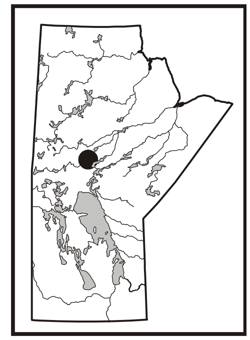
GS-6

MAPPING IN THE SETTING LAKE AREA (PARTS OF NTS 63J/15, 63O/1, 63O/2)

by H.V. Zwanzig



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SUMMARY

A composite stratigraphic section assembled from low-water shoreline exposures on Brostrom Lake provides a comparison with the Ospwagan group type section at the Pipe II Pit mine. The sections suggest a remarkable stratigraphic continuity along the Thompson Nickel Belt (TNB). Semipelitic units, which make up much of the southern section, are more garnetiferous and migmatitic (30% granitoid leucosome) than in the north, effects that are interpreted to be primarily metamorphic. Although tightly folded, the southern section shows no large-scale repetitions within the Ospwagan group indicative of early thrusting or nappe tectonics. The rocks are attenuated in narrow synclinal keels between chains of basement domes. The Pakwa Lake intrusive complex, comprising highly elongated calc-alkaline to alkaline plutons in the Setting Lake fault zone, is suggested to be related to sinistral transpression along the northwest boundary of the TNB.

INTRODUCTION

Remapping the boundary zone between the Thompson Nickel Belt and the Kisseynew Domain in the Setting Lake area was completed this summer. The work continued to focus on the structure, stratigraphy and geochemistry of the Ospwagan group, which hosts the nickel-bearing intrusions in the TNB. The mapping was extended northeast to the Soab Lake South mine site and Pisew Falls, on Brostrom Lake (Fig. GS-6-1b). Unusually low water levels in the lake exposed outcrops of most of the formations and members in the Ospwagan group that are commonly flooded. These are briefly described in this report to complement the type section at the Pipe II Pit mine (Bleeker and Macek, 1988; Macek and Bleeker, 1989; Bleeker, 1990). The mineral modes given in this report are field estimates that will be confirmed in thin section studies. Additional mapping and collection of samples for petrography and geochemistry were carried out on the wide range of mafic to felsic intrusions in the Setting Lake fault zone. This work concentrated on the synkinematic granitoid to alkaline rocks at Pakwa Lake, southwest of Setting Lake. Indicators of general strain, shear sense and metamorphic grade were recorded in these intrusions, which may be a key tectonic feature on the west boundary of the TNB.

STRATIGRAPHY OF THE BROSTROM-BAH LAKES AREA

Stratigraphy in the Setting Lake region is compiled in large part from exploration drill core (Macek et al. GS-4, this volume). The area northeast of Setting Lake has enough exposure to recognize a northeast-trending chain of Archean basement domes, flanked by attenuated synclines or narrow basins developed in the Ospwagan group cover rocks (Fig. GS-6-1b). The saddles between the domes are underlain by gently dipping basement gneiss (e.g. Sasagiu Rapids) or steeply folded cover (e.g., west of Brostrom Lake). The best exposed sections are on the west-central shore of Brostrom Lake, and at its north and south ends. The top of the section is exposed southeast of Bah Lake. The field characteristics of units in the Brostrom-Bah lakes area are outlined below.

Although in general use in the TNB, the formation names introduced by Bleeker (1990) and used for these units (herein designated by letters) are informal. Subunits (designated by numbers) represent lithologies (not members as designated by Bleeker, 1990) and do not have a unique stratigraphic position. The name 'Ospwagan formation' within the Ospwagan group contradicts the stratigraphic code and is herein changed to 'Bah Lake formation' with a type locality southeast of Bah Lake.

Basement gneiss (Ag)

Basement rocks remapped in the Brostrom Lake area consist mainly of pink- to grey-weathering migmatitic felsic gneiss. Biotite gneiss with white leucosome, probably a paragneiss, occurs locally west of the lake, and strongly layered garnetiferous mafic tectonite forms a several hundred metres thick unit to the east. Elsewhere (for example at the cairn for Pisew Falls) the dark fraction grades from diorite gneiss (30-50% hornblende) to granitoid gneiss. Local, stubby to square hornblende aggregates (>30 mm) in a granitoid matrix may be pyroxene pseudomorphs retrogressed after early granulite-facies metamorphism. Leucosome comprises thin layers of fine-grained white granitoid rock and larger lenses of pink pegmatite. These components are all tentatively interpreted as being Archean in age.

A cross-cutting pegmatite stockwork interpreted to be Proterozoic, generally also cuts mafic dykes that truncate the gneissic layering of the Archean components. However, pegmatite veins parallel to the layering are intermingled with the Archean migmatite and their age is uncertain.

Granodiorite gneiss or quartz-monzonite gneiss with 7 mm aggregates of hornblende (20%) and local 40 mm square aggregates of hornblende with a diopside core closely resembles the Proterozoic Bucko quartz monzonite (Ki2 in Fig. GS-6-1a). However, west of Brostrom Lake this orthogneiss forms thick layers in the basement gneiss and is part of, or mixed with the Archean rocks. Moreover, some leucosomal veins in the interleaved basement gneiss also carry the diopside-cored hornblende aggregates. Detailed U-Pb geochronology is required to unravel the history of these injection complexes.

Ospwagan group (O)

Many of the units described by Bleeker and Macek (1988), Macek and Bleeker (1989) and Bleeker (1990) are locally exposed in the Brostrom Lake area. Partial sections of the Ospwagan group with easy access in the vicinity of Pisew Falls, occupy a tight northeast-trending syncline (Fig. GS-6-1b). The exposed sections are dominated by Pipe formation pelite to semipelite with more garnet and granitic leucosome than in the type section at Pipe II Pit. On the thinned southeast limb of the fold, the Archean gneiss has a strong (Proterozoic?) planar and linear fabric typical of the uppermost basement exposures. Semipelitic rocks and amphibolite in the core of the fold were also highly strained. The complete stratigraphic section in the limbs of the fold is about 125 m thick and is highly flattened. Along strike, at the south end of the lake, the section is about 150 m thick, but in a northwest-trending branch of the syncline (crossing Highway 6) the limbs are thicker. This compares to a possible 600 m section at Pipe II Pit, where chert, iron formation, calc-silicate rock and marble are much thicker, and deformation is less intense (Macek and Bleeker, 1989).

Manasan formation (Om)

Basal Manasan formation (Om1) occurs on a small outcrop southeast of Pisew Falls, near the sheared basement. These rocks include yellow weathering quartzite and interbedded quartzite (<80 cm beds) with 20% brown semipelite (<5 cm beds) and are cut by a gabbro dyke. On the west (east-facing) limb of the fold, 60% beds (3-40 cm) of massive orthoquartzite are interlayered with beds (0.5-15 cm) of brown weathering quartz-rich semipelite. Local garnet is <7 mm in diameter. Black biotite-rich partings are spaced 5-10 mm apart. The folded basal contact of Om1 is occupied by a sheet of white granite (unit Pld).

Semipelite (Om2) is probably the weak rock under the bay above the Pisew Falls. It is exposed at the south end of Brostrom Lake as biotite gneiss with 10% garnet porphyroblasts (<15 mm) and 35% thin veins of granite leucosome or porphyroclasts of feldspar.

Thompson formation (Ot)

Thompson formation-type calc-silicate rock or 'skarn' is not exposed but pale buff marble in thin beds or veins occurs in angular float on the west shore of Brostrom Lake, adjacent to Om semipelite and close to basement gneiss.

Pipe formation (Op)

Northwest-facing Pipe formation pelite and semipelite also probably underlie the bay above Pisew Falls. In the east-facing sections, the lowest

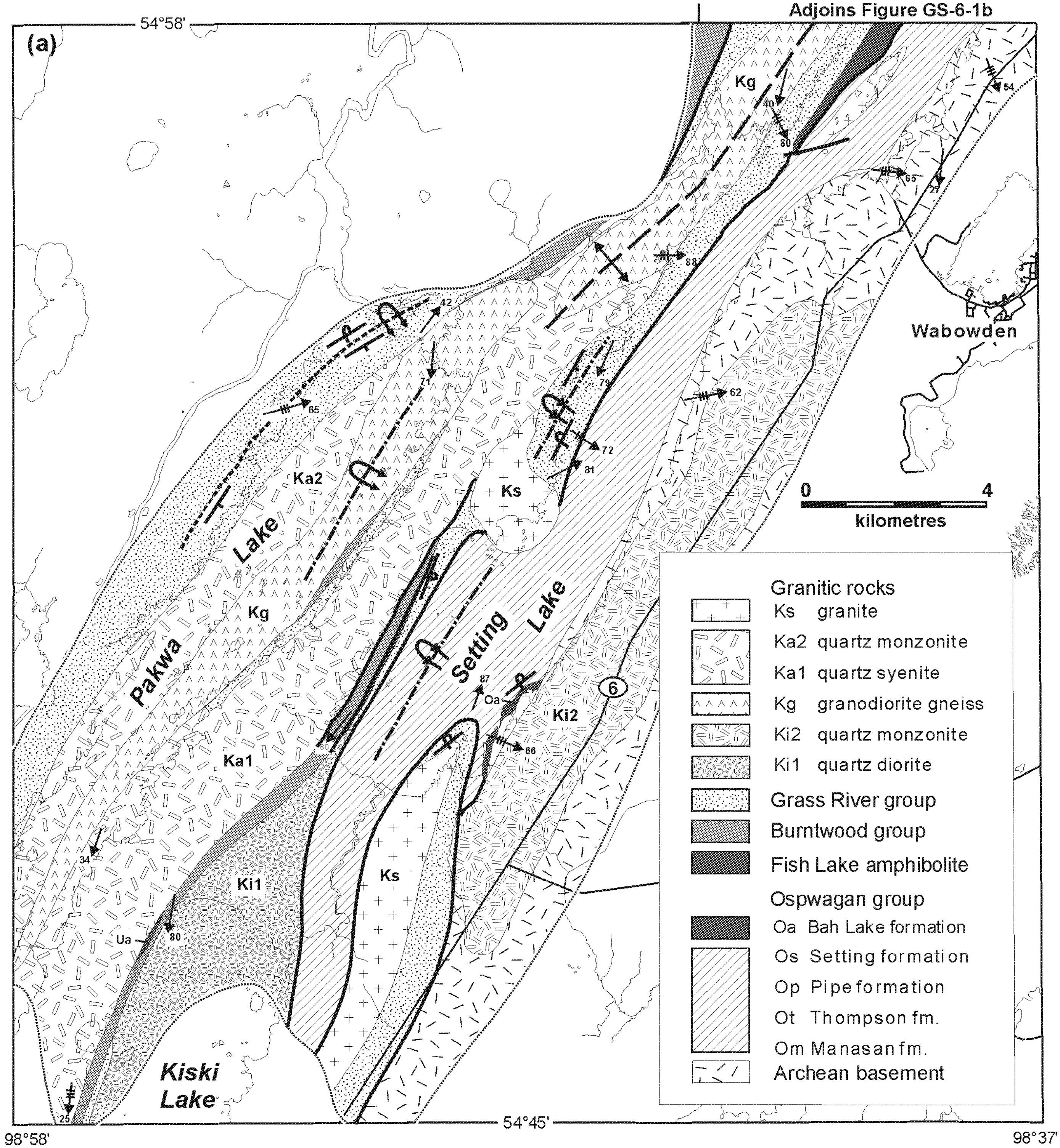
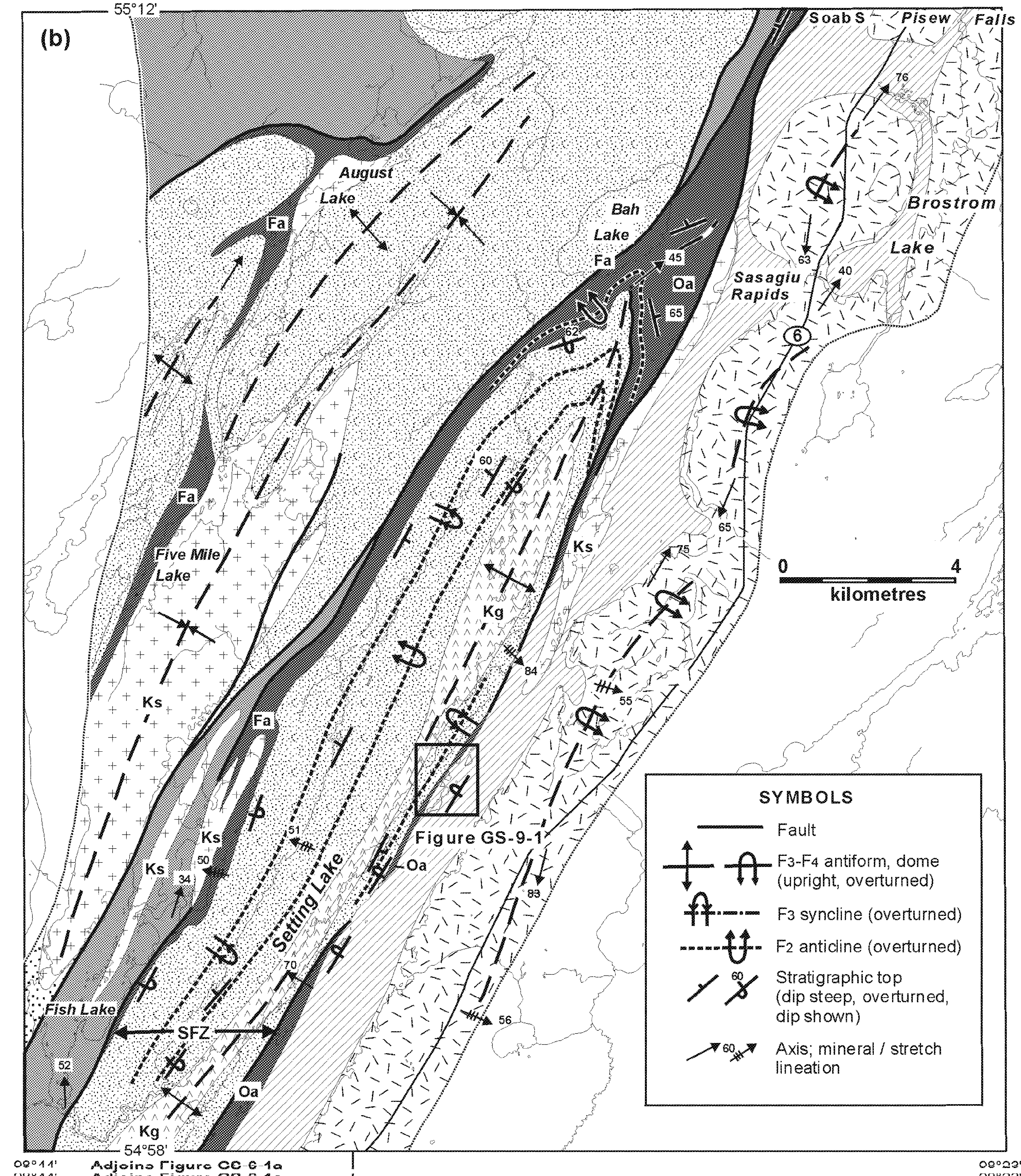


Figure GS-6-1a and b: Sketch map of the Setting Lake area (modified after Zwanzig, 1998): (a) southwest part, (b) northeast part, showing the distribution of major units and a preliminary structural interpretation. SFZ = Setting Lake Fault Zone. Stratigraphic tops are generalized from the regional succession of formations, pillow tops, graded bedding and crossbedding. Unlabelled dips are steep. Axes are mostly from F_3 and F_4 minor folds. Lineations are mainly from hornblende alignment, interpreted to have formed during D_3, but commonly parallel to the L_4 stretching lineation.

units in the Ospwagan group are mylonitic or not exposed, but 150 m of pelite to semipelite interpreted as Pipe formation occurs on the west-central shore of Brostrom Lake. This unit includes siliceous biotite gneiss with <15% garnet (<3 mm) and 20-40% granitic leucosome (<3 cm thick), and the same rock with 15% fine-grained quartzitic interbeds (4-40 cm thick). This rock is probably equivalent to pelitic schist and interlayered quartzite and schist that represent more than one member in the section at Pipe II. About 100 m higher in the section, the semipelite contains 10 cm laminated layers with garnet and amphibole and 5-10 cm layers of garnet-amphibolite, interpreted as iron formation. This is overlain by thin-layered (1-3 cm) biotite-garnet (<55%) gneiss.

Along strike, on Highway 6, Pipe formation is exposed in the west branch of the syncline. The roadside outcrop comprises semipelite interlayered with 20-50% fine-grained protoquartzite. Some individual members of brownish grey semipelite are over 1 m thick. Garnet porphyroblasts (5%) and rare lenses of calc-silicate (3-10 cm thick) occur in some of the semipelite layers. Distinctive thin discontinuous layers of salmon-pink granitoid leucosome make up 30% of the outcrop.

Directly north of Pisew Falls, Pipe formation forms biotite schist and felsic mylonite in the walls of the gorge. The upper part of the formation,



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close to Pisew Falls, includes 7 m of pelitic diatexite with 25% biotite, 15% garnet and 75% pegmatitic leucosome and 1 m of iron formation. The top of the formation is semipelitic metatexite (with 30% quartzofeldspatic leucosome) and scattered garnet. This is intruded by fine-grained (<2 mm) gabbro sills, one of which is 20 m thick and forms the main ledge in the falls.

Setting formation (Os1)

East of Pisew Falls, about 8 m of laminated (3-10 mm) quartz-biotite gneiss occurs that may be transitional between the Pipe and Setting formations. The main part of the Setting formation comprises 17 m of interlayered quartzite (<15 cm beds) and rusty weathering (sulphidic) semipelite.

Bah Lake formation (Oa)

The upper ledge of Pisew Falls exposes 16 m of layered amphibolite lying directly on Setting formation. The amphibolite contains 5 mm thick, transposed selvages (locally with garnet) and is interpreted as pillow basalt. Highly elongate calc-silicate lenses rich in epidote and diopside were derived from intrapillow alteration domains. The rock is identical to amphibolite that adjoins moderately deformed northwest-facing pillow basalt and gabbro in the upper part of the Ospwagan group west of the Soab South mine site. The unit extends southwest to Bah Lake and is herein designated as Bah Lake formation (Oa).

Six kilometres southwest of the Soab South mine site, on the ridges between the north ends of Setting and Bah lakes, a 500 m thick, homoclinal, north-northwest facing succession of weakly deformed basalt and gabbro is exposed. Much of the section is pillowed, locally with relict cooling cracks at the top of the pillows. Up to 10% of the pillows consist of lenses of calc-silicate alteration. One gabbro unit is 17 m thick and has cooling joints at the margins. The basalt in the section was sampled for chemical analysis to establish a possible link with the Fish Lake amphibolite, which is the southwestern extension of the same mafic pile (Fig. GS-6-1a).

Contacts with the Burntwood group (B1) and the Grass River group (Gc)

Typical brown weathering garnet-biotite gneiss of the Burntwood group is exposed on a small ridge west beyond the west-facing Bah Lake basalt near Soab Mine South. A reef in Bah Lake, west of the same unit, consists of Grass River group hornblendic arenite (Gc). Farther south near Fish Lake the unit adjoining the amphibolite is the Burntwood group. These relationships indicate that the sedimentary greisses are in fault contact with the pillow basalt (Oa1) and related amphibolite (Fa) on the northwest margin of the Setting Lake fault zone.

INTRUSIVE ROCKS OF THE PAKWA LAKE AREA

The full suite of intrusive rocks in the Setting Lake area was briefly described in Zwanzig (1998). These rocks are being regrouped based on ongoing petrographic and geochemical work. The groups include early-kinematic granodiorite gneiss (Kg), quartz diorite to quartz monzonite (Ki), porphyroclastic syenite to diorite (Ka), and porphyroclastic granite and leucogranite (Ks) (Fig. GS-6-1a and b). In this report only the result of work carried out during this summer on Kg and Ka is described.

Large, highly elongate bodies of units Kg and Ka make up the northeast-trending Pakwa Lake intrusive complex, which is emplaced into the Burntwood and Grass River groups, in the Setting Lake fault zone. Other sampled intrusions include leucogranite sheets and a newly observed suite of late-kinematic mafic to lamprophyric dykes to the northeast, in the Setting Lake fault zone. These are not further described.

Pakwa Lake intrusive complex

The Pakwa Lake intrusive complex is 4 km wide and over 25 km long. Its core comprises layered granodiorite gneiss, whereas its flanking plutons are deformed quartz monzonite to syenite and monzodiorite. The southeastern body of syenite is separated from the granodiorite gneiss by a narrow screen of the Grass River group and a sliver of the Burntwood group. Crosscutting relations indicate that hornblende tonalite and leucogranodiorite dykes are younger than biotite-quartz monzonite, and that granodiorite was likely the oldest phase.

The long, narrow shape of the individual intrusions, and petrographic details such as phenocryst type and habit, can be traced along strike for tens of kilometres, and suggest an original sheet-like morphology for the intrusions. Local igneous layering, sinistral shear bands with axial-planar granite layers and axial-planar dykes cutting folded dykes suggest intrusion during D_3 deformation in the Setting Lake fault zone (see below).

Granodiorite gneiss (Kg)

The body of granodiorite gneiss in the core of the Pakwa Lake intrusive complex is 750-2000 m wide and over 20 km long. The rock comprises medium grey- to buff-weathering, gneissic, biotite granodiorite that includes a coarser phase (<10 mm) with 8-15% biotite and local hornblende, and a finer (<2 mm) more leucocratic phase in 3 cm to 1 m thick layers. Locally, the fine-grained phase appears to be derived from a Grass River group sedimentary protolith. There is <10% pink granitic leucosome and 0-30% pegmatite stockwork (<1 m thick). Up to 12 mm feldspar porphyroclasts and local screens of Grass River group occur on the southwest side. The granodiorite gneiss has mafic and ultramafic inclusions; rare ultramafic dykes cutting the gneissic layering.

Porphyroclastic granite to syenite (Ka)

Potassic granitoid rocks flanking the granodiorite gneiss form elongate intrusions with mildly alkaline affinity (unpublished geochemical data).

Porphyroclastic biotite±quartz monzonite (Ka2)

Grey- to pink-weathering potassic porphyroclastic quartz monzonite occurs on the northwest side of the granodiorite gneiss and is 1.5 km wide and over 12 km long. Pink to white feldspar phenocrysts or augen (25-30%) are up to 15-30 mm long, and are locally contained in a fine-grained grey matrix. Biotite (15-20%) is up to 5-10 mm long; magnetite is abundant and hornblende is rare.

The main phase of this unit is cut by <15% granodiorite or leucogranodiorite dykes (0.5-15 m thick). Locally there is a hornblende quartz syenite stockwork or monzodiorite inclusions. Younger pegmatite stockwork makes up 0-30% of the outcrops.

Porphyritic quartz syenite (Ka1)

Grey- to pink-weathering porphyritic quartz syenite or augen gneiss occurs on the southeast side of the granodiorite gneiss and forms a body over 18 km long and 2 km wide. It was intruded between a fault slice of Burntwood group to the southeast and a screen of Grass River group to the northwest. Only its margins were mapped, and there the intrusion contains 0-30% granodiorite dykes (<1 m thick), and local granite layers or pegmatite stockwork. Preliminary petrographic and geochemical work suggests that the body is a mildly alkaline hornblende quartz syenite locally grading into monzodiorite. The syenitic phase contains 10-15% hornblende (<8 mm) and generally 10% biotite plus magnetite. Feldspar phenocrysts (15-20%) are up to 8 cm long but <5 cm augen are more common. These phenocrysts weather pink (K-feldspar) with a thin white rim (plagioclase?) or white with pink patches. Augen have a phenocrysts in the core and a felspar or granite overgrowth in the pressure shadows. The augen are locally sigmoidal and suggest sinistral shear during the overgrowth and deformation. Cognate intermediate xenoliths are common; some igneous mixtures of diorite and syenite with identical phenocrysts show banding that suggests magma mixing.

STRUCTURAL EVOLUTION

No large-scale repetitions are apparent to suggest development of an early system of thin-skinned thrusts or large recumbent folds in the Brostrom Lake area. Nevertheless, shallow-dipping Proterozoic (S_1?) foliation parallel to Archean gneissic layering in saddle structures such as at Sasagiu Rapids indicates that the early plane of deformation in the basement was subhorizontal. Small recumbent folds and a shallow-dipping shear zone with a north-over-south component of slip may be F_1 structures, and northwest-trending crenulation at Sasagiu Rapids may be F_2.

Large, southwest-verging, recumbent F_2 folds were interpreted to have formed in the supracrustal rocks at the north end of Setting Lake (Zwanzig, 1998). An F_2 southwest-directed thrust, which placed Ospwagan group over Grass River group, formed at the south end of the lake (Fig. GS-6-2). In low-strain domains like the upright homoclinal Bah Lake basalt succession (above), S_2 is preserved as planar alignment of fine-grained amphibole and mica. The average strike in these areas is 250° and dip is northwest, suggesting a south-southeast vergence. Such trends are also locally preserved in the adjacent parts of Kisseynew Domain, as at August Lake (Fig. GS-6-1a). Regional juxtaposition of the TNB and the Kisseynew Domain (Zwanzig, 1998) must have preceded the local F_2 thrusting at the boundary.

F_2-F_3 structures and fabrics are interpreted to dominate the Pakwa Lake intrusive complex. A well developed gneissosity is associated with high-temperature metamorphism and intrusion of potassic granitoid sheets along the northwest side of the Setting Lake fault zone. Strike is north-northeast and plunge is curved along the complex, indicating that it is domal (Fig. GS-6-1a). Sinistral shear bands filled with granitoid leucosome (Fig. GS-6-3) and local flow banding are structures that suggest regional sinistral shear during intrusion and deformation of the Pakwa Lake complex. 'Straight gneiss' in the granodiorite core of the complex

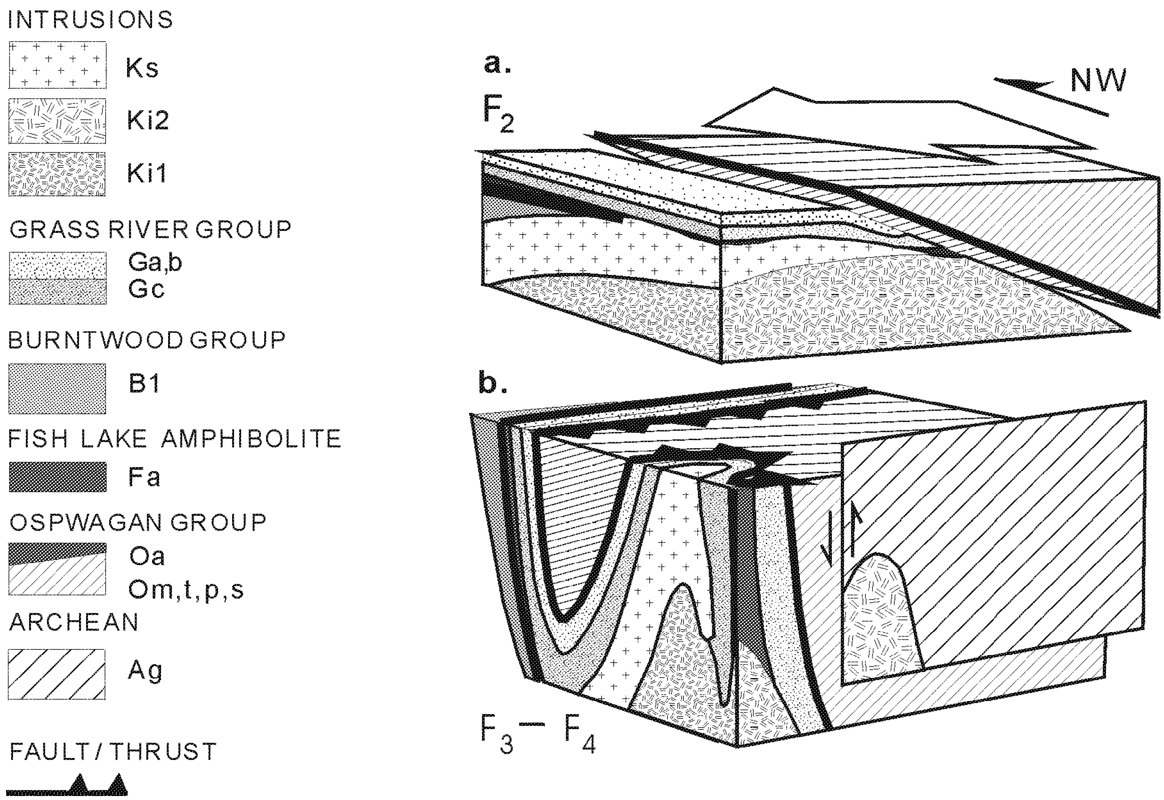

Figure GS-6-2: Model of the structural evolution of the southwest Setting Lake area: F_2 faulting is interpreted as having placed Ospwagan group on the (younger) Grass River group. This was intruded by calc-alkaline to high-K plutons and refolded by F_3 - F_4 upright structures.

indicates high strain, and the asymmetric (sinistral) overgrowths on feldspar augen indicate non-coaxial strain during high-grade metamorphism. Similar structures occur elsewhere on the northwest side of the Setting Lake fault zone (Fig. GS-6-4).

The Pakwa Lake intrusive complex and the highly elongate body of granodiorite gneiss to the northeast (Fig. GS-6-1b) dominate the Setting Lake fault zone for a strike length of 50 km. They occupy the boundary between the Kisseynew Domain and the TNB. Seismic profiles (Lucas et al., 1994) indicate that the juvenile crust of the Trans-Hudson Orogen dips east under the TNB basement crust and that early steep (transcurrent?) structures probably terminated at mid-crustal level. The steep F_3 structures are tentatively interpreted as the result of strain partitioning during sinistral transpression.

Basins and domes are interpreted to have evolved in the basement and the Ospwagan group cover during progressive or polyphase (F_3-F_4) deformation overprinting the F_2 structures (Zwanzig, 1998). The result is a type 1 interference pattern (Ramsey, 1967) that suggests that originally large upright F_2 folds occurred in the basement-cover contact northeast of Setting Lake. The diverging plunge at the north and south end of the basement domes indicates a strong curvature of the hinge lines (Fig. GS-6-1b). However, the domes are herein not interpreted as true sheath folds because high-strain zones in the Ospwagan group do not penetrate the basement and cover as regional shear zones. High coaxial strain is common in the incompetent core of the elongate synclines and basins as at Pisew Falls. In the Setting Lake fault zone, hook-shaped structures form a type 2 fold interference pattern (Fig. GS-6-1b; Fig. GS-10-3 in Zwanzig, 1998). In domains of intermediate strain F_3-F_4 folds most commonly plunge northeast at a moderate angle (e.g. Ducharme and Zwanzig, GS-9, this volume). These relations are consistent with overprinting of large, southerly-verging, upright to recumbent F_2 folds by

Figure-GS-6-3: Asymmetric granite overgrowth on feldspar phenocrysts in quartz syenite, and leucosomal layers (e.g. 4 cm above the 10 cm long tape) oblique to the foliation and suggesting sinistral shear in the Pakwa Lake intrusive complex.

Figure-GS-6-4: Small shear zone with pegmatite (top) and sinistral shear bands in granitic augen gneiss of the Fish Lake pluton, northwest of the Pakwa Lake intrusive complex.

the northeast-trending upright F_3-F_4 structures.

The F_4 brittle-ductile structures are concentrated along the southeast side of the Setting Lake fault zone. They are interpreted to have a large component of southeast-side-up slip; the horizontal component is locally sinistral and elsewhere dextral (Zwanzig, unpublished data,1998).

TECTONIC AND ECONOMIC IMPLICATIONS

A remarkable stratigraphic continuity of formations in the Ospwagan group is implied by the similarity between the composite sections at Brostrom Lake and the type section in Pipe II Pit. The more common garnetiferous and migmatitic semipelitic units in the southern section are interpreted to be primarily the result of a higher metamorphic grade than in the north. The stratigraphic continuity is consistent with that of a foundered platform succession on the margin of the Superior Craton and supports a simple stratigraphic model in exploration for nickel-bearing intrusions that are confined to one or two formations.

Although tightly folded, the southern section shows no large-scale repetitions within the Ospwagan group that would indicate early thrusting or nappe tectonics. At Brostrom Lake the Ospwagan group occupies simple synclines or basins that flank basement domes. The validity of early (F_1) nappe tectonics (Bleeker, 1980) in the entire TNB has been questioned by Potrel et al. (in prep.), and the overall northwest-facing sedimentary succession on central Setting lake is also consistent with a simple structural style (Ducharme and Zwanzig, GS-9, this volume). These observations lend support for drawing a compilation map with a relatively simple style for much of the TNB (Macek et al., GS-4, this volume).

The Setting Lake fault zone along the northwest boundary of the TNB, on the other hand, features thrusts and recumbent F_2 folds that were refolded by F_3-F_4 upright structures. The Pakwa Lake intrusive complex, comprising highly elongated calc-alkaline to alkaline plutons in the Setting Lake fault zone, is suggested to be related to sinistral transpression along the margin of the Trans-Hudson Orogen. The original margin probably lay farther west; blocks of the TNB were likely transported to the southwest, but remnants may still exist on the margin of the Kisseynew Domain.

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