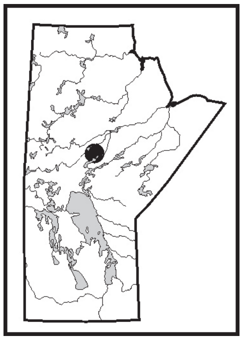
GS-5 Bedrock geology of northern and central Wintering Lake, Manitoba (parts of NTS 63P5 and 12)

by C.O. Böhm



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Summary

The nature and age of granulite-grade rocks of the Pikwitonei Domain have been a matter of contention for decades. The granulites have been mainly interpreted as orthogneiss, with the inferred paucity of supracrustal rocks within the middle to lower crustal granulites an enigma. New mapping, supported by geochemical, isotopic and geochronological studies, focuses on resolving the origin of high-grade (granulite- and upper-amphibolite–grade) rocks at Wintering Lake.

The study area is located in the Superior Boundary Zone at the west margin of the Pikwitonei Domain and east of the Thompson Nickel Belt. The main rock types are variably retrogressed felsic and mafic high-grade gneisses and migmatites at granulite and upper amphibolite grade. Within the Archean felsic crust, mafic and ultramafic rocks form enclaves and larger igneous bodies. Quartz-rich and alumina-rich granulite gneisses interlayered with amphibolite constitute at least 25% of the Archean rocks at Wintering Lake and may represent an extensive, previously unrecognized supracrustal assemblage. The detection of abundant supracrustal rocks within the high-grade gneiss at the margin of the Pikwitonei Domain has significant implications for the tectonic framework and mineral potential of the region.

Introduction

This report summarizes field observations and data collected during five weeks of bedrock mapping in the northern and central parts of Wintering Lake. The field and analytical studies are intended to characterize the nature of intrusive rocks, provide constraints on the magmatic history and subsequent tectonometamorphism, and reevaluate the extent and origin of possible supracrustal rocks in the Wintering Lake area.

Previous geological mapping at Wintering Lake (Hubregtse, 1978; Hubregtse et al., 1978), which describes the area as consisting of various types of felsic plutonic rocks and migmatite gneiss, reflects the widely held notion that complex high-grade terrains at granulite grade, such as the Pikwitonei and adjacent high-grade domains of the northwestern Superior Province, are orthogneiss that lacks or rarely contains supracrustal rocks. The purpose of this study is to reexamine the Wintering Lake high-grade rocks and reevaluate the scarcity of contained supracrustal rocks through detailed petrographic and structural mapping, geochemistry, and isotopic and geochronological analyses. In addition, mafic and ultramafic igneous rocks and their relationship with other basement rocks were examined, as they are of economic interest (e.g., Dawson, 1952; Peck et al., 1996).

Regional setting

Wintering Lake is located about 30–50 km southeast of Thompson within the eastern part of the Superior Boundary Zone and along the west margin of the granulite-dominated Pikwitonei Domain (Figure GS-5-1). Felsic granulite and retrogressed granulite (migmatite and gneiss) dominate the area. They are part of the Archean Superior Province basement, which has a complex plutonic and metamorphic history extending from 3.0 to 2.65 Ga (e.g., Hubregtse, 1980). As schematically illustrated in Figure GS-5-1, these high-grade felsic rocks contain larger bodies and xenoliths of mafic rocks (summarized as amphibolite). The rocks at Wintering Lake appear to represent a westward extension of the Pikwitonei Domain (Figure GS-5-1), and much of the tectonometamorphic history known from the Pikwitonei Domain may therefore apply to the Wintering Lake area rocks. In the Pikwitonei Domain, the felsic granulites in the Partridge Crop–Natawahunan and Cauchon lakes areas are Meso- and Neoarchean in age and underwent polyphase, amphibolite- and granulite-grade tectonometamorphism at ca. 2.71–2.64 Ga (Heaman et al., 1986a; Mezger et al., 1990; Weber and Mezger, 1990; Böhm et al., 1999). Amphibolite-grade metamorphism was followed by a peak granulite metamorphic phase, which produced abundant plagioclase-quartz±orthopyroxene neosome in the metatonalite, enderbite and mafic granulite. Garnet, a common constituent in many rocks at Wintering Lake, probably formed after peak metamorphism from plagioclase and pyroxene during retrogression at amphibolite grade. Possibly related to this thermotectonic event is the emplacement of granodiorite-granite in the central Wintering Lake area. This rather homogeneous, schlieric layered and weakly to moderately foliated intrusion seems to predate presumably 2.1 to 1.88 Ga (Heaman et al., 1986b; Halls and Heaman, 1997), northeast-trending mafic dikes, development of intense northeast-trending high-strain zones, and a large, ca. 1.82 Ga (Percival et al., 2004) post-tectonic granite that intruded prior to or during ca. 1.82–1.78 Ga Hudsonian tectonothermal reworking (e.g., Zwanzig et al., 2003).

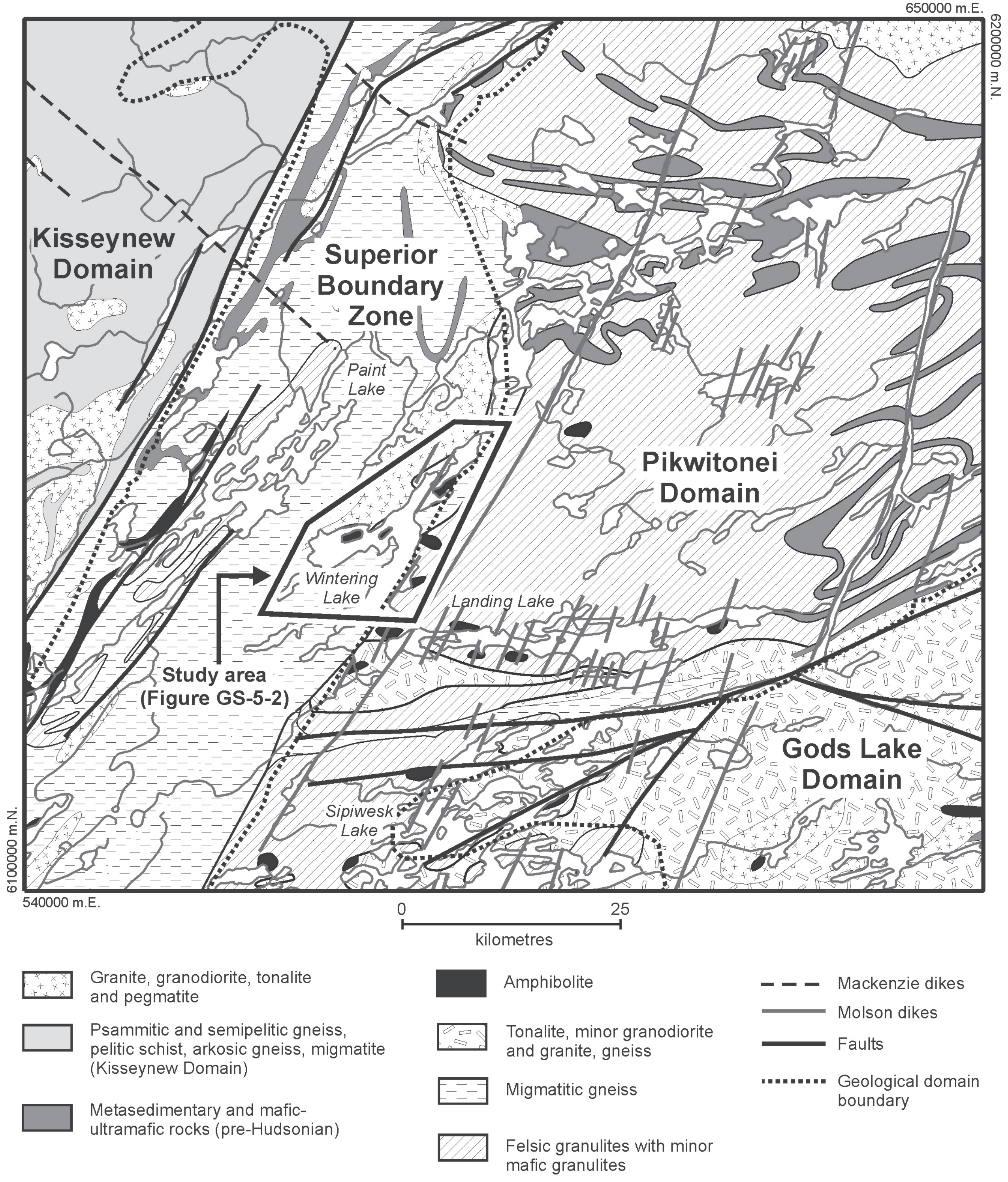

***Figure GS-5-1:** Main lithotectonic elements of the northwestern Superior Province, Superior Boundary Zone and Kisseynew Domain in the Wintering Lake region (*modified after *Manitoba Energy and Mines, 1995).*

Bedrock geology of Wintering Lake

The simplified bedrock geology of northern and central Wintering Lake, based on the 2005 field season mapping at 1:20 000 scale (Böhm, 2005), is summarized in Figure GS-5-2. Geological observations in 2005 were limited to partly submerged outcrops as a result of exceptionally high water levels. An additional impediment to mapping, which is shared by many high-grade terrains as a result of migmatization and polyphase tectonometamorphic processes, is that mappable lithological units are irregularly distributed and discontinuous, with primary contact relationships obliterated by partial anatexis,

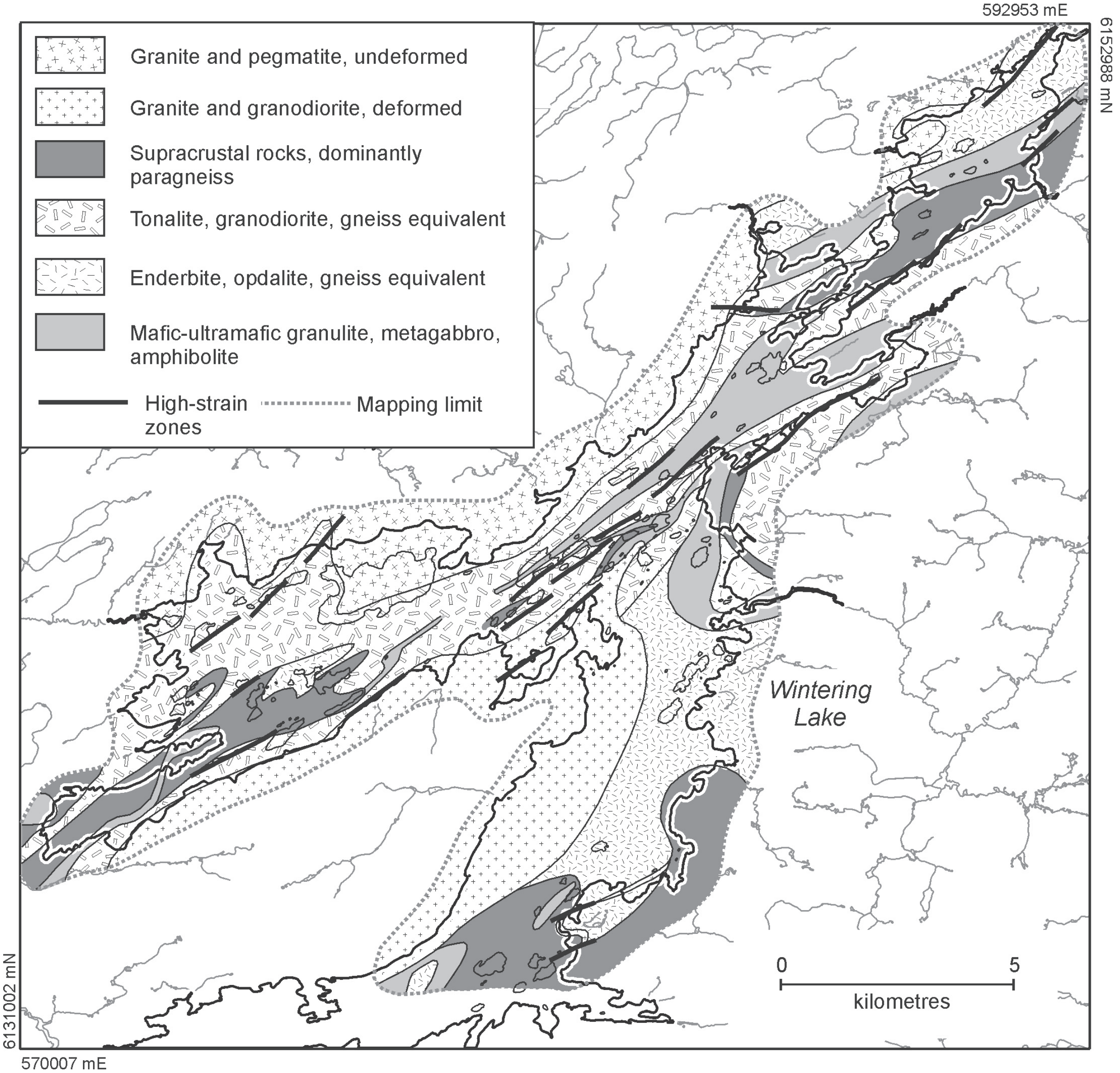

Figure GS-5-2: *Simplified bedrock geology of northern and central Wintering Lake.*

recrystallization and shearing. Consequently, emphasis in this study is placed on structurally based correlation of the main lithological assemblages rather than attempts to map out individual small units.

The high-grade rocks at Wintering Lake show evidence of polyphase deformation, with at least three generations of foliation and folds recognized. Isoclinal folding locally affected older structural elements, including an early metamorphic layering (S_1) prior to the main foliation (S_2). The dominant trend of S_1 is east to northeast but locally varies; S_1 is overprinted and transposed by zones of medium to high D_2 strain. The D_2 structures seem to be subparallel to, and thus related to, peak metamorphic melts (main mobilizate and neosome pods). The D_2 structures were variably overprinted by D_3 deformation, expressed as folding and foliation. The S_3 foliation locally contains minor amounts of mobilizate, and neosome pods similar to mobilizate formed during D_2. The D_4 deformation is expressed in northeast-trending high-strain zones that locally formed cataclastic augen gneiss and protomylonite along shear zones (Figure GS-5-2). It affects all lithological units at Wintering Lake including mafic dikes, with the exception of the main portion of the Wintering Lake granite intrusion. The D_4 structures are therefore interpreted to be related to Hudsonian tectonism.

The main lithological units exposed in the northern and central Wintering Lake area are described in the following paragraphs, from oldest to youngest.

Archean basement rocks

At Wintering Lake, the oldest lithological units are metagabbro and minor picrite and anorthositic gabbro.

They form enclaves and larger igneous bodies within the various high-grade felsic rocks, which consist mainly of tonalite-trondhjemite-granodiorite (TTG) and granulite-equivalent (enderbite-opdalite) crust.

Mafic rocks

Mafic granulite displays compositional variations from gabbroic anorthosite to pyroxenite. Metagabbro contains minor amounts of tonalite gneiss that forms layers and dikes within the mafic gneiss. Hubregtse (1977) reported that least deformed gabbroic bodies in the Wintering Lake area locally preserve primary rhythmic layering and diffuse compositional variations from picrite to gabbro. This layering in gabbro (Figure GS-5-3a) is described here as metamorphic banding that is subparallel to the main, weakly to moderately developed foliation (S_2) in the layered mafic gneiss. Locally, a later foliation (S_3) is developed, typically at a 30–50° angle to the main fabrics. At one outcrop, mafic granulite (metagabbro) is weakly to moderately foliated with two main fabrics. At this location, boudins of possible ultramafic garnetiferous xenoliths are aligned along the main metamorphic layering and foliation S_2, and these fabrics are overprinted by a later foliation S_3, into which the xenoliths are rotated.

Dawson (1952) and Peck et al. (1996) described sulphide occurrences associated with metapyroxenite and garnet-plagioclase-hornblende±biotite gneiss, the latter interpreted by them to be metagabbro. Peck and Theyer (2000) observed that the deformed metagabbro-metapyroxenite bodies at Wintering Lake locally contain semimassive to massive Cu- and PGE-rich sulphide mineralization where emplaced into paragneiss. This relationship has been confirmed during field studies in 2005, and the approximate distribution and interpreted extent of the mentioned paragneiss is outlined in Figure GS-5-2.

Mafic granulite is migmatitic in places and contains quartz-rich mobilizate layers and patches of dominantly

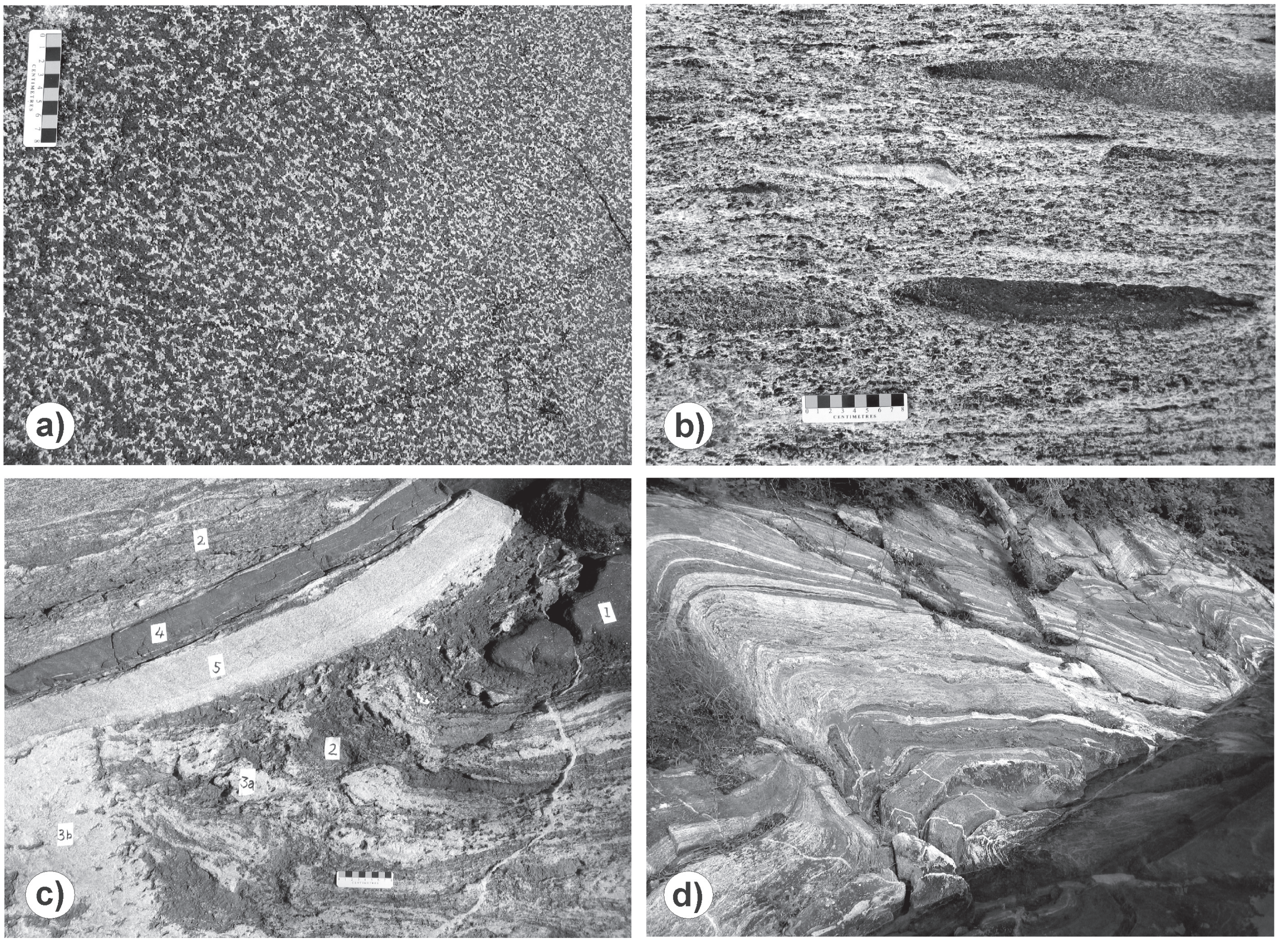

***Figure GS-5-3:** Outcrop photographs of meta-igneous rocks at Wintering Lake: **a)** garnet-pyroxene/hornblende-plagioclase granulite displaying graded, coarse- to medium-grained recrystallized, possibly primary magmatic layering in gabbro; **b)** biotite-hornblende enderbite gneiss with highly strained mafic and neosome lenses; **c)** migmatitic biotite-hornblende opdalite gneiss (2) containing amphibolite layers and metapyroxenite lenses (1), migmatitic quartz-feldspar neosome patches (3a) and injection layers (3b), intruded by mafic (4) and leucogranite (5) dikes; **d)** migmatitic and folded tonalite gneiss interlayered with amphibolite, quartz-feldspar–rich injection and leucogranite dikes; outcrop height approximately 2 m.*

fine-grained pyroxene/amphibole and garnet-rich aggregates, which are interpreted as lenses of silicate-facies iron formation within metabasalt.

Enderbite and opdalite

At northeastern and southeastern Wintering Lake, enderbite, opdalite (felsic granulite) and their gneiss equivalents form the predominant felsic metaplutonic rocks of the presumed western margin of the Pikwitonei Domain (Figure GS-5-1). In addition, relatively smaller bodies of preserved felsic granulite occur farther to the west within the predominantly upper amphibolite tonalite-granodiorite and supracrustal rocks (Figure GS-5-2). The felsic granulites are variably migmatitic and foliated, and typically contains agmatitic zones, layers and lenses of mafic granulite, pyroxenite, anorthosite and amphibolite (Figure GS-5-3b, c). Some mafic xenoliths show an earlier fabric (S_0 and/or S_1) that predates migmatization (D_2). The felsic granulite typically contains up to 70% neosome layers and patches generally aligned subparallel to the main metamorphic layering and foliation (S_2), as well as along S_3 where S_3 is developed. A coarse granoblastic, equigranular, recrystallized texture is characteristic of the felsic granulites and their neosome. Hornblende (up to 30%) represents the dominant mafic mineral in the felsic granulites, and garnet is common where enderbite is interlayered with, or in contact with, mafic rocks.

Foliated tonalite, granodiorite and granite

Tonalite, granodiorite, minor granite and their gneiss equivalents form the predominant portion of Archean felsic crust in the northern, central and western parts of Wintering Lake (Figure GS-5-2), where peak metamorphic conditions seem not to have reached granulite grade. These felsic rocks are similar in composition to the TTG-type crust typical of Archean cratons. The relationship of the upper-amphibolite–grade meta-igneous rocks and the felsic granulites is uncertain, but the two could be related and may only differ in metamorphic grade and/or degree of retrogression. Hornblende and biotite are the main mafic minerals and are typically concentrated by metamorphic segregation in mafic layers separated from quartzofeldspathic layers. Migmatitic layering is folded by F_3, predates mafic-dike emplacement, and is therefore interpreted to be Neoarchean, likely contemporaneous with and related to high-grade metamorphism, anatexis and mobilizate formation in the high-grade rocks. The felsic migmatites are strongly layered, highly strained and structurally intercalated with mafic rocks and granitic dikes (Figure GS-5-3d) along much of the north-central and western channels of Wintering Lake, which trend approximately 050° (Figures GS-5-2).

Wintering Lake supracrustal rocks

A significant portion of the Archean high-grade rocks at Wintering Lake (approximately 25%; Figure GS-5-2) is interpreted to have been derived from supracrustal rocks. They comprise gneisses of metasedimentary origin, including biotite, hornblende-biotite-garnet, cordierite-sillimanite-biotite-garnet and quartz-rich gneiss interpreted to have formed from arenite to arkosic wacke to pelitic greywacke. Minor quartzite and iron formation were also encountered. Except for strongly layered alumina-rich gneiss that was likely derived from layered clay-rich pelite, the sedimentary derivation of these gneisses has been inferred from observations of the entire supracrustal assemblage rather than from features on individual exposures. The supracrustal 'belts', which may be as wide as 1–2 km, typically occur as outcrop-scale rafts and semicontinuous sequences (assemblages) in the migmatite gneiss and granulite complex. Locally, rafts of the supracrustal rocks could be traced into the compositional banding of the host migmatite gneiss. Similar to the meta-igneous felsic granulites, the supracrustal rocks largely preserve granulite texture, (remnants of) granulite-grade mineral assemblages and mobilizate pods, suggesting an Archean age. Layered metagabbro and metapyroxenite that occur within, adjacent to or close to metasedimentary rocks may also be part of the supracrustal assemblage.

Quartz-rich metasedimentary rocks

The majority of the leucocratic, quartz-rich granulite gneisses exposed at Wintering Lake were likely derived from quartzite, arkosic arenite and arkosic wacke (Figure GS-5-4a). These rocks have previously been included in the enderbite and opdalite suite of meta-igneous rocks (e.g., Hubregtse, 1978). They contain characteristic aggregates of garnet-hornblende-biotite ±sillimanite±cordierite up to 2 cm in diameter. These mineral aggregates, which form 15–25% of the rocks, are composed mainly of lavender to pink (presumably Al-rich) garnet. Quartz, which commonly exceeds 50–60% in abundance, locally displays a blue colour. Minor (up to 20%), variably altered, waxy green to beige feldspar aggregates are characteristic of granulite-grade rocks. The quartz-rich metasedimentary rocks locally contain 'layers' of quartzite, banded (silicate-, minor oxide- and sulphide-facies) iron formation and amphibolite (Figure GS-5-4b) that are interpreted to possibly be part of a typical Archean supracrustal rift sequence. The best exposures of these assemblages can be found in the western arm of Wintering Lake and north of Thicket Portage (Figure GS-5-2). In addition, exposures of metaconglomerate were recognized within the paragneiss at the northwestern end of Wintering Lake, but were underwater in the summer of 2005 (M.T. Corkery, pers. comm., 2005).

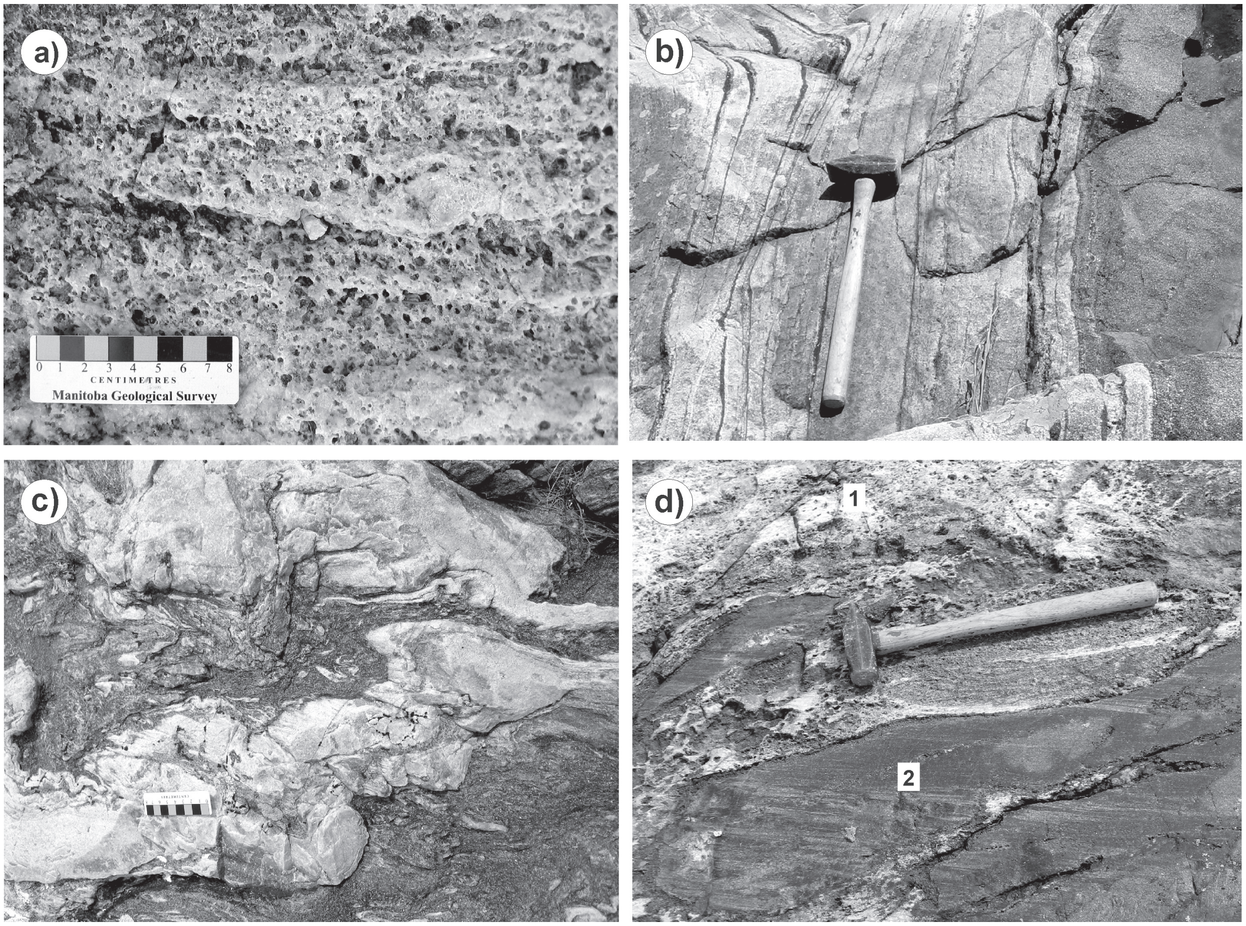

***Figure GS-5-4:** Outcrop photographs of supracrustal rocks at Wintering Lake: **a)** garnet-rich, layered quartzitic gneiss, interpreted as granulite-grade quartz-rich arkosic wacke; mafic clots are aggregates of garnet-biotite-hornblende±sillimanite±cordierite; **b)** quartzite and quartz arenite interlayered with amphibolite (hammer for scale); the quartzite in this outcrop also contains layers of banded iron formation (mainly silicate and magnetite facies); **c)** strongly folded, protomylonitic, garnet-biotite paragneiss (originally semipelite), interlayered with meta-arenite (originally subarkose or quartz arenite); **d)** garnet-biotite-quartz–rich granulitic metasedimentary rock (1) containing deformed garnet-pyroxene/hornblende–rich mafic layers and lenses (2), interpreted as silicate-facies iron formation or calcsilicate (hammer for scale).*

Semipelitic paragneiss

Garnet-biotite-quartz–rich, strongly layered and foliated gneiss is interpreted as alumina-rich semipelitic paragneiss (metagreywacke). Quartz-rich lenses and layers in this gneiss are likely meta-arenite. Amphibolite intercalations occurring within them are interpreted as remnants of mafic to intermediate metavolcanic rocks. Structurally more competent and resistant meta-arenite typically forms well-developed, centimetre- to decimetre-scale folds within the strongly foliated, cataclastic to protomylonitic, semipelitic paragneiss and amphibolite (Figure GS-5-4c). Semipelitic paragneiss locally contains garnetiferous boudins or xenoliths (Figure GS-5-4d), interpreted to have been derived from silicate-facies iron formation.

Schlieric layered granite and granodiorite

A large deformed body of mainly granite and subordinate granodiorite, which occupies much of central and southwestern Wintering Lake, separates the southeastern and southwestern arms of the lake (Figure GS-5-2). The granite, which is weakly to moderately foliated and migmatitic, displays schlieren structure at the centimetre to decimetre scale. Schlieren and layers consist of pink to beige granite and light grey to beige granodiorite. The two phases are interpreted to be comagmatic. Biotite (up to 15%) and minor hornblende are the main mafic minerals in the generally leucocratic granite. Larger granite layers contain diffuse pegmatitic patches. Locally, the granite gneiss contains sheared amphibolite layers. The schlieric layered granite, which is locally openly folded with a weak S_3 axial-planar cleavage, is sheared and overprinted by late high-strain zones. At central Wintering Lake, the granite forms a strongly layered to migmatitic granite gneiss that seems to have undergone strong deformation together with, and to a similar degree as, the adjacent high-grade rocks (migmatite, granulite and paragneiss). This is taken to mean that the layered granite is Archean in age. Rare contacts with Paleoproterozoic mafic dikes are sheared (where observed).

Paleoproterozoic intrusive rocks

Mafic dikes

Paleoproterozoic mafic dikes, commonly assigned to the 'Molson dike swarm' but here referred to only as 'mafic dikes', are undeformed to variably deformed at Wintering Lake (mafic dikes are not shown on Figure GS-5-2). They provide an excellent tool for the separation of Archean deformation from later, Hudsonian deformation (1.82–1.78 Ga), since they intruded in the interval between ca. 2.1 and 1.88 Ga (Heaman et al., 1986b; Halls and Heaman, 1997). Mafic dikes are only metamorphosed and/or deformed in the areas overprinted by Hudsonian thermotectonism. Larger mafic dikes at Wintering Lake generally trend in a northeasterly direction, dip subvertically and are straight walled. They are metamorphosed (amphibolite) and range in composition and texture from gabbro to diabase. Isolated exposures of amphibolite can be distinguished from mafic granulite based on absence of mobilizate and a homogeneous massive character.

Granite (Wintering Lake granite)

The Wintering Lake pluton is an elongate body of massive, homogeneous, biotite leucogranite. Its southeastern margin shapes much of the northwestern shore of Wintering Lake (Figure GS-5-1, -2). The granite appears compositionally uniform along its ~30 km length, but ranges in texture from K-feldspar porphyritic to pegmatitic and aplitic. Percival et al. (2004) reported a SHRIMP U-Pb zircon crystallization age of 1820 ±10 Ma for a sample collected on the west-central shore of Wintering Lake. Zircons from the dated granite sample also yielded a range of inherited ages from 2380 to 3230 Ma and, together with an ε_{Nd} value (calculated at 1820 Ma) of –6.4 and a T_{CR} of 2.49 Ga, indicate that the granite was emplaced into and partially recycled the Archean crust (Percival et al., 2004).

Pegmatite and aplite

Pegmatite and minor aplite dikes form the youngest intrusive phases at Wintering Lake. They are generally straight walled and undeformed except in late (reactivated?) high-strain zones, where they are weakly drag folded or sheared. Pegmatite dikes are dominantly leucogranite and likely related to the felsic magmatic event that formed the main Wintering Lake granite body. Such leucogranite pegmatite dikes and small pegmatitic bodies can be found invading the high-grade gneiss at distances of several kilometres east of the Wintering Lake granite.

Economic considerations

The tectonic position of Wintering Lake at the western margin of the Pikwitonei Domain and east of the Thompson Nickel Belt suggests potential for base metals in both Archean and Paleoproterozoic mafic intrusive rocks, and for shear-hosted precious metals along late high-strain zones within the metasedimentary-dominated supracrustal rocks. Metagabbro and metapyroxenite occurrences at northeastern Wintering Lake are associated with Fe-Cu-Ni sulphide mineralization (Dawson, 1952; Peck et al., 1996). The possible primary layering in these rocks is similar to well-layered Pipestone Lake and West Channel anorthosite-gabbro complexes that contain Ti-V-Fe deposits. In addition, Peck et al. (1996) reported anomalously high PGE values for pyrrhotite-rich samples from sheared metagabbro-metapyroxenite contacts from northeastern Wintering Lake. These mafic and ultramafic rocks are part of, or in structural contact with, supracrustal assemblages of previously unknown existence or extent. The current study proposes that supracrustal rocks, although difficult to recognize, are present in the high-grade rocks at Wintering Lake in amounts similar to those in lower grade granite-greenstone belt terranes (e.g., Molson and God Lake domains). In light of the extensive supracrustal rocks present at Wintering Lake, the mineral potential of the Archean 'high-grade rocks', including mafic and ultramafic gneisses, in the area should be reevaluated.

Acknowledgments

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