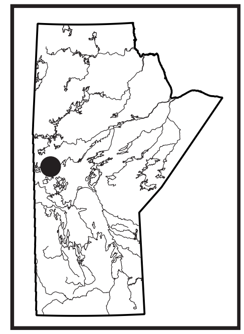
GS-6

Update on the geology and geochemistry of the west Reed Lake area, Flin Flon greenstone belt, west-central Manitoba (part of NTS 63K10)

by S. Gagné and S.D. Anderson



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Summary

During June and July 2014, a six-week geological mapping program was conducted in the area immediately west of Reed Lake. The project area is underlain by two south-trending packages of bimodal volcanic and volcaniclastic rocks that flank the Reed Lake complex (RLC) and are intruded by the West Reed pluton (WRP). Toward the north, the western package is truncated by a late fault and appears to have been eliminated north of this structure by granitoid intrusions. North of the fault, the eastern package is bounded on the west by layered tectonite of the West Reed–North Star shear zone (WRNS). The eastern package is geochemically similar to volcanic-arc rocks of the Fourmile Island assemblage, host to several volcanogenic massive-sulphide (VMS) deposits, and can be traced continuously southward from the past-producing Dickstone deposit to Reed Lake. The western package is geochemically distinct from the eastern package but likewise characterized by arc signatures typical of VMS-hosting volcanic sequences throughout the Flin Flon belt. The western package is intruded to the west by tonalite–granodiorite of the Gants Lake batholith (includes older components at 1888 ±4 Ma), whereas the eastern package is intruded by the 'type' Josland Lake sill (1886 ±3 Ma), indicating that both packages are part of the early 'juvenile arc' assemblage. The presence of arc-affinity rocks on both sides of the RLC contradicts previous interpretations of a fundamental tectonic boundary in this location, previously thought to separate rocks of oceanic affinity (including the RLC) on the west from rocks of arc affinity on the east; any such boundary must lie farther west of the study area. The RLC is a gabbro-dominated layered intrusion of tholeiitic composition, perhaps representing a fault-bounded panel in the WRNS shear zone, whereas the WRP is a comparatively massive gabbro–leucogabbro intrusion that appears to stitch this shear zone.

Introduction

A multiyear field-mapping and compilation project was initiated in 2013 to revisit and expand our geoscience knowledge of the Reed Lake area, a critical component for understanding the tectonic evolution of the Flin Flon belt (FFB) as a whole. The Reed Lake area is located in the central part of the Flin Flon belt (Figure GS-6-1), which consists of a collage of distinct Paleoproterozoic (1.92–1.88 Ga) tectonostratigraphic assemblages and minor Archean crustal slices that were juxtaposed during a period of 1.88–1.87 Ga intraoceanic accretion (Lucas and Stern, 1994; Stern and Lucas, 1994) to form the 'Amisk collage' (Lucas et al., 1996). Paleoproterozoic assemblages within the Amisk collage are subdivided into juvenile-arc, ocean-floor, ocean-plateau and evolved-arc (Figure GS-6-1; Syme and Bailes, 1993; David and Syme, 1994; Reilly et al., 1994; Stern et al., 1995a, b; Lucas et al., 1996). The Amisk collage formed the basement to widespread postaccretion magmatism, between 1.87 and 1.83 Ga, which produced voluminous calcalkaline plutons and calcalkaline–alkaline volcanic rocks (Lucas et al., 1996). Younger sedimentary and subordinate volcaniclastic and volcanic rocks (1.85–1.83 Ga Missi and Burntwood groups) may represent depositional basins that formed contemporaneously with postaccretion ('successor') arc magmatism and deformation (Ansdell et al., 1995; Lucas et al., 1996).

Significant stratigraphic, geochemical and isotopic differences between arc-volcanic rocks in the Flin Flon and Snow Lake areas (Stern et al., 1995a) suggest that the two segments of the FFB formed in distinct tectonic settings (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. The Reed Lake area also includes the Fourmile Island assemblage (FIA), a bimodal succession of arc-affinity volcanic and volcaniclastic rocks that hosts five significant VMS deposits, including the currently producing Reed Lake Cu-Zn deposit (Figure GS-6-2). Previous geological work (Leclair and Viljoen, 1997; 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 bedrock exposures in the vicinity of Reed Lake may have important implications for base-metal exploration in the Reed Lake area, as well as in the covered area immediately to the south. The Reed Lake area was the focus of a four-week geological reconnaissance study in the summer of 1995 (Syme et al., 1995a, b) that provided significant new information but was limited to shoreline exposures on Reed Lake and roadcuts along the abandoned Chisel railbed, with only minor reconnaissance (1:50 000 scale) mapping of inland areas west of Reed Lake (Morrison et al., 1996).

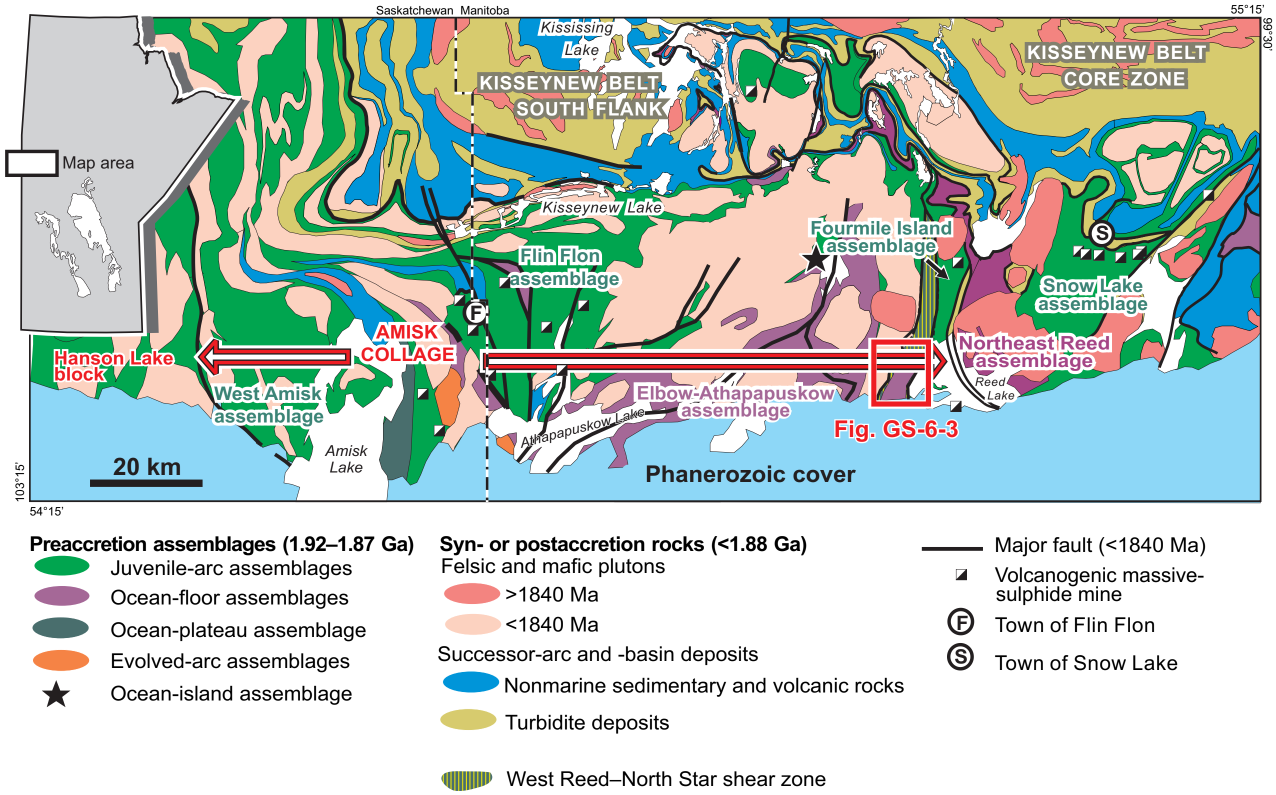

Figure GS-6-1: *Geology of the Flin Flon belt, showing major tectonostratigraphic assemblages, plutons and volcanogenic massive-sulphide deposits (modified from Syme et al., 1998). The location of the west Reed Lake area is indicated by the heavy red rectangle.*

A new multiyear project was initiated by the Manitoba Geological Survey in 2013 and will include a compilation of earlier data and new detailed (1:20 000 scale) mapping of critical areas, with an emphasis on volcanic rocks (Gagné, 2013a). The project also entails the acquisition of new whole-rock geochemical, Sm-Nd isotopic and U-Pb geochronological data. In 2014, six weeks were spent mapping the west Reed Lake area (Figure GS-6-3). The results from this geological mapping are presented in a 1:20 000 scale geological map (Gagné and Anderson, 2014). This paper summarizes the preliminary results of the mapping program.

Previous work

Reconnaissance mapping 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), and the results of follow-up geochemical and structural studies were presented by Syme and Bailes (1996). Prior to 1995, the supracrustal rocks at Reed Lake were simply subdivided into mafic volcanic, volcaniclastic and sedimentary types (Stanton, 1945; Rousell, 1970). Preliminary Map 1995F-1 (Syme et al., 1995b) was compiled from older maps, most notably those of Rousell (1970) and Stanton (1945), and new data from the 1995 field season, and represented a significant upgrade to our understanding of the local geology. Morrison and Whalen (1995) reported on mapping of the granitoid rocks in NTS 63K10, west of Reed Lake; a simplified version of their map was included in Preliminary Map 1995F-1 (Syme et al., 1995b) and their complete work was presented in Morrison et al. (1996). The inland area north and east of Reed Lake was not mapped. In 2013, the northwestern Reed Lake area, including Rail, Sewell and Prieston[1] lakes was mapped at 1:10 000 scale (Gagné, 2013b).

Geological framework

The exposed Flin Flon belt contains several distinct panels of juvenile-arc assemblages, which are separated by major faults; some of these panels also contain ocean-floor rocks, Burntwood group sedimentary rocks or plutonic rocks (Figure GS-6-1). These assemblages are internally complex, comprising fault-bounded and folded volcanic suites (e.g., Bailes and Syme, 1989) that are typically bimodal and include a wide range of arc-related

[1] formerly Preaston Lake

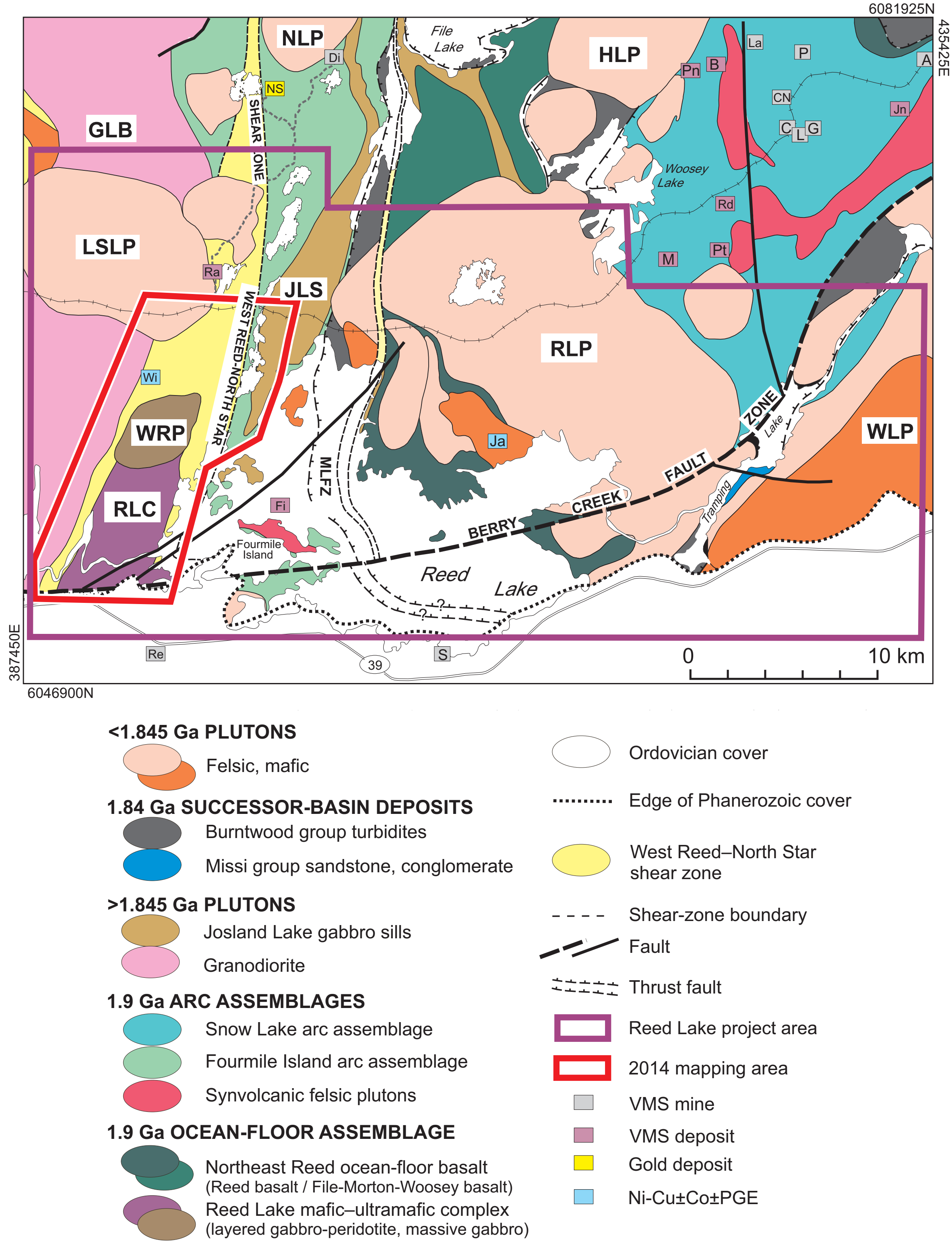

***Figure GS-6-2:** Generalized geology of the Reed Lake area (Syme et al., 1995a). The planned extent of the multiyear Reed lake project is outlined in purple and the location of the 2014 mapping area is outlined in red. Intrusive rocks: GLB, Gants Lake batholith; HLP, Ham Lake pluton; JLS, Josland 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; Di, Dickstone; FI, Fourmile Island; G, Ghost; Ja, Jackfish; Jn, Joannie; L, Lost; La, Lalor; M, Morgan; NS, North Star; P, Photo; Pn, Pen; Pt, Pot; Ra, Rail; Rd, Raindrop; Re, Reed; S, Spruce Point; Wi, Wine. Other: VMS, volcanogenic massive sulphide.*

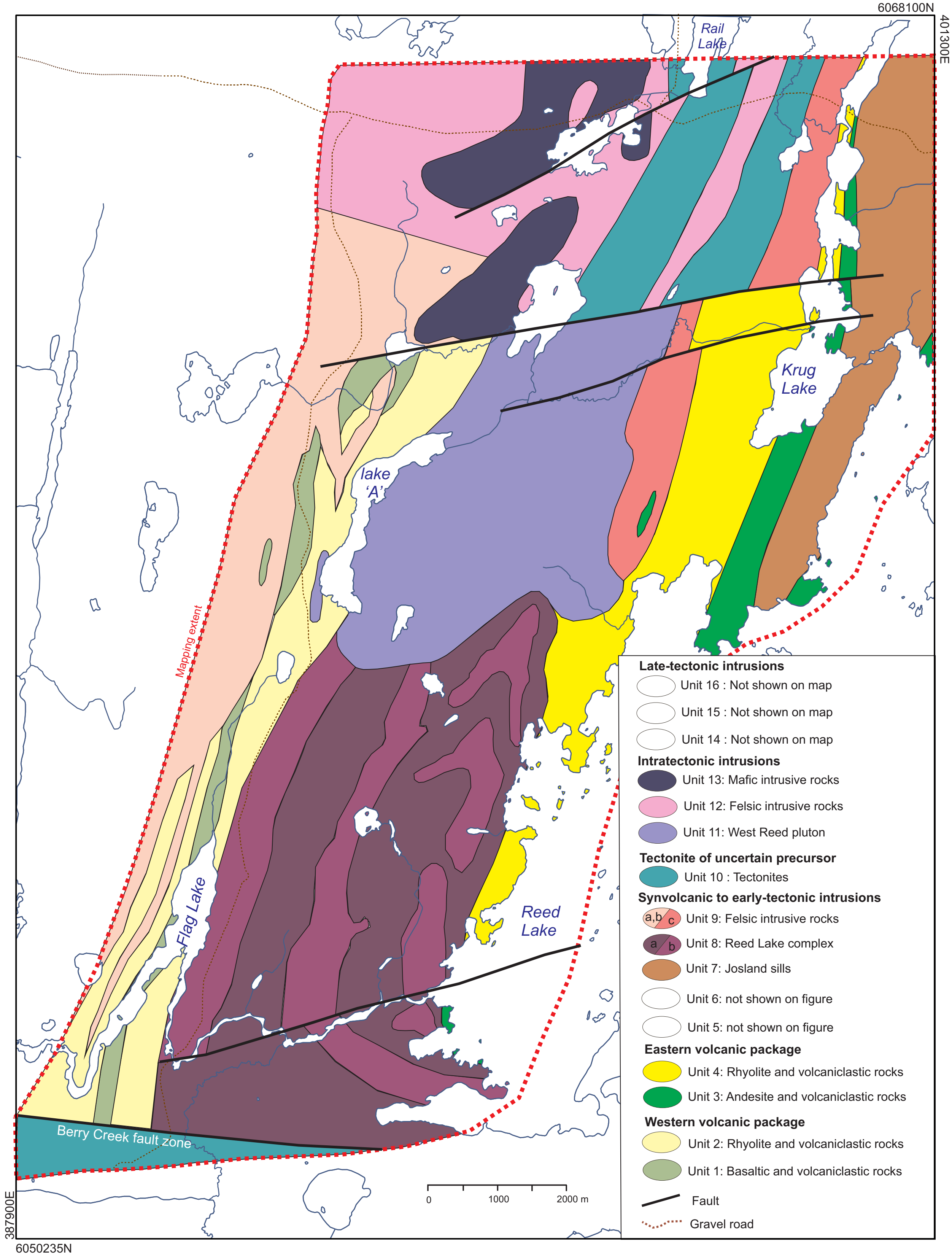

***Figure GS-6-3:** Geology of the west Reed Lake area, simplified from Preliminary Map PMAP2014-5 (Gagné and Anderson, 2014).*

volcanic, volcaniclastic and synvolcanic intrusive rocks (Bailes and Syme, 1989; Syme and Bailes, 1993; Stern et al., 1995a; Lucas et al., 1996; Bailes and Galley, 2007). The ocean-floor assemblages are composed mainly of mid-ocean-ridge–like basalt and related kilometre-scale, layered, mafic–ultramafic intrusive complexes (Syme and Bailes, 1993; Stern et al., 1995b). Uranium-lead zircon ages for the ocean-floor assemblages in the exposed portion of the FBB indicate that ocean-floor magmatism was coeval with juvenile-arc volcanism at ca. 1.9 Ga (David et al., 1993; Stern et al., 1995b). Voluminous successor-arc plutons and coeval volcanic and sedimentary rocks, formed between 1.88 and 1.83 Ga, occur throughout the belt and include the Schist-Wekusko assemblage, the Missi group and the Burntwood group. The fluvial-alluvial Missi group is characterized by thick packages of conglomerate, pebbly sandstone and massive sandstone, whereas the basinal-marine Burntwood group comprises greywacke, siltstone, mudstone and rare conglomerate.

The Reed Lake region is characterized by a major (kilometres wide), regionally extensive zone of tectonite, exposed in the west Reed Lake area and referred to as the West Reed–North Star (WRNS) shear zone, that was previously thought to juxtapose rocks of ocean-floor affinity on the west with rocks of juvenile-arc affinity (FIA) on 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, which juxtaposes the FIA in the footwall with the Northeast Reed assemblage, the composite Reed Lake pluton and the Snow Lake arc assemblage (Figure GS-6-2; Syme et al., 1995a, b; Syme and Bailes, 1996) in the hangingwall. The fault zone itself includes a panel of Burntwood group turbidites.

Local geology

The geology west of Reed Lake is characterized by two distinct packages of variably deformed bimodal volcanic and volcaniclastic rocks that flank the Reed Lake complex (RLC) and are intruded by the West Reed pluton (WRP; Figure GS-6-3). The western edge of the map is defined by granodiorite–tonalite of the Gants Lake batholith in the south and granodiorite of the Little Swan Lake pluton in the north, whereas the eastern edge in defined by a layered gabbroic sill, representing the 'type' intrusion of the regionally extensive Josland Lake sills.

This section provides preliminary field descriptions of the main rock types encountered in the west Reed Lake area. Mineral assemblages throughout the study area indicate mid- to upper-greenschist–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. Unit codes correspond to those on Preliminary Map PMAP2014-5 (Gagné and Anderson, 2014).

Volcanic and volcaniclastic rocks

Two distinct packages of bimodal volcanic and volcaniclastic rocks were identified in the west Reed Lake area. The eastern package varies from 500 to 1000 m in thickness and can be traced continuously from Morton Lake and the Dickstone mine area through Krug Lake to the Berry Creek fault zone. The eastern package is bounded to the west by the RLC and WRP in the southern part of the map; to the north, it lies in contact with a zone of heterogeneous tectonite (WRNS shear zone). The younging direction of the eastern package is to the east, based on younging criteria preserved in the northern portion.

The western package is bounded to the east by the RLC and WRP, and is truncated to the north by a late fault. North of this fault, the western package is eliminated by younger granitoid intrusions. The best exposures, found in a recent small burn (~10 years old; 2 km^2) west of 'lake A', include abundant examples of primary volcanic features. In contrast to the eastern package, the western package is characterized by a very high abundance of dikes, which represent 10–30% of the stratigraphy but locally account for as much as 70% of individual outcrops. Multiple generations and compositions of dikes are recognized, some of which texturally resemble the host volcanic rocks, suggesting synvolcanic emplacement and an extensional geodynamic setting.

Western volcanic package: basalt (unit 1)

Unit 1 is exposed along the eastern margin of the Gants Lake batholith and consists mostly of basaltic volcaniclastic rocks intercalated with thin intervals of massive and pillowed basaltic flows. Rocks in this unit typically exhibit moderate to high strain, although lower strain domains are also preserved. The basalt weathers medium brown/green to dark green and is medium to dark green on fresh surfaces. Pillows are highly elongate, with aspect ratios up to 10:1 (Figure GS-6-4a). Selvages are relatively thin (3–6 mm), with local concentrations of quartz amygdules (1–2%) varying from 2 to 20 mm in diameter. The basalt is typically aphyric but locally contains 2–5% plagioclase phenocrysts (1–4 mm). Associated volcaniclastic rocks include tuff breccia, lapilli tuff and tuff, which are planar bedded in some locations. Due to the high amount of strain and the poor quality of exposure outside the burn, only a few younging directions were observed, but these consistently indicate an upright sequence younging to the east. Flows typically show little indication of alteration except for small patches of weak to moderate epidote alteration, ranging from 5 to 15 cm. The western volcanic package is characterized by abundant syn- and postvolcanic dikes ranging in composition from mafic to felsic. Synvolcanic dikes are strongly foliated and transposed, and are typically porphyritic with a fine-grained to aphanitic groundmass. Postvolcanic dikes include granodiorite–tonalite, pyroxenite and diabase that

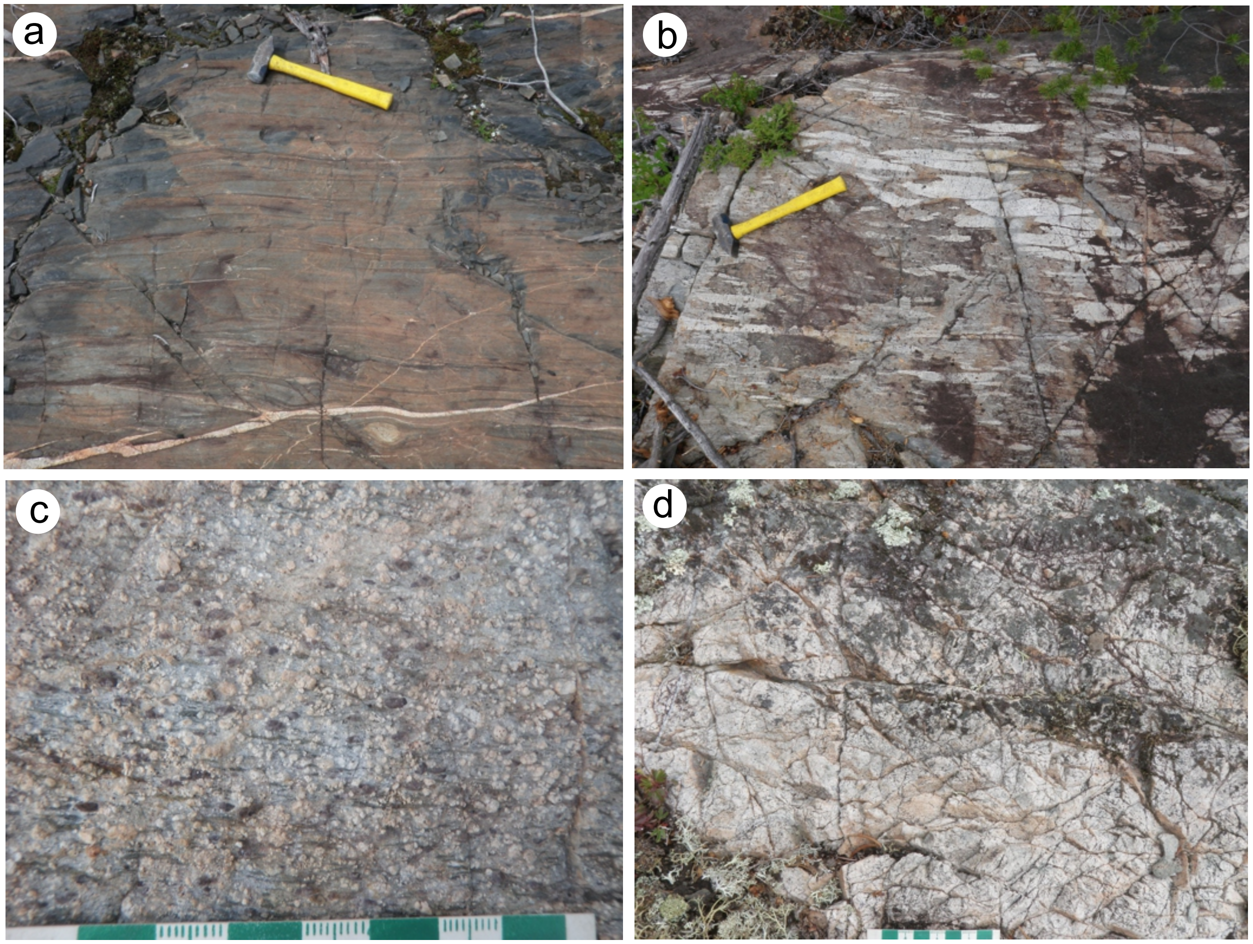

***Figure GS-6-4:** Outcrop photographs of representative rock types from the west Reed Lake area: **a)** highly strained, pillowed basaltic flow with minor epidote nodules, unit 1, 300 m west of 'lake A' (hammer is 40 cm; UTM zone 14, 391987E, 6060665N, NAD 83); **b)** stratified felsic lapilli tuff and tuff breccia, unit 2, west of 'lake A' (hammer is 40 cm; UTM 392561E, 6061387N); **c)** felsic crystal-rich tuff with biotite-chlorite wisps, possibly representing fiamme, unit 2 (UTM 392113E, 6059395N); **d)** massive, sparsely quartz-phyric rhyolite, unit 4 (UTM 400298E, 6067552N).*

are deformed but clearly crosscut at least one generation of fabric in the wallrock, as well as earlier dikes.

Western volcanic package: rhyolite, dacite (unit 2)

Felsic volcanic and volcaniclastic rocks of unit 2 include dacitic to rhyolitic flows and abundant volcaniclastic material. This narrow but extensive unit extends along the eastern contact of the Gants Lake batholith from north of 'lake A' through Flag Lake and terminates just south of the Grass River against the Berry Creek fault zone (Figure GS-6-3). The felsic volcanic and volcaniclastic rocks are generally highly strained in the south and adjacent to the contact of the Gants Lake batholith. However, the burn area just west of 'lake A' reveals some moderate- to low-strain felsic volcaniclastic rocks. The flows are more prevalent in the south and are typically plagioclase-quartz phyric. Volcaniclastic facies include massive to crudely stratified crystal tuff (quartz and plagioclase crystals) to stratified lapilli tuff and tuff breccia, locally with up to 30% angular fragments of quartz-phyric rhyolite (Figure GS-6-4b). Volcaniclastic facies are generally monolithic and show little evidence of reworking. Thin biotite-chlorite wisps in some exposures of crystal tuff may represent collapsed pumice (fiamme; Figure GS-6-4c).

The contact between the western volcanic package and the Gants Lake batholith is characterized in the south by a high-strain zone that contains sheets of granodiorite alternating with felsic tectonite over a width of 600 m. The contact is clearly intrusive, but some of this map pattern may also result from structural interleaving.

Eastern volcanic package: basaltic andesite, andesite (unit 3)

Unit 3 consists mostly of volcanic and volcaniclastic rocks of andesitic composition, which generally appear to exhibit lower strain than those in the western package. Pillowed flows are accompanied by lesser amounts of massive flows, mafic volcaniclastic rocks and gabbro dikes. The andesite weathers dull brown to light green or medium green. The pillows range in diameter from 0.2 to 3.0 m and average between 0.6 and 1.0 m, with relatively thin selvages (3–6 mm). The pillowed flows are generally aphyric but locally contain 2–5% plagioclase phenocrysts (1–4 mm). Amygdules are common (4–5 %), vary from 2 to 25 mm in diameter and are generally filled with either quartz or epidote. Patches of weak to moderate epidote alteration generally range from 5 to 20 cm but are locally up to 45 cm. Due to the poor quality of outcrop, only a few younging directions were observed, and only in the northern portion; these indicate an upright sequence younging to the east. This unit is tentatively correlated on the basis of lithology and geochemistry (see below) with the Preaston formation in the Dickstone mine area, which was described by Bailes (1980).

Eastern volcanic package: rhyolite, dacite (unit 4)

Felsic volcanic and volcaniclastic rocks exposed along the western shore of Reed Lake are traced northward through Krug Lake and Sewell Lake to north of Prieston Lake, where they correspond to the Dickstone formation of Bailes (1980). In the west Reed Lake area, this unit comprises coherent dacitic and rhyolitic flows with only minor volcaniclastic material. The dacite is commonly aphyric to locally plagioclase phyric, whereas the rhyolite is typically plagioclase and quartz phyric, with distinctive blue-quartz ‘eyes’ (Figure GS-6-4d). Lobe and tongue facies with 0.3–1.5 m thick lobes of coherent dacite or rhyolite and associated breccia are observed in the northern portion. Minor intervals of plagioclase- and quartz-phyric dacitic to rhyolitic tuff and lapilli tuff include horizons of massive crystal-rich tuff or thin-bedded tuff with 5–10% lithic lapilli.

Synvolcanic to early-tectonic intrusions

Mafic to ultramafic intrusive rocks (dike and sills; unit 5)

Unit 5 comprises mafic to ultramafic dikes and sills that intrude the western volcanic package and are typically strongly foliated and transposed into near-parallelism with the tectonite fabric, indicating relatively early emplacement. These intrusions vary from equigranular to porphyritic, and include distinctive plagioclase-, pyroxene- and plagioclase-pyroxene–phyric varieties (Figure GS-6-5a); layered gabbro sills and a distinctive phase of medium- to coarse-grained pyroxenite were also identified. No definitive sequence of dike emplacement was established; whole-rock geochemistry will be used to assess the possibility of an association with the RLC.

Felsic to intermediate intrusive rocks (unit 6)

Dikes of felsic to intermediate porphyry in the western volcanic package include quartz-, plagioclase- and quartz-plagioclase–phyric varieties, and are characterized by aphanitic to very fine grained groundmass, indicative of hypabyssal emplacement. Phenocrysts vary in abundance up to 25% and range from 3 to 6 mm in size. These dikes are particularly abundant in the felsic volcanic and volcaniclastic rocks of unit 2, suggesting a possible synvolcanic association. Contacts are sharp and highly irregular; the latter aspect may relate to emplacement in poorly consolidated volcaniclastic material in some cases; in others, it appears to result from ptygmatic folding. The dikes range up to 3 m wide and are strongly transposed and variably foliated.

Josland Lake sills (unit 7)

The east shore of Krug Lake is underlain by a thick, differentiated gabbro sill that represents the ‘type’ intrusion of the Josland Lake sills and yielded a U-Pb zircon age of 1886 ±3 Ma (Zwanzig et al., 2001). This intrusion represents the along-strike extension of the >17 km long Josland Lake sill that was mapped and described in detail by Bailes (1980) in the File Lake–Morton Lake area. It consists of strongly fractionated, tholeiitic gabbro that displays extreme iron enrichment (Bailes, 1980) and includes three zones: lower gabbro, middle ferrogabbro, and upper granophyric to porphyritic quartz ferrodiorite and tonalite. These zones were mapped east of Sewell Lake (Gagné, 2013b) and are interpreted to extend south of Krug Lake; however, only a few outcrops were visited by the authors and readers are therefore referred to Bailes (1980) for a comprehensive description of this unit.

Reed Lake complex (unit 8)

The Reed Lake complex (RLC) is a layered to locally heterogeneous, mafic intrusion that separates the eastern and western volcanic packages and has been studied in detail by Young and Ayres (1985), Ayres and Young (1989) and Young (1992). These authors subdivided the intrusion into three units: Lower Mafic (100–300 m thick), Mafic–Ultramafic (335–700 m) and Upper Mafic (3200 m). The Lower Mafic unit consists of modally layered gabbro and minor pyroxenite; the Mafic–Ultramafic unit of modally layered pyroxenite, olivine pyroxenite, orthopyroxene-bearing pyroxenite, peridotite, melagabbro, gabbro, leucogabbro and rare anorthosite; and the Upper Mafic unit of leucogabbro, gabbro, melagabbro and minor anorthosite, olivine-bearing gabbro and magnetiferous gabbro (Young, 1992).

Due to the very poor quality of exposure, the stratigraphy proposed by previous workers could not be verified and the map pattern shown in Figure GS-6-3 is based mostly on detailed aeromagnetic survey data (Assessment File 73859, Manitoba Mineral Resources, Winnipeg).

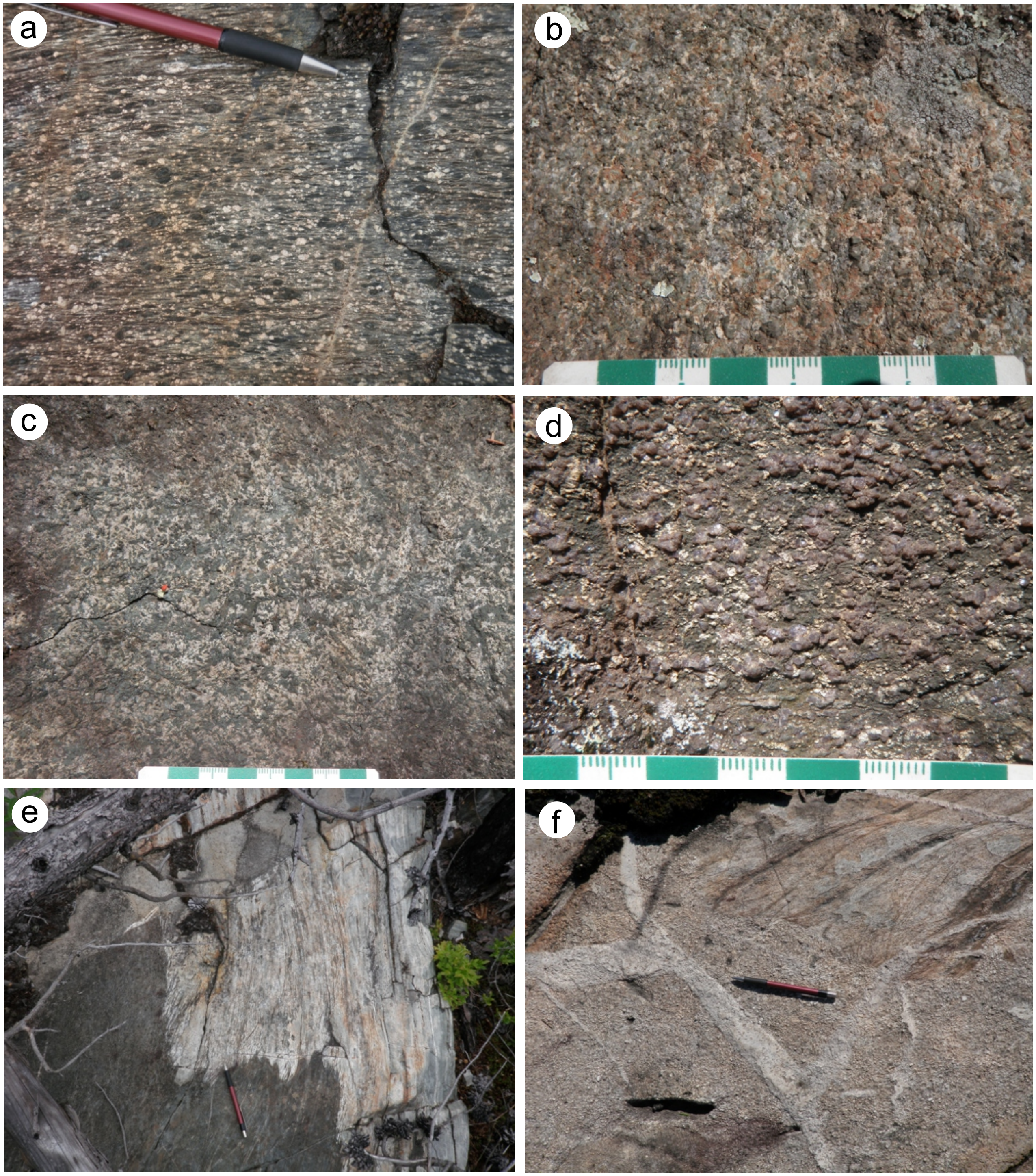

Figure GS-6-5: *Outcrop photographs of representative rock types from the west Reed Lake area:* ***a)*** *plagioclase-pyroxene–phyric gabbro dike, unit 5, northwest of 'lake A' (UTM Zone 15, 392113E, 6059395N, NAD 83);* ***b)*** *mesocratic olivine gabbro, unit 8 (UTM 401930E, 6057163N);* ***c)*** *mesocratic gabbro, unit 8 (UTM 391728E, 6053661N);* ***d)*** *mesocratic gabbro, unit 11 (UTM 392114E, 6052616N);* ***e)*** *strongly deformed rhyolitic breccia (unit 2) intruded by an early-tectonic gabbro dike (unit 5; lower left) and a late-tectonic, sparsely amphibole-phyric intermediate dike (unit 5, from centre left to upper right; pen is 13 cm; UTM 392153E, 6060045N);* ***f)*** *medium-grained granodiorite (subunit 9a) cutting earlier gneissic tonalite–granodiorite (subunit 9b) and intruded by late granodiorite dikes (unit 16; pencil is 13 cm; UTM 391959E, 6061199N).*

The complex is subdivided into two units: unit 8b has a higher magnetic signature and consists mainly of melagabbro, pyroxenite and olivine gabbro (Figure GS-6-5b), whereas unit 8a has a lower magnetic signature and consists mostly of mesogabbro (Figure GS-6-5c) and leucogabbro. These rocks vary from homogeneous to layered to patchy heterogeneous. Centimetre- to decimetre-scale magmatic layers have a near-vertical orientation. Olivine-bearing rocks were observed only in the easternmost portion of the intrusion, which geochemical studies by Young (1992) and Williamson and Eckstrand (1995) indicate is the less evolved part of the complex. The rocks are generally massive to weakly foliated. Domains of higher strain are confined to late narrow shear zones and the margins of the complex. Closely spaced traverses across the entire complex were completed during this study and a representative suite of samples was collected for future geochemical and petrographic study. These data will be used to better characterize the complex and to test the idea of Syme et al. (1995a) that it may be correlative with mafic–ultramafic complexes exposed at Elbow Lake and Claw Lake (Williamson, 1993; Syme and Whalen, 2012).

Felsic intrusive rocks (unit 9)

Tonalite–granodiorite of unit 9 defines large intrusions along the western extents of both the western and eastern volcanic packages. Subunits 9a and 9b occur in the western intrusion, which appears to represent the east margin of the regionally extensive Gants Lake batholith, which includes older components dated at 1888 ±4 Ma (Whalen and Rayner, unpublished data, 2012). Medium- to coarse-grained, equigranular, moderately to strongly foliated granodiorite (subunit 9a) is the dominant rock type and contains subordinate rafts and xenoliths of gneissic tonalite–granodiorite (subunit 9b), the latter of which perhaps represent an older phase of the batholith, or are entirely unrelated. Subunit 9b is particularly abundant in a wide (800–1000 m) zone northwest of ‘lake A’ just south of the contact with unit 12. Near the contact with the western volcanic package, strain increases significantly in the granodiorite and local mylonite horizons are observed. In the contact zone west of Flag Lake, the granodiorite is also interleaved with the felsic volcanic rocks of unit 2.

The eastern intrusion is an elongate, sheet-like body that occurs north of Reed Lake and defines the western extent of the eastern volcanic package. West of Krug Lake, it is disposed in three fault blocks that are bounded by late northeast-trending faults. This intrusion is homogeneous in comparison to the western intrusion and consists of fine- to medium-grained, equigranular to sparsely plagioclase-phyric, massive to moderately foliated granodiorite (subunit 9c). The eastern margin of the intrusion locally contains thick (5–10 m) zones of finely disseminated pyrite, which are associated with patchy, weak to moderate gossan on outcrop surfaces.

Tectonite of uncertain precursor

Tectonite, mylonite (unit 10)

Unit 10 consists of two wide bands of strongly layered, foliated to mylonitic tectonite in the north-central portion of the map area, corresponding to the southern extension of WRNS shear zone. Much of the eastern band consists of rhythmically interleaved mafic tectonite and granodiorite sheets, such that outcrop surfaces in some locations have very prominent ridges and grooves due to differential glacial sculpting. Intense fabric within the mafic tectonite makes determination of protolith difficult; however, a fairly abrupt transition (over 50–100 m) farther north can be mapped from laminated mafic tectonite eastward to ‘intact’ mafic volcanic rocks of the FIA, suggesting the eastern band may been derived from these rocks. The western band continues north through the Rail Lake area, where geochemical data indicate mafic volcanic rocks that are distinct from the FIA, in that they include rocks of arc and ocean-floor affinity (Simard et al., 2010). However, the available data do not allow for definitive correlation with units along strike to the north or south. In lower strain domains, possible remnant pillow selvages indicate that the protolith for this unit was, at least locally, mafic flows. The tectonite also includes minor horizons (0.3–10 m thick; <10%) of highly deformed felsic rocks of unknown precursor.

Intratectonic intrusions

West Reed pluton (unit 11)

The West Reed pluton (WRP) is an ovoid (3 by 3.5 km) gabbroic intrusion that cuts the RLC to the north. This unit tends to be much more homogeneous than the RLC but nevertheless varies from medium-grained mesocratic gabbro to fine-grained leucogabbro and quartz gabbro (Figure GS-6-5d), with minor granodiorite, particularly along the northern and southern margins. Homogeneous, fine- to medium-grained, equigranular and massive leucogabbro underlies large areas in the centre of the intrusion. Small zones of magmatic breccia, comprising gabbroic fragments in a leucogabbro matrix, were observed in a few exposures near the northern margin and locally contain trace to a few percent pyrrhotite (±chalcopyrite).

Felsic intrusive rocks (unit 12)

Unit 12 occupies the northwestern portion of the map area and consists of very homogeneous biotite (±hornblende) granodiorite, representing the southeast margin of the Little Swan Lake pluton (Figure GS-6-2). The granodiorite is typically medium to coarse grained with a distinct quartz-porphyritic texture and weak to moderate foliation. Weathered surfaces have a buff-beige colour and very distinct knotted appearance due to the more resistant quartz phenocrysts.

Mafic intrusive rocks: diorite, gabbro (unit 13)

Unit 12 in the northwestern corner of the map area contains three dioritic intrusive bodies that are assigned to unit 13. The diorite varies from aphyric to plagioclase phyric and is typically fine to medium grained and very homogeneous, although it grades locally to more gabbroic or quartz dioritic compositions. The diorite contains a weak to moderate foliation.

Late-tectonic intrusions

Highly discordant, planar intrusions are exposed in several locations in the west-central portion of the map area, with the best examples occurring in the recently burned area west of 'lake A'. These dikes include mafic, intermediate and felsic varieties, the relative ages of which are unknown, but they are nowhere cut by other intrusions. Contacts are sharp, planar, aphanitic to fine grained, and generally 'intact' or locally reactivated by late brittle-ductile shears.

Mafic intrusive rocks (unit 14)

Unit 14 consists of a series of diabase dikes (0.1–2.0 m) that cut the western volcanic package west and north of 'lake A'. The diabase varies from aphyric to sparsely plagioclase phyric but is otherwise homogeneous, fine grained and massive. These dikes locally have very narrow chilled margins (<2 cm) and strike consistently to the east-northeast, with subvertical dips.

Intermediate intrusive rocks (unit 15)

Medium to dark grey, fine- to medium-grained diorite occurs as narrow dikes (<50 cm) cutting supracrustal rocks west of 'lake A'. The diorite is aphyric to sparsely amphibole phyric and massive (Figure GS-6-5e).

Felsic intrusive rocks (unit 16)

Buff to light grey biotite granodiorite occurs as small plugs and irregular dikes in the western and northwestern parts of the map area. The granodiorite is equigranular, medium to coarse grained and generally homogeneous, and varies from massive to weakly foliated. It is characteristically leucocratic with only minor biotite (2–4%; 1–2 mm in size). It clearly postdates at least two older phases of granodiorite, corresponding to subunits 9a and 9b (Figure GS-6-5f).

Whole-rock geochemistry

Fifty-eight samples, representing most of the major rock types in the west Reed Lake area, were collected for whole-rock geochemical analysis during the geological mapping program. The geochemical sampling was designed to provide a representative suite of samples from the various lithological units, with the purpose of characterizing the trace- and rare-earth-element (REE) signatures to assist with distinguishing volcanic rocks. Results presented here focus on samples from the eastern and western volcanic packages. Where possible, samples were collected from the least-altered rocks, but some may include slightly altered material. All samples were trimmed to remove weathered surfaces, joints and veinlets; some samples may contain minor amygdules. Altered samples are not included on any of the geochemical plots in this report, except where noted. The trimmed samples were prepared in the Manitoba Geological Survey laboratory and analyzed using the '4-litho' analytical package by Activation Laboratories Ltd. (Ancaster, Ontario). Major and minor elements were analyzed by inductively coupled plasma–emission spectrometry, and trace elements and REE were analyzed using inductively coupled plasma–mass spectrometry.

Mafic volcanic and volcaniclastic rocks

Mafic samples from the western volcanic package consist of basalt (Figure GS-6-6a) and show evidence of a weak arc affinity, transitional to typical normal mid-ocean-ridge basalt (N-MORB; Figure GS-6-6b). The basalt is subalkaline and tholeiitic, and displays a slightly negative slope on a chondrite-normalized trace-element diagram (Figure GS-6-7a), indicating light rare-earth-element (LREE) enrichment. On a primitive mantle–normalized incompatible trace-element diagram (Figure GS-6-7c), the basalt shows an almost flat profile with variable Nb, Zr and Ti anomalies. Basalt in the western volcanic package shows some similarities to mafic rocks of the FIA in terms of tholeiitic subalkaline character. However, it is more mafic with a signature that is distinctly transitional to N-MORB.

Mafic samples from the eastern volcanic package plot near the boundary between the andesite and basalt fields on a Zr/TiO_2 versus Nb/Y diagram (Figure GS-6-6a). On a Th-(Hf/3)-Ta discrimination diagram (Figure GS-6-6b), the basaltic andesite–andesite shows a primitive volcanic-arc affinity. On both discriminant diagrams, mafic rocks from the western and eastern volcanic packages plot in the arc field but define distinct clusters. Unaltered andesite from the eastern volcanic package is subalkaline and tholeiitic in character, and displays a slightly enriched heavy rare-earth-element (HREE) profile, with a small negative Eu anomaly, on a chondrite-normalized trace-element diagram (Figure GS-6-7b). On a primitive mantle–normalized incompatible trace-element diagram (Figure GS-6-7d), the basalt signature includes distinct positive Th and negative Nb anomalies, and depleted Ti. These chemical characteristics are very similar to those of samples from the Preaston andesite (Zwanzig and Bailes, 2010), indicating that the eastern volcanic package is likely correlative with the FIA.

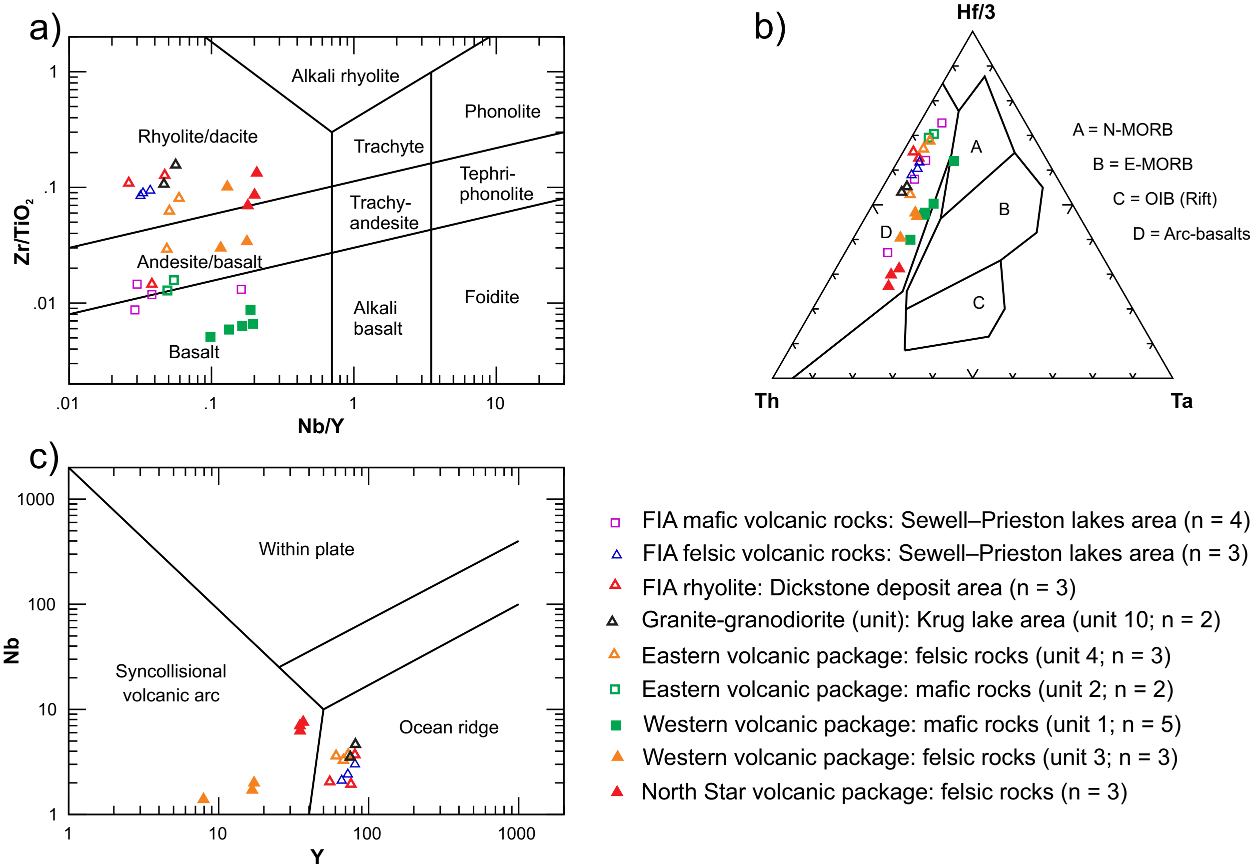

***Figure GS-6-6:** Geochemical discrimination diagrams for volcanic rocks of the west Reed Lake area: **a)** Zr/TiO_2 vs. Nb/Y (modified from Winchester and Floyd, 1977); **b)** Th-(Hf/3)-Ta (Wood, 1980); **c)** Nb vs. Y (Pearce et al.,1984). Abbreviations: E-MORB, enriched mid-ocean-ridge basalt; N-MORB, normal mid-ocean-ridge basalt; OIB, ocean-island basalt.*

Felsic volcanic and volcaniclastic rocks

Felsic volcanic and volcaniclastic samples from the western volcanic package plot within the rhyolite/dacite and the andesite fields on a Zr/TiO_2 versus Nb/Y diagram (Figure GS-6-6a). On a Th-(Hf/3)-Ta discrimination diagram (Figure GS-6-6b), the rhyolite-dacite shows a weak arc affinity to transitional N-MORB in a similar manner to the basalt of the western volcanic package. On a Nb versus Y discriminant diagram (Figure GS-6-6c), the felsic rocks plot in the syncollisional volcanic-arc field similar to the North Star rhyolite, which also occurs on the west side of the WRNS shear zone. The felsic rocks display flat to slightly negative slopes, indicating LREE depletion, on a chondrite-normalized trace-element diagram (Figure GS-6-7e), a signature distinct from both the North Star and Dickstone rhyolites. On a primitive mantle–normalized incompatible trace-element diagram (Figure GS-6-7g), the felsic rocks show an almost flat profile with little to no Nb anomaly and slight to moderate Ti depletion, with one sample showing a positive Zr anomaly. Thus, the felsic volcanic rocks from the western volcanic package have a geochemical signature distinct from the Dickstone and North Star rhyolites.

Felsic samples from the eastern volcanic package plot in the rhyolite/dacite field on a Zr/TiO_2 versus Nb/Y diagram (Figure GS-6-6a), except for one sample that falls in the andesite field. On a Th-(Hf/3)-Ta discrimination diagram (Figure GS-6-6b), the rhyolite-dacite shows a definite volcanic-arc affinity similar to that of the Dickstone rhyolite and Sewell Lake felsic volcanic rocks. On a Nb versus Y discriminant diagram (Figure GS-6-6c), the felsic rocks from the eastern volcanic package, the Dickstone rhyolite and the Sewell Lake felsic volcanic rocks all distinctly plot in the ocean-ridge field. Zwanzig and Bailes (2010) interpreted the geochemistry of the FIA to indicate a transition from arc to arc-rift environment. Rhyolite-dacite from the eastern volcanic package displays a slightly enriched HREE profile, with a small negative Eu anomaly, on a chondrite-normalized trace-element diagram (Figure GS-6-7f). On a primitive mantle–normalized incompatible trace-element diagram (Figure GS-6-7h), the signature includes positive Th and negative Nb anomalies, and strongly depleted Ti. These chemical characteristics are very similar to those of other samples collected in 2013 from the Sewell–Prieston lakes area (also shown on Figures GS-6-6 and -7) and to published

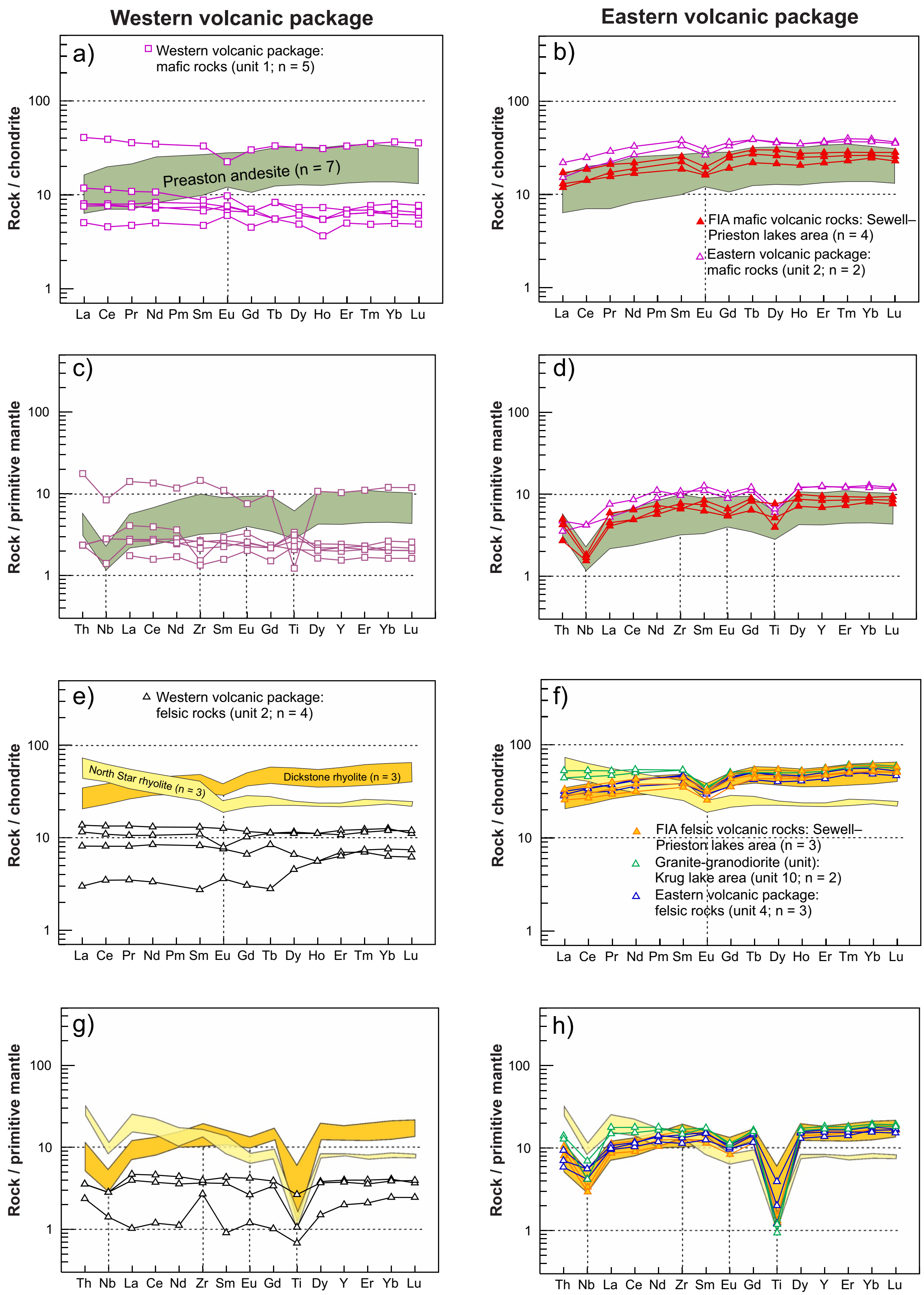

Figure GS-6-7: *Chondrite-normalized rare-earth-element plots (normalizing values from McDonough and Sun, 1995) and primitive mantle–normalized incompatible trace-element plots (normalizing values from Sun and McDonough, 1989) for rocks of the west Reed Lake area:* ***a)****,* ***c)****,* ***e)*** *and* ***g)*** *western volcanic package;* ***b)****,* ***d)****,* ***f)*** *and* ***h)*** *eastern volcanic package. Abbreviations: FIA, Fourmile Island assemblage.*

data from the Dickstone formation (Zwanzig and Bailes, 2010), indicating that the eastern volcanic package is very similar in geochemical character to the rocks hosting the Dickstone mine and is thus likely correlative with the FIA. Two samples of biotite granodiorite-granite (unit 9c) occurring with the felsic volcanic rocks west of Krug Lake were also analyzed. The geochemical signature of the biotite granite is very similar to that of host felsic volcanic rocks, suggesting that it may represent a synvolcanic intrusion sourced from a similar parent magma.

Structural geology

The west Reed Lake area is polydeformed, so additional field and laboratory study, as well as targeted U-Pb geochronology, will be required to correlate local deformation structures and events to the regional tectonic framework. The sequence of deformation presented here is based largely on observed crosscutting relationships and is not intended to imply correlation with deformation structures beyond the map limits.

Abundant moss and lichen in the map area hinder recognition of primary features. Hence, only a few younging directions were documented. Nevertheless, graded beds and pillow asymmetry consistently indicate that the direction of younging is toward the east for both the eastern and western volcanic packages. An overall easterly, upright younging direction for the eastern volcanic package is also in agreement with observations to the north (Bailes, 1980; Gagné, 2013a).

The oldest and most prominent fabric observed in the map area is a weak to strongly developed mineral foliation (S_1). The S_1 foliation generally trends north-northeast (010–025°) with a near vertical dip (80–90°). In fragmental or pillowed volcanic rocks, the S_1 fabric is also defined by flattened primary features (Figure GS-6-8a). The S_1 fabric is parallel to the general orientation of the WRNS shear zone and may represent the earliest increment of deformation along, or may entirely predate, this structure. A down-dip lineation ($L_{1;}$ Figure GS-6-b) in the plane of the S_1 fabric is defined by elongated clasts, amygdules and quartz grains, as well as aligned amphibole porphyroblasts, indicating that this fabric may have been coeval with the local metamorphic peak. Inside the WRNS shear zone, S_1 is characterized by a protomylonitic to mylonitic fabric.

The second episode of deformation is marked by reactivation of earlier foliation surfaces and development of dextral asymmetric fabrics and minor Z-folds (Figure GS-6-8c, d). The F_2 Z-folds vary from tight chevron to isoclinal and do not typically have a penetrative axial-planar fabric, indicating that they formed relatively late during D_2 deformation. The S_2 fabric is generally oriented at 335–350° with a steep dip (70–85°). Fold axes and crenulation lineations typically trend to the northwest with a steep plunge (70–90°)

The third episode of deformation (D_3) is characterized by the development of discrete dextral shear zones (Figure GS-6-8e, f) that strike northeast and are subvertical. Minor S-folds and left-lateral offsets of dikes and quartz veins in zones of reactivated S_1 or S_2 fabric may also be related to D_3 deformation. The Berry Creek fault zone, which is very poorly exposed in the map area, contains a 200–300 m wide zone of mafic tectonite and is characterized by an inward-increasing strain gradient along its north margin. The S_1 and S_2 foliation rotate into parallelism with the fault zone, consistent with a ductile increment of deformation that postdates D_2 deformation. The timing of ductile deformation along the Berry Creek fault zone is interpreted to be syn D_3 to early D_4.

A series of late narrow faults (D_4) with apparent dextral offset at map scale typically trends east-northeast. These brittle faults clearly cut all earlier foliations. Minor chloritic alteration is locally observed along the walls of the larger brittle faults. The east-trending portion of the Berry Creek fault zone in western Reed Lake contains evidence for late brittle deformation, probably related to D_4 reactivation. Regional magnetic data suggest dextral offset along the fault, similar to that observed along other minor D_4 faults.

Economic considerations

Recent and historical mineral exploration in the Reed Lake area has resulted in the discovery of several base-metal volcanogenic massive-sulphide (VMS) deposits, including two former producers (Dickstone and Spruce Point) and the currently producing Reed Lake mine. The area also contains several showings of orogenic Au and magmatic Ni-Cu (±Co, PGE) mineralization, thus demonstrating significant potential for a number of important deposit types. Potential for each of these major types is discussed below in light of the results from the 2014 mapping program.

Base-metal potential

The eastern volcanic package (units 3 and 4) is interpreted to be correlative with the Fourmile Island assemblage, which is host to several significant VMS deposits, including Dickstone, located 12 km along strike to the north of the mapping limit. Moderate to strong chlorite alteration, which is commonly associated with VMS systems, was observed within mafic volcaniclastic rocks of unit 3 along the eastern contact of felsic volcanic rocks of unit 4, which trend through Krug Lake. Local silicification was also recognized in mafic flows of unit 3. One sample collected for whole-rock geochemistry showed an alteration signature (moderate silica enrichment and disseminated magnetite) very similar to that exhibited by a flow in the footwall of the Dickstone deposit. The presence of alteration, together with the fact that the host horizon of the Dickstone deposit can be traced uninterrupted from

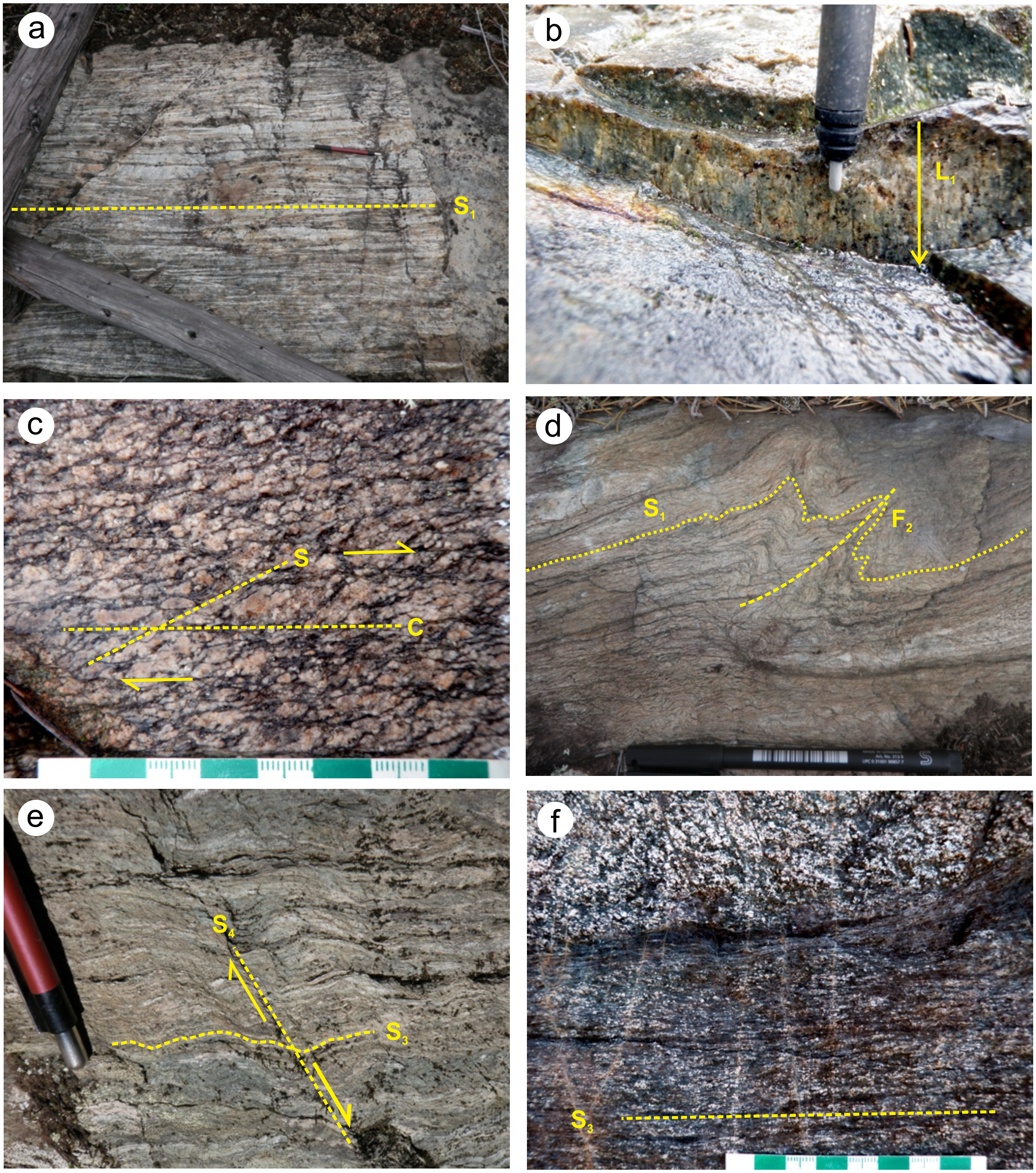

Figure GS-6-8: *Outcrop photographs of deformation structures from the west Reed Lake area:* ***a)*** *well-developed* S_1 *foliation defined by flattened clasts in felsic breccia of unit 2 (pencil tip is 2 cm; UTM Zone 15, 392153E, 6060045N, NAD 83);* ***b)*** *down-dip stretching lineation* (L_1) *in felsic volcaniclastic rocks of unit 2 (photo is 8 cm across; UTM 390539E, 6056828N);* ***c)*** *dextral C-S fabric in granodiorite; C-plane is parallel to lower edge of photo (UTM 390795E, 6056765N);* ***d)*** *mylonitic foliation with minor* F_2 *Z-fold in felsic volcaniclastic rocks of unit 2 (pencil is 13 cm; UTM 390250E, 6055729N);* ***e)*** *mylonitic foliation* (S_3*, parallel to bottom edge of photo) within a ductile shear zone in gabbro (unit 7), overprinted by spaced shear-band cleavage (late-*S_3*, parallel to pencil edge; photo is 8 cm across; UTM 397090E, 6062960N);* ***f)*** *narrow (40 cm) ductile shear zone in massive to weakly foliated gabbro (unit 8), with mylonitic foliation* (S_3) *parallel to bottom edge of photo (UTM 392089E, 6058540N).*

the Dickstone mine through most of the map area, suggest that the Krug Lake vicinity has significant potential for VMS mineralization.

The western volcanic package lies roughly along strike to the south of the Rail deposit, which is hosted by mafic and felsic tectonites of the WRNS shear zone. However, the available data are insufficient to suggest any correlation. Nevertheless, the western volcanic package exhibits some key features of VMS-hosting volcanic sequences elsewhere in the Flin Flon belt, including: 1) bimodal geochemistry, with common volcaniclastic horizons; 2) volcanic-arc geochemical signature; and 3) high abundance of synvolcanic to postvolcanic dikes, which are commonly interpreted as evidence of rifting and subsidence (Gibson et al., 1999, 2003) and are thus considered favourable indicators of VMS potential.

Orogenic Au

Although no Au occurrences have been reported in the west Reed Lake area, the WRNS shear zone hosts several significant Au showings farther north in the North Star Lake area. The major structures associated with Au mineralization in the North Star Lake area appear to extend continuously southward to the west Reed Lake area, which is considered to have similar potential for shear-hosted (i.e., orogenic) Au mineralization. Several minor occurrences of shear-type quartz veins were encountered within highly deformed supracrustal rocks along the eastern margin of the Gants Lake batholith. One sample of vein quartz with trace amounts of pyrite, chalcopyrite and malachite, collected from west of 'lake A', yielded an assay of 425 ppb Au and 9660 ppm Cu. Quartz vein–hosted Au mineralization is also found in proximity to the Berry Creek fault zone at Bartlett Point, just south of Fourmile Island, as well as along Berry Bay on the east shore of Wekusko Lake, suggesting that this major structure, or one of its subsidiary structures, may also have potential to host Au mineralization in the 2014 map area.

Magmatic Ni-Cu-Co-PGE mineralization

Both the RLC and the WRP 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). Of 124 grab samples, 24 yielded values above 20 ppb Pt, 32 yielded values of greater than 20 ppb Pd, and 5 showed combined (Pt+Pd) values greater than 100 ppb. The highest reported PGE values were 117 ppb Pt and 176 ppb Pd (Williamson, 1993).

The Wine Ni-Cu-Co-PGE occurrence (Figure GS-6-2) is located northwest of the RLC and was discovered through drilling of a ground geophysical anomaly by Hudson Bay Exploration and Development Co. Ltd. in the early 1980s. The mineralization 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). Significant results for the Wine showing include 3.96 m (13 ft.) averaging 0.69% Cu, 1.12% Ni and 0.009 oz./ton Pt+Pd (diamond-drillhole Eel-302; A.F. 94669); and 6.37 m (20.9 ft.) averaging 1.52% Cu and 1.67% Ni (diamond-drillhole Eel-346; A.F. 94660). More recently (2007), Cream Minerals Inc. drilled two additional holes on the property (A.F. 74528). One drillhole hit the same conductor as drillholes Eel-302 and -342, and returned 0.05% Co, 2.27% Cu, 1.30% Ni, 0.319 g/t Au, 0.132 g/t Pt and 0.270 g/t Pd over 20.36 m (66.8 ft.); the true width was estimated at 13.28 m (43.6 ft.). The north margin of the WRP includes examples of leucogabbro-hosted magmatic breccia, locally associated with trace to a few percent sulphide (pyrrhotite±chalcopyrite), indicating that the WRP may have potential to host mineralization similar to that of the Wine showing.

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