GS2021-3

Collection of samples for high-resolution detrital-zircon geochronology and lithogeochemistry in the Thompson nickel belt, central Manitoba (parts of NTS 63O8, 9, 63P12)

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In Brief:

- Samples of Manasan and Setting formation rocks from the Ospwagan group were collected for high-resolution U-Pb dating of detrital zircon
- Metasedimentary rocks of uncertain affinity were collected from roadcuts near Joey Lake; geochemistry suggests they might be correlative with Paint sequence rocks; further study is warranted

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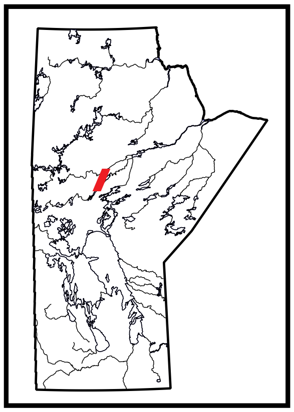

Summary

A project was initiated in 2021 to conduct sampling for high-resolution U-Pb dating of detrital zircon in the Ospwagan group. Samples were collected of Manasan formation M1 member conglomerate and sandstone, and M2 member semipelite, as well as a sample of Setting formation sandstone. All known economic Ni-Cu deposits in the Thompson nickel belt are associated with ultramafic bodies hosted in Ospwagan group stratigraphy. Having additional insight into the source region (provenance) and depositional history (age) of the Ospwagan group could help differentiate it from other metasedimentary rocks considered less prospective for Ni exploration.

Additional metasedimentary rocks of uncertain affinity were collected for lithogeochemistry from recent roadcuts in the Joey Lake area. The roadcuts are adjacent to a belt of rocks previously identified as undifferentiated Ospwagan group and Archean gneiss. Although somewhat inconclusive, the geochemistry of the metasedimentary rocks appears more similar to Paint sequence than Ospwagan group rocks. The belt of undifferentiated rocks is also reported to contain ultramafic bodies toward the northern terminus. Further study of this belt, the metasedimentary rocks and their potential relationship with ultramafic bodies is warranted.

Introduction

All known economic Ni-Cu deposits in the Thompson nickel belt (TNB) are associated with ultramafic bodies hosted by the Ospwagan group stratigraphy. Understanding these sedimentary rocks is therefore of great importance for mineral exploration in the belt. Several geochronological studies of detrital zircon in the Ospwagan group have been completed in the last 20 years (Bleeker and Hamilton, 2001; Rayner et al., 2006; Zwanzig, unpublished data, 2008; Machado et al., 2011). However, the results of some of these studies were either not published or published only in an abstract (e.g., Bleeker and Hamilton, 2001; Zwanzig, unpublished data, 2008), while the most recent study utilized laser-ablation, inductively coupled plasma–mass spectrometry techniques that determined only ^{207}Pb/^{206}Pb isotope ages with a large variation in analytical errors and no quantification of data discordance (Machado et al., 2011). The availability of published, high-resolution U-Pb detrital-zircon data for the Ospwagan group is therefore relatively limited, and confined only to the P2 member of the Pipe formation (Rayner et al., 2006).

The discovery of a new sedimentary rock package in the TNB with potential to host ultramafic bodies (Paint sequence; Couëslan, 2016, 2018) has increased the need for high-resolution detrital-zircon data for the Ospwagan group. Although the Paint sequence appears to be geochemically distinct from the Ospwagan group, there is a large overlap in crustal residence Nd-model ages between the two sedimentary rock packages (Couëslan, 2016, 2018; Manitoba Geological Survey, 2020). High-resolution U-Pb detrital-zircon data are needed for further comparative studies.

Five samples of Ospwagan group rocks were collected during the 2021 field season for prospective U-Pb detrital-zircon analysis. These include samples from the M1 and M2 members of the Manasan formation and a sample from the Setting formation. Furthermore, the detrital-zircon data for a Setting formation sample from Setting Lake (Zwanzig, unpublished data, 2008) have been released as Data Repository Item DRI2021013 (Zwanzig et al., 2021). This new DRI, combined with the samples collected in this study and the data published by Rayner et al. (2006), will provide high-quality detrital-zircon age information from the base, middle and top of the Ospwagan group stratigraphy.

In addition to the Ospwagan group samples collected for U-Pb detrital-zircon geochronology, five rock samples were collected from relatively recent roadcuts in the Joey Lake area for lithogeochemistry. These samples consist of metasedimentary rocks and spatially associated units of uncertain affinity. All rocks discussed in this report were subjected to metamorphic conditions of at least middle-amphibolite facies; however, the 'meta-' prefix has been omitted from rock names for brevity.

Regional geology

The TNB forms a segment of the Superior boundary zone, flanked to the northwest by the Kisseynew domain of the Trans-Hudson orogen and to the southeast by the Pikwitonei granulite domain (PGD) of the Superior craton (Figure GS2021-3-1). The TNB is underlain largely by reworked Archean gneiss of the Superior craton, which is typically quartzofeldspathic with enclaves of mafic to ultramafic rock; clearly recognizable paragneiss is rare. It is commonly migmatitic and characterized by complex internal structures that are the result of multiple generations of Archean and Paleoproterozoic deformation and

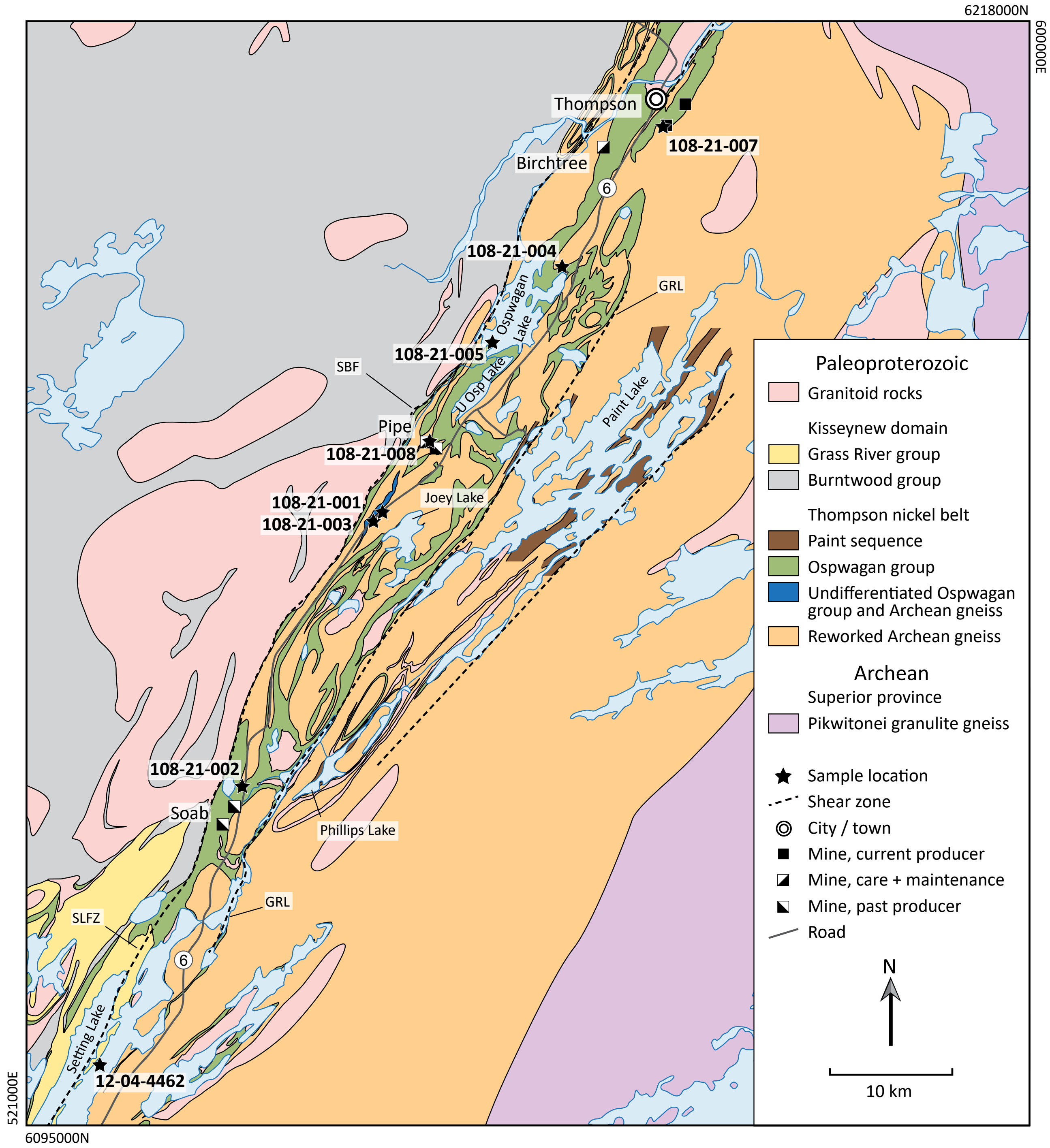

Figure GS2021-3-1: *Geology of the central Thompson nickel belt and adjacent portions of the Kisseynew domain and Superior province (modified from Macek et al., 2006; Manitoba Mineral Resources, 2013; Couëslan, 2016). Abbreviations: GRL, Grass River lineament; SBF, Superior boundary fault; SLFZ, Setting Lake fault zone; U Osp L, Upper Ospwagan Lake.*

metamorphism. The gneiss is derived from the adjacent PGD, which was subjected to granulite-facies metamorphic conditions from ca. 2720 to 2640 Ma (Hubregtse, 1980; Mezger et al., 1990; Heaman et al., 2011; Guevara et al., 2020; Couëslan, 2021a). The granulites of the PGD were exhumed and unconformably overlain by Paleoproterozoic supracrustal rocks of the Ospwagan group prior to intrusion of the Molson dike swarm and associated ultramafic intrusions ca. 1883 Ma (Bleeker, 1990; Zwanzig et al., 2007; Heaman et al., 2009; Scoates et al., 2017). The Archean basement gneiss and Paleoproterozoic supracrustal rocks were subjected to multiple generations of deformation and metamorphic conditions, ranging from middle-amphibolite facies to lower-granulite facies, during the Trans-Hudson orogeny (Bleeker, 1990; Burnham et al., 2009; Couëslan and Pattison, 2012).

The dominant phase of penetrative deformation is D_2, which affected the Ospwagan group, Paint sequence and ca. 1883 Ma magmatic rocks. This deformation phase resulted in the formation of F_2 nappe structures, which incorporated the underlying Archean gneiss. The nappe structures have been interpreted as either east verging (Bleeker, 1990; White et al., 2002) or southwest verging (Zwanzig et al., 2007; Burnham et al., 2009). The recumbent folds are associated with regionally penetrative S_2 fabrics. The D_2 phase of deformation is interpreted to be the result of convergence between the Superior craton margin and the Reindeer zone of the Trans-Hudson orogen ca. 1830–1800 Ma. This D_2 phase was accompanied by prograde metamorphism, with peak metamorphic conditions likely being attained prior to or during early D_3 (Couëslan and Pattison, 2012). The D_3 phase of deformation resulted in isoclinal folds with vertical to steeply southeast-dipping axial planes (Bleeker, 1990; Burnham et al., 2009). Mylonite zones with subvertical stretching lineations parallel many of the regional F_3 fold structures. Tightening of D_3 structures continued during D_4, marked by localized retrograde greenschist metamorphism along northeast-striking, mylonitic and cataclastic shear zones that commonly record southeast-side-up sinistral movement (Bleeker, 1990; Burnham et al., 2009). The $D_{3–4}$ structures exert a first-order control on the pattern of metamorphic-field gradients in the TNB (Couëslan and Pattison, 2012).

Ospwagan group stratigraphy

The following summary of the Ospwagan group is sourced largely from Bleeker (1990) and Zwanzig et al. (2007). The Paleoproterozoic Ospwagan group unconformably overlies Archean basement gneiss in the TNB (Figure GS2021-3-2). The lowermost unit of the Ospwagan group is the Manasan formation, which consists of two members: the lower M1 member, consisting of layered to laminated sandstone with local conglomerate layers near the base; and the overlying M2 member, consisting of semipelitic rock. The Manasan formation is interpreted as a transgressive, fining-upward sequence deposited along a passive margin. This siliciclastic system grades into the overlying calcareous sedimentary rocks of the Thompson formation.

The Thompson formation consists of three members: the T1 member comprises a variety of calcareous–siliceous rocks, including chert, calcsilicate and impure marble; the T2 member is a semipelitic calcareous gneiss that is rarely present; and the T3 member consists of impure dolomitic marble with local horizons of calcsilicate. The Thompson formation represents a transition from a siliciclastic-dominated to a carbonate-dominated system.

The Pipe formation is subdivided into three members. The P1 member consists of a graphite-rich, sulphide-facies iron formation at the base (the locus of the Pipe II and Birchtree orebodies), overlain by a silicate-facies iron formation. The top of the P1 member consists of a reddish, laminated, siliceous rock. The P1 member grades into the overlying mudstone of the P2 member, the top of which is marked by a sulphide-facies iron formation (the locus of the Thompson orebody). The overlying P3 member consists of a wide variety of rock types, including laminated, siliceous, sedimentary rocks; silicate-, carbonate- and local oxide-facies iron formations; and semipelitic rocks, calcsilicate and a local horizon of relatively pure dolomitic marble. The Pipe formation represents a mix of chemical, and fine to very fine siliciclastic sedimentary components that were deposited in either an open-marine environment (Zwanzig et al., 2007) or during the development of a foredeep basin (Bleeker, 1990).

The Setting formation is divided into two members and is defined to include all siliciclastic rocks above the uppermost iron formation of the P3 member. The S1 member consists of rhythmically interbedded quartzite and wacke–mudstone with local calcareous concretions, which are characteristic of the S1 member. The S2 member consists of thickly layered greywacke, with local horizons grading from conglomerate at the base to mudstone at the top. No contact has been observed between the S1 and S2 members. It is possible that they represent a lateral facies change as opposed to a vertical succession. The Setting formation is interpreted to have been deposited by turbidity currents in a relatively deep-marine environment, possibly a foredeep basin (Bleeker, 1990). The coarse clastic material and thick turbidite bedding of the S2 member may record the shallowing of the basin, the onset of active tectonism or a lateral sedimentary-facies change to a submarine-channel or upper-fan environment (Zwanzig et al., 2007).

At the top of the Ospwagan group is the Bah Lake assemblage, which consists of mafic to ultramafic volcanic rocks dominated by massive to pillowed basalt flows with local picrite and minor synvolcanic intrusions. The Bah Lake assemblage is dominated by a high-Mg suite, similar to normal mid-ocean–ridge basalt (N-MORB), that occurs throughout much of the main TNB; and an incompatible-element–enriched suite, similar to enriched mid-ocean–ridge basalt (E-MORB), that occurs

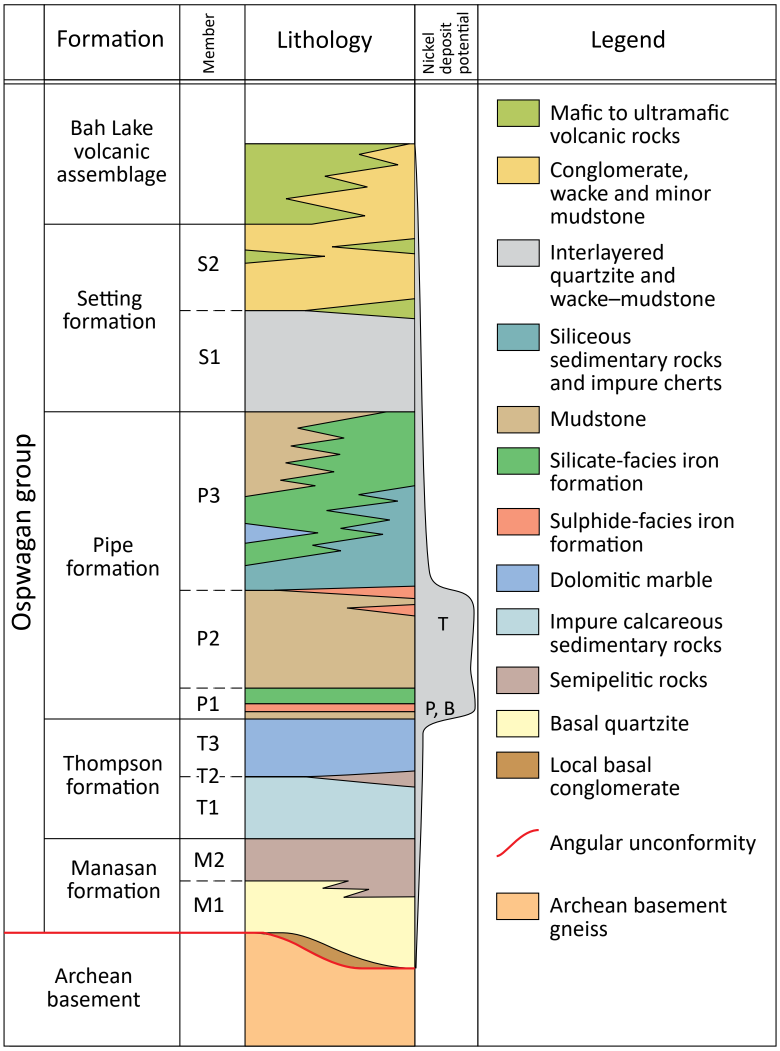

***Figure GS2021-3-2:** Schematic stratigraphic column of the Ospwagan group (adapted from Bleeker, 1990). 'T', 'P' and 'B' indicate the stratigraphic positions of the mineralized ultramafic sills at the Thompson, Pipe II and Birchtree mines, respectively.*

in the northwestern Setting Lake area and along the margin of the Kisseynew domain (Zwanzig, 2005). The enriched suite is interpreted to overlie the high-Mg suite; however, it is uncertain if this represents a stratigraphic or tectonic relationship. The Bah Lake assemblage may indicate the onset of active rifting in the TNB (Zwanzig, 2005; Zwanzig et al., 2007), or that the foredeep basin was magmatically active (Bleeker, 1990).

A maximum age for the Ospwagan group is provided by a ca. 1974 Ma zircon recovered from Setting formation greywacke (Bleeker and Hamilton, 2001). A minimum age for the Ospwagan group is provided by crosscutting amphibolitized dikes interpreted to be part of the Molson dike swarm, and the possibly comagmatic Ni-ore–bearing ultramafic sills, which intruded the Ospwagan group at all stratigraphic levels ca. 1883 Ma (Bleeker, 1990; Zwanzig et al., 2007; Heaman et al., 2009; Scoates et al., 2017). Ospwagan group rocks yielded crustal-residence Nd-model ages of ca. 3.22–2.82 Ga, which are largely younger than model ages obtained from the Archean basement (ca. 3.70–3.14 Ga; Figure GS2021-3-3; Böhm et al., 2007).

Paint sequence rocks

The 'Paint sequence' refers to a suite of sedimentary rocks that occur in three northeast-striking belts in the Paint Lake area and appear to continue along strike to the Phillips Lake area (Figure GS2021-3-1; Couëslan, 2016, 2018). The stratigraphy of the Paint sequence is unconstrained but consists dominantly of wacke, with subordinate arenite and iron formation, and rare mudstone and calcsilicate. To date, the Paint sequence has only been recognized in areas of granulite-facies metamorphism where primary textures and structures are all but obliterated, except for centimetre-scale compositional layering.

Wacke is the most abundant member of the sequence. It commonly contains centimetre- to decimetre-thick layers of arenite and iron formation. Pods of in situ to in source leucosome are abundant. Outcrops of wacke are characterized by rusty weathered surfaces because of the presence of minor but ubiquitous pyrrhotite. The compositions of the wacke and arenite are gradational into each other and they can be interbedded. The arenite is typically interlayered with centime-

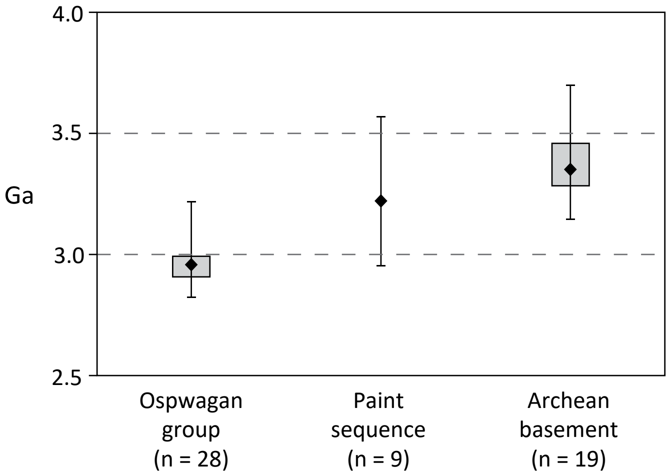

Figure GS2021-3-3: *Crustal-residence Nd-model ages of the Ospwagan group, Paint sequence and Archean basement gneiss. Black lines indicate the minimum and maximum ages for each population, grey boxes the interquartile range (middle 50% of the data from 25th to 75th percentile) and black diamonds the median age. Data sources: Ospwagan group and Archean basement from Böhm et al. (2007); Paint sequence from Couëslan (2016), Manitoba Geological Survey (2020).*

tre- to metre-thick layers of wacke. Mudstone has only been observed in east-central Paint Lake and near the marina, where it is interbedded on a centimetre scale with quartz-rich arenite. The interbedded mudstone-arenite unit contains rare garnet-rich concretions (Couëslan, 2016). The mudstone contains graphite and pyrrhotite, and is characterized by gossanous weathered surfaces. The iron formation occurs as discontinuous layers and lenses, which are up to 3 m thick but typically <1 m, within the wacke. Iron formations are typically of the silicate facies; however, significant pyrrhotite and magnetite can be present. Calcsilicate occurs only as rare centimetre-thick boudins in the wacke and arenite on Paint Lake (Couëslan, 2016); however, layers of calcsilicate and marble 2–5 m thick are observed in drillcore from Phillips Lake (Couëslan, 2018). It remains uncertain if the calcareous rocks at Phillips Lake are part of the Paint sequence stratigraphy or represent infolds or tectonic slivers of Ospwagan group rocks.

A maximum age for the Paint sequence is provided by five ca. 2435 Ma detrital-zircon grains obtained from a sample of wacke (Couëslan, 2016; Figure GS2021-3-4a). The Paint sequence rocks are intruded by relatively straight-walled mafic dikes, which are tentatively interpreted to be part of the Paleoproterozoic Molson dike swarm, suggesting a minimum age of ca. 1883 Ma for the sequence. The Paint sequence rocks differ from the Ospwagan group rocks in having unique trace-element compositions and containing early Paleoproterozoic detrital zircon (Figure GS2021-3-4); however, there is a significant overlap in crustal-residence Nd-model ages (ca. 3.57–2.95 Ga; Figure GS2021-3-3; Couëslan, 2016; Manitoba Geological Survey, 2020). The stratigraphic relationship between the Ospwagan group and Paint sequence is not known.

Geochronology samples

Five samples of Ospwagan group rocks were collected for prospective detrital-zircon U-Pb dating: three samples from the Manasan formation M1 member, one sample from the Manasan formation M2 member and one sample from the Setting formation. Whole-rock lithogeochemistry results for these samples can be found in (Couëslan, 2021d).

Manasan formation, M1 member samples

Sample 108-21-004 consists of quartz-pebble conglomerate and was collected from talus at the east end of Manasan quarry (Figure GS2021-3-1). Fifty centimetre to one metre lenses of quartz-pebble conglomerate are visible in quartzite along the north wall of the quarry, immediately above the talus pile. The conglomerate is beige, coarse grained, clast supported and strongly foliated. Pebbles are <1 cm across but commonly stretched to a length of 4 cm. Pebbles consist dominantly of quartz and are rarely quartzofeldspathic. The matrix consists of quartz with relatively abundant muscovite, chlorite and carbonate, suggesting it was likely derived from a muddy sand with some carbonate cement, or possibly a feldspathic sand where the feldspar component was altered during diagenesis or metamorphism.

Sample 108-21-002A is a quartzite that was collected from a quarry along Highway 6 near the former Soab North mine (Figures GS2021-3-1, -5a). The rock is light grey to beige, medium to coarse grained and foliated, with bedding <15 cm thick. It is quartz rich with abundant epidote, minor plagioclase and K-feldspar, and trace muscovite and Ca-amphibole. The mafic minerals appear to be pseudomorphous after feldspar, which suggests that the rock was derived from a feldspathic arenite. The abundance of epidote in the sample suggests a post–peak metamorphic alteration event. The quartzite at this location is intruded by a gabbro dike at least 50 m wide, which cuts across the south end of the quarry and is interpreted to be part of the Molson dike swarm. The quartzite sample was collected at the north end of the quarry, approximately 30 m from the dike margin, to minimize the chance of zircon U-Pb resetting caused by the intrusion of the mafic dike. A sample of fine-grained chill margin was collected from the gabbro dike for lithogeochemistry.

Sample 108-21-007 consists of well-laminated micaceous quartzite (unit M1b8 of Macek et al., 2004, 2005), which was collected from the shoulder of the South pit at the Thompson mine (Figures GS2021-3-1, -5b). The micaceous quartzite forms a 2–3 m thick layer that is underlain and overlain by cleaner, arenaceous sandstone. The micaceous quartzite is brown, medium grained and foliated, with laminations <5 mm thick. It is quartz- and K-feldspar rich, with abundant plagioclase and minor biotite and muscovite, and was likely derived from a feldspathic wacke.

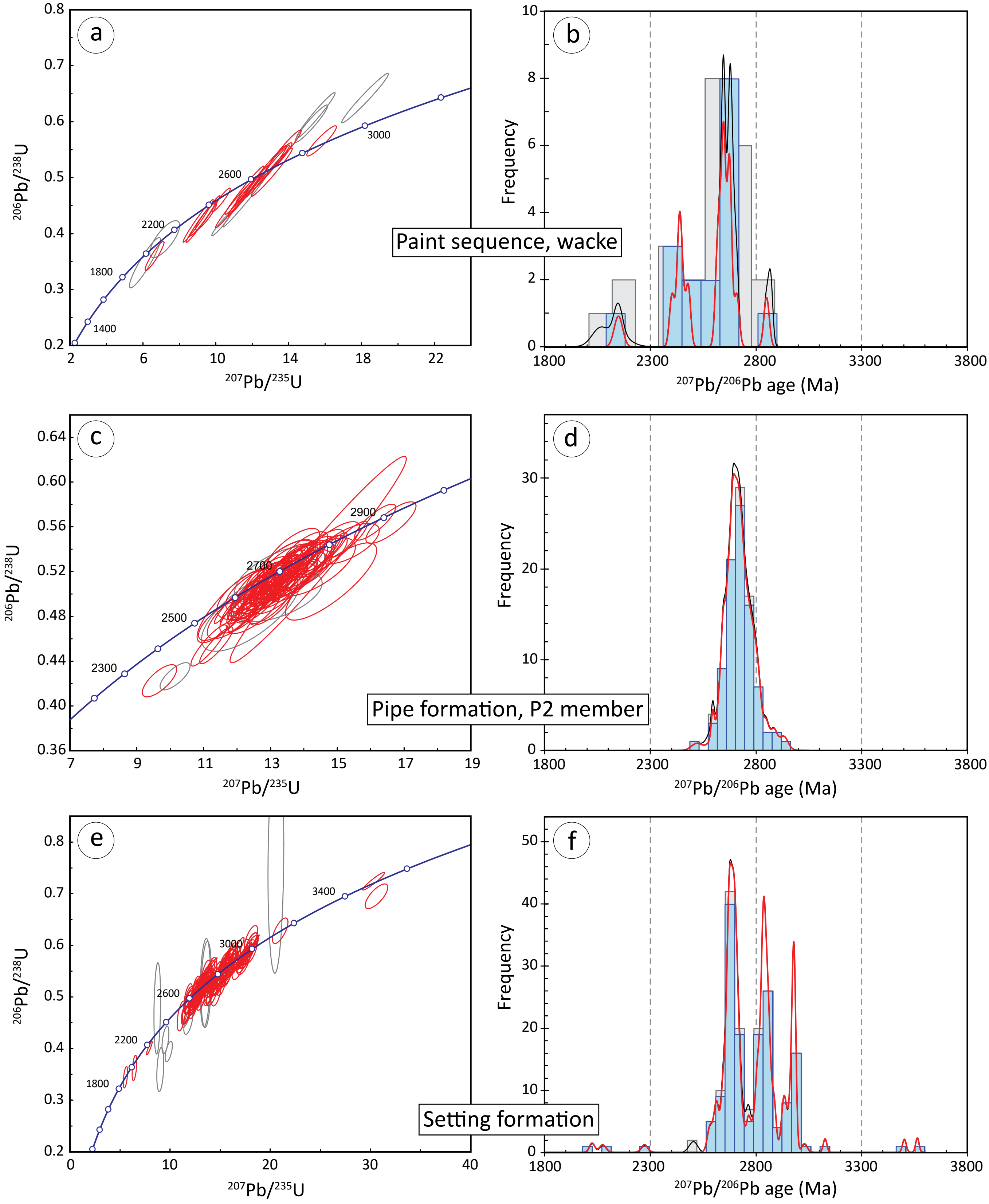

***Figure GS2021-3-4**: High-resolution detrital-zircon U-Pb results for sedimentary rocks from the Thompson nickel belt: **a)** concordia diagram and **b)** frequency histogram and probability curve for Paint sequence wacke (Couëslan, 2016); **c)** concordia diagram and **d)** frequency histogram and probability curve for Pipe formation, P2 member (Rayner et al., 2006); **e)** concordia diagram and **f)** frequency histogram and probability curve for Setting formation wacke (Zwanzig et al., 2021). In the concordia diagrams, red analyses are <10% discordant and rejected analyses are in grey; error ellipses are shown at 2σ. Coloured frequency histograms and probability curves represent analyses that are <10% discordant; grey and black represent all analyses combined.*

Figure GS2021-3-5: *Outcrop photographs of sampled units:* ***a)*** *station 108-21-002, Manasan Formation M1 member quartzite at the Soab North quarry;* ***b)*** *station 108-21-007, M1 member micaceous quartzite at the Thompson mine, south pit (tape is approximately 2.5 cm wide and arrow points upsection);* ***c)*** *station 108-21-008, M2 member semipelite at Pipe II mine open pit;* ***d)*** *station 108-21-005, Setting formation interbedded arenite and wacke at Niven Point, Ospwagan Lake;* ***e)*** *station 108-21-001, biotite gneiss of uncertain affinity at Joey Lake area roadcut;* ***f)*** *station 108-21-003, garnet-bearing wacke of uncertain affinity at Joey Lake area roadcut;* ***g)*** *station 108-21-003, garnet 'concretion' at Joey Lake area roadcut.*

The M1 member is a shallow-water marine sandstone (and minor conglomerate) package deposited along the Superior craton passive margin (Bleeker, 1990; Zwanzig et al., 2007). It represents a transgressive sequence that fines upward into the overlying M2 member (Bleeker, 1990; Zwanzig et al., 2007). The quartz-pebble conglomerate (108-21-004) was likely deposited toward the base of the M1 member (Bleeker, 1990; Zwanzig et al., 2007). The relative stratigraphic position of quartzite 108-21-002A within the M1 member is not known; however, the relatively clean sand is characteristic of deposits near the base and middle of the succession (Macek et al., 2004). The micaceous quartzite (108-21-007) occurs toward the middle of the M1 member and is characterized by an increased abundance of finer grained clastic material. It likely represents a period of transgression during a transgressive-regressive cycle.

Manasan formation, M2 member sample

Sample 108-21-008 is a fine-grained semipelitic schist collected roughly 2 m above the M1 contact at the open pit of the Pipe II mine (Figures GS2021-3-1, -5c). The schist is dark grey-brown, fine grained and foliated, with laminations <1 cm thick. Local quartz-rich segregations <2 cm across occur within the unit but were avoided during sampling. The rock consists dominantly of quartz with abundant biotite and K-feldspar, minor plagioclase, muscovite and iron oxide, and trace tourmaline. The M2 member was likely derived from offshore marine siltstone or mud-rich wacke that was deposited along the Superior craton passive margin (Bleeker, 1990; Zwanzig et al., 2007).

Setting formation sample

Sample 108-21-005 is a well-bedded quartzite collected from Niven Point on Ospwagan Lake (Figures GS2021-3-1, -5d). It occurs as part of a sequence of interbedded arenite and wacke. The quartzite is brown, fine grained and foliated, with layering <3 cm thick. It is quartz rich with abundant plagioclase, minor muscovite and biotite, and trace sulphide and garnet, and was likely derived from a feldspathic wacke. The Setting formation is interpreted as offshore marine turbidite deposits that were shed from the Superior craton (Zwanzig et al., 2007), possibly into a foredeep basin (Bleeker, 1990).

Joey Lake area samples

Five samples were collected for lithogeochemistry from relatively recent roadcuts along Highway 6 in the Joey Lake area (Figure GS2021-3-1). The samples include three sedimentary rocks of unknown affinity, a spatially associated ultramafic schist and a spatially associated biotite gneiss of uncertain affinity. The roadcuts occur within 70 m of an area indicated to be underlain by undifferentiated Ospwagan group and Archean rocks on the Thompson nickel belt geological compilation map of Macek et al. (2006). The aim is to determine if these rocks share affinity with the Ospwagan group, the Archean basement or the Paint sequence.

Sample descriptions

A roadcut approximately 1.4 km northeast of the Manitoba Hydro radio tower near Joey Lake consists largely of biotite gneiss of uncertain affinity, intruded by diabase and pegmatitic granite dikes (Figures GS2021-3-1, -5e). Sparse horizons <1 m thick within the biotite gneiss are garnet bearing. A sample of gneiss was collected from one of the garnet-bearing zones (108-21-001). The gneiss is brown-grey, coarse grained and strongly foliated, with crude layering <10 cm thick. It is quartz and plagioclase rich, with 10–20% biotite, 2–3% garnet and 1–2% hornblende. It is uncertain if the biotite gneiss represents a quartzofeldspathic sedimentary rock or is part of the Archean basement gneiss.

A roadcut approximately 0.3 km northeast of the radio tower contains a >50 m thick package of sedimentary rocks consisting dominantly of garnet-bearing wacke (108-21-003A; Figures GS2021-3-1, -5f). The wacke is brownish grey, medium grained and foliated, with bedding <5 cm thick. It is quartz and plagioclase rich, with 10–20% biotite and trace–2% garnet. The wacke contains sparse layers of ironstone <20 cm thick (108-21-003B), ferruginous mudstone <10 cm thick (108-21-003D) and boudins of ultramafic schist <50 cm thick (108-21-003C). Rare, pinkish brown ‘concretions’ <15 cm thick occur within the wacke (Figure GS2021-3-5g). The concretions are mantled by dark selvages <3 cm thick. Similar concretions are found in quartzite and wacke of the Setting formation, and in the interbedded pelite-arenite unit of the Paint sequence (Bleeker, 1990; Zwanzig et al., 2007; Couëslan, 2016).

Lithogeochemistry

Following the methodology outlined by Zwanzig et al. (2007), whole-rock geochemical data for the Joey Lake rocks was normalized by average Pipe formation, P2 member and plotted on multi-element diagrams in order to compare with wackes, mudstones and iron formations of the Ospwagan group (Figure GS2021-3-6a–d) and Paint sequence (Figure GS2021-3-6e–f). The diagrams utilize elements considered to be relatively immobile in the metamorphic environment (e.g., rare-earth elements [REE] and high-field-strength elements [HFSE]). The lithogeochemical data, and sampling and analytical methods for the Joey Lake rocks are being released in Data Repository Item DRI2021017[1] (Couëslan, 2021d).

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[1] MGS Data Repository Item DRI2021017, containing the data or other information sources used to compile this report, is available online to download free of charge at https://www.gov.mb.ca/iem/info/library/downloads/index.html, or on request from minesinfo@gov.mb.ca, or by contacting the Resource Centre, Manitoba Agriculture and Resource Development, 360–1395 Ellice Avenue, Winnipeg, Manitoba R3G 3P2, Canada.

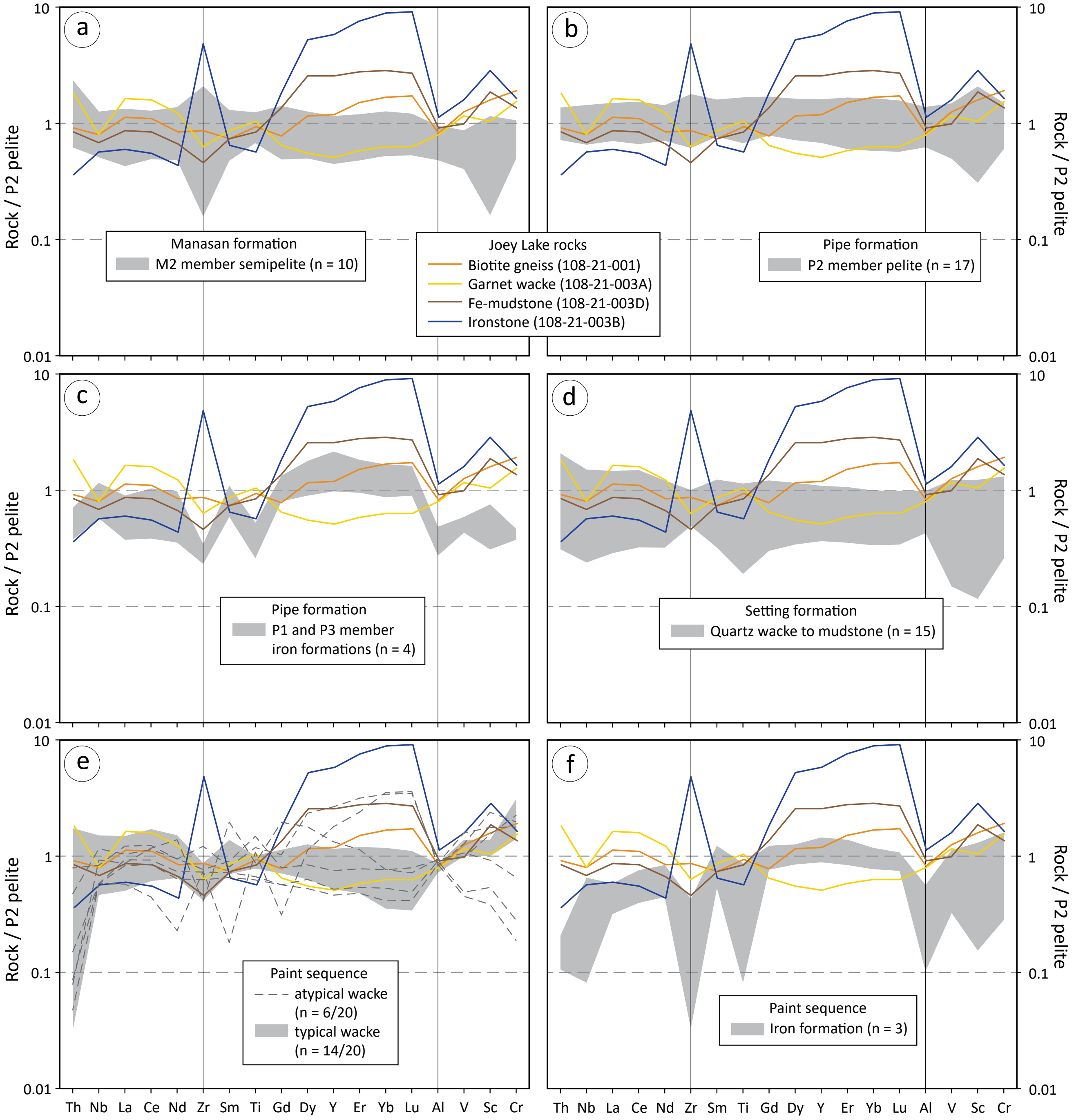

Figure GS2021-3-6: *Multi-element profiles of Joey Lake area samples normalized to average P2 mudstone of Zwanzig et al. (2007) and compared to the profile ranges of other TNB stratigraphy:* ***a)*** *Manasan formation, M2 member semipelite;* ***b)*** *Pipe formation, P2 member mudstone;* ***c)*** *Pipe formation silicate-facies iron formation;* ***d)*** *Setting formation wacke to mudstone;* ***e)*** *Paint sequence wacke;* ***f)*** *Paint sequence silicate-facies iron formation. Data sources: Ospwagan group rocks, Zwanzig et al. (2007), Couëslan (2020, 2021c); Paint sequence rocks, Couëslan (2016, 2021b).*

The shallow positive slope of the biotite gneiss profile (108-21-001) is not a close fit to any of the other profiles (Figure GS2021-3-6), although it does largely fit within the range of Pipe formation, P2 member profiles (Figure GS2021-3-6b) and bears some similarities to atypical Paint sequence wacke (Figure GS2021-3-6e). The negative slope of the Joey Lake garnet wacke profile (108-21-003A) largely fits within the range of Setting formation rocks (Figure GS2021-3-6d) and typical Paint sequence wacke (Figure GS2021-3-6e). In particular, the enrichment of Cr and overall positive slope from Al to Cr is a characteristic shared by the Paint sequence rocks. However, the concave-upward heavy rare-earth element (HREE) portion of the profile does not correlate with either the Paint sequence or the Setting formation rocks.

The positive-sloping profile of the ferruginous mudstone (108-21-003D) does not correlate well with any of the profile ranges in Figure GS2021-3-6; however, it strongly resembles some atypical profiles of the Paint sequence wacke

(Figure GS2021-3-6e). The profile of the ironstone (108-21-003B) does not correlate well with any of the profiles in Figure GS2021-3-6 and, most notably, it differs greatly from both the Ospwagan group and Paint sequence iron formations (Figure GS2021-3-6c, f). The values for Zr and HREE are anomalous, especially for a sedimentary rock believed to have a significant chemical component; however, zircon is found to be relatively abundant in thin section. The ironstone profile does resemble the overall shape of some of the atypical Paint sequence wacke profiles (Figure GS2021-3-6e).

Overall, the Joey Lake sedimentary rocks appear to correlate more closely with the Paint sequence than the Ospwagan group; however, none of the samples are a precise match with 'typical' Paint sequence wacke. All previously documented examples of Paint sequence rocks occur in the Paint Lake–Phillips Lake area and contain granulite-facies metamorphic assemblages. If these rocks do represent Paint sequence, they are the first to occur west of that area and the first to consist of amphibolite-facies metamorphic assemblages. Because the rocks occur at a lower metamorphic grade, there may be better potential for the preservation of primary sedimentary features. This suggests that additional study of the rocks contained within the belt of undifferentiated Ospwagan group and Archean gneiss of Macek et al. (2006) is warranted.

Economic considerations

All known economic Ni-Cu deposits in the TNB are associated with ultramafic bodies hosted by Ospwagan group rocks. High-resolution U-Pb detrital-zircon ages for the Ospwagan group stratigraphy could provide additional insight into the source region(s) and depositional history of the sedimentary sequence. Differences in source regions between the Ospwagan group and Paint sequence could indicate differences in tectonic setting at the time of their deposition. Variations in detrital-zircon populations could also help differentiate Ospwagan group rocks from other sedimentary units within the TNB, which are considered to be less prospective for hosting Ni deposits.

If the sedimentary rocks sampled near Joey Lake correlate with the Paint sequence, it could be that the nearby belt of undifferentiated Ospwagan group and Archean gneiss in Macek et al. (2006) actually consists largely of Paint sequence rocks. This belt, which has a strike length of approximately 7.6 km, is known to contain ultramafic bodies toward its northern terminus. Paint sequence rocks are known to contain sedimentary sulphide (a potential source of sulphur for intruding ultramafic magmas), and it has been suggested that the mineralized ultramafic body at Phillips Lake could be hosted by Paint sequence rocks (Couëslan, 2018). Further study of this belt of sedimentary rocks could provide additional information regarding the relationship between the Paint sequence and the Ni-hosting ultramafic bodies of the TNB.

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