GS2019-3

Geological investigations in the Russell–McCallum lakes area, northwestern Manitoba (parts of NTS 64C3–6)

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Summary

Bedrock mapping at a scale of 1:20 000 was undertaken by the Manitoba Geological Survey in the Russell–McCallum lakes area in the summer of 2019. The information gathered resulted in an updated regional framework and interpretation of this part of the Kisseynew basin. Outcrops in the Russell–McCallum lakes area are dominated by the coeval sedimentary rocks of the Burntwood and Sickle groups, granodiorite, and minor intrusive bodies and volcanic rocks. These rock units were sampled for lithogeochemical, petrographic, metamorphic, isotopic and geochronological studies. Details provided in this report are restricted to field descriptions and observations. Graphite contents of Burntwood sedimentary rocks suggest widespread economic potential for this commodity in the study area and possibly the Kisseynew domain in general.

In Brief:

- Updated bedrock geology and regional framework and interpretation of this part of the Kisseynew basin of the Trans-Hudson orogeny
- Bedrock outcrops are dominated by the coeval sedimentary rocks of the Burntwood and Sickle groups
- Graphite contents of Burntwood sedimentary rocks suggest widespread economic potential for this commodity in the Kisseynew domain

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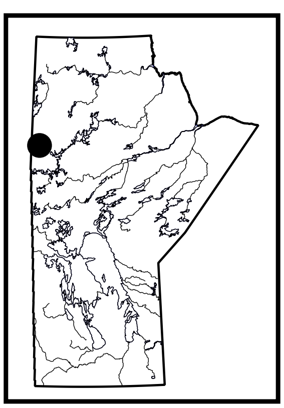
Introduction

Multidisciplinary geological fieldwork, investigating bedrock and surficial geology, was undertaken by the Manitoba Geological Survey (MGS) in the Russell–McCallum lakes area during July and August of 2019. Bedrock mapping was focused on the central and southern areas of Russell Lake, as well as the east–west channel that links Russell Lake to McCallum Lake. A few outcrops of Burntwood group rocks and iron formation were also examined and sampled at McCallum Lake. Results from bedrock mapping are presented here and on the accompanying map PMAP2019-3 (Martins and Couëslan, 2019), while surficial geology results are reported in Hodder (2019).

The main objectives of bedrock mapping in the Russell–McCallum lakes area were to

1) update the bedrock geology of the area and carry out lithogeochemistry, isotope and geochronology studies;
2) update the regional framework and tectonic interpretation of the area by taking into account recent work in the Trans-Hudson orogen (THO), particularly in the Granville Lake area (e.g., Zwanzig, 2019) on the north flank of the Kisseynew domain (KD);
3) provide an updated interpretation of the metamorphic conditions of the study area; and
4) update the knowledge of the economic potential of the KD, especially graphite occurrences reported by previous authors (e.g., Lenton, 1981) in light of the current market trends and growing interest in this commodity.

Rock descriptions and mineral estimates given in this report are based on outcrop observation. Further studies are needed to carry out metamorphic, tectonic and stratigraphic interpretations of the Russell–McCallum lakes area. All rocks in the study area were metamorphosed at upper-amphibolite–facies conditions (Lenton, 1981); however, for the sake of brevity, the term 'meta' has been omitted from rock names. Where possible, protolith interpretation was used in the naming of rock units.



Previous work

The Russell–McCallum lakes area was previously mapped by Downie (1936) of the Geological Survey of Canada (GSC) at a scale of one inch to four miles. Later, geological mapping by Hunter (1953) extended the regional coverage into McKnight Lake at a scale of one inch to two miles. The area last saw geological mapping by the MGS in the 1970s. McRitchie (1975a, b) mapped Russell Lake at a scale of one inch to one-half mile. The adjoining areas were mapped by Baldwin (1976) and Zwanzig and Wielezynski (1975) at a scale of one inch to one-half mile, and Pollock (1966) at a scale of one inch to one mile. The area to the west of Russell–McCallum lakes was mapped by Gilboy (1976) at a scale of 1:100 000. Lenton (1981) mapped from the Russell–McCallum lakes area to McKnight Lake. The Russell Lake area was also the target of economic studies focused on base-metal mineralization along the contact zone between two major stratigraphic units (Baldwin, 1976, 1980).

There are records of base-metal exploration work in the Russell–McCallum lakes area from 1954 until 1983 (e.g., Assessment Files 91616, 93803, Manitoba Agriculture and Resource Development, Winnipeg). As a result of this work, airborne electromagnetic surveys located a number of areas with good conductors. The airborne anomalies were commonly followed up by diamond-drilling. Base- and precious-metal assay results (e.g., Ni, Au, Ag, Cu) were not promising and led to abandonment of the claims. However, significant graphite mineralization was reported in the majority of drillholes (e.g., Assessment Files 92387, 93001, 93804). For example, graphite was described in Assessment File 90985 on work completed by Hudson Bay Exploration and Development Company Limited. The company drilled six holes in 1962 and reported up to 2.23 m (7.3 feet) of near-solid to solid graphite, pyrite and pyrrhotite; 1.9 m (6.2 feet) of well-mineralized graphite; and 1.2 m (4.1 feet) of mineralized graphite.

Regional geology

The Russell–McCallum lakes area is located along the north flank of the KD, a subdivision introduced by Zwanzig and Bailes (2010; Figure GS2019-3-1). The Kisseynew north flank is dominated by Paleoproterozoic metasedimentary rocks of the Burntwood and Sickle groups and granitoid rocks, which are bounded to the north by the Lynn Lake belt, to the east by the Thompson nickel belt and to the south by the central KD.

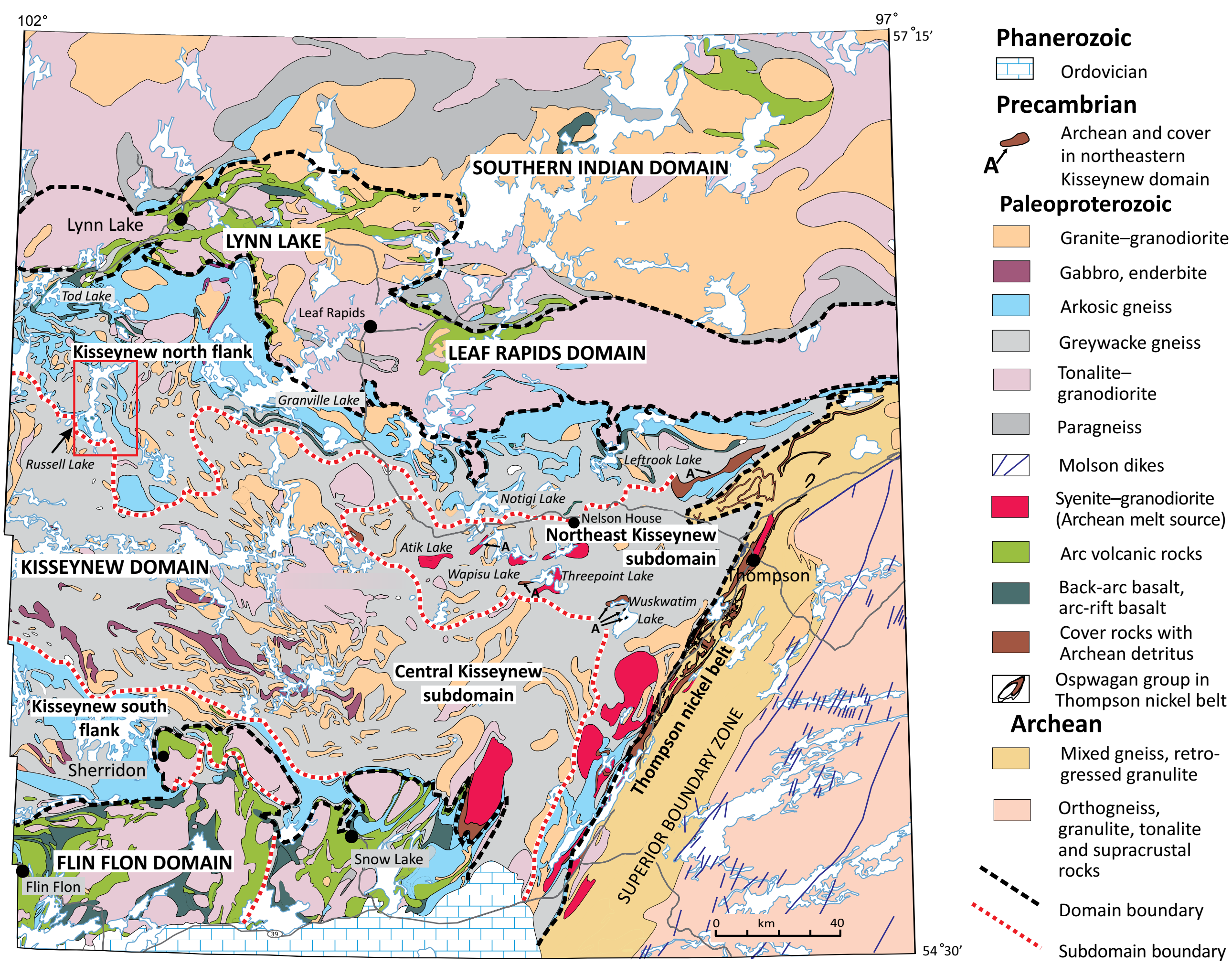


Figure GS2019-3-1: *Regional geology of the Trans-Hudson orogen (THO) in Manitoba, indicating the subdivision of the KD proposed by Zwanzig and Bailes (2010). Red rectangle outlines the study area.*

The KD forms the large central part of the predominantly juvenile Paleoproterozoic internides, which make up the Reindeer zone of the THO in Manitoba (Stauffer, 1984; Lewry and Collerson, 1990). It is dominated by metamorphosed greywacke and mudstone of the Burntwood group. The provenance of the Burntwood group is interpreted to be the adjacent magmatic-arc terranes. Detritus from the arcs was deposited in coalescing turbidite fans (Bailes, 1980; Zwanzig, 1999). The turbidites were deformed and metamorphosed to amphibolite and transitional granulite facies, resulting in migmatization. Rocks from the Sickle group are typically metamorphosed arkosic units interpreted to have been deposited unconformably on the Lynn Lake arc massif (Zwanzig, 2008), and prograded over the Burntwood group during the onset of terminal continental collision. Intrusive bodies in rocks of both the Burntwood and Sickle groups include foliated granitoid bodies ranging from granite to tonalite and later pegmatite (e.g., Lenton, 1981; Zwanzig and Bailes, 2010; Zwanzig, 2019).

The geological setting of the KD is a matter of debate. Some authors (Ansdell, 2005; Corrigan et al., 2005, 2009) favour the interpretation of the KD as a back-arc basin to the Flin Flon volcanic arc that was filled during its opening. However, other authors (e.g., Zwanzig, 1999; Zwanzig and Bailes, 2010) favour an interpretation of a longer lived and dynamic evolution in which the present geographic distribution of rocks resulted from crustal-scale overturning and oroclinal bending during continental collision.

Description of rock units

The majority of outcrops in the Russell–McCallum lakes area are dominated by sedimentary rocks of the Burntwood and Sickle groups, granodiorite and minor intrusive bodies, and volcanic rocks (Figure GS2019-3-2). The Burntwood and Sickle groups are interpreted to be coeval (e.g., Zwanzig and Bailes, 2010); therefore, the succession of units presented below is not to be interpreted as a true chronostratigraphic sequence. Figure GS2019-3-3 represents an idealized stratigraphic column for the area.

Mafic to ultramafic rocks (unit 1a–d)

Massive basalt (subunit 1a) is dark green-grey, medium to coarse grained and foliated, with massive layering <2 m thick. The composition is variable but typically consists of 60–70% amphibole, 20–30% plagioclase and 5–10% biotite, with trace amounts of pyrite and chalcopyrite, and rare magnetite. Local layers contain up to 10% garnet, which can be partially or completely pseudomorphously replaced by plagioclase (Figure GS2019-3-4a). Gossanous zones, typically <40 cm wide, are often associated with the mafic volcanic flows near the contact with the sedimentary rocks. In selected outcrops, discontinuously and heterogeneously banded (<10 cm) basalt may represent flow breccia. Local, patchy, green-coloured layers could either be a product of calcsilicate alteration or represent strongly attenuated pillowed basalt.

Pillowed basalt (subunit 1b) was identified in a few outcrops in the central and south parts of Russell Lake, as well as in the channel to Moyer Lake (Figure GS2019-3-1). The best preserved outcrops are located in the central area of Russell Lake. Pillowed flows, up to 5 m thick, range in colour from very dark green to black (Figure GS2019-3-4b). Pillows vary in size from 15 cm to 2 m and are typically densely packed or bun shaped with a 1:10 ratio of flattening. Pillow selvages are composed mostly of coarse-grained hornblende and plagioclase, or locally of only plagioclase, and exhibit positive relief. Selvages are typically 2–3 cm wide but can locally reach 12 cm. Rare top indicators are present west of Marshall Island, where pillow cusps indicate younging to the northeast. In the channel to Moyer Lake, pillow tops appear to young toward the south. Patchy to irregular, pale green calcsilicate alteration, present in some pillowed basalts, consists of varying amounts of epidote and carbonate. Where strain is high, this alteration was transposed parallel to the dominant deformation fabric, imparting a structural and metamorphic layering on the rock. The pillowed basalt is locally associated with gossanous zones that can be up to 20 cm in width. Assay results from these zones are pending.

Sparse intrusions (subunit 1c) of coarse-grained gabbro are associated with the basalt along the channel to Moyer Lake. The gabbro is dark green-grey, foliated and relatively homogeneous, with 50–60% hornblende in a groundmass of plagioclase. Discrete, relatively equant hornblende, <1 cm across, may be pseudomorphous after pyroxene phenocrysts. The contact between the basalt and gabbro appears disconformable. At one location, melagabbro with 10–20% plagioclase appears to grade over ~5 m into peridotite.

Ultramafic rocks (subunit 1d) range in composition from pyroxenite to peridotite. The pyroxenitic rocks are very dark green-brown to black, coarse grained, foliated and moderately to locally magnetic. Composition is variable, with 30–40% black clinoamphibole, 20–30% orthoamphibole, 20–30% green clinoamphibole, 3–5% serpentine and trace amounts of magnetite. Outcrops locally contain abundant biotite and magnetite, which are likely the result of hydrothermal alteration.

Peridotite is dark brown on weathered surfaces and very dark grey when fresh. It is weakly foliated to foliated and weakly to strongly magnetic. Outcrops are character-

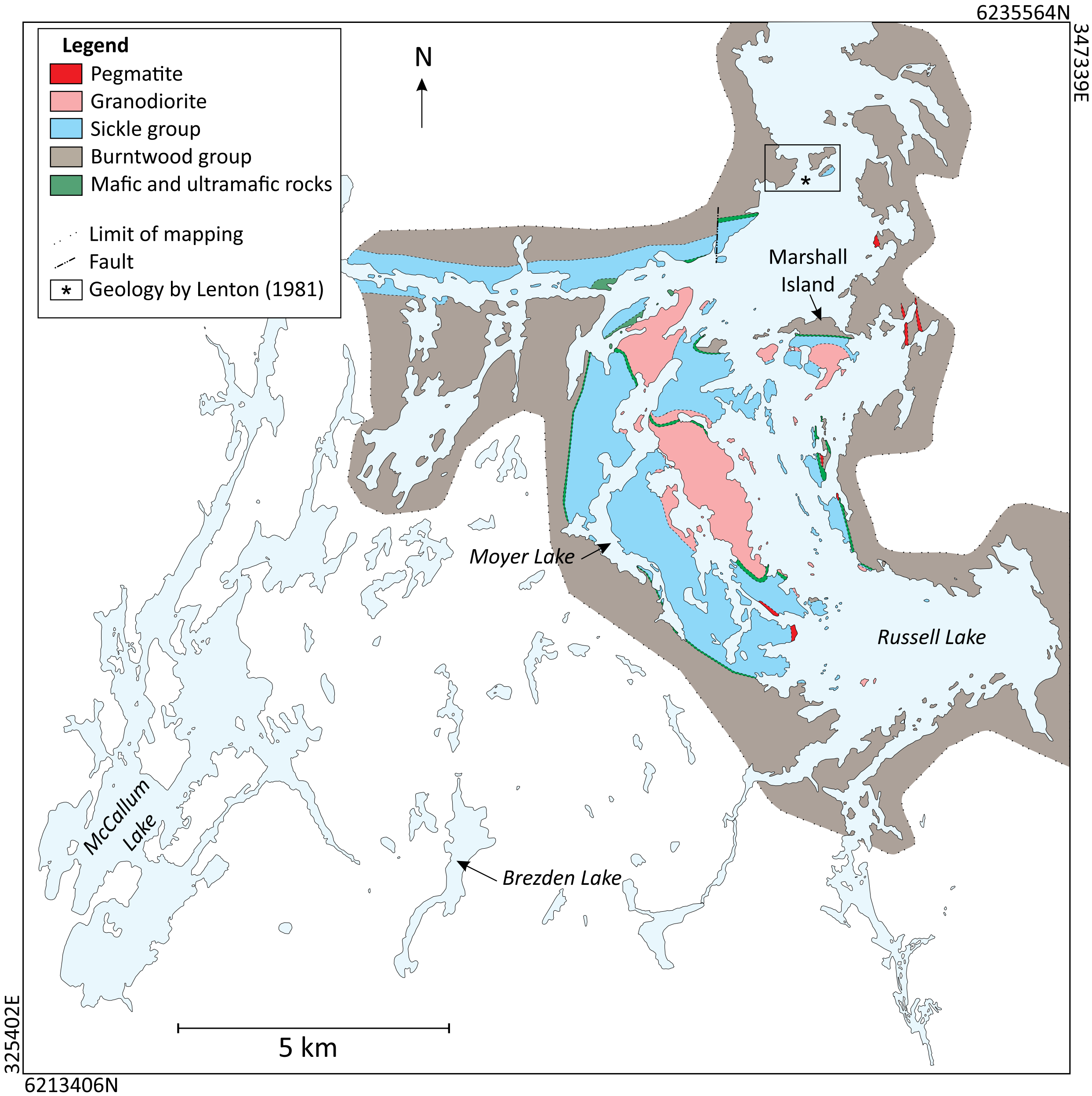


Figure GS2019-3-2: *Simplified geology of Russell Lake (after Martins and Couëslan, 2019; Lenton, 1981).*

ized by a fine- to medium-grained, amphibole-rich groundmass, commonly with patchy zones of knobby-textured surfaces dominated by coarse-grained orthoamphibole and/or orthopyroxene, alternating with zones dominated by a fine- to medium-grained, brown granular mineral, possibly olivine, with negative relief (Figure GS2019-3-4c). The composition of the groundmass is variable but typically consists of green clinoamphibole (10–20%), brown orthoamphibole (10–20%) and black clinoamphibole (hornblende, 20–30%). Local plagioclase (<5% as segregations <3 cm in width) and biotite (<15%) were identified at a few outcrops. Outcrops are locally transected by arrays of dextral shear bands separating relatively undeformed lenses of peridotite <1 m across. Local vuggy textures may be the result of differential weathering of carbonate or olivine, and local gossanous patches are present. The majority of peridotite outcrops occur as isolated reefs and islands, commonly surrounded by exposures of granodiorite (unit 11). These are interpreted as large-scale (tens of metres) xenoliths within the granodiorite. At one outcrop in the channel to Moyer Lake, a succession of massive and pillowed basalt, melagabbro and peridotite was observed, suggesting that the ultramafic rock is a subunit of the mafic volcanic rock suite. Samples were submitted for lithogeochemistry and results are pending.

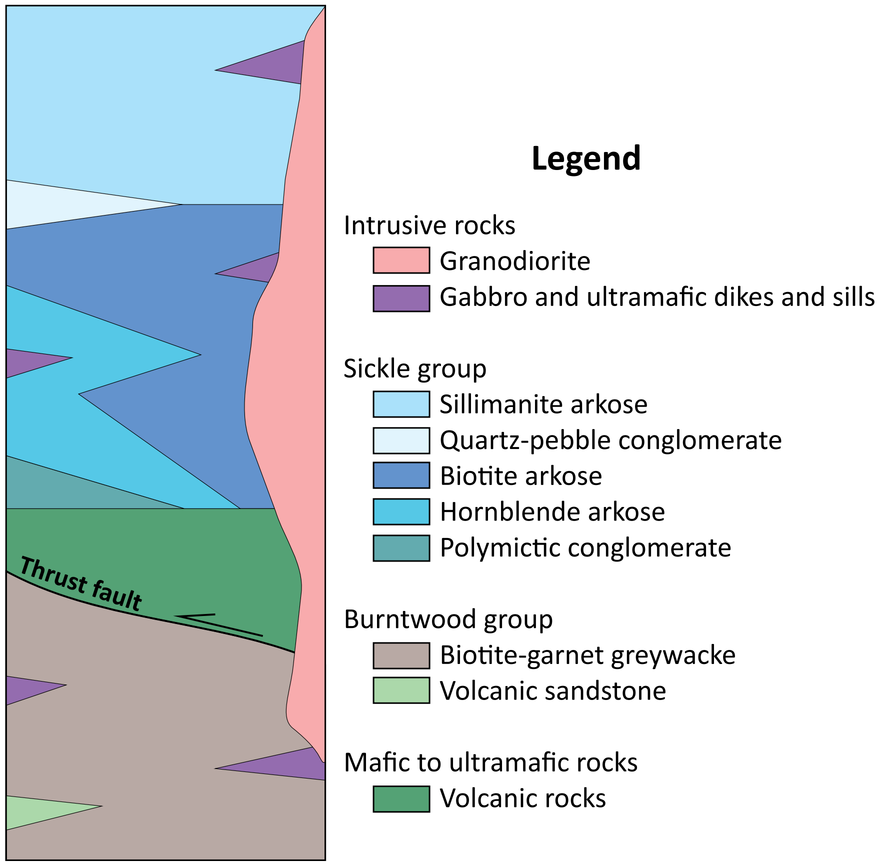


Figure GS2019-3-3: *Idealized, schematic stratigraphic column of the Burntwood and Sickle group rocks and volcanic rocks found in the Russell–McCallum lakes area.*

Burntwood group rocks (unit 2)

Typical outcrops of Burntwood group rocks consist of monotonous and rhythmically interbedded psammitic and pelitic layers with local pods of calcsilicate and sparse iron formation. The lack of unique marker horizons, combined with ubiquitous isoclinal folding, does not allow for the subdivision of Burntwood group rocks into smaller stratigraphic packages, nor for the tracing of stratigraphy between outcrops. A package of volcaniclastic rocks was identified within the Burntwood group in southern Russell Lake.

Garnet-biotite greywacke (subunit 2a)

The Burntwood group is dominated by garnet-biotite greywacke. It is typically light grey on weathered surfaces and medium grey where fresh, and nonmagnetic. Bedding typically varies from 30 cm to 1 m thick and alternates between psammitic and pelitic compositions. Psammitic layers are typically composed of quartz (30–40%), feldspar (20–30%), biotite (up to 15%), garnet (up to 10%) and graphite (trace amounts to 6%). The pelitic layers are composed of quartz (10–20%), feldspar (20–30%), biotite (20–30%), garnet (10–12%) and graphite (trace to 7%), with local sillimanite (<10%) and cordierite (<5%). Graphite is ubiquitous with apparently no preferential association with either the psammitic or the pelitic beds. Garnet can be absent in local exposures, with rare beds containing 3–5% orthoamphibole and/or orthopyroxene in place of garnet.

Younging-direction information is scarce. Graded bedding (Figure GS2019-3-4d) is visible at some outcrops, but opposite younging directions can be observed in the same outcrop, a characteristic also observed by Lenton (1981). The garnet-biotite greywacke is commonly isoclinally folded. Folding becomes complex with proximity to large-scale fold noses, making primary structural observations and measurements difficult. Local centimetre-scale calcsilicate nodules and minor layers consist of varying amounts of epidote, carbonate, amphibole, plagioclase and quartz. A combination of both in-source leucosome and pegmatite injections is present in the majority of outcrops. Pods of leucosome <20 cm thick commonly contain peritectic garnet±cordierite. Typically, more than a single generation of injections is present.

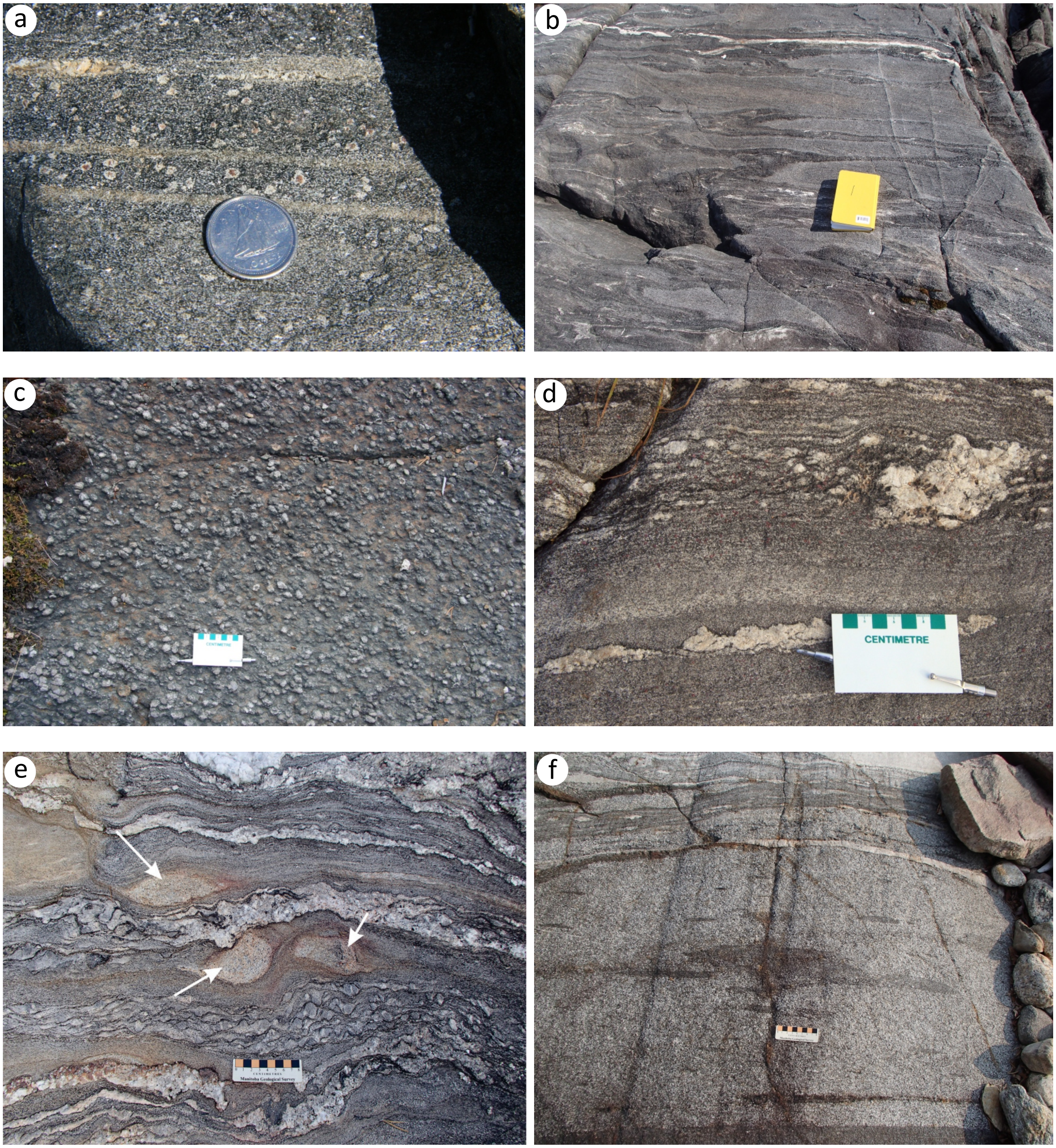


***Figure GS2019-3-4:** Outcrop photographs from the Russell Lake area: **a)** basalt (subunit 1a) with garnet partially replaced by plagioclase; **b)** pillowed basalt (subunit 1b), characterized by pillow selvages with positive relief; **c)** peridotite (subunit 1d), exhibiting knobby-textured surfaces dominated by coarse-grained orthoamphibole and/or orthopyroxene in a fine- to medium-grained, brown granular groundmass of possibly olivine, with negative relief; **d)** garnet-biotite greywacke of the Burntwood group (subunit 2a), showing a rare example of preserved graded bedding (younging toward the top of the photo); **e)** rounded felsic clasts (arrows) in garnet-biotite greywacke of the Burntwood group (subunit 2a); **f)** fragmental volcaniclastic rock of the Burntwood group (subunit 2b).*

In the south basin of Russell Lake, an outcrop of Burntwood group contains a pebbly layer (Figure GS2019-3-4e) that possibly marks the base of a turbidite sequence, or the pebbles could represent a low-stand or deposits in close proximity to a submarine channel. Clasts and cobbles within the pebbly layer are rounded and mostly felsic in composition; alternatively, the clasts and cobbles could represent intensely boudinaged felsic dikes.

On the east shoreline of central Russell Lake and in minor bays south of the channel to McCallum Lake, rose quartz was found in boudinaged segregation pieces up to 30 cm wide in quartz veins within the garnet-biotite greywacke. Rusty layers in the garnet-biotite greywacke were observed in the south part of the mapping area, and a graphitic, sulphide-facies iron formation, >5 m thick, occurs along the west shore of McCallum Lake. Assay results for these rusty layers are pending.

Volcaniclastic rocks (subunit 2b)

Volcaniclastic rocks were found associated with the garnet-biotite greywacke of the Burntwood group along the southwest shore of Russell Lake. This subunit is variable in composition (felsic to mafic) and texture (massive to fragmental; Figure GS2019-3-4f). The more felsic variety is coarse grained, homogeneous, foliated and nonmagnetic. It weathers medium grey and is dark grey on fresh surfaces. It contains plagioclase (60–70%), quartz (10–15%) and biotite (12–15%). The mafic variety is locally coarse grained and magnetic, and contains hornblende and biotite (55–65%), plagioclase (20–30%), quartz (5–8%) and trace amounts of magnetite. The matrix of the fragmental rock is felsic to mafic in composition, with hornblende and biotite. Fragments (<15 cm) are subrounded to angular and typically intermediate to mafic but rarely felsic. Rare calcsilicate nodules were also observed within the fragmental rock unit. Locally, the intermediate fragmental rock grades into the garnet-biotite greywacke with sparse layers of mafic tuff. All the outcrops are cut by 15–20 cm wide tonalitic injections.

The more felsic and massive variety of the volcaniclastic rock subunit could be interpreted as tonalite, recrystallized felsic volcanic sandstone or a dacitic flow. The more mafic rock could be interpreted as a gabbro intrusion or recrystallized mafic volcaniclastic rock. The fragmental variety could be interpreted as a volcanic sandstone or conglomerate, or the fragments could be considered cognate xenoliths of an intermediate to mafic intrusion. Pending further analyses, the authors favour a volcaniclastic origin. Volcanic deposits within the Burntwood group were described by Zwanzig and Bailes (2010) near Puffy Lake on the south flank of the KD.

Gabbro and pyroxenite (unit 3)

Gabbro and pyroxenite were identified at two locations in the south basin of Russell Lake. A crosscutting intrusive contact between pyroxenite and Burntwood group rocks was observed at both locations.

Gabbro is dark grey weathering to salt and pepper, medium to coarse grained and nonmagnetic. It contains hornblende (50–60%), plagioclase (40–50%) and quartz (<5%). Pyroxenite is dark grey, coarse grained, foliated and weakly magnetic. At the contact with the Burntwood group garnet-biotite greywacke, partially digested calcsilicate nodules are observed, likely originating from the sedimentary rocks. An intrusive breccia consisting of pyroxenite fragments in a tonalitic matrix is locally associated with the pyroxenite (Figure GS2019-3-5a).

Sickle group rocks (units 4–8)

Five different arkosic rocks were distinguished within the Sickle group (listed by inferred stratigraphic order): polymictic conglomerate, hornblende arkose, biotite arkose, quartz-pebble conglomerate and sillimanite arkose.

Polymictic conglomerate (unit 4)

Polymictic conglomerate is poorly exposed in the map area. Outcrops of this unit were found on a peninsula on the east–west channel that connects Russell and McCallum lakes, and in the channel to Moyer Lake. Typically, outcrops are highly deformed and the conglomerate assumes a strongly banded, gneissic texture. A less deformed portion of an outcrop in the channel to Moyer Lake shows conglomerate in direct contact with gabbro (subunit 1c; Figure GS2019-3-5b). Conglomerate is clast supported, with clasts varying in size (up to 30 cm but typically <15 cm across). Composition of the clasts varies from felsic (20–30%) to mafic (20–30%), and the matrix is intermediate. Clasts of intermediate composition may also be present but would be indistinguishable from the matrix due to recrystallization.

Hornblende arkose (unit 5)

This unit typically occurs at the contact with the mafic to ultramafic rocks (unit 1). It is crudely layered but can be well bedded in close proximity to basalt; however, this could be the result of strain partitioning toward the contact. Compositional layering was observed in some outcrops where 20–40 cm thick light grey layers alternate with 5–15 cm thick dark grey layers, reflecting variations in the mafic mineral content. Hornblende arkose is green-pink and weathers to green-grey. It is foliated, weakly magnetic and typically medium to coarse grained. Composition is variable but typically consists of feldspar (40–50%), quartz (25–30%, locally up to 50%), hornblende (10–15%, locally up to 30%), biotite (5–7%), epidote (2–3%) and magnetite (trace to 1%). Hornblende arkose locally grades into mafic sandstone at the basalt contact. The mafic sandstone is quartzofeldspathic (plagioclase>>K-feldspar), with

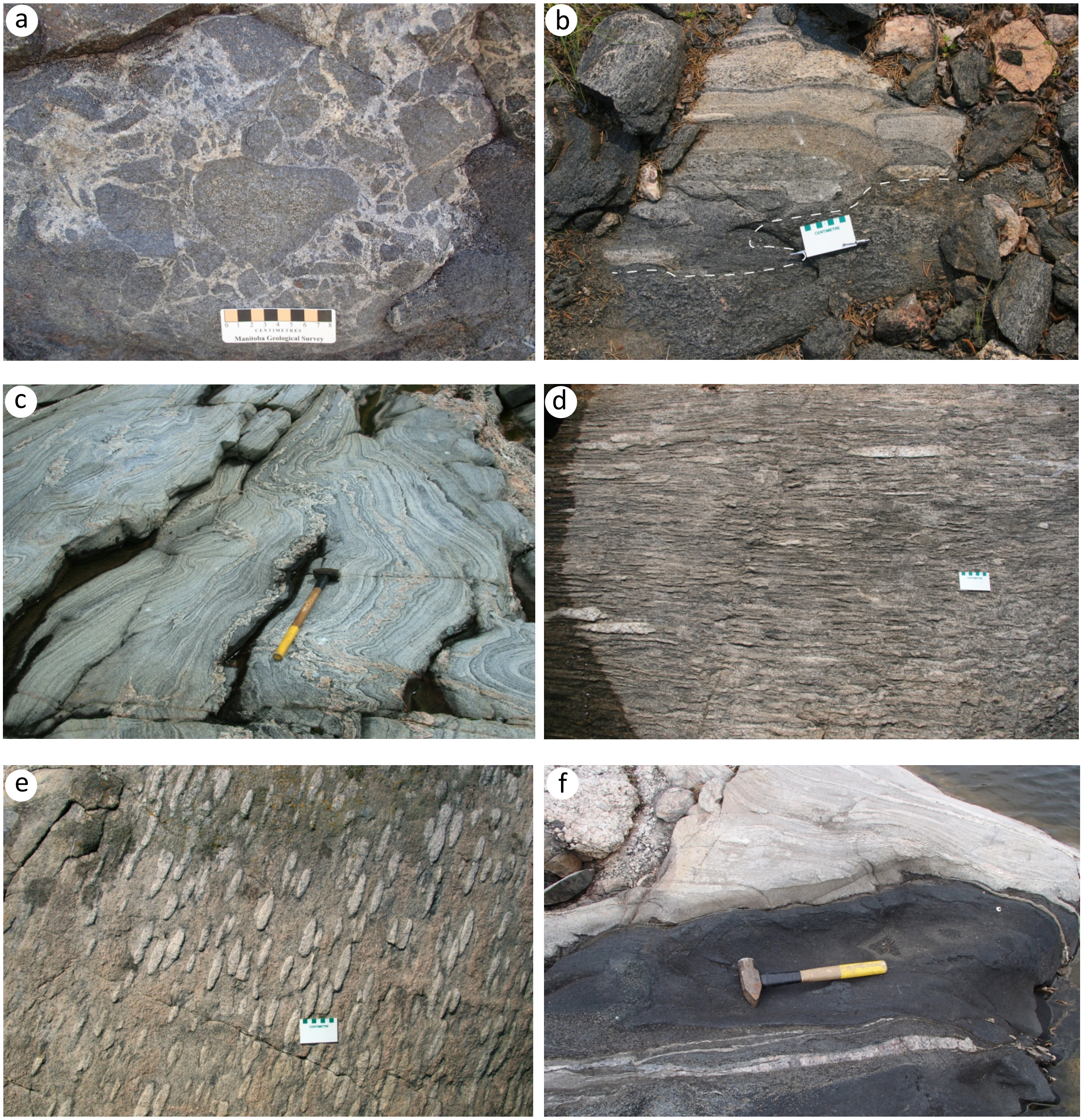


***Figure GS2019-3-5:** Outcrop photographs of mafic and ultramafic rocks and Sickle group rocks from the Russell Lake area: **a)** intrusive breccia (unit 3) with tonalitic matrix; **b)** polymictic conglomerate of the Sickle group (unit 4) in contact (dashed line) with gabbro, along the channel to Moyer Lake; **c)** example of well-bedded biotite arkose of the Sickle group (unit 6); **d)** attenuated clasts of the quartz-pebble conglomerate of the Sickle group (unit 7); **e)** sillimanite knots in sillimanite arkose (unit 8); **f)** ultramafic dike cutting biotite arkose of the Sickle group.*

30–50% hornblende. Granitic injections are common. Hornblende arkose contains calcsilicate boudins up to 75 cm wide.

A local variation of hornblende arkose is a coarsely recrystallized gneiss with a slightly different composition. It appears bleached and is strongly foliated and strongly magnetic, with nodules of carbonate, epidote and scapolite. The rock contains feldspar (40–50%), quartz (20–30%), green pyroxene (10–15%), titanite (3–5%), epidote (3–5%), magnetite (1–2%) and scapolite (1–2%). Lithogeochemical results may aid in determining the petrogenesis of this unit. Contacts between hornblende arkose and overlying biotite arkose are generally gradational; however, relatively sharp contacts were also observed.

Biotite arkose (unit 6)

Biotite arkose is light pink-grey and weathers to light grey (Figure GS2019-3-5c). It is medium to coarse grained, layered to locally laminated, magnetic, foliated and folded with minor isoclinal folds. Biotite arkose typically consists of quartz (30–40%, locally up to 50%), feldspar (20–30%), biotite (7–10%, locally up to 20% in more aluminous layers) and magnetite (trace to locally 2%). Layering typically consists of thin biotite-enriched laminations (2–3 mm) alternating with thicker quartzofeldspathic layers (<10 cm). Sparse crossbedding was identified. Local calcsilicate layers and nodules are composed mostly of epidote, quartz and plagioclase, with local carbonate. Biotite arkose locally contains well-rounded pebbles, especially along the channel to Moyer Lake. Both concordant and discordant granitic injections are present in most outcrops, which suggests more than one generation. Local pods of leucosome were also identified (commonly <7 cm wide). A local variety of biotite arkose in the channel to McCallum Lake contains garnet (up to 5%) and sillimanite (up to 7%). There, biotite arkose appears to grade into the overlying sillimanite arkose.

Quartz-pebble conglomerate (unit 7)

Quartz-pebble conglomerate was only recognized in and near the channel to Moyer Lake, where it grades into the underlying biotite arkose and overlying sillimanite arkose as discrete conglomerate and pebbly beds <50 cm thick. It is dark grey weathering to light grey on fresh surfaces and locally magnetic. The conglomerate ranges from clast to matrix supported and is massively bedded at a scale of <2 m. Gravel clasts are well rounded, <10 cm and consist dominantly of quartz. Local felsic and sparse granite, calcsilicate, mafic and intermediate clasts are also present. The clasts are typically stretched and attenuated (Figure GS2019-3-5d). The matrix of the conglomerate varies from compositions similar to the biotite and sillimanite arkoses with minor garnet to a plagioclase-rich matrix with 2–3% garnet, 10–20% biotite and 10–20% quartz. Local plagioclase-rich clasts of similar composition can occur within these same beds. The conglomerate contains calcsilicate concretions and discontinuous calcareous layers, <1 m thick, that are epidote and quartz rich.

Sillimanite arkose (unit 8)

Sillimanite arkose is dark grey weathering to light pinkish grey on fresh surfaces. It is medium grained, foliated, massively bedded and weakly magnetic (local <15 cm thick beds are strongly magnetic), with local calcsilicate layers. Sillimanite arkose contains quartz (30–40%, locally up to 50%), plagioclase and K-feldspar (30–50%), biotite (3–5%), sillimanite (up to 30% in the more aluminous layers), magnetite (trace to 1%) and trace amounts of ilmenite. The amount of sillimanite in this unit can be variable, with less aluminous horizons containing 3–5% and more aluminous sections 15–30%. Sillimanite commonly occurs along foliation planes; in more aluminous layers, it occurs as abundant sillimanite knots, typically <2 cm but locally up to 20 cm (Figure GS2019-3-5e). Magnetite is commonly present in the core of the sillimanite knots.

Mafic to ultramafic dikes and sills (unit 9)

Mafic to ultramafic dikes and sills intrude both the Sickle and Burntwood group rocks. Although generally similar, the intrusions in the Sickle group are typically ultramafic (Figure GS2019-3-5f), whereas intrusions in the Burntwood group are usually mafic and locally layered. The intrusions are typically <40 cm but reach up to 2 m in width; are black, medium to coarse grained, foliated and locally boudinaged; and range from nonmagnetic to magnetic. Conformable and layered examples could represent flows rather than sills; however, local discordancy suggests an intrusive origin for at least some of this unit. The composition is variable but is typically hornblende (90–95%), plagioclase (5–7%) and phlogopite (2–5%) for the ultramafic sills intruding the Sickle group; and hornblende (70–80%), plagioclase (10–15%, locally up to 30%), biotite (1–2%) and trace amounts of magnetite for mafic intrusions in Burntwood group greywacke. Mafic sills were described from the Missi group on the south flank of the KD (Zwanzig and Bailes, 2010) and could be similar to the ones observed at Russell Lake. Lithogeochemical data may help clarify the petrogenesis and potential relationships between these intrusions.

Hornblende-biotite diorite (unit 10)

Hornblende-biotite diorite was recognized in two locations along the channel into Moyer Lake, where it occurs enclosed in granodiorite. The diorite weathers dark grey to light grey and is medium grained and foliated. Mafic minerals consist of 5–10% biotite and 10–15% hornblende. It is relatively homogeneous and has local granitic pegmatite injections. An exposed contact suggests that granodiorite is intrusive into diorite. The close spatial association and textural similarity, however, may suggest that diorite is an early magmatic phase related to granodiorite.

Granodiorite (unit 11)

Granodiorite forms the most abundant type of granitoid rock in the Russell Lake area. These intrusions are interpreted as domes within the cores of major fold structures (Zwanzig and Bailes, 2010). Granodiorite is pale pink and weathers white to beige. It is medium grained, foliated and nonmagnetic. It typically contains 40–50% plagioclase, 20–30% quartz, 10–15% K-feldspar and 5–7% biotite. Granodiorite is relatively homogeneous, with local pods of leucosome and pegmatite injections. Local exposures display a discontinuous gneissosity. Minor isoclinal folds were observed in gneissic sections. A porphyritic texture of relatively coarse-grained quartz (<0.5 cm) was observed at selected outcrops. Local, partially digested xenoliths of Burntwood or Sickle group, as well as mafic rocks (unit 1), can be present in the granodiorite.

Granitic pegmatite (unit 12)

Pegmatite bodies are common in the Russell–McCallum lakes area and cut all map units; however, multiple generations of intrusions are present. They are typically albite dominant, but K-feldspar–dominant pegmatite bodies are also present. Other major constituents are quartz and biotite. Common accessory minerals are magnetite, muscovite, garnet and, locally, cordierite and sillimanite. Pegmatite bodies are typically steeply dipping and occur either discordant to the main foliation and gneissosity or concordant and locally folded (most likely by F_3). Most pegmatite dikes are <2 m wide (some can be up to 30 m) and unzoned or very crudely zoned, with characteristic granitic pegmatite textures such as graphic and local comb textures. Dikes locally display both pegmatitic and aplitic zones.

Metamorphism

The metamorphic history of the Russell–McKnight lakes area, which includes the present study area, was described in detail by Lenton (1981) based on textures identified in both outcrop and thin section. Four metamorphic events (M_1 to M_4) were identified: two prograde events culminated in upper-amphibolite–facies metamorphic conditions and two events were retrograde. The M_1 event is best preserved in psammitic rocks, whereas the M_2 event is best preserved in pelitic rocks. It is possible that this discrepancy is simply the result of different metamorphic reactions that occurred in different bulk compositions during a single prograde event. Maximum temperature and pressure during peak metamorphism were estimated at 600–700°C and 2–3 kbar, respectively. A zone of lower metamorphic grade was interpreted to occur at the south end of McCallum Lake. Metamorphic conditions there were estimated to be subsolidus (middle amphibolite facies) and attained 600–630°C and 2.5 kbar; however, examples of in-situ and in-source leucosome were observed, calling this interpretation into question. Additional work is planned to re-examine the metamorphic geology of the Russell Lake area.

Structural geology

The central area of Russell Lake presents a complex structural history. The structural interpretation from McRitchie (1975a, b) and Lenton (1981) was adopted for this project. Various discussions with H. Zwanzig (MGS, retired) also contributed to the understanding and interpretation of the structural geology of the central Russell Lake area. Lenton (1981) divided the deformation history of the Russell–McCallum lakes area into five components: three generations of folding and two generations of brittle fractures with different orientations. All deformation is interpreted to postdate the deposition of the Burntwood and Sickle groups. The D_1 event resulted in large-scale recumbent isoclinal F_1 folds with major inversions and repetitions. Subsequent deformation largely obscures D_1 structures. The D_2 phase resulted in northwest-trending, shallowly plunging, inclined isoclinal F_2 folds. The F_2 folds are characterized by large amplitude to wavelength ratios. As a result, fold noses were rarely observed and the presence of F_2 folds was recognized by repetitions of the stratigraphic section. The D_3 event resulted in northeast-trending, irregularly shaped and disharmonic open folds, and associated strong linear and planar fabrics in the direction of the F_3 fold axes. Most linear fabrics observed in the map area parallel regional F_3 fold axes. The D_4 and D_5 events are manifested by brittle faults and cataclastic zones, which are northwest trending and north trending, respectively. The brittle structures postdate all phases of folding.

Economic considerations

Infrastructure and accessibility are important aspects in any mineral-development project. The Russell–McCallum lakes area is easily accessible by float plane out of Lynn Lake and rail from The Pas, and a power line and two power-generating stations (Laurie River I and II) are present nearby.

Sediment-hosted stratiform base-metal mineralization and volcanogenic massive-sulphide exploration took place in the Russell–McCallum lakes area until the early 1980s. However, the area was abandoned when no significant occurrences of Ni, Cu, Zn, Au or Ag were found. Assessment files from the area reveal that drill testing of geophysical conductors typically resulted in the intersection of graphite mineralization, and graphite is noted in the majority of drill logs. Because graphite was not a widely sought commodity at that time, no significance was given to those findings.

Natural graphite has several uses, including anode material for Li-ion batteries, brake linings, lubricants, powdered metals, refractory applications and steelmaking (U.S. Geological Survey, 2019). Currently, natural graphite is a highly-sought commodity due to its anticipated demand associated with the production of Li-ion batteries. Graphite is listed by the U.S. Department of the Interior as one of 35 critical minerals for the United States (U.S. Department of the Interior, 2018) and by the European Commission as part of its list of critical raw materials for the European Union (European Commission, 2017).

The Russell–McCallum lakes area shows clear evidence of and economic potential for graphite mineralization. Lenton (1981) reported up to 0.16 wt. % total carbon in pelitic rocks from the Burntwood group. During this study, however, it was not possible to establish a clear relationship between the graphite content and the composition of the Burntwood group rocks (psammitic versus pelitic bulk compositions). It is possible that the graphite is widespread throughout the Burntwood group sequence. Field observations identified up to 7% graphite in Burntwood group garnet-biotite greywacke. Assay results from graphite mineralization associated with sulphide-facies iron formation at McCallum Lake, as well as from garnet-biotite greywacke at Russell Lake, are pending.

A syenite complex with potential to host rare-earth–element mineralization occurs at Brezden Lake (Martins et al., 2012; Martins, 2016), between Russell and McCallum lakes (Figure GS2019-3-2). Similar intrusions were not observed during the course of the 2019 fieldwork, even though the KD in general is considered to have potential for these types of intrusions (e.g., Martins et al., 2011).

Archean cratons can be important regional vectors for diamond exploration. In east-central Saskatchewan, two diamond occurrences (the Fort à la Corne kimberlite field and the Pikoo kimberlite) are located in areas thought to be underlain at depth by the mostly buried Archean Sask craton. Determining the potential extent of Archean crust in the KD may help to inform diamond exploration in the region. Some authors have interpreted the Sask craton to extend significantly under the KD, including the Russell–McCallum lakes area (Zwanzig and Bailes, 2010). Currently, the MGS has little evidence for diamond potential in this area; therefore, a kimberlite-indicator–mineral survey was carried out this summer (Hodder, 2019). Additional information regarding drift prospecting in the Russell–McCallum lakes area is available in Hodder (2019).

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