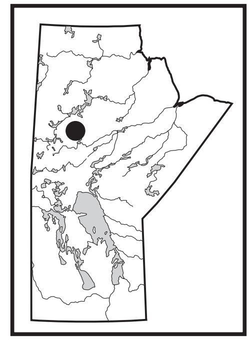
GS-5 Update on geological investigations of the Notigi Lake area, Manitoba (parts of NTS 63O14, 64B3)

by L.A. Murphy



Murphy, L.A. 2008: Update on geological investigations of the Notigi Lake area, Manitoba (parts of NTS 63O14, 64B3); *in* Report of Activities 2008, Manitoba Science, Technology, Energy and Mines, Manitoba Geological Survey, p. 53–65.

Summary

The second of two field seasons undertaken at Notigi Lake, located within the northern flank of the Kisseynew Domain, involved key traverses at low water levels and the application of a new high-resolution aeromagnetic survey. The fieldwork has contributed significant details to the structure, extent and composition of previously described rock types including the layered amphibolite, subdivisions in the Burntwood and Sickle groups and mafic to felsic intrusive rocks.

The layered amphibolite unit is grouped with siliciclastic metasedimentary rocks in a volcano-sedimentary assemblage, (herein referred to as the 'Notigi assemblage'). The Notigi assemblage is correlated with units that occur elsewhere along the northern flank of the Kisseynew Domain. Whole-rock major- and trace-element geochemistry and Nd-isotope data for the layered amphibolite support this correlation. Local sillimanite±garnet–bearing gneiss has been identified adjacent to the Notigi assemblage and the Burntwood Group. On the eastern side of the Notigi structure, Sickle Group arkosic units occur in the following order: 1) sillimanite-bearing gneiss, 2) biotite-bearing gneiss, 3) hornblende-biotite gneiss, and 4) biotite gneiss. It is unknown if the most easterly sillimanite-bearing gneiss represents the base of the stratigraphic section or if this succession is the result of isoclinal F_1 folding above a fault that cuts off much of the section. The structural analysis at Notigi Lake can be directly applied to the structural style of similar units to the southeast, in the Thompson Nickel Belt.

The geochemistry of monzodiorite that intruded Sickle Group rocks, including a newly found occurrence, establishes it to be part of the regional Black Trout diorite with a Nd-model age of 2.58 Ga.

Introduction

This project was undertaken in collaboration with the Geological Survey of Canada as part of the federal Targeted Geoscience Initiative 3 (TGI-3) Flin Flon Project (Percival et al., 2006; Percival et al., 2007; Zwanzig, GS-4, this volume). The purpose of the work at Notigi Lake is to define the tectonostratigraphy, structural geology and tectonic history of an accessible and well-exposed area on the eastern part of the northern flank of the Kisseynew Domain (Murphy and Zwanzig, 2008). Ongoing work and interpretation will involve structural, geochemical and isotopic analysis of the supracrustal rocks and granitoid intrusions.

The eastern part of the northern flank of the Kisseynew Domain was mapped in the early 1970s, and the results published mainly as a set of 1:50 000-scale geological maps completed under the Burntwood Project (Baldwin et al., 1979).

Previous mapping in the Notigi Lake area by the Manitoba Geological Survey began in 1969, during the Southern Indian Lake Project (Elphick, 1972; Schledewitz, 1972). Mapping in the Notigi Lake area was carried out by Frohlinger (1979). However, despite this regional-scale mapping, the local structure, stratigraphy and mineral potential of this part of the Kisseynew Domain have remained poorly understood.

More recent reconnaissance mapping, geochemistry, geochronology and Nd-isotope work in an area extending from southeast of Notigi Lake to the Thompson Nickel Belt (TNB) has revealed the existence of narrow belts of Archean gneiss with a thin supracrustal succession similar to that of the Ospwagan Group, which hosts the deposits in the TNB (Percival et al., 2005, 2006; Zwanzig et al., 2006; Figure GS-5-1). The origin, structure and extent of these older rocks in the predominantly greywacke-derived migmatite of the northeastern Kisseynew Domain are not fully understood and form part of this study. Geological investigations in the Notigi Lake area, with its well exposed tectonostratigraphy, may serve as a guide for determining the structural style and three-dimensional extent of older and economically-promising rocks in less well-exposed areas.

The emphasis during the Burntwood Project was to distinguish and map the pelitic to psammitic gneiss (Burntwood Group), the quartzofeldspathic paragneiss (Sickle Group) and the associated intrusive rocks, in order to determine the mineral potential of the Kisseynew Domain. Although subdivisions of the Sickle Group were delineated locally, this was not done at Notigi Lake, nor was the presence of Archean rock suspected or identified.

Notigi Lake is located approximately 100 km west of Thompson along Provincial Highway 391, and along strike of areas that contain rocks of Archean provenance such as the Ospwagan Group. During the summers of 2007 and 2008, an area of 350 km^2 was remapped at 1:20 000 scale. The mapping concentrated on clean shoreline exposures and key traverses along the eastern part of Notigi Lake (Figure GS-5-2; Murphy and Zwanzig, 2007). The work delineated stratigraphic units in the

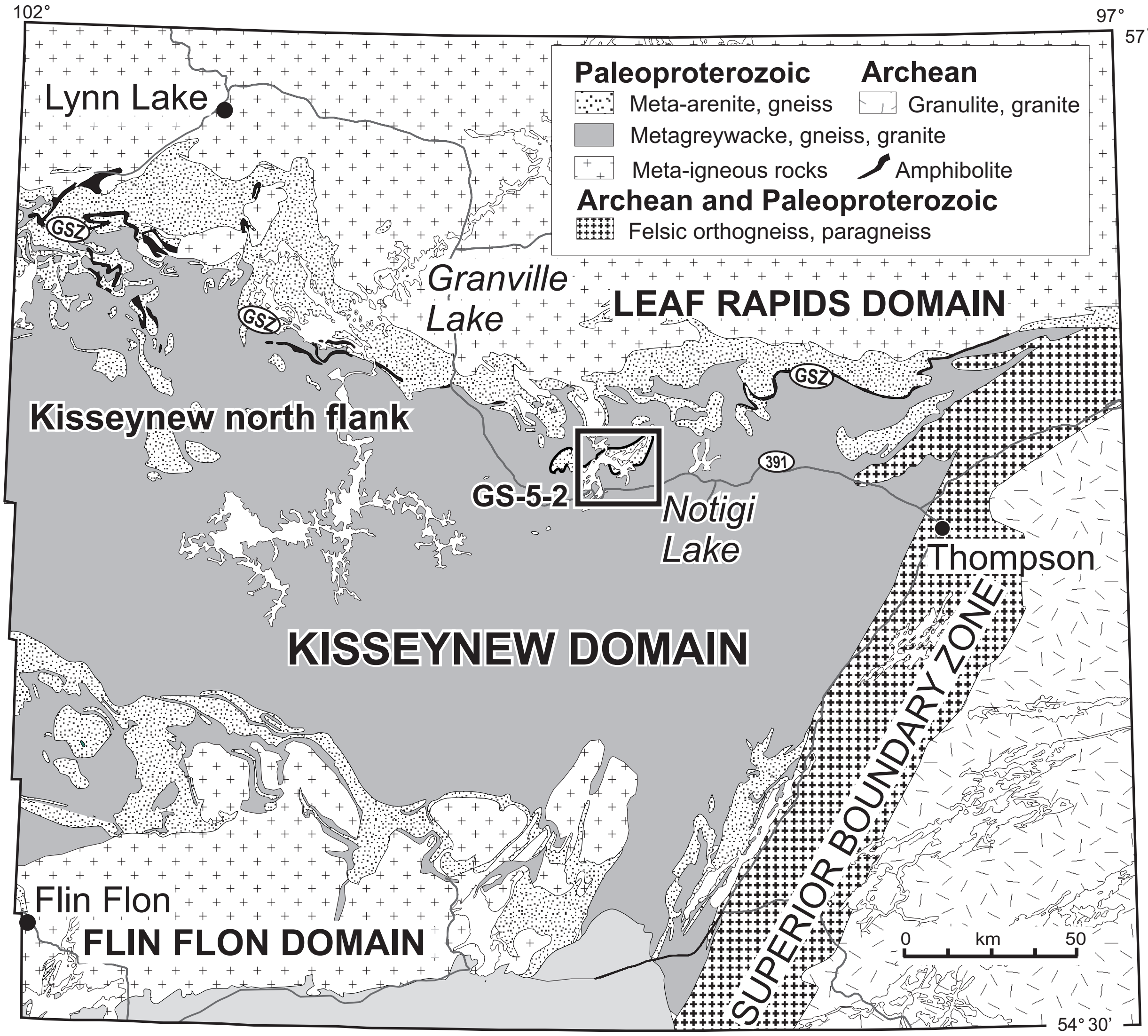


Figure GS-5-1: *Simplified geology of the northeastern Kisseynew Domain outlining the Notigi Lake area. Abbreviation: GSZ Granville Lake structural zone (*see also *Zwanzig, GS-4, this volume).*

Sickle Group and provided data for a structural interpretation of the history of the Notigi Lake area within the internal zone of the Trans-Hudson Orogen along the northern flank of the Kisseynew Domain (Figure GS-5-2).

Notigi Lake is a reservoir along the Churchill River system. Manitoba Hydro completed the Churchill River Diversion in 1977 and redirected water from the Churchill River south along the Rat River through Notigi Lake into the Burntwood River. When Notigi Lake was flooded to its present level, new shoreline exposures developed. This mapping project captures structural data and geological contacts from the original Burntwood Project mapping, which was undertaken on pre-flood shoreline outcrops, and combined this information with new mapping data from the Sickle Group and adjacent parts of the Burntwood Group at the current lake level. Additional information is provided by an aeromagnetic survey completed in May 2008 (Kiss and Coyle, 2008).

Regional setting

The northern flank of the Kisseynew Domain is dominated by Paleoproterozoic high-grade metasedimentary rocks and migmatite of the Burntwood and Sickle groups, generally with a thin and discontinuous intervening volcano-sedimentary unit, previously referred to as 'layered amphibolite' (Murphy and Zwanzig, 2007). Burntwood Group metamorphic rocks are derived from greywacke, siltstone and mudstone deposited by turbidity currents (Bailes, 1980; Zwanzig, 1990), while Sickle Group metamorphic rocks derive from lithic arenite and arkose deposited in a shallow-water environment (Milligan, 1960). The intervening volcano-sedimentary assemblage appears to be predominantly derived from mafic volcanic rocks and associated mafic intrusive rocks. Similar assemblages are better preserved at Granville Lake and at the southwestern end of the Lynn Lake belt, where they have been interpreted as having formed during a ca. 1.9 Ga

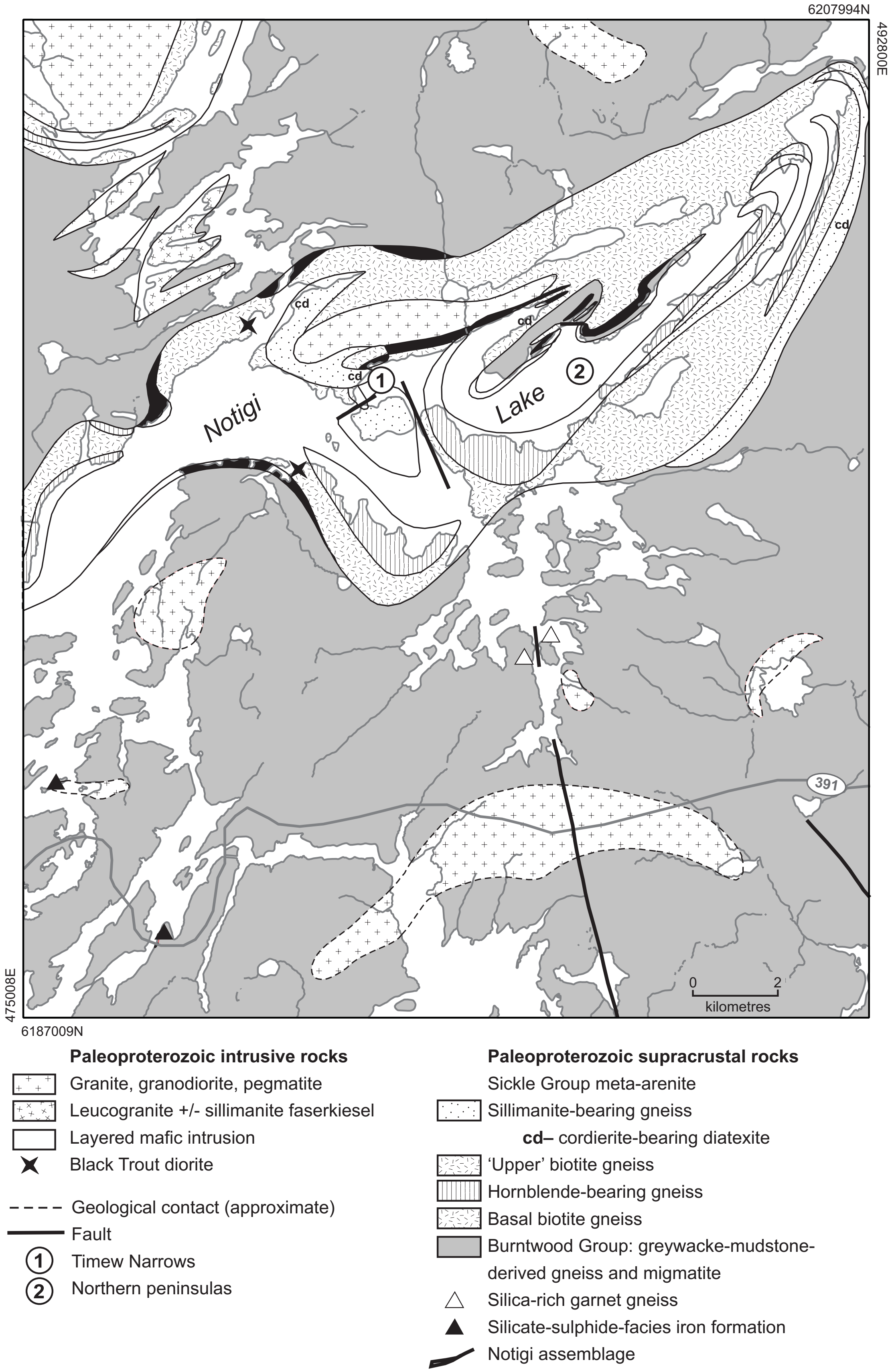


***Figure GS-5-2**: Schematic geology of the Notigi Lake area based on Frohlinger (1979) and updated with data from fieldwork done in 2007 and 2008.*

episode of arc-rifting and back-arc magmatism (Zwanzig et al., 1999; Zwanzig, GS-4, this volume). In those locations where primary structures are preserved at Granville Lake, the mafic assemblage appears to be unconformably overlain by the ca. 1.83–1.84 Ga Sickle Group, and this relationship is assumed to be valid for the more highly deformed amphibolite and meta-arenite along the entire northern flank of the Kisseynew Domain, including the Notigi Lake area (C. Beaumont-Smith personal communication, 2008). This assumption implies the presence of a thrust fault between the volcano-sedimentary assemblage (amphibolite) and underlying younger (1.83 to 1.85 Ga) Burntwood Group (David et al., 1996; Machado, et al., 1999).

No inliers of Archean orthogneiss, Thompson-Nickel-Belt–type paragneiss or K-rich intrusions, which mark the occurrence of such inliers (Whalen et al., GS-6, this volume), have been found at Notigi Lake; however some Archean inliers of isotopically evolved granitic rock occur directly south of Notigi Lake (Zwanzig, GS-4, this volume). Further geochemistry, petrology and Nd-isotope work will test if quartz-rich rock identified in the Notigi assemblage at Notigi Lake can be correlated to Ospwagan Group rocks from the TNB. The area lies between the newly proposed northern flank and the northeastern subdomain of the Kisseynew Domain (Zwanzig, GS-4, this volume), which does not include Archean rocks. Notigi Lake therefore serves as an important northern limit for nickel exploration.

General geology

The supracrustal rocks at Notigi Lake include a layered volcano-sedimentary assemblage, herein referred to as the 'Notigi assemblage'; Burntwood Group migmatite derived from greywacke-mudstone with minor iron formation; and Sickle Group quartzofeldspathic paragneiss derived from lithic arenite and arkose. The stratigraphic order of these units may vary within the map area, but the main structural order is the same as elsewhere along the northern flank of the Kisseynew Domain. That order is inferred to be Burntwood Group–fault–Notigi assemblage–unconformity–Sickle Group (Zwanzig, GS-4, this volume). The Notigi assemblage is considered to be the oldest unit, and the Sickle Group, the youngest.

Units in the Sickle Group were mapped using distinct compositional changes defined by their dominant mineralogy. Unit contacts are gradational and are interpreted as stratigraphic. Detailed mapping during the last two summers, however, revealed previously unrecognized units or differences in the order in which the units occur throughout the study area. Recent mapping at low water conditions has identified sillimanite- and sillimanite-garnet–bearing gneiss and, locally, cordierite-bearing diatexite instead of the regionally basal biotite-bearing paragneiss that occurs in some areas adjacent to the Notigi assemblage and the Burntwood Group.

The intrusive rocks at Notigi Lake include gabbronorite to gabbro (now included in the Notigi assemblage); monzodiorite (Black Trout diorite); granite (Notigi granite); and quartz diorite, granodiorite, tonalite, leucogranite (±sillimanite faserkiesel) and pegmatite (Figure GS-5-2). The gabbro appears to be in fault or shear contact with the Burntwood and Sickle groups and is interleaved with the supracrustal rocks of the Notigi assemblage. The Black Trout diorite intrudes only the Sickle Group biotite-bearing gneiss, whereas the granitoid rocks intrude both Burntwood and Sickle group rocks.

The structure that exposes the Notigi assemblage and Sickle Group within the widespread Burntwood Group has been interpreted as involving D_1 faulting, which formed the contact between the Burntwood Group and the Notigi assemblage, followed by F_2 isoclinal recumbent folding and F_3 upright folding (Murphy and Zwanzig, 2007). This polyphase deformation has produced overturning and inversion of the supracrustal gneiss units. Subsequent F_3-F_4 doming and granitic intrusion have further complicated the structural geometry.

A new aeromagnetic map displays a sharp contrast between the low magnetic signature of the Burntwood Group and the highly magnetic Sickle Group (Kiss and Coyle, 2008). Although individual units in the Sickle Group cannot be delineated based on magnetic data, major F_2 folds are identified on the map and can be traced along the trend of the high magnetic signature (Murphy and Zwanzig, 2008; Figure GS-5-2). This technique is useful combined with ground-truthing where traverses identify the units across strike. Caution must be used, however, interpreting the aeromagnetic trends where the dip is shallow and the magnetic pattern is lessened or disturbed. Accounting for this effect allows the extension of F_4 folds identified in hornblende-, biotite- and sillimanite-bearing paragneiss located in the south-central portion of Notigi Lake, toward the hinge zone of the main F_2 fold located to the northwest. This corroborates a previous interpretation according to which the overall shape of the Notigi structure is an asymmetric dome with a moderately plunging northeasterly closure and a steeply dipping southern margin. This geometry may have formed during late D_2 and/or D_4 south-verging anticlinal folding of a previously folded hinge line.

All units in the Notigi Lake area have been metamorphosed to upper amphibolite or transitional granulite facies; the prefix 'meta-', although not used in the protolith names, is implied.

Layered volcano-sedimentary assemblage (Notigi assemblage)

Recent mapping at low lakewater levels indicates that the layered amphibolite at Notigi Lake (Murphy and Zwanzig 2007) is part of a volcano-sedimentary assemblage best exposed on peninsulas along the northern shore. Therefore the layered amphibolite unit, with or without siliciclastic rocks, is herein referred to as the 'Notigi assemblage'. This assemblage is at least 110 m wide, up to 50 m of which may be sedimentary and the rest consisting of layered amphibolite and metagabbro. The Notigi assemblage is exposed in fault contact with the Burntwood Group migmatite and is unconformably overlain by Sickle Group paragneiss. A simplified sketch of outcrops along one of the northern peninsulas illustrates the complex contact relationship of the Notigi assemblage with rocks of the Sickle and Burntwood groups (Figure GS-5-3).

The assemblage varies from uniformly straight amphibolite gneiss (Figure GS-5-4a) to strongly folded (Figure GS-5-4b) and boudinaged layers characterized by the presence of discontinuous pods and lenses. Layer thickness ranges from 1 cm to 1 m. Variations in mineral content reflect the colour of each layer within the assemblage. The amphibolite includes layers of hornblende-pyroxene-plagioclase (dark grey to black); hornblende-diopside-pyroxene-plagioclase (dark green to grey); plagioclase±diopside and carbonate–bearing rocks (pale grey to green); and coarser, more uniform amphibolite-gabbro (dark green to grey). Diopside-rich layers are interpreted as structurally transposed high-grade metamorphic products of epidosite and carbonate alteration domains.

The siliciclastic rocks include quartz-plagioclase± hornblende siliceous rocks (medium grey to brown), calcsilicate with a moderate to high quartz content (grey, green to white) and possibly chert (white). Eroded pockets in both the amphibolite and siliceous sedimentary rock observed in the field suggest the presence of carbonate. Rare gossanous (rusty) patches and <2% chalcopyrite occur sporadically throughout the assemblage.

The sillimanite-garnet–bearing gneiss that has been tentatively assigned to the Sickle Group (above) may, in fact, represent semipelite that could be included in the Notigi assemblage.

Geochemistry of the Notigi assemblage

Whole-rock major- and trace-element analysis was carried out on amphibolite samples from the Notigi assemblage (Table GS-5-1). Based on trace-element characteristics, two samples taken along the Rat River appear to be related to the arc-rift basalt defined as Tod Lake basalt in the western part of the Kisseynew Domain's northern flank (Zwanzig, et al., 1999; Zwanzig, 2000; Zwanzig, GS-4, this volume; Figure GS-5-5a). The arc affinity of the rock is illustrated in a primitive-mantle–normalized multi-element plot by negative Nb and Zr anomalies and a Th spike. The rift affinity is suggested by weak fractionation of rare-earth elements (REE) and lack of negative

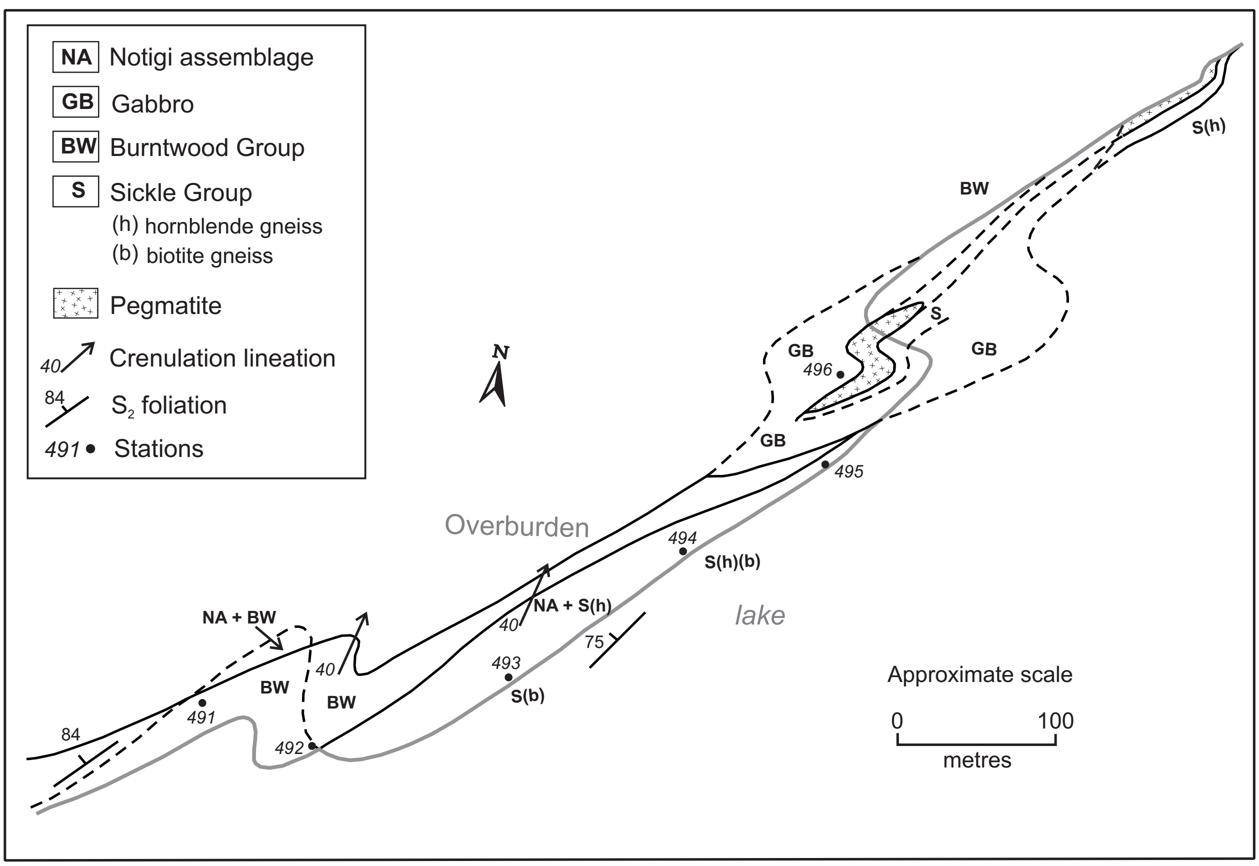


__Figure GS-5-3:__ Simplified sketch along a northern peninsula at Notigi Lake showing the complex contact relationship the Notigi assemblage has with the Sickle and Burntwood groups and the mafic intrusive rock.

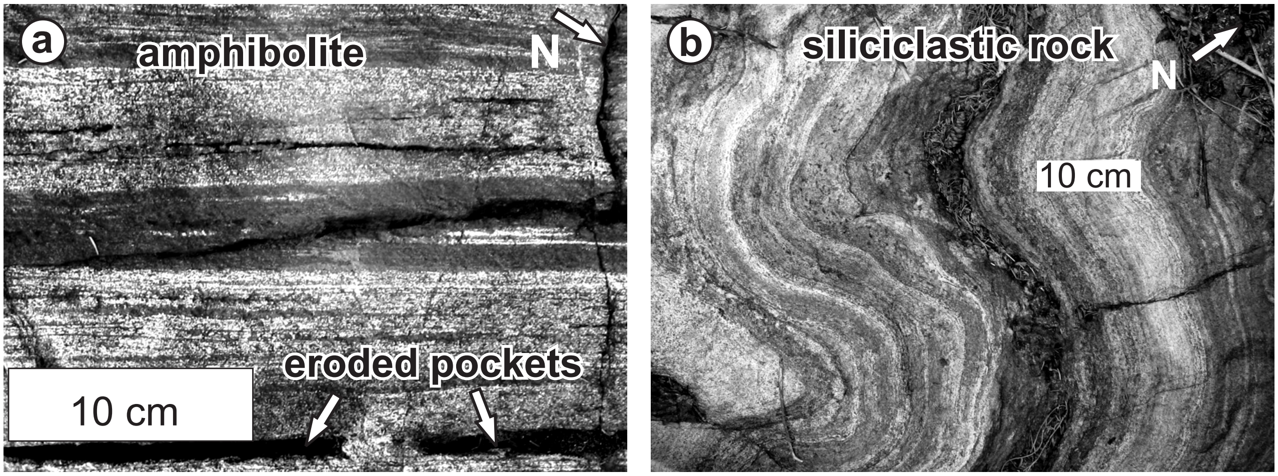


Figure GS-5-*4: Outcrop photographs of Notigi assemblage features:* ***a)*** *straight gneiss showing darker hornblende-rich and lighter diopside-plagioclase–rich layers including eroded pockets that may have originally contained carbonate pods;* ***b)*** *alternating darker mafic and lighter plagioclase-diopside layers in an F_2 fold along a northern peninsula.*

Table GS-5-1: Whole-rock major- and trace-element analyses of selected samples from Notigi Lake including the Notigi assemblage, Black Trout diorite and granodiorite.

Sample	104-07-204-2	104-07-378-1C	12-06-162-4	12-06-162-3	104-07-121-2	12-06-160-1	104-07-017	104-07-085-2
SiO_2	46.76	45.5	47.3	48.2	50.45	49.8	70.57	68.1
Al_2O_3	12.8	10.2	12.7	13.28	13.49	12.82	14.57	14.82
Fe_2O_3	16.91	9	13.5	4.98	13.06	14.41	3.59	3.48
MnO	0.26	0.17	0.23	0.15	0.19	0.2	0.014	0.015
MgO	5.5	5.73	3.54	1.52	4.03	4.34	0.69	0.81
CaO	8.45	22.7	14.87	18.23	6.62	7.38	1.67	1.75
Na2O	2.53	0.75	2.25	1.14	2.71	2.49	3.01	3.18
K2O	1.38	0.31	0.32	3.81	2.81	2.3	5.47	5.22
TiO_2	3.8	1.34	1.94	2.41	3.186	3.01	0.632	0.761
P_2O_5	0.46	0.19	0.33	0.4	1.78	2.2	0.23	0.25
LOI	1.37	3.91	1.87	4.9	0.17	0.29	0.29	0.44
Total	100.3	99.83	98.83	99.03	98.5	99.21	100.7	98.86
Sc	31	29	42	36	30	27	5	4
Be	3	3	2	2	3	2	1	<1
V	468	253	468	411	204	264	34	45
Cr	90	920	<20	<20	<20	<20	<20	<20
Co	49	38	38	42	25	32	5	5
Ni	50	120	20	30	<20	20	<20	<20
Cu	50	30	300	10	70	20	40	<10
Zn	120	60	110	90	140	80	80	70
Ga	25	15	21	24	24	24	21	21
Ge	1.8	1.5	1.1	0.9	2	1	1	<1
Rb	50	9	4	49	76	57	110	150
Sr	241	346	220	180	620	549	253	376
Y	41.5	13.2	36.5	42.9	65	58	18	19
Zr	259	90	86	175	599	473	596	632
Nb	19.4	8.6	45	10	31	27	16	20
Sn	2	2	1	2	2	2	1	<1

Table GS-5-1: Whole-rock major- and trace-element analyses of selected samples from Notigi Lake including the Notigi assemblage, Black Trout diorite and granodiorite. *(continued)*

Sample	104-07-204-2	104-07-378-1C	12-06-162-4	12-06-162-3	104-07-121-2	12-06-160-1	104-07-017	104-07-085-2
Sb	3.3	<0.2	<0.2	5.8	0.6	0.9	<0.5	<0.5
Cs	0.3	0.2	<0.1	0.9	2.2	1.1	<0.5	<0.5
Ba	283	131	220	541	2000	1575	1870	1889
La	18.1	8.21	8.72	11.6	124	123	130	79.1
Ce	48.3	19.6	22	32.6	264	267	262	149
Pr	6.6	2.52	3.29	4.98	31.3	33.9	28.3	15.6
Nd	32.6	11.2	15.3	24.7	121	129	94.8	55.5
Sm	8.68	3.02	4.46	6.3	23.3	22.4	15.2	8.4
Eu	2.74	1.05	1.71	1.67	5.37	5.07	1.49	1.56
Gd	8.6	2.91	5.14	6.58	17.9	16.6	9.9	5.7
Tb	1.39	0.44	0.95	1.19	2.3	2.2	0.9	0.8
Dy	7.67	2.47	6.02	7.17	12.1	11.6	4.1	3.7
Ho	1.46	0.47	1.24	1.43	2.3	2.1	0.6	0.6
Er	4.19	1.3	3.56	4.06	6.4	5.3	1.5	1.7
Tm	0.569	0.172	0.529	0.588	0.88	0.75	0.17	0.2
Yb	3.32	0.95	3.4	3.84	5	4.7	0.9	1.1
Lu	0.463	0.13	0.54	0.589	0.7	0.68	0.12	0.15
Hf	6.5	2.3	2.7	5	12.5	10.4	13.2	12.6
Ta	1.49	0.63	0.26	0.57	1.8	1.5	0.5	0.7
W	1.6	2.1	6.3	1.6	<1	<1	<1	<1
Tl	0.52	0.08	<0.05	0.28	0.7	0.3	0.9	1.1
Pb	9	8	<5	6	31	27	18	20
Th	1.23	1.23	1.31	2.26	6.8	6.8	30	15.9
U	1.11	1.03	0.64	0.87	1.2	0.9	2.1	1.6
La/Yb	5.45	8.64	2.6	3	24.8	26.2	144.44	71.91

104-07-204-2 Notigi assemblage
104-07-378-1C Notigi assemblage
12-06-162-4 Notigi assemblage-layered amphibolite (Murphy and Zwanzig, 2007)
12-06-162-3 Notigi assemblage -layered calcsilicate (Murphy and Zwanzig, 2007)
104-07-121-2 Black Trout diorite
12-06-160-1 Black Trout diorite (Murphy and Zwanzig, 2007)
104-07-017 Granodiorite
104-07-085-2 Granodiorite
Major elements in weight percent, trace elements in ppm.

Ti anomaly. Trace-element characteristics of two carbonate-bearing samples collected from the Notigi assemblage in the southern portion of Notigi Lake show similar subparallel negative slopes that indicate fractionation to enrichment alteration trends (Figure GS-5-5b). The Th spike in both samples is likely due to contamination by small quartz veins in the rock. A mid-ocean-ridge-basalt (N-MORB)–normalized plot of the Notigi assemblage indicates that the samples are similar in composition to the field of 1.9 Ga ocean-island basalt from the Flin Flon Belt (Syme et al., 1999). Neodymium-isotope data indicate a juvenile source for the Notigi assemblage, with an ε_{Nd} value of 2.4 at 1.9 Ga (Table GS-5-2).

Whole-rock major- and trace-element analysis was carried out by Activation Laboratories Ltd., in Ancaster, Ontario, using methods described by Gilbert and Bailes (2005), and Nd-isotope data were provided by the University of Alberta.

Burntwood Group

The Burntwood Group at Notigi Lake, as in the Kisseynew Domain, is composed of originally psammitic and pelitic (greywacke-mudstone) turbidite layers (Bailes, 1980; Zwanzig, 1990). Throughout Notigi Lake the nature of exposed contacts between the Burntwood and Sickle groups varies from interleaved to gradational to faulted. The interbedded greywacke and mudstone have undergone progressive migmatization to mostly metatexite (10–15% leucosome) and local diatexite (up to 90% leucosome). A previous report has described in detail the

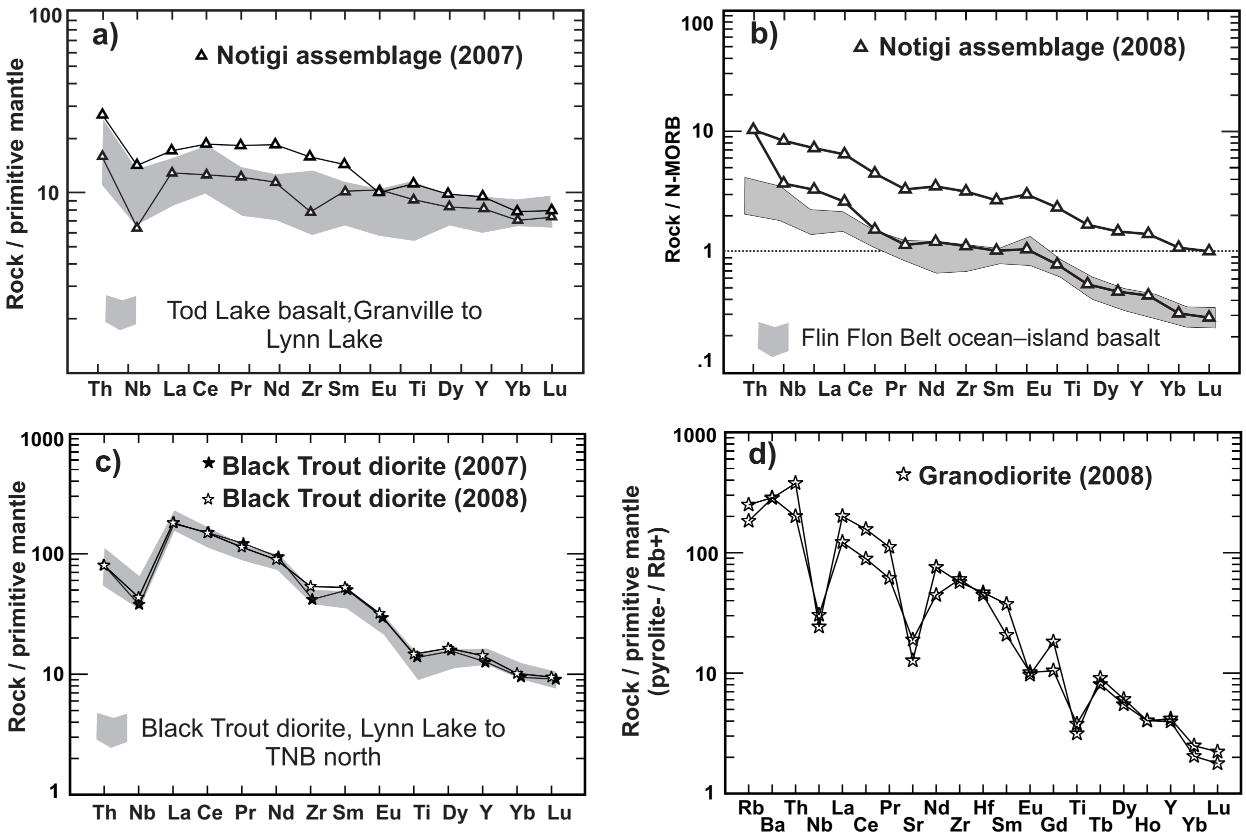


***Figure GS-5-5**: Multi-element plots of selected samples from the Notigi Lake area, normalized by primitive mantle and N-MORB: **a)** Notigi assemblage (2007 data), also showing the field of Tod Lake basalt; **b)** Notigi assemblage (2008 data), also showing the field of ocean-island basalt (Flin Flon Belt); **c)** Black Trout diorite (2007 and 2008 data), also showing the field of Black Trout diorite (Lynn Lake to TNB north); **d)** granodiorite.*

Table GS-5-2: Sm-Nd–analysis data from the Notigi Lake area, northeastern Kisseynew Domain[1].

Sample	104-07-378-1C	104-07-121-2	104-07-085-2
Rock type	Notigi assemblage	Black Trout diorite	Granodiorite
Easting[2]	486568	480721	476766
Northing[2]	6201672	6198490	6191648
Sm (ppm)	2.617	22.69	7.069
Nd (ppm)	10.81	139.23	47.67
147Sm/144Nd	0.1464	0.0985	0.0897
143Nd/144Nd	0.512129	0.511202	0.511419
Uncertainty (±2σ)	0.000008	0.000008	0.000007
Tdm	N/A	2.58	2.13
~Tma	1900	1900	1900
εNdT	2.4	-4.1	2.3
145Nd/144Nd	0.348381	0.348387	0.348390

[1] Analysis performed at the Radiogenic Isotope Facility, University of Alberta, Edmonton, Alberta
[2] Zone 14 (NAD 83)

garnet-biotite migmatite, rare silicate-facies iron formation and biotite schist of the Burntwood Group at Notigi Lake (Murphy and Zwanzig, 2007). An anomalous sillimanite-bearing leucosome occurs in Burntwood Group migmatite north of Notigi Lake along the Rat River and in rare exposures in the southernmost bays of Notigi Lake. The leucosome is mostly grey, white and pink and forms up to 30% of the outcrop in thin sheets, 3 cm to 1 m wide, that contain up to 3% oval sillimanite-quartz faserkiesel 1 cm in length (Figure GS-5-6a). The faserkiesel, restricted to the Rat River area, also appear in nearby leucogranite. The sillimanite-bearing leucosome is interpreted as deriving from originally more arkosic or pelitic sediment deposited within the Burntwood Group turbidites.

Garnet-bearing siliceous gneiss

Garnet-bearing siliceous gneiss is exposed in thin layers in the southern bays of Notigi Lake and in one location along the northeast shoreline. The unit is most easily traced at the southern limit of Notigi Lake where its apparent offset indicates the presence of a sinistral fault. The unit is clear grey to pink and forms distinct straight gneiss layers up to 30 m wide within the Burntwood Group. The rock is very hard and contains up to 5% rounded garnets less than 2 mm within quartz-rich layers and thin pink leucosome (Figure GS-5-6b). The garnet-bearing siliceous gneiss is interpreted as deriving from fine-grained quartz-rich sandy beds.

Sickle Group

The Sickle Group rocks are derived from shallow-water deposits of lithic arenite and arkose (Milligan, 1960). The rocks consist of layered quartzofeldspathic magnetite-bearing paragneiss that contains up to 20% pink and/or white granitic leucosome. Units in the Sickle Group were mapped using distinct compositional changes defined by the presence or absence of hornblende or sillimanite. These units appear gradational and are interpreted as stratigraphic. Along the southeastern shoreline of Notigi Lake, the Sickle Group units occur above the Notigi assemblage in the following order: 1) basal biotite gneiss, 2) hornblende-biotite gneiss, 3) generally more

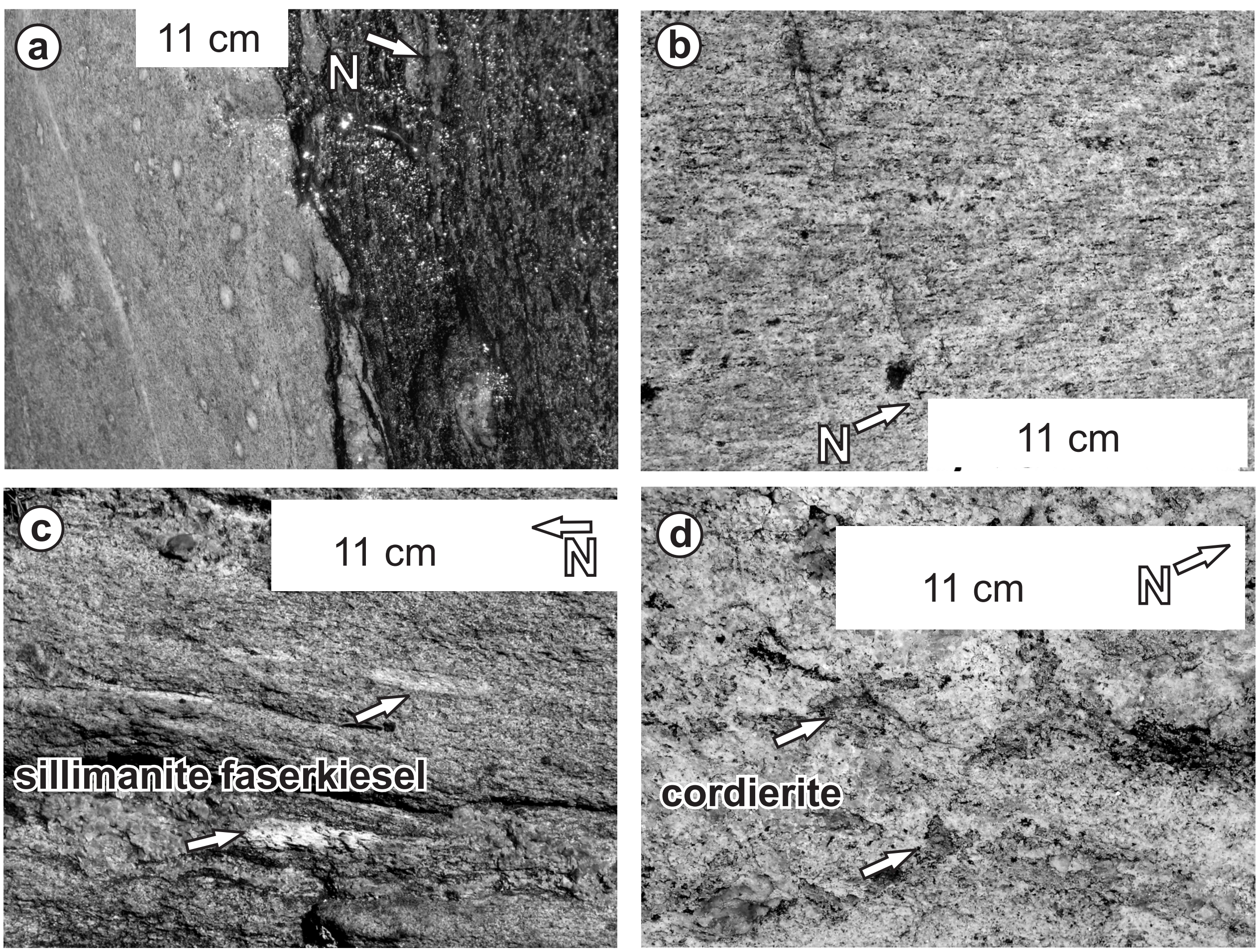


***Figure GS-5-6:** Outcrop photographs of characteristic features of the Burntwood and Sickle groups: **a)** sillimanite-bearing leucosome in Burntwood migmatite, **b)** garnet-rich siliceous gneiss interpreted as deriving from quartz-rich sandy beds in the Burntwood Group; **c)** coarse grained sillimanite-bearing paragneiss in the Sickle Group proximal to the Notigi assemblage; **d)** cordierite-bearing sillimanite diatexite from the Sickle Group showing uniform texture.*

siliceous upper biotite gneiss and 4) sillimanite-bearing arkosic gneiss that may form the uppermost unit. Detailed mapping has revealed the presence of a local sillimanite-bearing unit possibly belonging to the Sickle Group, that is interpreted as stratigraphically overlying amphibolite of the Notigi assemblage. In addition, a unit of cordierite-sillimanite–bearing diatexite occurs close to the Notigi assemblage, along a northern peninsula and along the easternmost part of Notigi Lake. On the east side of the Notigi structure, the Sickle Group units appear in the following order: 1) sillimanite-bearing gneiss, 2) biotite-bearing gneiss, 3) hornblende-biotite gneiss and 4) biotite gneiss. The latter succession may be interpreted as being the result of isoclinal F_1 folding above a fault that cuts out much of the section. Alternatively, the most easterly sillimanite-bearing unit may represent the base of the section that grades laterally into rocks containing no sillimanite. Local variations in the composition of the lowest unit in the Sickle Group are also described in Zwanzig (GS-4, this volume).

Sillimanite-bearing gneiss

The sillimanite-bearing paragneiss was previously described as being most abundant in the central to northern part of the map area and interpreted as the uppermost unit of the Sickle Group (Murphy and Zwanzig, 2007). The sillimanite-quartz faserkiesel vary in abundance (>2%, average of 5% of mineral content) and size (1–5 cm in length). Larger faserkiesel are found next to garnet-bearing gneiss greater than 1 m wide of uncertain affinity that is in shear contact with the Notigi assemblage (Figure GS-5-6c). On the southeastern side of the Notigi structure, up to 750 m of sillimanite-bearing gneiss are sporadically exposed across strike and can be traced for more than 6 km along strike (Figure GS-5-2).

Cordierite-sillimanite diatexite

Cordierite-sillimanite diatexite forms thin rafts and schlieren between the biotite and sillimanite paragneiss. The unit is found in several locations, proximal to the Notigi assemblage north of Timew Narrows, within the biotite paragneiss along a northern peninsula and within sillimanite paragneiss along the easternmost part of the map area. Cordierite-sillimanite diatexite is light grey to buff to pink and appears uniform with layering defined by prominent sillimanite knots up to 3 cm in length and cordierite aggregates about 1 cm in size (Figure GS-5-6d). This unit is interpreted as a progression from metatexite to diatexite in the sillimanite- and biotite-bearing paragneiss, possibly due to partial melting induced by the intrusion of the Notigi granite into the Sickle Group rocks.

Intrusive rocks

Gabbronorite–leucogabbro

The gabbroic rocks at Notigi Lake underlie the Notigi assemblage and are interpreted as sills related to the original flows that were transposed into the layered amphibolite. Further geochemical and petrological work will test this theory. Only south of Timew Narrows is gabbro bounded by the Sickle Group rocks, but there is evidence of early faulting that may have caused this juxtaposition. Compared to the amphibolite in the Notigi assemblage, the gabbro has a more uniform appearance and does not exhibit well-defined layering. In places, the base of the strained gabbro grades into tightly layered amphibolite (Figure GS-5-3). The gabbro unit north of Timew Narrows is in shear contact (Figure GS-5-7a) with, and locally folded into, an east-plunging synformal pair with Burntwood migmatite (Figure GS-5-7b). The contact of gabbro with sillimanite-bearing gneiss is locally faulted and commonly intruded by pegmatite.

Two exposures of dark green to black layered mafic rocks have been described by Murphy and Zwanzig, (2007). These rocks are exposed in several localities including west of the Rat River along the north shore, south of Timew Narrows, south of the Notigi granite and along the northeastern peninsulas on the northern shore of Notigi Lake (Figure GS-5-2). Recent focused mapping has indicated that these mafic rocks form exposures up to 70 m wide and range in mineral composition from gabbronorite to melagabbro to leucogabbro. Secondary weak layering is defined by leucosome lenses that are folded in places (Figure GS-5-7c). At the base of the gabbronorite, a biotite-rich and/or garnet±plagioclase rock unit about 1 to 2 m thick may be a contact unit or an alteration product. The gabbronorite contains altered orthopyroxene (possibly bastite after enstatite), hornblende and plagioclase with orthopyroxene-bearing leucosome (Figure GS-5-7d). The melagabbro contains altered orthopyroxene (possibly to phlogopite) and clinopyroxene (Figure GS-5-7e). The gabbro contains hornblende, plagioclase, diopside with lesser orthopyroxene and diopside-bearing neosome (Figure GS-5-7f).

Monzodiorite

Monzodiorite intrudes the Sickle Group rocks on the western side of the Rat River channel and south of Timew Narrows. Whole-rock major- and trace-element analysis data show that the monzodiorite has a geochemistry that is transitional to alkaline and is characterized by high contents of K_2O, Na_2O, P_2O_5, MgO and TiO_2, with a high La/Yb ratio (Table GS-5-1). A comparative primitive-mantle–normalized multi-element plot shows that the monzodiorite has trace-element characteristics similar to those of the type Black Trout diorite (Figure GS-5-5c). Neodymium -isotope results indicate an older crustal source for the Black Trout diorite with a negative ε_{Nd} value (-4.1) at 1.9 Ga and a Nd-model age of 2.58 Ga (Table GS-5-2).

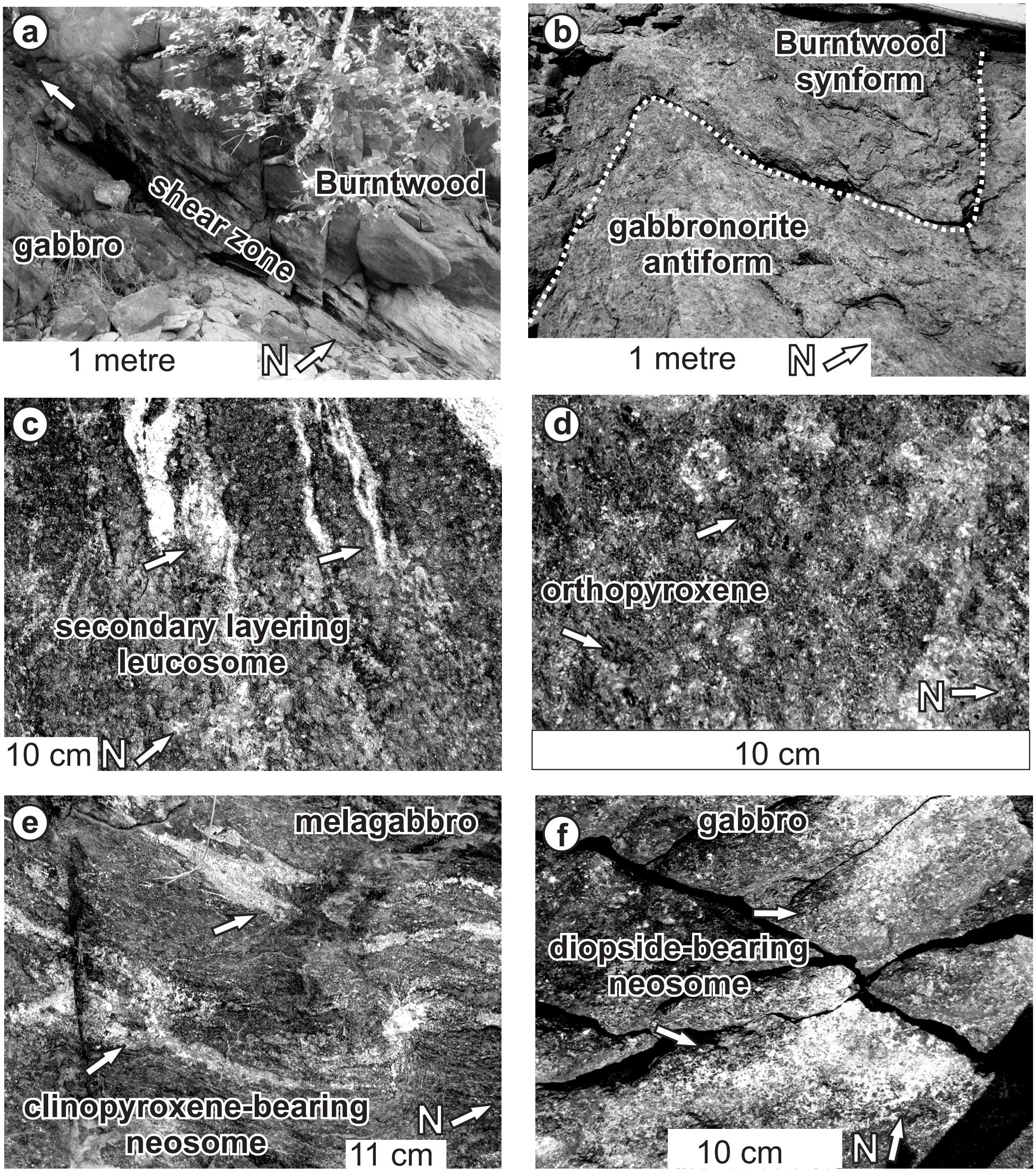


***Figure GS-5-7** Outcrop photos of mafic intrusive rocks in the Notigi Lake area: **a)** gabbro in shear contact with Burntwood Group; **b)** gabbronorite (antiform) and Burntwood Group metasedimentary rocks (synform); **c)** secondary layering exhibited by leucosome in gabbronorite; **d)** gabbronorite with orthopyroxene pseudomorphs; **e)** clinopyroxene in melagabbro; **f)** diopside-bearing neosome in gabbro.*

Granodiorite and sillimanite-bearing leucogranite

Granodiorite and porphyry sheets intrude the Burntwood Group at the southern end of Notigi Lake. Whole-rock major- and trace-element geochemistry data indicate that these felsic intrusive rocks are of typical granitic composition containing relatively high SiO_2 and Al_2O_3 (Table GS-5-1). A primitive-mantle–normalized multi-element plot of the granodiorite exhibits negative Nb, Sr, Ti, Yb and Lu and a highly fractionated trend. The depletion of heavy REEs (Yb and Lu) was likely caused by the loss of Fe due to the presence of garnet (Figure GS-5-5d). Nd-isotope results indicate a juvenile source for the granodiorite with a Nd-model age of 2.1 Ga (Table GS-5-2).

A unit of sillimanite-bearing leucogranite not found elsewhere at Notigi Lake intruded Burntwood Group migmatite along the Rat River north of Notigi Lake. This light grey, quartz- and plagioclase-rich unit contains up to 2% sillimanite-quartz faserkiesel. Granite at that locality may have assimilated pelite from the Burntwood Group.

Discussion and economic considerations

Updated geological maps provide a modern structural context for future mineral exploration of the area along the northern flank of the Kisseynew Domain. Recent investigations at Notigi Lake indicate that the entire tectonostratigraphic package at Notigi Lake has undergone an extreme attenuation and large-scale isoclinal folding in the north and northeastern parts of the Kisseynew Domain. The early isoclinal folding caused repetition of the stratigraphic sequences in a vertical stack that was later involved in reclined folding and doming. This structural style is characteristic of the poorly exposed narrow belts of Archean orthogneiss with a supracrustal cover that may host Thompson-type nickel deposits found south of Notigi Lake. The inferred, strongly layered crustal structure of the northeastern part of the Kisseynew Domain appears to be similar in style to the Notigi structure and shares much of its deformation history with the more prospective rocks directly to the southeast. The best preserved units of such rocks, and possible nickel deposits, may be in the hinge zones of F_2 recumbent folds brought to surface by F_3 crossfolds.

A comparison of geochemical plots shows that rocks from the Notigi assemblage may be related to the Tod Lake basalt at Granville Lake (Zwanzig, GS-4, this volume) and juvenile ocean-island basalt (Flin Flon Belt). The presence of small gold showings in similar rock at Granville Lake make the correlative layered volcano-sedimentary assemblage at Notigi Lake and in adjoining areas possible exploration targets. This widely regional association is tentative and remains the focus of continued research. Traces of malachite staining in the Sickle Group arkosic rocks may indicate a sedimentary copper origin similar to that of more significant showings at Russell Lake (Baldwin, 1980).

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