GS-13 Far North Geomapping Initiative: geological investigations in the Great Island area, Manitoba (parts of NTS 54L13, 54M4, 64I15, 16, 64P1, 2)

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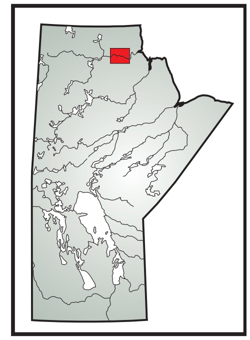

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Summary

A major new phase in the remapping of selected portions of Manitoba's far north was initiated in 2008 with a scoping study and continued with a focused effort in 2009. The Great Island area, 120 km west of Churchill, was chosen because of its importance to the resolution of several fundamental questions pertaining to the Precambrian geology and mineral potential of northern Manitoba. It provides key exposures of metasedimentary cover successions, includes the only known exposures of metavolcanic rocks in Manitoba's far north and contains several important mineral occurrences.

Neoarchean and possible Mesoarchean 'basement' rocks at the Hearne craton margin are represented by the Seal River intrusive complex, which is exposed in shoreline outcrops on the Seal River, 30 km downstream from the east end of Great Island. From oldest to youngest, components of the complex include multicomponent orthogneiss (with enclaves of amphibolite and metagabbro), heterogeneous biotite (±hornblende) granite and discordant dikes of biotite granodiorite, hornblende porphyry (diorite), feldspar porphyry (rhyolite) and diabase (diorite).

At Great Island, the Neoarchean Garlinski Lake greenstone belt is comprised of subaqueous mafic-intermediate volcanic rocks (Sosnowski Lake assemblage) and an unconformably overlying clastic succession (Omand Lake assemblage) that are in turn unconformably overlain by the Paleoproterozoic Great Island Group, exposed in a structurally complex, north-trending synclinorium.

The Great Island Group is divided into lower and upper subgroups, which are provisionally interpreted to represent marine-deltaic and basinal-marine depositional settings, respectively. Sandstone beds in the former are mostly composed of relatively mature quartz arenite, whereas those in the latter consist of relatively immature feldspathic greywacke. Oxide-silicate–facies iron formation forms the base of each of the subgroups, which in addition feature distinct units of dolomitic marble and mudstone.

Intrusive rocks ranging in composition from granite to peridotite are a significant component of both the Seal River intrusive complex and the Garlinski Lake greenstone belt, but are nowhere observed in the overlying Great Island Group. Emplacement is thus constrained to the late Neoarchean to earliest Paleoproterozoic. On the basis of composition and texture, these rocks are divided into seven map units, the relative and absolute ages of which remain unknown.

Introduction

This report summarizes the results of fieldwork completed in 2009 during the first full season of bedrock mapping under the auspices of the Far North Geomapping Initiative – a three-year study of the Hearne craton margin in Manitoba being undertaken by the Manitoba Geological Survey (MGS) in conjunction with the Geological Survey of Canada (GSC) Geo-mapping for Energy and Minerals (GEM) program. This new work extends from and builds upon recent work completed by the MGS in selected areas of Manitoba's far north (*see* Böhm et al., 2004; Anderson and Böhm, 2005; Anderson et al., 2005; Matile, 2005; Anderson and Böhm, 2006; Böhm and Anderson, 2006a, b; Matile, 2006a, b; Figure GS-13-1), with the objective of furthering current understanding of the nature, evolution and mineral potential of one of the principal geological building blocks of Manitoba's Precambrian shield.

The MGS launched this initiative in 2008 with a one-week program of reconnaissance mapping and bedrock sampling of the lower Seal and North Knife rivers (Anderson and Böhm, 2008), which was followed-up in the fall of 2008 by a GSC-funded aeromagnetic and gamma-ray spectrometric geophysical survey of a 6200 km^2 area centred on Great Island on the Seal River (Fortin et al., 2009). The Great Island area was last mapped in 1974–1975 (Schledewitz, 1986) and was chosen for further study because it provides key exposures of metasedimentary cover successions, includes the only known exposures of metavolcanic rocks in Manitoba's far north and contains several important mineral occurrences. As such, this area is considered to be key to the resolution of several fundamental questions pertaining to the Precambrian geology and mineral potential of northern Manitoba.

Fieldwork in 2009 included helicopter-supported bedrock mapping by MGS geologists in a roughly 2900 km^2 area centred on Meades Lake, near the northeastern tip of Great Island on the Seal River (Figure GS-13-2), as well as a surficial geology scoping study (Trommelen and Ross, GS-14, this volume). The mapping program

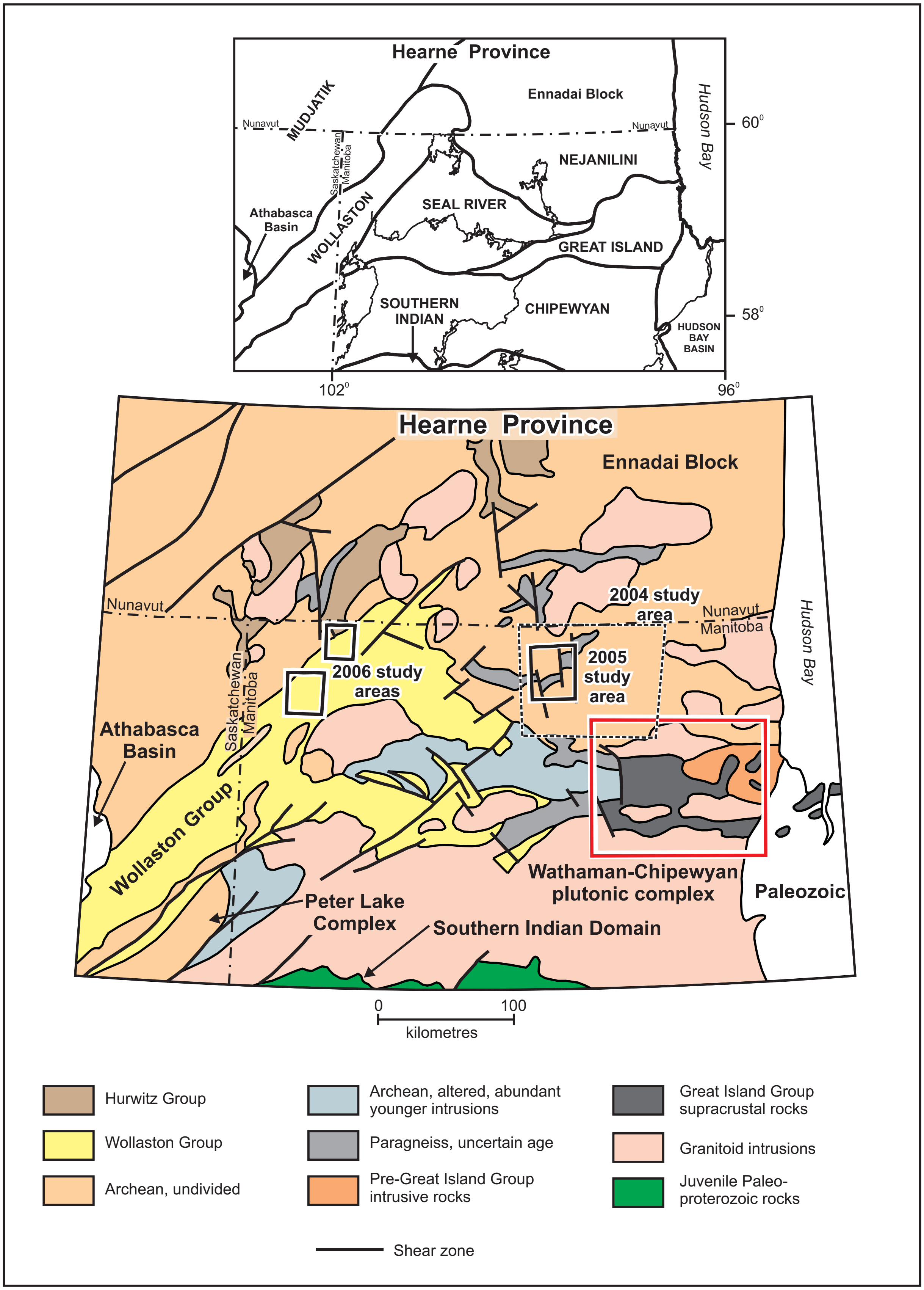

***Figure GS-13-1:** Lithotectonic elements of the Trans-Hudson Orogen–Hearne craton region (after Manitoba Industry, Trade and Mines, 2000) with the area of the Far North Geomapping Initiative outlined in red (locations of previous study areas are outlined in black). Inset map shows the major geological domains in Manitoba's far north.*

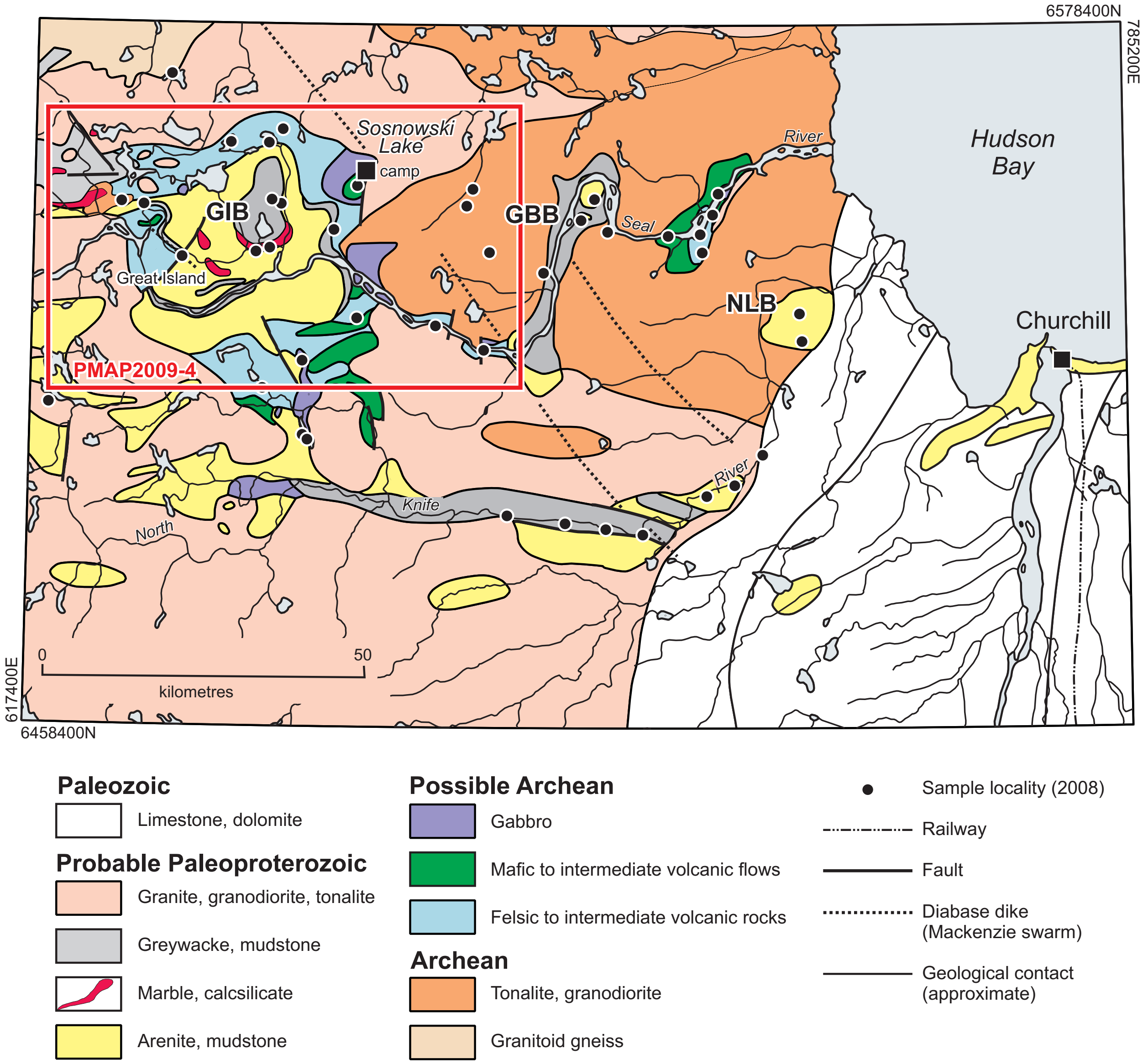

***Figure GS-13-2:** Simplified geology of the eastern Great Island Domain (after Schledewitz, 1986), showing the area mapped during the 2009 field season. Abbreviations: GBB, Grand Bend basin; GIB, Great Island basin; NLB, Nowell Lake basin. Shown for reference are the localities from the 2008 reconnaissance program and the outline of the area mapped in 2009.*

was based out of an exploration camp owned by Whetstone Minerals Inc. at Sosnowski Lake, which is located 114 km west-northwest of Churchill. Although bedrock exposure in this area is generally less than 2%, and large areas were found to be devoid of outcrop, a significant upgrade of the existing geological map has been achieved by integrating the results of the 2009 mapping program with newly acquired aeromagnetic data. These data will be augmented by the results of ongoing lithogeochemical, Sm-Nd isotopic and U-Pb geochronological studies. In 2010, the mapping coverage will be extended south and east of the 2009 study area.

Regional setting

The Archean continental crust of the southeast Hearne craton is overlain by Paleoproterozoic cover rocks and, together with the cover rocks, has been variably overprinted by tectonothermal and magmatic activity associated with the Paleoproterozoic Trans-Hudson orogeny. In Manitoba, the southeastern margin of the Hearne craton is divided into the Mudjatik, Wollaston, Seal River, Great Island and Nejanilini domains, which are distinguished by their respective proportions of cover and possible basement rocks and, to a lesser extent, by their structural trends and metamorphic grade. The area investigated in 2009 lies wholly within the Great Island Domain, which is bounded to the north by the Nejanilini Domain and to the south by the Wathaman–Chipewyan plutonic complex (Figure GS-13-1).

The Nejanilini Domain is dominated by granulite-grade metaplutonic rocks, with minor enclaves of metasedimentary rocks, and is interpreted to include vestiges of the Meso- to Neoarchean basement of the Hearne craton (Böhm et al., 2004). The Great Island Domain, in contrast, is characterized by the presence of widespread metasedimentary rocks of generally lower-metamorphic grade and inferred Paleoproterozoic age that were assigned to the Great Island Group by Schledewitz (1986). These rocks unconformably overlie metaplutonic rocks of probable Archean age and are inferred to be broadly correlative with similar, comparatively well-dated rocks of the ca. 2.1–1.9 Ga Wollaston Supergroup in Saskatchewan (*see* Yeo and Delaney, 2007; Tran et al., 2008) and the partially time-equivalent Hurwitz Group in Nunavut (ca. 2.5–1.9 Ga; *see* Davis et al., 2005). In the study area, the Great Island Group defines a largely intact, though structurally complex, synclinorium (the 'Great Island basin' of Schledewitz, 1986), which is everywhere underlain by metavolcanic rocks of presumed Archean or Early Paleoproterozoic age. To the west, the Great Island Domain transitions into partially equivalent, though generally higher-grade, rocks of the Seal River Domain (Schledewitz, 1986).

The Wathaman–Chipewyan plutonic complex separates the Great Island Domain from accreted juvenile Paleoproterozoic terranes farther south in the Reindeer Zone of the Trans-Hudson Orogen, and is interpreted to represent a remnant of a vast continental magmatic arc emplaced between 1.87 and 1.85 Ga (Meyer et al., 1992). Widespread syn- to late-tectonic granodiorite, quartz monzonite and granite plutons in the Great Island Domain (Schledewitz, 1986) are superficially similar to plutons in the Wollaston Domain in Saskatchewan that have yielded ages ranging from 1.84 to 1.80 Ga (Annesley et al., 1992, 1997), which corresponds to the main period of Hudsonian granite emplacement throughout the western Churchill Province (Peterson et al., 2002).

As described by Schledewitz (1986), mineral assemblages in supracrustal rocks in the eastern Great Island Domain, including the Great Island Group, indicate peak metamorphism in the greenschist to lower-amphibolite facies. Upper-amphibolite–facies assemblages (biotite-sillimanite±cordierite±garnet) are observed in paragneiss northwest of Great Island and appear to require the presence of a local metamorphic discontinuity with the overlying Great Island Group. In the interest of brevity, the prefix 'meta' is dropped from the lithological descriptions in this report.

Description of units

The geology of the Great Island area is described below, in general order of decreasing known or inferred age of the constituent rock units. Unit numbers in this report correspond to those on Preliminary Map PMAP2009-4 (Anderson et al., 2009). Figure GS-13-3 is a simplified version of this map.

Seal River intrusive complex (units A1–A6)

The Seal River intrusive complex is exposed in shoreline outcrops on the Seal River, approximately 30 km downstream from the eastern end of Great Island. Aeromagnetic data indicate that these outcrops are situated in the northeastern portion of a roughly elliptical (12x25 km) body of generally high magnetic intensity that trends east-southeast and is unconformably overlain at both ends by the Great Island Group.

The oldest component of the complex is a multicomponent orthogneiss (unit A1) that exhibits a pervasive and locally intense gneissosity defined by tabular to wispy layers of medium-grained equigranular light grey granodiorite, pink granite and dark grey quartz diorite (Figure GS-13-4a). Hornblende and biotite are the principal ferromagnesian phases. The gneissosity varies from straight to highly contorted, and is locally overprinted by tight to isoclinal folds and an associated axial-planar foliation defined by hornblende and biotite. Enclaves of amphibolite and metagabbro are abundant locally (subunit A1a) and are cut by granite dikes, which are transposed at the margins of the enclaves into the surrounding gneiss.

The orthogneiss is cut by voluminous dikes and irregular intrusions of light pink to buff biotite (±hornblende) granite (unit A2) that is characteristically heterogeneous; on the scale of individual dikes or outcrops, this rock shows irregular textural variations from equigranular to porphyritic to cataclastic to pegmatitic. External contacts are sharp, irregular and generally discordant to the host orthogneiss. Some dikes display a weak to moderate foliation or gneissosity that subparallels the host orthogneiss. These features are suggestive of multiphase emplacement.

The orthogneiss and heterogeneous granite are cut by dikes of light grey homogeneous biotite granodiorite (unit A3), which range up to 15 m in thickness. This rock is fine-grained and equigranular, with a faint augen texture defined by 1–2 cm aggregates of feldspar and quartz. The contacts are sharp, slightly wavy and cut the host orthogneiss at a shallow angle (Figure GS-13-4b); some contacts appear to be chilled. The augen define a penetrative foliation that generally parallels the contacts of the dikes. A sample of granodiorite from one of these dikes returned a preliminary U-Pb zircon age of ca. 2860 Ma. (N. Rayner, pers. comm., 2009).

Units A1–A3 are crosscut by swarms of generally northwest-trending dikes that are not mappable at a regional scale. They are characterized by three distinct textural types identified as hornblende porphyry (diorite), feldspar porphyry (rhyolite) and diabase

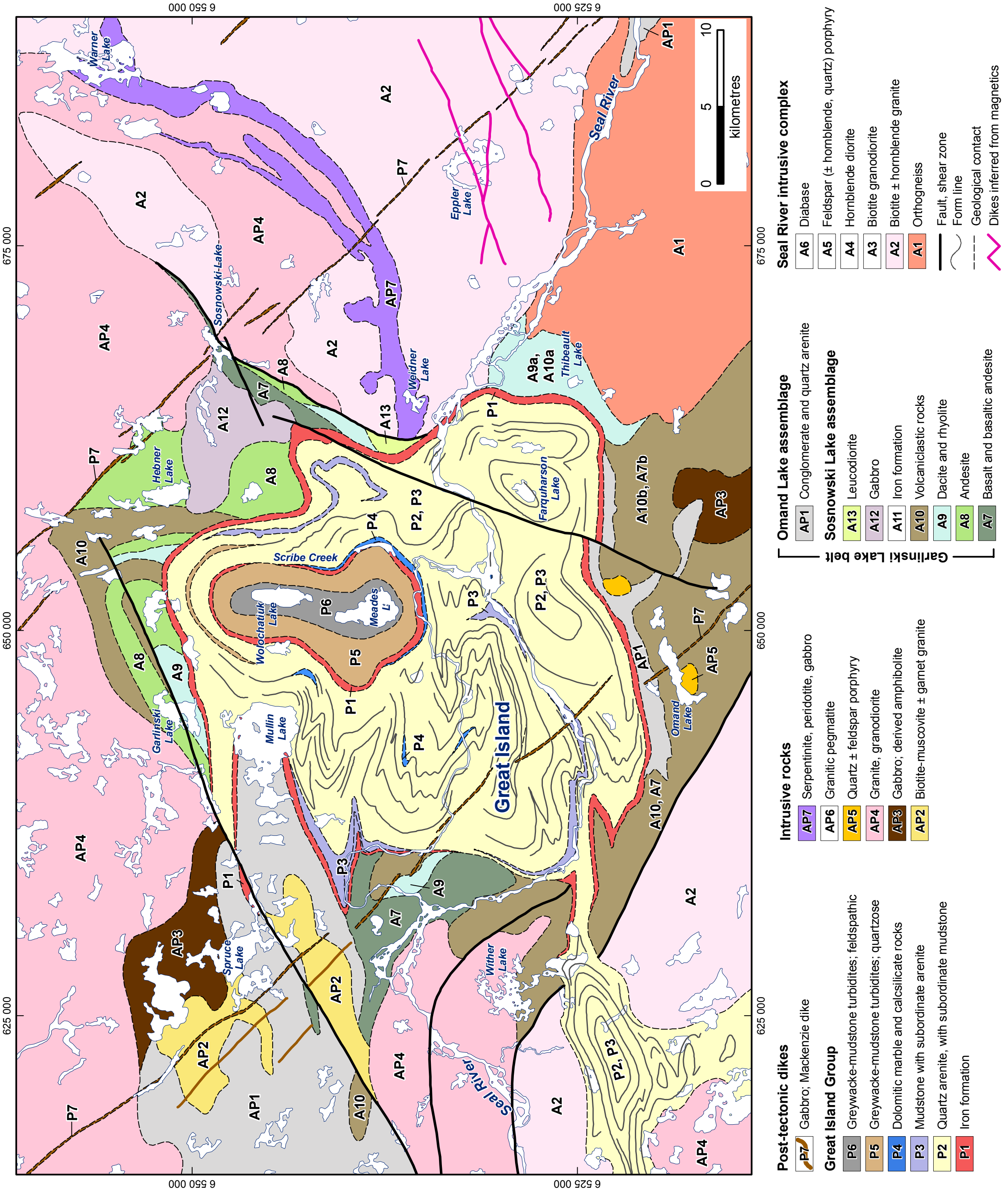

Figure GS-13-3: Simplified geology of the Great Island area, showing the locations cited in the text.

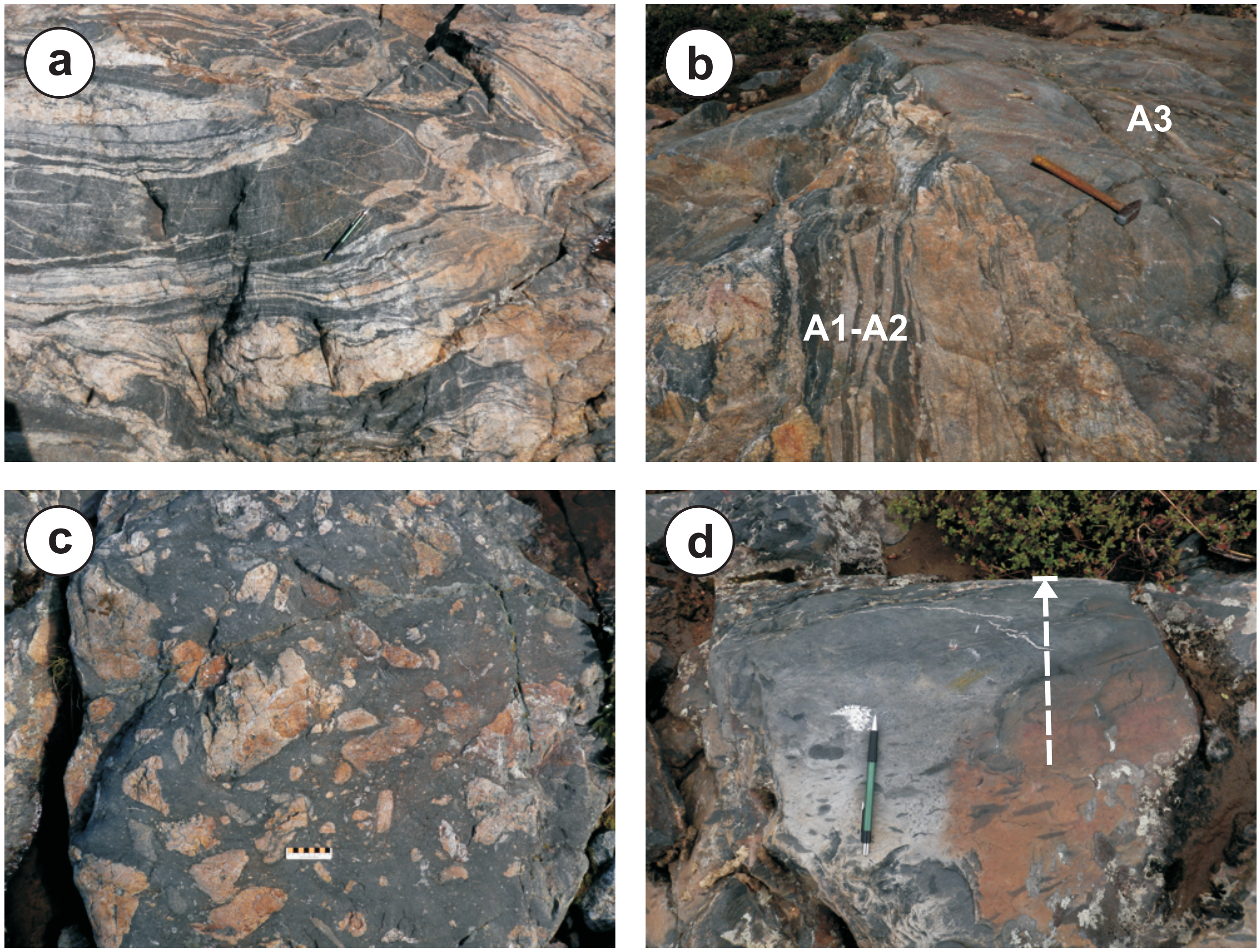

Figure GS-13-4: *Outcrop photographs of rock types in the Seal River intrusive complex at the type locality on the Seal River, east of Great Island:* ***a)*** *multicomponent orthogneiss (unit A1);* ***b)*** *orthogneiss and biotite granite (units A1 and A2) crosscut by a granodiorite dike (unit A3);* ***c)*** *intrusion breccia composed of angular granitoid xenoliths in a matrix of hornblende porphyry (diorite; unit A4);* ***d)*** *thick chilled margin (indicated by arrow) on feldspar-porphyry dike (unit A5).*

(diorite); consistent crosscutting relationships indicate these correspond to three distinct generations of magmatism. Some of these dikes are strongly magnetic and may thus account for the distinctive magnetic signature of the Seal River intrusive complex at the type locality; none are observed elsewhere.

The hornblende porphyry (unit A4) dikes weather dark grey-brown and consist of acicular black hornblende phenocrysts (30–40%, 0.5–2.0 mm) in a fine-grained feldspathic matrix, which imparts a distinctive 'salt and pepper' texture to the rock. These dikes range up to 1.5 m in thickness and show sharp, wavy to planar contacts and thick chilled margins. Most dikes contain metaplutonic xenoliths similar in appearance to those in units A1–A3; some dikes contain up to 40% xenoliths and are properly described as intrusion breccia (Figure GS-13-4c). A moderate to strong S-L fabric is defined by aligned hornblende and elongate xenoliths.

Feldspar porphyry (unit A5) dikes weather light grey to pink to buff and contain subhedral plagioclase phenocrysts (5–15%, <5 mm) in an aphanitic to very fine-grained feldspathic matrix. Some specimens contain acicular hornblende or quartz (1–5%, <2.0 mm) phenocrysts. Xenoliths of dark grey, aphanitic to fine-grained, sparsely plagioclase(±quartz)–phyric dacite are ubiquitous and abundant. These xenoliths are wispy to tabular and very angular, although a subset shows more rounded, equant shapes, and others have highly irregular, amoeboid shapes suggestive of magma-mingling. An intrusive origin for the precursor dacite is suggested by the presence of granitoid inclusions in some xenoliths. Most dikes also contain lesser xenoliths of granite, melagabbro, coarse leucogabbro and granitic pegmatite; in some cases these xenoliths account for up to 50% of the dike. The dikes range up to at least 30 m in thickness and have sharp, wavy to planar contacts, with thick (10–20 cm) chilled margins (Figure GS-13-4d). Many of these dikes core, and are chilled against, dikes of hornblende diorite, which indicates reuse of existing conduits. The feldspar porphyry dikes discordantly cut orthogneiss and contain a pervasive and locally intense S-L fabric defined by flattened and stretched xenoliths.

Diabase (unit A6) dikes represent the youngest phase identified in the Seal River intrusive complex. These dikes show sharp contacts and well-developed chilled margins, and are generally less than 1.0 m thick. The diabase is dark green-grey, fine-grained and varies from equigranular to sparsely plagioclase-porphyritic. Most examples lack abundant xenoliths and contain a weak to moderate foliation. A locally penetrative S-L fabric in these dikes indicates they are unrelated to the post-tectonic diabase dikes of the Mackenzie swarm (see below).

Based on the field relationships and available U-Pb zircon age data, units A1–A3 are provisionally interpreted to represent a vestige of Neoarchean and possible Mesoarchean ‘basement’ rocks at the Hearne craton margin. The discordant swarms of relatively high-level dikes (units A4–A6) likely represent feeders to overlying mafic and felsic volcanic rocks, and are perhaps related to volcanism in the adjacent Garlinski Lake belt (see below). Outside of the type locality on the Seal River, the distribution of these potential ‘basement’ rocks is poorly constrained. Granitoid orthogneiss is widespread in the area east of Eppler Lake and is also observed in scattered outcrops northeast of Sosnowski Lake and southwest of Great Island. However, none of these outcrops display the intrusive complexity of the type locality. The significance of this distinction remains to be determined.

Garlinski Lake greenstone belt

The Garlinski Lake greenstone belt, as newly defined here, is interpreted to consist of two distinct assemblages of supracrustal rocks, both of which are crosscut by diverse suites of intrusive rocks and overlain by the Great Island Group cover sequence. Subaqueously deposited volcanic rocks predominate in the belt and are referred to as the ‘Sosnowski Lake assemblage’ (SLA), whereas the ‘Omand Lake assemblage’ (OLA) consists of subaerial sedimentary rocks, which are interpreted as unconformably overlying the SLA. The map-scale distribution of these assemblages is suggestive of a macroscopic synclinorium, cored by the OLA, which trends in a general northwesterly direction through Omand Lake to Spruce Lake, beneath the Great Island basin. In this regard, the belt-scale stratigraphy and structural geometry of the Garlinski Lake belt appear analogous to the classical Archean greenstone sequence, as observed in both the Hearne and Superior cratons; however, the age of these rocks is poorly constrained. The belt is everywhere bound by granitoid intrusive rocks. Local discordance between primary stratification and the external margin of the belt indicates an intrusive contact relationship.

Sosnowski Lake assemblage (units A7–A13)

The SLA consists of subaqueous, mafic to intermediate lava flows and related intrusions, felsic volcanic rocks, derived volcaniclastic and epiclastic rocks, and iron formations. These rocks crop out on the entire periphery of the Great Island basin, but are best exposed along the northern and eastern margins. Neither the base nor the top of the assemblage is exposed and younging reversals, as well as local ‘back-to-back’ younging relationships, indicate the presence of tight to isoclinal folds and fault-bounded panels; hence, the stratigraphic sequence and thickness remain unknown. Most outcrops show a penetrative S-L fabric that includes a pronounced, steep stretching lineation.

Basalt and basaltic andesite (unit A7) flows are most extensive southwest of Sosnowski Lake and at the northwestern end of Great Island; continuous sections in the former location range up to 300 m in thickness. These rocks weather dark grey to dark green and vary from aphyric (subunit A7a) to sparsely plagioclase-phyric (subunit A7b). Many flows contain quartz, carbonate or epidote amygdules, typically in pillow margins. Flows are predominantly pillowed rather than massive and some flows are clearly of compound type; the pillowed flows consist of variably flattened bun-shaped pillows up to 1.5 m across, with centimetre-thick dark green selvages and interpillow hyaloclastite 1–3 cm thick. These rocks are characterized by patchy epidotization and silicification. Massive flows in each of the locations cited above transition upward into amoeboid pillow breccia and are locally capped by discontinuous iron formations up to 50 cm thick (unit A11) that include oxide-silicate (subunit A11a) and silicate-sulphide (A11b) facies.

Andesite flows (unit A8) are extensive northeast of Garlinski Lake and south of Hebner and Sosnowski lakes. These rocks weather light green-grey to buff and are typically plagioclase-phyric (subunit A8b), although aphyric flows are present locally (subunit A8a). Fine-grained biotite and chlorite replace a mafic phenocryst phase in some locations. Pillowed flows consist of generally large, bun-shaped to amoeboid pillows (Figure GS-13-5a) that range up to more than 4 m across; these are locally subordinate to intercalated pillow-fragment breccia. Massive flows are rare. Most pillows have relatively thick (2–5 cm) selvages and contain round to irregular quartz amygdules, which locally range up to 20 mm across. Interpillow hyaloclastite typically is 2–5 cm thick: some flows contain up to 25% hyaloclastite, which forms the matrix to bulbous or irregular lobes of highly amygdaloidal andesite. Spherulites and concentric thermal contraction cracks characterize certain flows but are not widespread. Pillows commonly display patchy to pervasive epidotization, silicification or carbonatization.

Dacite and rhyolite of possible effusive origin (subunit A9a) are a minor component of the SLA in several areas, including around Garlinski and Thibeault lakes, and at the northwestern end of Great Island. These rocks weather pinkish or greenish-grey and contain sparse quartz and plagioclase phenocrysts in an aphanitic siliceous matrix. Most outcrops show evidence of variations from massive

***Figure GS-13-5:** Outcrop photographs of characteristic rock types in the Sosnowski Lake and Omand Lake assemblages of the Garlinski Lake greenstone belt: **a)** pillowed flow of plagioclase-phyric andesite (unit A8b), east of Garlinski Lake; **b)** heterolithic volcaniclastic rock (unit A10c), Seal River at the western end of Great Island; **c)** stratified polymictic conglomerate (unit AP1a; well-rounded quartzite clasts indicated by arrows) and planar-bedded quartz arenite, southwest of Spruce Lake; **d)** trough-crossbedded quartz arenite showing quartz-pebble conglomerate bottomsets (unit AP1a), southeast of Omand Lake.*

to subtle fragmental textures. A distinctive rhyolite at Thibeault Lake contains blue-quartz phenocrysts and very fine-scale compositional layers, interpreted to represent flow-banding. A sample of this outcrop collected in 2008 has yielded a preliminary U-Pb zircon age of 2570 Ma (N. Rayner, pers. comm., 2009). Dikes of light grey, aphanitic to sparsely plagioclase-phyric dacite (subunit A9b) cut andesite and basalt flows in several locations and locally contain round quartz amygdules, indicative of hypabyssal emplacement.

Locally-derived volcaniclastic rocks (unit A10) are intercalated with volcanic rocks of units A7–A9 and also occur in isolated outcrops around the western and southern margins of the Great Island basin. The most extensive outcrop areas are found south and west of Hebner Lake and along the western side of Great Island. These rocks are subdivided into intermediate to felsic (subunit A10a), mafic to intermediate (A10b) and heterolithic (subunit A10c) end-members based on clast populations, which are generally representative of adjacent volcanic units. In general, these rocks are matrix supported, poorly sorted and unstratified on the scale of individual outcrops (Figure GS-13-5b). Clasts are angular to subrounded and typically less than 10 cm across, and are of similar composition to the matrix; very coarse or significantly reworked volcaniclastic deposits are scarce. The volcaniclastic rocks along the western side of Great Island are characterized by widespread calcsilicate alteration, which locally obliterates the primary volcaniclastic texture.

Unit A10 includes a distinctive subunit (A10d) of felsic volcanic sandstone south of Hebner Lake that occurs within a succession of pillowed and massive basalt flows and gabbro. This sandstone is at least 50 m thick and is well-bedded, medium-grained and pebbly; the presence of abundant detrital quartz indicates a non-proximal source area. Intervals of thinly interbedded sandstone and mudstone up to 5 m thick show turbidite bedforms and load structures, which indicate deposition via turbulent density flows in a relatively quiescent subaqueous setting. The middle of the subunit contains a massive bed of medium- to coarse-grained pebbly sandstone 20 m thick, the base of which is scoured deeply into underlying beds and thus suggests deposition by high-density grain flow. Silicate iron formation, chert, graphitic mudstone and thin-bedded turbidites in an interval 1–3 m thick at the top of this unit indicate a period of relative quiescence, and perhaps coeval exhalative activity, prior to emplacement of a conformably overlying mafic unit that represents either a massive basalt flow or gabbro sill. A sample of the sandstone will be processed for U-Pb dating of detrital zircons to constrain the age of this potentially significant marker horizon.

Gabbro of unit A12 is associated with, and presumed to be related to, mafic volcanic rocks in the northeastern portion of the belt and includes a large intrusion west and southwest of Sosnowski Lake. This gabbro weathers medium to dark green and is typically massive with a medium-grained, diabasic to ophitic texture. Some outcrops show evidence of irregular variations between meso- and leucogabbro or localized zones of intrusion breccia composed of angular inclusions of mesogabbro in a leucogabbro matrix. Gossanous zones in the gabbro measure up to several metres in diameter and contain up to 5% disseminated to blebby, fine-grained pyrrhotite; assays are pending.

Leucodiorite (unit A13) is exposed in a series of large clean outcrops along the eastern margin of the belt, north of the Seal River; it weathers pale yellow-green to buff and is massive with a fine- to medium-grained, equigranular, diabasic texture. This rock consists mostly of plagioclase, with 2–5% interstitial or phenocrystic quartz. Most outcrops show evidence of weak to moderate, pervasive sericite (±ankerite) alteration. Crosscutting gabbro dikes with sharp contacts and thick chilled margins are common. In the northern outcrops, the leucodiorite appears to be hosted by mafic volcaniclastic rocks and pillowed andesite flows, although the contact relationships are not exposed.

Omand Lake assemblage (unit AP1)

The OLA is exposed along the southern and western margins of the Great Island basin, in areas where the exposed SLA is comparatively thin. The OLA is dominated by quartz arenite and conglomerate and is interpreted to lie unconformably on the SLA, given that the conglomerate locally contains volcanic detritus of apparently local derivation. Neither the base nor the top of this assemblage is exposed and the internal stratigraphy is unknown. Metamorphic mineral assemblages west of Great Island indicate peak metamorphism in the upper-amphibolite facies, and thus require an increasing metamorphic gradient in that direction.

Conglomerate (subunit AP1a) is the characteristic rock type of the OLA. Individual beds are matrix supported, poorly sorted and massive to normal-graded, and locally range up to at least 20 m in thickness. Well-rounded and high-sphericity clasts account for a significant proportion of the clast population (Figure GS-13-5c), a feature consistent with significant subaerial transport; this material likely represents channel deposits in a braided fluvial-alluvial system. Polymictic pebble and cobble conglomerate southeast of Great Island is dominated (>80%) by white, pink and grey quartz clasts but includes medium-grained granitoid, felsic volcanic quartzite and altered ultramafic components. The conglomerate occurs as pebble lags at the base of crossbed sets (Figure GS-13-5d) and as lenticular beds up to 75 cm thick interstratified with the crossbedded arenite. Quartz-pebble conglomerate south of Great Island is characterized by patchy to pervasive hematite-sericite alteration of the matrix. Polymictic pebble to cobble conglomerate is more prevalent west of Great Island and contains a more heterolithic clast population, which includes texturally variable quartzite and granitoid clasts up to 25 cm across, with minor plagioclase-phyric andesite, quartz-phyric rhyolite and gabbro.

The conglomerate is interstratified at various scales with quartz arenite (subunit AP1b) and interbedded quartz arenite and mudstone (subunit AP1c). Subunit AP1b is mostly trough crossbedded, medium- to coarse-grained and pebbly, whereas subunit AP1c is generally finer grained and planar bedded, with subordinate (<10%) beds of sericitic mudstone less than 5 cm thick. These rocks may represent active and abandoned channel-fill deposits, respectively, in the braided fluvial-alluvial system. Subunit AP1b dominates south of Great Island, where most outcrops contain weak to strong sericite-fuchsite alteration, which imparts an emerald-green colour to bedding and fracture surfaces. Uranium-lead ages of detrital zircons in a sample of quartz arenite collected 6 km southeast of Omand Lake in 2008 define an essentially bimodal distribution (ca. 2680 Ma and 2970 Ma) and indicate a maximum depositional age of ca. 2613 Ma (N. Rayner, pers. comm., 2009).

West of Great Island, the OLA is dominated by strongly foliated and layered paragneiss (subunit AP1d), which contains subordinate units of crossbedded quartz arenite and polymictic conglomerate. Planar bedforms are locally well preserved, which suggests that most of the paragneiss is derived from thinly interbedded quartz arenite and mudstone (i.e., subunit AP1c). Metamorphic mineral assemblages consist of biotite-sillimanite±cordie rite±garnet, which is consistent with peak metamorphism in the upper-amphibolite facies.

Intrusive rocks (units AP2–AP7)

Intrusive rocks ranging in composition from granite to peridotite are a significant component of both the Seal

River intrusive complex and the Garlinski Lake greenstone belt, but are nowhere observed in the overlying Great Island Group. Emplacement is thus constrained to the late Neoarchean to earliest Paleoproterozoic, based on the ca. 2.1-1.9 Ga age presumed from regional relationships for the Great Island Group. On the basis of composition and texture, these rocks are divided into six map units, the relative and absolute ages of which remain unknown.

Two-mica granite (unit AP2) forms mappable plutons in the Spruce Lake area, where it is hosted by sillimanite-grade sedimentary rocks of the OLA. The granite weathers white to light grey and has a fine- to medium-grained equigranular texture defined by feldspar and subordinate quartz. Biotite (3-5%) and muscovite (1-2%) are the characteristic minor phases, although some specimens also contain garnet or cordierite. Individual outcrops are homogeneous or heterogeneous, the latter of which are characterized by pegmatitic segregations and irregular inclusions or screens of quartz arenite or paragneiss. These features are indicative of 'S-type' granite produced through anatexis of the adjacent metasedimentary rocks.

Unit AP3 consists of isolated outcrops of gabbro spatially associated with the OLA at the western end of Mullin Lake and along the northern margin of the belt, north of Spruce Lake. Whether the gabbro intrudes the OLA, or represents part of the underlying SLA, remains unknown. These rocks weather medium green to black and are fine to medium-grained, equigranular and typically homogeneous; hand specimens are nonmagnetic. North of Spruce Lake, the gabbro is strongly recrystallized and contains a penetrative S-L fabric and weak gneissosity.

Granite and granodiorite plutons of unit AP4 intrude both the SLA and OLA and, at least locally, define the margins of the Garlinski Lake belt. These plutons are also extensive beyond the margins of the belt, where they may include significantly older components of the type exposed in the Seal River intrusive complex. These rocks generally weather pale pink and consist of varying proportions of medium-grained plagioclase, quartz and K-feldspar, with minor (<15%) biotite and magnetite, and local hornblende. Three textural subunits are distinguished: equigranular (AP4a), porphyritic (AP4b) and augen (AP4c). Most outcrops are crosscut by aplite and granitic pegmatite dikes and show a weak to moderate foliation.

Quartz-feldspar porphyry (unit AP5) forms mappable intrusions in the Garlinski belt, south of Spruce Lake and at Omand Lake, and is observed in isolated outcrops north of the Seal River, downstream from Great Island. This rock weathers light grey to pale pink to brick-red and contains up to 10% feldspar and/or quartz phenocrysts in a fine-grained matrix of feldspar and quartz, with minor (<5%) biotite; these rocks are homogeneous and weakly foliated.

Dikes and irregular intrusions of granitic pegmatite (unit AP6) are common in the Spruce Lake area, where they discordantly intrude sillimanite-grade rocks of the OLA. Pegmatite also cuts lower-grade rocks of the SLA along the north margin of the Garlinski Lake belt, and is widespread in the outlying granitoid plutons. The pegmatite consists of K-feldspar and quartz, with minor biotite, and local accessory muscovite and/or tourmaline. Where contacts with supracrustal rocks are exposed, pegmatite dikes crosscut the local deformation fabric, which indicates their emplacement occurred relatively late in the regional deformation history.

East of Great Island, a prominent series of arcuate and branching linear aeromagnetic anomalies delineate the surface trace of an ultramafic-mafic intrusion (unit AP7), which extends in a continuous manner from Weidner Lake northeast to Warner Lake for a total strike length of 32.6 km. The northeastern and central portions of this intrusion have been tested by at least eight diamond-drill holes, which intersected mostly serpentinite, with minor peridotite and gabbro (Assessment Files 92108, 92184, Manitoba Innovation, Energy and Mines, Winnipeg). Only two outcrops have been found. Reddish-brown weathering and faintly layered peridotite (subunit AP7a) is exposed in a small outcrop 7 km south of Warner Lake and contains equant serpentine pseudomorphs after olivine in a fine-grained serpentine matrix. Mesocratic to leucocratic gabbro (subunit AP7b) with a fine-grained, equigranular texture is exposed in a large outcrop 6.5 km east of Weidner Lake. Elsewhere, the surface trace of the intrusion coincides with abundant frost-shattered boulders of serpentinite and peridotite and areas of orange-brown glacial sand. To the west, the intrusion appears to be truncated by the basal unconformity of the Great Island Group. The northeastern termination is somewhat less distinct, perhaps indicating a primary pinch-out of gabbroic (as opposed to ultramafic) composition.

Great Island Group (units P1–P6)

As described in detail by Schledewitz (1986), the Great Island Group occurs as a series of erosional remnants throughout the Great Island Domain. The thickest and most extensive remnant occupies the central portion of the 2009 map area and defines a structurally complex, north-trending synclinorium referred to as the 'Great Island basin'. Schledewitz (1986) considered this the type locality of the Great Island Group. Other prominent synclinoria (that likewise trend north) are delineated by regional aeromagnetic data east of Great Island, along the north-trending section of the Seal River and in the area of Nowell Lake. Although the basal contact is nowhere exposed, the Great Island Group is interpreted to unconformably overlie the Garlinski Lake greenstone belt and possible basement orthogneiss of the Seal River intrusive complex. Along the northeastern margin of the Great Island basin, bedding and linear magnetic anomalies in the Sosnowski Lake assemblage show a marked angular discordance with the basal contact of the Great Island

Group, which is interpreted to indicate a pronounced angular unconformity in this location.

The Great Island Group is herein divided into lower and upper subgroups, which are provisionally interpreted to represent marine-deltaic and basinal-marine depositional settings, respectively. Sandstone beds in the former are mostly composed of relatively mature quartz arenite, whereas those in the latter consist of relatively immature feldspathic greywacke.

The Great Island Group includes two laterally extensive iron formations (unit P1), both of which are clearly defined by formational aeromagnetic anomalies. The stratigraphically lower iron formation marks the base of the lower subgroup, whereas the upper iron formation defines the base of the upper subgroup. The lower iron formation is continuously traced for 70 km along the northern, eastern and southern margins of the basin, but is structurally disrupted and appears to be less continuous along the western margin. North of the Seal River, on the eastern margin, a single outcrop on the flank of this anomaly was found to consist of thinly bedded greywacke, mudstone and silicate-facies iron formation (subunit P1a), the latter of which occurs in layers up to 20 cm thick, which consist of thin (<1 cm) alternating garnetiferous and amphibolitic beds (Figure GS-13-6a). Diamond-drill–hole intercepts of this unit along strike are described to consist of interlayered graphitic phyllite and thinly bedded siliceous greywacke and mudstone, typically with minor pyrite, pyrrhotite or arsenopyrite (Assessment Files 92108, 92184, 93287). This unit is interpreted from aeromagnetic data to be up to 800 m thick and appears to record relatively quiescent deposition in a marine setting, prior to the onset of major sedimentation in the lower subgroup.

The upper iron formation (subunit P1b) defines a major synclinorium in the centre of the Great Island basin and is interpreted from aeromagnetic data to be up to 600 m thick. In outcrop, this unit is thinly layered to laminated (layers <3 cm) with reddish-brown weathering layers composed of felted fine-grained amphibole,

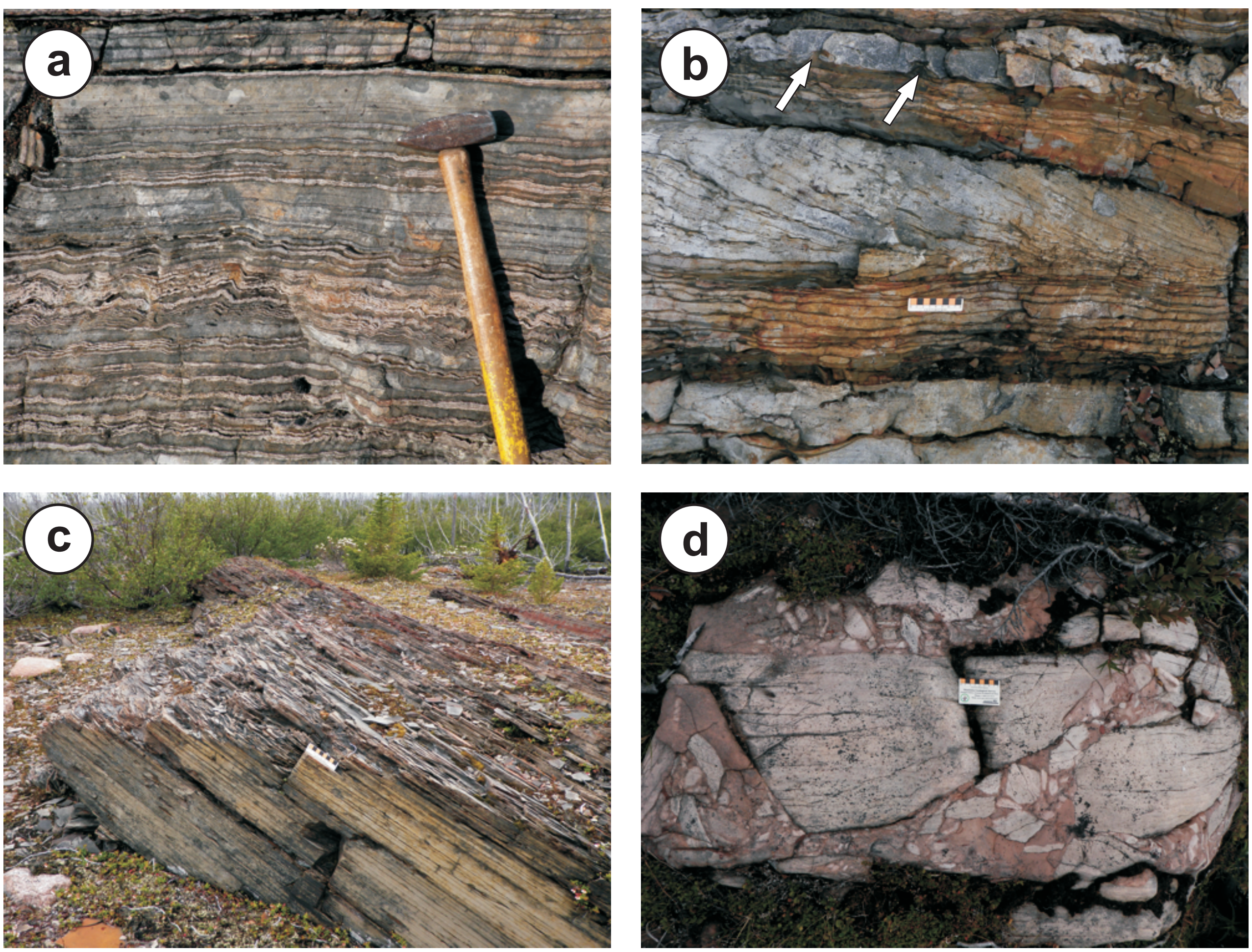

***Figure GS-13-6:** Outcrop photographs of rock types in the Great Island Group: **a)** silicate-facies iron formation (unit P1a) near the base of the Great Island Group, east of Great Island; **b)** interlayered quartz arenite and mudstone showing beds of massive and crossbedded quartz arenite and well-developed load structures (arrows; unit P2b), Great Island; **c)** thin-bedded and laminated mudstone (unit P3), east of Meades Lake; **d)** possible karstic breccia in buff marble (unit P4b), east of Meades Lake.*

gunmetal-grey layers of magnetite and boudins of grey to white aphanitic chert. Some layers contain abundant fine-grained magnetite in a dominantly amphibolitic matrix. The layering is strongly contorted in places.

Quartz arenite with subordinate mudstone (unit P2) is exposed in prominent outcrop ridges throughout the southern portion of the Great Island basin and is a major component of the lower subgroup of the Great Island Group. The quartz arenite weathers white to light grey to pale yellow-green and is composed of fine- to medium-grained quartz (>80%), with minor feldspar, and secondary biotite, sericite, hematite and pyrite. Well-bedded exposures dominate and consist of massive to normal-graded quartz arenite beds up to 2 m thick. Planar-bedded sections (subunit P2a) contain subordinate interbeds of graphitic or sericitic mudstone and locally well-developed ripples, whereas crossbedded sections (subunit P2b; Figure GS-13-6b) contain fewer mudstone interbeds and include both tabular-planar and trough crossbeds, which in some outcrops are defined by detrital magnetite or hematite (predominantly in subunit P2c). The latter sections may represent distributary sand deposits in a marine-deltaic system, whereas the former may represent interdistributary or delta-slope deposits. Intervals of massive quartz arenite range up to more than 150 m in thickness in some locations and are devoid of mudstone interbeds, which could indicate deposition as sheet sands, perhaps in a delta-front setting. Uranium-lead analyses of detrital zircons from a sample of quartz arenite collected on the northern channel of the Seal River at Great Island indicate a maximum depositional age of ca. 1984 Ma (N. Rayner, pers. comm., 2009). The majority of the zircons in this sample yielded ages between 2350 and 2450 Ma, and none were found to be older than 2550 Ma, in contrast to superficially similar quartz arenite in the underlying OLA (ca. 2613 Ma maximum depositional age, no zircons <2600 Ma).

Mudstone with subordinate arenite (unit P3) is only extensively exposed in sections along the Seal River at Great Island, but may nevertheless be the dominant rock type in the lower subgroup of the Great Island Group, since it is likely under-represented in outcrop due to differential weathering and erosion. This unit consists of thick successions of laminated to thin-bedded mudstone (Figure GS-13-6c), with only subordinate, and typically thin, planar interbeds of fine- to medium-grained quartz arenite. The mudstone shows evidence of significant compositional variability and is therefore subdivided into several subunits: graphitic-sulphidic (P3a), micaceous (P3b), hematitic (P3c), sericitic (P3d), garnetiferous (P3e), and garnet-andalusite (P3f). Sediment fluidization structures are common and completely disrupt bedding in places. In a marine-deltaic system, such features would be consistent with distal pro-delta deposits.

Calcsilicate rocks of unit P4 define a laterally continuous unit at the top of the lower subgroup of the Great Island Group, just below the upper iron formation (subunit P1b), and also occur as isolated exposures in four locations lower down in the stratigraphy. Pink (P4a) and buff (P4b) dolomitic marble are well-exposed in a few localities, most notably north of the confluence of Scribe Creek and the Seal River. These rocks have a fine-grained equigranular sucrose texture and prominent layering (1–30 cm) defined by colour; units P4a and P4b are, at least locally, interlayered on the scale of 7–60 m. Porphyroblasts of olive-green metamorphic olivine (?) and amphibole are well-developed in some layers, possibly as a consequence of subtle primary compositional variations. Primary structures, besides layering, include clastic interlayers and a pocket of breccia (measuring 2x3 m), possibly of karstic origin (Figure GS-13-6d). Subunit P4c consists of interlayered pale green to grey calcsilicate and siliceous mudstone. The calcsilicate layers range up to 50 cm in thickness and consist almost entirely of randomly-oriented, acicular, pale green amphibole porphyroblasts. The mudstone beds are up to 20 cm thick and contain up to 10% disseminated pyrrhotite.

Greywacke-mudstone turbidites define the upper subgroup of the Great Island Group and are divided into two map units based on the thickness and composition of the constituent greywacke beds. Both units are characterized by thick successions of rhythmically-interbedded greywacke and mudstone. Greywacke beds are planar and have sharp bases locally scoured into underlying beds, normally-graded tops and local ripple crosslaminations, which indicate deposition via subaqueous turbulent density flows. Soft-sediment deformation structures, including load and flame structures, slump folds and sand dikes, are common. Unit P5 is characterized by relatively thick (generally >30 cm; up to 1.5 m) beds of light grey fine- to coarse-grained greywacke containing abundant coarse detrital quartz, plagioclase and felsic rock fragments at the bases of normally-graded beds, whereas unit P6 is characterized by relatively thin (generally <10 cm; up to 40 cm) beds of light grey to brown, fine- to medium-grained feldspathic greywacke, which are generally subordinate to mudstone and lack the coarse detrital components. Elongate, concentrically-zoned calcsilicate or ironstone concretions up to several centimetres long occur in some of the mudstone beds. Uranium-lead analyses of detrital zircons from a sample of greywacke collected from unit P5 east of Meades Lake indicate a maximum depositional age of ca. 1879 Ma (N. Rayner, pers. comm., 2009). The majority of the detrital zircons in this sample returned ages between 2500 and 2550 Ma, and none were found to be older than 2575 Ma.

Post-tectonic dikes (unit P7)

Prominent linear magnetic anomalies that transect the Great Island area from northwest to southeast were found to coincide with exposures of unfoliated gabbro (unit P7) in four locations. The gabbro weathers a distinctive reddish-brown to green and has a medium-grained diabasic texture defined by plagioclase laths (50–60%, 1–2 mm), interstitial pyroxene (30–35%) and magnetite (5-15%). Most outcrops are homogeneous, although one locality on the southern channel of the Seal River at Great Island is faintly layered, likely as a result of compound emplacement. The dikes and coincident magnetic anomalies trend subparallel to post-tectonic dikes of the Mackenzie swarm (1.27 Ga; LeCheminant and Heaman, 1989), to which they are likely related.

Structural geology

Preliminary structural analysis of the Great Island area indicates significant differences in style and sequence of deformation structures from one stratigraphic and/or structural level to another. However, at present there is insufficient information to determine what, if any, level-to-level structural correlations might exist. Hence, for the purpose of the following descriptions, the various structural elements are separated into generations (e.g., S_1, S_2, S_3) based on the overprinting relationships observed at the specified stratigraphic and/or structural level, and no regional correlation of S_1 fabrics, for example, is implied.

At least five generations of ductile deformation fabrics are apparent in the probable basement rocks of the Seal River intrusive complex. The orthogneiss component of the complex contains an early gneissic fabric (S_1) that trends generally northeast and is overprinted by tight to isoclinal folds (F_2) and an associated axial-planar foliation (S_2) defined by hornblende and biotite. The resulting S_1-S_2 composite fabric and a later swarm of weakly-foliated biotite granite dikes are cut by granodiorite dikes that contain a penetrative foliation defined by feldspar-quartz augen, which is assigned to the S_3 generation. These dikes and early fabrics are discordantly cut by northwest-trending hornblende-diorite, feldspar-porphyry and diabase dikes. A variably-developed S-L fabric in these dikes represents the fourth generation of ductile fabric and is defined most prominently by flattened and stretched xenoliths. The S_4 fabric typically trends west-northwest and the L_4 fabric plunges steeply northeast. In two locations, these fabrics are overprinted by discrete (5–10 m thick) high-strain zones characterized by penetrative mylonitic foliations (S_5), shallow-plunging mineral lineations (L_5), Z-asymmetrical folds (F_5) and dextral kinematic indicators on horizontal outcrop surfaces. One of these high-strain zones contains fault-fill quartz veins up to 2 m thick.

In the overlying Garlinski Lake greenstone belt, map patterns of the Sosnowski Lake and Omand Lake assemblages appear to define a macroscopic F_1 synclinorium, which trends northwest beneath the Great Island basin. Younging reversals in northeast-trending volcanic strata along the northeastern margin of the belt may be related to parasitic F_1 folds, or a younger generation of crossfolds. Most outcrops show a single generation of planar fabric defined by aligned minerals and flattened primary features (e.g., clasts, pillows, amygdules). This fabric (S_1?) generally trends northeast and contains a steeply to moderately plunging stretching lineation (L_1?); some rocks southwest of Sosnowski Lake approach pure L-tectonite. In the Spruce Lake area, a moderate to strong S-L fabric is best defined by flattened and stretched clasts in sillimanite-grade conglomerate of the Omand Lake assemblage. This fabric is overprinted by tight, upright, shallowly southwest-plunging (F_2) folds and an associated axial-planar foliation (S_2). Asymmetric boudins in surfaces perpendicular to the plane of the early S-fabric and containing the moderately west-plunging L-fabric (i.e., the X-Z plane of the finite strain ellipsoid) show evidence of top-to-the-east shear, which could indicate that the relatively high-grade rocks in this area were exhumed in the hangingwall of an east-verging thrust system.

Bedded sedimentary rocks of the Great Island Group cover sequence show evidence of at least three generations of folds, the oldest of which are recognized as isoclinal F_1 closures of bedding that are transected by a regionally-developed east-to northeast-trending cleavage (S_2). Local younging reversals without a corresponding change in the vergence of the transecting cleavage indicate the presence of macroscopic isoclinal F_1 folds. These folds are associated with a weak axial-planar S_1 foliation defined by aligned biotite or chlorite. The regional S_2 cleavage varies from a penetrative foliation to a widely-spaced crenulation cleavage and is axial-planar to open-to-tight upright F_2 folds, which trend east or northeast and are doubly-plunging on a macroscopic scale. The absence of widespread overturned bedding and the prominent basin-and-dome patterns in the aeromagnetic data indicate that the F_2 folds were superposed on upright F_1 folds; the principal F_1 closure is a syncline that trends through Wolochatiuk and Meades lakes, and across the central portion of Great Island. South of Meades Lake, the S_2 fabric is locally overprinted by a weak crenulation fabric and open north-trending folds assigned to a third generation of folding, which appears to have had little influence on map patterns.

Economic considerations

The diverse geology in the Great Island area has the potential to host a variety of mineral deposits. Much of the area was burned in 1998 and outcrops are cleaner than when last mapped in the 1970s; as a result, a number of new localities with mineralization or alteration were documented.

The Sosnowski Lake assemblage is dominated by mafic to intermediate volcanic rocks that vary considerably in composition and include rocks of both tholeiitic and calcalkalic affinity. Volcaniclastic sequences are prominent, which suggests that accumulation occurred in intravolcanic basins or synvolcanic structures. A thin horizon of silicate iron formation, chert and graphitic mudstone at the top of a felsic epiclastic unit south of Hebner Lake indicates a depositional hiatus, and perhaps coeval exhalative activity, within the volcanic succession. Widespread semiconformable alteration (silica, epidote or calcsilicate) is locally sufficiently intense to obscure or obliterate primary volcanic and volcaniclastic textures (Figure GS-13-7a), and is similar to high-temperature alteration associated with volcanogenic massive sulphide deposits.

In three locations along the eastern margin of the belt, intermediate volcanic rocks of the Sosnowski Lake assemblage host unusual zones of intense quartz veining and alteration, which were misidentified as rhyolite breccia by Anderson and Böhm (2008). These zones trend northeast to east-southeast and range from 30 to 150 m in thickness over exposed strike lengths of more than 100 m. Closed-framework breccia in the central portions of these zones consists of angular fragments and slabs of vein quartz and intensely silicified wallrock in a matrix of fine-grained quartz, sericite, fuchsite and minor pyrite (Figure GS-13-7b). Minor through-going quartz veins in the breccia locally appear to 'bleed out' into the surrounding rock. One zone is sharply bound by a brittle fault, whereas another shows a more gradational transition over 2–3 m from breccia, through a marginal zone of stockwork quartz veins and intensely altered wallrock, to weakly-veined and altered intermediate volcanic rocks. Both matrix and fragments in the breccia are moderately to strongly foliated, which indicates that multiphase quartz veining, alteration and brecciation preceded the latest increments of ductile deformation. Falconbridge Limited reported values up to 520 ppb Au from grab samples of this breccia (Assessment File 92910), which have never been followed up in detail.

Crossbedded quartz arenite and quartz-pebble conglomerate in the Omand Lake assemblage southeast of Great Island display intense pervasive fuchsite alteration, as well as fracture-controlled to patchy to semiconformable

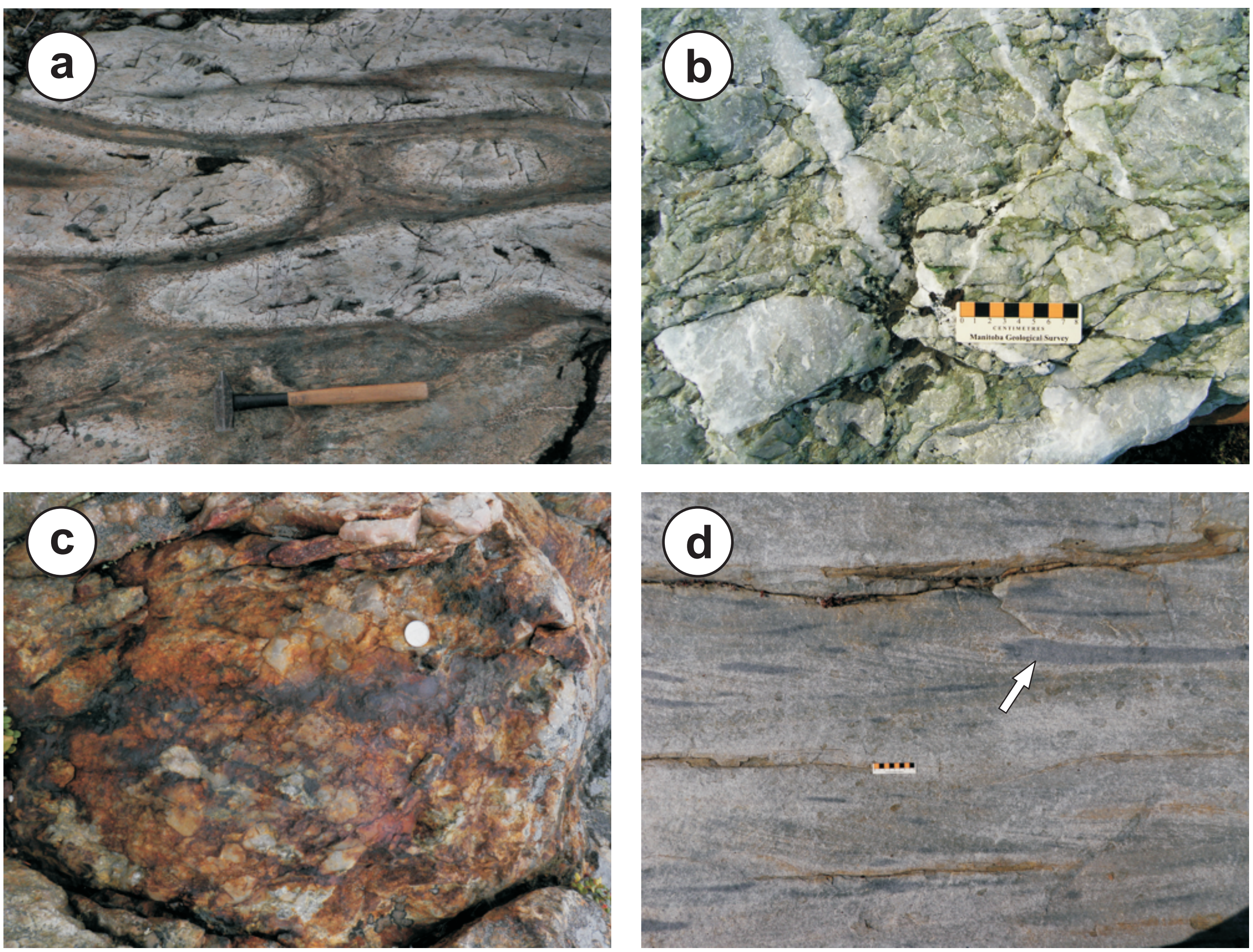

Figure GS-13-7: *Outcrop photographs of alteration and mineralization in supracrustal rocks in the Great Island area:* ***a)*** *intense calcsilicate alteration of pillowed andesite flow, southwest of Sosnowski Lake;* ***b)*** *closed-framework breccia composed of fragments of vein quartz and silicified wallrock in a matrix of quartz, sericite and fuchsite, northwest of Weidner Lake;* ***c)*** *sulphidic quartz-pebble conglomerate, northeast of Omand Lake;* ***d)*** *patchy quartz-magnetite alteration (arrow) in crossbedded quartz arenite, central Great Island.*

gossan (locally confined to conglomeratic beds) due to the presence of finely-disseminated sulphide minerals (Figure GS-13-7c). Boulders of quartz-pebble conglomerate observed northeast of Omand Lake are characterized by intense sericite-hematite alteration of the matrix material, resulting in a distinctive brick-red appearance. The metallogenic significance of these alterations, if any, remains unclear, but similar rocks further to the southeast are reported to contain anomalous concentrations of Au (up to 430 ppb; Assessment File 92910) and show evidence of significant potential for paleoplacer Au deposits.

Quartz arenite and associated mudstones in the Great Island Group locally contain fracture-controlled, disconformable to semiconformable hematite or silica alteration. The hematite-altered rocks are characterized by brick-red weathered surfaces and locally well-developed Liesegang banding, which indicates repeated fluid infiltration. Zones of intense and pervasive semiconformable silica alteration locally range up to at least 150 m in thickness. The silicification obscures primary features in quartz-arenite beds and is associated with stockwork and/or sheeted quartz veins. Other outcrops of quartz arenite show patchy to stratabound silica-magnetite alteration (Figure GS-13-7d). The metallogenic significance of these alterations, if any, remains unclear.

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