GS-8 New tectonostratigraphic framework for the northeastern Kisseynew Domain, Manitoba (parts of NTS 63O)

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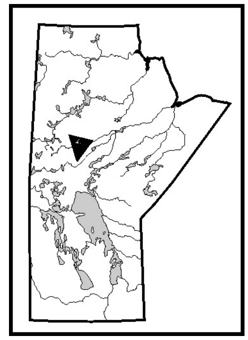

Summary

High-resolution images from the 2006 Wuskwatim Lake aeromagnetic survey were used in conjunction with new mapping and isotopic data to reinterpret the geology of the Kisseynew Domain (KD) west of the Thompson Nickel Belt (TNB). The results suggest that a 60 km wide zone, previously considered to consist entirely of Burntwood Group migmatite and younger granite, is structurally interleaved with heterogeneous orthogneiss and paragneiss resembling Superior Province basement and the lower part of its cover sequence (Ospwagan Group). These units are exposed in structural culminations suggesting a widespread distribution under a structural cover of the Burntwood Group in the northeastern KD. Iron formations that form aeromagnetic markers may correspond to similar units within the Pipe Formation, making parts of the region prospective for Thompson-type nickel mineralization.

Introduction

As part of the Flin Flon project of the Targeted Geoscience Initiative III Program, a field program was initiated to examine possible westward extensions of Thompson Nickel Belt strata in the northeastern Kisseynew Domain (Figure GS-8-1). The study was prompted by drillcore data provided by Inco Limited and New Insco Mines (now Nuinsco Resources Ltd.) from a nickel-sulphide orebody hosted in the Ospwagan Group in the Mel zone, 10 km west of the exposed Superior Province margin (Zwanzig and Böhm, 2002, 2004); and in the Wuskwatim Lake area to the southwest, by data from a new high-resolution aeromagnetic survey (Coyle and Kiss, 2006) and recent Sm-Nd isotopic data that indicate >3 Ga ages for plutonic and supracrustal units (Percival et al., 2005). Together, these observations have suggested the possible existence of Ospwagan Group inliers up to 60 km west of the Superior margin within an area dominated by Burntwood Group metasedimentary rocks and granitoid rocks characterized by juvenile Nd isotopic signatures. The presence of such inliers would extend the area for nickel exploration in Manitoba because all significant deposits in the main part of the TNB are hosted by the Paleoproterozoic Ospwagan Group, which lies unconformably on Neo- to Paleoarchean basement gneiss.

This report provides a revised tectonic framework and structural interpretation based on the results from local remapping in the northeastern part of Kisseynew Domain (KD) in July 2006 (Zwanzig et al., GS-9, this volume; Growdon et al., GS-10, this volume). The results broadly support the presence of TNB crust: they are consistent with the presence of Archean orthogneiss (possibly TNB basement) and confirm that associated paragneiss consists primarily of Archean detritus. Preliminary stratigraphy, geochemistry and new Nd isotope data of the newly mapped assemblages compiled in a companion paper (Zwanzig et al., GS-9, this volume) indicate that a first-order correlation between the paragneiss sequence and the Ospwagan Group in the main part of the TNB is probable.

Access to the region is by fixed-wing aircraft to water bodies including the Burntwood River. Exposure is sparse and limited to low shoreline outcrops best viewed at low water conditions. Water levels were at historical highs during the 2006 field season, limiting both the quality and quantity of exposures.

Tectonic elements

Basement-type orthogneiss

Orthogneiss is exposed in the core of several structural windows: at Wuskwatim Lake, a few kilometres to the northwest on the Burntwood River and at Tullibee Lake (Figures GS-8-1 and GS-8-2a, 2b). A diffuse, oval (3 by 12 km) positive aeromagnetic anomaly (Coyle and Kiss, 2006; Zwanzig et al., 2006b) arises from the Wuskwatim Lake occurrence. Outcrops on islands in central Wuskwatim Lake consist dominantly of foliated to gneissic tonalite with characteristic orthopyroxene-biotite assemblages. Sporadic enclaves of garnet-orthopyroxene-hornblende-biotite paragneiss and ortho-pyroxene-clinopyroxene-hornblende-plagioclase metabasite constitute less than 5% of the exposed bedrock. In one location, metabasite with rusty-weathering patches grades to a layered sedimentary or volcaniclastic unit (Figure GS-8-2c), suggestive of supracrustal origin. Other more massive pyroxene-bearing metabasite bodies transect gneissic layering and

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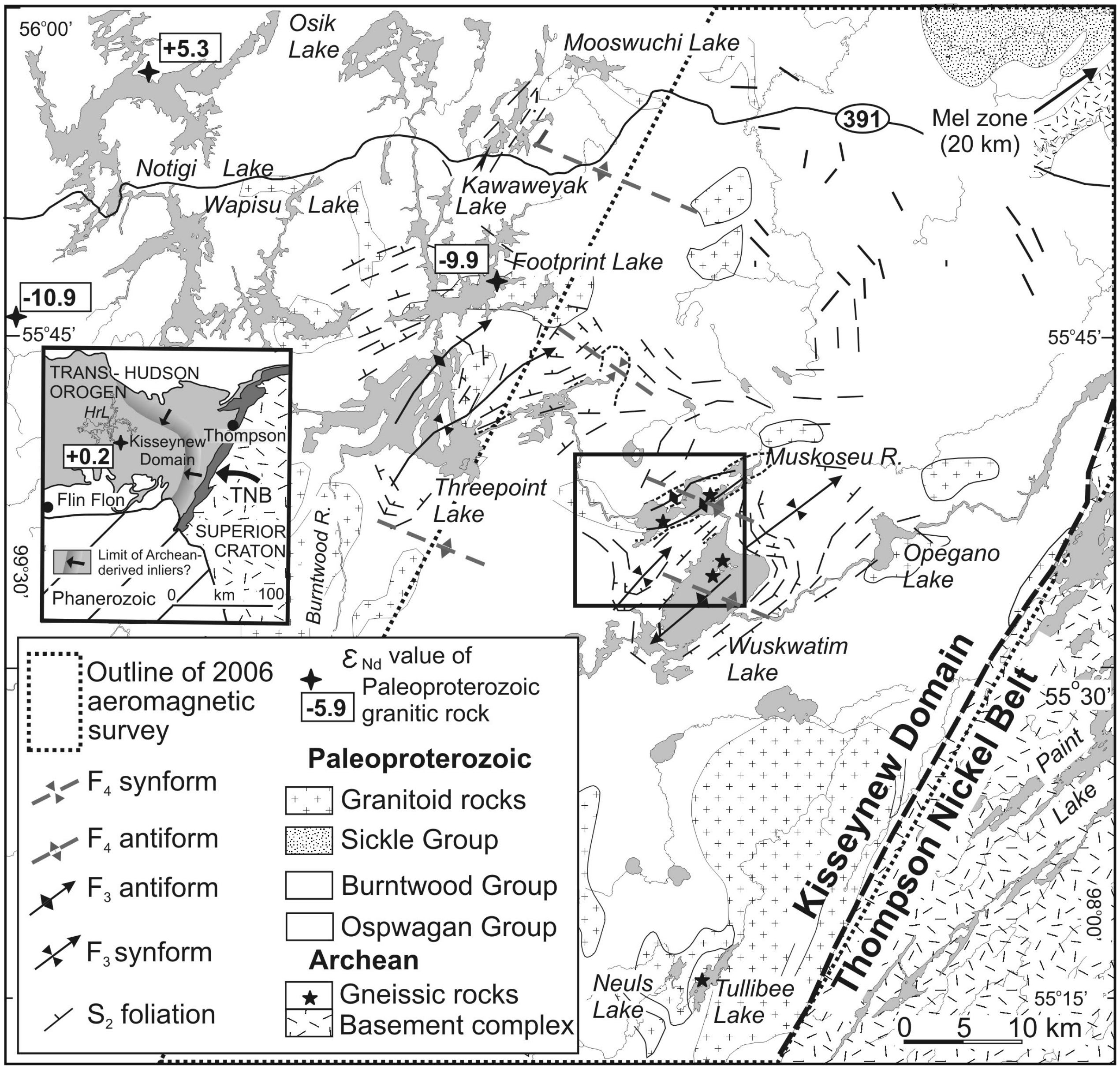

Figure GS-8-1: *Location map showing features referred to in the text. Outlined area near Wuskwatim Lake shows the location of Figure GS-8-4. Inset map shows the possible distribution of Archean crust beneath the northeastern Kisseynew Domain and the locations of Highrock Lake (HrL) and sample 25-72-4030.*

are clearly intrusive. Brown-weathering, coarse-grained orthopyroxene-biotite granite (charnockite) has massive and gneissic phases, including schlieren of older gneiss.

At the mouth of the Muskoseu River, 5 km northwest of Wuskwatim Lake, heterogeneous tonalite gneiss occurs in contact with quartz-rich supracrustal units. The tonalitic unit comprises gneissic and foliated phases with orthopyroxene-clinopyroxene-hornblende-biotite-plagioclase-quartz assemblages. Sparse enclaves include garnet-orthopyroxene-biotite paragneiss and orthopyroxene-clinopyroxene-hornblende-plagioclase metabasite. Concordant leucosome and discordant leucogranite dikes are common (Figure GS-8-2a).

At the Muskoseu River locality, a contact interpreted as an unconformity is exposed between a polyphase tonalitic gneiss unit and quartz-rich metasedimentary rocks (Figure GS-8-2a, 2d). The contact is defined by the change from orthopyroxene-bearing tonalitic orthogneiss to quartz-rich rocks with centimetre-scale layering defined by biotite-rich seams. In addition to the evidence for the unconformity provided by this contact, the granulite-facies orthogneiss is inferred to be depositional basement to the quartzite-bearing supracrustal sequence based on several observations: 1) the orthogneiss occurs in structural culminations; 2) the orthogneiss is uniformly at granulite facies, compared to the variable upper amphibolite

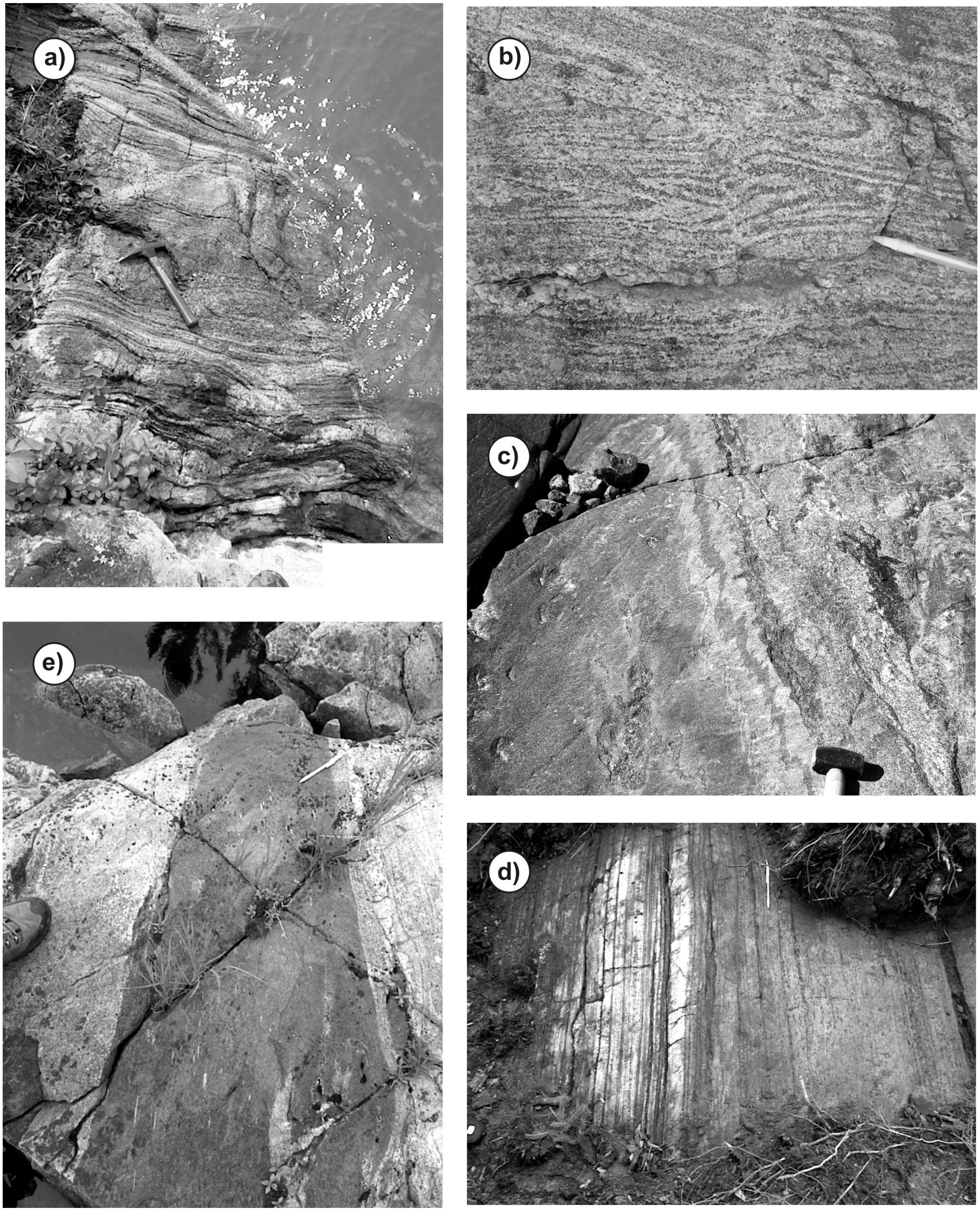

Figure GS-8-2: *Field photographs of characteristic rock types:* ***a)*** *orthopyroxene-biotite tonalite gneiss, Burntwood River near Muskoseu River (33 cm long hammer for scale);* ***b)*** *orthopyroxene-clinopyroxene-biotite tonalite gneiss showing polyphase deformation, Tullibee Lake (9 mm pen barrel for scale);* ***c)*** *metabasite with rusty patches grades into layered sedimentary or volcaniclastic rock, central Wuskwatim Lake (10 cm long hammer head for scale);* ***d)*** *unconformity at the mouth of the Muskoseu River between orthopyroxene-clinopyroxene tonalitic orthogneiss (right) and quartz-rich sandstone (left);* ***e)*** *boudinaged dike with plagioclase phenocrysts cutting orthopyroxene-clinopyroxene tonalite gneiss, Tullibee Lake (11 cm wide boot for scale).*

to granulite facies of the Burntwood Group (Growdon et al., GS-10, this volume); 3) although U-Pb ages are not yet available, the tonalite gneiss at the Muskoseu River location has a model age of 3.3 Ga (Zwanzig et al., GS-9, this volume) and the charnockite from the complex in central Wuskwatim Lake yielded a Nd model age of 3.1 Ga (Percival et al., 2005), both ages similar to those of Superior Province basement to the east; and 4) the orthogneiss is cut by variably boudinaged mafic sills or dikes not present in the nearby Burntwood paragneiss (e.g., Figure GS-8-2e).

Ospwagan-type supracrustal rocks

Occurrences of quartz-rich and associated sedimentary rocks are sporadically exposed in several widely spaced locations. In most locations, they are associated with thin magnetic anomalies where local exposures correspond to sulphide-facies iron formation (Zwanzig et al., GS-9, this volume). In some areas, there appears to be a negative correlation between magnetic anomalies and bedrock exposure. Due to the limited exposure and structural complexity, a composite section has been constructed (Zwanzig et al., Figure GS-9-2, this volume).

Basal quartz-rich units are exposed on the Burntwood River, northwest of Wuskwatim Lake. The arkosic arenite unit is medium- to fine-grained sandstone to siltstone, with layering on the centimetre to metre scale, and an aggregate thickness up to 100 m. Concordant layers and pods of metagabbro constitute up to 5% of the unit. Zircons from quartz-rich sandstone (Nd model ages of 3.1–3.2 Ga) gave U-Pb sensitive high-resolution ion microprobe (SHRIMP) ages between 2.6 and 3.3 Ga (Percival et al., 2005; Zwanzig et al., Figure GS-9-4, this volume). The unit is tentatively correlated with the Manasan Formation of the Ospwagan Group, which also contains exclusively Archean (2.6–2.85 Ga) zircons (Hamilton and Bleeker, 2002; Rayner et al., GS-11, this volume).

Skarn units are exposed in a few locations. At Kawaweyak Lake, a 20 m thick section includes layered and massive carbonate-bearing units with characteristic weathering pits. Calcsilicate assemblages include wollastonite-quartz-carbonate-diopside, with possible vesuvianite. At Wuskwatim Lake, a thinly layered 2 m thick section contains diopside-quartz-calcite. The carbonate-bearing units could correlate with the Thompson Formation of the Ospwagan Group but *see also* Zwanzig et al. (GS-9, this volume).

In a few locations, iron formation is exposed on magnetic anomalies. On the Burntwood River northwest of Wuskwatim Lake, lean sulphide-facies iron formation occurs within garnet- and biotite-bearing semipelite with local calcsilicate-bearing layers. Angular boulders of massive sulphide (pyrrhotite-pyrite) suggest an association with the magnetic anomaly. In northwestern Wuskwatim Lake, a 5 m thick unit of sulphide (pyrrhotite)- and silicate-facies iron formation occurs on a prominent magnetic anomaly. At Kawaweyak Lake, lenses of massive pyrrhotite up to 3 m thick in greywacke and semipelite represent sulphide-facies iron formation. Silicate-facies iron formation pods up to 3 m thick are present in southern and western Threepoint Lake. Elsewhere, garnet- and biotite-bearing semipelite with concordant, millimetre scale quartz veins may represent equivalents of the Pipe Formation. The iron formation–semipelite occurrences are tentatively correlated with the Pipe Formation of the Ospwagan Group.

Burntwood Group metasedimentary rocks

The Burntwood Group consists of metagreywacke and derived schist, migmatite and diatexite. Metamorphic assemblages include combinations of garnet, biotite, cordierite, sillimanite, an inferred melt phase in the amphibolite facies and garnet-orthopyroxene-biotite melt in the granulite facies (*see* Growdon et al., Figure GS-10-1, this volume). Small quantities of graphite are ubiquitous. Migmatitic leucosome constitutes from 5% to 50% of most outcrops and contains garnet in the Wuskwatim Lake area. The migmatite is cut by concordant and discordant leucogranitic pegmatite dikes.

Intrusions

Several intrusive suites are recognized throughout the region. Deformed and metamorphosed metabasite occurs as dikes and boudins within tonalitic gneiss and quartz-rich metasedimentary units (Figure GS-8-2e). At Kawaweyak Lake, an ~15 m thick gabbro-pyroxenite body cutting sulphidic iron formation contains metre-scale zones of massive pyrrhotite, closely resembling the setting of Thompson-type mineralization. At Tullibee Lake, a 10 m thick gabbro sill within Burntwood paragneiss exhibits 1 to 20 cm igneous pyroxenite layers. Sheets of biotite granodiorite and orthopyroxene-biotite granodiorite cutting Burntwood paragneiss in the Tullibee Lake area are strongly foliated and reflect regional deformation patterns. In the Wuskwatim Lake area, small bodies of massive garnet-biotite granite and garnet-orthopyroxene-biotite granite appear to postdate regional deformation. Dikes and sills of leucogranite and pegmatite are present throughout the region and have variable timing relationships with respect to regional deformation events.

Four intrusive samples of inferred Paleoproterozoic age were selected for tracer isotope analysis. The four samples form a roughly east-west transect across approximately 100 km of the Kisseynew Domain, from near Footprint Lake to Highrock Lake (Figure GS-8-1). These Paleoproterozoic granitoids act as probes, their Sm-Nd signatures indicating the presence or absence of ancient crust beneath Burntwood paragneiss. Details

Table GS-8-1: Location and lithology of samples collected for Sm-Nd isotope analysis, from west to east, northeastern Kisseynew Domain.

Lab number	Sample number	Rock type	UTM zone	UTM E	UTM N
8958	25-72-4030	gneissic garnetiferous granodiorite	14	413748	6170734
8957	25-71-328	porphyroblastic granite	14	463212	6179568
8956	25-73-1455	gneissic granite	14	481102	6200749
8955	29-71-412	porphyroclastic granite-monzonite	14	511677	6183356

UTM coordinates measured using NAD 83

of the rock types and specific locations are found in Table GS-8-1 and are listed from west to east.

Tracer isotopic analyses were conducted using the multicollector ICP-MS Nu Plasma™ at the Geological Survey of Canada. Samarium and Neodymium were analyzed using an array of fixed Faraday collectors in static multicollector mode. The isotopic ratios were corrected for spike contribution and mass discrimination by numeric solution of the isotope dilution equations with exponential normalization. Quality control was performed by monitoring the uniformity of nonradiogenic isotopic ratios and by analyzing of the standards (La Jolla Nd and Ames Sm). Analytical results are presented in Table GS-8-2 and plotted on Figure GS-8-1, except for sample 25-72-4030 from Highrock Lake to the west of the figure area. Model ages (Goldstein et al., 1984) range from 1.91 to 2.85 Ga, indicating crustal contamination; however, there does not appear to be a systematic decrease in model ages moving away from the Superior margin as would be expected for a continuous margin that thins to the west.

Structural elements

At least four phases of deformation have affected the Burntwood Group regionally (cf. Zwanzig, 1990; Zwanzig and Böhm, 2002) and three of these ($D_{2–4}$) are recognized in the Wuskwatim corridor. The principal outcrop-scale fabric is a synmetamorphic S_2 foliation and migmatitic layering, through which older events are inferred based on map relationships.

Pre-D_1 (Archean) fabrics

In exposures of tonalitic gneiss on Wuskwatim Lake, boudinaged metagabbro dikes transect an early gneissic layering. The dikes are observed in basement gneiss and quartz-rich metasedimentary units, but generally not in Burntwood Group paragneiss, analogous to the timing of the 1.883 Ga Molson dike swarm of the Thompson Nickel Belt (Bleeker, 1990). Based on this analogy, the gneissic fabric defined by granulite-facies minerals could represent a pre–1.883 Ga high-grade tectonothermal event, possibly an Archean fabric of Superior Province affinity. Little additional information can be drawn from these observations owing to the strong Proterozoic tectonothermal overprint.

Deformation D_1: early thrusting

An early (D_1) period of Paleoproterozoic deformation was inferred based on map relationships at the Mel zone, 60 km northeast of Wuskwatim Lake (Zwanzig and Böhm, 2002; Zwanzig et al., GS-9, this volume). Similar tectonostratigraphic assemblages are present in this

Table GS-8-2: Analytical results for samples collected for Sm-Nd isotope analysis, northeastern Kisseynew Domain.

Sample number	Sample wt, g	Age, Ga (assumed)	[Nd][1] ppm	[Sm][1] ppm	$^{147}Sm^{1}/^{144}Nd$	2σ[1]	$^{143}Nd^{2}/^{144}Nd$	2σ[2]	$\varepsilon^{143}Nd^{3}$	TDM, Ma (Goldstein)
25-72-4030	0.097	1.84	43.37	8.17	0.114	0.000	0.512	0.000	0.20	2297
25-71-328	0.098	1.84	70.08	9.80	0.085	0.000	0.511	0.000	-10.90	2851
25-73-1455	0.098	1.84	159.02	33.90	0.129	0.000	0.512	0.000	5.31	1915
29-71-412	0.102	1.84	70.08	9.78	0.084	0.000	0.511	0.000	-9.88	2790
29-71-412 (dupl.)	0.096	1.84	69.43	9.69	0.084	0.000	0.511	0.000	-9.94	2793

[1] Sm and Nd concentrations and $^{147}Sm/^{144}Nd$ ratios are corrected for blank of 2 ±2 pg for both Sm and Nd. The uncertainty is propagated into the error of $^{147}Sm/^{144}Nd$ ratio

[2] Nd isotopic ratios are corrected for fractionation relative to the ratio of $^{146}Nd/^{144}Nd = 0.7219$, using exponential law and real atomic masses. The $^{143}Nd/^{144}Nd$ isotopic ratios are adjusted to $^{143}Nd/^{144}Nd = 0.51186$ in the La Jolla standard.

[3] $\varepsilon^{143}Nd$ at the time indicated in the column "Age, Ga" relative to the accepted Chondritic Uniform Reservoir with $^{143}Nd/^{144}Nd = 0.512636$ and $^{147}Sm/^{144}Nd = 0.1966$.

location, including Superior Province basement, Ospwagan Group strata and Burntwood Group paragneiss. A D_1 thrust is inferred to have placed Burntwood Group metagreywacke over the Pipe Formation of the Ospwagan Group, cutting out stratigraphically higher units of the Ospwagan Group. Observed in several drillcores, deformed strata are parallel and the contact is invariably obscured by intrusive material (Zwanzig et al., 2003). In the Wuskwatim Lake corridor, Burntwood paragneiss structurally overlies iron-formation-bearing units tentatively correlated with the Pipe Formation, presenting a similar relationship.

Deformation D_2: synmetamorphic layering

A prominent synmetamorphic D_2 foliation and migmatitic layering is the dominant outcrop-scale fabric element in most units. Defined by alignment of biotite grains, leucosome veins and mesosome selvages, the fabric parallels bedding in sedimentary units, where preserved. In a few locations, a component of shear strain is apparent in the D_2 fabric. The offset of markers indicates ductile, top-to-the-south shear. The D_2 structures are inferred to have formed in subhorizontal orientations throughout most of the area, and were subsequently folded about upright F_3 folds.

Structural analysis of the KD in Manitoba (Zwanzig, 1990) and detailed analysis of its southern flank (Zwanzig, 1999), as well as ongoing work at the margin of the TNB indicate that D_2 spans a protracted period (probably 1.82–1.79 Ga), with several phases of folding and a variety of structural styles. Where these originally west-northwest-trending structures are tracked over an extended area, they include midcrustal recumbent folds and upper crustal inclined to upright structures. The same crustal-scale geometry is inferred in the Wuskwatim Lake corridor (see below) and suggests a protracted development of the structural culminations that expose the older gneisses in the northeastern KD.

Large-scale D_2 structures are probably responsible for the interleaving of the relatively thin structural sheets of the heterogeneous Archean-derived gneiss units with the juvenile Proterozoic Burntwood Group. In the Mel zone, basement gneiss occurs structurally above and below the Burntwood paragneiss, in a probable D_2 nappe-like structure (Zwanzig et al., 2003). Therefore, the possibility of allochthonous basement must be considered in interpreting the structural geometry of the Wuskwatim corridor.

F_3 folds

A set of northeast-trending folds defines the map pattern throughout much of the Wuskwatim corridor. Map units and S_2 foliation in migmatitic rocks are folded into open to tight, upright to northwest-dipping F_3 folds. Moderate northeasterly plunges characterize folds in the northern part of the area. In addition to the map-scale structures, mesoscopic F_3 folds and associated L_3 rodding lineations are common. In some locations, axial surfaces of symmetrical F_3 folds are defined by leucosome segregations. At least one suite of granitic dikes appears to be syntectonic with respect to D_3. At Kawaweyak Lake, a west-trending dike transects a mesoscopic F_3 fold at a high angle, and the dike margin is affected by a fracture cleavage parallel to the F_3 axial surface.

Folds belonging to F_3 are present in submigmatitic Burntwood metagreywacke in a structural basin southeast of Footprint Lake. The northeast-trending folds have subvertical hinges and reorient steeply dipping S_2 cleavage. It is apparent that the dip of S_2 foliation varied significantly prior to D_3 deformation, from gentle in migmatitic rocks, to upright at lower metamorphic grade and presumed higher structural levels.

To the southeast in the Tullibee Lake region, F_3 folds are notably tighter and more upright.

F_4 folds

The interaction between F_3 folds and F_4 crossfolds is inferred to be responsible for dome-and-basin interference patterns and for significant regional structural relief. On the northern flank of a west-northwest-trending F_4 antiform centred on Wuskwatim Lake, map-scale F_3 folds have consistent northeasterly plunges and metamorphic grade decreases from granulite facies through upper amphibolite to mid-amphibolite facies. This structural culmination exposes the basement and Ospwagan-type supracrustal occurrences in the Wuskwatim Lake–Burntwood River–Threepoint Lake region. To the north, an F_4 synform encloses basins of submigmatite-grade Burntwood Group.

Late-metamorphic high-strain zones were observed on the Burntwood River northwest of Wuskwatim Lake (Figure GS-8-3). The west-southwest-trending, steeply dipping protomylonitic to mylonitic fabric involves migmatitic leucosome and pegmatite that elsewhere truncate S_2 foliation. Fractures in orthopyroxene and garnet crystals are filled with quartz. Locally developed shear bands indicate dextral transcurrent displacement. In a few locations, ultramylonite seams up to a few millimetres thick extend over strike lengths of more than 20 cm. A single generation of late granite dikes postdates the straight gneissosity. Based on their orientation and ductile nature, the shear zones are inferred to have formed during D_4 deformation; however, their geometric significance is not understood.

Structural geometry

This section uses field, isotopic (Percival et al., 2005; Zwanzig et al., GS-9, this volume; Rayner et al., GS-11, this volume; Growdon et al., GS-10, this volume) and geophysical information (Coyle and Kiss, 2006) to describe the regional structural geometry.

The regional structures resulting from the polyphase deformation are narrow discontinuous belts of Archean-derived paragneiss marked by high-intensity aeromagnetic signature, hosted in a terrane of the Paleoproterozoic Burntwood Group marked by low magnetic intensity. The structures have an overall northwesterly trend established during the early periods of deformation (D_{1-2}) but generally thrown into open to tight northeast-trending folds during the later phases.

Wuskwatim Lake crossfold

A moderate positive aeromagnetic anomaly beneath Wuskwatim Lake corresponds to exposures of granulite-facies tonalite gneiss and granite (charnockite), interpreted as Archean basement (T_{DM}=3.1 Ga). Subhorizontal S_2 foliation and L_3 lineation characterize the core of the structure. The central anomaly is separated from the surrounding magnetically quiet background, which corresponds to Burntwood paragneiss, by a positive anomaly identified as sulphide-facies iron formation (T_{DM}=3.3 Ga) at one location in the northwest. A gently southwest-plunging F_3 antiform is defined by the orientation of S_2 foliation and layering in the southern part of the structure. Along the axis of the D_3 structure to the northeast is a moderately northeast-plunging F_3 synform. Its juxtaposition with the antiform suggests post-F_3 lateral displacement. The west-southwest-trending, late-metamorphic, high-strain zones could have accommodated this movement. A broad, west-northwest-trending F_4 antiform is inferred to be responsible for the reversal in F_3 plunge. Alternatively, there may have been an independent development of F_3 folds with symmetry reversal and detachment across a northwest-trending F_2 antiform. Such structures have been mapped on the southern flank of the KD (Zwanzig, 1999) and were also achieved in experiments of superposed buckle folding (Skjernaa, 1975). In this interpretation, the late-metamorphic shear zone was long lived and served as a displacement transfer zone during D_3 and as a transpression zone during D_4.

***Figure GS-8-3:** High-strain zone in quartz-rich sandstone, Burntwood River. Note transposition of pegmatite dikes (pale). The high-strain fabric is transected by a late granite dike.*

Burntwood River 'M' fold zone

Neither basement nor quartz-rich supracrustal units can be traced the few kilometres across the synform between Wuskwatim Lake and the Burntwood River, although the lithological components are similar on the river. Gneissic tonalite is exposed in the cores of a pair of narrow, steeply northwest-dipping structural belts of orthogneiss flanked by paragneiss units that are marked by magnetic anomalies. The belts are interpreted as Archean basement with Ospwagan-type cover. The basement in the southern belt is gneissic, granulite-facies tonalite, whereas the basement in the north is orthopyroxene granite (charnockite). The Ospwagan-type section comprises basal quartz-rich sandstone and a greywacke-pelite unit, including sulphide-facies iron formation, which forms the magnetic marker.

The fold zone may represent antiform-synform pairs forming an upright M-shaped structure (Figure GS-8-4). The structure is about 10 km long and 3.5 km wide, including an unexposed area with linear aeromagnetic anomalies northwest of the river. The entire fold zone is surrounded by Burntwood Group migmatite. It is canoe-shaped and tentatively interpreted as an F_3 structure refolded by a northwest-trending F_4 antiform. The structure can alternatively be interpreted as a series of early recumbent folds of Archean orthogneiss with paragneiss cover, structurally overlain by the Burntwood Group along a roof thrust (Figure GS-8-4c). In this interpretation, a tight F_3 antiform has refolded the structure along with the thrust and brought it up to the level of erosion. Very similar structures with the same Mesoarchean Nd model ages (Zwanzig et al., GS-9, this volume) occur northeast of Thompson along the northern termination of the TNB. The magnetic anomalies that mark the fold zone on the Burntwood River are truncated abruptly at the southwestern end of the structure, probably along a D_4 shear zone.

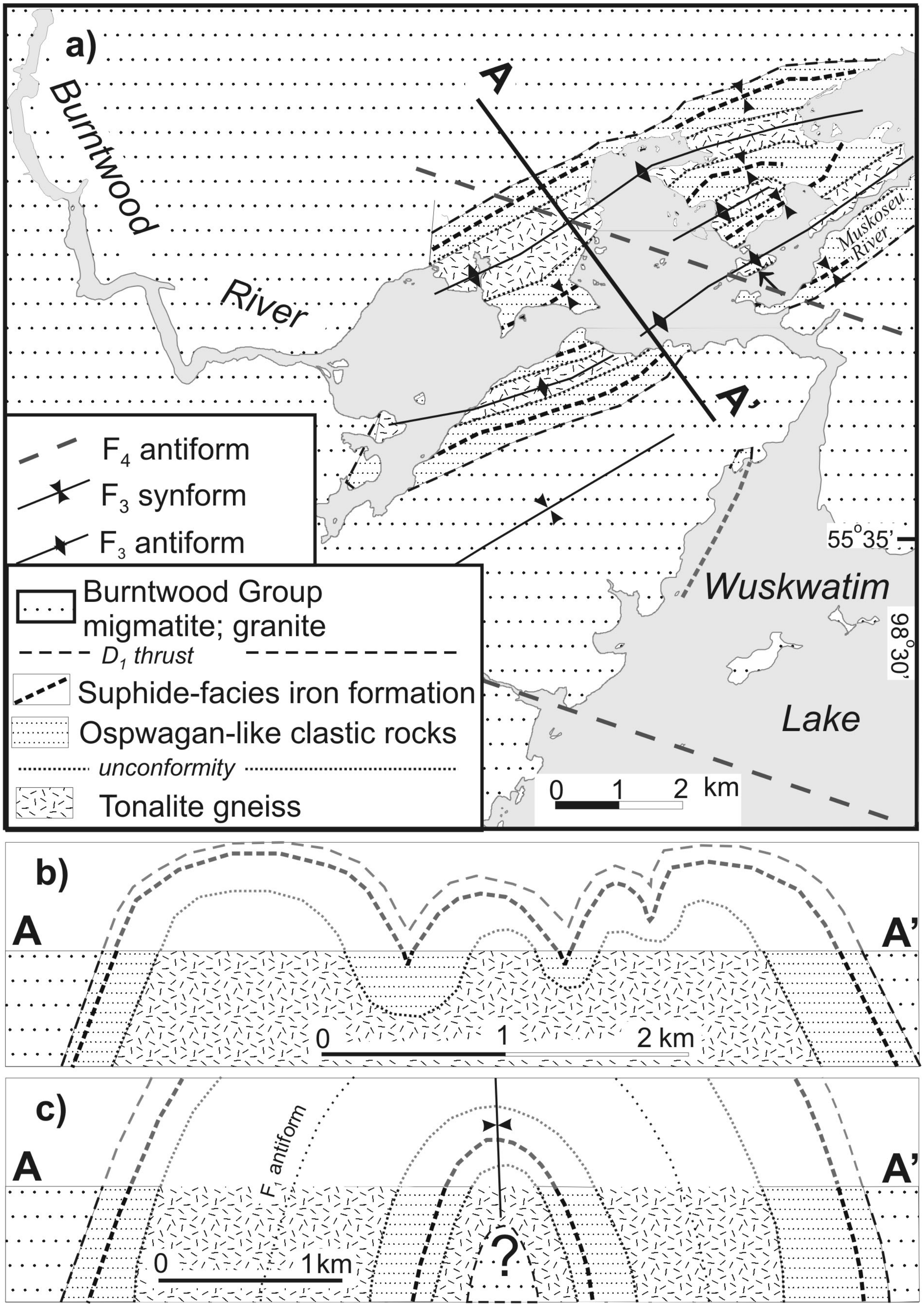

Figure GS-8-4: Burntwood River area northwest of Wuskwatim Lake; ***a)*** *map showing field relationships, with the location of the exposed unconformity at the mouth of the Muskoseu River indicated by the small arrow;* ***b)*** *interpretive cross-section;* ***c)*** *alternate interpretive cross-section.*

Threepoint Lake

The structure at Threepoint Lake is dominated by a large F_3 antiform-synform pair in the central and eastern bays, and west-northwest linear trends to the west. The antiform is cored in a large folded granite pluton with a hypersthene-bearing phase that intruded mainly the Burntwood Group. Felsic gneiss derived from arkosic quartzite, amphibolite, garnet-biotite gneiss and sulphidic gneiss, all interpreted to be part of the Ospwagan-like sequence, occur on small isolated shoreline outcrops on an elongate island on the northwestern limb of the antiform. Abundant granite shows that these rocks may represent large rafts at the margin of the pluton. A magnetic anomaly in the strait to the northwest suggests the presence of iron formation. Similar rocks, but containing mostly garnet-biotite, and sillimanite-biotite gneiss, commonly with disseminated pyrrhotite, as well as hypersthene intermediate gneiss, extend west along the north shore of the western bay. As on the Burntwood River northwest of Wuskwatim Lake, the narrow belt of heterogeneous paragneiss is bounded on the north and south by the Burntwood Group and is therefore interpreted as a thrust sheet, possibly refolded into a tight early recumbent fold.

Narrow magnetic anomalies extend also for 15 km northeast along the flooded Burntwood River on the southeastern limb of the F_3 synform. There is little present exposure, but previous mapping (Baldwin et al., 1979) has suggested that the anomalies also mark a thin sheet of heterogeneous gneiss and amphibolite. The east-trending river channel to the south has small outcrops of sheared orthogneiss and highly foliated granitoid rocks, including multiphase agmatite, that appear to occupy another long-lived east-trending shear zone. The gently to moderately northeast-plunging core of the synform is occupied by garnet-biotite schist and metagreywacke with only traces of quartz-plagioclase veining. The nearest occurrence of hypersthene is in intrusive rock of intermediate composition (possible enderbite), only 5 km south of the nonmigmatitic rocks. The average dip of 40°N indicates that biotite-granulite–facies rocks presently occur only 3 km below the roof of the migmatite complex. This suggests considerable post-peak thermal attenuation of the structures in the northeastern KD or anomalously high paleothermal gradients.

Tullibee and Neuls lakes

High-grade tonalite gneisses containing boudinaged mafic dikes represents probable Archean basement in western and central Tullibee Lake. Prominent north-north-west-trending magnetic anomalies arise from strongly foliated, biotite-magnetite granodiorite of probable Paleoproterozoic age. Less than 2 km to the west at Neuls Lake, sulphide-facies iron formation and metagabbro occur within quartz-rich sandstone and semipelite, inflated more than 50% by dikes of granite and pegmatite. The iron formation forms a linear magnetic high that is part of a chain of positive anomalies that describe north-trending folds in the poorly exposed area south and west of Neuls Lake. An Ospwagan-like package, dismembered by Paleoproterozoic intrusions, may be present in this region.

Possible regional extent

Based on the distribution of observed Ospwagan-like supracrustal rocks and gneisses of probable Archean age with Superior Province affinity, it is suggested that the Superior margin basement and its cover sequence, exposed in structural culminations and thin sheet-like structures through Burntwood migmatite, extends at least 60 km west of the Thompson Nickel Belt into the Kisseynew Domain. Because the basement-cover sequence occurs in structural culminations, it is likely that Archean basement underlies this part of the Kisseynew Domain. It is also possible that the sequence represents the upper limb of a large F_2 nappe structure such as that suggested to occur in the Mel zone (cf. Zwanzig et al., 2003). Evidence for the latter is provided by the long sheet-like structures bounded by thicker packages of Burntwood Group migmatite and by the presence of long-lived shear zones locally containing a variety of foliated intrusive rocks. The larger domes of granulite-facies orthogneiss, best interpreted as basement, and the overall high gravity signature of the northeastern part of the KD (e.g., White et al., 2005), however, suggest that Archean granulite with remnants of cover rocks may constitute much of the crust below the present level of exposure. In addition to the structural observations, ca. 1840 Ma granitoid rocks within this 60 km wide zone show Nd isotopic evidence of contamination by Archean crust (this study), which is inconsistent with a model involving post-Burntwood collisional emplacement of a thin nappe of basement. At the present level of knowledge, it is also possible that the ancient crust occurs as rifted epicratonic fragments (Percival et al., 2005).

Using the structural geometry model developed in the Wuskwatim corridor, the authors infer that a second belt of Ospwagan-like rocks may be present north of Highway 391 (Figure GS-8-1). Occurrences of supracrustal rocks at Osik and Mooswuchi lakes (Baldwin et al., 1979), in addition to those described at Kawaweyak Lake, may represent an Ospwagan-like sequence. It is unlikely that the package extends as far west as Notigi Lake, based on the juvenile Nd signature of Paleoproterozoic granitoid rocks in that area (Figure GS-8-1).

Economic Considerations

A major implication of this work is that Thompson-type nickel mineralization may exist within the Ospwagan-like strata present in the 60 km wide zone west of the Thompson Nickel Belt proper. Although a complete stratigraphic section is not preserved, the most economically prospective part of the section — sulphide iron-formation-bearing rocks equivalent to the Pipe Formation — are present on a regional scale. Furthermore, the sulphide-bearing mafic-ultramafic intrusive rocks in the Ospwagan-like section at Kawaweyak Lake provide rare exposures of Thompson-type magmatic rocks. More groundwork and detailed geophysical information are required to map the distribution of Ospwagan-type rocks in that area.

The depth to the basement beneath Burntwood cover is critical in evaluating the economic prospectivity of the eastern Kisseynew Domain. More detailed structural reconstructions, in conjunction with the re-interpretation of seismic reflection profiles (cf. White et al., 2002), are necessary to determine the subsurface configuration of the Ospwagan-like strata.

The region could also have potential for iron-formation-hosted gold mineralization, based on similar environments elsewhere. The presence of stratiform sulphides in iron formation and structurally complex geometry could be significant factors in localizing gold.

A further ramification of the regional observations concerns diamond prospectivity. The inference that Archean basement underlies the eastern 60 km of the Kisseynew Domain presents the possibility that Archean mantle lithosphere is attached, with its enhanced diamond potential. Kimberlitic intrusions within this zone would therefore be more prospective than areas further west.

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References

Baldwin, D.A., Frohlinger, T.G., Kendrick, G., McRitchie, W.D. and Zwanzig, H.V. 1979; Geology of the Nelson House – Pukatawagan Region (Burntwood Project); Manitoba Mineral Resources Division, Geological Maps 78-3-1 to 78-3-22.

Bleeker, W. 1990: New structural-metamorphic constraints on Early Proterozoic oblique collision along the Thompson nickel belt, northern Manitoba; *in* The Early Proterozoic Trans-Hudson Orogen of North America, J.F. Lewry and M.R. Stauffer (ed.), Geological Association of Canada, Special Paper 37, p. 57–74.

Coyle, M. and Kiss, F. 2006: First vertical derivative of the magnetic field, Wuskwatim Lake aeromagnetic survey, Manitoba, Wuskwatim Lake (NTS 63O/10), Manitoba; Geological Survey of Canada Open File 5145; Manitoba Industry, Economic Development and Mines, Manitoba Geological Survey, Open File Report OF2006-24, scale 1:50 000.

Goldstein, S.L., O'Nions, R.K. and Hamilton, P.J. 1984: A Sm-Nd study of atmospheric dusts and particulates from major river systems; Earth and Planetary Science Letters, v. 70, p. 221–236.

Hamilton, M.A. and Bleeker, W. 2002: SHRIMP U-Pb geochronology of the Ospwagan Group: provenance and depositional age constraints of a Paleoproterozoic rift sequence, SE externides of the Trans-Hudson orogen; Geological Association of Canada–Mineralogical Association of Canada, Joint Annual Meeting, Program with Abstracts, v. 27, p. 44–45.

Percival, J.A., Whalen, J.B. and Rayner, N. 2005: Pikwitonei–Snow Lake Manitoba transect (parts of NTS 63J, 63O and 63P), Trans-Hudson Orogen–Superior margin metallotect project: New results and tectonic interpretation; *in* Report of Activities 2005, Manitoba Industry, Economic Development and Mines, Manitoba Geological Survey, p. 69–91.

Skjernaa, L. 1975: Experiments in superimposed buckle folding; Tectonophysics, v. 27, p. 255–270.

White, D.J., Lucas, S.B., Bleeker, W., Hajnal, Z., Lewry, J.F. and Zwanzig, H.V. 2002: Suture-zone geometry along an irregular Paleoproterozoic margin: the Superior boundary zone, Manitoba, Canada; Geology, v. 30, p. 735–738.

White, D.J., Thomas, M.D., Jones, A.G., Hope, J., Németh, B. and Hajnal, Z. 2005: Geophysical transect across a Paleoproterozoic continent-continent collision zone: the Trans-Hudson Orogen; Canadian Journal of Earth Sciences, v. 42, p. 385–402.

Zwanzig, H.V. 1990: Kisseynew gneiss belt in Manitoba: stratigraphy, structure, and tectonic evolution; *in* The Early Proterozoic Trans-Hudson Orogen of North America, J.F. Lewry and M.R. Stauffer (ed.), Geological Association of Canada, Special Paper 37, p. 95–120.

Zwanzig, H.V. 1999: Structure and stratigraphy of the south flank of the Kisseynew domain in the Trans-Hudson orogen, Manitoba: implications for 1.845–1.77 Ga collision tectonics; Canadian Journal of Earth Sciences, v. 36, p. 1859–1880.

Zwanzig, H.V. and Böhm, C.O. 2002: Tectonostratigraphy, Sm-Nd isotope and U-Pb age data of the Thompson nickel belt and Kisseynew north and east margins (NTS 63J, 63O, 63P, 64A, 64B), Manitoba; *in* Report of Activities 2002, Manitoba Industry, Trade and Mines, Manitoba Geological Survey, p. 102–114.

Zwanzig, H.V. and Böhm, C.O. 2004: Northern extension of the Thompson Nickel Belt, Manitoba (NTS 64A3 and 4); *in* Report of Activities 2004, Manitoba Industry, Economic Development and Mines, Manitoba Geological Survey, p. 115–119.

Zwanzig, H.V., Böhm, C.O., Potrel, A. and Machado, N. 2003: Field relations, U-Pb zircon ages and Nd model ages of granitoid intrusions along the Thompson Nickel Belt–Kisseynew Domain boundary, Setting Lake area, Manitoba (NTS 63J15 and 63O2); *in* Report of Activities 2003, Manitoba Industry, Economic Development and Mines, Manitoba Geological Survey, p. 118–129.

Zwanzig, H.V., Percival, J.A. and Murphy, L. 2006: Revised geology of the Wuskwatim–Threepoint lakes area, Manitoba (NTS 63O10 and parts of 63O11); Manitoba Science, Technology, Energy and Mines, Manitoba Geological Survey, Preliminary Map PMAP2006-3, 1:50 000 scale.