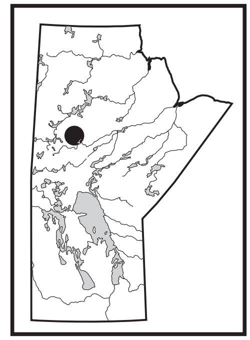
GS-5 Preliminary stratigraphy and structure of the Notigi Lake area, Manitoba (parts of NTS 63O14, 64B3)

by L.A. Murphy and H.V. Zwanzig



Murphy, L.A and Zwanzig, H.V. 2007: Preliminary stratigraphy and structure of the Notigi Lake area, Manitoba (parts of NTS 63O14, 64B3); *in* Report of Activities 2007, Manitoba Science, Technology, Energy and Mines, Manitoba Geological Survey, p. 51–62.

Summary

The Notigi Lake area is an example of the stratigraphic and structural geology typical of the north flank of the Kisseynew Domain. It includes clean exposures of the Paleoproterozoic Burntwood and Sickle groups, as well as an amphibolite unit that is herein reinterpreted as metavolcanic and marking a regional crustal suture proposed by White et al. (2000). The updating of previous geological investigations, which involves subdividing the Sickle Group and taking new structural measurements, provides new details of the structural geometry and tectonic history of this important area. Interpretation of the field data compiled during the summer of 2007 delineates four stratigraphic units in the Sickle Group at Notigi Lake. This is based on the presence of certain metamorphic minerals that denote the compositions of arkose- and lithic arenite–derived gneiss. The structure is tentatively interpreted as a small refolded nappe, which may serve as a model for the crustal-scale structure that appears to feature recumbent isoclinal folding and upright refolding. With further work, this model may help to determine the three-dimensional distribution of 1) the amphibolite, which is gold bearing elsewhere; 2) newly discovered iron formation in the Burntwood Group; 3) traces of copper (malachite staining) in the Sickle Group; and 4) older gneiss southeast of Notigi Lake with nickel potential.

Introduction

The eastern part of the north flank of the Kisseynew Domain (Zwanzig, 1990) was mapped in the early 1970s and published mainly as a set of 1:50 000 scale geological maps (Baldwin et al., 1979). However, despite this mapping, the structure, stratigraphy and mineral potential of this part of the Kisseynew Domain have remained poorly understood. In addition, recent work in this area has found hitherto unknown Archean orthogneiss and associated paragneiss with Archean provenance, and economic potential that may be similar to that of rocks in the Thompson Nickel Belt (TNB; Percival et al., 2006; Zwanzig et al., 2006).

Notigi Lake is located approximately 100 km west of Thompson along Provincial Highway 391, and along strike from areas that contain rocks now known to be of Archean age or provenance. During the summer of 2007, an area measuring 7 km by 25 km was remapped at 1:20 000 scale. The mapping concentrated on clean shoreline exposures along the eastern part of Notigi Lake (Murphy and Zwanzig, 2007). The work was undertaken to delineate stratigraphic units in detail and to start a structural interpretation that, after further work, will cover a total of about 350 km^2 (Figure GS-5-1).

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) and was completed during the Burntwood Project (Baldwin et al., 1979). Mapping of the Notigi Lake area (Figure GS-5-2) was carried out by Frohlinger in 1971 and 1973 (Frohlinger, 1979). The emphasis during the Burntwood Project was to distinguish and map the pelitic to psammitic gneiss (present 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 Archean rock identified.

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. Notigi Lake was flooded to its present level and, in the process, new clean shoreline exposures were developed. The present project captures structural data and geological contacts from the original Burntwood Project mapping, which was undertaken on pre-flooding shoreline outcrops, and combines this information with remapping of the Sickle Group and adjacent parts of the Burntwood Group at the present lake level.

This project has been undertaken in collaboration with the Geological Survey of Canada as part of the Targeted Geoscience Initiative III (TGI-3) Flin Flon Project (Percival et al., 2006; Percival et al., GS-7, 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 north flank of the Kisseynew Domain. Future work and interpretation will involve additional mapping (2008), as well as geochemical and isotopic analysis of the granitoid intrusions, amphibolite and sedimentary rocks. A new aeromagnetic survey (Coyle, pers. comm., 2007), which will be available by next field season, will provide additional data to assist mapping.

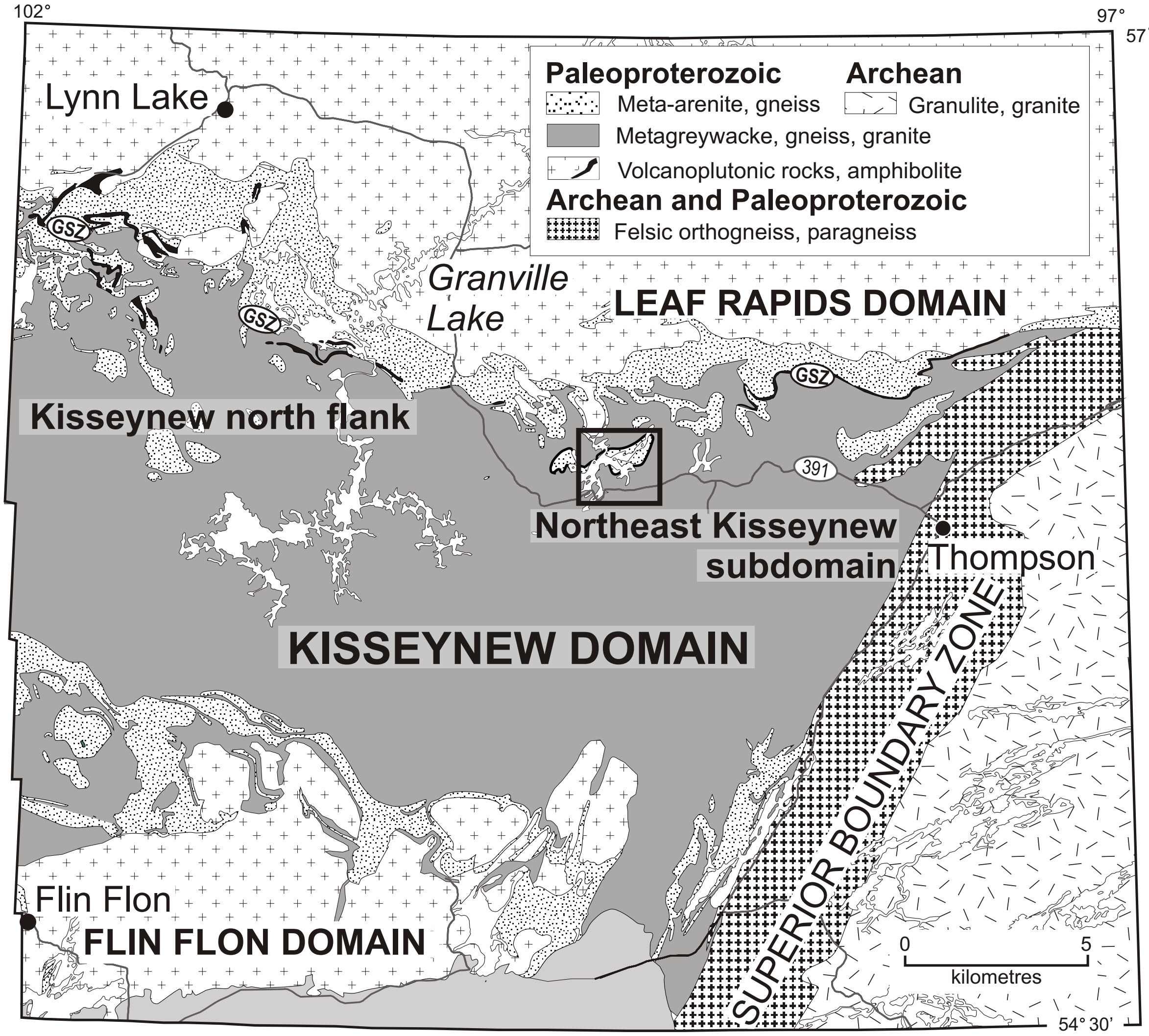


Figure GS-5-1: *Simplified geology of the northeastern Kisseynew Domain, showing the project location.*

Regional setting

The north flank of the Kisseynew Domain is dominated by high-grade metasedimentary rocks and migmatite of the Burntwood and Sickle groups, generally with a thin intervening unit of amphibolite. Burntwood Group rocks are derived from greywacke, siltstone and mudstone deposited by turbidity currents (Bailes, 1980; Zwanzig, 1990), and the Sickle Group rocks from lithic arenite and arkose deposited in a shallow-water environment (Milligan, 1960). The amphibolite is derived from mafic volcanic rocks (Tod Lake basalt) and associated mafic intrusive rocks. This mafic assemblage is better preserved at Granville Lake and the southwest end of the Lynn Lake belt (Figure GS-5-1), where it is interpreted to have formed during an episode of arc-rifting and back-arc magmatism at about 1.9 Ga (Zwanzig et al., 1999). Where primary structures are preserved, the mafic assemblage is seen to be unconformably overlain by the ca. 1.84 Ga Sickle Group, and this relationship is assumed to hold for the more highly deformed amphibolite and meta-arenite along the entire north flank of the Kisseynew Domain, including the Notigi Lake area. This assumption infers a thrust fault between the amphibolite and underlying younger (ca. 1.85 Ga) Burntwood Group, and is discussed in more detail in a later section.

Recent reconnaissance and local mapping, geochemistry, geochronology and Nd-isotope work in an area extending from southeast of Notigi Lake to the TNB has revealed the existence of narrow belts of Archean gneiss with a thin supracrustal succession similar to the Ospwagan Group, which hosts the deposits in the TNB (Percival et al., 2005, 2006; Zwanzig et al., 2006). The origin, structure and extent of these older rocks in the predominantly greywacke-derived migmatite of the northeastern Kisseynew Domain are still poorly understood. The structural style of the Notigi Lake area, with its better known tectonostratigraphy, may serve as a guide for determining the structural style and three-dimensional extent of the older, economically promising rocks.

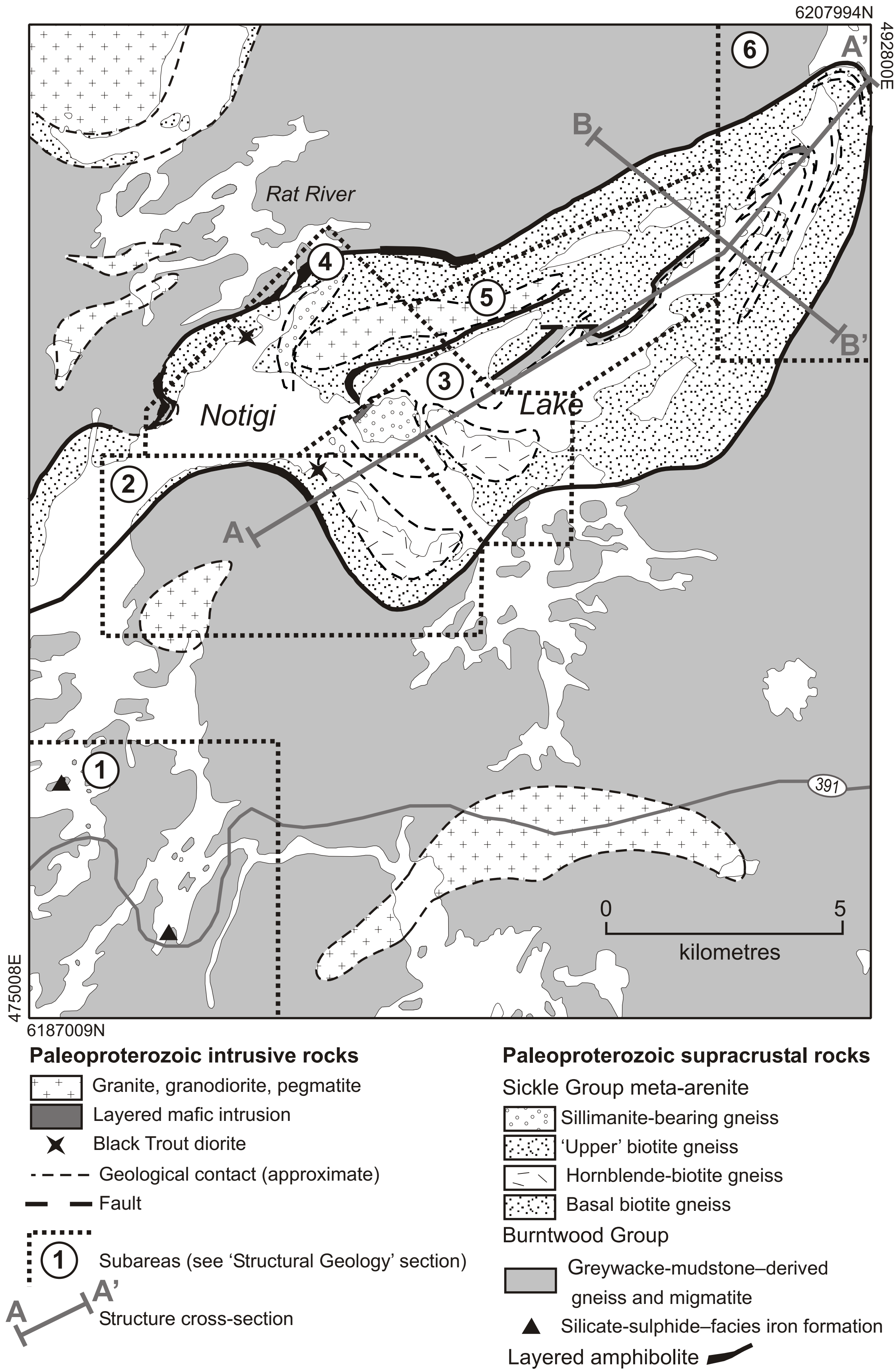


Figure GS-5-2*: Updated map of the Notigi Lake area, incorporating data from Frohlinger (1979) with recent hydrology and geology from fieldwork in 2007. Subareas mentioned in the ‘Structural geology’ section are indicated by dashed lines.*

Geological units

The main supracrustal units at Notigi Lake are 1) layered amphibolite with local calcsilicate rock; 2) the Burntwood Group migmatite, derived from greywacke-mudstone with minor iron formation; and 3) quartzofeldspathic paragneiss of the Sickle Group. The stratigraphic order of these units cannot be determined in the study area, but the structural order is the same as in the regional setting and, by correlation, is inferred to be Burntwood Group–fault–amphibolite–unconformity–Sickle Group. The amphibolite is inferred to be the oldest unit, and the Sickle Group the youngest. No depositional or early fault contacts between the major units are preserved at Notigi Lake.

Subunits in the Sickle Group were mapped using distinct compositional changes defined by their dominant mineralogy. Subunit contacts are gradational and are interpreted to be stratigraphic. These subunits generally appear adjacent to (stratigraphically above) the amphibolite in the following order: 1) basal biotite gneiss; 2) hornblende-biotite gneiss; 3) generally more silicic biotite gneiss that is probably stratigraphically higher in the succession; and 4) sillimanite-bearing arkosic gneiss of uncertain stratigraphic position but most likely forming the uppermost subunit. This lithological assemblage is not consistent because of structural influences. For example, hornblende-biotite gneiss may not appear in the sequence and, in places, sillimanite-bearing gneiss is found at the base along the layered amphibolite and is succeeded by biotite gneiss followed by biotite-hornblende gneiss. Both biotite units are similar in composition and appearance. At one locality, the basal biotite gneiss contains a hematite-bearing meta-arkose that does not repeat elsewhere and is therefore included with the biotite gneiss.

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 amphibolite

Layered amphibolite, up to 20 m wide, lies between the Burntwood greywacke-mudstone and the Sickle arkose-arenite. The amphibolite consists of uniform layers that can grade into discontinuous pods and lenses (Figure GS-5-3a). The mineral content reflects the layering and includes hornblende, plagioclase, orthopyroxene, clinopyroxene and, locally, magnetite, biotite and siliceous carbonate matrix. The layers are dark grey-green to black where the dominant minerals are hornblende-plagioclase, and medium grey-green where dominated by diopside-pyroxene-plagioclase. Siliceous calcsilicate layers are pale green to white. Diopside layers are interpreted as structurally transposed high-grade metamorphic products of epidosite ocean-floor alteration domains, and carbonate in more intense alteration.

In the core of the Notigi structure is a body of layered hornblende-gabbro, with 1 m wide, less mafic layers that contain 60% plagioclase and 40% hornblende and sparse hornblende-rich layers with diopside lenses. The presence of carbonate cement and diopside lenses suggests that this narrow body may be related to the main amphibolite unit, which occurs along strike.

Whole-rock major- and trace-element analysis on a sample of relatively unaltered-looking dark green amphibolite (Table GS-5-1) suggests derivation from a mafic rock similar to the Tod Lake arc-rift basalt. The Tod Lake basalt occurs in the western part of the Kisseynew Domain north flank on the southwest end of the 1.9 Ga volcanic rocks of the Lynn Lake belt (Zwanzig, et al., 1999; Zwanzig, 2000). The arc affinity of Notigi Lake amphibolite is illustrated in a normal mid-ocean-ridge basalt (N-MORB)–normalized multi-element plot by negative Nb and Zr anomalies and a Th spike (Figure GS-5-4). The rift affinity is suggested by its weak fractionation of rare earth elements (REE) and lack of negative Ti anomaly.

Burntwood Group

The Burntwood Group is composed of mostly medium and dark grey, psammitic and pelitic (greywacke-mudstone) layers and lesser concordant iron formation. The contact between rocks of the Burntwood Group and the amphibolite is not directly exposed at Notigi Lake, except along a late fault (Figure GS-5-3b). Biotite schist occurs along shear contacts with a mafic intrusion and the layered amphibolite

Greywacke-mudstone migmatite

All Burntwood Group greywacke and mudstone (Figure GS-5-3c) have undergone high-grade metamorphism and various degrees of migmatization. White leucosome is usually 10–15% of the rock, but can range from 5 to 90%. Progressive melting and injection resulted in metatexite with well-developed *lit-par-lit* layering and more uniform coarser diatexite. Late-stage pegmatite and granitic injections have contributed to the migmatitic layering in some places. The mineral content of the Burntwood Group greywacke-mudstone includes garnet, biotite, cordierite, tourmaline and locally orthopyroxene. Graphite is identified locally. Small 0.5 cm diameter garnets occur ubiquitously in psammite, and larger garnets (up to 2 cm) occur in the pelite. Retrograde metamorphism has, in places, reduced tourmaline to chlorite, pinitized cordierite and partly chloritized the garnet.

Iron formation

Lean silicate-facies iron formation is found in two locations at the south end of Notigi Lake. The units are grey to brown, contain rusty patches and are slightly darker than the surrounding Burntwood greywacke, with which they are locally intercalated. They display similar layering to the greywacke or can form concordant pods

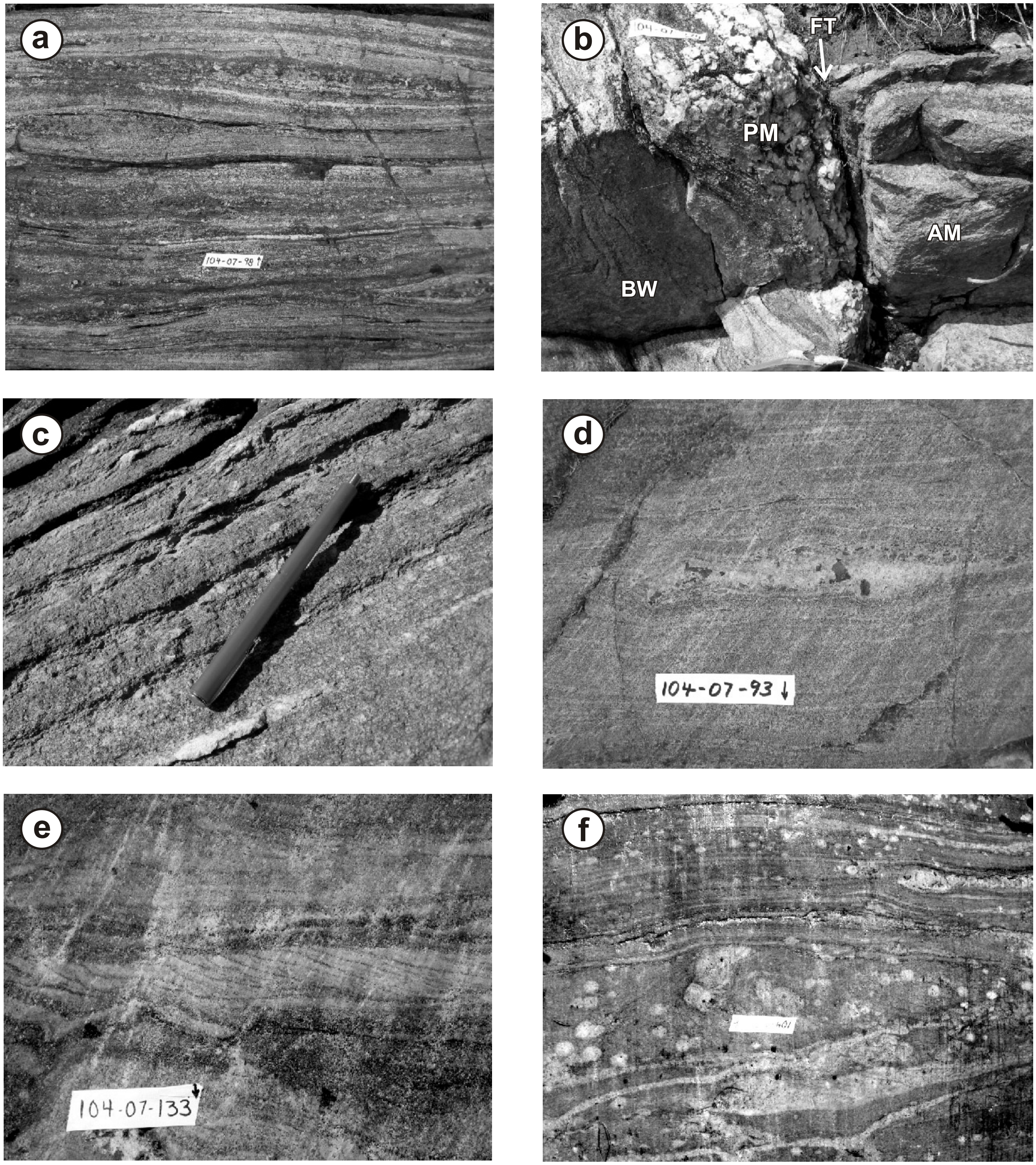


Figure GS-5-3: *Characteristic features of the major units, Notigi Lake area:* ***a)*** *amphibolite with darker hornblende-rich and lighter diopside-plagioclase–rich layers, similar to recrystallized mafic tectonite that can be traced into pillow basalt northeast of the study area;* ***b)*** *pegmatite (PM) along late fault-contact (FT) between the Burntwood Group (BW) and the layered amphibolite (AM);* ***c)*** *Burntwood Group with 2 cm layers of semipelitic gneiss alternating with 1 cm layers of veined pelitic gneiss, interpreted to be derived from turbiditic Bouma divisions of greywacke to mudstone, also with thicker metagreywacke bed (lower right), probably attenuated in the order of 20% of original thickness;* ***d)*** *laminated hornblende gneiss derived from thin-bedded arenite with hornblende blasts in lens of leucosome;* ***e)*** *remnant crossbedding of pro-toquartzite in biotite gneiss (arenite) at margin of sillimanite-bearing unit;* ***f)*** *quartz-sillimanite faserkiesel (light ovals) in arkose gneiss. Tape is 9–10 cm long and pencil magnet 12 cm long.*

Table GS-5-1: Whole-rock major- and trace-element analyses of layered amphibolite (hornblende-plagioclase layer), calcsilicate gneiss (probably altered layered amphibolite) and monzodiorite (Black Trout diorite), Notigi Lake area.

	Sample (12-06-)		
	162-4	162-3	160-1
	%	%	%
SiO_2	47.3	48.2	49.8
Al_2O_3	12.70	13.28	12.82
Fe_2O_3	13.50	4.98	14.41
MnO	0.23	0.15	0.20
MgO	3.54	1.52	4.34
CaO	14.87	18.23	7.38
Na_2O	2.25	1.14	2.49
K_2O	0.32	3.81	2.30
TiO_2	1.94	2.41	3.01
P_2O_5	0.33	0.40	2.20
LOI	1.87	4.90	0.29
Total	98.83	99.03	99.21
	ppm	ppm	ppm
Sc	42	36	27
Be	2.0	2.0	2.0
V	468	411	264
Cr	<20	<20	<20
Co	38	42	32
Ni	20	30	20
Cu	300	10	20
Zn	110	90	80
Ga	21	24	24
Ge	1.1	0.9	1.0
Rb	4	49	57
Sr	220	180	549
Y	36.5	42.9	58.0
Zr	86	175	473
Nb	4.5	10	27

	Sample (12-06-)		
	162-4	162-3	160-1
	ppm	ppm	ppm
Sn	1	2	2
Sb	< 0.2	5.8	0.9
Cs	< 0.1	0.9	1.1
Ba	220	541	1575
La	8.72	11.6	123
Ce	22	32.6	267
Pr	3.29	4.98	33.9
Nd	15.3	24.7	129
Sm	4.46	6.3	22.4
Eu	1.71	1.67	5.07
Gd	5.14	6.58	16.6
Tb	0.95	1.19	2.20
Dy	6.02	7.17	11.6
Ho	1.24	1.43	2.10
Er	3.56	4.06	5.30
Tm	0.529	0.588	0.75
Yb	3.40	3.84	4.70
Lu	0.537	0.585	0.68
Hf	2.7	5.0	10.4
Ta	0.26	0.57	1.50
W	6.3	1.6	< 1
Tl	< 0.05	0.28	0.3
Pb	< 5	6	27
Th	1.31	2.26	6.8
U	0.64	0.87	0.90
La/Yb	2.6	3.0	26.2

12-06-162-4: layered amphibolite

12-06-162-3: layered calcsilicate

12-06-160-1: Black Trout diorite

1.5 m in width. The mineralogy of the iron formation indicates alternating greywacke layers, cherty layers and layers laminated with pyrrhotite, magnetite and rare chalcopyrite.

Biotite schist

Biotite schist occurs almost exclusively along the sheared contact between the Burntwood greywacke and the layered amphibolite. The unit is grey-brown to black and, along with the dominant biotite, may contain very small, sparse garnets, muscovite and magnetite. The rock is interpreted as a recrystallized shear zone.

Sickle Group

The Sickle Group is composed of quartzofeldspathic paragneiss generally containing magnetite. Much of the Sickle Group, particularly the biotite gneiss, is relatively massive with no migmatitic layering. Locally, the biotite- and sillimanite-bearing gneiss can exhibit thin pink or white layers of granitic leucosome. Thicker sheets of granite occur locally. The different styles of migmatite in the Sickle and the Burntwood groups reflect their difference in composition, the thickness of original beds and the more massive structure of the arenite.

Basal biotite gneiss

The basal arenite-derived biotite gneiss varies in weathering colour from light to medium grey and brown to reddish brown and can rarely have up to 60% pink to reddish leucosome. The unit varies in appearance from a

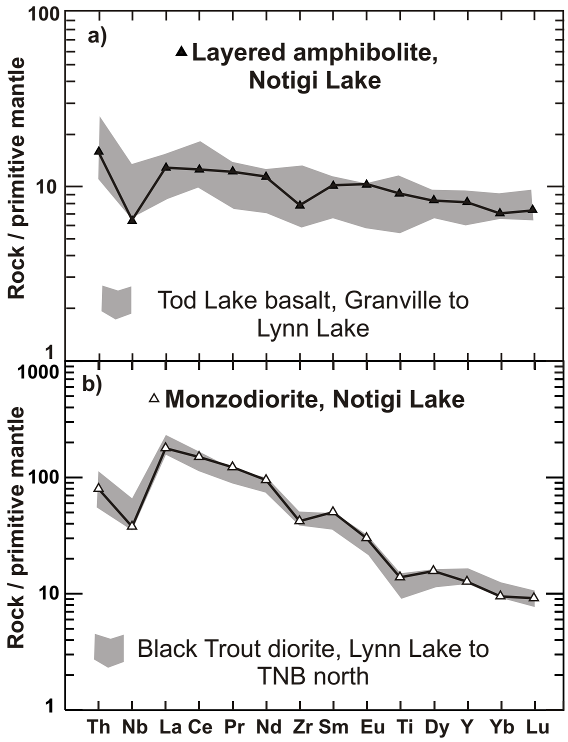


***Figure GS-5-4:** Multi-element plots of rocks from the Notigi Lake area, normalized by primitive mantle: **a)** layered amphibolite, also showing the field of Tod Lake basalt; and **b)** monzodiorite, also showing the field of Black Trout diorite.*

very fine grained and uniform arenite to thin-bedded (at centimetre scale). coarser grained, more felsic paragneiss. It can be sheared and present as biotite-rich rafts of restite within pegmatitic granite.

The mineral content of the basal biotite gneiss includes quartz, feldspar and magnetite, with local cordierite, tourmaline, garnet, epidote, diopside, muscovite, sillimanite, hematite and rare malachite. Magnetite is moderately abundant (up to 10%) as subhedral crystals that range up to 3 cm and can occur in 10 cm clusters that may have formed, in part, from original placers. In places, the basal biotite gneiss is coarsely recrystallized near granitic intrusions.

The unit can be interleaved with magnetite-free garnet-biotite gneiss, possibly derived from greywacke. More commonly, it is interlayered with hornblende-biotite gneiss. The lower part of the basal biotite gneiss may contain garnet and sillimanite and is locally sheared. The faserkiesel in the lower section are composed mainly of plagioclase rimming magnetite cores up to 3 mm wide. Retrograde metamorphism is locally present in the sheared rocks and manifest as chloritization of biotite and muscovite replacement of sillimanite.

Hornblende-biotite gneiss

The hornblende-biotite–bearing arenite weathers greenish grey to pink. Massive grey varieties, which are locally laminated with a green and pink mesosome, generally contain up to 15% pink leucosome. The mineral content of the hornblende-biotite gneiss includes quartz, feldspar, diopside, tourmaline and magnetite, although generally less magnetite than the other subunits. Amphibole is present in both mesosome and leucosome (Figure GS-5-3d). Diopside is enriched in certain layers and in cores of hornblende-rich lenses that occur sporadically in the leucosome.

Hornblende-biotite gneiss is everywhere interlayered with hornblende-free biotite gneiss. Uniform layers of hornblende biotite gneiss are up to 2 m wide and tend to be fine grained. Coarser arkosic gneiss, by contrast, is thinly bedded (0.5–10 cm).

'Upper' biotite gneiss

The biotite arenite gneiss that lies closer to the centre of the Notigi structure ('upper' biotite gneiss) weathers from light to medium grey, brown and pink, and can have up to 10% pink to red leucosome; rarely, up to 80% of the rock is injected granite. The unit is very fine grained and uniform. Although similar to the basal biotite gneiss in appearance and main mineral content, the different stratigraphic position of this unit is indicated by the structure of the area. The structural complexity is discussed below. The 'upper' biotite unit is interleaved with the hornblende-biotite gneiss. Closest to the core of the Notigi structure, it is interlayered with the sillimanite-bearing gneiss.

Sillimanite-bearing gneiss

Sillimanite-bearing gneiss, which is interpreted to have been derived from arkose, is mostly light grey to grey and pink in colour, and may have up to 40% leucosome. The largest domain of this unit, located in the central to northern part of the map area, is inferred to be the uppermost part of the Sickle Group. The rock is generally rich in quartz and feldspar, and locally interbedded with light grey protoquartzite. The unit varies from having centimetre-scale uniform layering to millimetre-scale biotite-rich laminae. Recrystallization has obscured nearly all primary textures other than transposed bedding (i.e., layering) and, at one location, remnant crossbeds in the protoquartzite (Figure GS-5-3e). These beds are overturned with tops to the south, consistent with the general structural interpretation (*see* below). The sillimanite in this unit reflects local concentrations of alumina, probably from an original clay component, which later generated faserkiesel up to 2 cm in diameter, formed by sillimanite and quartz knots and, in places, plagioclase-feldspar rimming magnetite cores. The faserkiesel are concentrated within certain beds (Figure GS-5-3f).

Intrusive rocks

Mafic and intermediate intrusive rocks

Two exposures of mafic rocks within the Sickle

Group sillimanite gneiss are distinctly coarser grained than the layered amphibolite at the base of the Sickle, indicating an intrusive origin. The exposures are widely separated but at the same stratigraphic level in the central and northeastern parts of Notigi Lake. Both contain dark green to black layers that suggest fractionation in separate sills or possibly in a long single sill.

The central occurrence is up to 20 m wide, with layering composed of four separate rock types that grade into one another: 1) coarse-grained garnetiferous and biotite unit, 2) hornblende-rich unit that grades to less hornblende; and 3) plagioclase-rich unit up to 1.5 m wide and containing up to 60% plagioclase at the top; overlain by 4) darker amphibolite. Layers are thick and internally uniform, and are interpreted to result from crystal fractionation. The zonation of units in this amphibolite body, if due to fractionation of a sill, indicates that it tops to the northeast.

The occurrence in the northeastern part of Notigi Lake has similar layering to that in the central part but also contains garnet-bearing lenses and a trace of carbonate. The relationship between the two occurrences is uncertain but may be resolved by additional structural analysis and petrology.

A biotite-rich monzodiorite unit up to 8 m wide intrudes the Sickle Group on the west side of the Rat River channel. This is an extension of the Black Trout diorite that extends from Granville Lake (Zwanzig and Cameron, 2002) to areas southeast of Lynn Lake (Milligan, 1960) and is interpreted to extend into an area north of Notigi Lake. The unit contains abundant magnetite and titanite, and displays a uniform schistosity. Its geochemistry is transitional to alkaline and characterized by high contents of K_2O, Na_2O and P_2O_5, with a high La/Yb ratio at relatively high MgO and TiO_2 (Table GS-5-1). On a multi-element plot (Figure GS-5-4b), it shows a distribution of elements identical to that shown by the type Black Trout diorite.

Granitic intrusive rocks

Granite intrusion and pegmatite

All units in the Notigi Lake area have been injected by granite and pegmatite sheets. The granitoid rocks intruding Burntwood greywacke in the southern part of the map area range from white plagioclase-rich tonalite to leucogranite. Several ages of pink to red pegmatite have been injected as sheets into all units. Minor minerals of note in both granite and pegmatite include cordierite, tourmaline, biotite, muscovite, garnet and magnetite. Retrogressive metamorphism can be identified by cordierite replaced by garnet+chlorite and biotite replaced by chlorite.

North of Timew Narrows, a large granite intrusion (Notigi granite) that cuts mainly Sickle Group rocks is in local contact with the layered amphibolite unit. It is a pink feldspathic rock with a biotite parting.

Structural geology

In this report, structural geology is described for six geographic subareas distributed around Timew Narrows, at the centre of Notigi Lake, each illustrating different aspects of the structure (Figure GS-5-2). Explaining the differences in structural style, trends and ages in these subareas provides a preliminary interpretation of the entire Notigi structure and has a bearing on the regional structure. Preliminary interpretations indicate that large-scale regional folding has occurred throughout the Notigi Lake area, with faults and shears disrupted and overprinted on a regional northeasterly trend. Future traverses to key locations will refine the preliminary interpretations presented in this report.

The structural interpretation assumes that, like farther west on the north flank of the Kisseynew Domain, an early (D_1) fault forms the contact between the Burntwood Group and the amphibolite unit. Recumbent and moderately inclined folds and foliation are considered to have developed during D_2 (Figure GS-5-5a, b) but, due to strong D_3 folding and flattening on the northeasterly trend, the foliation formed initially during D_2 now trends northeast and is typically a composite S_{2-3} fabric. Abundant mineral and intersection lineations occur in F_3 hinge areas where there is interference with the F_2 folds and foliation. Evidence that some F_2 folds were recumbent or small fold nappes is in the shallow plunge of the major F_3 fold in some central parts of the lake and at its northeast end. A curved northeast-steepening hinge line, together with the steep hinge in the southwest and general outward dip of the foliation, indicates that the major F_3 Notigi structure is domal. Late faults (D_4), although not exposed, are inferred from structural complications involving F_{2-3} crossfolds.

Subarea 1

Subarea 1 encompasses the south end of Notigi Lake in the Burntwood Group migmatite. Layering with boudinaged and folded leucosome exhibits the D_3 regional northeast trend or is partly transposed into that trend (Figure GS-5-5c). The dip changes from steeply west-northwest in the southeast to steeply southeast in the northeast. Linear fabric and minor folds plunge southwest, but this changes to northeast at the south end of the lake. This geometry suggests the presence of a large-scale F_3 synform with a variable plunge.

Subarea 2

Subarea 2 is centrally located in Notigi Lake, south of Timew Narrows, and includes the Burntwood Group migmatite, the layered amphibolite and Sickle arenite. The subarea exhibits north-northeast-trending folds. The Sickle Group rocks display good structural information, including layering, mineral and intersection lineations,

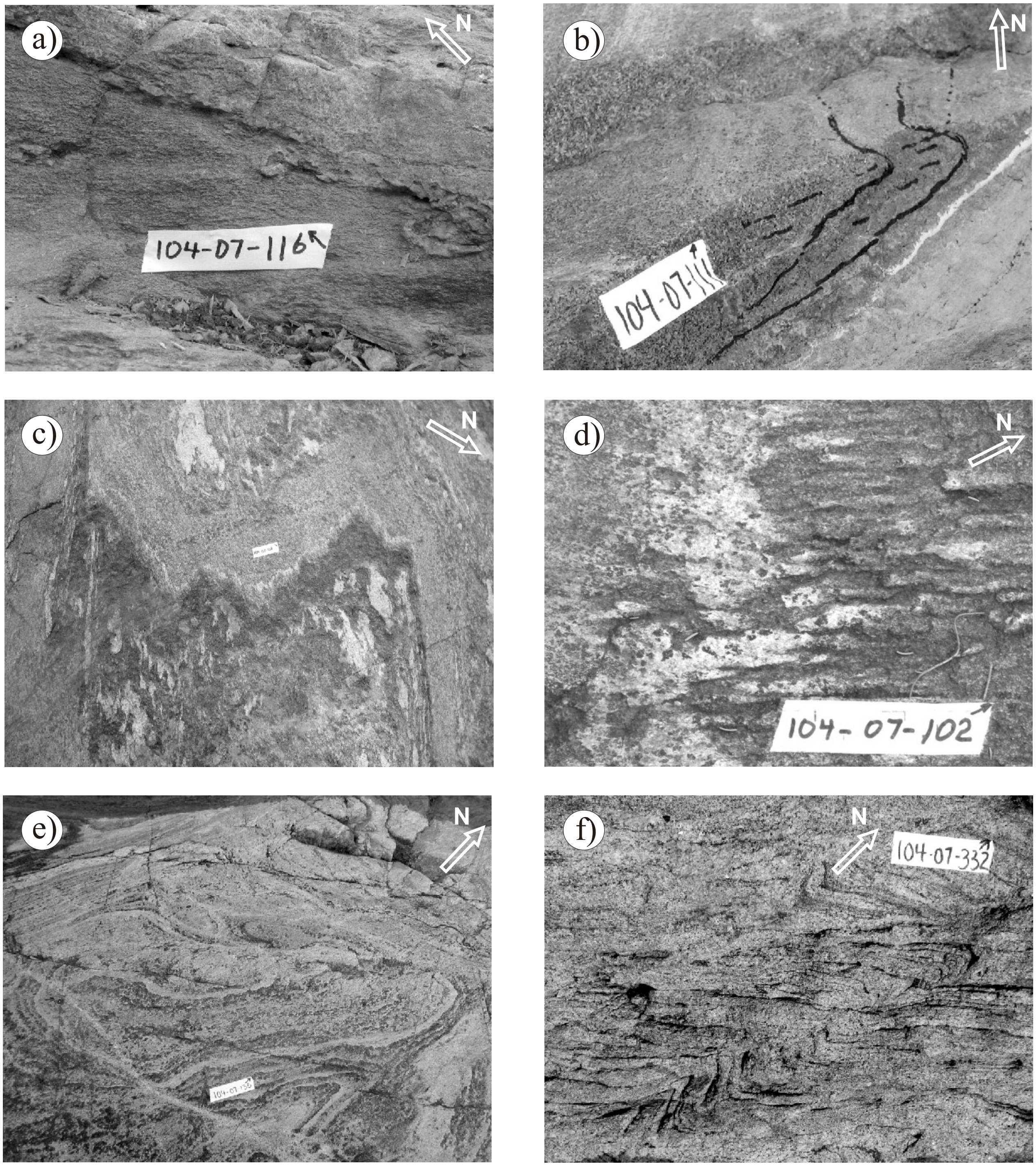


***Figure GS-5-5:** Field photographs of structural features in the Notigi Lake area: **a)** gently east-dipping bedding cut by gently north-dipping S_2 foliation (parallel to tape) most noticeable in biotite-rich bed (under tape), looking northeast at steep rock face; **b)** minor F_2 recumbent fold (bedding contacts marked by solid line) and axial-planar S_2 foliation (dashed line), looking north and down at stepped face; **c)** bedding, leucosome veins and S_2 foliation partly transposed along northeast-trending F_3 folds, S_3 foliation and a D_3 shear; note how irregular leucosome pods line up along S_2, having formed parallel to bedding and possibly S_1 cleavage; **d)** gently northeast-plunging rodding produced by constriction and stretching along S_2-S_3 intersection; **e)** minor domal structure in thin bedding and foliation (west of tape), interpreted as northeast-tending F_3 fold interfering with east-trending F_2 fold; **f)** late F_3 or F_4, north-northeast-trending minor folds with chevron style typical of high-level structures, suggesting uplift after D_2. Tapes are 9–10 cm long.*

and rodding (Figure GS-5-5d). The unit also contains L-tectonite and pseudotachylite. Map-scale structures are a pair of open F_3 folds with north-northeast-trending axial surfaces. They form a steeply south-plunging synform in the west and a gently north-plunging synform in the east. Minor F_2 structures with shallow-dipping foliation (S_2) and axial surfaces (F_2) are preserved in the core of the eastern F_3 fold (Figure GS-5-5a, b). This suggests that F_2 was recumbent before refolding.

Subarea 3

Subarea 3 includes the island at Timew Narrows and farther east. The layered mafic intrusion and the sillimanite and biotite gneiss display structures that differ from the more typical, north-northeasterly F_3 trends found elsewhere on the lake. The trends in subarea 3 are broadly east-west with highly variable dips. Lineations plunge at 10–27° toward the north and northeast.

The area contains the continuation of the map-scale F_3 fold pair in subarea 2, but a reversal in plunge is indicated by changes in the northeast dip of the layering. This is probably due to the presence of a tight, map-scale F_2 syncline that closes to the south. The interpretation is supported by a reversal in stratigraphic sequence, which is upright in subarea 3 and overturned farther to the northeast. Therefore, the highest stratigraphic unit (sillimanite-bearing gneiss) occurs in the core of the F_2 structure. The presence of this structure is consistent with the northeast-topping sill on the south side of the sillimanite-bearing gneiss, and a south-topping sequence (overturned), indicated by crossbedding, on the north side of the gneiss. The area also contains examples of minor fold interference (Figure GS-5-5e). Relatively young faults may have further disrupted the structure north and east of the island, but further work is required.

Subarea 4

Subarea 4 extends north and west of Timew Narrows to the Rat River channel. It encompasses Burntwood migmatite, layered amphibolite, Notigi granite and Sickle gneiss; internal boundaries are yet to be mapped in the latter. The layered amphibolite crosses both sides of the Rat River channel on the northeast side of the large-scale Notigi structure. Dips are dominantly northeast in a highly attenuated succession. A late (D_4) sinistral fault is inferred on the west side of the channel.

Subarea 5

Subarea 5 is located along the north shore of the eastern part of the lake. The area forms the core of the Notigi structure and is underlain by Burntwood greywacke, the layered amphibolite, and both biotite- and sillimanite-bearing gneiss of the Sickle Group. The greywacke and overlying amphibolite occur in two narrow northeast-trending belts surrounded by the Sickle Group. This upright succession is tentatively interpreted as a structural window exposing the F_2 under-limb of the Notigi structure in the core of the main F_3 fold (Figure GS-5-6).

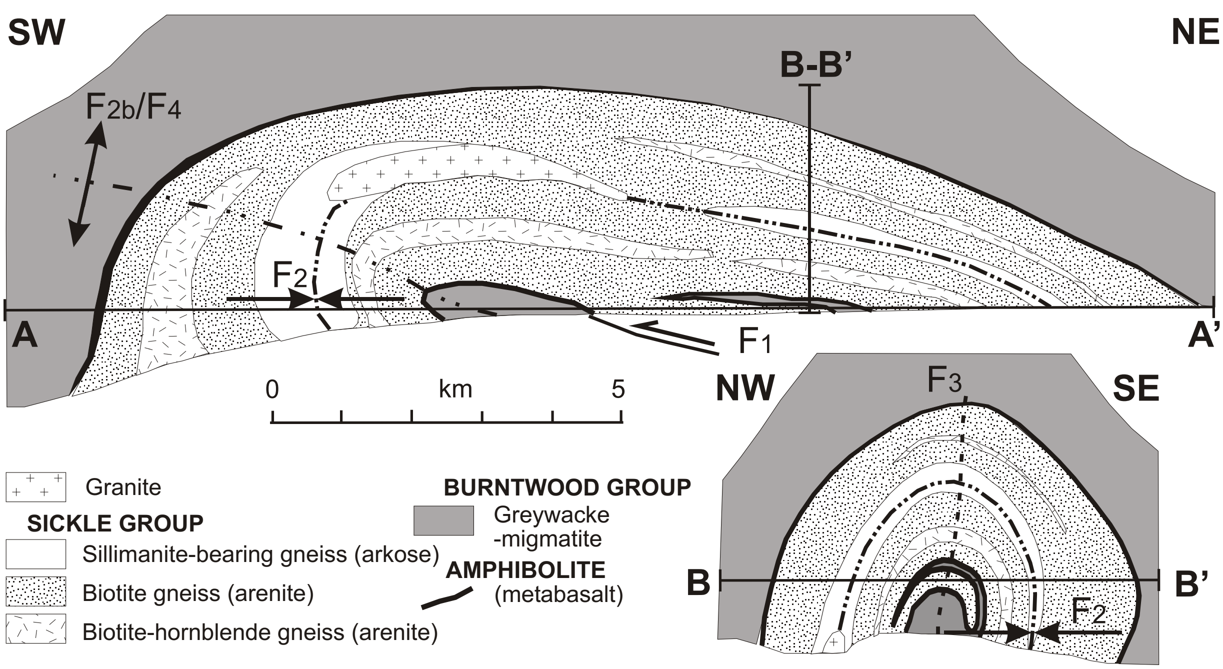


Figure GS-5-6: *Highly simplified vertical sections of the Notigi structure, showing the repetition of units across a major S_2 syncline that experienced complex refolding. The oldest units (amphibolite and Burntwood Group greywacke-migmatite) in the core and above the structure indicate that the large F_2 fold was recumbent before the refolding. Section **A–A'** has the observer looking northwest at a possible southerly-verging, gently inclined F_{2b} or F_4 antiform traced out by the F_2 hinge line. Section **B–B'** has the observer looking northeast at the tight F_3 antiform.*

A third narrow belt of layered amphibolite occurs along part of the southeastern contact of the Notigi granite. Its stratigraphic and structural position is as yet unknown. Repetition of the tight fold cores may be due to northeast-trending upright folds and shears, identified at small scales as late D_3 (Figure GS-5-5f).

Subarea 6

Subarea 6 is located at the northeast end of Notigi Lake. The area includes the Burntwood greywacke, a thin gabbroic unit and a complete section through the Sickle Group. The area contains both upright and inverted stratigraphic sequences, with a narrow unit of sillimanite-bearing gneiss in the core of the F_2 syncline refolded in the hinge zone of the F_3 Notigi structure. Mineral and intersection lineations vary in plunge from 6 to 16° in the southwest, and from 22 to 52° in the northeast. The northerly increase in plunge and the outward dip of the limbs shows that the northeastern part of the major F_3 structure is domal.

Structural interpretation and regional implications

The new mapping and the early work in the vicinity of Notigi Lake indicate that 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 by noncylindrical, northeast-trending, F_3 upright folding superimposed on a large, recumbent F_2 synform. Another possible origin involves gentle F_4 refolding of the F_3 hinge on an east-west trend, but no related fabrics or minor structures were observed. It is also possible, alternatively, that a late F_2 south-verging anticline has caused the curved hinge line and an inherited asymmetry of the later dome. This last interpretation is most consistent with the preliminary structure section (Figure GS-5-6).

The tight or isoclinal F_2 folding has caused repetition of the Sickle Group stratigraphic sequence in a vertical stack that was later involved in possible F_{2b} reclined folding and the F_3 doming. The Burntwood Group and layered amphibolite, overlain by the lowermost (upright) succession of the Sickle Group, is interpreted to be a structural window. Therefore, the Burntwood Group overlies and underlies the sheet-like F_2 structure. If the F_2 synclinal closure is to the south, as suspected, tectonic transport was north and consistent with the occurrence of (inverted) Burntwood Group in structural basins north of Notigi Lake (Schledewitz, 1972). Fold vergence was reversed to a southerly direction during later (F_{2b} and/or F_4) folding.

The best indication of a regional F_1 thrust contact between the Burntwood Group and the layered amphibolite is the correlation of the latter with the inferred 1.9 Ga (allochthonous) Tod Lake basalt. The correlation is based on the geochemistry of the amphibolite and its alternating hornblende- and diopside-rich components that are formed from pillow structure and prominent calcsilicate alteration domains. The thin interlayering of these components at Notigi Lake is shared with a mafic tectonite on Granville Lake that was traced along strike into well-preserved Tod Lake pillow basalt. The regional thrust is interpreted as part of the Granville Lake structural zone (Zwanzig, 1990), a crustal suture in which the amphibolite forms a remnant of the upper part of a back-arc ophiolite (White et al., 2000). This zone extends from the Saskatchewan border east for 300 km to an area north of Thompson (GSZ in Figure GS-5-1).

A belt of Sickle Group rocks, up to 25 km wide, lies north of the Granville Lake structural zone, separating it from the Leaf Rapids arc domain. Outliers of the Sickle Group, up to 40 km long and including the 30 km long Notigi structure, occur in the marine basinal terrane of predominantly Burntwood Group gneiss to the south (e.g., Lenton, 1981). The Notigi structure and many of the other outliers contain the same distinctive mappable units in the Sickle Group, and are mantled by the same amphibolite, as in the Granville Lake structural zone. The conversion of pillows and alteration domains into thinly layered mafic tectonite (undivided amphibolite of Zwanzig and Cameron, 2002) argues for an extreme attenuation of the entire tectonostratigraphic package at Notigi Lake and isoclinal folding at a crustal scale in the northern and northeastern parts of the Kisseynew Domain. Archean orthogneiss and associated paragneiss are expected to occupy deeper levels than the Notigi structure but are part of the same crustal-scale layering.

Economic considerations

The updated geological maps provide a modern geological context for future nickel, platinum group element and gold exploration along the north flank of the Kisseynew Domain. The presence of small gold showings in the Tod Lake basalt, south of Granville Lake, make the correlative layered amphibolite at Notigi Lake and in adjoining areas a possible exploration target. Traces of malachite staining in the Sickle Group may indicate a style of mineralization similar to that of the sedimentary copper mineralization reported by Baldwin (1980) at Russell Lake.

The inferred, strongly layered crustal structure in the northeastern part of the Kisseynew Domain has an implication for the geometry of Archean orthogneiss and Ospwagan-like paragneiss that have competency and probable structural style similar to the Notigi structure. The extreme attenuation suggests that the best chance for preservation 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.

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