GS-9 New results from geological mapping in the west-central and northeastern portions of Southern Indian Lake, Manitoba (parts of NTS 64G1, 2, 8, 64H4, 5)

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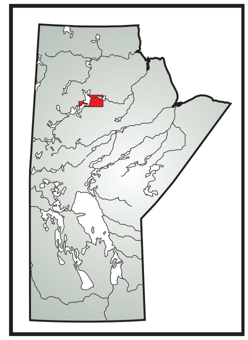

Kremer, P.D., Rayner, N. and Corkery, M.T. 2009: New results from geological mapping in the west-central and northeastern portions of Southern Indian Lake, Manitoba (parts of NTS 64G1, 2, 8, 64H4, 5); *in* Report of Activities 2009, Manitoba Innovation, Energy and Mines, Manitoba Geological Survey, p. 94–107.

Summary

This report summarizes results from new whole-rock geochemical, isotopic, and geochronological analyses conducted on rock samples collected during the 2008 mapping campaign in the Pukatawakan Bay area, as well as during new bedrock mapping in and around the northeastern portion of Southern Indian Lake, Partridge Breast Lake, and Gauer Lake in northern Manitoba (Kremer et al., 2009).

The Southern Indian Domain in northern Manitoba is dominated by variably migmatitic metasedimentary rocks with minor screens of volcanic rocks, and variable amounts of plutonic rocks (Corrigan et al., 2007). Two belts dominated by volcanic rocks occur in the west-central (Pukatawakan Bay) and northeastern (Partridge Breast Lake) parts of Southern Indian Lake. In the Pukatawakan Bay area, a continuous sequence of juvenile pillowed to massive mafic volcanic flows is tectonically juxtaposed with Archean (ca. 2.5 Ga) ortho- and paragneiss. To the southeast in Whyme Bay, isotopically evolved arc volcanic and volcaniclastic rocks and overlying clastic sedimentary rocks are preserved as kilometre-scale screens in a quartz-dioritic to monzogranitic intrusion. The Partridge Breast Lake area is dominated by mafic to felsic arc volcaniclastic, resedimented volcaniclastic and sedimentary sequences, which are themselves overlain by polymictic conglomerate with lesser amounts of quartz and feldspathic arenite. The supracrustal sequences in both areas were flooded by voluminous granitic intrusions between ca. 1.86 and 1.80 Ga.

New bedrock mapping and laboratory analyses of the rocks in the Southern Indian Lake area have provided further insights into the tectonomagmatic evolution of the Trans-Hudson Orogen in northern Manitoba. Rocks exposed in the Southern Indian Lake area record the development and closure of the Paleoproterozoic Manikewan ocean between the Archean Rae-Hearne, Superior and Sask cratons; the development and accretion of volcanic arc complexes and associated basinal sedimentary sequences to the southern margin of the Archean Rae-Hearne craton; continental arc magmatism; orogenic sedimentation; and intrusion of late- to post-orogenic plutonic rocks.

Introduction

Southern Indian Lake is located approximately 160 km north of Thompson along the Churchill River system. This portion of the Trans-Hudson Orogen (THO) in Manitoba has seen little mineral exploration in recent decades and has not been systematically mapped since the late 1960s (Cranstone, 1972; Frohlinger, 1972). The purpose of the present work is to re-examine the bedrock geology of the Southern Indian Lake area with particular emphasis on documenting the nature, age, tectonic affinity and mineral potential of the Pukatawakan Bay and Partridge Breast belt areas, both of which are dominated by volcanic rocks (Figure GS-9-1). This mapping project will provide a new geological framework for comparing the rocks in the Southern Indian Lake area with similar sequences that occur along regional strike, in both Manitoba and Saskatchewan (e.g., Lynn Lake and Rusty Lake greenstone belts). The tectonostratigraphic position of the volcanic rocks in the Southern Indian Domain is similar to that of the volcanic rocks in the well-documented Lynn Lake and Rusty Lake greenstone belts; therefore, it is possible that the supracrustal sequences in the Southern Indian Lake area represent time-correlative and/or tectonically and magmatically dismembered equivalents of the Lynn Lake and/or Rusty Lake belt supracrustal sequences. As such, rocks in the Southern Indian Lake area may share similar potential for volcanogenic massive sulphide (VMS)-type, orogenic lode gold and magmatic sulphide mineralization.

The current project was initiated in 2008 with mapping at 1:25 000 scale of the Pukatawakan Bay area in west-central Southern Indian Lake (Kremer, 2008a, b) and continued, in the summer of 2009, with mapping in the northeastern portion of Southern Indian Lake, Partridge Breast Lake, and Gauer Lake. Mapping has been bolstered by a detailed aeromagnetic survey conducted in the spring of 2008 by the Geological Survey of Canada (Coyle and Kiss, 2008). The aeromagnetic survey provides an excellent complement to bedrock mapping by allowing the development of more accurate interpretations in areas with limited to no exposure.

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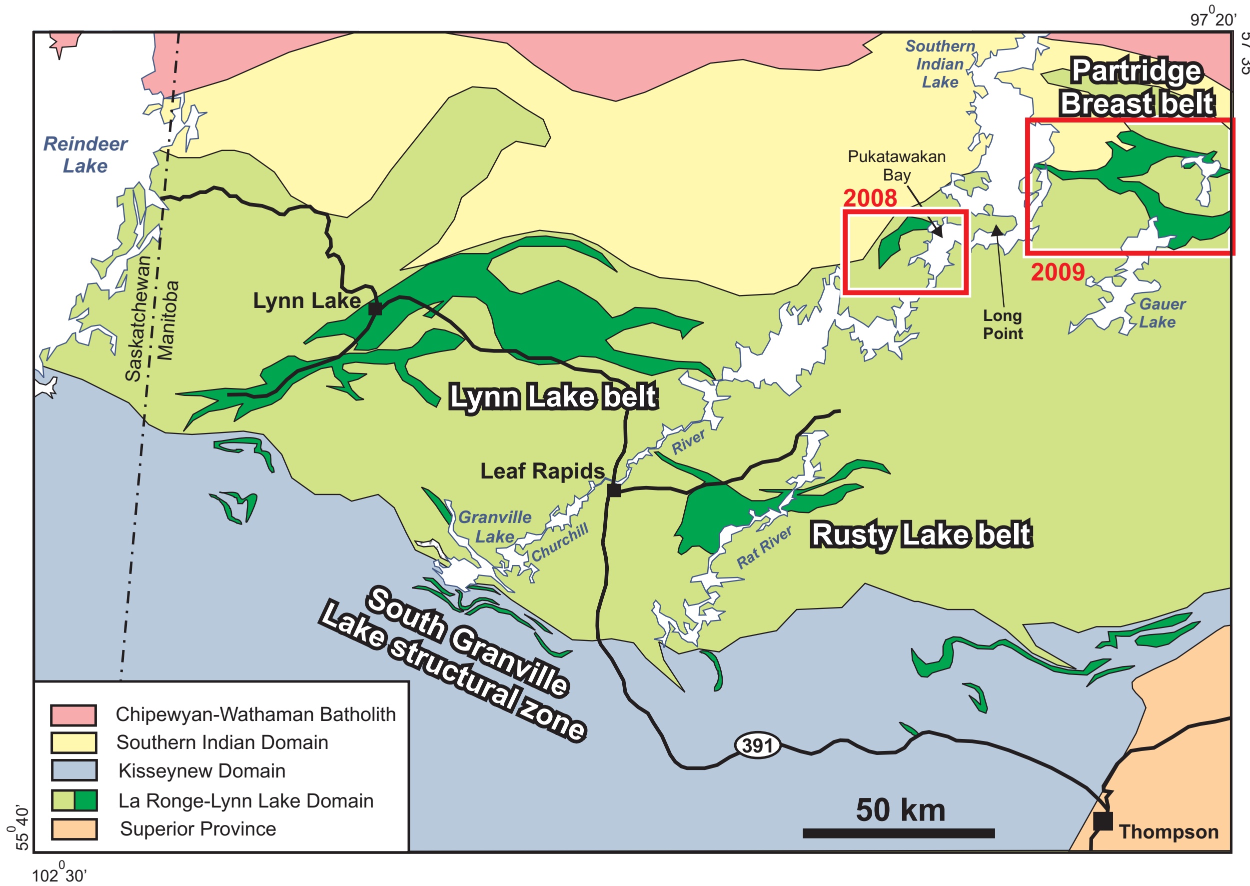

Figure GS-9-1: *Simplified regional geology of the Trans-Hudson Orogen in northern Manitoba. The 2008 and 2009 mapping areas are outlined.*

Regional Geology

The Southern Indian Domain is one of three main tectonostratigraphic terranes that form the northern flank of the Trans-Hudson Orogen in northern Manitoba (Figure GS-9-1). It is dominated by variably migmatitic orthogneiss and metasedimentary rocks, bounded to the south by the volcanic-rock–dominated Lynn Lake–Leaf Rapids Domain, and intruded to the north by the voluminous ca. 1.86–1.85 Ga Chipewyan/Wathaman Batholith (Corrigan et al., 2000). Sedimentary rocks in the Rottenstone Domain (the equivalent of the Southern Indian Domain in Saskatchewan) have been subdivided into several lithotectonic assemblages (Maxeiner et al., 2001; Corrigan and Rayner, 2002). The Clements Island Belt, located near the southern margin of the Wathaman Batholith, is dominated by mafic volcanic and volcaniclastic rocks; geochronological analysis results from an interbedded rhyolite in the sequence (1905 +17/–5 Ma) suggest that these rocks are contemporaneous with parts of the Lynn Lake belt (Corrigan et al., 2001). The ca. 1.89–1.87 Ga Milton Island assemblage, consisting of sillimanite-muscovite-biotite±garnet±graphite migmatitic greywacke, psammite and psammopelite, is interpreted as a fore-arc accretionary complex north of the La Ronge–Lynn Lake arc (Corrigan et al., 1999). The Park Island assemblage, consisting of polymictic conglomerate, arkose and psammite, is interpreted as part of a foreland basin; the fact that this assemblage is cut by the Wathaman Batholith indicates it is older than 1.86 Ga. Suites of younger gabbroic to monzonitic plutonic rocks occur throughout the Southern Indian Domain with ages ranging between 1.855 Ga and 1.80 Ga (MacLachlan et al., 2004; Rayner and Corrigan, 2004; Corrigan et al., 2007).

Analytical procedures

Uranium-lead geochronology was carried out using the sensitive high-resolution ion micro probe (SHRIMP) at the Geological Survey of Canada in Ottawa. Analytical procedures followed those described by Stern (1997), with standards and U-Pb calibration methods following Stern and Amelin (2003). The internal features of the zircons (such as zoning, structures, alteration) were characterized in back-scattered electron mode (BSE) utilizing a Zeiss Evo® 50 scanning electron microscope. Analyses were carried out over four separate sessions. Analyses using secondary standard z1242 were interspersed throughout the analytical sessions and the measured $^{207}Pb/^{206}Pb$ age compared with the accepted age determined by thermal ionization mass spectrometry (2679.7 Ma; B. Davis, pers. comm., 2009). The 'Isoplot version 3.00' application of

Ludwig (2003) was used to generate concordia diagrams and calculate weighted means. All errors reported in the text are given at the 2σ uncertainty level.

Whole-rock geochemical analyses were conducted at Activation Laboratories Ltd. in Ancaster, Ontario. Major-element concentrations were determined by x-ray fluorescence and trace and rare earth elements, by inductively coupled plasma-mass spectrometry using fusion sample preparation and instrumental neutron activation analysis. Samples selected for Nd isotopic analysis were submitted to the Radiogenic Isotope Facility at the University of Alberta in Edmonton.

Results

Partridge Breast Lake

Geological mapping conducted in the summer of 2009 was focused in and around Partridge Breast Lake. The lithological associations in the Partridge Breast Lake area are similar to those reported for Pukatawakan Bay (Kremer, 2008a, b), and consist of pelitic to quartzofeldspathic migmatitic paragneiss; pillowed to massive basaltic flows, spatially associated with sillimanite-bearing psammitic to pelitic greywacke; a sequence of mafic to felsic volcaniclastic and reworked volcaniclastic rocks with associated synvolcanic intrusions and sedimentary rocks; and a younger sequence of magnetite-bearing clastic sedimentary rocks, including clast-supported polymictic conglomerate, and quartz and feldspar arenite. As in the Pukatawakan Bay area, these supracrustal sequences are intruded by voluminous amounts of syn- to post-tectonic plutonic rocks (Figure GS-9-2).

Migmatitic paragneiss is well exposed in the western portion of the map area, and likely extends westward to the north of Pukatawakan Bay (Kremer, 2008a). Paragneiss weathers dark grey and consists largely of medium-grained, garnetiferous greywacke. Quartzofeldspathic mobilizate occurs as stringers, veins and dikes that are generally oriented subparallel to the main transposition fabric in the sedimentary rocks (Figure GS-9-3a). Similar rock types have been identified on the southern shore of Partridge Breast Lake, and are tentatively correlated with the exposures on Long Point pending further analyses.

Pillowed to massive mafic volcanic flows form relatively narrow sequences to the north and south of Strawberry Island. Basalt weathers dark grey-green and is aphyric and nonamygdaloidal. Pillows are flattened parallel to the regional foliation with aspect ratios ranging between 5:1 and 20:1 (Figure GS-9-3b). Light grey-green streaks of calcsilicate alteration occur throughout all basalt exposures. Basalt is interbedded with psammitic to pelitic, sillimanite-bearing greywacke (Figure GS-9-3c) with occasional sulphidic horizons containing up to 70% pyrrhotite and pyrite. On Turtle Island, these rocks are intruded by the Turtle Island intrusive complex, which consists of multiple layered injections ranging in composition from pyroxenite to quartz diorite (Figure GS-9-3d). The Turtle Island complex, dated at 1889 ±11 Ma, provides a minimum age for the mafic volcanic rocks and associated greywacke (Rayner and Corrigan, 2004).

Mafic to felsic volcaniclastic rocks with minor flows form a continuous sequence that extends from Partridge Breast Lake southeastward to the northern shore of Gauer Lake. On Partridge Breast Lake, volcaniclastic rocks are often interbedded with psammitic sedimentary rocks, which suggests that some degree of reworking of the original volcanic stratigraphy occurred. Alternatively, synvolcanic sedimentation from distal sources into a fore-arc–type basin may be responsible for the widespread intercalation of volcanic and clastic rocks in the area. The rocks around Partridge Breast Lake are strongly recrystallized and homogenized by metamorphism and deformation, and interpretation of primary lithofacies is difficult. At Gauer Lake, volcaniclastic rocks are better preserved and include pyroxene-phyric mafic flows and tuff, and heterolithic tuff (Figure GS-9-3e). Primary features such as normal graded bedding can be observed in a number of outcrops.

A younger sequence of magnetite-bearing polymictic conglomerate occurs between Strawberry Island and Gauer Lake (Figure GS-9-3f). Conglomerate is clast-supported and massive, although it is locally interbedded with crudely- to well-bedded quartz and feldspathic arenite. Normal-graded bedding and trough crossbedding are preserved at a few locations. Cobbles are well-rounded and range in size from less than 2 cm to 80 cm and are generally granitic in composition with lesser amounts of volcanic and mafic intrusive components. Although the conglomerate is generally well-preserved, it is highly strained where it is intruded by adjacent plutonic domes.

Supracrustal assemblages are intruded at various scales by numerous plutonic rocks. The northern flank of supracrustal assemblages is bounded by relatively homogeneous medium- to coarse-grained tonalite to granite. The tonalite is well-foliated to gneissic and locally includes abundant partially resorbed rafts of supracrustal rocks (Figure GS-9-4a). Foliated K-feldspar–megacrystic granite occupying the southern shore of Gauer Lake is petrographically similar to, and likely represents a satellite pluton associated with, the Chipewyan Batholith. The area south of Strawberry Island is dominated by weakly- to moderately-foliated K-feldspar–porphyritic biotite±hornblende monzogranite (Figure GS-9-4b). This intrusive body is compositionally and texturally identical to the 1829 Ma monzogranite reported in the Whyme Bay area (Rayner and Corrigan, 2004; Kremer, 2008a, b). Undeformed, locally K-feldspar–porphyritic pink biotite granite forms a large body extending from Strawberry Island to Gauer Lake. It contains numerous xenoliths (up to hundreds of metres in size) of young, magnetite-bearing clastic sedimentary rocks, often with well-preserved

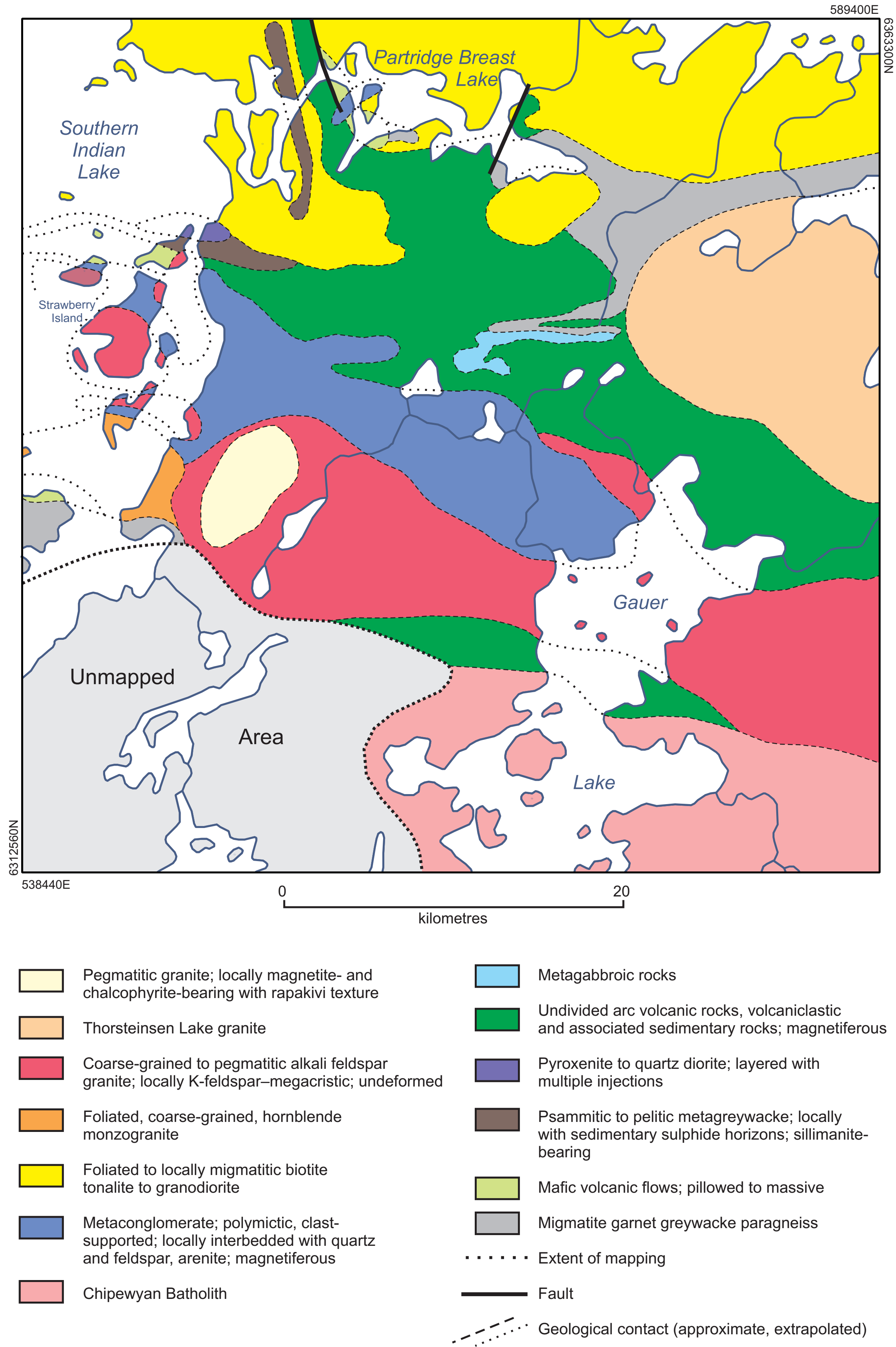

Figure GS-9-2: *Simplified geology of the Partridge Breast Lake area, northern Manitoba.*

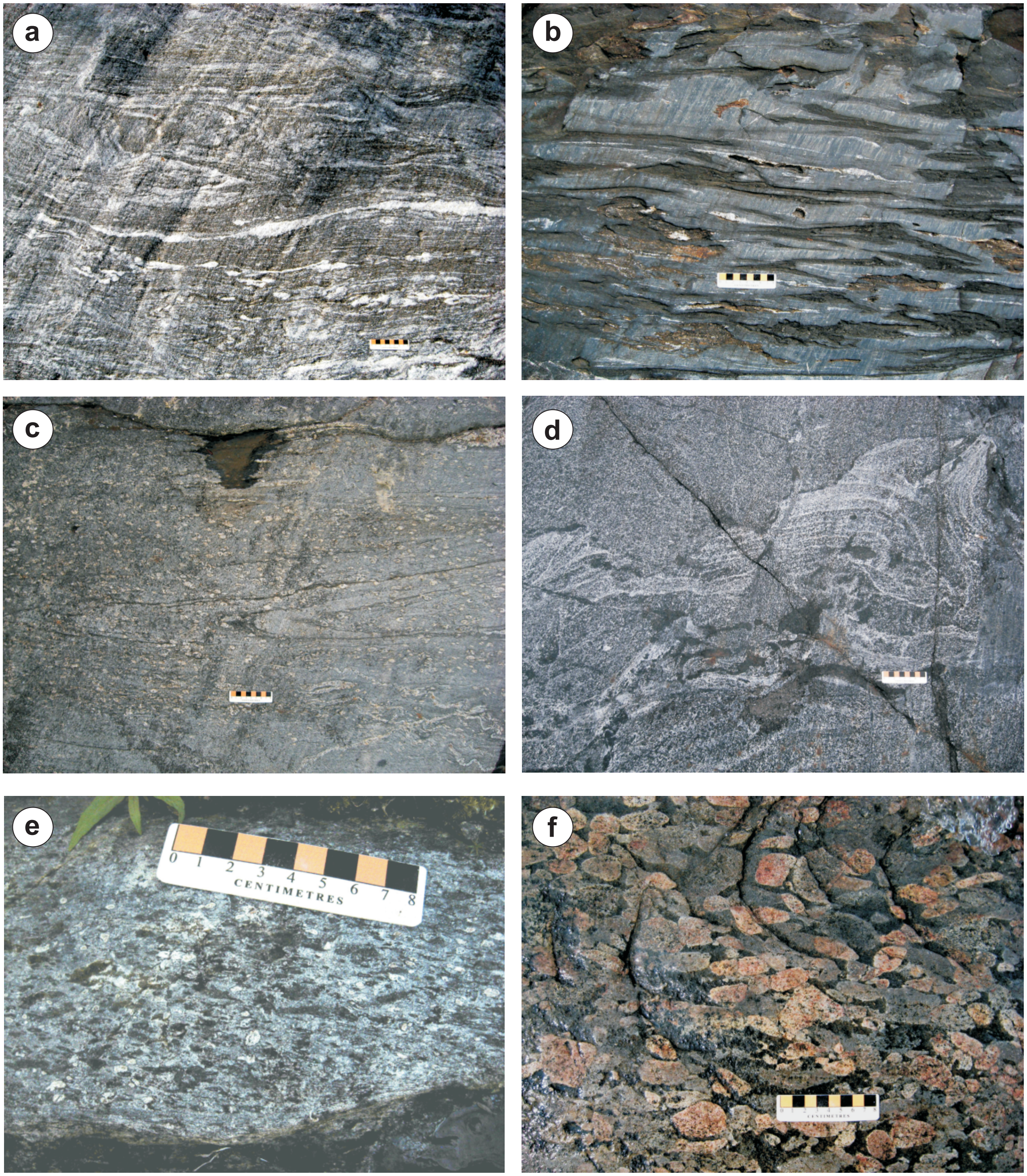

***Figure GS-9-3:** Outcrop photographs of supracrustal rocks, Partridge Breast Lake area: **a)** migmatitic garnet greywacke gneiss, northern shore of Long Point; **b)** deformed pillow basalt, north of Strawberry Island; **c)** isoclinally folded sillimanite-bearing greywacke, northwestern shore of Turtle Island; **d)** disrupted layering in Turtle Island intrusive complex, northern shore of Turtle Island; **e)** heterolithic lapilli tuff, northern shore of Gauer Lake; **f)** clast-supported polymictic conglomerate, eastern shore of Southern Indian Lake.*

primary structures (Figure GS-9-4c). East of Long Point, a plug of very coarse-grained to pegmatitic granite corresponds to a magnetic high approximately 10 km wide. The granite consists of 50% K-feldspar megacrysts up to 5 cm in size characterized by rapakivi-like zonation patterns (Figure GS-9-4d). The matrix consists of coarse-grained biotite, medium-grained quartz and feldspar, and abundant magnetite, pyrite, and chalcopyrite. Leucogranite containing fluorine has been identified on the shores of Thorsteinson Lake (Lenton and Corkery, 1981; Corkery,

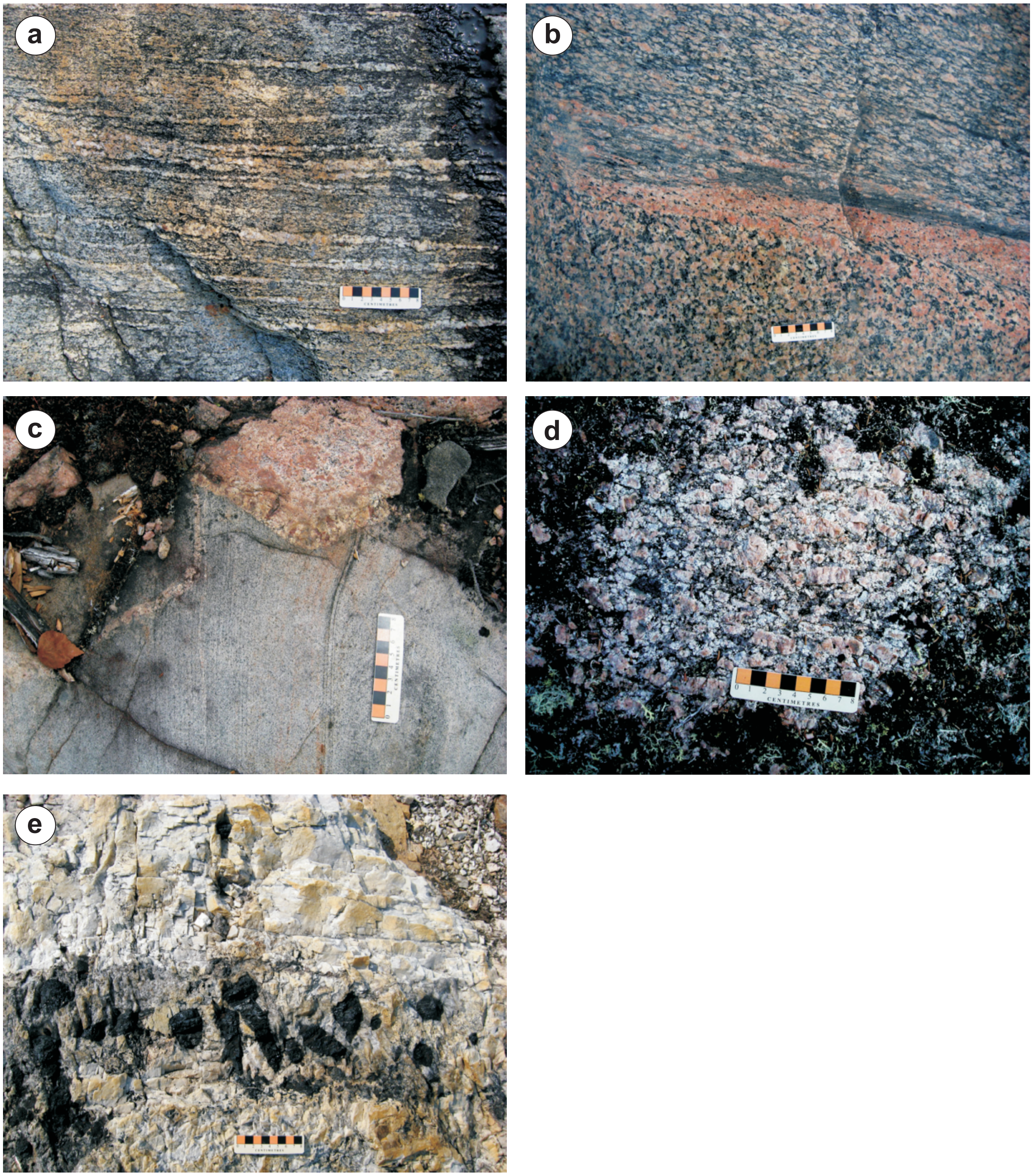

***Figure GS-9-4:** Outcrop photos of intrusive rocks, Partridge Breast Lake area: **a)** well-foliated to gneissic granodiorite gneiss, west of Missi Falls; **b)** K-feldspar–porphyritic biotite monzogranite, south of Strawberry Island; **c)** large xenolith of well-bedded arenite in undeformed pink granite, west of Gauer Lake; **d)** pegmatitic granite with zoned K-feldspar megacrysts, east of Long Point; **e)** tourmaline-bearing pegmatite, Partridge Breast Lake.*

1993) and may be related to tourmaline- and beryl-bearing pegmatitic rocks that occur throughout the Partridge Breast Lake area (Figure GS-9-4e).

U-Pb geochronology

Tuff sample 107-08-649

A sample of reworked dacitic tuff was collected on the western shore of Partridge Breast Lake. Based on outcrop scale interbedding of tuff with mafic volcanic wacke, a tuff sample was selected to determine the age of volcanism in the area. Approximately 50 variable, small, poor-quality, subrounded to resorbed zircon grains were recovered from the sample, which suggests they share a volcaniclastic rather than volcanic origin. Thirty-eight zircon grains were analyzed by SHRIMP and yielded ages ranging from 2741 to 1877 Ma. The most prominent detrital mode is centred at ca. 1.91 Ga, and older detritus is dominated by ca. 2.0 and 2.4 Ga modes (Figure GS-9-5a). Due to the small size and poor quality of the zircons, replicate analyses on the youngest grains to more precisely constrain the maximum age of sedimentation could not be carried out. Assuming that the youngest population of zircon is sourced from the volcanic rocks below, the weighted mean for this detrital population yields a $^{207}Pb/^{206}Pb$ age of 1908 ±9 Ma, which could thus represent an age estimate for volcanism in the Partridge Breast Lake area. A conglomerate on Partridge Breast Lake is dominated by slightly younger zircons of 1884 Ma and contains older detritus that yielded ages of between 2.54 and 2.27 Ga (Rayner and Corrigan, 2004). The older detrital ages from the conglomerate correspond well with detrital ages from the tuff sample as well as basement and inherited zircon ages from other nearby samples (this report; Rayner and Corrigan, 2004).

Arkose sample 107-08-598C

Along the Churchill River, west of Partridge Breast Lake, arkosic sedimentary rocks are interbedded at regular intervals with pillowed basalt. A sample of sedimentary material locally containing garnet and sillimanite (pseudomorph after andalusite) was collected for detrital zircon analysis to provide constraints on the age of the mafic volcanic rocks at Partridge Breast Lake and for comparison with other detrital results and refinement of the stratigraphy. The arkosic sedimentary rocks are interpreted as representing a separate, older sedimentary package than the polymictic conglomerate reported in Rayner and Corrigan (2004). Zircons recovered from the sample are highly variable in quality and morphology. They include clear, colourless, high-quality equant grains, prismatic zircons and slightly resorbed prisms that range from clear and colourless with rare fractures and inclusions to

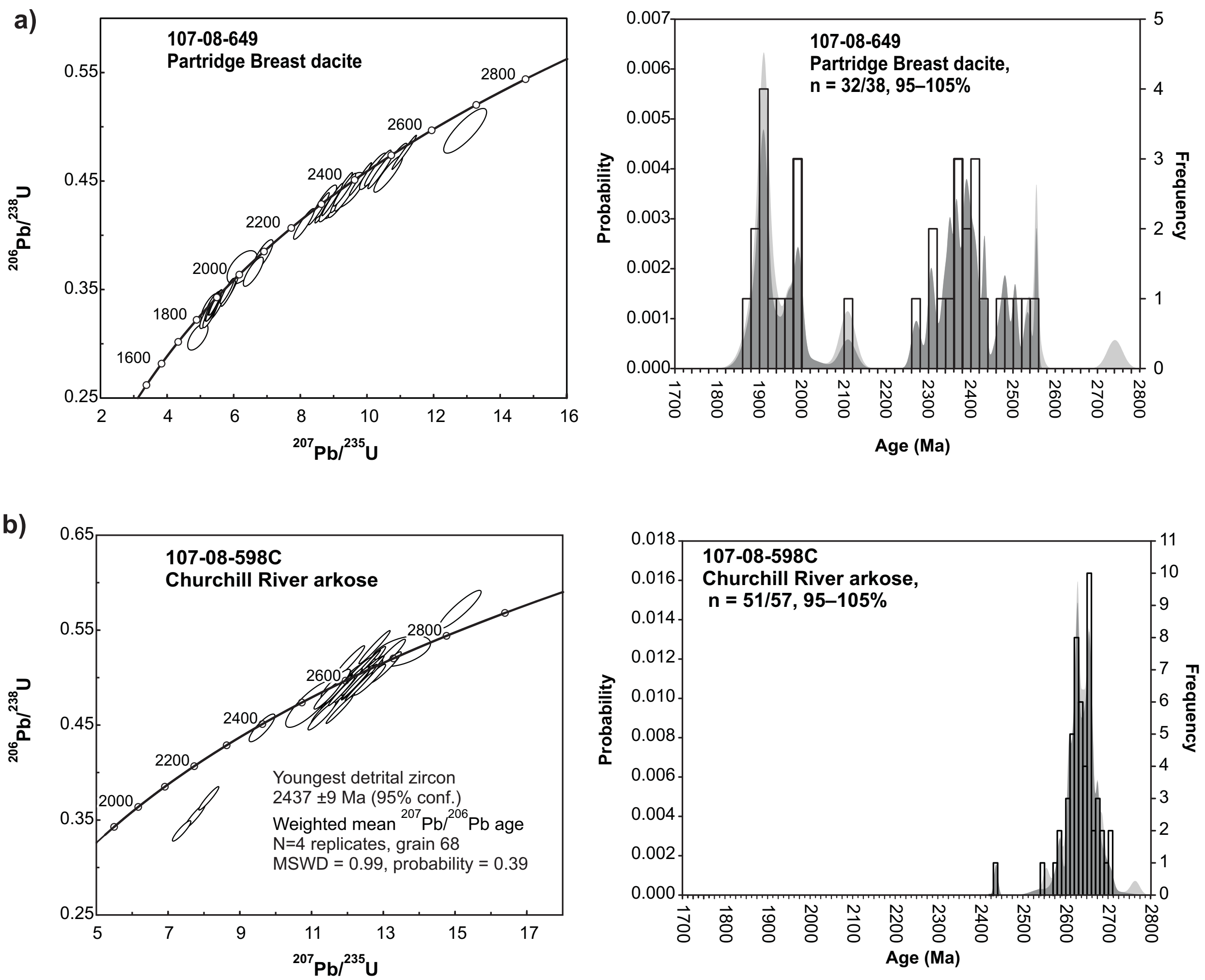

***Figure GS-9-5:** Results from U-Pb geochronological analyses, Partridge Breast Lake area: **a)** U-Pb concordia diagram and probability-density distribution curve for detrital zircons from tuff sample 107-08-649; **b)** U-Pb concordia diagram and probability-density distribution curve for detrital zircons from arkose sample 107-08-598C. Ellipses on concordia diagrams are plotted at the 2σ uncertainty level. MSWD refers to mean square of weighted deviates. All data is shown by light grey curves on probability density diagrams, dark grey curves and histograms represent data that is within 5% concordant.*

brown, turbid, highly altered grains. Fifty-seven detrital zircons were analyzed and the majority of the ages they yielded fall between 2.7 and 2.6 Ga; prominent modes occur at 2630 Ma and 2655 Ma (Figure GS-9-5b). The oldest analyzed detrital zircon is 2764 ±22 Ma (2σ, minimum age) and the youngest, 2437 ±9 Ma, thus providing a maximum age of sedimentation. This detrital profile, dominated by Archean detritus and an early Paleoproterozoic maximum age, stands in distinct contrast to the detrital profile of volcaniclastic rocks at Partridge Breast Lake and, albeit given limited constraints, to the local basement in the area.

Pukatawakan Bay

Mapping of the Pukatawakan Bay area in the summer of 2008 resulted in the subdivision of five main lithological packages (Figure GS-9-6; Kremer, 2008a, b). Tonalitic ortho- and paragneiss are interpreted as the oldest (basement) rocks in the area. These are in fault contact with mafic metavolcanic rocks with associated synvolcanic intrusions and metasedimentary rocks referred to as the Pukatawakan Bay assemblage. A second, distinct suite of mafic metavolcanic and volcaniclastic rocks, referred to as the Whyme Bay assemblage, is isolated from the Pukatawakan Bay assemblage by an intrusion of quartz diorite. The Whyme Bay assemblage rocks are spatially associated with fluvial-alluvial sedimentary rocks, dominated by polymictic conglomerate and well-bedded to massive arenite. Although the contact is not directly observed, the conglomerate contains clasts similar to rocks of the Whyme Bay assemblage, supporting the interpretation of a younger, and possibly unconformably overlying, fluvial-alluvial sequence. All three supracrustal sequences are cut by voluminous syn- to post-tectonic intrusive rocks. A more detailed description of rocks in the Pukatawakan Bay area can be found in Kremer (2008a).

Volcanic geochemistry and Nd isotopic composition

Volcanic rocks from the Pukatawakan Bay and Whyme Bay areas were collected in 2008 for whole-rock geochemical and selected Sm-Nd tracer isotopic analyses. The results corroborate existing field observations and indicate the presence of two chemically distinct packages of volcanic rocks in Pukatawakan Bay.

The Pukatawakan Bay assemblage consists of a continuous sequence of massive to pillowed basaltic flows with rare sillimanite-bearing sedimentary layers that extends from Pukatawakan Bay northeast through Pine Lake (Kremer, 2008a). Flows are aphyric, nonamygdaloidal, and are characterized by abundant zones of light grey-green calcsilicate alteration. Rare-earth and trace-element geochemical analyses indicate an affinity to modern mid-ocean-ridge basalt (Figure GS-9-7a). Tracer isotopic analyses yielded positive epsilon Nd (ε_{Nd}) values between +1.0 and +4.7 (at 1.9 Ga) and indicate a dominantly juvenile, depleted mantle source. These results for the Pukatawakan Bay assemblage are consistent with an ocean floor setting, which may indicate that this sequence of rocks represents a preserved vestige of the Manikewan oceanic crust.

The Whyme Bay assemblage occurs as kilometre-scale screens in a quartz-dioritic to monzogranitic intrusion and consists of quartz-chlorite amygdaloidal mafic flows associated with abundant heterolithic volcanic breccia. These mafic volcanic and volcaniclastic rocks are interbedded with magnetiferous greywacke-mudstone turbidite sequences containing garnet-cordierite-anthophyllite metamorphic assemblages. Rare earth and trace element geochemistry results from two samples of the volcanic rocks at Whyme Bay indicate an affinity to modern arc magmas (Figure GS-9-7b). An ε_{Nd} value of -3.2 (at 1.9 Ga) and a depleted mantle Nd model age of 2.58 Ga for one of the samples suggest that interaction with and/or recycling of ancient continental rocks in a subduction zone setting occurred.

U-Pb geochronology

Granodiorite gneiss sample 107-08-448

A sample of relatively homogeneous granitic to granodioritic gneiss collected on a small island east of Pukatawakan Bay is interpreted as representing basement rocks to the volcanic and sedimentary rocks of the Pukatawakan Bay and/or Whyme Bay supracrustal assemblages. The gneissosity, which is locally at an angle to the main foliation in adjacent supracrustal rocks, is cut by basaltic and gabbroic dikes petrographically and chemically similar to those observed throughout the supracrustal assemblages. Tracer isotopic analysis of samples collected from this location yielded an ε_{Nd} value of -7.1 (D. Corrigan, pers. comm., 2008), which supports the interpretation that the granodiorite gneiss is (derived from) older continental crust. The abundant prismatic zircons recovered are mostly clear and colourless, with few inclusions but numerous fractures. In BSE images core/overgrowth relationships are commonly observed. SHRIMP $^{207}Pb/^{206}Pb$ ages fall into two groups, one at ca. 2520 Ma and another at ca. 2385 Ma (Figure GS-9-8a). Older ages are documented in zircon cores, younger ones in rims. The weighted mean $^{207}Pb/^{206}Pb$ age of the five oldest analyses, all from zircon cores, is 2520 ±6 Ma. This is interpreted as the crystallization age of the granodiorite gneiss. The weighted mean $^{207}Pb/^{206}Pb$ age of eight unzoned zircon rims is 2385 ±9 Ma and is interpreted as the time of a metamorphic overprint. Overgrowths are typically unzoned, which is consistent with a metamorphic origin, but have relatively high Th/U, an unusual occurrence in amphibolite-grade metamorphic zircon. While it is possible that the older age represents an inherited component and the younger age the time of crystallization, the interpretation described

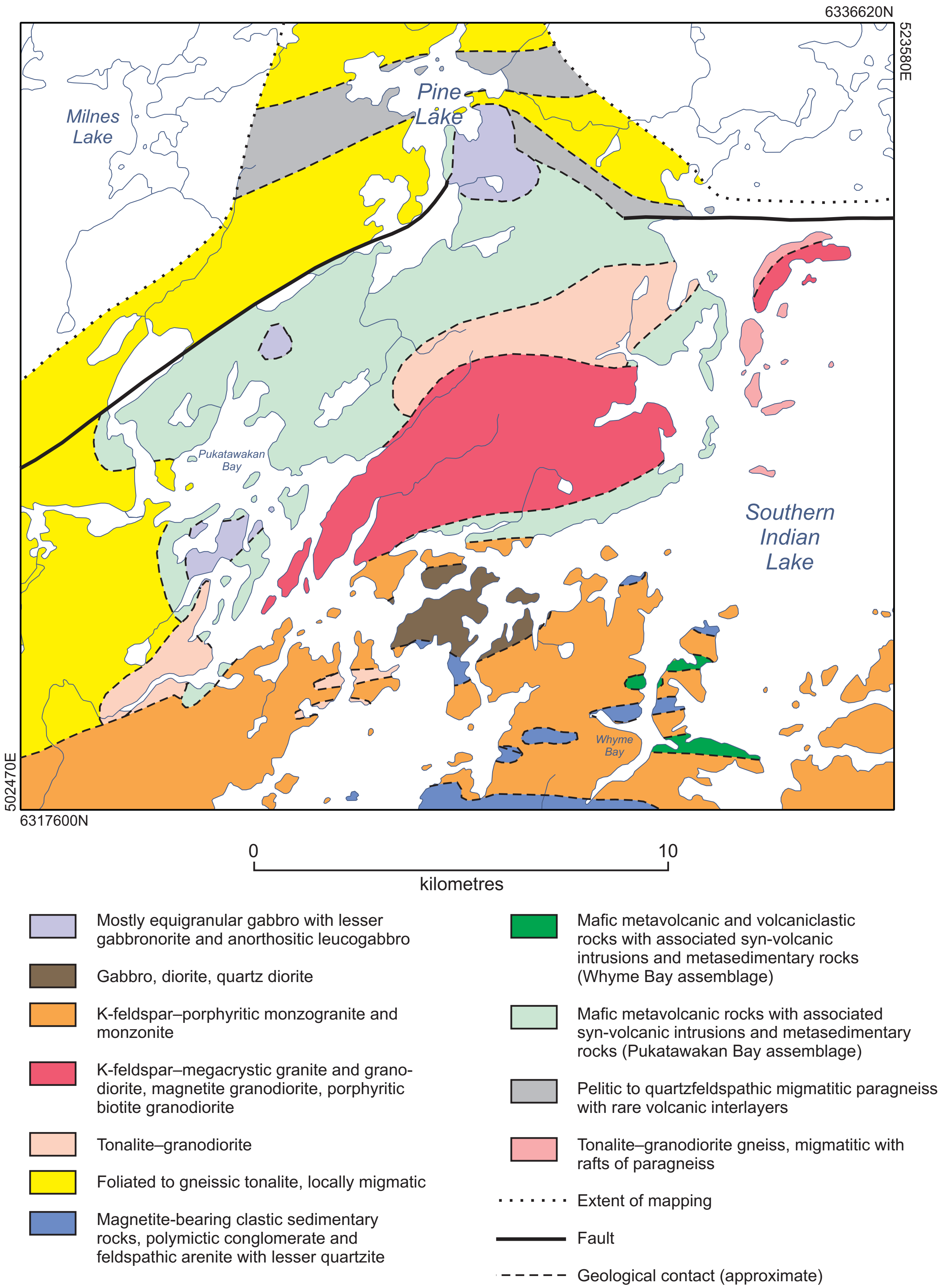

Figure GS-9-6: *Simplified geology of the Pukatawakan Bay area, Southern Indian Lake, Manitoba.*

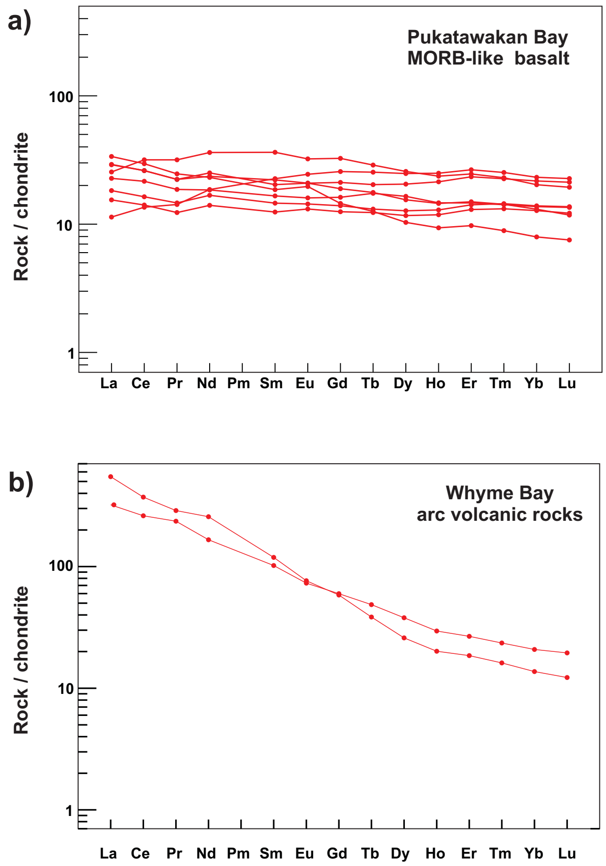

***Figure GS-9-7:** Chondrite-normalized extended element profiles of **a)** mid-ocean-ridge basalt (MORB)–like mafic volcanic rocks from the Pukatawakan Bay assemblage, and **b)** arc-like mafic volcanic rocks from the Whyme Bay assemblage. Normalization values are after Sun and McDonough (1989).*

above is favoured. The consistent preservation of young ages as zircon rims, as opposed to preservation as entire grains as well as rims, suggests that they are the product of solid-state zircon growth. It should be noted that there is no distinct record of Trans-Hudsonian metamorphism in the zircon data of the granodiorite gneiss.

Porphyry dike sample 107-08-029

Sample 107-08-029 is a mineralized felsic porphyry dike intruding basalt at Pukatawakan Bay. The dike is interpreted as a structure emplaced during D_2 deformation and is subparallel to, and boudinaged along, northeast-trending S_2 foliation surfaces. The dike is associated with up to 5% disseminated and stringer sulphide mineralization concentrated both along dike margins and within proximal altered zones of the mafic volcanic wall rocks. A porphyry dike thus constrains the timing of D_2 deformation and its associated mineralizing event. Zircons recovered from this sample are euhedral, prismatic grains with prominent oscillatory zoning visible in transmitted light and BSE images. Secondary alteration, observed as low BSE response patches, is common in many of the zircons and is consistent with their elevated U content. Core/overgrowth relationships are rare. Nineteen separate zircon grains were analyzed by SHRIMP; seventeen of them yielded ages ranging from 1866 to 1818 Ma (Figure GS-9-8b). The weighted mean $^{207}Pb/^{206}Pb$ age of eleven of these zircons, excluding analyses of five young grains interpreted as having experienced Pb-loss and of one older grain at 1866 Ma, which may represent an inherited component, is 1843 ±3 Ma. This result is interpreted as representing the crystallization age of the felsic porphyry dike. Two older, distinctly lower U grains at 2111 and 2330 Ma are clearly inherited.

Intermediate sediment sample 107-08-273

A well-bedded intermediate to mafic turbiditic sediment, which locally contains garnet and cordierite and is interbedded with arc-volcanic rocks, was collected from the Whyme Bay assemblage. Detrital zircon analyses were carried out to refine the current stratigraphy of the belt and provide constraints on the minimum age of volcanism associated with the Whyme Bay volcano-sedimentary assemblage. The few zircon grains recovered from this sediment are small, of poor-quality, altered, and typically exhibit high U overgrowths and/or recrystallized patches. Thirty-six detrital zircons of suitable size and quality for analysis range in age from 2950 to 1850 Ma, with a dominant mode at ca. 2350 Ma (Figure GS-9-8c). The weighted mean $^{207}Pb/^{206}Pb$ age of twelve analyses of high U rims is 1832 ±4 Ma; this result is interpreted as representing a time of metamorphic overprint and the minimum age of deposition of the sediment. The maximum age of deposition, normally constrained by multiple analyses on the youngest detrital zircon(s), could not be determined due to the poor quality of the zircons. Although the youngest individual analysis is imprecisely constrained at 1852 ±32 Ma (2σ), there are three concordant results at ca. 1.90 Ga which appear to be consistent with the age of other volcanic units and synvolcanic plutons in the area.

Arenite sample 107-08-271

A second sample collected from the eastern shore of Whyme Bay represents the clastic sedimentary sequence that is presumed to overlie the volcano-sedimentary assemblage constrained by the intermediate sediment sample 107-08-273. The outcrop consists of well- to crudely-bedded arenitic to quartzitic sandstone. Detrital zircons were analyzed to constrain the age of orogenic sedimentation associated with the Pukatawakan Bay belt and similar sedimentary packages along regional strike (Partridge Breast and Lynn Lake belts). A uniform population of prismatic, well-faceted to subrounded zircons with few inclusions or fractures were separated from the arenite sample. In BSE images, the zircons are typically concentrically zoned, some exhibiting high U cores. Seventy-two detrital zircons were analyzed from a range of

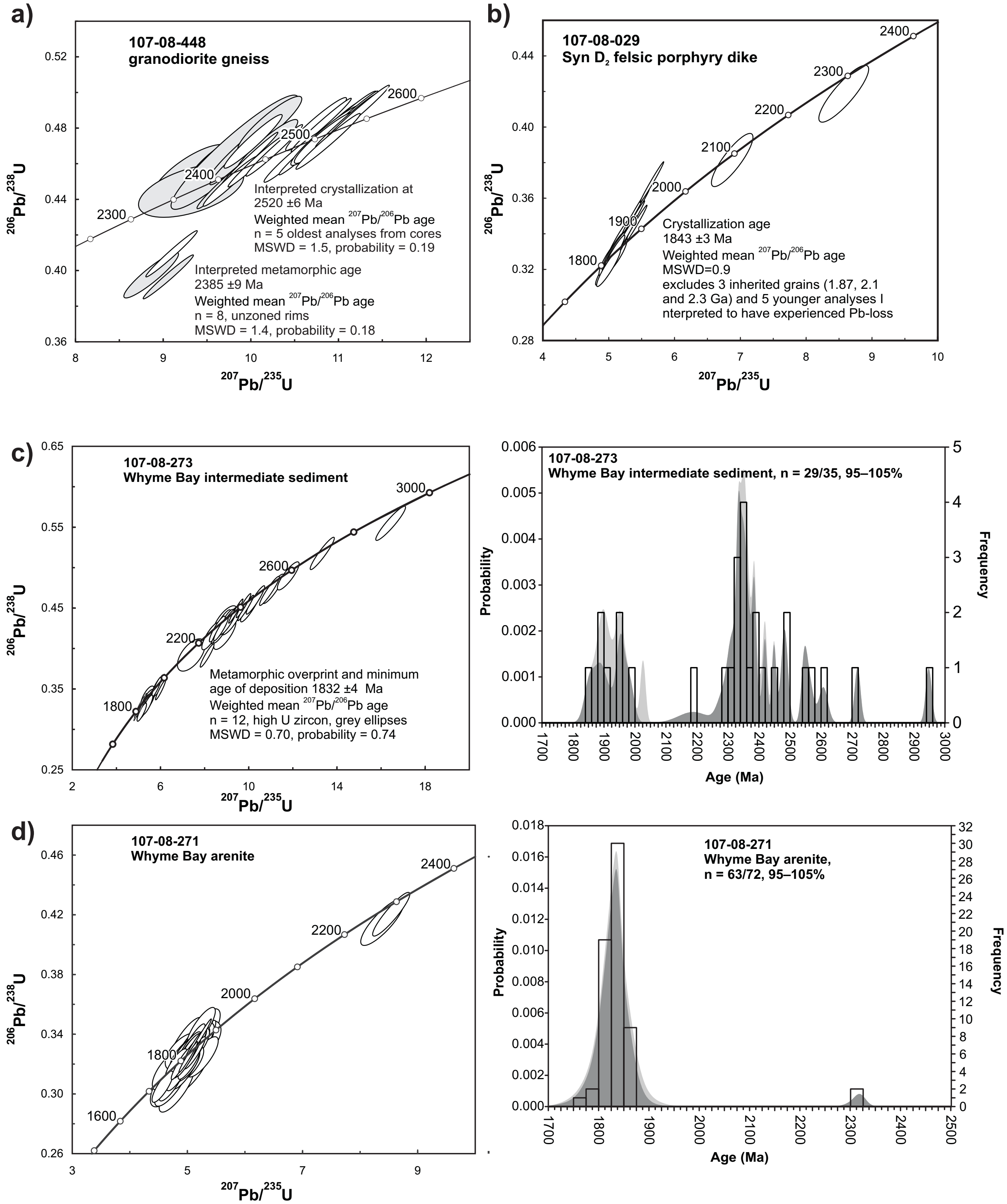

Figure GS-9-8: *Results from U-Pb geochronological analyses, Pukatawakan Bay area:* ***a)*** *U-Pb concordia diagram for detrital zircons from granodiorite gneiss sample 107-08-448;* ***b)*** *U-Pb concordia diagram for zircons from porphyry dike sample 107-08-029;* ***c)*** *U-Pb concordia diagram and probability-density distribution curve for detrital zircons from intermediate sediment sample 107-08-273;* ***d)*** *U-Pb concordia diagram and probability-density distribution curve for detrital zircons from arenite sample 107-08-271. Ellipses on concordia diagrams are plotted at the 2σ uncertainty level. MSWD refers to mean square of weighted deviates. All data is shown by light grey curves on probability-density diagrams; dark grey curves and histograms represent data that is within 5% concordant.*

morphologies. All analyzed zircons fell within the age range of 1897 to 1753 Ma except for two older grains at 2320–2310 Ma (Figure GS-9-8d). Excluding six statistical outliers, sixty-six of these analyses form a single statistical population centred at ca. 1832 Ma. Replicate analyses of the youngest detrital grain imprecisely constrain the maximum age of deposition to 1818 ±19 Ma (2σ). In addition, a crystallization age of 1829 ±1 Ma for an intrusive monzonitic granite (Rayner and Corrigan 2004) provides an independent, precise constraint on the minimum age of sedimentation. This tight time bracket between the dominant detrital mode and crosscutting monzogranite indicates rapid burial, lithification, and folding of the supracrustal sequence at Whyme Bay.

Discussion

The identification of ca. 2.5 Ga orthogneiss at Southern Indian Lake adds to the growing body of evidence suggesting the presence of Sask-age crust in the northwestern flank of the Trans-Hudson Orogen internides (Rayner and Corrigan, 2004; Corrigan et al., 2007). The extent of orthogneiss of this age is poorly constrained, as exposures occur on isolated islands throughout Southern Indian Lake. Orthogneiss could be limited to a relatively small, tectonically interleaved wedge of Archean to earliest Proterozoic crust. Alternatively, the orthogneiss exposures, in addition to common, similar-aged inherited zircons in intrusive rocks and detrital zircons in sedimentary rocks throughout this portion of the THO, could indicate that the extent of Sask craton-aged crust is much greater than suggested by current models (Corrigan et al., 2007).

Detrital zircon analyses conducted to date on sedimentary and reworked volcaniclastic rocks in the Southern Indian Lake area yield three distinct age profiles. Sedimentary rocks associated with arc volcanism at Whyme Bay and Partridge Breast Lake contain two main zircon populations (Figure GS-9-8c): 1) a dominant mode ranging between 1.86 and 1.91 Ga, which is consistent with the age of volcanism elsewhere in the THO, and 2) an older population with ages ranging between 2.55 and 2.3 Ga, which overlaps with known ages of the Sask craton. This bimodal detrital input is consistent with similar results from analyses carried out on psammitic rock samples from the Hickson Lake area (MacLachlan et al., 2004) and the Milton Island Assemblage (Ansdell et al., 1999) in Saskatchewan, both of which have been interpreted as fore-arc–basin deposits north of the La Ronge volcanic arc (MacLachlan et al., 2004; Corrigan et al., 2007). The detrital-zircon profile for arkosic rocks interbedded with pillow basalt along the Churchill River shows prominent modes at 2.63 and 2.655 Ga (Figure GS-9-5b); this result suggests that these rocks were most likely sourced from the southern margin of the Rae-Hearne craton, with no input from the advancing arc, and therefore represent an altogether different basin. Quartz arenite sampled at Whyme Bay contains a uniform zircon population centred at 1.832 Ga (Figure GS-9-8d). This data is consistent with the interpretation that these fluvial-alluvial rocks unconformably overlie the Whyme Bay assemblage. This sedimentary sequence contains a dominant population of detrital zircon younger than the ca. 1.855 Ga Chipewyan Batholith, and therefore shares temporal links to the Sickle Group rather than the Park Island Assemblage in Saskatchewan.

Economic considerations

The work conducted in the Southern Indian Lake area has identified a variety of mineral exploration targets in an area that has seen little such activity in recent decades. Emerging geoscience data, both in Manitoba and Saskatchewan, are establishing temporal links between volcanic rocks in the Southern Indian Lake, Rottenstone, Lynn Lake–Leaf Rapids domains, and therefore indicate the possible presence of VMS-type mineralization at the regional scale. Frohlinger (1972) reported assay results up to 2.2% Cu from a narrow malachite-rich fracture 1.2 m long in volcanic rocks of the Whyme Bay assemblage, providing a first indication of base metal mineralization in the Southern Indian Lake area.

Similar malachite-rich showings were found near the base of the clastic sedimentary sequence around Partridge Breast Lake (M.T. Corkery, pers. comm., 2008). Assay results from the margin of a weakly gossanous tonalitic intrusion cutting these sedimentary rocks yielded anomalous Zn values of 1.36% and elevated As values, and could indicate the presence of sediment-hosted Cu-Zn-Pb mineralization.

Sulphidic and graphitic sedimentary horizons on the northwestern shore of Turtle Island contain up to 70% pyrite and pyrrhotite with minor chalcopyrite. Perhaps more interesting is the fact that this sequence is intruded by the sulphide-bearing, ultramafic to intermediate Turtle Island intrusive complex, which shows evidence of multiple injections in a fluidly dynamic magma chamber. The host sedimentary rocks may have provided the source of sulphur to the intruding magma which allowed for the fractionation of magmatic Ni–Cu–platinum-group element sulphides.

Widespread late- to post-tectonic plutonism associated with the margins of long-lived Archean cratons presents a prospective setting for iron-oxide copper-gold–type mineralization. In addition, the presence of locally intense potassic alteration throughout plutonic and supracrustal rocks in the study area is also considered a favourable indication. Lastly, abundant magnetite and pyrite-chalcopyrite identified in late pegmatitic to rapakivi-like granite on the eastern shore of Southern Indian Lake could prove to be a viable exploration target.

Assay results from samples collected during the summer of 2009 are pending.

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