GS2020-4

Detrital zircon and whole-rock lithogeochemical analyses of poorly exposed and sub-Phanerozoic metasedimentary basement rocks in the Watts, Mitishto and Hargrave rivers area, north-central Manitoba (parts of NTS 63J5, 6, 11–14)

by K.D. Reid

In Brief:
- Metasedimentary rocks with Archean provenance and Ospwagan-like geochemistry occur west of the traditional Thompson nickel belt
- A significant portion of the metasedimentary rocks has geochemistry similar to the Burntwood group
- Detrital zircons in metasedimentary rocks have, depending on the sample, either a dominant Paleoproterozoic or Archean provenance

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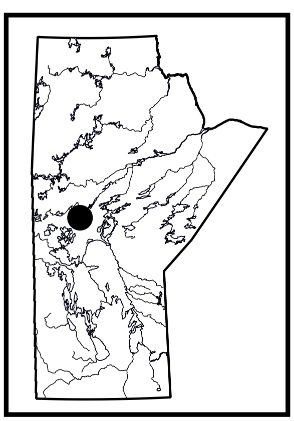

Summary

The area southeast of Snow Lake and west of Highway 6, occupied by the Watts, Mitishto and Hargrave rivers, represents a complex structural confluence along the Superior boundary zone where rocks of the Paleoproterozoic Flin Flon and Kisseynew domains are juxtaposed and interleaved with Paleoproterozoic and Archean rocks of the Superior province margin. Poor exposure or cover by Phanerozoic rocks limits direct methods of data collection of Precambrian rocks to the examination and sampling of drillcore. Presented here is a geochemical comparison of metasedimentary rocks from select drillcore normalized to the average pelite from the P2 member of the Pipe formation of the Ospwagan group. This data is complemented by detrital zircon analyses on two samples from these drillcore, providing additional constrains on the provenance of the metasedimentary rocks.

Introduction

The Manitoba Geological Survey (MGS) continued a multiyear geological mapping project focused on parts of the Paleoproterozoic Flin Flon and Kisseynew domains that extend beneath Phanerozoic rocks (Figure GS2020-4-1). This project was initiated in 2009–2010 and continued in 2017 after a hiatus. The objective of the project is to enhance the geological understanding of the poorly exposed and sub-Phanerozoic Flin Flon and Kisseynew domain rocks (e.g., Simard et al., 2010; Reid, 2017). Geological knowledge of this region is limited, but exploration drilling for volcanogenic massive-sulphide (VMS) and magmatic nickel deposits has indicated that many of the tectonostratigraphic elements that make the exposed rocks economically significant extend under the Phanerozoic rocks.

Discussed in this report are the results of whole-rock lithogeochemical and detrital zircon analyses of metasedimentary rocks from drillcore in the Watts, Mitishto and Hargrave rivers area (southeast of Snow Lake and west of Highway 6) that was relogged and sampled during the 2017 and 2018 field seasons (Reid, 2017, 2018). These metasedimentary rocks have variable composition (impure quartzite, psammite, psammopelite, pelite) and are interpreted to represent a significant portion of the rocks located in the study area.

Previous work

Previous work in the study area includes regional mapping, with integrated aeromagnetic, gravity and drillcore data, of the sub-Phanerozoic portion of the Flin Flon and Kisseynew domains by the Geological Survey of Canada (Leclair et al., 1997; NATMAP Shield Margin Project Working Group, 1998). This work resulted in the recognition of several lithotectonic subdomains (Figure GS2020-4-2), some of which occur exclusively under the Phanerozoic cover (e.g., Cumberland domain, Namew gneiss complex, Cormorant batholith) and others that are both exposed and under Phanerozoic cover (e.g., Athapapuskow domain/Elbow-Athapapuskow assemblage, Clearwater domain/Snow Lake assemblage, eastern Kisseynew domain and Superior boundary zone). Macek et al. (2006) reviewed drillcore from along the Superior boundary zone, from Hargrave River south-southwest approximately 150 km to Cedar Lake, providing new information on the distribution and structure of the Paleoproterozoic sedimentary and volcanic cover succession (Ospwagan group) on the northwestern margin of the Archean Superior province. Macek et al. (2006) approximated the contact between apparent Burntwood group turbidites (broad aeromagnetic low) and undifferentiated Archean basement (aeromagnetic highs) of the Superior province.

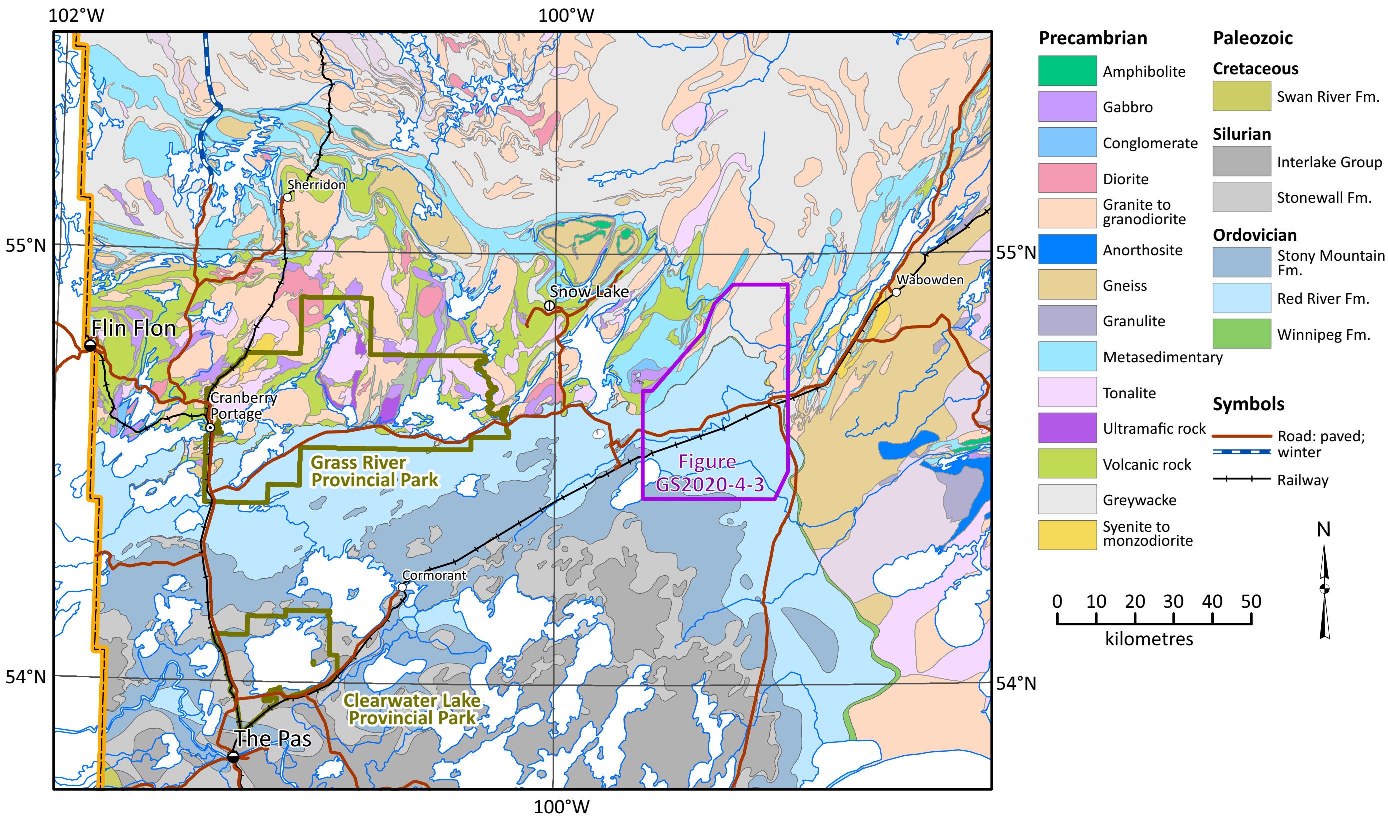

Figure GS2020-4-1: *General bedrock geology of the Flin Flon and Snow Lake region, north-central Manitoba (modified from Reid, 2018).*

Simard and McGregor (2009) initiated data compilation to aid in mapping the sub-Phanerozoic portion of the Flin Flon and Kisseynew domains. The authors' objectives were to better characterize the various geophysical subdomains outlined by Leclair et al. (1997) using existing and new geochronological, isotopic and geochemical data, which aided a comparison between the sub-Phanerozoic rocks and the tectonostratigraphic assemblages of the exposed Flin Flon domain. Simard et al. (2010) completed detailed work on eight poorly understood VMS deposits from the Clearwater and eastern Kisseynew domains showing that they formed in different lithotectonic environments. Deposits in the Clearwater domain (Moose, Limestone, Sylvia, Kofman) are hosted in bimodal tholeiitic to transitional oceanic-arc rocks at 'lower metamorphic grade', whereas those of the eastern Kisseynew domain (Watts River, Fenton, Harmin, Talbot) are hosted by volcanic and sedimentary rocks formed in a rifted arc and/or back-arc environment and metamorphosed at relatively 'high metamorphic grade'. More recently, Reid (2017, 2018) has conducted regional drillcore review coupled with aeromagnetic interpretation to subdivide the Watts, Mitishto and Hargrave rivers area (e.g. Figure GS2020-4-3).

Whole-rock lithogeochemistry of metasedimentary drillcore samples

Detailed lithostratigraphy for rocks along the Superior boundary zone from Setting Lake to Thompson has been described by several authors (e.g., Bleeker, 1990; Zwanzig and Böhm, 2002). More recently, Zwanzig et al. (2007) characterized the stratigraphy of the Ospwagan group—the cover sequence to the Thompson nickel belt basement—by normalizing whole-rock lithogeochemistry of all stratigraphic formations and members to the average pelite of the P2 member of the Pipe formation (P2 pelite). Normalized samples were plotted on extended-element spider diagrams, which include rare-earth elements (REEs), high-field-strength elements (HFSEs: Nb, Ti, U, Th) and some large-ion lithophile elements (LILEs: Rb, Ba, Sr, K). The results are useful when attempting to interpret the lithostratigraphic setting of highly metamorphosed rocks in drillcore. For further discussion and a more in-depth review regarding geochemical characterization of sedimentary rocks along the northwestern flank of the Superior province, the reader is referred to Zwanzig et al. (2007).

Adopting the method of Zwanzig et al. (2007), individual analyses of metasedimentary rocks in the study area were normalized to the average P2 pelite. From this data, the 75th percentile (upper dash line), median (middle dash line) and 25th percentile (lower dash line) were calculated for sample groups and then plotted (Figure GS2020-4-4). Median values of stratigraphic components of the Ospwagan, Burntwood and Grass River groups are plotted on Figure GS2020-4-4a–c (data from Zwanzig et al., 2008) so the reader can make a comparison to the unclassified metasedimentary rocks in drillcore from the study area. The drillcore submitted for geochemical analysis

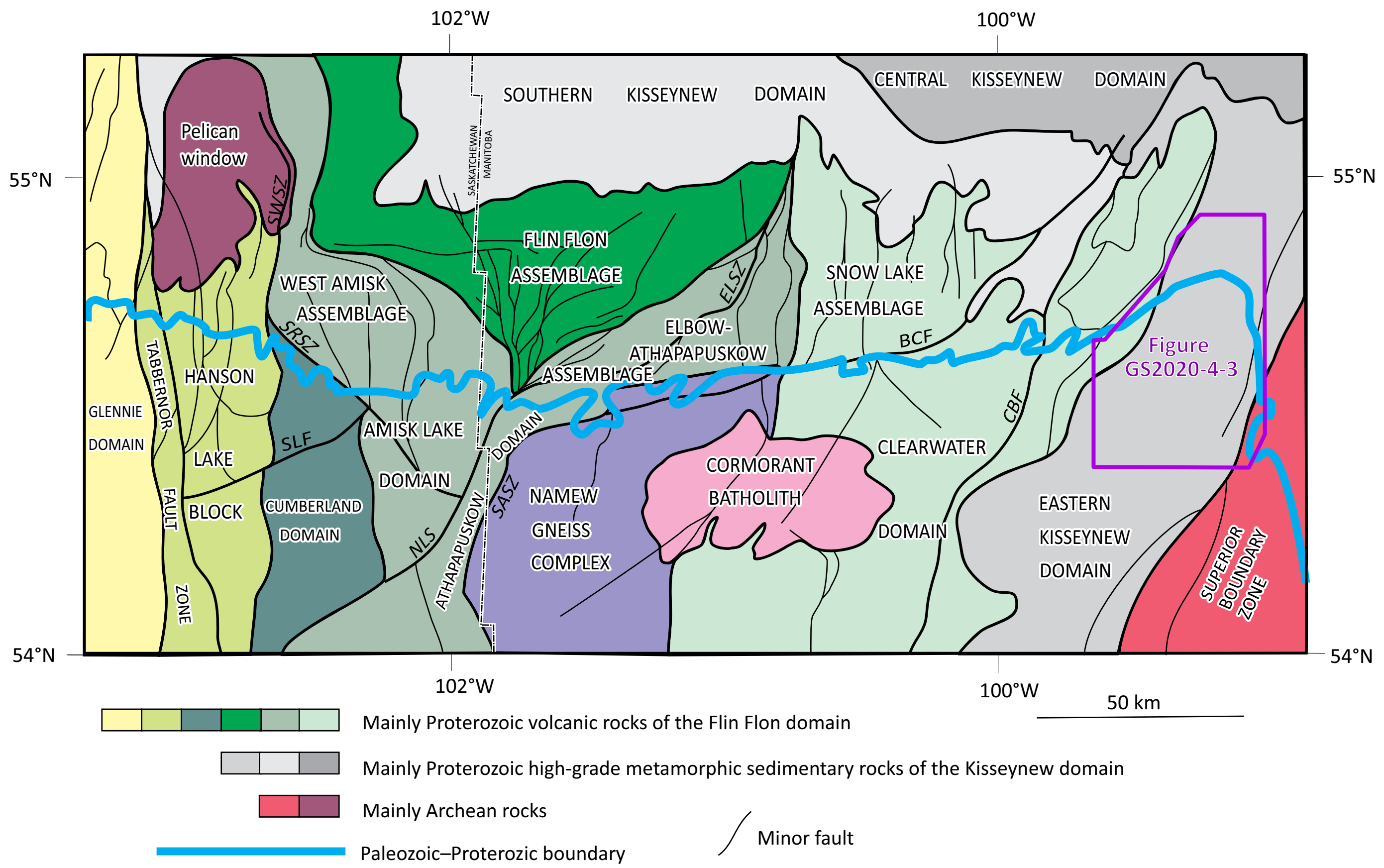

Figure GS2020-4-2: *Interpreted lithotectonic subdomains of the Flin Flon and Kisseynew domains in west-central Manitoba and east-central Saskatchewan (after NATMAP Shield Margin Project Working Group, 1998). Abbreviations of major faults and shear zones: BCF, Berry Creek fault; CBF, Crowduck Bay fault; ELSZ, Elbow Lake shear zone; NLS, Namew Lake structure; SASZ, South Athapapuskow shear zone; SLF, Suggi Lake fault; SRSZ, Spruce Rapids shear zone; SWSZ, Sturgeon Weir shear zone. The heavy blue line is the contact between the exposed Precambrian rocks to the north and Phanerozoic-covered Precambrian rocks to the south.*

are from Hudbay Minerals Inc. exploration programs between 2000 and 2018. More details regarding sampling and analytical methods are being prepared as a Data Repository Item (K.D. Reid, work in progress).

Lithogeochemistry of drillcore samples from Zwanzig et al. (2008)

Ospwagan group

Figure GS2020-4-4a shows that iron formation and semipelite of the Pipe formation, P3 member (yellow), and calcareous semipelite and marlstone of the Thompson formation (T, purple) have median profiles that are relatively flat or gently negatively sloped and have slightly lower concentrations of heavy rare-earth elements (HREEs) compared to average P2 pelite. Silicate- and sulphide-facies iron formation of the Pipe formation, P1 member (Figure GS2020-4-4a, orange), has a similar profile to that of P2 pelite with the exception of lower HREE concentrations. The M1 member of the Manasan formation, composed of impure quartzite, quartzite and minor conglomerate with minor pelite, has a median profile that is irregular, has a somewhat gentle positive slope and is generally less enriched than P2 pelite except for elevated concentrations of K and P (Figure GS2020-4-4b, red). Manasan formation M2 member semipelite has very similar element concentrations compared to P2 pelite (Figure GS2020-4-4b, grey). Setting Lake formation psammite and pelite (Figure GS2020-4-4b, S, light green) have similar concentrations of LILEs to P2 pelite but have lower HREE concentrations.

Burntwood and Grass River groups

Figure GS2020-4-4c shows that Burntwood group greywacke (blue) and Grass River group sandstone and conglomerate (green) have similar median profiles when normalized to P2 pelite. Both have a consistent gentle positive slope from LILEs to HREEs with distinctly lower concentrations of Rb, K and Zr and higher concentrations of U, Sr and P relative to P2 pelite.

Lithogeochemistry of drillcore samples from the study area

Impure quartzite and pelite

Drillholes KUS318 and KUS342 are representative of an area of narrow northeast-trending magnetic highs and lows

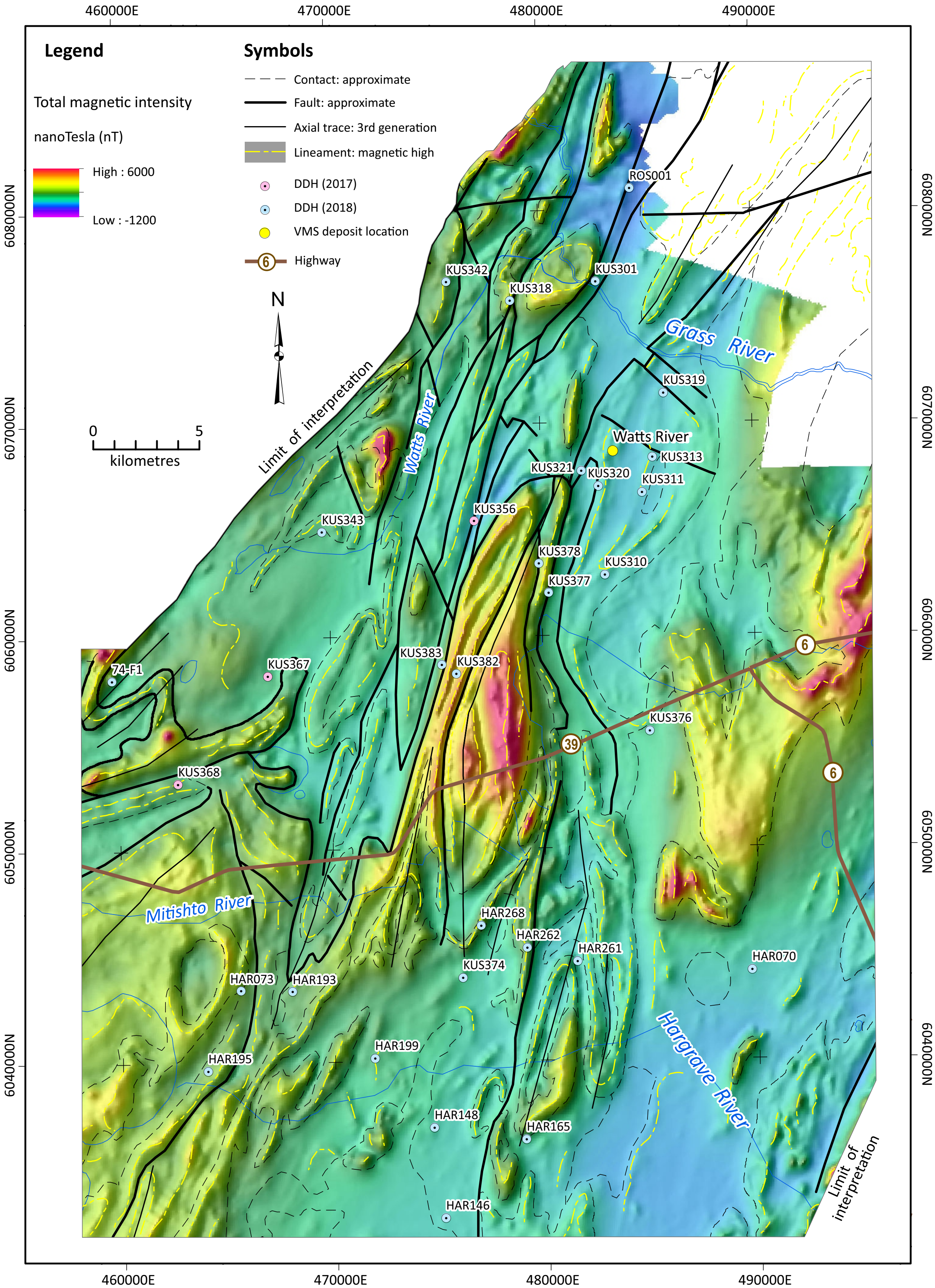

***Figure GS2020-4-3:** Detailed aeromagnetic map (after Keating et al., 2012) for the study area showing interpreted geological contacts, faults and drillhole locations (modified after Reid, 2018, Figure GS2018-4-2). UTM Zone 14, NAD83. Abbreviations: DDH, diamond drillhole; VMS, volcanogenic massive-sulphide.*

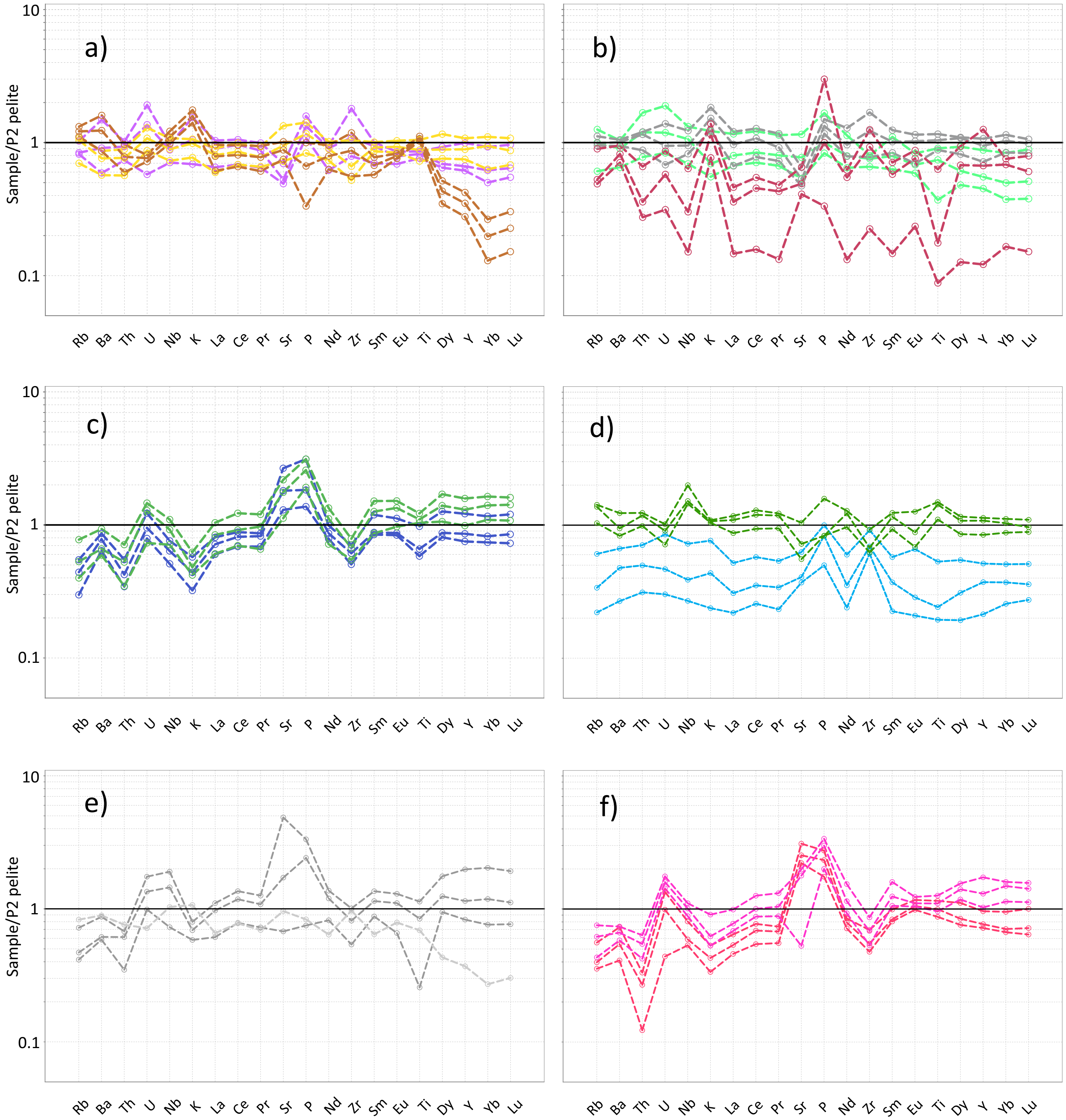

Figure GS2020-4-4: *Extended-element diagrams showing the 75th percentile (upper dash line), median (middle dash line) and 25th percentile (lower dash line) of trace-element whole-rock compositions of metasedimentary rocks from the study area normalized to the average pelite of the P2 member of the Pipe formation (P2 pelite, black line) of Zwanzig et al. (2007): **a)** Pipe formation (P1 member, orange, n=2; P3 member, yellow, n=9) and Thompson formation (T, purple, n=5); **b)** Manasan formation (M1 member, red, n=7; M2 member, grey, n=7) and Setting Lake formation (S, light green, n=12); **c)** Burntwood group (blue, n=14) and Grass River group (green, n=12); **d)** psammite and impure quartzite (drillcore KUS318 and KUS342, light blue, n=8) and psammopelite to pelite (drillcore KUS318 and KUS342, green, n=4); **e)** psammite and quartzofeldspathic gneiss (drillcore KUS378, dark grey, n=4; drillcore HAR195, light grey, n=1); **f)** psammopelite and pelite (drillcore KUS343, KUS356 and KUS367, magenta, n=10; drillcore KUS376 and HAR070, red, n=13). The data in **a)–c)** are from Zwanzig et al. (2008).*

near the Watts River in the northwestern portion of the study area (Figure GS2020-4-3). Reid (2018) described these rock units as being mainly psammite and conglomerate but further review of the geochemical composition indicates these drillcore contain impure quartzite and psammite interleaved with psammopelite to pelite (K.D. Reid, work in progress). Impure quartzite and pelite in close association is not a stratigraphic association commonly observed in the Kisseynew domain (Zwanzig and Bailes, 2010). Normalizing the metasedimentary rocks of KUS318 and KUS342 to P2 pelite (Figure GS2020-4-4d), it is apparent that the median composition of the psammopelite to pelite is not much different than that of the Pipe, Thompson and Manasan formations (Figure GS2020-4-4a, b). Psammite and impure quartzite (Figure GS2020-4-4d, light blue) have lower concentrations of all elements relative to P2 pelite, but in this respect are similar to the subarkosic sandstone of the M2 member of the Manasan formation (Figure GS2020-4-4b, grey).

Drillhole KUS378 penetrates rocks associated with an ovoid magnetic high in the middle of the study area (Figure GS2020-4-3) and contains psammite to psammopelite, which display layering at the centimetre to decimetre scale. These rocks have a gently positive slope and elevated U, Nb, Sr, P and HREEs relative to P2 pelite (Figure GS2020-4-4e, dark grey), this pattern most closely resembles that of the Grass River group (Figure GS2020-4-4c, green).

Near the Hargrave River, drillhole HAR195 intersects highly strained felsic gneiss that is interpreted to represent psammite (Reid, 2018). It has a relatively flat profile with similar element concentrations to that of P2 pelite with the exception of the HREEs, which are depleted (Figure GS2020-4-4e, light grey). Overall it is similar to the P1 member of the Pipe formation (Figure GS2020-4-4a, orange) suggesting it may be related to Ospwagan group stratigraphy.

Psammopelite and minor pelite

Drillholes KUS343 and KUS367 occur in a broad aeromagnetic low in the western portion of the study area whereas drillhole KUS356 occurs in a narrow northeast-trending aeromagnetic low to the east (Figure GS2020-4-3). These drillcore are composed of gradational rock types ranging from psammopelite to pelite with variable amounts of biotite and garnet and minor sillimanite present in the more pelitic intervals (Reid, 2018). Metasedimentary rocks in drillholes KUS376 and HAR070, in the eastern part of the study area, are similar to the psammopelite and pelite described in the western half of the study area (KUS343, KUS356, KUS367) but have increased quartzofeldspathic neosome and biotite-garnet–rich melasome, with sillimanite being rare or absent. The median compositions from samples from the western and eastern side of the study area both have consistent positive slopes with generally elevated U, Sr and P and reduced Th, K and Zr compared to P2 pelite (Figure GS2020-4-4f). However, psammopelite and pelite from the eastern study area (Figure GS2020-4-4f, red) show slightly lower concentrations of LILEs, HFSEs and REEs than corresponding rocks in the west (Figure GS2020-4-4f, magenta). These psammopelite and pelite have similar geochemical profiles (Figure GS2020-4-4f) to average Burntwood and Grass River groups (Figure GS2020-4-4c) along the northwestern flank of the Superior province (Zwanzig et al., 2007) suggesting these rocks may have a genetic link to the broader Burntwood group in the Kisseynew domain.

Detrital zircons from metasedimentary rocks in drillcore

Metasedimentary rocks from drillcore HAR070 and KUS378 were processed for detrital zircon extraction; Figure GS2020-4-3 shows the location of the drillholes. Sampling targeted the paleosome, avoiding the neosome (both leucosome and melanosome) material. Sample information, analytical methods and raw data are summarized in Data Repository Item DRI2020026 (Reid, 2020)[1]. Detrital zircon data presented in this report were plotted with P. Vermeesch's DensityPlotter software using the kernel density estimator (KDE), which is similar in appearance to the probability density plot (PDP). The KDE was selected because it uses a more solid theoretical foundation and is statistically more robust than the PDP (Vermeesch, 2012). This study used Epanechnikov kernel with an adaptive bandwidth based on the equation of Botev et al. (2010) and a bin width of 10 Ma for the histogram. Only data that are greater than 95% concordant or less than 5% discordant were used to produce the kernel density estimate.

Drillcore HAR070

Figure GS2020-4-5a shows a typical garnet-biotite psammopelite sampled from drillcore HAR070. Zircon analyses plotted on a concordia diagram (Figure GS2020-4-6a) show a significant distribution, whereas the kernel density estimate (Figure GS2020-4-6b) shows that the majority of the 150 zircon analyzed (~75%) are between 1.91 and 1.79 Ga, broadly corresponding with previously published ages for juvenile oceanic-arc volcano-sedimentary rocks of the Paleoproterozoic Flin Flon domain (e.g., David et al., 1996; Syme et al., 1999). Discrete peaks around 1852 and 1819 Ma likely record two known regional processes. The younger age peak around 1819 Ma corresponds to peak thermal metamorphism in the region (e.g., Gordon et al., 1990; Kraus and Williams, 1999). The second peak around 1852 Ma records the age of the dominant

[1] MGS Data Repository Item DRI2020026 containing the data or other information sources used to compile this report is available online to download free of charge at https://www.manitoba.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, MB R3G 3P2, Canada.

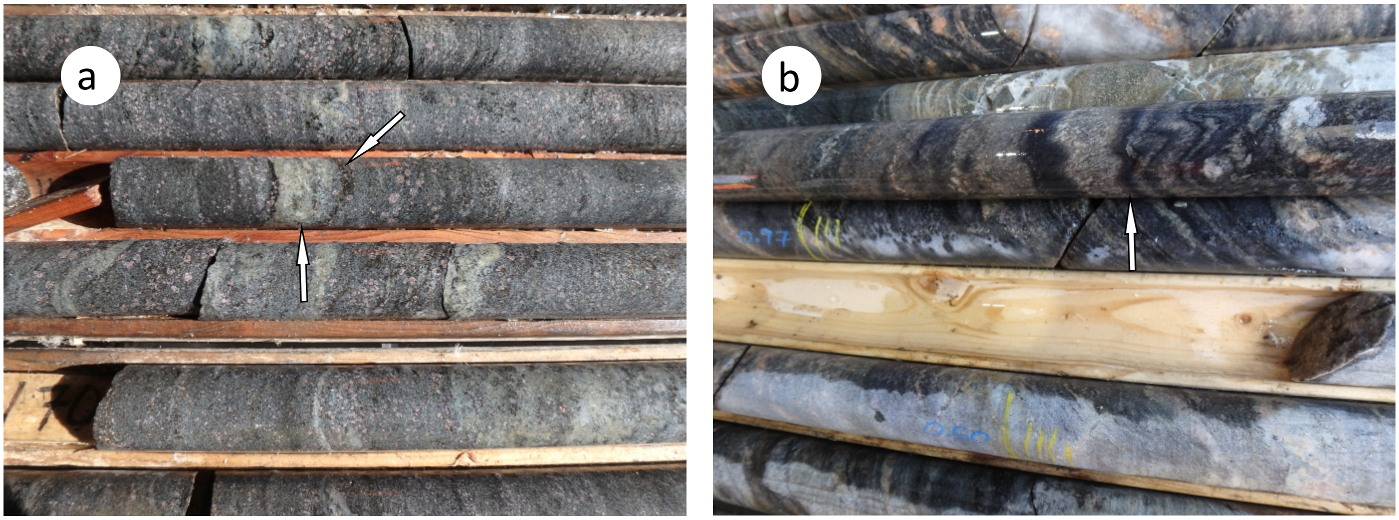

Figure GS2020-4-5: *Photographs of the different rock types from drillcore sampled for detrital zircon dating:* ***a)*** *garnet-biotite psammopelite with leucosome (lower arrow) and melanosome (upper arrow), drillhole HAR070;* ***b)*** *psammite showing primary sedimentary layering (arrow), drillhole KUS378. Drillcore is NQ and has a diameter of 47.6 mm.*

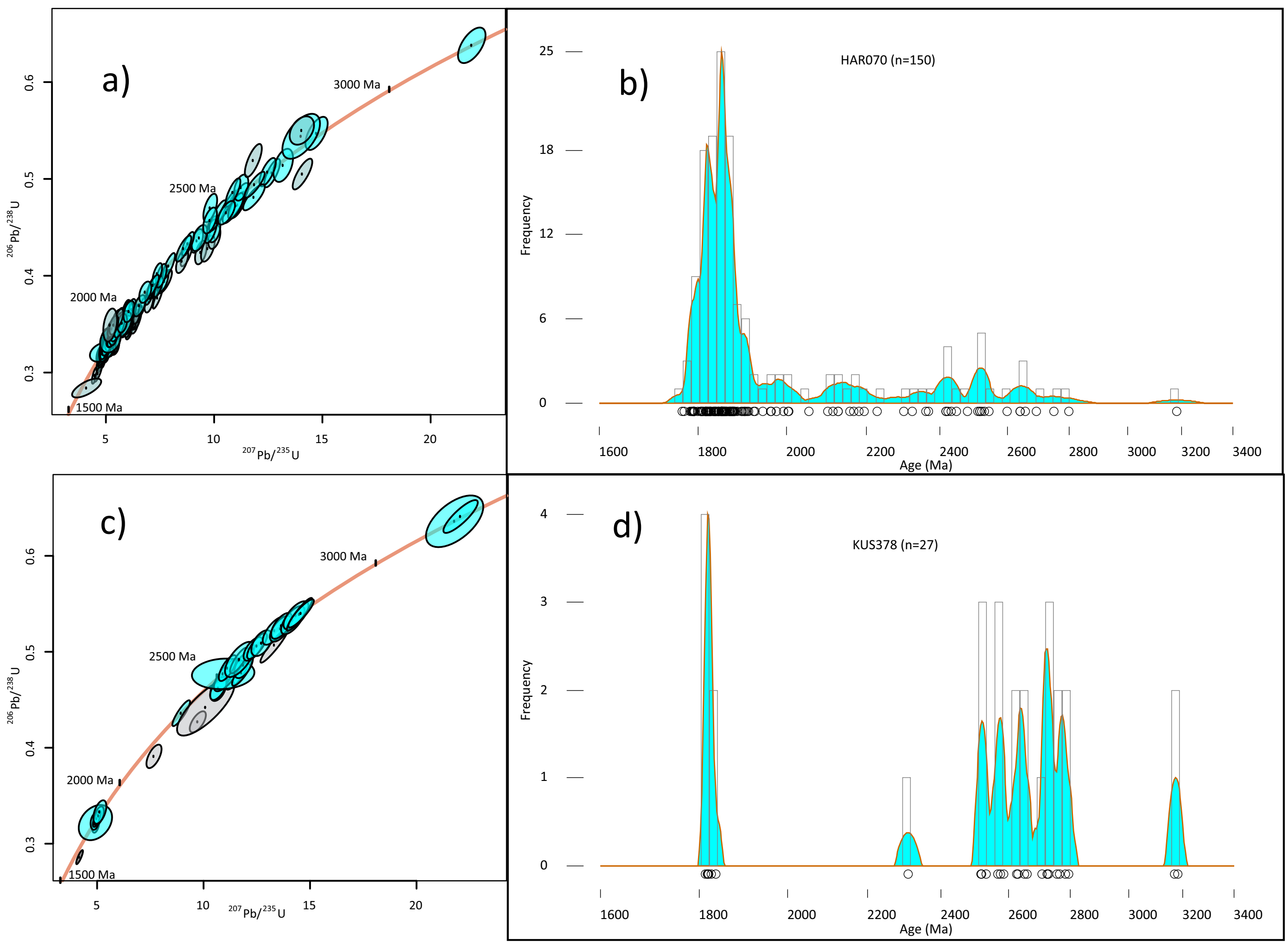

Figure GS2020-4-6: *Detrital zircon U-Pb age results:* ***a)*** *concordia diagram for zircons in the sample from drillcore HAR070;* ***b)*** *kernel density estimate for zircons in the sample from drillcore HAR070;* ***c)*** *concordia diagram for zircons in the sample from drillcore KUS378;* ***d)*** *kernel density estimate for zircons in the sample from drillcore KUS378.*

detrital input and corresponds very closely with the youngest detrital zircons in Burntwood group turbidites, 1856 Ma at Wekusko Lake and 1854 Ma at File Lake (David et al., 1996), and is comparable to other estimates of sedimentation dates for Burntwood group rocks (e.g., Machado and Zwanzig, 1995).

Minor clusters of ages occur around 2.54–2.50, 2.45–2.41, 2.20–2.10 and 2.00–1.96 Ga, and a single grain has an age of ~3.18 Ga (Figure GS2020-4-6b). The older ~2.70–2.10 Ga zircons in drillcore HAR070 overlap with the older detrital zircons observed at File Lake and inherited older Archean zircon ages in Snow Lake arc volcanic rocks (David et al., 1996), whereas the ~3.18 Ga age is correlative to igneous ages in the Assean Lake block to the north (Böhm et al., 1999).

Drillcore KUS378

Figure GS2020-4-5b shows psammite with primary sedimentary layering in drillcore KUS378. Zircons in the sample from drillcore KUS378 yielded both Paleoproterozoic and Neoarchean ages and a few older Archean ages (Figure GS2020-4-6c). The kernel density estimate data (n=27) show a discrete peak centred around 1818 Ma as well as peaks around 2.77, 2.72, 2.64, 2.57 and 2.52 Ga, a range from 2.79 to 2.52 Ga (Figure GS2020-4-6d). Only three zircons fall outside of this range; one dated around 2.31 Ga and two with ages around 3.18 and 3.17 Ga. The sample lacks zircons with ages before 1.84 Ga, typical of the Flin Flon domain (1.92–1.83 Ga; Syme et al., 1999), except for the discrete peak at 1818 Ma, which is interpreted to represent metamorphic overprint (e.g., Gordon et al., 1990; Kraus and Williams, 1999). Considering that rocks at drillholes HAR070 and KUS378 have a close spatial association it would be expected that they have undergone a similar peak metamorphism around 1819 Ma. The Neoarchean component of drillcore KUS378 has detrital ages that correspond with the tectonometamorphic history of the adjacent Superior province, making it the most likely source of the sediments. This includes an older >3.0 Ga basement, ~2.8–2.7 Ga volcanic and plutonic rocks, and ~2.70–2.64 Ga metamorphism (e.g., Mezger et al., 1990; Böhm et al., 1999; Heaman et al., 2011), however, the <2.64 Ga record in drillcore KUS378 is problematic and not generally recognized as a common component of the Superior province. The 2.52 Ga component of drillcore KUS378 is comparable to 2.52–2.50 Ga tonalite that is structurally imbricated between 1.90–1.88 Ga oceanic rocks in the Northeast Arm shear zone (David and Syme, 1994), and is similar to ages that represent the Sask craton (Rayner et al., 2005). Therefore, it is possible that part of the provenance for this rock may include the Sask craton. Although not a reproducible age, assuming the ~2.31 Ga zircon is the youngest detrital grain, the maximum depositional age would be <2.31 Ga.

It is noteworthy that the detrital zircons in the psammite of drillcore KUS378 have similarities to detrital zircons in the Saw Lake protoquartzite approximately 25 km to the north-northwest (Bailes and Böhm, 2008). Excluding the single ~2.31 Ga zircon in drillcore KUS378, these samples have comparable youngest detrital zircons, 2.52 Ga in drillcore KUS378 versus 2.51 Ga in the Saw Lake protoquartzite (Bailes and Böhm, 2008), and both have age ranges from ~2.79 to 2.51 Ga.

Geological implications

Geochemical and detrital zircon data indicate that the Watts, Mitishto and Hargrave rivers area contains metasedimentary rocks related to both i) an Ospwagan group rift-related and passive margin sequence derived from the Archean Superior province and ii) Burntwood and Grass River groups greywacke, sandstone and conglomerate derived from Paleoproterozoic juvenile oceanic arcs. For example, drillcore KUS318 and KUS342 both contain impure quartzite and pelite in close association, which is not a stratigraphic association commonly observed in the Kisseynew domain (Zwanzig and Bailes, 2010), and have geochemistry that resembles Ospwagan group rocks found in the Thompson nickel belt more so than rocks of the Kisseynew domain (Figure GS2020-4-4d). Detrital zircon analyses of psammite in drillcore KUS378, which is associated with a large north-northeast trending ovoid magnetic high in the centre of the study area (Figure GS2020-4-3), contains metasedimentary rocks of only Archean provenance.

Aeromagnetic interpretation coupled with the drillhole observations and geochemistry suggest that metasedimentary rocks similar to those of the Burntwood group in the Kisseynew domain make up a significant portion of the study area (e.g., drillcore KUS343, KUS356, KUS367, KUS376, HAR070). The dominantly Paleoproterozoic detrital zircons (1.91–1.79 Ga; Figure GS2020-4-6b) from drillcore HAR070 corroborate this interpretation.

The observations indicate that metasedimentary rocks with Archean provenance occur tens of kilometres west of the traditional Superior province margin (Thompson nickel belt) and are surrounded by rocks with Burntwood group geochemical affinity. Similarities can be drawn to the northeastern Kisseynew domain where Ospwagan group–like rocks at Wuskwatim Lake, which have an Archean provenance, are surrounded by Burntwood group rocks of the Kisseynew domain approximately 60 km from the exposed Thompson nickel belt (Zwanzig et al., 2006; Rayner and Percival, 2007).

Economic considerations

The study area contains the Watts River VMS deposit, which has a NI 43-101 compliant inferred resource of 6.62 million tonnes grading 1.88% copper, 2.63% zinc, 0.66 g/t gold and 25.61 g/t silver using a 3.0% zinc cut-off (Carter, 2007). Currently, the extent of prospective VMS-hosting stratigraphy in the study area is not well understood. Satellite deposits of varying size should accompany a deposit of the size and grade of the Watts River, but to date no other deposits have been found in the immediate vicinity.

If metasedimentary rocks with Archean provenance and Ospwagan group–like geochemical characteristics are indeed related to the Ospwagan group of the Superior province margin, arguably there is heightened potential for nickel-copper deposits west of the traditionally documented Thompson nickel belt in the area of the Watts, Mitishto and Hargrave rivers.

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