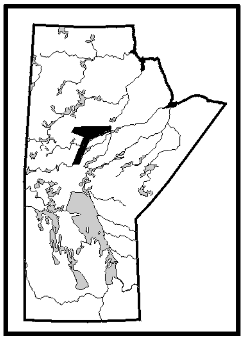
GS-14 TECTONOSTRATIGRAPHY, SM-ND ISOTOPE AND U-PB AGE DATA OF THE THOMPSON NICKEL BELT AND KISSEYNEW NORTH AND EAST MARGINS (NTS 63J, 63O, 63P, 64A, 64B), MANITOBA

by H.V Zwanzig and Ch.O. Böhm[1]



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SUMMARY

This report demonstrates an application of combined remapping, core relogging and isotopic dating techniques to unravel the complex tectonostratigraphy across the Superior Boundary Zone. The work aims to clarify the structure, mineral potential and extent of the Thompson Nickel Belt and the adjacent Kisseynew Domain in north-central Manitoba. The Sm-Nd isotope methods and U-Pb dating applied to these Precambrian medium- to high-grade gneiss units provide a clear distinction between 1) Neoarchean basement, 2) cover rocks (hosting nickel deposits), 3) juvenile Paleoproterozoic paragneiss (probably thrust in from the Kisseynew Domain), and 4) a Mesoarchean gneiss complex (the likely host of important precious metal prospects). A summary of preliminary results is presented from Pearson Lake, the Mel zone and Setting Lake. The continuing work encompasses Rock Lake, Assean Lake, Leftrook and Harding lakes, and various locations in the Thompson Nickel Belt.

INTRODUCTION

The key to rigorous mapping of Precambrian gneiss in north-central Manitoba lies in establishing unique stratigraphic sequences and determining their ages. Mapping and core logging have been combined with Sm-Nd isotope and U-Pb age data to test stratigraphic, tectonic and metallogenic models (Zwanzig et. al., 2001). The project area currently extends along the boundary between the Kisseynew Domain (KD) and Thompson Nickel Belt (TNB) in the southeast, and the Lynn Lake–Leaf Rapids domains and Assean Lake crustal complex (Böhm et al., 2002) in the north (Fig. GS-14-1). Because outcrop is limited in large parts of the area, surface mapping was combined with relogging of company-owned drill core (Inco Technical Services Ltd., Nuinsco Resources Limited, Hudson Bay Exploration and Development Co. Ltd. and Strider Resources Ltd.). This collaborative work has led to the recognition of previously distinguished stratigraphic sequences, which include the Neoarchean basement gneiss and the Paleoproterozoic Ospwagan Group in the TNB, the Mesoarchean Assean Lake crustal complex in the northeast, and the Paleoproterozoic Burntwood, Sickle and Grass River groups in the KD. Many of these assemblages contain similar looking orthogneiss and migmatitic greywacke-gneiss or semipelite derived from turbidite to marine shelf or basin deposits, units that cannot be distinguished using petrographic analysis alone. The ages (T_{CR} Nd model and U-Pb igneous, metamorphic and detrital zircon ages) of these units are critical in establishing a geological and therefore metallogenic framework for the region. Major- and trace-element geochemistry and petrographic work provide additional data to distinguish the various units.

This report provides a current geological overview of the project area and delineates the areas of new mapping, core logging and sampling. Also included is a preliminary summary of tectonostratigraphy and the geochronology determined from samples collected during 2001 along the northern extension of the TNB (Mel zone), from further to the northeast (Pearson Lake) and from earlier sampling in the south (Setting Lake). During the summer of 2002, mapping and surface sampling were carried out on Leftrook and Harding lakes, 60 km northwest of Thompson. This ongoing work is expected to provide petrographic and isotopic data for stratigraphic units typical of the north flank of the KD. Drill core was relogged and samples collected from five sites along the TNB and possibly beyond its northern extension. These sites are, from southwest to northeast,

1) Soab Lake area,
2) Tailor River (Kipper),
3) Birchtree Mine area,
4) Rock Lake (50 km northeast of Thompson), and
5) Assean Lake (Hunter and Tex claims).

The new samples from these areas are expected to provide petrographic, geochemical, isotopic and geochronological data for the Paleoproterozoic rocks and the Archean gneiss in the TNB and the northern part of the Superior Boundary

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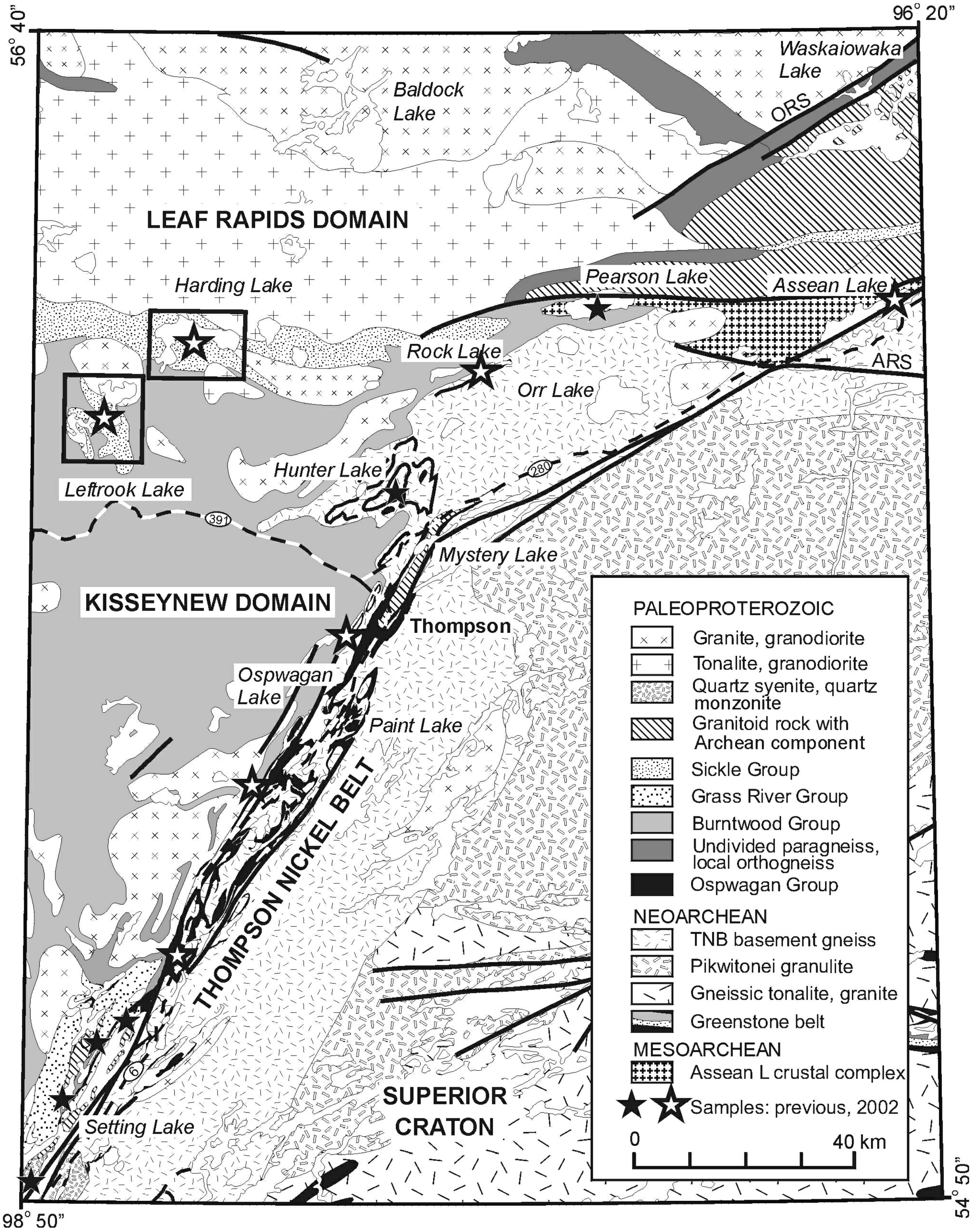


Figure GS-14-1: Sample location map and simplified geology of the Thompson Nickel Belt (TNB), part of the Kisseynew Domain, the margins of the Lynn Lake–Leaf Rapids domains, and the Assean Lake crustal complex. The distribution of the Ospwagan Group in the Hunter Lake–Rock Lake area is schematic and speculative; the full extent of the TNB is unknown. Abbreviations: ORS, Owl River Shear Zone; ARS, Aiken River Shear Zone.

Zone. The dataset will augment the results of the work done in the Mel zone and at Pearson Lake in 2001. The work is intended to delineate the extent of the various tectonic domains more fully and to help resolve stratigraphic and structural problems where units are interleaved at their boundaries.

GEOLOGICAL OVERVIEW

The region between Setting Lake, Assean Lake and Leftrook Lake includes the collisional boundary zone of the Superior Craton with the internal zone of Trans-Hudson Orogen. The region is dominated by the TNB, a northeast-trending belt of migmatitic orthogneiss that is unconformably overlain by the Paleoproterozoic Ospwagan Group (Fig. GS-14-1). North of Mystery Lake, the shape and extent of the TNB is largely speculative. In the main part of the belt, the Ospwagan Group is recognized as a distinctive succession of platform (rift-drift) metasedimentary formations with rift-related volcanic rocks at the top (Fig. GS-14-2). It is intruded by ca. 1.88–1.86 Ga ultramafic-mafic sills and dikes and is host to the largest nickel deposits in Manitoba. The Ospwagan Group, which was affected by early nappe tectonics and amphibolite-facies metamorphism, occupies long, narrow, northeast-trending folds at the northwest margin of the basement-dominated TNB (Bleeker, 1990). The basement gneiss grades into the Pikwitonei granulite gneiss to the southeast. In fact, much of the TNB basement gneiss was derived from the granulite by retrogression and structural overprinting along the Superior Boundary Zone, which, in Manitoba, is the southeastern external zone of the Trans-Hudson Orogen.

In the northwest, the TNB is bounded by younger Paleoproterozoic juvenile gneisses (Burntwood Group, Grass River Group and Proterozoic intrusions) in the KD, where they form part of the internal zone of Trans-Hudson Orogen. The Burntwood and Grass River groups are marine (turbidite) and nonmarine (fluvial-alluvial) deposits that were probably formed during the early stages of collision between the internal zone and the Superior Craton (Zwanzig, 1998). A syncollisional conglomeratic unit in the Grass River Group is interpreted to lie unconformably on the upper unit of basalt in the Ospwagan Group along the northwest shore of Setting Lake (Zwanzig, 1998). Previously, the entire northwest contact of the TNB was considered to be a fault (Bleeker, 1990). However, aeromagnetic trends, exploration

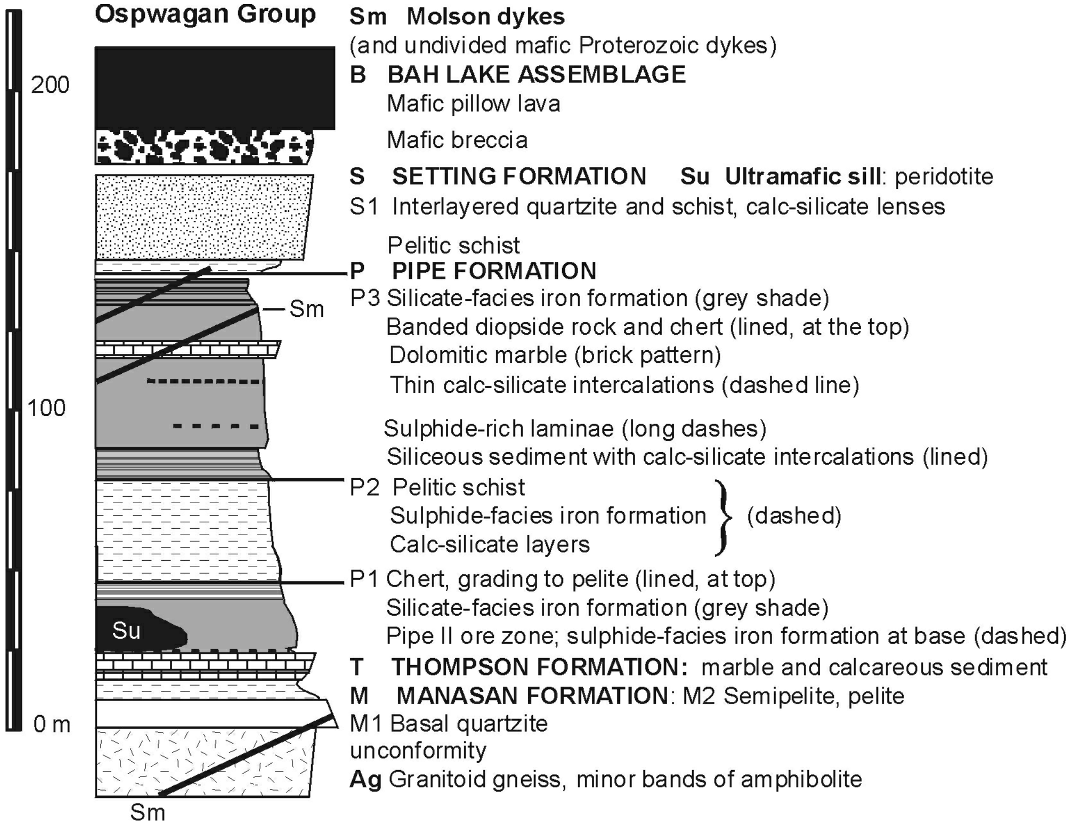


Figure GS-14-2: Typical stratigraphic section of the Ospwagan Group, based on the Pipe II open pit (modified after Bleeker and Macek, 1988). Thickness of units is a minimum (i.e., measured on flattened fold limbs).

drill core and new structural mapping indicate that many faults and mylonite zones are relatively young and some cut northeast across the northern extension of the TNB (Fig. GS-14-1). Moreover, previously unpublished Sm-Nd isotope data suggest that granites within the eastern margin of the KD were contaminated by Archean crust. They may have been locally derived completely from Archean rocks and are now structurally interleaved with the juvenile Proterozoic units. Thus, the collisional boundary zone involves depositional contacts and structural contacts that were refolded and faulted during protracted deformation, and injected by various crust- to mantle-derived melts.

In the west, at Leftrook and Harding lakes, paragneiss and local amphibolite units form a succession typical of the north flank of the KD. They are mapped as greywacke-migmatite, similar to the Burntwood Group, and arkosic gneiss, equivalent to the Sickle Group exposed in the southern part of the Lynn Lake Domain (Corkery and Lenton, 1980). These rocks have the potential to provide an important stratigraphic section, with geochronological and Sm-Nd isotopic data, for the presumably juvenile rocks in the northern KD.

At Assean Lake, an ancient (Mesoarchean) crustal complex and prominent shear zones mark the margin of the Superior Craton. This complex was previously considered to be Proterozoic (Corkery and Lenton, 1980), but isotope and geochronological studies by Böhm et al. (2000, 2002) revealed Mesoarchean ages for felsic magmatism and greywacke-gneiss, with the latter containing ca. 3.2 to 3.9 Ga detrital zircons. Units of amphibolite and iron formation were also interpreted to be part of the Assean Lake crustal complex by Böhm et al. (2000). Mesoarchean ages to the south, along the Aiken River Shear Zone (Böhm et al., 2000 and unpublished data), suggest that the ancient crust is structurally interleaved with the Neoarchean, Superior-type gneiss and that the full extent of Mesoarchean crust along the Superior Boundary Zone is unknown. Predominantly Archean Nd model ages for orthogneiss between Assean Lake and the Owl River Shear Zone, further to the north, indicate the presence of mixed gneiss and variably contaminated plutons (Böhm et al., 2002). The orthogneiss was previously considered to represent simple Proterozoic intrusions and minor paragneiss of the Trans-Hudson internal zone (Leaf Rapids Domain). The convergence of the major shear zones and crustal elements is located at Pearson Lake and may make this area particularly important for a tectonic interpretation of the collisional boundary zone.

OBJECTIVES AND METHODOLOGY

Mapping

Surface mapping was carried out from fly-in camps on Leftrook and Harding lakes. Outcrop examination and sampling were restricted to shoreline exposures. Sample sets were collected for petrographic work on all units, and the most typical, least-veined varieties were collected and trimmed for geochemical and Sm-Nd isotopic studies. A limited set of predominantly intrusive rocks was collected as fresh broken samples of 15 kg or greater for U-Pb dating (zircon, monazite, sphene). The purpose of this work is to determine the age and test the validity of the stratigraphic sequence of sedimentary units established by Corkery and Lenton (1980) along the northern margin of the KD. The resulting geochronological and geochemical database will serve as a reference for a comparison with similar units that are structurally intercalated at, or adjoining, the margin of the TNB. The data are expected to help identify lithotectonic units in the blocks of complex, mixed gneiss.

Additional surface samples for U-Pb dating and Sm-Nd isotope work were collected on Fish Lake (west of Setting Lake), 100 km southwest of Thompson. These samples may verify preliminary Nd model ages, given in this report, that suggest interleaving of Archean- and Proterozoic-derived gneissic units in an area that was previously considered to contain only juvenile Proterozoic rocks.

Core logging

Much of the bedrock, particularly the sedimentary units in the TNB and northeastern part of the KD, are covered by lakes and muskeg. Access to mineral exploration drill core is therefore essential to reinterpreting these areas. At present, five exploration companies are collaborating with the Manitoba Geological Survey (MGS) and the University of Alberta Radiogenic Isotope Facility by providing critical company-owned core, drill logs, location data, funding and/or other support. Core is laid out in the company yard or at the MGS storage site, contacts are marked and units are described and sampled. Particular attention is given to distinctive units (e.g., marble or basal quartzite) and contacts that may be faults or unconformities. Stratigraphic successions are then compared to type sections in the TNB (e.g., Bleeker and Macek, 1988; Fig. GS-14-2) or assemblages in the KD (e.g., Corkery and Lenton, 1980) or elsewhere (e.g., Böhm, 1997; Böhm et al., 2002). Petrographic and geochemical studies carried out on core samples provide a database for comparing core in different areas. Radiometric dating can yield rigorous constraints for different tectonic units with similar appearance.

Sm-Nd isotope methods

The various units of orthogneiss and paragneiss along the Superior Boundary Zone and in the adjacent KD have yielded a wide range of ages that are not apparent from mapping and petrographic work. The Sm-Nd isotope methods provide a convenient technique of distinguishing the major tectonic assemblages at lower expense than precision U-Pb geochronology. However, these methods do not yield simple ages and may require a discussion of their application, interpretation and limitations, as provided in this section of the report.

The Sm-Nd isotope methods are useful in establishing the crustal evolution of Precambrian terrains such as the western Superior Province and the Trans-Hudson Orogen in Manitoba. Radiogenic isotopes can either be used for dating (e.g., U-Pb zircon dating) or, in the context of geochemistry, to identify provenance and study petrogenetic processes (e.g., Rb-Sr and Sm-Nd isotope methods). Since the different elements used in the isotope studies vary in their chemical and physical properties, individual isotope systems vary in their sensitivity to particular petrological processes. Samarium and neodymium — both being rare earth elements (REE) — have very similar chemical and physical characteristics. Rubidium and strontium, in contrast, are geochemically distinct, incompatible trace elements that are commonly fractionated by secondary processes (e.g., tectonometamorphic processes, fluid-rock interaction). Rubidium-strontium isotope data for metamorphic rocks are therefore rarely useful for constraining crust formation ages. Samarium and neodymium, on the other hand, are compatible trace elements (preferentially enriched in the mineral phases), have small bulk partition coefficients for most petrogenetic processes and are relatively immobile, even at higher metamorphic grade. Thus, the Sm-Nd whole-rock technique can be used in determining crust formation ages. However, relatively small variations in the Sm/Nd ratio are common in cogenetic gneissic rock types and therefore limit the time resolution of the Sm-Nd isotope system. For medium- and high-grade gneisses, crust formation ages are protolith ages and approximately represented by Nd model ages.

A model age is a measure of the length of time a rock has been separated from the mantle from which it was originally derived. A Nd model age can be calculated for an individual rock (bulk-rock sample) from a single pair of parent-daughter isotopic ratios (^{147}Sm/^{144}Nd and ^{143}Nd/^{144}Nd), and Nd model ages for the continental crust are usually calculated with reference to the depleted mantle (DM) reservoir. The two most commonly used models for depleted mantle evolution and the respective Nd model ages are by DePaolo (1981; T_{DM} Nd = depleted mantle separation Nd model age) and Goldstein et al. (1984; T_{CR} Nd = crustal residence Nd model age), with the latter being used here. Three assumptions form the basis of the Nd model age calculation:

1) The isotopic evolution of the reservoir from which the rock was originally derived (commonly mantle) is known.

2) The Sm-Nd isotopic composition of the rock has not been modified by fractionation or alteration after its separation from the mantle source.

3) The rock formed from the mantle in a single event.

For medium- and high-grade gneisses, these assumptions are not always fully applicable or reconstructable, as illustrated in Figure GS-14-3. Model ages must therefore be interpreted with care.

In order to discuss the common use of Nd model ages and the Nd isotopic composition of an analyzed bulk-rock sample, Figure GS-14-3 illustrates the Nd isotopic evolution plotted against time (in billion years) for depleted mantle and continental crust (*see* DePaolo, 1988). The Nd isotopic evolution, ^{143}Nd/^{144}Nd, is expressed as epsilon units, where

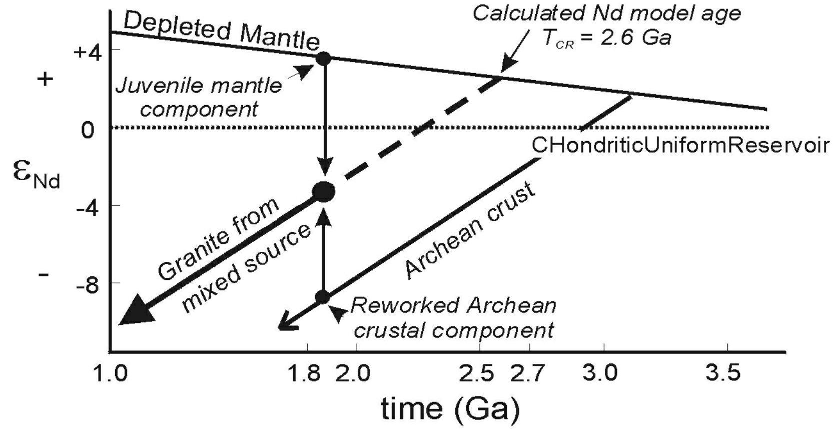
$\varepsilon_{Nd,t} = ((^{143}Nd/^{144}Nd_{initial}/^{143}Nd/^{144}Nd_{CHUR,t}) - 1) \times 10^4$

Relative to CHUR (chondritic uniform reservoir = bulk Earth composition), the depleted mantle shows increasing ^{143}Nd/^{144}Nd (increasingly positive ε values) with time, whereas the continental crust extracted from the mantle shows increasingly negative ε values with time.

In Figure GS-14-3 (Example 1), a granite formed at 1.87 Ga from a mixture of juvenile, mantle-derived material and from Archean crust with an average protolith age of ca. 3.1 Ga. The calculated Nd model age of the granite sample is ca. 2.6 Ga, reflecting neither the crystallization age of the granite nor the age of the crustal source but that of the mixed source materials. It is important to note that the Nd model age of the granite sample can be calculated without knowing the crystallization age of the granite, the latter being commonly determined by U-Pb zircon dating methods. Knowing the age of the granite, however, the Nd isotopic evolution can be used to estimate the degree of involvement of older crust (inheritance or contamination), and the Nd model age represents a minimum protolith age.

In Figure GS-14-3 (Example 2), a sediment formed at ca.1.83 Ga from various source rocks with average residence ages of ca. 1.9, 2.3, 2.8 and 3.1 Ga. The Sm-Nd isotope analysis of the sedimentary sample yields a Nd model age of ca. 2.6 Ga. In this case, the Nd model age represents an estimate of the average provenance of the sediment. Complementary methods, such as U-Pb detrital zircon studies, can then be used to unravel the exact ages and proportions of source rocks involved.

Example 1: 1.87 Ga granite with a Nd model age of 2.6 Ga and ε_{Nd} = -4 (at 1.87 Ga)



Example 2: 1.83 Ga sedimentary rock with a Nd model age of 2.6 Ga and ε_{Nd}= -4 (at 1.83 Ga)

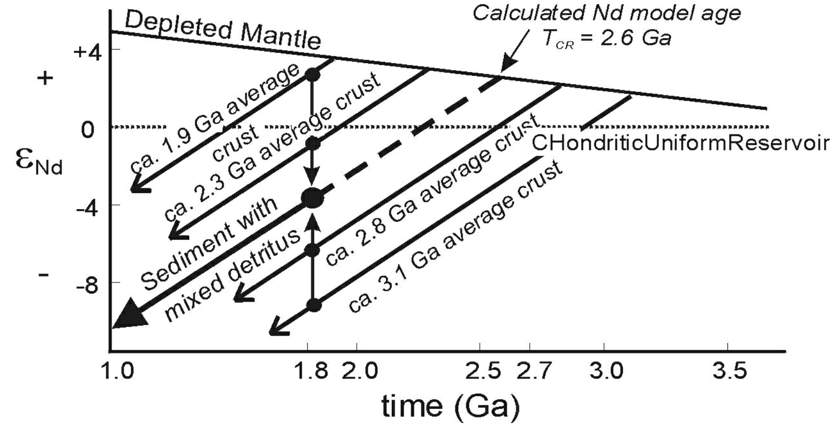


Figure GS-14-3: Neodymium isotopic evolution with time, for depleted mantle and Precambrian continental crust (granite and sedimentary rock examples; see text for explanations).

In summary, the Sm-Nd isotope method represents a relatively rapid and inexpensive technique that is most successfully applied in the reconnaissance of Precambrian metamorphic terrains. The method has the potential to yield the protolith history of old high-grade gneisses and to distinguish between Archean and Proterozoic crust. As such, Nd isotopic mapping works best on a regional scale by comparing Nd model ages of felsic meta-igneous and metasedimentary rocks of similar composition across major crustal sutures, such as the Superior Boundary, Assean Lake and Aiken River deformation zones along the northwestern margin of the Superior Province (Fig. GS-14-1).

PRELIMINARY RESULTS

Pearson Lake

The geotectonic position of Pearson Lake is important for at least two reasons:

1) The northeast-trending Superior Boundary Zone and Owl River Shear Zone, which possibly separate mixed Archean and Proterozoic crust from dominantly Proterozoic crust along the northwestern margin of the Superior craton, meet in the Pearson Lake area (Fig. GS-14-1).

2) The northern extension of the Thompson Nickel Belt could be located along this margin.

A dominant granodiorite orthogneiss unit has been identified and dated at Pearson Lake (e.g., Zwanzig et al., 2001). Samarium-neodymium isotope analysis of the granodiorite gneiss yields a crustal residence (T_{CR}) Nd model age of ca. 3.3 Ga and current ε_{Nd} of approximately –39, clearly indicating the antiquity of the granodiorite gneiss precursor. Based on our U-Pb zircon dating, the crystallization age of the granodiorite gneiss is 3185 ± 7 Ma, similar to orthogneiss in the ancient Assean Lake crustal complex (e.g., Böhm et al, 2002). The granodiorite orthogneiss at Pearson Lake was metamorphosed at 1782.6 ± 1.1 Ma (metamorphic zircon), and separates paragneiss on the north shore from migmatized metagreywacke on the south shore. Results from Sm-Nd isotope analysis show that these paragneiss units are not related to each other. The southern metagreywacke yielded a ca 2.2 Ga T_{CR} Nd model age and ε_{Nd} at 1.8 Ga of approximately +2, which suggests that this metagreywacke dominantly or entirely consists of source rocks that are less than 2.0 Ga, similar to Burntwood Group metasedimentary rocks of the KD with which it can possibly be correlated. Metamorphic zircons from a leucosome sample in the southern metagreywacke indicate that it was metamorphosed at ca. 1802 Ma, a typical age for the thermal peak in the KD (Machado et al., 1999). A T_{CR} Nd model age of ca. 2.5 Ga and ε_{Nd} of approximately –1 at 1850 Ma, in comparison, indicate that the paragneiss to the north likely sampled Paleoproterozoic and Neoarchean crust (detrital zircon ^{207}Pb/^{206}Pb ages of 2258, 2571 and 2696 Ma were determined in this study).

In summary, Sm-Nd isotope and U-Pb age data suggest that orthogneiss at Pearson Lake might represent a westerly extension of the Mesoarchean Assean Lake crustal complex. At Pearson Lake, Mesoarchean orthogneiss is interleaved with Paleoproterozoic- to Neoarchean-derived paragneiss in the north, and in fault contact with predominantly Paleoproterozoic-derived greywacke-migmatite (probably Burntwood Group) to the south.

Mel zone

The Mel zone was previously shown on compilation maps as part of the KD (e.g., Manitoba Energy and Mines, 1995). However, magnetic trends extend northwest from the TNB at Mystery Lake and exploration drilling by Inco Technical Services Limited has encountered high-grade paragneiss similar to the Ospwagan Group (Fig. GS-14-4). A collaborative program of relogging, geochemistry and Sm-Nd isotope work was undertaken to resolve the geology of this complex area. This paper presents a summary of new petrographic and Nd isotopic results, which suggest that the Mel zone between Mystery Lake and Hunter Lake is part of the northwestern extension of the TNB.

The following lithological units from the TNB are based on a summary review of the Inco drillhole records and were tentatively identified during relogging:

1) Archean basement gneiss

2) lower part of the Ospwagan Group (Manasan Formation M1 quartzite to Pipe Formation P2 pelite and P3 silicate iron formation)

3) greywacke-mudstone–derived gneiss (garnet-biotite gneiss with granitoid leucosome belonging to, or similar to, the Burntwood Group)

4) amphibolite

5) pegmatite and granite veins and sheets, considered to be Proterozoic

The Ospwagan Group is very coarsely recrystallized with garnet porphyroblasts and quartz-sillimanite knots (faserkiesel) reaching 60 mm in length. True thicknesses of Ospwagan Group encountered in the various sections range from 35 to 100 m. Basal quartzite lies — where recognized or preserved — adjacent to basement-type gneiss, which is unusually garnetiferous (probably due to paleoweathering). This suggests that, as in the main TNB, the Ospwagan Group lies unconformably on the basement gneiss. However, unlike the main TNB, the Mel zone features Burntwood-type greywacke migmatite in sharp contact with the Pipe Formation, and the upper part of the Ospwagan Group seems to be absent. True thickness of the Burntwood Group is less than 200 m. Greywacke gneiss, petrographically similar to the Burntwood Group, and amphibolite are the main units encountered in the northwesternmost drillhole.

Neodymium model ages provide a clear distinction between the Archean basement gneiss (T_{CR} = 3.2–3.5 Ga), Ospwagan Group (T_{CR} = 2.8–3.0 Ga), Burntwood Group gneiss (T_{CR} = 2.3–2.4 Ga) and petrographically similar greywacke gneiss derived from older crustal material (T_{CR} approx. 3.2 Ga). The model ages and suggested stratigraphic positions of the analyzed samples are shown in Table GS-14-1.

The oldest Nd model ages of basement gneiss (T_{CR} = 3.4–3.5 Ga) occur in the core of a large oval structure (bottom of DDH 102519, top of DDH 102520; Fig. GS-14-4), whereas banded orthogneiss and paragneiss surrounding the structure (DDH 102523 and top of DDH 102524) yielded T_{CR} Nd model ages of ca. 3.2 Ga. The data indicate a heterogeneous TNB basement with significant Mesoarchean (>3.0 Ga) components in orthogneiss and paragneiss (metagreywacke) along the outer margin of the Superior Boundary Zone.

The Ospwagan Group detritus was eroded from crust with an average time of residence that ranges from 2.8 to 3.0 Ga, consistent with a provenance containing a larger contribution from juvenile Neoarchean rocks than the TNB

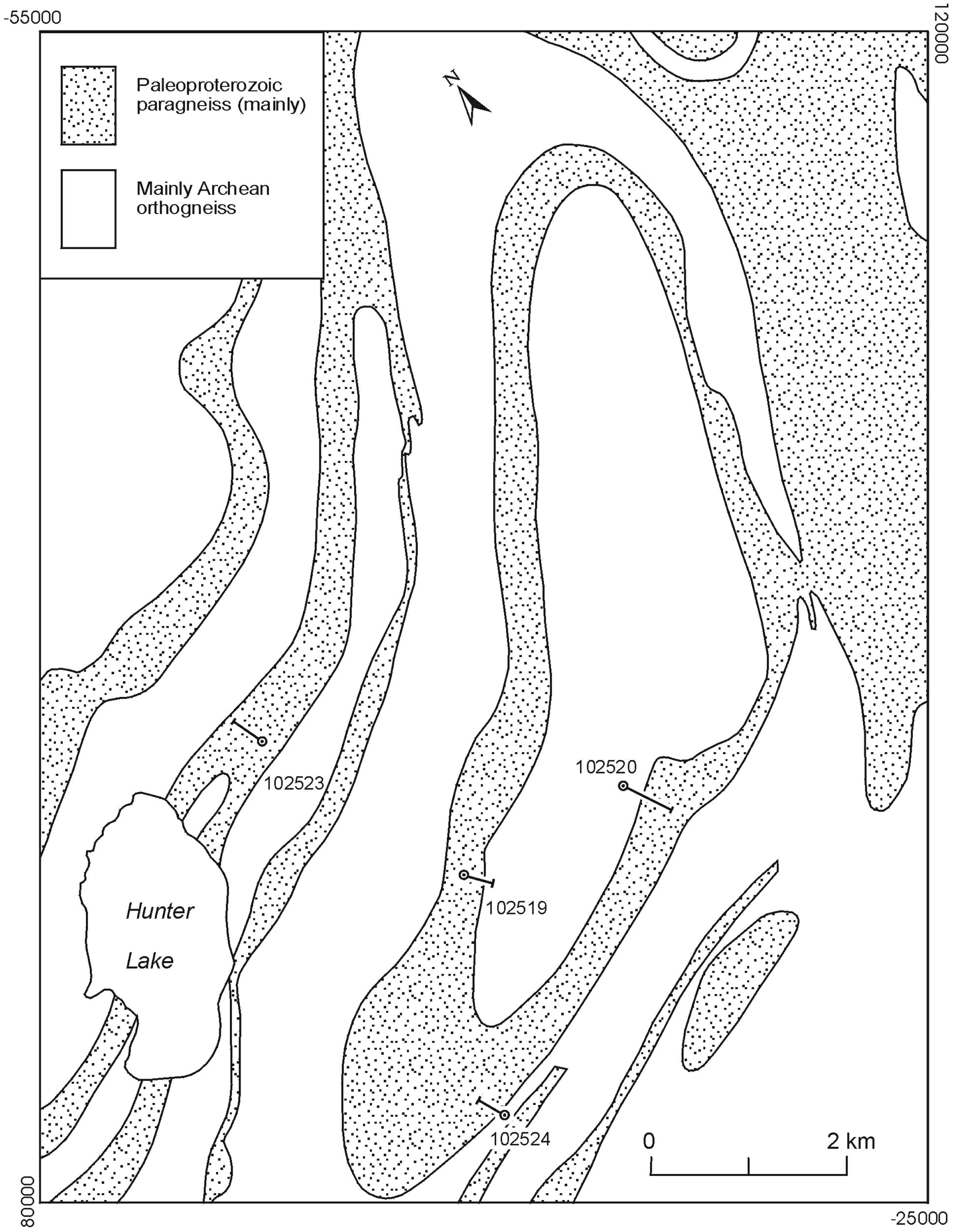


Figure GS-14-4: Simplified geological map of the Hunter Lake area (Mel zone), derived from geophysical data (courtesy of Inco Technical Services Limited), showing location of relogged and sampled diamond-drill holes. Inco Thompson grid is shown at the map corners in feet.

Table GS-14-1: Summary of Mel zone drill core stratigraphic interpretation and Nd model ages (T_{CR}).

From (m)	To (m)	Unit / lithology	T_{CR} (Ga)
DDH 102519, 11 km northwest of Mystery Lake:			
33.2	33.8	Burntwood Gp: garnet-biotite greywacke-gneiss	2.3
129.8	130.6	Pipe Fm. (P2): biotite gneiss, mica schist	2.9
205.9	206.8	Basement: Laminated to banded gneiss	3.5
DDH 102520, 10 km northwest of Mystery Lake:			
153.0	154.5	Basement: banded quartzofeldspathic ±garnet gneiss	3.4
389.4	390.2	Manasan Fm. (?M1): garnet-biotite gneiss, biotite quartzite	3.0
404.8	405.1	Manasan Fm. (M2): coarse-grained sillimanite-garnet-biotite gneiss	2.8
536.1	536.7	Burntwood Gp: garnet-biotite metagreywacke-migmatite	2.4
DDH 102523, 2 km northeast of Hunter Lake:			
93.0	536.0	garnet-biotite±sillimanite±cordierite gneiss (greywacke derived)	3.2
DDH 102524, 10 km northwest of Mystery Lake:			
129.2	129.8	Basement: quartzofeldspathic gneiss ±garnet	3.2
389.8	390.5	Thompson Fm. (T3): biotite gneiss	2.9

n.d., not detected

basement. Such rocks are common in the interior part of the Superior Province, which may have been the dominant sediment source. The significantly younger Nd model ages (T_{CR} = 2.3–2.4 Ga) of the Burntwood Group indicate a largely juvenile, Paleoproterozoic detrital component, exotic to the TNB.

A preliminary structural interpretation of the Mel zone is that the Burntwood Group may have been thrust over the TNB with the footwall detachment in the lower part of member P3 of the Pipe Formation. This would suggest that the oval band of paragneiss in Figure GS-14-4 is a recumbent syncline that was developed from an early thrust stack and refolded into a dome (Fig. GS-14-5). If the syncline closes in the southeast, the Burntwood Group and the more ancient orthogneiss are rooted west and north of the TNB, consistent with the regional geology.

Setting Lake area

Samarium-neodymium geochemistry was done under CAMIRO Project 97E-02 (unpublished) at the University of Saskatchewan on several samples collected during regional structural mapping in the Setting Lake area (Zwanzig, 1998). Burntwood Group and Grass River Group paragneiss and dikes, and a quartz-syenite pluton intruding the Grass River Group, all yielded Paleoproterozoic Nd model ages (T_{CR} = 2.2–2.4 Ga) similar to the Burntwood Group in the Mel zone and south of Pearson Lake (Table GS-14-2). The data show that such Nd model ages are regionally typical of the KD paragneiss and intrusions.

New U-Pb zircon crystallization ages, determined at Geotop (Université du Québec à Montréal) by A. Potrel and N. Machado are ca. 1.835 Ga and ca. 1.82 Ga for the mildly alkaline quartz syenite and the granite intruding the quartz syenite, respectively (Table GS-14-2). The ε_{Nd} at the time of crystallization is variably negative and indicates a small to moderate amount of contamination by older rocks, presumably Archean basement gneiss. Archean model ages (T_{CR} = 2.7–2.9 Ga) of the highly foliated K-feldspar–phyric granite and granodiorite gneiss show that these intrusions are moderately to highly contaminated; some may represent remobilized basement gneiss. The data suggest that, similar to the Mel zone, the Kisseynew paragneiss was probably thrust over the Superior Craton margin early during the Hudsonian Orogeny.

Soab Lake–Birchtree Mine area

Relogging of proprietary drill core from Inco Ltd. properties along the west side of the central part of the TNB indicates a good potential for structural slices of juvenile Proterozoic rocks belonging to the KD to occur within the TNB. Conversely, Ospwagan Group and ultramafic rocks associated with nickel deposits elsewhere may be intercalated with juvenile gneiss at the eastern margin of the KD. Sampling from four drill cores for petrographic, geochemical and geochronological analysis has been carried out and sample analysis is in progress. The samples were taken from units of uncertain origin, as well as from recognizable Ospwagan Group metasedimentary rocks. Ten new samples are expected to augment the Nd-Sm database for the TNB and its extensions, and to help solve local problems in structural and exploration geology.

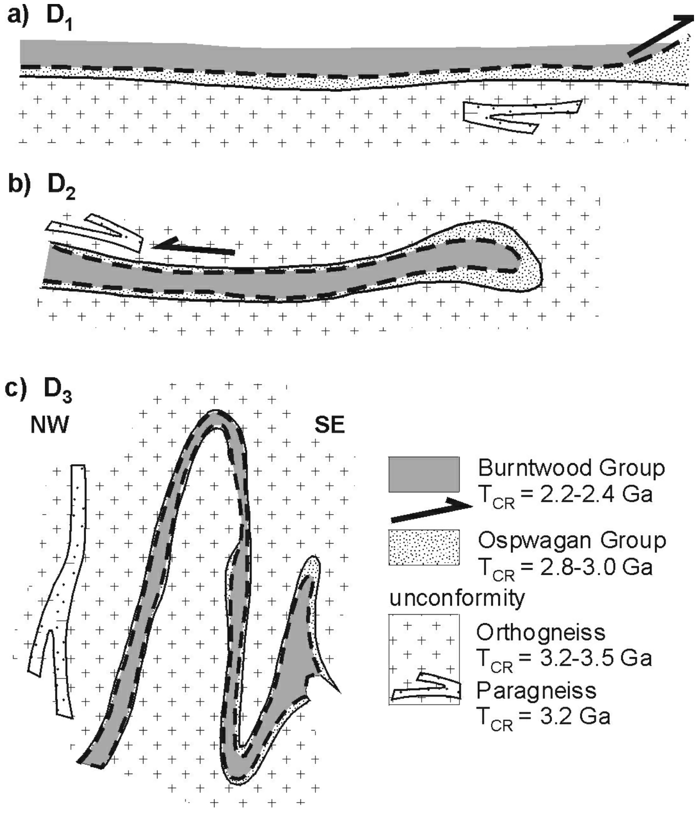


Figure GS-14-5: Possible structural interpretations of the Mel zone in three major phases of deformation. The D_1 thrust fault is inferred from the abrupt change in Sm/Nd isotope ratio between the Ospwagan and Burntwood groups.

Table GS-14-2: Summary of Nd model ages (T_{CR}) and U-Pb zircon ages for the Setting Lake area.

Sample	Location	Unit / lithology / U-Pb zircon age	T_{CR} (Ga)
12-97-7-2B	Setting Lake	Grass River Gp: meta-arenite	2.2
12-98-546-1	Fish Lake	Burntwood Gp: metagreywacke	2.4
12-97-122-21	Setting Lake	Intermediate dike	2.4
12-97-14-3	Setting Lake	Tonalite dike	2.4
12-97-258-1	Setting Lake	Granite (U-Pb zircon age = 1.82 Ga; $\varepsilon_{Nd,1.82\ Ga}$ = –7.4)	2.7
12-97-34-3A	Setting Lake	Quartz syenite (U-Pb zircon age = 1.835 Ga; $\varepsilon_{Nd,1.84\ Ga}$ = –2.3)	2.4
12-97-99-1	Setting Lake	Granodiorite gneiss	2.9
12-98-624-1	Setting Lake	Porphyroclastic granite	2.7
12-99-915-1	Fish Lake	Porphyroclastic granite	2.9

Rock Lake area

Three recent drill cores of Hudson Bay Exploration and Development Co. Ltd. were re-examined from an area southeast of Rock Lake and extending toward Pearson Lake. Systematic sampling was carried out on the cores for petrographic analysis, and five samples are in preparation for Sm-Nd isotope and detailed geochemical analyses. The resulting data could help delineate the various narrow lithotectonic domains in this critical part of the Superior Boundary Zone.

Assean Lake

Drill core from two holes of Strider Resources Ltd. on the northeast part of Assean Lake was re-examined and sampled for Sm-Nd, geochemical and petrographic work. The cores are mylonitic and units, although poorly preserved, may include clastic and possible cherty to ferruginous metasedimentary members, as well as amphibolite of possible volcanic origin. A comparison of the expected data with surface data from the Assean Lake crustal complex (Böhm et al., 2000, 2002) may place mineralized zones into their regional tectonic context.

Leftrook–Harding lakes area

Although water levels were high and some contacts must be assumed to be faults, the stratigraphic succession identified by Corkery and Lenton (1980) as typical of this part of the north flank of the KD was confirmed during remapping of the shorelines. The succession forms part of the Burntwood and Sickle groups, and locally contains intervening amphibolite (Table GS-14-3).

The regionally widespread greywacke-derived gneiss and migmatite, interpreted as belonging to the Burntwood Group, is exposed for distances of 2 to 5 km in bays, channels and islands, where a set of representative samples was collected.

In several locations, a narrow amphibolite unit occurs at or near the inferred contact between the Burntwood Group and the overlying Sickle Group. The amphibolite is predominantly intrusive into the basal unit of the Sickle Group and the top of the Burntwood Group. However, a 5 to 10 m unit of banded mafic tectonite was probably derived from pillow basalt, but no contacts are exposed to determine its field relationship.

The Sickle Group is generally magnetite bearing and has four distinctive units (undefined formations), recognized mainly by mineral contents of the gneiss (Table GS-14-3). The basal unit (protoquartzite) on Leftrook Lake is 200 to 400 m thick and grades into meta-arenite. This generally grades upward into a unit of medium grey paragneiss. Higher in the section on Leftrook Lake is hornblende-bearing paragneiss that is a minimum of 600 m thick. A quartz-rich, hornblende-bearing unit on Harding Lake grades into an upper unit of meta-arkose that is a minimum of 1000 m thick.

A key observation is that all units compare well to ‘stratigraphic’ units in the high-grade parts of the Sickle Group further northwest along the north flank of the KD, where they occur within an area of 5000 km^2. Leftrook Lake is an additional 100 km to the east and provides an important link with the paragneiss units in the KD along the Superior Craton boundary. Neodymium model ages and detrital zircon ages of these rocks, and crystallization ages of felsic plutons that cut them, will provide critical tests of the regional tectonostratigraphic correlation.

APPLICATION TO MINERAL EXPLORATION

Distinguishing the relatively juvenile paragneiss of the KD from the Ospwagan Group platform-rift succession and from more ancient paragneiss along the northwestern margin of the Superior Boundary Zone is a key requirement for structural mapping, tectonic modelling, metallogeny and mineral exploration. A recent geological compilation, based primarily on proprietary drill core information (Thompson Nickel Belt Geology Working Group, 2001), has shown that all presently known nickel deposits are hosted in the Ospwagan Group at the site of ultramafic intrusions. Tracing these

Table GS-14-3: Unit description, Leftrook–Harding lakes area.

Lithology	Field description and origin	Petrology
Sickle Group:		
Arkosic gneiss	Grey to buff meta-arkose, ranging from coarse grained to finer grained its upper part	3–50 mm quartz-sillimanite knots (faserkiesel), most abundant high in the unit
Meta-arenite	Greenish grey and pink weathering paragneiss, massive to thinly laminated; locally pebbly or crossbedded on Harding Lake and with rare layers of fine-grained pink felsic gneiss and hornblende-rich gneiss (possibly tuffaceous)	Magnetite and variable amounts of hornblende (<15%) and biotite; local epidote in pebbly layers
Meta-arenite	Uniform, medium grey paragneiss or migmatite interpreted to be derived from lithic arenite	Biotite (<10%) and magnetite (locally 1–2%) as only mafic minerals
Protoquartzite	Biotite-rich laminations with local concentrations of magnetite, interpreted as bedding-plane partings with placer minerals in crossbedding	Quartz rich (50–70%), magnetite-bearing, 3–10% biotite, ~1% garnet (<8 mm, rarely <30 mm), local faserkiesel (<20 mm)
Unnamed amphibolite:		
Gabbro	Concordant bodies; mafic sills, possible dikes	Fine- to medium-grained gabbro, coarse-grained melagabbro and anorthositic gabbro
Mafic tectonite	Possible fault slices derived from pillowed basalt	5–20 mm thick layers rich in hornblende±garnet (sheared selvages); layers, <15 cm thick, rich in diopside (highly metamorphosed epidosite alteration domains)
Burntwood Group:		
Greywacke gneiss and migmatite	Generally dark grey paragneiss, reddish brown cast in graphitic layers; migmatitic leucosome ± garnet ± cordierite porphyroblasts (<20 mm); probably derived from turbidite	Garnet (10–15 %), generally 2 mm, <5 mm in pelitic layers; <5 mm faserkiesel

units at the highest grade of metamorphism (amphibolite to granulite facies) and under a thick cover of Pleistocene clay relies on geophysical and drill core interpretation. However, these exploration techniques present difficulties when attempting to distinguish such units as the sillimanite-garnet-biotite gneiss and migmatite that may be derived from pelite in the Ospwagan Group, the barren Burntwood Group or similar-looking Mesoarchean paragneiss. In addition, the Mesoarchean paragneiss forms part of the Assean Lake crustal complex where gold-bearing zones are under exploration. Unravelling the complex geology at Assean Lake could help to trace these zones further.

The three different tectonic assemblages at the Superior Boundary Zone appear to be structurally interleaved at their margins. Neither the full regional extent nor the structural complexities of these assemblages is presently known. Our Sm-Nd isotope methods, in conjunction with U-Pb dating, applied to the various units provide a clear distinction between the tectonic assemblages. The Sm-Nd isotope work is considerably less expensive than U-Pb zircon dating that has so far provided only very limited data on the age of deposition of the Ospwagan Group (Bleeker, 2001). Furthermore, Nd model ages can be obtained from relatively small samples (i.e., drill core). The preliminary results reported here suggest that this will become a powerful tool for regional metallogeny and local exploration.

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