New Results and Ideas from the Rottenstone Domain Project

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Abstract

In 2004, geological mapping was continued near Rottenstone Lake and initiated at Davin Lake. At Rottenstone Lake, pink and white migmatite successions were recognized. The pink migmatite succession is characterized by pink leucosome and grey psammitic paleosome, with magnetite in both the granite and sedimentary components. In contrast, the volumetrically predominant white migmatite succession is graphite bearing. The white migmatite was derived from a sedimentary package with abundant pelite, as well as various amounts of psammite and psammopelite, calc-silicate, quartzite, amphibolite, and melanocratic biotite ± hornblende-quartzofeldspathic gneiss. Similar pink and white migmatites occur in the Davin Lake area.

SHRIMP detrital zircon studies of two samples, quartzite and psammite from east of Hickson Lake in the Crew Lake Belt, indicate that these rocks are composed of both Archean and Paleoproterozoic detritus. Zircon ages from the quartzite suggest that it is derived entirely from a continental source. Prominent peaks in the cumulative probability plot at ca. 2.44 and 2.51 Ga are most compatible with continental crust similar in age to the Sask Craton, although some contribution from Hearne age crust cannot be ruled out. The psammite has a significant proportion of detrital grains in the same age range as the quartzite, but also has a prominent and well-defined age mode at 1.89 Ga, likely derived from volcanic detritus from the La Ronge arc.

U-Pb ages for metamorphic and igneous rocks in the central Rottenstone domain indicate that transposition of compositional layering and the pre-migmatization metamorphic fabric into the composite tectonic foliation (S_{main}) occurred after ca. 1833 +5/-4 Ma, the age of a foliated biotite monzogranite sheet that pre-dated S_{main}. This granite sheet is in the core of an early (F_2) tight to isoclinal fold of S_{main} and thus, provides a maximum age constraint for F_2 folding. F_2 folding was probably more or less synchronous with the main migmatizing event. A biotite granodiorite with pelitic restite inclusions has an age of about 1825 Ma and monazite from the adjacent pelitic migmatite is 1822 ±2 Ma. The final phase of upright to inclined, open asymmetric folding occurred after 1814 ±4 Ma, the age of late K-feldspar porphyritic monzogranite.

Keywords: *Rottenstone Domain, migmatite, mapping, U-Pb geochronology, detrital zircon, thermotectonic history.*

1. Introduction

The Rottenstone Domain is a predominantly sediment-derived migmatite terrane (*e.g.*, Gilboy, 1982) within the Paleoproterozoic Trans-Hudson Orogen. It lies between the oceanic La Ronge arc to the southeast, and the Wathaman continental arc batholith to the northwest (Figure 1). Rocks of the Rottenstone Domain have undergone middle to upper amphibolite facies metamorphism and poly-phase deformation, however, throughout this manuscript the prefix "meta" has been omitted for simplicity. The higher grade rocks comprise the "tonalite-migmatite complex" (TMC; Ray, 1975), and the lower grade rocks comprise the Crew Lake Belt in the eastern part of the domain (Figure 1). The tectonic setting and age of deposition of the sedimentary protoliths, as well as their subsequent thermotectonic history, and their relationship to the evolution of the Trans-Hudson Orogen are poorly constrained (see Johnson and Thomas, 1984; Lewry and Collerson, 1990; Corrigan *et al.*, 2001).

To the northeast of this study area mapping and integrated geoscience studies on Reindeer Lake, as part of the La Ronge–Lynn Lake Bridge Project (Harper, 1996; Corrigan *et al.*, 1997, 2001; Maxeiner, 1997; Maxeiner *et al.*, 2001), led to the recognition of several distinct lithotectonic assemblages of different ages and tectonic origin. Two of these assemblages are of particular relevance to the Rottenstone Domain. The *ca.*1.865 to 1.860 Ga Milton Island

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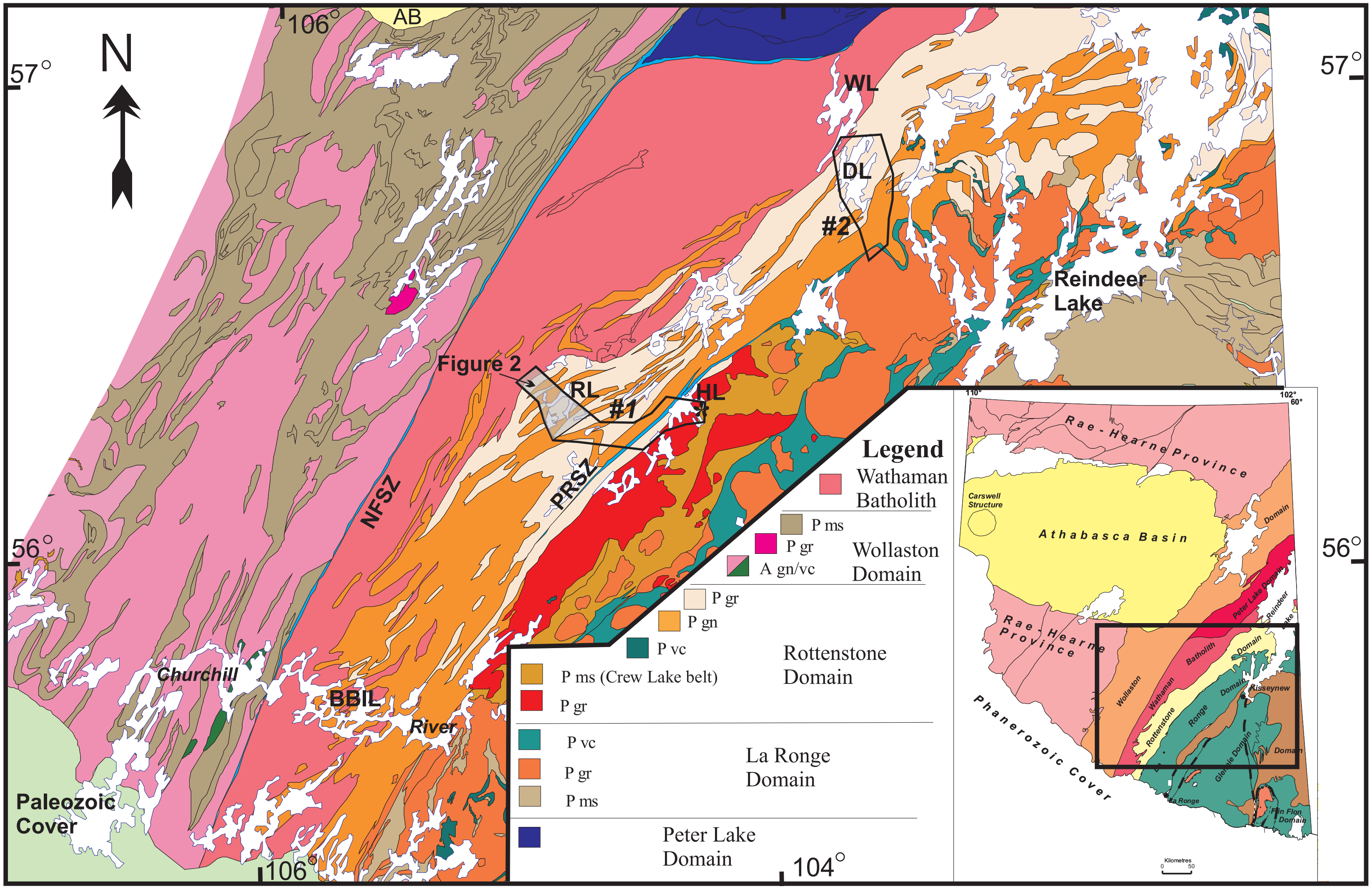


Figure 1 - Simplified regional geology of the Rottenstone and adjacent domains in northern Saskatchewan. Inset shows domains of the Precambrian Shield of northern Saskatchewan and the location of the regional geology map. Lake name abbreviations are: BBIL, Black Bear Island Lake; DL, Davin Lake; HL, Hickson Lake; RL, Rottenstone Lake; WL, and Wathaman Lake. In the legend abbreviations are: A, Archean; AB, Athabasca Basin; gn, gneissic rocks; gr, granite; ms, (meta) sedimentary rocks; P, Proterozoic; and vc, volcanic rocks. Shear zones are shown in bright blue: NFSZ, Needle Falls Shear Zone; and PRSZ, Paul River Shear Zone. Locations of the mapping transects are outlined and labeled #1 and #2. The shaded western part of transect #1 is the map area in Figure 2. The location of SHRIMP samples (6403-GC9 and 6403-GC10) from the Crew Lake Belt are indicated with an asterisk.

Assemblage, which comprises psammopelitic migmatitic gneisses (Corrigan *et al.*, 1998; Maxeiner *et al.*, 1999), has stratigraphic continuity across the previously defined boundary between the La Ronge and Rottenstone domains. The Park Island Assemblage is a fluvial to littoral siliciclastic package that sits structurally, and possibly stratigraphically, on top of the Milton Island Assemblage (Corrigan *et al.*, 1998). Although the Park Island Assemblage has some characteristics similar to the *ca.* 1.84 Ga McLennan/Sickle groups south of the La Ronge Domain, it was intruded by the Wathaman Batholith and must therefore be older than 1.86 Ga (Corrigan *et al.*, 2001).

In the Black Bear Island Lake area at the southwestern end of the Rottenstone Domain (Figure 1), Archean rocks occur in the core of a structural dome (Bickford *et al.*, 2001). It is unclear whether these rocks are related to either the Hearne or Sask cratons, or if they are an exotic fragment of unknown affinity. However, based on limited data, an age of *ca*. 2.50 Ga has been determined for a monzonitic augen gneiss in the inlier (*ibid*). This age is comparable to the youngest ages for Archean rocks of the Hearne margin and the oldest ages for basement inliers of the Sask Craton within the internides of the Trans-Hudson Orogen (THO) (Rayner *et al.*, in press). Regardless of the ultimate affinity of this Archean crust, it indicates involvement of Archean crust in the formation and evolution of the Rottenstone Domain.

Three objectives of the Rottenstone Project being addressed herein are to: 1) gain a better understanding of the lithologies, tectonostratigraphy, depositional setting, and provenance of the sedimentary rocks in the Rottenstone Domain; 2) outline new ideas about potentially mappable sedimentary assemblages that have been recognized within the "tonalite-migmatite-complex"; and 3) characterize the timing and nature of the thermotectonic history. This will be augmented by new U-Pb geochronology. Preliminary results from a detrital zircon SHRIMP study on sedimentary rocks in the domain will help answer two questions. Can the lithotectonic assemblages mapped on Reindeer Lake be extrapolated throughout the rest of the Rottenstone Domain, or are the sedimentary rocks farther southwest different in origin? Has the Archean basement contributed a significant component of detritus to the sedimentary rocks of the Rottenstone Domain? A corollary to this question is whether such an Archean source can be linked to a particular craton based on the age distribution of the detritus. New U-Pb thermal ionization mass spectrometry (TIMS) results that help to constrain the timing of folding and migmatization are presented. These specific objectives contribute to the one primary objective, to better characterize the metallogenic framework of the Rottenstone Domain, including the origin of Cu-Ni-PGE mineralized mafic-ultramafic intrusions.

This paper is based primarily on a mapping transect in the central Rottenstone Domain, from Deighton Lake in the west, to Hickson Lake in the east. Mapping was initiated in 2003 (MacLachlan, 2003a, 2003b, 2003c) and was scheduled to be completed this past summer, but a forest fire in the map area in mid-field season prevented this. Instead, in the latter three weeks of the summer, a second mapping transect was initiated in the Davin Lake area. Tentative comparisons between that area and the central Rottenstone Domain will be discussed.

2. Previous Work

The earliest geological mapping was by McMurchy (1938a, 1938b). Regional mapping in the Rottenstone Lake area was undertaken by Gilboy (1982). Contiguous rock units to the east and north of the present study area were mapped by Harper (1986, 1990). The structure, geochronology, and geochemistry of the TMC in the Deception Lake area was the subject of an M.Sc. thesis by Coolican (2001) at University of Saskatchewan.

The Davin Lake area was mapped by Johnson (1985). The area surrounding Davin Lake, from Macoun Lake in the southwest to Oliver Lake in the northeast, was mapped by Lewry *et al.* (1980). A LITHOPROBE study in the Davin Lake area by Clarke *et al.* (2002, in press) focused on geochemistry, Sm-Nd isotope composition, and U-Pb geochronology of granitoid rocks in the TMC.

3. Regional Geology

The Rottenstone Domain is part of the Reindeer Zone (Stauffer 1984), which constitutes the internides of the THO. The name 'Rottenstone Domain' was first used by Ray (1974), and included rock units of both the later named Wathaman Batholith, and the 'tonalite-migmatite-complex' (Gilboy, 1975; Lewry, 1975, 1976; Ray, 1975; Stauffer *et al.*, 1976). With the realization that the Wathaman Batholith is a continent-scale plutonic complex (Lewry *et al.*, 1981; Fumerton *et al.*, 1984; Stauffer, 1984), it was excluded from the Rottenstone Domain, leaving the TMC as the sole constituent. Recent reclassification of the Precambrian domains in Saskatchewan by the Saskatchewan Geological Survey (2003) included low-grade metasedimentary rocks of the Crew Lake Belt, formerly part of the La Ronge Domain, in the Rottenstone Domain (Figure 1).

At Reindeer Lake, several different lithotectonic assemblages have been distinguished within the Rottenstone Domain (Corrigan *et al.*, 1998; Maxeiner *et al.*, 1999). The Clements Island Belt, near the margin of the Wathaman

Batholith, is predominantly made up of mafic volcanic and volcaniclastic rocks. An interbedded rhyolite dated at 1905 +17/-5 Ma (Corrigan *et al.*, 2001), suggests a temporal link with components of the Lynn Lake belt (Baldwin *et al.*, 1987). The Crowe Island Complex (Corrigan *et al.* 1998) comprises banded tonalite-granodiorite-granite gneiss. The tonalitic and granitic components have been dated at 1891 ±3 Ma and 1884 +5/-3 Ma respectively (Corrigan *et al.*, 2001) and the complex is interpreted as the plutonic root of the La Ronge arc. The Milton Island Assemblage (Corrigan *et al.*, 1998) is composed of migmatized psammopelitic rocks that have detrital zircon populations ranging in age from 2.83 Ga to 1.86 Ga (Ansdell *et al.*, 1999). It has been interpreted as a fore-arc or accretionary prism formed on the northwest side of the La Ronge arc (Corrigan *et al.*, 2001). Peak metamorphism in the Milton Island Assemblage is interpreted to have occurred at *ca*. 1.795 to 1.794 Ga during terminal collision in the Trans-Hudson Orogen (Ansdell *et al.*, 1999; Corrigan *et al.*, 2001). The Park Island Assemblage is a fluvial to littoral siliciclastic package that sits structurally and possibly stratigraphically on top of the Milton Island Assemblage (Corrigan *et al.*, 1998). It comprises a polymictic conglomerate at the base that grades up into pink arkose with laminae and cross-beds (Corrigan *et al.*, 1998). The Park Island assemblage is intruded by the Wathaman Batholith and must therefore be older than 1.86 Ga (Corrigan *et al.*, 2001).

4. Geology of the Deighton-Hickson Transect

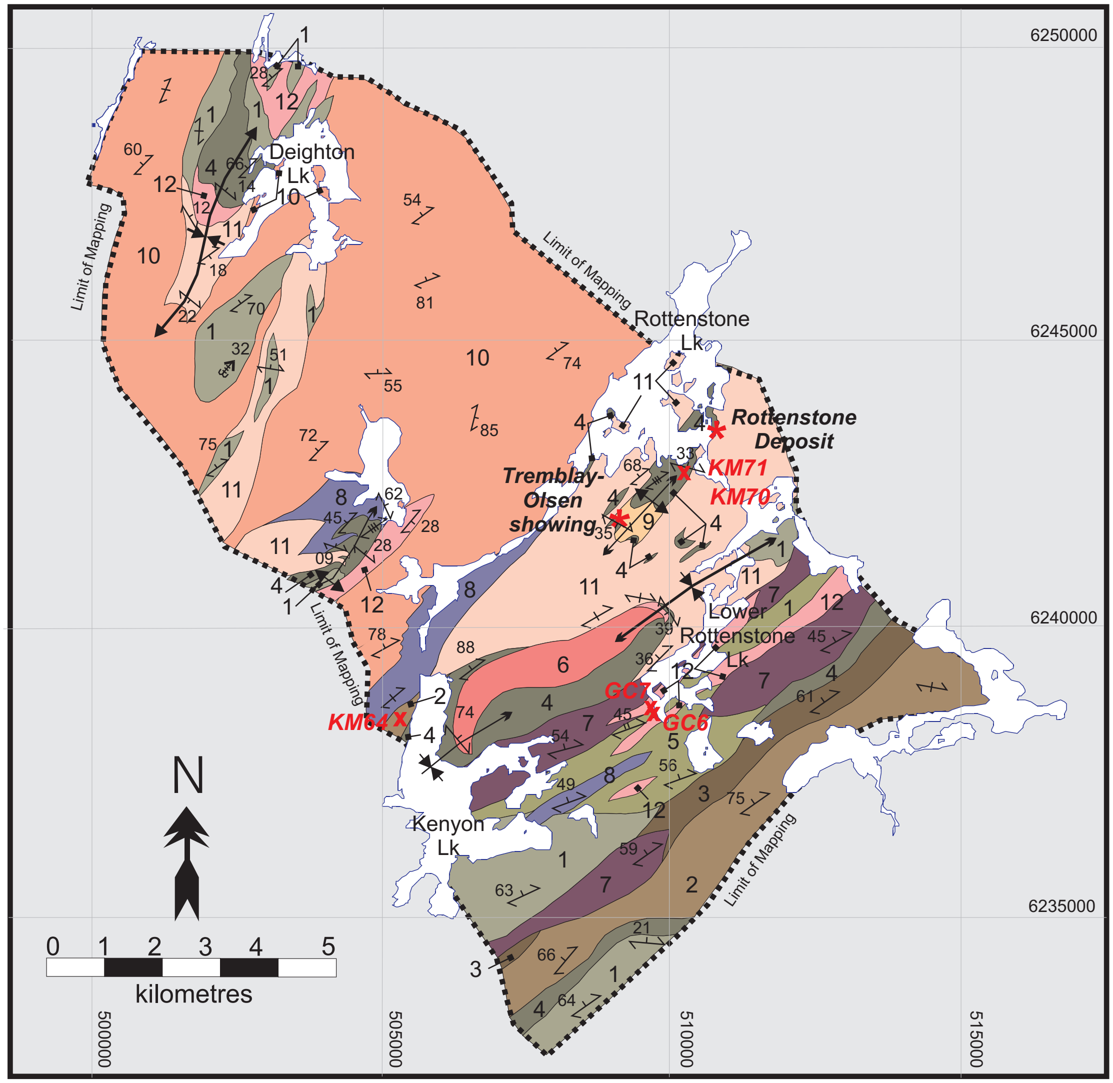
To date, the Rottenstone project has entailed 1:20 000 scale mapping of two transects across the Rottenstone Domain (Figure 1). The first transect is from Hickson Lake in the east, through Rottenstone Lake, to Deighton Lake in the west. The second transect is in the Davin Lake area. The first transect was planned for completion in the summer of 2004. This was prevented by a forest fire in the Grayson Lake area; thus, there is still a gap between the west side of Hickson Lake and the east side of Lower Rottenstone Lake. For this reason it is not possible to discuss lateral variations across the domain, or to determine confidently the extent, distribution, and character of some of the lithologic assemblages that have been observed within the TMC. With this caveat, the granitoid rocks on the west side of Hickson Lake are tentatively included in the TMC, following previous workers (*e.g.*, Gilboy, 1982). The lithologies of the TMC in the Rottenstone Lake area were described in detail by MacLachlan (2003a). These units, with some modification, have been traced into the Deighton Lake area (Figure 2); their main characteristics are briefly summarized.

Rock units in central and eastern Hickson Lake are not part of the TMC. The Hickson Lake pluton, a weakly foliated to massive biotite granodiorite to monzogranite lies in the central part of Hickson Lake. On the eastern side of Hickson Lake the Hickson Lake pluton intrudes lower to middle amphibolite grade sedimentary rocks that have undergone only limited migmatization (MacLachlan, 2003a, 2003c). Bedding in these sedimentary rocks can still be recognized despite three episodes of folding. These rocks are part of the Crew Lake Belt, formerly of the La Ronge Domain, but recently reassigned to the Rottenstone Domain (Saskatchewan Geological Survey, 2003). The relationship of the Hickson Lake pluton to the TMC is uncertain, as the contact is not exposed in the map area. The two are separated by the long straight western arm of Hickson Lake, which may occupy a major fault zone. This interpretation is supported by evidence for a major change in structural level on either side of the Hickson Lake pluton. Psammopelite and pelite on the east side have preserved bedding, whereas those on the west side are largely metatexite to diatexite with map-scale intact lozenges of more refractory units such as amphibolite, psammite, and calc-silicate rock.

a) Tonalite Migmatite Complex

Structure

The supracrustal rocks have a well-defined composite tectonic fabric (S_{main}) that is parallel to compositional layering (transposed bedding). A variety of early granitoid rocks that occur as sheets parallel to compositional layering and S_{main} contain a parallel tectonic foliation interpreted to be S_{main} (MacLachlan, 2003a, 2003b). These rocks were intruded by heterogeneous, schleiric granitoid rocks that post-date S_{main} and formed as a result of migmatization. The heterogeneous granitoids commonly have a weak tectonic foliation defined by schleiren and alignment of mica. This fabric is generally parallel to that in the sedimentary rocks. Homogeneous, massive to weakly foliated, variably K-feldspar porphyritic monzogranites cross-cut the migmatitic granitoids and appear to be the youngest intrusive phase, with the exception of late granitic pegmatites that cross-cut everything. Two phases of folding were recognized during mapping in 2003 (MacLachlan, 2003a, 2003b). The earlier phase (F_2) is isoclinal and post-dates S_{main} in the supracrustal rocks. The map-scale F_2 fold described by MacLachlan (2003a, 2003b) is now re-interpreted to be an F_3 fold based on its geometry. Because no large-scale F_2 folds have been mapped, it is difficult to determine the time of intrusion of the large granitoid bodies with respect to folding. In general, granitoid dykes with compositions similar to the larger bodies occur along, and roughly parallel to, the limbs of the early isoclinal folds, but clearly cut the fabric that is being folded. Locally, small apophyses of these dykes intruded parallel to the tectonic fabric and are folded, along with S_{main}. These relationships suggest that the migmatitic



Post-S_{main} intrusives rocks

12 Pink , biotite monzogranite ± K-feldspar phenocrysts, massive to weakly foliated

11 White to buff leucogranite muscovite > biotite, ± garnet ± K-feldspar phenocrysts, weakly foliated to schlieric

10 Heterogeneous white to pale pink biotite-leucogranodiorite-monzogranite with abundant metasedimentary screens, schlieric to weakly foliated

9 White biotite-granodiorite, massive, equigranular to sparsely K-feldspar porphyritic

Pre-S_{main} intrusives rocks

8 Biotite granodiorite ± hornblende, foliated to gneissic

7 Biotite monzogranite ± hornblende, includes hornblende diorite, granodiorite, and quartz monzonite, well foliated

6 Biotite-hornblende-magnetite K-feldspar megacrystic monzogranite

5 Mixed supracrustal rocks with abundant layer- and foliation-parallel granitoid sheets

Supracrustal Rocks

4 Mixed supracrustal rocks: psammite-pelite, calc-silicate, quartzite, melanocratic volcanic/sedimentary rocks

3 Mixed pink and white migmatite

2 Migmatitic psammopelitic to arkosic sedimentary rocks (pink leucosome)

1 Migmatized psammitic to pelitic sedimentary rocks (white leucosome)

Plunging F_3 fold: antiform; synform

Foliation, generation : main, 2nd, 3rd

Figure 2 - Simplified geological map of the Rottenstone Lake–Deighton Lake area. Red asterisks indicate locations of the Rottenstone Deposit and the Tremblay-Olsen showing. Red X's with red numbering show locations of TIMS geochron samples collected in 2003. Abbreviations are: bio, biotite; gar, garnet; hb, hornblende; k, potassium; Mt, magnetite; mu, muscovite; and qtz, quartz.

granitoids intruded prior to and/or during F_2 folding. The isoclinal folds were refolded by upright to inclined, asymmetric F_3 folds that post-dated the late K-feldspar porphyritic monzogranites (MacLachlan, 2003a, 2003b). The F_3 folds are upright to inclined, doubley plunging and have moderately northwest-dipping long limbs and steep, northwest-dipping to subvertical short limbs. The map-scale fold of biotite-hornblende-magnetite monzogranite (unit 6, Figure 2), is a good example of the F_3 fold geometry.

Lithologic Units

Rocks of the TMC are heterogeneous on all scales and the units described are defined on the basis of predominant rock type within a given area. Any particular outcrop of the supracrustal units, however, may comprise a large proportion (>50%) of younger cross-cutting granitoids. Similarly, any given outcrop of the younger intrusive phases may contain abundant screens of earlier intrusive and supracrustal units. Consequently, contacts between all units are gradational and approximate. The units described below are in approximate order from oldest to youngest. The sedimentary rocks as a group are the oldest rocks, but there are no constraints on the relative age of different units.

MacLachlan (2003a, 2003b) distinguished two lithological assemblages composed predominantly of sedimentary rocks within the TMC in the Rottenstone Lake area. These supracrustal rocks can now be subdivided into four mappable units.

Unit 1: Migmatitic Psammitic to Pelitic Rocks (White Migmatites)

Interlayered psammitic schists and psammopelitic to pelitic gneisses occur both as a distinct map unit and interlayered with other supracrustal rocks in some of the other map units. These psammopelitic rocks occur throughout the area as map-scale rafts, "floating" in heterogeneous schleiric granitoids derived from migmatization (Figure 2). They are commonly associated with muscovite-garnet-bearing granite to granodiorite (unit 10). The pelitic units have been pervasively migmatized and consist of biotite ± sillimanite ± garnet melanosome and biotite-garnet ± muscovite granodioritic leucosome (Figure 3). The majority of psammitic schists are composed of fine-grained, well-foliated biotite ± garnet (<2%, <3 mm) quartzofeldspathic material with discrete, foliation-parallel and cross-cutting veins of leucosome (Figure 4). The leucosome is interpreted to be locally derived but injected, and varies from >50% to <5%. Locally, however, the psammitic rocks are strongly garnetiferous (up to 20%, 3 to 10 mm) and rusty (Figure 5). The rusty zones typically result from weathering of biotite, although rare layers contain up to 1% pyrrhotite and pyrite. The psammopelites have a smaller proportion of *in situ* leucosome than the pelites and do not contain sillimanite. They commonly have both an injected and an *in situ* leucosome component. The magnetic susceptibility of this unit is very low (0.01 to 0.10 x 10^{-3} SI), except locally where pyrrhotite is present.

Figure 3 - White pelitic migmatite of unit 1, with biotite-sillimanite-garnet paleosome and white granodiorite leucosome; pen for scale is about 15 cm long (UTM 508026 E, 6237180 N). Note that all UTM coordinates are NAD 83, Zone 13.

Figure 4 - Grey psammite with injected white leucosome (unit 1); pen for scale is roughly 15 cm long (UTM 502841 E, 6249659 N).

***Figure 5** - Thinly layered rusty-weathering psammite (unit 1) cut by massive biotite-monzogranite dyke (unit 12); pen for scale is roughly 15 cm long (UTM 502606 E, 6248791 N).*

Although graphite was not observed, it has been described by others (*e.g.*, Gilboy, 1982) and is thought to be characteristic of this unit. Rocks of unit 1 are transitional to schleiric, white leucogranodiorite (unit 11) and white to buff coloured muscovite ≥ biotite ± garnet leucogranite (unit 10).

Unit 2: Migmatitic Psammopelitic Magnetite-bearing Rocks (Pink Migmatites)

This unit was previously included in unit 1 (MacLachlan, 2003a, 2003b), but has been found to be more extensive. It is characterized by pink leucogranite leucosome (Figure 6) and commonly magnetite in both the sedimentary and granitoid components. The paleosome is commonly layered on the scale of several centimetres to several tens of centimetres, with alternating psammopelite and psammite (Figure 6B). The psammopelite is migmatitic, comprising pale pink *in situ* leucosome and schistose, grey to brown biotite-rich (up to 30%) quartzofeldspathic paleosome (Figure

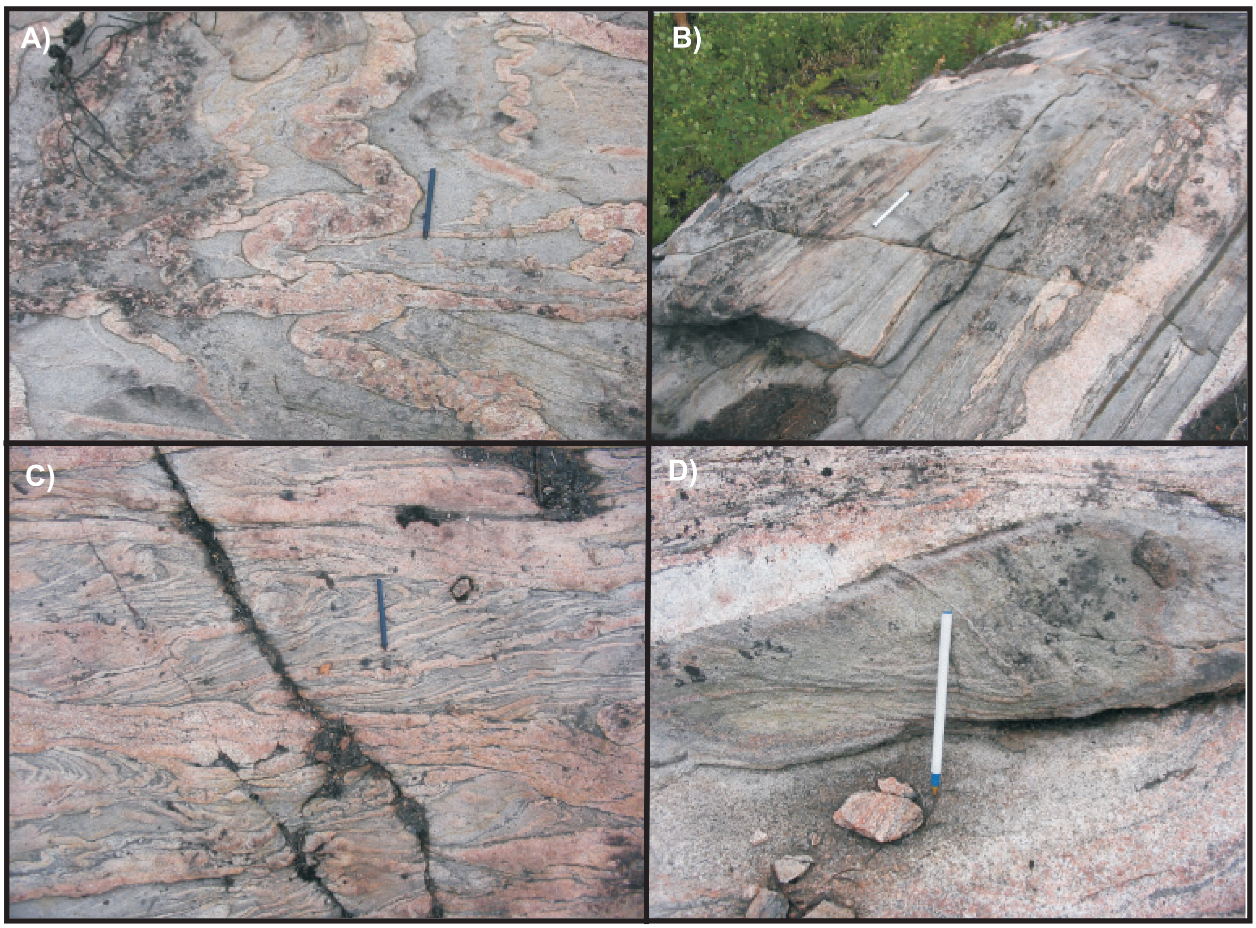


***Figure 6** - Photographs of the pink migmatite (unit 2); pen for scale is 15 cm long. A) Injected pink leucosome in quartz psammite to feldspathic psammite (UTM 508553 E, 6235932 N); B) layered psammopelite and psammite, with thin in situ leucosome in the psammopelitic layer, cut by larger injected pink leucogranite dyke (UTM 505365 E, 6239523 N); C) injected pink leucosome cutting earlier, folded, in situ pink leucosome (UTM 508553 E, 6235932 N); and D) lozenge of finely laminated calc-silicate in schlieric pink leucogranite (UTM 508554 E, 6235753 N).*

6C). The psammite is fine-grained, equigranular, quartzofeldspathic centimetres to several tens of centimetres, with alternating psammopelite and psammite (Figure 6B). The psammopelite is migmatitic, comprising pale pink *in situ* leucosome and schistose, grey to brown biotite-rich (up to 30%) quartzofeldspathic paleosome (Figure 6C). The psammite is fine-grained, equigranular, quartzofeldspathic material with less biotite and no *in situ* leucosome, but commonly abundant injected leucosome (Figure 6A). It is typically fairly massive with only a weak schistosity or cleavage. These migmatitic sedimentary rocks grade into schleiric pink leucogranite, which is included in this map unit. The leucogranite locally contains clusters of small (up to 75 cm in length) xenoliths of finely laminated diopside-garnet calc-silicate rock (Figure 6D) that are interpreted to have originally been interbedded with the psammopelitic to psammitic sediments. unit 2 is also characterized by abundant dark pink pegmatite veins that cut all the other phases and also commonly contain magnetite. These magnetite-bearing pegmatites also cut other units in close proximity to this one. Similar dark pink pegmatite without magnetite cuts all units. This pink migmatite and schleiric granite unit has the highest magnetic susceptibility recorded, with average values typically greater than 1×10^{-3} SI and up to 30×10^{-3} SI. Readings are erratic, however, and values less than 1×10^{-3} SI do occur.

Unit 3: Mixed Pink and White Migmatite

In some areas the pink and white migmatite of units 1 and 2 cannot be separated into discrete map units as they are mixed on a scale of several metres to several tens of metres. This suggests that either they were originally interbedded or that they were structurally interleaved early in the evolution of this area.

Unit 4: Mixed Supracrustal Rocks

This unit contains a wide variety of supracrustal rocks that are interlayered on a scale of tens of centimetres to tens of metres. The mixed supracrustal rock unit (unit 4) contains psammite to pelite interbedded with the other rock types. In addition, discreet successions of unit 1 psammopelitic rocks commonly occur in proximity to unit 4. Rocks of unit 4 occur throughout the area as map-scale rafts within heterogeneous schleiric migmatitic granitoids. These rafts commonly occur in the hinge zones of asymmetric F_3 folds, for example on the northwest side of Deighton Lake and on the southeast side of Rottenstone Lake where they host the ultramafic intrusion that contains the Rottenstone Deposit (Figure 2). Unit 4 includes calc-silicate rock, amphibolite, melanocratic quartzofeldspathic biotite gneiss, psammite, migmatized psammopelite and pelite, and quartzite. These lithologies have been described in more detail previously (MacLachlan, 2003a, 2003b).

Layered calc-silicate and “amphibolite” locally dominate unit 4. There is some amphibolite (*sensu-stricto*) composed predominantly of hornblende and plagioclase with little or no quartz; however, most amphibolite contains variable amounts of quartz and biotite and is really melanocratic hornblende-biotite quartzofeldspathic gneiss. Garnet-bearing amphibolite and melanocratic biotite ± garnet quartzofeldspathic gneiss also occur. Layering occurs on scales ranging from centimetres to metres. The calc-silicate is typically medium to coarse grained and green, except where garnet is abundant. In the garnet-rich phase, garnet typically forms round, reddish-brown clots or layers in the green, diopside-rich phase (Figure 7A). The calc-silicate ranges from massive to gneissic (Figure 7B). It commonly has a streaky appearance caused by alteration of calc-silicate minerals to hornblende ± biotite (Figure 7C), which resulted in a brown to dark grey colour. This alteration is commonly adjacent to layer-parallel veins of quartz and/or granite as well as cross-cutting granite dykes (Figure 7D). Thus, some of the “amphibolite” is clearly a secondary alteration feature. In places the alteration is pervasive and little of the original calc-silicate minerals are evident. Some of the amphibolite “*sensu-stricto*” is massive and locally plagioclase porphyritic (or porphyroblastic?) and may be igneous in origin. Throughout the rest of this report “amphibolite” will be used to encompass both true amphibolite (plagioclase and hornblende only) and melanocratic hornblende-bearing quartzofeldspathic gneiss, unless otherwise specified. Most of the melanocratic quartzofeldspathic gneiss is interpreted to be sedimentary in origin, but the possibility of a volcanic origin cannot be ruled out. This unit has relatively low susceptibility with the lowest values in the psammopelitic rocks (average 0.01 to 0.10×10^{-3} SI) and the highest values in the amphibolite and calc-silicate rock (average 0.2 to 0.8×10^{-3} SI).

Large gabbro/diabase intrusions also occur in unit 4, but because of the high degree of transposition it is unclear if they were originally dykes or sills. They are composed of hornblende and plagioclase ± biotite, are dark brown to black on the weathered surface and are medium to coarse grained, locally with pegmatitic patches (Figure 8). They range from massive with relict igneous textures, to schistose where the original fabric has been completely eradicated. The degree of fabric development increases concomitantly with biotite content.

Early Granitoid Rocks (Pre-S_{main})

The following descriptions are modified from MacLachlan (2003a, 2003b). In some areas the mixed supracrustal rocks (unit 4) contain up to 50% layer- and foliation-parallel sheets of foliated granitoid rocks. These are predominantly biotite ± hornblende granite to granodiorite, but diorite, tonalite and quartz monzonite also occur.

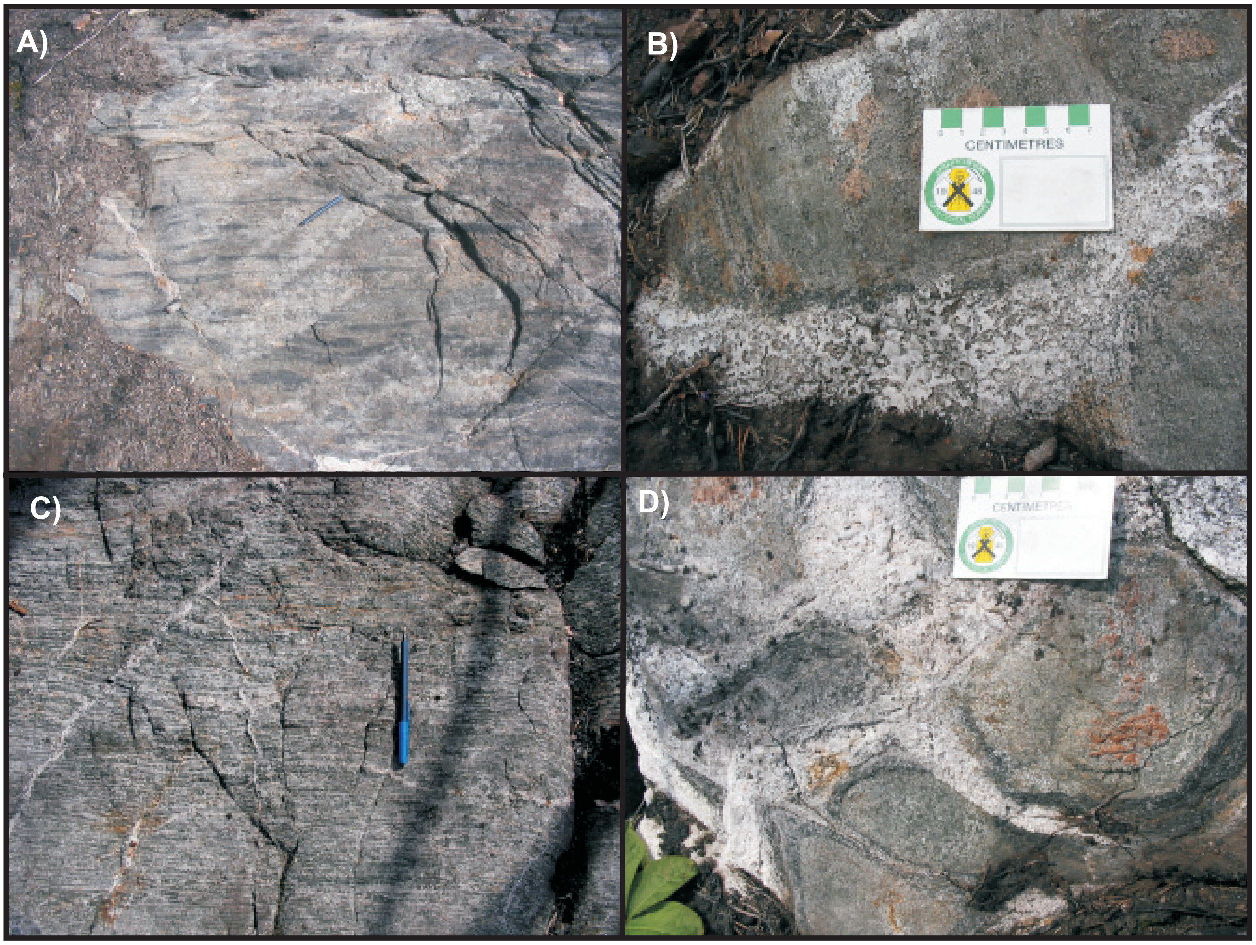


Figure 7 - Photographs of calc-silicate in unit 4. A) Streaky calc-silicate with darker bands containing abundant biotite and hornblende as a result of alteration (UTM 502150 E, 6248675 N), pen for scale is about 15 cm long; B) close-up of granite vein cutting green calc-silicate rock with reddish-brown clots of garnet (UTM 502687 E, 6249244 N); C) gneissic calc-silicate rock (UTM 502606 E, 6248791 N), pen for scale is about 15 cm long; and D) zoned reaction halos in calc-silicate rock adjacent to cross-cutting granite dykes (UTM 502687 E, 6249244 N).

Figure 8 - Gabbro dyke with coarse-grained to pegmatitic patches; hammer for scale is about 40 cm long (UTM 502303 E, 6250036 N).

This succession of mixed supracrustal and granitoid rocks (unit 5) is ubiquitously tightly to isoclinally folded and cut by massive, K-feldspar porphyritic biotite monzogranite that post-dates the main foliation. The mixed supracrustal and granitoid rocks occur as a belt trending northeast from central Kenyon Lake to the north arm of Lower Rottenstone Lake. Three other early, foliated granitoid bodies without a significant sedimentary component are distinguishable as discrete map units, although their relative ages are uncertain. These granitoids occur as irregular sheet-like bodies approximately parallel to and containing the main tectonic fabric (S_{main}). The first granitoid is a weakly foliated to banded, variably K-feldspar megacrystic, biotite-hornblende-magnetite monzogranite (unit 6). It occurs north of Kenyon Lake in the core of a doubly plunging F_3 synform. This unit creates a very distinct magnetic high on the regional aeromagnetic map (Slimmon, 2002). The second is K-feldspar megacrystic biotite ± hornblende monzogranite with associated subordinate quartz monzonite to monzogranite, granodiorite, diorite, and tonalite (unit 7). Several northeast-trending belts of this unit occur at and southeast of Kenyon and Lower Rottenstone lakes. The third is a homogeneous, light grey-weathering foliated to gneissic biotite-granodiorite (unit 8). A large northeast-trending belt of this unit occurs between Kenyon and Rottenstone lakes. A smaller belt occurs at the southeast edge of Kenyon Lake. Another small body occurs adjacent to mixed supracrustal rocks (unit 4) in the hinge of an F_3 fold west of the south end of Rottenstone Lake. Xenoliths of the foliated to gneissic biotite granodiorite (unit 8) are common in the white to pink schleiric leucogranodiorite.

Post-S_{main} Intrusions

A range of granitoid rocks post-date the main tectonic fabric in the supracrustal rocks (units 1 to 4). In the Rottenstone Lake area a small body of homogeneous white biotite granodiorite to tonalite (unit 9), commonly with clots of biotite-garnet-quartz (restite?) cuts and surrounds the mixed supracrustal rocks (unit 4). This granodiorite has gradational contacts, with leucosomes of pelitic migmatite inclusions within it. Most of the northwestern part of the map area is underlain by white to pale pink granitoid rock (unit 10) that is heterogeneous in both composition and texture. Unit 10 is predominantly granodioritic in composition, but ranges from tonalitic to granitic and is massive to weakly foliated. It contains abundant screens and inclusions of sedimentary rock and foliated biotite granodiorite, and biotite-rich schleiren. The spatial association of biotite-rich schleiren with abundant sedimentary screens suggests that the schleiren represent incompletely melted remnants of sedimentary rock. Within this heterogeneous granodiorite are more compositionally and texturally homogeneous bodies of white to buff muscovite ≥ biotite ± garnet leucogranite (unit 11). A separate, larger body of this unit occurs between Rottenstone and Lower Rottenstone lakes. The leucogranite is generally weakly to moderately foliated and weakly schleiric locally. Both units 10 and 11 typically have low magnetic susceptibility with the biotite granodiorite having average readings between 0.04 and 0.1×10^{-3} SI and the muscovite-garnet-leucogranite having average readings between 0.01 and 0.06×10^{-3} SI. The pink schleiric biotite (± magnetite) monzogranite that is intermixed with and transitional to pink migmatite is a post-S_{main} granitoid, but was not mappable and was thus included in the pink migmatite (unit 2).

The latest granitoid is homogeneous, massive to weakly foliated, variably K-feldspar porphyritic biotite monzogranite (unit 12). It occurs throughout the area as sheet-like intrusions ranging from tens of centimetres to hundreds of metres wide. This unit cuts the foliation in the heterogeneous schleiric granitoids as well as all earlier units. It pre-dates F_3 folding, as indicated by the small sheet that wraps around the northeast-plunging hinge of the F_3 fold west of lower Rottenstone Lake.

5. Comparison with the Davin Lake area

A small part of the Davin Lake section, adjacent to and including the contact with the Wathaman Batholith, was mapped and several reconnaissance traverses in other areas were completed in August 2004. A B.Sc. thesis on the contact with the Wathaman Batholith is being done by Chad Leugner at University of Regina and thus it will not be discussed here. Some preliminary comparisons between lithological units in the Davin Lake and Rottenstone Lake areas are discussed.

A northeast-trending belt of rocks with low magnetic susceptibility occurs between the Wathaman Batholith on the southeast side of Wathaman Lake and central Davin Lake. This unit was mapped as white leucogranodiorite by Johnson (1985). Detailed mapping of the northwest arm of Davin Lake facilitated subdivision of the white leucogranodiorite into three units. The first map unit is schleiric to locally massive or weakly foliated leucogranodiorite that has gradational contacts with screens of white, migmatitic, psammopelitic gneisses within it. The leucogranodiorite commonly contains screens of intact psammite, psammopelite and compositionally layered, melanocratic, hornblende-bearing, quartzofeldspathic gneisses, and amphibolite. This unit is similar to the white to pale pink schleiric granodiorite (unit 10) in the Rottenstone Lake area. Map-scale rafts of sedimentary rocks (unit 1 and unit 4) that occur in unit 10 in the Rottenstone area have not yet been recognized in the Davin Lake area. The second map unit comprises relatively intact interlayered psammite and gritty quartzite to quartz-arenite, with minor calc-silicate rock, melanocratic psammite, and hornblende-bearing gneiss, cut by abundant leucogranodiorite and pegmatite dykes. This unit has similar lithological variation to the mixed supracrustal package (unit 4) in the Rottenstone Lake area. The third map unit recognized is a strongly-foliated, grey-weathering fine- to medium-grained, garnet-biotite granodiorite. This unit is very similar to unit 8 in the Rottenstone area except that it contains garnet in addition to biotite. Two reconnaissance traverses were done southeast of Davin Lake in an area with high magnetic signatures on regional airborne total field maps. This area was burned in a 2002 forest fire and consequently the exposure is excellent. The traverses crossed two map units of Johnson (1985), pink granite and migmatite. In the former, both pink monzogranite and pink migmatite similar to unit 2 in the Rottenstone area were observed. As in the Rottenstone area both the granite and the sedimentary rocks contain magnetite. Considering the excellent exposure, both along the lake shore and in the burn, it is likely that the pink granite unit of Johnson (1985) can be further subdivided. Within the migmatite unit of Johnson (1985), both pink and white migmatite, similar to units 1 and 2 in the Rottenstone area were observed. Hand-held magnetometer readings confirmed that the white migmatite has low magnetic susceptibility whereas the pink one has high. Hence it should be possible to distinguish pink and white migmatites in this area as well as a unit where they are intermixed on a scale too fine to delineate at 1:20 000 scale. Although the mappable rocks units are superficially similar, a sample of psammite from the low-magnetic susceptibility sedimentary rocks was sampled for SHRIMP detrital zircon analysis. Samples of psammitic sedimentary rocks from pink migmatites in both the Davin and Rottenstone lakes areas will be taken when they are mapped next summer. The geochemical and Nd isotopic composition of sedimentary and intrusive rocks from the various units in each area will also be analyzed to facilitate the comparison.

6. Geochronology

The geochronology component of this project has two main objectives. The first is to better understand the age of detritus in the sedimentary rock, and hence the provenance and tectonostratigraphic associations. This is being done using the SHRMP technique on detrital zircons from the sedimentary rocks. This work is being done at the Geological Survey of Canada. The second is to determine the timing of metamorphism and deformation. This is being done using conventional TIMS on zircon, monazite, and titanite from igneous and metamorphic rocks at Memorial University of Newfoundland.

a) SHRIMP Detrital Zircon Study

Previous Work

Based on the present understanding of the Rottenstone Domain (*e.g.*, Lewry and Collerson, 1990; Bickford *et al.*, 2001; Corrigan *et al.*, 2001; Maxeiner *et al.*, 2001), there are three main potential sources of the sediments: the Hearne Craton, the Sask Craton, and the La Ronge arc. The age of the La Ronge arc and correlative Lynn Lake belt are fairly well constrained to *ca*. 1.91 to 1.88 Ga (*e.g.*, Baldwin *et al.*, 1987; Corrigan *et al.*, 2001). A recent geochronological study of the Sask Craton, Hearne Margin, and Peter Lake Domain by Rayner *et al.* (in press) provided a good summary of new and previous U-Pb geochronology for Archean rocks in the vicinity of the Rottenstone Domain (Figure 9). The Sask Craton has plutonic ages at *ca*. 2.45 Ga as well as zircon growth and/or recrystallization in older rocks at *ca*. 2.45 Ga and at ~1.80 Ga. The Sask Craton also comprises older precursor material, in part as old as 3117 Ma (Rayner *et al.*, in press). This is reflected in Sm-Nd depleted mantle model (T_{DM}) ages that range from 2.7 to 3.0 Ga (Chiarenzelli, 1989; Bickford *et al.*, in press) The Peter Lake Domain yielded magmatic and metamorphic ages from *ca*. 2540 to 2630 Ma (Corrigan *et al.*, 2001; Rayner *et al.*, in press). Depleted mantle model ages of 2850 Ma and 2580 Ma have been obtained for two samples from the Peter Lake Domain (Bickford *et al.*, in press). On four samples from the Hearne margin, crystallization ages of 2566 to 2593 Ma were determined from four basement inliers in the Wollaston Domain, two of which have T_{DM} ages of 2802 and 2858 Ma (Hamilton and Delaney, 2000). The ages of the Peter Lake Domain overlap with those for inliers of Hearne basement in the Wollaston Domain. An Archean rock in the core of a structural dome in the Black Bear Island Lake area of the southwestern Rottenstone Domain has a poorly constrained age of *ca*. 2.50 Ga (Bickford *et al.*, 2001). More work is required to determine if it is a fragment of either the Hearne or Sask cratons.

The proximity of sedimentary rocks in the Wollaston and La Ronge domains to those of Rottenstone Domain suggests possible partial correlation. By way of comparison, the distribution and range of detrital zircon ages in these tectonostratigraphically better understood sedimentary successions should provide some insight into the origin and nature of sedimentary rocks of the Rottenstone Domain. The sedimentary rocks of Wollaston Domain unconformably overlie the Hearne basement inliers dated by Hamilton and Delaney (2000). Quartzite and conglomeratic quartzite from the base of the succession have SHRIMP detrital zircon ages predominantly in the range of 2450 to 2600 Ma although a few grains as young as 2340 Ma, and one as old as 2933 Ma, also occur (Hamilton and Delaney, 2000). SHRIMP detrital zircon results on three other sedimentary rocks from the Wollaston Domain were presented by Tran (2001). In a general sense there are two predominant age modes in these three samples, one between 1870 and 1920 Ma and one between 2450 and 2590 Ma (Tran, 2001).

The Milton Island Assemblage is thought to have formed in a fore-arc or accretionary prism on the northwest side of the La Ronge arc, and straddles the boundary between the La Ronge and Rottenstone domains. As such, it is probably the most likely analogue for the rocks farther southwest in the Rottenstone Domain. The Milton Island Assemblage is characterized by detrital zircon ages ranging from about 1860 to 2830 Ma (Ansdell *et al.*, 1999). Only 19 zircons were analyzed and thus, it is difficult to say whether this distribution is truly representative of the detrital population in this sample. The Park Island Assemblage, which structurally overlies the Milton Island Assemblage in the Reindeer Lake area might also extend farther to the southwest. On cumulative probability plots of SHRIMP detrital zircon analyses, two samples from the Park Island Assemblage have a prominent age mode at 1875 Ma (Corrigan, pers. comm., 2004). The sample from the lower part of the succession also has a few single grains in the age range 2320 to 2540 Ma (Corrigan, pers. comm., 2004).

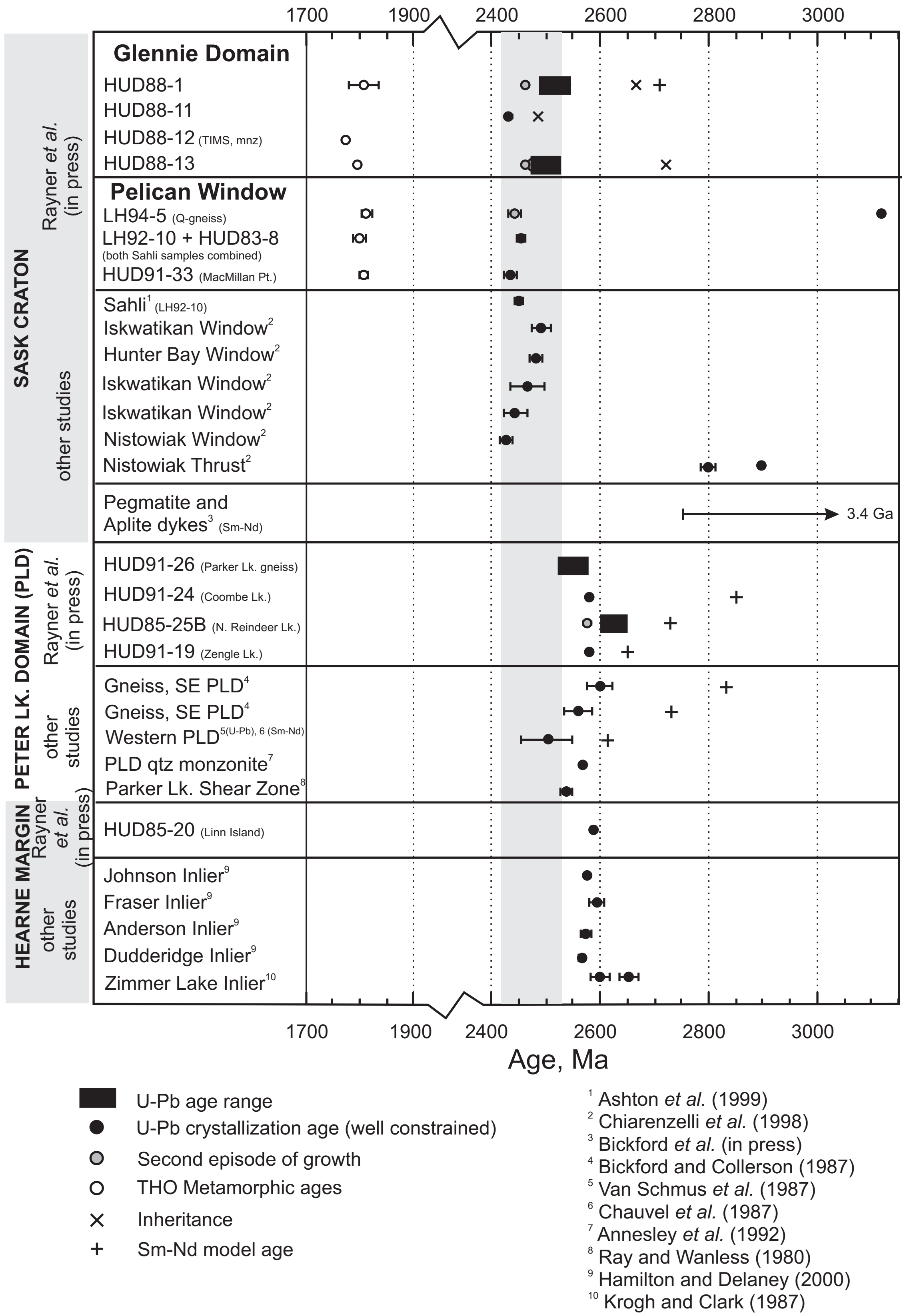


Figure 9 - Summary of U-Pb ages from the Hearne Margin, Sask Craton, and Peter Lake Domain (from Rayner** et al.**, in press).

Results

Two samples of lower to middle amphibolite facies sedimentary rocks from the east side of Hickson Lake (see Figure 1 for location) were sampled in 2003 for SHRIMP detrital zircon studies. One is a gritty quartzite from the mixed sedimentary succession including psammopelite, calc-silicate, amphibolite, and quartzite (Figure 10A MacLachlan, 2003a, 2003b).The other is a biotite psammite from the interbedded psammitic to pelitic sedimentary rocks (Figure 10B, MacLachlan, 2003a, 2003c). The stratigraphic relationship between these two successions is uncertain, and a gradational contact cannot be ruled out (MacLachlan, 2003a, 2003c). Both samples come from the Crew Lake Belt. The errors reported for the data are given at the 1σ uncertainty level.

Hickson Lake Quartzite (6403-GC9; UTM 542430 E, 6240885 N)

On a cumulative probability plot of analyses on 57 grains (for grains with replicate analyses, only the mean age was plotted), two prominent modes occur at 2440 Ma (37 analyses) and 2507 Ma (17 analyses, Figure11A). These peaks overlap and include grains ranging from 2403 ±5 Ma to 2540 ±10 Ma (1 σ). The weighted mean $^{207}Pb/^{206}Pb$ age of three replicates on the youngest zircon is 2373 ±5 Ma and is taken as a maximum age for deposition of this unit. This age is distinct from the dominant mode at 2440 Ma. Three other single analyses fall outside of these peaks.

Hickson Lake Psammite (6403-GC10; UTM 542994 E, 6239744 N)

On a cumulative probability plot of analyses on 58 grains (replicate analyses on individual grains are not plotted, in the cases of replicates the mean of the analyses was plotted), a dominant mode at 1890 Ma (25 analyses) and two broad modes at 2386 to 2430 Ma (eight analyses) and 2465 to 2550 Ma (22 analyses) are defined (Figure 11B). Three grains at 2320 Ma, 2599 Ma, and 3060 Ma are outside the main age groupings.

Interpretation

The predominant grouping of detrital zircon ages for the quartzite sample indicates a Paleoproterozoic to Neoarchean source. The predominant peak in the Hickson Lake quartzite at 2440 Ma corresponds closely to one of the prominent ages in the Sask Craton (Rayner *et al*., in press). The smaller, but still pronounced, peak at 2507 Ma overlaps with the some of the older and less abundant ages from the Sask Craton (Rayner *et al.*, in press). The oldest detrital grains in the main age grouping do overlap with the youngest ages for the Hearne margin and Peter Lake Domain (Figure 9). The prominent 2550 to 2600 Ma age range of the Hearne Margin and Peter Lake Domain, however, is almost completely absent from the quartzite. The dominant modes at 2440 and 2507 Ma in the Hickson Lake quartzite are younger than those in the Souter Lake Formation quartzite of the Wollaston Group (2515, 2537,

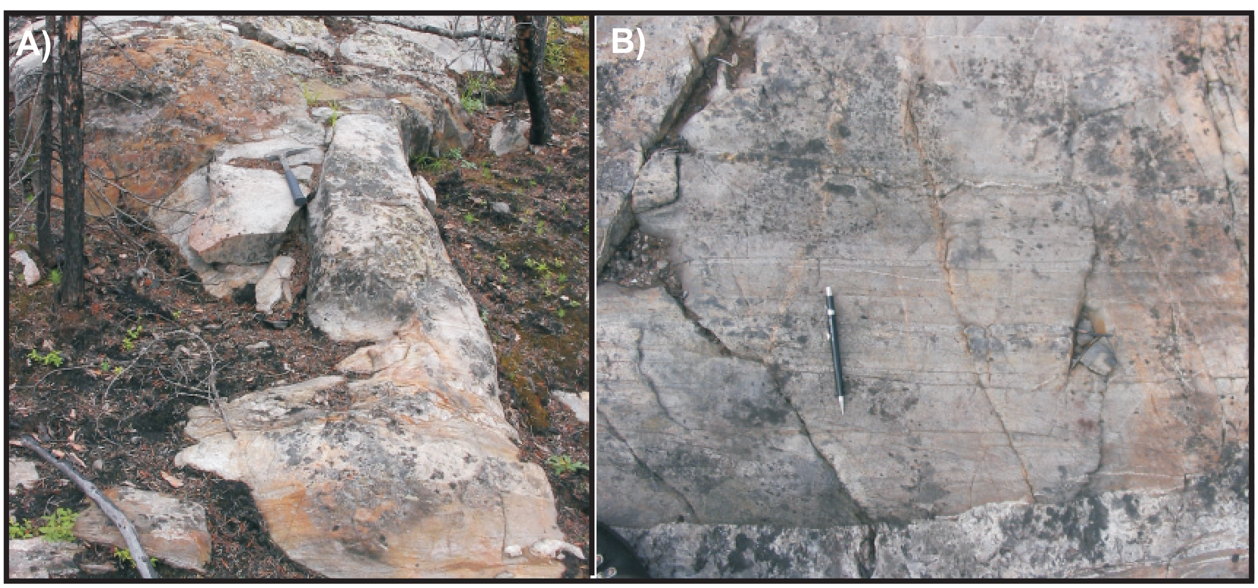


Figure 10 - Photographs of the sample location of: A) quartzite sampled for SHRIMP detrital zircon study (UTM 542430 E, 6240885 N); view of the outcrop showing interlayering of quartzite (white) and psammite (light orange–brown); the sample is from the thick bed that the hammer (40 cm long) is resting on; and B) thinly bedded psammite at the outcrop where psammite was sampled for SHRIMP detrital zircon study (UTM 542994 E, 6239744 N); pencil for scale is about 15 cm long.

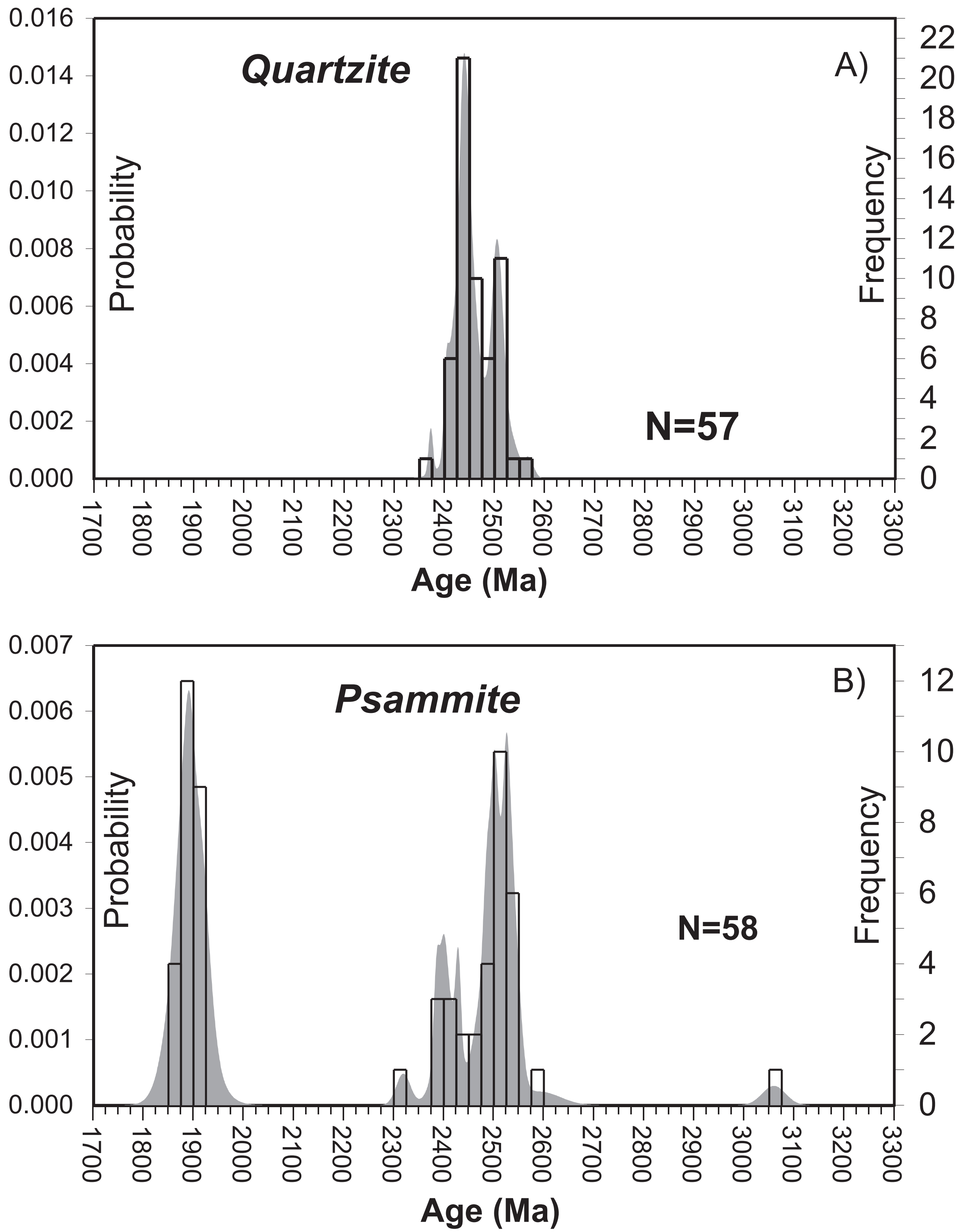


Figure 11 - Cumulative probability and histogram plot of detrital zircon U-Pb ages for: A) quartzite and B) psammite of the Crew Lake Belt east of Hickson Lake.

and 2563 Ma; Hamilton and Delaney, 2000), although the overall range of ages is similar. Similar to the Johnson River quartzite, the Hickson Lake quartzite lacks younger ages in 1.9 to 1.8 Ga range that are common in the upper part of the Wollaston Group (*e.g.*, Tran, 2001) and in the Milton Island (Ansdell, pers. comm., 2004) and Park Island assemblages (Corrigan, pers. comm., 2004) of the Rottenstone Domain in Reindeer Lake.

The Hickson Lake psammite has a prominent peak at 1890 Ma which almost certainly indicates a component of detritus from the La Ronge arc. This is compatible with previous interpretations that the Crew Lake Belt formed in a fore-arc or accretionary prism on the north side of the La Ronge arc (Corrigan *et al.*, 1998, 2001; Maxeiner *et al.*, 2001). The youngest cluster of ages in the Hickson Lake psammite overlaps the main cluster of ages in the Milton Island Assemblage (Ansdell, pers. comm., 2004). The psammite also has a number of zircons with ages that span a range similar to the older ages observed in the quartzite. This suggests that the psammite has at least two primary sources, the La Ronge arc and continental crust of similar age to the Sask Craton.

Based on field observations, it is not clear whether the quartzite and psammite are from two successions with a gradational contact or whether they are from two discrete successions with an unconformable contact. It is possible that both units were derived from different sources that shed detritus into the same basin and that the transition from the quartzite-bearing to the quartzite-absent succession is a lateral facies change. Alternatively, these two successions could have been deposited in separate basins either: 1) contemporaneous, but separated in space, such that detritus from the La Ronge arc was restricted from the quartzite-bearing succession; or 2) the contact is unconformable with the quartzite succession being older and deposited either before the La Ronge arc formed or before it was close enough to provide sediment to the basin. A sample of psammite interbedded with the quartzite was sampled for SHRIMP detrital zircon analyses in the hopes of shedding light on this question.

It is interesting that both samples show a strong signature of late Archean to Paleoproterozoic continental crust. Furthermore, these preliminary results suggest a continental source more like the Sask Craton than the Hearne Margin for detritus in sedimentary rocks of the Crew Lake Belt. Detrital zircons from two psammite samples from the TMC are also being analyzed by the SHRIMP to test the hypothesis that they represent higher grade equivalents of the Crew Lake Belt (Saskatchewan Geological Survey, 2003).

b) TIMS U-Pb geochronology

Five samples were taken for TIMS analysis to help constrain the tectonometamorphic evolution of the area. Preliminary results are presented below. Ages are quoted with 1σ error at 95% confidence level.

Results

Pre-S_{main} Foliated Biotite-Monzogranite (6403-GC6; UTM 509876 E, 6238962 N)

This sample is from a foliated biotite-monzogranite sheet that is parallel to compositional layering in the sedimentary rocks that it intrudes (Figure 12A). It was dated to provide a maximum age for development of S_{main} within it. This granite sheet and the surrounding sedimentary rocks are folded by an F_2 isoclinal fold and thus, this sample also provides a maximum age for F_2 folding. A well-defined crystallization age of 1833 +5/-4 Ma has been determined based on two fractions of clear prismatic zircon with overlapping concordant ages (Figure 13A). A third discordant fraction has an overlapping $^{207}Pb/^{206}Pb$ age. Two fractions of dark brown titanite have overlapping concordant ages of 1811 and 1806 Ma.

Biotite-Granodiorite (6403-KM71; UTM 510279 E, 6243678 N)

This sample is from a massive homogeneous, sparsely K-feldspar porphyritic white leucogranodiorite that contains inclusions of migmatitic pelitic gneiss (biotite-sillimanite-garnet-leucosome). The leucogranodiorite has a gradational contact with the leucosome of the migmatite (Figure 12B) from which it is interpreted to be derived; however, it clearly cross-cuts the metamorphic fabric in the adjacent mixed supracrustal succession (Figure 12C). The zircon systematics of this sample is complicated by inheritance, but a tentative crystallization age of 1825 ±5 Ma has been determined.

Biotite-Sillimanite-Garnet Pelitic Migmatite (6403-KM70; UTM 510279 E, 6243678 N)

This sample is from a migmatitic pelitic gneiss adjacent to the dated leucogranodiorite (above). The leucogranodiorite is interpreted to be derived from melting of these pelitic rocks. Monazite from this sample was dated to provide constraints on the time of metamorphism. Three single grains of monazite with good crystal faces have overlapping concordant ages with a mean of 1822 ±2 Ma (Figure 13B).

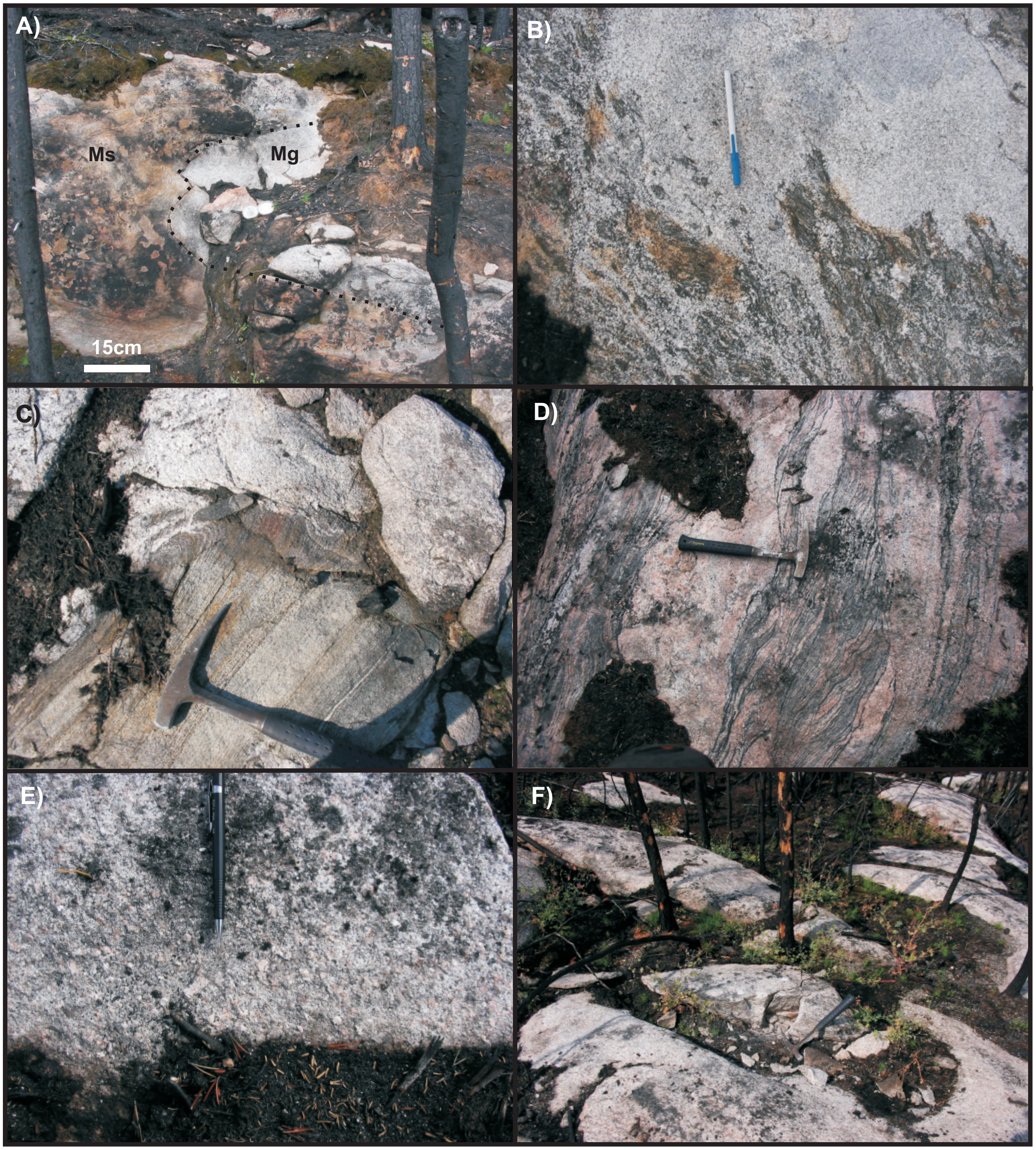


Figure 12 - Photographs showing the units sampled for TIMS U-Pb geochronology. A) 6403-GC6, pre-S_{main} monzogranite sheet (Mg) in the core of an F_2 fold of sedimentary rocks (Ms; UTM 509876 E, 6238962 N); B) 6403-KM71, white biotite granodiorite transitional to inclusions of migmatitic pelitic gneiss (pen for scale is about 15 cm long; UTM 510279 E, 6243678 N); C) white biotite granodiorite cutting compositional layering and the metamorphic fabric in non-migmatitic biotite-hornblende quartzofeldspathic gneiss (hammer for scale is about 40 cm long; UTM 510205 E, 6243561 N); D) 6403-KM64, injected pink granite leucosome in pink migmatite (hammer for scale is about 40 cm long; UTM 505365 E, 6239523 N); E) weathered surface of late K-feldspar porphyritic monzogranite (pencil for scale is about 15 cm long, UTM 509847 E, 6239129 N); and F) sample location of 6403-GC7, K-feldspar porphyritic monzogranite (hammer for scale is about 40 cm long; UTM 509847 E, 6239129 N).

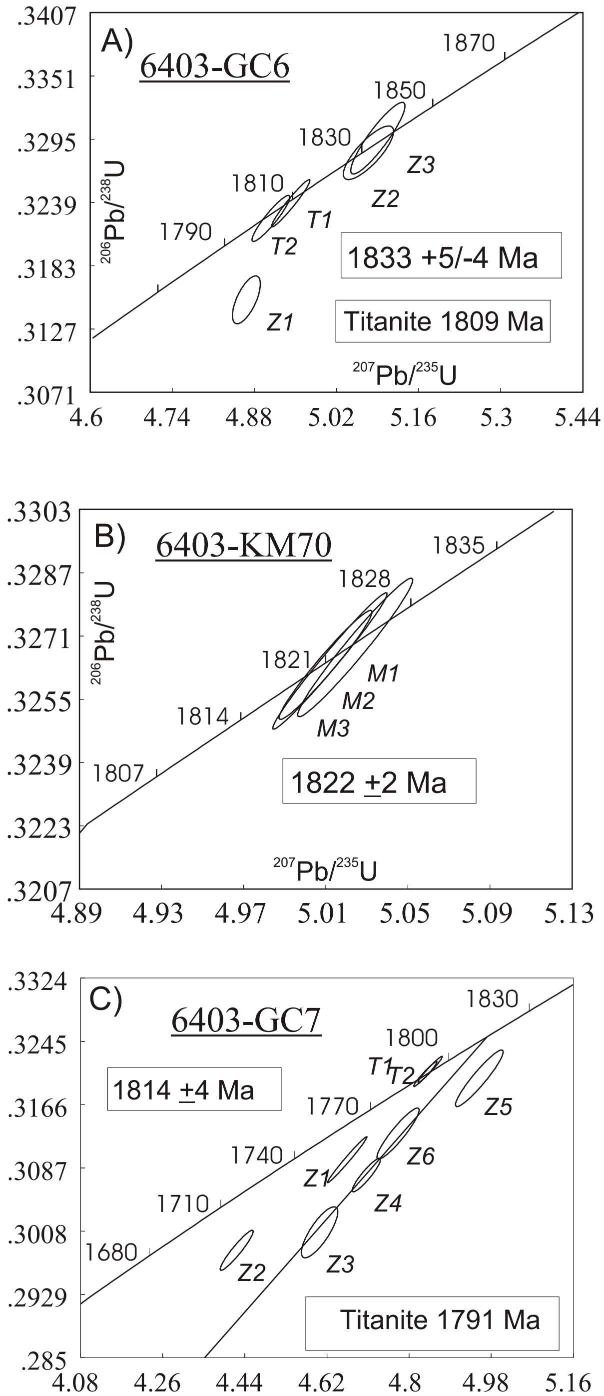


Figure 13 - Concordia plots for TIMS U-Pb analyses on igneous and metamorphic rocks in the tonalite-migmatite complex. A) Sample 6403-GC6 pre-Smain foliated monzogranite; B) sample 6403-KM70, migmatitic pelitic gneiss; and C) sample 6403-GC7 late K-feldspar porphyritic monzogranite.

Injected Pink Leucogranite Leucosome (6403-KM64; UTM 505365 E, 6239523 N)

This injected pink leucogranite leucosome occurs in the psammopelitic to psammitic sedimentary rocks and cuts an earlier phase of pale pink leucosome that is interpreted to be *in situ* (Figure 12D). The zircon systematics of this sample is complicated by inheritance, but a crystallization age of 1814 ±1.5 Ma was determined based on discordant zircon and two concordant monazite fractions.

K-feldspar Porphyritic Biotite-Monzogranite (6304-GC7; UTM 509847 E, 6239129 N)

This sample is from a map-scale sheet of homogeneous, massive to weakly schleiric K-feldspar porphyritic biotite monzogranite (Figures 12E and 12F). Five single grain and one multi-grain fraction of zircon were analyzed. Three of these fractions define a discordia line with an upper intercept age of 1814 ±4 Ma which is interpreted to be the crystallization age of this granite (Figure 13C). The multi-grain fraction has an older age and is interpreted to contain an inherited component. The other two fractions have younger ages, higher uranium content, lower Th/U ratios, and have likely been more strongly affected by later metamorphism. Two titanite fractions have overlapping concordant ages at 1791 Ma.

Interpretation

The 1833 +5/-4 Ma crystallization age of the foliated granite sheet (6403-GC6) that contains the main tectonic fabric (S_{main}) provides a maximum age for that fabric and transposition of compositional layering into parallelism with that fabric. The fabric defined by metamorphic minerals in the adjacent non-migmatitic melanocratic paragneiss is also parallel to S_{main} and composition layering and thus, this sample also provides an indirect minimum age for the older metamorphic fabric. This sample also provides a maximum age for early isoclinal (F_2) folding. The zircon crystallization age of *ca*. 1825 Ma for the granodiorite (6403-KM71) agrees well with the 1822 ±2 Ma metamorphic monazite age for the pelitic migmatite (6403-KM70) from which the granodiorite is interpreted to have been derived. Thus, significant migmatization in the low-magnetic susceptibility psammopelitic rocks (unit 1) in the Rottenstone Lake area occurred at about 1822 Ma. The 1814 ±1.5 Ma crystallization age of the injected pink leucogranite leucosome from the pink migmatites (unit 2, 6403-KM64) is the same as the 1814 ±4 Ma crystallization age of the late K-feldspar porphyritic monzogranite (unit 12, 6403-GC7). By correlation with the small body of unit 12 that folds around the hinge of the F_3 fold north of Kenyon Lake (Figure 2), the latter sample provides a maximum age of *ca*. 1814 Ma for F_3 folding. The approximately 20 million year range in titanite ages (1.81 to 1.79 Ga) suggests that they cannot be simply interpreted as regional cooling ages.

The younger age for the late K-feldspar porphyritic monzogranites and injected pink leucosome suggests that they could be genetically related. The fact that they are younger than the white migmatites and related granitoids is compatible with field observations that pink granite generally cuts white granitoids and migmatites.

7. Discussion

With additional mapping it has been possible to further subdivide the supracrustal rocks in the Rottenstone Lake area into four units compared to two as was done previously (MacLachlan 2003a, 2003b). The distinction between white migmatite with low magnetic susceptibility and pink migmatite with high magnetic susceptibility may indicate something fundamental about the nature of the original sedimentary successions. Previous workers have observed that graphite is common in the migmatite (*e.g.*, Gilboy, 1982; Johnson, 1985). In the Davin Lake area Johnson (1985) particularly describes graphite associated with the white migmatite, and this association is assumed to hold for the Rottenstone area. Given that reducing conditions are required for graphite, it is presumed that graphite is not characteristic of the magnetite-bearing pink migmatite. In the Reindeer Lake area, graphite has commonly been observed in the migmatitic psammopelitic rocks of the Milton Island Assemblage, whereas magnetite is common in the arkosic migmatites of the Park Island Assemblage (Corrigan *et al.*, 1998). In the case of the Reindeer Lake area, it is clear that the Park Island and Milton Island assemblages are distinct in age, tectonic setting, and lithological composition. This is less clear in the Rottenstone Lake area where the degree of migmatization and abundance of granitoid rocks is much higher. It is possible that the magnetic susceptibility of these two mappable units indicates a fundamental difference in the oxidation state of the original sedimentary successions, which may be telling us something about the depositional setting. More work is required to determine if the white and pink migmatites might correspond to the Milton Island and Park Island assemblages, respectively.

8. Acknowledgments

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