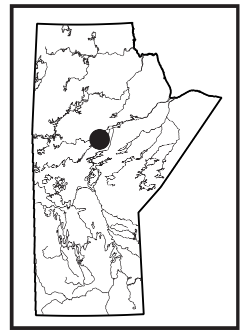
GS-2 Preliminary results from bedrock mapping in the Partridge Crop Lake area, eastern margin of the Thompson nickel belt, central Manitoba (parts of NTS 63P11, 12) – Year Two

by C.G. Couëslan



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Summary

This report follows the second summer of mapping on Partridge Crop Lake, focusing on the Fish Bay area and with an emphasis on protolith interpretation of Pikwitonei granulite domain rocks. This area was subjected to relatively uniform, high-grade Neoarchean metamorphism and deformation, and was variably overprinted by moderate- to high-grade Paleoproterozoic metamorphism and deformation. Exposures in the Partridge Crop Lake area are divided into Archean and Paleoproterozoic rocks. Archean rocks include a mafic volcanic assemblage, gabbro, tonalite-granodiorite gneiss, diorite gneiss, schollen-bearing tonalite–granodiorite gneiss, leucotonalite-leucogranodiorite and two-mica granite. Paleoproterozoic rocks consist of syenite, mafic to ultramafic dikes, granite dikes, granitic pegmatite and carbonate-quartz veins. A roughly east-trending, subvertical Archean gneissosity is intersected by a generally northeast-trending, subvertical Paleoproterozoic foliation that is axial planar to minor folds. The degree of Paleoproterozoic deformation increases toward the west, where the Archean gneissosity is transposed into the Paleoproterozoic foliation. Archean granulite-facies metamorphic assemblages are progressively overprinted by Paleoproterozoic middle-amphibolite–facies metamorphic assemblages from east to west across the map area. The middle-amphibolite–facies assemblages are in contrast to the Paleoproterozoic granulite-facies assemblages that characterize the rocks on Paint Lake, roughly 6 km west across strike, and suggest the presence of a crustal-scale structure between Partridge Crop and Paint lakes.

Exhalative rocks, hydrothermally altered rocks and gossanous zones associated with mafic volcanic rocks suggest potential for Archean gold and base-metal (volcanogenic massive-sulphide, VMS) mineralization.

Introduction

A project was initiated in 2012 to remap portions of the Pikwitonei granulite domain (PGD; Couëslan et al., 2012; Couëslan, 2013a, b). The objective was to re-examine the mafic, intermediate and enderbitic (orthopyroxene-bearing tonalite) gneisses, with an emphasis on protolith interpretation rather than descriptive petrography (e.g., hornblende-biotite gneiss). Additionally, the information gathered through the course of mapping should provide further insight into the tectonic significance of the PGD (e.g., Weber, 1983) and the mineral potential of the region. Due to the high metamorphic grade and the apparent lack of supracrustal rocks, the PGD has traditionally been considered to have insignificant or lower mineral potential compared to the adjacent, lower-grade metamorphic domains.

Two weeks of geological mapping was conducted at 1:20 000 scale in the Fish Bay area of Partridge Crop Lake in July of 2014 (Figure GS-2-1; Couëslan, 2014). Mapping is continuous with geological mapping from 2013 (Couëslan, 2013b). Previous workers recognized that the Partridge Crop–Natawahunan lakes region contains a larger proportion of supracrustal rocks than other portions of the PGD (Dawson, 1952; Weber, 1978); hence, the Partridge Crop Lake area was revisited to better constrain the nature of these supracrustal rocks through the use of petrography, geochemistry and isotopic methods. In addition, Partridge Crop Lake is situated on the eastern margin of the Thompson nickel belt (TNB), so the map area was investigated for potential Ni mineralization hosted in ultramafic rock and the possible presence of Ospwagan Group metasedimentary rocks.

Regional geology

The PGD is a Neoarchean high-grade metamorphic domain along the northwestern margin of the Superior province. It is exposed over a length of approximately 200 km, with a maximum width of 75 km in the Split Lake area (Hubregtse, 1980; Böhm et al., 1999). A regional orthopyroxene-in isograd, which is oblique to the generally east-trending fabrics of the Superior province, marks the southeastern boundary of the domain (Hubregtse, 1980; Heaman et al., 2011). The northwestern boundary is defined by Paleoproterozoic Hudsonian (ca. 1.83–1.70 Ga) north-northeast-trending deformational fabrics of the TNB that truncate the east-trending Neoarchean fabrics of the PGD (Hubregtse, 1980; Bleeker, 1990; Heaman et al., 2011; Kuiper et al., 2011; Couëslan et al., 2013).

The PGD is underlain by dominantly enderbitic, opdalitic (orthopyroxene-bearing granodiorite), and minor leuconoritic gneiss and mafic granulite (metagabbro, metapyroxenite and metabasalt; Hubregtse, 1978, 1980; Heaman et al., 2011). Supracrustal rocks are considered to be relatively rare in the PGD, which has experienced two main generations of Archean deformation and

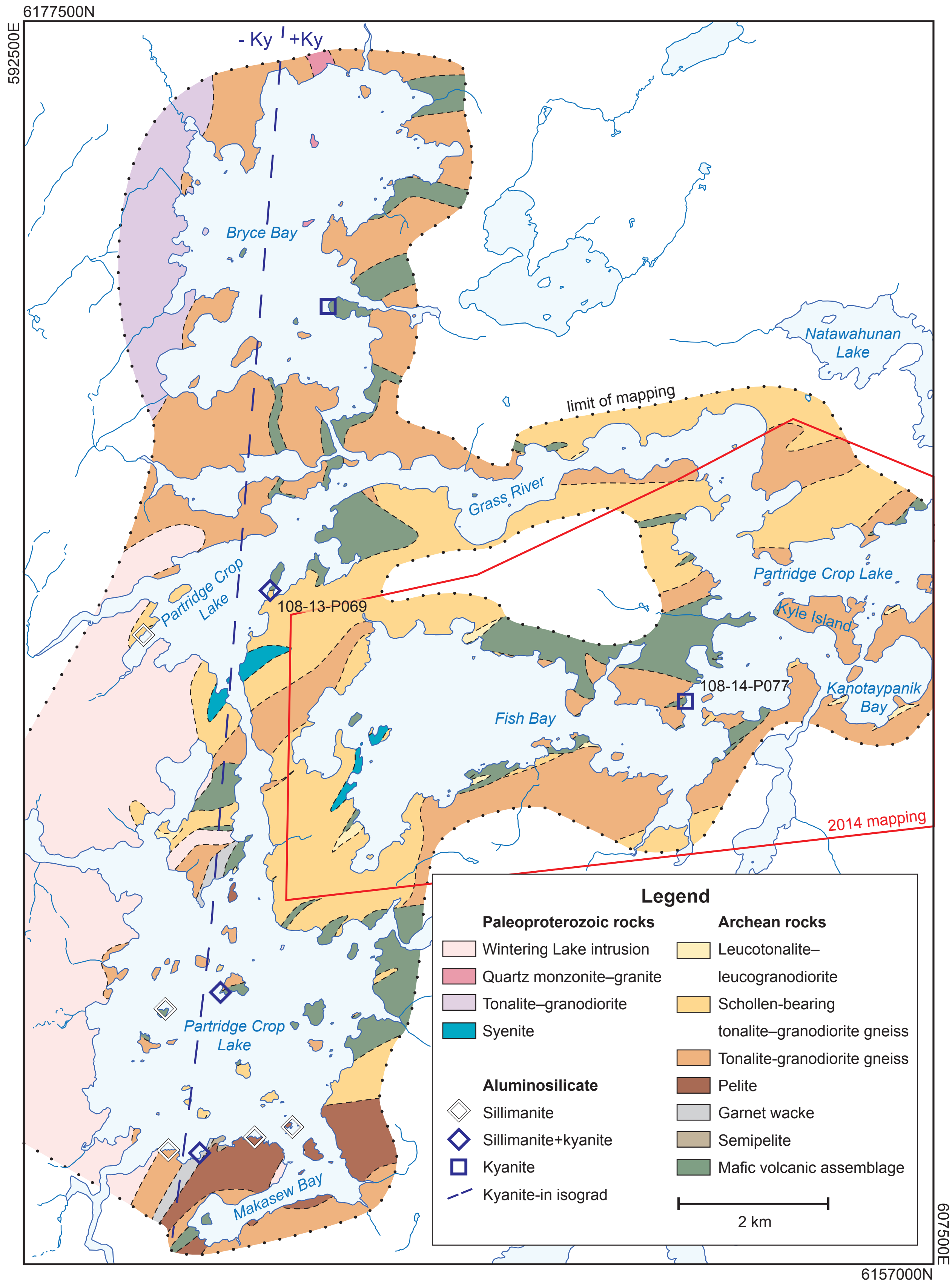

Figure GS-2-1: *Simplified geology of the Partridge Crop Lake area, showing the 2014 study area, the locations of aluminosilicate occurrences, aluminous rock samples and the kyanite-in isograd (modified from Couëslan, 2014).*

metamorphism. The D_1–M_1 generation (ca. 2695 Ma; Heaman et al., 2011) resulted in well-defined, northwest-trending metamorphic banding (S_1) accompanied by isoclinal folding (Hubregtse, 1980). The accompanying M_1 metamorphism is interpreted to have attained amphibolite– to locally lower-granulite–facies conditions (Hubregtse, 1978, 1980). This was followed by M_2 metamorphism (ca. 2680 Ma; Heaman et al., 2011), which resulted in pervasive granulite-facies metamorphic conditions throughout the PGD (Hubregtse, 1980; Mezger et al., 1990). Mezger et al. (1990) interpreted the M_2 event to follow a counter-clockwise P–T–t path; however, textural evidence observed on Cauchon, Armstrong and Partridge Crop lakes is more suggestive of a clockwise P–T–t path (Couëslan, 2013b; Couëslan, GS-1, this volume). The M_2 metamorphism was largely postdated by D_2, which resulted in the development of S_2 fabrics and transposition of S_1 into west-southwest-trending shear folds (Hubregtse, 1980; Heaman et al., 2011; Couëslan, 2013a).

In the TNB region, the granulitic rocks of the PGD were exhumed and unconformably overlain by the Paleoproterozoic supracrustal rocks of the Ospwagan group (Scoates et al., 1977; Bleeker, 1990; Zwanzig et al., 2007). A minimum age for the Ospwagan group is provided by crosscutting amphibolitized dikes, interpreted to be part of the ca. 1880 Ma Molson dike swarm, and possibly comagmatic ultramafic sills, which intruded the Ospwagan group supracrustal rocks at all stratigraphic levels and host the magmatic nickel deposits (Bleeker, 1990; Burnham et al., 2009; Heaman et al., 2009; Scoates et al., 2010).

The Ospwagan group and underlying gneisses were affected by three main generations of deformation during the Trans-Hudson orogeny (Bleeker, 1990; Burnham et al., 2009). Early deformation (D_1) predates the ca. 1880 Ma mafic magmatism (Molson dikes); however, this early deformation is largely obscured by later deformation. The dominant phase of penetrative deformation (D_2, ca. 1830–1775 Ma; Bleeker, 1990; Couëslan et al., 2013) resulted in the refolding and tightening of F_1 folds and the development of isoclinal to recumbent F_2 folds. The recumbent folds are accompanied by regionally pervasive S_2 fabrics. Microstructural observations suggest that peak metamorphic conditions of middle-amphibolite– to lower-granulite–facies were attained during, and possibly outlasted, D_2 (Couëslan and Pattison, 2012). The D_3 generation of deformation resulted in tight, vertical to steeply southeast-dipping, isoclinal F_3 folds (ca. 1760–1700 Ma; Bleeker, 1990, Burnham et al., 2009; Couëslan et al., 2013). The isoclinal nature of both F_2 and F_3 results in a coplanar relationship between S_2 and S_3 along F_3 fold limbs. Mylonite zones with subvertical stretching lineations parallel many of the regional F_3 folds and are characterized by retrograde lower-amphibolite– to greenschist–facies mineral assemblages (Bleeker, 1990; Burnham et al., 2009). Kinematic indicators in these northeast-striking shear zones commonly suggest southeast-side-up sinistral movement (Bleeker, 1990; Burnham et al., 2009). The D_3 structures appear to exert a first-order control on the present day distribution of metamorphic zones within the belt (Couëslan and Pattison, 2012).

Local geology

The Partridge Crop Lake area is underlain by dominantly granitoid gneiss, with irregular belts of supracrustal rocks and mafic gneiss (Dawson, 1952; Weber, 1978; Böhm, 1998). Although Dawson (1952) suggested a sedimentary origin for garnet- and quartz-bearing gneisses in the area, Weber (1978) interpreted these rocks to be derived from fumarolic alteration, or possibly metasomatism related to granitic magmatism, of basaltic rocks. Numerous gabbroic and locally peridotitic dikes occur throughout the area, and typically crosscut the gneissic rocks (Dawson, 1952; Böhm, 1998). The dikes likely correspond to two periods of mafic magmatism related to the Molson dike swarm (ca. 1880 Ma) and an older east-northeast-trending swarm (e.g., Cauchon Lake, Gull Rapids, Birthday Rapids [ca. 2090 Ma]; Scoates and Macek, 1978; Heaman et al., 1986; Halls and Heaman, 2000; Heaman et al., 2009). The western part of the Partridge Crop Lake area is underlain by the extensive granitic to granodioritic Wintering Lake intrusion, which has yielded U-Pb ages of 1846 ±8 and 1822 ±5 Ma (Machado et al., 2011a, b).

The Partridge Crop Lake area represents a transition zone approximately 10 km wide, where east-striking Archean granulite-facies rocks of the PGD grade structurally and mineralogically into north-northeast-trending amphibolite-facies rocks of the TNB (Weber, 1976). East-striking gneisses in the eastern part of the transition zone are folded with axial planes of minor folds striking 010–020°. The deformation intensifies toward the west, where the Archean gneissosity becomes transposed into a northeast or north-northeast direction (Weber, 1976). Peak metamorphic conditions during the Archean are estimated to have reached 790–850 °C and 8.3–10.7 kbar in the Partridge Crop Lake area (Paktunç and Baer, 1986; Mezger et al., 1990). Peak metamorphism during the Paleoproterozoic is estimated to have reached upper-amphibolite–facies conditions (Couëslan and Pattison, 2012).

Lithological units

The lithological units identified in the Partridge Crop Lake area are divided into Archean rocks and Paleoproterozoic rocks, based on crosscutting relationships and the presence or absence of Archean metamorphic textures and fabrics. Archean rocks were subjected to granulite-facies metamorphic conditions during the Archean, and both the Archean and Paleoproterozoic rocks were subjected to amphibolite-facies conditions during the Trans-Hudson orogeny; however, to improve the readability of the text the ‘meta-’ prefix has been omitted from rock names. The rocks described in this section consist only of units that were observed in the Fish Bay area (Figure GS-2-2). Many of these units are exposed elsewhere in the Partridge Crop Lake area and descriptions and interpretations include updates from Couëslan (2013b).

Archean rocks

Archean rocks in the Partridge Crop Lake area are characterized by a weak to strong gneissosity. Archean textures and metamorphic assemblages are overprinted to varying degrees of intensity by the effects of the Trans-Hudson orogeny. Archean granulite-facies metamorphic assemblages and textures are typically best preserved in the mafic volcanic rocks; however, they can be locally preserved in other units.

Mafic volcanic assemblage

The mafic volcanic assemblage consists dominantly of mafic volcanic rocks, with subordinate ultramafic volcanic rocks, garnet-rich hydrothermally altered rocks, garnetite, iron formation, calcsilicate and aluminous rocks. The mafic gneiss unit of Couëslan (2013b, c) consists of the mafic and ultramafic volcanic rocks and garnet-rich hydrothermally altered rocks.

Mafic volcanic rocks

Exposures of mafic volcanic rocks are most abundant in the southern and eastern portions of the Fish Bay area. The rocks are grey-green to dark grey, medium grained, foliated and locally magnetic (Figure GS-2-3a). The unit is relatively equigranular and consists of plagioclase, with typically 10–20% orthopyroxene, 20–30% clinopyroxene, and local minor magnetite and garnet. Pyroxenes locally occur in roughly equal proportions and can form up to 50% of the rock. The unit can be discontinuously and/or diffusely banded on a 0.5–30 cm scale, which is typically defined by variations in the proportions of mafic minerals. Local boudinaged bands up to 30 cm thick of more mafic rock contain only 10–20% plagioclase. These bands are commonly laminated and grade compositionally into ultramafic rock, which occurs as lenses up to 2 m thick. Exposures of mafic volcanic rocks commonly contain 10–20% leucosome as a network of interconnected veins and pods up to 20 cm thick. The leucosome is coarse grained, foliated and plagioclase-rich. It typically contains 10–20% mafic minerals consisting of varying proportions of orthopyroxene, clinopyroxene and magnetite. Garnet is locally present. Local zones of amphibolitization can occur within the mafic volcanic rocks and appear to be most pervasive along the northern shore of Fish Bay.

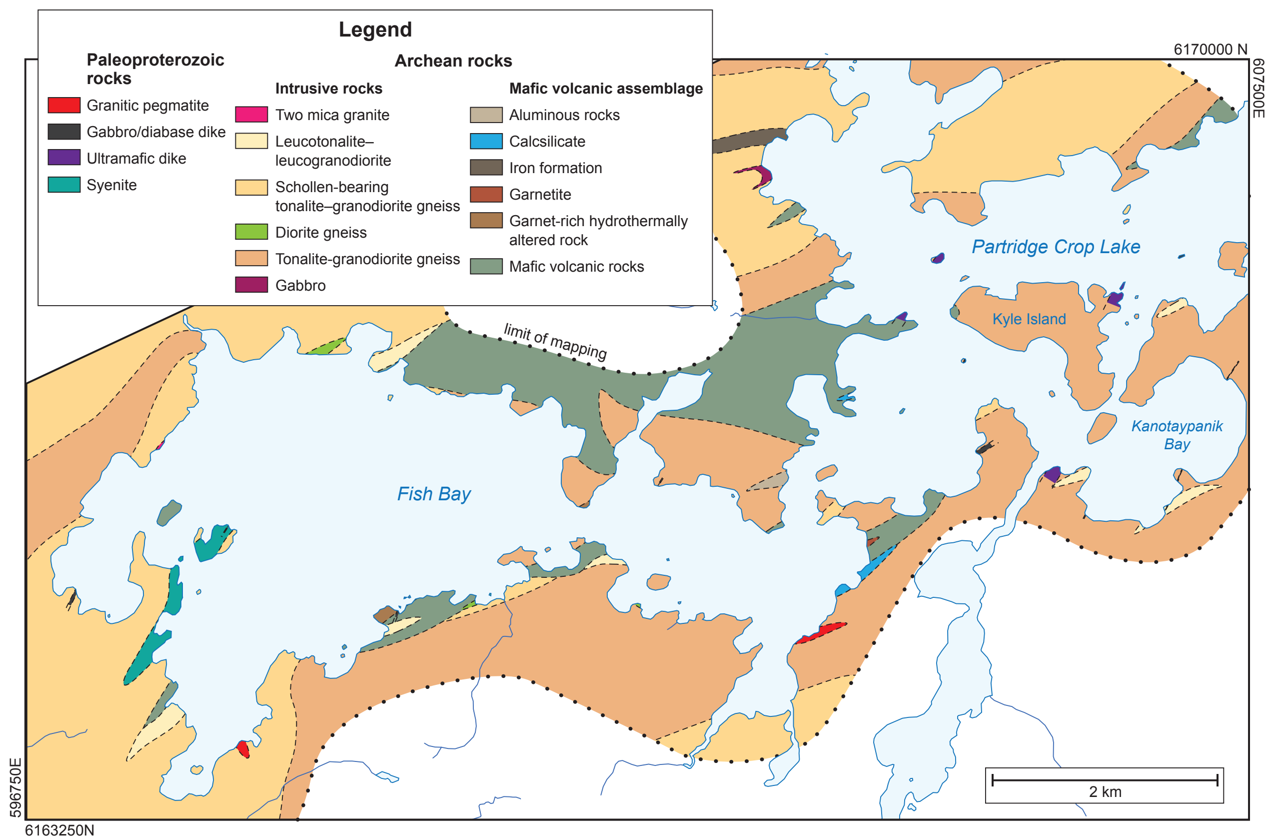

Figure GS-2-2: *Simplified geology of the Fish Bay area (modified from Couëslan, 2014).*

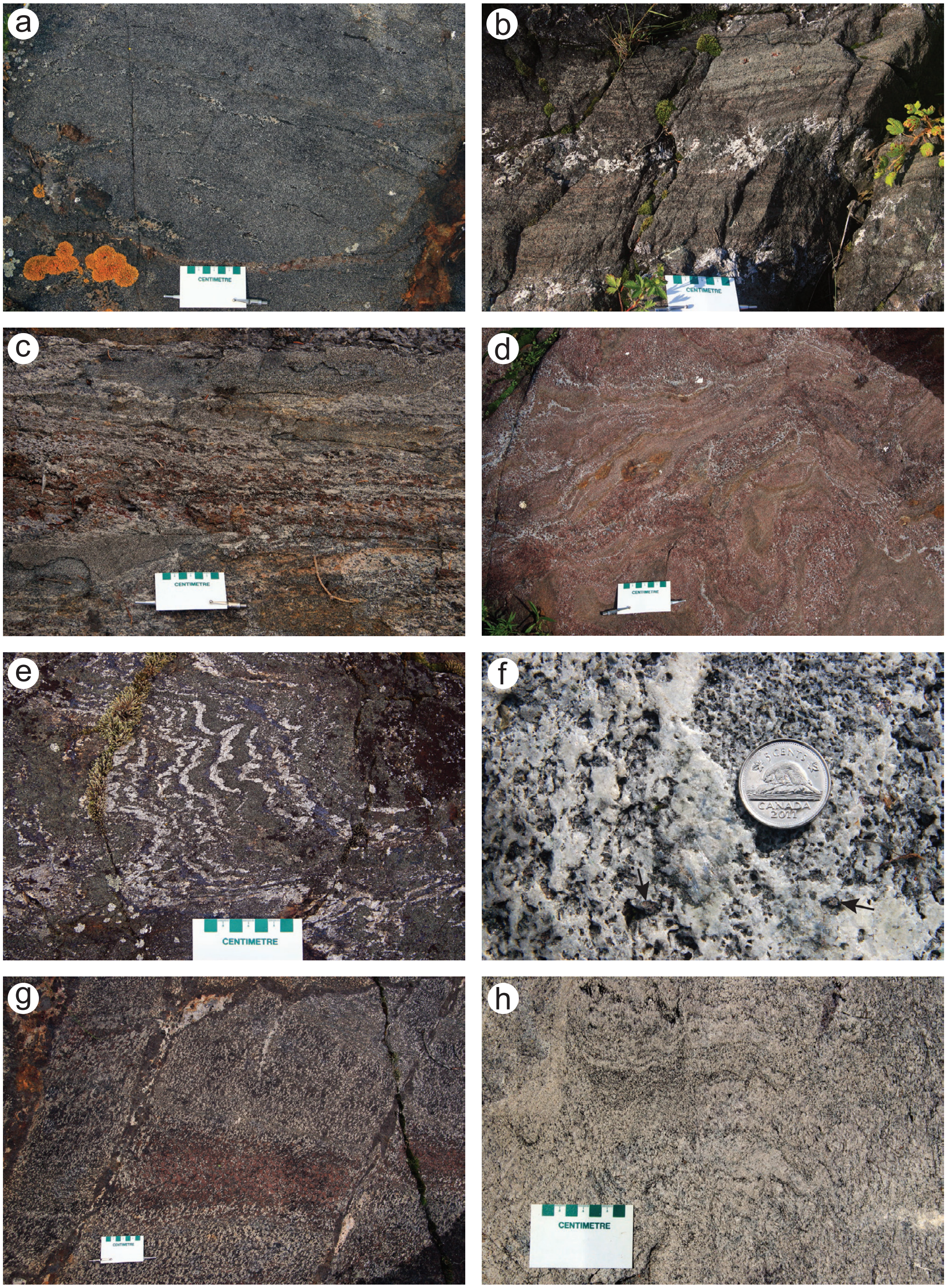

Figure GS-2-3: *Outcrop images of Archean rocks from the Fish Bay area:* ***a)*** *mafic volcanic rock with incipient pods of leucosome and showing a gossanous fracture at the lower right-hand edge of the image;* ***b)*** *layered ultramafic band interpreted as volcanogenic and hosted in mafic volcanic rock;* ***c)*** *quartz- and garnet-rich band hosted in mafic volcanic rock and interpreted as hydrothermally altered rock;* ***d)*** *banded garnetite containing local bands of mafic and ultramafic volcanic rock (not in image);* ***e)*** *magnetite-rich silicate-facies iron formation containing local bands of mafic volcanic rock (not in image);* ***f)*** *staurolite- and kyanite-bearing aluminous rock (kyanite is the blue mineral at the centre of the image), and garnet partially overprinted by biotite and chlorite (indicated by the arrows);* ***g)*** *garnet-rich band hosted in gabbro, in which the light speckles are aggregates of fine-grained plagioclase, possibly pseudomorphous after plagioclase phenocrysts;* ***h)*** *relatively uniform tonalite gneiss.*

The mafic volcanic rocks contain local garnet-rich lenses up to 15 cm thick, which are medium to coarse grained and internally layered on a scale of 1–10 mm. These lenses typically contain 10–20% garnet and may be gradational into the garnet-rich hydrothermally altered rock and garnetite. The mafic volcanic rocks also contain local bands of silicate-facies and oxide-facies iron formation up to 3 m thick. Contacts between the iron formation and volcanic rocks are typically marked by a 1–20 cm thick zone of gossanous, massive pyroxene and magnetite. Gossanous patches and discontinuous bands, ranging from 15 to 300 cm in width, are common. Locally, these gossanous zones could be related to incipient iron formation, but more commonly they appear to be fracture hosted. At one location, the mafic volcanic rocks are in contact with a zone of calcsilicate at least 5 m wide.

Ultramafic volcanic rocks

There are no map-scale occurrences of this unit in the map area; however, lenses and bands of ultramafic rock up to 2 m thick are relatively common within the mafic volcanic rocks (Figure GS-2-3b). Because of this association, the ultramafic rocks are interpreted as either volcanic rocks or subvolcanic intrusions. The ultramafic rocks are dark grey-green to brown-green, medium to coarse grained, locally strongly magnetic, and vary from massive to laminated or layered. The ultramafic rocks consist of varying proportions of clino- and orthopyroxene, with typically 10–20% hornblende, and minor amounts of magnetite, plagioclase and rare garnet. Hornblende commonly forms laminations and layers 1–10 mm thick within the pyroxene-rich groundmass.

Garnet-rich hydrothermally altered rock

Garnet-rich bands typically less than 3 m thick occur locally within the mafic volcanic rocks and are interpreted as zones of premetamorphic hydrothermal alteration. Although these bands typically make up less than 30% of the exposures, they form rare map-scale zones and can make up as much as 80% of the exposure. This rock is dark red to green, fine to coarse grained, crudely banded, foliated and variably magnetic. It is typically quartz-bearing and contains 1–2% sulphide, 1–5% magnetite, 7–20% orthopyroxene, 20–30% plagioclase and 30–40% garnet. Banding is defined by diffuse variations in grain size and modal composition. In rare map-scale occurrences, the variations in composition can be relatively extreme, ranging from compositions similar to those cited above to plagioclase-rich rocks with 5–7% magnetite, 10–20% Fe-orthopyroxene and 20–30% clinopyroxene, to plagioclase-rich rocks with 30–40% green amphibole and local bands containing as much as 50% quartz (Figure GS-2-3c). Interbanding of the above compositions occurs on a scale of 1–200 cm. The favoured interpretation for this unit is that it is the product of premetamorphic Fe-Mg±Si hydrothermal alteration; however, some variety of impure or incipient iron formation could also be a possibility.

Garnetite

Although small bands and lenses of garnet-rich rock occur as scattered occurrences in the mafic volcanic rocks, one map-scale exposure of garnetite is present at the eastern end of Fish Bay. The garnetite is dark red, medium to coarse grained, foliated and banded on a 1–100 cm scale (Figure GS-2-3d). It is typically composed of garnet with 5–7% orthopyroxene and 30–40% quartz; however, the rock is compositionally and texturally heterogeneous. Local bands range in composition from orthopyroxene with 3–5% quartz and 20–30% garnet, to quartz with 20–30% garnet. Rare, irregular and discontinuous bands of laminated ultramafic rock up to 40 cm thick occur within the garnetite. Local accumulations of sulphide are indicated by discontinuous gossanous bands and patches up to 30 cm thick. The garnetite occurs interbanded with mafic volcanic rocks on a 0.2–10 m scale.

Iron formation

Exposures of both silicate-facies and oxide-facies iron formation occur in the Fish Bay area. They are typically not at map-scale, but form centimetre- to metre-scale bands hosted within the mafic volcanic rocks. Although iron formation in the Fish Bay area is only associated with mafic volcanic rocks, it also occurs with pelitic and semipelitic rocks in the southern basin of Partridge Crop Lake (Couëslan, 2013b). The oxide-facies iron formation is dark grey, medium to coarse grained, foliated, laminated and strongly magnetic. It consists of discontinuous chert laminations, along with 5–7% garnet, 10–12% Fe-orthopyroxene and 20–30% magnetite. The magnetite commonly appears to be mantled by Fe-orthopyroxene. The oxide-facies iron formation occurs as bands up to 3 m thick within the mafic volcanic rocks.

The silicate-facies iron formation is dark green, medium to coarse grained, foliated, laminated and strongly magnetic (Figure GS-2-3e). The rock is Fe-orthopyroxene-rich, with 5–20 % magnetite, 5–20% quartz and 5–20% garnet. The quartz occurs as discontinuous chert laminations up to 7 mm wide. The presence of gossanous bands up to 60 cm wide suggests local accumulations of sulphide. One exposure in the channel north of Fish Bay occurs at map scale and contains bands of mafic volcanic rock up to 1.5 m thick.

Calcsilicate

Isolated exposures of calcsilicate are associated with mafic volcanic rocks in the eastern portion of Fish Bay and in the channel north of the bay. In one exposure, the calcsilicate is in direct contact with mafic volcanic rocks, suggesting it could represent a zone of premetamorphic carbonate alteration within the volcanic rocks. The calcsilicate is grey-green, medium to coarse grained, and massive. The rock consists mostly of diopside, with locally varying amounts of green amphibole and plagioclase, rare carbonate, scapolite, and sulphide.

Aluminous rocks

Scattered exposures of pelitic rock associated with rocks of the mafic volcanic assemblage occur in the southern basin of Partridge Crop Lake and in the channel between the southern basin and Bryce Bay (Couëslan, 2013b, c). These rocks were interpreted as sedimentary by Couëslan (2013b); however, thin-section petrography and bulk-rock geochemistry could suggest a hydrothermal origin for these rocks. They contain variable proportions of quartz, plagioclase, biotite, garnet±sillimanite, kyanite, staurolite, Fe–Mg amphibole and cordierite. Muscovite and K-feldspar are not present, suggesting relatively low potassium concentrations. This is supported by bulk-rock geochemistry, which typically yields relatively low alkali concentrations and corresponding high alumina saturation indices (molar ratio Al_2O_3/[CaO+Na_2O+K_2O]), and elevated Cr and Ni concentrations (Tinkham, 2011; Couëslan, unpublished data, 2013).

A single exposure of aluminous, staurolite- and kyanite-bearing rock occurs at the outlet of Fish Bay into the Grass River (Figure GS-2-3f). The rock is white to grey, medium to coarse grained, foliated and gneissic, with diffuse banding on a scale of 2–10 cm. It is quartz- and plagioclase-rich, with 5–7% kyanite, 7–10% garnet, 10–20% biotite, and minor chlorite and staurolite. The chlorite appears to be prograde and is partially overprinted by biotite. Chlorite, biotite and kyanite partially overprint much of the garnet. The rock exhibits a migmatitic texture, which is likely a preserved Archean texture, superimposed by a Hudsonian amphibolite-facies mineral assemblage. The rock could represent a low-potassium pelite or, alternatively, it could be a product of premetamorphic hydrothermal alteration.

Intrusive rocks

Gabbro

A single exposure of Archean gabbro was identified in the Grass River channel northwest of Kyle Island. The gabbro is dark grey, fine to coarse grained, foliated and banded. It typically consists of plagioclase with 40–50% orthopyroxene. The plagioclase occurs as fine-grained aggregates that appear to be pseudomorphous after plagioclase phenocrysts (Figure GS-2-3g). Five to seven percent of the exposure consists of garnet-rich bands up to 20 cm thick, which also contain 10–20% biotite, 10–20% plagioclase and 20–30% hornblende. Weber and Maylon (1978) interpreted this unit to be related to anorthositic rocks present throughout the PGD and northwestern Superior province (Peck et al., 1996; Couëslan, 2013a; Couëslan, GS-1, this volume). This could help explain the presence of anorthosite rafts within the schollen-bearing tonalite-granodiorite gneiss along the Grass River channel between Bryce Bay and the southern bay of Partridge Crop Lake (Couëslan, 2013b), both of which lie roughly along strike. An equally valid interpretation is that the gabbro is related to the mafic volcanic rocks as a subvolcanic intrusion and the garnet-bearing layers could represent primary compositional layering of the gabbro or bands of premetamorphic hydrothermal alteration.

Tonalite–granodiorite gneiss

The tonalite–granodiorite gneiss is the dominant unit in the Partridge Crop Lake area and underlies a large portion of the central and eastern Fish Bay area. Outcrops are white to light grey to light pink, medium to coarse grained, and gneissic (Figure GS-2-3h). The gneissosity varies from discontinuous mafic laminations to relatively continuous, mafic-enriched bands up to 40 mm thick. The composition of this unit varies from tonalitic to granodioritic, with 10–30% mafic minerals consisting of varying proportions of amphibole and biotite. The amphibole and biotite commonly occur as flattened aggregates of grains that could be pseudomorphous after orthopyroxene. This is supported by the presence of up to 10 % orthopyroxene and 10% clinopyroxene in place of hornblende in rare lower-strain zones. The gneiss typically contains deformed and diffuse pods and veins of coarse-grained, quartz-rich, tonalitic to granodioritic, and rarely granitic, leucosome. The leucosome generally contains little to no mafic minerals. Local rafts up to 2 m thick of banded mafic, and rarely ultramafic, rock could represent xenoliths of volcanic rock.

Diorite gneiss

Scattered exposures of diorite gneiss occur in the Fish Bay area. The gneiss is grey to pinkish grey, medium grained, weakly gneissic to gneissic, and locally magnetic (Figure GS-2-4a). The diorite gneiss contains 10–30% mafic minerals, with varying proportions of biotite, amphibole, clinopyroxene, orthopyroxene, and minor magnetite and quartz. The amphibole locally forms clots up to 7 mm. Pinkish grains could indicate the composition locally grades toward monzodiorite; however, it could also indicate the presence of antiperthite, as observed in dioritic gneiss on Cauchon Lake and in tonalitic gneiss on Sipiwesk Lake (Couëslan et al., 2012). Coarse-grained granodioritic leucosome occurs as veins and pods up to 60 cm thick and makes up 10–20% of exposures. The leucosome contains 5–10% amphibole as discrete grains and polycrystalline aggregates that may be pseudomorphous after pyroxene.

Schollen-bearing tonalite–granodiorite gneiss

The schollen-bearing tonalite–granodiorite gneiss underlies a large portion of the southern basin of Partridge

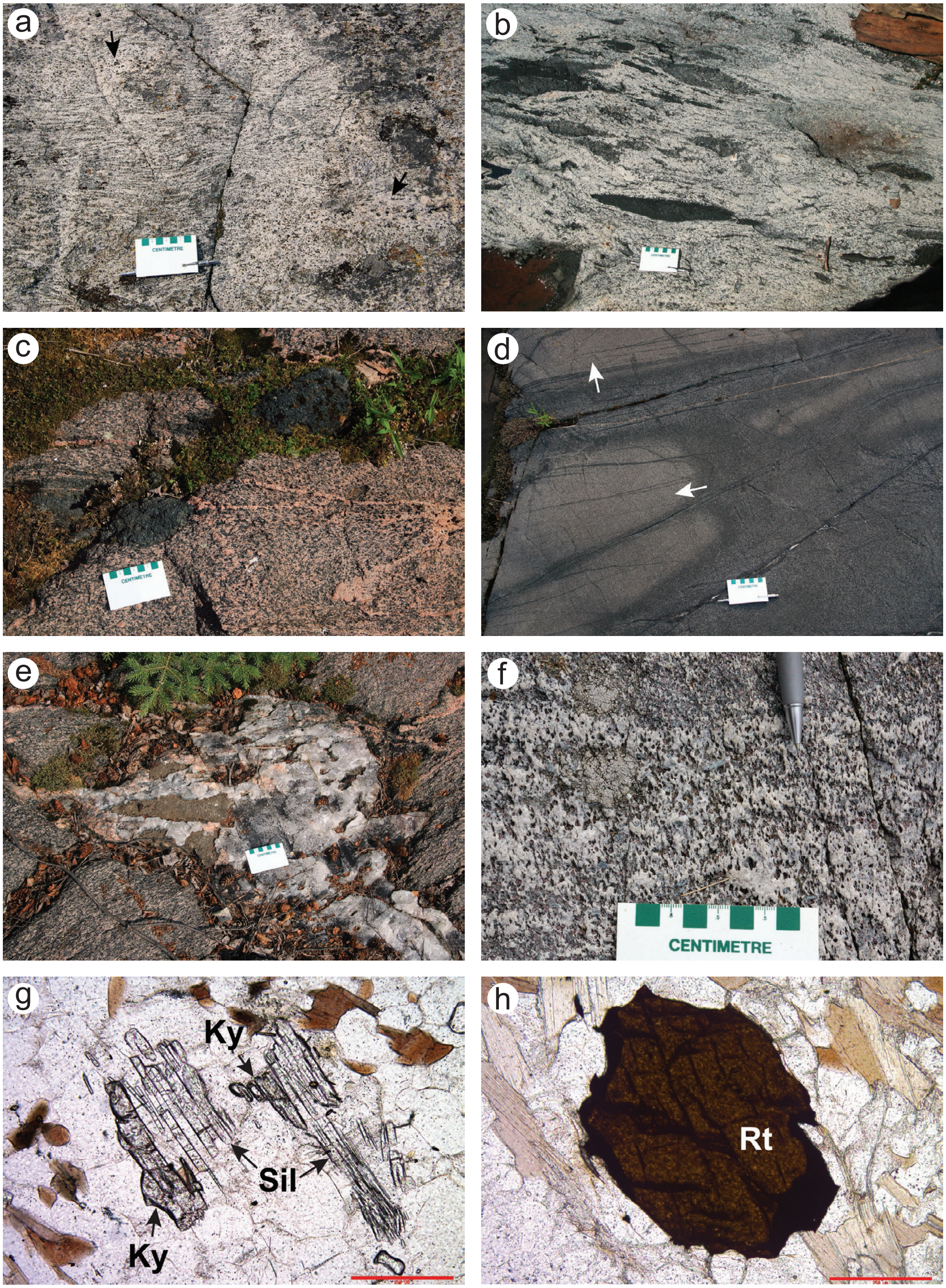

Figure GS-2-4: *Outcrop images of rocks of the Partridge Crop Lake area and photomicrographs from kyanite-bearing rock sample 108-13-P069:* ***a)*** *diorite gneiss with granodioritic leucosome (arrows);* ***b)*** *schollen-bearing tonalite–granodiorite gneiss with abundant mafic lenses representing flattened xenolithic rafts (schollen);* ***c)*** *syenite with ultramafic enclaves;* ***d)*** *variably amphibolitized mafic dike with zones of relict, unmetamorphosed diabase (arrows);* ***e)*** *carbonate-quartz vein hosted in syenite with brown-weathering carbonate, left of the scale card;* ***f)*** *kyanite-bearing rock from Bryce Bay mapped in 2013;* ***g)*** *photomicrograph in plane-polarized light of kyanite (Ky) overprinted by prismatic to acicular sillimanite (Sil);* ***h)*** *photomicrograph in plane-polarized light of rutile (Rt) with a partial rim of opaque ilmenite. Scale bar in photomicrographs is 250 µm.*

Crop Lake and the western portion of Fish Bay, as well as the Grass River channel north of Fish Bay. The gneiss is pink to grey, coarse grained, mylonitic to foliated, and weakly gneissic to gneissic. Rare exposures are locally massive. The schollen-bearing gneiss is typically tonalitic but locally grades into granodiorite. It typically contains 3–5% hornblende and 5–7% biotite, which are intergrown as flattened aggregates, likely pseudomorphous after orthopyroxene. Lower-strain outcrops locally contain 7–10% hornblende as equant porphyroblasts, or partially uralitized orthopyroxene. A single unretrogressed outcrop contains 3–5% biotite and 3–5% orthopyroxene, with trace amounts of sulphide and magnetite. Schollen, or xenolithic rafts, make up 5–20% of exposures (Figure GS-2-4b). The rafts are typically <80 cm thick and are dominantly mafic rock, with subordinate ultramafic rock and tonalite gneiss. The gneissosity is typically weakly defined as discontinuous bands 2–20 cm thick, and is largely derived from the flattening of schollen and attenuation of veins and pods of leucosome.

Leucotonalite–leucogranodiorite

The leucotonalite–leucogranodiorite occurs as minor isolated outcrops throughout the Fish Bay area. It is white to light pink, medium to coarse grained, and foliated. It typically contains 2–7% biotite, but locally hornblende, or rarely orthopyroxene, occurs in place of biotite. Quartz-rich tonalitic to granitic leucosome makes up 10–30% of exposures; however, the diffuse nature of the leucosome-mesosome contacts and the similarity in composition often make the quantification of leucosome difficult to determine. The attenuation of veins and pods of leucosome locally defines a weak gneissosity. This unit is likely equivalent to the weakly gneissic granodiorite mapped in 2013 in the southern basin of Partridge Crop Lake (Couëslan, 2013b).

Two-mica granite

A single exposure of two-mica granite occurs along the northwestern shore of Fish Bay. It is light pink, coarse grained, foliated and weakly gneissic. The granite contains trace amounts of sulphide, 3–5% muscovite and 7–10% chlorite. The chlorite appears to be pseudomorphous after biotite. The gneissosity is defined by diffuse coarser-grained leucosome and finer-grained mesosome, which are interbanded on a scale of 5–70 cm.

Paleoproterozoic rocks

Paleoproterozoic rocks in the Fish Bay area, with the exception of the carbonate-quartz veins, consist entirely of intrusive rocks. These units were subjected to amphibolite-facies metamorphic conditions during the Trans-Hudson orogeny; however, original igneous textures and mineralogy are locally preserved, especially in the eastern portions of the map area.

Syenite

A body of syenite, roughly 0.2 by 2 km, is exposed in the southwestern corner of Fish Bay. The syenite is texturally and compositionally similar to a body mapped in the Grass River channel north of the southern bay of Partridge Crop Lake in 2013 (Couëslan, 2013b). The rock is grey-pink, coarse grained and foliated. A locally present, weak gneissosity may represent remnant igneous banding. In addition to K-feldspar, the syenite contains 7–10% biotite and 20–30% dark green amphibole. Exposures typically contain 3–5% leucosyenite dikes, up to 7% ultramafic enclaves and local blocks of melasyenite. The leucosyenite dikes can reach a thickness of 15 cm and contain only 1–2% amphibole. The ultramafic enclaves, which occur as rounded rafts up to 100 cm thick and as sheets up to 5 by 100 cm (Figure GS-2-4c), consist of dark green, coarse-grained amphibole, with minor apatite. The melasyenite occurs as blocks up to 1 m thick and locally makes up as much as 7% of exposures. The melasyenite is dark pinkish green, coarse grained, foliated and porphyritic. It contains 2–3% apatite, 5–7% biotite, 10–20% green amphibole, 30–40% K-feldspar and 40–50% black amphibole. The melasyenite also contains local enclaves of the ultramafic rock up to 20 cm thick. In one instance, the syenite is intruded by a Paleoproterozoic mafic dike trending 035°, which suggests it predates the Molson dike swarm (ca. 1880 Ma, Heaman et al., 2009). A Paleoproterozoic age is preferred for this unit because of the preservation of angular blocks forming an intrusion breccia in portions of the syenite body mapped last year (Couëslan, 2013b, Figure GS-3-3d). The foliation and weak gneissosity observed in the syenite are continuous with the foliation in the intruding mafic dike. The syenite could be related to the ca. 1885 Ma Footprint Lake plutonic suite of the Northeast Kisseynew subdomain and the adjacent TNB described in Whalen et al. (2008).

Mafic to ultramafic dikes

Variably amphibolitized diabase, gabbro and ultramafic dikes, ranging from centimetre-scale up to 180 m thick, occur throughout the Fish Bay area (Figure GS-2-4d). Only dikes in the easternmost portion of the map area are typically free of metamorphic overprint. The majority of dikes trend roughly 020–035° and likely correspond to dikes of the ca. 1880 Ma Molson swarm (Heaman et al., 2009), while two other dikes, possibly corresponding to the ca. 2090 Ma Cauchon swarm, trend 046° and 058° (Halls and Heaman, 2000).

Ultramafic dikes

Ultramafic dikes vary in composition from pyroxenitic to peridotitic. Pyroxenite dikes are brown-grey to green-brown, medium to coarse grained, and massive. They contain variable amounts of clinopyroxene and orthopyroxene, along with up to 20% hornblende and minor plagioclase. The dikes are typically uniform and even grained. Local zones of hydration vary in composition from 30–40% brown amphibole and 60–70% green amphibole, to hornblende with <15% plagioclase. Local pegmatitic segregations contain roughly equal proportions of plagioclase and hornblende.

Peridotite dikes are dark green, coarse grained and massive. They contain 5–7% hornblende, 10–20% olivine, 20–30% orthopyroxene and clinopyroxene. Hornblende forms local poikilitic grains up to 2 cm across, with oikocrysts of olivine and pyroxene. Pegmatitic segregations up to 15 cm thick consist of plagioclase, with 30–40% hornblende. The segregations are locally comb textured, with hornblende oriented perpendicular to the vein and/or pod margin.

Gabbro and diabase dikes

Amphibolitized gabbro and diabase dikes are dark grey-green, medium to coarse grained, and massive to foliated. They typically contain 30–40% plagioclase and 60–70% hornblende. Diabase dikes locally contain hornblende porphyroblasts that are likely pseudomorphous after pyroxene phenocrysts. Unmetamorphosed diabase dikes are brown-grey, fine grained, massive and locally magnetic. They contain 40–60% plagioclase, variable amounts of orthopyroxene and clinopyroxene, and up to 5% magnetite. Rare, unmetamorphosed gabbro dikes are dark grey-green, coarse grained and massive, with locally subophitic textures. They contain 10–20% hornblende, 10–20% clinopyroxene, 20–30% orthopyroxene and 50–60% plagioclase. Gabbro dikes locally contain pegmatitic pods up to 30 cm across, which consist of plagioclase with 30–40% prismatic hornblende.

Granite dikes

Pink, medium-grained and massive to weakly foliated granite dikes up to 3 m thick occur in the western portion of Fish Bay. Biotite accounts for 3–5% of the dikes, which commonly contain gossanous pits and fractures that range from 3 to 150 mm in width, and abundant pegmatitic pods up to 60 cm across. The dikes are likely related to the nearby Wintering Lake intrusion (Couëslan, 2013b).

Granitic pegmatite

Granitic pegmatite occurs as dikes in the majority of exposures in the Fish Bay area; however, the dikes are typically <1.5 m wide. Two map-scale exposures of pegmatite occur along the southern shore of Fish Bay. The pegmatite is pink, medium to very coarse grained, and locally banded. It contains trace amounts of garnet, 1–2% biotite and 3–7% muscovite. The garnet typically occurs in close association with the biotite and muscovite, which could represent schlieric material. Graphic textures are locally present.

Carbonate-quartz veins

Discordant veins of massive quartz and pink carbonate up to 15 cm thick occur sporadically throughout the Fish Bay area. The carbonate typically has a chalky, yellow-orange to brown weathered surface (Figure GS-2-4e). Chlorite is commonly abundant and epidote is locally present. The veins locally contain minor amounts of sulphide and a platy, black oxide, which can occur in aggregates up to 2 cm across. The oxide is nonmagnetic and locally displays a slightly reddish cast. The carbonate-quartz veins were observed hosted in the mafic volcanic rocks, syenite, mafic dikes and tonalite–granodiorite gneiss. Plagioclase in the host mafic volcanic rocks and mafic dikes is typically replaced by epidote immediately adjacent to the vein margin. The discordant nature of the veins, coupled with the epidotization of plagioclase in adjacent rocks, suggest that the veins were emplaced late relative to peak Hudsonian metamorphism and ductile deformation.

Structural geology

The earliest structure recognized in the Partridge Crop area consists of a roughly east-trending, subvertical Archean gneissosity (S_A). Over much of the map area, the gneissosity is intersected by a subvertical Paleoproterozoic foliation (S_P) that typically trends northeast. The S_A fabric is locally transposed subparallel to S_P and this relationship becomes increasingly common toward the western portion of the map area. The S_P fabric is axial planar to minor folds that generally have moderate to steeply northeast- or southwest-plunging fold axes.

Metamorphic geology

Archean granulite-facies assemblages are best preserved in the mafic volcanic rocks, which commonly retain orthopyroxene- and clinopyroxene-bearing assemblages. The tonalitic rocks that underlie most of the area appear to be more susceptible to metamorphic overprint and, as a result, Archean pyroxene-bearing mineral assemblages are rare. Aluminous rocks with suitable mineral assemblages for estimating P–T conditions are rare in the Fish Bay area and none were observed with Archean granulite-facies mineral assemblages. However, pelite with locally preserved granulite-facies assemblages occurs in the southern bay of Partridge Crop Lake (Couëslan, 2013b).

Kyanite was identified in an outcrop of aluminous rock in Bryce Bay in 2013 (Figure GS-2-4f) and again this year, in an outcrop at the outlet channel of Fish Bay (Figures GS-2-1, 3f). Kyanite, along with sillimanite, was also identified in thin sections of several other samples stretching from the channel south of Bryce Bay to the southern shore of the southern bay of Partridge Crop Lake. These occurrences define a roughly north-trending kyanite isograd (Figure GS-2-1). Kyanite has also been reported in granitoid rocks on south-central Wintering Lake and western Sipiwesk Lake (Hubregtse, 1977; Bleeker, 1990). Bleeker (1990) interpreted the kyanite on Sipiwesk Lake to occur in Hudsonian pegmatite dikes that crosscut retrogressed granulite. These occurrences suggest a kyanite isograd could be present along the entire eastern margin of the TNB.

Many of the aluminous rocks in the Partridge Crop Lake area contain the assemblage quartz-plagioclase-biotite-garnet-rutile-sillimanite and/or kyanite±staurolite, cordierite, and chlorite. This is a typical middle amphibolite-facies mineral assemblage for low-potassium, aluminous rocks. Equilibrium-assemblage diagrams were calculated for two samples of aluminous rock, one collected in the channel south of Bryce Bay (108-13-P069, Figure GS-2-5a) and one collected at the outlet of Fish Bay (108-14-P077, Figure GS-2-5b). Sample 108-13-P069 contains the prograde metamorphic assemblage quartz-plagioclase-biotite-garnet-cordierite-sillimanite-kyanite-rutile-ilmenite. The kyanite occurs as isolated grains that are partially overprinted by acicular to prismatic sillimanite, which suggests the kyanite is likely a metastable relic (Figure GS-2-4g). Assuming the kyanite is metastable, this assemblage defines an area in P–T space of roughly 650–700 °C and 6.5–7.7 kbar (Figure GS-2-5a). The presence of metastable kyanite, as well as partial rims of ilmenite around rutile (Figure GS-2-4h), suggest isothermal decompression during prograde metamorphism and a clockwise P–T–t path during the Trans-Hudson orogeny. Sample 108-14-P077 contains the prograde metamorphic assemblage quartz-plagioclase-biotite-garnet-kyanite-chlorite-staurolite-white mica-rutile, which defines an area in P–T space of roughly 640–650 °C and 7.5–8.0 kbar, suggesting similar P–T conditions across the Partridge Crop Lake area.

The metamorphic grade in the Partridge Crop Lake area contrasts sharply with the Hudsonian granulite-facies rocks located to the southwest at Paint Lake, a distance of approximately 6 km projected across strike. Such a steep metamorphic-field gradient could indicate the presence of a major crustal-scale structure such as a fault. The location of this fault could be the topographic lineament that corresponds to the long, narrow southwestern channel of Partridge Crop Lake, a feature that continues for more than 20 km. However, an issue that remains to be resolved is the similarity in pressure estimates for Paint Lake (6.5–7.0 kbar; Couëslan and Pattison, 2012) and Partridge Crop Lake (6.5–7.7 kbar, this study), which seems to suggest a steep temperature gradient, with little change in pressure.

Economic considerations

Mafic volcanic rocks in the Partridge Crop Lake area are characterized by widespread gossanous bands, spatially associated zones of premetamorphic Fe-Mg aluminous and possibly calcareous hydrothermal alteration, and spatially associated iron formation and garnetite. Evidence for hydrothermal activity, and the presence of gossanous zones and exhalative sedimentary rocks, suggest a potential for both gold and base-metal (VMS) mineralization. A lower-grade analogue of these rocks could be found at Utik Lake, approximately 100 km to the southeast in the Superior province. At Utik Lake, crosscutting pipes and stratiform zones of hydrothermal alteration are present in mafic volcanic rocks, and are associated with base-metal mineralization and auriferous exhalative sedimentary rocks (Bernier and MacLean, 1989; Böhm et al., 2007).

Chemical analyses of possible ultramafic volcanic rocks in the mafic volcanic assemblage yielded Cr, Ni and Cu concentrations as high as 1630, 1520 and 350 ppm, respectively. This could suggest a potential for magmatic Ni–Cu–platinum-group element mineralization within the volcanic assemblage. The ultramafic rocks locally occur in the same outcrop as gossanous iron formation, indicating that a potential source of sulphur was present at the time of magmatism. Assimilation of sulphidic material into the ultramafic magma could have resulted in sulphide saturation and the separation of a metal-enriched sulphide melt (Eckstrand and Hulbert, 2007). It should be emphasized that the ultramafic rocks in the volcanic assemblage are interpreted as Archean, as opposed to the Paleoproterozoic (ca. 1880 Ma) ultramafic intrusions that host the magmatic Ni-Cu deposits of the adjacent TNB (Hulbert et al., 2005; Scoates et al., 2010).

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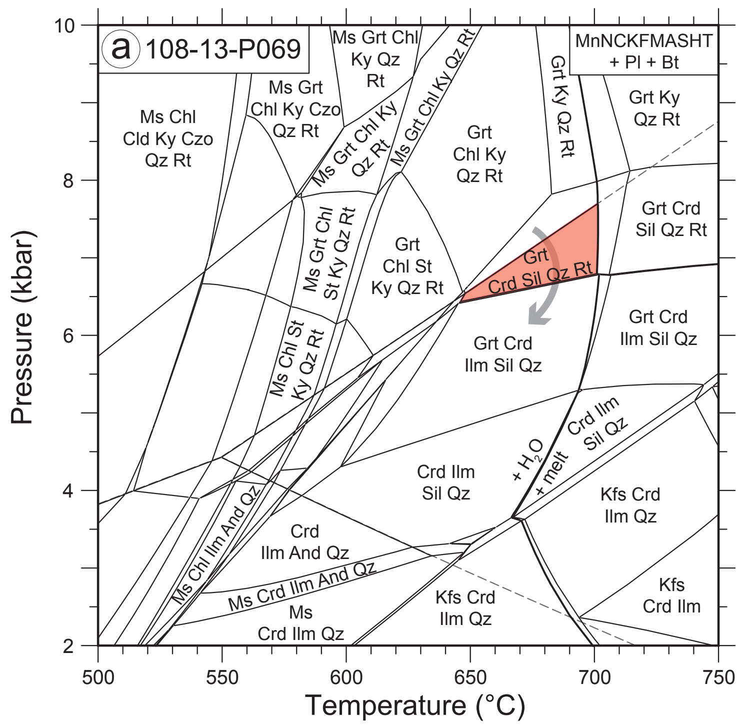

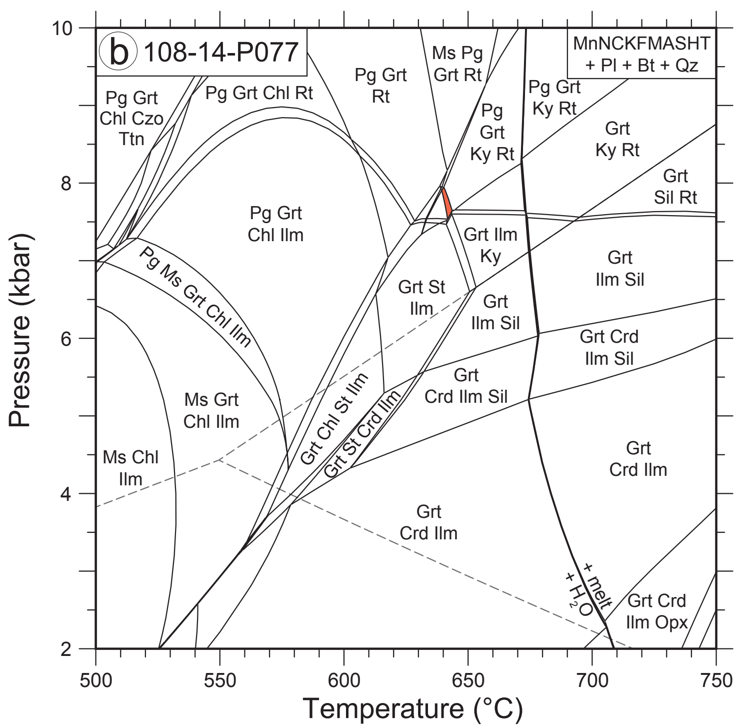

Figure GS-2-5: *Equilibrium-assemblage diagrams calculated for samples* ***a)*** *108-13-P069 and* ***b)*** *108-14-P077 in the system MnO–Na_2O–CaO–K_2O–FeO–MgO–Al_2O_3–SiO_2–H_2O–TiO_2 (MnNCKFMASHT). The observed peak metamorphic assemblages are indicated by the red fields. The grey dashed lines indicate the aluminosilicate stability fields in the system Al_2O_3–SiO_2–H_2O, as defined by Holland and Powell (1998), based on Pattison (1992). A possible clockwise P–T–t path is indicated by the grey arrow. The diagrams were calculated using the Theriak–Domino software package (de Capitani and Petrakakis, 2010) and the updated 2003 ds5.5 thermodynamic dataset of Holland and Powell (1998), based on activity models outlined in Tinkham and Ghent (2005), Pattison and Tinkham (2009), and Couëslan et al. (2011). Abbreviations: And, andalusite; Bt, biotite; Chl, chlorite; Crd, cordierite; Cld, chloritoid; Czo, clinozoisite; Grt, garnet; Ilm, ilmenite; Kfs, K-feldspar; Ky, kyanite; Ms, muscovite; Opx, orthopyroxene; Pg, paragonite; Pl, plagioclase; Qz, quartz; Rt, rutile; Sil, sillimanite; St, staurolite; Ttn, titanite.*

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