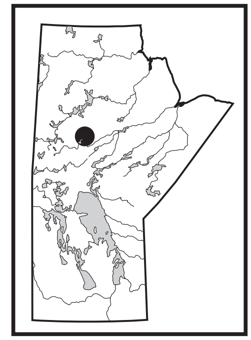
GS-6 Unique amphibolite–iron formation assemblage in the Kawaweyak Lake area, Manitoba (part of NTS 63O15)

by L.A. Murphy and H.V. Zwanzig



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Summary

This report summarizes two weeks of fieldwork carried out during the summers of 2006 and 2007 in the northeastern portion of the Paleoproterozoic Kisseynew Domain. The purpose of the project, which is part of a collaborative Targeted Geoscience Initiative III (TGI-3) project with the Geological Survey of Canada, is to determine whether gneiss equivalent to the nickel-bearing Ospwagan Group, which has an Archean provenance in the Thompson Nickel Belt (TNB), is also exposed within dominantly Burntwood Group greywacke gneiss at Kawaweyak Lake.

Mapping during 2007 showed that the Burntwood Group greywacke gneiss and psammitic to semipelitic units of quartz-rich, calcareous and biotitic gneiss at Kawaweyak Lake are in gradational contact with a distinctive amphibolite–iron formation assemblage. The latter assemblage, which is well exposed at the south end of the map area, can be traced 6 km northeast along strike to the eastern shoreline of Notakikwaywin Lake. A Nd model age of 2.15 Ga on a sample of the semipelite from the quartz-rich rocks at the south end of the Kawaweyak Lake is not consistent with an affinity for the Ospwagan Group, and more consistent with belonging to the juvenile Paleoproterozoic Burntwood Group or an assemblage of amphibolite and siliciclastic rocks that generally overlies the Burntwood Group. The amphibolite has minor gold showings south of Granville Lake, northeast of the map area.

Introduction

The Kawaweyak Lakes area is accessible along Highway 391, approximately 80 km west of Thompson. The study area encompasses a 1.5 km by 6 km strip along the shorelines on Kawaweyak Lake and northeast across a small channel to Notakikwaywin Lake (Figure GS-6-1). The outcrop around the lakes is sparse and shoreline exposures are small but relatively clean.

Mapping in 1971 by Kendrick (Baldwin et al., 1979) indicated that the Kawaweyak Lake area contains greywacke-derived gneiss and migmatite (present Burntwood Group), hornblende-diopside gneiss and pyrite- and pyrrhotite-bearing amphibolite gneiss (originally assigned to the Sickle Group). During the summer of 2006, magnetic highs delineated by an aeromagnetic survey (Coyle and Kiss, 2006) along the Wuskwatim corridor (Percival et al., 2005) were selectively re-examined (Percival et al., 2006; Zwanzig et al., 2006). This was prompted by the hypothesis that rocks similar to those in the Thompson Nickel Belt (TNB), including iron formation, may be exposed farther west of the TNB than previously realized. The geological investigations in 2005 and 2006 indicated that paragneiss with iron formation and orthogneiss of Archean age, similar to units in the TNB, are interleaved with, or lie structurally below, Burntwood Group migmatite. Rocks in the Kawaweyak Lake area were found to include calcareous gneiss, iron formation and metagabbro. Further investigation in 2007, described in this report (Murphy and Zwanzig, 2007), indicates that an assemblage of amphibolite and iron formation and associated quartz-rich and calcareous biotite gneiss at Kawaweyak Lake forms a package that is unusual for the Kisseynew Domain but appears to be unrelated to rocks in the TNB or those in the Wuskwatim corridor. Instead, the package may be part of the Burntwood Group or older Paleoproterozoic rocks, including Tod Lake basalt (Zwanzig et al., 1999), which are better exposed in the northwestern part of the Kisseynew Domain.

Regional setting

The Kawaweyak Lake area is located within the northeastern part of the Kisseynew Domain, bounded by the Leaf Rapids Domain in the north and the TNB in the southeast. It is part of the internal zone of the Paleoproterozoic Trans-Hudson Orogen (Figure GS-6-1). The dominant supracrustal rock of the Kisseynew Domain is the Burntwood Group migmatite gneiss, which is interpreted to have been derived from greywacke-mudstone turbidite deposited within a marine basin (Zwanzig, 1990, 1999). Generally overlying the turbidite is an amphibolite unit, interpreted as arc-related ocean-floor basalt, that extends to the Lynn Lake belt (Tod Lake basalt of Zwanzig et al., 1999; Murphy and Zwanzig, GS-5, this volume). Intrusive bodies in the Kisseynew Domain include foliated tonalite, granite, diorite and late-stage pegmatite. During 1.85–1.83 Ga terminal subduction in the Trans-Hudson Orogen, the basin opened (Ansdell et al., 2005) or closed (Zwanzig, 1999), with local obduction of Tod Lake basalt (White et al., 2000) and deposition of the turbidite and related terrestrial rocks (e.g., Sickle Group). Progressive deformation generated large-scale regional nappe-style folds, refolded by northeast-trending crossfolds (Zwanzig, 1990; Murphy and Zwanzig, GS-5, this volume). Granite and pegmatite intrusion, and

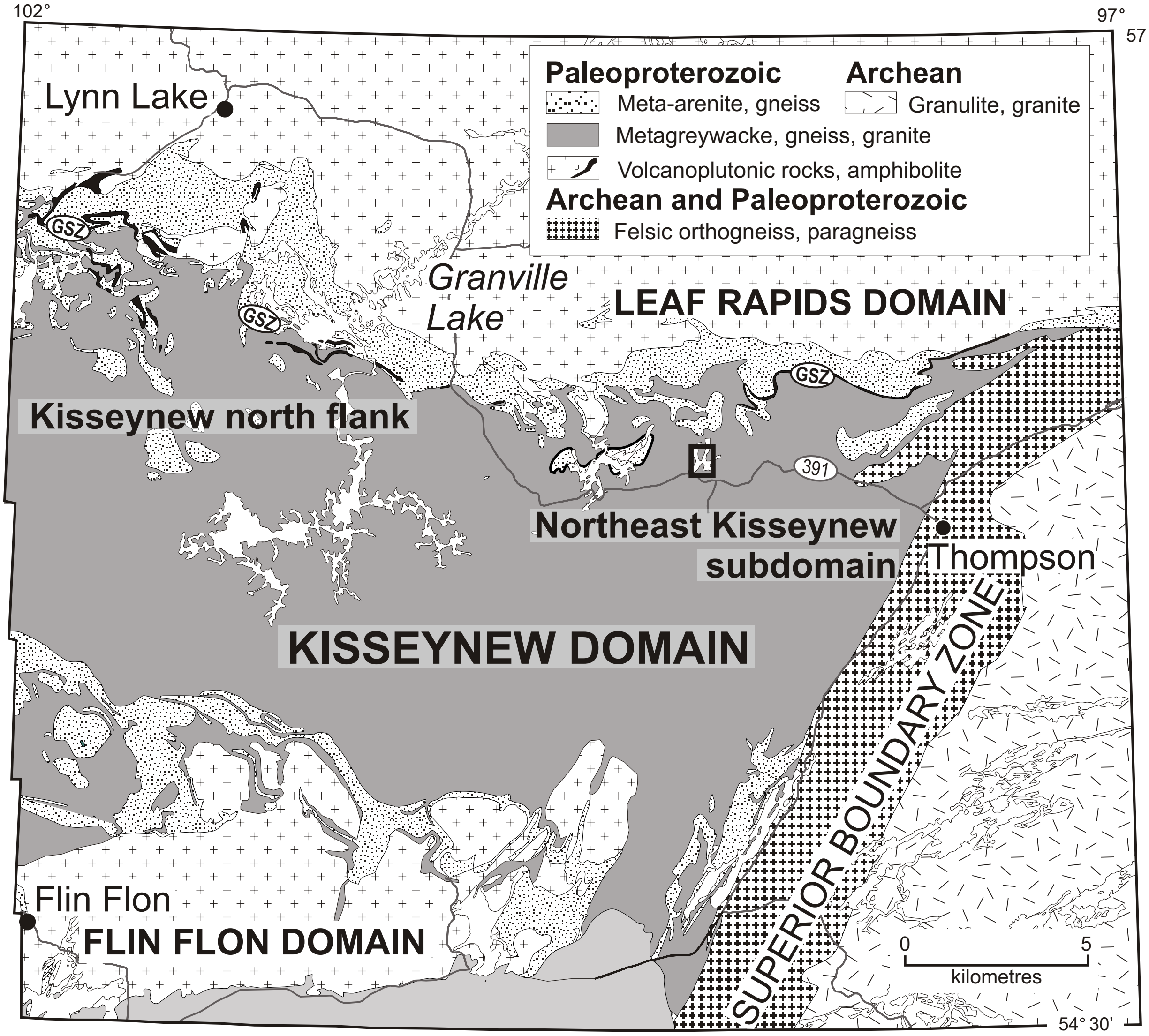

Figure GS-6-1: *Simplified geology of the southeastern part of Trans-Hudson Orogen in Manitoba, showing the location of the Kawaweyak Lake area on the north flank of the Kisseynew Domain.*

metamorphism led to migmatization of the greywacke-mudstone and development of local orthopyroxene and the regional assemblage of garnet-biotite-sillimanite±cordierite. This has produced distinctive grey and white *lit-par-lit* gneiss in the Burntwood Group.

General geology

The map area at Kawaweyak and Notakikwaywin lakes (Figure GS-6-2) includes four main rock assemblages:

1) Burntwood Group gneiss and migmatite
2) interlayered quartz-rich and calcareous biotite gneiss, and semipelitic to pelitic gneiss
3) layered amphibolite and gabbro that are spatially associated with calcsilicate-, silicate-sulphide– and sulphide-facies iron formation, as well as sulphidic biotite gneiss
4) intrusions of granodiorite, granite and pegmatite

They occur from west to east in the following order: Burntwood Group gneiss, followed by biotite-bearing gneiss to calcareous rocks, in turn followed by layered amphibolite or iron formation. Quartz-rich units occur along the margin of this assemblage, adjoining granite and Burntwood Group gneiss.

Many of the contacts between assemblages 2 and 3, and between different rock types within them, exhibit a gradual compositional change. The layered amphibolite and iron formation are also internally gradational, with calcsilicate- and biotite-rich units becoming progressively more amphibole or sulphide bearing. Contacts of assemblages 2 and 3 with the Burntwood Group are not exposed, but the Burntwood Group lies very close to different units along strike and the presence of a major strike fault cannot be ruled out. The intrusive contact between the gabbro unit and the amphibolite–iron formation assemblage may be sharp and have a slight chill zone. The

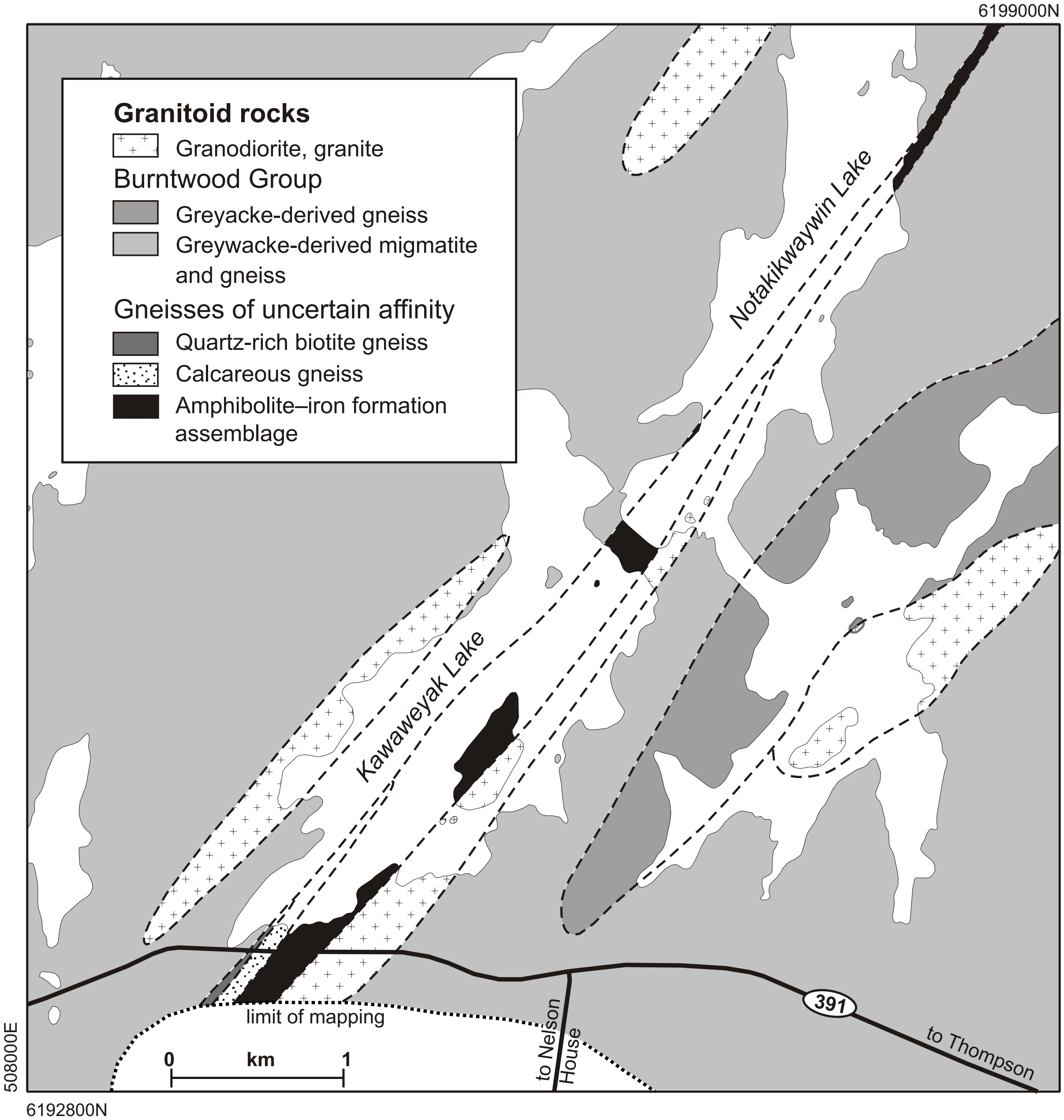

Figure GS-6-2: *Simplified geological map of the Kawaweyak Lake area.*

granodiorite has inclusions of Burntwood Group gneiss, and amphibolite, indicating that these rocks are older than the granodiorite. Granite and pegmatite are the youngest units to have intruded throughout the Kawaweyak Lake area.

Regional metamorphism peaked at the granulite facies and is displayed in mineral assemblages that include garnet, biotite, sillimanite and cordierite, with local orthopyroxene in the Burntwood Group and the gabbro. Retrogressive garnet has partly replaced cordierite in the Burntwood Group gneiss. All rock types are metamorphosed, but the prefix 'meta' is generally omitted from their names.

Burntwood Group

The Burntwood Group migmatite contains up to 20% granitoid leucosome and consists of alternating medium grey to brown layers produced by metamorphism of a greywacke-siltstone-mudstone sequence. Mineralogically, it contains biotite, garnet and cordierite, with smaller garnets and less biotite in psammitic layers (Figure GS-6-3a), and orthopyroxene in fine-grained leucogranite lenses. Retrogressive metamorphism in the leucosome caused replacement of cordierite by garnet.

The contact is not exposed between the Burntwood Group gneiss and the calcareous rock. There are inclusions of the Burntwood Group in the granodiorite unit.

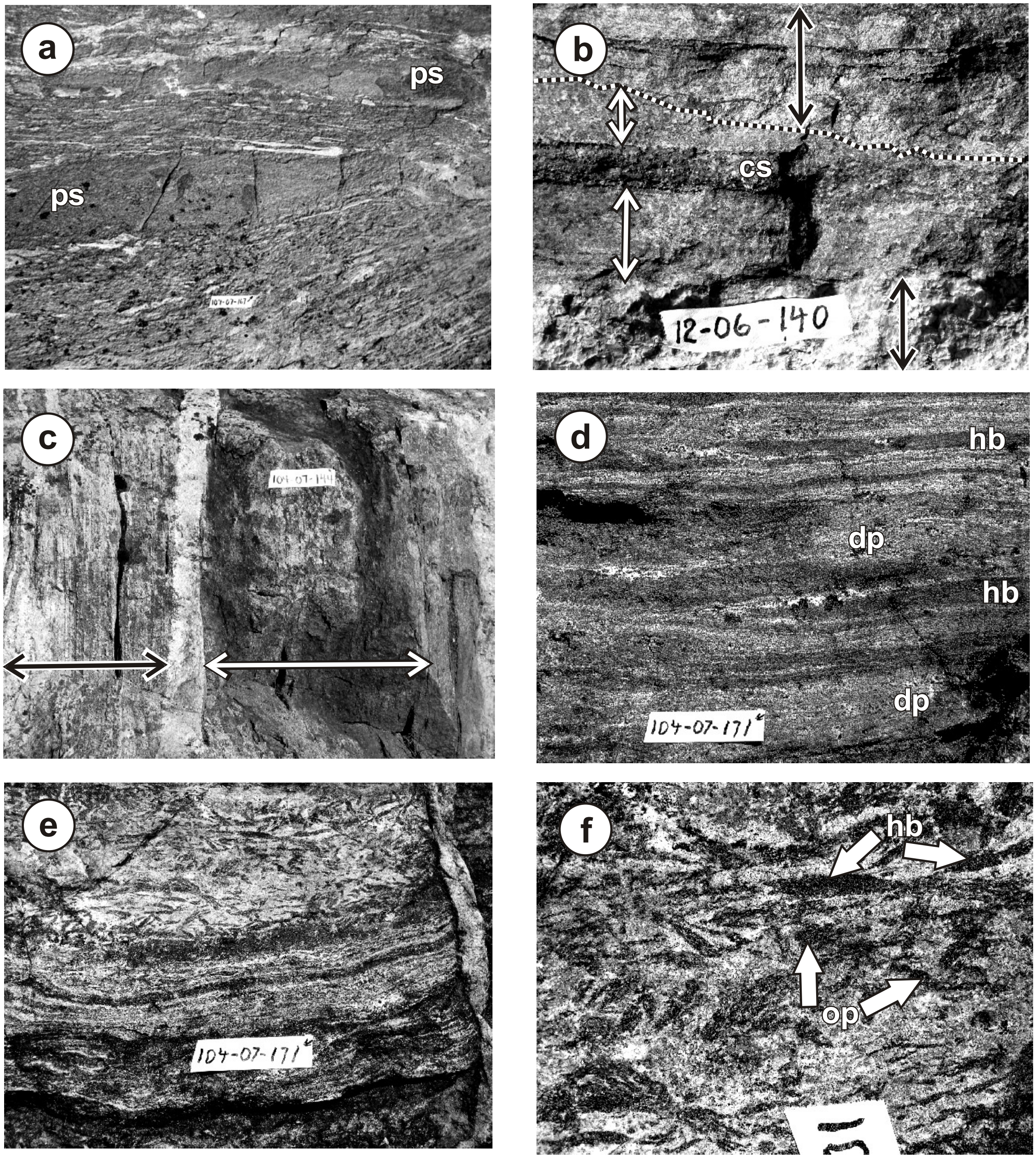

Figure GS-6-3: *Typical supracrustal rocks in the Kawaweyak Lake area, northeastern Kisseynew Domain:* ***a)*** *Burntwood Group gneiss with pelite surrounding psammite lenses (labelled 'ps');* ***b)*** *quartz-rich biotite gneiss (white arrows), with carbonate-bearing interbeds (black arrows) and a thin layer interpreted as calcsilicate (cs); white dotted line marks interlayered beds;* ***c****) interlayered iron formation, with black arrow marking the extent of calcareous gneiss on the left and white arrow marking the iron formation on the right, and a late granite dike in the middle; biotite gneiss occurs on the extreme right;* ***d)*** *amphibolite showing alternating hornblende (hb)- and diopside (dp)-rich layers;* ***e)*** *layered amphibolite with metamorphic hornblende and orthopyroxene at the top of the photograph; and* ***f)*** *close-up of bladed hornblende (hb) and equant orthopyroxene (op) in the layered amphibolite. White tape for scale is 9–10 cm long and 2.5 cm wide.*

Quartz-rich and calcareous biotite gneiss

The quartz-rich biotite gneiss is typically grey in colour, but also includes light grey to cream calcite-bearing layers and brown biotite-rich layers. This unit of quartz-rich gneiss is interpreted to have been formed from fine-grained sandstone and siltstone (psammite) with interlayered semipelite to pelite, the latter forming the biotite-rich layers. The carbonate may have originated from calcite cement between clastic quartz and feldspar grains. Glassy grey layers, in this metasedimentary succession, are interpreted as protoquartzite. Layering and interlayering occur at a centimetre scale (Figure GS-6-3b). Quartz and feldspar are the dominant minerals in the gneiss, with lesser biotite, calcite, diopside, garnet and local pyrrhotite. In the southern part of the map area, the western part of the succession contains a relatively thick member dominated by quartz-rich gneiss with only biotite and local garnet.

Neodymium isotope data of a slightly biotite-enriched layer of psammite to semipelite (Table GS-6-1) yielded a Nd model age of crustal residence of 2.15 Ga, indicating that the detritus was derived from a juvenile Paleoproterozoic source similar to the internal zone of the Kisseynew Domain.

Calcareous gneiss

The most prominent calcite-bearing section occurs at the south end of the map area, where up to 8 m are exposed on the east side of the quartz-rich gneiss. The calcite-bearing beds are interlayered with more quartz- and more biotite-rich gneiss (above). The sedimentary section becomes amphibole rich and grades into the amphibolite–iron formation assemblage farther to the east (Figure GS-6-3c). The calcareous gneiss is light grey, with local green calcsilicate interlayers and brown- to rusty-weathering layering that has a higher content of biotite ± iron sulphide. The best exposures display differential erosion, wherein calcareous layers and lenses are recessive. The mineral content of the calcareous layers includes quartz, plagioclase, diopside, calcite, pyrrhotite and, possibly, scapolite. Layers can vary from biotite to carbonate rich. The unit appears to grade into the iron formation and amphibolite.

Semipelitic to pelitic biotite gneiss

This variety of biotite gneiss forms layers up to 2 m wide that weather grey to brown and occur mostly between Burntwood Group gneiss and quartz-rich calcareous gneiss. Its mineral content includes quartz, biotite, clinopyroxene, ±magnetite ±orthopyroxene.

Layered amphibolite–iron formation assemblage

The amphibolite–iron formation assemblage is a northeast-trending linear unit exposed in several locations in the map area: 1) at the south end of the area; 2) north along a small peninsula in Kawaweyak Lake; 3) northeast on an island in the centre of the lake; and 4) northeast along the shoreline of Notakikwaywin Lake. The layered amphibolite comprises

- well-layered, medium- to fine-grained amphibolite that was possibly derived from pillow basalt, and coarse- to medium-grained layered amphibolite of uncertain origin; and
- coarse-grained amphibolite derived from uniform and layered gabbro.

The assemblage also includes four variations of sulphide-facies iron formation and sulphidic gneiss:

- silicate-sulphide–facies iron formation to sulphidic gneiss
- calcsilicate-sulphide–facies iron formation to sulphidic calcsilicate
- semimassive sulphide
- sulphidic biotite gneiss

The assemblage appears to grade into the calcareous rock and quartz-rich biotite gneiss. It is in sharp contact with intrusive granodiorite and gabbro.

Well-layered amphibolite

The well-layered amphibolite, up to 20 m wide, is dark grey to brown and consists of alternating hornblende- and diopside-rich layers that range in width from 5 mm to 1.5 m (Figure GS-6-3d). It is composed of plagioclase, amphibole, orthopyroxene, pyrrhotite, secondary biotite and calcite±diopside. The well-layered amphibolite may contain boudinaged orthopyroxene-bearing amphibole-rich layers, up to 10 cm wide, with pure amphibole lenses. The orthopyroxene is equant and the hornblende is bladed

Table GS-6-1: Samarium-neodymium isotope data for semipelitic gneiss (sample 12-06-141-1), Kawaweyak Lake.(1)

Sm (ppm)	Nd (ppm)	$^{147}Sm/^{144}Nd$	$^{143}Nd/^{144}Nd$	Uncertainty (±2σ)	T_{CR} (2)	ε_{Nd}^{T} (3)	$^{145}Nd/^{144}Nd$	UTM(4) Easting	UTM(4) Northing
3.85	17.34	0.1343	0.51204	0.00001	2.15	3.6	0.34840	509562	6193724

(1) Analysis performed at the Radiogenic Isotope Facility, University of Alberta, Edmonton
(2) Nd model ages of crustal residence (T_{CR}) calculated according to the model of Goldstein et al. (1984) for samples with $^{147}Sm/^{144}Nd < 0.14$.
(3) ε_{Nd}^{T} calculated for the time (T) 1.9 Ga
(4) Zone 14 (Nad 83)

(Figure GS-6-3e, f). Locally, eroded pockets of probable metacarbonate lenses are exposed in the unit.

The amphibolite occurs in a 100 m wide belt that includes >50% interlayered granodiorite on the large island in Kawaweyak Lake. It is thinly sandwiched between the biotite gneiss and the calcareous rock along the south shore of the lake, where it also repeats within the iron formation–amphibolite assemblage to the east. The gabbro and granodiorite are in sharp intrusive contact with the layered amphibolite.

Coarse- to medium-grained amphibolite, gabbro

A coarse- to medium-grained dark grey amphibolite is interpreted to be derived from gabbro. It generally forms massive and uniform sheet-like bodies up to 4 m wide but is locally layered (Figure GS-6-4a). It intrudes the layered amphibolite–iron formation assemblage with sharp contact relationships, some of which are marked by fine-grained chilled margins. In several places, the gabbro occurs between granodiorite and the layered amphibolite, or within layers of silicate-sulphide–facies iron formation. The close spatial association with the layered amphibolite suggests that parts of these units may be comagmatic. The gabbro is intruded by pegmatite.

The gabbro is composed of hornblende, plagioclase and minor pyrrhotite. Internal layering is defined by varying proportions of plagioclase and is interpreted as primary crystal layering. Plagioclase up to 1 cm locally rims crystals of orthopyroxene (Figure GS-6-4b).

Iron formation to sulphidic gneiss

Various facies of interleaved rusty, green and grey-brown iron formation occur within the layered amphibolite–iron formation assemblage. Each facies exhibits gradational changes in mineral content and ranges from 0.3 to 7 m in width.

Sulphide-facies iron formation

The unit of sulphide-facies iron formation, about 1 m wide, is composed of quartz, pyrite, massive pyrrhotite and local bornite. It forms a layer adjacent to calcsilicate-sulphide, sulphide-bearing biotite-gneiss and the layered amphibolite. Lenses of sulphide-facies iron formation are present as inclusions in granodiorite.

Silicate-sulphide–facies iron formation

The unit of silicate-sulphide–facies iron formation varies from 0.3 to 7 m wide and includes sulphidic gneiss or 'lean iron formation'. It includes orthopyroxene, clinopyroxene and pyrrhotite. This unit generally occurs on the northwest side of the amphibolite–iron formation assemblage, with the sulphide facies to the southwest. It is in contact with Burntwood Group gneiss and intruded by granodiorite and gabbro (Figure GS-6-3f).

Calcsilicate-sulphide–facies iron formation

A unit of interlayered calcsilicate- and sulphide-facies iron formation is up to 5 m wide, with sulphidic calcsilicate gneiss included. It occurs in the south-central part of the lake between calcareous biotite gneiss and the true sulphide-facies iron formation. Its mineral content varies from carbonate rich near the calcareous rock to pyrrhotite rich toward the sulphide-facies layer in the amphibolite assemblage.

Sulphidic biotite gneiss

The biotite gneiss within the amphibolite–iron formation assemblage occurs in local brown-weathering interlayers that can be up to 2 m wide but are generally about 10 cm. The unit is generally schistose and can be very fine grained. Its mineral content includes pyrrhotite and rarely bornite.

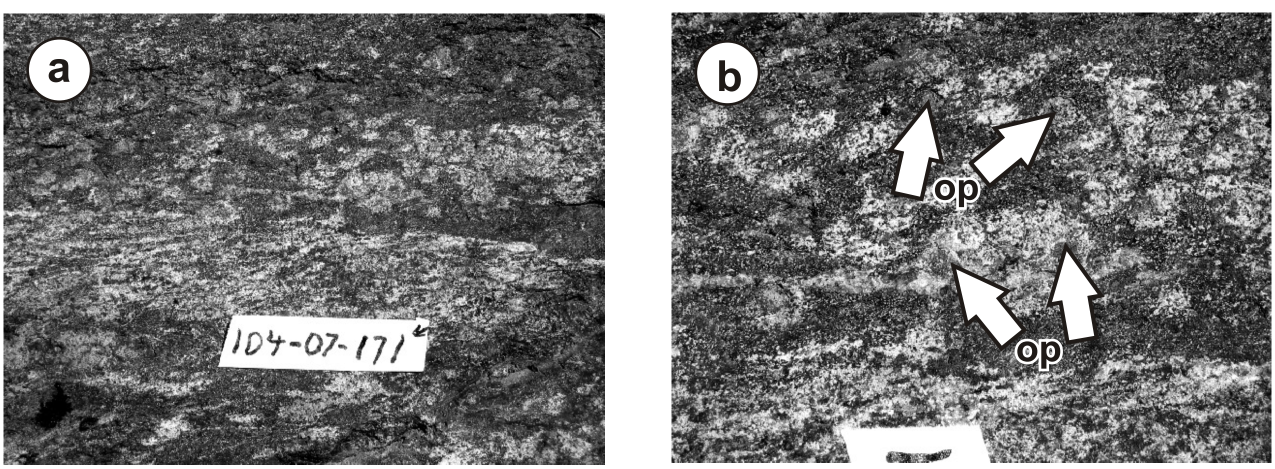

***Figure GS-6-4**: Gabbro at the north end of the Kawaweyak Lake area: **a)** gabbro showing primary crystal layering in plagioclase concentrations; plagioclase-rich lenses up to 1 cm in width (above tape) may be part of leucogabbro layers; **b)** close-up of same gabbro, showing a core of orthopyroxene rimmed by plagioclase (arrows). White tape for scale is 9–10 cm long and 2.5 cm wide.*

Granitoid intrusive rocks

Burntwood Group gneiss and the amphibolite–iron formation assemblage in the Kawaweyak Lakes area are intruded by granodiorite, granite and pegmatite, which are described below.

Granodiorite

The granodiorite weathers cream to grey-brown and is foliated to massive. It is generally equigranular, the grain size ranging from medium to coarse. It is synmetamorphic and contains the regional metamorphic assemblage of garnet, biotite, sillimanite and cordierite. In places, the granodiorite contains inclusions of Burntwood Group gneiss, amphibolite, silicate-sulphide–facies iron formation and rusty lenses up to 3 cm wide. The granodiorite is composed of quartz, feldspar, hornblende, biotite, cordierite, sillimanite and garnet. The unit intrudes the Burntwood Group, the quartz-rich to calcareous gneiss and the amphibolite–iron formation assemblage. In each location, the mineral content of the granodiorite close to the contact displays contamination by the adjacent country rock, expressed as 1) garnet and biotite adjacent to Burntwood Group gneiss; and 2) hornblende, diopside, magnetite and pyrrhotite adjacent to amphibolite. The granodiorite is injected by younger pegmatite and finer grained granitic veins.

Granite and pegmatite

The granite is white to grey, relatively coarse grained and, in places, contains garnet and cordierite. The unit also forms veins and finer grained dikes with a pegmatitic margin phase intruding the Burntwood Group gneiss. The granite locally contains up to 50% pink pegmatite.

Pegmatite is located in all of the rock units and may constitute up to 80% of the outcrop, especially along the west shoreline of Kawaweyak Lake.

Discussion and economic considerations

Rocks similar to the amphibolite–iron formation assemblage overlying the Burntwood Group occur elsewhere in the Kisseynew Domain (Zwanzig, 1990). They are preserved as pillow basalt (Tod Lake basalt), gabbro and sulphide-facies iron formation associated with siliciclastic sedimentary rocks and calcsilicate rocks in the Granville Lake structural zone (GSZ in Figure GS-6-1) at Granville Lake and the southwest end of the Lynn Lake belt (Zwanzig et al., 1999). That succession has been interpreted as part of a crustal suture extending from an area north of the TNB west into Saskatchewan (White et al., 2000). The rocks are part of the juvenile Paleoproterozoic internal zone of the Trans-Hudson Orogen and unrelated to the TNB.

The Paleoproterozoic Nd model age of 2.15 Ga from the semipelitic gneiss in the study area further supports an origin in the Trans-Hudson internal zone. A sample from quartz-rich calcareous biotite gneiss (calcsilicate) from Wuskwatim Lake yielded a Nd model age of 2.4 Ga, also juvenile Paleoproterozoic (Zwanzig et al., 2006). The latter unit was considered part of the Burntwood Group, an alternate interpretation that is also possible for Kawaweyak Lake because sulphide-facies iron formation is clearly interlayered with the Burntwood Group at Notigi Lake (Murphy and Zwanzig, GS-5, this volume).

The various possible associations of the amphibolite–iron formation assemblage indicate that the tectonostratigraphy of the northeastern Kisseynew Domain is complex and thorough ground-truthing is therefore required before maps can be redrawn based on new aeromagnetic data.

Regardless of its exact origin, the amphibolite–iron formation assemblage is best interpreted as unrelated to similar-looking rocks in the TNB and the adjacent Wuskwatim corridor because these rocks include more pelitic gneiss, yield Archean Nd model ages and are more clearly in fault contact with the Burntwood Group (Zwanzig et al., 2006). If the assemblage at Kawaweyak Lake is equivalent to the assemblage at Granville Lake, it may have economic potential for gold rather than for nickel, since showings containing trace gold occur in similar amphibolite with a sulphidic layer directly south of Granville Lake.

Acknowledgments

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