Porter Bay Complex. Evidence of a low-grade metamorphic overprint that coincided with emplacement of the Porter Bay Complex marks the initiation of west-verging (present day) subduction beneath the Hearne Craton. This, in turn, led to emplacement of an extensive Andean-type continental arc pluton, the 1865 to 1855 Ma Wathaman Batholith, comprising predominantly granitic to quartz monzonitic rocks and minor diorite and gabbro. The Peter Lake Domain remained at high crustal levels during terminal collision and formation of the Trans-Hudson Orogen between 1820 to 1800 Ma. This collision signaled the final regional thermotectonic event recorded in the Peter Lake Domain, and was accompanied by open folding and shearing.

Lithological, textural, and metallogenic similarities between PGE occurrences in the Peter Lake Domain and those at the Lac des Iles mine and the Marathon deposit of the Coldwell Complex in northwestern Ontario are striking. As in the Ontario examples, disseminated sulphides in the Peter Lake Domain are closely associated with brecciated, 'varitextured' to pegmatitic gabbros and minor rhythmically layered cumulates, and are believed to be magmatic in origin.

A high-resolution fixed-wing airborne gamma-ray spectrometric and total field magnetic survey was completed over the Peter Lake Domain and part of the northeastern Wollaston Domain. The survey comprised 57 765 line km, flown along northwest-trending flight lines spaced 400 m apart and southwest-trending magnetic control lines spaced 4000 m apart. It aided in discerning map patterns and structural features during completion of the bedrock compilation maps. Ground gamma-ray spectrometric measurements of ultramafic to intermediate rocks of the 2562 Ma Swan River Complex and the 1917 to 1913 Ma Porter Bay Complex show important distinctions;

rocks of the older Swan River Complex have lower average K and eTh concentrations than rocks from the 1917 to 1913 Ma Porter Bay Complex.

The various mafic igneous suites in the Peter Lake Domain show distinct geochemical signatures. Gabbroic rocks of the Swan River Complex are characterized by low Sm/Y and La/Sc ratios, and trace element patterns that lack negative high field strength element (HFSE; *e.g.*, Ti) anomalies. Mafic rocks related to both the Wathaman Batholith and the Zengle Lake gabbro have similarly low Sm/Y and La/Sc ratios, but have trace element patterns with distinct negative HFSE anomalies. In contrast, Porter Bay Complex gabbroic rocks have high Sm/Y and La/Sc ratios and trace element patterns with negative HFSE anomalies.

Key Findings

Bedrock Geology and Geochronology

- Mafic rocks are grouped into four temporally discrete plutonic complexes; two Archean and two Paleoproterozoic.

- Of the mafic plutonic complexes, the 2562 Ma Swan River Complex is the most extensive, covering an estimated 1400 km^2.

- The Paleoproterozoic Campbell River Group consists of two stratigraphic sequences, the older of which was metamorphosed to amphibolite facies (see 'Peter Lake Domain Geology' subsection).

- An Archean high-temperature metamorphic event affected the Peter Lake Domain at about 2540 Ma, and is possibly related to an influx of large volumes of mafic magma.

Lithogeochemistry

- Gabbroic rocks from the Peter Lake Domain are characterized by low Sm/Y and La/Sc ratios, and a trace element signature that lacks a negative Ti anomaly. These rocks are probably part of the Swan River Complex.

- Gabbroic rocks with low Sm/Y and La/Sc ratios and negative high field strength element (HFSE) anomalies are related to either the Wathaman Batholith or the Zengle Lake gabbro.

- Gabbroic rocks with high Sm/Y and La/Sc ratios coupled with negative HFSE anomalies are most probably, but not conclusively, part of the Porter Bay Complex.

- The Porter Bay Complex has major and trace element characteristics consistent with emplacement in a subduction-related continental arc environment and the complex was intruded into the southeastern Hearne Craton margin between 1.92 to 1.91 Ga, 60 Ma prior to emplacement of the world's largest Paleoproterozoic continental arc, the Wathaman Batholith (see 'Mafic Plutonic Complexes' subsection).

Geophysics

- A high-resolution fixed-wing airborne gamma-ray spectrometric and total field magnetic survey was completed over the Peter Lake Domain and part of the northeastern Wollaston Domain; the airborne survey comprised 57 765 line km, flown along northwest-trending flight lines spaced 400 m apart and southwest-trending magnetic control lines spaced 4000 m apart.

- Ground gamma-ray spectrometric measurements of ultramafic to intermediate rocks of the 2562 Ma Swan River Complex and the 1917 to 1913 Ma Porter Bay Complex show important distinctions; the older Swan River Complex has K concentrations between 0.2 and 2%, with an average eTh concentration of approximately 2.8 ppm, while the younger Porter Bay Complex has higher K concentrations, typically between 1.3 and 6.5%, with a distinctly higher average eTh concentration of about 4.5 ppm. Although there is a zone of overlap, these findings may prove to be useful in interpreting data from unknown gabbroic intrusions (see ‘Geophysics’ section).

Economic Geology

- Platinum-group-element (PGE) occurrences are found in at least two of the four mafic plutonic complexes.

- Most occurrences are characterized by disseminated sulphides, which are interpreted to be magmatic in origin and closely associated with brecciated and varitextured to pegmatitic gabbros, as well as with minor rhythmic cumulate layering.

- PGE occurrences in the Peter Lake Domain have striking lithological, textural, and metallogenic similarities to those at the Lac des Iles mine and the Marathon deposit in northwestern Ontario (see ‘Economic Geology’ section).

Quaternary Geology

- Multiple ice-flow directions were documented. The dominant ice-flow direction was to the south-southwest (205° to 210°), becoming more southwestward (215° to 220°) towards the southern boundary of the Quaternary map area of 2003 and 2004. Two older regional ice-flow directions are oriented at ~188° (175° to 195°) and 228° to 240°. Rare, faint striae sets trending 154° (two sets) and 295° (one set) were also recorded.

- Raised beaches and winnowed till were documented at ~425 m asl and indicate the area was inundated by a proglacial lake to at least this elevation. The previous proglacial lake level was indicated at ~350 m asl. This higher lake level indicates that at one time Reindeer and Wollaston lakes were likely connected forming one large proglacial lake that extended into Manitoba, which may represent the northwest extension of glacial Lake Agassiz between 8,400 and 8,200 C^{14} BP (non-calibrated radiocarbon years before present).

- Much of the area is unsuitable for drift prospecting. In the east, near Reindeer Lake, bedrock with interspersed organic deposits dominates the terrain. Till in this region is commonly very thin, patchy, and wave winnowed. Ice-contact drift and ablation till are common within and adjacent to subglacial channels and esker systems. This material commonly occurs as a thin veneer and is difficult to distinguish by surface characteristics from the subglacially derived till. Drift prospecting is more suited in the central and western parts where the drift cover is more extensive; however, there are significant expanses of fens and bogs, which would inhibit till sampling.

- Regionally, the elemental signature of the mafic and ultramafic bodies is reflected in the till geochemistry. Cu, Ni, Co, and Cr are good indicators of the mafic source rocks. This indicates that till geochemistry can be used to prospect for favourable rock types, which host PGEs, particularly in areas where bedrock exposure is poor, such as in the interior part of the Peter Lake Domain. The key will be to identify regions overlain by thin subglacially derived till, which best reflects the local bedrock.

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‘Home’

This site presents the final results of the Peter Lake Domain platinum-group element (PGE) project (Figure A-01), an integrated Saskatchewan Geological Survey and Geological Survey of Canada geoscience initiative that was conducted between 2002 and 2005.

The multidisciplinary project included components of bedrock and surficial mapping, geochronology, metallogeny, geochemistry and geophysics, including high-resolution fixed-wing airborne gamma-ray spectrometric and total field magnetic surveys.

Situated at the southeastern margin of the Hearne Province, the Peter Lake Domain is made up predominantly of Archean granitoids and tonalite migmatite complexes (brownish yellow polygon, Figure A-01). Paleoproterozoic siliciclastic sequences and associated minor mafic volcanic rocks of the Wollaston Supergroup (dark purple polygons in Hearne Province, Figure A-01) unconformably overlie the granitoids of the Peter Lake Domain to the north-west while granitioids of the Wathaman Batholith intrude it on its southeastern side. The domain flanks the northwestern margin of the 1.9 to 1.8 Ga Trans-Hudson Orogen and, in contrast to the rest of the Hearne Province, contains four mafic plutonic complexes that vary in age from 2.56 to 1.85 Ga and locally host PGE occurrences.

Introduction

In 2002, the Saskatchewan Geological Survey initiated a multifaceted collaborative project to investigate the geological setting of platinum-group element (PGE) occurrences in the Peter Lake Domain of the Canadian Shield in northern Saskatchewan (Figure D-01). The main objective of the project was to perform detailed bedrock and surficial mapping in order to guide mineral exploration and enhance our geological understanding of the Peter Lake Domain and its relationship to neighbouring lithotectonic elements.

Geological mapping performed in the 1960s revealed large accumulations of Precambrian gabbroic rocks in the Peter Lake Domain that were host to several disseminated sulphide occurrences. Subsequent detailed bedrock mapping by the Department of Mineral Resources between the late 1960s and early 1980s established an initial, four-fold subdivision of the domain (Figure D-02). This included the Peter Lake Complex (Ray and Wanless, 1980), Swan River gabbroic rocks or Complex (Stauffer *et al.*, 1981; MacDougall, 1988a; Corrigan, 2001), Parker Lake gneisses (Ray, 1975; Ray and Wanless, 1980), and Campbell River Group (Lewry, 1976; Lewry *et al.*, 1981).

Currently, a more complex subdivision of the domain is adopted (see the 'Peter Lake Domain Geology' subsection for details). It includes four temporally distinct mafic complexes, two monzonitic intrusive suites, two temporally separate stratigraphic successions of the Campbell River Group, and granitoid rocks of unkown age that postdate the Wathaman Batholith. All of these units are interpreted to postdate Neoarchean granitic to granodioritic basement rocks of the Hearne Craton.

Location and Accessibility

The area described in this report covers approximately 5296 km^2, extending from the Warner and Peter lakes area in the southwest to the Zengle and Reindeer lakes area in the northeast (Figure D-03). The Wathaman River and Reindeer Lake lie along the southeast edge of the domain, while the northwestern margin follows an ill-defined line in a poorly exposed area between Courtenay Lake in the southwest and Reynolds Lake in the northeast. The Peter Lake Domain covers portions of NTS sheets 64E/03, /04, /05, /06, /07, /10, /11, /15, and /16, and 74H/01 and /08.

An all-weather gravel road, Highway 905, connects La Ronge with Points North Landing (unofficial place name) and provides access to the southwestern portion of the domain. The northeastern portion of the domain is accessible via boat across Reindeer Lake from the communities of Kinoosao or Southend, located on east-central and south Reindeer Lake, respectively. All portions of the domain can be accessed with float-equipped aircraft available from Points North Landing, located 60 km to the northwest of the study area, or from Missinipe (Otter Lake), located about 160 km to the south-southwest.

Physiography

The Peter-Reindeer-Zengle lakes region of the Precambrian Shield lies within the Churchill River upland ecoregion and the Hudson Bay drainage basin. The landscape is characterized by bedrock outcrop, glacial deposits, wetlands, and lakes. Local relief can be as high as 50 m but rarely exceeds 25 m. The natural vegetation essentially consists of black spruce and jack pine interspersed with white birch. The wetlands are commonly underlain by permafrost and support black spruce and tamarack. The lakes are predominantly southwest trending and parallel the regional bedrock structure and direction of glacial ice movement.

The northwestern half of the domain, between Courtenay Lake and MacKenzie Lake, is characterized by very limited bedrock exposure and extensive, almost continuous, glacial and fluvioglacial deposits. Where there is exposed bedrock in the domain, it is relatively free of vegetative cover, although deadfall and new growth after a 1981 forest fire have made traversing on foot difficult in the southern Peter Lake area.

The best exposed bedrock is located between Patterson Island and Feaviour Peninsula along the north shore of Reindeer Lake. Low water levels at the time of mapping insured excellent lakeshore exposures, and inland outcrops were completely cleared of vegetation during a forest fire in 2000.

Previous Bedrock Geology Mapping

The map below (Figure D-04) displays a new 1:1 000 000-scale compilation of the bedrock geology of the Peter Lake Domain (areas in white with grey-stippled background represent Quaternary deposits; Figure D-04). Areas outlined by solid black lines were mapped at 1:20 000 to 1:50 000 scale between 2002 and 2005.

The thumbnail on the left (Figure D-05) is an interactive map that opens in a separate window and allows access to historical maps.

Previous bedrock geological mapping of the Peter Lake Domain dates back to the late 1960s, when Shklanka (1962) and Scott (1969, 1970) mapped the northeastern and southwestern parts of the domain, respectively (Table D-01). The remainder of the domain was mapped between 1978 and 1981 at 1:100 000 scale (Ray, 1979, 1980; MacQuarrie, 1980; Lewry *et al.*, 1980, 1981; Stauffer *et al.*, 1980, 1981). Revision mapping at 1:20 000 scale was carried out by MacDougall (1987, 1988a, 1990b) in the Campbell River, Patterson Island, and Pyett Lake areas. The most recent work predating the current report was carried out by the Geological Survey of Canada (Corrigan *et al.*, 1999, 2000; Corrigan, 2001).

The attached table (Table D-01) summarizes previous work completed over the Peter Lake Domain project area and, where available, gives access to PDFs of the reports and the maps; the maps can also be accessed via the above thumbnail (Figure D-05) in a spatially referenced format.

Previous Surficial Geology Mapping

The attached map (Figure D-06) displays a 1:1 000 000-scale compilation of the surficial geology of the Peter Lake Domain (Schreiner, 1984c). Areas outlined by solid black lines were mapped at 1:50 000 scale during this project (Campbell, 2003b, 2004b).

The surficial deposits of the entire Peter Lake Domain were mapped at 1:250 000 scale in the late 1970s (Schreiner, 1984b, 1984c, 1984d, 1984e, 1984f), as part of a large reconnaissance-scale Quaternary mapping program of the Precambrian Shield (Table D-02). This program included limited overburden drilling along Highway 905 to gain stratigraphic information. The lithologs of the drillholes are provided on the margins of the corresponding surficial maps and descriptions of the sediments and the Quaternary geology are provided in the accompanying compilation report (Schreiner, 1984b).

Campbell (1992) conducted a regional orientation study aimed at determining the applicability of drift prospecting for mineral exploration in the Peter Lake Domain. Selected Saskatchewan Research Council archived till samples, collected during the reconnaissance mapping program, were analyzed for major and trace elements, as well as gold. Ten bulk till samples were collected in 1992, primarily along Highway 905, for more detailed studies of till composition. On a regional scale, the till composition reflects the local bedrock geology, either underlying or immediately up-ice of the sample site (Campbell, 1992; Campbell *et al.*, 1999). The geochemistry of the silt-clay fraction (<0.063 mm) revealed elemental associations characteristic of the metasedimentary, granitic, and mafic source rocks. Campbell's (1992) unpublished analytical data is included in the 'Data and Downloads' section of this report.

Additionally, Swanson (1996) collected samples from eskers in the Peter Lake Domain as part of a reconnaissance kimberlite indicator minerals (KIM) sampling program in northern Saskatchewan. The data from these samples are included in the Kimberlite Indicator Minerals Digital Database housed on the Saskatchewan Ministry of Energy and Resources' website (www.er.gov.sk.ca).

The attached table (Table D-02) summarizes previous work completed over the Peter Lake Domain project area and, where available, gives access to PDFs of the reports and the maps.

Summary of Investigations (SOI) Bedrock Geology Maps and Reports, 2002 to 2005

The Peter Lake Domain covers approximately 5296 km^2, with an estimated 40% being covered by till, swamps, and lakes. Between 2002 and 2004, the most accessible and best exposed areas of the Peter Lake Domain were mapped along two north-south transects: one in the southwest and one in the northeast of the domain. In addition, the most notable mineral occurrences were visited during the 2005 field season.

The attached map (Figure D-07) shows the maping completed during the course of the Peter Lake Domain project. Table D-03 summarizes the resultant reports and includes hyperlinks to PDFs of the reports.

Bedrock Geology Compilations

Based on the new regional bedrock geological mapping, carried out at 1:20 000 and 1:50 000 scales (Maxeiner and Hunter, 2002a; Maxeiner and Leatherdale, 2003d; Maxeiner *et al.*, 2004b; Maxeiner and Rayner, 2005), the older 1 inch=1 mile and 1:100 000-scale maps of the Peter Lake Domain (Shklanka, 1962; Scott, 1969, 1970; MacQuarrie, 1980; Ray, 1978, 1979; Lewry *et al.*, 1980, 1981; Stauffer *et al.*, 1980, 1981; Corrigan *et al.*, 1999, 2000; Corrigan, 2001) have been reinterpreted and compiled into two new 1:100 000-scale map sheets (Maxeiner, 2006a, 2006b). The map below (Figure D-08) shows the areas of the two compilation maps (click to view the PDFs).

For the 1:100 000-scale maps, no attempt has been made to interpret the nature of the underlying bedrock geology in areas of thick till cover. In better exposed areas, however, data from the airborne magnetic and radiometric surveys (Ford *et al.*, 2005c) were used to extrapolate geological contacts. Geochronology, whole-rock geochemistry, and ground spectrometer data were used to further classify some of the gabbroic rocks of previously undetermined affinity. Click this link to read the detailed report that accompanies the 1:100 000-scale compilation map (Maxeiner *et al.*, 2006c).

The new maps (Figure D-08) have also been used to revise 1:250 000 and 1:1 000 000 scale regional compilation maps. The 1:250 000-scale and 1:1 000 000-scale compilations will be integrated into the existing geological framework of the province.

Summary of Investigations (SOI) Surficial Geology Maps and Reports, 2003 to 2004

Surficial geology mapping was conducted by the Saskatchewan Geological Survey in a central part of the Peter Lake Domain during the 2003 and 2004 field seasons. The areas were chosen to complement the bedrock geology mapping areas of the respective years. Figure D-06 outlines the two 1:50 000 scale maps completed in 2003 and 2004 (black outlines). Click on each polygon to display the PDF of the corresponding surficial geology map (Campbell, 2003b, 2004b).

Figure D-04 of the corresponding reports which outline the details of the mapping and discuss the surficial units**.** The PDFs of the reports are hyperlinked to the author’s name.

Regional Bedrock Geology

The Hearne Province (Figure E-01) forms part of the Western Churchill Structural Province and is bordered to the northwest by the Snowbird Tectonic Zone and to the southeast by the Trans-Hudson Orogen. In Nunavut, it is subdivided into the northwestern Hearne and the central Hearne (Davis *et al.*, 2000), based on varying thermotectonic histories of contained greenstone belts. The northwestern Hearne Province is characterized by Neoarchean granitoids and younger greenstone belts that show local involvement of Mesoarchean crust. The rocks were thermotectonically overprinted between 2.56 to 2.50 Ga (Stern and Berman, 2000) and again by a high-pressure metamorphic event at *ca*. 1.9 Ga (Berman *et al.*, 2000). In contrast, the Rankin-Ennadai greenstone belt of the central part of the Hearne Province lacks isotopic evidence for Mesoarchean crustal involvement and any thermotectonic overprints between 2.65 to 1.85 Ga. The boundary between the northwestern and central parts of the Hearne Province is marked by the Tyrell Shear Zone, which represents a Paleoproterozoic high-strain zone that was superimposed on a proposed Neoarchean thrust fault (MacLachlan *et al.*, 2005).

The Peter Lake Domain in northern Saskatchewan is part of the southern Hearne Province, which is dominated by *ca*. 2.8 to 2.6 Ga granitic to tonalitic rocks. A compilation of Archean ages suggests a southeast-directed younging trend (Figure E-02; C. Harper, pers. comm., 2005). The Archean basement rocks also include outliers of the 2.72 to 2.68 Ga Rankin-Ennadai greenstone belt. The basement is unconformably overlain by Paleoproterozoic supracrustal sequences of the 2.45 to 2.11 Ga lower Hurwitz Group, the <2.1 Ga Wollaston Supergroup, and the <1.91 Ga upper Hurwitz Group.

The Wollaston Supergroup (Yeo and Delaney, 2007) has three main subdivisions (Figure E-03 – click on thumbnail below): the <2.075 Ga Courtenay Lake Group (a rift-fill succession), the unconformably overlying Souter Lake Group (a passive margin succession), and the <1.880 Ga Daly Lake–Geikie River groups representing a foreland basin succession.

The Peter Lake Domain is wedged between the Wollaston Domain to the northwest and the Paleoproterozoic Wathaman Batholith of the Trans-Hudson Orogen to the southeast, bounded in part by the Needle Falls Shear Zone (Money, 1965; Stauffer and Lewry, 1993) and the Parker Lake Shear Zone (Ray, 1975; LaFrance and Varga, 1996), respectively. It has been given separate domain status because of its unusual lithological character and its partly fault-bounded nature (Macdonald and Thomas, 1983; Saskatchewan Geological Survey, 2003). Although considered to represent the southeastern margin of the Hearne Province (Bickford *et al.*, 2002; Rayner *et al.*, 2005a), it is unique from the rest of the province in that it contains four mafic plutonic complexes, which locally host platinum-group element occurrences.

For more information about the geological framework of the Peter Lake Domain, go to the 'Peter Lake Domain Geology' subsection.

Peter Lake Domain Geology

The Peter Lake Domain (approximately 5296 km^2), which represents a southeastern component of the Hearne Province (Bickford *et al.*, 2002; Rayner *et al.*, 2005a), is a Neoarchean to

Paleoproterozoic, predominantly plutonic terrain dominated by granitoid rocks (red and orange polygons in Figure E-04).

The oldest identified rocks in the domain comprise the tonalitic to granodioritic Archean basement, which was intruded by 2.580 to 2.566 Ga granitoid rocks and overlain by Neoarchean supracrustal rocks. Gabbroic rocks of varying age (blue and turquoise polygons, Figure E-04) also intrude the basement rocks and are subdivided into four temporally distinct complexes, two Neoarchean and two Paleoproterozoic. With reference to the pie chart (Figure E-05) below, approximately 27.3% of the domain is interpreted to be underlain by the 2.56 Ga gabbroic Swan River Complex (Psm); <0.1% is underlain by 2.53 Ga Zengle Lake gabbro (included within Psm); about 1.7% forms part of the Paleoproterozoic 1.91 Ga monzodioritic to gabbroic Porter Bay Complex (Pbm); and <0.1% (not shown) is represented by the mafic components of the 1.86 Ga Wathaman Batholith.

The Archean plutonic rocks are unconformably overlain by the Paleoproterozoic Campbell River Group (light yellow polygons, Figure E-04), which comprises two temporally and metamorphically distinct siliciclastic sequences that are interpreted to be correlative with older and younger components of the Wollaston Supergroup, respectively. The Wathaman Batholith intrudes the Peter Lake Domain along its southeastern margin and in larger masses in the northeastern part of the domain.

The next subsection will discuss the main lithological subdivisions of the domain.

Main Lithological Subdivisions of the Peter Lake Domain

The following links allow direct access to the various lithological subdivisions described in this subsection:

- Granodiorite-tonalite migmatite complex
- Lueaza River granitoid suite
- Archean supracrustal rocks
- Swan River Complex
- Monzonitic intrusive suite
- Zengle Lake gabbro
- Campbell River Group
- Porter Bay Complex
- Wathaman Batholith
- Other intrusive rocks

Granodiorite-Tonalite Migmatite Complex (minimum age of ?2630 Ma)

The oldest known component of the domain (Figure E-06) is the granodiorite-tonalite migmatite complex (Figure E-07), which is most abundant along the north shore of Reindeer Lake, west of Feaviour Peninsula (Maxeiner *et al.*, 2004b). A sample of a pink granitic gneiss cutting an older grey (?tonalitic) gneiss (sample HUD85-25B; Bickford *et al.*, 1986) was collected southwest of Crane Island in 1985 (Bickford *et al.*, 1987); the sample was re-analyzed in 2005 and yielded complex zircon populations (Rayner *et al*., 2005b). One interpretation of this data set suggested a crystallization age of between 2586 and 2566 Ma for the granitic gneiss, based on several generations of zircon overgrowths. A subset of the six oldest zircon analyses from the pink granitic gneiss yielded a weighted mean average $^{207}Pb/^{206}Pb$ zircon age of 2629 ±10 Ma (Rayner *et al.*, 2005b). The older grey gneiss likely represents the tonalitic to granodioritic components of the migmatitic complex, while the younger pink granitic gneiss is likely related to the Lueaza River granitoid suite. Another sample of foliated to migmatitic biotite granite (CXA99-D89b) collected from an unnamed island west of Feaviour Peninsula yielded similar results (Rayner *et al.*, 2005a) with an interpreted crystallization age of 2577 ±2 Ma and an indication of an older, inherited component of >2622 ±2 Ma.

The granodiorite-tonalite migmatite complex includes a widespread unit of granodioritic to tonalitic migmatite, and a number of strongly foliated to mylonitic granodiorite to granite gneisses that lack partial melt phases. The migmatitic units locally grade into and are cut by more homogeneous and massive granodiorite and tonalite, which is likely a product of migmatization during the 2550 Ma high-grade metamorphic event. Amphibolitic rafts and boudinaged microdioritic to microgabbroic dykes are common. Some of the mafic dykes that cut the granodiorite-tonalite migmatite complex are likely related to the Swan River Complex and/or the Porter Bay Complex, but some may also be much older.

Lueaza River Granitoid Suite (2580 to 2566 Ma)

The granodiorite-tonalite migmatite complex was intruded by widespread hornblende-biotite–bearing granitic rocks of the Lueaza River granitoid suite (Stauffer *et al.*, 1980; Maxeiner *et al.*, 2004b), which range in age from 2580 to 2566 Ma (Maxeiner *et al.*, 2004b; Rayner *et al.*, 2005b). The Ettle Creek Pluton (Macdonald and Thomas, 1983), situated in the centre of the domain and extending into the Patterson Island area on Reindeer Lake, is a granite and forms the most prevalent unit of the Lueaza River granitoid suite. Other megacrystic and locally augened monzogranites are exposed throughout the domain. The Lueaza River granitoid suite underlies large parts of the Zengle Lake–MacKenzie Lake–Crane Island (Reindeer Lake) area. A geochronology sample (CXA-99-D221) of this rock was taken in Porter Bay in the 2003 map area and yielded a U-Pb zircon age of 2569 Ma (Rayner et al., 2005a).

A several-kilometre wide belt of highly strained granitic to gabbroic rocks with minor supracrustal components crops out along the southwest shore of Zengle Lake; these 'Zengle Lake gneisses' (Stauffer *et al*., 1981) were previously interpreted as being largely of supracrustal origin, but are now recognized as being multicomponent intrusive rocks. The predominant phase comprises pink to pinkish grey, medium- to coarse-grained, strongly foliated to mylonitic and locally lineated granitoid rocks, which are in part lithologically and texturally similar to the Lueaza River granitoid suite. The granitoids locally contain xenoliths and metre-wide discontinuous units of gabbroic and dioritic composition, and are in turn cross-cut by other outcrop- to map-scale gabbroic bodies. Supracrustal enclaves are rare and include: metre-wide zones of grey, fine-grained garnetiferous psammite and psammopelite; grey to bluish grey impure quartzite; pink, fine-grained psammitic gneisses; and grey, fine-grained, hornblende-bearing intermediate rock and greenish black, fine-grained, feldspar-phyric amphibolite, both of probable volcanic origin. Leucogranite veins and dykes are abundant, as are map-scale units of younger leucogranite and syenogranite. A sample of 'granitoid gneiss' collected on the southwest shore of Zengle Lake (HUD-91-19) yielded a weighted $^{207}Pb/^{206}Pb$ zircon crystallization age of 2580 ±4 Ma (Rayner *et al*., 2005b), which is similar to the Ettle Creek granite.

The granodiorite-tonalite migmatite complex and the Lueaza River granitoid suite are of similar age and composition to some granitoid basement rocks of the neighbouring Wollaston Domain, northeast of Wollaston Lake (Harper *et al*., 2005), and likely represent a southeastern extension of the Hearne Craton.

Archean Supracrustal Rocks (>2562 Ma)

Archean mafic volcanic and pelitic rocks make up ≤0.1% of the Peter Lake Domain. Although they have not been dated directly, their implied age is >2562 Ma because they are cross-cut by the Swan River Complex and are affected by a *ca*. 2550 Ma upper amphibolite facies metamorphic event (R. Berman, pers. comm., 2005; Maxeiner and Rayner, 2005). There are currently no maximum age constraints for any rocks interpreted as Archean supracrustal rocks.

Three areas containing units of mafic volcanic rock were identified during mapping and are situated on Feaviour Peninsula, southwest of Patterson Island, and south of Peter Lake. Near Feaviour Peninsula, the mafic volcanic rocks are commonly associated with discontinuous metre-thick layers of banded oxide-facies iron formation and migmatitic pelite. The iron formation consists of centimetre-thick, very fine grained, quartz-rich cherty layers alternating with millimetre-thick, fine-grained, magnetite-rich layers. Large xenoliths and rafts of iron formation are contained in surrounding megacrystic quartz monzonite and monzodiorite of the 1.86 Ga Wathaman Batholith (Maxeiner *et al*., 2004b). The mafic volcanic rocks are also cut by the Wathaman Batholith. West of Feaviour Peninsula, a 2 km long unit of mafic volcanic rocks is surrounded by the ?2.63 Ma granodiorite-tonalite migmatite complex, although contact relationships between the two are obscured.

Pillowed mafic volcanic rocks associated with MgO-rich ultramafic rocks (MgO=24-32 wt. %) southwest of Patterson Island, together possibly representing komatiitic flows, are intruded by gabbros and gabbronorites of the 2562 Ma Swan River Complex. North of Patterson Island, felsic volcanic rocks, including tuff breccia and flow-banded rhyolite, are intercalated with pelitic units that contain metamorphic monazite dated at 2545 ±18 Ma (Berman, pers. comm., 2005). The latter is interpreted to provide a minimum age for the felsic volcanism. The relationships between these felsic volcanic rocks and their mafic counterparts are uncertain.

South of Peter Lake, proximal to the 2562 ±1 Ma Love Lake gabbronorite of the Swan River Complex, a fine-grained, plagioclase-phyric mafic rock is interpreted as volcanic in origin; xenoliths of this unit can also be seen within the Love Lake leucogabbro. Several units of fine-grained amphibolite occur within or around the Love Lake gabbronorite, but are texturally nondescript. Some may have been derived from intermediate to mafic volcanic rocks; others may represent sheared equivalents of dykes or may have dioritic to gabbroic protoliths.

Partially migmatized pelitic to psammitic rocks occur throughout the Peter Lake Domain, either as *in situ* units of metre-scale thickness or as enclaves within younger intrusive rocks. Rare fine-grained pink feldspathic ('arkosic') paragneisses, containing minor amounts of sillimanite and granitic leucosome, are interpreted to represent migmatized psammitic to psammopelitic rocks. They are closely associated with mafic volcanic rocks in the Feaviour Peninsula area (Maxeiner *et al.*, 2004b) and are likewise intruded by the Wathaman Batholith. Migmatization of all epiclastic sedimentary rocks in the Peter Lake Domain is believed to have predated emplacement of the 2540 ±1 Ma (Heaman *et al*., 2003) monzonitic intrusive suite, as the latter were observed to truncate migmatitic fabrics preserved within psammopelitic rocks south of Peter Lake (Maxeiner and Hunter, 2002a).

A several kilometre-wide belt of highly strained rocks in the Zengle Lake area, previously interpreted as being largely of supracrustal origin ('Zengle Lake gneisses', Stauffer *et al.*, 1981; Macdonald and Thomas, 1983), is now recognized as comprising granitic to gabbroic intrusive rocks. Although the belt is predominantly composed of highly strained Ettle Creek granitoids and intercalated gabbroic to dioritic rocks, it also contains metre-wide enclaves of garnetiferous psammitic to psammopelitic gneisses, quartzite, hornblende-bearing intermediate rock and feldspar-phyric amphibolite. The latter two are likely derived from volcanic precursors. There are currently no age constraints for these supracrustal rocks.

Swan River Complex (2562 Ma)

The granitoid basement of the Hearne Craton was intruded by plutons of the Swan River Complex *ca.* 2562 Ma (Corrigan *et al.*, 2000, 2001; Corrigan, 2001; Maxeiner *et al.*, 2004b; Rayner *et al.*, 2005a). It is the most widespread of the four gabbroic complexes identified in the Peter Lake Domain and is dominated by gabbro, diorite, and gabbronorite, accompanied by minor anorthosite, melagabbro, and ultramafic rocks. Most of the boudinaged mafic dykes within the granodiorite-tonalite migmatite complex are also probably related to the Swan River Complex.

The gabbroic rocks are characterized by rhythmic cumulate layering, pegmatitic and varitextured zones, and brecciated zones containing both autoliths and xenoliths. Most of them have been pervasively amphibolitized and only relict clinopyroxene and orthopyroxene are preserved locally, though plagioclase is commonly euhedral and zoned. Preserved ophitic textures are common.

The 2562 ±1 Ma Love Lake Pluton, which includes a leucocratic gabbronorite (Leatherdale *et al.*, 2003) as its most prominent unit, is located south of Peter Lake and represents one of the Swan River Complex's larger, more homogeneous mafic intrusions. It is characterized by abundant breccia zones and hosts one of the most notable platinum-group element (PGE) occurrences, Peter Lake East Cu-Ni showing, in its eastern part (Maxeiner and Rayner, 2005). A small, zoned gabbroic pluton in the Swan Lake area also contains a central brecciated zone that contains disseminated magmatic pyrrhotite-chalcopyrite with associated high Cu and Ni values (Maxeiner and Rayner, 2005). Similar brecciated and varitextured to pegmatitic gabbro is also preserved in the northeastern part of the Peter Lake Domain, establishing a minimum strike extent for the Swan River Complex of approximately 120 km and possibly as long as 190 km.

Monzonitic Intrusive Suite (2540 Ma)

A suite of monzonite, quartz monzonite, monzodiorite, and quartz monzodiorite cuts the Swan River Complex in the southwestern part of the Peter Lake Domain. One such intrusion, located south of Warner Lake along Highway 905, has been dated at 2540 ±1 Ma (Heaman *et al.*, 2003). The pluton has intruded minor supracrustal rocks that have been migmatized, whereas the intrusion, while foliated, seems to have escaped this high-grade metamorphic event.

This epidote-, hornblende-, and titanite-bearing intrusive suite is commonly megacrystic and resembles rocks of the Wathaman Batholith. Several other quartz monzonitic to monzodioritic rocks in the Campbell Lake (unofficial place name), Lyle Lake, Swan Lake, and Zengle Lake areas have also been assigned to this intrusive suite, based on their intrusive relationships and/or geochemical characteristics (see ‘Lithogeochemistry’ section).

At Campbell Lake, massive to weakly foliated equigranular monzodiorite and quartz monzodiorite are gradational into monzonite. They contain up to 20% hornblende and biotite, local millimetre-sized euhedral plagioclase phenocrysts, as well as up to 5 to 10% microcline and 5 to 10% quartz. Both units contain magnetite and are characterized by variable magnetic susceptibilities and low ground gamma-ray spectrometer readings. The age of the monzonitic rocks in the Campbell Lake area is speculative. They intrude the gabbroic rocks and are tentatively correlated with a 2.540 Ga quartz monzonite (Heaman *et al.*, 2003), situated in a similar structural position along Highway 905, approximately 35 km to the southwest (Maxeiner and Hunter, 2002a).

Zengle Lake Gabbro (2529 Ma)

In the Zengle Lake area, a massive to weakly foliated, coarse-grained, ophitic gabbro forms part of a 2529 ±5 Ma (Rayner *et al.*, 2005a) dioritic to gabbroic suite that cuts highly tectonized neighbouring granitoid units. The gabbroic sheets have been traced along strike for a few kilometres and are intruded locally by diorite and syenogranite of unknown age. The gabbro contains abundant partly zoned plagioclase, ~40 to 50% hornblende, and minor biotite and magnetite. Relict clinopyroxene phases are not present. Because of its limited extent and lack of distinguishing textural or geochemical characteristics, the Zengle Lake gabbro was included as part of the undivided gabbros on the accompanying 1:100 000-scale maps.

Campbell River Group and Wollaston Supergroup (2075 to ?1920 Ma)

In the Courtenay Lake area, the highly strained contact between the Wollaston and Peter Lake domains likely represents a northeastward continuation of the Needle Falls Shear Zone (Maxeiner and Hunter, 2002a). Farther northeast, in the Cook Lake area, MacNeil *et al.* (1997) recognized an unconformity between the Courtenay Lake Group of the Wollaston Supergroup and older granitic gneisses of the Peter Lake Domain.

Rifting along the southeast margin of the Hearne Craton, *ca.* 2075 Ma (MacNeil *et al.*, 1997; Ansdell *et al.*, 2000), resulted in deposition of the lower sequence of the Wollaston Supergroup (Yeo and Delaney, 2007). This includes the basal Courtenay Lake Group, which represents a rift-fill succession, and the unconformably overlying passive margin succession of the Souter Lake Group. The overlying stratigraphic units of the Wollaston Supergroup are interpreted as a foreland basin succession (Tran *et al.*, 2003; Yeo and Delaney, 2007).

As a result of several transects across the Campbell River Group (Lewry *et al.*, 1980; MacDougall, 1987, 1988b; Maxeiner and Hunter, 2002a; Hunter, 2003; Maxeiner and Rayner, 2005), this sedimentary succession was informally subdivided into two distinct sequences (Maxeiner and Rayner, 2005): a lower sequence (Sequence 1) of boulder conglomerate, cross-bedded feldspathic arenite, subfeldspathic arenite, and amphibolite; and an upper sequence (Sequence 2) of feldspathic wacke, lithic wacke, and abundant black carbonaceous argillite. Sequence 1 was metamorphosed at upper amphibolite facies and is possibly correlative with the Courtenay Lake Group of the Wollaston Supergroup, while Sequence 2 was metamorphosed at middle greenschist to lower amphibolite facies and is possibly correlative with the Souter Lake Group. The southwestern extent of the main Campbell River Group succession is underlain by quartz diorite, granodiorite, and quartz monzodiorite (Maxeiner and Rayner, 2005). Based on their unusual composition and location, several outcrops of highly strained, garnet-bearing quartz monzodiorite located next to the basal unit of the Campbell River Group are interpreted to represent a metamorphosed paleosaprolite.

The contact between the upper and lower sequences of the Campbell River Group, although not observed, is likely unconformable. The upper sequence of the Campbell River Group (Sequence 2), exposed along Highway 905 in the southwestern part of the Peter Lake Domain and in the Campbell Lake area, is dominated by argillaceous material. Way-up indicators suggest a north-facing homoclinal succession disrupted by a series of southeast-dipping normal faults. Sequence 2 is interpreted to have been deposited on a wave- and storm-influenced, shallow, siliciclastic marine shelf (Maxeiner and Hunter, 2002a; Hunter, 2003). The more argillaceous sequences near the top of the succession are likely indicative of a lower-energy depositional setting, significantly below storm wave base. Several lamprophyre dykes and sills ranging in width between 30 cm and 3 m cut the succession. According to MacDougall (1987), the lamprophyre dykes most frequently intruded argillite and consist of several subunits comprising feldspar-mica, mica-amphibole, and fine-grained mica-amphibole varieties.

The age of Sequence 2 of the Campbell River Group with respect to the Porter Bay Complex is unclear. Deposition of the sediments is here speculated to have preceded or possibly have coincided with eruption of early Porter Bay lavas. This assumption is, in part, based on recognition of low-grade mafic volcanic and psammitic xenoliths (possibly related to the Campbell River Group) within a monzodioritic pluton west of Korvin Lake (unofficial place name; Maxeiner and Rayner, 2005), which is now considered to be part of the Porter Bay Complex.

Porter Bay Complex (1917 to 1913 Ma)

The Porter Bay Complex is one of two Paleoproterozoic dioritic to gabbroic intrusive suites recently recognized in the Peter Lake Domain (Maxeiner *et al.*, 2004b; Maxeiner and Rayner, 2005; Rayner *et al.*, 2005a). It is a partly layered suite with intrusive centres located in the Patterson Island area (Figure E-08) and southeast of Peter Lake. The complex is dominated by monzodioritic and monzonitic rocks, and includes lesser gabbro, leucogabbro, diorite, quartz monzodiorite, and a minor volcanogenic component. A distinguishing characteristic of the plutons of this complex is the presence of augite and apatite, as well as abundant hornblende, biotite, titanite, and magnetite. The complex has an approximate aerial extent of 89 km^2 and hosts one of the most notable PGE occurrences of the Peter Lake Domain. The Antoine's Cu-Ni-Pt-Pd showing, west of Patterson Island, is characterized by disseminated, presumably magmatic, chalcopyrite-pyrrhotite found within gabbroic rocks. Similar, but less PGE-rich mineralization is also known in the Ant Lake (unofficial place name) area and other parts of the Patterson Island Pluton.

Spectacularly well-preserved, cross-bedded igneous layering in the Porter Bay Complex gabbro north of Patterson Island (Maxeiner and Leatherdale, 2003d) is similar to features described in the Tertiary Skaergaard Complex of Greenland (Irvine *et al.*, 1998). Intermediate to mafic plutonic rocks of the Porter Bay Complex are texturally similar to those of the Swan River Complex in other respects, including cumulate layering, autolithic and xenolithic breccia zones, varitextured rocks, and pegmatitic zones. Feldspar porphyritic and ophitic textures are also characteristic; the central monzodioritic zone of the monzodioritic Patterson Island Pluton contains up to 5 cm-long tabular K-feldspar megacrysts, commonly forming about 50% of the rock. Although the textural and lithological similarities between the two complexes make them difficult to distinguish in the field, the use of geochemical, ground spectrometer and petrographic data facilitated recognition of a second intrusive centre, believed to be part of the Porter Bay Complex southeast of Peter Lake.

Intermediate volcanogenic rocks occur as inclusions and minor units throughout the Patterson Island Pluton (Maxeiner and Leatherdale, 2003d), but are particularly well preserved along its northwestern edge (Sulz, 2004). Three distinct phases of andesitic to trachyandesitic rocks are recognized: laminated ash tuff or calcic psammopelite with a weak tectonic foliation parallel to the layers; massive to weakly foliated plagioclase-porphyritic amygdaloidal andesite to trachyandesite that intrudes the laminated rock; and minor intermediate tuff-breccia containing felsic volcanic clasts in an intermediate hornblendic matrix. The inclusions have similar age and geochemistry (see 'Lithogeochemistry' section) to the host intrusions, which suggests the supracrustal rocks probably represent remnants of a collapsed volcanic edifice that once topped the rocks of the Porter Bay Complex.

Wathaman Batholith (1865 to 1855 Ma)

Emplacement of the *ca.* 1.86 to 1.85 Ga Wathaman Batholith (Van Schmus *et al.*, 1987), the remnant of the world's largest known Paleoproterozoic continental arc (Fumerton *et al.*, 1984; Meyer *et al.*, 1992), was the final and most voluminous intrusive event along the southeastern Hearne Craton margin. Composed predominantly of quartz monzonite and granite, it was also recently recognized to contain minor dioritic and monzodioritic to gabbroic components that are partly well layered (Maxeiner *et al.*, 2004b; Maxeiner and Rayner, 2005; Rayner *et al.*, 2005a).

In the southwestern part of the Peter Lake Domain, the Wathaman Batholith is composed of thin sheets of megacrystic monzonite and quartz monzonite that cut quartz diorite gneiss and granite. Towards the northeast, the number of Wathaman Batholith intrusions and their percentage of dioritic to gabbroic components increases, and west of Feaviour Peninsula it consists of megacrystic diorite and gabbro with cumulate layering, intermingled with and grading into megacrystic monzonite and quartz monzonite.

The Reynolds Lake Pluton (Stauffer *et al.*, 1981), located to the north, west, and southwest of Zengle Lake, comprises megacrystic monzogranite and is one of the largest outliers of the Wathaman Batholith within the Peter Lake Domain. The pluton has been deformed into a large, northeast-trending, tight to isoclinal fold that results in its re-emergence in the Wollaston Domain, where it intrudes sedimentary rocks of the Wollaston Supergroup (Stauffer *et al.*, 1981).

Other Intrusive Rocks

Many of the granitoid rocks in the Peter Lake Domain are of poorly constrained age and areal extent and are therefore not assigned to a specific suite. Many of the locally fluorite-bearing widespread syenogranitic and leucogranitic components of the domain could be related to the Wathaman Batholith, or possibly the younger Hudson granite suite (emplaced *ca.* 1.83 Ga) that is widespread throughout the Western Churchill Province (*e.g.,* Harper *et al.*, 2005). One such young intrusion is a syenogranite, recognized north of Patterson Island, which cuts the 2569 +4/-3 Ma (Maxeiner *et al.*, 2004b) Ettle Creek granite. New SHRIMP U-Pb zircon dating of this intrusion yielded an age of 1829 ±5 Ma (see 'Geochronology' section). Furthermore, a nepheline-bearing syenite, described by MacDougall (1987) and Quirt (1992) yielded a preliminary age of 1830 ±20 Ma (Quirt, 1992 and references therein). Many of the gabbros and diorites of the Peter Lake Domain are likewise of undetermined age and affinity and are shown as such on the accompanying 1:100 000-scale maps.

Structural and Metamorphic Geology

Primary features are rare throughout the domain and, where present, consist mainly of igneous layering in gabbro and compositional layering in supracrustal rocks. In the >2562 Ma supracrustal succession (Figure E-07), layering is preserved as laminations in banded iron formation, layers of pillowed flows in mafic volcanic rocks, and poorly preserved compositional layering in psammopelitic to pelitic rocks. The 2562 Ma Swan River Complex locally exhibits very well preserved cumulate igneous layering, particularly in the Crane Island and Patterson Island areas of Reindeer Lake, as well as northeast of Korvin Lake (unofficial place name). Argillite and arenite of the <2080 Ma Campbell River Group are thin to medium bedded. Spectacular examples of cumulate and cross-bedded igneous layering are preserved in gabbroic rocks of the 1920 Ma Porter Bay Complex (Maxeiner and Leatherdale, 2003d) and the 1860 Ma Wathaman Batholith (Maxeiner *et al.*, 2004b). Concentric foliation in the core of the Patterson Island Pluton is partially characterized by alignment of inclusions and mafic minerals, both of which likely represent an igneous fabric predating emplacement of the Wathaman Batholith.

Deformation De (>2562 Ma)

Evidence for the earliest preserved deformation in the Peter Lake Domain comes from xenoliths within the Love Lake Pluton (Maxeiner and Hunter, 2002a), a component of the 2562 Ma Swan River Complex. A weak, layer-parallel schistosity is present within fine-grained mafic and ultramafic xenoliths. This xenolith-hosted fabric is oriented randomly within the massive to weakly foliated leucocratic gabbronorite host, suggesting that the fabric formed prior to emplacement of the pluton (Figure E-09).

Deformation D1-M1 (?2549 Ma)

The gneissic fabric developed within the granodiorite-tonalite migmatite complex between Zengle Lake and Reindeer Lake is, in part, defined by tonalitic to granodioritic *lit-par-lit* leucosome; this is probably a composite fabric. Rootless isoclinal folds might also have formed contemporaneously with the D1 deformation.

The original orientation of S1 might be preserved as a steeply northeast-dipping fabric within the central phase of a concentrically zoned gabbroic intrusion in the Swan Lake area. This fabric is characterized by alignment of igneous inclusions, layering, and a tectonic foliation; all are oriented perpendicular to the regional structural grain (Maxeiner and Rayner, 2005).

Partial melt development in pelitic and mafic volcanic rocks of the Patterson Island and Feaviour Peninsula areas of Reindeer Lake, together with widespread amphibolitization and rare garnet and diopside occurrences in the Swan River Complex, suggest that an upper amphibolite facies metamorphic event affected the Hearne Craton after 2562 Ma, possibly coeval with D1. Migmatization of granodioritic precursors produced tonalitic to granitic partial melt during the same upper amphibolite facies metamorphic event. Growth of orthopyroxene and clinopyroxene in leucosome patches in the Patterson Island mafic volcanic rocks marks the local onset of granulite facies conditions during this event.

Isoclinally folded (F1) migmatitic psammopelite east of Warner Lake predates emplacement of 2540 ±1 Ma (Heaman *et al.*, 2003) monzonitic rocks (Maxeiner and Hunter, 2002a). This first deformation (D1) and metamorphic event (M1) in the Peter Lake Domain is tentatively dated at 2549 ±18 Ma (Berman, pers. comm., 2005), based on one monazite grain from a garnet-rich pelite north of Patterson Island (see 'Geochronology' section for details). Reinterpretation of U-Pb dates from a quartz monzonite (Annesley *et al.*, 1992) from south of Peter Lake might corroborate this age. This intrusion yielded a U-Pb zircon crystallization age of 2566 ±2 Ma, but also gave a U-Pb titanite age of 2529 ±4 Ma. Annesley *et al.* (1992) originally interpreted both dates as igneous crystallization events. However, in view of the identification in this study of earlier metamorphic events in the domain, this titanite age could be reinterpreted as reflecting a metamorphic event, possibly representing prolonged cooling through the titanite blocking temperature following the proposed 2550 Ma thermotectonic event. This interpretation would imply that the D1 deformation and upper amphibolite metamorphism (M1) took place at about 2550 to 2530 Ma, and that the monzonitic rocks were emplaced syntectonically. Alternatively, the extensive 2560 Ma mafic magmatism might have provided the heat for a widespread high-grade contact metamorphic event between 2550 and 2530 Ma, and the observed early tectonic fabric could actually be related to the De event.

Deformation ?D2-M2 (<2075 Ma, but before deposition of Sequence 2 of the Campbell River Group)

Deposition of the Campbell River Group (CRG) is thought to postdate the documented age of rifting along the Hearne Craton margin at 2075 Ma (MacNeil *et al.*, 1997; Ansdell *et al.*, 2000; Maxeiner and Rayner, 2005; Rayner *et al.*, 2005a). The D2-M2 event is recognized as a separate event as a result of the work completed within the CRG (Maxeiner and Hunter, 2002a; Maxeiner and Rayner, 2005). The abrupt juxtaposition of a middle greenschist facies sedimentary assemblage over an upper amphibolite facies assemblage (Maxeiner and Rayner, 2005) suggests the existence of two temporally discrete sedimentary successions within the CRG that were affected by distinct metamorphic and deformational events. Calc-silicate nodules contained within Sequence 1 of the CRG contain garnet, diopside, actinolitic hornblende, and minor granitic melt, all of which are consistent with upper amphibolite facies metamorphic conditions. The second metamorphic event (M2) predates deposition of Sequence 2 of the CRG and two subsequent deformation events, the earlier of which produced tight to isoclinal folding.

This high-grade metamorphic event was probably accompanied by domain-wide deformation involving the development of a northeasterly trending structural fabric and northeast-trending map-scale folds. One possible F2 structure is preserved in gabbroic units of the granodiorite-tonalite migmatite complex on Reindeer Lake west of Feaviour Peninsula (Maxeiner *et al.*, 2004b; map), where a map-scale, tight to isoclinal fold has a northwest-dipping axial plane and moderately northwest-plunging fold axis. Rodding and hornblende lineations in the core of the fold that affect the gabbroic rocks of the Swan River Complex are parallel to the fold axis. Truncation of the fold by the Fontaine Island quartz monzonite, which represents a phase of the Wathaman Batholith, suggests that it formed prior to 1.86 Ga maybe during the D2-M2 event.

Gabbronorite and gabbro of the Love Lake Pluton exhibit evidence of two metamorphic events (Leatherdale *et al.*, 2003). The first is an upper amphibolite facies event, which resulted in the extensive replacement of clinopyroxene by tschermakitic hornblende and actinolite, and of orthopyroxene by cummingtonite. Actinolite cores preserved within hornblende grains in a few samples can be explained by a variety of alteration scenarios, of which only two are discussed here. One scenario involves a prograde greenschist to lower amphibolite facies metamorphic event prior to attainment of peak amphibolite grade conditions. During this event, magmatic clinopyroxene grains may have largely been replaced by metamorphic actinolite, which was, in turn, replaced by hornblende during later amphibolite facies metamorphism. Alternatively, the pluton may have been subjected to autopneumatolysis, leading to the replacement of clinopyroxene by actinolite prior to an amphibolite facies metamorphic event. The high-grade metamorphic event may have therefore developed during the regional M1 (?2540 Ma) event or the M2 (between 2075 and 1917 Ma) event.

Deformation D3-M3 (?1917 to 1913 Ma)

The D3-M3 event was accompanied, in part, by the formation of tight northeast-trending fold structures, which affect garnet-bearing argillaceous layers and layers of granitic leucosome in Sequence 1 of the CRG. Abundant reversals of facing directions in Sequence 2 are also related to this folding event (Maxeiner and Rayner, 2005), although very few outcrop-scale folds were observed. A steeply dipping fracture cleavage and/or schistosity are generally well preserved in rocks of Sequence 2 of the CRG. The schistosity is defined by biotite and/or muscovite, and is approximately axial planar to the F3 folds. This fabric developed under low-grade (middle greenschist to possibly lower amphibolite facies) metamorphic conditions. Within some of the oldest units throughout the Peter Lake Domain, the gneissic fabric is also overprinted by a steeply dipping schistosity that is generally defined by biotite and is also attributed to the D3 event.

The D3 deformation postdated deposition of Sequence 2 of the CRG, and field relationships suggest that it was probably contemporaneous with emplacement of the Porter Bay Complex. The potential age of D3-M3 is resolvable from the geological relationships observed in the

Patterson Island area on north Reindeer Lake. The 1917 to 1913 Ma Patterson Island Pluton, which is a component of the Porter Bay Complex, has a weak tectonic foliation that is preserved only within some of its older gabbroic units. The youngest and most central unit remained undeformed during subsequent deformational events. Deformed autoliths in the marginal zone of the pluton suggest, however, that deformation affected some of its supracrustal precursors prior to their being incorporated into the younger magmas. This deformation is characterized by layer-parallel tectonic foliations and open to tight folding of layered 1917 Ma supracrustal inclusions prior to their inclusion in the Patterson Island Pluton (Maxeiner and Leatherdale, 2003d). This deformation is therefore temporally constrained to between 1917 and 1913 Ma (Rayner *et al.*, 2005a).

Gabbronorite and gabbro of the Love Lake Pluton were overprinted by a second metamorphic event (Leatherdale *et al.*, 2003) at lower amphibolite to greenschist grade; it is characterized by the replacement of plagioclase by epidote and of hornblende by actinolite, biotite, and chlorite. Additional evidence of this retrograde event is found in the biotite rims around hornblende and/or actinolite grains (Leatherdale *et al.*, 2003). This second metamorphic event is of a lower grade, is retrograde in nature, and developed during either M3 (*ca.* 1917 Ma) or M4. Alternatively, it might be related to a weak overprint during the Trans-Hudson Orogeny between 1820 and 1800 Ma.

Deformation D4 (1820 to 1805 Ma)

The main metamorphic event in the Trans-Hudson Orogen is related to closure of the Manikewan Ocean and terminal collision between the Hearne and Superior provinces, and is constrained to between 1820 and 1805 Ma (*e.g.*, Syme *et al.*, 1998 and references therein). In the Peter Lake Domain, a Trans-Hudson Orogen overprint is only of retrograde nature.

In the Peter Lake Domain, the thermotectonic overprint derived from this latest deformation was weak. It caused formation of open to close folds having west-northwest–dipping axial planes and gently to moderately north-plunging fold axes. Folding postdated emplacement of the Wathaman Batholith and caused a weakly developed, moderately northwest-dipping fabric that is defined by alignment of mafic minerals and flattening of quartz and feldspar. Fold patterns, locally observed in the granodiorite-tonalite migmatite complex, resulted from interference between F4 folds and earlier tight to isoclinal folds. The effects of this second coplanar refolding event on Sequence 2 of the CRG is manifested only as a reorientation of the fracture cleavage and schistosity developed within it.

Several northwest-dipping mylonite zones transect the interior of the Peter Lake Domain. Mylonitic orthogneisses that measure tens of metres wide are continuous for several kilometres within otherwise homogeneous and massive units of granitic and gabbroic rocks. The mylonite zones are of unknown age, but must be younger than 1860 Ma, as they postdate rocks of the Wathaman Batholith and are probably related to the dextral Trans-Hudson–age Parker Lake (LaFrance and Varga, 1996) and Needle Falls (Stauffer and Lewry, 1993) shear zones.

Late Brittle Deformation

Northerly trending lineaments and a subvertical fracture set are common throughout the Peter Lake Domain and are locally paralleled by late granite-pegmatite dykes. Large-scale, north-trending lineaments, identified on airphotos and presumed to be related to the Tabbernor Fault, are also visible on the newly acquired aeromagnetic maps and are generally accompanied by sinistral offset in the order of hundreds of metres to a few kilometres. In the CRG and along the south side of the Love Lake Pluton, steeply dipping, northeast-trending normal faults were identified, but are of uncertain age (Maxeiner and Hunter, 2002a; Maxeiner and Rayner, 2005).

Geochronology

Introduction

This section and its subsections present historical and new geochronological data (Figure E-06), assembled during the course of the Peter Lake Domain project. The data are also accessible through a separate Microsoft® Excel spreadsheet and through the attached Microsoft® Access database. In addition, the geochronological data are included with the ESRI® ArcReader project. Two of the Summary of Investigations papers, written during the course of the Peter Lake Project, report on preliminary geochronology results (Maxeiner *et al.*, 2004b; Rayner *et al.*, 2005a). Although we summarize some of these early findings here, the data and interpretations remain preliminary.

Highlights

- At least three episodes of mafic plutonism have now been identified in the Peter Lake Domain: the gabbroic 2562 Ma Swan River Complex; the 1917 Ma gabbroic to monzonitic Porter Bay Complex; and an 1860 Ma gabbroic to monzodioritic component of the Wathaman Batholith. A fourth distinct age (2530 Ma) has been identified in zircons from gabbroic to dioritic rocks in the Zengle Lake area, although the interpretation of that material (*i.e.*, whether it originated from igneous crystallization, metamorphic crystallization, or inheritance) is unclear.

- Magmatic Cu–Ni–platinum-group-element (PGE) sulphides at Swan Lake have been constrained to 2562 ±3 Ma by dating the host gabbro.

- Archean high-grade metamorphism is likely to have affected the Peter Lake Domain, based on a 2550 Ma monazite grain from a migmatitic pelite.

- The Campbell River Group has been found to consist of two sequences: a) an older (<2380 Ma) amphibolite facies sequence that consists of a basal boulder conglomerate overlying feldspathic arenite, cross-bedded subfeldsarenite, calcic feldspathic wacke, and minor black argillite; and b) a younger (<2250 Ma) greenschist to lower amphibolite facies succession consisting of feldspathic arenite.

- The areal extent of rocks belonging to the 1917 to 1913 Ma Porter Bay Complex is greater than originally indicated by field mapping. The complex contains leucogabbroic, monzodioritic, and monzonitic components, and also includes a porphyritic volcanic to subvolcanic element. The Antoine's and Ant Lake South Ni-Cu-Pt-Pd showings are hosted by the Patterson Island Pluton of the Porter Bay Complex.

- The extent and compositional range of the Wathaman Batholith in the Peter Lake Domain are also greater than previously anticipated. Megacrystic granite north of Zengle Lake has yielded a preliminary age of 1860 Ma. Based on regional geological maps, rocks of both the Peter Lake and Wollaston domains are intruded by this granite. Rhythmically layered gabbro-anorthosite, megacrystic monzodiorite, and quartz diorite are newly recognized components of Wathaman magmatism in the Peter Lake Domain and along the northwestern edge of the batholith.

- A potentially widespread and locally fluorite-bearing 1830 Ma syenogranite suite has also been recognized.

Results of Geochronological Analyses by the Geological Survey of Canada

Sample descriptions and analytical results are given in chronological order:

- *Love Lake leucogabbro: 2562 Ma*
- *Swan Lake gabbro: 2562 Ma*
- *Wiley Bay leucogabbro: 2560 Ma*
- *Zengle Lake gabbro: 2529 Ma*
- *Cross-bedded subarenite: <2380 Ma*
- *Porter Bay gabbro: 1917 Ma*
- *Andesitic porphyry: 1915 Ma*
- *Patterson Channel leucogabbro: 1913 Ma*
- *Fontaine Island megacrystic monzogranite: 1865 Ma*
- *Gabbro pegmatite near Crane Island: 1859 Ma*
- *Crane Island quartz diorite:* ca. *1853 Ma*
- *Zengle Lake megacrystic monzogranite: 1858 Ma*
- *Feaviour Peninsula zebra gabbro: 1854 Ma*
- *Syenogranite: 1829 Ma*
- *Garnet-rich pelite: 2549 Ma (metamorphic age)*

Uranium-lead zircon geochronology on most of the samples was carried out using a combination of thermal ionization mass spectrometry (TIMS) and sensitive high-resolution ion microprobe (SHRIMP) techniques at the Geochronology Laboratory of the Geological Survey of Canada in Ottawa.

Samples were prepared by standard crushing and grinding techniques, followed by separation of heavy minerals using heavy liquids and sorting with a Frantz isodynamic separator. Samples analyzed by TIMS were heavily abraded before being submitted for U-Pb chemistry. All ages quoted in the text are given at the 2σ confidence level.

TIMS: Analytical Techniques

Analytical methods are as described in Roddick *et al.* (1987) and Parrish *et al.* (1987). Analytical uncertainties were generated by the error propagation method of Roddick (1987). Age uncertainties are based on the regression method of York (1969).

SHRIMP: Analytical Techniques

Selected samples were analyzed using the sensitive high-resolution ion microprobe at the Geological Survey of Canada. Prior to SHRIMP analysis, the internal features of the U-Pb minerals (zoning, structures, alteration, etc.) were characterized in back-scattered electron mode (BSE) using a scanning electron microscope. Detailed zircon SHRIMP analytical procedure and U-Pb calibration details are given in Stern (1997) and Stern and Amelin (2003). Detailed monazite analytical methods are outlined in Stern and Berman (2000). The analytical work presented here was collected over multiple analytical sessions on separate ion probe epoxy mounts with varying instrumental conditions. No fractionation correction was applied to the Pb-isotope data; common Pb correction utilized the Pb composition of the surface blank (Stern, 1997). Isoplot v. 2.49 (Ludwig, 2001) was used to calculate weighted means.

Sm-Nd Tracer Isotopes: Analytical Techniques

(See also separate write-up in the 'Lithogeochemistry' section)

Tracer isotopic analyses were carried out using the Nu Plasma multi-collector inductively coupled plasma–mass spectrometer (MC-ICP-MS) at the Geological Survey of Canada. Isotopic compositions of Sm and Nd were analyzed using an array of fixed Faraday collectors in static multi-collector mode. All εNd values were calculated at the time indicated in the text relative to the accepted Chondritic Uniform Reservoir, with $^{143}Nd/^{144}Nd = 0.512636$ and $^{147}Sm/^{144}Nd = 0.1966$.

Sample Descriptions and Results

Love Lake Leucogabbro (Swan River Complex): 2562 ±1 Ma

RM0301-115 (GSC Lab No. z7880)

This sample was collected in 2002 (Maxeiner and Hunter, 2002a) along Highway 905 (Figure F-01) and consists of gabbronorite. In the field, the gabbronorite is in contact to the south and north with granites; the granite to the south previously yielded a U-Pb zircon age of 2566 Ma (Annesley *et al.*, 1992). The southern contact is not exposed, but, based on airphoto interpretation and a seismic profile (LITHOPROBE line S2B), it coincides with an interpreted late structure, the Korvin Lake Fault (Maxeiner and Hunter, 2002a). The gabbronorite (Figure F-02) weathers bluish grey to grey owing to the presence of Ca-rich plagioclase, and contains hornblende. Magnetite and pyrite are ubiquitous accessory minerals. Locally, the gabbronorite contains abundant mafic (Figure F-03) to ultramafic (Figure F-04) xenoliths, some of which are of volcanic origin. The 2562 Ma Love Lake leucogabbro was overprinted by a high-grade and a later low-grade metamorphic event (Maxeiner and Hunter, 2002a; Leatherdale *et al.*, 2003).

Three overlapping, concordant zircon fractions gave a crystallization age of 2562 ±1 Ma (TIMS, weighted mean $^{207}Pb/^{206}Pb$ age), confirming that the Love Lake leucogabbro forms part of the Swan River Complex (Maxeiner *et al.*, 2004b). This also provides a maximum age for the proposed high-grade metamorphic event (Leatherdale *et al.*, 2003), whereas a minimum age for this event is provided by a 2529 ±4 Ma U-Pb titanite age from a quartz monzonitic to granitic pluton south of the Love Lake Pluton (Annesley *et al.*, 1992). The titanite was originally interpreted as igneous in origin, but the host quartz monzonite also provided 2566 ±2 Ma igneous zircons (Annesley *et al.*, 1992), so the titanite is reinterpreted here as metamorphic. The age of upper amphibolite to granulite facies metamorphism in the Peter Lake Domain is thereby bracketed to between 2562 and 2530 Ma. However, in at least one location, a tectonic foliation within some of the mafic xenoliths is randomly oriented, suggesting that deformation affected the area prior to emplacement of the Swan River Complex (Maxeiner and Hunter, 2002a).

Swan Lake Gabbro (Swan River Complex): 2562 ±3 Ma

RM0401-039 (GSC Lab No. z8487)

Granodiorite foliate (after the definition of Ashton and Leclair, 1990) and 2570 Ma monzogranite (Maxeiner *et al.*, 2004b; Maxeiner and Rayner, 2005) east of Swan Lake are intruded by a 3 by 0.5 km gabbroic pluton (Figure F-05). The gabbro has a central zone of leucogabbroic breccia with gabbro and pyroxenite inclusions, surrounded by coarse-grained homogeneous gabbro and an outer zone of fine-grained microgabbro. At the southern end of the central leucogabbroic breccia zone, several trenches (Figure F-06) reveal disseminated magmatic sulphides. A sample of a coarse-grained to pegmatitic, massive, sulphide-bearing gabbro (Figure F-07) was collected from this zone.

Three TIMS fractions (two multi-grain, one single grain) of clear, colourless, anhedral zircons yielded an upper intercept age of 2562 ±3 Ma, interpreted as the time of pluton crystallization (Rayner *et al.*, 2005a). This age is identical to that of a pegmatitic gabbro from north Reindeer Lake (Corrigan *et al.*, 2001) and to a leucogabbro from Highway 905 (Maxeiner *et al.*, 2004b), and confirms the rock as a component of the 2562 Ma Swan River Complex. It also, for the first time in the Peter Lake Domain, provides constraints for the age of magmatic sulphides. The Swan River Complex represents the most voluminous gabbroic suite in the Peter Lake Domain.

Wiley Bay Leucogabbro (Swan River Complex): 2560 ±1 Ma

RM0301-108 (GSC Lab No. z7879)

This sample (Figure F-08, Figure F-09) is very similar in appearance to the Love Lake leucogabbro (RM0301-115) and represents one of the main phases of the Swan River Complex. It has well-preserved rhythmic igneous layering (Figure F-10) and poorly defined breccia pipes with abundant autoliths (Figure F-11). Based on field relationships, the intrusion is interpreted to postdate deposition of the Wiley Bay mafic volcanic rocks and the protolith of the migmatitic pelite. The gabbro is located just south of, and is intruded by, the 1920 to 1910 Ma Patterson Island Pluton of the Porter Bay Complex.

A regression through three TIMS fractions (one concordant and two discordant) yielded an upper intercept age of 2560 ±1 Ma, interpreted as the time of crystallization of the pluton and a lower limit for the age of the supracrustal rocks (Maxeiner *et al.*, 2004b). This is within error of the age for sample RM0301-115, described above. The εNd for sample RM0301-108 is +1.64 (at t = 2560 Ma).

Zengle Lake Gabbro: 2529 ±5 Ma

RM0401-021 (GSC Lab No. z8620)

A massive to weakly foliated, coarse-grained gabbro with ophitic texture (Figure F-13) was sampled on an island at the north end of Zengle Lake (Figure F-12). No intrusive relationships were observed locally, though the adjacent, highly tectonized granitoid units are intruded by a gabbro that forms part of a dioritic to gabbroic suite. The gabbroic sheets are traceable along strike for about 10 km and are intruded locally by diorite and syenogranite. The rock contains abundant, partly zoned plagioclase, about 40 to 50% hornblende, minor biotite, and magnetite. Relict clinopyroxene phases were not observed.

Three multi-grain zircon fractions were analyzed using TIMS. One fraction is concordant with an age of 2435 ±9 Ma. Two other fractions are approximately 2% discordant, but do not form a chord with the concordant fraction (Rayner *et al.*, 2005a). Further analyses using the SHRIMP were performed to constrain the time of crystallization and aid in the interpretation of the TIMS results. A crystallization age of 2529 ±5 Ma was determined from the weighted mean $^{207}Pb/^{206}Pb$ ages of 23 zircon grains. An additional 11 SHRIMP analyses document an ancient (post–2.0 Ga) Pb-loss event from the zircons of this sample, which explains the nonlinearity of the TIMS data.

Porter Bay Gabbro (Porter Bay Complex): 1917 +4/-3 Ma

RM0301-099 (GSC Lab No. z7878)

This sample was collected in a bay north of Patterson Island (Figure F-08), from a 400 m wide and >8 km long unit of complex gabbroic rocks that are locally characterized by spectacular rhythmic igneous layering. Locally, centimetre-thick layers of alternating black gabbroic and white anorthositic components produce a zebra pattern. Outstanding examples of cross-bedded layering (Figure F-14) also occur, although they are rare (Maxeiner and Leatherdale, 2003d). The sampled gabbro (Figure F-15) is medium to coarse grained, comprising predominant plagioclase, 25% hornblende, 10% biotite, and trace amounts of epidote, carbonate, quartz, K-feldspar, and titanite.

Analyses were conducted on four zircon fractions (single grain to small multi-grain) using TIMS. The majority of the zircons were elongate prisms with broken terminations. A regression line through three discordant analyses of zircon fractions with this morphology provided an upper intercept age of 1917 +4/-3 Ma, interpreted as the time of crystallization. A fourth discordant fraction, composed of moderate quality, stubby prismatic zircons, does not lie on the regression line and gives a slightly younger $^{207}Pb/^{206}Pb$ age of 1910 Ma (Maxeiner *et al.*, 2004b). This fraction is interpreted to have been affected by minor Pb loss. The determined εNd value for this sample is -3.92 (at t = 1900 Ma).

Andesitic Porphyry (Porter Bay Complex): 1915 ±8 Ma

RM0301-104 (GSC Lab No. z8708)

Intermediate volcanogenic rocks occur as xenoliths and minor units within monzodiorite along the northwestern edge of the Patterson Island Pluton (Maxeiner and Leatherdale, 2003d; Sulz, 2004) and in leucogabbro within the west-central zone of the pluton (Figure F-08). Three distinct phases of volcanogenic rocks are recognized: 1) grey, fine-grained, laminated ash tuff or calcic psammopelite of intermediate to mafic composition that contains a weak, layer-parallel tectonic foliation; decimetre to metre-size blocks of this rock are incorporated within the surrounding monzonitic rocks, which postdate the S1 foliation, but possess a later fabric; 2) minor intermediate tuff breccias, containing felsic volcanic clasts in an intermediate hornblendic matrix; and 3) massive to weakly foliated, plagioclase-porphyritic, amygdaloidal, subvolcanic trachyandesite (Figure F-16), intrusive into the laminated rock (1). Contained amygdules in the andesitic porphyry are up to 2 cm in diameter and are filled with carbonate, epidote, and/or amphibole. Xenoliths of the porphyritic andesite are also encountered within monzodiorite and within the leucogabbro. A sample of porphyritic trachyandesite (RM0301-104) was collected west of Patterson Island along the northwestern margin of the pluton. The sampled outcrop displays millimetre-size plagioclase phenocrysts in a fine-grained matrix of plagioclase, hornblende, biotite, and augite (Figure F-17). Only the outlines of the phenocrysts are preserved, with igneous plagioclase having been replaced by a mosaic of polycrystalline metamorphic plagioclase.

The sample was initially analyzed by TIMS, but the rare, small, fractured zircons gave non-linear, discordant results. As zircon recovery was poor, no further TIMS analyses were attempted and the remaining zircons were instead analyzed by SHRIMP. Sixteen zircons were analyzed and together gave a weighted mean age of 1915 ±8 Ma, which is interpreted as the crystallization age of the volcanic xenolith. This result is identical, within error, to the age of the associated plutonic rocks.

Patterson Channel Leucogabbro (Porter Bay Complex): 1913 ±1 Ma

RM0401-036 (GSC Lab No. z8619)

In the western part of the Patterson Island Pluton (Figure F-08), leucogabbroic to gabbroic rocks dominate and host a number of significant PGE occurrences (Maxeiner and Leatherdale, 2003d). The gabbroic rocks are intruded by the monzodioritic phase of the pluton, at both map scale and outcrop scale. The main leucogabbroic phase (Figure F-18) weathers a characteristic mottled light bluish grey to greenish black (Figure F-19), caused by calcic plagioclase and about 15 to 35% hornblende, actinolite, minor relict pyroxene, biotite, epidote, and magnetite, as well as accessory apatite, ilmenite, pyrite, and chalcopyrite. Pyroxene is replaced by actinolite and hornblende which, in turn, is partially replaced by biotite (close-up view). Locally abundant inclusions of mafic and intermediate volcanic rocks and porphyritic andesite are present. These are angular to subrounded, up to 50 cm in diameter, and have a tectonic fabric that predates emplacement of the pluton. Centimetre- to decimetre-scale rhythmic layering, defined by alternating layers of anorthosite and gabbro, are locally preserved.

A sample of the leucogabbro (RM0401-036) was collected west of Patterson Island. Three single-grain fractions of high-quality, anhedral/fragmental zircon were analyzed by TIMS. Although slightly discordant (0.2%), all fractions overlap and give a weighted mean $^{207}Pb/^{206}Pb$ age of 1913 ±1 Ma, interpreted as the crystallization age of the pluton (Rayner *et al.*, 2005a).

Fontaine Island Megacrystic Monzogranite (Wathaman Batholith): 1865 +4/-2 Ma

RM0401-105 (GSC Lab No. z8485)

A large body of quartz monzonite to monzogranite (Figure F-20), centred on Fontaine Island (Figure F-12), was tentatively mapped as part of the Wathaman Batholith (Maxeiner *et al.*, 2004b). The rocks are homogeneous and deformation textures range from massive megacrystic to strongly foliated and augened. Large, tabular, euhedral crystals of K-feldspar, measuring up to 5 cm long, account for 10 to 20% of the rock. The coarse-grained matrix contains plagioclase, K-feldspar, and quartz, and 10 to 20% combined hornblende, biotite, epidote, and magnetite (Figure F-21). Northwest-dipping shear zones, several metres wide and continuous for kilometres, transect the Fontaine Island quartz monzonite and locally separate it from thin, structurally imbricated gabbroic bodies. Large xenoliths and rafts of gabbro are observed at some locations, and several generations of mafic and felsic dykes cross-cut the pluton. The quartz monzonite intrudes the granodiorite-tonalite migmatite complex at its northeastern termination.

Three TIMS multi-grain zircon fractions from this rock yielded an upper intercept age of 1865 +4/-2 Ma, interpreted as the age of crystallization. The age and appearance of this rock are consistent with its assignment to an early phase of the Wathaman Batholith (Rayner *et al.*, 2005a).

Zengle Lake Megacrystic Monzogranite (Wathaman Batholith): 1858 ±6 Ma

RM0401-028 (GSC Lab No. z8486)

A large body of megacrystic monzogranite to syenogranite is located along the northeast shore of Zengle Lake (Figure F-12) and forms part of the Reynolds Lake Pluton (Stauffer *et al*., 1981), which is now considered to represent a phase of the Wathaman Batholith. The beige to light pink, coarse-grained rock contains 10 to 20% K-feldspar crystals that are subhedral and locally occur as augen measuring up to 7 cm long (Figure F-22). Mafic minerals account for about 15% of the rock and comprise hornblende, biotite, and epidote. The granite is generally massive and has xenoliths of fine-grained, grey to pinkish grey, feldspathic psammite (Figure F-232). A localized weak foliation is defined by mafic minerals and flattened xenoliths. The pluton is mylonitic along its eastern margin and comprises augen granite. In contrast to the Fontaine Island quartz monzonite on Reindeer Lake, the Reynolds Lake Pluton is slightly more quartz rich, less magnetic and distinctly more radioactive (~2× measurement by scintillometer). On the regional geology map, this 'Wathaman-type megacrystic granitoid' (Stauffer *et al.*, 1981) is folded around a large northeast-trending isoclinal fold that causes the unit to re-emerge in the Wollaston Domain northwest of Zengle Lake.

The TIMS results from zircons of the Zengle Lake megacrystic monzogranite are complex, with two single-grain fractions giving slightly discordant (~1%) $^{207}Pb/^{206}Pb$ ages of 1843 and 1855 Ma. Three multi-grain fractions yielded discordant (5 to 7%) $^{207}Pb/^{206}Pb$ ages as old as 2050 Ma, indicating the presence of an older inherited component (Rayner *et al.*, 2005a). This sample was subsequently reanalyzed by SHRIMP, from which a crystallization age of 1858 ±6 Ma was determined from the weighted mean $^{207}Pb/^{206}Pb$ ages of 24 zircon grains. No inherited zircons were documented during the SHRIMP study.

Crane Island Quartz Diorite (Wathaman Batholith): Circa 1853 Ma

RM0401-035 (GSC Lab No. z8483)

Gabbro, diorite, and quartz diorite plutons that are located southwest of Crane Island (Figure F-12) lie along strike from the 1917 Ma Porter Bay gabbro identified in the Patterson Island area, and display compositional and textural similarities. These include rhythmic zebra layering (Figure F-24) and pegmatitic diorite phases. The gabbroic rocks also display textural and compositional similarities to the 2562 Ma gabbroic rocks of the Swan River Complex (Corrigan *et al.*, 2001; Maxeiner *et al.*, 2004b; Rayner *et al.*, 2005a) mapped to the northeast. In the 1980s, a sample of a pegmatitic diorite collected along the Reindeer Lake shoreline southwest of Crane Island yielded an age of 1865 ±10 Ma (Bickford *et al.*, 1986), which was later revised to an upper intercept age of 1908 ±27 Ma because of additional analyses (Bickford *et al.*, 1987).

To resolve whether the gabbroic rocks southwest of Crane Island are part of the Swan River Complex or the Porter Bay Complex, a sample of magnetite-rich quartz diorite (Figure F-25) that cuts and intermingles (Figure F-26) with the main gabbroic units was collected. Of the five

TIMS fractions analyzed, the two most concordant results yielded $^{207}Pb/^{206}Pb$ ages of 1853 and 1852 Ma, indicating that this quartz diorite is part of the Wathaman Batholith.

Gabbro Pegmatite, Near Crane Island (Wathaman Batholith): 1859 ±6 Ma

HUD85-24 (GSC Lab No. z8933) (same location as RM0401-035)

In order to further refine the age of the Crane Island quartz diorite (see sample RM0401-035 above), the zircon separates from Bickford's original sample (sample HUD85-24; Bickford *et al.*, 1986) were obtained and reanalyzed using the SHRIMP.

Thirteen such zircons were analyzed, of which eleven yielded a weighted mean $^{207}Pb/^{206}Pb$ age of 1859 ±6 Ma. This is interpreted as the crystallization age of the pegmatite and is consistent with the known age of the Wathaman Batholith. Two of the zircons yielded ages of *ca.* 2.6 Ga, comparable with the known age of the Swan River Complex and thus presumed to be inherited. The presence of inherited zircons accounts for the older upper intercept age determined from large multi-grain fractions (Bickford *et al.*, 1987).

Feaviour Peninsula Zebra Gabbro (Wathaman Batholith): 1854 +5/-4 Ma

RM0401-121 (GSC Lab No. z8484)

Southwest of Feaviour Peninsula (Figure F-12), gabbro-anorthosite has well-developed zebra layering and grades westward into a layered, autolith-rich megacrystic monzodiorite. Since identical lithological relationships and textures were observed in the Patterson Island area, the Feaviour Peninsula succession was equated with the 1920 to 1910 Ma Porter Bay Complex during completion of the fieldwork (Maxeiner *et al.*, 2004b). Both the layered gabbro-anorthosite (Figure F-27) and the megacrystic monzodiorite (Figure F-28) were sampled for geochronology to test whether the Porter Bay Complex extends to this location. Sample RM0401-121 (Figure F-29) is characterized by rhythmic modal layering of anorthositic and gabbroic composition, and is locally pockmarked. The mafic mineral content of the rock is 50%, dominated by hornblende with lesser biotite. Zircons from the gabbro-anorthosite were analyzed and yielded a surprising result.

Four TIMS fractions of prismatic zircon gave an intercept age of 1854 +5/-4 Ma, which is interpreted to be the age of crystallization (Rayner *et al.*, 2005a). There is some excess scatter in this regression, which is possibly the result of complex Pb loss. Despite this scatter, the sample clearly belongs to the Wathaman Batholith.

Although homogeneous dioritic components to the Wathaman Batholith have previously been recognized (*e.g.*, Corrigan *et al.*, 2000; Maxeiner and Leatherdale, 2003d), rhythmically layered gabbro and megacrystic monzodiorite are previously unknown components of the batholith.

Isotopic analysis of Sm-Nd was carried out for sample RM0401-121, from which an εNd value of -4.3 (at t = 1850 Ma) was determined.

Syenogranite: 1829 ±5 Ma

RM0301-105 (GSC Lab No. z8618)

A suite of relatively late syenogranite to alkali-feldspar granite is widespread throughout the Peter Lake Domain. These intrusions are most abundantly exposed in the northern half of the domain (see also Maxeiner and Hunter, 2002a) and account for approximately 20% of the bedrock in the Patterson Island area (Figure F-30). The syenogranite (Figure F-31) is pink to brick red, coarse- to very coarse grained, homogeneous, equigranular, and massive to weakly foliated. Mafic minerals (5 to 10%) comprise biotite, epidote, magnetite, and titanite. Mafic xenoliths occur locally and syenogranite postdates (Figure F-32) the variably recrystallized megacrystic Ettle Creek granite of Stauffer *et al.* (1981), which was dated at 2569 Ma (Maxeiner *et al.*, 2004b).

Prismatic, well-faceted zircons of varying quality were recovered from this sample. Four multi-grain TIMS fractions range from concordant (0.2 and 0.3%) to moderately discordant (1.8 and 2.8%). The upper intercept age, derived by linear regression through analyses of all four fractions, is 1829 ±5 Ma and is interpreted as the crystallization age (Rayner *et al.*, 2005a).

This is the youngest plutonic unit identified thus far in the Peter Lake Domain. Plutons of this age have been recognized in the Wollaston Domain (Annesley *et al.*, 1997), the Southern Indian Domain, the La Ronge–Lynn Lake Belt (Rayner and Corrigan, 2004), the Rottenstone Domain (MacLachlan *et al.*, 2004), and farther to the north in the Hearne and Rae provinces, where they are referred to as the Hudson Granites (Peterson *et al.*, 2002). The Hudson Granites have unique geochemical and lithological characteristics (Peterson *et al.*, 2002); similar characteristics have yet to be verified for the Peter Lake Domain samples.

Garnet-rich Pelite: 2549 ±18 Ma

RM0301-101 (GSC Lab No. z8697) (Figure F-30)

An upper amphibolite facies migmatitic pelite (Figure F-33), sandwiched between units of fragmental felsic volcanic rocks (Figure F-34), can be traced for several kilometres north of Patterson Island, adjacent to the 1917 Ma Porter Bay gabbro. The pelite, interpreted to be Archean in age, is a strongly foliated quartzofeldspathic rock containing abundant biotite, garnet, sillimanite, and tonalitic leucosome with biotite-rich melanosome selvages.

Three replicate analyses from one monazite grain gave a weighted mean $^{207}Pb/^{206}Pb$ age of 2549 ±18 Ma.

Results of Geochronological Analyses by the University of Alberta

Sample descriptions and analytical results are given in chronological order:

- *Megacrystic monzonite: 2540 Ma*
- *Cross-bedded subfeldsarenite: <2380 Ma*
- *Feldspathic arenite, Upper Campbell River Group (<2250 Ma)*

- *Highway 905 granodiorite: 1.85 Ga*

ID-TIMS and LA-MC-ICP-MS: Sample Details and Analytical Techniques

The samples processed for isotope dilution–thermal ionisation mass spectrometry (ID-TIMS) and laser-ablation multi-collector inductively coupled plasma–mass spectrometry (LA-MC-ICP-MS) isotopic analysis were prepared using a jaw crusher and Bico disk mill. Mineral concentrates were obtained using a Wilfley table followed by standard magnetic and density separation techniques. The procedure of purifying uranium and lead from selected mineral fractions for ID-TIMS analyses is outlined in Heaman *et al.* (2002). All fractions were analyzed on a VG354 thermal ionization mass spectrometer operating in single-collector Faraday or Daly detector mode. Age calculations were made using the uranium decay constants reported by Jaffey *et al.* (1971), and the isotopic composition of common Pb in excess of analytical blank was estimated using the two-stage terrestrial Pb-evolution model of Stacey and Kramers (1975).

The U-Pb laser-ablation analyses were conducted using a Nu Plasma MC–ICP-MS coupled to a frequency quintupled (λ = 213 nm) Nd:YAG laser-ablation system (Simonetti *et al.*, 2005). The analysis spots were 40 μm in diameter and U-Pb data were acquired for 60 seconds per spot.

Samples Descriptions and Results

Megacrystic Monzonite (Monzonitic Intrusive Suite): 2540 ±1 Ma

RM0201-182

A widespread monzonitic suite, which is dominated by monzonite with gradational variation into quartz monzonite, monzodiorite, and syenite, is exposed in the southwestern portion of the Peter Lake Domain (Maxeiner and Hunter, 2002a; Figure F-01). The pink to grey, coarse-grained, and commonly megacrystic rocks can be massive, weakly foliated, or locally mylonitic. Their mafic mineral content varies between 10 and 20%, and is dominated by biotite with minor amounts of epidote, hornblende, and titanite. Megacrystic components are characterized by pink K-feldspar phenocrysts up to 3 cm long, constituting up to 30% of the rock and generally defining a tectonic foliation. The megacrystic varieties compositionally and texturally resemble rocks of the *ca.* 1860 to 1850 Ma Wathaman Batholith (Maxeiner and Hunter, 2002a). The monzonitic intrusive suite intrudes diorite and gabbro of the Warner Lake gabbroic suite (Maxeiner and Hunter, 2002a), which forms a component of the 2562 Ma Swan River Complex, as well as upper amphibolite facies migmatitic supracrustal rocks. The monzonitic intrusive suite appears to have postdated the main regional high-grade metamorphic overprint, but has been affected by a weaker thermotectonic overprint attributed to the Trans-Hudson Orogeny at *ca.* 1.8 Ga. The suite is postdated by pink to brick-red syenogranite to alkali-feldspar granite, as well as minor mafic dykes.

A sample of the monzonite (Figure F-35) was collected from an outcrop located at kilometre 114 of Highway 905 (UTM Zone 13, 568233 m E, 6331842 m N, NAD 83) in order to provide minimum age constraints for the Swan River Complex, the migmatitic supracrustal rocks, and the upper amphibolite facies metamorphic event. The sample was collected on a relatively small (5 ´ 5 m) outcrop close to a cross-cutting leucogranite (Figure F-36) that also postdates a weakly developed foliation preserved within the monzonite. The monzonite sample is pink to pinkish grey and contains large K-feldspar megacrysts measuring up to 2 cm long, set in a medium- to coarse-grained matrix.

Abundant tan to pink zircons showing large variations in grain size were recovered from the least magnetic fraction of this sample. The majority of the crystals are equant to prismatic, and many have turbid regions (alteration?) and fractures. Core/overgrowth relationships were not observed. Three analyses of this material showed that the zircons have moderate to low U contents (160 to 260 ppm) and Th/U ratios (0.38 to 0.44) typical of zircons that crystallize directly from a felsic magma. The $^{207}Pb/^{206}Pb$ dates from two multi-grain and one single-grain zircon fractions are all similar (2539 to 2544 Ma), and all analyses are nearly concordant (*i.e.*, <0.7% discordant). Zircon fraction #1 has a slightly older $^{207}Pb/^{206}Pb$ date and was not used in the age calculation. A best-fit reference line constructed to pass through zircon fractions 2 and 3 yielded an upper intercept date of 2540.1 ±0.7 Ma, interpreted as the best estimate for the emplacement age of the monzonite.

Cross-bedded Subfeldsarenite (Lower Campbell River Group): <2380 Ma

RM0501-031 (Figure F-37)

The base of the Campbell River Group is defined by a paleosaprolite developed in a pink leucogranite and topped by a boulder conglomerate (Maxeiner and Rayner, 2005). The boulder conglomerate (Figure F-38) and overlying interbedded succession of pink feldspathic arenite (Figure F-39), bluish grey subfeldsarenite, and grey calcic feldspathic wacke (unit CRq) make up the lower sequence of the Campbell River Group. Black argillite and amphibolite represent minor components. Rocks of unit CRq are generally aphanitic to fine grained and medium to thick bedded. Feldspathic arenite and subfeldsarenite locally have well-defined cross-bedding; they also contain calc-silicate nodules (Figure F-40) up to 20 cm in diameter, with rosettes of green amphibole, pink feldspar, diopside, garnet, and quartz. They could possibly represent metamorphosed concretions. Sample RM0501-031 was collected in a cross-bedded subfeldsarenite (Figure F-41) close to the stratigraphic base of the sequence.

The subfeldsarenite sample contained many different generations of zircons of varying morphologies and colours, of which 84 were analyzed by LA-ICP-MS. A concordia line constructed through all zircon analyses give an upper $^{207}Pb/^{206}Pb$ date of 2577±29 Ma. The youngest, roughly concordant, detrital zircon grain was 2383 ±17 Ma, which is 4% discordant and therefore likely represents the maximum depositional age for the lower sequence of the Campbell River Group. On a relative probability plot, 69 zircons define a relatively sharp peak between 2480 and 2590 Ma, with a distinct peak at 2550 Ma. Four slightly discordant (1 to 10%) grains gave the oldest $^{207}Pb/^{206}Pb$ dates, which range from 2.60 to 2.70 Ga.

Feldspathic Arenite, Upper Campbell River Group (<2250 Ma)

RM0201-179

This sample was collected on a large outcrop from unit 1 (Hunter, 2003), representative of the basal section of the upper sequence of the Campbell River Group in an outlier along Highway 905 (Figure F-01). The outcrop is characterized by a thinly bedded, ripple-laminated sequence of feldspathic arenite and argillite (Figure F-42). Blue quartz grains (Figure F-43), measuring up to

5 mm in diameter, are common in the quartz arenite beds. The feldspathic arenite contains 70% quartz, with lesser amounts of feldspar and muscovite.

The upper sequence of the Campbell River Group has only been metamorphosed to lower amphibolite facies and is overprinted by two foliations. The nature of its contact with surrounding plutonic rocks of the Peter Lake Domain is indeterminate, but the lower amphibolite facies metamorphism of the group is in stark contrast to upper amphibolite facies assemblages of the remaining Peter Lake Domain, suggesting that the sedimentary rocks either postdate an earlier high-grade metamorphic event or that they are allochthonous. The lower sequence of the Campbell River Group is not exposed along Highway 905. Measurements from 20 rippled foresets (Figure F-44) in unit 1 yielded a unimodal, east-southeast-trending paleocurrent direction. Despite the fact that the sequence has been doubly folded, the geometry of the folds suggests that this paleocurrent direction is likely correct, as it is located on the northwest-dipping normal limb of a synformal syncline. Specifically, it is located on the s-limb of an F2 isoclinal syncline and on the z-limb of a major, slightly east-plunging F3 fold that refolded the F2 isocline (Figure F-45).

Isotopic analysis of U and Pb in zircons from this sample was carried out using both the ID-TIMS and LA-ICP-MS technique. For ID-TIMS analysis, zircon grains were generally selected from a heavy mineral fraction where only the most magnetic material was removed, in order to select the most random population of detrital zircon grains possible. The sample is characterized by abundant colourless zircons, most of which are small with iron staining and fractures. Subhedral prisms are the dominant zircon population. There is little evidence for significant abrasion (*i.e.*, minimum evidence for extensive saltation) for this detrital suite. Subordinate blue-grey anatase was also recovered. Four single zircon crystals had low to moderate U contents (215 to 460 ppm) and similar Th/U ratios (0.3 to 0.38), with three of the four yielding similar $^{207}Pb/^{206}Pb$ dates (2477 to 2489 Ma). All four zircon analyses are significantly discordant (up to 60%), indicating a substantial amount of post–1800 Ma Pb loss. A best-fit regression line, constructed to pass through three of the zircon crystals (2, 3, and 5), yielded an upper intercept age of 2487 ±20 Ma, which could reflect the dominant age of detritus in this sample. The lower intercept date of this regression line is close to zero.

A total of 36 zircons were analyzed using the laser ablation technique. The resulting $^{207}Pb/^{206}Pb$ ages vary between 1984 and 2548 Ma, with a strong peak between 2360 and 2460 Ma. About 16 of the zircons plot near concordia (-10% to +7% discordant) and give $^{207}Pb/^{206}Pb$ dates between 2253 and 2482 Ma. Most of the remaining, strongly discordant zircons have likely been affected by younger Pb loss, and a concordia line can be constructed through them that gives an upper intercept age of about 2500 Ma, which is similar to, but slightly younger than, the results from the Campbell River Group sample collected in the lower sequence. The youngest concordant grain is 2253 ±45 Ma, which is the current best estimate for a maximum depositional age of the upper sequence of the Campbell River Group.

Highway 905 Granodiorite (Wathaman Batholith): 1.85 Ga

RM0201-171

A large, highly attenuated pluton (approximately 500 m by >10 km) of grey to pinkish grey, medium-grained, homogeneous granodiorite (Figure F-46) is exposed along Highway 905 (Figure F-01). The equigranular, massive rock contains 30 to 40% plagioclase, 20 to 30% quartz, 15 to 25% K-feldspar, up to 10% hornblende and biotite, and minor titanite. The pluton postdates strongly foliated to gneissic gabbros and diorites of the Warner Lake gabbroic suite (Maxeiner and Hunter, 2002a), a component of the Swan River Complex. The granodiorite predates at least two phases of regional folding, and its marginal zones are, in part, strongly foliated to mylonitized due to shearing and deformation related to the Trans-Hudson Orogeny. Internally, the pluton contains minor chlorite-coated fractures/shears and is cut by minor leucogranite sheets.

The least magnetic mineral fractions from this sample contained abundant apatite (90%), graphite, and a small amount of zircon. The recovered zircon grains were generally very small (30 to 60 μm), varied from colourless to light tan, and ranged from subhedral to euhedral prisms and colourless equant spheres or stubby prisms. A number of thin platy zircon grains were also observed. Some zircon fractions contained mineral inclusions. Despite the fact that quite different morphological zircon grain types were selected (*i.e.*, one fraction consisted of 13 tan subhedral prisms and a second fraction of 11 colourless tiny spheres), these two multi-grain fractions (#1, #3) yielded comparable uranium U contents (189 to 192 ppm), similarly high Th/U ratios (0.61 to 0.72), and similar $^{207}Pb/^{206}Pb$ dates (1837 and 1826 Ma, respectively) A reference line constructed to pass through these two analyses yielded an upper intercept age of 1843 ±12 Ma, which could reflect the time of significant zircon growth in this sample. The third zircon analysis consisted of a single tan euhedral prism (#2), which had a significantly lower Th/U ratio (0.40) and yielded a much older $^{207}Pb/^{206}Pb$ date of 2371 ±1 Ma. This date could be interpreted in one of two ways: 1) it represents a minimum age for the crystallization of primary igneous zircon and the 1843 Ma date is closer to the time of metamorphism; or 2) the emplacement age of this granodiorite was *ca.* 1843 Ma and the zircon population contains a proportion of older Paleoproterozoic or Archean inherited zircons.

Sm-Nd Tracer Isotopic Analyses by the Geological Survey of Canada

Analytical Techniques

Tracer isotopic analyses were conducted using the Nu Plasma multi-collector ICP-MS at the Geological Survey of Canada. Isotopic compositions of Sm and Nd were analyzed using an array of fixed Faraday collectors in static multi-collector mode. The εNd values are calculated at the time indicated in the text relative to the accepted Chondritic Uniform Reservoir, with $^{143}Nd/^{144}Nd = 0.512636$ and $^{147}Sm/^{144}Nd = 0.1966$, according to the model of Goldstein *et al*. (1984).

Results

This section displays several new Sm-Nd analyses (*see accompanying Excel file*) from samples of mafic intrusive rocks of the Swan River and Porter Bay complexes. The Wiley Bay leucogabbro, which yielded a U-Pb zircon crystallization age of 2560 ±1 Ma, was sampled near

Wiley Bay (Figure F-08), south of Patterson Island on Reindeer Lake (sample RM0301-108). To view the geochronological results, refer to the 'Results (GSC)' section of this report. Two Sm-Nd isotopic analyses were performed on this sample, yielding calculated εNd of +1.6 and +1.0 (Figure F-47). Both of these values indicate a relatively juvenile source. Considering an estimated εNd of approximately +6.5 for contemporaneous depleted mantle (Goldstein *et al.*, 1984), the data suggest possible prior enrichment at the source or contamination during ascent. Additional εNd values were previously reported for rocks of the Peter Lake Domain (Rayner *et al.*, 2005b), including Neoarchean amphibolite, gabbro, granite, granite gneiss, and tonalite, which ranged between -0.84 and +3.70, although four of the values were based on assumed crystallization ages.

Three other Sm-Nd analyses were obtained during this study. The sampled rocks included a gabbro and a monzodiorite from the Patterson Island Pluton (samples RM0301-099, CXA-99-D103; Figure F-08), and a gabbro from the Wathaman Batholith (sample RM0401-121; Figure F-12). The Patterson Island Pluton samples, dated at 1913 and 1917 Ma, respectively, yielded εNd values of -2.28 and -3.92, respectively, and the Wathaman Batholith gabbro, dated at 1854 +5/-4 Ma, yielded an εNd value of -4.3.

Summary

Based on previous geochronology in the Peter Lake Domain, an early granitic plutonic event is known to range in age from 2580 to 2566 Ma (Maxeiner *et al.*, 2004b; Rayner *et al.*, 2005b) and postdates an older (?>2.63 Ga) granodiorite-tonalite migmatitic complex containing enclaves of minor supracrustal gneisses. Three new samples of gabbroic rocks from across the Peter Lake Domain, in association with an historical age from north Reindeer Lake (Corrigan, 2001; Corrigan *et al.*, 2001), constrain the age of Swan River Complex plutonism to between 2562 and 2560 Ma. Monazite from a garnet-rich pelite, dated at 2550 Ma, is interpreted as having grown during a Neoarchean metamorphic overprint. This is broadly consistent with the 2530 Ma age from titanite that grew in a 2566 Ma quartz monzonite (Annesley *et al.*, 1992). A 2540 Ma monzonitic rock from the southwestern part of the domain, and a 2529 Ma gabbroic rock from the Zengle Lake area in the northeast, confirm a late Neoarchean magmatic event in the domain. Based on these results, the 40 m.y. period between ca. 2570 Ma and ca. 2530 Ma appears to have been a time of active magmatism in this area, dominated by ca. 2570 Ma granitic (66 to 76 wt% SiO_2; Figure G-15) and 2560 Ma dioritic to gabbroic (43 to 56 wt% SiO_2; Figure G-01) intrusions. The presence of these two voluminous plutonic suites and their apparent bimodal character may indicate that they were emplaced during a period of extensional tectonics. The 2550 Ma metamorphic overprint may have been related to thermal heating as a result of the emplacement of the voluminous plutons.

The Campbell River Group has been found to consist of two sequences:

1) An older amphibolite-facies sequence, consisting of a basal boulder conglomerate, feldspathic arenite, cross-bedded subfeldsarenite, calcic feldspathic wacke, and minor black argillite, is constrained to be younger than 2383 ±17 Ma, based on the youngest roughly concordant zircon. Most of the detritus has a 2590 to 2480 Ma provenance, and four grains give ages between 2.7 and 2.6 Ga.

2) A younger, greenschist to lower amphibolite facies succession, consisting of feldspathic wacke, black argillite, and cross-cutting lamprophyre sills and dykes, is constrained to be younger than 2253 ±45 Ma, again based on the youngest roughly concordant zircon. The provenance of zircons contained in the sample from this upper sequence is different, giving $^{207}Pb/^{206}Pb$ ages between 2480 and 2250 Ma, with the largest zircon population between 2460 and 2360 Ma.

Minimum depositional ages for the two sequences are not available. The maximum depositional age for both sequences is speculated to postdate the age of rifting along the Hearne Craton margin (i.e., 2075 Ma). The geochronology supports the idea that the Campbell River Group comprises two distinct supracrustal successions. Zircons within the older sequence suggest derivation from the 2.63 to 2.56 Ga granitic to gabbroic basement of the Peter Lake Domain, supported by a basal unconformity discovered during fieldwork. The younger sequence has a different provenance, involving detritus from a source other than the southern Hearne Province. Granitoid rocks within the Sask Craton, exposed in two tectonic windows in the Glennie and Flin Flon domains, record zircon growth between 2525 and 2425 Ma (Rayner *et al*., 2005b). It is possible that detritus within the younger sequence of the Campbell River Group was in part derived from the Sask Craton, although paleocurrent measurements indicate easterly to southeasterly directed flow during deposition of unit 1 of the sequence (Hunter, 2003). The younger sequence could also represent an allochthonous sheet, as originally suggested by Maxeiner and Hunter (2002a).

Emplacement of the gabbroic to monzonitic Porter Bay Complex in two areas within the Peter Lake Domain occurred between 1917 and 1912 Ma, and was also accompanied by deposition of tuffaceous sequences and emplacement of subvolcanic intrusions of trachyandesitic composition, all entrained within the younger plutonic rocks. The Porter Bay Complex was emplaced along the margin of the rifted Hearne Craton.

Rhythmically layered gabbro, monzodiorite, and quartz diorite, and abundant, partly megacrystic monzogranite intruded large parts of the Peter Lake Domain between 1865 and 1854 Ma. These magmatic rocks are particularly widespread towards the northeastern end of the domain and form part of the Wathaman Batholith.

Lithogeochemistry

Introduction

This section and its subsections present details on the geochemical characteristics of the various lithological suites of the Peter Lake Domain. The geochemical data and analytical techniques can be found in a Microsoft® Excel spreadsheet and are also part of the main Microsoft® Access database, both accessible through the 'Data and Downloads' section of the report. The whole-rock geochemical data are also included with the ESRI® ArcReader project.

Sample Details

Whole-rock geochemical data from 205 samples (Maxeiner and Leatherdale, 2003d; Maxeiner *et al.*, 2004b; Maxeiner and Rayner, 2005; Maxeiner, 2006c) were used to assess the characteristics of Peter Lake Domain rocks. These samples include 120 gabbroic rocks, 24 granitoids, 23 volcanic rocks, 14 diorites, ten ultramafic rocks, and a number of other assorted rocks.

The thumbnail on the right provides access to a table (Table G-01) containing a list of samples for which whole-rock geochemical analysis was performed. Major, trace, and rare earth element (REE) concentrations of whole-rock grab samples were determined at Activation Laboratories Ltd. in Ancaster, Ontario by inductively coupled plasma–mass spectrometry (ICP-MS). A fusion digestion technique (lithium metaborate/tetraborate fusion) was used to ensure complete dissolution of the more refractory minerals (*e.g.*, zircon, sphene). Replicate analyses of samples and traditional standards (STM-1, MAG1, BIR1, W2, MRG1, SY3, and GXR1) were analyzed with the samples to check analytical accuracy and precision. Analytical errors for the REEs are generally <5%; for all other trace elements, they are 10% or better. The CIPW norms were calculated using a spreadsheet designed by K. Hollocher(http://minerva.union.edu/hollochk/c_petrology/; last accessed, Jan-2009).

The geochemical data are presented below as broad compositional groupings, within which results from the main lithological suites in the Peter Lake Domain can be accessed:

- Mafic Complexes
    - Swan River Complex
    - Zengle Lake gabbro
    - Porter Bay Complex
    - Wathaman Batholith (mafic components)
- Granitoids
    - Lueaza River granitoid suite
    - Monzonitic intrusive suite
    - Other intrusive rocks
- Volcanic Rocks
    - Mafic-ultramafic volcanic rocks

Highlights

- An early finding of this project was the recognition of four separate mafic plutonic complexes in the Peter Lake Domain, which had previously been grouped together into an individual suite. Lithologically very similar, the individual complexes were distinguished initially through geochronology; however, a further objective was to discern geochemical differences that would facilitate discrimination between Archean and Paleoproterozoic gabbros. This was achieved for the two main mafic complexes (Swan River and Porter Bay) using Sm/Y and La/Sc ratios, which are generally higher in rocks of the Porter Bay Complex. Radiometric signatures of the mafic complexes also revealed distinct differences, with the Porter Bay Complex generally having higher eTh and K concentrations (see the 'Geophysics' section for more details).

- Based on a combination of geochemical data and petrological criteria, our preferred model is emplacement of the Swan River Complex in a continental rift and the Porter Bay Complex in an arc environment. Furthermore, gabbros and diorites of the Wathaman Batholith have continental-arc geochemical signatures, consistent with the existing geodynamic interpretation for this suite, whereas the data set for the Zengle Lake gabbro is too small to allow a lithotectonic interpretation. These interpretations have important implications for the tectonic evolution of the northwestern margin of the Trans-Hudson Orogen.

- Analyses of the mafic igneous rocks for Pt, Pd, Ni, Cu, Au, Ag, and other metals helped in locating new economically prospective areas in the Peter Lake Domain. This aspect of the geochemical data set is discussed in the 'Economic Geology' section.

Mafic Plutonic Complexes

As discussed in more detail in the 'Regional Geology' section, the mafic plutonic components of the Peter Lake Domain have been separated into four discrete plutonic suites:

- *2562 Ma Swan River Complex*
- *2529 Ma Zengle Lake gabbro*
- *1917 to 1913 Ma Porter Bay Complex*
- *Wathaman Batholith (1859 to 1850 Ma mafic component)*

The geochemistry of these four suites is discussed below, followed by an overview of some important differences between the suites and then a discussion of the results and conclusions.

2562 Ma Swan River Complex

Data from samples of Swan River Complex gabbros from across the Peter Lake Domain show considerable scatter when plotted on Harker diagrams (Figure G-01).

Major element concentrations of most Swan River Complex gabbro samples are 43 to 56 wt. % SiO_2, 10 to 23 wt. % Al_2O_3, 7 to 13 wt. % CaO, and 2 to 5 wt. % K_2O+Na_2O. The Ni and Cr contents of these rocks are highly variable and, although they do not typically exceed 200 ppm, values as high as 1700 and 600 ppm were obtained from the more mafic to ultramafic samples of the suite (Table G-02). The proportion of mafic to ultramafic rocks within the Swan River Complex is extremely low.

The considerable scatter on the Harker diagrams could be due to one or a combination of the following reasons: variable amounts of crustal contamination and/or fractional crystallization; heterogeneity in the mantle source; possible temporal and lithotectonic heterogeneity of plutonic suites within the Swan River Complex; and/or disturbance of primary compositions during post-crystallization metamorphic and/or hydrothermal events.

Combined trace and rare earth element compositions for gabbros of the Swan River Complex are plotted on chondrite-normalized spider diagrams (Figure G-02). They show relatively consistent sample-to-norm ratios and thus produce patterns with similar shapes, although the relative abundance of trace elements varies. The La/Lu_N ratios of these rocks generally range from 3 to 10, indicating significant fractionation of these magmas from primordial mantle composition. The Swan River Complex rocks show slight enrichment of some of the incompatible elements, such as La, Ce, Pr, and Nd, relative to the high field strength elements (HFSE; *e.g.,* Nb, Zr), resulting in noticeable negative anomalies of the latter. Heavy rare earth element concentrations relative to norm are quite low (generally less than 10 times chondritic values) and characterized by relatively flat patterns.

2529 Ma Zengle Lake Gabbro

For simplicity, the geochemistry of the MacKenzie Lake gabbros, which are situated along strike and to the southwest of the Zengle Lake gabbros, is discussed here with the 2529 Ma Zengle Lake gabbros, despite being treated as undivided gabbros on the 1:100 000-scale compilation map (Maxeiner, 2006b). The La/Lu_N ratio of the Zengle Lake gabbro sample that was dated (RM0401-021) is 4.3, and it has a relatively flat trace element signature at about ten times chondritic value (Figure G-03), with minor negative Nb, Zr, and Ti anomalies. The MacKenzie Lake gabbro data were divided into two groups based on the trace element diagrams. Group 1 samples are characterized by slightly less fractionated trace element patterns (La/Lu_N = 6 to 14) with minor or no negative Ti anomalies. Group 2 samples are more fractionated (La/Lu_N = 7 to 25) with more distinctive negative Ti anomalies, as well as negative Nb and Zr anomalies.

Despite the subtle differences in trace element concentrations for these two groups, coherent trends are apparent on Harker diagrams (Figure G-04). The Fe_2O_3, MgO, CaO, and Sc in analyzed gabbros from the Zengle Lake and MacKenzie Lake areas are negatively correlated with respect to SiO_2; Na_2O, P_2O_5, Zr, Nb, Y, La, and Nd are positively correlated; and K_2O and TiO_2 show no correlation.

If all Zengle Lake and MacKenzie Lake gabbros represent part of the same 2530 Ma gabbroic suite, the geochemistry suggests a temporal evolution of more primitive (Zengle Lake and MacKenzie Lake Group 1) to more evolved and possibly slightly younger MacKenzie Lake Group 2 magmas. Group 1 samples may, in part, be related to the 30 m.y. older Swan River Complex. Alternatively, Group 2 magmas may be related to the geochemically similar but much younger Porter Bay Complex.

1917 to 1913 Ma Porter Bay Complex

Based on the CIPW norm and petrographic work, plutonic samples of the Porter Bay Complex are characterized as gabbro, diorite, monzodiorite, and monzonite, and volcanic rocks are classified as trachyandesite to andesite (Figure G-05). Major element concentration ranges of samples that were analyzed in this study are 49 to 57 wt. % SiO_2, 15 to 23 wt. % Al_2O_3, 5 to 9 wt. % CaO, 5 to 9 wt. % K_2O+Na_2O, <52 ppm Ni, <45 ppm Cr, and Mg numbers around 0.25 (total iron as Fe_2O_3). The overall TiO_2, Fe_2O_3, MgO, and CaO contents decrease with increasing SiO_2, whereas K_2O and Na_2O increase (Table G-02). With the exception of MgO, K_2O, and P_2O_5, all other major and trace elements compare favourably with a reference suite of samples of the Wathaman Batholith (Figure G-06). The data for that reference suite are derived from previous studies (Fumerton *et al.*, 1984; Meyer *et al.*, 1992; MacHattie, 2001) and augmented with samples from the present study.

Most of the analyzed samples from the Porter Bay Complex have high total Fe relative to SiO_2, characterizing them as 'ferroan' (rather than 'magnesian') according to Frost's classification scheme for granitoids (Figure G-07), which also includes monzonitic, dioritic, and gabbroic rocks (Frost *et al.*, 2001). The modified alkali-lime index (MALI; Frost *et al.*, 2001), derived from the alkali-lime index of Peacock (1931), characterizes most samples as calc-alkaline to alkali-calcic (MALI = –4.1 to +3.6), with one sample being slightly alkaline. A subalkaline character for these rocks of the Porter Bay Complex is supported by their Nb/Y ratios of <1 (Pearce, 1996), although their Na and K concentrations suggest slightly alkaline signatures, indicative of potential mobility of the alkali elements. Based on the aluminium saturation index (ASI = Al_2O_3 / [CaO + Na_2O + K_2O – 1.67*P_2O_5]; Frost *et al.*, 2001), which is a modification of Shand's index (Maniar and Piccoli, 1989), the volcanic and plutonic rocks are considered metaluminous. When compared to the Wathaman Batholith reference suite, samples of the Porter Bay Complex are more ferroan, but have a similar MALI.

The K_2O concentrations for plutonic and volcanic rocks of the Patterson Island Pluton–Porter Bay Complex are relatively high and, when plotted against SiO_2, classify the rocks as having been derived from high-K calc-alkaline to shoshonitic magmas (Figure G-08). The Wathaman Batholith reference suite is classified as high-K calc-alkaline in character.

The Porter Bay Complex plutonic and volcanic rocks have Th/Yb and Th/Ta ratios between 0.8 and 5, and 5 and 20, respectively (Figure G-09). These ratios are comparable to those of mafic (Pearce, 1983) and intermediate to felsic volcanic rocks from modern settings (Gorton and Schandl, 2000), generated in active continental-margin environments. Similarly, relatively low overall abundances of Y, Nb, and Rb (not shown) are comparable to those of modern granitoid rocks (Pearce *et al.*, 1984), implying formation in an arc environment.

Incompatible trace element and REE compositions for monzodiorite and gabbro of the Porter Bay Complex are shown as chondrite-normalized spider diagrams (Figure G-10). The patterns have similar overall shapes but variable relative elemental abundances. The La/Lu_N ratios of the analyzed samples range from 12 to 31, indicating moderate degrees of fractionation between magmas. Porter Bay Complex rocks are enriched in incompatible elements, such as Th, La, Ce, Pr, and Nd, relative to HFSE (Nb, Zr, and Ti), thus producing distinct negative HFSE anomalies. The heavy rare earth element (HREE) patterns are relatively flat, indicating that garnet was stable in the source area of magma generation.

Wathaman Batholith (1859 to 1850 Ma mafic component)

Major and trace element Harker variation diagrams for dioritic to gabbroic rocks of the Wathaman Batholith are shown in Figure G-11, with data from Maxeiner's sample set (circles) plotted alongside some historical data (circles; Fumerton *et al.*, 1984; Meyer *et al.*, 1992; MacHattie, 2001). The data adhere to the criteria established for the Wathaman Batholith by MacHattie (2001), with good correlation between SiO_2 and most of the major and trace elements.

Using the same geochemical classification procedures as for the Porter Bay Complex, the mafic Wathaman Batholith samples are characterized as magnesian, metaluminous, calc-alkaline rocks (not shown), consistent with their interpreted emplacement in a continental-arc tectonic setting (*e.g.,* Meyer *et al.*, 1992).

Chondrite-normalized trace element diagrams for samples analyzed in this study (Figure G-12) show HFSE and REE concentrations very similar to those reported elsewhere for the Wathaman Batholith (Fumerton *et al.*, 1984; Meyer *et al.*, 1992; MacHattie, 2001). Notable characteristics of the suite include pronounced negative HFSE anomalies and variably enriched incompatible element abundances. The latter feature is consistent with differentially fractionated magma suites (Table G-02).

Geochemical Differences Between Gabbroic Complexes

As mentioned on the introductory page, gabbroic rocks of the Peter Lake Domain were the principal lithological focus for geochemical characterization in this project. In conjunction with the bedrock mapping and radiometric dating, we were able to identify differences between the two main mafic complexes of the domain using geochemistry (Figure G-13).

Rocks of the Porter Bay Complex rocks have distinctly higher La/Sc and slightly higher Sm/Y ratios than those of the older Swan River Complex. This difference is also reflected in their chondrite-normalized extended trace element signatures, with Porter Bay Complex rocks displaying slightly more fractionated trace element patterns (Figure G-14). Porter Bay Complex rocks are also characterized by very distinct negative HFSE (*i.e.*, Nb, Zr, Ti) anomalies. In contrast, extended trace element signatures for the Swan River Complex rocks are, overall, less fractionated (*i.e.*, relatively flat), with the exception of negative Zr anomalies and slightly positive Eu anomalies. Gabbroic and dioritic rocks of the Wathaman Batholith, the youngest of the mafic suites, have Sm/Y and La/Sc ratios similar to those of the Swan River Complex but can be distinguished from the latter by their negative Ti anomalies on extended trace element signatures. Mafic rocks from the 2530 Ma Zengle Lake (and presumably contemporaneous MacKenzie Lake) gabbroic rocks have somewhat variable signatures on chondrite-normalized extended trace element plots: they have quite variable overall enrichment levels and degrees of REE fractionation, and some exhibit negative Nb, Zr, and Ti anomalies, whereas others do not. Their Sm/Y and La/Sc ratios are not useful inter-suite discriminators, as they extend from Swan River Complex field into that of the Porter Bay Complex (not shown).

The following guidelines will help to geochemically distinguish among the various gabbroic suites of the Peter Lake Domain (Figure G-14):

1. Gabbroic rocks characterized by low La/Sc and Sm/Y ratios and multi-element patterns that lack negative Ti anomalies are probably part of the Swan River Complex.

2. Gabbroic rocks with low La/Sc and Sm/Y ratios and negative anomalies for all HFSE (including Ti) are related to the Zengle Lake gabbros or the Wathaman Batholith.

3. Gabbroic rocks with high La/Sc and Sm/Y ratios, coupled with negative HFSE anomalies, are probably, but not conclusively, part of the Porter Bay Complex.

Discussion and Conclusions

Despite the relatively large whole-rock geochemical data set presented here for mafic rocks of the Peter Lake Domain, the observations above and the discussion below must be treated carefully. Many of the samples were collected in cumulate or pegmatitic phases, or include porphyritic rocks, none of which represent the true bulk composition of the host pluton or suite. When assessing the chemical composition of large mafic intrusions and in order to make predictions about the parental magma, rapidly chilled magmas (*i.e.*, fine grained) are the most desirable sample targets. No such unequivocal chilled magmas were sampled or even encountered during this mapping project.

The trace element data for the Swan River Complex, characterized by relatively low La/Lu_N ratios, but slightly elevated overall REE abundances and negative Nb and Ti anomalies, could indicate a) emplacement in a convergent plate tectonic setting, b) derivation from an enriched mantle source in a non-convergent tectonic setting, and/or c) the effects of crustal contamination processes. An εNd of around +1.6 for the 2560 ±1 Ma Wiley Bay leucogabbro (sample RM0301-108; see 'Sm-Nd Tracer Isotopic Analyses' page in the 'Geochronology' section) is considerably lower than the expected depleted mantle composition for that time (calculated εNd of +4.3 at 2560 Ma; Goldstein *et al.*, 1984), which is consistent with input of evolved crustal material into the magma.

Many layered intrusions throughout the world, including the Bushveld Complex, the Munni Munni Intrusion, the Great Dyke, and the Stillwater Complex, display highly fractionated incompatible trace element patterns with negative HFSE anomalies (*e.g.*, Hoatson and Sun, 2002; Maier and Barnes, 2005; Wilson and Chunnett, 2006). Debate still exists in the literature about whether the crustal signature in these mafic magmas is due to crustal contamination during magma ascent or reflects an enriched source in the sub-continental lithospheric mantle. However, there is general agreement that these intrusive complexes were emplaced within extensional, mid-continental rifts. Similarly, given the extent, lithological make-up, and petrography of the Swan River Complex, we interpret it to have been emplaced in an extensional environment and therefore suggest that the magmas were subject to some degree of crustal contamination, at least in the early stages of rift development. Further detailed geochemical and isotopic data from individual plutons of the Swan River Complex are needed to further elaborate on the petrogenetic processes that affected the magmas during ascent and emplacement.

The Porter Bay Complex, which is exposed only in two localized intrusive centres near Patterson Island and southeast of Peter Lake, is a distinctive mafic to intermediate igneous suite that was emplaced *ca.* 1920 Ma. The generation and evolution of these magmas was controlled, to some degree, by the lithotectonic environment, which influences the source composition, the degree and depth of partial melting, and the role of later processes such as fractional crystallization and crustal contamination. The compositional character of the Porter Bay Complex volcanic and plutonic rocks, which have intruded >2560 Ma basement of the Hearne Craton, thus have significant implications for the interpreted plate tectonic evolution of the northwestern Trans-Hudson Orogen at this time.

Previous tectonic models for the evolution of the Trans-Hudson Orogen during this time period (*e.g.,* Lewry, 1981; Bickford *et al.,* 1990; Meyer *et al.,* 1992; Ansdell *et al.,* 1995; Tran *et al.,* 2003; Maxeiner *et al.,* 2005) suggest that the proto–Peter Lake Domain was located along the northwestern edge of the Manikewan Ocean. Closure of the ocean is documented to have been well underway by 1870 Ma (*e.g.,* Meyer *et al.,* 1992; Lucas *et al.,* 1996; Ansdell *et al.,* 2005), as evidenced by the generation and amalgamation of voluminous arc assemblages in the Flin Flon, Glennie and La Ronge domains. Along the Hearne Craton margin, rift-related quartzofeldspathic sediments interbedded with mafic flows were deposited at the base of the Wollaston Supergroup and are overlain by foreland basin sediments. Although the presence of these sedimentary successions records the closure of the Manikewan Ocean, the age of the foreland basin succession is not well established. Neodymium isotope and detrital zircon U-Pb studies of the foreland basin succession of the Wollaston Supergroup (Tran, 2001; Tran *et al.,* 2003) found evidence for deposition of 1920 to 1880 Ma detritus, which they suggested had been derived from the east. This interpretation implies the presence and erosion of a tectonically active area along the eastern Hearne Craton margin at about 1880 Ma, proposed to be the *ca.* 1900 Ma 'Rottenstone Continental Arc' (Tran *et al.,* 2003). The existence of an earlier continental arc along the southeastern Hearne margin prior to emplacement of the Wathaman Batholith at *ca.* ?1865 Ma has previously been postulated (Ray and Wanless, 1980; Lewry *et al.,* 1981). However, in a revised version of this model, it was proposed that accretion of oceanic island arcs to the continental margin occurred prior to emplacement of the Wathaman Batholith. Bickford *et al.* (1990) and Meyer *et al.* (1992) suggested that the La Ronge oceanic arc was accreted to the Hearne Craton prior to being 'stitched' to the continent by the Wathaman Batholith between 1865 and 1855 Ma. They invoked southeast-directed subduction for arc accretion due to a lack of evidence for an older volcano-plutonic assemblage along the Hearne Craton margin. However, Maxeiner *et al.* (2005) subsequently suggested that the La Ronge arc could not have been involved in continental accretion prior to emplacement of the Wathaman Batholith, since there is evidence that it was caught up in intraoceanic accretion with the Glennie–Flin Flon Complex at about 1860 Ma.

Based on the fieldwork and geochronological and geochemical constraints presented in this report, emplacement of a volcanic edifice (volcanic xenoliths of the Porter Bay Complex) on top of a granitic, tonalitic, and gabbroic Neoarchean continental basement is envisaged. This was accompanied by crystal fractionation processes in magma chambers at the base of the crust and in the plutonic root zones of the volcanic edifice, as evidenced by the presence of cumulate textures in the Porter Bay Complex gabbroic rocks. The Patterson Island Pluton was emplaced at a higher structural level, a few million years after the volcanic rocks (1915 Ma volcanic xenoliths were found in a 1913 Ma leucogabbroic host) and some of the earlier gabbroic rocks. Deformed volcanic xenoliths in some plutons suggest that some deformation occurred after eruption of the volcanic rocks and before emplacement of the latest plutonic rocks. Geochemical evidence shows that all volcanic and plutonic rocks of the Porter Bay Complex display a common fractional crystallization trend (*i.e.*, a common parental magma, with decreasing TiO_2, Fe_2O_3, MgO, and CaO, and increasing K_2O and Na_2O, towards higher SiO_2 contents). Such relationships are common calc-alkaline differentiation trends, possibly due to the crystallization of early Fe-Ti phases and/or An-rich plagioclase. The volcanic components are generally more primitive than the plutonic rocks. In a temporal sense, this is consistent with the observed field relationship of deformed volcanic rock inclusions within the monzodiorite. However, overall low Ni and Cr concentrations may suggest that even the most ‘primitive’ rocks of the Porter Bay Complex are already a product of fractionation, possibly a result of secondary fractionation processes in a 'staging' magma chamber at the base of the crust. Trace element signatures suggest that Ti-magnetite and apatite were also crystallizing phases in this magma chamber, as these elements are less abundant in the younger, more fractionated rocks. Most of the volcanic rocks and some of the more mafic plutonic rocks were probably emplaced relatively early, whereas most of the monzodioritic plutonic rocks with lower Mg# and higher K_2O and Na_2O concentrations were emplaced later. Further crystal fractionation took place in the highest level magma chamber during final cooling and solidification of the Paterson Island Pluton.

The major and trace element concentrations for volcanic and plutonic rocks of the Porter Bay Complex are virtually indistinguishable from historical and newly acquired data for the Wathaman Batholith, which has been well established as a continental magmatic arc (*e.g.*, Fumerton *et al.*, 1984; Meyer *et al.*, 1992; MacHattie, 2001). Negative HFSE anomalies, Nb-Y ratios, Th-Ta-Yb ratios, and major element ratios all are consistent with magma generation of both igneous complexes in a subduction-generated continental-arc environment (Pearce, 1996).

Initial Nd isotopic compositions for the Wathaman Batholith and Porter Bay Complex magmas are also comparable, with εNd values for both suites ranging between -4 and -2 at their respective times of emplacement. In a detailed Sm-Nd study of the Wathaman Batholith, MacHattie (2001) suggested that the negative εNd values determined for the northern part of the batholith are characteristic of magmas derived from an enriched lithospheric mantle source, which were also affected by crustal contamination processes. Similar conditions are likely to have existed 60 m.y. earlier, during emplacement of the Porter Bay Complex magmas along the same craton margin. Unlike many Andean continental-arc plutons, the Porter Bay Complex does not seem to contain comagmatic granodioritic to granitic rocks. This could be explained by the observation that the geochemical sample suite used in this study is limited to monzonitic and gabbroic rocks that have well-constrained field relationships to the four U-Pb geochronology sample sites. As a result, the sample set is biased towards gabbroic and monzonitic rocks. Many of the granodioritic to granitic rocks in the Peter Lake Domain have unresolved age constraints; granitoids emplaced contemporaneously with identified mafic rocks of the Porter Bay Complex are likely also present, but have not yet been identified.

A recent petrogenetic study of the Wathaman Batholith in the Reindeer Lake area (MacHattie, 2001) concluded that this remnant of a complex continental-margin magmatic arc could be subdivided into two geochemically distinct zones, termed the Northeast Zone and Southern-Central Zone. In order to explain the unique high-K, calc-alkaline to alkaline geochemical characteristics of the Northeast Zone Monzonitic Series of the batholith, MacHattie (2001) invoked an involvement of enriched lithospheric mantle in the generation of these northernmost magmas, which he interpreted to have resulted from northward-directed subduction. However, at least five of the ten samples that defined the Northeast Zone Monzonitic Series in that study were taken from within the Patterson Island Pluton, now known to be a separate magmatic complex about 60 m.y. older than the Wathaman Batholith. Although this casts doubt on a small component of MacHattie's (2001) study, more significantly it emphasizes the overall similarity between rocks of the northern margin of the Wathaman Batholith and the Porter Bay Complex. Similar to the interpretations in MacHattie's thesis, the overall more alkaline (high-K) nature of the Porter Bay magmas compared to the central zones of the Wathaman Batholith magmas could be explained in terms of their emplacement towards the continental interior (*i.e.*, at greater distance and depth from an active northward-dipping subduction zone; Gill, 1970). This might also explain why rocks of this age are relatively scarce along the present-day southeastern Hearne margin: the ancient continental margin was located farther to the southeast, in the area now largely occupied by the Wathaman Batholith.

An alternative possibility is that the Porter Bay Complex is representative of sanukitoid melts. Neoarchean sanukitoid suites have been recognized in several places around the world, including the northwestern Superior Province (Shirey and Hanson, 1984; Stern *et al.*, 1989). Sanukitoids are also often associated with Phanerozoic subduction settings and are thought to originate as melts of subducted oceanic crust. The Porter Bay Complex has some lithological and mineralogical similarities to sanukitoid suites, but differs in terms of its overall geochemical composition, which is a key criterion in their definition. The Porter Bay Complex has lower SiO_2 concentrations (generally around 50 wt. %, compared to 55 to 60 wt. % for sanukitoids), lower Ni and Cr concentrations (<100 ppm, compared to >100 ppm for sanukitoids), and distinctly lower MgO concentrations and Mg#.

In summary, the Porter Bay Complex is interpreted to represent an Andean-type continental arc emplaced along the southeastern Hearne Craton margin between 1920 and 1910 Ma, approximately 60 m.y. prior to emplacement of the world's largest known Paleoproterozoic continental arc, now represented by the Wathaman Batholith. The current extent of the Porter Bay Complex is somewhat limited, as it was likely cannibalized by the Wathaman Batholith. A test of this hypothesis would be to date some of the abundant gabbroic, dioritic, and tonalitic xenoliths reported to occur within the northwestern margin of the batholith (*e.g.*, Fumerton *et al.*, 1984; Corrigan *et al.*, 1999; Maxeiner *et al.*, 2004b). Fumerton *et al.* (1984) were unable to reconcile the presence of diorite and tonalite xenoliths with a comagmatic origin during the formation of the Wathaman Batholith. It is suggested here that some of these xenoliths are actually remnants of the older continental arc represented by the Porter Bay Complex.

Granitoids

- *Lueaza River granitoid suite*
- *Monzonitic intrusive suite*
- *Other intrusive rocks*
- *Discussion and conclusions*

A limited number of samples was used to geochemically characterize the Lueaza River granitoid suite (n = 7), the monzonitic intrusive suite (n = 4), and late syenogranitic rocks (other intrusive rocks; n = 4). Unfortunately, no geochemical analyses are available for granitoid samples taken from within the granodiorite-tonalite migmatite complex or from the Wathaman Batholith.

When the K_2O, Na_2O, and CaO concentrations from whole-rock analyses of all of these rocks are compared to a compilation of more than 500 late Archean granitoids (see Moyen *et al.*, 2003), the Peter Lake Domain rocks are characterized by fairly high K_2O concentrations relative to Na_2O and CaO (Figure G-15), suggesting that anatectic granites represent the closest analogues. However, since the alkalis are notoriously mobile elements and since the Peter Lake Domain has experienced several episodes of late to post-Archean regional metamorphism and potential contact metamorphism, it is likely that the present-day concentration of these elements in most of these rocks is not reflective of their original concentrations. Also, rocks of the Lueaza River granitoid suite are generally hornblende bearing and mesocratic, which are features not commonly shared by anatectic granites.

When compared to trace element concentrations of young granitoids from known geotectonic settings (Pearce *et al.*, 1984), the rocks of the Lueaza River granitoid suite are characterized by relatively high Nb, Y, and Rb values (Figure G-16), suggesting they formed in within-plate settings. The limited number of whole-rock analyses from samples of the 1830 Ma syenogranitic suite yielded the highest Rb concentrations compared to the other granitoid suites. The monzonitic intrusive suite is characterized by relatively lower concentrations of Nb, Y, and Rb, consistent with emplacement in a volcanic arc environment. It should be noted, however, that considerable overlap exists between the three suites on diagrams involving Nb, Y, and Rb (see graphs on right), that the data sets for the individual suites are relatively small and that, like alkalis, Rb is also easily mobilized.

Lueaza River Granitoid Suite

These hornblende- and biotite-bearing, commonly K-feldspar porphyritic granitoids are common throughout the Peter Lake Domain and are characterized by SiO_2 content of 66 to 76 wt. %, K/Na ratio (molar) between 1 and 1.8, ASI index (after Frost *et al.*, 2001: [Al_2O_3/[CaO +Na_2O+K_2O- 1.67*P_2O_5] [molar]) of about 1.00, and Mg# of between 0.1 and 0.2 (see Table G-02). Based on this compositional character, the Lueaza River granitoid suite can be classified as alkali-calcic, ferroan, and transitional between metaluminous and peraluminous. Chondrite-normalized trace element patterns of these rocks (Figure G-17) show negative HFSE anomalies (*e.g.,* Nb, Ti) and strongly fractionated REE patterns with pronounced negative Eu anomalies.

Monzonitic Intrusive Suite

Incompatible trace element patterns of the monzonitic intrusive suite (Figure G-18) are distinct from the Lueaza River granitoid suite in that they lack the distinct negative Eu anomaly and the weak negative Zr anomaly, and are characterized by more fractionated light rare earth element (LREE) contents (La/Lu_N ratios = 60 to 80, as opposed to 12 to 25 for the Lueaza River granitoid suite). They are ferroan, alkaline, and very weakly peraluminous according to the classification scheme of Frost *et al.* (2001). Based on these geochemical criteria and their relatively low concentrations of Rb, Nb, and Y (Figure G-18), the monzonitic intrusive suite has similarities to magmas produced in modern arc environments. The normalized trace element patterns with negative Nb and Ti concentrations generally support this interpretation.

Other Intrusive Rocks

Multi-element patterns for four syenogranitic rocks have similar overall shapes, but strongly varying relative abundances. One of the most pronounced trace element features, relative to the other granitoid rocks of the Peter Lake Domain, is the strong negative Ti anomaly (Figure G-19; note the change in scale from previous diagrams). As with all other granitoid suites, the syenogranites are also characterized by negative Nb anomalies, strongly fractionated REE pattern and overall relatively flat HREE patterns.

Discussion and Conclusions

The geochemistry on this page is provided mainly for data presentation and has not significantly contributed to the interpretation of lithotectonic setting for the granitoid rocks. Considerable overlap exists between the various granitoid suites of the Peter Lake Domain in terms of their major and trace element geochemistry (Figure G-20). Nonetheless, a few general statements can be made, particularly regarding the multi-element patterns.

Generally, negative Eu anomalies, such as that displayed by the Lueaza River granitoid suite, suggest a plagioclase-rich source because Eu is readily accommodated by plagioclase. Alternatively, it could indicate that the magmas underwent significant plagioclase differentiation before their final emplacement. This geochemical character, coupled with the largely hornblende-biotite-bearing nature of the mesocratic monzogranitic rocks, suggests that the Lueaza River granitoid suite rocks likely represent I-type granites.

For example, similar high-K monzogranites with negative Eu anomalies have been described from the Corunna Downs granitoid complex in Western Australia, where they are thought to have resulted from remelting of older tonalite-trondhjemite-granodiorite (TTG) crust (Champion and Smithies, 1999).

For the monzonitic intrusive suite, plagioclase was apparently not a significant factor during melt generation or crystal fractionation processes, as inferred from the lack of a pronounced Eu anomaly. The more depleted Y concentrations and negative HFSE anomalies of this suite possibly suggest that they were generated in a subduction-related environment.

The leucocratic nature of the biotite-bearing syenogranitic suite, in association with its characteristically elevated K/Na ratios and Rb contents, is consistent with its interpretation as anatectic melt sheets derived from partial melting of the granodiorite-tonalite migmatite complex and the Lueaza River granitoid suite.

Mafic-Ultramafic Volcanic Rocks

Two main mafic volcanic units were mapped in the Peter Lake Domain: one northwest of Wiley Bay (Figure G-21) and the other in the McLean Bay area (Figure G-22), both of them on Reindeer Lake. Both of these volcanic successions are interpreted to be Archean, based on cross-cutting relationships of Archean plutonic rocks. Smaller units can be found throughout the Peter Lake Domain and decimetre- to metre-scale mafic volcanic xenoliths, interpreted to have originated from these Archean units, occur within gabbros of the Swan River Complex, as well as in some of the younger plutonic complexes. Geochemical data were only obtained for the two *in situ* mafic volcanic units.

Only one whole-rock geochemical analysis (RM0401-103) of the McLean Bay unit was obtained. It is characterized by a relatively flat normal mid-ocean ridge basalt (N-MORB)–normalized trace element pattern, with slightly elevated Th and a minor negative Nb anomaly (Figure G-23).

Several analyses were carried out on samples collected in a north- to northwest-dipping unit of mafic volcanic rocks that was exposed in an unnamed bay west of Wiley Bay (southwest of Patterson Island) and was traceable westward for several kilometres (Figure G-21). Metamorphic grade increases from upper amphibolite facies to lower granulite facies along strike from southwest to northeast, as shown by changes in the mineralogy and an increase in the prevalence of leucosome. The unit comprises four identifiable lithological subunits, from structural base to top:

1. The most extensive subunit is a fine-grained, heterogeneous, strongly foliated hornblende-plagioclase rock characterized by colour patterns and structures interpreted as deformed pillows (Figure G-24). Local, centimetre-scale, gradational patches of dioritic leucosome contain coarse hornblende, diopside, and cummingtonite after orthopyroxene. Towards the west, this subunit is characterized by local concentrations of garnet and an absence of leucosome (sample RM0301-057).

2. A fine-grained, homogeneous, plagioclase-porphyritic mafic rock (Figure G-25) that intruded subunit 1, but has also been subjected to partial melting (sample RM0301-058).

3. An 8 m-thick subunit of fine- to medium-grained, pale brown–weathering, Mg-rich ultramafic rock (Figure G-26) characterized by fine-grained tremolite, serpentine, phlogopite, talc, and magnetite, and relict olivine. The protolith of this rock is interpreted as a peridotitic sill (sample RM0301-056).

4. An 8 m-thick subunit of fine-grained, pale green- to dusky green–weathering, homogeneous ultramafic rock (Figure G-27) composed of actinolitic tremolite, spinel, magnetite, and relict olivine. This is interpreted as a separate, more Fe-rich ultramafic sill (sample RM0301-055).

All Wiley Bay mafic volcanic rocks (subunits 1 and 2) are characterized by slightly fractionated trace element patterns with negative HFSE anomalies (Figure G-23). They also differ from the McLean Bay unit with respect to field relationships, as the latter is associated with iron formation.

In terms of their relative Na, K, and Si concentrations, all of the mafic volcanic rocks have basaltic compositions (Figure G-28). Two ultramafic rocks, sampled along the structural top and proposed stratigraphic base of the Wiley Bay unit (subunits 3 and 4), have trace element concentrations that yield relatively flat normalized multi-element patterns below unity (Figure G-23). When normalized against chondrite (not shown), they have flat multi-element patterns at 5 to 10 times chondritic concentrations. Based on their Na_2O+K_2O versus SiO_2 ratios and elevated MgO (24 to 32 wt. %) and low TiO_2 (0.26 to 0.45 wt. %) concentrations, the ultramafic rocks are classified as komatiites. However, komatiitic rocks generally have trace element patterns depleted in incompatible elements (*i.e.*, low La/Lu ratios), as, for example, in the

Superior Province (*e.g.*, Hollings *et al.*, 1999), due to the high degree of partial melting required to produce such highly magnesian melts. Pearce Element Ratio diagrams for these rocks suggest that the original mineralogy of both ultramafic units (triangles) is orthopyroxene normative, whereas the mafic rocks are suggested to have all been olivine bearing (Figure G-29).

Discussion and Conclusions

Recrystallization of the mafic and ultramafic volcanic rocks of the Wiley Bay and McLean Bay units under upper amphibolite to granulite facies conditions has resulted in the destruction of all primary mineral assemblages, although some of the original outcrop-scale (*e.g.*, pillows; Figure G-30) and sample-scale (*e.g.*, cumulates?; Figure G-31) textures remain. Based on Harker diagrams of the mafic and ultramafic rocks (Figure G-32), it seems plausible that, despite recrystallization, element mobility has been limited and that, with the exception of two samples (RM0301-004 and RM0301-024), coherent geochemical trends representing primary compositions exist within the Wiley Bay and some smaller mafic volcanic units of the Peter Lake Domain. Based on one analysis of a mafic volcanic rock collected in the McLean Bay area, this unit has distinctly different and more MORB-like trace element signatures compared to those of the Wiley Bay units. This unit also has field relationships distinct from those of the Wiley Bay volcanic rocks in that it is associated with iron formation, intruded by the Wathaman Batholith, and not associated with the Swan River Complex; thus, a different lithotectonic origin and age are possible. Additional geochemical data and geochronology are needed to clarify the nature of the relationship between the McLean Bay and Wiley Bay mafic volcanic units.

The Wiley Bay unit, which is characterized by slight enrichment of incompatible trace elements and LREE, coupled with negative HFSE anomalies, has geochemical similarities to modern arc or back-arc basin basalts. The closely associated Wiley Bay ultramafic rocks, despite their high-Mg, low-Ti, komatiitic major element composition, do not have komatiitic trace element concentrations because they are lacking the distinctive LREE depletion. Instead, they may represent syn- to slightly postvolcanic ultramafic intrusive sills.

Geophysics

Geophysical Survey Data – Peter Lake and Wollaston Lake Areas

In 2003, Fugro Airborne Surveys of Saint-Laurent, Quebec, conducted a high-resolution fixed-wing airborne gamma-ray spectrometric and total field magnetic survey of the Peter Lake Domain (Figure H-01). In 2004, the airborne survey, which was funded as part of Saskatchewan's Mineral Exploration Incentive Program, was extended to include the Wollaston Domain northeast of Wollaston Lake. The survey was designed cooperatively by Saskatchewan Ministry of Energy and Resources (SMER) and the Geological Survey of Canada (GSC). The GSC's Radiation Geophysics and Regional Geophysics sections in Ottawa, under the Northern Resources Development Program, provided contract supervision and quality control to National Gamma-Ray Spectrometry (NATGAM) standards. The airborne survey comprised 47 986 line km, flown along northwest-trending flight lines spaced 400 m apart and southwest-trending magnetic control lines spaced 4000 m apart. Sensors included a large volume gamma-ray spectrometric detector (NaI, 50 litres downward looking and 8 litres upward looking) sampling every one second, and a caesium vapour magnetometer sampling ten times per second. Data acquisition was completed on September 30, 2004. These new data provide important geophysical and geochemical information that will enhance our current understanding of tectonic and metallogenic aspects of the southeast margin of the Hearne Province, where there is significant platinum-group element (PGE) potential within gabbroic complexes and base metal potential within supracrustal successions.

During the bedrock and surficial mapping activities by ER staff in the Peter Lake Domain, total radioactivity and magnetic susceptibility measurements were collected. In addition, ground gamma-ray spectrometer, total radioactivity, and magnetic susceptibility measurements were acquired at 320 sites by GSC staff (K. Ford) during an 11-day visit to the ER field camp located at Spider Island (unofficial place name; Maxeiner *et al.*, 2004b). Further gamma-ray spectrometric measurements at an additional 283 outcrops in selected areas throughout the Peter Lake Domain were made by R. Maxeiner during the 2005 field season (Maxeiner and Rayner, 2005). For ultramafic rocks to granitic pegmatites, respectively, average K concentrations ranged from 0.2 to 7.7% and equivalent thorium (eTh) concentrations from 0.1 to 73.4 ppm.

Radioactive element concentrations of gabbroic, dioritic, and monzonitic rocks from the main two mafic intrusive complexes were compared and revealed distinct signatures. For gabbroic to dioritic rocks of the older (2.56 Ga) Swan River Complex, K concentrations are typically between 0.2 and 2%, with an average eTh concentration of approximately 2.8 ppm (Figure H-02). Gabbroic to monzodioritic rocks from the younger (1.91 Ga) Porter Bay Complex have K concentrations that are typically between 1.3 and 6.5%, with a distinctly higher average eTh concentration of approximately 4.5 ppm. Although there is a zone of overlap between 1.0 to 2.0% K and 1 to 6 ppm eTh, the plot does define two large fields which may prove to be useful in delineating data from unknown gabbroic intrusions. This apparent difference between the two gabbroic suites may be recognizable in the airborne data and may have exploration significance. Data from the Wathaman Batholith or the Zengle Lake gabbros were not collected in sufficient quantity to warrant comparisons.

Interpretation of airborne gamma-ray spectrometric data requires an understanding of the radioactive element signatures of the different surficial deposits and their relationship to the underlying bedrock units. Ten sites were selected in the 2004 map area, where multiple *in situ* gamma-ray spectrometric measurements were taken on bedrock and adjacent surficial material. Average K and eTh concentrations for the bedrock measurements from the ten sites ranged between 0.5 and 4.5% K, and 1.1 and 19.1 ppm eTh. Average K and eTh concentrations for adjacent surficial deposits from the ten sites ranged between 2.1 and 3.1% K, and 8.3 and 13.6 ppm eTh. In general, tills adjacent to gabbroic units have higher average K and eTh concentrations compared to adjacent bedrock values. Tonalitic to granodioritic units averaged lower eTh but similar K values compared with adjacent tills, and monzogranitic units tended to have higher K and similar or higher eTh concentrations compared with adjacent tills. The radioactive element concentrations from these ten sites reflect a partial homogenization of the bedrock radioactive element signatures.

Aeromagnetic Maps: Peter Lake and Wollaston Lake Areas Survey

The PDFs of aeromagnetic maps from the Peter Lake and Wollaston Lake areas survey (Figure H-03), at a scale of 1:250 000, can be accessed through the links below.

Geological Survey of Canada Open File 4865 - north sheet at 1:250 000 scale (NTS 64L, Wollaston Lake; Ford *et al.*, 2005b):

- magnetic total field (nT; Figure H-04)
- calculated magnetic vertical gradient (nT/m; Figure H-05)

Geological Survey of Canada Open File 4847 - south sheet at 1:250 000 scale (NTS 64E, Compulsion Bay (Peter Lake area); Ford *et al.*, 2005a):

- magnetic total field (nT; Figure H-06)
- calculated magnetic vertical gradient (nT/m; Figure H-07)

Radiometric Maps: Peter Lake and Wollaston Lake Areas Survey

The PDFs of radiometric maps from the Peter Lake and Wollaston Lake areas survey(Figure H-08), at a scale of 1:250 000, can be accessed through the links below.

Geological Survey of Canada Open File 4865 - north sheet at 1:250 000 scale (NTS 64L, Wollaston Lake; Ford *et al.*, 2005b):

- potassium (K, %; Figure H-09)
- equivalent uranium (eU, ppm; Figure H-10)
- equivalent thorium (eTh, ppm; Figure H-11)
- ternary (K, eU, eTh; Figure H-12)

Geological Survey of Canada Open File 4847 - south sheet at 1:250 000 scale (NTS 64E, Compulsion Bay (Peter Lake area); Ford *et al.*, 2005a):

- potassium (K, %; Figure H-13)
- equivalent Uranium (eU, ppm; Figure H-14)
- equivalent Thorium (eTh, ppm; Figure H-15)

- ternary (K, eU, eTh; Figure H-16)

Accessing the Data

Survey data is available from Natural Resources Canada (NRCan) as a series of Open files (Ford *et al.*, 2005a, 2005b, 2005c; Figure H-17 and Table H-01 below). Printed colour maps and digital data on CD-ROM can be purchased from NRCan's Geophysical Data Centre. Digital line and grid data and the maps for this survey are available for download at no cost through the NRCan's Geoscience Data Repository (Aeromagnetic Survey, Peter Lake, Saskatchewan – Internet connection required). The individual 1:50 000-scale geophysical maps for parts of 64D, 64E, 64L, 64M, 74A, and 74H can also be downloaded from the NRCan website (see Table H-01).

Each Open File contains ten geophysical maps:

- natural air absorbed dose rate (NADR, nGy/h),
- potassium (K, %),
- equivalent uranium (eU, ppm),
- equivalent thorium (eTh, ppm),
- equivalent uranium/equivalent thorium (eU/eTh),
- equivalent uranium/potassium (eU/K, ppm/%),
- equivalent thorium/potassium (eTh/K, ppm/%),
- ternary (K, eU, eTh),
- magnetic total field (nT),
- calculated magnetic vertical gradient (nT/m).

Customized line and/or gridded digital data may be obtained, for a fee, from the Radiation Geophysics Section, Ottawa.

Telephone: (613) 996-3695 or (613) 995-1235
Fax: (613) 996-3726
e-mail: natgam@nrcan.gc.ca

Economic Geology

Introduction

With respect to economic potential, the primary focus of the Peter Lake Domain project was the description and metallogeny of selected Ni-Cu-platinum-group element (PGE) occurrences. Consequently, this final report will not discuss the potential for the discovery of base metal, gold, or any other deposit types.

A brief overview of the exploration history of the area, again with a focus on the search for Ni-Cu-PGE deposits, can be found in this section. Geochemical data, assay results, lake sediment geochemistry, and till geochemistry can be found through the Access databases (‘Data and Downloads’ section) or in a graphical representation through the ESRI® ArcReader project (‘Interactive Map’ section). For current mineral disposition maps covering the Peter Lake Domain, the reader is referred to the Saskatchewan Mineral Disposition Map on the Ministry of Energy and Resources' website.

Here, we present the findings and observations from our own work. As part of the project, a number of PGE deposits were visited in northwestern Ontario for comparison with the Peter Lake Domain PGE showings. Field photographs with descriptive captions of the Ontario deposits can be viewed by going to the appropriate directory (Data/fieldphotos/2005DC3) on the project DVD and scrolling through the images using Microsoft® Windows Explorer or other image-viewing software.

The map below (Figure I-01) illustrates the location of some of the most notable PGE occurrences that have been discovered to date in the Peter Lake Domain. From northeast to southwest, the names of the areas currently identified as prospective for PGE mineralization are Haglund East Lake (unofficial place name), Ant Lake (unofficial place name), Swan Lake, and Peter Lake East (unofficial place name). The map also contains links (Figure I-02; Figure I-03; Figure I-04; Figure I-05) to a field photograph of each of these occurrences.

Brecciated and varitextured gabbros of the Peter Lake Domain show many similarities in lithology, texture, and style of mineralization (Maxeiner and Rayner, 2005) to gabbros observed in northwestern Ontario that host the Lac des Iles and Marathon PGE deposits. Varitextured gabbros are those having variable grain size, ranging from fine to very coarse, and are locally pegmatitic (Lavigne and Michaud, 2002; Hinchey *et al.*, 2005). Less than 5%, but typically only approximately 1 to 2%, disseminated chalcopyrite and pyrrhotite are locally associated with magnetite. Cumulate textures and rhythmic layering are also present at both localities. Pyrite predominates at the High-Grade zone at Lac des Iles, where Pd enrichment is interpreted to derivate from aqueous fluids (Hinchey *et al.*, 2005), likely as a result of remobilization of primary magmatic mineralization. The High-Grade zone is associated with secondary amphiboles, talc, chlorite, and sericite and coincides with a north-trending mylonite zone. Varitextured gabbro is also commonly found at the Noril’sk-Talnakh Cu-Ni-PGE deposits in Russia, where it is referred to as taxitic (L. Hulbert, pers. comm., 2004).

The presence of magmatic sulphide mineralization in the contact zones of mafic-ultramafic intrusions has caused some workers to create a separate deposit classification, termed contact type (*e.g.*, Peck *et al.*, 2001). Examples include the East Bull Lake intrusion and the Marathon deposit of the Coldwell Complex, both located in Ontario. The preeminent example of contact type mineralization is the Platreef camp in South Africa, where 2.1 Ga pyroxenite and gabbronorite of the northern Bushveld Complex are in contact with Neoarchean granite and dolomite. Paragenetic interpretations of this mineralization style are, however, as varied as the deposits (*e.g.*, Macdonald, 1988; Peck *et al.*, 2001; Iljina and Lee, 2005). Although the Lac des Iles and Marathon deposits have been the focus of several studies, there is still debate about their classification and origin (*e.g.*, Macdonald, 1988; Barrie, 1996; Lavigne and Michaud, 2002; Hinchey *et al.*, 2005). Recently, these deposits have been reclassified as PGE-(Ni-Cu) magmatic breccia-type (Eckstrand and Hulbert, 2007), which are developed within stock-like or layered mafic-ultramafic intrusions and are characterized by sparsely disseminated sulphides in mafic magmatic breccias. Eckstrand and Hulbert (2007) view the Lac des Iles intrusion, where the main type of inclusions are autoliths and mineralization is not preferentially located along its margins, as a potential conduit for a larger layered intrusion. If intruded to a higher level, the magmatic breccia could have formed a basal breccia unit of a stratiform intrusion (Eckstrand and Hulbert, 2007).

Summary of Ni–Cu–Platinum-group Element (PGE) Exploration History

The following summary of exploration work in the Peter Lake Domain touches only on some important highlights. For a detailed account of the exploration history and current mineral dispositions the reader is referred to the Saskatchewan Ministry of Energy and Resources' (SMER) website under the Our Mineral Resources heading and then choosing the link to Saskatchewan's Mineral Resource Databases. This allows access to the Saskatchewan Mineral Deposits Index and Assessment Work Database. Paper copies of the Ministry's mineral assessments files are also available for viewing at the head office in Regina. Also under the Our Mineral Resources heading is the link to the Mines Branch, from here there is access to Mineral Dispositions (maps and databases) and the Geological Atlas of Saskatchewan.

Some of the earliest exploration in the Peter Lake Domain was carried out in the Peter Lake East (unofficial place name; Figure I-01) area, commencing in the mid-1960s, when Don Fisher Syndicate flew an airborne magnetic survey and followed it up with ground geophysical surveys. They excavated 40 trenches in the Peter Lake East area prior to acquisition of the claims by Hanna Mining Corporation in 1969 (Saskatchewan Ministry of Energy and Resources asessment files 74A-0006 and 64E04-0003).

In the late 1960s, exploration work was carried out in the Swan Lake area by Voyager Petroleums Ltd., who conducted regional airborne electromagnetic (EM), magnetic, and radiometric surveys in conjunction with ground exploration and prospecting.

Work by Husky Oil Ltd. in the Patterson Island area, including an airborne magnetic and EM survey, led to the discovery of the Wiley Bay Cu showing in 1970.

In the 1980s, Saskatchewan Mining and Development Corporation (SMDC) became involved in the Peter Lake Domain, taking out permits and staking claims throughout the domain. Subsequently, prospectors discovered Cu showings in several locations, which were followed up with ground geophysics, trenching, lake sediment and soil sampling surveys, mapping, and chip and grab sampling. Grab samples from Peter Lake East, for example, returned encouraging results (SMER assessment file 64E-05-0028) of up to 0.60% Cu (sample PL20-74), 1.3% Ni (sample PL20-114), 3580 ppb Pt (sample PL20-115), and 4275 ppb Pd (sample PL20-115). Anomalous PGE and Cu-Ni concentrations in previously unknown gabbro intrusions were also recorded near Swan Lake in 1981. Exploration work in this area over the next few years included further prospecting, trenching, and sampling, as well as geochemical and geophysical surveys (SMER assessment files 64E05-0028, 64E11-0032, 64E11-0033, and 64E11-0034).

As part of a regional PGE exploration program, Lacana Mining Corporation (Lacana) acquired several dispositions throughout the domain in 1985 and later entered into a partnership with SMDC. Their exploration program included mapping, prospecting, and sampling. Resampling of the Peter Lake East trenches only yielded up to 1595 ppm Cu, 408 ppm Ni, 135 ppb Pd, and 75 ppb Pt, but several new prospects were discovered as a result of their work (SMER assessment file 64E-0008). Northwest of Campbell Lake (unofficial place name), they identified a 13 km long and 5 km wide gabbro-anorthosite-diorite body. At one location within this body, disseminated chalcopyrite and pyrrhotite were reported in gabbroic rocks that contained up to 477 ppb combined Pt and Pd. No further trenching or drilling was carried out. In the Swan Lake area, the joint venture conducted further mapping, prospecting, and sampling, which returned anomalous PGE concentrations of up to 1920 ppb Pd and 654 ppb Pt (SMER assessment file 64E-0008). The SMDC-Lacana joint venture also discovered and trenched a number of showings near Ant Lake (unofficial place name) in the Patterson Island area; a grab sample from one of the trenches at the Antoine’s Cu-Ni-Pt-Pd showing returned 6350 ppm Cu, 99 ppm Ni, 3460 ppb Pd, and 382 ppb Pt (SMER assessment file 64E-0008). In 1998, a bulk till sampling program carried out by Golden Band Resources Inc. found no platinum-group mineral (PGM) grains in till samples collected down-ice from the showing.

Anomalous Pt-Pd concentrations were reported in the Haglund East Lake (unofficial place name) area. Sulphides in the Haglund East Lake area were first discovered by SMDC in 1979 and a ground, very low frequency electromagnetic (VLF-EM) survey was completed over the showing. In the mid-1980s, the joint venture conducted further geological mapping, prospecting, and rock sampling and followed up with an airborne radiometric survey (*e.g.*, SMER assessment files 64L01-0007, 64E-0008, and 64E-05-0028). Cameco Corp. staked the Haglund gabbro Cu-Pt-Pd showing in 1986. L. Hulbert of the Geological Survey of Canada visited known Cu-Ni-PGE prospects in the Peter Lake Domain and described them in a report on the metallogeny of mafic and ultramafic rocks of the Trans-Hudson Orogen (Hulbert, 1989).

In 2000, Golconda Resources Ltd. acquired a relatively large ground position and conducted prospecting, trenching, sampling, and drilling on some of their properties. Their highest reported assays for the Peter Lake East area, where most of their work was focused, were 53 ppb Au, 2.6 ppm Ag, 33 ppb Pt, 21 ppb Pd, 3720 ppm Cu, 103 ppm Zn, and 740 ppm Ni (SMER assessment file 64E04-0016). In 2004, Trend Mining Company and R. Studer acquired claims in the Peter Lake Domain, while Golconda Resources Ltd. and Cameco Corp. continued to hold a few small parcels of land.

In 2004, the Lacana-SMDC trenches were visited and sampled by L. Hulbert (Geological Survey of Canada), J. Campbell, S. Modeland, and R. Maxeiner (all Saskatchewan Geological Survey). A sample of varitextured gabbro with disseminated magmatic chalcopyrite and pyrrhotite was collected for geochronology. A preliminary age of 2562 ±3 Ma (Rayner *et al.*, 2005a) was obtained for the host gabbro. Based on the magmatic nature of the sulphides, the mineralization is inferred to be coeval.

Also in 2004, rock from the leucogabbroic phase of the Patterson Island Pluton was collected for geochronology. The sample site lies approximately 1 km southeast of the Antoine's showing, which hosts disseminated chalcopyrite interpreted to be magmatic in origin. The leucogabbro yielded an age of 1913 ±1 Ma, interpreted to precisely record a second Ni-Cu-PGE–bearing mineralizing event in the Peter Lake Domain.

Ni–Cu–Platinum-group Element (PGE) Occurrences in the Peter Lake Domain

Table I-01 contains direct hyperlinks to the individual Ni-Cu-PGE occurrences in the Peter Lake Domain that are listed in the Saskatchewan Mineral Deposits Index (SMDI) database (a connection to the Internet is necessary for these hyperlinks to work). The UTM coordinates that are provided are from the SMDI database, but have been corrected and updated for some of the showings that were visited during the course of the Peter Lake Domain project. All listed UTMs are in Zone 13 and are referenced to NAD 83. The complete SMDI can be accessed through the government's website at: www.er.gov.sk.ca and following the links from there.

Our own observations on some of the mineral occurrences that were visited between 2002 and 2005 are given below under four headings:

- *Haglund East Lake area*
- *Ant Lake area*
- *Swan Lake area*
- *Peter Lake East (or Korvin Lake) area*

Haglund East Lake area

A layered and tightly folded succession of dioritic to gabbroic rocks is situated south of a small lake referred to as Haglund East Lake (unofficial place name), approximately 8 km east of Haglund Lake (Figure I-06). Exploration work in this area dates back to the late 1970s, when Saskatchewan Mining Development Corporation (SMDC) and Lacana Mining Corporation (Lacana) acquired dispositions (*e.g.*, SMER assessment files 64L01-0007, 64E-0008, and 64E-05-0028), and followed up with airborne radiometric surveys. In 1979, NTS sheet 64L/01 was mapped at 1:100 000 scale by the Saskatchewan Geological Survey (Ray, 1979), and the area of the Haglund East Lake gabbro was mapped in detail (Potter, 1979). Sulphides were first discovered by SMDC in 1979 and a ground very low frequency-electromagnetic (VLF-EM) survey was completed over the Haglund East Lake gabbro Cu-Pt-Pd showing. A Lacana-SMDC joint venture partnership, created in 1985, first reported anomalous Pt-Pd concentrations after a geological mapping, prospecting, and rock sampling program. Cameco Corp. staked the Haglund East Lake gabbro showing in 1986 (SMDI# 2385).

The dioritic rocks have subtle, centimetre-scale igneous layering preserved (Maxeiner and Rayner, 2005). One megacrystic monzodiorite unit could be traced for close to 5 km, constituting the only example of possible intrusion-scale layering in the Peter Lake Domain. An alternative interpretation of this unit is that it may represent a later sill (Potter, 1979). There are no ultramafic rocks, little varitextured gabbros and no breccias. As previously identified by Ray (1979) and Potter (1979), a northeast-trending fold has deformed the intrusion. The gabbros have a very low magnetic susceptibility but there are some notable exceptions, particularly in the vicinity of the sulphide occurrences. Stratigraphic tops in the pluton could not be identified, but Potter (1979) identified several younging indicators, all but one of which pointed to the northwest. The mafic mineral content in the pluton is variable, grading from approximately 70% to as low as approximately 15%, locally approaching anorthositic compositions. The eastern limb of the fold is much more recrystallized and appears partly dismembered, as the megacrystic tracer horizon and the dioritic components appear to be lost.

Potential supracrustal gneisses northwest of Haglund East Lake (Ray, 1979) were reinterpreted as sheared granodioritic to granitic rocks with transposed aplitic, pegmatitic, and mafic dykes. They feature layers of fine-grained biotite-hornblende schist, which are interpreted as transposed mafic dykes within a major mylonite zone. A coarse-grained megacrystic monzogranite with large K-feldspar megacrysts is similar to a unit on the east side of Zengle Lake (Maxeiner *et al.*, 2004b), which has a preliminary U-Pb zircon age of 1850 Ma (Rayner *et al.*, 2005a).

The Mineral Showing

Two small trenches containing small quantities of mainly disseminated, millimetre-sized chalcopyrite, bornite, covellite, pyrite, and minor pyrrhotite make up the Haglund gabbro showing (SMDI# 2385). Gabbroic rocks in the immediate vicinity of the showing vary from homogeneous to heterogeneous. They are characterized by variable grain size and mafic mineral content; coarse-grained to pegmatitic, in part varitextured gabbros grade into megacrystic, locally trachytic-textured diorite or leucogabbro. Disseminated sulphides occur preferentially in the coarse-grained gabbroic phases and are accompanied by appreciable amounts of magnetite, which is otherwise absent from the Haglund East Lake gabbro. Pyrite occurs on faults and minor shear planes; malachite on late fractures.

Conclusions

The monzodiorite at Haglund East Lake is traceable for close to 5 km and might either represent a rare example of intrusion-scale layering in the Peter Lake Domain or alternatively a younger sill. Outcrop-scale layering is not widespread and generally very weakly preserved in the Haglund East Lake area.

Similar to all other PGE occurrences in the Peter Lake Domain, the disseminated nature of chalcopyrite-bornite mineralization at Haglund East Lake suggests that it is magmatic in origin. It is hosted in a coarse-grained to pegmatitic gabbro that has similarities to the Korvin Lake gabbro, which hosts the Peter Lake East occurrences. The sulphides are preferentially associated with magnetite and therefore this may be a first-order exploration tool for finding additional mineralized areas in the Haglund gabbro, something that does not seem to be applicable to most of the other Peter Lake Domain occurrences.

No significant supracrustal components were identified (Maxeiner and Rayner, 2005). Instead, several mylonite zones were mapped. Abundant northeast-trending shear zones have affected the intrusion and are particularly prevalent along its margins, as well as in the granodioritic to granitic basement. The area has likely been affected by two phases of folding and associated metamorphism. All of the gabbroic and dioritic rocks are heavily amphibolitized.

Ant Lake Area

Three mineral occurrences are known in the Patterson Island area (Figure I-07): the Ant Lake South and Antoine's showings, which are hosted in gabbroic rocks of the Porter Bay Complex (SMDI# 2373, 2374), and the Wiley Bay Cu showing, which is hosted in mafic to ultramafic volcanic rocks (SMDI# 0569). Two additional sulphide occurrences were discovered in 2003 (Max-12 and Max-13) south of the Ant Lake South trenches (Maxeiner and Leatherdale, 2003d). The Ant Lake South and Antoine's showings are among the best PGE occurrences in the Peter Lake Domain on record (SMER assessment file 64E10-NE-009R).

The Mineral Showings

The Ant Lake South Cu-Ni-Pt-Pd Showing (SMDI# 2373)

Discovered in 1985 by Lacana Exploration Inc., this showing returned up to 1% Cu and up to 250 ppb Pt plus Pd (SMER assessment file 64E-0008). The two trenches at the Ant Lake South showing that were visited are within 10 m of each other and trend at 100°. They are in a relatively homogeneous and massive, yet strongly amphibolitized central part of the Patterson Island Pluton in the Porter Bay Complex. Zones of brecciation and cumulate igneous layering are present in the general vicinity of the occurrences. The gabbro contains <5% disseminated pyrrhotite and chalcopyrite, as well as some fracture-filling pyrite.

The Antoine's Cu-Ni-Pt-Pd Showing (SMDI# 2374)

This showing was also discovered by Lacana Exploration Inc. in 1985 and trench samples returned values of up to 1.5% Cu, up to 4910 ppb Pd and 477 ppb Pt (SMER assessment files 64E-0008 and 64E-0009). The one Antoine's showing trench that was rediscovered in 2003, trends at 190°. It is in an isolated unit of gabbroic rocks, completely surrounded by heterogeneous, xenolith-rich monzonitic rocks related to the Patterson Island Pluton. The gabbro, containing approximately 50% mafic minerals, is mottled black and white to rusty brown, coarse grained, relatively homogeneous and massive. Chalcopyrite (<5%) and minor pyrite are mostly disseminated and interpreted to be of magmatic origin.

New Sulphide Occurrences

Two additional sulphide occurrences were located near the Ant Lake South trenches; one is 300 m to the southeast and the other approximately 200 m to the southwest. Both occur within 10 m of recognizable rhythmic layering and close to zones of brecciation; the gabbro contains approximately 5% combined disseminated and fracture-bound sulphides, comprising (in order of decreasing abundance) pyrite, chalcopyrite, and pyrrhotite. Several percent magnetite and hematite are also present. The sulphides appear to be restricted to a few square metres.

Conclusions

The mineral occurrences in the Ant Lake (unofficial place name) area are significant for a number of reasons: 1) a grab sample collected by R. Maxeiner in 2004 at one of the Antoine's showing trenches returned the highest concentrations (2790 ppb Pd in sample RM0301-075) of

Pd in the Peter Lake Domain; 2) chalcopyrite is disseminated and speculated to be of magmatic origin; and 3) in contrast to most other PGE showings in the Peter Lake Domain, the Ant Lake South and Antoine's showings are not hosted by the 2.56 Ga Swan River Complex, but rather by the much younger 1.92 Ga Porter Bay Complex.

Mineralization occurs in central portions of the Patterson Island Pluton, where it appears in close association with breccia zones, which is remarkably similar to the Lac des Iles PGE deposit in northwestern Ontario. Zones of pegmatitic gabbros were also encountered in several places in the pluton. The discovery of two new small occurrences during the 2003 mapping suggests that the pluton is underexplored.

Swan Lake Area

Exploration work in the Swan Lake area (Figure I-08) dates back to the late 1960s, when Voyager Petroleums Ltd. conducted regional airborne EM, magnetic and radiometric surveys in conjunction with ground exploration and prospecting (SMDI# 1896). Regional geological mapping at 1:100 000 scale was completed in the late 1970s and early 1980s and identified several small diorite to gabbro intrusions around Swan Lake (Stauffer *et al.*, 1981; Lewry *et al.*, 1981). Anomalous PGE and Cu-Ni concentrations in previously unknown gabbro intrusions were first recorded by SMDC in 1981. Exploration work over the next few years included further prospecting, trenching, and sampling, as well as geochemical and geophysical surveys (SMER assessment files 64E05-0028, 64E11-0032, 64E11-0033, and 64E11-0034). Lacana Mining Corporation entered into a joint venture with SMDC and in 1985 further mapping, prospecting, and sampling returned anomalous PGE concentrations of up to 1920 ppb Pd and 654 ppb Pt (SMER assessment file 64E-0008).

The Mineral Showing

In 2004, the Lacana-SMDC trenches were visited and a sample of varitextured gabbro with disseminated magmatic chalcopyrite and pyrrhotite was collected for geochronological analysis. A preliminary age of 2.562 Ga (Rayner *et al.*, 2005a) was obtained for the host gabbro and based on the magmatic nature of the sulphides, the mineralization is inferred to be coeval.

In 2005, a concentrically zoned intrusion hosting the Swan Lake showing was mapped (Maxeiner and Rayner, 2005). This Swan Lake intrusion has a heterogeneous, varitextured leucogabbro core with abundant gabbro and pyroxenite inclusions, surrounded by a homogeneous medium-grained gabbro and a fine-grained mafic microgabbro fringe. Sulphides were observed in the heterogeneous core of the intrusion, and in one of the trenches are confined to a discontinuous igneous melagabbro layer. Another gabbroic intrusion with very well-preserved primary igneous layering was discovered 2 km southwest of the Swan Lake intrusion, but no sulphides or anomalous PGE concentrations were identified.

Several sulphide occurrences are described to the north, south and west of Swan Lake, but only the Swan Lake showing (SMDI# 1896) could be located in the field. Several metre-sized trenches are situated along the south margin of the central varitextured leucogabbro breccia unit of the concentric Swan Lake gabbro. Trench 6 is the longest and exposes a succession of brecciated gabbros that pass southward into relatively homogeneous melagabbro and ultramafic rocks. The breccia is characterized by a leucogabbroic matrix with subrounded to subangular autoliths of melagabbro and pyroxenite; the inclusions measure 30 to 70 cm in diameter and form up to 70% of the surface area of the outcrops. Disseminated millimetre-sized pyrrhotite, chalcopyrite, and pyrite are present throughout trench 6, but become more prevalent towards the southern end and are generally most abundant in the varitextured to pegmatitic zones. In one location in the central part of the trench, weak igneous layering preserved in a melagabbro lies along strike with igneous layering observed in trench 4 approximately 25 m to the southeast. In that trench, sulphides are particularly abundant in a 10 cm thick gabbro layer, although it is questionable whether the layering is part of a large inclusion or developed within the matrix. The inclusion to matrix ratio in trench 4 is larger, with about 70% of the rock consisting of leucogabbro. The south end of the main trench 6 is in a pyroxenitic rock with abundant disseminated sulphides; varitextured to pegmatitic gabbro is also present in smaller proportion.

Conclusions

The Swan Lake gabbro, which is host to the Swan Lake showing, coincides with an aeromagnetic high. The pluton is zoned and features a more magnetite-rich, finer grained margin and a less magnetite-rich central zone consisting of a leucogabbroic breccia with gabbro inclusions. The mineral occurrences are located at the southern contact between the leucogabbroic breccia and the surrounding gabbro. This area is also characterized by an increase in melagabbroic and pyroxenitic inclusions within the leucogabbro. The sulphides are disseminated and magmatic in origin and are therefore of the same age as the 2562 Ma host rock. This is the first locality in the Peter Lake Domain where sulphide mineralization has been dated, albeit indirectly (Rayner *et al.*, 2005a).

Gabbroic intrusions related to the 2562 Ma Swan River Complex are found in three areas around Swan Lake and represent the youngest rocks in the area. The rest of the area is dominated by granodiorite-tonalite migmatite complex basement intruded by 2569 Ma monzogranite (Corrigan *et al.*, 2001) of the Lueaza River granitoid suite, as well as by syenogranitic rocks of unknown affiliation and age.

One of the areas with gabbros is situated south of the lake, where poorly exposed units of gabbro and melagabbro underlie an area covered by thick and widespread glacial drift. These gabbroic rocks are generally homogeneous and nondescript, with only minor pegmatitic sections and some poikilitic gabbros, although they contain the largest concentration of melagabbroic to pyroxenitic material in the Swan Lake area.

A well-exposed gabbro intrusion east of the south end of Swan Lake contains spectacularly well-preserved igneous features, including trough cross-bedding, rhythmic zebra-layering and varitextured gabbros. Breccias are absent from this intrusion and the rocks do not contain sulphides or magnetite. The intrusion coincides with an aeromagnetic low on the newly acquired airborne geophysical map (Ford *et al.*, 2005).

Peter Lake East Area

Based on previous exploration work by Don Fisher Syndicate, SMDC and Lacana Mining Corporation, the Peter Lake East (unofficial place name) area (SMDI# 1845a), located approximately 50 km southeast of Peter Lake (Figure I-09), is considered one of the two most prospective areas for PGE exploration. Reported PGE values from chip samples collected by SMDC totalled >7 ppm, but could not be reproduced in two subsequent exploration programs.

In 2005, eight days were spent investigating a 40 km^2 area around Korvin Lake (unofficial place name) and What Lake (unofficial place name; Maxeiner and Rayner, 2005), and the resulting 1:20 000 scale map ties into the 2002 transect along Highway 905 (Figure I-09; Maxeiner and Hunter, 2002a). The What Lake area was mapped in more detail (see inset in Figure I-09).

Key findings are that the What Lake trenches are in an east-striking belt of partly layered gabbroic rocks, immediately south of their contact with granitic rocks. The gabbroic succession is folded by an east-trending set of tight to isoclinal folds, which are refolded by north-northeast trending and plunging open folds. Mineralization was originally magmatic in origin and follows igneous layering. Varitextured gabbros with local pegmatitic zones are common. The age of the mineralization and of the host gabbro are believed to be coeval with the 2562 Ma Love Lake leucogabbro. Sulphides were locally remobilized into small north-trending shear zones.

The Mineral Showings

Most of the mineral occurrences between Korvin Lake and What Lake (Table I-02) are associated with the Korvin Lake gabbro, a relatively nondescript strongly amphibolitized gabbro (Maxeiner and Rayner, 2005). Similar to observations made by Leatherdale *et al.* (2003), two generations of amphibole were recognized in the gabbro: the first is related to a 2.55 to 2.54 Ga high-grade metamorphic event that resulted in the widespread replacement of pyroxenes; the second event, which was accompanied by lower amphibolite facies metamorphism, is possibly related to the Trans-Hudson Orogen and produced tschermakite and cummingtonite. Magnetite concentrations are highly variable, in part higher than in the surrounding granitoids, in part lower. Many of the showings are accompanied by pegmatitic gabbro zones, subtle layering, and breccia zones, and are gradational into, and interlayered with, anorthositic and leucogabbroic zones.

Trenched sulphide occurrences were visited in five separate areas, all hosted by the Korvin Lake gabbro, and are described from northeast to southwest: What Lake trenches; SMDC trench 10; Muskeg trenches; Creek trenches; and Pyroxenite trenches 11 to 13.

What Lake Trenches

Seven of the old SMDC trenches, each approximately 4 m long and 1 m wide, are located south of What Lake, approximately 100 m south of the contact between the Korvin Lake gabbro and a granite to the north. Coarse-grained to varitextured gabbro and pegmatitic gabbro within these trenches are characterized by up to 5% disseminated pyrrhotite, chalcopyrite, and pyrite. Narrow late north- to northeast-trending fracture zones and low-grade, epidote-lined ductile shear zones also contain pyrite. The proportions of magnetite are highly variable and magnetic susceptibility ranges between 2 and 130 (in 10^{-3} SI). Igneous layering, observed near two of the trenches, dips to the north and is parallel to the main regional foliation. The gabbro at trench 8 was cut by pyrite-bearing, fine-grained, rusty mafic dykes. Breccia zones are uncommon, but one is situated 20 m east of trench 3, where a very coarse-grained anorthositic gabbro intrudes the main gabbro. Minor layers of melagabbro to pyroxenite were only observed near trenches 2 and 6.

SMDC Trench 10

The trench, approximately 6 m long and 1 m wide, exposes gabbro with chalcopyrite, pyrite, and pyrrhotite, which are uniformly disseminated in hand sample. Southwest-dipping igneous layering in anorthositic gabbro and melagabbro was observed 10 m east of the trench and has been disrupted and brecciated by cross-cutting tonalitic veins. Homogeneous pink granite occurs another 10 m farther to the east.

Muskeg Trenches

Two trenches, each approximately 10 m long and 1 m across, originally excavated by Don Fisher Syndicate in the late 1960s, are located on a little ridge directly west of a small creek and are here referred to as the Muskeg trenches. The main rock type at the Muskeg trenches is a coarse-grained to pegmatitic varitextured gabbro with up to 5% disseminated pyrrhotite, chalcopyrite, and pyrite. The magnetic susceptibility near the Muskeg trenches and in the adjacent area is generally between 2 and 15 (in 10^{-3} SI), therefore considerably lower than that in the What Lake trenches.

The trench located farthest to the west contains large leucogabbroic sections, as well as a breccia zone with angular clasts of melagabbro and pyroxenite in a gabbro matrix. A 50 cm-wide breccia zone of quartz diorite with gabbro inclusions, situated 20 m east of the Muskeg trenches, dips steeply to the south and trends parallel to the regional foliation. This breccia zone is also parallel to the local orientation of igneous layering and may represent either an original layer in the gabbro or a replacement feature. Replacement anorthosite and resulting breccias similar to those in the Skaergaard intrusion in Greenland (Irvine *et al.*, 1998) were noted at several localities in the Korvin Lake gabbro. In two outcrops, about 300 m west of the Muskeg trenches, igneous layering within the gabbro to leucogabbro dips to the south and is defined by 2 cm-thick melagabbro layers 10 to 20 cm apart. Contacts between the layers are sharper and more melanocratic on the north side, but gradational and more leucocratic on the south side, which suggests that the succession is the right way up. Some of the layers are very coarse grained to almost pegmatitic in nature.

The Muskeg trenches are situated on one of the interpreted north-northwest–trending airphoto lineaments. Late fracture sets observed in outcrop are oriented at 345° and 190°. A small shear zone cutting the gabbro is also oriented at 345°.

Creek Trenches

Two other trenches, excavated by Don Fisher Syndicate in the late 1960s, are located on either side of a small fast-flowing creek and are here referred to as the Creek trenches. Sulphides in the trench west of the creek consist of disseminated pyrrhotite, pyrite, and chalcopyrite. The host rock is a relatively massive and homogeneous gabbro that is cut by subvertical, 10 to 20 cm wide shear zones trending at 350°. This is identical to the orientation of two other small shear zones mapped to the north. All of these shear zones are epidote-lined, brittle-ductile structures that appear to be parallel to an airphoto lineament and are probably related to the Tabbernor Fault Zone. Some of the sulphides appear to have been concentrated and remobilized along these north-northwest–trending structures. A small trench on the east side of the creek exposes a similar homogeneous and massive gabbro. A small outcrop to the north suggests subtle layering defined by thin sheets of melagabbro to pyroxenite. A small brecciated zone with a coarse-grained leucogabbro invading a melagabbro is exposed southeast of the trench.

Pyroxenite Trench

The Pyroxenite trench, situated directly northeast of Korvin Lake, is approximately 1 m by 1 m, overgrown, caved in and strongly weathered. The trench is in a thin pyroxenite to melagabbro unit within the Korvin Lake gabbro. Only very small amounts of sulphide, most of which is pyrite, were identified.

Conclusions

Most of the sulphides are disseminated in character. The showings exposed in the What Lake trenches and SMDC trench 10 are situated at the contact between the Korvin Lake gabbro and thin granitic sheets. The age of the granite is unknown, but its similarity to the 2.570 Ga Ettle Creek granite suggests that it predates emplacement of the gabbro. In that case, sulphides at both What Lake and SMDC trench 10 occur near the margin (base?) of the gabbroic intrusion. The other occurrences are well within the centre of the Korvin Lake gabbro, but two of them (Creek and Muskeg trenches) lie near north-northwest–trending airphoto lineaments, with associated narrow north-northwest–trending shear zones, as well as conjugate sets of brittle faults. Although sulphides at both localities are disseminated and apparently magmatic in origin, they have been remobilized to a small extent along these narrow shear zones.

Some of the drilling completed by Golconda Exploration near the What Lake trenches tested the possibility of structurally controlled mineralization (SMER assessment file 64E-04-0016R). A total of approximately 400 m of gabbro were drilled. Drill holes were spotted south of the area containing the main trenches, with two holes drilled east-southeast and one hole drilled west-northwest (see inset map in Figure I-09 above). No significant sulphides or sections with anomalous PGE values were intercepted. If mineralization in the What Lake trenches was originally magmatic in nature and restricted to certain layers (*i.e.*, a layered intrusion model with reef-type mineralization or marginal mineralization), then future holes should be drilled north of the showings and directed towards the south.

Mineral Deposit Profiles for Ni–Cu–Platinum-group Element Occurrences

In 1986, the U.S. Geological Survey prepared a set of mineral deposit models (Cox and Singer, 1986), which it continues to refine and update through their website (available online at URL <http://pubs.usgs.gov/bul/b1693/html/bullfrms.htm>).

These deposit models are based on the tectonic setting in which the rocks hosting the deposits were formed and have been used over the years as the basis for the creation of mineral deposit profiles by a number of jurisdictions (*e.g.*, British Columbia Geological Survey (Lefebure and Ray, 1995)).

Deposit classifications are also provided in the *Mineral Deposits of Canada* volume (Goodfellow, 2007), which also evolved over time. Deposit models pertaining to Ni–Cu–platinum-group element (PGE) bearing mafic-ultramafic rocks were written by Macdonald (1988) and Eckstrand *et al.* (1996). The most recent classification of magmatic Ni-Cu-PGE deposits is that of Eckstrand and Hulbert (2007) in a revised edition of the *Mineral Deposits of*

Canada volume. In the following discussion, we present a summary of this classification and the most important characteristics of Ni-Cu-PGE deposits, as proposed by Eckstrand and Hulbert (2007), and as they pertain to the Peter Lake Domain.

1) Ni-Cu-PGE sulphide deposit types (high S, Ni rich):

a) meteorite impact mafic melt sheet (Sudbury is the only example);
b) rift- and continental-flood basalts (e.g., Noril'sk-Talnakh and Duluth); Table I-03);
c) komatiitic flows (e.g., Thompson, Raglan, Kambalda, and Agnew; Table I-04)
d) other mafic-ultramafic intrusions (Voisey's Bay and Lynn Lake).

2) Magmatic PGE deposit types (low S, PGE rich):

a) reef-type or stratiform (e.g., Merensky Reef and UG-2, JM Reef, Skaergaard, and Great Dyke; Table I-05);
b) magmatic breccia type (e.g., Lac des Iles, Marathon, Platreef (Bushveld); Table I-06).

The links in the list above will take you to an abbreviated descriptive table of those deposit types for which the Peter Lake Domain is believed to be prospective for. We do not believe that there is significant potential for the discovery of type 1a (meteorite impact mafic melt sheet). Type 1d (other mafic-ultramafic intrusions) is somewhat hard to assess, as it contains a plethora of various types of deposits. Of the types listed, we feel that there is most potential for types 2b and, to a lesser extent, 2a in the Peter Lake Domain. Sulphur-rich deposit types, such as rift- and continental-flood basalts and komatiitic flows, are much less likely to be present, as the external sources of sulphur are considered to be limited.

Other Potential PGE Targets in the Peter Lake Domain

Other potential PGE targets in the Peter Lake Domain are shale-hosted Ni-Zn-Mo-PGE deposits (Lefebure and Coveney, 1995). These deposits are characterized by thin layers of pyrite, vaesite (NiS_2), jordisite (amorphous MoS_2), and sphalerite in black shale sub-basins with associated phosphatic chert and carbonate rocks. They typically form in continental platform sedimentary sequences, and all of the known deposits are associated with orogenic belts. The associated sulphides are generally massive to semi-massive and occur as nodules, spheroids, and framboids and can be rhythmically laminated. This unusual type of PGE mineralization possibly originates from syngenetic deposition of metals expelled by hydrothermal vents at or directly beneath the seafloor.

Argillitic rocks of the Campbell River Group (MacDougall, 1988b) comprise weakly metamorphosed varieties of black shale and sulphidic mudstone, and may provide some potential for the discovery of deposits that belong to this class. They are, in part, characterized by finely banded aphanitic carbonaceous material with continuous layers of fine-grained pyrite and pyrrhotite. They contain high concentrations of Zn and elevated concentrations of Ni. The Mo and PGE concentrations in these rocks are unknown.

Important Exploration Criteria for Platinum-group Element (PGE) Deposits in the Peter Lake Domain

- There are two mafic intrusive complexes that are currently known to host PGE mineralization in the Peter Lake Domain: 1) the 2562 Ma Swan River Complex, and 2) the 1917 Ma Porter Bay Complex.

- Host rocks include gabbro, leucogabbro, anorthositic gabbro, gabbronorite, and to a lesser extent melagabbro, pyroxenite, diorite, and monzodiorite.

- Associated rock textures are varitextured, pegmatitic, and/or brecciated, and less frequently include cumulate layering and basal contact zones.

- The style of mineralization consists of disseminated (<5%) and fracture-bound pyrrhotite, pyrite, and chalcopyrite, with occasional bornite and secondary covellite. Several percent disseminated magnetite can be present locally. Primary sulphides are believed to be magmatic in origin, and can be remobilized into shear zones.

Most of the known PGE occurrences in the Peter Lake Domain are in or near areas of varitextured, pegmatitic, and/or brecciated gabbros. Consequently, these features constitute key exploration targets. A series of ArcView shape files illustrating the distribution of these textures in the Peter Lake Domain have been developed from field notes and can be viewed through the ESRI® ArcReader project. Some examples and potential exploration hotspots are also highlighted below (Figure I-10).

The new 1:100 000 scale bedrock geological maps (Maxeiner, 2006a, 2006b) that were created during the course of this project and the existing regional geological maps of the domain are largely lithological in nature, *i.e.*, they separate units of diorite, gabbro, gabbronorite, etc. When exploring for PGE-(Ni-Cu) magmatic breccia-type deposits, attention to texture becomes critical in identifying prospective areas. Therefore, a search through field notes was performed for keywords such as brecciated, inclusion, xenolith, and pegmatitic, and a set of textural maps were created. This was only possible for areas that were remapped during the course of the Peter Lake Domain project.

Below, we highlight a number of new exploration areas that include these characteristic textures.

West of Patterson Island (NTS 64E/10)

The first example is from west of Patterson Island (Figure I-10) on Reindeer Lake (64E-10), and is close to previously known PGE occurrences (trenches at the Antoine's and Ant Lake South Cu-Ni-Pt-Pd showings; Figure I-11).

The Patterson Island Pluton, which forms part of the 1917 to 1913 Ma Porter Bay Complex, consists primarily of monzodioritic, monzonitic, leucogabbroic, and gabbroic rocks. The Antoine's showing is hosted along the northern margin of the pluton and is associated with partly layered and brecciated gabbro and monzonite. The grab sample with the highest Pd concentration (2790 ppb) was collected at the Antoine's showing. South of Ant Lake (unofficial place name), two trenches constitute the Ant Lake South showing. In 2003, we discovered two new occurrences (Max-12; Max-13; Figure I-07) with slightly anomalous Pd concentration in leucogabbroic rocks, a few hundred metres south of the Ant Lake South trenches. These occurrences are located close to the southwestern edge of the Patterson Island Pluton, where there is an in intrusive contact with older granitic (G) and gabbroic (SGa) rocks. It is unclear whether the relatively more mafic gabbroic inclusions found in a leucogabbro intrusion beccia (see the field photograph) are autoliths or instead part of the older Swan River Complex. Regardless, these new areas of anomalous Pt-Pd concentrations with associated cumulate layering and breccia zones, located near the margin of the pluton, represent an interesting exploration play.

Southwest of Patterson Island (NTS 64E/10)

The second example is also from the Patterson Island area (Figure I-10), slightly further south and west than the previous example. Here, a unit of gabbroic rocks (SGa) related to the 2562 Ma Swan River Complex extends south-westward from Wiley Bay (Figure I-12). It is cut by the Wathaman Batholith (WQm) to the southeast, and to the northwest it is structurally overlain by dioritic components (SDi) of the Swan River Complex. A unit of highly strained quartz dioritic gneisses (Xqd), which is heavily invaded by granitoid rocks related to the Wathaman Batholith, is also in contact with the Swan River Complex gabbroic unit.

North of Porter Bay (NTS 64E/10)

Another interesting area is located north of Porter Bay (Figure I-10), near the Patterson Island Pluton (Figure I-13). A northeast-striking gabbroic body (SGa), several kilometres in length and up to 2 km in thickness, is interpreted to represent a component of the Swan River Complex. The gabbro is cut by a suite of syenogranitic rocks (Gs) to the north and the northeast. Along its southern margin, the gabbro is in intrusive(?) contact with augened monzogranite (RGm) of the older Lueaza River granitoid suite. Along that contact and towards its centre, the intrusion is characterized by a relatively large zone of pegmatitic gabbro, in part with minor rusty zones and enriched magnetite concentrations. The only grab sample that we collected in this gabbro returned no anomalous PGE concentrations. Yet, given the size of the pluton and its association with pegmatitic zones similar to those at the Marathon PGE deposit in northwest Ontario, it may warrant further investigation.

Northeast of Pearce Lake (NTS 64E/15)

This area (Figure I-10) is quite different from the other locations documented on this page, as the mapping failed to identify brecciated or pegmatitic zones within this gabbroic, melagabbroic to ultramafic, to dioritic pluton, which is located northeast of Pearce Lake (Figure I-14). The pluton is relatively poorly delineated, and was only encountered on one traverse that crossed it southwest of an unnamed lake and by several outcrops along the north shore of Pearce Lake. A fist-sized grab sample of a melagabbro with about 1% disseminated chalcopyrite and pyrrhotite returned anomalous concentrations of Cu, Ni, and PGE. Rhythmic cumulate layering was identified in a number of the outcrops. The pluton is completely surrounded by granitic rocks, most interpreted to be part of a younger syenogranite suite, except at its western extent where it cut granitoids and granitoid gneisses of the Lueaza River granitoid suite. Two distinct aeromagnetic highs within the confines of the pluton are of unknown origin and also warrant further investigation.

Korvin Lake (NTS 64E/15)

The area northeast of Korvin Lake (unofficial place name) is one of the most prospective regions for PGEs in the Peter Lake Domain (Figure I-10) and is described in detail above. West and northwest of Korvin Lake (Figure I-15), monzodioritic rocks of the Porter Bay Complex represent a second potentially prospective area in this region. Breccia zones and minor pegmatitic enclaves were discovered at the location where the Johnson River flows into Korvin Lake. Unfortunately, two grab samples collected in that area returned no significant values of Ni, Cu, or PGEs.

Plate Tectonic History

The presence of the >2630 Ma granodiorite-tonalite migmatite complex and the 2580 to 2566 Ma Lueaza River granitoid suite, suggest that the Peter Lake Domain is part of the southern Hearne Craton as it too is dominated by *ca.* 2800 to 2600 Ma granitic to tonalitic rocks. Emplacement of a voluminous 2562 Ma layered gabbroic complex (the Swan River Complex) into the Peter Lake Domain portion of the Hearne Craton is an event not identified elsewhere in the craton. The exposed surface area of the Swan River Complex is between 6.5% and 27% of Peter lake Domain (Figure E-05), if other diorites and gabbros of presently unknown affinity are cogenetic. Other large mafic intrusive complexes known worldwide (*e.g.*, Bushveld Complex in South Africa, Great Dyke in Zimbabwe, Duluth Complex in North America) are tied to continental break-up events or failed rifts (*e.g.*, Von Gruenewaldt and Harmer, 1992). The trace element geochemistry of Swan River Complex gabbros suggests a subduction signature. Whereas such signatures have also been observed in other rift-related layered intrusive complexes (*e.g.*, Von Gruenewaldt and Harmer, 1992), their significance might be attributed to crustal contamination. The occurrence of a high-temperature metamorphic event at *ca.* 2550 Ma, suggests that a collisional event accompanied by regional shortening and crustal thickening followed emplacement of the Swan River Complex. Subsequent emplacement of a *ca.* 2540 Ma megacrystic monzonite to quartz monzonite suite and the later 2530 Ma Zengle Lake gabbro might be related to renewed post-collisional extension, though 30 m.y. could be considered an insufficient time interval between the onset of rifting (2562 Ma) and a high-grade metamorphic overprint (2540 Ma) followed by renewed extension at 2540 to 2530 Ma. Furthermore, no geological evidence exists for the development of any type of depositional basin at that time. Alternatively, the extensive 2562 Ma mafic magmatism could have provided the heat for a widespread high-grade contact metamorphic event between 2550 to 2530 Ma, thus eliminating the need for a compressional regime at this time. Our preferred interpretation of the significance of the 2562 Ma mafic magmatic event (Figure J-01) recognized in the Peter Lake Domain, is that it represents a period of crustal extension and rifting that did not lead to continental break-up (failed rift).

Preservation of rift, passive margin, and foreland basin successions in the Wollaston Supergroup (Yeo and Delaney, 2007) provides evidence for opening and closing of the Manikewan Ocean (Stauffer, 1984) between 2100 Ma (Ansdell *et al.*, 2000) and *ca.* 1820 Ma (Figure J-02). In the Peter Lake Domain, the Campbell River Group is an internally disconformable sedimentary succession that can be separated into two individual sequences that display lithological similarities to components of the Wollaston Supergroup. The stratigraphically lower sequence (Sequence 1) of the Campbell River Group is here tentatively correlated with the Courtenay Lake Group, which is interpreted as a rift-fill succession at the base of the Wollaston Supergroup (Yeo and Delaney, 2007). Although no unconformity has been directly identified between Sequence 1 and Sequence 2, the strongly contrasting metamorphic grade of the two successions suggests a major depositional break. This inference is supported by geochronological analyses. Preliminary results of a detrital zircon study of the Campbell River Group (L. Heaman, pers. comm., 2006) suggest that Sequence 1 is younger than 2380 Ma, in accordance with the proposed 2100 Ma age of the sequence based on correlation with the Wollaston Supergroup. Sequence 2 is suggested here to be younger than 2250 Ma and could predate or coincide with emplacement of the 1917 Ma Porter Bay Complex (Figure J-03), which also lacks evidence for a high grade metamorphic overprint. Sequence 2 is tentatively correlated with the Souter Lake Group, which represents a component of the passive margin sequence of the Wollaston Supergroup. The timing of the D2-M2 thermotectonic event is therefore tentatively bracketed between 2075 Ma (deposition of Sequence 1) and 1917 Ma (emplacement of Porter Bay Complex), although independent evidence for contemporaneous accretionary processes along the southeastern margin of the Hearne Craton does not currently exist.

Emplacement of the 1917 to 1913 Ma Porter Bay Complex along the rifted continental margin (Figure J-03) of the Hearne Craton signalled the onset of subduction related to the closure of the Manikewan Ocean. This is supported by the dioritic to monzodioritic composition of the Porter Bay Complex magmas, an associated volcanic edifice, and by a trace-element geochemical signature that is characteristic of destructive plate margins (Maxeiner and Rayner, 2011). Emplacement of the Porter Bay Complex was accompanied by deformation and weak metamorphism (D3-M3), presumably related to crustal thickening due either to arc emplacement or to accretion of juvenile arcs from the Manikewan Ocean. Juvenile island arc volcanism within the Manikewan Ocean (Stauffer, 1984) began as early as 1915 Ma (Baldwin *et al.*, 1987) and was well-advanced by 1905 Ma (Corrigan *et al.*, 2001).

Further subduction at the margin ended when one of the juvenile island arcs was accreted to the Hearne Craton margin by 1900 Ma (Figure J-04). However, development of other juvenile island arcs continued within the Manikewan Ocean (*e.g.,* Syme *et al.*, 1998; Maxeiner *et al.*, 2005). The >1870 Ma Reed Lake calc-alkaline island arc assemblage, exposed in the La Ronge Domain on southern Reindeer Lake, developed on top of the Lawrence Point back-arc ocean floor assemblage. This island arc assemblage was probably formed above a north-directed subduction zone (Maxeiner *et al.*, 2001).

Rocks now exposed in the Flin Flon area comprise 1900 to 1890 Ma tholeiitic oceanic arc rocks, 1890 to 1880 Ma calc-alkaline oceanic arc rocks, and an 1885 Ma shoshonitic suite (Syme *et al.*, 1998 and references therein), all of which were amalgamated to form an accretionary collage, termed the Amisk Collage (Lucas *et al.*, 1996). Younger 1870 Ma tholeiitic to calc-alkaline arc rocks exposed in the Hanson Lake area were also accreted to the Amisk Collage (Maxeiner *et al.*, 1999), as were rocks of the Glennie Domain (Ashton *et al.*, 1997). Maxeiner *et al.* (2001) proposed that the Reed Lake and Lawrence Point assemblages and other lithotectonic assemblage located further southeast, first interacted with the Glennie–Hanson–Flin Flon arc components as opposed to the Hearne Craton margin (Figure J-05). Beginning at about 1865 Ma, the Wathaman Batholith continental arc was emplaced along the southeastern Hearne Craton margin (Meyer *et al.*, 1992), indicating renewed subduction at this margin. Quartz monzonitic and granitic magmas were intruded into the Peter Lake and the Wollaston domains at this time. Within the Peter Lake Domain, the abundance of Wathaman Batholith magmatic rocks increases northeastward and it is now also recognized that some of these originated from mafic magmas. Emplacement of the batholith initiated uplift and erosion of the southeastern margin of the Hearne Craton, which provided detritus for deposition of the Wollaston Supergroup foreland basin (Daly Lake and Geikie River groups).

By 1850 Ma, the Lawrence Point suprasubduction ophiolite (Figure J-06), which consists of the Lawrence Point and Reed Lake assemblages, had been thrust over the Glennie–Hanson–Flin Flon arc complex (Maxeiner *et al.*, 2001). The intervening Levesque Bay assemblage (Corrigan *et al.*, 1999) is interpreted to have been a tectonically imbricated accretionary complex consisting of abundant pelitic to psammopelitic sedimentary rocks and slivers of oceanic crust (Maxeiner *et al.*, 2001, 2005). Wathaman Batholith magmatism ceased between 1855 to 1850 Ma, probably as a result of thrusting of the Lawrence Point-Glennie-Hanson-Flin Flon accretionary complex onto the margin of the Hearne Craton.

The 1820 to 1800 Ma thermotectonic overprint related to the peak metamorphic event of the Trans-Hudson Orogen is negligible in the Peter Lake Domain.

Quaternary Geology

Introduction

In conjunction with the bedrock mapping and a multiparameter airborne geophysical survey, Quaternary geological investigations were initiated in 2003 in the Patterson Island area of Reindeer Lake (parts of NTS 64E/10 and /15; Campbell, 2003a). This work focused primarily on the region underlain by dioritic to gabbroic rocks of the Swan River Complex (Corrigan, 2001), and involved 1:50 000-scale mapping, recording of ice-flow indicators, and a regional till sampling survey. Quaternary geological investigations continued in 2004 in the MacKenzie Lake, Zengle Lake, and Crane Island (Reindeer Lake) areas (parts of NTS 64E/15 and /16; Campbell, 2004a) immediately north of the Patterson Island map area. The objectives of the project were to

1) provide a Quaternary geological framework for drift prospecting,
2) determine the signatures of precious and base metals in till that is down-ice from known platinum-group element (PGE) occurrences,
3) determine whether till composition reflects that of the local bedrock,
4) reconstruct the ice-flow chronology for the region,
5) provide till geochemical and surficial materials databases to serve as a baseline for mineral exploration and environmental assessment, and
6) provide ground truthing for the multiparameter geophysical surveys of the Peter Lake Domain.

Summary (after Campbell, 2003a, 2004a)

Quaternary geological investigations in the Patterson Island (south map), and the MacKenzie Lake, Zengle Lake, and Crane Island (north map) areas involved surficial mapping at 1:50 000 scale, recording of ice-flow indicators, and a regional till sampling survey. Multiple ice-flow directions were documented. The dominant ice-flow direction was to the south-southwest (200° to 210°), becoming more southwestward (215° to 220°) towards the southern boundary of the map area. Two older regional ice-flow directions are oriented at ~188° (175° to 195°) and 228° to 240°. Rare, faint striae sets trending 154°, 220˚, 250-260˚ and 295/115° were also recorded and predate the main regional flow.

Drift cover is variable in the study area. The eastern and northern portions of the study area are dominated by bedrock (approximately 50 to 70%) mantled by <2 m of discontinuous drift cover. Here the present-day landscape is controlled by the bedrock topography with little geomorphic expression of the glacial deposits. In the west half of the study area and south of Patterson Island, the drift thickens and is more extensive, with <10% bedrock exposure. The landscape is more subdued there and reflects both glacial geomorphic features and bedrock topography.

The dominant surficial sediments are till and organic deposits. Sand and gravel deposits are associated with esker systems, minor meltwater drainage channels, stagnant-ice hummocky moraines, and glaciolacustrine littoral deposits. Till occurs primarily as ground moraine veneer <2 m thick, and ground moraine plain >2 m thick, as well as hummocky moraine and stagnant-ice moraine. Ridged moraine and streamlined forms such as drumlins and crag and tails are less common. Till composition varies with the type of deposit, thickness, and source rocks from which it is derived. At least four facies were identified: a silty-sand to sandy till, a very sandy till, a silty-sand matrix-rich diamicton, and a gravelly sand diamicton.

Winnowed and reworked sediments and raised strandlines, such as sand and cobble beaches, terraces, wave-cut notches, and ice-contact deltas indicate that glacial Lake Agassiz extended further north and west than previously thought. The highest strandlines were found at about 425 to 430 m asl. The vast majority of the south map area lies below 425 m and was inundated by glacial Lake Agassiz. Raised beaches found in this area were predominantly at ~350 m asl with the highest found at ~362 m asl. Much of the area below ~350 m asl is characterized by exposed outcrop, boulder lags, winnowed till, and sporadic lacustrine sediments indicating a stable lake level over a time; a level approximately 14 m above the present water level of Reindeer Lake.

Several large southwest-trending subglacial meltwater drainage systems cross, or terminate in, the map area. These systems consist of subglacial tunnel valleys and/or esker complexes, and associated ice-contact deposits including ice-contact deltas.

During the late Wisconsinan glaciation, the Keewatin Lobe of the Laurentide Ice Sheet advanced south-southwestward over the region from a dispersal centre in Nunavut (Prest *et al.*, 1968; Prest, 1984). As the ice retreated from the Reindeer Lake area approximately 8500 to 8200 yrs BP (Schreiner, 1984c), parts of the region were inundated by a proglacial lake, which probably was the northwest extension of glacial Lake Agassiz. Reindeer Lake is a modern remnant of glacial Lake Agassiz, which apparently abandoned the area by 7800 to 8000 yrs BP (Schreiner, 1984c; Teller and Leverington, 2004). Models for deglaciation and the northern extent of the proglacial lakes in Saskatchewan are presented by Schreiner (1983), Teller *et al.* (1983), Dyke and Prest (1987), Dyke and Dredge (1989), Dyke *et al*. (2002, 2003), and Teller and Leverington (2004).

A large part of the area is not suitable for drift prospecting, as bedrock, organic, ice marginal, and wave-reworked deposits dominate the terrain. Drift prospecting techniques are more applicable in the southern and western areas where the drift cover is more extensive.

Ice-flow History

The main ice-flow event during the Late Wisconsin was to the south-southwest out of the Keewatin Ice Sector in Nunavut (Figure K-01). This flow was subparallel to the regional bedrock structural grain, which suggests bedrock topographic control.

Multiple ice-flow directions were documented in the area. The reconstruction of ice-flow directions and chronology compiled from the detailed mapping of erosional ice-flow indicators and landform analysis is shown in this regional map (Figure K-02). In the mapping area, the main ice flow to the south-southwest ranges from 200 to 220°, but was mainly between 205° and 210°. South of Patterson Island, the main ice-flow direction swings slightly more to the southwest ranging 215 to 220˚. At least four older regional ice-flow directions were recognized although the relative age could only be determined for two of them. Striae and roche moutonnées record more southwestward flows; 228° to 240°, and a distinct, but rare 220° ice-flow direction. The 220° may be a transitional shift in ice flow related to the 228° to 240° event and not considered a separate ice flow event. A southward regional flow direction of approximately 188° was also documented by striae ranging 175° to 195°. Cross-cutting relationships indicate that the 220° and the 230° to 240° ice-flow directions predate the southward ice flow which predates the main southwest ice flow.

In the Porter Bay area of northwest Reindeer Lake, three sets of striae are preserved on an outcrop of granitic rocks (Figure K-03a). A set of 184 to 194° striae on a protected outcrop surface provide evidence of a southerward ice flow predating the main south-southwesterward ice flow (evidenced by a 212° striae). Also evident are sets of 154/334° and 295/115˚striae (denoted as blue arrows on Figure K-02) , Their ages relative to each other could not be determined, but both are older than the 184° and 212° striae.

Another key set of multiple striae was located west of Wiley Bay, south of Patterson Island. The early 191° striae are preserved on a south-angled, polished, protected surface and the main set of 213° striae is preserved on top of the granitic outcrop (Figure K-03b).

In another example (Figure K-04a) from the northwest Reindeer Lake area, striae oriented at 176° on a protected outcrop surface predate the main ice flow direction (striae at 204°).

A remolded outcrop on the shore of Reindeer Lake also records two ice-flow directions. The dashed arrow denotes the original roche moutonées oriented at ~240°. Subsequent remoulding and striae(204°) on the surface record the main ice-flow event (Figure K-04b).

In the northern part of study area, two rare sets of faint striae (140° to 150°, 250° to 260°) were found on protected surfaces and are cross-cut by both the main south-southwest and the earlier south ice-flow directions however their relative ages to each other and with respect to the other older southwest direction are unknown. The two rare directions are denoted in blue, relative age unknown, on the ice-flow map (Figure K-02) and their sense of movement is uncertain. Similar sets were also encountered in the northeast quarter of the Phelps Lake map sheet (Campbell, 2002). Schreiner (1984b, 1984c, 1984d) and Campbell (1992) reported a similar southeast (~151°) striae direction in the western part of the Peter Lake Domain. Johnston (1978) and Schreiner (1984e) also reported a northwest- to west-trending ice-flow direction around the southern part of Reindeer Lake. Rare due east-west striae were also reported in northwestern Manitoba (Dredge *et al*., 1986; Kaszycki, 1989a, 1989b).

Extrapolation of these earlier flow directions into other areas is tenuous. The southeast and westward ice-flow have been interpreted as events that predate the main Late Wisconsinan advance. Dredge *et al.* (1986) proposed an eastward flow into northwestern Manitoba, north of 58°N, from an initial position of the Keewatin ice divide in the south-central part of the Northwest Territories with the ice sheet extending down to at least the Fond du Lac River in Saskatchewan. In contrast, Johnston (1978), Schreiner (1984c), and Kaszycki (1989a and 1989b) suggested that these east-west striae reflected an early westward flow. Kaszycki (1989a and

1989b), suggested the westward striae record may reflect a pre-Late Wisconsinan advance of the Labradorean Ice Sheet across the Prairies, as postulated by Prest and Neilson (1987) and Prest (1990), to account for the distribution of distinctive greywacke erratics derived from eastern Hudson Bay.

The remaining ice-flow directions most likely represent shifts in response to changing glacial conditions related to the advance and retreat of the Keewatin ice lobe, as well as interaction with the Hudson ice lobe of the Labradorean Sector to the east, during the Late Wisconsinan glaciation. It is proposed that early ice flow was initially to the southwest then swung eastward into Manitoba. This eastward flow is correlated with an early south-southeastward flow from 140° to 170° documented in Manitoba (Kaszycki, 1989a and 1989b). The subsequent swing of the southeastward ice flow to the south-southwest appears to be transitional, as there is a continuum of striae orientation recorded from 175° to 212°. The main regional ice-flow direction to the south-southwest reflects ice flow during deglaciation. Local variations in the striae record are due to topographical variations.

Glacial Dispersal

Glacial erratics are boulders or clasts of exotic lithology, with respect to the region they are found in, that have been transported and deposited by the ice sheets. If the source area is known, transport distances and direction can be determined. Several distinct glacial erratics were found primarily in the northwest Reindeer Lake area and demonstrate sustained regional-scale ice flows over long distances.

An unmetamorphosed sandstone (quartz arenite) erratic (Figure K-05) found in the Crane Island area suggests that a south-southeast ice-flow event transported this cobble either from the Athabasca Basin or further north from the Thelon Basin, Northwest Territories. The erratic was likely derived from the Thelon Formation rather than the Athabasca Group based on the >5% detrital feldspar grains noted in thin section of the quartz arenite (D. Quirt, pers. comm., 2004).

Several slightly deformed and metamorphosed polymictic conglomerate boulders were found in the Crane Island area of northwest Reindeer Lake (Figures K-06 and K-07). A greater abundance of similar conglomerate boulders was also encountered in the northeast quadrant of the Phelps Lake map sheet (Campbell, 2002; Harper *et al.*, 2002), approximately 200 km to the north, and were probably derived from the Hurwitz Group several hundred kilometres to the north in Nunavut.

A white, fine-grained quartzite boulder (Figure K-08), found in the Patterson Island area in 2003, is tentatively attributed to the Kinga Formation, lower Hurwitz Group (C. Harper, pers. comm., 2004). These boulders are indicators of regional dispersal of glacial debris over distances >250 km from sources to the north-northeast.

The map below (Figure K-09) shows the source locations of the erratics found in the Reindeer Lake area. The sandstone, proposed to have been derived from the Thelon Basin, is hard to accurately pinpoint without more diagnostics information. The erratic was most likely transported either by southeastward to southward ice flow (dashed black line on Figure K-09). The conglomerates and white quartzite were transported by south-southwestward ice flow (dashed blue line on Figure K-09).

Proglacial Lakes in the Reindeer Lake Area

Surficial mapping in the northwestern Reindeer Lake area has identified ice-contact deltas, sporadic lacustrine deposits, and raised strandlines, such as sand and cobble beaches, terraces, and wave-cut notches, indicating that glacial Reindeer Lake and/or glacial Lake Agassiz extended farther north and west than previously recognized (Figure 2, Schreiner, 1983; Teller *et al.*, 1983; Teller and Leverington, 2004). Numerous well-developed beaches, wave-cut notches, and terraces are at ~350 to 355 m asl. Much of the area below ~350 m asl is characterized by outcrop, boulder lags, and winnowed till. This elevation is consistent with the previously published water level for glacial Lake Agassiz in the Reindeer Lake area (Schreiner, 1983, 1984c).

Although the majority of the well-developed beaches were formed at or below approximately 350 ±5 m asl, sand and cobble beaches were found as high as 420 to 425 m asl with winnowed till surfaces above the strandlines, suggesting that the water level was at an even higher elevation at some time. Several moderately well-developed strandlines were also found between 370 and 410 m asl. Ice-contact deltas occur at elevations ranging from 370 to 405 m asl. The higher elevation strandlines were not observed in the southern portion of the study area since it is mostly below 410 m asl. Figures K-10a and b illustrate the raised strandlines south of Zengle Lake. The aerial view depicts a series of well-developed beaches above 410 m asl (Figure K-10a) and the ground view taken at the same location illustrates a cobble beach at approximately 425 m asl (Figure K-10b).

On the map below (Figure K-11), areas in dark blue represent terrain below 420 m asl illustrating the region that would have been inundated by the proglacial lake when the water level stood at 420 m asl. Glacial Wollaston and Reindeer lakes would have formed one lake. The Fond du Lac River and Cochrane River outlets would have had to have been blocked by ice to maintain this high water level.

Kaszycki and Way Nee (1990) mapped strandlines at elevations >400 m asl east of Brochet, Manitoba (approximately 70 km east of the northern part of the study area, on NTS Map sheet 64-F) indicating a proglacial lake also occupied the region immediately to the east of the Reindeer Lake basin. Schreiner (1984c, 1984f) recorded strandlines as high as 420 m asl west-northwest of the area, which he attributed to glacial Wollaston Lake. Based on their regional extent, these high elevation strandlines suggest the presence of one large proglacial lake that covered both Reindeer and Wollaston lakes basins rather than two separate glacial lakes. Based of similar elevations of 420 m asl, this larger proglacial lake appears be a northwestern extension of glacial Lake Agassiz, present in Manitoba during Dredge's Money Lake phase of glacial Lake Agassiz (Dredge *et al.*, 1986; Dyke *et al.*, 2005). Dyke *et al.* (2005) suggest this northern fragment of the lake is probably related to the Ojibwa phase of glacial Lake Agassiz, when outlet flow was to the southeast via the Ottawa River. Therefore, it is proposed that the northwest extent of glacial Lake Agassiz between 8400 and 8200 C^{14} BP (non-calibrated radiocarbon years before present) was more extensive than previously reported (Schreiner, 1983, 1984c; Teller *et al.*, 1983; Teller and Leverington, 2004). Alternatively, it may have been a separate proglacial lake independent of glacial Lake Agassiz that drained northward. However, based on our present knowledge of the deglaciation history of northern Saskatchewan and Manitoba, it is more likely that this proglacial lake was part of glacial Lake Agassiz. Further controls on glacio-isostatic rebound, ice-margin positions, drainage timing, and dates of deglaciation for this region are needed to confirm this interpretation.

Surficial Deposits

Drift cover is variable in the study area. There is a relatively sharp break approximately 5 km west of Reindeer Lake between bedrock-dominated terrain and drift-dominated terrain. The bedrock-dominated terrain is characterized by 40 to 80% outcrop mantled by <2 m of discontinuous drift cover. The amount of outcrop is greatest in the northern part of the study area (60-80%).The present-day landscape is controlled by the bedrock topography with little geomorphic expression of the glacial deposits. Westward, the drift thickens and is more extensive, with <10% bedrock exposure. The landscape in this region is more subdued there and reflects both glacial geomorphic features and bedrock topography.

Till and organic deposits are the dominant surficial sediments in the northwest Reindeer Lake area.. Scattered sand and gravel deposits are associated with esker systems, minor meltwater drainage channels, stagnant-ice hummocky moraines, and glaciolacustrine littoral deposits.

Till Deposits and Associated Landforms

Till occurs primarily as ground moraine, and to a lesser extent, as hummocky moraine and stagnant-ice moraine. Streamlined moraine constitutes a small component of the surficial geology and is primarily restricted to the north and northwest parts of the map area. Other streamlined landforms such as crag and tails are locally present. The composition of the till varies with the type of deposit, thickness, and source rocks.

Only one till unit composed of several facies was recognized. This surface till unit was deposited by the Late Wisconsinan glacial event. Based on stratigraphic drilling, Schreiner (1984c and 1984d) found two till units in the western Peter Lake Domain where the lower till was preserved in topographic lows. Therefore, in areas where the drift is thick, it is possible that multiple till units exist.

Till veneers consist primarily of locally derived material, whereas the thicker till deposits, such as till plains, crag and tails, and stagnant-ice deposits, have a higher component of exotic or allogenic debris.

Four till facies were identified and their associated landforms are described below. For detailed descriptions of the till deposits, refer to Campbell (2003).

Silty-sand to Sandy Till

The most common till is the silty-sand to sandy till (Figure K-12), the texture of which is dependent on the dominant rock type from which it was derived. Tills with greyish silty-sand matrix and higher clay content tend to be rich in mafic intrusive, metavolcanic, and/or metasedimentary detritus. Tills derived from felsic intrusive rocks and orthogneisses are brown, sandier, and have a lower clay content. The majority of these deposits are interpreted as subglacial meltout tills (Shaw, 1979; Campbell, 2001, 2002, 2003a).

In the southern and west-central parts of the area, where the drift cover is thick, the surface till tends to be sandier and less compact, with a lower boulder- to pebble-size content. There is a greater mixture of clast lithologies, including rock types exotic to the area, indicating inclusion of far-travelled detritus.

The silty-sand to sandy till is mainly associated with flat to low-relief till plains and veneers (Figure K-13). These deposits are associated with the main south-southwest ice-flow direction.

Sandy Till

A brown to greyish brown, bouldery, sandy till (Figure K-14) with a sandy to very sandy matrix is the dominant surface deposit in the Thyme Hill River–MacKenzie Lake–Pearce Lake area, and east and north of Zengle Lake. Less extensive deposits of the very sandy till occur elsewhere. Compositionally, this till is highly variable both vertically and laterally. The sandy till is associated with ice marginal deposits, subglacial drainage systems, and hummocky, stagnant-ice moraine. The terrain underlain by the very sandy till is typically hummocky, and characterized by gently undulating to high relief (>10 m) knob and kettle topography (Figure K-15). The surface of the moraine is commonly strewn with boulders of variable size and lithology. This sandy till is differentiated from the previously described silty-sand to sandy till by its lower silt-clay content, bouldery nature, lack of textural mottling, looser compaction, and its landform association.

Sand and Gravel Diamicton

The sand and gravel diamicton is most prevalent in the Patterson Island area, particularly along the shores of Reindeer Lake. It is also found in the vicinity of MacKenzie Lake. The diamicton occurs sporadically as a discontinuous veneer, overlying either bedrock or the silty-sand till. It consists of a loose, poorly to moderately sorted, gravelly medium to coarse sand, which locally contains small amounts of silt and clay (Figure K-16). The sand and gravel diamicton has no geomorphic expression and its similarity to bouldery till made it difficult to distinguish on aerial photographs and on the ground (Figure K-17). In sample holes, it is difficult to distinguish it from ice-contact sands and gravels or washed tills. The diamicton is interpreted as an ice-marginal ablation till deposited by retreating ice during the final phase of deglaciation.

Matrix-rich Diamicton

A matrix-rich silty-sand diamicton is present north of Zengle Lake and around the south-southeastern part of MacKenzie Lake. The matrix is texturally and structurally very similar to the silty-sand till; however, the clast-size fraction is sorted and constitutes a low percentage of the deposit. Boulders were rare or absent at the surface. Within the sample hole (Figure K-18), all of the clasts were pebble size, generally <20 mm in diameter, were uniformly angular to subangular, and were generally exotic rock types. The deposits were commonly normally graded. At one site, the deposit consisted of graded matrix-rich diamicton overlying dirty, yet well-sorted gravel. Matrix-rich diamictons have been interpreted as flow tills, most likely deposited in a subaqueous environment.

Eroded and Washed (Reworked) Tills

Wave Winnowed

Boulder lags commonly armour the surface of the terrain, particularly below 360 m asl. A coarse-grained, poorly sorted diamicton is commonly associated with the boulder lags (Figure K-19a). These deposits are generally <50 cm thick and grade into the underlying till (Figure K-19b). They are interpreted to have been produced by winnowing of the fines from the till by wave action when the region was occupied by a proglacial lake. The winnowed material from the till was redistributed to lower elevations as linear, sandy, pebbly glaciolacustrine deposits.

Fluvial Erosion

It is evident in the digital elevation model (DEM) and airphoto mosaics that much of the area was modified by fluvial erosion. Low-lying areas between the uplands channelled meltwater draining from the ice. Localized boulder pavements, boulder fields, and small deposits of modified till occur in these channels, which were active both beneath (subglacial) and/or in front of the ice (proglacial). Undulating to flat-topped, streamlined landforms with terraced and/or scarp slopes northeast and west of Zengle Lake, east-southeast of MacKenzie Lake, and between Porter Bay and Pearce Lake are erosional remnants of till uplands dissected by meltwater flow(Figure K-20). They are similar to those in the northern Phelps Lake map sheet (NTS 64M; Campbell, 2001, 2002), which were interpreted as products of subglacial meltwater erosion

Glaciofluvial Sediments (Stratified Drift) and Associated Landforms

Stratified sand and gravel, and minor silts constitute approximately 20 to 30% of the surficial sediments. The largest stratified drift deposits are the dendritic esker and/or subglacial meltwater channel systems, some of which are part of larger regional drainage systems (Figure K-21a). Grain size varies considerably over their length, from sorted sand, to matrix-supported gravels, to cobbles and boulders with no matrix. Other associated deposits that flank the eskers include kames, transverse crevasse-fill ridges, ice-contact deltas (Figure K-21b), hummocky ice-contact drift (Figure K-21c) and outwash sand plains (Figure K-21d). Minor, thin discontinuous veneers of well-sorted sands capping till and bedrock are scattered throughout the map area. For more detailed descriptions of the glaciofluvial deposits see Campbell (2003a, 2004a).

Subglacial Drainage Systems

The largest subglacial drainage system is the south-southwestward–trending Thyme Hill River–MacKenzie Lake–Pearce Lake corridor. North of MacKenzie Lake, the Thyme Hill River, occupies a subglacial meltwater channel. The meltwater flow beneath the ice was confined between the two uplands and carved a valley into till and ice-contact stratified deposits to produce scarp slopes. The floor of the valley is characterized by boulder-armoured eroded till, boulder fields, and a small discontinuous esker.

The landscape in the southwest part of the MacKenzie Lake area (Figure K-22) is dominated by stagnant-ice hummocky moraine composed of very bouldery till and ice-contact deposits. The unique characteristics of this terrain are the abundance, size (up to 3 m diameter), and monolithologic composition (megacrystic granite) of the subrounded to rounded boulders that dominate the surface. This boulder moraine is associated with the subglacial drainage system and indicates high energy and volume of meltwater flow under confined conditions.

Glaciolacustrine Sediments and Associated Features

Glaciolacustrine sediments constitute <5% of the surficial materials. Rare glaciolacustrine deposits of silt and fine sand were found in flat low-lying areas near the Patterson Island area. The dominant glaciolacustrine deposits are nearshore and littoral sediments, such as sand and cobble beaches, terraces, and wave-cut notches. The majority of the beaches were formed at approximately 350 ±5 m asl and were well developed, indicating that the lake level stood at this elevation for some time. The highest strandlines were found at 425 ±5 m asl southeast of Zengle Lake. Strandlines above 355 m asl are poorly developed and less common, suggesting that these lake levels were short-lived. The significance of the raised beaches is discussed in the 'Proglacial Lakes in the Reindeer Lake Area' section.

Organic Terrain

Many of the streams and small lakes are bordered by wetlands. Peatlands commonly occupy low-lying areas between bedrock ridges and uplands. In the north, peatlands are relatively small and shallow. In areas of thicker drift, they are more extensive and commonly thick enough to obscure the underlying topography. Discontinuous permafrost is most commonly found within the peat deposits. Peat plateaus and mounds, and thermokarst features related to the presence of permafrost were observed in bogs and fens.

Drift Prospecting

Introduction

In total,288 overburden samples were collected for the Peter Lake Domain project (Figure L-01). This includes 273 till/diamicton samples (including 16 field duplicates), 2 weathered bedrock, 3 sand and gravel and five esker kimberlite indicator minerals (KIMS) samples collected by the Quaternary field crew during the 2003 and 2004 field seasons from the Patterson Island and northwest Reindeer Lake map areas (parts of NTS map sheets 64E/9, /10, /15, and /16). Five till samples were collected by R. Maxeiner from selected locations outside the 2003 and 2004 project areas (*e.g.,* Campbell Lake (unofficial place name)). Bulk till samples for Au grains and indicator minerals were collected from 154 of the till/diamicton sites.

The samples were submitted to Saskatchewan Research Council's (SRC) Geoanalytical Laboratories, Saskatoon, Saskatchewan for major and trace-element geochemical analyses (55 elements plus Au) and for textural (sand/silt/clay) determinations. A few samples were not included in for textural and/or geochemical analyses due to the nature of the sediment (ie sand).

In total 128 of the 154 bulk till samples were processed. 124 were submitted to Overburden Drilling Management, Nepean, Ontario for Au, Pt, and Pd grain counts, KIMs and base metals indicator minerals (metamorphosed massive sulphide indicator minerals (MMSIMs)). Four samples collected in 2003 as part of the oreintation study on the Antione showing were processed by Saskatchewan Research council for Au, Pt and Pd grains. Pebble lithology counts were done on 183 till samples. Thirty-two samples were counted in the field during 2004 and the another 151 samples were completed by Consorminex, Gatineau, Quebec, and are available in an Excel spreadsheet.

The interpretation of the data presented in this section is limited to identification of possible anomalies of Au, PGE, and/or selected elements related to PGE and base metals mineralization. The data for these analyses are included on the DVD in Microsoft® Excel workbooks and as shape files in the ESRI® ArcReader project for further analysis and interpretation by our clients. The links to the datasheets and descriptions of the analytical data and procedures are provided under the 'Data and Downloads' section and under the related subsections below.

Also included on the DVD is the unpublished till compositional data from a 1992 Saskatchewan Research Council study in the Peter Lake Domain (Campbell, 1992). Ten bulk till samples were collected in 1992, primarily along Highway 905, for more detailed studies of till composition. Data includes <0.063 mm till geochemistry and textural analysis as well as pebble counts, heavy mineral analyses, and Au grain counts for the 10 bulk tills. As part of this study, selected SRC archived till samples, collected during a 1970s reconnaissance mapping program, were also analyzed for major and trace elements, as well as Au. This data will not be discussed in this report but is available in the 'Data and Downloads' section.

Implications for Mineral Exploration

1) Much of the area is unsuitable for drift prospecting. In the east, near Reindeer Lake, bedrock with interspersed organic deposits dominates the terrain. Till in this region is commonly very thin, patchy, and wave winnowed. Ice-contact drift and ablation till are

common within and adjacent to the subglacial channels and esker systems. This material commonly occurs as a thin veneer and is difficult to distinguish by surface characteristics from the subglacially derived till. Drift prospecting is more suited to the central and western parts, where the drift cover is more extensive, although there are significant expanses of fens and bogs, which would inhibit till sampling.

2) Although the area has been influenced predominantly by ice flowing to the south-southwest, the complex ice-flow history (multiple directions and relative ages) must be taken into account when applying dispersal models to geochemical or indicator-mineral anomalies.

3) Soil profiles are well developed, with thick Ae and B horizons, indicating heavy leaching and oxidation of the sediments. Till is oxidized to depths >1 m in some areas. Due diligence is needed when sampling in order to obtain results that are representative of the metal concentrations in the till and minimize the contamination of secondary accumulations associated with soil-forming processes.

4) Boulder lags and winnowed till are common below 350 m asl elevation. The boulders could hamper till sampling. The upper 40 cm of the till has commonly been affected by wave action, resulting in removal of the fines and natural concentration of heavy minerals. This concentration effect must be taken into account when interpreting grain count data. Till samples should be collected from the underlying, unmodified till.

5) Field observations suggest that the silty-sand to sandy till is, for the most part, locally derived and the preferred sampling medium. The thickness of the till deposit, however, is an important factor in controlling renewal distances (distance from source) of rock detritus and the degree of dilution by exotic material. Consequently, the thicker the deposit, the larger the component of distally derived material.

6) Exotic debris derived from outside the Peter Lake Domain, as a result of regional-scale dispersal, can hinder interpretation of regional till geochemistry by influencing background element concentrations and affecting the resolution of local geochemical anomalies. For instance, the far-traveled debris might be geochemically impoverished with respect to the local bedrock, and could therefore mask or suppress local mineralization. Alternatively, if the exotic material is geochemically distinctive and dispersed over a large area of metal-poor rock lithologies, false geochemical anomalies can result. Either case would lead to an incorrect assessment of the mineral potential of a region.

7) Till composition studies, surficial geological mapping, and ice-flow history are crucial components for drift prospecting programs in this region of the Peter Lake Domain.

8) Till geochemistry reflects regional bedrock geology. Only where drift is thin and locally derived does the till geochemistry reflect local bedrock geology.

Till Geochemistry

The geochemical data, including analytical results for the <0.063 mm size fraction, standards with accuracy checks, lab repeats, and field duplicates, and the analytical techniques and detection limits can be found in an Excel spreadsheet accessible through the 'Data and Downloads' section. The till geochemical data are also included with the ESRI® ArcReader project.

Samples and Analytical Methods

All the till samples were submitted to the Saskatchewan Research Council's (SRC) Geoanalytical Laboratories for geochemical analyses using their 6.3+6.3R, 55 element package. A split of the archived till samples was air-dried and dry sieved using a stainless steel –230 mesh screen to obtain the <0.063 mm (silt and clay) fraction. Approximately 1 g of the <0.063 mm fraction was analyzed at SRC for a suite of trace elements using inductively coupled plasma-atomic emission spectrometry (ICP-AES) after a partial digestion (8:1 HNO_3:HCl, heated at 95°C for one hour). A 0.25 g pulp sample was gently heated in a mixture of HF:HNO_3:$HClO_4$ until dry; the residue was dissolved in dilute HNO_3 and analyzed using ICP-AES for major and trace elements. Concentrations of Au, Pt, and Pd were determined on 30 g of <0.063 mm pulp by fire assay with axial ICP finish. Partial U concentrations were determined by fluorimetry in 2003, while 2004 and 2005 samples were analyzed by ICP-AES.

Analysis of laboratory duplicate samples and analytical standards were used to monitor analytical precision and accuracy of geochemical results. Field duplicates were included to test the concentration variability within the sample medium. In every analytical batch, approximately 3% laboratory duplicates and 5% standard samples were included, using SRC's in-house control reference samples. In 2003, the lab used in-house standards ARS1 and ARS2 for both partial and three acid near-total digestions. In 2004, in-house standard CG509 was used for three acid near-total digestion and in-house standard LSR3 for partial digestion to check analytical accuracy and precision. It is difficult to compare the analytical accuracy between sample years as, unfortunately, different standards were used. Analytical errors for the major and trace elements are considered within acceptable range in light of the small number of standards used. The expected values reported by SRC for their in-house standards have a low precision; therefore the accuracy is probably lower than stated.

Geochemical Data

For this report, only the test results for selected elements associated with PGEs and base metals will be discussed. All of the 2003 samples were analyzed for Pt and Pd and returned concentrations at or below the detection limit of 2 ppb. Considering these disappointing results and the expense of the tests, it was decided not to analyze the 2004 samples for Pt and Pd. Unfortunately, the samples from the Swan Lake Pt-Pd-Ni-Cu showing were included in the 2004 samples thus there are no Pt and Pd results for these samples. Pt and Pd was included for the 2005 samples.

1. Using descriptive statistics and proportional dot plots based on five classes of natural breaks (Jenks), the results for near-total Cu, Ni, Co, Cr, Pb, and Zn concentrations in the <0.063 mm size fraction of the till samples are presented in Figures L-02, L-03, L-04, L-05, L-06, L-07, and L-08.

When interpreting the till geochemical data presented on the -0.063 mm geochemistry worksheet in the accompanying Microsoft® Excel workbook (PeterLk2003-2005till_geochemistry.xls), particularly in the case of the anomalous samples, it is important to refer back to the sample site description, textural data, and loss-on-ignition (LOI) content to determine how reliable and relevant the reported concentrations are. For instance, several of the anomalous samples for Cu, Pb, and Ni are from diamictons of undetermined origin. Where the diamicton overlies subglacial till, the till samples generally have lower concentrations than the diamictons (*e.g.*, sample numbers 0360-0054 (till) and 0360-0055 (diamicton)).

In general, the variations in elemental concentrations primarily reflect variation in bedrock composition from which the till is derived. Other than in the Campbell Lake (unofficial place name) area, a direct geochemical correlation between till and bedrock could not be determined in the study area. This is primarily due to the relative locations of the bedrock and till samples. Elevated Zn-Pb-Co concentrations in till samples from the Campbell Lake area likely reflect incorporation of sedimentary rocks of the Campbell River Group, which hosts a number of Zn-Pb occurrences. The samples were collected down-ice from one such occurrence (Saskatchewan Mineral Deposits Index (SMDI) #0565 – all SMDI files noted in this section are accessible through links in Table I-01).

The McLean Bay area on north Reindeer Lake has a distinctive till geochemical signature with elevated to anomalous values of Cu-Ni-Cr-Zn (+Pb), possibly due to the presence of mafic to ultramafic intrusive rocks of the Swan River Complex and associated sulphides in the area (SMDI# 1834 and 1837; and Cu and PGE occurrences newly discovered by this project; see SMDI# preceded by 'Max' in Table I-01). The most anomalous Ni sample (0460-0140) in the McLean Bay area, collected on the southern tip of Feaviour Peninsula, is from a gravely diamicton overlying till, which contains lower, yet elevated concentrations of Ni (sample numbers 0460-0139 and 0460-0141).

Similarly, southwest of Crane Island, the elevated Cu-Ni-Cr concentrations in the till are likely related to the incorporation of Swan River Complex mafic to ultramafic rocks, which are present locally. Also in the area, a small lake within one of the ultramafic units was sampled as part of the National Geochemical Reconnaissance (NGR) program. The lake sediment sample had an anomalous Cu value (GSC sample 841189; Hornbrook et al., 1985). Till samples were collected both up-ice and down-ice of the lake to test the lake sediment anomally and demonstrated the elevated Cu-Ni-Cr were within background for the ultramafic rocks that underlie the lake and surrounding area.

Northwest of Crane Island, the majority of the till samples overlie granodiorite, yet they have a geochemical signature enriched in Cu-Ni-Cr and are similar to samples taken up-ice, which overlie a Swan River Complex leucogabbronorite body. The geochemical signature of the till samples collected over the granodiorite suggests glacial dispersal from the adjacent leucogabbronorite body. The highest mineral concentrations in the samples are of Cu. The McLean Bay Cu occurrence (SMDI# 1834) is located approximately 2.5 km up-ice of several of the samples. The till may be reflecting this and other unknown occurrences in the area.

In the till south of Patterson Island, a large area of regional enrichment of Co-Cr-Zn with a corresponding minor enrichment of Cu-Ni exists. This may reflect glacial dispersal from the

Patterson Island Pluton of the Porter Bay Complex, related to the earlier more southerly ice-flow direction (see 'Ice-flow History' section). Alternatively, the till may be reflecting an unknown intermediate to mafic source beneath Reindeer Lake to the northeast.

There is a regional Pb enrichment (Figure L-06) and a marked depletion in Co (Figure L-04) and Cr (Figure L-05) in the MacKenzie Lake and Zengle Lake area. The elevated Pb cannot be attributed to any local bedrock source at present and may be a result of analytical error. The depletion of Co and Cr is likely related to the increased proportion of felsic detritus in the till from syenogranite and Wathaman Batholith megacrystic monzogranite, which predominate the bedrock in this area. Further interpretation of the complete till and lithogeochemical datasets is necessary to comment on the significance of this regional trend.

Regionally, the elemental signature of the mafic and ultramafic bodies is reflected in the till geochemistry. Cu, Ni, Co, and Cr are good indicators of the mafic source rocks. This indicates that till geochemistry can be used in the search for prospective rock types that may potentially host PGEs, particularly in areas where bedrock exposure is poor such as in the interior part of the Peter Lake Domain.

Till Matrix Texture

The till samples were submitted to Saskatchewan Research Council for textural determinations. The sand fraction (0.063 to 2 mm) was determined by wet sieving of the <2 mm fraction. The silt (0.002 to 0.063 mm) and clay (<0.002 mm) fractions were determined by the pipette method. The results were calculated as a percentage weight of the <2 mm fraction and are presented on the textural worksheet in the linked Microsoft® Excel workbook. The clay content is accurate to 0.5%. The results of laboratory repeats, field duplicates, and in-house analytical standards are also included in the textural data worksheet.

The till matrix (<2 mm) of relatively unweathered till varies significantly across the study area (Figure L-09). The sand content ranges from 14.0 to 95.6% (mean of 64.8%), silt from 2.9 to79.2% (mean of 32.8%), and the clay content from below detection limits (<0.5%) to 17.1% (mean of 2.4%). The variability is related to provenance, depositional facies, soil horizon, and associated landforms (see 'Surficial Deposits' section). The majority of the tills (Figure L-10 were classified as silty-sand (69.7%) and sandy (20.2%). The sandy-silt tills are found predominantly in the northern part of the project area and are generally matrix-rich diamictons (Figure L-09).

Although the clay content of the tills has a large range (<0.5% to 17.1%) , only four samples contained >8% clay. Ninety percent of the samples contained <5% clay in the matrix. This pattern is reflected in the clay to silt ratio, which is relatively uniform, varying only from 0.01 to 0.64 (mean of 0.08) with 98% of the samples having a ratio of <0.03. This suggests that variability in the clay content of the till is not a concern with respect to creating false anomalies of labial elements related to increased clay content of the samples. The highest ratios are predominantly associated with the sandy tills in which the silt and clay contents are equally low (Figure L-11).

Pebble Counts

Pebble lithologies provide information on till provenance, which, in turn, is an indicator of glacial transport distances and directions. These data and the reconstruction of the ice-flow chronology derived from the ice-flow indicators are essential components for the application of drift-prospecting principles and the delineation of the source of glacial-dispersed mineralization detected by till sampling.

The 5.6 to 25 mm fraction of 151 bulk till samples were submitted to Consorminex Inc., Gatineau, for lithological classification. An additional 32 samples were classified in the field by J. Campbell and R. Kulach in 2004. The goal was to classify 200 pebbles per sample. For samples where this number of clasts was not available in this size fraction, all clasts were counted and recorded.

Interpretation of the data is not included with this report but the data is provided for the user. The pebble counts for the bulk till samples can be found in a Microsoft® Excel spreadsheet accessible through the 'Data and Downloads' section. The pebble count data are also included with the ESRI® ArcReader project.

Gold and Platinum-group Elements (PGE) in Till

Gold

To ensure detection of both fine- and coarse-grained Au as well as occluded Au in sulphides or quartz, it is best to carry out Au grain counts (Figure L-12), as well till fine fraction (-.063 mm) Au analyses (Figure L-13) for bulk till samples (data in accompanying Microsoft® Excel spreadsheet). Fine fraction Au analysis was done on all till samples but Au counts were only obtained for sites where bulk tills were collected. However, the quantity and distribution of bulk tills collected allows for detection of fine and coarse gold at a regional scale. As demonstrated in the proportional plots for Au grains (not normalized) and fine fraction Au, there is a poor correlation between the two fractions.

Although 30 g of sample was requested to be used for the analyses, it is unclear if this was always the case. Therefore fine fraction (<0.063 mm) Au results should be interpreted with caution due to the possibility of nugget effect and/or possible contamination in the fire assay oven. This is especially true for the 2004 results as higher values could not be repeated during analytical reruns of the samples (see 'Data and Downloads' section).

Gold grain counts are a more reliable method of determining the presence of Au in till. The size and shape provides information on transport distances as well as the type of mineralization (DiLabio, 1985, 1988, 1990; Averill and Zimmerman, 1986; Averill, 1988, 1999). The mineralogy of the heavy mineral fraction can provide information on the type of mineralization and its host rock (Averill and Zimmerman, 1986; Averill, 1988, 1999). Regionally, the Au grain counts in till (~10 to 12 kg sample) are very low. Eighty-three percent of the samples contained two or less grains, while 37% of the samples contained no Au grains. The 95th percentile is four grains, however, samples with greater than two grains, particularly with modified to pristine shapes, should be considered significant and worth further investigation. The highest count was from sample 0460-0063 with 53 Au grains, which are predominantly fine grained and pristine shaped. This sample is located immediately down ice of the Swan Lake Pt-Pd-Cu-Ni showing, which is known to contain gold (Maxeiner and Rayner, 2005). Till samples from down ice of the Swan Lake showing also showed slightly to elevated Au values in the fine fraction – either in the initial analysis or the repeat. Two other significant samples, 0360-0067 (nine reshaped grains) and 0460-0124 (six reshaped grains and one modified grain), occur in the Wiley Bay and Crane Island areas. Other samples from these areas, as well as from McLean Bay, south of Zengle Lake, and the Porter Bay area all contain elevated values for Au, either in the grain counts or geochemical analysis. The grains, however, are predominantly reshaped indicating long transport distances and may represent background Au in the till.

Platinum and Palladium

No Pt or Pd grains were found in the heavy mineral concentrates of the bulk till samples. Geochemical analyses indicate that both Pt and Pd concentrations in the fine fraction of the 2003 and 2005 till samples were at or below the analytical detection limits. Due to the cost of the analyses and poor results, which in part, is related to poor detection limits, the decision was made not to analyze for Pt or Pd in 2004, relying on pathfinder elements to indicate the possible presence of PGEs for follow-up analyses. With the exception of the samples from the Swan Lake showing, there were no samples which warranted further analyses for PGEs.

Orientation Studies for PGE-Au in Till

Gold drift prospecting techniques have been proven applicable to the exploration for PGEs I n orientation studies by Coker *et al.* (1991) at Rottenstone Lake, Saskatchewan, Ferguson Lake, Northwest Territories, and Sudbury, Ontario, and by Barnett (2007) at Lac des Iles, northwestern Ontario.

At Rottenstone Lake, the geochemistry of both the fine fraction (<0.063 mm) and heavy mineral concentrates (HMC) proved useful. Copper and nickel of the <0.063 mm size fraction best outlined the mineralization and associated glacial dispersal. Gold and PGEs showed little response in the fine fraction with values close to or at the detection limit. Moderate to high concentrations of Au and Pt were found in the HMC of the tills. These values extended for at least 1 km down-ice of the deposit.

Barnett (2007) reported that at Lac des Iles, glacial dispersal trains of up to 7 km are observed in the till (C horizon) fine fraction geochemistry (*e.g.*, Ni, Cr, Cu, and Co). Platinum and pallidium dispersal trains are not well defined and tend to be very short (<1 km in length). The fine fraction geochemistry indicate that Pd, Pt, Ni, and Cu appear to be mobilized in solution both within the soil profile and downslope out of the soil system into surface and shallow groundwater.

Antoine's and Ant Lake South Showings

Previous Work

In 1998, Lehnert-Thiel of Golden Band Resources (Saskatchewan Ministry of Energy and Resources assessment file 64-E-10-0009) collected 18 bulk till samples immediately down-ice of the Ant Lake South and Antoine's Cu-Ni-Pt-Pd showings to test for the response of Pt, Pd, and Au in till, both as particulate grains in the sand fraction and in the geochemistry of the till matrix. No analyses for pathfinder elements were conducted. At the Ant Lake South showing, samples were collected adjacent to the mineralization (<50 m) and along a line 300 m down-ice of the showing.

The results were not encouraging. No Pt-bearing minerals were detected from either showing, although one sample from each showing had encouraging results. At the Ant Lake South showing, sample ANT 10 contained elevated concentrations for Au (71 ppb), Pt (34 ppb), and Pd (55 ppb), and seven Au grains. This sample was taken adjacent to the trench. No response was detected in the samples down-ice from the Ant Lake South showing.

Sample ANT 1 from the Antoine's showing contained 11 ppb Au, 7 ppb Pt, 21 ppb Pd, and nine Au grains. Again, the sample was taken immediately adjacent to mineralization (~20 m). No samples were taken down-ice of the Antoine's showing. Lehnert-Thiel attributed the poor results to the poor quality of the sample media.

Current Study

During the 2003 field season, a detailed orientation study (Figure L-14) was carried out at the Antoine's showing (Saskatchewan Mineral Deposits Index #2374) to investigate dispersal and detection of Pt-Pd in till (Campbell, 2003a). No geochemical, indicator minerals or Pt-Au-Cu grains dispersal was detected in the till at approximately 200 and 450 m down-ice from the showing. Platinum and palladium were at or below detection limits. Copper (Figure L-15) showed no response and only nickel (Figure L-16) showed a very slightly elevated response with respect to samples from the surrounding area.

This was not completely unexpected as the surficial geology of the area surrounding the Antoine's showing is not considered favourable for drift prospecting. Thin drift, the abundance of ice-contact and organic deposits, and a high water table hampered sample collection. With the exception of sample 0360-0130, the till also contained a high portion of more distally derived detritus (Figure L-17). Sample 0360-0130 (Figure L-18) was taken from a good subglacial till and contained locally derived angular intermediate to mafic intrusive clasts. Note that the mafic clasts only constitute a minor proportion of the clast fraction.

Swan Lake Showing

An attempt was made to collect samples down-ice from the Swan Lake showing, but the surficial geology was not conducive for sampling representative till. A large muskeg lies immediately down-ice of the mineralization. Three samples were taken within 25 m of the trenches. One sample (0460-0063), taken approximately 20 m southwest of the westernmost trench, contained an abundance of oxidized regolith detritus. This sample returned 263 ppm Cu, 84 ppm Ni, 150 ppb Au, and 53 Au grains. Clearly Au is associated with this deposit. A small till sample, 0460-0064, was taken 2 m away from sample 00460-0063 and till sample 0460-0062 was taken about 10 m down-ice from 0460-0064. Both returned anomalous concentrations of Cu and Ni in the <0.063 mm size fraction (0460-0064, 70 ppm Cu and 24 ppm Ni; 0460-0062, 84 ppm Cu and 26 ppm Ni). Both samples contained Au concentrations at or below the detection limit. Unfortunately, these samples were not analyzed for PGEs. Although only a few till samples were collected from the Swan Lake showing, the results suggest that Cu and Ni, in the fine fraction of the till, could be used as pathfinder elements in the exploration for PGEs in the Peter Lake Domain.

Further detailed studies are warranted at other known mineral occurrences to characterize the signatures of PGEs and associated base metals in till.

Data and Downloads

Bedrock Geology Database

A Microsoft® Access database, which contains data relating to bedrock geology fieldwork, samples, photos, whole-rock geochemistry, and geochronology, is included with this final report and can be accessed through the link below. The database also allows access to folders containing over 5,000 jpg images of field photographs, which were taken with 2.1 and 3.1 mega pixel cameras. Before inclusion on this DVD, the files were compressed to 25% of their original size.

All of the field data was collected by R. Maxeiner and a number of senior geological assistants during four field seasons between 2002 and 2005. Mapping was carried out from a base camp with two-person traverse teams who investigated outcrops along lakeshores with a boat or traversed on foot across country. Navigation was facilitated by the use of handheld global positioning devices (Garmin® GPS 12XL and GPS 76™) and compasses. The precision of the UTM coordinates (given in NAD 83, Zone 13) is generally ±5 m or better.

Most of these datasets can also be accessed within a geographic information system (GIS) via an ESRI® ArcReader project supplied with this final report.

Lithogeochemistry

Whole-rock geochemical analyses were performed on 207 grab samples (Table G-01) collected between 2002 and 2005. Major, trace and rare earth element (REE) concentrations of whole-rock grab samples were determined by Activation Laboratories Ltd. in Ancaster, Ontario, by inductively coupled plasma-mass spectrometry (ICP–MS). The fused sample digestion technique (lithium metaborate/tetraborate fusion) was used to ensure that heavy rare earth elements and other elements contained in refractory minerals, such as zircon or sphene, were completely dissolved. Replicate analyses of samples and traditional standards (STM-1, MAG1, BIR1, W2, MRG1, SY3, and GXR1) were analyzed together with the samples to verify the accuracy and precision of the analyses. Analytical errors for the REEs are generally less than 5%; for all other trace elements they are 10% or better. CIPW norms were calculated using a spreadsheet designed by K. Hollocher: (www.union.edu/PUBLIC/GEODEPT/hollocher/kth/, accessed 7 Jan 2009). All the original spreadsheets provided by Activation Laboratories are also provided on this DVD (..//data/original_lab_geochem). These files contain information about the standard, blanks, and duplicate analyses.

The main data table is also provided as a comma delimited text file (csv file).

Additional whole-rock geochemical analyses were provided by L. Hulbert and are included as a Microsoft® Excel spreadsheet (PLD-LarryHulbertData.xls). The file contains data assembled by L. Hulbert, including data from Steven Walters' M.Sc. thesis, industry data, samples collected by L. Hulbert, full platinum-group element (PGE) analyses and S-isotope data for selected samples. These data were not used in the lithogeochemical assessment of the Peter Lake Domain as there is considerable uncertainty in the exact sample locations. They are also not included in the accompanying ESRI® ArcReader project.

Geochronology

The geochronological database for the Peter Lake Domain contains 49 records, 16 of which were acquired between 2003 and 2006.

A geochronology data table can be viewed as a Microsoft® Excel spreadsheet and is also available as part of the Microsoft® Access database for the project.

Quaternary Data

A Microsoft® Access database (view surficial Peter Lake database) that contains data relating to surficial geology fieldwork, samples, ice-flow indicators, and photos is included with this final report and can be accessed through the link below. The Quaternary field photographs have not been linked to the database, but have been included on the DVD (..//Report_261\Doc\field-photos\photo-library\m-Quaternary). All photos have been labelled by site or UTM coordinates.

The majority of the field data was collected by J. Campbell. Mapping was carried out from a base camp with two-person teams who investigated the surficial sediments and outcrops along lakeshores with a boat or traversed on foot across country. Navigation was facilitated by the use of handheld global positioning devices (Garmin® GPS 12XL and GPS 76™) and compasses. Precision of UTM coordinates (given in NAD 83, Zone 13) is generally ±5 m or better. Data for samples collected by Campbell and Saskatchewan Research Council's (SRC) archived samples submitted for geochemistry in 1991 are also in this database.

A Microsoft® Excel spreadsheet containing the essential site data and sample descriptions for the till and esker sample sites is included separately (view sample information spreadsheet). The data has been extracted from the Quaternary Access database noted above.

Till Geochemistry and Textural Data

All the till samples were submitted to the Saskatchewan Research Council's (SRC) Geoanalytical Laboratories for geochemical analyses using their 6.3+6.3R, 55 element package. A split of the archived till samples were air dried and dry sieved using a stainless steel –230 mesh screen to obtain the <0.063 mm (silt and clay) fraction. Approximately 1 g of the <0.063 mm size fraction was analyzed at SRC for a suite of trace elements using inductively coupled plasma-atomic emission spectroscopy (ICP-AES) after a partial digestion (8:1 HNO_3:HCl, heated at 95°C for one hour). A 0.25 g pulp was gently heated in a mixture of HF:HNO_3:$HClO_4$ until dry; the residue was dissolved in dilute HNO_3 and analyzed using ICP-AES for major and trace elements. Concentrations of Au, Pt, and Pd were determined on 30 g of <0.063 mm pulp by fire assay with axial ICP finish. Partial U concentrations were determined by fluorimetry in 2003, while 2004 and 2005 samples were analyzed by ICP-AES.

Analysis of laboratory duplicate samples and analytical standards were used to monitor analytical precision and accuracy of geochemical results. Field duplicates were included to test the concentration variability within the sample medium. In every analytical batch, approximately 3% laboratory duplicates and 5% standard samples were included, using SRC's in-house control reference samples. To check analytical accuracy and precision, in 2003 the lab used in-house standards ARS1 and ARS2 for both partial and three acid near-total digestions. In 2004, in-house standard CG509 was used for three acid near-total digestion and in-house standard LSR3 for partial digestion. It is difficult to compare the analytical accuracy between sample years as, unfortunately, different standards were used. Analytical errors for the major and trace elements are considered within acceptable range in light of the small number of each standard. The expected values reported by SRC for their in-house standards have a low precision; therefore, the accuracy is probably lower than reported. Detection limits, analytical results for the <0.063 mm fraction and standards with accuracy check, lab repeats, and field duplicates are presented on separate worksheets in the Microsoft® Excel workbook (view till geochemistry spreadsheet).

Textural (Grain Size) Till Analyses

Approximately 20 g of each till sample were used for textural (grain size) analyses at SRC's Geoanalytical Laboratories. The sand fraction (0.063 to 2 mm) was determined by wet sieving of the <2 mm fraction. The silt (0.002 to 0.063 mm) and clay (<0.002 mm) fractions were determined by the pipette method. The results were calculated as a percentage weight of the <2 mm fraction and are presented on the textural worksheet in the accompanying Microsoft® Excel workbook (PeterLk2003-2005till_textural_data.xlsx). The clay content is accurate to 0.5%. The results of laboratory repeats, field duplicates, and in-house analytical standards are also included in the textural data worksheet.

Gold, Platinum and Palladium Grains, Kimberlite Indicators Minerals (KIM), and Metamorphosed Massive Sulphide Indicator Minerals (MMSIMs)

During the 2003 and 2004 field seasons, 149 bulk till samples were collected for the Peter Lake Domain project. The samples were collected from the Patterson Island and northwest Reindeer Lake map areas, and parts of NTS map sheets 64E/9, /10, /15, and /16. In 2005, five bulk till samples were collected by R. Maxeiner, outside the project areas mapped in 2003 and 2004. Only 128 of the 154 samples were submitted for analyses. In 2003, four bulk till samples (0360-0127 to 0360-0130) collected from the vicinity of the Antoine's Ni-Cu-Pt-Pd showing were processed for Au, Pt, and Pd grains and KIMs by Geoanalytical Laboratories, Saskatchewan Research Council. In 2004, 71 of the bulk till samples were submitted to Overburden Drilling Management for Au, Pt, and Pd grains, KIMs, and MMSIMs. In 2005, the remaining 53 bulk till samples were submitted to Overburden Drilling Management for precious metal grains and indicator mineral processing and identification.

The sample processing and reporting of results differ between the labs; therefore, the data has generally been kept separate. The included spreadsheet (/PeterLk2003-2005till_Au&indicators.xls) and its contained worksheets present the results from the SRC lab (prefaced SRC) and from the Overburden Drilling Management lab (prefaced ODM). The processing procedures and lab report abbreviations are provided in separate PDF files:

1. SRC GOLD GRAIN and KIM ANALYSIS.pdf
2. ODMSTANDARD 2 mm Gold + KIM + MMSIM.PDF
3. ODM Lab Abbreviations.pdf

Saskatchewan Research Council (SRC)'s estimated Au weights are not comparable to ODM's calculated ppb due to different processing techniques. ODM calculates ppb based on table concentrate. SRC extracts Au using a Nelson concentrator on the -1.7 mm fraction. The ppb value can only be calculated based on the original sample size.

Pebble Counts

The 5.6 to 25 mm fraction of 151 of the 154 bulk tills were submitted to Consorminex Inc., Gatineau, Quebec, for lithological classification (see accompanying pebble count spreadsheet). An additional 30 samples collected in 2004 were classified in the field by J. Campbell and R. Kulach. The goal was to classify 200 pebbles per sample. For samples where this number of clasts was not available in this size fraction, all clasts were counted and recorded. Pebble lithologies provide information on till provenance, which in turn is an indicator of glacial transport distances and direction.

Ice-flow Indicators

All small-scale erosional ice-flow indicators measured in the field by J. Campbell, R. Maxeiner, and a number of senior geological assistants during the 2002 to 2005 field seasons, have been compiled into a single dataset using an Excel spreadsheet (see accompanying ice-flow spreadsheet). The spreadsheet contains UTM coordinates, type of ice-flow indicator, azimuth, and relative ages, where it could be determined at sites with cross-cutting indicators.

Other SRC Till Compositional Data

Campbell (1992) conducted a regional orientation study aimed at determining the applicability of drift prospecting for mineral exploration in the Peter Lake Domain. Ten bulk till samples were collected in 1991, primarily along Highway 905, for more detailed studies of till composition. As part of this study, selected SRC archived till samples, collected during a reconnaissance mapping program in the 1970s, were also analyzed for major and trace elements, as well as Au. Resultant data includes <0.063 mm till geochemistry and textural analysis as well as pebble counts, heavy mineral analyses, and Au grain counts (Campbell *et al.*, 1999).

Interactive Maps

Getting Started

The Peter Lake Domain maps, geophysical images, and many of the datasets are also accessible in a spatially referenced format. With the new 1:100 000-scale bedrock geological compilation map as the main base, the project can be viewed with ESRI® ArcReader 9.2 GIS software and is provided with several geological datasets. These include photographs, sample sites, geochemistry, geochronology, structural data, mineral showings, and geophysical maps. Please view the Installation Instructions on the DVD for further details on using the ESRI® ArcReader project.

The following datasets can be accessed through the ESRI® ArcReader project:

Maps and Images

- Index of previous maps
- 1:250 000- and 1:50 000-scale surficial geology
- new 1:100 000-scale bedrock geology
- new 1:250 000-scale bedrock geology
- new 1:1 000 000-scale bedrock geology
- previous geological map images (mapping at various scales)
- 2004 aeromagnetic and radiometric images
- gravity image
- digital elevation model (DEM) image
- selected mineral assessment file map images
- air photo mosaics
- PGE exploration targets
- metamorphic grade

Data

- 2002-2005 field photographs
- 2002-2005 geological field measurements and historic structures
- 2002-2002 lithogeochemistry
- 2002-2005 whole-rock geochemistry sample locations
- 2003 and 2004 surficial geology data, photographs, and till geochemistry
- lake sediment geochemistry (Geological Survey of Canada dataset)
- geochronology (historic and new data)
- revised mineral showings from Saskatchewan Mineral Deposits Index (SMDI)

Bedrock and surficial mapping at 1:20 000 and 1:50 000 scales was carried out by R. Maxeiner and J. Campbell for the Saskatchewan Geological Survey. Digital compilation of the bedrock geology at 1:100 000, 1:250 000, and 1:1 000 000 scales was done by R. Maxeiner. The digital compilation map was combined with geological databases in ESRI® ArcMap and output to ESRI® ArcReader 8.3 by B. Slimmon of the Saskatchewan Geological Survey.

Photo Library

An extensive photo library is included on the DVD. All the photos taken during the project are included at 25% of their original resolution and are accessible by year and traverse numbers. The photos can also be viewed using the ESRI® ArcReader project or a selection of 14 thematic libraries with photo captions is accessible through a set of dedicated pages. The themes are as follows:

- General
- Granodiorite Complex
- Lueaza River granitoid suite
- Archean supracrustal rocks
- Swan River Complex
- Zengle Lake suite
- Monzonitic intrusive suite
- Porter Bay Complex
- Campbell River Group
- Wathaman Batholith
- Other intrusive rocks
- Economic
- Quaternary
- Terrain

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