GS2018-3

Summary of key results and interpretations from the Fox River belt compilation project, northeastern Manitoba (parts of NTS 53M, N, O, 54B, C, D)

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In Brief:

- Ca. 300 km long greenstone belt that forms part of the metallogenic circum-Superior belt
- Demonstrates potential for Ni (±Cu, PGE, Co, Cr) mineralization in widespread intrusive and volcanic units
- Proposed stratigraphic correlations with the Ospwagan group of the Thompson nickel belt

Citation:

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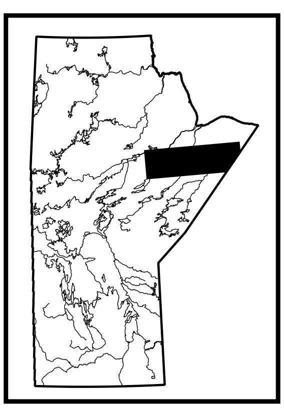

Summary

The Fox River belt forms a large but sparsely exposed segment of the circum-Superior belt in northeastern Manitoba and demonstrates potential to host Ni (±Cu, platinum-group elements, Co, Cr) mineralization of the same age as that in the Thompson nickel belt. This report summarizes the results of a recent geological compilation of the Fox River belt, incorporating the results of several past studies and more recent industry data.

Mafic–ultramafic intrusions and flows of the Fox River belt record high-volume, possibly mantle-plume–derived magmatism of the widespread Molson igneous event (ca. 1.88 Ga). Although the Fox River sill contains the highest Ni-Cu-platinum-group element (PGE) values sampled in the belt to date, the lower intrusions are also considered prospective for magmatic sulphide mineralization. Additional potential for mineralization in the mafic–ultramafic flows is proposed based on their cogenetic relationship with the locally mineralized intrusions, and on anomalous PGE contents in part of the Upper Volcanic formation.

Clastic sedimentary rocks of the Fox River belt are interpreted to have recorded marine sedimentation shed off the margin of the Superior craton. A regional stratigraphic correlation between rocks of the Lower and Middle Sedimentary formations (Fox River belt) and the Ospwagan group (Thompson nickel belt) is implied by their similar depositional and geodynamic environment, their shared regional detrital source (as reflected by similar trace-element characteristics and Archean Nd model ages that are distinct from rocks of the Kisseynew domain) and their deposition prior to Molson magmatism. From the perspective of mineral exploration, confirming an eastward extension of the Ospwagan group would further the potential for Ni mineralization in the Fox River belt.

Introduction

The Fox River belt (FRB) is a large (~6000 km^2) greenstone belt located along the northwestern margin of the Superior province (Figure GS2018-3-1a). Forming part of the circum-Superior belt, it records a sequence of Paleoproterozoic seafloor sedimentation and ca. 1883 Ma mafic-ultramafic magmatism (Heaman et al., 1986). As in other segments of the circum-Superior belt, the rocks were emplaced along the margins of the Superior craton prior to the closure of the Manikewan Ocean, culminating in the suture of the Superior and Churchill provinces (Baragar and Scoates, 1981; Corrigan et al., 2009). Circum-Superior segments both east and west of the FRB are host to significant magmatic sulphide mineralization: in the Cape Smith belt of northern Quebec, Ni-Cu±PGE deposits are hosted in ca. 1882–1881 Ma komatiite flows (Raglan horizon; Bleeker and Kamo, 2018); and in the Thompson nickel belt, magmatic sulphide deposits are hosted in (or were remobilized from) ca. 1883–1880 Ma ultramafic sills (Lightfoot et al., 2017; Scoates et al., 2017).

In 2015, the Manitoba Geological Survey (MGS) initiated a new geological compilation of the FRB. The aims of the project were to

- produce an up-to-date bedrock geology map of the FRB informed by a combination of previous mapping, detailed airborne magnetic surveys and drillcore data;
- provide an updated emplacement history and stratigraphic summary of the FRB; and
- investigate regional stratigraphic relationships between the FRB and the Thompson nickel belt.

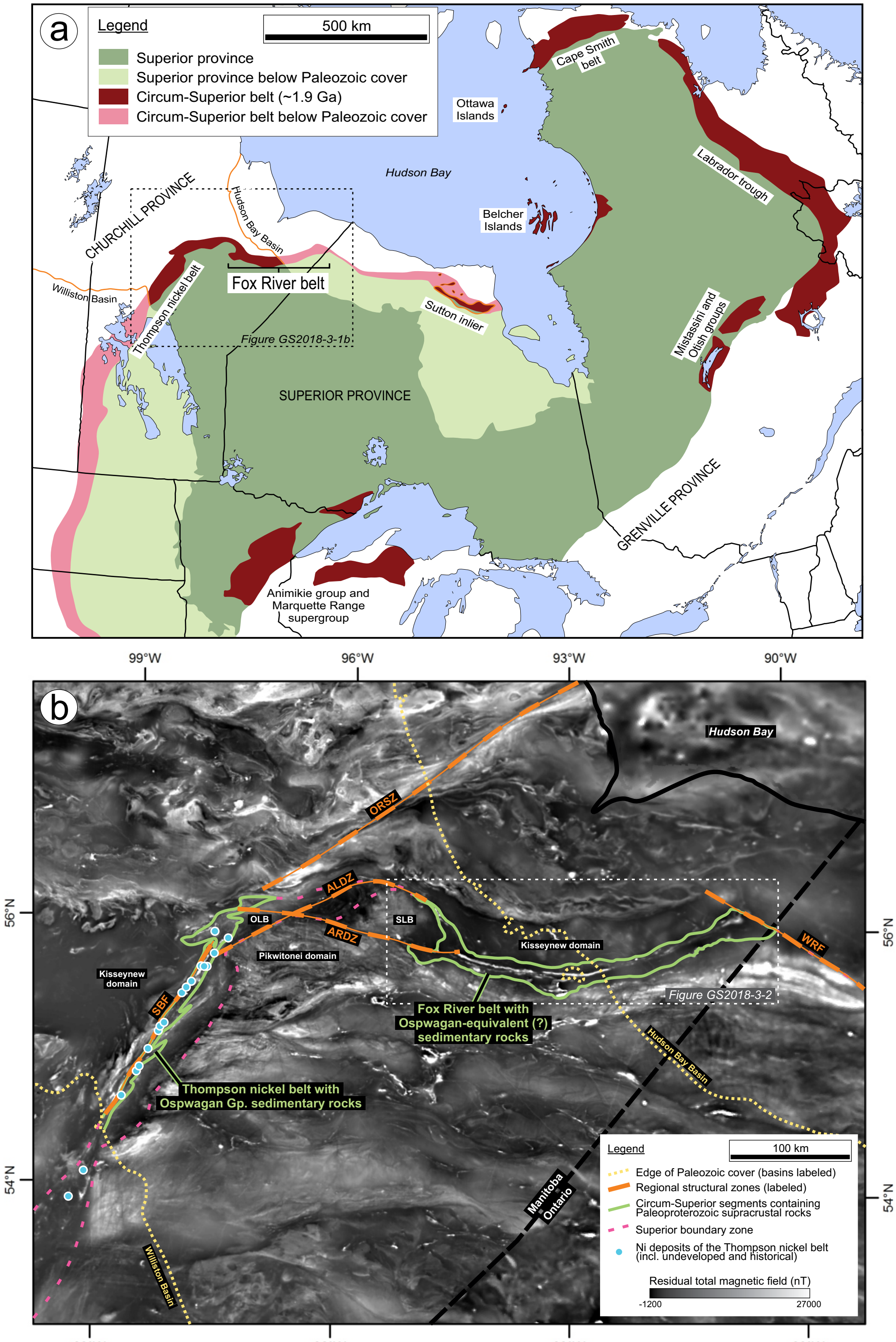

Figure GS2018-3-1: *Geological maps, showing* ***a)*** *the location of the Fox River belt along the circum-Superior belt, between the Ni deposits of the Thompson nickel belt and the Cape Smith belt (modified after Baragar and Scoates, 1981 and Minifie et al., 2013);* ***b)*** *an overview of the northwestern portion of the circum-Superior belt, northeastern Manitoba, extending from the buried portion of the Thompson nickel belt in the southwestern part of the map to the Fox River belt in the east. Major structural zones are shown over a greyscale map of the residual total magnetic field. The Superior boundary zone includes supracrustal segments of the circum-Superior belt as well as regions dominated by highly deformed Archean gneiss of the Superior province (such as the eastern portion of the Thompson nickel belt). Abbreviations: ALDZ, Assean Lake deformation zone; ARDZ, Aiken River deformation zone; OLB, Orr Lake block; ORSZ, Owl River shear zone; SBF, Superior boundary fault; SLB, Split Lake block; WRF, Winisk River fault.*

Exploration history

Following the first regional mapping in 1878 (Bell, 1879), the FRB was subject to several mineral exploration campaigns (Table GS2018-3-1). In addition to a number of airborne and ground magnetic and electromagnetic surveys, multimedia geochemical surveys and limited outcrop mapping, a total of 230 drillholes were collared within the FRB between 1955 and 2010. Approximately half of all drilling in the FRB was undertaken by the International Nickel Company of Canada Ltd. between 1955 and 1972 (Table GS2018-3-1). Approximately one quarter of drilling in the FRB was undertaken by Falconbridge Ltd. (later Xstrata Nickel Inc.) between 1977 and 2007, and the remainder by the companies identified in Table GS2018-3-1.

Geology of the Fox River belt

The dominantly east-striking FRB is approximately 15–20 km wide by 300 km long and consists of a series of mostly northward-younging and steeply north-dipping submarine sedimentary rocks, and mafic–ultramafic flows and intrusions. The belt is almost entirely drift covered; known outcrop locations are limited to the western part of the belt, mostly in river exposures (Figure GS2018-3-2).

Geological units of the FRB are described briefly in this section, moving up stratigraphy (Figure GS2018-3-3). More detailed geological descriptions are provided by Scoates (1981, 1990) and Desharnais (2005).

Southern gneiss domain (Superior province)

The Southern gneiss domain contains Archean quartz-feldspar-biotite gneiss, locally augen-bearing granite, granodiorite, and amphibolite dikes and rafts. The rocks outcrop near the southern edge of the FRB. Metamorphic grade is estimated to be middle amphibolite facies (Peck et al., 2000). Three samples of granitoid and granitoid gneiss, collected within 10 km of the southern margin of the FRB, yielded possibly reset K-Ar (biotite, hornblende) ages ranging from 2695 ±80 Ma to 2355 ±72 Ma (Wanless et al., 1968, 1973).

Lower Sedimentary formation

The Lower Sedimentary formation is a package of planar-bedded quartzofeldspathic to argillaceous mudstone and fine sandstone 4 km thick. The beds are normally graded and locally calcareous, with minor oxide-facies (magnetite±specular hematite) iron formation documented throughout the unit. Graphitic layers and sulphide-bearing horizons are also common in drillcore.

Rocks of the Lower Sedimentary formation are interpreted to have been deposited in a distal marine basin, consisting mostly of continent-derived turbidites (Baragar and Scoates, 1987). This is partly supported by a Nd model age of 2.86 Ga (Desharnais, 2005), consistent with material shed from the Archean Superior craton (i.e., the Southern gneiss domain). A possible northward-increasing abundance of iron formation in the Lower Sedimentary formation was interpreted by Peck et al. (2000) as recording the onset of rifting prior to emplacement of the overlying igneous units.

Mafic dikes

East-trending, locally well-layered dikes of gabbroic to dioritic composition have crosscut basement rocks of the Southern gneiss domain, along with the southernmost kilometre of the Lower Sedimentary formation. The dikes outcrop partly along the Stupart, Sipanigo and Bigstone rivers (Peck et al., 2000). One such dike has been dated at 1900 ±14 Ma (Heaman et al., 2009), indicating that they collectively form part of the ca. 1.88 Ga Molson igneous event, which includes the Molson dike swarm and Fox River sill (Heaman et al. 1986; Peck et al., 2000; Heaman et al., 2009).

Lower intrusions

The lower intrusions crosscut rocks of the Lower Sedimentary formation. Most of the intrusions are approximately parallel with the FRB stratigraphy, and occur near the contact between the Lower Sedimentary and Lower Volcanic formations (Figures GS2018-3-2, 3). Magnetic signatures and limited drill intersections indicate that the intrusions range from 50 to 500 m in thickness and up to tens of kilometres in length (Desharnais, 2005). Most of the intrusions exhibit cumulate segregation into a basal (southern) peridotite, a thin central pyroxenite layer and an upper gabbro.

The lower intrusions are mineralogically and geochemically identical to the later described Fox River sill. Although the lower intrusions have not been dated, Sm-Nd and La-Hf contents of least-contaminated samples plot along Nd and Hf 1883 Ma isochrons (Desharnais, 2005), further supporting a genetic relationship with the ca. 1883 Ma Fox River sill.

Lower Volcanic formation

The Lower Volcanic formation consists of up to 2.5 km of mafic–ultramafic (komatiitic basalt) flows with minor, locally sulphide-bearing interflow mudstone. Scoates (1981) subdivided the western part of the Lower Volcanic formation into three zones, namely the lower

Table GS2018-3-1: Summary of field and exploration work in the Fox River belt and adjacent areas, northeastern Manitoba.

Company / Organization	Dates	Summary of work
Geological Survey of Canada	1879-1955	Early regional surveys by Bell (1879), Brock (1911), Merritt (1925; first identification of ultramafic rocks), and Quinn (1955)
International Nickel Company of Canada Ltd.	1955-1972	Airborne (400 m) and ground geophysical surveys; river outcrop mapping; 116 holes drilled (30406 m; approximately half targeting the Fox River sill)
Sherritt Gordon Mines Ltd.	1956-1971	Airborne (800 m) and ground geophysical surveys; 8 holes drilled (1134 m)
Icon Syndicate Ltd.	1962	Airborne geophysical surveys (300 m); no documented follow-up
Selco Exploration Company Ltd. + Amax Exploration Inc.	1968	Airborne geophysical surveys (400 m); 2 holes drilled (387 m)
Manitoba Mineral Resources, Exploration Operations Branch	1976	Ground geophysical surveys; overburden drilling and basal till geochemistry (covering a small portion of the Fox River sill); regional glacial stratigraphic studies
Manitoba Geological Survey	1975-1977	Mapping of available river outcrop (1969, 1975, 1976, 1977 field seasons); extensive relogging of INCO drillcore; petrographic studies; detailed summaries published in 1981 and 1990
Falconbridge Nickel Mines Ltd.	1977-1981	Airborne and ground geophysical surveys; 12 holes drilled (2601 m)
BP Resources Canada Ltd. (Selco Division) + Platinum Exploration Canada Inc.	1985-1989	Airborne (115 m and 200 m) geophysical surveys (covering the western half of the Fox River sill), ground geophysical surveys; 13 holes drilled (2841 m)
Westminer Canada Ltd.	1991-1993	Lake sediment sampling (333 samples); ground geophysical surveys; 10 holes drilled (1921 m)
BHP Minerals Canada Ltd.	1998	Regional till sampling (KIM, Au, base metals; 503 samples collected, most south of the Fox River belt)
Manitoba Geological Survey	1999	Reconnaissance mapping in areas of known outcrop (in collaboration with Falconbridge); detailed mapping of volcanic stratigraphy in four river outcrop sections
Falconbridge Ltd.	1999-2000	Airborne (250 m) and ground geophysical surveys; reconnaissance mapping; 1:1000 scale mapping in the Great Falls area (with G. Desharnais); discovery of sulphide-bearing KO zone; 12 holes drilled (4123 m)
Marum Resources Inc.	2001	Ground geophysical surveys; 3 holes drilled (59 m; 2 collared in northwest corner of Fox River belt)
Falconbridge Ltd. + Rockwell Ventures Inc.	2001-2005	Airborne, ground, and borehole geophysical surveys; soil geochemical surveys; treetop biogeochemical surveys (482 samples); 9 holes drilled (1543 m)
Falconbridge Ltd. + Donner Minerals Ltd.	2003-2004	Airborne and ground geophysical surveys (mostly north as well as north and northwest of the Fox River belt); 10 holes drilled (2467 m)
Callinan Mines Ltd. + Bell Resources Ltd.	2002 - 2008	Airborne (200 m) and ground geophysical surveys (including gravity); snow hydrogeochemical survey; Mobile Metal Ion soil survey; till sampling; 18 holes drilled (4801 m)
Diamonds North Resources Ltd.	2004-2005	Airborne geophysical surveys (250 m; eastern end of the Fox River belt); till sampling (12 samples)
Pure Nickel Inc. + Xstrata Nickel	2007	Airborne geophysical surveys (150 m); 10 holes drilled (3506 m)
Auriga Gold Corp.	2010	1 hole drilled (562 m; targeting sulphide-bearing KO zone of Fox River sill)

Notes: Geophysical surveys refer to magnetic and electromagnetic methods unless otherwise specified. Bracketed distances for airborne surveys indicate flight line spacing. The table does not include all work on properties adjacent to the Fox River belt, such as a small ground geophysical survey by Inco Ltd. in 2006, and nearby till sampling programs by BHP Billiton World Exploration Ltd. (1999-2001), Indicator Explorations Ltd. (1999-2002) and Kennecott Canada Exploration Inc. (2000-2001).

Abbreviation: KIM, kimberlite-indicator mineral

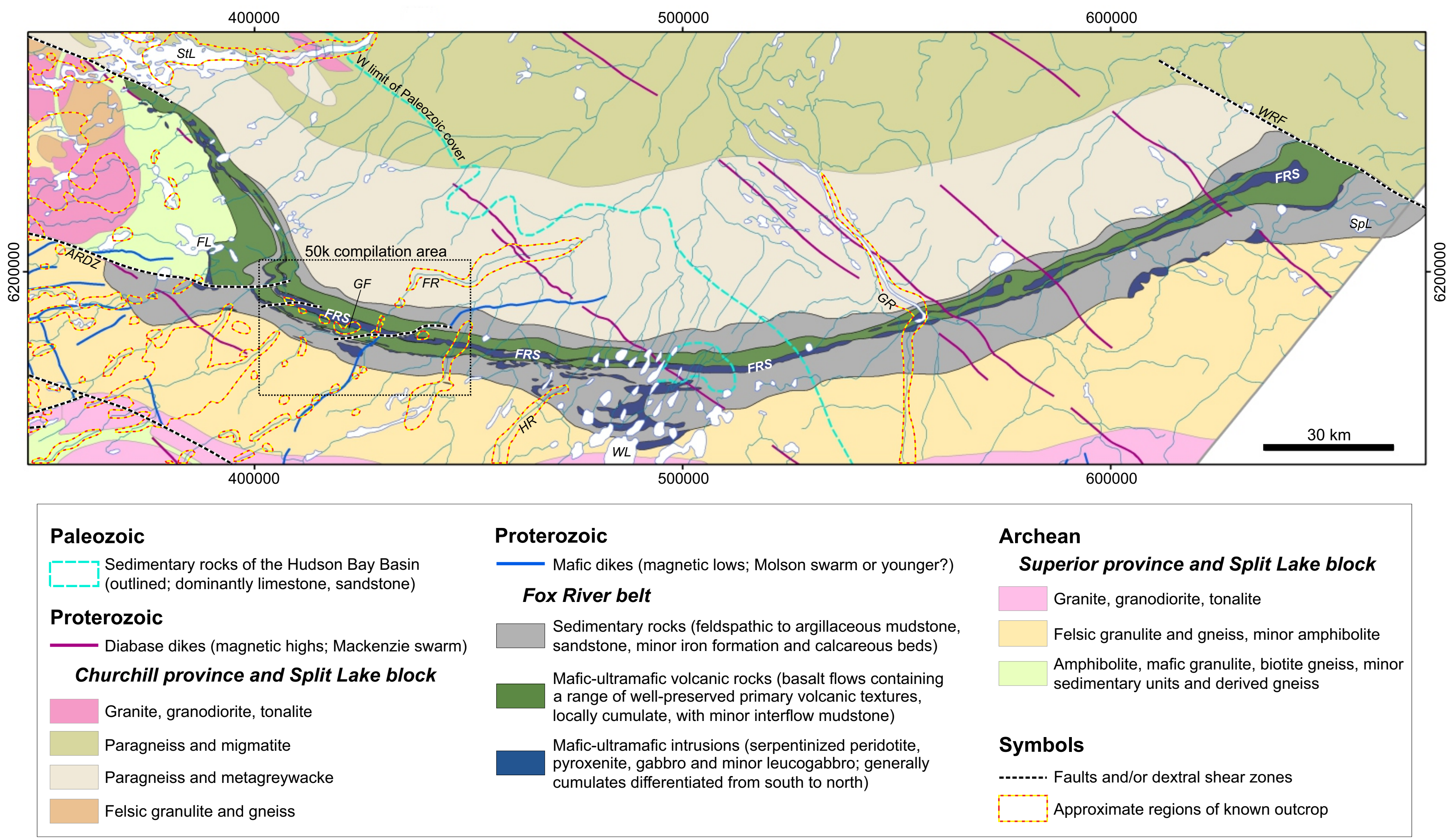

Figure GS2018-3-2: *Simplified geology of the Fox River belt, northeastern Manitoba. The dashed blue line marks the western edge of Paleozoic cover; units shown east of this line are projected through Paleozoic rock of the Hudson Bay Basin. Fox River belt units were drawn mostly on the basis of drillcore intercepts, known outcrop exposures, aeromagnetic data, and geological sections and map interpretations by Scoates (1981, 1990), and Hulbert and Scoates (2005). The figure area corresponds to a 1:250 000 scale compilation map with an expected release in early 2019, along with a 1:50 000 scale area over the western part of the belt (outlined area labeled). Abbreviations: ARDZ, Aiken River deformation zone; FL, Fox Lake; FR, Fox River; FRS, Fox River sill; GF, Great Falls outcrop area; GR, Gods River; HR, Hayes River; SpL, Spector Lake; StL, Stephens Lake; WL, Whitefish Lake; WRF, Winisk River fault. All co-ordinates are in UTM Zone 15 (NAD83).*

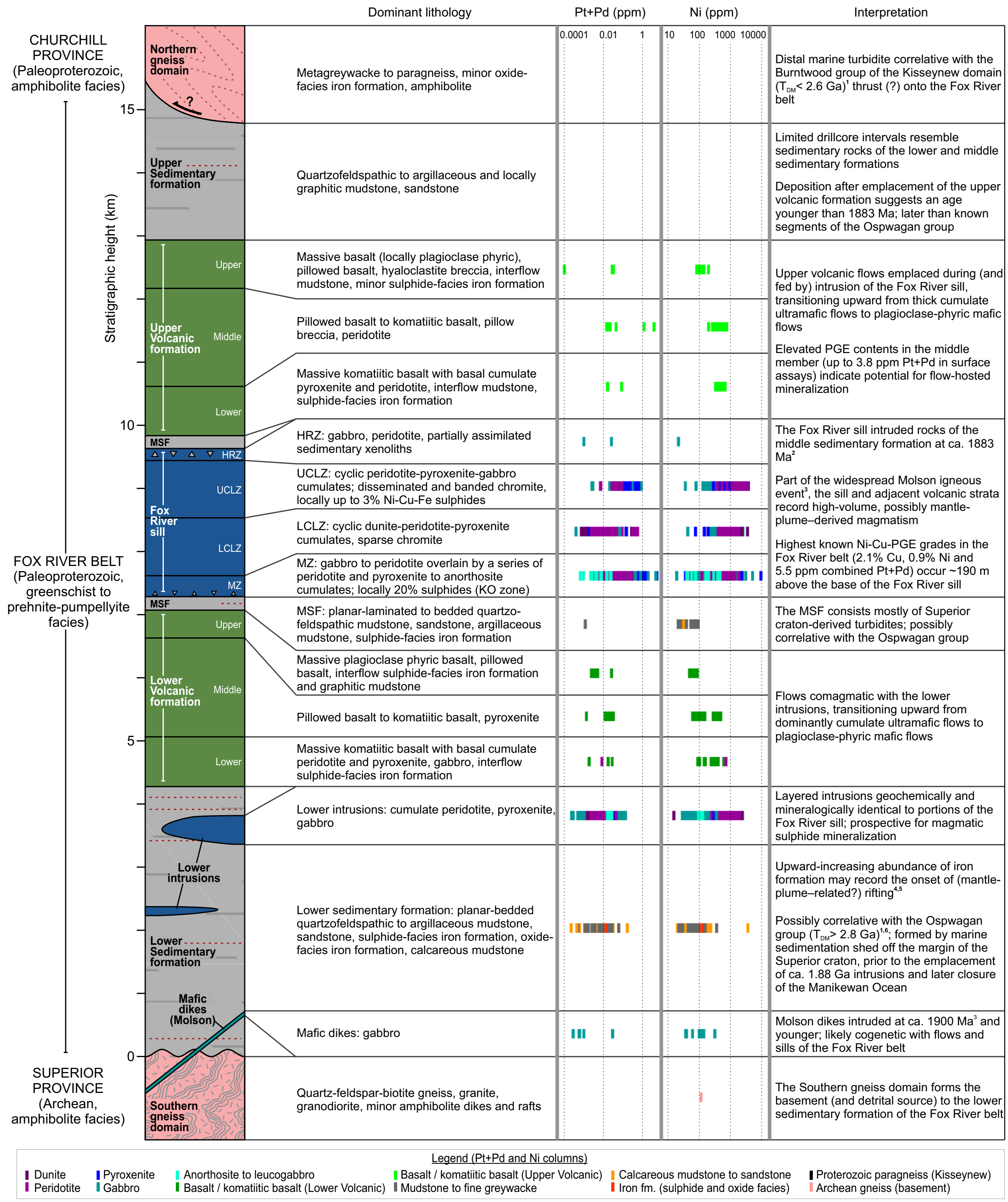

Figure GS2018-3-3: *Simplified stratigraphic summary of the Fox River belt, northeastern Manitoba. Red dashed lines in the stratigraphic column denote occurrences of iron formation in sedimentary strata. Platinum+Pd and Ni data are from sources compiled in Desharnais et al. (2004a) and assessment files (Assessment Files 73666, 73726, 73837, 73965, 74240, 93695, Manitoba Growth, Enterprise and Trade, Winnipeg). References cited with superscript numbers in the interpretation column are: 1) Böhm et al., 2007; 2) Heaman et al., 1986; 3) Heaman et al., 2009; 4) Scoates, 1981; 5) Peck et al., 2000; 6) Desharnais, 2005. Abbreviations: fm., formation; HRZ, hybrid roof zone; LCLZ, lower central layered zone; MSF, Middle Sedimentary formation; MZ, marginal zone; PGE, platinum-group elements; UCLZ, upper central layered zone.*

(dominantly massive), middle (dominantly pillowed) and upper (dominantly massive) zones (Figure GS2018-3-3). The plagioclase-phyric upper zone exhibits the most evolved composition, with elevated total rare-earth element concentrations compared to the lower and middle members (Scoates, 1981; Desharnais, 2005).

Flows of the Lower Volcanic formation vary from approximately 1 to 70 m in thickness (Syme et al., 1999). Well-preserved volcanic features consist of columnar jointing structures, northward-younging flow-top textures including pillows and flow-top hyaloclastite deposits, pyroxene and olivine spinifex textures, pillow shelves (Figure GS2018-3-4a), and cumulate layers (Scoates, 1981; Syme, 2010). In the lower zone, some thick flows are differentiated into a clinopyroxene-rich basal margin, a thick cumulate olivine centre, an upper gabbroic zone containing spherulitic and dendritic plagioclase and clinopyroxene, and a brecciated and vesiculated flow top (Scoates, 1981).

Middle Sedimentary formation

The Middle Sedimentary formation (MSF; Figure GS2018-3-3) occurs along both the northern and southern margins of the Fox River sill, with a total combined thickness of up to 800 m. It contains planar-laminated to bedded quartzofeldspathic mudstone to fine-grained sandstone (Figure GS2018-3-4b), argillaceous mudstone and minor calcareous mudstone (Figure GS2018-3-4c). Laminae and disseminated grains of pyrite and pyrrhotite occur throughout the unit. Hornfels texture has been documented in the MSF along both the southern

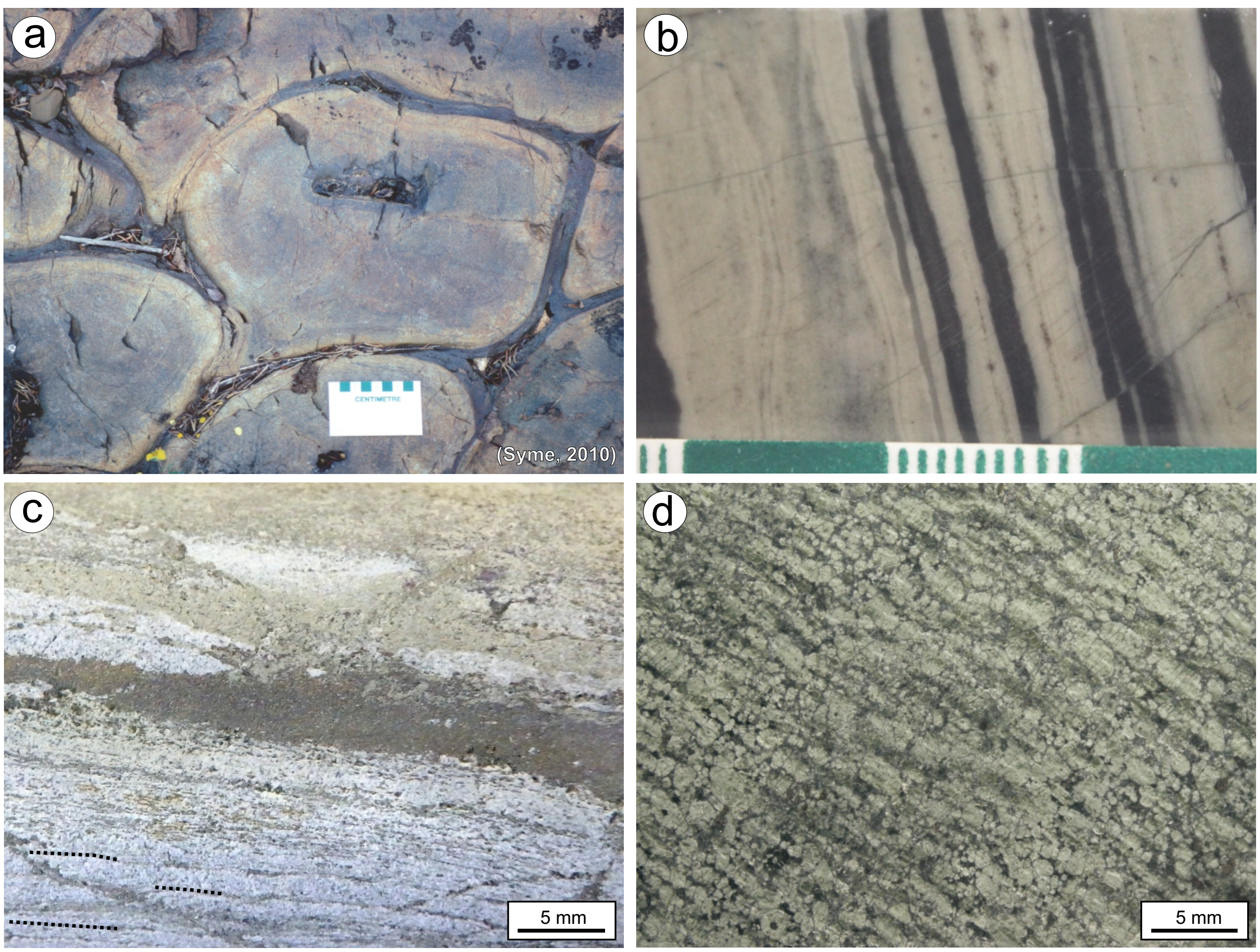

Figure GS2018-3-4: *Core and outcrop photos of stratigraphic units of the Fox River belt, northeastern Manitoba, showing **a)** well-preserved pillowed basalt of the Lower Volcanic formation, with dark grey selvages and an isolated shelf cavity at image centre (Syme, 2010, photo 5-30); **b)** planar-laminated to bedded quartzofeldspathic mudstone to fine-grained sandstone typical of the Lower and Middle sedimentary formations (International Nickel Company of Canada Ltd. hole 38512, 198 m depth); **c)** oxide-facies iron formation with magnetite laminae (bottom of image; partially indicated with dotted black lines), sulphide bed (centre) and calcareous mudstone (top) of the Middle Sedimentary formation (International Nickel Company of Canada Ltd. hole 38517, 82 m depth); **d)** medium-grained dunite cumulate of the Fox River sill, with elongated olivine cumulus crystals (Selco Exploration Company Ltd. hole FOX86-1, 144 m depth).*

and northern contacts of the Fox River sill (Hulbert and Scoates, 2005).

No material from either the Lower or Middle Sedimentary formations was found to be of suitable grain size for detrital zircon geochronology. However, as in the Lower Sedimentary formation, an Archean Nd model age (3.24 Ga; Desharnais, 2005) is consistent with the MSF originating from the Superior craton/Southern gneiss domain.

Fox River sill

The Fox River sill is among the largest of Earth's layered mafic–ultramafic intrusive complexes, with an average thickness of approximately 2 km, and an eastward strike of at least 250 km (based on its well-defined aeromagnetic anomaly). The sill complex has intruded rocks of the Middle Sedimentary formation, the latter entrained as variably assimilated xenoliths near the lower and upper contacts of the sill (Scoates, 1990). Olivine cumulates (peridotite, dunite) make up approximately 78% of the sill (Scoates, 1990), with MgO contents locally exceeding 50 wt. % (Figure GS2018-3-5a).

Scoates (1990) divided the Fox River sill into four zones (Figure GS2018-3-3), summarized in this section from south to north. Although much of the sill has been hydrothermally altered to serpentine- and magnetite-bearing assemblages, metamorphic rock names such as serpentinite are omitted from the following descriptions.

The lowermost portion of the sill, the marginal zone (MZ; Figure GS2018-3-3), is up to 275 m thick, but

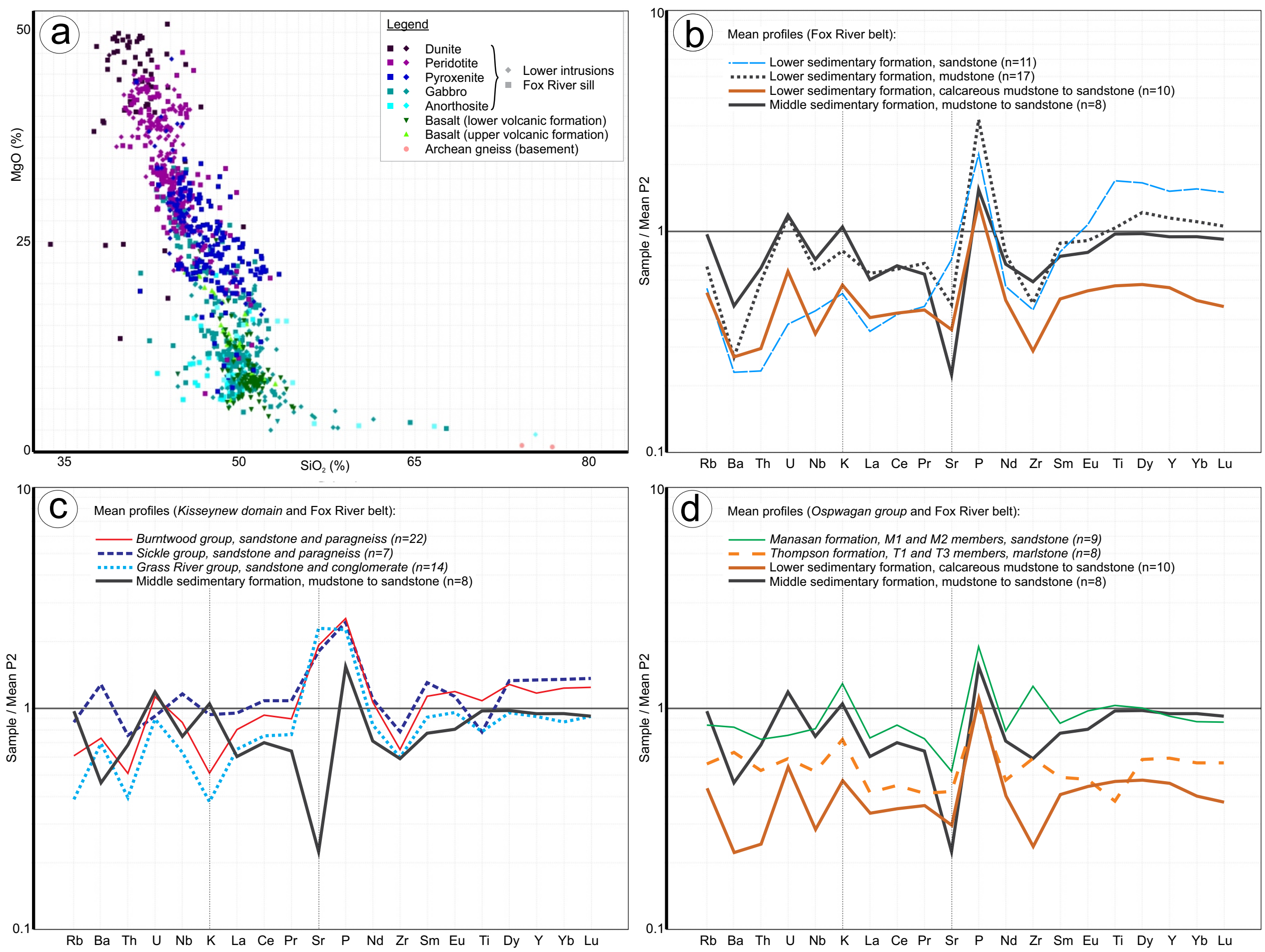

***Figure GS2018-3-5:** Selected geochemical profiles of Fox River belt units, showing: **a)** MgO versus SiO_2, with an overall trend in intrusive samples corresponding to olivine abundance; **b)** mean P2 pelite-normalized profiles for all sampled sedimentary units of the Fox River belt (as applied by Zwanzig et al., 2007 to rocks of the Thompson nickel belt); **c)** mean profile of the Middle Sedimentary formation compared to metasedimentary rocks of the Kisseynew domain; **d)** mean profiles of the Middle and Lower Sedimentary formations compared to metasedimentary rocks of the Ospwagan group. Note greater similarity between profiles in panel d (e.g., relative enrichment in K, and relative depletion in Nb and Sr) compared to panel c. Along with comparable Nd model ages, these similarities are consistent with a regional stratigraphic correlation between the Ospwagan group (Thompson nickel belt) and the Lower and Middle Sedimentary formations (Fox River belt). Fox River belt data are mostly from Desharnais et al. (2004a), and Ospwagan and Kisseynew data are from Zwanzig et al. (2007) and C. Couëslan (pers. comm., 2017).*

is locally absent (Scoates, 1990; Peck et al., 1999). Its lower contact with (hornfelsed) mudstone is sharp and irregular. It contains locally pegmatitic and hornblende-bearing melagabbro overlain by two cyclic cumulate layers with sharp lower contacts, each grading upward from peridotite (±pyroxenite) to leucogabbro or anorthosite (Scoates, 1990; Peck et al., 1999). Heaman et al. (1986) reported a U-Pb zircon age of 1882.9 +1.5/-1.4 Ma from the marginal zone.

A discontinuous layer of stratabound sulphides occurs near the top of the MZ in the Great Falls outcrop area (Figure GS2018-3-2), approximately 190 m above the base of the Fox River sill. Termed the KO zone, this occurrence yields the best Ni-Cu-PGE grades in the FRB known to date (Figure GS2018-3-3; Desharnais et al., 2004b). Outcrops of the KO zone contain an average of 1–2% (locally <20%), dominantly disseminated (locally net-textured) pyrrhotite, chalcopyrite and pentlandite, typically concentrated along the scalloped lower contact of the overlying cyclic unit. The best-mineralized sample of the KO zone yielded 2.1% Cu, 0.9% Ni, 1 ppm Pt and 4 ppm Pd (Desharnais et al., 2004a).

The lower central layered zone (LCLZ; Figure GS2018-3-3), approximately 850 m thick, is made up of at least nine cyclic layers of thick olivine cumulates (peridotite to dunite) overlain by thin (<6 m) pyroxenite cumulates. Scoates (1990) interpreted each of the peridotite-pyroxenite pairs to be incomplete or 'beheaded' cyclic units in the Fox River sill; the LCLZ would therefore record at least nine injections of ultramafic magma. Up to 2% disseminated chromite occurs throughout the olivine cumulates, along with sparse bands of chromite (Scoates, 1990). Relict olivine cumulus crystals are commonly elongated parallel to the major unit contacts and chromite bands (Figure GS2018-3-4d), which Scoates (1990) interpreted as the result of magma flow during cumulus crystal settling.

The upper central layered zone (UCLZ; Figure GS2018-3-3) is approximately 900 m thick. Compared to the LCLZ, it contains thinner cumulate units of more variable composition, with an overall higher proportion of upper plagioclase cumulates and minor cumulus orthopyroxene (Scoates, 1990). Disseminated chromite is common and chromite bands occur locally. Sulphide contents and PGE tenor of the UCLZ are slightly higher than in the LCLZ, though generally low (<1 ppm Pt+Pd in the best metre assays; Figure GS2018-3-3). Weak mineralization in the UCLZ includes pyrrhotite, pentlandite, chalcopyrite, cubanite and mackinawite ($[Fe,Ni]_9S_8$), along with rare awaruite (Ni_3Fe) and heazlewoodite (Ni_3S_2; Scoates and Eckstrand, 1986; Scoates, 1990).

The uppermost portion of the Fox River sill, the hybrid roof zone (HRZ; Figure GS2018-3-3), is a thin (<100 m) zone of peridotite to gabbro with partially melted sedimentary xenoliths, quartz phenocrysts and granophyre patches (Scoates, 1990), in sharp intrusive contact with mudstone of the MSF. The character and spatial extent of the HRZ is constrained by drilling at only a few locations.

Upper Volcanic formation

As in the Lower Volcanic formation, the Upper Volcanic formation consists of a succession of mafic–ultramafic flows with minor interflow sedimentary units, demonstrating an overall upward trend from primitive, dominantly cumulate ultramafic flows to locally plagioclase-phyric mafic flows of more evolved composition. It contains the same variety of primary volcanic textures as in the Lower Volcanic formation, including columnar jointing structures, various flow-top textures (hyaloclastite, pillow shelves, spinifex) and cumulate layers (Scoates, 1981). However, vesicles are reportedly more common in the Upper Volcanic formation than in the Lower (Scoates, 1981).

The Upper Volcanic formation is interpreted by Scoates (1981) as the record of magmas expelled in stages from the Fox River sill magma chamber(s). Desharnais (2005) presented geochemical evidence for this comagmatic relationship, illustrating that the upward evolution of Upper Volcanic formation lavas may have been controlled by crystallization of cumulate phases (olivine, orthopyroxene, clinopyroxene and plagioclase) in the Fox River sill. Although historical drill logs also note rare felsic intervals within the Upper Volcanic formation, recent petrographic investigation of these intervals revealed sericite-altered basalt with relict pyroxene.

Two samples of the Upper Volcanic formation, collected by D. Peck (Peck et al., 1999) along the banks of the Fox River, returned 1.1 and 3.5 ppm Pd. These values significantly exceed background PGE contents (Figure GS2018-3-3), suggesting potential for flow-hosted magmatic sulphide mineralization in the Upper Volcanic formation.

Upper Sedimentary formation

The Upper Sedimentary formation forms the uppermost stratigraphic unit preserved in the FRB. Outcrops of the unit have not yet been identified. Based on the few intervals intersected in drillcore, it consists of up to 6 km of rocks resembling the Lower and Middle Sedimentary formations, with variably quartzofeldspathic to argillaceous and locally graphite-bearing beds dipping steeply to the north.

Northern gneiss domain (Churchill province)

The northern gneiss domain (previously termed the 'northern gneiss belt'; Scoates, 1990; Peck et al., 2000) is assigned to the Kisseynew domain of the Churchill province (Figure GS2018-3-1). It contains locally garnet-, staurolite- and hornblende-porphyroblastic metagreywacke and/or paragneiss, with minor iron formation. Unlike the weakly metamorphosed and relatively undeformed sedimentary units of the FRB, the northern gneiss domain exhibits amphibolite-facies metamorphism and south-dipping fold axes (Peck et al., 2000).

A sample of metagreywacke along the Fox River, from an outcrop located approximately 3.5 km north of the FRB, returned a Nd model age of 2.30 Ga (Böhm, pers. comm., 2000). This result indicates derivation from a source younger than the Superior craton and could imply correlation with the Burntwood group of the Kisseynew domain (T_{DM} <2.6 Ga; Böhm et al., 2007). Scoates (1981) proposed that the domain boundary between the northern gneiss domain and upper sedimentary formation is likely a north-dipping thrust fault (Figure GS2018-3-3).

Structure and metamorphism

Rocks of the FRB exhibit low-grade metamorphism, from lower greenschist facies in the south to prehnite-pumpellyite facies in the north (Scoates, 1981). In marked contrast to rocks of the Thompson nickel belt, the rocks record minimal structural complexity; nearly all of the FRB contains northward-younging and weakly strained units that dip ~80°N (Scoates, 1981). Exceptions occur in the buried northwestern part of the belt (between Stephens Lake and east of Fox Lake [also known unofficially as Atkinson lake]; Figure GS2018-3-2) where sparse drillcore intercepts reveal northwest-striking and steeply dipping units, and in the area along the northern shore of Whitefish Lake (Figure GS2018-3-2), where drill intercepts indicate possible near-horizontal bedding planes in the Lower Sedimentary formation. Dextral offsets interpreted from aeromagnetic data suggest the presence of east-northeast-trending dextral fault zones or shears through the FRB, including an eastward extension of the Aiken River deformation zone (Figures GS2018-3-1b, 2). The eastern boundary of the FRB is interpreted to correspond to the Winisk River fault (Figures GS2018-3-1b, 2).

Paleozoic and Quaternary cover

Marine and glaciomarine sedimentary rocks of the Hudson Bay Basin overlie the eastern part of the FRB, thickening toward Hudson Bay. Drill intercepts northeast of Whitefish Lake also delineate a zone of flat-lying Paleozoic cover currently interpreted as an outlier of the Hudson Bay Basin (Figure GS2018-3-2). Quaternary glacial material (dominantly glaciofluvial and glaciolacustrine) covers greater than 99% of the FRB, with sparse Precambrian outcrop limited to areas along and west of Hayes River, in addition to some Paleozoic outcrops along Gods River (e.g., Scoates, 1981; Peck et al., 2000; Desharnais, 2005).

Regional correlations and interpretations

Deposits of the Thompson nickel belt are primarily hosted by Paleoproterozoic sedimentary rocks of the Ospwagan group and are overlain, or were overthrust, by rocks of the Kisseynew domain (Bleeker, 1990; Zwanzig et al., 2007; Figure GS2018-3-1b). Delineating the extension of the Ospwagan group or identifying Ospwagan-equivalent units outside of the Thompson nickel belt is therefore applicable to nickel exploration in northern Manitoba (Böhm et al., 2007; Zwanzig et al., 2007).

Samples of the Lower and Middle Sedimentary formations of the FRB yield Nd model ages of 2.9 and 3.2 Ga (Desharnais, 2005), which are interpreted to indicate derivation from the Archean Superior province/Southern gneiss domain. Representative extended-element profiles of mudstone to sandstone samples of the Lower and Middle sedimentary formations, normalized to mean P2 pelite as in Zwanzig et al. (2007), show relative enrichments in K and depletions in Nb and Sr (Figure GS2018-3-5b). No geochemical data are available from the Upper Sedimentary formation.

Metasedimentary rocks of the Ospwagan group include both clastic and chemical components in a package up to 3 km thick (prior to deformation), metamorphosed to amphibolite- or granulite-facies conditions (Zwanzig et al., 2007; Couëslan and Pattison, 2012). The rocks are characterized by Nd model ages ranging from 2.8 to 3.2 Ga (Böhm et al., 2007), reflecting the Archean source material. Like the FRB sedimentary units—and unlike the overthrust rocks of the Kisseynew domain (Figure GS2018-3-5c)—most of the lower Ospwagan-group rocks show relative enrichments in K and depletions in Nb and Sr compared to P2 pelite (Figure GS2018-3-5d; Zwanzig et al., 2007).

Both the Ospwagan and FRB rocks are interpreted as passive marine sedimentary packages deposited on Superior cratonic basement. Both contain packages of quartzofeldspathic to argillaceous mudstone and sandstone, calcareous beds, and oxide- and sulphide-facies iron formation (Zwanzig et al., 2007). Although a maximum age has not been established for sedimentary rocks of the FRB, they share a minimum age with the Ospwagan group; both were deposited prior to the intrusion of locally ore-forming, ca. 1883 Ma mafic–ultramafic magmas of the circum-Superior belt, followed by the closure of the Manikewan Ocean and related overthrusting by rocks of the Kisseynew domain.

Despite significant differences in strain and metamorphism, the above-described similarities suggest that sedimentary rocks of the Ospwagan group and the Lower and Middle Sedimentary formations of the Fox River belt could be stratigraphically equivalent. Although correlations at the formation level may not be possible (nor necessarily expected, given the likelihood of lateral facies variations between the Thompson nickel belt and Fox River belt), the identification of sulphide-bearing packages similar to the Pipe formation may be the key to nickel exploration in the Fox River belt.

Economic considerations

In addition to regional potential for diamonds and gold mineralization, the FRB remains prospective for magmatic Ni (±Cu, PGE, Co, Cr) deposits. A setting within the metallogenic circum-Superior belt, extensive ultramafic to mafic igneous rocks, a range of potential external sulphur sources, proposed stratigraphic correlations with the deposit-hosting Ospwagan group, and known occurrences of Ni-Cu-PGE sulphides in the FRB collectively support some prospect of economic mineralization. Renewed exploration strategies for magmatic sulphide deposits in the FRB may incorporate the following considerations

- Although intrusions were the main focus of past exploration, flows of the Upper and Lower Volcanic formations are also possible hosts to mineralization.
- A number of potential external sulphur sources have been documented throughout the sedimentary and volcanic stratigraphy, including sulphide-facies iron formation, widely disseminated sediment-hosted sulphide and discordant sulphide veins or alteration features (Syme et al., 1999).
- Previous workers have identified several ultramafic intrusive targets, including the MZ of the Fox River sill (containing the best known Ni-Cu-PGE mineralization discovered to date in the FRB), the LCLZ of the Fox River sill (wherein the 'beheaded' cyclic layers could imply a more prospective 'flow-through' as opposed to quiescent magma chamber) and the lower intrusions (containing geochemical evidence for assimilation of country rock and local chalcophile-element depletions; Desharnais, 2005).
- Large portions of the belt remain unexplored and include untested conductors identified in mafic–ultramafic-bearing stratigraphy (e.g., Hosain, 2003).
- Quaternary investigations, including till geochemical analyses, may prove an effective strategy for base-metal exploration in the extensively drift-covered belt.

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