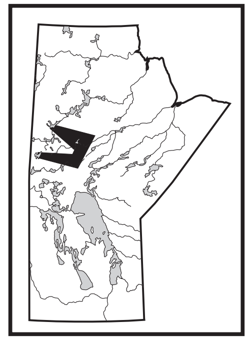
GS-4 Correlation of lithological assemblages flanking the Kisseynew Domain, Manitoba (parts of NTS 63N, 63O, 64B, 64C): proposal for tectonic/metallogenic subdomains

by H.V. Zwanzig



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Summary

Lithotectonic assemblages on the margins of the Kisseynew Domain include lithological units that extend up to hundreds of kilometres, and thus define new tectonic subdomains with different mineral potential. Tracing these assemblages in the high-grade metamorphic terrane depends on the distinctive field appearance, petrology, geochemistry, Nd isotope ratio and/or U-Pb age of the contained units. Areas examined this summer to better define such units were at Granville and Notigi lakes on the north flank of the Kisseynew Domain and near Sherridon on the south flank. Additional data considered are from original mapping and recent remapping and reanalysis under phases 1, 2 and 3 of the federal government's Targeted Geoscience Initiative (TGI-1, -2 and -3) and industry exploration. Discussed are 1) outliers of the greenstone belts that surround the Kisseynew Domain; 2) the volcano-sedimentary Granville Lake assemblage formed at the early Kisseynew basin margin from sediments and older back-arc basin floor; 3) an Archean basement and a cover assemblage similar to rocks in the Thompson Nickel Belt (TNB) and associated isotopically evolved granite; and 4) the younger sedimentary rocks that dominate the Kisseynew Domain. The wide extent of the assemblages and bounding structures allows the subdivision of the Kisseynew Domain into four tectonic subdomains. Each is defined by mappable units and is shown to represent a separate tectonic environment or evolution. Subdomains highlight potentials for economic minerals because of their unique metallogeny. Subdomains can guide the first step in mineral exploration: choosing and understanding a specific area.

Introduction

In the summer of 2008, three weeks were devoted in the field under the scope of TGI-3 to establish the structural relations of various recently defined lithotectonic assemblages with mineral potential surrounding the Kisseynew Domain, and collecting samples for petrography, geochemistry and geochronology. About one week each was spent at Sherridon on the north side of the Flin Flon Domain, the Notigi Lake area (Murphy, GS-5, this volume) and the Granville Lake area on the north side of the Kisseynew Domain (Figure GS-4-1).

The purpose of this report is to provide a tectonic framework that explains the large-scale interlayering of the various disparate assemblages surrounding the Kisseynew Domain. New domain boundaries and new subdomains are proposed to foster tectonic and metallogenic interpretations as a guide for mineral exploration. Previous work and archived photographs are used in summarizing the geological characteristics of the various areas. Petrography, geochemistry, Nd isotope ratios, U-Pb ages of intrusions and detrital zircon ages will be determined from collected samples and used to test some of the preliminary conclusions.

Early mapping projects in the Kisseynew Domain and on its north, east and south flanks were at 1:50 000 to 1:63 360 scale and had assumed a simple stratigraphy. The widespread metagreywacke–mudstone and derived migmatite were considered to be stratigraphically interlayered with amphibolite (Barry, 1965) or overlain by a thin para-amphibolite unit followed by shallow-water arkosic deposits (Schledewitz, 1972; Baldwin et al., 1979; Gilbert et al., 1980; Lenton, 1981; Zwanzig and Cameron, 1981). The metagreywacke was considered to be coeval with the metavolcanic rocks that surround the Kisseynew Domain, even where adjacent volcanic units were interpreted to occupy a lower stratigraphic position (e.g., Bailes, 1980). Plutonic rocks were generally taken to be younger than the metagreywacke. Detrital zircon ages, however, have indicated that widespread greywacke deposition on the Kisseynew south flank and in the Snow Lake area occurred between ca. 1855 and ca. 1842 Ma (David et al., 1996; Machado et al., 1999), 40–50 million years after deposition of most adjoining volcanic rocks but partly coeval with 1848–1832 Ma deposition of the overlying arkosic rocks and local volcanic rocks (Manitoba Geological Survey, 2006). Where contacts are exposed, the arkosic rocks are seen to lie unconformably on the amphibolite but to grade downward into the metagreywacke (Burntwood Group *in* Zwanzig, 1999). The various successions of arkosic rocks on the flanks of the Kisseynew Domain (Sickle, Grass River and Missi groups) are time-equivalent correlatives (Zwanzig et al., 2007).

Recent U-Pb zircon dating and Sm-Nd isotope work, geochemistry and remapping have provided the following details concerning newly defined lithological units and the relationships among known units:

- The succession of metagreywacke–mudstone and derived migmatite (Burntwood Group) has a similar age of deposition (1855 to ca. 1840 Ma) throughout the Kisseynew Domain but also includes minor

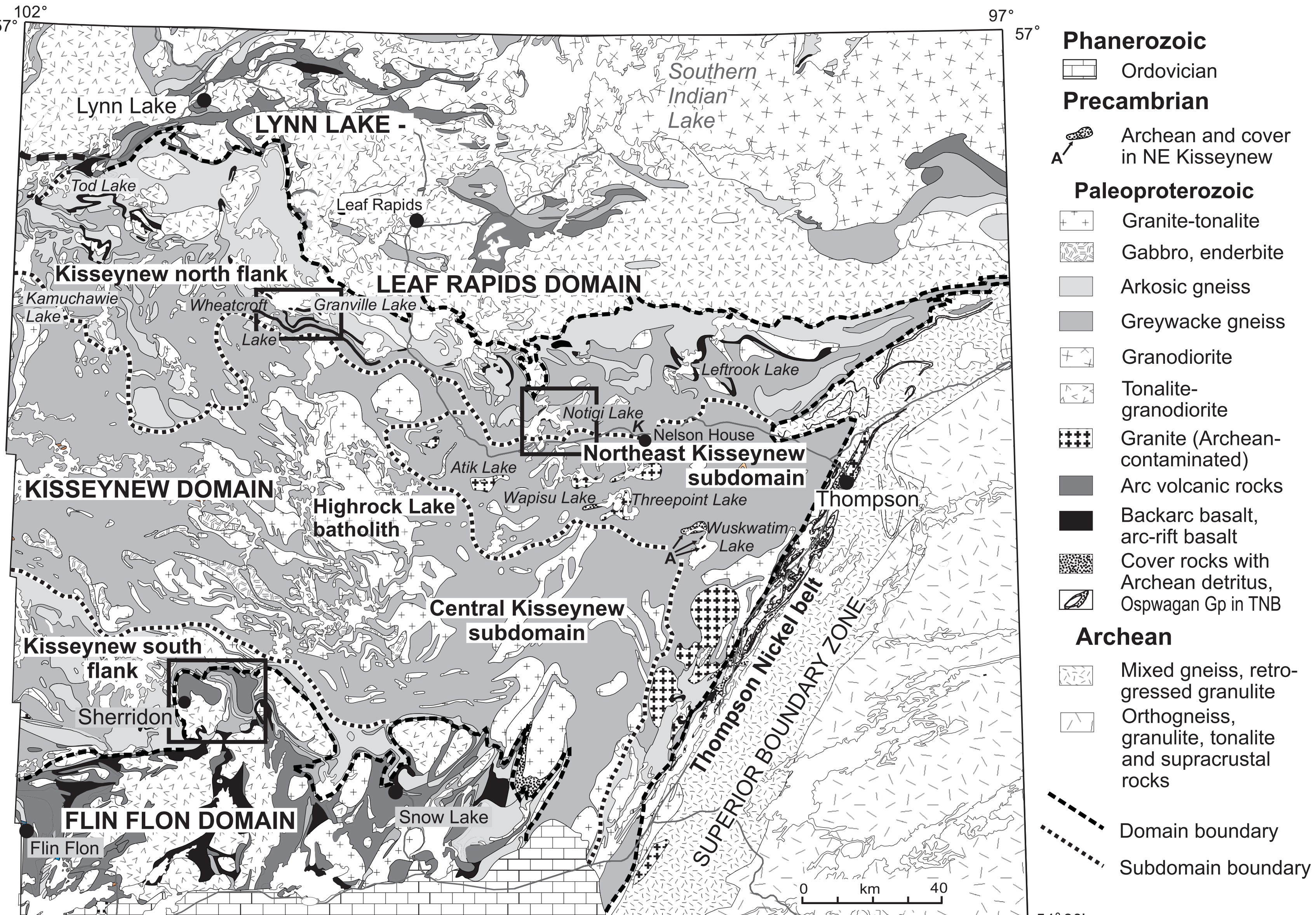

Figure GS-4-1: *Simplified map of the Kisseynew Domain and surrounding areas showing domain boundaries and subdomain divisions proposed in this report. Areas of fieldwork are outlined.*

quartz-rich, weakly calcareous rocks (Zwanzig et al., 2006) and rare sulphidic silicate-facies iron-formation (Murphy and Zwanzig, 2007a).

- The Burntwood Group in the northeastern part of the Kisseynew Domain is locally intercalated with, and/or underlain by, Archean gneiss with a thin quartzite–iron formation–pelite cover succession containing only Archean detrital zircons (Rayner and Percival, 2007).
- A suite of potassic granodiorite to granite rocks with 1880–1890 Ma crystallization ages and Archean Nd model ages is associated with the Archean rocks (Zwanzig et al., 2003; Percival et al., 2004, 2007).
- The Burntwood Group forms large-scale structural intercalations with the rocks on the margins of the TNB and the Flin Flon Domain.
- Amphibolite units that surround the Kisseynew Domain and are locally intercalated with the Burntwood Group have geochemical affinities for back-arc basin basalt (BABB), arc-rift basalt and ocean-island mafic–ultramafic rocks (Zwanzig et al., 1999; Zwanzig, 2000a, 2000b, 2005).
- The amphibolite units extend into, and are broadly correlated with, the early (ca. 1.9 Ga) volcanic rocks in the Lynn Lake area in the north, the TNB in the east and the Flin Flon–Snow Lake area in the south, where they are cut by the 1886 Ma Josland Lake sills (Zwanzig et al., 2001).
- The contacts between the amphibolite units and the Burntwood Group are interpreted as thrust faults that mark a crustal suture in the north (White et al., 2000), probably also in the east and possibly in the south.

Sherridon area

Work in the Sherridon area with geologists of Halo Resources Ltd. was aimed at comparing the local assemblage of rocks with those encountered in the Meat Lake (Figure GS-4-2) and northern Snow Lake areas (Zwanzig and Schledewitz, 1992; Zwanzig and Bailes, work in progress, 2008). This also provides the scope for future mapping, possibly concentrated in a newly burned-over area that partly crosses the Sherridon structure.

The ~10 by 14 km Sherridon structure of felsic and lesser mafic–intermediate gneiss has been interpreted to have been derived by high-grade metamorphism from the predominantly volcanic rocks of the Flin Flon Domain (Ashton and Froese, 1988; Zwanzig and Schledewitz, 1992; Zwanzig, 1999). A preliminary comparison of geochemical data of selected units from the Meat Lake and Snow Lake areas indicates similar extended-element patterns for these rocks but with local differences that suggest the presence of several broadly related felsic volcanic centres. The rocks at Sherridon appear to be slightly less fractionated, with higher mafic contents and less elevated light rare earth elements (LREE) and Th than those near Meat Lake and Snow Lake (Figure

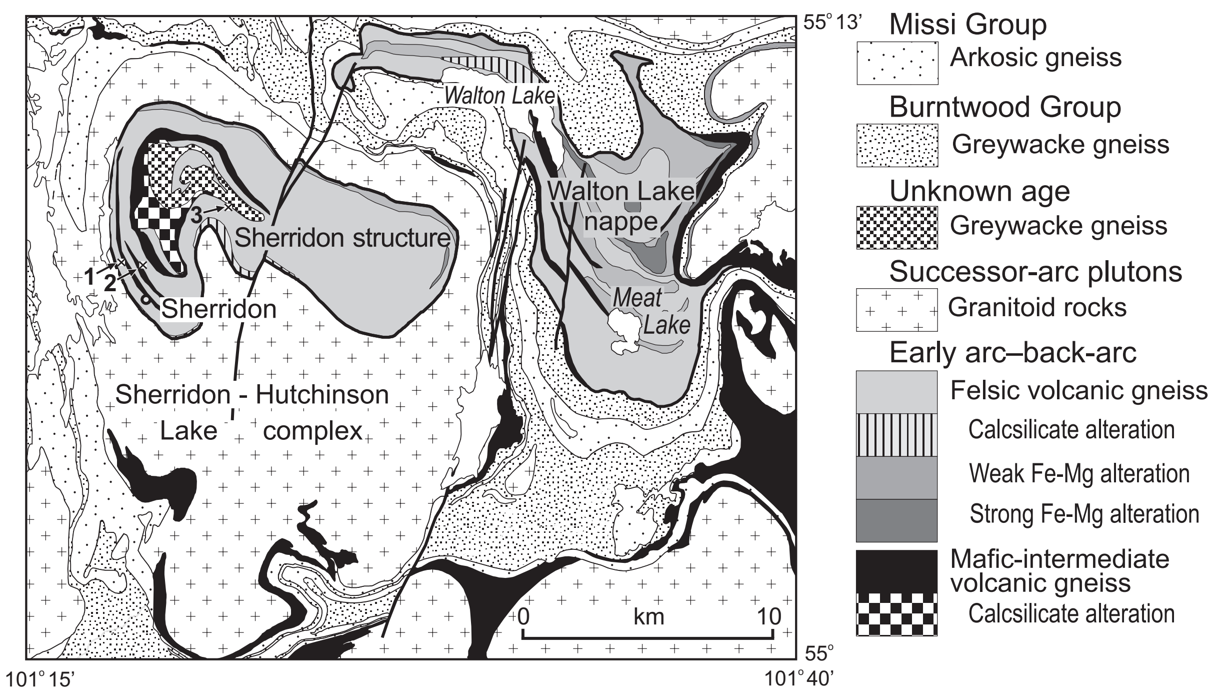

***Figure GS-4-2**: Map of the Sherridon–Meat Lake area adapted from NATMAP Shield Margin Project Working Group (1998), showing an interpretation of variably garnetiferous gneiss ±sillimanite or amphibole in the Walton Lake nappe as regional hydrothermal Fe-Mg enrichment and alkali depletion of a felsic volcanic protolith. Strong alteration includes gedrite-cordierite–bearing assemblages. Similar rocks in a sheath-like domal core (Sherridon structure) include alteration that is not shown except for calcsilicate with carbonate. Sample sites are near the VMS deposits of East Sherridon (1), Cold Lake (2) and Bob Lake (3). Map location shown in Figure GS-4-1.*

GS-4-3). The compositional differences of large-scale layering that forms poorly defined units of gneiss at Sherridon are expressed by variations in the contents of major elements, particularly SiO_2, Fe_2O_3, MgO and alkalis, but some of these show little change in incompatible element patterns. Some units are primary but others represent structurally transposed and attenuated regional and focused hydrothermal alteration zones. This interpretation is supported by the common presence of garnet (alkali loss and Fe concentration), as well as layers that are strongly enriched in quartz (silicification), others containing sillimanite (probably after sericite), and local areas with gedrite, cordierite and sulphides (focused alteration). Alteration is associated with iron-sulphide and base-metal deposits that are interpreted as volcanogenic massive sulphides (VMS). Detailed mapping of such zones is underway by Halo Resources Ltd. A large area of carbonate-bearing rocks is locally mafic and generally resembles rocks that have been traced into altered and sheared basalt elsewhere on the flanks of the Kisseynew Domain (e.g., Kisseynew north flank, this report). This calcareous unit was previously interpreted to be of sedimentary origin (e.g., Froese and Goetz, 1981) and requires remapping.

The Sherridon structure forms the core of the overturned Sherridon–Hutchinson Lake domal complex (Figure GS-4-2; Zwanzig and Schledewitz, 1992). The volcanic-derived gneiss in the Sherridon structure occurs as a window through the surrounding deformed 'successor-arc' (1860–1874 Ma) plutons (Zwanzig, 1999). Sections drawn by W.A. Barclay (pers. comm., 2008) suggest that the core structure is even more sheath-like than shown by Zwanzig (1999) and that there is likely extreme thickening in the hinges and attenuation in the limbs of early nappe-like folds. The high penetrative strain explains the shape and size of the large body of calcsilicate to calcareous alteration in the fold hinge, 2.5 km north-northeast of Sherridon. If this conjecture is confirmed by future mapping, similar thickening and boudinage may be expected in sulphide bodies, including Cu-Zn VMS deposits. The mantle of the Sherridon–Hutchinson Lake dome comprises unconformably overlying Missi Group metasedimentary and lesser metavolcanic rocks. The Missi Group locally grades outward, across strike, into the (older) Burntwood Group and back into structurally inverted Missi Group (e.g., south of Walton Lake in Figure GS-4-2) These structures have been interpreted as refolded early recumbent folds (Zwanzig, 1999). There is an indication from the large-scale layering of the felsic (volcanic) gneiss in the Sherridon structure that highly altered rocks and sillimanite-bearing layers are overlain by an SiO_2-rich unit, locally with associated VMS deposits and overlain, in turn, by little-altered rocks. Structural reversals of these sections indicate the presence of large isoclinal recumbent folds within the Sherridon structure like those in the mantle of the Sherridon–Hutchinson Lake Complex. Early large-scale folds are confirmed by the presence of similar mafic units in the refolded limbs.

Eight drillcore samples were chosen from holes that penetrate the footwall and hangingwall of the Cold Lake, East (Sherridon) and Bob Lake VMS deposits (Figure GS-4-2). After geochemical analysis, some of these will be used for Sm-Nd isotope work to further characterize changes or the uniformity in the felsic succession that hosts the Cu-Zn deposits in the Sherridon–Meat Lake area.

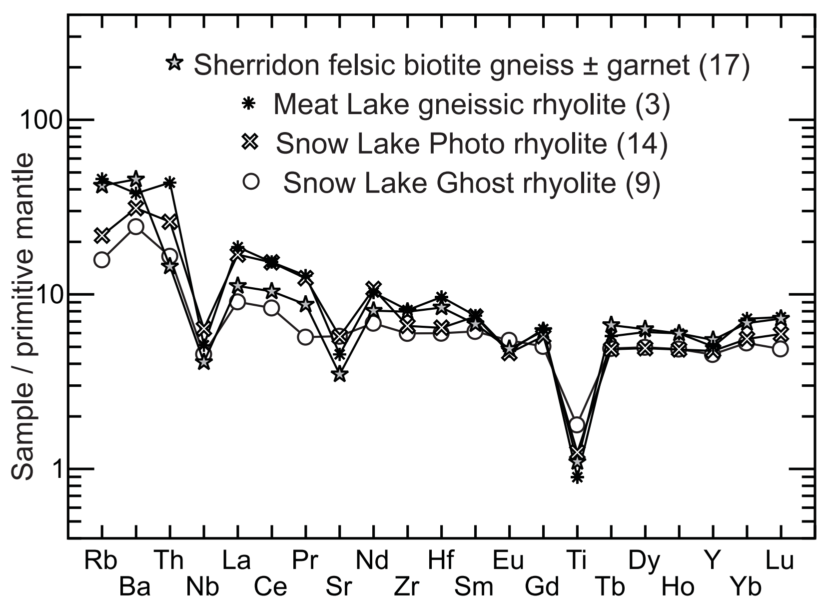

***Figure GS-4-3**: Primitive-mantle–normalized extended-element plot comparing averages from the most common gneissic and lower grade felsic metavolcanic units in the Sherridon, Meat Lake and Snow Lake areas on the north margin of the Flin Flon Domain adjoining the Kisseynew Domain. The number of samples in each average is in brackets. Sherridon area data are from Halo Resources Ltd.*

Granville Lake area

A transect from Wheatcroft Lake north through Pickerel Narrows on Granville Lake (Figure GS-4-4) offers the best exposure across the north flank of the Kisseynew Domain. The area crosses the contacts between the Granville Lake assemblage of volcanic, siliciclastic and chemical sedimentary rocks in the Granville Lake structural zone (GLSZ; Zwanzig, 1990) and between the Burntwood and Sickle groups of siliciclastic rocks to the south and north. This work was aimed at better defining the units and their field relations to allow their regional correlation and tracing of the GLSZ, which has been interpreted as a crustal and mantle suture (White et al., 2000). The importance to mineral exploration of tracing this zone is the abundance of arc-volcanic and intrusive rocks that locally contain VMS and Au deposits in the Lynn Lake–Leaf Rapids Domain to the north, but the apparent absence of such rocks south of the GLSZ.

The volcanic rocks and associated amphibolite in the southern Granville–Wheatcroft lakes area were originally mapped with the metagreywacke as part of the 'Wasekwan Series' (Barry, 1965). Cranstone (1968) mapped the volcanic rocks and closely associated metasedimentary rocks at Pickerel Narrows as part of the Sickle Group of otherwise sedimentary rocks, which lie to their north and south. A nearly identical volcanic succession, however, was recognized as forming the southwest end of the Lynn Lake metavolcanic belt at Tod Lake (Gilbert et al., 1980). This succession, like the similar rocks at Pickerel Narrows, is interpreted to be unconformably or disconformably overlain by the Sickle Group and therefore older (Zwanzig and Cameron, 2002). A correlation between metabasalt at the southwest end of the Lynn Lake belt (Tod Lake basalt) and the metabasalt and layered amphibolite at Granville Lake is supported by their similar geochemistry, which is characterized by relatively TiO_2-enriched tholeiite with a

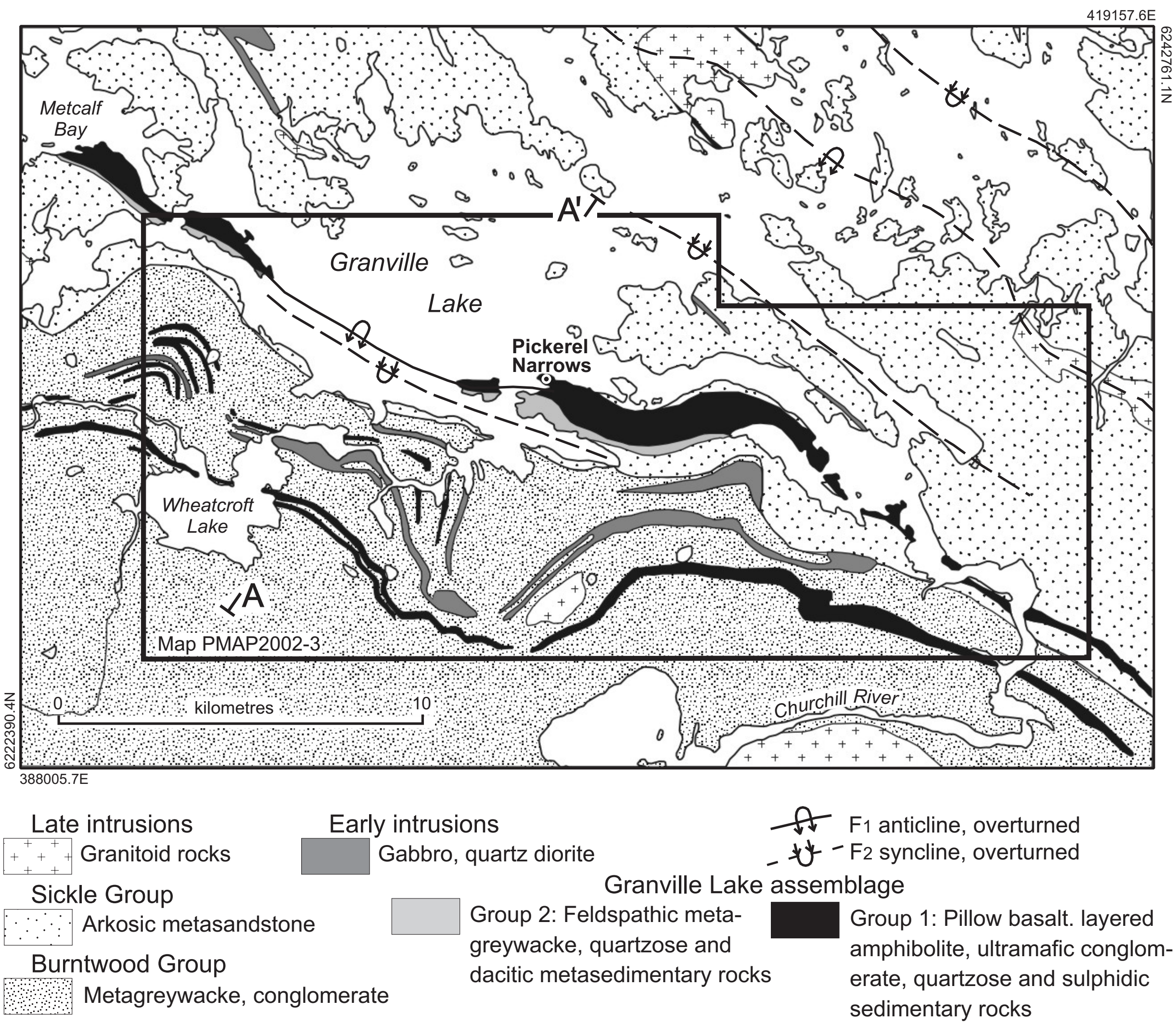

***Figure GS-4-4**: Geology of the southern Granville Lake–Wheatcroft Lake area (*after *Zwanzig and Cameron, 1981), showing the Granville Lake assemblage that locally defines the Granville Lake structural zone (GLSZ) and surrounding younger metasedimentary rocks. A complete lithotectonic section is exposed along transect A-A'. Location shown in Figure GS-4-1.*

moderate to weak arc signature, suggesting an origin as arc-rift basalt or back-arc basin basalt (BABB; Zwanzig et al., 1999). These mafic rocks form a regional marker unit at or near the contact between the Burntwood Group and the Sickle Group (Zwanzig, 2000a). The correlation suggests that the basalt at Granville Lake belongs to the dominant volcanic assemblages dated as 1.89 Ga at Lynn Lake (Beaumont-Smith and Böhm, 2002). Stratigraphically intercalated high-Mg amphibolite has been interpreted as mafic–ultramafic rock with an ocean-island affinity (Zwanzig et al., 1999). A very distinctive sedimentary succession dominated by feldspathic greywacke, some with metre-scale exotic blocks, is in contact with Tod Lake basalt at both Granville Lake and the southwest end of the Lynn Lake belt (Gilbert et al., 1980; Zwanzig, 1990). A dacitic unit within the feldspathic greywacke at Granville Lake has yielded ca. 1874 Ma zircons (D. Corrigan and N. Rayner, pers. comm., 2008).

The monotonous, ~1000 m thick, greywacke-mudstone turbidite succession (Burntwood Group) south of Granville Lake is folded but overall faces north (Zwanzig and Cameron, 1981). The succession is upward-fining and upward-thinning but coarsens rapidly at the top into a conglomerate that, in turn, grades upward into the metasandstone and thin conglomerate of the Sickle Group (Zwanzig, 1990). Detrital zircon populations from a southern exposure of the Burntwood Group at Wheatcroft Lake and the conglomerate on Granville Lake, to the north, are very similar and suggest ca. 1840 Ma deposition (D. Corrigan and N. Rayner, pers. comm., 2008).

Based on structural data and lithological correlation, Zwanzig (1990) interpreted that the Wheatcroft–Pickerel Narrows transect formed at the Kisseynew basin margin, and was then telescoped in a southerly directed fold-and-thrust stack (Figure GS-4-5) that was subsequently overturned to the north with inversion of some of the faults. The zircon dating and geochemical correlation support this model and confirm that the predominantly north-facing (but south-dipping) panels are successively younger to the south and formed during normal (piggy-back) stacking in either a fold-and-thrust belt or at the toe of an accretionary wedge. To further test these hypotheses in the field, office and laboratory, contacts and early deformation structures were re-examined and samples were collected for geochemistry, geochronology and Nd isotope analyses.

Granville Lake assemblage

The mafic–ultramafic igneous rocks and stratigraphically related sedimentary rocks exposed on the peninsulas on the south side of Granville Lake are herein referred to as the Granville Lake assemblage. A detailed account of these rock types is given in Zwanzig and Cameron (1981). The Granville Lake assemblage is tentatively divided into two groups (Figure GS-4-4) that can be distinguished only where they contain their most characteristic rock types. The first group, which is probably ca. 1.9 Ga, includes the Tod Lake basalt (BABB-like), the Pickerel Narrows amphibolite of ocean-island (OIB) affinity and thinly layered siliceous to calcareous and sulphidic

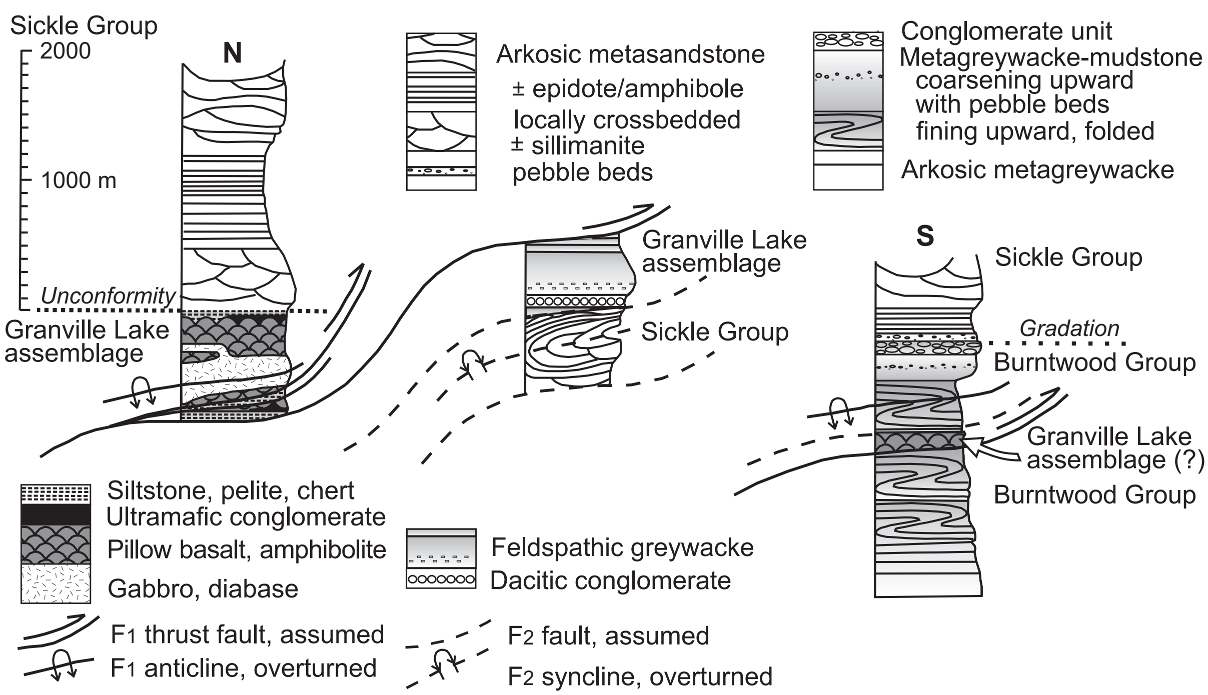

***Figure GS-4-5**: Illustration (*modified *after Zwanzig, 1990) of early structural and stratigraphic relations of the Granville Lake assemblage, Sickle Group and Burntwood Group near Pickerel Narrows, as restored to the probable style that preceded northerly overturning and compression. Ages of the structures are speculative because of the F_2 and later reactivation.*

sedimentary rocks. The second group, which yielded the ca. 1874 Ma zircons from dacitic rock tentatively interpreted as a successor-arc deposit, is predominantly a quartz- and/or feldspar-rich turbidite that occurs directly south of the volcanic rocks. This section is similar in composition and age to the Pool Lake intrusions in the Lynn Lake belt and may thus represent their supracrustal equivalents.

Newly recorded pillow tops in group 1 (Figure GS-4-6a) on the east shore of the island west of Pickerel Narrows confirm the previously suggested structure of the mafic rocks in a large anticline. The fold has a thick north-facing limb and a thinner southern limb that is locally highly sheared and faulted. The structure is consistent with an early southerly fold vergence and thrusting of the mafic–ultramafic volcanic rocks over the younger sedimentary rocks to the south (Figure GS-4-5). Ultramafic–mafic conglomerate and schist of the Pickerel Narrows amphibolite (Figure GS-4-6b) occur on both outer limbs of the anticline and are interlayered with the Tod Lake basalt. The conglomerate locally grades upward into a fine-grained ultramafic–mafic rock that, in turn, grades rapidly upward into fine-grained siliceous metasedimentary rock, probably chert and siltstone (Figure GS-4-6c). This relationship indicates that these clastic to chemical sediments were deposited conformably on the volcanic rocks and are part of group 1 in the Granville Lake assemblage. Fine-grained siliceous sedimentary rocks, including sulphidic semipelite layers (Figure GS-4-6d), lean sulphide-facies iron formation and calcareous layers, occur mostly on the south limb of the anticline, where they are difficult to distinguish from some of the rocks in group 2. The group 1 sediments may have formed the cover of the early backarc basin floor. The whole volcano-sedimentary succession is overlain on the north limb of the major anticline by Sickle Group basal protoquartzite that grades upward into arkosic rocks (Figure GS-4-6f) at the base of the Sickle Group (Figure GS-4-5).

The main sedimentary succession (group 2) in the Granville Lake assemblage lies south of the anticline cored in group 1 (Figure GS-4-4) and is interpreted to be bounded by major faults (Figure GS-4-5). Well-preserved graded bedding shows that this succession faces north and may be unrelated to group 1. Group 2 is dominated by plagioclase-rich metagreywacke locally intruded by gabbro sills, but mafic flows are not present. Grading that indicates deposition from turbidite flows in deep water occurs in thin quartz-rich beds (Figure GS-4-6e) and thicker coarse-grained beds rich in plagioclase with local metamorphic amphibole. One bed is 7 m thick; it has a base containing grains up to 5 mm in size with abundant centimetre-scale intraclasts and exotic blocks, some over 1 m long. This chaotic deposit grades upward into finer grained greywacke and siltstone (Figure GS-4-7a). The blocks include greywacke, laminated siliceous rock, calcareous and intermediate rock, and rare rhyolite. Most blocks are similar in lithology to adjacent turbidite beds. The thick bed must have formed from an erosive, high-density turbidite flow, probably initiated as a slump on an exceptionally steep slope. Local pockets of sedimentary breccia with shaly intraclasts in a greywacke matrix are found elsewhere in the succession and attest to an unstable depositional slope. Pebbles in nearly monomictic conglomerate are interpreted as porphyritic dacite (Figure GS-4-7b). This unit lies along strike from the dated felsic unit and is probably related to it.

The plagioclase-rich succession of sedimentary rocks in group 2 of the Granville Lake assemblage is strikingly similar to the unit of feldspathic greywacke described by Gilbert et al. (1980) on Laurie Lake at the southeast end of the Lynn Lake belt. Correlations include the presence of metre-scale blocks of similar composition, the association with intermediate tuff and the structural position below Tod Lake basalt and the Sickle Group. Similar feldspathic greywacke with sparse amphibole also forms a prominent map unit below the Sickle Group at Kamuchawie Lake, farther south in the Kisseynew Domain (unit 2c hornblende-greywacke *in* Zwanzig and Wielezynski, 1975). These areas are 100 km west of Pickerel Narrows but are the only other good exposure with preserved primary structures on the north flank of the Kisseynew Domain. Consequently, the feldspathic greywacke is considered to extend along much of the north flank. The exceptionally steep paleoslope associated with the block-bearing turbidite and sedimentary breccia may be a regional tectonic feature representing growth faulting at a basin margin, possibly a trench slope at a destructive plate boundary during early successor-arc magmatism.

Burntwood Group

The stratigraphic section through the Burntwood Group from Wheatcroft Lake to Granville Lake is somewhat anomalous compared to the highly metamorphosed Burntwood turbidite exposed elsewhere in the Kisseynew Domain. Graded bedding is exceptionally well-preserved in the Granville Lake area (Figure GS-4-7c); beds are thicker and have a more arkosic composition, with mudstone containing only muscovite and sillimanite yet lacking garnet and staurolite. The latter minerals are common elsewhere at this metamorphic grade. Moreover, there is an unusual upward gradation into a conglomerate at the top (Figure GS-4-7d). These characteristics, along with deep local scour channels in sandstone below the conglomerate, suggest that the area acted as a point source of sediments on the upper slope of a fan delta. The local composition of the Burntwood Group turbidite closely resembles that of the gradationally overlying fluvial and shallow-marine Sickle Group, which probably had the same source of sediments as the coeval turbidite deeper in the marine basin. The upward coarsening

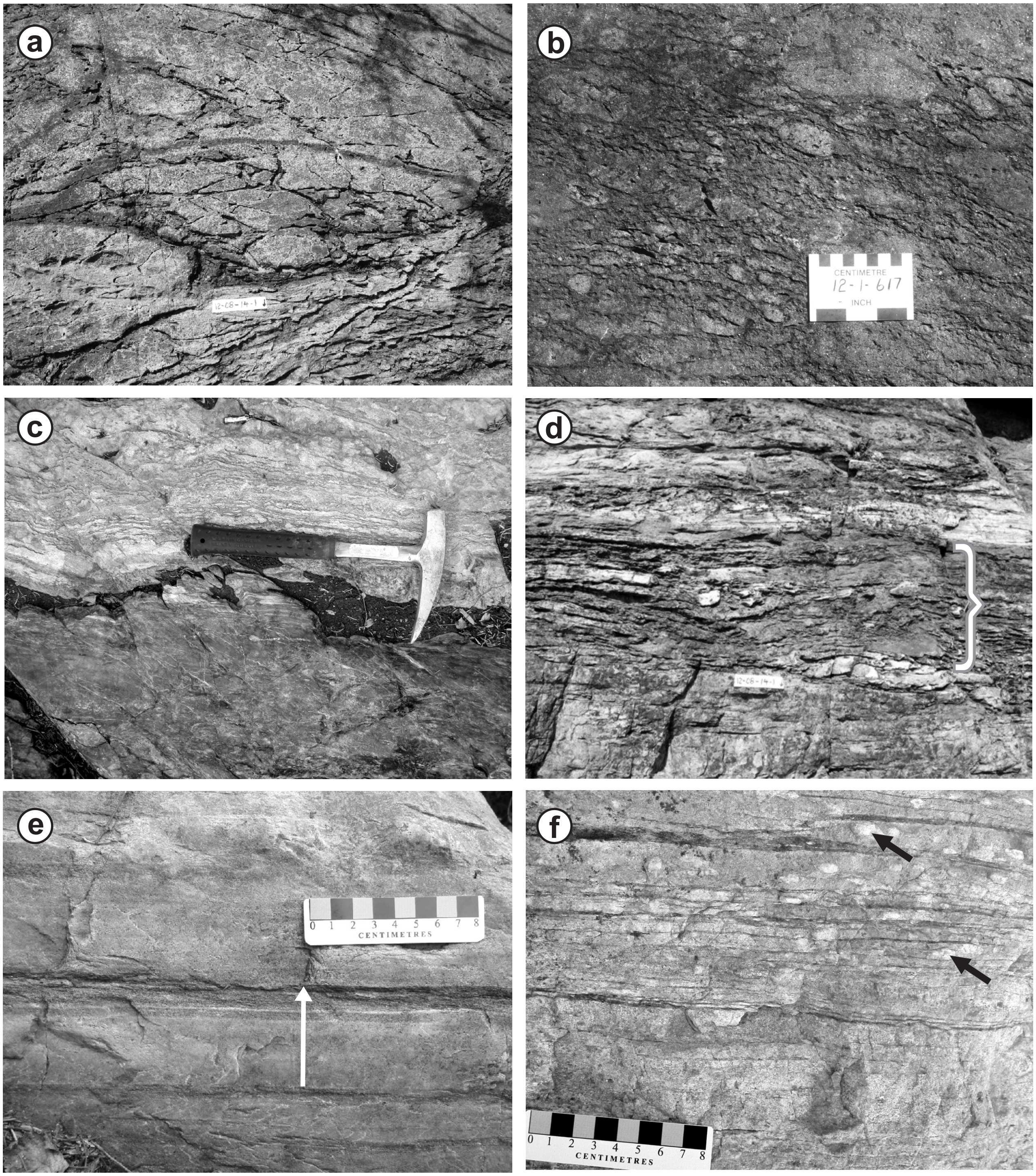

***Figure GS-4-6**: Field photographs of the Granville Lake assemblage and overlying Sickle Group: **a)** Tod Lake basalt with south-facing pillows in the south limb of a major anticline; **b)** Pickerel Narrows ultramafic–mafic conglomerate; **c)** short gradation from the fine-grained top of the Pickerel Narrows ultramafic–mafic sediment unit into thin-bedded siliceous sedimentary rocks; **d)** quartzose greywacke (below 10 cm long tape), weakly sulphidic semipelite (see bracket) and thin to laminated siliceous beds of chert and/or siltstone (white); **e)** quartz-rich to semipelitic graded beds indicating turbidite origin (arrow is on a Bouma cycle); **f)** basal Sickle Group protoquartzite grading upward into arkosic rock with quartz-sillimanite knots (faserkiesel).*

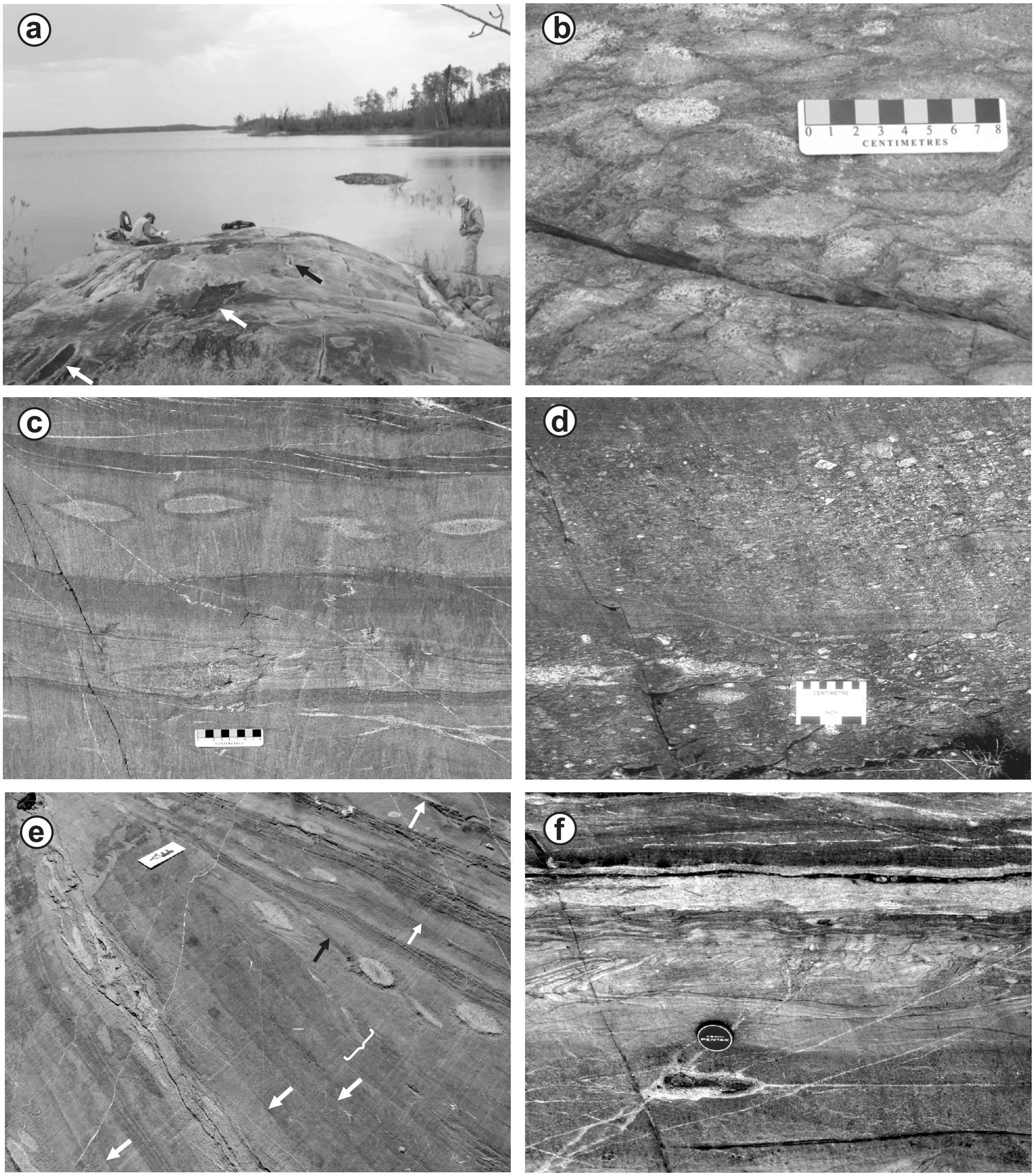

***Figure GS-4-7**: Field photographs of the Granville Lake assemblage (a, b) and Burntwood Group (c–f): **a)** ultra-thick bed of feldspathic greywacke containing exotic blocks (e.g., white arrows) at the base (at boat with assistant) grading through greywacke with calcareous concretions (e.g., black arrow) and up into thinly layered siltstone (at author on the right); **b)** nearly monomictic dacite-pebble conglomerate; **c)** Burntwood Group metagreywacke–mudstone with graded, laminated and shaly Bouma subdivisions; zoned lenses contain calcsilicate rock formed from carbonate in concretions; **d)** Burntwood Group pebble conglomerate grading into greywacke in the coarsening-upward stratigraphic top; **e)** deformation structures in Burntwood Group turbidite, with early isoclinal folding; grading tops are indicated by white arrows; bedding disruption (at the bracket) was probably before complete lithification; shaly injection (black arrow) emerges from the detachment layer; truncations occur at the detachment (next to 15 cm long scale card); north is to the left; **f)** disrupted to transposed bedding (above 4 cm lens cap) underlain by a planar bed and overlain by a calcsilicate layer (white) and more planar beds; deformation is interpreted to have occurred during dewatering and carbonate cementation of a liquefied layer capped by an impervious shaly layer.*

indicates that the shallow-water sediments in the upper Burntwood Group and the Sickle Group prograded over their deep-water turbidite facies, an interpretation that is consistent with the similar detrital zircon populations in these facies.

The succession is isoclinally folded, with north-facing limbs between 50 and 750 m in true thickness and thinner south-facing limbs. Overall facing of the section is therefore north. In a closely examined hinge zone, beds are internally disrupted and the north-facing panel is detached at the base along a shaly bed that has apophyses squeezed into the hinge zone (Figure GS-4-7e). Other folded, disrupted and transposed beds occur between planar beds and locally below planar calcsilicate layers that may have acted as dewatering channels during rapid sedimentary or structural burial (Figure GS-4-7f). Early thrusting and folding may have occurred along liquefied beds during dewatering. This synsedimentary deformation may have occurred on the steep delta slope or on the inner slope of a shallow trench that persisted at the destructive plate boundary suggested for the coarse sediments (group 2) in the Granville Lake assemblage. The asymmetry of the folds and the truncation of north-facing beds at a detachment surface indicate that tectonic transport was southerly, similar to the sediment transport indicated by the location of the deep-water facies (Burntwood Group) south of the southerly prograding shallow-water facies (Sickle Group).

A thin but laterally continuous layer of amphibolite, derived from pillow basalt, gabbro and sulphidic sedimentary rock, was re-examined on Wheatcroft Lake. The adjacent folded Burntwood Group has closely spaced axial surfaces. There is no change in composition of the sediments above the volcanic layer to suggest sedimentation coeval with volcanism. Contacts are not exposed and the amphibolite geochemistry is similar to that of the Tod Lake basalt (Zwanzig, 2000a). Consequently, the amphibolite may have been in the hangingwall of a thrust that placed volcanic basement over younger Burntwood Group rocks, as illustrated in Figure GS-4-5. The sulphidic contact may, therefore, mark the stratigraphic base of this Burntwood section that has the Sickle Group gradationally at the top. Alternatively, this unexposed northern contact is also a fault. A Burntwood age and stratigraphic interlayering of the thin amphibolite and the greywacke cannot be ruled out but is less likely. Northward overturning of the entire fold-and-thrust stack occurred later, and an overprinting foliation cuts obliquely across some isoclinal folds.

Regional correlation and tectonic interpretation

Within the Granville Lake area, well-preserved Tod Lake basalt can be traced into flattened pillows (Figure GS-4-8a) and layered amphibolite containing transposed and flattened diopside-rich domains derived from original epidosite and carbonate alteration (Figure GS-4-8b). Some diopsidic layers show incipient development of feldspathic leucosome around large diopside porphyroblasts. Identical layered amphibolite, interpreted as transposed and altered pillow basalt, occurs all along the north flank of the Kisseynew Domain. It abuts either the Sickle Group (Murphy and Zwanzig, 2007a) or quartzose and sulphidic sedimentary rocks in narrow belts between areas of the Burntwood Group (Murphy and Zwanzig, 2007b). The volcanic origin of the layered amphibolite is supported by preliminary chemical analyses at Kamuchawie Lake, South Bay at Laurie Lake in the west, and Notigi Lake and Kawaweyak Lake in the east. These analyses show trace-element patterns similar to the Tod Lake basalt and more highly enriched BABB-like and OIB-like basalt (Zwanzig, 2000a; Murphy and Zwanzig, 2007a; Murphy, GS-5 this volume). As at Granville Lake, the amphibolite in various parts of the north flank of the Kisseynew Domain contains massive layers derived from gabbro. The quartz-rich and locally calcareous sedimentary rocks

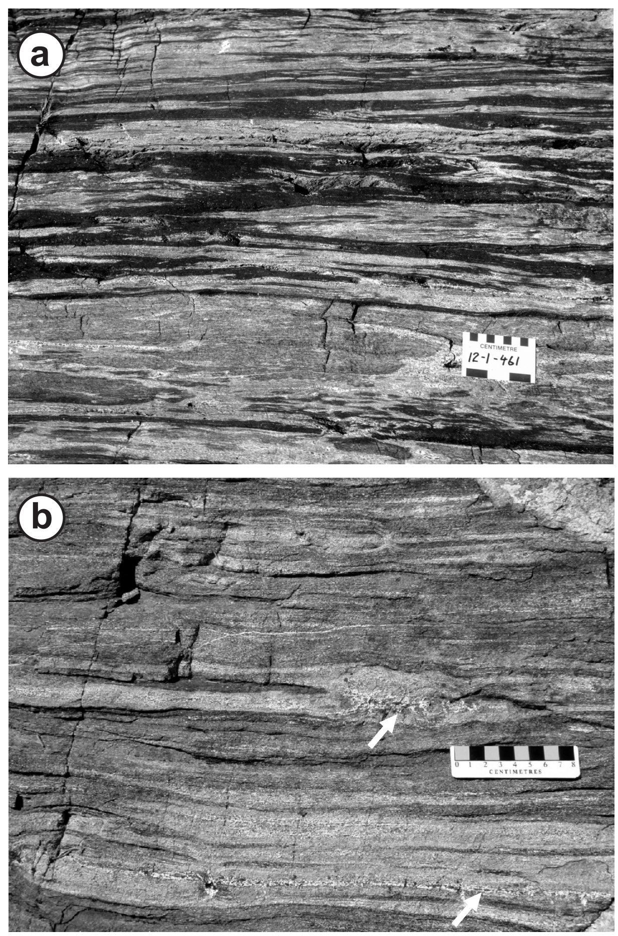

***Figure GS-4-8**: Deformed and recrystallized Tod Lake basalt: **a)** highly flattened pillows with metamorphic-hornblende–rich rinds (black) disrupted and partly resorbed (below card); alteration domains are epidote-diopside rich (e.g., lighter area grey next to scale card); **b)** layered amphibolite with expanded diopside-rich layers and incipient leucosome around epidote porphyroblasts (arrows).*

with interlayered sulphidic pelite and sulphide-facies iron formation adjacent to the amphibolite at Kawaweyak Lake are very similar to the sedimentary rocks in the Granville Lake assemblage and strongly suggest a correlation of the entire amphibolite-quartzofeldspathic (volcano-sedimentary) succession assigned to the Granville Lake assemblage in this report.

In the centre of the Notigi structure (Murphy, GS-5, this volume), the unit of the Sickle Group in contact with the Granville Lake assemblage consists of arkosic metasandstone with prominent faserkiesel, a relation similar to that found north of Pickerel Narrows on Granville Lake. On the outer margin of the Notigi structure, the Granville Lake assemblage–type amphibolite is in contact with biotite±hornblende–bearing metasandstone like that found along the south shore of Granville Lake. This contact appears to be the regional stratigraphic base of the Sickle Group. Its stratigraphic nature is indicated by the occurrence of basal quartzite in the west, and by basal conglomerate marking an unconformity along the Lynn Lake greenstone belt. The contact is tightly folded and sheared in the northeastern Kisseynew Domain but is assumed to be stratigraphic there as well.

East and west of Granville Lake, the other contact of the Granville Lake assemblage, away from the Sickle Group, is with the Burntwood Group. Much of the contact unit is layered amphibolite but can locally be quartz-rich or weakly calcareous sedimentary rock (Zwanzig, 2000a; Murphy and Zwanzig, 2007b). The younger age of the adjoining Burntwood Group predicates that the contact is a regional system of thrust faults in which the Granville Lake assemblage and the overlying Sickle Group originally formed the hangingwalls. The extent of this fault system over hundreds of kilometres indicates that it is part of the major suture marked by the GLSZ (White et al., 2000). The tectonic importance of this zone is vital because it marks the hangingwall of the crustal block forming the arc massif of the Lynn Lake–Leaf Rapids Domain that was thrust into the turbidite basin. It represents the southern limit of a tectonic and metallogenic domain containing VMS and gold deposits.

Most units of the type Granville Lake assemblage are present at Kawaweyak Lake (directly northwest of Nelson House at K in Figure GS-4-1). Even the tectonostratigraphy is the same: the mafic and quartzose units occur on either side of a long narrow outcrop belt. Both outer contacts, however, are with the Burntwood Group or associated granodiorite (Murphy and Zwanzig, 2007b). This relationship is similar to that on Wheatcroft Lake and suggests that thrust slices of the Granville Lake assemblage are interleaved with the Burntwood Group. Amphibolite units at Wheatcroft and Kawaweyak lakes are 100 km apart and lie south of the main belt of the Granville Lake assemblage, suggesting regional-scale thrusting of relatively thin slivers of older rocks deeper into the Kisseynew Domain south of the main GLSZ.

The present complex fold pattern of the GLSZ is a result of polyphase deformation related to continental collision and mid-crustal metamorphism. Mid-crustal recumbent folding, which postdates the synsedimentary deformation as well as the upper-crustal folding and thrusting, has inverted large stretches of the stratigraphic and thrust contacts. Subsequent upright folding and doming has further complicated the present geometry. A similar structural style has been described by Zwanzig (2000a) at Laurie Lake, farther west in the Kisseynew Domain.

Exotic Archean basement with sedimentary cover

Preliminary Sm-Nd isotope work shows that the Granville Lake assemblage contains juvenile Paleoproterozoic volcanic and sedimentary rocks (Murphy and Zwanzig, 2007b; Murphy, GS-5, this volume). Its tectonostratigraphy and local proximity indicate that it is closely related to the Lynn Lake greenstone belt. In the northeastern Kisseynew Domain, the Granville Lake assemblage, therefore, has to be distinguished from the sequence of Archean gneiss with sedimentary cover that contains only Archean detrital zircon and yields Archean Nd model ages (Rayner and Percival, 2007). The latter cover succession is closely related to the Ospwagan Group, which hosts the Thompson-type nickel deposits. Criteria that distinguish these evolved sedimentary successions from the Granville Lake assemblage in the field are clearly important for mineral exploration.

Similarities in the field include 1) the presence of highly siliceous metasedimentary rocks, pelite, sulphidic semipelite and sulphide-facies iron-formation; 2) contacts with the Burntwood Group; and 3) occurrence in narrow outcrop belts within the northeastern part of the Kisseynew Domain.

Differences useful in the field to identify the TNB-related rocks are 1) the presence of granitoid orthogneiss, generally at granulite metamorphic grade; 2) the absence of mafic volcanic successions or layered amphibolite; 3) the presence of distinctive bodies of porphyritic granite or augen gneiss with abundant K-feldspar; and 4) a greater abundance of mafic dikes.

The orthogneiss, which is Archean, and its sedimentary cover appear to be restricted to the northeastern part of the Kisseynew Domain that lies south of the Sickle Group and Granville Lake assemblage.

Economic considerations: new domain boundaries and proposed subdomains

The distribution of the various lithotectonic assemblages with different mineral potential along the Kisseynew Domain margins provides a basic guide for the first step in mineral exploration: choosing and understanding a specific area. These areas can be defined on a regional scale using domains and subdomains with different tectonic histories and mineral potentials.

Boundaries between domains are defined by contacts between major units. Contacts can be structural, (e.g., along the TNB), stratigraphic (e.g., the basal Missi unconformity along the Lynn Lake–Leaf Rapids Domain) or structurally complex (e.g., the Flin Flon Domain boundary). Boundaries between subdomains are defined by the limit of distribution of certain assemblages and cut across widely distributed units like the Burntwood Group. Metamorphic grade and structural style, however, are not directly related to the nature of the units and can be ignored in defining domains and subdomains. This is a departure from the definition of domains in current use by the MGS in geological map compilations (e.g., Manitoba Energy and Mines, 1986).

Flin Flon Domain

The area outlined as Flin Flon Domain in Figure GS-4-1 is underlain by Paleoproterozoic metavolcanic and volcaniclastic rocks with abundant coeval and younger intrusions. Siliciclastic metasedimentary rocks are subordinate. Large areas of orthogneiss, including high-grade metavolcanic rocks previously considered as part of the south flank of the Kisseynew Domain, are herein included. The Flin Flon Domain has a high potential for VMS and gold deposits. Geochemistry and geochronology have shown that there are a number of assemblages defined by tectonic affinity and age, and among these only the early juvenile-arc assemblages have yielded economic VMS deposits (Syme et al., 1999). The Sherridon area features such an assemblage and shares a history of base-metal mining with the main part of the Flin Flon Domain.

Lynn Lake–Leaf Rapids Domain

This domain is identical in age and character to the Flin Flon Domain, except in the south and east where the Lynn Lake–Leaf Rapids Domain contains only intrusive rocks with local supracrustal screens. The Tod–Laurie lakes area at the southwestern end of the domain serves as a second type area for the Granville Lake assemblage. Although it is in direct contact with an arc assemblage that contains the Fox Lake VMS deposit, the area north of Tod Lake in Figure GS-4-1 has a mineral potential mainly for gold mineralization, consistent with its back-arc basin- and arc-derived sedimentary basin affinity. A gold showing occurs on Laurie Lake.

Kisseynew Domain

Four proposed subdomains of the Kisseynew Domain are outlined in Figure GS-4-1. Each is dominated by the Burntwood Group but contains different intercalated assemblages and/or intrusive suites.

South Flank Kisseynew subdomain

The south flank of the Kisseynew Domain is underlain by Burntwood Group metaturbidite that locally grades upward into a thin quartzite and pelite unit. This succession is conformably overlain by Missi Group arkosic rocks, some with local pebble conglomerate beds near the base and volcanic rocks and gabbro in the middle of the group (Zwanzig, 1999). Thin, highly deformed and altered volcanic units, related sedimentary rocks and mafic sills also occur west of the most distal of the large outliers of the Flin Flon Domain in the Sherridon–Hutchinson Lake Complex. These isolated volcanogenic units occur at or near the contact between the Burntwood and Missi groups and can be interpreted as the original hangingwall of a thrust sheet (Zwanzig, 1999). Several showings of base metals are consistent with an origin of the sheets as structural extensions of an arc assemblage rooted in the Flin Flon Domain. Intrusive rocks, although less highly metamorphosed on the south flank, resemble those in the Central Kisseynew subdomain (below). The geometry of the south flank appears to be dominated by large recumbent folds (e.g., File Lake nappe; Zwanzig, 1999) in which local structural slivers from the Flin Flon Domain became interleaved with assemblages from the margin of the Kisseynew Domain.

Central Kisseynew subdomain

The large core area of the Kisseynew Domain is underlain by migmatite that was derived from the Burntwood Group and intruded by large plutons, sheets and lenses of felsic to ultramafic rocks. Large-scale recumbent folds and probable sheath folds characterize the southwestern half of the subdomain. The intrusions there include hypersthene-bearing ultramafic to granitoid rocks, commonly enderbite. The enclosing Burntwood Group contains belts of coarse, garnet-cordierite–rich diatexite that suggest significant melt extraction. Folds are progressively steeper to the northeast at higher structural levels where large weakly peraluminous granite–granodiorite sheets and the tonalitic Highrock Lake Batholith occur (Zwanzig, 1990). Preliminary Nd isotope data indicate that the intrusions in the Central Kisseynew subdomain are nearly juvenile with only limited contamination or assimilation of Archean material, much like the Burntwood Group hostrocks (Zwanzig, unpublished data, 2006). Although sulphide mineral showings are present (Baldwin et al., 1979; McRitchie et al., 1979), the Central Kisseynew subdomain is considered to be barren of base-metal and gold deposits.

Northeast Kisseynew subdomain

The boomerang-shaped area adjacent to the TNB and the north flank of the Kisseynew Domain is characterized by Burntwood Group migmatite with leucosome containing local hypersthene. Sheets of granodiorite intruding the Burntwood Group are locally abundant. Narrow belts and a dome containing hypersthene-bearing Archean granitoid orthogneiss are locally overlain by the succession of quartzite, semipelite and lean sulphide-facies iron formation that is similar to rocks in the Ospwagan Group in the TNB but lacks marble (Percival et al., 2005, 2006; Zwanzig et al., 2006). The suite of potassic porphyritic intrusions and augen gneiss with 1880–1890 Ma crystallization ages and Archean Nd model ages is spatially associated with known occurrences of Archean rocks (Zwanzig et al., 2003; Percival et al., 2004, 2007; Whalen et al., GS-6, this volume) and provides a possible analogue for currently unknown Archean crust and Archean-derived sediment. These distinctive potassic intrusions, originally considered to be younger than the Burntwood and Sickle groups, generally do not have exposed contacts, except for one intrusive contact into older amphibolite. The same pluton is apparently unconformably overlain by the (Sickle Group–age) Grass River Group (Zwanzig et al., 2003). At southwestern Wapisu Lake, one of the porphyritic plutons may be unconformably overlain by a marble-free Ospwagan-like supracrustal succession, but the contact is not exposed (Percival et al., 2007). The presence of Archean rocks, higher P-T conditions and older U-Pb monazite ages than elsewhere in the Kisseynew Domain (Growdon et al., 2006; Growdon, pers. comm., 2008) suggest that the Northeast Kisseynew subdomain has experienced earlier and greater uplift, possibly resulting from crustal-scale stacking and escape tectonics during collisional convergence between the Superior craton and the internal zone of Trans-Hudson orogen.

At two localities on Wuskwatim Lake, the Burntwood Group is separated from the early sedimentary succession derived from Archean detritus by a unit of weakly calcareous quartz-rich sedimentary rocks (Zwanzig et al., 2006). Contacts are not exposed but appear to be conformable with the Burntwood Group. The early sedimentary succession at Wuskwatim Lake may thus be related to part of the Granville Lake assemblage, which it resembles and whose juvenile Nd isotope ratios it shares.

The boundaries of the Northeast Kisseynew subdomain are with the Archean basement and the Ospwagan Group cover in the TNB to the east, and the juvenile Paleoproterozoic rocks of the Central Kisseynew subdomain to the southwest (Figure GS-4-1). The evolved rocks of the Northeast Kisseynew subdomain may define a pericontinental terrane fragment that was thinned and separated from the Superior craton before 1890 Ma, possibly during rift magmatism represented by the Bah Lake assemblage at the top of the Ospwagan Group (Zwanzig et al., 2007). The similarity of the early sedimentary succession derived from Archean detritus with the Ospwagan Group in the TNB and the presence of mafic–ultramafic dikes supports a potential for nickel mineralization. These evolved rocks were juxtaposed with the juvenile Burntwood Group, which has no nickel potential.

North Flank Kisseynew subdomain

Contiguous and interfolded metasedimentary rocks of the Burntwood and Missi groups, as well as the narrow belts of the Granville Lake assemblage, are included in the North Flank Kisseynew subdomain. These rocks are intruded by leucogranodiorite sheets and pegmatite and, south of Granville Lake, by fine-grained gabbro to quartz diorite. Limited data indicate that the intrusive and supracrustal rocks are juvenile Paleoproterozoic. An exception is the Black Trout diorite (Murphy and Zwanzig, 2007a), which is apparently contaminated by Archean crust (Murphy, GS-5, this volume; D. Corrigan and H. Zwanzig, unpublished data, 2003). The southern boundary of the north flank is defined as the southern limit of outliers of the Sickle Group or the Granville Lake assemblage.

The known mineral potential for the north flank is restricted to gold, with minor showings in the vicinity of Wheatcroft Lake (Barry, 1965).

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