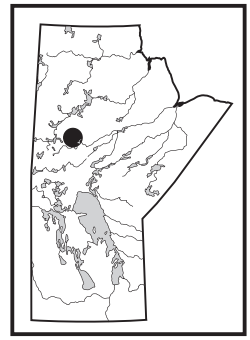
GS-7

New field and geochronological results for the Osik–Atik–Footprint lakes area, Manitoba (NTS 63O13, 14, 15, 64B2, 3)

by J.A. Percival[1], N. Rayner[1], M.L. Growdon[2], J.B. Whalen[1] and H.V. Zwanzig



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Summary

The oldest recognized units in the Osik–Atik–Footprint lakes are porphyritic granodiorite rocks identified by sensitive high-resolution ion microprobe (SHRIMP) U-Pb zircon ages on plutons at Atik Lake (1879 ±13 Ma) and Footprint Lake (1882 ±10 Ma). A supracrustal sequence containing quartz-rich sandstone and silicate-facies iron formation that borders a similar pluton at Wapisu Lake may be unconformable and underlie Burntwood Group (<1850 Ma) migmatite rocks, which make up most of the northeastern Kisseynew Domain. At Osik Lake, a hook-shaped body of homogeneous biotite tonalite is enveloped by a sheath of enderbite–quartz diorite–gabbro in structural contact with the Burntwood migmatite. The tonalite contains at least one layered mafic-ultramafic body that may be the source of a nickel-in-till anomaly south of Osik Lake.

Structurally, the area is characterized by a set of upright, gently northeast-plunging F_3 folds that reoriented a prominent S_2 foliation developed in all rock types except late granite and pegmatite. The map pattern of an outlier of Sickle Group rocks north of Osik Lake may be the product of structural interference.

Introduction

Recent work in the northeastern Kisseynew Domain of the Trans-Hudson Orogen has suggested potential for Thompson-type nickel mineralization within a supracrustal sequence resembling the Ospwagan Group (Growdon et al., 2006; Percival et al., 2006; Rayner et al., 2006; Zwanzig et al., 2006a, b). In the Wuskwatim Lake–Burntwood River area, inliers of Archean orthogneiss (Rayner and Percival, GS-8, this volume) and an overlying quartz-rich sandstone–iron formation package suggest the widespread presence of Superior Province crust beneath migmatite rocks of the Burntwood Group in this region. Recently acquired high-resolution aeromagnetic images (e.g., Coyle and Kiss, 2006) allow the tracing of magnetic units farther west, into areas where isotopically contaminated granitoid rocks are exposed (Percival et al., 2005, 2006; Zwanzig et al., 2006a) and nickel anomalies are present in till (DiLabio and Kaszycki, 1988).

This report stems from the Flin Flon project of the Targeted Geoscience Initiatives Program, aimed at identifying new base-metal exploration targets in northern Manitoba and Saskatchewan. In conjunction with concurrent work by Murphy and Zwanzig (GS-6, this volume; GS-5, this volume), the paper describes the regional geology of the Footprint–Osik–Notigi lakes area, last mapped by Frohlinger and Kendrick (1979) and Kendrick et al. (1979). It includes significant modifications to the geology of the Osik Lake area. In particular, the recognition of plutonic rocks, including a layered mafic-ultramafic complex, rather than arkose of the Sickle Group, increases the nickel exploration potential of the area.

Regional geological setting

Traditionally, the boundary between the Archean Superior Province and the Paleoproterozoic Trans-Hudson Orogen is a north-northeast–trending, steeply dipping zone located a few kilometres west of Thompson (Figure GS-7-1; Zwanzig et al., 2003; Macek et al., 2006). Based on seismic reflection images, the boundary is interpreted to dip eastward (White et al., 2002). The Paleoproterozoic Ospwagan Group, lying unconformably on Superior Province basement (Bleeker, 1990), hosts mafic-ultramafic sills (ca. 1885 Ma; Hulbert et al., 2005) and their contained nickel deposits (Macek et al., 2006).

Recent work has shown extensions of the Superior Province, including Meso- to Paleoarchean gneiss (cf. Böhm et al., 2003) and associated Paleoproterozoic cover rocks northwest of the traditional Superior Boundary Zone (Zwanzig and Böhm, 2004). Inliers of similar material in structural culminations within the Kisseynew Domain extend the Superior basement another 50 km to the west (Percival et al., 2006; Zwanzig et al., 2006a, b; Rayner and Percival, GS-8, this volume). Metamorphic grade is uniformly high in the northeastern Kisseynew Domain, reaching granulite facies in some culminations (Growdon et al., 2006). Throughout the region, abundant pegmatite and granite of anatectic origin cut the Burntwood migmatite.

To the northwest of the basement orthogneiss culminations are several elongate bodies of K-feldspar–porphyritic granodiorite, surrounded by migmatitic

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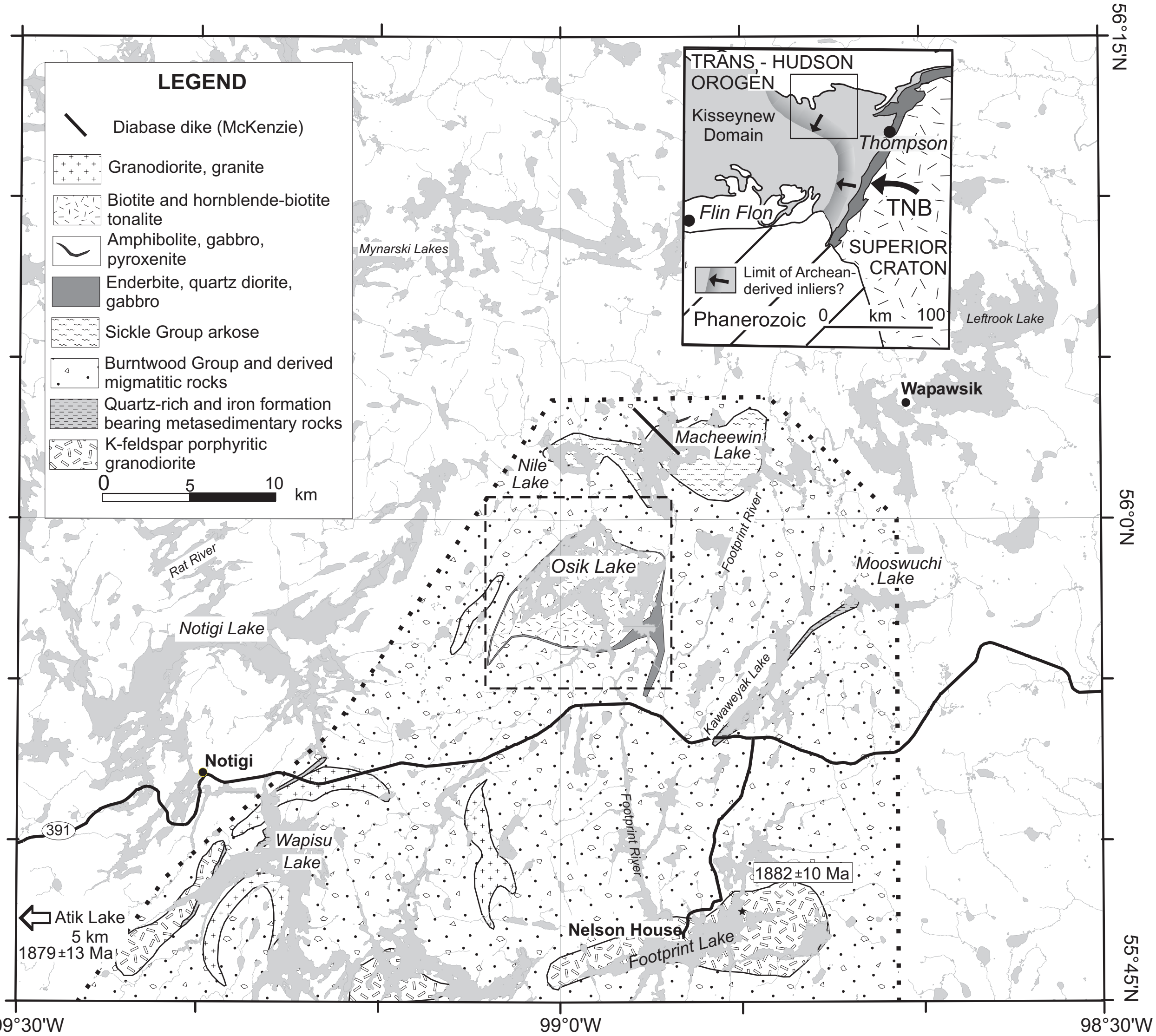

***Figure GS-7-1:** Generalized geological map of the Osik–Atik–Footprint lakes area showing the distribution of major rock units, the location of geochronological sites and place names referred to in the text (*modified after *Baldwin et al., 1979). Inset map shows the location of the study area with respect to regional tectonic features. The box outlined with the dashed line shows the location of Figure GS-7-2.*

metasedimentary rocks (Kendrick et al., 1979; Frohlinger and Kendrick, 1979; Hollings and Ansdell, 2002). Bodies at Footprint and Atik lakes yielded ε_{Nd} values of –9.3 and –10.3 (at t = 1885 Ma), respectively, suggesting either an Archean age or contamination by Archean crust (Percival et al., 2006).

The Kisseynew Domain is bounded to the north by the Lynn Lake–Leaf Rapids Domain (Zwanzig, 1990; Ansdell, 2005; Corrigan et al., 2007). This major tectonic boundary (White et al., 2000) is marked by the Granville Lake structural zone (Zwanzig, 2000; Corrigan et al., 2007; Murphy and Zwanzig, GS-5, this volume).

Tectonostratigraphic units

Several units in addition to the dominant metasedimentary migmatite of the Burntwood Group were identified in the Osik–Atik–Footprint lakes area (Figures GS-7-1, -2).

K-feldspar porphyritic granodiorite

Four bodies of porphyritic granodiorite were examined at Footprint Lake, eastern and western Wapisu Lake, and Atik Lake. All are homogeneous, hornblende-biotite granodiorite with K-feldspar phenocrysts up to 4 cm (Figure GS-7-3a). They are commonly strongly foliated to augen gneiss and variably intruded by granitic and pegmatitic dikes. Mafic dikes up to 4 m wide (Figure GS-7-3b) occur within all of the plutons, and diffuse enclaves of diorite to gabbro are present in the Atik Lake body. Contacts with surrounding rocks are

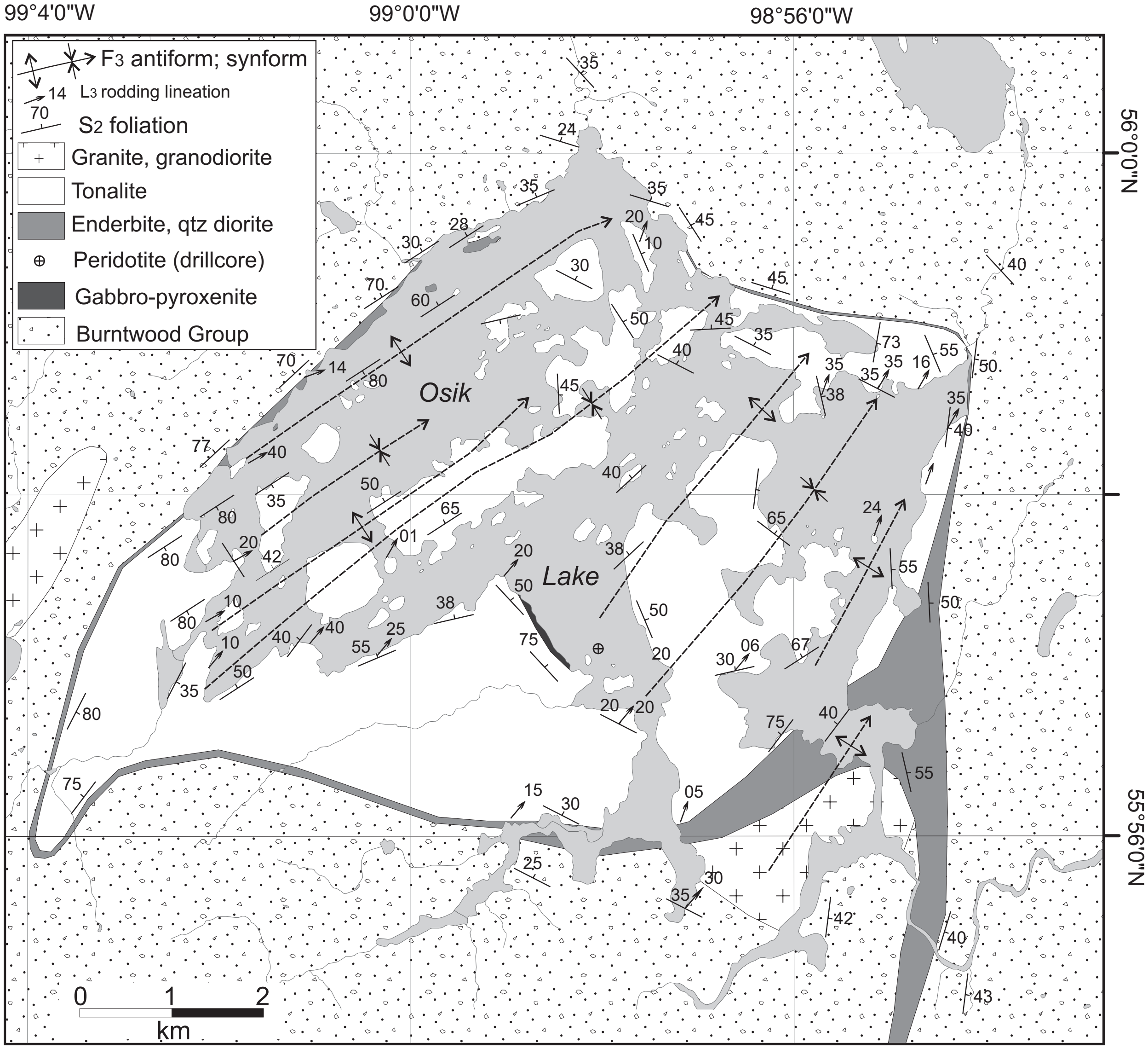

Figure GS-7-2: *Revised geological map of the Osik Lake area showing the distribution of lithological units and structural attributes.*

generally obscured by dikes of pegmatite.

Based on the Nd isotopic results reported in Percival et al. (2006), the granodiorite bodies could represent Archean basement inliers. Zircon grains from the two bodies were therefore analyzed with the sensitive high-resolution ion microprobe (SHRIMP) to determine their crystallization ages. A brief description of the analytical method is found in Rayner and Percival (GS-8, this volume) and details of the instrument settings are given in the footnotes to DRI2007003[1].

Zircon grains recovered from the Atik Lake granodiorite (25-71-328; lab #8957) are generally prismatic with slightly resorbed facets. In transmitted light, they range in appearance from very high quality, clear and colourless zircon to strongly zoned, fractured, medium brown zircon with numerous inclusions. In backscattered electron (BSE) images, the zircon grains exhibit oscillatory zonation and few apparent core-rim relationships.

Twenty-four analyses were conducted on 14 separate zircon grains, targeting the entire spectrum of morphologies and internal structures. Uranium concentrations are low, ranging from 30 to 100 ppm, and most have distinct Th/U ratios of greater than 1. The weighted mean $^{207}Pb/^{206}Pb$ age of all but one of the analyses yields an age of 1879 ±13 Ma (2σ), which is interpreted as the crystallization age (Figure GS-7-4). The analysis with the youngest

[1] MGS Data Repository Item DRI2007003, containing the data or other information sources used to compile this report is available online to download free of charge at http://www2.gov.mb.ca/itm-cat/freedownloads.htm, or on request from minesinfo@gov.mb.ca or Mineral Resources Library, Manitoba Science Technology, Energy and Mines, 360–1395 Ellice Avenue, Winnipeg, MB R3G 3P2, Canada

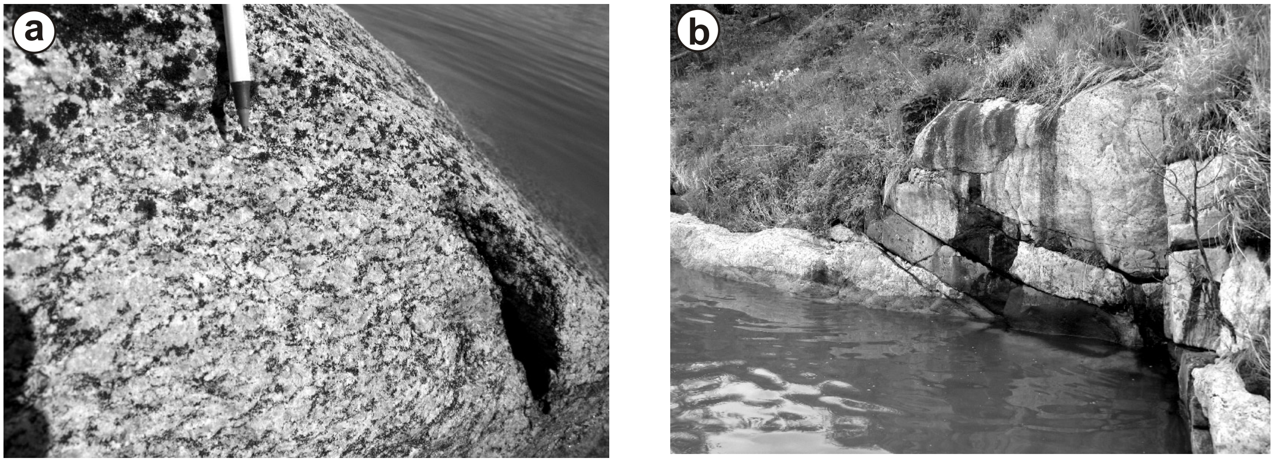

Figure GS-7-3: *Porphyritic granodiorite:* ***a)*** *foliated homogeneous granodiorite, Wapisu east pluton; pen for scale;* ***b)*** *foliated granodiorite cut by a 25 cm thick foliated mafic dike.*

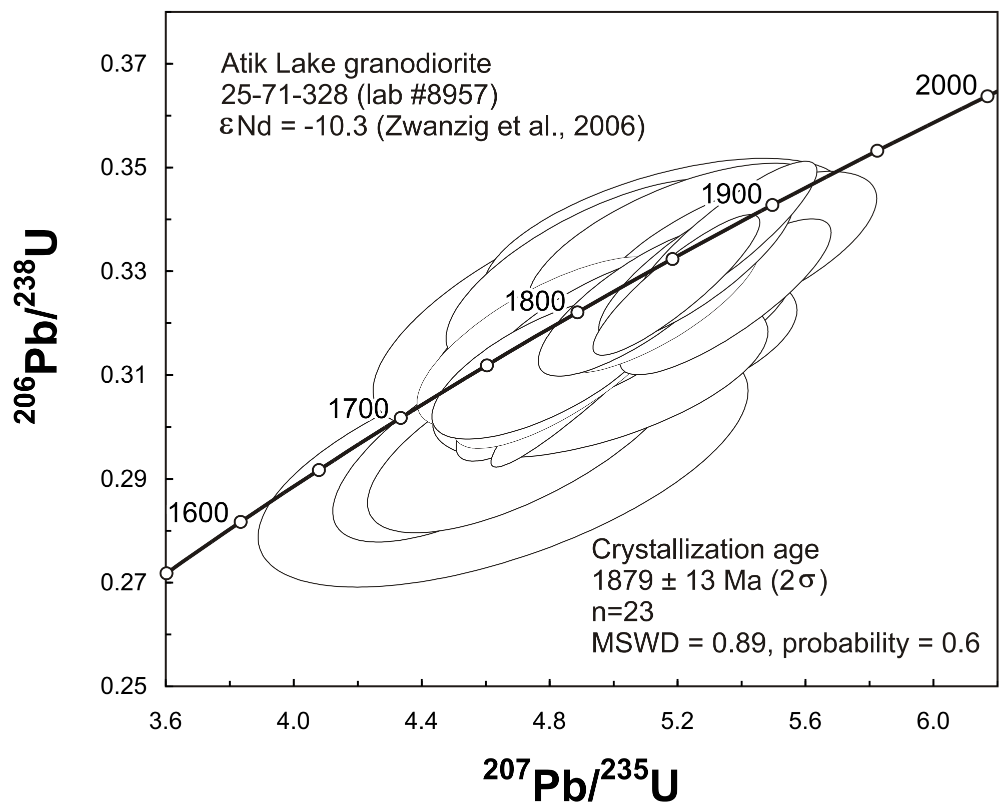

Figure GS-7-4: *Concordia diagram with U-Pb sensitive high-resolution ion microprobe (SHRIMP) data from the Atik Lake granodiorite. The rock has a whole-rock ε_{Nd} value (t = 1885 Ma) of –10.3, suggesting contamination by crust of Archean age.*

date (8957–97.1) was excluded on the basis of its distinct Th/U ratio of 0.08, but it is statistically indistinguishable from the rest of the analyses. Due to the low U concentrations, the errors for individual analyses are quite large. To determine if any of the observed scatter is distinct from the analytical uncertainty, four or five replicate analyses were conducted on the apparent youngest, oldest and intermediate-aged zircon. The within-grain scatter is comparable to the scatter observed in the entire population and therefore suggests that these zircon grains form a single statistical population.

The Footprint Lake granodiorite (25-71-412; lab #8955) yielded abundant, slightly resorbed, prismatic zircon that exhibited strong oscillatory zoning in BSE images. The zircon grains are variably fractured and altered and many contain large inclusions. A range of morphologies was targeted for SHRIMP analysis.

Twenty-four analyses were carried out on 15 separate zircon grains. As with the previous sample, U concentrations were low to moderate (20–250 ppm) and Th/U ratios typically greater than 1; values were up to 2.7. Replicate analyses were conducted on three grains. Again, the intra-zircon variability reflected the scatter in the entire dataset, allowing the dataset to be interpreted as a single statistical population. The weighted mean $^{207}Pb/^{206}Pb$ age of all analyses is 1882 ±10 Ma (2σ), which is interpreted as the crystallization age (Figure GS-7-5).

No inherited Archean cores were observed in either of the samples despite the strongly negative ε_{Nd} results (Percival et al., 2006). The new ages resemble that of the Clarke Lake granodiorite, a porphyritic granodiorite pluton intruding into Superior Province basement near Wabowden (1885 ±5 Ma; Percival et al., 2005). Furthermore, zircon grains from all three granodiorite bodies have distinctive Th/U values, typically greater than 1 and up to 2.7. In light of the isotopic contamination and age, the authors conclude that the Footprint and Atik plutons, and by inference, the Wapisu east and west bodies, represent part of a basement complex that includes 1880–1885 Ma plutons. Forthcoming geochronology will confirm the age of the Wapisu west body.

Sedimentary cover sequence

In a few locations, contacts between plutons of porphyritic granodiorite and surrounding rocks are relatively well preserved. In southwestern Wapisu Lake, a north-trending, vertically dipping panel of metasedimentary rocks of diverse composition may represent an unconformable sequence. The section is variably intruded by pegmatite sheets up to 5 m thick. Immediately east of the granodiorite is a 1 m thick section of massive to thick-bedded, gritty quartz arenite and fine-grained, thinly layered quartz-rich sandstone (Figure GS-7-6a, b). Sparse enclaves and rafts in pegmatite over the succeeding 15 m are biotite-rich schist with rare garnet. A well-preserved 20 m section to the east consists of biotite-rich schist and silicate- and sulphide-facies iron formation, interlayered on a 50–100 cm scale. Also present are 20–100 cm thick layers of amphibolite, sulphidic garnet-biotite schist and fine-grained, quartz-rich rocks whose protolith may be chert. Approximately half of this section is made up of sheets of granitic pegmatite. The eastern end of the section is dominantly pegmatite, containing screens and rafts of medium-grained biotite-garnet granite. To the east, pegmatite contains screens and rafts of migmatitic garnet-biotite paragneiss, resembling rocks of the Burntwood Group.

Iron formation is present elsewhere within metasedimentary rocks to the northeast, in the Osik–Kawaweyak–Mooswuchi lakes area. This is an atypical association for the Burntwood Group, which elsewhere consists of metagreywacke and derived migmatite (Baldwin et al.,

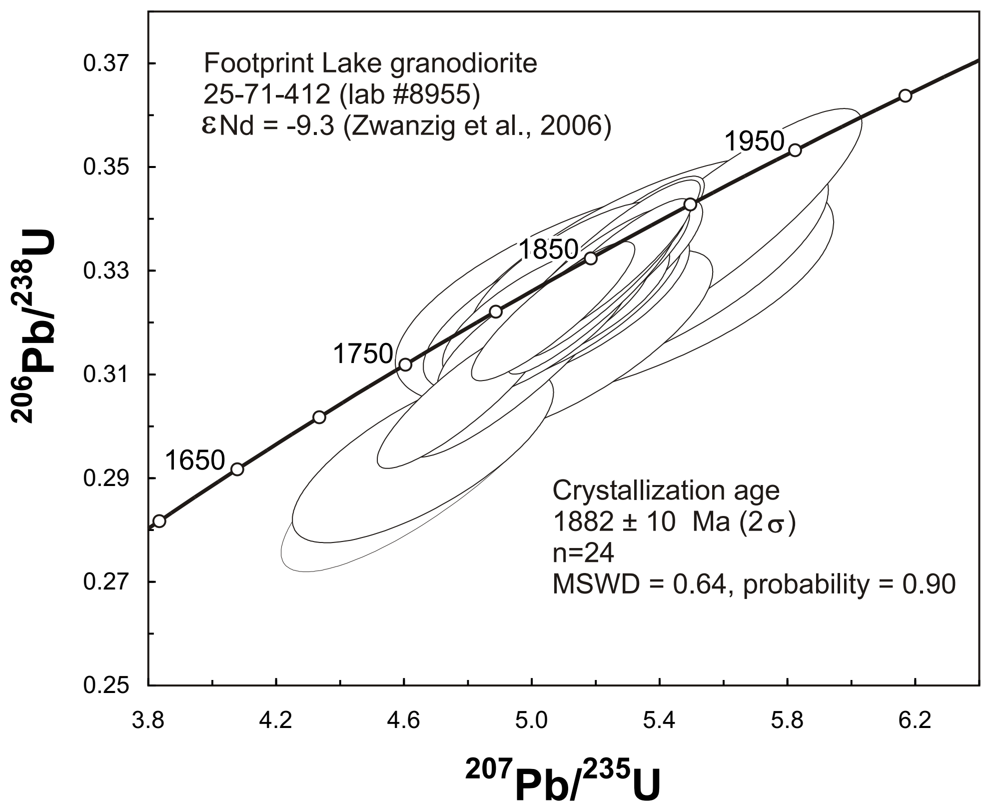

Figure GS-7-5: *Concordia diagram with U-Pb sensitive high-resolution ion microprobe (SHRIMP) data from the Footprint Lake pluton. The rock has a whole-rock ε_{Nd} value (t = 1885 Ma) of –9.3, suggesting contamination by crust of Archean age.*

Figure GS-7-6: *Field photographs of metasedimentary units:* ***a)*** *quartz-rich sandstone above possible unconformable contact with the Wapisu west granodiorite pluton (to right of photograph); pen for scale;* ***b)*** *folds in thinly layered quartz-biotite sandstone, western Wapisu Lake; hammer for scale.*

1979; Murphy and Zwanzig, GS-6, this volume). The extent and distribution of the iron-rich units will be clarified by forthcoming high-resolution aeromagnetic maps.

Work is underway to date detrital zircon grains from quartz-rich rocks of the sedimentary section. The results will determine whether a pre-Burntwood sedimentary succession is present, as well as constrain the age of the source terrane. Based on field relationships, the assemblage could be of a similar age to the Duck Lake or Levesque Bay assemblages in Saskatchewan (Maxeiner et al., 2005), or possible correlatives in the Granville structural zone (Murphy and Zwanzig, GS-5, this volume) in Manitoba, although results to date would suggest Superior Province affinity (Percival et al., 2006).

Burntwood Group

The Burntwood Group and derived anatectic granitic rocks makes up most of the Kisseynew Domain (Zwanzig, 1990). In the present area, Burntwood rocks are garnet–biotite±cordierite±sillimanite migmatite rocks with up to 30% white granitic leucosome. Coarse cordierite is locally abundant in leucosome. With the exception of rare pelite-psammite couplets, primary features are not preserved. Metamorphic grade ranges from upper-amphibolite facies, defined by the assemblage garnet–cordierite–inferred melt, to granulite facies, indicated by the presence of orthopyroxene (cf. Growdon et al., 2006).

In northern Macheewin Lake (Figure GS-7-1), a mafic-ultramafic sill about 20 m thick was traced over a 1.2 km strike length within the Burntwood migmatite. The mafic rocks range from medium-grained, homogeneous amphibolite to layered, migmatitic, rusty amphibolite with ortho- and clinopyroxene. Massive to layered ultramafic rocks were observed at one location (UTM Zone 14, 506097E, 6212130N, NAD83). The coarse-grained pyroxenite contains up to 15% olivine in some metre-scale layers.

At Nile Lake (Figure GS-7-1), a 30 m thick sulphide-rich zone was traced over 1.5 km of strike length. It consists mainly of rusty garnet-biotite schist with up to 20% disseminated sulphide minerals, mainly pyrrhotite and pyrite. Layers of fine-grained, layered amphibolite up to several metres thick contain some carbonate and could be calcsilicate. Gabbroic layers up to 1 m thick contain some sulphide-rich zones. A 50 cm thick layer of rusty, muscovite-rich schist of possible tuffaceous origin occurs within a section of layered amphibolite and sulphidic chert.

Sickle Group

Units of the Sickle Group occur in the Nile and Macheewin lakes area (Figure GS-7-1). At Nile Lake, thinly bedded hornblende arkose and biotite±sillimanite arkose occur in a structural basin surrounded by the Burntwood migmatite (Figure GS-7-1). At Macheewin Lake, a map-scale unit of Sickle arkose has irregular geometry. Amphibolite is present at the Burntwood–Sickle interface at one location, whereas the contact appears conformable at another, where a 10 cm bed of thinly bedded quartz-rich sandstone characterizes the interface. In the same vicinity, layers of migmatitic garnet-biotite paragneiss resembling the Burntwood paragneiss occur within a sequence dominantly made up of thinly bedded biotite arkose.

Osik Lake plutonic units

Several plutonic units in the Osik Lake area correspond directly with rocks previously thought to be Sickle arkose (Frohlinger and Kendrick, 1979). Enderbite-suite rocks are dominantly medium-grained, homogeneous, hornblende–biotite±orthopyroxene±clinopyroxene quartz diorite. The suite contains metre-scale layers of diorite and gabbro with similar assemblages. The intensity of foliation varies inversely with the thickness of the body.

At the map scale, the body varies in thickness from 20 to 1000 m and forms a rim separating the Burntwood paragneiss on the outside from the Osik Lake tonalite pluton on the inside (Figures GS-7-1, -2). Sulphide-rich dioritic layers up to 50 cm thick are present in western Osik Lake (Figure GS-7-7).

Tonalitic rocks underlie most of Osik Lake. The main phase is a medium-grained, homogeneous, moderately foliated biotite tonalite containing 5–10% biotite and 20–30% quartz (Figure GS-7-8). It contains sparse enclaves of diorite and gabbro (Figure GS-7-9), including a distinctive 'snowflake-textured' metagabbro with poikilitic plagioclase phenocrysts up to 1 cm in diameter (Figure GS-7-10), as well as a layered mafic-ultramafic complex (*see* below). An older tonalitic phase with sparse orthopyroxene was noted locally. The penetrative foliation (S_2) in the main tonalitic phase has variable strike and dip that appear to be related by a set of northeast-trending F_3 folds (Figure GS-7-2).

At one location (UTM Zone 14, 501693E, 6200559N, NAD83), a layered gabbro-pyroxenite body at least 15 m thick and 100 m long is exposed on the lakeshore (Figure GS-7-11). Rhythmic centimetre-scale layers in gabbro give way to anorthositic gabbro, pegmatitic gabbro and pyroxenite. Abundant garnet is present in some layers. The body occurs in the vicinity of ultramafic cobbles noted by DiLabio and Kaszycki (1988), an aeromagnetic anomaly beneath the lake and about 100 m west of a drillhole that intersected peridotite containing 0.22% nickel (Figure GS-7-2; Canmine Resources Corporation, 1999). Work is underway to constrain the age of the body by dating zircon grains from a pegmatitic gabbro.

At least one younger phase of tonalite is present as sheets and dikes cutting the main phase tonalite. It is a homogeneous, medium-grained, hornblende-biotite

***Figure GS-7-7:** Sulphide-bearing layers in gabbro-diorite of the enderbite suite, western Osik Lake; hammer for scale.*

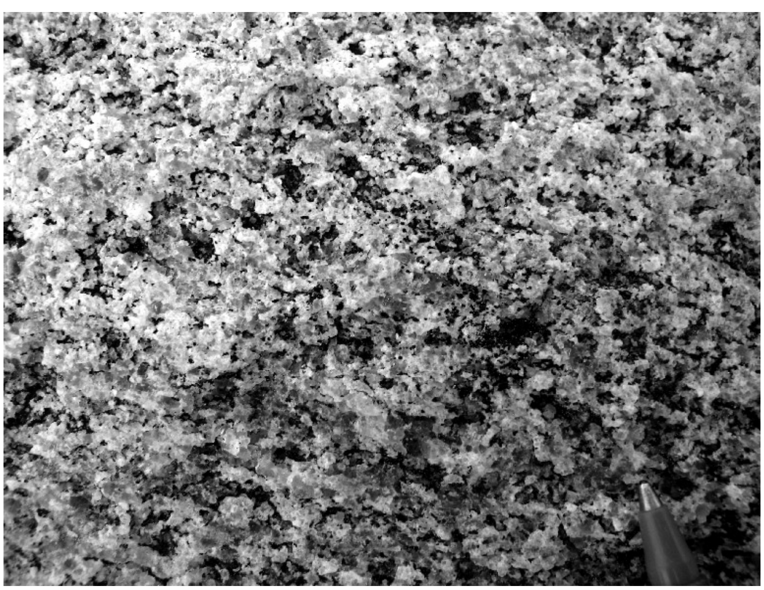

***Figure GS-7-8:** Homogeneous, medium-grained biotite tonalite, southeastern Osik Lake; pen tip for scale.*

***Figure GS-7-9:** Large gabbroic enclaves in tonalite, southwestern Osik Lake; width of photograph is 8 m.*

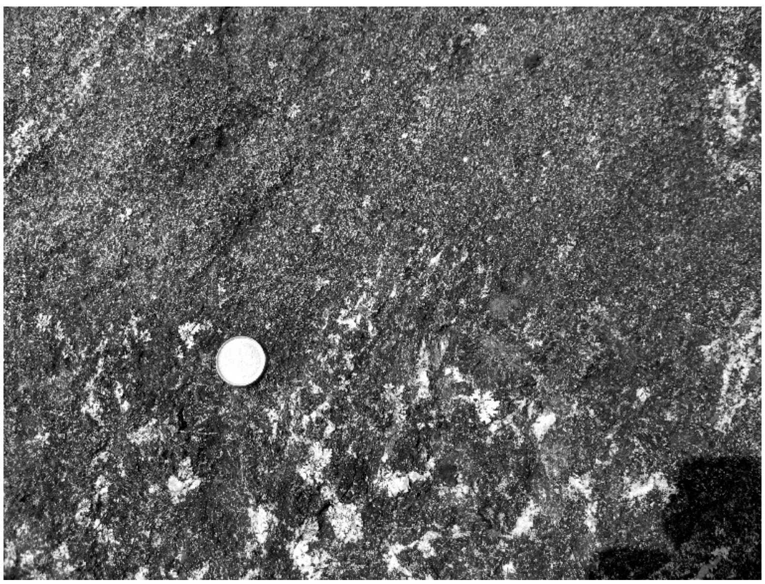

***Figure GS-7-10:** Distinctive 'snowflake-textured' metagabbro, characteristic of metaplutonic enclaves within the Osik Lake tonalite; coin is 1.5 cm in diameter.*

***Figure GS-7-11:** Layered gabbro-pyroxenite showing the range of variation in the proportion of plagioclase and amphibole; hammer for scale.*

tonalite with a weak, northeast-striking foliation. These small bodies may be syntectonic with respect to the northeast-trending folds. Pods of younger granite to granodiorite have no foliation.

Structural geology

Polyphase regional deformation has been recognized throughout the Kisseynew Domain (Zwanzig, 1990), and Percival et al. (2006) reported evidence for at least four structural events in the northeastern Kisseynew Domain. Evidence of D_1 structures is sparse regionally and was not observed in the present area.

The most prominent structural element in the present area is a penetrative S_2 gneissosity developed in all rock types except late pegmatite and granite. In the Burntwood paragneiss, S_2 is a migmatitic layering and foliation defined by biotite alignment. Granodiorite carries a strong S_2 alignment of mafic minerals and K-feldspar augen, accentuated by leucosome veins. Tonalite at Osik Lake has a modest S_2 foliation produced by biotite alignment, whereas the enclosing enderbite rim is generally more strongly foliated. The fabric is typically defined by the alignment of mafic minerals. In several locations, the contact between enderbite and the structurally overlying Burntwood paragneiss is a high-strain zone characterized by flaggy, straight-layered gneiss (Figure GS-7-12) with deformed garnet porphyroblasts (Figure GS-7-13). These relationships suggest late D_2 timing for the high-strain event.

Geometrically, the Osik Lake structure has a northeast-dipping, northeast-plunging hook shape. Contacts dip moderately to the northeast at the northeastern (35–55°) and southwestern (25–55°) margins, and moderately to steeply outwards on the southeastern and northwestern flanks. The tonalitic core of the structure is separated from the Burntwood paragneiss by an envelope

***Figure GS-7-12:** Straight gneiss developed from the Burntwood paragneiss, northern Osik Lake. Leucosome and pegmatitic veins are transposed parallel to the prominent foliation in this zone of strong deformation; hammer for scale.*

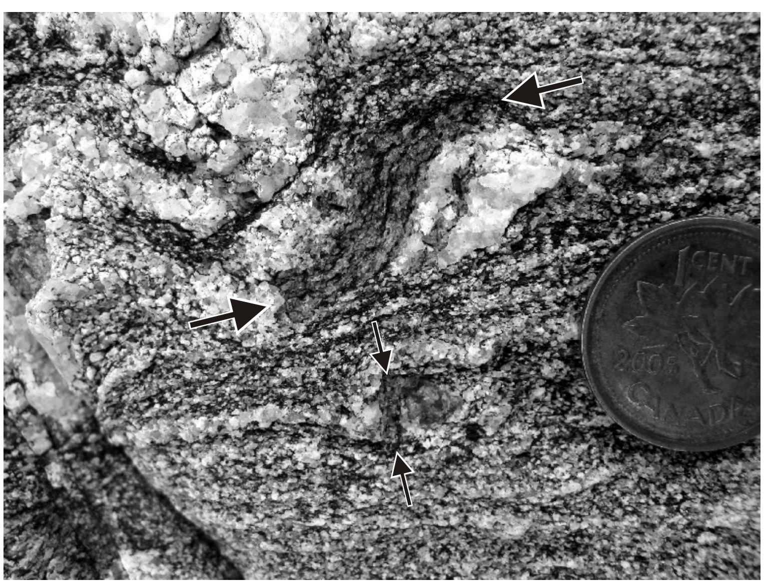

***Figure GS-7-13:** Close-up view of deformed garnet, southern Nile Lake. Curved shapes (identified by large arrows) and pressure shadows (example shown by small arrows) indicate strong deformation subsequent to the metamorphic peak; penny for scale.*

of enderbitic rocks, and virtually all enclaves in tonalite are derived from igneous rocks. In addition, contacts between the Burntwood paragneiss and enderbite appear highly strained (late S_2), making it unlikely that the tonalite intruded the Burntwood migmatite directly. The origin, age and isotopic characteristics of the tonalite are under investigation to determine the tectonostratigraphic affinity of the body.

A set of upright, northeast-plunging F_3 folds forms map-scale structures (Figure GS-7-2). Gentle plunges suggest that S_2 structures consistently had low dips prior to reorientation in F_3 folds. The wavelength and amplitude of folds vary regionally from broad open structures in the south to tighter 'wrinkles' in the Osik Lake area. To the north, in the Macheewin–Nile lakes area, the distribution of the Sickle and Burntwood units may be the result of fold interference patterns (Figure GS-7-1).

At Notigi Lake, 20 km to the west, the Granville Lake structural zone is marked by an amphibolite unit at the complexly folded interface between the Burntwood and Sickle units (Murphy and Zwanzig, this volume, GS-5). This zone does not appear to be present in the Osik–Macheewin lakes area, where Burntwood–Sickle contacts were observed. The significance of the high-strain zone at the margin of the Osik Lake structure is unlikely to be related to the Granville Lake structural zone in light of its dissimilar tectonostratigraphic setting and late-metamorphic timing.

Economic considerations

Several parts of the area warrant further exploration. At Osik Lake, nickel geochemical anomalies in till (DiLabio and Kaszycki, 1988) are explained partly by the presence of peridotite beneath the lake, but coincident gold values remain enigmatic. Sulphide-bearing horizons observed within Burntwood rocks north of Osik Lake could be the gold source and may be imaged on forthcoming aeromagnetic maps. Also possible is hydrothermal sulphide mineralization associated with intrusions in the northern Kisseynew Domain reported by Mumin and Trott (2003). To the north, the layered mafic-ultramafic body exposed at Macheewin Lake could also have nickel potential.

The occurrence of pre-Burntwood intrusions as far west as Atik Lake suggests the possibility of a basement complex beneath the region. Although these rocks could potentially host Thompson-type deposits (Percival et al, 2006; Zwanzig et al., 2006a), the potential would be limited by depth except near exposed culminations. Conversely, the region could be prospective for diamonds, provided that Archean lithosphere is still present and that kimberlitic conduits exist.

Acknowledgments

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