The Phelps Lake Area: A Look at the Hearne Province in Northeast Saskatchewan – Field Trip Guide

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Introduction

Located in the far northeast corner of Saskatchewan, the Phelps Lake Project (Figure 1) was designed to update the geological database and determine the mineral potential of this poorly understood corner of the province. The centre of the area is approximately 170 km north of Points North Landing and 180 km east-northeast of Stony Rapids (Figure 1) and is accessible from either location by float- or ski-equipped aircraft. Because of extensive glacial deposits, the project began in the summer of 2000, with the completion of a multiparameter airborne geophysical survey flown over the entire Phelps Lake area, NTS 64M. The survey was undertaken by the Geological Survey of Canada (GSC) as part of their Targeted Geoscience Initiative and was partially funded by Saskatchewan Northern Affairs through the provincial Centenary Fund. Digital and paper copy maps derived from the gamma ray spectrometer, and magnetic, surveys were released in May 2001 (Carson et al., 2001a and b).

Figure 1 - Location and regional setting of the Phelps Lake Project area. A) Phelps Lake area with respect to domainal subdivision of northern Saskatchewan: B'lodge, Beaverlodge; STZ, Snowbird Tectonic Zone. Communities: PN, Points North Landing; SR, Stony Rapids. B) Regional geologic setting of the Phelps Lake region in the northern Hearne Province showing areas mapped in 2001, 2002 and 2003 (within heavy dashed line). Lake names show approximate location of some lakes named in text.

During the summer of 2001, the SGS began a multiyear program of 1:100 000 scale geological (Harper et al., 2001, 2002b, 2003) and surficial (Campbell, 2001, 2002) mapping of the northern half of the Phelps Lake map area (Figure 1). An evaluation of known mineral occurrences in 64M was also begun (MacDougall, 2001, 2002; Harper et al., 2002a). In conjunction with the regional mapping, Dr. I. Coulson of the University of Regina, began a more detailed (1:20 000 scale) study of part of the Ennadai Greenstone Belt in the northwest quarter (Coulson et al., 2001).

Previous Work

The GSC completed one inch to 4 miles reconnaissance geological mapping of the Phelps Lake sheet in the late 1950s (Tremblay, 1960). The Saskatchewan Department of Mineral Resources carried out one inch to one mile geological mapping of the Hara Lake (part of 64M-1; Kays, 1972) and Many Islands Lake (part of NTS 64M-9; Munday, 1973) areas adjacent to Manitoba. The SGS then completed 1:100 000 scale reconnaissance mapping of the southeast (Lewry, 1983), southwest (Scott, 1986), and northeast, (Reilly, 1989a, 1993a) quarters. Reilly (1989b, 1993b) also mapped part of the Ennadai Greenstone Belt at 1:50 000 scale. Adjacent areas to the north, northeast, and east were mapped by Taylor (1963), Wright (1967) and Fraser (1962) for the GSC. The area to the east was also mapped by Weber et al. (1975) for the Manitoba Mineral Resources Division and recently compiled at 1:250 000 scale (Manitoba Industry, Trade and Mines, 2000). To the west, Gilboy (1978, 1979) mapped the eastern parts of the Stony Rapids area (NTS 74P), at 1:100 000 scale for the SGS and compiled a preliminary 1:250 000 scale geological map of 74P (Gilboy, 1980).

The surficial geology of the Phelps Lake area was included in a series of 1:250 000 scale maps completed by the Saskatchewan Research Council and released as Open File reports by the SGS (Schreiner, 1984a; McNamara, 1984) and in a 1:1 000 000 scale compilation and companion report (Schreiner, 1984b). As part of that project, the Phelps Lake area was the subject of an MSc thesis by McNamara (1987). Quaternary geology in the northern Phelps Lake area is spectacular, with well-preserved features, such as: recessional, rogen, and ice-pushed moraines, boulder-draped ridges, extensive esker-kettle-outwash systems, boulder and felsenmeer fields, eroded drumlins, and enormous erratics. The largest erratic encountered was approximately 9 m by 10 m by 8 m high (see Campbell, 2001, 2002 for more details).

General Geology

The Phelps Lake area lies within the western part of the Hearne province, mainly in the northern Mudjatik Domain, but also includes part of the Wollaston Domain in the southeast corner. In the extreme northwest corner, mylonitic granites and amphibolites probably mark the southeast limit of the Striding-Athabasca mylonite zone (Hanmer and Kopf, 1993; Hanmer, 1997), which occurs on the Hearne side of the Snowbird Tectonic Zone (STZ). The STZ marks the boundary between the Rae and Hearne cratons.

The Phelps Lake area is largely underlain by presumed Archean granitoid rocks (ca. 3.3 to 2.6 Ga; see Aspler and Chiarenzelli, 1996 and references therein, Orrell et al., 1999; Harper et al., 2004). Archean volcanic and sedimentary rocks (ca. 2.73 to 2.68 Ga) of the Ennadai Greenstone Belt are less abundant, occurring primarily in the northwest, but also in smaller pockets elsewhere (Figure 1). Paleoproterozoic Hurwitz Group sedimentary rocks (ca. 2.4 to 1.9 Ga) occur across the area, being more widely distributed than previously indicated, whereas the partially time-equivalent Wollaston Group sedimentary rocks (ca. 2.1 to 1.9 Ga) are only known in the southeast. Paleoproterozoic gabbros, leucogranites, granites, and leucotonalites (ca. 1.85 to 1.75 Ga intrude these rocks. The youngest rocks are west- and northwest-trending diabase dykes; the former possibly belonging to the ca. 2.19 Ga Tulemalu or 1.9 Ga Chipman dyke swarms (Tella et al., 1997; Williams et al., 1999), and the latter, mainly defined by aeromagnetic trends, are probably related to the ca. 1.27 Ga McKenzie swarm (LeCheminant and Heaman, 1989).

The area has been affected by multiple thermotectonic events, including an Archean history and the Trans-Hudson Orogen. The rocks generally exhibit amphibolite facies mineral assemblages, with a gradual increase from lower amphibolite grade in the Ennadai Group volcanic rocks in the northeast, to upper amphibolite grade southwestwards, and locally some rocks attained granulite facies conditions.

As a result of the extensive glacial cover, bedrock exposure is generally poor, although better in the west where the terrain is more rugged, and relief of 50 to 60 m above adjacent lakes is common. Topographic relief is generally 20 m or less producing a rather gently undulating, poorly exposed, terrain. The greatest relief occurs adjacent to MacKenzie Creek, near the Saskatchewan - Northwest Territories (NWT) border where the valley walls reach 90 m above the level of Bradford Lake. Bedrock exposures are enhanced along several northeast-southwest trending corridors. One such corridor extends across the area following MacKenzie Creek from the NWT border, southwest through Gebhard, Bonokoski, and Pikwuche lakes. This corridor and the others are coincident with major esker systems which cross the area and represent subglacial channels (Campbell, 2001, 2002), along which the high volume of water flow effectively removed much of the earlier deposited sediments and till.

Felsenmeer, and slightly transported boulder fields are common. The angularity, large average size (typically 1 to 2 m across), predominance of a single rock type, and common association with felsenmeer, indicate that many of the boulders have not been transported very far, and thus these boulder fields were used to map the underlying bedrock. Abrupt changes in the boulder composition (e.g. a change from metasedimentary rock to granite) were observed in many places and signaled the change in the underlying or nearby bedrock. Many of the areas underlain by granitic rocks are very poorly exposed, but have the most extensively developed boulder fields. These essentially monolithologic boulder fields differ from extensive, heterolithologic boulder-rich tills, which comprise a very diverse population of well-rounded, much traveled, boulders, some having been derived from sedimentary and volcanic rocks of the Dubawnt Group and other source terrains in the NWT and Nunavut.

Archean Rocks

It is well established that Archean rocks constitute a large part of the Hearne Craton. They include: a locally developed older basement complex ca 3.3 to 2.82 Ga (e.g. Aspler and Chiarenzelli, 1996: Orrell et al., 1999; Harper et al., 2004) comprising various migmatitic orthogneisses; and younger supracrustal sequences comprising volcanic and sedimentary rocks ranging from ca. 2.73 to 2.68 Ga (ibid). The supracrustal belts, generally referred to as the Ennadai Greenstone Belt, is part of a regionally discontinuous belt that extends over 700 km from northeast Saskatchewan to Rankin Inlet on Hudson's Bay. These rocks were intruded by ca. 2.72 to 2.6 Ga mafic to felsic plutons (Peterson and Lee, 1995; Peterson et al., 2000; Harper et al., 2004), that overlapped the volcanic activity and predated late Archean deformation and metamorphism at ca. 2.55 to 2.5 Ga (Davis et al., 2000b).

Basement Rocks

Rocks suspected of being basement, to the Ennadai Group volcano-sedimentary rocks, included the gneissic granitic and tonalitic migmatites and the mylonitic granite gneiss and amphibolite forming part of the Striding-Athabasca mylonite zone. The migmatites comprise multiple intrusive phases ranging from diorite to granite and from well foliated to massive. Although they tend to have higher magnetic signatures than many of the supracrustal rocks and younger granitoids, there are also areas where these rocks have low magnetic character. Locally they contain abundant xenoliths, rafts, or large boudins of strongly foliated and folded paragneiss and orthogneiss (Figures 2 and 3).

Figure 2 – Probable basement rocks.

Figure 3 – Deep structural level exposed in Mudjatik Domain.

There was some evidence to suspect that the older basement component existed in the Phelps Lake area. Hanmer (1997) had obtained U-Pb zircon ages of ca.3.3 to 3.1 Ga on mylonitic leucogranite and granite within the Striding-Athabasca mylonite zone in adjacent NWT between Selwyn Lake and the south end of Snowbird Lake. Orrell et al. (1999) obtained a ca. 3.0 Ga U-Pb zircon age from tonalitic migmatite from the southern Mudjatik Domain and Loveridge et al. (1988) obtained U-Pb zircon ages ranging from ca. 3.3 to 2.77 Ga for a group of granodioritic and tonalite gneisses from east of Kasba Lake in adjacent Nunavut. This has now been confirmed by a U-Pb zircon age of ca. 2.82 Ga for a tonalite gneiss (Harper et al., 2004), by an age of 3.11 Ga for a population of inherited zircons in a ca. 1.86 Ga granite (ibid), as well as ca. 3.0 Ga inherited zircon cores in a 2.68 Ga granite (van Breeman, unpublished SHRIMP data).

Ennadai Greenstone Belt

Rocks of the Saskatchewan portion of the Ennadai Greenstone Belt were informally referred to as the Ennadai Group by Macdonald (1984) and the term was also used by Reilly (1989b, 1993b). The extent of the main part of the belt was originally defined by Tremblay (1960) and subsequently, Reilly (1993b) included some of the metasedimentary rocks lying west of Hatle Lake (Figure 1). Reilly also recognized that calc-silicate and carbonate rocks along parts of the eastern and southern margins of the belt, probably belonged to the Hurwitz Group. On the basis of the current mapping, the Ennadai Group has been extended to the west beyond Wayow Lake and southwest through Wapistan Lake. Other areas containing probable Ennadai Group rocks are most notably developed in the Gebhard Lake - Bonokoski Lake area; however, many smaller outliers are scattered across the area in apparent structural keels in interference fold structures (Figure 1). Small amphibolitic gneiss outliers within the tonalite migmatite, although they might be older supracrustal remnants, are generally considered to be equivalent to the Ennadai Group.

The Ennadai Group comprises mainly mafic volcanic rocks, with subordinate intermediate and felsic volcanic rocks, associated mafic to ultramafic synvolcanic sills and dykes, and locally intercalated psammopelitic and pelitic schists and iron formation (Figure 4). The mafic volcanic rocks include massive and pillowed flows and tuffs, the latter typically interlayered with minor intermediate and felsic tuffs, producing a colour-banded rock. In a few places tuff breccias are developed. Locally developed epidote, calcite, and/or diopside-rich rocks are common and attributed to calcareous alteration. Quartz veining with accompanying pyrite and/or pyrrhotite is almost ubiquitous. With increasing metamorphic grade garnet porphyroblasts become common, but they are also partially to completely replaced by plagioclase.

Figure 4 – Ennadai Group.

Intermediate volcanic rocks are commonly represented by tuffs and tuff breccias, and felsic volcanic rocks by massive flows and/or high-level subvolcanic intrusions, as well as tuffs and rare tuff breccias (Figure 5).

Figure 5 – Ennadai Group felsic volcanic sequence.

A distinctive, faserkiesel-rich psammopelitic schist is locally interlayered with the volcanic rocks on Hamill Lake. The white quartz-muscovite faserkiesel, (possibly retrogressive after andalusite) stand out in relief on weathered surfaces (Figure 4), and are generally concentrated in what were probably the muddier parts of graded beds. Also interlayered with mafic flows are iron formations, consisting of alternating quartz-rich (chert) layers with oxide, or sulphide and/or silicate facies layers, on a centimetre to metre scale. Strong iron staining is developed on outcrops of sulphide and silicate-sulphide facies varieties, such as the prominent 'gossan' on the peninsula separating the east and west arms of Gebhard Lake. Banded quartz magnetite iron formation is best developed in a zone about 10 m wide along the east side of several large ridges of mafic volcanic rocks on the peninsula extending south into Bonokoski Lake.

Weakly rusty weathering, and locally graphitic psammopelitic to pelitic gneiss and less commonly psammitic gneiss, underlie a large area west of Hatle Lake. These rocks are not well represented by bedrock exposures, but more commonly by extensive boulder fields and felsenmeer. Interlayering with silicate facies iron formation and intermediate to felsic tuffs occur in a few places.

Feldspathic psammitic and minor pelitic gneisses structurally underlie and are locally interlayered with garnet-bearing mafic volcanic rocks south of Emmerson Lake. They also structurally overlie tonalitic migmatite in this same area. Similar feldspathic psammitic gneiss occurs about 1 km east of Bonokoski Lake, in close association with mafic to felsic volcanic rocks. This psammitic - pelitic sequence resembles Aspler and Chiarenzelli's (1996) basal unit A1 of the Archean Henik Group, part of the Ennadai Greenstone Belt in the Henik Lake area in Nunavut.

Timing of felsic volcanism in the Ennadai Greenstone Belt is constrained by a U-Pb zircon age of 2682 +-6 Ma (Chiarenzelli and Macdonald, 1986) from a felsic volcanic near Hamill Lake (Figure 1) and from a second felsic volcanic east of McKenzie Creek dated at 2681 ±4 Ma (Harper et al., 2003, 2004). A U-Pb zircon age of 2708 +3/-2 Ma (Delaney et al., 1990, and Reilly, 1993b) was obtained from a granodiorite that intruded Ennadai Group mafic volcanic rocks near Lichfield Lake (Figure 1). Similar zircon SHRIMP ages ranging from ca. 2.69 to 2.72 Ga (van Breeman, unpublished data) were obtained from tonalite gneisses in the east half of the area. The conflicting ages may be explained by the felsic volcanic rocks, located about 14 km northeast of the dated intrusion, being from a younger part of the volcanic sequence.

Paleoproterozoic Rocks

Paleoproterozoic rocks in the north half of the Phelps Lake area include the sedimentary rocks of the Hurwitz Group and a suite of younger granitoids related to the Trans-Hudson Orogen. The Hurwitz Group occurs in a southwest-trending belt from the NWT border along the MacKenzie Creek valley, then discontinuously to Milton Lake in the southwest corner (Figure 1). Northeast of Gebhard Lake, an extension of the main belt trends easterly towards Bailey Lake. Several small outliers occur west of Bonokoski Lake. Two major synclinoria occur in the northeast quarter, one around Hasbala Lake in the extreme northeast corner and the other extending for more than 40 km southwestwards from the Manitoba border along Many Islands Lake to Nunim Lake (Figure 1).

Hurwitz Group

In the northwest quarter, the Hurwitz Group has been extended far beyond the limits indicated by Reilly (1993b), and now includes several areas mapped as calc-silicate rocks and quartz-feldspar-biotite gneiss by Tremblay (1960). The group as a whole includes pelite, ferruginous pelite, calcareous pelite, calc-silicates, marble, psammopelite, and minor quartzite and mafic and felsic volcanic rock. Metamorphic grade increases from lower amphibolite facies near the NWT to upper amphibolite to transitional granulite facies towards the southwest. Most of the areas underlain by Hurwitz Group rocks correspond to sharply defined aeromagnetic lows, although some notable magnetic highs are associated with ferruginous pelite and locally developed oxide (magnetite) facies iron formation. As Hurwitz Group sedimentary rocks have now been identified at Milton Lake in the southwest corner of the map area, and trend southwesterly out of the area, it is seems likely that calc-silicates, pelites and quartzites mapped by Gilboy (1978, 1979) in the adjacent Stony Rapids area, also belong to the Hurwitz Group.

Primary features, which can be used to determine top directions, are rarely preserved in the northwest, but are present in the northeast. At the lowest exposed structural levels, are black, sulphidic pelites presumably representing deep-water anoxic conditions. With increasing metamorphic grade, these rocks become rusty weathering, graphitic, garnet-, cordierite-, +-sillimanite-bearing pelitic gneiss. In places this lower unit is a pelitic migmatite, which contains abundant highly boudinaged pink to red granitic and/or white tonalitic and/or quartz veins (Figure 6). A similar magnetite-bearing pelitic unit occurs in the northeast (Figure 7).

Figure 6 – Hurwitz Group NW quarter.

Figure 7 – Hurwitz Group NE quarter.

Calc-silicate rocks and interlayered calcic pelite and minor marble layers have a very distinctive ribbed weathered surface caused by alternating resistant, pale to medium green diopsidic layers, and recessive, disrupted layers, lenses and clots of dark grey to black biotite-rich pelite (Figure 6). Calcite is a common accessory mineral in these rocks. In places exceptionally coarse-grained diopside and possibly scapolite (up to 20 cm long) results in essentially monomineralic layers. Another variety has pink K-feldspar-rich veins or layers (aplite or pegmatite), alternating with green calc-silicate layers, and white quartz veins. A few gabbroic dykes intrude calcic pelite and calc-silicate rocks east of Jones Lake.

In a few places, 1 to 3 m thick, quartzite layers occur at the base of the pelite unit, but more commonly are interlayered with calc-silicate rocks and calcareous pelite. At Many Islands Lake, a calcareous cherty breccia occurs near the top of the pelite unit below the marble unit. A felsic volcanic occurs in close association with this breccia. Marble units are typically dolomitic, but commonly contain some calcite along with a diverse assemblage of accessory minerals including: phlogopite, diopside, scapolite, tremolite, idocrase, and possibly forsteritic olivine and wollastonite (Figures 6 and 7).

Quartzite apparently overlies the marble, northeast of the northeast end of Hein Lake, but more commonly, a psammopelitic-psammitic with minor calc-silicate layers overlies the carbonate unit.

Munday (1973) first suggested the correlation of these metasedimentary rocks in the Many Islands Lake area with the Hurwitz Group. He also speculated on their possible correlation with the Hidden Bay Assemblage (Wallis, 1971) of the upper part of the Wollaston Group. Reilly (1989a, b, 1993a, b) and Harper et al. (2001, 2002b) correlated the lower pelitic sequence in the Hasbala and Many Islands lakes areas with the Ameto Formation, lower Hurwitz Group, and the marble and calc-silicate rocks in those areas as well as adjacent to the Ennadai Greenstone Belt with the Watterson Formation of the upper Hurwitz Group (Aspler et al., 1992). In the northwest quarter, the lower pelitic and interlayered calcic pelite, quartzite, and calc-silicate rocks sequence was not previously recognized, and was correlated by Harper et al. (2001) with the Ameto Formation. Gabbroic sills in these rocks east of Jones Lake supported that correlation (c.f. Aspler et al., 1992), because it was gabbro sills intruding the Ameto Formation, which provided an age constraint of 2.11Ga (Heaman and LeCheminant, 1993) to mark the end of deposition of the lower Hurwitz Group. The Watterson Formation is the lowermost formation of the upper Hurwitz Group (Aspler et al., 1992). Harper et al. (2001, 2002b) noted that the overlying sequence of psammopelitic-psammitic-pelitic rocks (siltstone-mudstone) and possible local quartzite correlate best with the Ducker Formation (Aspler et al., 1992). Recent detrital zircon geochronological studies of the Hurwitz Group (Davis et al., 2000a) have shown that the Watterson, Ducker, and Tavani formations were deposited ca 1.9 Ga almost 200 million years after the end of lower Hurwitz Group deposition.

Recent stratigraphic analysis of the various Proterozoic basins across the Rae and Hearne provinces has suggested that lower Hurwitz Group rocks may be aerially restricted to the Central Hearne domain and that outlying basins (e.g., NE Saskatchewan) previously correlated with Ameto Formation (lower Hurwitz) and upper Hurwitz Group formations may be entirely upper Hurwitz sequences (Pehrssons, pers. comm., 2004). These sequences would then be time equivalent with the Wollaston Supergroup (Yeo et al., in press). To add further to this speculation are felsic volcanic rocks interlayered with the lower sequence pelites and calcic pelites at Many Islands Lake. These rocks may be equivalent to the felsic porphyry dated at ca. 2.1 Ga (Ansdell et al., 2000; Yeo et al., 2000) from the lower Wollaston Supergroup and indicate a younger age for the Ameto-like sediments.

Intrusive Rocks

In the NWT and Nunavut and also in northeast Saskatchewan pre- to syn- (ca. >2.75-2.7 Ga), syn- (ca. 2.69 to 2.65 Ga), and post-volcanic (ca. 2.62 to 2.6 Ga) Archean plutons have been identified (Sandeman et al., 2000; Harper et al., 2004). Two periods of Paleoproterozoic granitoid plutonism have also been recognized; the Hudson granitoids (ca. 1.85 to 1.81 Ga) and the Nueltin suite (ca. 1.76 to 1.75 Ga) (Peterson et al., 2000; Harper et al., 2004). Minor intrusions including mafic to felsic dykes and sills cover a similar time span as well as including diabase dykes of the 1.27 Ga MacKenzie dyke swarm.

Archean Intrusions

Early syn-volcanic intrusions include tonalites, and smaller ultramafic, gabbroic, dioritic, and granodioritic sills and stocks in the volcanic sequence (Figure 4). Larger intrusions, such as the elliptical pluton centred on Gilchrist Lake and other foliated to mylonitic leucogranite - granite bodies, are also considered to have a syn-volcanic age, and typically are younger than the tonalites.

Paleoproterozoic Intrusions

Paleoproterozoic intrusive rocks include some weakly to moderately foliated granitoids, but mainly massive leucotonalite and leucogranite and porphyritic fluoritic granites. Small granite and tonalite bodies that intrude Hurwitz Group rocks at Jones Lake have given U-Pb zircon crystallization ages of ca 1860 Ma (Harper et al., 2004) and 1814 Ma (Heaman et al., 2003) respectively, confirming their association with the Hudson granite suite. There is a younger pink to red, massive leucogranite and pegmatite that always intrudes the leucotonalite, and occurs as veins, dykes, sheets, and irregular- to ovoid-shaped intrusions throughout the area. Although locally porphyritic, and fluorite bearing the leucogranites never have the rapakivi texture prevalent in the fluorite-bearing Nueltin granites (Peterson et al., 2000) in the NWT and Nunavut. One such granite at Spratt Lake in the southeast, yielded a U-Pb zircon crystallization age of 1751 Ma (Heaman et al., 2003; Harper et al., 2004) confirming its Nueltin association.

A zoned late granite pegmatite produced a skarn rind up to 10 cm wide in Hurwitz calc-silicate rocks at Wapiyao Lake. Development of this small scale skarn suggests that larger, possibly mineralized skarns could be developed in Hurwitz carbonate rocks where they are intruded by larger late granites. Muscovite- and tourmaline-bearing, and locally garnet-bearing granite pegmatites are abundant along the east shore of Gebhard Lake. These pegmatites can potentially host beryl (MacDougall, pers. comm., 2001).

Several straight-sided, easterly striking undeformed and weakly metamorphosed gabbroic to diabasic dykes intrude mylonitic granite in the Striding Athabasca Mylonite Zone. The apparent lack of deformation in these dykes suggests they were emplaced after Trans-Hudson Orogen deformation, and their easterly orientation precludes them from being part of the MacKenzie dyke swarm. They could be part of the ca 1.9 Ga Chipman dyke swarm. Reilly (1993b) reported narrow diabase dykes of MacKenzie affinity intruding the Ennadai Group near the NWT border. An unusual abundance of angular diabase boulders in a boulder field south-southwest of Emmerson Lake suggests the nearby presence of a dyke. Faint northwest-trending magnetic linear features (Carson et al., 2001a and b), are probably caused by diabase dykes of the 1.27 Ga Mackenzie dyke swarm (Lecheminant and Heaman, 1989).

Structure

Primary sedimentary and volcanic features that are useful in determining top directions are extremely rare in the Bonokoski Lake area, and although more numerous in the Many Islands Lake area, are of limited use in understanding the complex structural history (see Table 1). With limited geochronological data, it is difficult to constrain the timing of some of the early tectonothermal events. There is a striking similarity between the tonalitic and granitic migmatite complexes of the Bonokoski Lake area with tonalitic and layered felsic gneisses of the southern Mudjatik Domain (Harper, 1988a and b). In the latter region, these rocks are believed to form the basement to arcuate belts of volcanic and sedimentary supracrustal rocks.

They were deformed into basin and dome interference fold patterns resulting from orthogonal fold axes superimposed on earlier formed migmatite nappe lobes (Lewry and Sibbald, 1977, 1980) during the Trans-Hudson Orogeny. Orrell et al. (1999) obtained upper intercept U-Pb zircon ages of ca. 3.0 Ga for these tonalitic gneisses; however, the strongly discordant points on their conchordia plots reveal the complex character and history of zircons from these basement gneisses in the southern Mudjatik Domain. They do, however, indicate the existence of an older basement, and also the possibility of an older Archean thermotectonic event.

Table 1 - Generalized geological history of the Phelps Lake area.

In the Bonokoski Lake area, the earliest structures are believed to be the foliation, S1, and isoclinal folds in the older leucosomal-veined tonalitic and granitic phases of the migmatite complexes. These structures probably formed during a prolonged D1 event. The early isoclinal folds are commonly shallow to sub-horizontal plunging and probably reflect formation of migmatite nappe lobes. They show evidence of at least three superimposed events, the first being represented by a younger foliation, S2, in the migmatite complex, which locally is cross cutting, and axial planar to folds which fold xenoliths of the older gneissic migmatite. Generally S2 is indistinguishable from S1and probably represents a composite foliation except where these older phases are intruded by, or occur as rafts or xenoliths, in the younger foliated leucotonalitic and granitic gneiss of the migmatite complexes. Both of these foliations are refolded by two later (Paleoproterozoic) orthogonal fold axes, trending northwest and northeast, and responsible for producing dome and basin fold interference patterns. These later fold episodes don't normally produce a noticeable fabric, but may be represented in thin sections by a weak preferred alignment of biotite.

The first period of deformation, that affected the Ennadai Group, was responsible for the development of an essentially layer parallel foliation, in the volcanic and sedimentary rocks. Small-scale isoclinal folds, which fold the layering/bedding, are rare in the volcanic rocks, but are common in the more easily deformed psammopelitic and pelitic gneisses to the west. Several large-scale folds, some of which are related to pluton emplacement, are evident from the change in direction of the combined fabric. Although there is no unequivocal evidence, it is believed that the foliation in the Ennadai Group and the younger white foliated leucotonalite in the tonalite migmatite complex are equivalent and therefore considered to be S2, and the deformation D2. In lower grade parts of the Ennadai Greenstone Belt in the NWT and Nunavut, two deformation events, D1 and D2, are recognized as having affected the greenstone belt in the late Archean (e.g., Park and Ralser, 1992). In the Bonokoski Lake area, the D2 deformation event probably began when the Ennadai Greenstone Belt underwent a period of voluminous granitic and tonalitic intrusion ca. 2.68 to 2.6 Ga, possibly coinciding with amalgamation of the Rae and Hearne cratons, which culminated by about 2.5 Ga. According to Hanmer (1997), ca. 2.6 Ga is about the time that the Striding - Athabasca mylonite zone began developing along the Rae - Hearne boundary; therefore, this would correspond with the proposed D2 event. As a consequence D2 structures probably had a northeast trend. The mylonite zone affecting the Brown Lake granite and Ennadai Group volcanic rocks probably formed at this time as well, because it is deformed by later events.

The earliest deformation affecting Hurwitz Group rocks is D3, which produced a strong, layer-parallel, penetrative foliation, S3, accompanied by quartz and granite veining particularly in the lower sequences. Subsequent or continued deformation boudinaged and folded the veins as well as the thin pelitic interlayers within the calc-silicate rocks. There is no positive evidence of an S3 foliation in the granitoid basement rocks; however, the D3 event appears to have produced west-northwest- to northwest-trending open folds, which simply refolded the earlier structures. The northwesterly trend is obvious in the dome and basin structures in the western and southwestern part of the Bonokoski Lake area. This implies that D3 involved northeast-southwest compression. In response to D3 compression, the more rigid part of the Ennadai - Rankin greenstone belt (being at a higher crustal level) was thrust over the younger Hurwitz Group, notably along the southern margin of the greenstone belt. The Hurwitz Group rocks were in turn thrust over the granitic rocks, which lie to the south. In the basal part of the thrust, the Ennadai Group volcanic rocks became more intensely foliated and locally asymmetric folds were developed. The underlying Hurwitz Group sedimentary rocks in this region are also intensely foliated and locally have a north-northeast- to northeast-trending stretching lineation supporting a southwesterly thrust direction. In the area west of

MacKenzie Creek the thrust sequence of Ennadai and Hurwitz groups are also folded about northwest-trending axes. The northwest-trending structures are not particularly evident in the northeast quarter.

Subsequent northwest-southeast compression, D4, related to the terminal collision of the Reindeer Zone between the Hearne and Superior provinces, ca. 1.83 to 1.8 Ga, produced the dominant northeasterly trend of the Trans-Hudson Orogen in northern Saskatchewan. The D4 folds are generally upright to steeply northwest-dipping, open to tight folds that plunge shallowly to the northeast or southwest depending on the orientation of the rocks prior to folding. There does not appear to be an associated penetrative axial planar foliation in the basement rocks, but is evident in fold closures of Hurwitz Group rocks. The S3 and S4 fabrics are apparently coaxial along the fold limbs and produce a composite fabric. This is well demonstrated in the Many Islands Lake area, where S3 and S4 are clearly associated with separate metamorphic events.

In the northeast quarter continued northwest-southeast compression related to the Trans-Hudson Orogen apparently caused basement-cover shearing along the base of the Hurwitz Group. This period of deformation formed crenulation folds and locally a crenulation cleavage. Along the southeast margin of the Many Islands belt, the crenulation folds have northwesterly dipping axial planes and sub-horizontal axes (Figure 6E). The southeasterly verging crenulation folds and large drag fold along the margin, indicate southerly directed fold-related detachment. This contrasts with other areas in the belt where crenulation folds are also developed, and the axial planes dip southeasterly suggesting a northwest sense of movement. The same is true for the Hasbala Lake synclinoria. Along the western margin crenulation folds and large drag folds indicate northwest directed detachment, whereas along the southern margin a single outcrop shows the Hurwitz Group is transported southerly over the basement granites. Reilly (1993a) had only observed structures which he interpreted to indicate northwest thrusting. The opposing directions of movement documented here might have formed from the outward flow of Hurwitz Group rocks as they were progressively squeezed between rigid basement arches. The two Hurwitz synclinoria are separated by a basement arch composed mainly of the presumed late Archean granite – leucogranite unit.

The youngest folding event, D5, is represented by centimetre- to metre-scale, asymmetric crenulation and kink folds, which are most commonly developed in the Ennadai and Hurwitz groups. They are steep, northerly to northeasterly trending, and generally have a shallow northeasterly plunge. Many of these folds are northwest vergent, suggesting that the final stages of deformation involved northwest transport.

In the northeast a D5 east-west compressional event is responsible for open north-trending, shallowly, south-plunging folds best developed north of the north end of Many Islands Lake. Elsewhere this event is indicated by subvertical, delicate north-trending quartz stringers best developed in the marbles and calc-silicate rocks. Also related to this event are narrow, east-trending, partially quartz vein filled, discontinuous, tension gash/shear zones in the pelitic units

Northeast-trending faults that transect the area are post D5 in age. In the southwest they are characterized by steep-sided, boulder-strewn stream and lake-filled valleys. To the northeast they change to less obvious, muskeg-, stream-, or lake-filled depressions. The most prominent fault offset is along the Hein Lake Fault where the Ennadai Group - Hurwitz Group contact is displaced sinistrally about 8 km, with coincident large-scale drag folding. Bending of foliation traces towards the fault traces, e.g. Jones Creek Fault also indicates sinistral displacement on many of these faults. Late north-trending brittle faults of the Tabbernor fault system truncate the northeast-trending set. They are marked by cliffs with steeply dipping, closely spaced joint sets that parallel the fault trace, and as discreet low magnetic linear features on the aeromagnetic maps (Carson et al., 2001a and b). Northwest-trending faults probably provided a locus for emplacement of the ca 1.27 Ga MacKenzie dykes.

Metamorphism

The metamorphic grade varies across the area from lowest amphibolite facies in the Ennadai Group and Hurwitz Group rocks to generally upper amphibolite facies over most of the remaining area, with local occurrences of granulite facies rocks in the west and southwest. Two generations of partial melting have affected the tonalitic migmatite gneisses. In addition, the presence of hypersthene in some of the tonalite and amphibolite rocks of the migmatite complex indicates that granulite facies metamorphic conditions were attained. Gilboy (1978, 1979) also reports the presence of charnockitic felsic gneisses immediately west of the map area. These may have an Archean parentage, culminating with the ca. 2.55 to 2.5 Ga terminal Archean thermotectonic event (Relf and Hanmer, 2000; Berman et al., 2000). At higher crustal levels, the Archean Ennadai Group only attained lower amphibolite facies metamorphic conditions as indicated by the common presence of blue-green hornblende in the volcanic rocks (Coulson et al., 2001); however, these assemblages are most likely overprinted by a Trans-Hudson metamorphism. The flanking clastic sedimentary rocks of the Ennadai Group underwent partial melting which produced a granitoid leucosome.

In the north-central part of the area, the Paleoproterozoic Hurwitz Group rocks attained lower amphibolite facies metamorphic conditions. The metamorphic grade in these rocks increases gradually to upper amphibolite facies to the southwest, where garnet, cordierite, and sillimanite occur in pelitic rocks, plus cordierite is developed in patchy partial melt lenses and pods, and forsterite may be present in some marble layers. The timing of the earliest metamorphism predates intrusion of a foliated granite which has yielded a U-Pb zircon crystallization age ca. 1.86 Ga. Peak metamorphic conditions affecting the Hurwitz, are indicated by monazites with ages of 1.82 to 1.812 Ga in the same foliated granite at Jones Lake and by a massive leucotonalite which gave a U-Pb zircon age of 1.814 Ga (Harper et al., 2004) Younger massive granites, which also intrude the Hurwitz Group are believed to belong to the ca. 1.76 to 1.75 Ga post-tectonic Nueltin granite suite.

The effect of the 2.0 to 1.9 Ga Taltson - Thelon Orogen on the Bonokoski Lake area of the Hearne province is unknown. Recent U, Th, and Pb X-ray mapping and isotopic analyses of monazites, from the adjacent Tantato Domain (East Athabasca mylonite triangle), have obtained metamorphic ages ranging from 2.0 to 1.88 Ga (Williams et al., 1999), which suggests that a thermotectonic event of that age is a possibility. This is also supported by thermobarometric and geochronologic studies reported by Berman et al. (2000) from various parts of the Hearne province in the NWT and Nunavut. In the Bonokoski Lake area a lower intercept of ca. 1.90 Ga on the ca. 2.72 Ga Gilchrist Lake granite may be an indication of its existence in the Hearne. U-Pb sphene age of 1771 +- 14 Ma (Heaman in Reilly, 1993b) was obtained from the 2.708 Ga quartz porphyritic tonalite that intrudes the Ennadai Group volcanic rocks, indicating that Hudsonian metamorphism does overprint the Archean. In addition U-Pb titanite and sphene ages of 1.76 and 1.75 Ga (Harper et al., 2003, 2004) respectively were obtained from an Ennadai Group felsic volcanic rock, which corresponds to the post-tectonic period of Nueltin granite emplacement.

Economic Geology and Mineral Potential

There were few known mineral occurrences in the Phelps Lake area, the most notable being the silicate facies iron formation-hosted Nirdac Creek gold occurrence about 5 km west of Hatle Lake (Reilly, 1993b). The main mineral occurrence types comprise various iron formation facies, gold associated with iron formation and pyritic quartz veins in mafic volcanic rocks, volcanogenic sulphides, small radioactive pegmatites and elevated rare earth elements in fluoritic granites. A summary description of the known occurrences is given by MacDougall (2001, 2002) and new discoveries resulting from the mapping were described by Harper et al. (2001, 2002b, 2003). Apparently none have ever been examined before.

Mineral occurrences noted include: i) narrow zones of banded silicate-sulphide facies (quartz-garnet-amphibole-biotite-iron sulphides) and oxide facies (quartz-magnetite) iron formations in both Ennadai and Hurwitz groups; ii) disseminations of pyrite, pyrrhotite, and chalcopyrite and rarely molybdenite in Ennadai Group mafic metavolcanic rocks; iii) structurally controlled pyritic quartz veins in Ennadai Group metavolcanic rocks and silicified Hurwitz Group calc-silicate rocks; iv) disseminated chalcopyrite and malachite coatings on fractures in Hurwitz Group ferruginous pelites; v) asbestiform veins occur in ultramafic intrusions associated with Ennadai Group amphibolites, vi) molybdenite in granite; vii) allanite±molybdenite±pyrite-bearing granitic and tonalitic migmatites; and viii) weakly pyritic quartz-tourmaline veins in the Archean granites (Figures 8 and 9).

Figure 8 – Mineral occurrences and discoveries.

Figure 9 – New mineral occurrences in NE.

Rare earth elements are potential targets associated with late massive fluoritic granites, leucogranites and granite pegmatites and skarn-type mineralization could potentially be developed where these rocks intrude the Hurwitz marbles or calc-silicate rocks (Figure 8). Tourmaline-garnet-bearing muscovitic pegmatites are potential hosts for beryl (Figure 8). Of particular interest are the discovery of a strongly weathered boulder of a possible crater-facies type breccia, perhaps of kimberlitic affinity and a lepidolite-bearing pegmatite boulder. A previously reported rhodochrosite occurrence was found to be dolomite or ferroan dolomite (Senkow, 2003), accompanied by specular and crystalline hematite

Summary

Geological mapping in the northern Phelps Lake area has drastically altered our perception and knowledge of this under mapped and explored part of the province. Tonalitic and granitic migmatite complexes, which occupy large parts of the area probably, include older Archean basement to the Ennadai Greenstone Belt. Potentially base and precious mineral-bearing Archean Ennadai Group and Paleoproterozoic Hurwitz Group rocks are now recognized to be more extensive than previously thought. The geologic history of the area is complex and involved multiple episodes of magmatism, supracrustal deposition, deformation, and metamorphism, possibly spanning two billion years of earth history from 3.3 to 1.27 Ga.

The fact that reconnaissance geological mapping can find so many unrecorded mineral occurrences (i.e. potential exploration targets) in this area indicates the need for more focused research and exploration. As large parts of the area have been burned in the past decade, it is ideal for boulder prospecting, and offers many exceptionally clean bedrock exposures. This is an area that should be given serious consideration in future exploration programs.

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Field Trip Guide:

Day 1 will examine the basement migmatite complex, and higher metamorphic grade equivalents of the Ennadai and Hurwitz groups and some of the younger intrusive rocks. If possible a stop in the southeast margin of the Snowbird Tectonic Zone will be made. Quaternary features for the most part will be best seen from the air and will be specifically pointed out at some of the stops. Day 2 will chiefly examine the Ennadai Group in the main belt and in an outlying belt at Bonokoski Lake. Day 3 will chiefly examine Hurwitz Group rocks in the Many Islands Lake area and an example of the Nueltin Granite Suite.

As we will be traveling by float equipped aircraft, everyone should exercise caution while getting on and off the floats and entering and exiting the aircraft. Everyone should wear suitable boots for rugged bush conditions and come prepared for a variety of weather. Use caution when climbing or descending slippery or moss/lichen covered outcrops.

Day 1

Stop 1. Pikwuche Lake Tonalite Migmatite Complex
NTS 64M-12, UTM coordinates 584534E, 6600547N
This stop will highlight the multiphase tonalitic intrusive character of the complex, its structural complexity and presence of supracrustal remnants. Late undeformed granite pegmatites are also present. Preliminary U-Pb zircon results, from an outcrop at the south end of the lake, has indicated an age of ca. 2.82 Ga for the migmatite. The abundant water washed outcrops of Pikwuche Lake owe their existence to one of the major esker systems (tunnel valley) that transects the northwest quarter of 64M. As we fly into Pikwuche Lake you should note the various eskers traversing the length of the lake, as well as outwash flats developed along the esker system. You may also note that the amount of outcrop quickly disappears away from the lake under a cover of bouldery till.

Stop 2A. Jones Lake Granitic Migmatite
NTS 64M-12, UTM coordinates, 567054E, 6609398N
This stop will examine the character of the granitic migmatite on the west shore of Jones Lake, which corresponds to a prominent magnetic high. There are numerous medium-grained, granoblastic, magnetite-bearing pelitic gneiss rafts/blocks hosted by the well-foliated granitic migmatite. Some early pink granitic pegmatites are folded similar to the migmatite but not as tight as the migmatite. Younger, weakly foliated to massive leucogranite dykes are parallel to the axial planes of the open folded early pegmatites. These foliated granites may be equivalent to the 1.86 Ga granite dated at the north end of Jones Lake.

Stop 2B. Jones Lake Hurwitz Group sequence
NTS 64M-12, UTM coordinates 567389E, 6609110N
Opposite 2A on the east shore of Jones Lake, within a deep magnetic low, is a high-grade sequence of Hurwitz Group metasedimentary rocks. Starting at the lake shore are pelitic gneisses with abundant folded and boudinaged granitoid and quartz veins. Moving inland several different phases of white tonalite, from fine grained to pegmatitic, intrude the sedimentary gneisses. These are similar to a 1.814 Ga tonalite dated at the north end of Jones Lake and they tend to be axial planar to isoclinal folds in the pelitic gneiss. Next is a calc-silicate unit with a distinctive pale green colour punctuated by black, biotite-rich lenses representing highly disrupted pelitic interlayers. Large boudins of marble are also present in the calc-silicate unit. This passes easterly into a tonalite intrusion breccia with blocks of all the previous rock types and some of the larger pelitic blocks have truncated gabbro dykes in them. It is obvious from this outcrop that this is a late tonalite intrusion as the Hurwitz blocks are metamorphosed and deformed. The presence of the gabbro dykes in this dominantly pelitic sequence suggested possible correlation with the Ameto Formation of the Hurwitz Group as defined in Nunavut.

Stop 3. Wapiyao Lake South Hurwitz Group
NTS 64M-12, UTM coordinates 563164E, 6617384N
This stop will examine an interlayered sequence of garnetiferous pelitic gneiss, quartzite, calc-silicate rocks, and psammopelitic gneiss, which are also thought to be correlated with the Ameto Formation.

Stop 4. Optional Wapiyao Lake North
NTS 64M-13, UTM coordinates 566523E, 6628728N
Hurwitz Group calc-silicate rocks with a heavily iron stained zone of sulphide facies iron formation, all intruded by late pink granite, which is locally pegmatitic. This shows the potential for Hurwitz Group rocks to host base or precious metals.

Stop 5. Wapistan Lake High Grade Ennadai Group
NTS 64M-13, UTM coordinates 562753E, 6635405N
This is a good example of upper amphibolite grade metavolcanic rocks that have undergone local partial melting to produce medium to coarse-grained, dioritic-looking patches, in an otherwise granoblastic host. The outcrop also has a number of iron stained quartz veins and adjacent country rock containing disseminated pyrite and pyrrhotite in a 10 m wide zone. There is also epidote and/or diopside alteration. This combination may have gold potential.

Stop 6. Possible SE Margin of Snowbird Tectonic Zone
NTS 64M-13, UTM coordinates 558420E, 6648236N
If this spot is accessible we will examine a strongly foliated pink augen granite (presumed to be ca. 2.6 Ga) intruded by an easterly striking, 3 m wide, very weakly foliated diabase/gabbro dyke. This dyke could be part of the ca. 1.9 Ga Chipman dyke swarm, which is more prevalent farther southwest in the eastern Tantato Domain (East Athabasca Mylonite Triangle).

Stop 7. Optional Contact Zone Brown Lake Granite
NTS 64M-13, UTM coordinates 567103E, 6646207N
This stop will look at the mylonitic character of the Brown Lake granite, an elongate intrusion along the contact between metasediments and volcanic rocks of the Ennadai Group. This stop will also demonstrate the abrupt transition from dominantly granitic boulders plus felsenmeer, to dominantly psammopelitic boulders, marking the slightly disturbed contact between the two units. It also illustrates the importance of paying attention to the composition of the boulders in the angular boulder fields.

Day 2.

Stop 1. Hamson Lake Archean Granite
NTS 64M-13, UTM coordinates 572484E, 6645853N
In addition to examining the ca. 2.72 Ga Gilchrist Lake granite, this stop also demonstrates the local derivation of large angular boulders that clad steep sided recessional moraine ridges. These are seasonal ridges with the boulders being derived from nearby outcrops and from the adjacent low lying areas. If you come across these features you can be sure there is either outcrop, felsenmeer or large slightly transported boulder fields nearby. They are a good indicator of the underlying geology.

Stop 2. R Lake Ennadai Group
NTS 64M-13, UTM coordinates 580783E, 6648743N
Large outcrop consisting predominantly of mafic and ultramafic volcanic and intrusive rocks with localized alteration patches and minor intermediate to felsic porphyritic intrusions. This is near the Nirdac Creek gold showing (579910E, 6650400N) which is hosted by silicate facies iron formation interlayered with the psammopelitic metasediments. A large mineralized sulphide facies iron formation boulder is located about 150 m northeast of the outcrop (580910E, 6648818N).

Stop 3. Hatle Lake Ennadai Group Mafic Volcanic Sequence
NTS 64M-14, UTM coordinates 585120E, 6646396N to 585193E to 6645896N
Well-preserved, pillowed basalt flows with thick pillow selvages. Light colouration of pillows may indicate alteration has affected the rocks.

Stop 4. McLintock Lake Ennadai Group Mafic-Ultramafic sequence
NTS 64M-14, UTM approx. 589880E, 6650480N

This stop will demonstrate relationship between ultramafic-mafic sill and dyke complex as possible feeder system to the mafic volcanic flows. Structural elements can also be observed.

Stop 5. Hamill Lake Felsic Volcanic Rocks
NTS 64M-14, UTM coordinates 586714E, 6643411N
This outcrop shows dacitic to rhyodacitic flows or sills and some possible fragmental rock types. Some local in situ melting has produced coarser material with hornblende needle porphyroblasts.

Stop 6. Hamill Lake, Ennadai Group Psammopelitic Schist
NTS 64M-14, UTM coordinates 587754E, 6644511N
Small elongate island which has rare exposure of faserkeisel-rich psammopelitic schist. Faserkeisel, which were probably andalusite originally, are now quartz-muscovite aggregates. They stand in relief on weathered surface and display random orientation.

Stop 7. Bonokoski Lake Peninsula, Ennadai Group
NTS 64M-14, UTM coordinates 591297E, 6625515N
This stop will provide a short traverse through a relatively well exposed section of higher grade metavolcanic rocks and intercalated oxide facies iron formation, as well as, examine some pyritic quartz vein systems which are prevalent in these rocks. We will start in a felsic volcanic sequence with interlayered mafic to intermediate volcaniclastic rocks. We will move up onto to the ridge crest (591353E, 6625539N) where a predominantly mafic tuffaceous sequence with minor flows is exposed. Garnet porphyroblasts are a common constituent and display a decompression reaction assemblage including plagioclase, hornblende and magnetite. At the north end of the ridge (591413E, 6625608N) is a good example of 'crack-and-seal' type quartz veining cutting the amphibolites. Pyrite is a notable accompanying mineral suggesting gold potential in these rocks; however, grab samples were rather disappointing. We will then go SE to examine a mafic-ultramafic volcanic sequence (591541E, 6625299N) which contains an approximately 10 m section of banded oxide facies iron formation. Grab samples of the iron formation contain up to 50% Fe2O3. We will then walk back across the south end of the ridge.

Stop 8. Bonokoski Lake (Time permitting) Mineralized boulder field
NTS 64M-14, UTM coordinates 590425E, 6626536N
Located behind the 2001 base camp is a mineralized boulder fan consisting of heavily iron stained sulphide facies iron formation and massive sulphide boulders containing some disseminated chalcopyrite. Some of the iron formation is also magnetite bearing, and iron silicate minerals occur in some boulders. The host rocks to this mineralization are Ennadai Group amphibolite gneiss (mafic volcanic rocks). The source for these boulders could be nearby, or up to 6 km to the northeast at Gebhard Lake where a spectacular iron stained outcrop of the same rock types was discovered while flying over that area.

Day 3.

Stop 1. Archibald Lake Hurwitz Group felsic volcanic in lower sequence
NTS 64M-16, UTM coordinates 663034E, 6628866N
This series of outcrops and felsenmeer illustrate a potential felsic volcanic/sill unit within the upper part of the lower sedimentary sequence of the Many Islands Lake Belt. The rock is plagioclase phyric and relatively massive. Nearby outcrop on the slope to the north consists of a thin calcareous quartzite over a calcareous pelitic breccia. The rocks are crenulated and form part of large southerly plunging F5 synform. The felsic volcanic rock is important geochronology candidate to determine whether these Hurwitz group rocks are younger than our correlation to the Ameto Formation. They might be <2.1 Ga, and therefore, would be time equivalent to the lower Wollaston Supergroup.

Stop 2. Many Islands Lake Hurwitz Group: Lower sequence pelite and ferruginous pelite
NTS 64M-09, UTM coordinates 660314E, 6624989N to 660213E, 6625147N
A walk inland will examine two outcrops of the lower pelitic sequence of the Hurwitz Group. The first outcrop reveals some well-preserved primary sedimentary structures, including cross and graded bedding. The rocks are also folded about F4 NE trending, SE dipping axial surfaces and mainly plunge northeastward. Many quartz veinlets are axial planar to these folds.

Moving farther inland, we climb onto a high rocky ridge of ferruginous pelite that has abundant folded and boudinaged quartz veins. The rock contains up to 10% disseminated magnetite. The F4 folds are NE trending and shallow NE plunging.

Stop 3. MIL Hurwitz Group Marble
NTS 64M-09, UTM coordinates 660297E, 6624201N
Small island with very large erratics and some outcrop of phlogopitic marble. Some of the erratics show relationship between bedding and a cross-cutting foliation. Marble is predominantly dolomitic, but typically also contains some calcite. Other minerals like diopside may also be present as porphyroblasts. The marble typically develops very large erratics that have not traveled very far, and thus are a good indicator of the nearby geology.

Stop 4. MIL Hurwitz Group Upper psammopelitic sequence
NTS 64M-09, UTM coordinates 660833E, 6623330N
Small island with relatively well-preserved primary structures (graded bedding, possible scours) in psammopelitic, calcic psammopelitic, and calc-silicate rocks. Note the lack of quartz veining, compared to the lower sequence. Very tight to isoclinal folding evident in parts of outcrop.

Stop 5. MIL Hurwitz Group Folded Upper sequence
NTS 64M-09, UTM coordinates 663951E, 6625914N
On a hilltop overlooking rapids leading into the north end of Many Islands Lake is an interlayered sequence of pelite-psammopelite, calcic pelite and calc-silicate which show the relationship between bedding, S3 (first fabric in Hurwitz Group) and S4 related to D4 NE trending folds. The development of S3 and an early metamorphic event predates the S4 which is clearly cross-cutting in this location and indicating a younger metamorphic event. Elsewhere on the long parallel limbs, the foliation is probably a composite of S3 and S4. This outcrop is on the NW side of a SWerly plunging synform. D4 provides the dominant NE trend of the Wollaston and Mudjatik domains. A few tens of metres to the SW, is the core of the fold with W-shaped folds.

Optional Stop. MIL Former Rhodochrosite Showing
NTS 64M-09, UTM coordinates 653631E, 6614298N to 653688E, 6614454N
Series of large glacial erratics of Hurwitz Group dolomitic marble which contains individual crystals and veins of a pink to red carbonate mineral that was originally thought to be rhodochrosite, but later proven to be hematite stained dolomite and/or ferroan dolomite. It occurs with quartz veins which are locally accompanied by specular hematite and a rather unusual crystalline type of hematite that has an uncharacteristic black streak. A yellowish-green mineral aggregate is commonly associated with the pink carbonate and quartz veins and was found to be talc-altered diopside. Rosettes of diopside are notable in places and have been overgrown by a younger period of phlogopite, which defines a later foliation (probably S4). Isoclinally folded and boudinaged quartz veining is prevalent and indicates the high degree of strain that these rocks have been through. A source outcrop was found about another 100 m northeast of the second large erratic.

Stop 6. Aniska Lake SE Margin of Many Islands Lake Belt
NTS 64M-09, UTM coordinates 668434E, 6618524N
The southeast margin of the Many Islands Lake Belt is marked by an overturned thrust (décollement zone) of the Hurwitz Group rocks onto the migmatitic gneiss and Archean granites. This large outcrop of pelite and ferruginous pelite is typical of the lower sequence in having abundant isoclinally folded and boudinaged quartz veins. Many of these also show small scale interference folds indicating doubly plunging fold axes. Later crenulation folds indicate a southeast directed transport of the sediments over the basement. There are other quartz veins and small scale dextral shear zones which strike easterly and cross-cut the S3/S4 foliation at a high angle. These formed in response to east-west compression, D5, also responsible for forming north-trending open folds.

Stop 7. Spratt Lake Fluorite-bearing porphyritic granite
NTS 64M-09, UTM coordinates 667431E, 6606059N

Nueltin type granite that is massive, porphyritic, and well jointed. This location provided a U-Pb zircon crystallization age of 1751 Ma. These rocks also have notably elevated rare earth elements and their fluoritic character could have provided hyrothermal fluids capable of mineralizing the Hurwitz sediments. Fine-grained interstitial fluorite may be present locally.