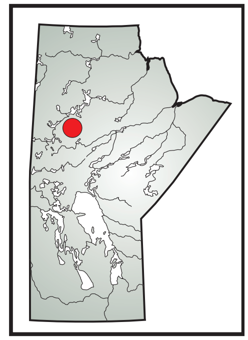
GS-7 Geology of the Notigi–Wapisu lakes area, Kisseynew Domain, Manitoba (parts of NTS 63O14, 64B3)

by L.A. Murphy, H.V. Zwanzig and N. Rayner[1]



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Summary

In 2009, the Manitoba Geological Survey (MGS) completed a field program undertaken in the Notigi–Wapisu lakes area, located along the north flank of the Kisseynew Domain. Significant structural and stratigraphic details were added to the local Paleoproterozoic metasedimentary rocks and to a thin ortho-amphibolite unit at Notigi Lake. Fieldwork also extended south to include parts of Wapisu Lake, where in 2007, Geological Survey of Canada (GSC) geologists documented metasedimentary rocks of the Wuskwatim Lake sequence similar to the nickel-hosting Ospwagan Group in the Thompson Nickel Belt. This work applied a new method of using the 2008 high-resolution aeromagnetic survey funded by the Geological Survey of Canada to traverse more effectively the burned-over areas surrounding Notigi Lake. This report concentrates on the stratigraphy of the Burntwood and Sickle groups as well as thin structural marker units of mafic to felsic meta-igneous and metasedimentary rocks (including the volcano-sedimentary assemblage, herein called the Granville Lake assemblage and the Black Trout diorite). These units were examined most closely within a structural inlier (herein called the Notigi Lake structure) that mainly exposes various units of the Sickle Group within the widespread metagreywacke and migmatite of the Burntwood Group. The Wuskwatim Lake sequence on Wapisu Lake was re-examined along the margin of a quartz monzonite intrusion whose geochemistry and Nd isotopic composition are evidence for Archean rocks at depth. New U-Pb ages are presented for the Wuskwatim Lake sequence, the quartz monzonite and a younger monzogranite at Notigi Lake. Short discussions in this and the accompanying report (Zwanzig and Murphy, GS-8, this volume) describe the structural geometry and history at Notigi Lake, including its economic implications.

Introduction

Notigi and Wapisu lakes, located approximately 100 km west of Thompson, Manitoba, are easily accessible by Provincial Highway 391 (Figure GS-7-1; Murphy and Zwanzig, 2009). During the summers of 2007–2009, an area totalling about 400 km^2 was remapped at 1:20 000 scale in collaboration with the Geological Survey of Canada (GSC) as part of the Flin Flon Targeted Geoscience Initiative Program (TGI-3; Percival et al., 2006; Murphy and Zwanzig, 2007; Percival et al., 2007; Murphy, 2008; Whalen et al., 2008; Zwanzig, 2008). The purpose of the work at Notigi Lake has been to define and detail the tectonostratigraphy, structural geology and tectonic history of an accessible and relatively well-exposed area in the eastern part of the Kisseynew Domain north flank. Mapping in 2009 concentrated on the eastern part of the Notigi Lake structure, an inlier of mainly arkosic gneiss (Sickle Group) that structurally underlies a larger area of greywacke-derived migmatite (Burntwood Group). The principal Notigi Lake structure is interpreted as three contiguous en échelon domes (Zwanzig and Murphy, GS-8, this volume). It is of similar competency and structural style as inliers of Archean gneiss, their cover and associated monzonitic intrusions southeast of Notigi Lake (Percival et al., 2005, 2007; Whalen et al., 2008). Therefore, work done at Notigi Lake in the Kisseynew north flank, can serve as a guide for the three-dimensional extent of the less well exposed but economically more promising inliers that characterize the Northeast Kisseynew subdomain. Understanding and delimiting the local stratigraphic units, the main focus of this report, has been fundamental in establishing the regional structure. A simplified map of the Kisseynew Domain shows the locations of its north flank and the northeastern subdomain, with the Notigi–Wapisu lakes area outlined in blue (Figure GS-7-1).

The Notigi Lake area was mapped previously by the MGS during the Southern Indian Lake Project (Elphick, 1972; Schledewitz, 1972), followed by mapping in the Notigi–Wapisu lakes area carried out by Frohlinger (1979). The results are published as a set of 1:50 000 scale geological maps completed under the Burntwood Project (Baldwin et al., 1979). The regional-scale mapping did not describe the different units in the Sickle Group. Consequently, the local structure, stratigraphy and mineral potential of this part of the north flank of the Kisseynew Domain remained enigmatic.

Describing a continuous tract from the margin of the Leaf Rapids (arc) Domain in the north across the Kisseynew north flank and into the Northeast Kisseynew subdomain is the second goal of this report. Reconnaissance mapping in 2005–2007 by the GSC and MGS in the Northeast Kisseynew subdomain southeast of Notigi

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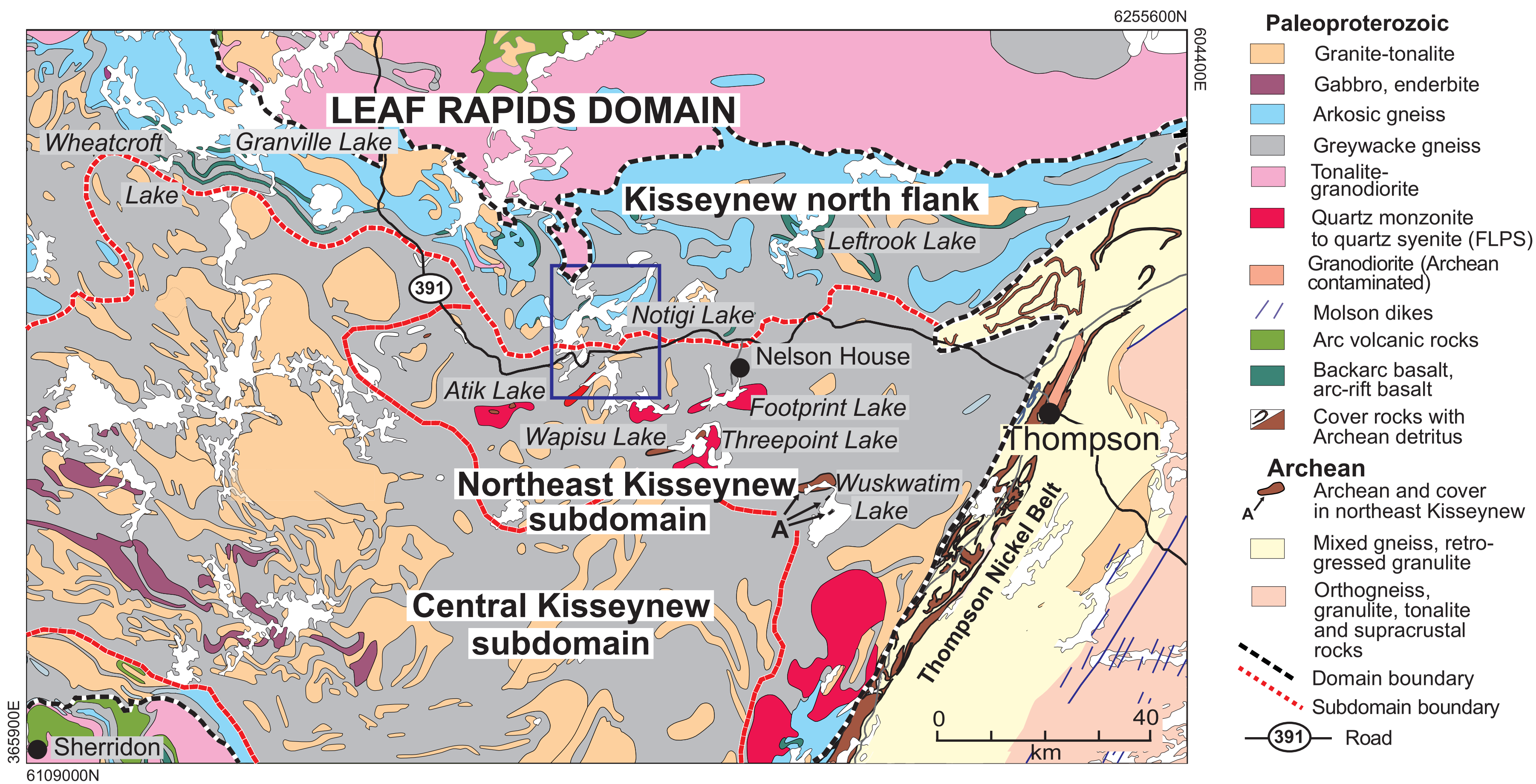

***Figure GS-7-1:** Geology of the Kisseynew Domain showing the Notigi Lake structure on the Kisseynew north flank, the Footprint Lake plutonic suite (FLPS) and small Archean inliers with cover rocks containing Archean detrital zircons in the Northeast Kisseynew subdomain. The outlined area is shown in Figure GS-7-2 and detailed in Murphy and Zwanzig (2009).*

Lake has found previously unknown Archean orthogneiss and associated paragneiss (Wuskwatim Lake sequence) with Archean provenance, ages and origins also found for the basement gneiss and Ospwagan Group cover rocks in the Thompson Nickel Belt (TNB; Percival et al., 2005, 2006; Zwanzig et al., 2006; Rayner and Percival, 2007; Whalen, et al., 2008;). The Wapisu Lake area is known to have similar cover rocks for which detrital zircon ages are presented. These rocks are associated with the Footprint Lake plutonic suite (FLPS), an older suite of granitic inliers that form south- and east-trending chains within the Kisseynew Domain (Percival et al., 2005, 2007; Whalen et al., 2008). Investigations at Wapisu Lake (Figure GS-7-2) focused on the northeast shoreline exposures and areas that show a positive anomaly related to the quartz monzonite and the Wuskwatim Lake sequence on the aeromagnetic map (Kiss and Coyle, 2008). Based on a new age given in this report, the quartz monzonite is confirmed to be part of the Footprint Lake plutonic suite (FLPS; Whalen et al., 2008). New examination of the Wuskwatim-type cover rocks and the new detrital zircon ages confirm the location of the northern boundary of the recently proposed Northeast Kisseynew subdomain (Zwanzig, 2008).

Methodology

Manitoba Hydro completed the Churchill River Diversion in 1977 and has since redirected water from the Churchill River south along the Rat River through Notigi Lake into the Burntwood River. Notigi Lake was flooded to its present level and in the process, new shoreline exposures developed. The present project captured structural data and geological contacts from the original Burntwood Project mapping, which was undertaken on preflooding shoreline outcrops and combines this information with remapping the Sickle and Burntwood groups on exposures at the present lake level.

Due to the complexity of deformation at Notigi Lake coupled with difficulties of traversing in the surrounding burn areas, a modified aeromagnetic overlay was used to traverse more effectively. This method used residual total field data from the aeromagnetic survey completed in May 2008 (Kiss and Coyle, 2008). A series of points were created that mark the maximum slope from the vertical gradient in the residual total field data. These points were then equalized in a slope analysis program, added to the total-field aeromagnetic map shaded in greyscale with black (low) to white (high) and printed on Mylar®. The modified aeromagnetic map was placed over the geological map and used to trace units through lakes and overburden as well as to pick sections for traversing. Targeted ground-truthing more efficiently delineated facies changes in the stratigraphic units of the Sickle Group, leading to a structural interpretation that enhances our understanding of the tectonic history of an inner zone of the Trans-Hudson Orogen.

Uranium-lead geochronology was carried out using a sensitive high-resolution ion microprobe (SHRIMP) at the Geological Survey of Canada in Ottawa. The results are given in Data Repository Item DRI2009005[2]. The SHRIMP analytical procedures followed those described by Stern (1997), with standards and U-Pb calibration methods following Stern and Amelin (2003). The internal features of the zircons (such as zoning, structures, alteration, etc.) were characterized in backscattered electron mode (BSE) using a Zeiss Evo® 50 scanning electron microscope. Analytical conditions and calibration parameters are listed in the footnotes to Table 1 in DRI2009005. Analyses of secondary standard z1242 were interspersed through the analytical sessions and the measured $^{207}Pb/^{206}Pb$ age was compared to the accepted age determined by thermal ionization mass spectrometry (2679.7 Ma; B. Davis, pers. comm., 2009). Isoplot v. 3.00 (Ludwig, 2003) was used to generate concordia plots and calculate weighted means. All errors reported in the text are given at the 2σ uncertainty level.

Regional Geology

The Notigi–Wapisu lakes area straddles the north flank of the Kisseynew Domain and part of the newly proposed Northeast Kisseynew subdomain (Zwanzig, 2008). The tip of the granite culmination that extends into the northwest corner of the map area is part of the Leaf Rapids (arc) Domain (Figure GS-7-1). The north flank of the Kisseynew Domain is dominated by Paleoproterozoic metamorphic rocks of the Burntwood and Sickle groups, including a thin, sporadically exposed intervening volcano-sedimentary unit, herein referred to as the Granville Lake assemblage. Later intrusive felsic to mafic rock includes the regionally occurring Black Trout diorite (Zwanzig, 2008). The Granville Lake assemblage is considered to be part of a thrust package above the younger (ca. 1.85 Ga) Burntwood Group and is unconformably overlain by the 1.85–1.83 Ga Sickle Group (David et al., 1996; Machado et al., 1999; Zwanzig and Murphy, GS-8, this volume).

The Burntwood Group includes marine sedimentary rocks comprising greywacke, siltstone and mudstone deposited by turbidity currents, whereas the Sickle Group is derived from lithic arenite and arkose deposited in a shallow-water environment (Milligan, 1960; Bailes, 1980; Zwanzig, 1990). Metamorphism up to granulite facies at midcrustal level throughout the Kisseynew Domain from 1818 to 1785 Ma (Machado et al., 1999; Parent et al.,

[2] MGS Data Repository Item DRI2009005, containing 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/web/freedownloads.html or on request from minesinfo@gov.mb.ca or Mineral Resources Library, Manitoba Innovation, Energy and Mines, 360–1395 Ellice Avenue, Winnipeg, Manitoba R3G 3P2, Canada.

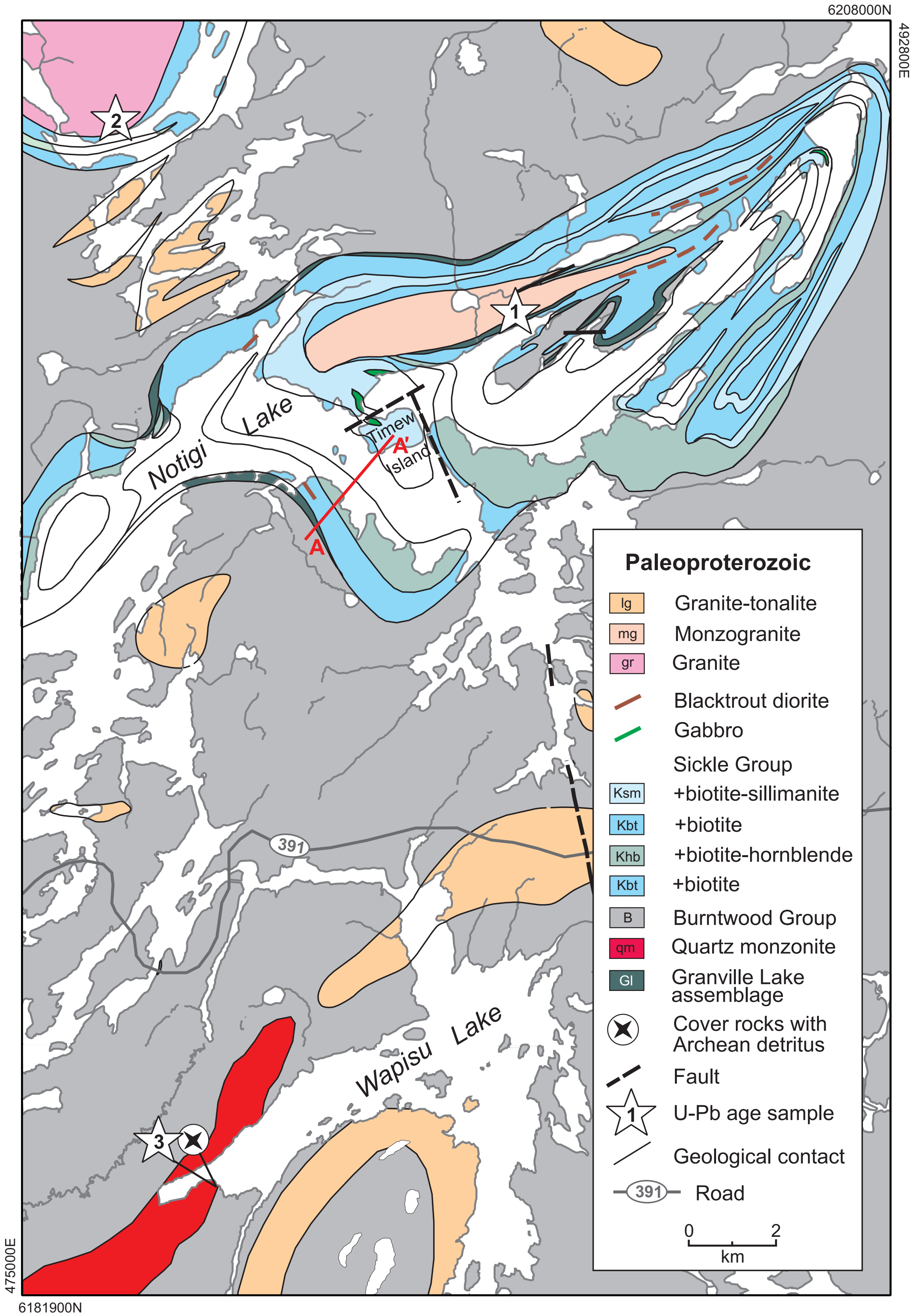

Figure GS-7-2: *Geology of the Notigi–Wapisu lakes area with trace of section A–A' from the Burntwood Group into the core of a major syncline in the Sickle Group used as typical tectonostratigraphic section in Figure GS-7-3. Interpretation of geological unit continuity in lakes and covered or inaccessible areas is based on aeromagnetic data (see text). Numbered stars correlate with 1, Notigi granite; 2, Rat granite; and 3, Wapisu quartz monzonite.*

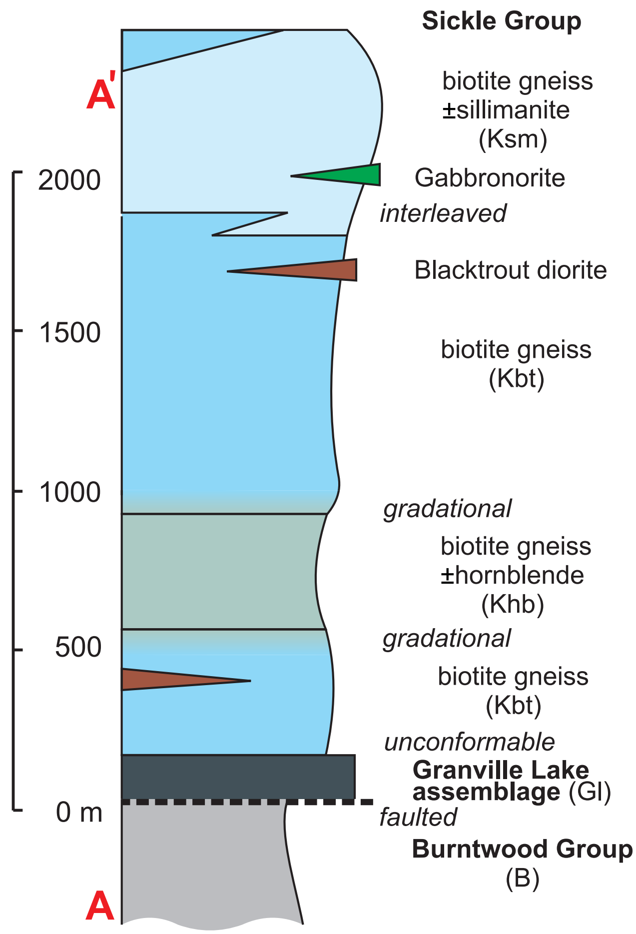

Figure GS-7-3: *Typical local tectonostratigraphic section in the Notigi structure using the regional relationships of the units to infer the fault at the contact between the Burntwood Group, Granville Lake assemblage and Sickle Group, as well as the unconformity between the Granville Lake assemblage and the Sickle Group. Units are shown at a scale close to true present thickness.*

1999; Growdon et al., 2006) produced distinctive layered migmatite of the Burntwood Group, and hornblende-, biotite- and sillimanite-bearing gneiss of the Sickle Group. The Granville Lake assemblage is interpreted as having formed during a ca. 1.9 Ga episode of arc rifting to possible successor arc and backarc magmatism (Zwanzig et al., 1999; Zwanzig, 2008). The proposed southern boundary of the north flank of the Kisseynew Domain has been determined in part by the presence of Sickle Group paragneiss and the Granville Lake assemblage. Historically, the Kisseynew north flank has no known nickel potential.

The Wapisu Lake area is directly south of Notigi Lake and lies within the recently proposed Northeast Kisseynew subdomain (Zwanzig, 2008). Mapping focused on northeast to central Wapisu Lake (*see* star on Figure GS-7-2; Percival et al., 2005, 2006; Growdon et al., 2006; Zwanzig et al., 2006) where heterogeneous gneisses are flanked by an early pluton and are succeeded by Burntwood Group migmatite. At Wuskwatim Lake, ortho- and paragneiss interpreted to represent equivalents of Archean basement and the overlying Ospwagan Group in the TNB occur either unconformable or in fault contact with rocks of the younger Burntwood Group (Percival et al., 2005; Zwanzig et al., 2006). The paragneiss of this older 'Wuskwatim Lake sequence' is lithologically similar to the heterogeneous supracrustal rocks exposed along Wapisu Lake.

Rock units at Notigi Lake

Rock units found in the Notigi–Wapisu lakes area are outlined in the accompanying geological map (Murphy and Zwanzig, 2009), a simplified version thereof in Figure GS-7-2, and the composite stratigraphy of the Notigi Lake geology is portrayed schematically in Figure GS-7-3, based on the section A to A′ marked in Figure GS-7-2. The column was constructed where units are in stratigraphic order after inferred early thrust faulting without major fold repetitions and where thicknesses are measured in nearly true section after deformation (Zwanzig and Murphy, GS-8, this volume). Relationships between units shown in Figure GS-7-3 are described in Zwanzig (2008). The column also integrates composite geology from throughout the Notigi map area to show the general tectonostratigraphic relationships of the units. Previous reports by the authors have described the Paleoproterozoic supracrustal rocks at Notigi Lake in detail (Murphy and Zwanzig, 2007, 2008; Murphy, 2008; Zwanzig, 2008). Rock types are summarized in this report and information on contact relationships and probable lateral sedimentary facies changes is added. Detailed information on the structural interpretation at Notigi Lake is given in Zwanzig and Murphy (GS-8, this volume).

The main units at Notigi Lake are uniform metagabbro and layered amphibolite with local calcsilicate and felsic rock, referred to as the Granville Lake assemblage; the Burntwood Group migmatite derived from greywacke-mudstone with minor iron formation; and quartzofeldspathic paragneiss of the Sickle Group. The structural order is considered the same as in the regional setting and is therefore inferred to be 1) Burntwood Group, 2) fault, 3) amphibolite, 4) unconformity and 5) Sickle Group (Zwanzig, 2008).

Units in the Sickle Group were mapped using distinct compositional changes defined by their dominant metamorphic mineralogy. The Sickle Group is subdivided into four lithostratigraphic subunits that commonly occur in the following order: 1) basal biotite gneiss, 2) hornblende-biotite gneiss, 3) biotite gneiss and 4) sillimanite-biotite gneiss.

Igneous rock types at Notigi Lake include gabbroic rocks interpreted to intrude the Sickle Group and a regionally exposed monzodiorite (Black Trout diorite) also in intrusive contact with the Sickle Group biotite gneiss (Figure GS-7-2). Felsic intrusions include monzogranite, biotite granite and granite pegmatite. The monzogranite (Notigi granite) forms a major pluton near the northeastern core of the Notigi Lake structure. A biotite-granite pluton (Rat granite) is located 5 km north of Notigi Lake along the Rat River within the Leaf Rapids Domain. All units in the Notigi Lake area have been metamorphosed to upper amphibolite or transitional granulite facies.

Granville Lake assemblage (Gl)

The Granville Lake assemblage is exposed discontinuously along the outer contact of the Notigi structure between the Burntwood and Sickle groups, as well as tightly folded with Burntwood migmatite within the eastern core of the Notigi Lake structure (Figure GS-7-2).

The Granville Lake assemblage at Notigi Lake contains mafic and felsic units interpreted to be composed of volcano-sedimentary components (Figure GS-7-4a). Mafic rocks occur mostly as straight gneiss with alternating layers of hornblende-pyroxene-plagioclase, hornblende-diopside-pyroxene-plagioclase and plagioclase±diopside. These were probably derived from mafic flows. In places, the assemblage appears to grade into or is in fault contact with a recrystallized gabbronorite to melagabbro to leucogabbro. These more uniform mafic rocks may be interpreted as sills related to the flows. The rock units have been described in more detail by Murphy and Zwanzig (2007).

Siliciclastic components of the Granville Lake assemblage include garnet-sillimanite–bearing gneiss, quartzofeldspathic gneiss of unknown provenance, quartz-plagioclase±hornblende siliceous gneiss (medium grey to brown), calcsilicate with a moderate to high quartz content (grey, green to white) and possibly chert (white). Their volcaniclastic origin is suggested by their close relationship to the mafic rocks and by correlation with better-preserved units at Granville Lake (Zwanzig, 2008).

Burntwood Group (B)

The Burntwood Group at Notigi Lake, as elsewhere in the Kisseynew Domain, is composed of originally psammitic and pelitic (greywacke-mudstone) turbidite layers (Bailes, 1980; Zwanzig, 1990). These have undergone progressive migmatization to mostly metatexite (10–35% leucosome; Figure GS-7-4b) and local diatexite (up to 90% leucosome). Several rare units are exposed within the Burntwood Group: silicate facies iron formation located at the south end of Notigi Lake, biotite schist interpreted as recrystallized shear zones occurring almost exclusively along the contact between the Burntwood Group and the Granville Lake assemblage, and thin layers of garnet-bearing siliceous gneiss located in the southern bays of Notigi Lake and along the northeast shoreline.

Graphite, which is incompatible with magnetite in the Burntwood Group migmatite, produces a magnetic low surrounding the highly magnetic Sickle Group that outlines an overall kidney shape for the northeastern Notigi Lake structure in map view (Kiss and Coyle, 2008). The Burntwood Group is also represented by a magnetic low where exposures form the core of the main northeast domal structure along the peninsulas on the north shore of Notigi Lake.

Sickle Group (K)

The Sickle Group is composed of quartzofeldspathic paragneiss, generally containing magnetite, which exhibits a strong positive anomaly in the aeromagnetic map (Kiss and Coyle, 2008). Units in the Sickle Group were mapped using distinct compositional changes defined by the presence or absence of metamorphic hornblende or sillimanite in the predominantly biotite-bearing gneiss. The metamorphic indicator minerals occur at outcrop scale (unit) but not in every layer (bed). The Sickle Group stratigraphically overlies the Granville Lake assemblage in the following order: basal biotite gneiss (Kbt); hornblende-biotite gneiss (Khb); a second unit of biotite gneiss (Kbt); and sillimanite-biotite gneiss (Ksm), which forms the uppermost unit or is overlain by more biotite gneiss. Contacts between the units are gradational and the units

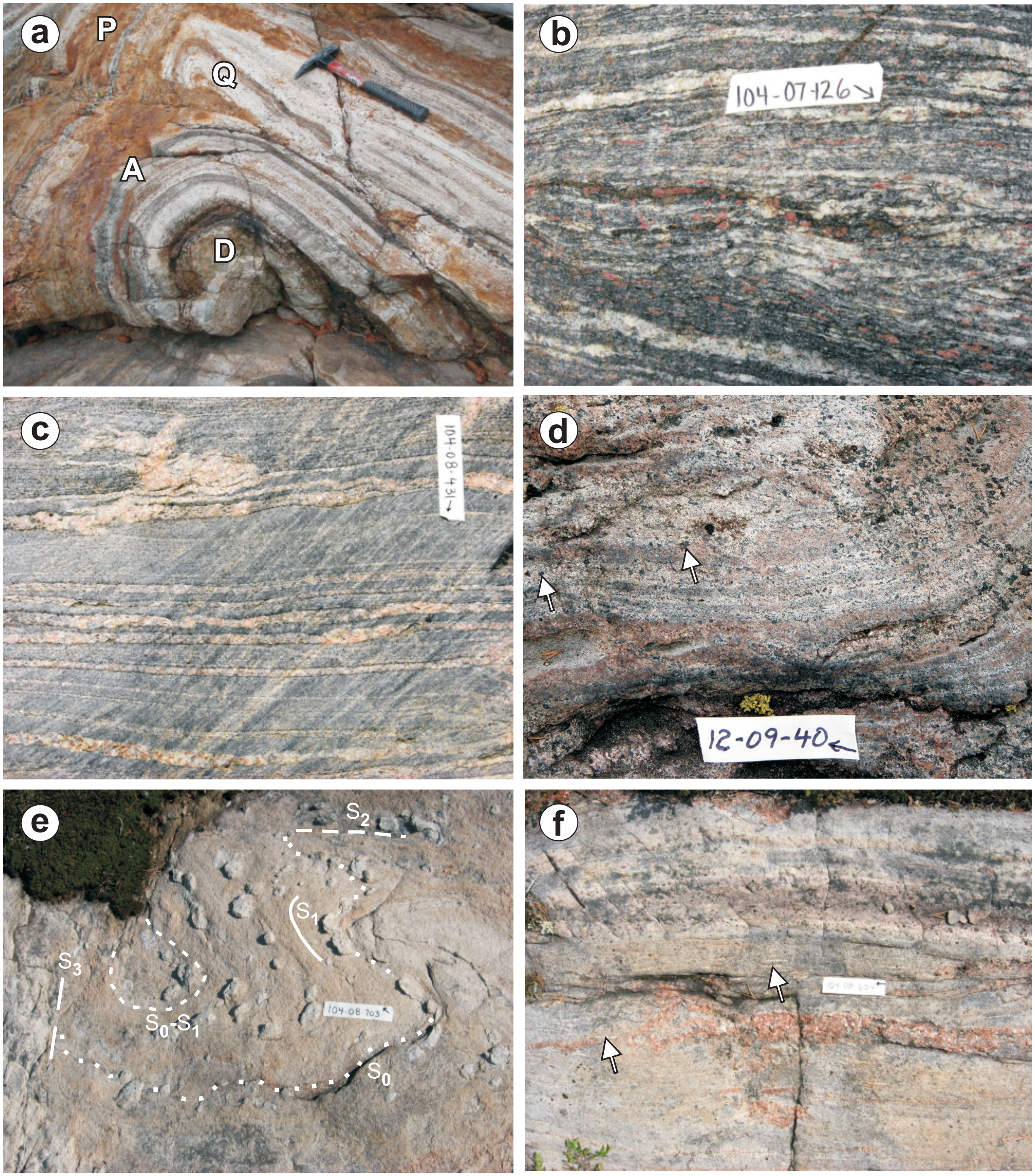

Figure GS-7-4: *Field photographs of typical units at Notigi Lake. Tape is 10 cm long:* ***a)*** *Granville Lake assemblage with interlayered sulphidic pelite (P), quartzofeldspathic gneiss (Q), amphibolite (A) and diopside-rich rock (D), interpreted to have been derived from mafic volcanic rocks and sedimentary rocks; the fold is F_3, showing a flexural style with a small thrust; hammer handle points northeast;* ***b)*** *Burntwood Group garnetiferous metagreywacke-mudstone–derived metatexite;* ***c)*** *Sickle Group magnetite-bearing biotite gneiss probably derived from nonmarine lithic arenite;* ***d)*** *Sickle Group hornblende-biotite gneiss (hornblende indicated by arrows) derived from arenite with probable calcite cement;* ***e)*** *Sickle Group sillimanite-biotite gneiss (meta-arkose) with quartz-sillimanite knots; tape is along the axial plane of an F_2 fold and fabric elements are interpreted as labelled; note overprinting of F_2 by S_3 (Zwanzig and Murphy, GS-8, this volume);* ***f)*** *Sickle Group sillimanite-biotite gneiss with flattened faserkiesel (arrows) interlayered with biotite gneiss, each representing transposed beds of slightly different composition.*

can appear interleaved. The units are interpreted as stratigraphic facies changes that occurred during deposition of the original arkosic to lithic arenite beds. Early isoclinal folding or faulting may also have caused local interleaving of the original section, particularly at the top, where the facing direction is unknown.

Basal biotite gneiss (Kbt)

The biotite gneiss at the base of the stratigraphic section varies in weathering colour from light to medium grey and brown to reddish brown and contains up to 60% pink to reddish leucosome. The unit varies from a very fine grained and uniform arenite to thin-bedded (at centimetre scale) coarser-grained, leucocratic paragneiss (Figure GS-7-4c). The unit can be interleaved with magnetite-free garnet-biotite gneiss, possibly derived from greywacke. More commonly, it is interlayered with hornblende-biotite gneiss, and more rarely, purely hornblende gneiss that is not magnetic. Although the main mineral content and appearance of the basal biotite gneiss is similar to the biotite gneiss throughout the Sickle Group, the different stratigraphic position of this unit overlying the Granville Lake assemblage and the Burntwood Group is indicated by the structure of the area.

Hornblende-biotite gneiss (Khb)

Hornblende-biotite gneiss overlies the basal biotite gneiss in the stratigraphic section. Amphibole is present in both the mesosome and leucosome. Unit Khb weathers greenish grey to pink and generally contains less magnetite than other units in the Sickle Group. The unit has interbeds of hornblende-free biotite gneiss, except in the south. Uniform layers of hornblende-biotite gneiss, which are up to 2 m thick, tend to be fine grained. Coarser arkosic biotite-bearing hornblende gneiss, by contrast, is thinly layered (0.5–10 cm) and generally migmatitic (Figure GS-7-4d). Unit Khb is attenuated and discontinuously exposed along the north limb of the Notigi Lake structure but forms the most dominant unit on the south side of the eastern dome. This is interpreted to be the expression of a lateral sedimentary facies change. Its position next to the Burntwood Group may also be due to a ramp in an early décollement that cut through the lower unit and into the biotite-hornblende gneiss (Figure GS-7-2; Zwanzig and Murphy, GS-8, this volume).

Biotite gneiss (Kbt)

The arenite-derived biotite gneiss that lies medial within the stratigraphic section is indistinguishable from the basal biotite gneiss in field appearance and main mineral content. Like the lower unit, biotite gneiss higher in the succession is very fine grained and uniform but varies locally in weathering colour and may have up to 10% pink to red leucosome or, rarely, up to 80% injected granite. The different stratigraphic position of this unit is indicated by its position between Khb and Ksm. Where Khb is missing, however, no contact can be drawn between a lower and a middle unit of biotite gneiss. Consequently, both stratigraphic divisions are designated as Kbt. This makes Kbt a lithofacies rather than a stratigraphic entity and therefore is used also where the uppermost section of the Sickle Group contains biotite gneiss. At the stratigraphic top and close to the core of the eastern dome, the unit is interleaved with sillimanite-bearing gneiss (Ksm).

Sillimanite-biotite gneiss (Ksm)

Sillimanite-biotite gneiss is commonly rich in quartz and feldspar and is locally interbedded with light grey protoquartzite. Rare exposures of remnant crossbeds in the protoquartzite indicate tops to the south at Timew Island where the units are overturned. The unit (Ksm) varies from having centimetre-scale uniform layering to millimetre-scale biotite-rich laminae that suggest compositional changes within the original interbeds containing more clay in otherwise predominantly arkosic arenite. In places, plagioclase- and feldspar-rimming magnetite cores may express the incipient development of sillimanite that was later consumed during a melt-forming reaction. Faserkiesel (sillimanite-quartz knots) in unit Ksm are commonly concentrated in layers interpreted as original beds (Figure GS-7-4e, -4f). The faserkiesel are variably stretched, most strongly along the attenuated limbs of the Notigi Lake structure. Coarser and more rounded faserkiesel occur within the hinge zone of the major folds. Rare cordierite porphyroblasts in parts of unit Ksm are interpreted to have formed in originally more clay-rich beds. Cordierite-sillimanite diatexite forms rare schlieren within unit Ksm. This subunit is interpreted as a progression from metatexite to diatexite, possibly due to partial melting in favourable compositions.

Intrusive rocks

Gabbronorite–leucogabbro (lm)

Exposures up to 70 m wide of dark green to black gabbronorite to melagabbro and leucogabbro are described in Murphy and Zwanzig (2007). At Notigi Lake, the mafic rocks appear to intrude the supracrustal rocks at two stratigraphic levels and thus represent two different ages of magmatism. The more uniformly textured rock is found with and grades into the layered Granville Lake assemblage. These may be interpreted as sills related to flows. Other similar looking rocks are apparently younger and intrude unit Ksm in the upper part of the Sickle Group. The younger sills are locally differentiated and include mesocratic to highly mafic compositions. Due to the complex structure and lack of exposure, not all mafic sheets can be assigned a relative age.

Monzodiorite (md)

Monzodiorite is part of the Black Trout diorite that is widely distributed along the north flank of the Kisseynew Domain (Zwanzig, 2008). The rock intrudes the Sickle Group as sills within the biotite gneiss, either stratigraphically below or above the unit Khb. It is exposed locally on the western side of the Rat River channel and southwest of Timew Island. The monzodiorite is uniformly dark grey to black with distinctively orange-weathering feldspar. It is biotite rich and strongly magnetic with abundant magnetite, titanite and apatite. Similar rock, but more schistose, also occurs in the northeastern part of Notigi Lake. Petrography is required to confirm that the more schistose rock is more highly strained Black Trout diorite.

Granite (gr)

The Rat granite (gr) is located along the Rat River 5 km north of Notigi Lake and is part of the Leaf Rapids Domain. This biotite granite is foliated to gneissic, pinkish grey and medium grained containing equal amounts of quartz, plagioclase and potassium feldspar with minor biotite and accessory magnetite. Preliminary U-Pb zircon data suggests a ca. 1838 Ma granite age, which would be slightly younger than the Sickle Group (L.A. Murphy, unpublished data, 2008) and in agreement with the granite forming an asymmetrical dome with a mantle of Sickle Group rocks. This age suggests that the granite intruded at least the base of the overlying Sickle Group, as did a 1.84 Ga granodiorite farther east at Leftrook Lake at the south margin of the Leaf Rapids Domain (H.V. Zwanzig and C.O. Böhm, unpublished data, 2003). Other granitoid rock dated as about 1.89 Ga at Leftrook Lake and as 1.86 Ga still farther to the east of the Notigi Lake area are therefore basement to the Sickle Group (H.V. Zwanzig and C.O. Böhm, unpublished data, 2003, 2008).

Monzogranite (mg)

The Notigi granite (mg) is located near the core of the northeastern dome in the Notigi structure, where it intruded mainly biotite gneiss (unit Kbt) of the Sickle Group but extends into unit Ksm (Figure GS-7-2). Monzogranite is commonly pink, phaneritic, feldspar rich and uniform with foliation defined by biotite (Figure GS-7-4f). Outcrops in eastern and western areas are separated by low ground with no exposures (Murphy and Zwanzig, 2008). Aeromagnetic data and inferred northerly trending shear zones, which may have permitted erosion and deposition of recent cover, prompt a re-interpretation as a single monzogranite body.

Whole-rock geochemical data (Table GS-7-1) support the composition of a relatively potassic high-silica granite. Primitive-mantle–normalized trace-element data show high contents of rare earth elements (REE) with fractionated light REE (LREE) and depleted Sr and Eu (Figure GS-7-5), suggesting magmatic fractionation with plagioclase removal or small-volume remelting of granodiorite. A high value of ε_{Nd} indicates a juvenile Paleoproterozoic source of melting (J.B. Whalen, unpublished data, 2008).

Geochronology

A sample of monzogranite was collected from the south side of the Notigi granite in 2007 (Figure GS-7-2). It yielded a population of zircon grains with distinct 1862 ±6 Ma cores and 1806 ±9 Ma rims (Figure GS-7-6, -7). The intrusive relationship of the Notigi granite indicates an age of crystallization that is younger than the 1850 Ma maximum age of deposition of the Sickle Group. Consequently, the cores are interpreted to represent an inherited component. This age is similar to the most common detrital zircon population in the Sickle Group at Granville Lake (H.V. Zwanzig, unpublished data, 2009); it falls in the range of successor arc intrusions in the Leaf Rapids Domain and is the same as granodiorite on the south margin of the Leaf Rapids Domain. The 1809 Ma age of the rims is interpreted to represent the crystallization age of the granite and is consistent with the timing of regional metamorphism in the Kisseynew and surrounding domains. The transitional to granulite facies metamorphic conditions and widespread migmatization is consistent with partial melting in the crust at this time. The most likely source of the monzogranite melt was probably the

Table GS-7-1: Whole-rock geochemical data of the Notigi Lake granite and Wapisu Lake quartz monzonite.

Unit	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI	Cr	Ni	Co	Sc	Zn	In	Sn
mg[1]	74.6	0.28	13.20	2.46	0.03	0.61	1.66	3.76	3.30	0.05	0.30	-10	7	3	4.6	50	0.11	4.1
qm	63.3	0.88	17.64	4.97	0.06	1.62	3.01	4.11	4.76	0.28	0.48	9	-7	4	9.9	60	0.71	1.8
	Mo	**S**	**Sb**	**Rb**	**Cs**	**Ba**	**Sr**	**Tl**	**Ga**	**Ta**	**Nb**	**Hf**	**V**	**Cu**	**Pb**	**Zr**	**Y**	**Th**
mg	0.5	0	1.23	77	0.4	772	129	0.43	19.7	0.57	13.0	6.4	18.3	-10	9	203	8.0	8.63
qm	0.4	282	0.80	116	1.8	1657	788	0.72	22.3	0.38	24.7	13.9	73.3	12	27	597	25.7	16.2
	U	**La**	**Ce**	**Pr**	**Nd**	**Sm**	**Eu**	**Gd**	**Tb**	**Dy**	**Ho**	**Er**	**Tm**	**Yb**	**Lu**	**Be**	**La/Yb**	
mg	1.8	40.0	82.6	10.4	40.8	9.9	1.17	11.3	2.0	12.5	2.7	7.7	1.25	7.97	1.16	1.3	5.0	
qm	1.6	125	241	27.3	94.5	13.2	2.5	8.18	1.1	5.01	0.9	2.1	0.32	1.87	0.28	2.0	66.6	

[1]Notigi monzogranite (average of 3); [2]Wapisu quartz monzonite to quartz syenite (average of 5)

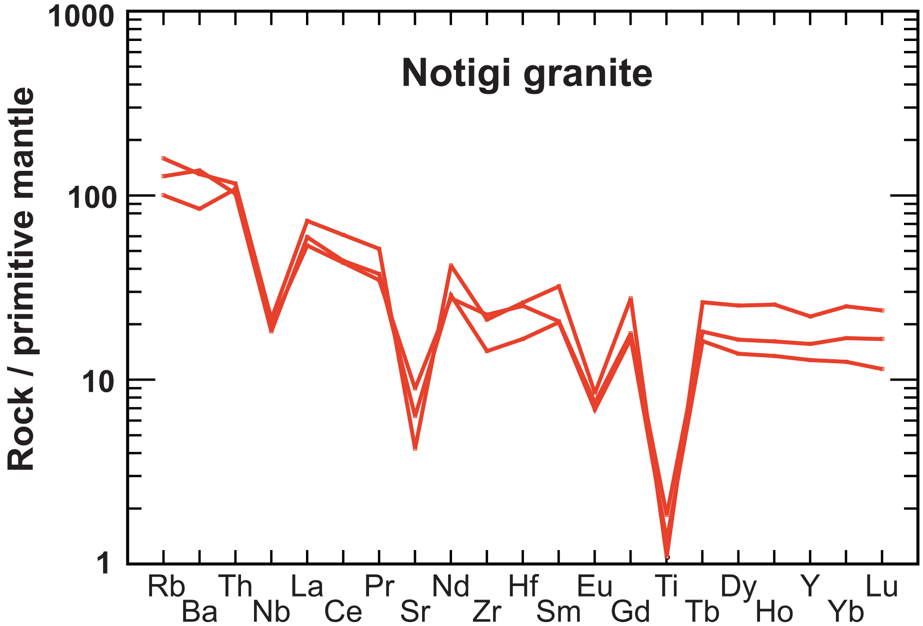

Figure GS-7-5: *Primitive mantle-normalized multi-element diagram of Notigi granite.*

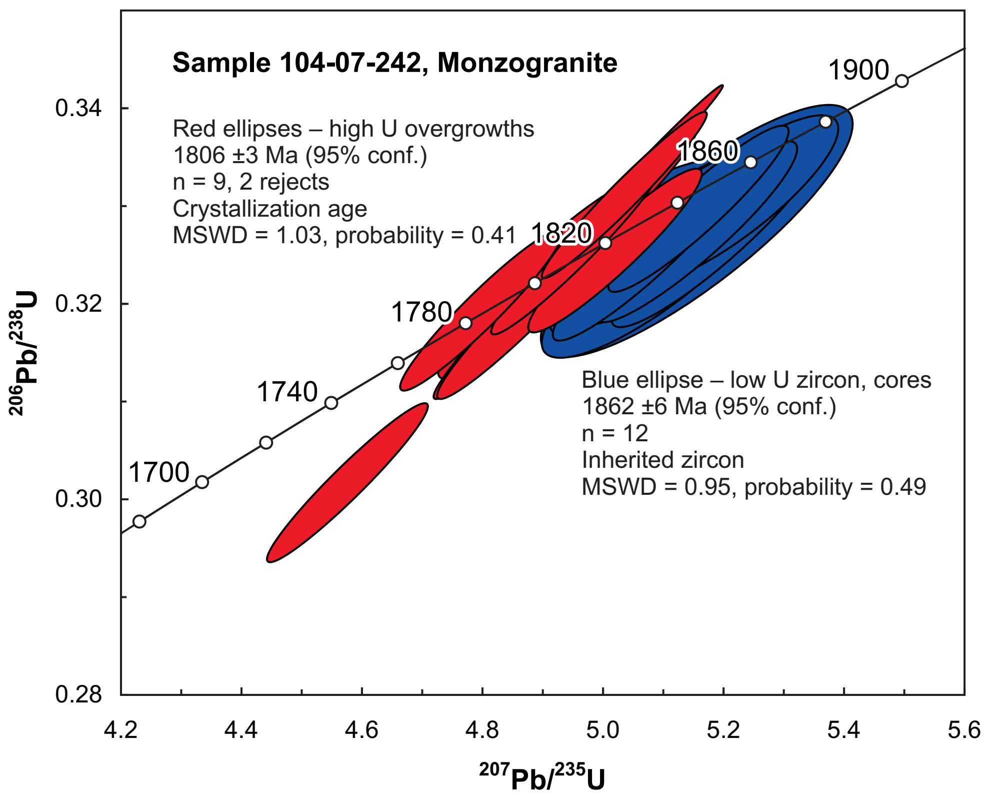

Figure GS-7-6: *Uranium-lead concordia diagram of zircons from the Notigi granite. Analyses of low U zircon, including cores, are shown by blue ellipses; analyses of high U rims are shown by red ellipses.*

deeply buried ca. 1860 Ma pre-Sickle basement of juvenile arc granite in the Leaf Rapids Domain. The alternate interpretation that the cores represent the age of crystallization cannot be ruled out. However, this requires faults at the contacts that were not observed in the overlying Sickle Group or an unconformable relationship, which is inconsistent with a contact in the highest part of the Sickle Group. The presence of pre-Sickle basement at depth in the Notigi Lake area and elsewhere on the north flank of the Kisseynew Domain, however, is indicated by the regional structure of the area (Zwanzig and Murphy, GS-8, this volume). Mapping and geochronological results on

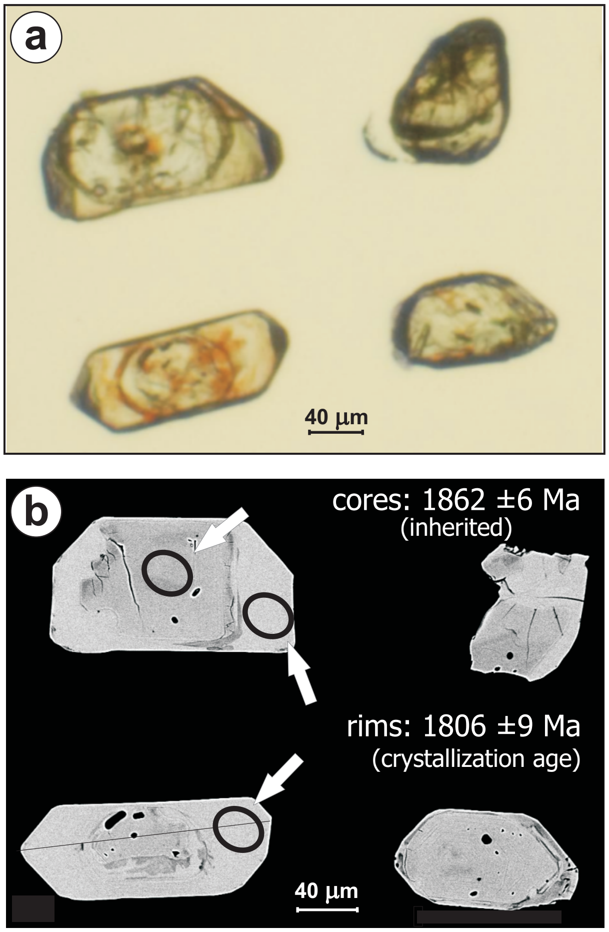

Figure GS-7-7: *Representative zircon fraction of the Notigi granite, showing both relatively large cores and rims that are interpreted to yield the ages of inheritance and crystallization during peak metamorphism.*

Granville Lake (N. Rayner and D. Corrigan, unpublished data, 2004) support the interpretation of a basement-cover relationship for similar rocks at Notigi Lake. The Notigi granite can thus be best explained as a deep crustal melt formed during collision tectonics and high-grade metamorphism of buried Paleoproterozoic juvenile arc crust. Its high content of K_2O is consistent with the breakdown of biotite during melting under conditions of granulite-facies metamorphism. The preservation of large zircon cores is consistent with the relatively low temperature of such granite melts.

Rock units at Wapisu Lake

The Wapisu Lake area, south of Notigi Lake, is underlain mainly by Burntwood Group migmatite and felsic intrusions. Paragneiss interpreted to belong to the Wuskwatim Lake sequence and mafic to intermediate intrusions occur locally. The felsic intrusions include an early quartz monzonite to quartz syenite, and younger leucogranite to tonalite and pegmatitic granite that are likely synmetamorphic and may contain members that are coeval with the 1806 Ma Notigi granite. Intermediate gneiss and rafts of greywacke similar to the Burntwood Group are found as schlieren or inclusions in the granitic rocks. Metagabbro, enderbite and plagioclase porphyry have uncertain relative ages but are interpreted to be younger than the ca. 1850 Ma Burntwood Group because they occur as narrow sheets within the unit.

Supracrustal rocks

The Burntwood Group forms the main supracrustal unit at Wapisu Lake, where it exhibits both primary psammitic to pelitic layering and migmatitic layering. Rafts of the Burntwood Group are incorporated in the leucogranite to tonalite unit as well as in the granite to granitic pegmatite unit. The Ospwagan-like supracrustal rocks at Wapisu Lake include a thin heterogeneous assemblage of paragneiss similar in mineralogy and appearance to the Wuskwatim Lake sequence found farther east in the Kisseynew Domain (Percival et al., 2007). Intermediate to mafic gneiss interlayered with that assemblage is of uncertain origin and not common elsewhere in the Northeast Kisseynew subdomain.

Heterogeneous gneiss (Wuskwatim-type sedimentary rocks)

The Wuskwatim-type rocks form a thin margin approximately 9 m wide adjacent to the FLPS quartz monzonite. These rocks were first described at Wapisu Lake by Percival et al. (2007). New observations did not confirm the presence of an unconformity above the FLPS intrusion because the contact is highly intruded by later leucogranite. The Wuskwatim-type supracrustal assemblage contains a 1.5 m layer and a 3.5 m layer of dark grey intermediate paragneiss separated by 1.6 m of semipelitic gneiss. The intermediate gneiss is layered with variable proportions of quartz-rich and biotite±garnet–rich layers (Figure GS-7-8a). The semipelite is garnet-biotite gneiss with 2–3 mm garnets, similar to biotite-garnet gneiss in the Wuskwatim Lake sequence and more uniform than the Burntwood Group. These paragneiss units are cut by leucogranite and pegmatite. A 10 cm wide lens of protoquartzite borders one of the pegmatite dikes. A 2 m section of sulphidic semipelite occurs next to granite and quartz monzonite to the west. It includes silicate-facies iron formation (hornblende-garnet bearing) and semipelite to pelite with 1% pyrrhotite (historically interpreted as iron formation in the TNB; Figure GS-7-8b). The section is missing key sulphide-rich layers but it has been extensively intruded by granite. The best evidence for a correlation with the Wuskwatim Lake sequence is the presence of Archean detrital zircons (*see* below).

Burntwood Group

The Burntwood Group at Wapisu Lake exhibits variable textures ranging from primary psammitic to pelitic graded bedding (with tops locally to the east and

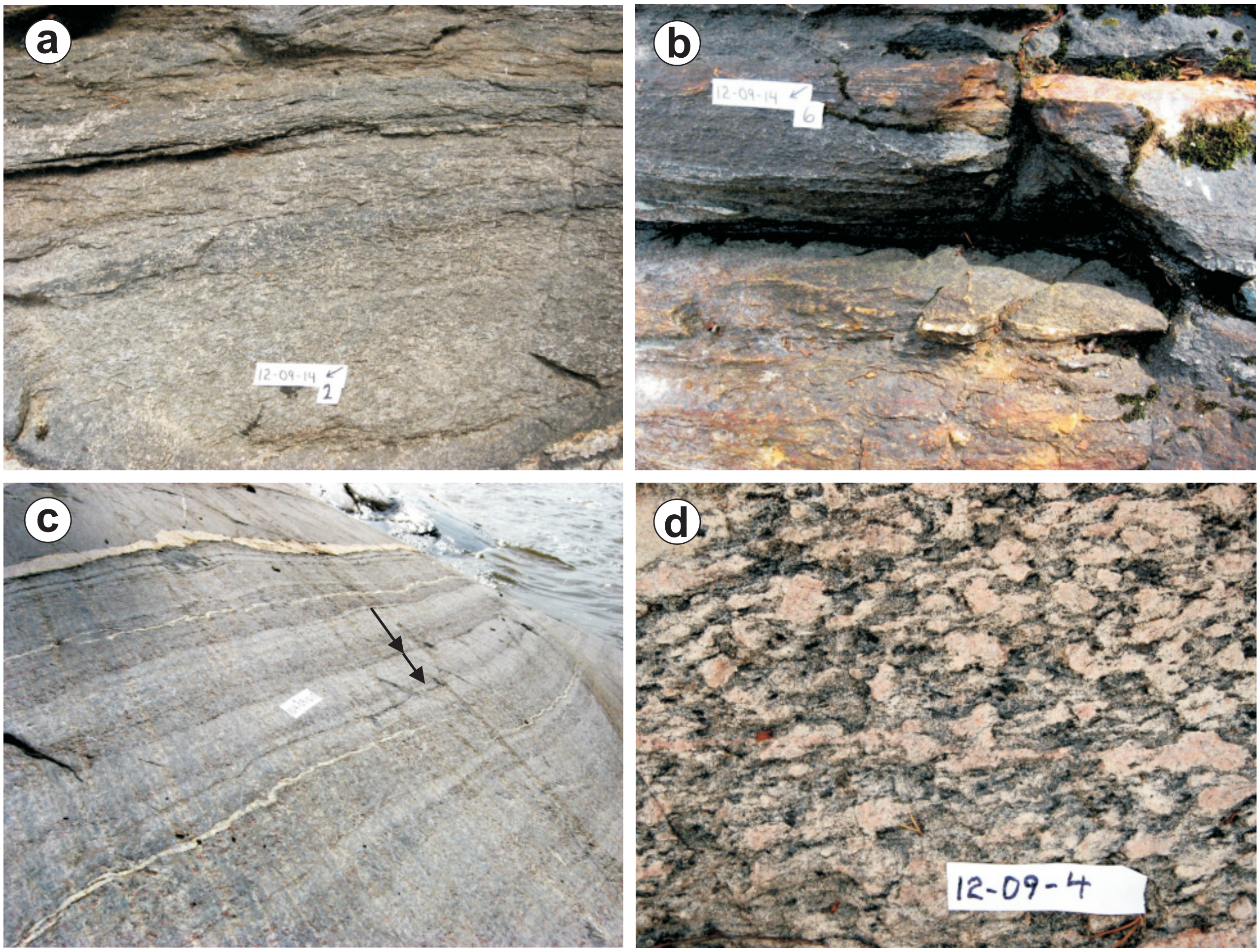

Figure GS-7-8: *Field photographs of typical units on Wapisu Lake. Tape is 10 cm long:* ***a)*** *layered intermediate paragneiss correlated with the Wuskwatim Lake sequence;* ***b)*** *iron formation–semipelite with iron sulphide;* ***c)*** *Burntwood Group metaturbidite grading from greywacke (pale) to mudstone (darker) with tops shown as arrows;* ***d)*** *quartz monzonite with variably deformed K-feldspar phenocrysts.*

north, Figure GS-7-8c) to progressive development of leucosome and melanosome in metatexite during migmatization. The unit contains abundant biotite, up to 15% garnet and, in places, cordierite. The overall leucosome development is up to 25%, less than that found at Notigi Lake. This migmatite displays three generations of leucosome that may attest to a long period of high-grade metamorphism and deformation. In rare locations, close to pegmatite, the unit is a leucosome-rich diatexite. The Burntwood Group rocks show a cataclastic foliation and intersection crenulation. Rafts of Burntwood Group rocks are incorporated in the leucogranite to tonalite and in the granite to granitic pegmatite.

Intrusive rocks

Quartz monzonite to quartz syenite

Quartz monzonite to quartz syenite form an elongate, about 10 km long and up to 2 km wide pluton as part of the FLPS at the west end of Wapisu Lake (Figure GS-7-1). The rock is buff to medium pinkish grey. It has up to 2 cm deformed feldspar phenocrysts (Figure GS-7-8d) that are largest in the central part of the pluton. The rock is rich in K_2O and Na_2O with variable silica and contains biotite-amphibole aggregates up to 1.2 cm long in the matrix. Quartz monzonite also occurs at the margin of the pluton as 5–20 m layers within sheets of leucogranite or as blocks in a stockwork of leucogranite, which obscure the character of the contact with the Wuskwatim Lake sequence. Contacts with the surrounding Burntwood Group were not observed.

Leucogranite to tonalite

The younger leucogranite to tonalite phases are white and medium grey to brown. Leucogranite occurs in large intrusive sheets to thin layers in paragneiss. The white, fine grained to pegmatitic tonalite phase is intruded by granite and pegmatite and forms a series of alternating sheets that, in some places, intrude the quartz monzonite. A grey and brown tonalite is boudinaged within granite. The tonalite or granodiorite is buff to light grey and also occurs as discrete sheets containing up to 1 m rafts and schlieren of differing rock types including a quartz-rich garnet-bearing gneiss and layered psammitic to semi-pelitic rocks of the Burntwood Group.

Granite to pegmatitic granite

Granite and pegmatitic granite weathers pale pink. It is strongly foliated to cataclastic close to sheared contacts with paragneiss. The granite is interlayered with up to 40% intermediate gneiss and schlieren that are similar to Burntwood Group migmatite. The granitic phases consist of alternating sheets of fine- to medium-grained granite and pegmatite. This variety also contains local garnet and rare cordierite and has incorporated inclusions of Burntwood and, in one location, enderbite.

Amphibolite

Weakly layered amphibolite is exposed sporadically in sections up to 25 m wide along the west shore of Wapisu Lake. It consists of massive quartz-diopside–bearing rock interlayered with plagioclase-hornblende-diopside amphibolite, similar in appearance to the amphibolite found at Kawawayak Lake (Murphy and Zwanzig, 2007), and may include rocks derived from flows, dikes and sills. A 3 m thick, uniform, medium-grained, hornblende-rich amphibolite lens or dike occurs adjacent to the Wuskwatim-type paragneiss. Locally the unit contains small gossan lenses. The amphibolite is commonly intruded by, or in sheared contact with, leucogranite and pegmatite.

Mafic rock

An unusual occurrence of mafic rocks up to 21 m wide is exposed along the west shore of Wapisu Lake. The unit comprises the outcrop from north to south: plagioclase-hornblende porphyry, 2 m wide; plagioclase-diopside gneiss, 1 m wide, which is folded; hornblende-diopside gneiss, 2 m wide; plagioclase porphyry, which appears to grade from its base from coarse- to fine-grained over a distance of 9 m; retrogressed enderbite, 7 m wide, containing garnet and biotite in aggregates that appear to be pseudomorphs after orthopyroxene. The units in the outcrop are intruded by a 9 m wide dike of coarse- to fine-grained garnetiferous leucogranite and pegmatite that contains greywacke xenoliths and enderbite rafts up to 2 m wide.

Geochronology

A sample of massive to thickly bedded, gritty quartzite was collected by Percival et al. (2007) for detrital zircon geochronology from a 1 m thick section of quartz-rich sedimentary rocks immediately east of the quartz monzonite (Figure GS-7-2). The results determine whether this sequence is a pre-Burntwood sedimentary succession (Wuskwatim Lake sequence), as well as constrain the age of the sediment source.

Sixty analyses were carried out on fifty-two detrital zircons, including replicate analyses on a number of grains (Figure GS-7-9a; DRI2009005) and yielded ages between 2266 Ma and 3498 Ma. Dominant age modes are between 2.65–2.72 Ga and at 2.88 Ga (Figure GS-7-9b). The youngest analyzed detrital zircon constrains the maximum age of deposition of the quartz-rich sandstone in the Paleoproterozoic at 2306 ±37 Ma, based on four replicate analyses of grain 65. Overall, the detrital zircon age distribution in the quartzite is consistent with observations from other early sedimentary sequences on the Burntwood River dominated by Archean detritus and interpreted as possible equivalents to the Ospwagan Group (Wuskwatim Lake sequence; Rayner and Percival, 2007).

A sample of strongly foliated to augen gneissic, hornblende-biotite quartz monzonite was collected from the western shore of Wapisu Lake to test whether it was part of the FLPS or basement to the overlying supracrustal rocks (Figure GS-7-2). Geochemical results reported in Whalen et al. (2008) indicate that the quartz monzonite has the high-K signature typical of the FLPS. A homogeneous population of zoned zircon was recovered that contain low to moderate U concentrations and high Th/U (most greater than 2), which was typical of other samples of the FLPS (Percival et al., 2007). Thirty-eight analyses of thirty-seven zircon grains yielded a range of ages from 1923 Ma to 1770 Ma. The weighted mean $^{207}Pb/^{206}Pb$ age of the twenty-seven oldest analyses is 1872 ±9 Ma and is interpreted as an estimate for the crystallization age of the quartz monzonite. The remaining six younger analyses are inferred to have recorded significant Pb loss, likely related to the high-grade metamorphic and partial melting event at ca. 1.81 Ga.

Economic considerations

The Burntwood and Sickle groups on the north flank of the Kisseynew Domain have been traditionally considered to be of low economic potential. The Granville Lake assemblage has a known gold showing at Wheatcroft Lake (Barry, 1965); traces of copper in the form of malachite occur locally in the Sickle Group at Notigi Lake and as occurrences elsewhere on the Kisseynew north flank (Baldwin, 1980). The Wuskwatim Lake sequence in the Northeast Kisseynew subdomain is interpreted to be related to the Ospwagan Group, which has a high nickel potential. Determining the stratigraphy at Notigi Lake and unravelling the complex deformation history may provide a new tool to explore for nickel in Ospwagan-like rocks exposed in the Northeast Kisseynew subdomain, adjacent to the TNB. The rocks in the Northeast Kisseynew subdomain are generally poorly exposed and in many places only assumed based on aeromagnetic data. Detailed mapping of rocks in the north flank at Notigi Lake as described in this report provides an understanding of structural geometry that may be applied in the Northeast Kisseynew subdomain (Zwanzig and Murphy, GS-8, this volume).

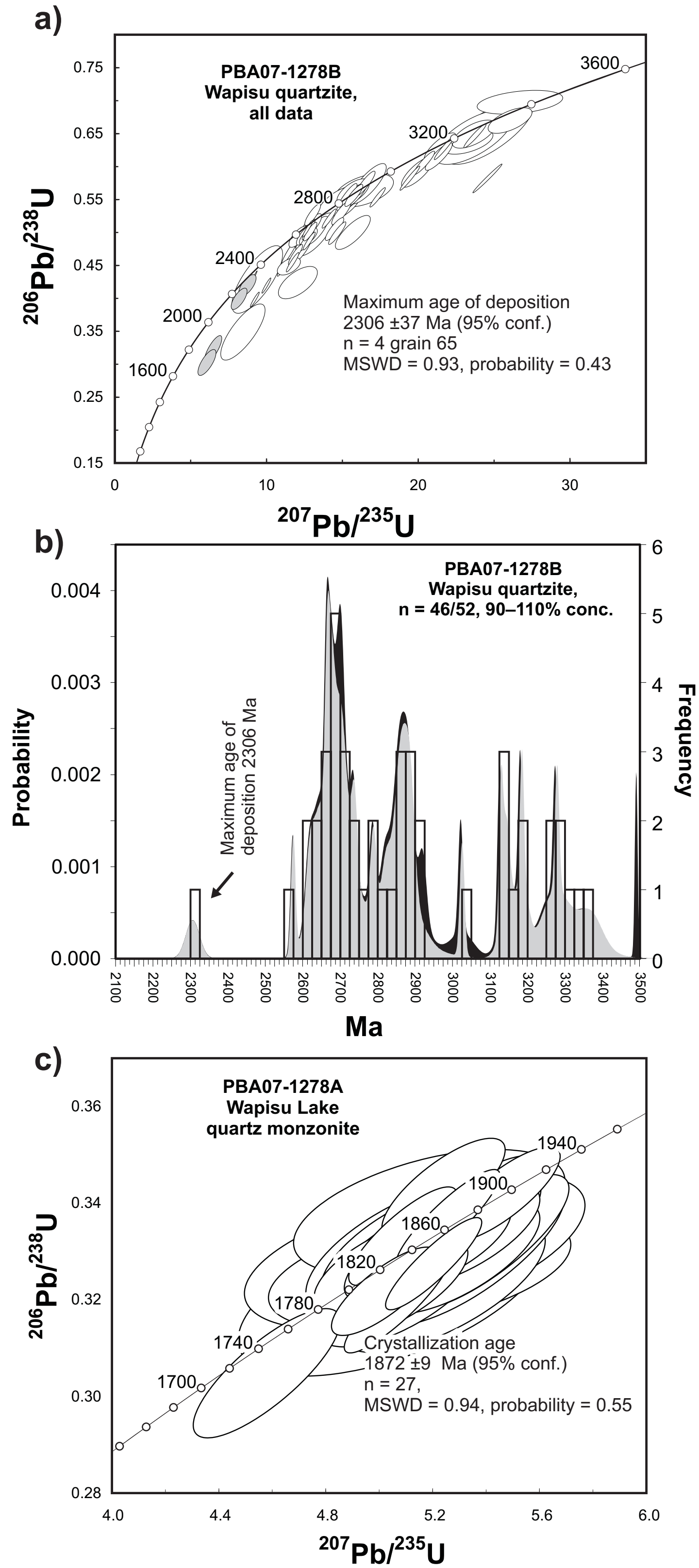

***Figure GS-7-9: a)** Uranium-lead concordia diagram of zircon data from the Wapisu quartzite. Replicate analyses of the youngest detrital grain (#65) are shown by grey ellipses. Abbreviation: MSWD, mean square weighted deviation. **b)** Probability density diagram of detrital zircon results from the Wapisu quartzite. All data (excluding replicates) is shown by light grey curves on the probability density diagram; dark grey curves and histograms represent data that is within 10% of concordia. **c)** Uranium-lead concordia diagram of zircon data from the Wapisu quartz monzonite.*

Exploration requires a regional understanding of the geology, tectonic evolution and crustal architecture to limit work to favourable areas. The remapped tract (Notigi–Wapisu lakes area) bridges the Leaf Rapids Domain via the Kisseynew north flank to the Northeast Kisseynew subdomain. The range of ages of the granitoid rocks on the margin of the Leaf Rapids Domain spans the entire period of arc magmatism known in the Trans-Hudson Orogen, but that magmatism is absent in the Kisseynew Domain. This highlights the profound difference in tectonic history and metallogeny of these two domains. The work at Notigi Lake indicates that the basinal rocks (Burntwood Group) on the Kisseynew north flank are intruded only by younger granitoid rocks. The Northeast Kisseynew subdomain has yielded quartz monzonite to quartz syenite to monzogranite (FLPS) from an Archean source and features rare exposures of supracrustal rocks (Wuskwatim Lake sequence) that may host, by analogue with the possibly related Ospwagan Group of the TNB, ultramafic intrusions and associated nickel deposits (Percival et al., 2006). Consequently, the mafic rocks of the Wuskwatim Lake sequence on Wapisu Lake warrant further exploration.

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Geological Survey of Canada contribution 2009054.

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