

Examination of exploration drillcore from the Reed Lake area and the sub-Phanerozoic extension of the Paleoproterozoic Flin Flon belt, west-central Manitoba (parts of NTS 63K7, 8, 9, 10)

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In Brief:

- Drillcore re-examination indicates areas with potential for volcanogenic Cu-Zn-Au-Ag deposits
- Favorable targets for magmatic Ni-Cu deposits identified
- Detailed lithological and geochemical data provide additional context for base metal mineralization at Reed Lake

Citation:

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Summary

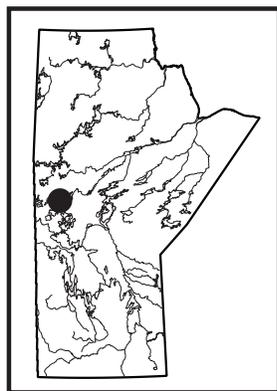
Three weeks of drillcore examination were conducted in June 2017 as part of a comprehensive multiyear compilation and geological mapping project of the Paleoproterozoic Flin Flon belt exposed in the Reed Lake area and its sub-Phanerozoic extension directly to the south. Thirty-five recent and historical exploration drillcores were examined, documented and sampled. These complement a set of 74 drillcores examined previously (2010–2016). The objectives of the program are to: 1) document the volcanic and sedimentary rocks from areas of the sub-Phanerozoic Flin Flon belt not yet examined; 2) provide a better understanding of the stratigraphic sequences hosting the Fourmile Island and Reed Lake volcanogenic massive sulphide (VMS) deposits by examining additional drillcore from the vicinity of the deposits; and 3) acquire additional samples for whole-rock geochemical analysis in order to expand the regional database and facilitate correlation of volcanic stratigraphy.

Key observations from this summer include the identification of several sulphide- and graphite-bearing mudstone successions, which contain local interbedded greywacke and form both thick sequences and thin intercalations within volcanic successions throughout the Reed Lake area. Intervals of sulphide-rich mudstone along the margins of late gabbroic intrusions indicate that these plutons may have the potential to host magmatic Ni-Cu mineralization, analogous to the Rice Island deposit at Wekusko Lake. The volcanic succession peripheral to the Reed VMS deposit contains a much larger proportion of felsic volcanoclastic rock than the sequence that hosts the deposit, which is dominated by coherent mafic flows and subordinate quartz-porphyry dikes. This change in lithological facies and composition is interpreted to reflect a key part of the internal stratigraphy of the Fourmile Island assemblage and will be investigated further using whole-rock geochemical data. Areas with variably altered bimodal volcanic and volcanoclastic rocks of possible arc to arc-rift origin have been extended to the Dolomite Lake–Cooper Lake area, as well as to Farwell Lake. Drillcore from the Cooper Lake to McClarty Lake area has mineral assemblages indicative of lower- to middle-amphibolite facies metamorphic conditions, in contrast to the rest of the Reed Lake region where the metamorphic grade is lower and the rocks contain lower- to upper-greenschist facies assemblages. Despite higher metamorphic grades, several intervals of potential volcanoclastic rocks were identified, expanding the known area of variably altered bimodal volcanic and volcanoclastic rocks with potential for VMS mineralization.

All geological data from drillcore and surface mapping have been integrated and compiled with a regional geochemical database and geophysical airborne surveys to produce two new preliminary maps, one for the exposed Flin Flon belt in the Reed Lake area and the other for its sub-Phanerozoic extension to the south.

Introduction

Paleoproterozoic rocks in the Reed Lake area (Figure GS2017-9-1) are a component of a larger tectonic collage of volcano-plutonic and sedimentary rocks assembled during the closure of an ancient ocean (ca. 1.9–1.8 Ga) and collectively termed the ‘Flin Flon belt’ (FFB). The Flin Flon belt contains numerous base-metal VMS deposits and is among the world’s most prolific VMS districts (Syme et al., 1999). The Flin Flon belt in the Reed Lake area, and its extension to the south beneath Phanerozoic sedimentary rocks, has significant potential to host additional VMS deposits. Despite the presence of several economic deposits, including the currently producing Reed Cu-Zn mine (Figure GS2017-9-1), the geological setting of VMS deposits in the Reed Lake area is not well understood. Previous workers (Stern et al., 1995a) recognized that significant stratigraphic, geochemical and isotopic differences exist between arc-volcanic rocks in the Flin Flon (Amisk collage) and Snow Lake areas, suggesting that these two segments of the FFB formed in distinct tectonic settings



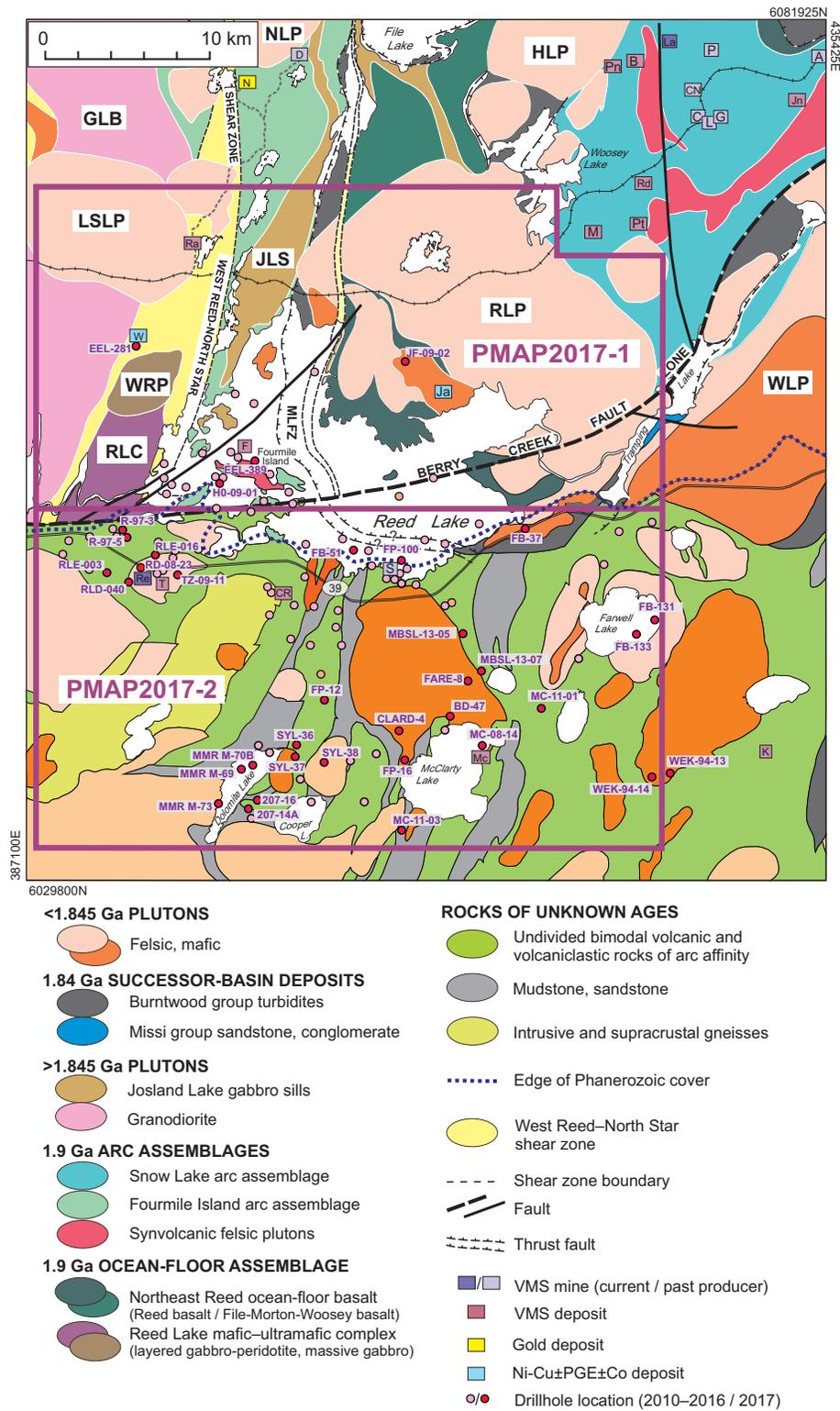


Figure GS2017-9-1: Generalized geology of the Reed Lake area (after Syme et al., 1995a), including the sub-Phanerozoic Flin Flon belt (Leclair and Viljoen, 1997; NATMAP Shield Margin Project Working Group, 1998) and showing the locations of drillholes included in this study. Intrusive rocks: GLB, Gants Lake batholith; HLP, Ham Lake pluton; JLS, Josland Lake sills; LSLP, Little Swan Lake pluton; NLP, Norris Lake pluton; RLC, Reed Lake mafic-ultramafic complex; RLP, Reed Lake pluton; WLP, Wekusko Lake pluton; WRP, West Reed pluton. Structural feature: MLFZ, Morton Lake fault zone. Mines (active or closed) and deposits: A, Anderson; B, Bomber; C, Chisel; CN, Chisel North; CR, Cowan River zone; D, Dickstone; F, Fourmile Island; G, Ghost; Ja, Jackfish; Jn, Joannie; K, Kofman; L, Lost; La, Lalar; M, Morgan; Mc, McClarty; N, North Star; P, Photo; Pn, Pen; Pt, Pot; Ra, Rail; Rd, Raindrop; Re, Reed; S, Spruce Point; T, Tower; W, Wine. Other abbreviations: PGE, platinum-group elements; VMS, volcanogenic massive sulphide.

(Lucas et al., 1996). The Reed Lake area represents a critical bridge between these two segments, as it lies at the boundary between the Amisk collage *sensu stricto* and the Snow Lake segment. One of the key geological units of the Reed Lake area, the Fourmile Island assemblage (FIA), is a bimodal succession of volcanic and volcanoclastic rocks of arc or arc-rift affinity that are known to host several VMS deposits.

To gain a better understanding of the geological framework and mineral potential of the Reed Lake area, a multiyear field-mapping and compilation project was initiated in 2013. A drillcore examination and sampling component was added to the project in 2015 to complement data acquired through surficial geological mapping. Drillcore provides essential information in areas that lack surface exposure. Previous geological work (Leclair et al., 1997) and geophysical data show that arc-affinity rocks extend south of Reed Lake beneath Phanerozoic cover for a distance of more than 50 km. Therefore, a better understanding of the exposed and sub-Phanerozoic geology of the Reed Lake area has important implications for base-metal exploration in this complex and challenging area.

Previous work

Reconnaissance mapping of Reed Lake was completed at 1:50 000 scale during a joint Manitoba Geological Survey–Geological Survey of Canada project in the summer of 1995 (Syme et al., 1995b). The results of follow-up geochemical and structural studies were presented by Syme and Bailes (1996). Prior to 1995, supracrustal rocks at Reed Lake were subdivided into mafic volcanic, volcanoclastic and sedimentary types (e.g., Stanton, 1945; Rousell, 1970). Preliminary Map PMAP1995F-1 (Syme et al., 1995a) was compiled from older maps, including those of Rousell (1970) and Stanton (1945), and new data from the 1995 field season, resulting in a significantly improved understanding of the local geology. Morrison and Whalen (1995) mapped granitoid rocks in the area west of Reed Lake (NTS 63K10); a simplified version of their map was included in Preliminary Map PMAP1995F-1 (Syme et al., 1995a) and their complete work was presented in Morrison et al. (1996). In 2013, the northwestern Reed Lake area, including Rail, Sewell and Prieston lakes, was mapped at 1:10 000 scale (Gagné, 2013a, b), and the inland area west of Reed Lake was subsequently mapped in 2014 at 1:20 000 scale (Gagné and Anderson, 2014a, b).

The southern shore of Reed Lake coincides with the northern extent of Phanerozoic sedimentary rocks, which unconformably overlie the Precambrian basement and increase in thickness southward from a few metres to 30 m in the area immediately south of Reed Lake. Despite geophysical discoveries of significant base-metal mineralization in the sub-Phanerozoic basement in the 1960s and 1970s, the geology of this area remained poorly understood. The NATMAP Shield Margin Project produced the first regional 1:100 000 scale map of the sub-Phanerozoic portion of the FFB by integrating high-resolution aeromagnetic and gravity data with drillcore information (Leclair et al., 1997; Leclair and Viljoen, 1997). Only a small

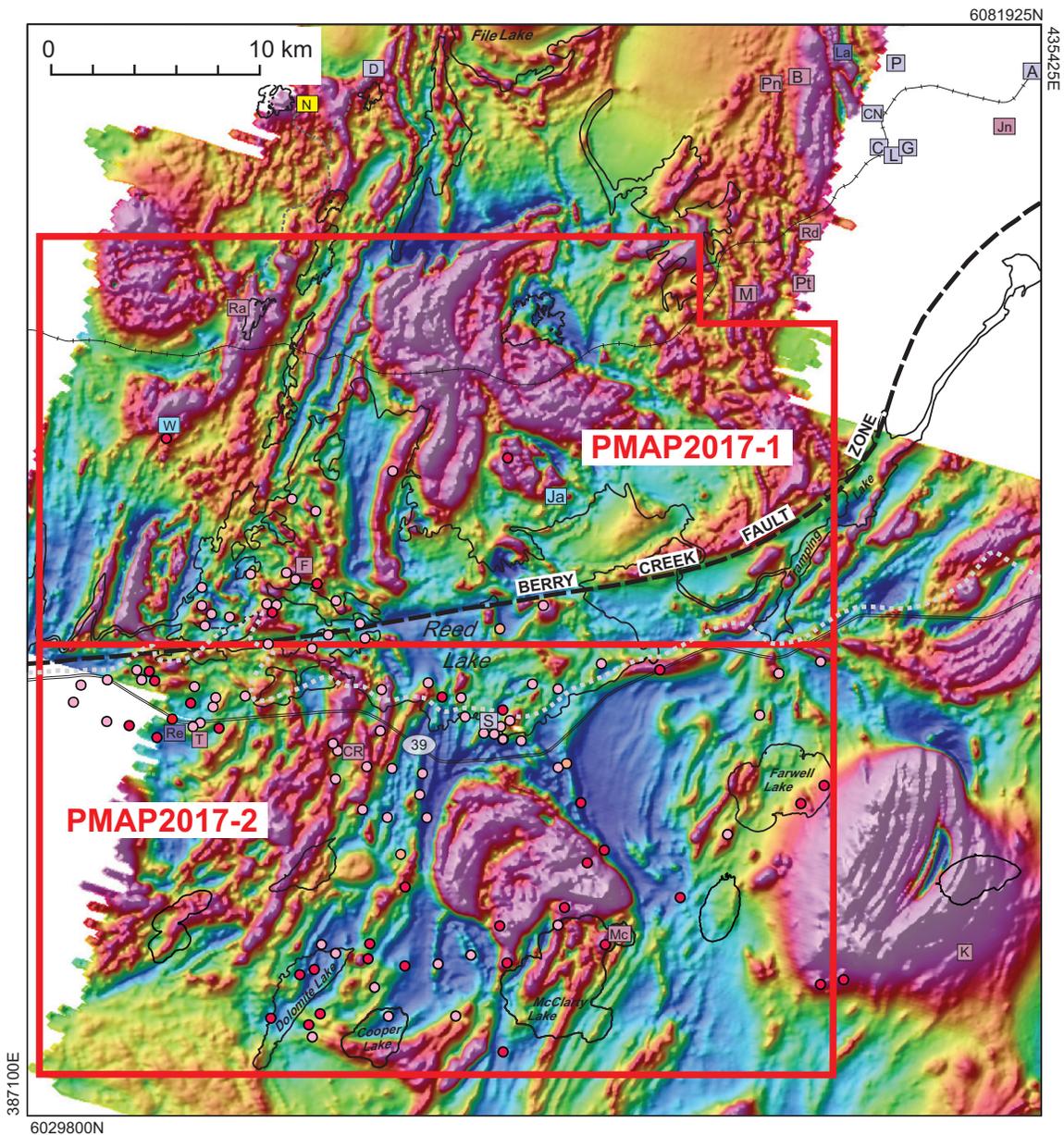
number of drillcores from the area south of Reed Lake were examined.

The recent discovery of the Reed VMS deposit has resulted in renewed interest in the sub-Phanerozoic geology south of Reed Lake. To address this interest, 74 drillcores were examined and sampled from the Reed Lake area (Simard et al., 2010; Gagné, 2015; Gagné, 2016). This report presents the preliminary results from the examination and sampling of an additional 35 drillcores from this area. A companion project focused on the sub-Phanerozoic basement immediately east of the Reed Lake area, south of Wekusko Lake, is ongoing (Reid and Gagné, 2016; Reid, GS-7, this volume). A compilation of geological data from surface mapping and drillcore was integrated with regional geochemistry and airborne geophysical surveys to produce two new preliminary maps, one for the exposed Flin Flon belt in the Reed Lake area (PMAP2017-1; Gagné et al., 2017) and the other for its sub-Phanerozoic extension to the south (PMAP2017-2; Gagné, 2017).

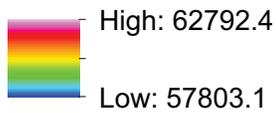
Geological framework of the Reed Lake area

The exposed portion of the FFB at Reed Lake contains several distinct fault-bounded panels of juvenile-arc volcanic rocks, some of which also contain interleaved slices of ocean-floor volcanic rocks, younger sedimentary rocks of the Burntwood group and successor-arc plutonic rocks (Figure GS2017-9-1). The juvenile-arc volcanic rocks are internally complex due to faulting and folding (e.g., Bailes and Syme, 1989) and include a wide range of typical bimodal, arc-related volcanic, volcanoclastic and synvolcanic intrusive rocks (e.g., Bailes and Syme, 1989; Syme and Bailes, 1993; Stern et al., 1995a; Lucas et al., 1996; Bailes and Galley, 2007). Ocean-floor volcanic rocks consist primarily of mid-ocean ridge basalt (MORB) and related kilometre-scale, layered, mafic–ultramafic intrusions (Syme and Bailes, 1993; Stern et al., 1995b). Voluminous successor-arc plutons and coeval volcanic and sedimentary rocks (1.88–1.83 Ga) occur throughout the Reed Lake area and include the Missi and Burntwood groups (Syme et al., 1995b). The Missi group is characterized by fluvial-alluvial conglomerate and sandstone, whereas the Burntwood group comprises basinal-marine turbiditic greywacke, mudstone and rare conglomerate.

The western Reed Lake area includes a regionally extensive (kilometres wide) north-trending zone of tectonite referred to as the West Reed–North Star (WRNS) shear zone, which was previously thought to juxtapose rocks of ocean-floor affinity on the west with rocks of juvenile-arc affinity (FIA) to the east (Syme et al., 1995a, b). Rocks east of the WRNS shear zone are further divided into two domains, separated by the Morton Lake fault zone: the FIA in the footwall and the Northeast Reed assemblage, Reed Lake pluton and Snow Lake arc assemblage in the hangingwall (Figure GS2017-9-1; Syme et al., 1995a, b; Syme and Bailes, 1996). The fault zone includes a narrow panel of Burntwood group rocks. The Berry Creek fault zone (BCFZ), a major east-trending fault, transects the southern part of Reed Lake near the northern limit of the Phanerozoic cover (Figure GS2017-9-1, -2).



Total magnetic intensity (nT)



- Edge of Phanerozoic cover
- Fault
- Abandoned railway
- Road
- /□ VMS mine (current / past producer)
- VMS deposit
- Gold deposit
- Ni-Cu±PGE±Co deposit
- /● Drillhole location (2010–2016 / 2017)

Figure GS2017-9-2: Total magnetic intensity of the Reed Lake area from a 1995 regional Spectrem airborne survey (Assessment File 73859, Manitoba Growth, Enterprise and Trade, Winnipeg), showing the locations of drillholes included in this study. Mines (active or closed) and deposits: A, Anderson; B, Bomber; C, Chisel; CN, Chisel North; CR, Cowan River zone; D, Dickstone; F, Fourmile Island; G, Ghost; Ja, Jackfish; Jn, Joannie; K, Kofman; L, Lost; La, Loral; M, Morgan; Mc, McClarty; N, North Star; P, Photo; Pn, Pen; Pt, Pot; Ra, Rail; Rd, Raindrop; Re, Reed; S, Spruce Point; T, Tower; W, Wine. Other abbreviations: PGE, platinum-group elements; VMS, volcanogenic massive sulphide.

Syme et al. (1995a) proposed that the exposed volcanic stratigraphy north and south of the BCFZ are related in a general sense. However, correlation of units across the BCFZ is hampered by poor exposures at Reed Lake, the presence of Phanerozoic cover farther south, and uncertainty surrounding the sense and magnitude of displacement on the fault zone.

The Phanerozoic cover in the Reed Lake area typically consists of 1–2 m of Ordovician quartz-rich sandstone (Winnipeg Formation) overlain by 12–25 m of Ordovician dolomitic limestone (Red River Formation), atop which generally sits several metres of unconsolidated glacial sediments and organic material. Precambrian rocks beneath the Ordovician cover are weathered to depths ranging from 5 to 30 m.

Drillcore logging

This report provides a summary of observations made from drillcore in 2017. In addition to the examination of 35 drillcores, 317 samples have been collected for reference purposes, whole-rock geochemistry, thin-section petrography, Sm-Nd isotopic analysis and U-Pb radiometric dating.

Mineral assemblages in the study area indicate lower greenschist- to middle amphibolite-facies metamorphism. However, in the interest of brevity, the prefix 'meta-' is not used in this report and the rocks are described in terms of their protoliths.

Fourmile Island deposit area

Two drillcores, EEL-389 and HO-09-01 (Assessment Files 72909, 74753), were examined to further refine the stratigraphy of volcanic rocks in the vicinity of the Fourmile Island deposit (Figure GS2017-9-1). Both drillholes encountered a diverse sequence of volcanic and volcanoclastic rocks, and displayed intervals of weak to moderate pervasive chlorite or silica±epidote alteration. On the north side of Fourmile Island, drillhole EEL-389 intersected a succession of andesite flows and mafic lapilli and crystal tuff showing weak to moderate, pervasive chlorite alteration and sporadic patches of weak silica alteration. The midsection of the drillcore consists of 50 m of thinly bedded, fine-grained sandstone and mudstone with minor graphite and local laminations (1–3 mm) of pyrite (2–5%). The drillhole terminates in mafic ash tuff and mafic wacke. Drillhole HO-09-01, collared on the south side of Fourmile Island and drilled to a depth of 1052 m, provides a long section through the deposit stratigraphy. Only the interval from 520 m to 890 m was re-examined, as it seemed to provide a representative section and offered the best interval of felsic volcanic rocks for geochronological sampling. A diverse succession of intercalated mafic and felsic flows and volcanoclastic rocks is present in the observed section. Andesite flows, 5–30 m thick, vary from aphyric to plagioclase phyric and are affected by weak to moderate, pervasive chlorite alteration. Quartz-phyric to quartz- and plagioclase-phyric felsic volcanic rocks form massive flows, 10–30 m thick, that vary in composition from dacitic to rhyolitic (Figure GS2017-9-3a). Felsic crystal tuff and lapilli

tuff form 5–20 m thick intervals and display varying intensity of silicification and sericitization.

Reed deposit area

Seven drillcores from the Reed Lake area were re-examined and sampled (Figure GS2017-9-1). Drillcores from adjacent to the Reed VMS deposit show much larger proportions of felsic volcanoclastic rocks than the sequence hosting the deposit (dominated by coherent mafic flows). Rocks in the Fourmile Island area on Reed Lake show a similar lithofacies transition (Gagné, 2015). Further geochemical fingerprinting of units and development of cross-sections will help investigate the detailed stratigraphy of the two areas and compare the two packages separated by the BCFZ (Figure GS2017-9-1, -2). Two drillholes northwest of the Reed deposit (R-97-3, R-97-5) show intense deformation and indicate the presence of a ductile high-strain zone; it could be a splay fault from the BCFZ zone to the north.

The company log for drillhole RD-08-23 (Assessment File 63K1127; collared 200 m west of the Reed deposit) indicates that it intersected a thick sequence of felsic flows and felsic volcanoclastic rocks; however, re-examination of the drillcore revealed a sequence of andesite flows and minor fragmental horizons that are light grey due to moderate to strong silicification (Figure GS2017-9-3b). One narrow dike of quartz-phyric rhyolite occurs near the middle of the silicified andesite succession. The andesite locally has late chlorite alteration developed along fractures, as well as in the matrix of some fragmental horizons. Drillhole RLD-040 (Assessment File 63K12199) was collared approximately 500 m southwest of the Reed deposit and intersected alternating successions of mafic crystal tuff and andesitic flows that are low strain and have weak to moderate chlorite alteration (Figure GS2017-9-3c). Drillhole RLE-003 (Assessment File 63K1143) was drilled about 1.2 km west of the Reed deposit and intersected a package consisting of several different intrusive phases. The upper portion of the drillhole includes a quartz-phyric phase with abundant (20–30%) angular, aphyric, mafic volcanic fragments (Figure GS2017-9-3d), followed by an altered gabbroic phase; the lower portion comprises massive quartz-plagioclase-phyric dacite.

Drillhole TZ-09-11 (Assessment File 74860), located 1.8 km east of the Reed deposit, intersected a sequence of aphyric and quartz-phyric rhyolite flows (Figure GS2017-9-3e) that are intruded by a multicomponent gabbro-diorite-feldspar porphyry intrusive unit. Drillhole RLE-016 (Assessment File 63K1151) intersected a thick sequence of plagioclase-rich crystal tuff with broken quartz amygdules, and includes a thin interval (30 m) of mafic tuff breccia followed by an approximately 20 m thick mineralized zone; the zone contains mainly disseminated sulphides but also a few narrow sections (<2 m thick) of near-solid to solid sulphides (mostly pyrrhotite-pyrite and minor chalcopyrite). Structurally above the mineralized zone is a halo of pervasive and patchy silica alteration that increases in intensity toward the mineralization (Figure GS2017-9-3f).

Two drillholes (R-97-3, R-97-5; Assessment File 73220), located ~2.7 km northwest of the Reed deposit, intersected

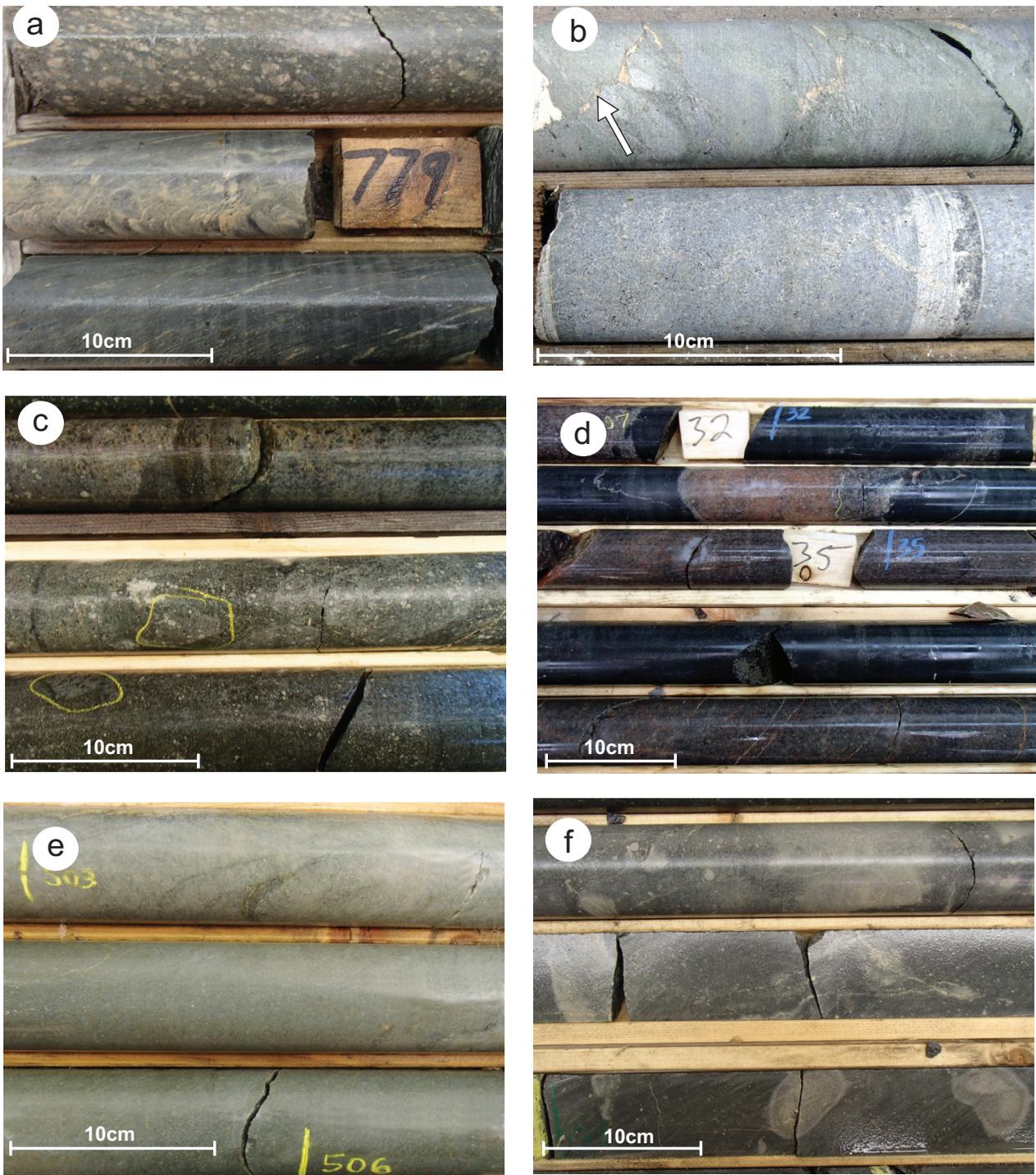


Figure GS2017-9-3: Drillcore photos: **a)** quartz-phyric felsic lapilli tuff (first row) underlain by sparsely quartz-phyric and weakly sericitized massive rhyolite flow, drillhole HO-09-01 (NQ core; start of interval [upper left] at 778.4 m); **b)** relict domains of intense silica alteration (light grey, upper row), replaced by late pervasive chlorite alteration (greenish colour) and cut by late carbonate veinlets (light brown colour; white arrow), drillhole RD-08-23; andesite in lower row is strongly silicified and shows very little late pervasive chlorite overprint (NQ core; 197 m); **c)** mafic lapilli tuff with ~30–50% plagioclase-pyroxene-phyric fragments (circled in yellow) in a plagioclase-pyroxene crystal-rich matrix, drillhole RLD-040 (NQ core; 137.1 m); **d)** quartz-phyric intrusion (pink to pinkish grey) with enclaves (dark green; 5–6 cm) of aphyric andesite, drillhole RLE-003 (NQ core; 31.9 m); **e)** massive, aphyric rhyolite with weak pervasive sericite alteration, drillhole TZ-09-11 (NQ core; 503 m); **f)** mafic crystal tuff with patchy silicification and circular silicification haloes developed around quartz amygdules, ~6 m above a narrow (1.5 m) solid-sulphide interval, drillhole RLE-016 (NQ core, 177 m). Drillcore diameter: NQ, 47.6 mm.

thick sequences of dominantly volcanoclastic rocks. Drillhole R-97-3 intersected mafic crystal tuff and lapilli tuff that contain fragments of amygdaloidal andesite (Figure GS2017-9-4a). These rocks vary from moderately to strongly foliated, with local transposition and isoclinal folding (Figure GS2017-9-4b). Moderate pervasive chlorite alteration is often overprinted by moderate to intense pervasive silica alteration. Drillhole R-97-5, collared only a few hundred metres south of R-97-3, also intersected a sequence of dominantly mafic lapilli and crystal tuff but also contains two sections (~30 m each) of felsic flows and lapilli tuff. The succession intersected in R-97-5 is strongly foliated and shows widespread chlorite alteration. Pervasive silica alteration is stronger and more widespread in R-97-5 than in R-97-3.

Spruce Point mine

Two drillcores from the vicinity of the past-producing Spruce Point mine (Figure GS2017-9-1, drillholes FP-100, FB-51; Assessment Files 98470, 94450) were re-examined. Drillhole FP-100 was collared in the footwall of the Spruce Point VMS deposit and intersected the near-vertical deposit sequence in reverse order. First encountered in the drillcore is a thick succession (~120 m) of footwall felsic lapilli tuff that is intruded by massive andesite (43 m thick) with sharp intrusive contacts. Sericite- and silica-altered massive rhyolite to rhyolite tuff breccia form the stratigraphic base of the solid-sulphide lens. The top of the lens is in sharp contact with massive andesite, suggesting that the andesite may be intrusive (Figure GS2017-9-4c).

Drillhole FB-51 intersected a sequence dominated by interbedded (2–20 mm) mudstone-sandstone (Figure GS2017-9-4d) with an interval (~56 m) of graphite- and sulphide-bearing mudstone. The low strain and metamorphic grade of these rocks allowed for the preservation of several good graded beds, all indicating an uphole younging direction. The bottom of the drillhole cuts through a sequence of thick-bedded sandstone (10–40 cm).

Dolomite Lake–Cooper Lake area

Nine drillholes (207-14A, 207-16, FP-12, MMR M-69, MMR M-70B, MMR M-73, SYL-36, SYL-37, SYL-38; Figure GS2017-9-1) from the Dolomite Lake–Cooper Lake region were selected for re-examination. Three drillholes east and northeast of Dolomite Lake (SYL-36, SYL-37, FP-12; Assessment Files 93486, 99449) confirmed that the north-trending package of supracrustal rocks just east of Dolomite Lake is dominated by mafic to intermediate volcanic and volcanoclastic rocks with minor intervals of sedimentary and felsic volcanic rocks. A package of sedimentary rocks (mudstone and greywacke) between Dolomite and Cooper lakes was confirmed by drillholes 207-14A and 207-16 (Assessment File 94808). Drillcore from MMR M-70B and MMR M-69 (Assessment File 99377) confirmed the presence of a sedimentary interval structurally juxtaposed to a sequence dominated by volcanic rocks. Representative core from two intrusions was examined in drillholes MMR M-73 and SYL-38 (Assessment Files 99377, 93486).

The upper section of drillcore FP-12 consists of massive to pillowed andesite with minor intervals of amoeboid flow-top breccia. Near the bottom of the drillhole, a short interval of graphitic mudstone (~5 m) and sulphide-facies iron formation (7 m) lies above a massive dacite flow (~3 m). The drillhole terminated in massive andesite that is similar in appearance to the andesite in the upper section. Drillholes SYL-36 and SYL-37 both contain a thick sequence of massive and pillowed basaltic flows intercalated with minor intervals of mafic crystal/lapilli tuffs. Local quartz amygdules (1–2%, 2–8 mm) are present in the mafic flows. Near the end of drillhole SYL-37, a short interval (~18 m) of thinly bedded, graphite-bearing (locally sulphidic) mudstone and sandstone is interlayered with narrow, intermediate ash tuff horizons.

Drillholes 207-14A, 207-16, MMR M-69 and MMR M-70B were examined to further document the sedimentary sequence from the Dolomite Lake area (Figure GS2017-9-1). The upper portion of drillhole MMR M-69 consists of aphyric, massive andesite flows overlying a thick sequence of greywacke interbedded with minor mudstone. The contact between these units is marked by a narrow high-strain zone (Figure GS2017-9-4e).

A thick sequence of massive, amygdaloidal, aphyric andesite flows overlies thinly bedded (1–3 cm) to massive, mafic crystal and ash tuff with broken quartz amygdules in drillhole MMR M-70B. Thin beds of tuff consistently become finer grained downhole, indicating that the sequence is overturned. The upper half of the core from drillhole 207-14A consists of a thick package of mudstone and sandstone interbedded with narrow intervals of sulphidic mudstone. The lower section of the core comprises mostly thick-bedded sandstone and feldspathic wacke with rare argillaceous bands containing traces of graphite. Small euhedral garnet porphyroblasts (1–3%, 1–3 mm) occur locally throughout drillhole 207-14A. Drillhole 207-16 intersected a thick sequence of quartzofeldspathic biotite gneiss, interpreted as metagreywacke, interbedded with narrower bands of quartzofeldspathic biotite-hornblende gneiss that may represent metamorphosed mafic wacke. An interval (~20 m) of sulphidic mudstone containing thin (1–3 mm) pyrite-rich laminations was intersected near the base of the hole.

Drillhole MMR M-73 intersected the northeastern margin of the Cormorant Lake batholith, encountering fine- to medium-grained, homogeneous and weakly foliated, leucocratic biotite granodiorite that includes minor phases of pink leucocratic granite pegmatite and aplite. The granodiorite intrudes medium-grained, homogeneous, massive to weakly foliated, mesocratic hornblende-biotite quartz diorite. Drillcore SYL-38 comprises granodiorite and gabbro (Figure GS2017-9-4f) with a narrow interval (~12 m) of thinly bedded sulphidic mudstone and sandstone that likely represents a large raft.

McClarty Lake area

Five drillholes from the McClarty Lake area were examined. All drillcore reviewed contains mineral assemblages indicative of amphibolite-facies peak metamorphic conditions. Two drillholes (MC-08-14, MC-11-01; Assessment Files 74613,

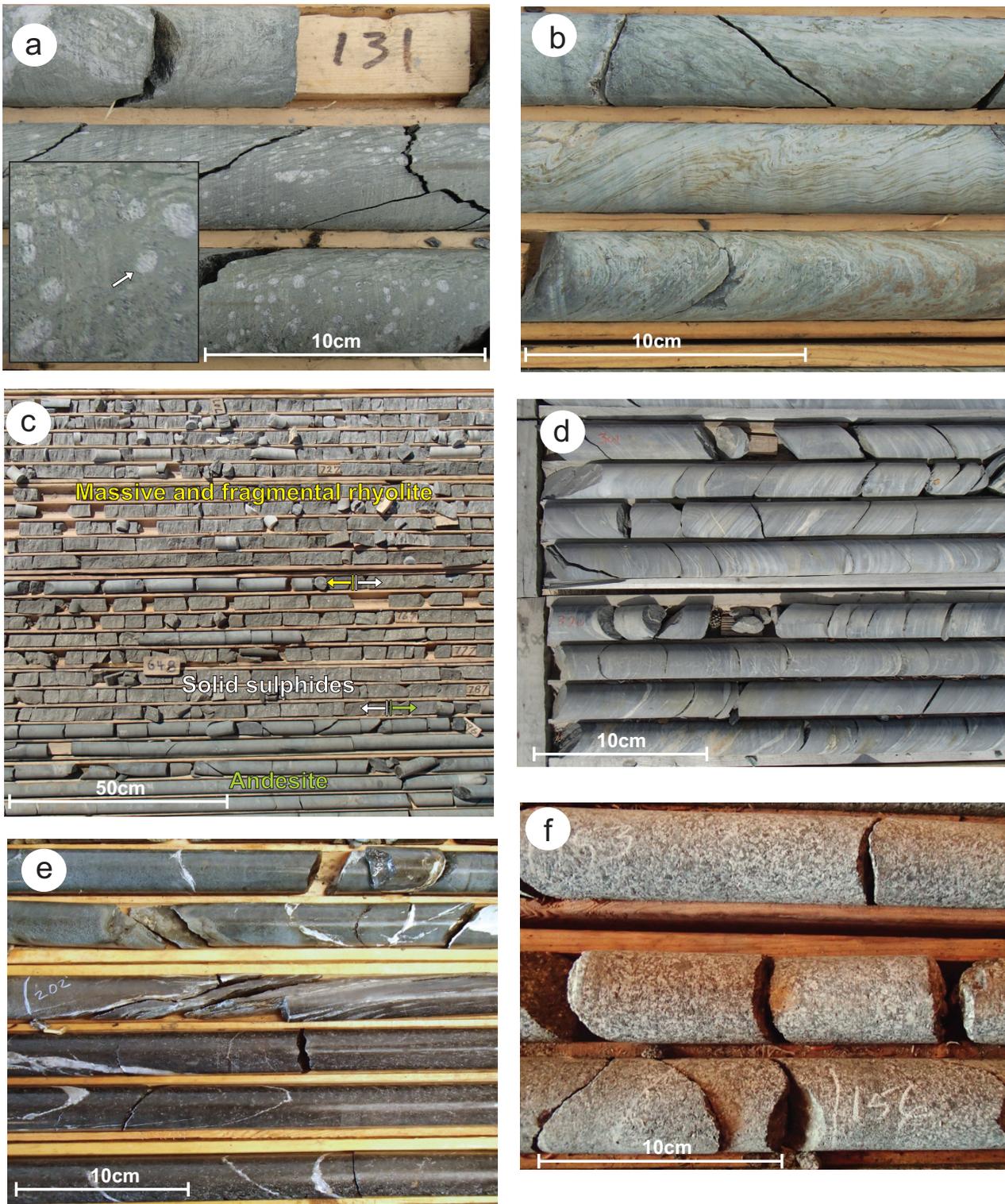


Figure GS2017-9-4: Drillcore photos: **a)** foliated mafic crystal tuff with 3–5% broken quartz amygdules (3–15 mm), 5–15% plagioclase crystals and sparsely distributed pyroxene, drillhole R-97-3 (BQ core; 130.9 m); **b)** strongly flattened, chloritized and carbonate-altered mafic lapilli tuff, drillhole R-97-3 (BQ core, 218.1 m); **c)** drillcore interval displaying the Spruce Point solid-sulphide horizon with overlying rhyolite (stratigraphic footwall) and underlying pillowed andesite, drillhole FP-100, (AQ core, 214.9–248.7 m [705–816 ft.]); **d)** thinly bedded wacke and mudstone, drillhole FB-51 (BQ core, 91.7 m [301 ft.]); **e)** massive, aphyric andesite (upper two rows) in sheared contact with underlying greywacke, drillhole MMR M-69 (AQ core, shear zone at 61.9 m [203 ft.]); **f)** massive, homogeneous, equigranular gabbro, drillhole SYL-038 (BQ core; 153 m). Drillcore diameter: AQ, 27 mm; BQ, 36.5 mm.

63K1171) were collared through sequences of variably altered rocks interpreted to be of volcanic origin. The other three drillholes (CLARD-4, FP-16, MC-11-03; Assessment Files 70825, 99449, 63K1171) intersected sequences of metamorphosed metasedimentary rocks.

The company log for drillhole MC-11-01, collared 3 km northeast of McClarty Lake (Figure GS2017-9-1), indicates that a sequence of mafic and intermediate volcanic rocks is interbedded with tonalite in the upper portion of the hole. However, re-examination of the drillcore showed that the entire interval is a thick sequence of mafic crystal and lapilli tuff with mafic tuff breccia horizons. Homogeneous to crudely stratified intervals of plagioclase-rich crystal tuff of intermediate composition represents horizons initially identified as tonalite. The tuff breccia horizons are matrix supported and heterolithic; the fragments are diverse but mostly of volcanic derivation. Several larger mafic fragments show concentric zonation, suggesting pre-metamorphic alteration (Figure GS2017-9-5a). The Edwards formation of the Snow Lake assemblage has many similarities to these heterolithic mafic breccias in that they both display complex and varied alteration, including fragments with haloes of silica and epidote replacement that developed during regional semi-conformable alteration associated with VMS deposit formation (Bailes et al., 2016). The rocks of MC-11-01 are also of higher metamorphic grade, as indicated by such mineral assemblages as biotite-hornblende-plagioclase-quartz-garnet-sillimanite.

Drillhole MC-11-03, 8 km southeast of McClarty Lake, intersected moderate to strongly foliated mafic to intermediate gneisses with centimetre-scale compositional layering, suggesting a possible sedimentary precursor. The gneisses are cut by several granitic injections (0.3–8 m). Mineral assemblages in the gneiss include biotite, hornblende, plagioclase, quartz, garnet and sillimanite. Horizons of quartzofeldspathic gneiss, initially logged as tonalite, are herein interpreted as metasedimentary.

Drillhole MC-08-14 was collared just north of the McClarty deposit to test the presence of mineralization along strike. It encountered granite and granodiorite in the upper third of the hole, whereas the remainder of the core is a sequence of mafic to intermediate volcanoclastic rocks with minor felsic bands. The rocks are generally well foliated and recrystallized, and have amphibolite-facies mineral assemblages that include various combinations of biotite, hornblende, plagioclase, quartz, garnet, sillimanite, anthophyllite, cordierite and staurolite (Figure GS2017-9-5b). Variations in composition and in the intensity and nature of alteration makes it difficult to recognize protoliths. Kutluoglu and Bailes (2008) indicated that textures and alteration assemblages in this drillcore are similar to those observed in the footwall of the Chisel and Lalor deposits in the Snow Lake area.

Drillhole CLARD-4 contains thinly bedded sandstone and graphitic mudstone with pyrite-bearing laminations. The drillcore terminates in a foliated mafic crystal tuff with centimetre-scale compositional layering. Drillhole FP-16 was located on the southwest edge of the McClarty Lake gabbro and intersected a

thick sequence of graphitic mudstone that is thinly interbedded with sandstone. The graphitic mudstone typically has trace to a few percent pyrite; however, one interval (~10 m) has pyrite content varying from 30 to 50%. The sequence of sedimentary rocks is underlain by fine- to medium-grained quartzofeldspathic biotite gneisses, which may represent recrystallized greywacke.

Southeast Reed Lake

Five drillcores from the Farwell Lake area were examined. Drillholes FB-131 and FB-133, collared in the middle of an interpreted pluton (Figure GS2017-9-1), intersected bimodal sequences of volcanic and volcanoclastic rocks. Drillholes MBSL-13-05, MBSL-13-07 and FB-37 (Figure GS2017-9-1; Assessment Files 63K13307, 94334) were collared along the same linear trend of moderate to high magnetic intensity (Figure GS2017-9-2); the first two drillholes intersected successions of mafic volcanoclastic rocks with minor sulphidic mudstone horizons, whereas as the latter drillhole encountered a thick succession of sandstone and graphitic mudstone with minor pyrite content.

Drillholes FB-131 and FB-133 (Assessment File 73218) were collared on the eastern shore of Farwell Lake about 1.8 km apart. The top of drillcore FB-131 contains an ~15 m section of medium-grained, homogeneous equigranular gabbro, followed by an ~50 m sequence of massive andesitic flows with 1–2% quartz-carbonate veins. Two narrow intervals (2–3 m) of silicified mafic fragmental rocks occur near the middle of the sequence, and a few narrow bands of variolitic andesite occur near the lower part of the interval. A second, sill-like body (~18 m) of medium-grained, homogeneous equigranular gabbro was encountered in the middle of the hole. The last ~100 m of the drillcore consists of massive, aphyric andesitic flows with 1–2% quartz-carbonate veins and contains an ~30 m interval of aphyric, felsic lapilli tuff (Figure GS2017-9-5c) that includes narrow (0.2–0.8 m; ~40% of the interval) dikes of andesite. Drillhole FB-133 intersected an ~30 m sequence of regolith and thinly laminated, chloritized mafic crystal tuff followed by a narrow interval (~13 m) of hematized, medium-grained, equigranular massive gabbro. Downhole of the gabbro is a thick sequence of matrix-supported, mafic lapilli tuff that contains 10–30% prominently flattened, intermediate to felsic clasts (0.5–3 cm) in a chlorite-rich matrix. Below that is ~40 m of graphitic argillite and greywacke. The graphitic sedimentary rocks transition downhole into mafic lapilli tuff that becomes progressively more felsic and grades into a 10 m interval of clast-supported (>90% fragments) rhyolitic lapilli tuff. The felsic fragmental interval is in sharp contact with the underlying matrix-supported mafic lapilli tuff (<10% felsic fragments). The core has a strong penetrative foliation made evident by flattened fragments. Graphite is common on foliation surfaces of more schistose volcanoclastic rocks and may be related to narrow zones of ductile shearing.

Drillholes MBSL-13-05 and MBSL-13-07 were drilled along the eastern margin of the McClarty Lake gabbro (located 5.6 km

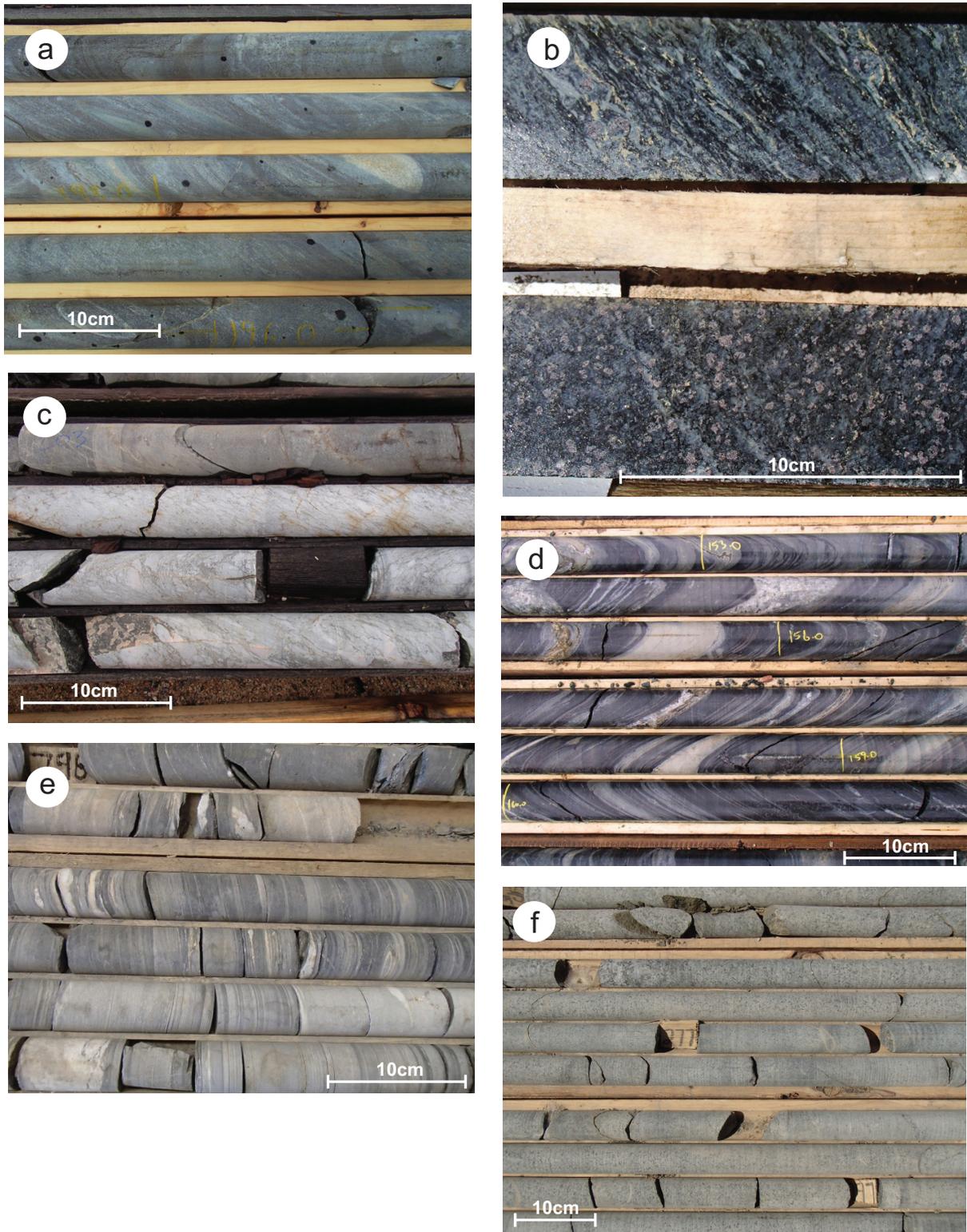


Figure GS2017-9-5: Drillcore photos: **a)** mafic heterolithic tuff breccia, drillhole MC-11-01; most fragments have a bleached rim, indicating silica replacement after deposition (NQ core; 189.9 m); **b)** strongly foliated biotite-sillimanite quartzofeldspathic gneiss (upper row) and more massive biotite-garnet quartzofeldspathic gneiss (lower row), drillhole MC-08-14; the rocks in the upper and lower rows may represent, respectively, intermediate tuffaceous and flow facies (NQ core, 236.5 m); **c)** massive, aphyric andesite (upper row) and rhyolitic lapilli tuff with a chloritized matrix, drillhole FB-131 (BQ core, 61.9 m [203 ft.]); **d)** foliated, mafic heterolithic tuff breccia, with flattened light-coloured felsic fragments and darker mafic fragments, drillhole MBSL-13-07 (NQ core, 152.7 m); **e)** thinly bedded wacke and mudstone (BQ core, 242.6 m [796 ft.]), drillhole FB-37; **f)** medium-grained, massive, homogeneous melanocratic gabbro, drillhole FARE-8 (BQ core; 78.3 m [257 ft.]). Drillcore diameter: BQ, 36.5 mm; NQ, 47.6 mm.

and 7.8 km, respectively, southeast of the Spruce Point mine) and intersected similar stratigraphy, consisting of intermediate to mafic, thinly bedded volcanoclastic rocks. The fine-grained bedded rocks include bands with lapilli-size fragments of rhyolite and andesite, as well as sparse broken quartz amygdules and epidote fragments, demonstrating a volcanogenic origin (Figure GS2017-9-5d). Sequences of mudstone with thin pyrite laminations vary from a few metres to tens of metres in thickness, and may indicate that these sediments were derived from both volcanic/hydrothermal activity and pelagic sources.

Drillhole FB-37, collared 8.3 km east-northeast of the Spruce Point mine along Highway 39, intersected a sequence of thickly laminated sandstone and mudstone (Figure GS2017-9-5e) that is locally graphitic and contains trace to a few percent pyrite. The rocks are strongly deformed, with attenuated quartz veinlets, isoclinal folds and transposed bedding.

Mafic–ultramafic intrusions

A series of six drillholes (BD-47, EEL-281, JF-09-02, FARE-8, WEK-94-14, WEK-94-13), collared in various mafic–ultramafic intrusions within the Reed Lake project area, were examined. Samples were collected from each drillcore for whole-rock geochemical analyses. All of the sampled mafic–ultramafic intrusions appear to truncate the dominant geophysical fabrics (Assessment File 73859), indicating they likely were emplaced late or after the main deformation event. The intrusions typically display minor lithological variations, from leucogabbro to mesogabbro, and rare diorite and pyroxenite. The gabbroic intrusions generally lack a penetrative foliation but are cut by ductile shear zones (a weak to moderate foliation extends on the metre scale away from these structures).

Drillholes BD-47 and FARE-8 (Assessment Files 72094, 93754) were collared in a large (8 by 8 km) ovoid gabbroic intrusion that extends from north of McClarty Lake to just south of the Spruce Point mine (Figure GS2017-9-2). Drillhole FARE-8 intersected a massive, medium-grained to locally fine-grained, homogeneous melanocratic gabbro (Figure GS2017-9-5f). The upper portion of hole BD-47 intersected pyroxenite followed by a zone of gabbro with minor quartz diorite. Mineralization within the pyroxenite consists of interstitial pyrrhotite and pyrite, with trace to a few percent pentlandite. The highest base-metal values from BD-47 were 0.39% Cu and 0.61% Ni over a length of 2.45 m (Assessment File 72094).

Drillholes WEK-94-13 and WEK-94-14 (Assessment File 94654) were collared in homogeneous, meso- to melanocratic, medium-grained massive gabbro at the southern extent of a large (12 by 9 km) ovoid mafic intrusion located immediately southeast of Farwell Lake.

Drillhole JF-09-02 (Assessment File 74754) was collared in the northwestern portion of the Jackfish gabbro. The hole intersected a layered gabbroic intrusion, as well as several granite to granitic pegmatite dikes. Sporadic blebs of pyrrhotite and pyrite were encountered in this drillhole, but no substantive mineralization was encountered.

Drillhole EEL-281 (Assessment File 94657), collared ~350 m west of the Wine Ni-Cu-Co-PGE occurrence (Figure GS2017-9-1), encountered an interval of heterogeneous, fine- to medium-grained, leucocratic to mesocratic gabbro that contains bands of disseminated to near-solid sulphide (at 20.7–24.3 m [68–80 ft.] and 26.2–27.7 m [86–91 ft.] in the hole), although no significant base-metal values were reported (Assessment File 94657). The mineralized zone at the Wine deposit is described as disseminated sulphides and stringers associated with a mafic magmatic breccia hosted by leucogabbro (Augsten, unpublished company report, 2006; Assessment Files 94660, 94667, 94669). It is interpreted that EEL-281 was drilled through the same gabbro that hosts the Wine occurrence.

Economic considerations

Bimodal volcanic and volcanoclastic rocks were recognized in drillcore throughout the Reed Lake area and the sub-Phanerozoic extension of the Flin Flon belt to the south, indicating that these volcanic successions were deposited in arc or arc-rift settings. The presence of moderate to intense pervasive alteration and local sulphide mineralization suggests that most volcanic-arc assemblages in these areas have potential to host significant VMS mineralization. Recent drillcore examination has extended the area of known, variably altered, bimodal volcanic and volcanoclastic rocks of possible arc to arc-rift origin to the Dolomite Lake–Cooper Lake area, as well as to Farwell Lake, which further expands the area with VMS potential. However, establishing the key criteria to target specific favourable horizons within these packages is the focus of ongoing work. One component of this work is deciphering the internal stratigraphy of the Fourmile Island assemblage using data collected from both the Reed deposit area and the Fourmile Island area.

Widespread occurrence of graphitic and locally sulphidic mudstone sequences throughout the sub-Phanerozoic basement south of Reed Lake has several implications. Regular narrow intercalations of sedimentary rocks within volcanic sequences suggest that at least some of the sediment was deposited during volcanism (ca. 1880–1890 Ma) and is thus significantly older than the ca. 1840 Ma Burntwood group metaturbidites. The deposition of sulphidic and graphitic mudstone may represent periods of volcanic quiescence with contemporaneous hydrothermal venting, and could represent significant stratigraphic markers. Thicker sequences of argillite and greywacke found in the sub-Phanerozoic may belong to the Burntwood group; they are often located at major boundaries between tectonostratigraphic blocks with different geological histories, suggesting they may indicate the locations of major structures, such as early thrust faults. Consequently, these sequences could be analogous to those in the Snow Lake and Reed Lake areas, where the Burntwood group rocks are tectonically juxtaposed with older volcanic rocks. Identifying the location of major structural breaks can help generate targets for orogenic gold mineralization. Finally, sulphide-rich mudstones provide an excellent source of sulphur when assimilated by gabbroic intrusions; the coincidence of these two rock types provides exploration targets for magmatic Ni-Cu (\pm PGE) deposits.

Mafic to ultramafic intrusions of various sizes occur in the Reed Lake area. Although no mineable deposits have been identified to date, several occurrences and zones of Ni-Cu sulphide mineralization have been identified. The Jackfish gabbro, just west of the Reed Lake pluton (Figure GS2017-9-2), is host to a Cu-Ni occurrence with minor to solid pyrrhotite and lesser pentlandite, pyrite and chalcopyrite in a gabbro/norite hostrock (Ferreira and Fedikow, 1990). Another occurrence of Ni-Cu mineralization is found along the southern margin of the gabbro intrusion between the Spruce Point mine and McClarty Lake (drillhole BD-47). These two gabbroic intrusions, as well as a few others (drillholes WEK-94-13, WEK-94-14), locally intrude S-rich sedimentary rocks in areas that have seen little exploration drilling and may thus represent strong exploration targets. The Rice Island Ni-Cu-Co deposit, located 30 km northeast of Reed Lake, is hosted by a late- to post-tectonic gabbro that intruded Burntwood group sedimentary rocks and represents an important example of this style of mineralization.

On the west shore of Reed Lake, the Reed Lake mafic-ultramafic complex (RLC) and the West Reed pluton (WRP; Figure GS2017-9-2) both represent prospective targets for PGE exploration. Grab samples collected on a transect along the Grass River indicate minor enrichment of PGE in the basal portion of the RLC (Williamson, 1993). Farther north, the Wine Ni-Cu-Co-PGE occurrence is associated with a mafic magmatic breccia hosted by leucogabbro (Figure GS2017-9-2; Augsten, unpublished company report, 2006) and was discovered through drilling of a ground geophysical anomaly by Hudson Bay Exploration and Development Co. Ltd. in the early 1980s. The northern margin of the WRP includes examples of leucogabbro-hosted magmatic breccia, locally associated with trace to a few percent sulphides (pyrrhotite±chalcopyrite), indicating that the WRP may have potential to host mineralization similar to that of the Wine showing.

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