Granitoid plutons in the Iskwasum Lake area, Manitoba; Part of the Flin Flon domain, Trans-Hudson orogen

by

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Abstract

Granites of the Iskwasum Lake area, Manitoba occupy greater than 60% of the exposed precambrian bedrock, and include seven different intrusive bodies. They are important indicators of the processes occurring during 1.88-1.83 Ga, a period in the formation of the Flin Flon domain of the Trans-Hudson orogen when volcanism was rare. Plagioclase, quartz, and biotite porphyritic lithologies are common. Hornblende is found in almost all instances, and alteration is ubiquitous, including varying amounts of muscovite, epidote and chlorite. Biotite is found in all but the most mafic rocks, and evidence for multiple mafic and felsic comagmatic lithologies is common. Pegmatite and aplite dikes are rare.

Shear zones dominate the fabric in the Iskwasum Lake area, although only one such structure is located entirely within granitoid rocks. Some of these shear zones may represent the traces of major sutures, formed during the amalgamation of tectonic assemblages prior to pluton emplacement. Subsequent reactivation of these structures is common after pluton emplacement. Despite a strong NNE-trending fabric throughout the study area, contact-sub parallel mineral foliations within many of the plutons can be attributed to pluton emplacement processes. The presence of zones of intrusion breccia with abundant proximal wall rock xenoliths at the margins of many plutons indicates these plutons were emplaced in their present location.

Geochemical and physical properties of granitoid plutons in the Iskwasum Lake area are consistent with their derivation in a continental arc environment. All plot within the volcanic arc field of Pearce *et. al.* (1984), exhibit strong negative Nb and Ti anomalies, and are geochemically similar to recent well-studied continental arc batholiths such as the Peninsular Ranges batholith. A preponderance of igneous microgranite enclaves, hornblende as a common mafic mineral, relict compositional zonation, and a broad range of compositions from gabbro to granodiorite with a predominance of intermediate composition rocks is further evidence of an arc setting for magmatism. Chondrite normalized rare earth element variations in granitoid rocks from the Iskwasum Lake area indicate that there was a change in the magma source over time, probably reflecting a change to partial melting at shallower depths.

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1.0 Introduction and Regional Geology

1.1 Topography and Location

The Iskwasum Lake sheet (NTS 63K/10) covers 835 km^2 in west central Manitoba, lying approximately 38 km east-southeast of Flin Flon and 23 km west-southwest of Snow Lake (figure 1). The entire map sheet is confined to the Grass River Provincial Park, and southern portions are easily accessible via provincial highway 39. Although the highway overlies Phanerozoic rocks, it provides easy access to Reed and Iskwasum Lakes (three provincial campgrounds are located on these two lakes). These lakes, as well as the Grass River provide good access to the southern portion of the Precambrian shield. The northern half of the map sheet is best accessed via the abandoned C.N.R. rail line which previously served the Chisel Lake mine, allowing for transport of ore to the Hudson Bay Mining and Smelting Corporation smelter in Flin Flon. The central portion of the map sheet was accessed with float-equiped aircraft. This allowed access to areas on and around Barb Lake, as well as two other unnamed lakes north and northeast of Loukes Lake. Minor logging and winter roads, trails and portages were utilized to a limited degree. They are typically overgrown and are located principally in the southern 1/3 of the map sheet (see figure 2).

The area covered by the Iskwasum Lake map sheet is underlain by granitoid plutons, synvolcanic mafic intrusions, metavolcanic rocks, and minor metasedimentary rocks, but the greatest proportion of the outcrops are granitoid in composition. Granitoid rocks comprise approximately 270 km^2 of the 460 km^2 of Precambrian rocks in the map sheet. The remaining 375 km^2 is covered by flat-lying Ordovician dolomite of the Red River Formation in the southern 1/3 of the map sheet. In general, outcrop exposure in the area is less than ideal, typically being covered by a thick blanket of moss. In addition, large lakes tend to have outcropping of mafic supracrustal rocks and synvolcanic mafic intrusions, as well as their sheared equivalents rather than granitoid rocks, and the best exposures of the granitoid rocks are typically found away from shorelines. Smaller lakes (*i.e.* Barb and Loukes Lakes) do overlay significant proportions of felsic intrusive rocks, most of which are well exposed on the lakeshore. A forest fire burnt through the northern 1/3 of the map sheet in 1989 and significantly increased exposure in this

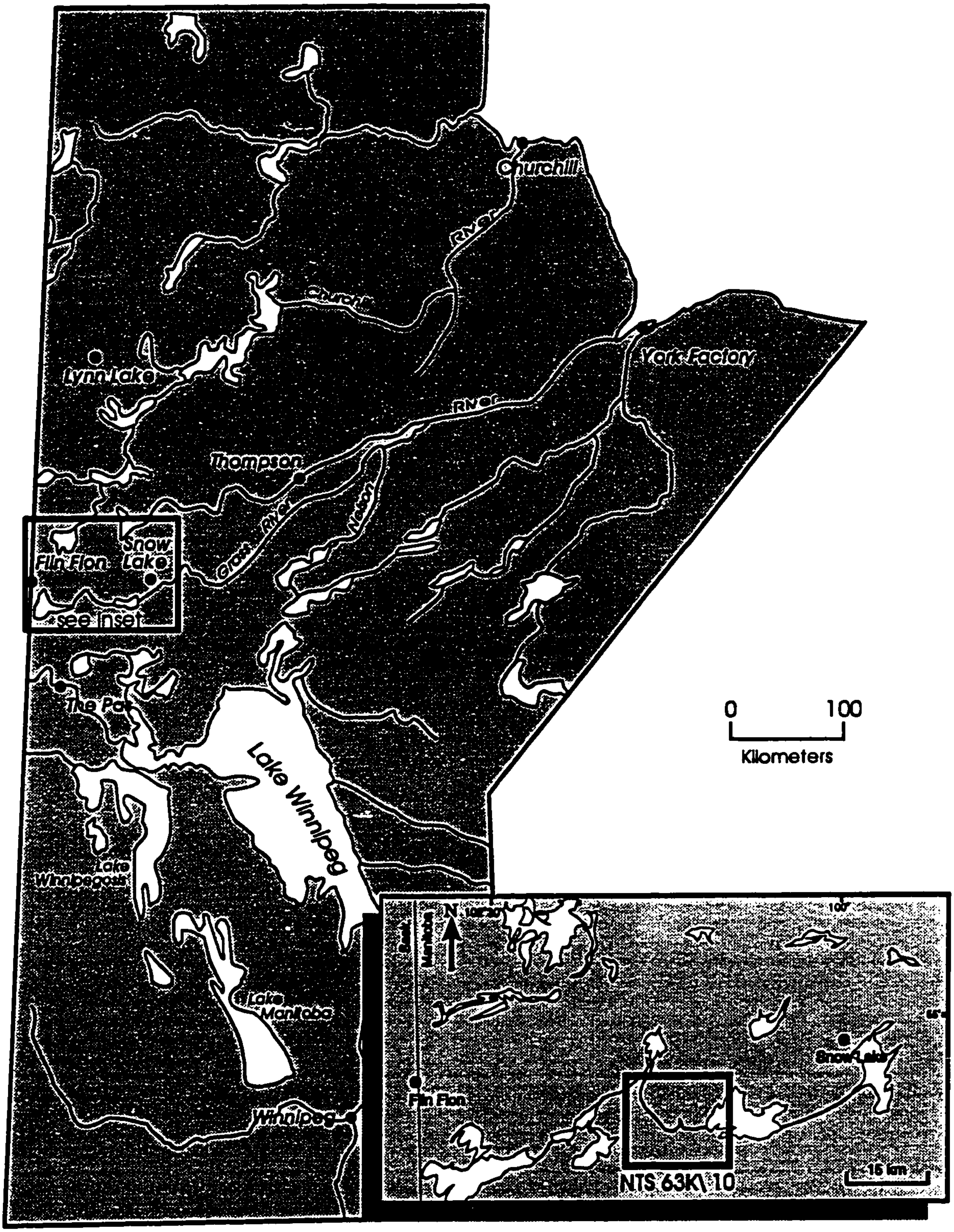


Figure 1. *Location map of Manitoba, showing major cities, lakes, rivers, and the Iskwasum Lake sheet (NTS 63K/10).*

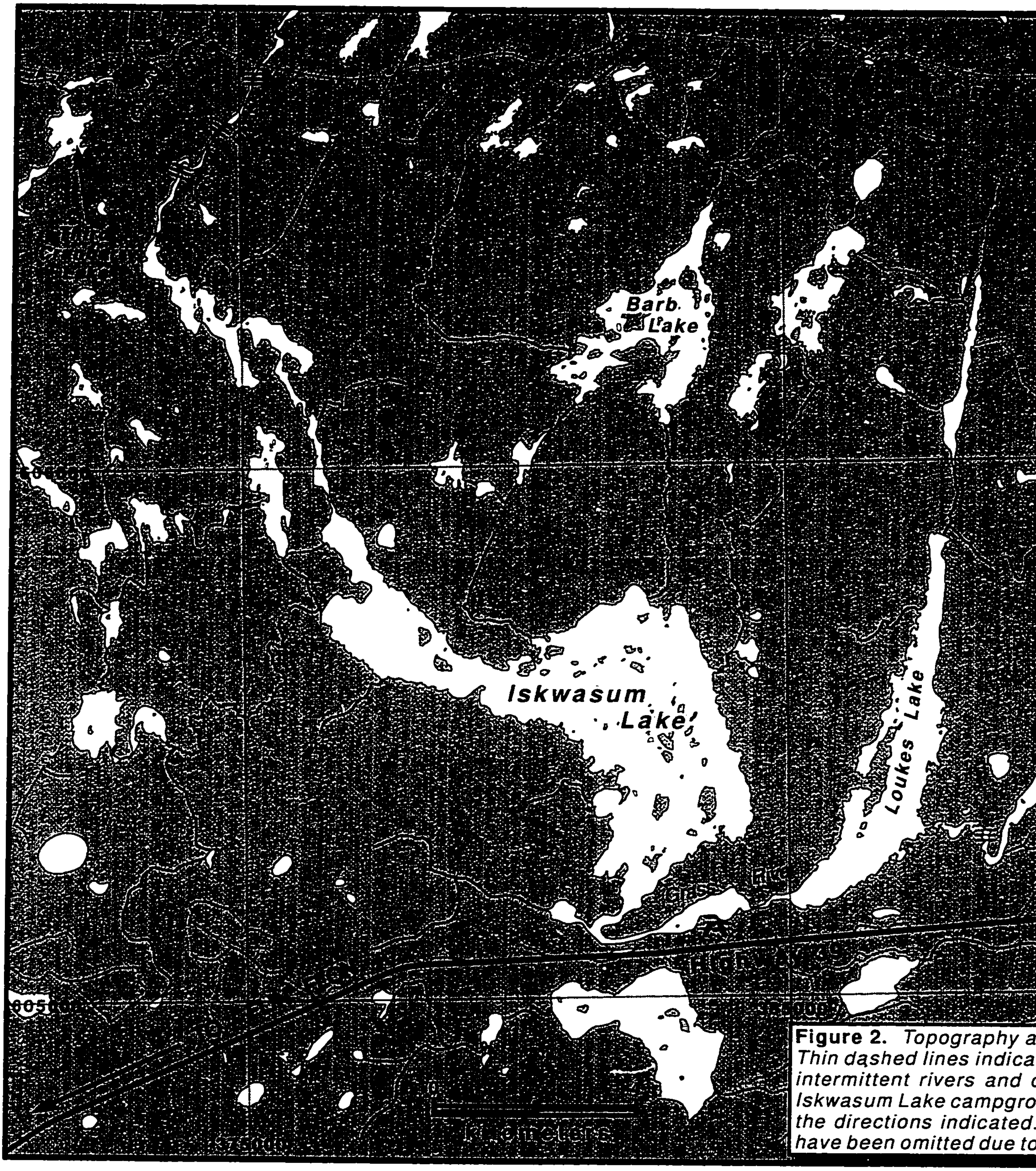


Figure 2. *Topography a*
Thin dashed lines indica
intermittent rivers and c
Iskwasum Lake campgro
the directions indicated.
have been omitted due to

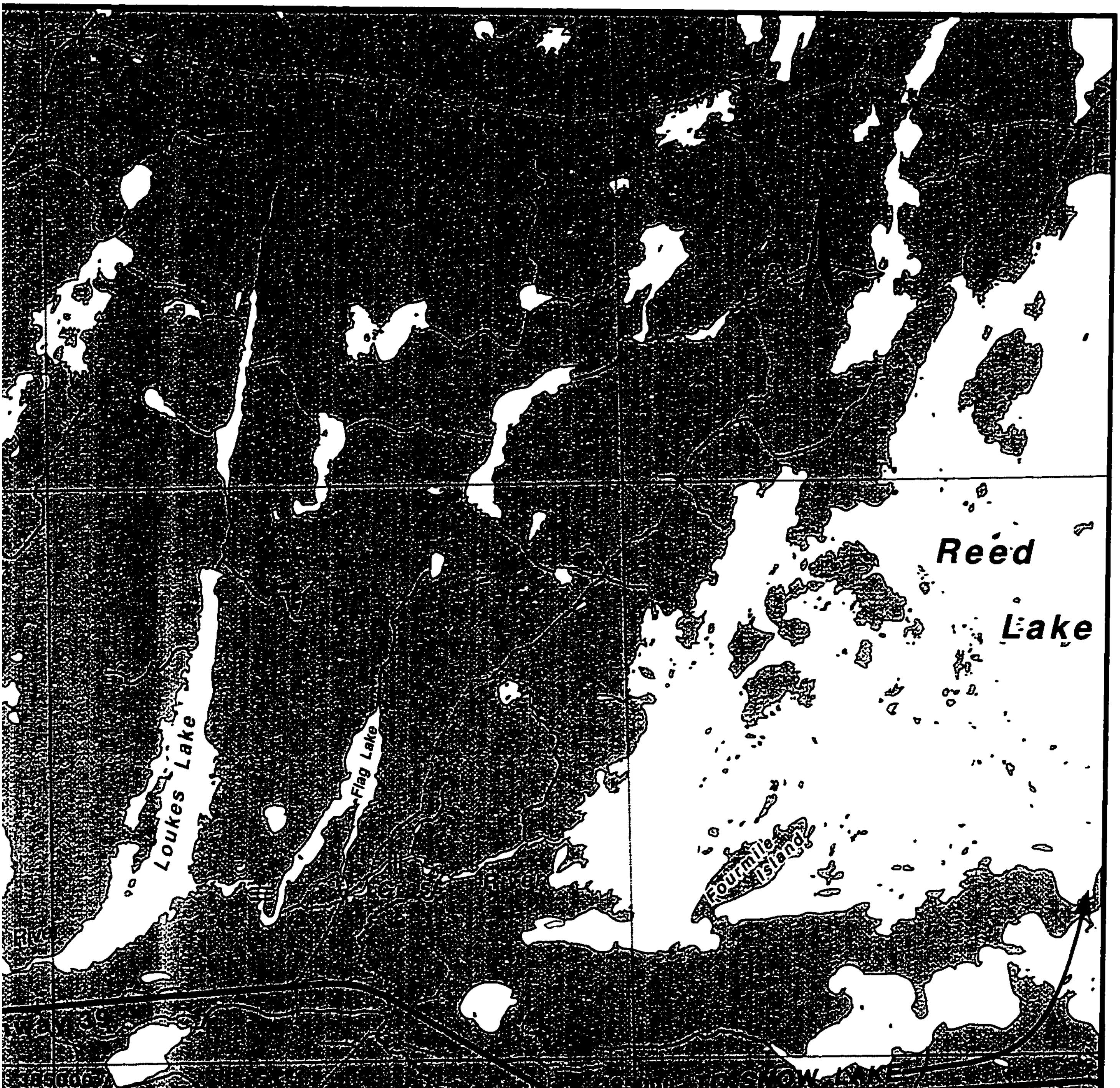
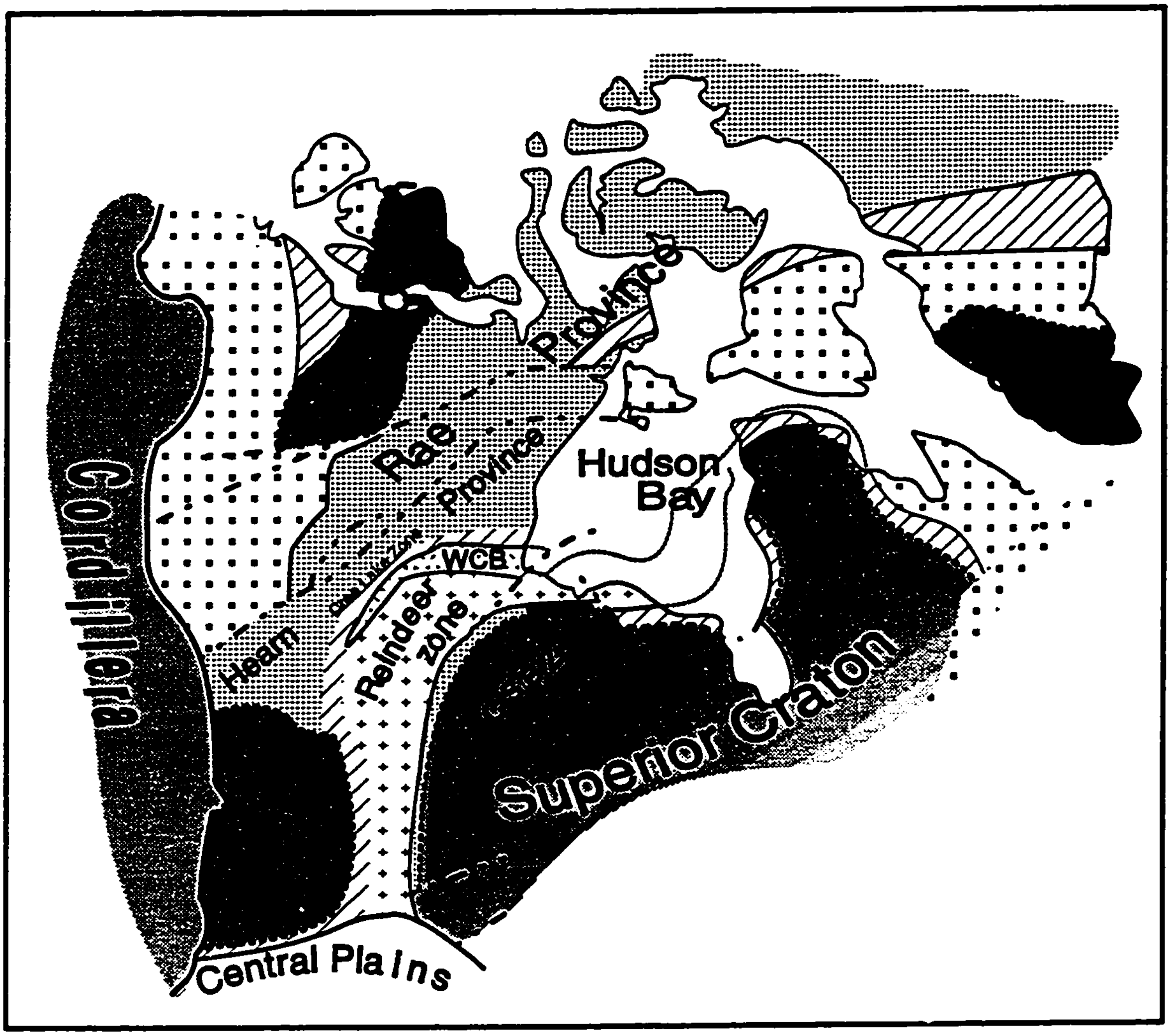


Figure 2. *Topography and access in the northern 2/3 of the Iskwasum Lake sheet (NTS 63K/10). Thin dashed lines indicate winter roads, logging roads, portages and trails. Thicker solid lines are intermittent rivers and creeks. Three dashes indicate rapids, and a picnic tabel indicates the Iskwasum Lake campground. Snow Lake and Flin Flon are approximately 100 kilometers by road in the directions indicated. North direction and UTM coordinates are approximate. Contour lines have been omitted due to the relatively low relief in the area.*



LEGEND

- little reworked Archean cratons
- Phanerozoic orogenic belts
- mafic-ultramafic allochtohons thrust over the Superior craton
- accreted Early Proterozoic arc terranes + major continental magmatic arc batholiths + Early Proterozoic foreland fold/thrust belts
- reworked Archean continental crust
- Early Proterozoic foreland fold/ thrust belt
- -------- margin of Archean cratons
- . . — . major shear zones

Figure 3. *Simplified tectonic element map of the exposed and subphanerozoic Precambrian in North America, including the Trans Hudson orogen, other Early Proterozoic orogenic belts and Archean cratons. Note the location of the Cree Lake zone, Churchill-Superior Boundary Zone and Wathaman-Chipeywan batholith with respect to other tectonic domaines. Abbreviations: CSBZ, Churchill-Superior boundary zone; CS, Cape Smith belt; WCB, Wathaman-Chipewyan batholith (Modified after Lewry et al., 1990).*

area. This is especially true where the fire affected areas that had been previously burnt. In these areas outcrop exposure is almost complete.

Relief in the Iskwasum Lake sheet is minimal. The area is generally flat-lying, with the granitoid plutons underlying the highest relief in the northern 2/3 of the map sheet The relief over the plutons is generally composed of gentle moss- and tree-covered hills rising less than 5 meters above surrounding swamps. The greatest relief in the area is at the Precambrian-Phanerozic unconformity, where Ordovician rocks constitute cliffs up to 10 meters in height.

1.2 Previous work

Little work has been done on the rocks of the Iskwasum Lake area, but the earliest work dates back to 1935 when Stockwell studied gold deposits in the Elbow-Morton area (Stockwell, 1935). His work focussed in the Elbow Lake area, but extended south into the northeastern portion of the Iskwasum Lake area.

Hunt (1970) mapped the west half of the study area, and subdivided the granitoid rocks into four units: a) Iskwasum Lake boss; 2) adamellite and associated rocks; 3)quartz-eye granite and associated rocks; 4) Loukes Lake granodiorite and associated rocks. These broadly correlate with intrusive bodies in the west half, and although Hunt recognized different lithologies within these units he did not attempt to separate them. In the eastern half of the map sheet, Roussell (1970) subdivided felsic intrusive rocks into granitoid rocks and sheared tonalite. Within Roussel's framework, sheared tonalite occurs on Fourmile Island and within granitoid rocks corresponding to the Gants Lake batholith. This work did not attempt to subdivide rocks within the map sheet to a great extent.

Regional metamorphism in the area varies from mid-greenschist (Roussell, 1970) to lower amphibolite grade (Hunt, 1970) and is comparable to studies of other areas in the Flin Flon belt (see Ansdell and Kyser, 1991). Structural and tectonic relationships in the Iskwasum Lake sheet are complex. During the course of their field studies Morrison and Whalen (1994), Syme (1994), and Syme et al. (1995) delineated numerous shear zones and faults in the area, some of which continue into the adjacent Elbow Lake sheet (63K\15). Syme (1994) delineated eight generations of deformation in the western half of the map sheet, including bedding and bedding-parallel foliations in McDougall's Point basalt, as well as numerous generations of shearing, faulting and related structures. The Elbow Lake, Loukes Lake and Flag Lake shear zones, and the Berry Creek fault are the dominant structural features in the map area, and the structural fabric in all rocks is strongly influenced by them. The dominant structural trend is NNW, but this is often disrupted by brittle and ductile structures.

All plutons in the Iskwasum Lake sheet can be characterized as calc-alkaline, peraluminous to metaluminous volcanic arc granites, encompassing a wide range of compositions from quartz diorite to tonalite and granodiorite (lithologic terminology from the IUGS classification of Streckeisen, 1976). They have geochemical signatures which are consistent with other arc-related magmatism (see section 4).

More recent work in the context of LITHOPROBE and NATMAP projects and the Canada-Manitoba Mineral Develpoment agreement has provided significant advances in our understanding of the area. Geologic mapping north of the study area (see Whalen 1993a, b) has aided in recognition and extrapolation of granitoid units into the map area. Reconaissance mapping of the supracrustal rocks and structures in the western half of the map sheet by Syme (1994) resulted in a better understanding of the relationships between the rocks of the Iskwasum Lake sheet and the central part of the Trans-Hudson orogen. Recent work on granitoid rocks in the area by Morrison and Whalen (1994) has resulted in a much more detailed description of granitoid rocks in the entire map sheet, and a preliminary map of the western half of the area by Syme and Morrison (1994) resulted from fieldwork in the summer of 1994. Syme *et al.* (1995a) mapped the supracrustal rocks and structures in the east half of the map sheet and also produced a preliminary map of these rocks (Syme *et al.*, 1995b). A geologic map of the entire Iskwasum Lake sheet has been completed, and involves detailed granitoid geology from the work of the author, and simplified supracrustal geology after Syme and Morrison (1994) and Syme *et al.* (1995) (Morrison *et al.*, 1996).

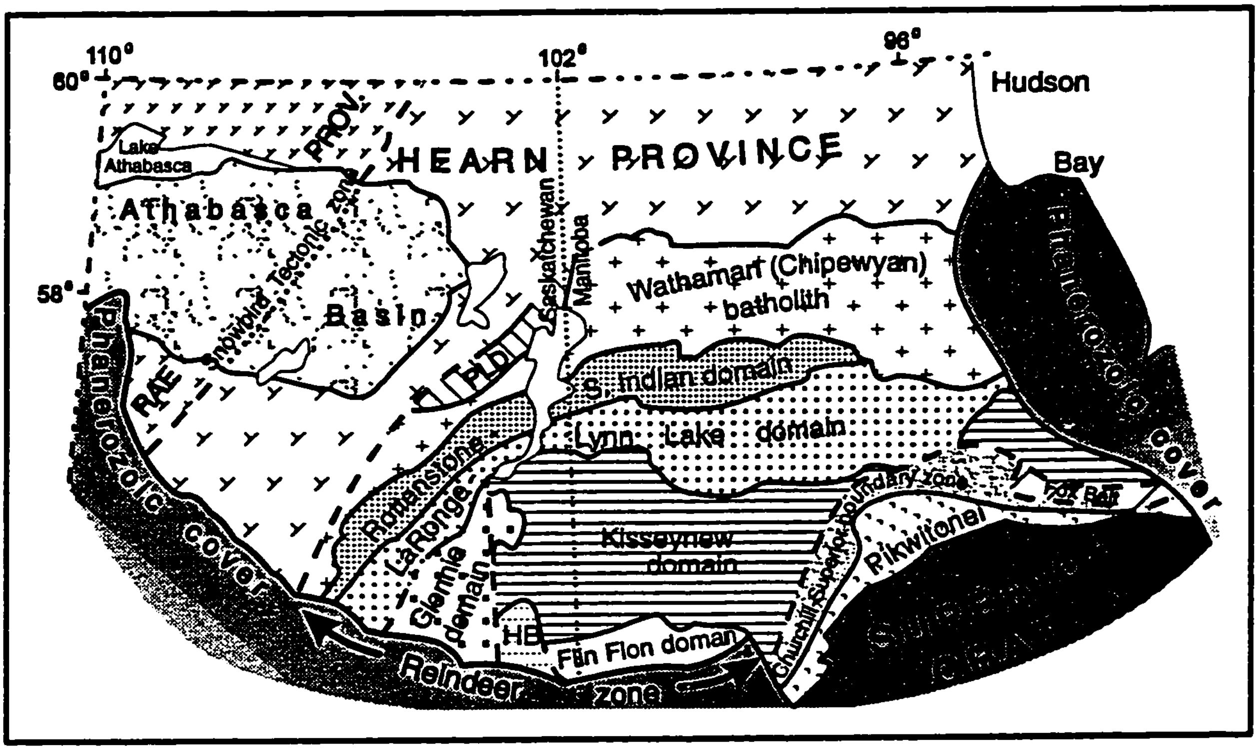


Figure 4. *Exposed tectonic domaines of the Trans Hudson orogen. Heavy dashed lines indicate major ductile shear zones and brittle-ductile faults, and heavy dotted lines indicate a subsurface expression of the Snowbird tectonic zone. PLD=Peter Lake domain; HB=Hanson Lake block. (Modified After Lewry and Collerson, 1990).*

1.3 The Trans-Hudson orogen

The Trans-Hudson orogen is an Early Proterozoic greenstone belt extending from a subphanerozoic extension in South Dakota, through Hudson Bay, and into Greenland and Labrador (figure 3). It includes the reworked margins of three Archean cratons, including the North Atlantic, Superior and Slave, and the suspect juvenile terranes of the Reindeer zone (Lewry *et al.*, 1990).

Hoffman (1981) proposed the name Trans-Hudson orogen in an attempt to delineate the Early Proterozoic collision between the Superior province and the Churchill's Archean provinces (Hoffman, 1990). The Hearn and Rae provinces, respectively to the north and northwest of the Trans-Hudson orogen (figure 3), are interpreted as being underlain by Archean crust (Hoffman, 1990), while the southeastern Churchill-Superior boundary zone is interpreted as the reworked margin of the Superior province.

The subphanerozoic extension of the Trans-Hudson orogen is truncated by the Central Plains orogen (Sims and Peterman, 1986), while the northern margin is delineated by the contact between the Wathaman-Chipeywan batholith and the Hearn province. This batholith separates the orogen from the Hearn and Rae provinces, and is interpreted by Thom (1990) and others as magmatic arc-related plutons, developed on Archean crust. Hoffman (1990) points out that this suggests the batholith represents arc-related magmatism developed during the collision between the foreland Superior craton and the hinterland Churchill provinces.

Terminal collision between the Hearn-Reindeer zone and the Superior craton occurred at 1.83-1.80 Ga (Bickford *et al.*, 1990, 1992; Gordon *et al.*, 1990; Lewry *et al.*, 1990; Machado, 1990) and is broadly coeval with south to southwest thrusting of the Hearn and Rae provinces over the Archean terrain, as well as regional metamorphism. LITHOPROBE seismic reflection profiles suggest that thrusted juvenile rocks of the Trans-Hudson orogen dip under both the Superior and Hearn cratons. With respect to the Superior craton, this probably represents late to post-collisional tectonics rather than oceanic subduction (Lucas *et al.*, 1995).

1.4 Flin Flon domain

1.4.1 General geology

The Flin Flon domain of the Trans-Hudson orogen is bounded to the north by the Kisseynew gneiss belt, and to the south by Ordovician dolomites of the Red River Formation (figure 4). Although the extent of its subphanerozoic extension is unknown, it appears to be significant (Green *et al.*, 1985, Leclair and Weber, 1993). In general the belt can be subdivided into variably deformed subaqueous to subaerial volcanic and sedimentary rocks (Amisk Group), unconformably overlying fluvial and alluvial metasedimentary rocks (Missi Group) and related granitoid intrusions (figure 5).

The Flin Flon domain is structurally and stratigraphically complex, the degree of complexity depending on the location within the belt. In the Flin Flon

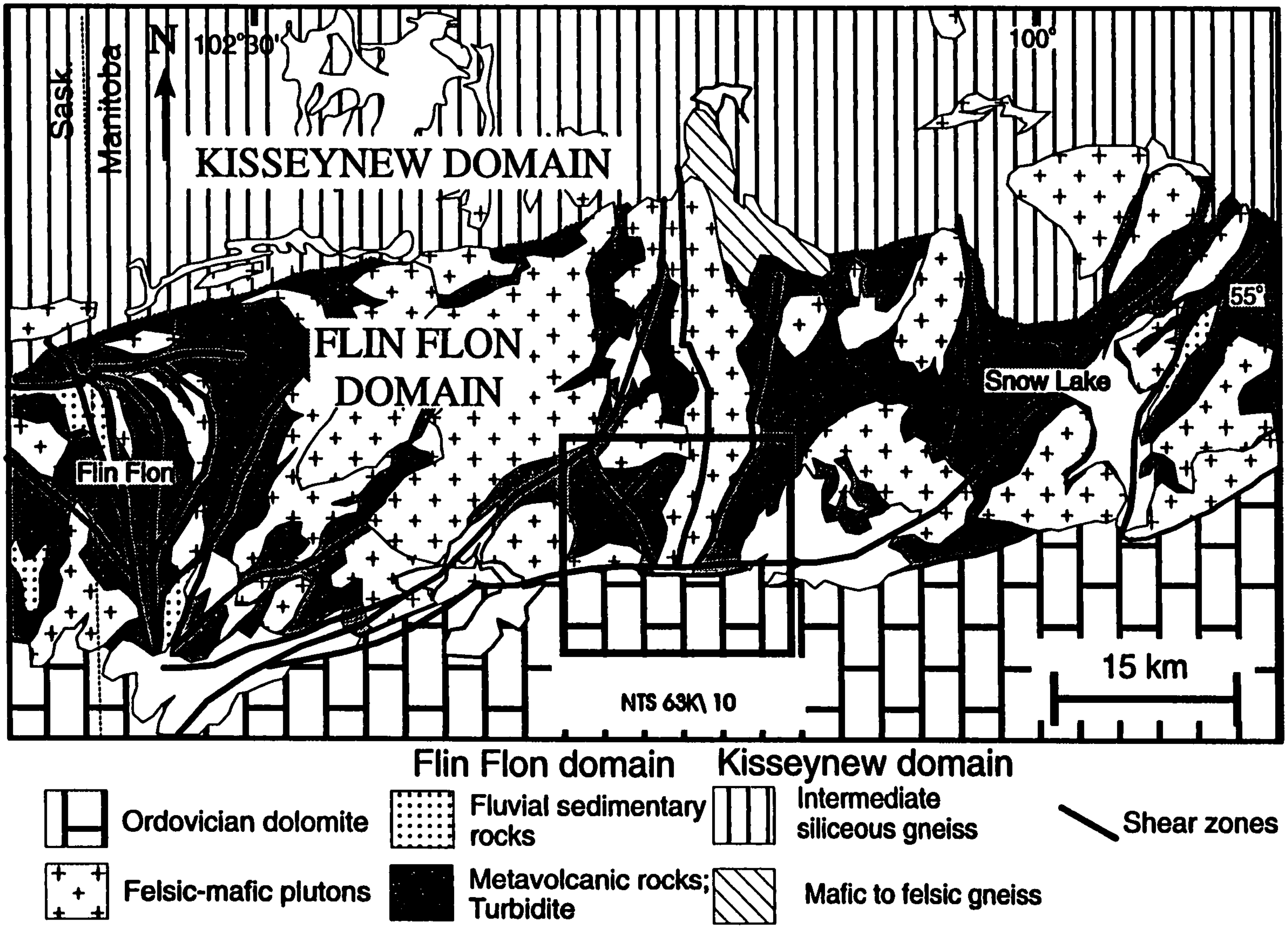


Figure 5. *Location of the Iskwasum Lake sheet (NTS 63K\10) in the central portion of the Flin Flon greenstone belt of the Trans Hudson orogen.*

area, stratigraphic sequences are bounded and cross cut by faults, and correlation of stratigraphic packages across these faults is impossible (Syme, 1990). In contrast, the Snow Lake area does not contain significant fault-bounded packages, and stratigraphic packages can be correlated over large distances (Bailes, 1980). In addition, the Snow Lake area is dominated by felsic volcanic packages and is overlain by a thick greywacke turbidite (Gordon *et al.*, 1990), whereas these rocks are less abundant in the Flin Flon area.

The Flin Flon greenstone belt is comprised of rocks from isotopically juvenile island arc and back-arc basins, as well as older crustal fragments (Bailes and Syme, 1989; Stern *et al.*, 1992, 1993a, 1993b; Syme, 1990; Syme and Bailes, 1993; Thomas, 1990, 1991; Watters *et al.*, 1993). The recent interpretation of Lucas et al. (1995a) presents evidence for intra-oceanic accretion, thus bridging the gap between oceanic and continental magmatism and deformation.

Recent investigations into the subphanerozoic geology south of the Flin Flon belt by Leclair and Weber (1993) and Leclair et al. (1994) have significantly extended the belt to the south. Combining total field and vertical gradient aeromagnetic data with gravity surveys and detailed drill hole analysis allows for determination of lithologically distinct regions in the subphanerozoic. Exposed Precambrian rocks in the Flin Flon belt generally trend north-northwest and Leclair et al. (1994) note a strong continuation of this trend in the subphanerozoic geology, further suggesting the extension of the Flin Flon belt under Phanerozoic cover.

The intrusive rocks in the Flin Flon domain are variable in composition, texture and age. The earliest plutonism in the belt is characterized by porphyritic textures, xenolith-rich margins and abundant dikes (Gordon *et al.*, 1990; Whalen and Hunt, 1994). Whalen and Hunt (1994) have dated two felsic intrusive bodies in the Elbow Lake sheet, the Gants Lake batholith and the Little Swan Lake pluton at 1876 $^{+7}/_{-6}$ Ma and 1826±5 Ma respectively. These are among the oldest and youngest plutons in the Flin Flon domain, and appear to represent two of three intrusive events in the area. The Gants Lake batholith is apparently an early intrusion, while the Little Swan Lake pluton may be a post-Missi plutonic suite. The third group of plutonism is syn-volcanic (emplaced during volcanism), often represented as mafic intrusions.

The central part of the Flin Flon domain of the Paleoproterozoic Trans-Hudson orogen is interpreted as an amalgam of 1.91-1.88 Ga oceanic and arc lithotectonic assemblages, termed the Flin Flon tectonic collage, stitched together by 1.87-1.84 Ga granitoid plutons, and overlain by 1.85-1.84 Ga sedimentary rocks (Lucas *et al.,* 1995a, b) (figure 5).

1.4.2 Economic geology of the Flin Flon belt

The Flin Flon belt in northern Manitoba and Saskatchewan is one of the most important base-metal mining areas of Canada. Volcanogenic massive sulphide deposits constitute the majority of base metal production. Syme and Bailes (1993) have subdivided these deposits into two types; those hosted by volcanic rocks and those hosted by sedimentary rocks within the volcanic succession.

In the Snow lake area, tholeiitic arc suites host all volcanogenic massive sulphide deposits, and in the Flin Flon area this is the dominant tectonic environment for mineralization (Syme and Bailes, 1993). Back-arc and ocean floor assemblages are apparently the least likely to host volcanogenic massive sulphide deposits, although they host small deposits in Saskatchewan (Syme and Bailes, 1993, Thomas, 1990, Reilly, 1991). In tholeiitic arc sequences, stratigraphic and compositional breaks and the appearance of felsic volcanic rocks appear to be the best areas for mineralization. These breaks are typically associated with footwall volcaniclastic rocks and local basinal structures (Syme and Bailes, 1993).

1.5 Economic geology of the Iskwasum Lake area

The Iskwasum Lake area has abundant mineral occurrences, primarily associated with mafic supracrustal and intrusive sequences. Much of the previous mineral exploration in the area focussed on talc and asbestos showings within serpentinites, as demonstrated by the abundance of exploration trenches and excavation pits in these rocks.

The only gold showing on Reed Lake appears to be in a sheared tonalite on Fourmile Island (figure 6) where it is associated with quartz-ankerite veins. Although Roussell (1970) considered the host rocks to be a sheared tonalite body, Heine (1994) suggests they may be tuffaceous felsic volcanic rocks or of hybrid origin. Based on Heine's (1993, 1994) evaluation of the showing, and his description of chlorite schist fragments within and adjacent to gold-bearing quartz veins, further evaluation of a sheared north-south trending Gants Lake batholith tonalite unit, north of the rapids on the Grass River east of Loukes lake (see figure 6), is warranted. The only significant difference appears to be that Heine (1994) mentions the presence of euhedral pyrite and trace chalcopyrite within the quartz. These mineral phases do not appear in the sheared tonalite north of the rapids, but poor exposure of the rocks may account for this. The only other gold occurrences are related to 7-20 meter wide quartz veins and masses, predominantly located near Iskwasum Lake and in the mafic volcanic sequences (Heine, 1994).

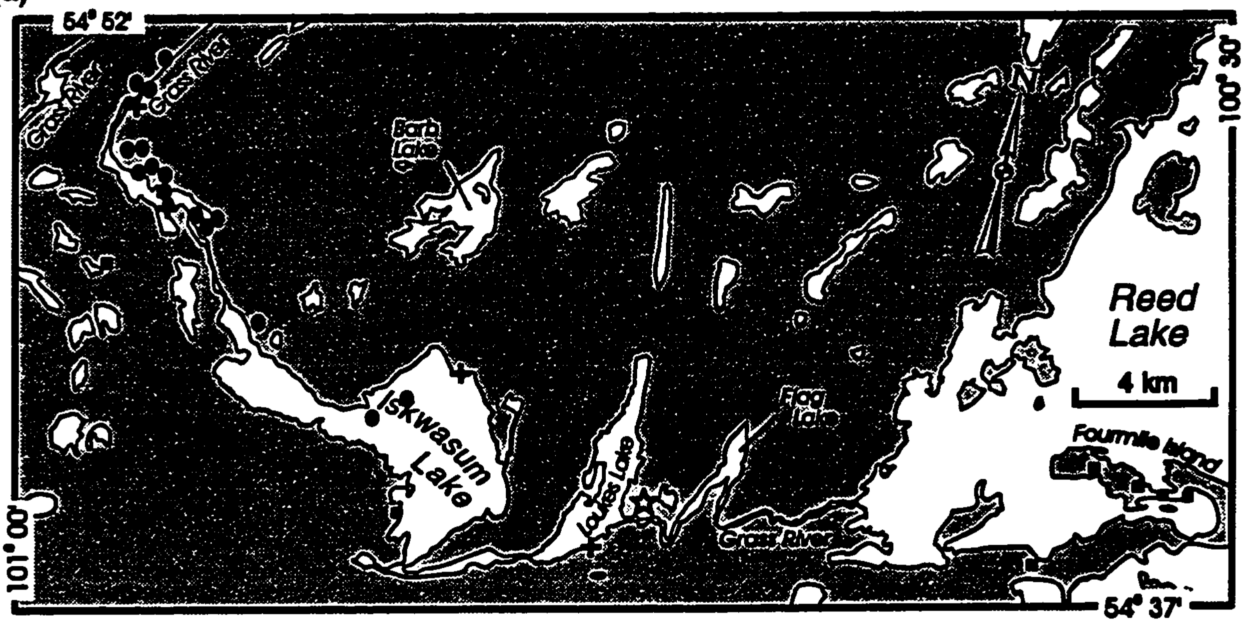
Based on exposed trenches and pits, the primary exploration target in the Iskwasum Lake sheet was asbestos and talc. Hunt (1970) notes 11 occurrences of talc in serpentinites in the west half of the area (figure 6).

Sulphide minerals in the map sheet are concentrated within massive mafic volcanic units and felsic volcaniclastic rocks. There is not a significant amount of this mineralization in the map area (see Heine, 1993, 1994).

The mineral occurrences mentioned above are almost entirely hosted by volcanic sequences, and have already been explored to some degree. Both felsic and mafic intrusive packages are possible targets for further exploration. Other possible targets may include the Reed Lake gabbro (for platinum group elements; see Williamson, 1993, 1994), and some felsic intrusive bodies.

Gold showings in the Iskwasum and Elbow Lake sheets are concentrated in mafic supracrustal rocks (Heine, 1993, 1994; Whalen, 1993a), particularly in high strain zones. However, as mentioned previously, a sheared tonalite on Fourmile island hosts five gold showings, and mapping of intrusive rocks in the Iskwasum Lake sheet has revealed that similar high strain zones (*i.e.* the Loukes

(a)



+ Base metals

▪ Gold

● talc and\or asbestos

☆ possible target area for gold exploration

(b)

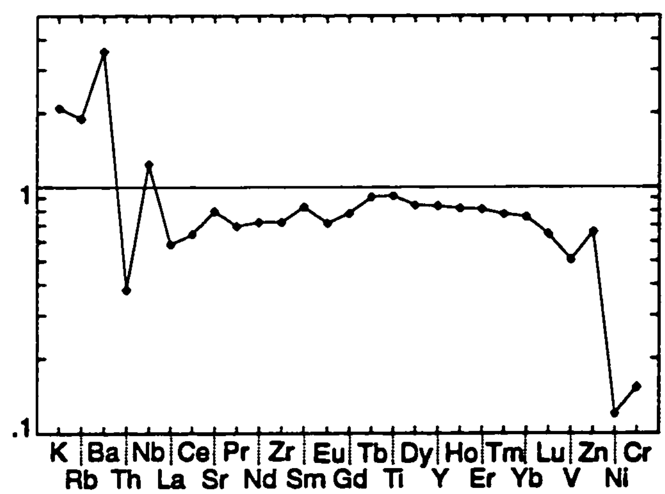


Figure 6. *(a) Areas of mineralization in the Iskwasum Lake sheet. Locations taken from Hunt (1970), and Heine (1993, 1994). Although only one specific location has been identified on the map for future exploration (gold), the Reed Lake gabbro (see Williamson (1993, 1994)) is a possible exploration target for platinum group elements, the Elbow Lake tonalite for late-stage hydrothermal gold deposits and the Loukes Lake shear zone for shear zone-hosted gold. See figure 5 for the location of the Elbow Lake tonalite, Reed Lake gabbro and figure 4 for the Loukes Lake shear zone. For more detail on the mineralization in the area refer to Heine (1993, 1994). (b) Trace element spider diagram of an altered Elbow Lake tonalite "protopegmatite" (sample 6268b), normalized to average Elbow Lake tonalite compositions. This is interpreted as reflecting late potassic "alteration" in the pluton.*

Lake shear zone) also occur within other felsic intrusive rocks. These shear zones host abundant variably deformed quartz veins which could be mineralized. In addition, the mapping of lithologic offsets along faults within plutons reveals areas which may be further examined.

Whalen (1993a), and Morrison and Whalen (1995) state that comparison of the Elbow Lake tonalite with the Phantom Lake stock (Galley and Franklin, 1989; Thomas, 1990) near Flin Flon and the Star Lake pluton (Poulsen *et al.*, 1986) in the LaRonge belt suggests that the Elbow Lake tonalite may be a possible target for late-magmatic hydrothermal gold deposits. Late fracture-related potassic alteration is common in the Elbow Lake tonalite, and quartz- and sulphide-bearing veins are abundant. A trace element spider diagram of an analysis of a late, pegmatitic segregation shows that it is much higher in K, Rb, and Ba (the incompatible elements) than the average Elbow Lake tonalite rocks (figure 6b), while being strongly depleted in Ni and Cr. These zones typically follow along pseudo-fractures, forming pods and lenses. One hypothesis for the formation of these features is pressure release and shattering of a solidifying magma, resulting in a fluid-rich phase being injected into, and "healing" the fracture. In all cases these zones appear to be similar in mineralogy to the host, but are generally coarser-grained, and becoming pegmatitic towards their core. More definite alteration occurs along fractures, and is particularly noticeable to the north, where a 1989 forest fire cleared much of the exposurs. This suggests that lesser exposed areas may also have significant alteration.

2.0 Petrography of Granitoid Plutons

The Iskwasum Lake sheet contains seven major felsic intrusive bodies, emplaced into mafic supracrustal rocks and synvolcanic intrusions. Felsic intrusive rocks comprise 60% of the exposed shield in the map area, and are significant in that they provide a means of determining the history of the area. With this in mind, the plutons are important indicators of processes occurring during the latter stages in the formation of the Flin Flon belt, a major Paleoproterozoic greenstone belt.

All felsic plutons are lithologically variable, ranging from biotite +/- hornblende quartz diorites to hornblende-biotite granodiorites. All plutons are circular to subcircular bodies and have magamatic foliations subparallel to the pluton margin (Figure 6). Lithologic zoning is often obscured by late brittle deformation within the plutons. The exception to this pattern is in the composite Gants Lake batholith, which has structures and fabrics related to NNE-trending structures, including the Loukes Lake shear zone. In the Elbow Lake sheet similar studies of granitoid plutons (Whalen, 1992, 1993a, b) have aided in the understanding of tectonic processes, particularly with respect to the Elbow Lake shear zone. Lithologic variations in many of the plutons are controlled by the structures within them. Brittle faults often juxtapose different lithologic units, often to such an extent that continuity is difficult to ascertain.

2.1 Iskwasum Lake stock

The ovoid Iskwasum Lake stock (ILS) consists mainly of leucocratic, biotite tonalite (Figures 8 and 9). Mafic minerals typically constitute <10%, and occasionally <5% of the rock. Pervasive and fracture-related alteration of plagioclase to epidote occurs east and west of the Barb Lake fault, respectively (Figures 9), although in both locations there is at least some pervasive alteration. Plagioclase is almost entirely altered to sericite (a very fine-grained, disseminated muscovite) in all locations, while biotite is altered to chlorite to some degree. Muscovite, which is found in all phases of the pluton, appears to be a post-solidification alteration of potassium feldspar. Some areas have almost complete alteration of plagioclase to sericite, and mafic minerals such as biotite have been pervasively altered to chlorite. Epidote is dominantly related to

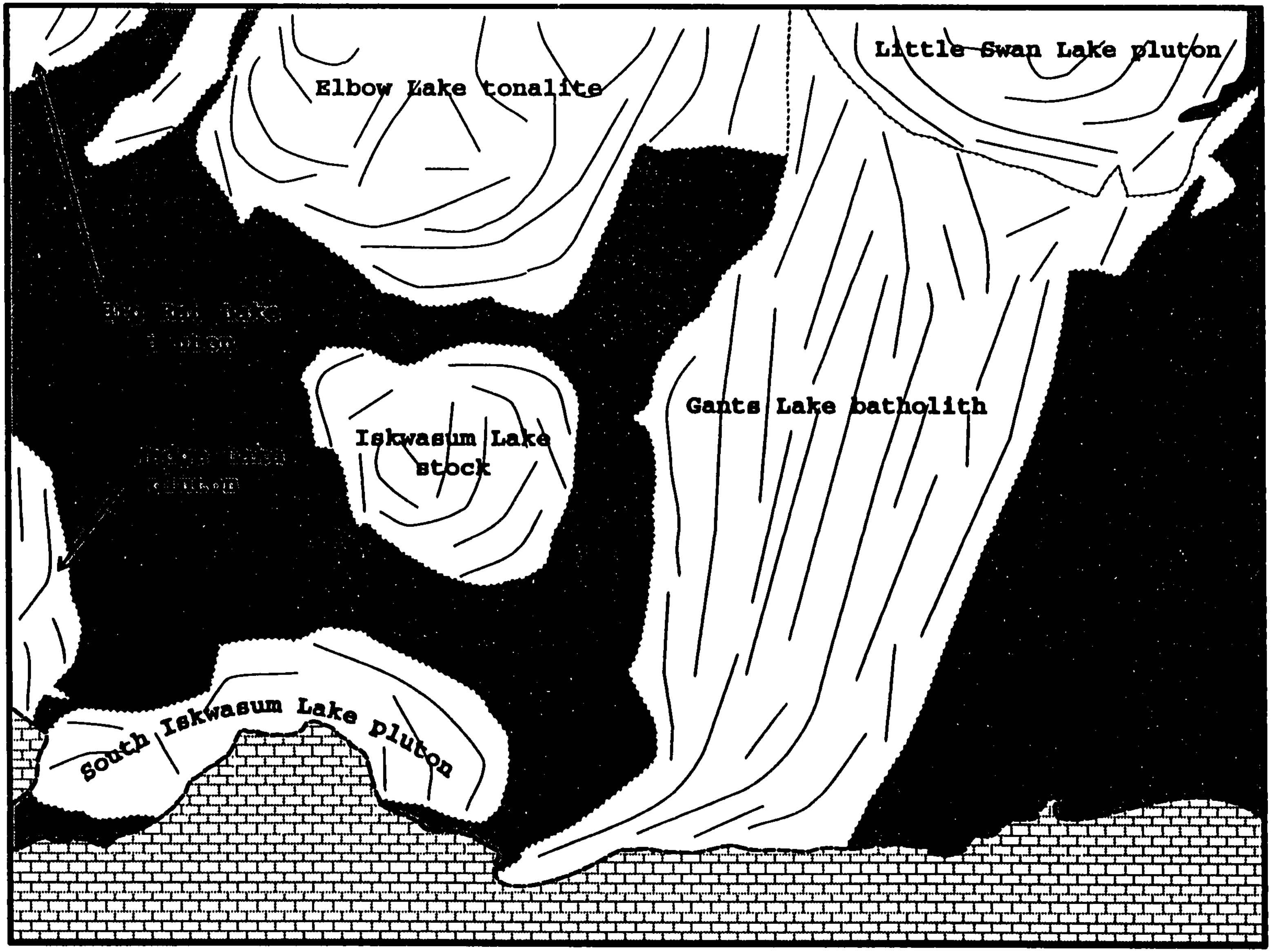


Figure 7. *Structural trend lines for felsic intrusive bodies in the Iskwasum Lake sheet. White areas are plutons, shaded areas are mafic supracrustal and synvolcanic plutons and minor felsic intrusions. Cross-hatched region is unconformably overlying Ordovician dolomite. Structural trend data is interpreted from primary foliations on map 1.*

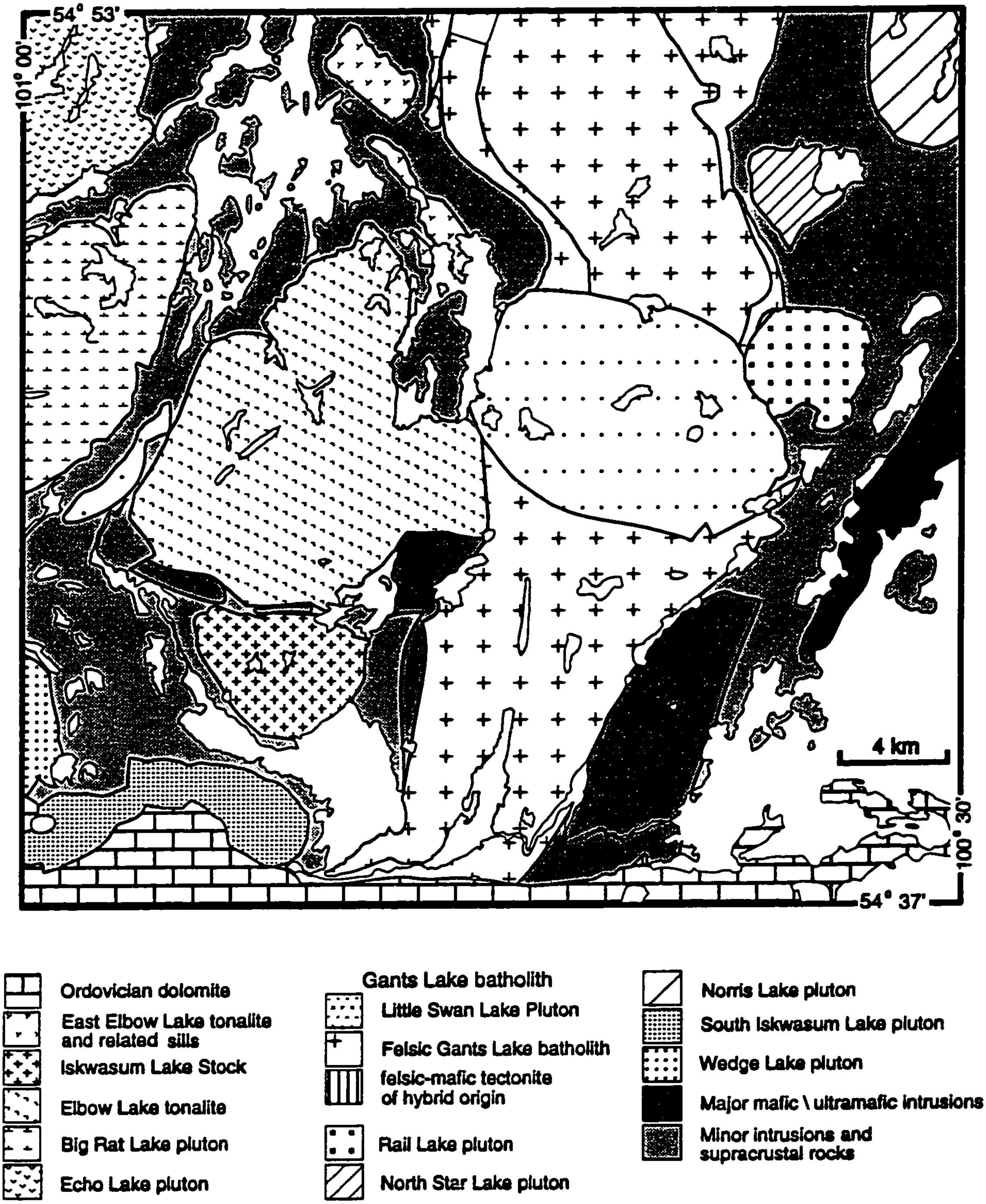


Figure 8. *Major intrusive bodies within the Iskwasum (NTS 63K/10) and Elbow (NTS 63K/15) Lake sheets. All structural elements have been omitted. For more detail on the Iskwasum Lake sheet see map 1 in the pocket. For more detail on the Elbow Lake sheet see Whalen, 1993a (map 2 in the pocket). (Modified after Morrison and Whalen, 1994).*

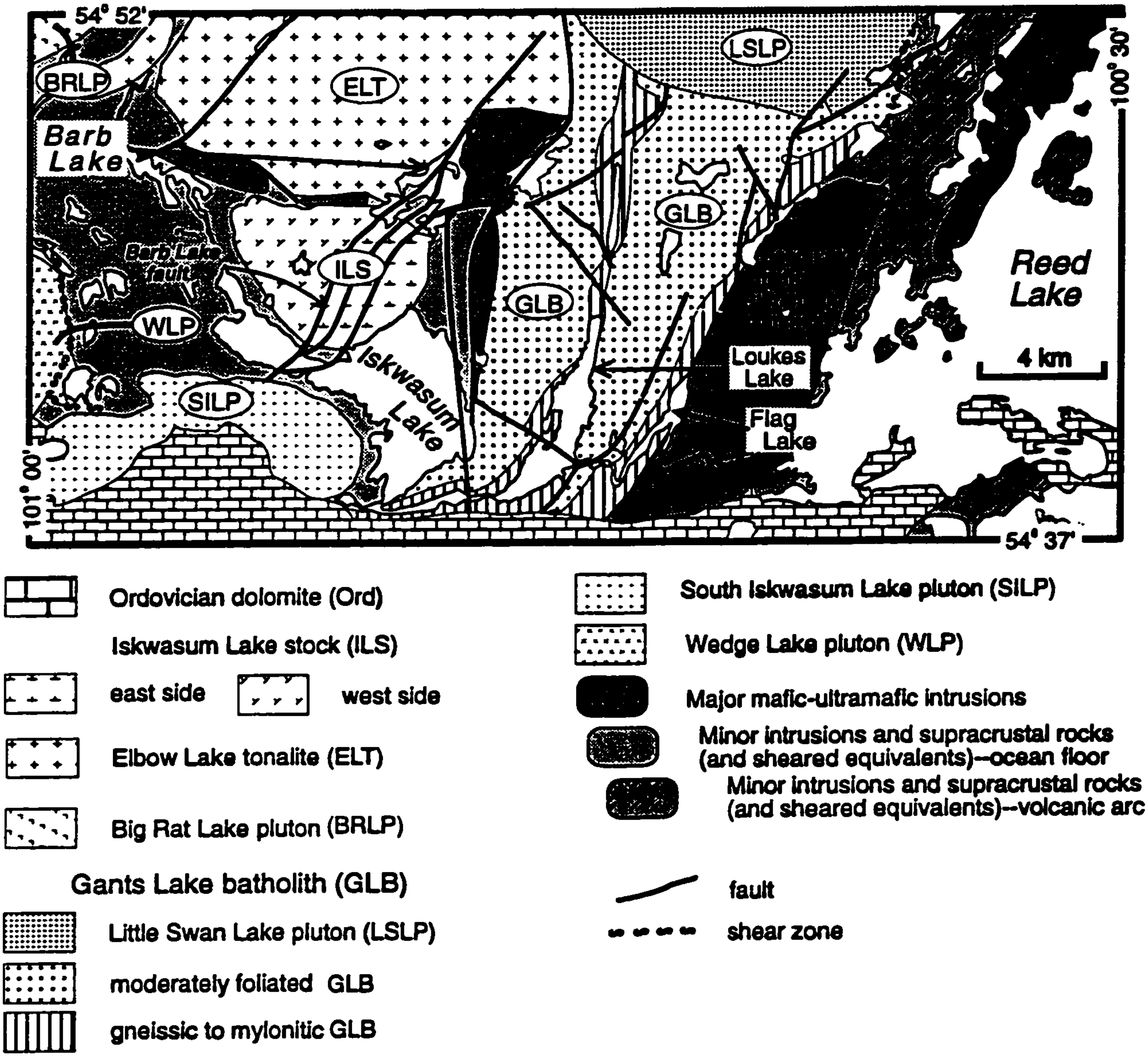


Figure 9. *Simplified lithologic map of the exposed shield in the Iskwasum Lake sheet. Letters in brackets (within the legend) indicate abbreviations used within the appendices and elsewhere. For a more detailed geologic framework see map 1 in the pocket.*

fractures, but as noted, pervasive alteration is not uncommon, dominating the alteration style east of the Barb Lake fault.

Lithologically the Iskwasum Lake stock resembles the Elbow Lake tonalite, which has an U-Pb zircon age of 1864+5/-4 Ma (Whalen and Hunt, 1994). Host rocks include mafic tectonite, mafic volcanic rocks and synvolcanic mafic intrusions. On the western and northern edges of the pluton two 100-200 m wide zones of tonalite enriched in wallrock inclusions (up to 75%) are found. The fabric in the mafic tectonite inclusions was folded prior to emplacement of the tonalite, which is itself strongly foliated concentric to the margin of the stock in these contact zones. The fabric in the tonalite of this zone crosscuts the fabric within the angular to subangular inclusions of mafic tectonite and gabbro (western and eastern zones respectively).

Elsewhere in the pluton, a weak to moderate concentric foliation is typical, and in thin section it is usually defined by an alignment of biotite phenocrysts. Quartz phenocrysts are small, but occasionally reach 8 mm in diameter. In all cases these phenocrysts are rounded, and show little evidence for deformation. The dominant minerals of the stock are quartz, plagioclase and biotite, although potassium feldspar can occasionally be recognized in thin section. Accessory minerals include titanite and rare opaque minerals.

The predominant exposed phase of the stock is a fine-grained equigranular biotite leucotonalite. This phase is found on both sides of the Barb Lake fault, with the intensity of alteration being the discernible discrimant between the two. Disregarding the differences in alteration and the presence of the intrusion breccia, the only other mappable phase in the Iskwasum Lake stock is a medium-grained biotite sub-porphyritic tonalite. This unit is somewhat more mafic than the equigranular phase (10-15% mafic minerals), and has biotite phenocrysts rarely larger than 4-5 mm.

Enclaves, and pegmatite and aplite dikes are common in most other plutons in the map area, but are rare within the stock. The exception to this is in the breccia zones at the margins, where the greatest concentration of aplite and pegmatite veins occurs. In these zones the veins and dikes are moderately deformed and crosscut xenoliths as well as the internal fabric. Contact with the host rocks is sharp and shows folding of previously deformed mafic supracrustal rocks into the intrusion contact. At present it is not certain whether this folding was due to the emplacement of the pluton, or if it is a result of late movement along the pluton-wall rock contact.

2.2 Elbow Lake tonalite

The Elbow Lake tonalite straddles the boundary between the Elbow Lake and Iskwasum Lake sheets (Figures 6 and 7). The northern portion of this unit was described by Whalen (1992; 1993a, b) and yielded an U-Pb age of $1864^{+5}/_{-4}$ Ma (Whalen and Hunt, 1994). Although compositions, textures and fabrics are variable in this pluton at the outcrop scale, at the map scale it is predominantly a quartz-biotite porphyritic ± hornblende tonalite.

Locally the pluton varies from quartz diorite to granodiorite, and from porphyritic to equigranular. Quartz and biotite phenocrysts range from 2 to 20 mm in size. In all cases the dominant mineralogy of the Elbow Lake tonalite is plagioclase, quartz, hornblende and biotite. Potassium feldspar occurs in all samples, but is not abundant. Hornblende is more abundant than in the Iskwasum Lake stock, but is significant only in the most mafic phases of the main lithologic unit of the pluton, and in a small zone in the center of the pluton (see map 1 in the pocket). At these locations the hornblende is better preserved than other mafic minerals. It is subhedral and exhibits good twinning.

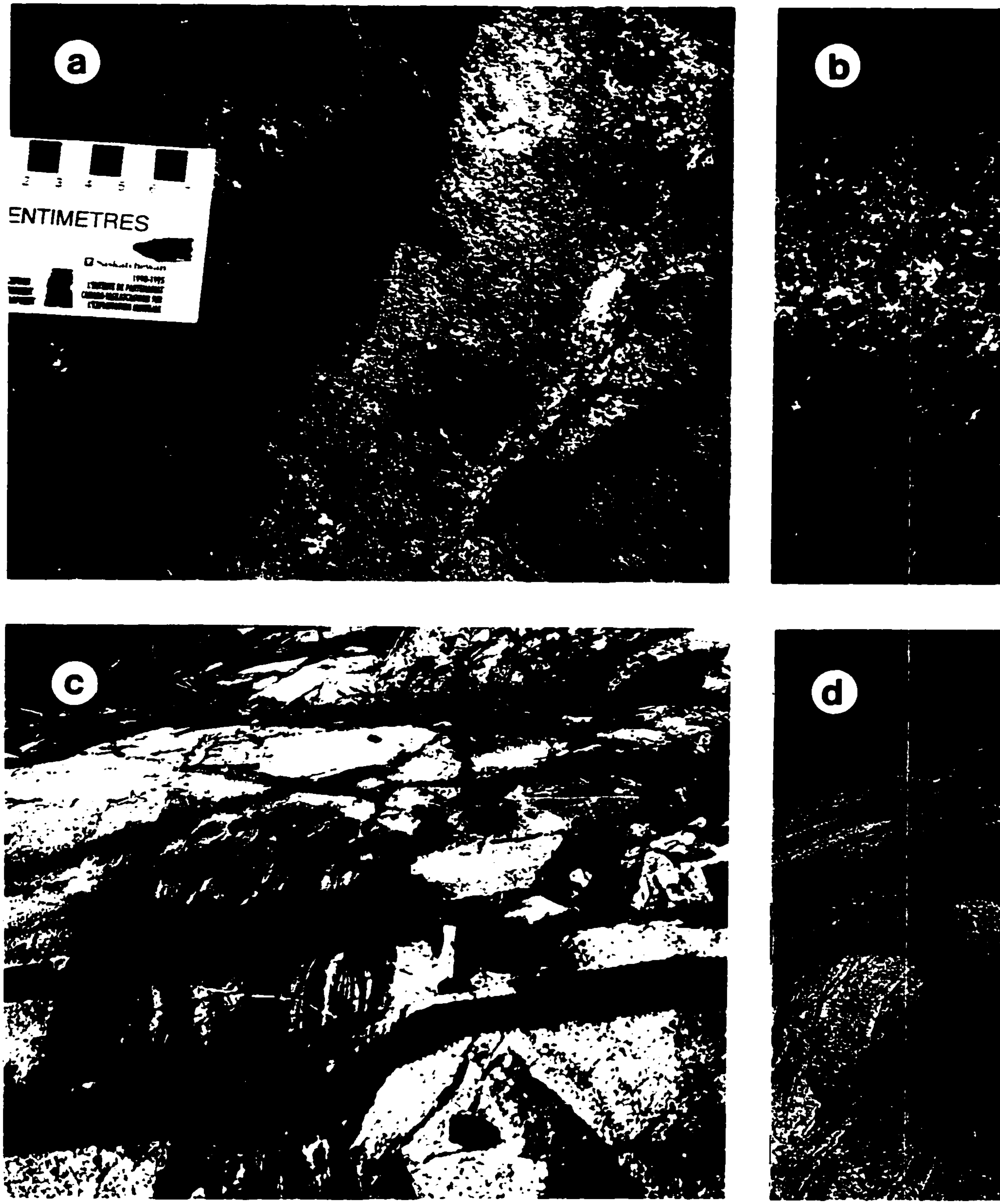
Although petrographic analysis of the body shows that the entire pluton has a remarkably uniform mineralogy, it does show broad variation in texture, and structure and alteration intensity throughout. Like the Iskwasum Lake stock, epidote and sericite are common alteration products in the Elbow Lake tonalite, but in addition it contains abundant accessory titanite phenocrysts. In contrast to the Iskwasum Lake stock is the abundant chlorite, while muscovite is absent in these rocks.

Compositional zonation has been outlined in portions of the Elbow Lake tonalite which appear to have escaped deformation by the prevalent, north-northeast-trending brittle faults. On the western margin of the pluton, an ovoid granodiorite unit grades outwards to equigranular tonalite, and finally to quartz-biotite-porphyritic tonalite. In the center of the pluton, a hornblende-rich tonalite unit has been outlined. West of the main Elbow Lake tonalite body, between the Grass River inlet and outlet, an arm of the pluton intrudes into mafic volcanic rocks (Figure 8). This portion of the pluton is texturally similar to the main phases of the pluton and shows the same typical macroscopic epidote and chloritic alteration. The significant difference between the two is a gradational change from tonalite in the north to quartz diorite in the south.

Plagioclase phenocrysts throughout the pluton are typically subhedral and show oscillatory zonation patterns. Evidence of late-stage fluid-rich magmatic activity is ubiquitous throughout the pluton, and includes pegmatite and aplite veins (rarely greater than 75 cm wide), mafic dikes and quartz stockworks. The latter are discontinuous even at the outcrop scale, disrupted by brittle deformation. Late diabase dikes (<2 m wide) are the only evidence for mafic magmas in the body, and these are rare. Fractures can sometimes be seen to have pegmatitic segregations within them. There is a gradation over several cm from these potassium-rich segregations to the typical quartz-biotite porphyritic tonalite of the Elbow Lake tonalite. This feature may be due to late magmatic fluids percolating through fractures in the pluton.

The best evidence that the pluton is intrusive into its host rocks is provided by the presence of abundant wall rock xenoliths. Although xenoliths can be found throughout the pluton, two distinct xenolith-rich zones, containing large angular fragments of proximal wall-rock lithologies, have been recognized at the margins of the Elbow Lake tonalite.

Xenoliths within the interior phases of the pluton are typically small (2-3 cm), angular to subangular fragments of proximal wall rock lithologies, although provenance can not be ascertained for them all. In general, contacts with the wall rock do not appear to be structurally controlled. A 50 m wide zone of banded gneisses and mylonites juxtaposes Elbow Lake tonalite and Gants Lake batholith units north of Barb Lake. This contact is thought to represent deformed felsic intrusive and mafic supracrustal rocks, and may result from shearing during the emplacement of the Elbow Lake tonalite into the Gants Lake batholith. The only other structurally controlled pluton-wall rock contact is on the southwest margin, where the contact is identified as a long linear fault which juxtaposes gabbroic host rocks and tonalite. The continuation of this fault to the east offsets structures and lithologies recognized within the host rocks to the west.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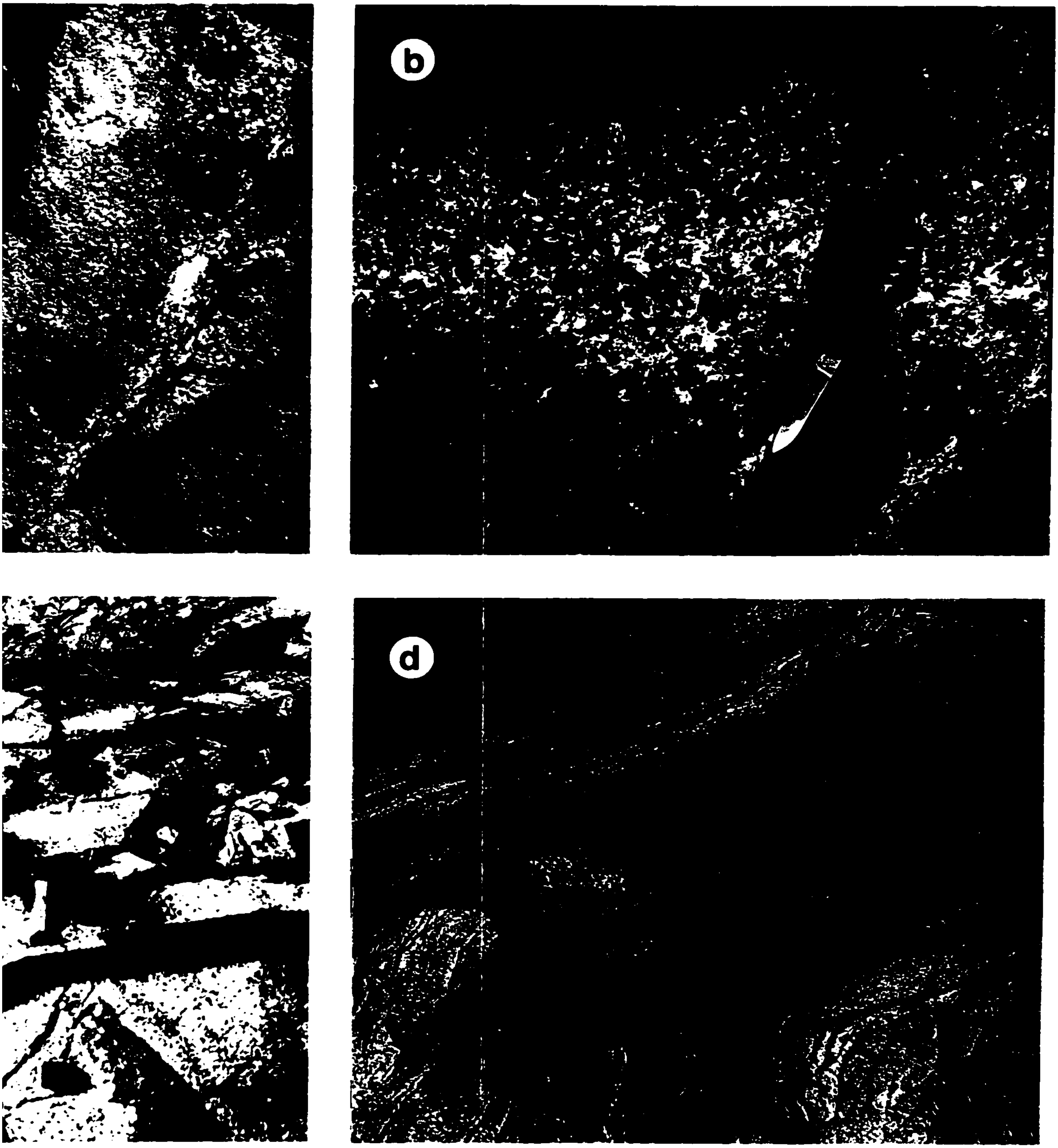
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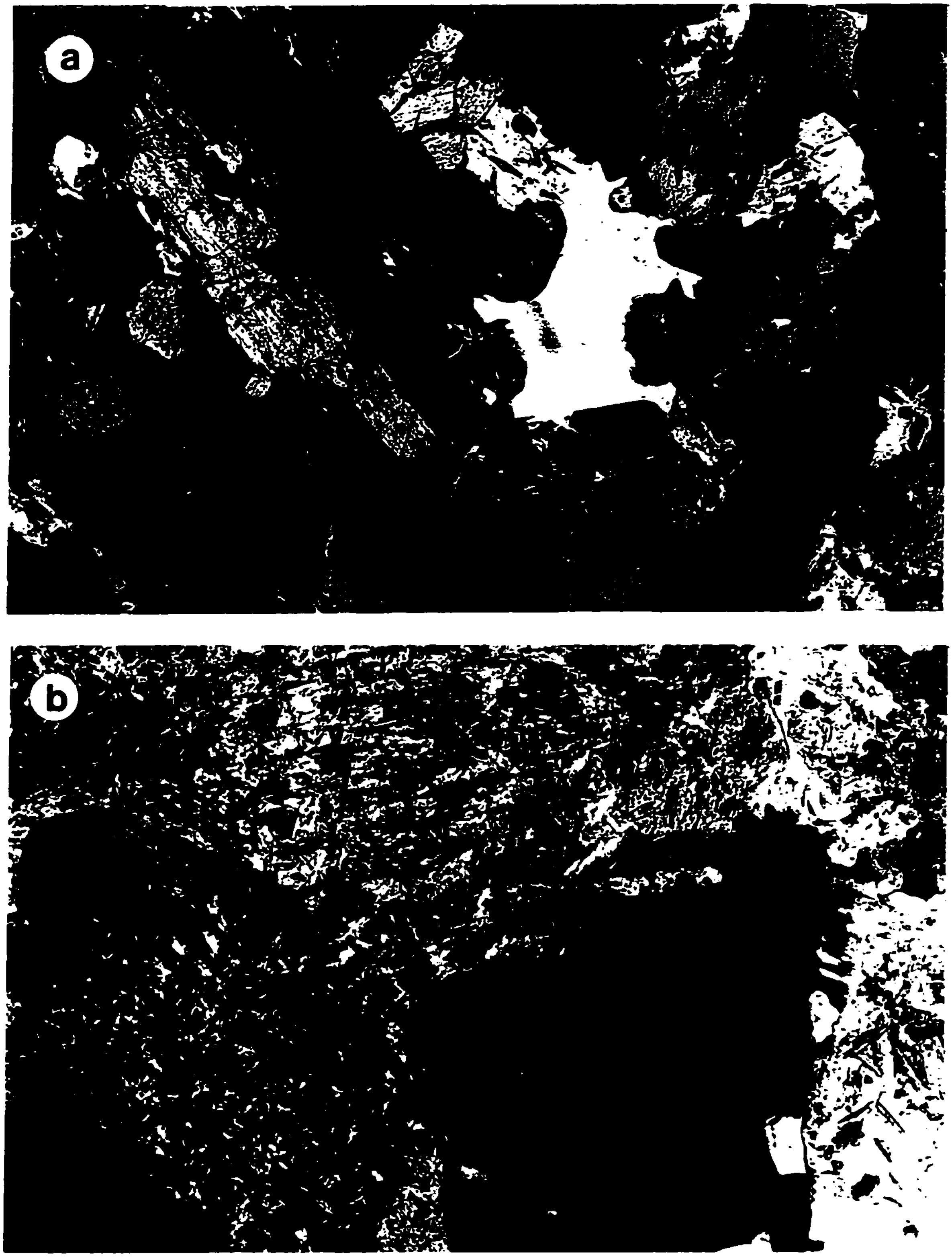


Plate 2. *Photomicrographs of; (a) Fresh, twinned hornblende phenocrysts in the most mafic phase of the Elbow Lake tonalite; (b) Extensive sericitization of plagioclase phenocrysts. Typical of Iskwasum Lake stock granites. Both photomicrographs under crossed polars. Field of view is 2 mm.*

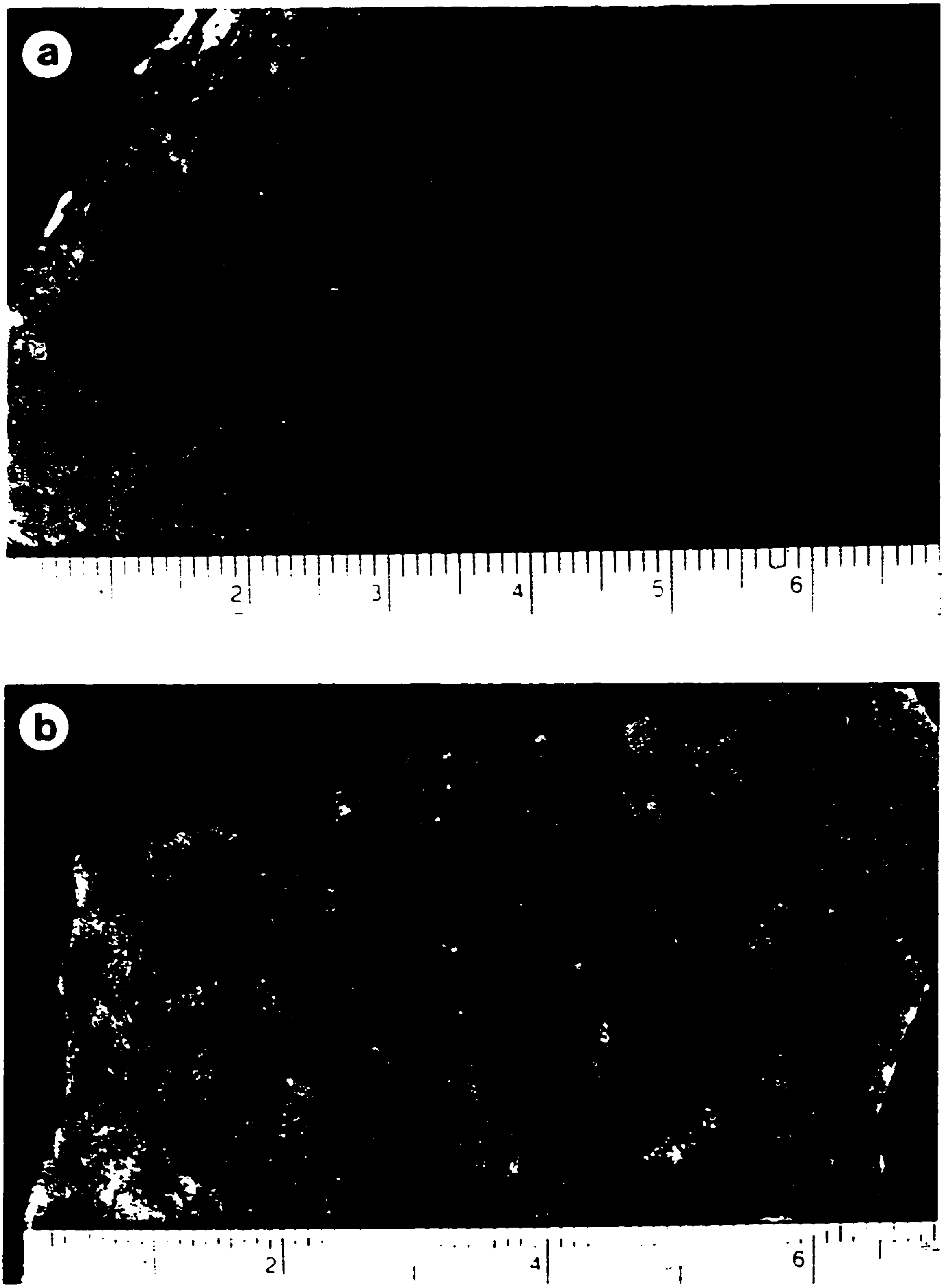


Plate 3. *(a) Highly altered leucocratic tonalite of the Iskwasum Lake stock. Epidote is abundant, particularly along fractures; (b) Quartz-biotite porphyritic tonalite of the Elbow Lake tonalite. Many plagioclase phenocrysts have a reddish color, presumably due to late potassic alteration, or oxidation of Fe in plagioclase. Scale shown is in centimeters.*

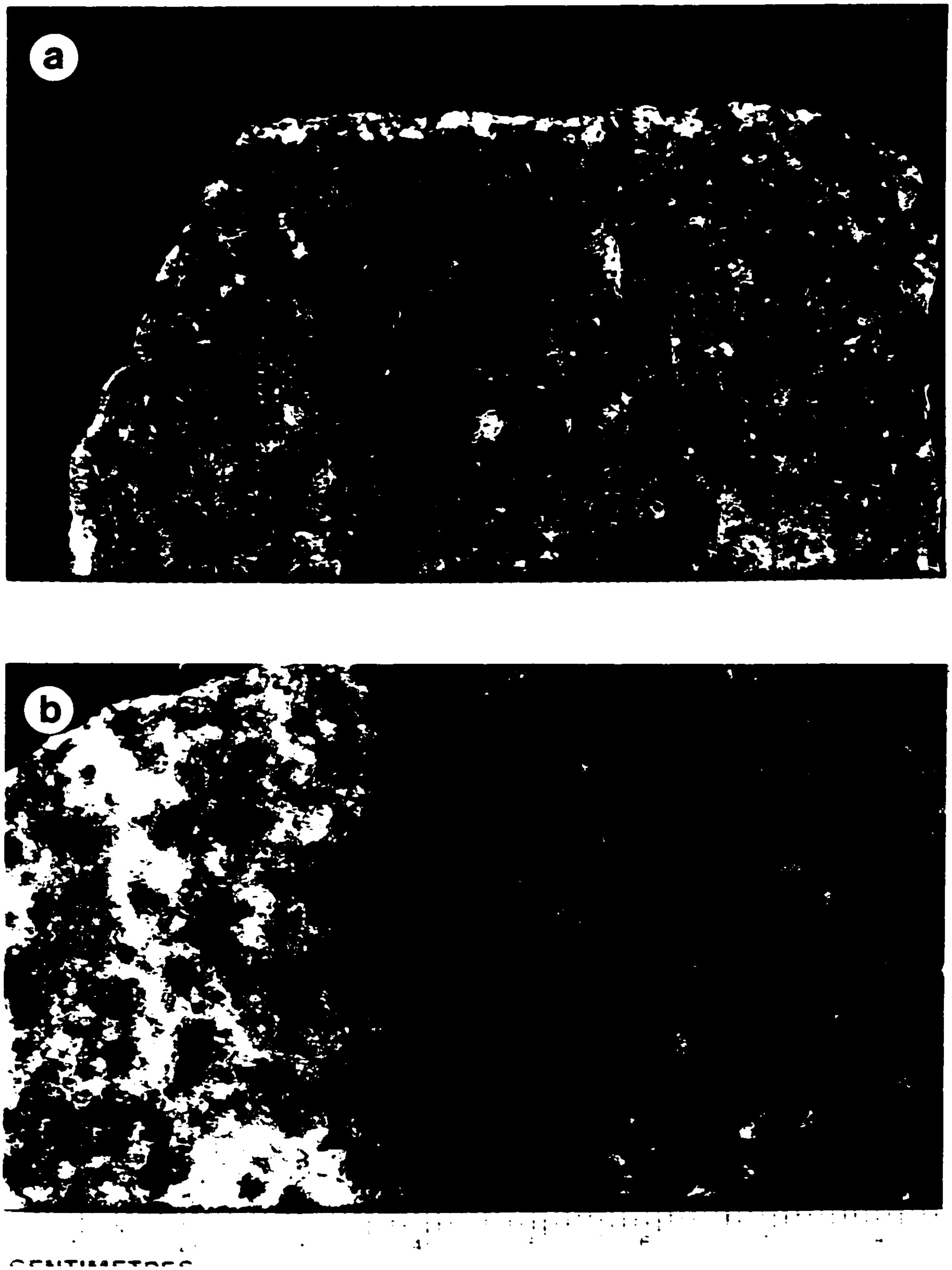


Plate 4. *(a) Quartz-biotite porphyritic tonalite of the Elbow Lake tonalite. This shows an area with less alteration than plate 3b; (b) Detail of the contact between mafic and felsic lithologies in the Elbow Lake tonalite. Large hornblende phenocrysts in the mafic rock are rimmed by plagioclase, quartz and potassium feldspar. Both lithologies are presumed to be broadly coeval. Scale shown is in centimeters.*

Plate 1. *(a) Sharp contact between reddish leucotonalite of the Iskwasum Lake stock and strongly deformed basaltic(?) host rocks. Color and texture of the tonalite are typical of the pluton. Note that strongly deformed mafic host rocks are folded into the contact, suggesting some lateral movement along the contact. Folding of the mafic supracrustal rocks suggests that the pluton was emplaced after significant deformation had taken place.*

(b) Pinkish-grey quartz-biotite pegmatitic segregation in the Elbow Lake tonalite. The contact with the coarse-grained quartz-biotite porphyritic tonalite is gradational over several centimeters. The pegmatitic segregation occurs along fractures, and may be a result of late, high-level magmatic fluids.

(c) Large mafic tectonite xenolith in intrusion breccia of the Elbow Lake tonalite on the western margin of the pluton. The xenolith is derived from the proximal Elbow Lake shear zone. Xenoliths are variable in size and orientation, larger ones typically being oriented with their long axes parallel to the foliation in the tonalite. Smaller xenoliths have been rotated and the fabric in them is cross cut by the tonalite. Photo is taken from the center of the zone The size and abundance of xenoliths increases westward and decreases eastwards.

(d) Heterogeneous gneisses at the contact between the Gants Lake batholith and the Elbow Lake tonalite. Dark rocks are considered to have supracrustal protoliths and exhibit complex folding. Thin granitic sheets in the mafic portion (center of photo) are also complexly folded, while larger granite dikes appear to be boudinaged. Sledge hammer for scale.

2.3 Big Rat Lake pluton

This pluton occupies only about 10 km^2 in the northwest corner of map area (Figure 8). The main part of the pluton continues north into the Elbow Lake sheet and west into the Cranberry Lake sheet (Figure 7). In the Elbow Lake sheet there is significant lithologic variation, but only two of the phases mapped by Whalen (1993a) continue into the Iskwasum Lake sheet. These units consist of fine- to medium-grained equigranular biotite granodiorite to granite, and a medium-to coarse-grained equigranular biotite granodiorite to granite. Relative to within the Elbow Lake sheet, in the Iskwasum Lake sheet the Big Rat Lake pluton has few mafic minerals (20-25%). Based on field relationships in the Elbow Lake sheet (Whalen, 1991, 1992, 1993b), these units intrude into an 1845±3 Ma dated unit of the Big Rat Lake pluton (Whalen and Hunt, 1994). Enclaves, which are ubiquitous in most granitoid intrusions in the map sheet are rare in these units of the Big Rat Lake pluton, as are pegmatite and aplite veins and dikes.

2.4 South Iskwasum Lake pluton

The exposed South Iskwasum Lake pluton, located south of Iskwasum Lake, consists of extremely homogeneous, moderately foliated, biotite-hornblende granodiorite. The pluton consists predominantly of quartz, plagioclase, biotite and potassium feldspar. Accessory minerals include variable amounts of epidote, muscovite, titanite and zircon. Alteration in the pluton is similar to that seen elsewhere in the map sheet. Sericite and chlorite are ubiquitous as alteration products of plagioclase and biotite, respectively, and epidote occurs sporadically throughout the pluton as small subhedral to euhedral crystals. Like the Iskwasum Lake stock and Elbow Lake tonalite hornblende, is rare but present.

The pluton is bounded to the north by the Elbow Lake shear zone and is overlain in the south by Ordovician dolomite (Figures 8 and 9). The pluton has a weak to moderate, roughly concentric contact-subparallel foliation, defined in thin section by a weak alignment of biotite. Although the Berry Creek fault is interpreted as juxtaposing the pluton with the subphanerozoic Precambrian, the low degree of deformation in the pluton may be interpreted as a result of the area most likely to be affected by the fault lying beneath Phanerozoic cover.

Relatively undeformed granodiorite of the South Iskwasum Lake pluton and mafic tectonite of the Elbow Lake shear zone occur in close proximity. Small-scale NNE-trending brittle faults and shear zones which are ubiquitous in other plutons are relatively rare in this body. This may be due to the South Iskwasum Lake pluton intruding previously deformed mafic host rocks or by post-emplacement deformation being localized within the mafic host rocks. Mafic and felsic dikes are conspicuously absent in most of the exposed portion of the pluton, and enclaves are rare. The exception is at the western margin of the pluton where sheared mafic volcanic sheets are located within the pluton. It is not certain whether these represent mafic dikes, sheared upon emplacement, or whether they are sheets of supracrustal rocks caught up during the emplacement of the pluton.

The fact that much of the pluton is low-lying and swamp-covered may explain the structural and lithologic simplicity of the pluton. The Berry Creek fault to the south affects many of the southern exposures in the Gants Lake batholith and the mafic supracrustal rocks in the area, but this is not the case in the South Iskwasum Lake pluton. In the west the pluton intrudes pillowed basalts.

2.5 Gants Lake batholith

The bulk of the Gants Lake batholith is located within the Elbow Lake sheet, and was mapped and subdivided by Whalen (1993b) (Figure 8). Significant structural complexities within, and at the margin of the batholith are related mainly to the NNE-trending Loukes Lake and West Reed-North Star shear zones, and the E-trending Berry Creek fault (Figure 10). These structural features are described in greater detail in the section 3.1 of the thesis.

The Gants Lake batholith is dominated by plagioclase-porphyritic hornblende-biotite granodiorite in the Iskwasum Lake area. The main minerals in this unit include quartz, plagioclase, hornblende, biotite and potassium feldspar. A similar plagioclase porphyritic granodiorite unit in the Elbow Lake sheet (map unit 9j of Whalen (1993a, b)) yielded an U-Pb age of 1876+7/-6 Ma (Whalen and Hunt, 1994) making it one of the oldest Paleoproterozoic granites in the Flin Flon belt. Intensity of deformation within the pluton varies from only slightly foliated, to strongly foliated, to gneissic, intensity typically reflecting proximity to the Loukes

Lake shear zone. In the areas of least deformation the fabric is defined by an alignment of mafic minerals, and in the most deformed areas by a complete alignment of minerals, compositional banding, and a corresponding decrease in grain size. At present the age of phases around the shear zone is not known, but future U-Pb geochronologic work will attempt to solve this problem.

Accessory minerals in the pluton are variable in abundance and size. The most deformed samples appear to have little alteration, suggesting that there has been an almost complete recrystallization of the intrusive rock or that alteration was concentrated outside of shear corridors. Epidote is large in these samples (5-8 mm) and is typically subhedral to euhedral. These characteristics are remarkably similar to the subphanerozoic Namew Gneiss complex described by Leclair and Weber (1994). Other similarities to the Namew Gneiss include the banded nature of some gneisses in the Gants Lake batholith, particularly on the eastern shore of Iskwasum Lake (Plates 2a and 2b).

Alteration in the main phases of the pluton is similar to seen elsewhere in the map sheet, including sericite, chlorite and epidote. Muscovite is rare in deformed phases of the pluton, and where found is often completely enclosed within plagioclase phenocrysts. Biotite crystals can typically be seen bending around larger, more resistant plagioclase phenocrysts, even in the least deformed samples. Euhedral titanite is often partially replaced by opaque minerals, retaining the original crystal shape.

In the more deformed phases of the pluton, particularly on the eastern shore of Iskwasum Lake, the presence of concentric zones of mineral inclusions within plagioclase phenocrysts suggest that saussuritic alteration preferentially occurred along calcium-rich zones within the crystal. Epidote is typically large and subhedral, overgrowing the compositional banding, with larger crystals being concentrated in the center of these bands. Where this occurs the epidote is found at the interstices between plagioclase and potassium feldspar phenocrysts. Although there is a strong compositional banding in intrusive rocks on the eastern shore of Iskwasum Lake, mafic minerals within bands do not show a strong preferential orientation. This may be due to realignment during subsequent tectonic stresses on the pluton. It is apparent in thin section analysis of this phase of the pluton that the intensity of deformation is not uniform. Some areas have a strong compositional banding, while others have a strong preferential alignment of minerals, with biotite phenocrysts typically bending around the larger, more resistant plagioclase phenocrysts.

Although most plagioclase crystals on the western margin of the pluton remain euhedral to subhedral, exhibiting a well-defined cleavage, some of the more deformed phases of the pluton nearer to the Loukes Lake shear zone contain plagioclase phenocrysts that show evidence of deformation. Rare oscillatory zoning and lamellae are bent within the phenocrysts. Similar to deformed phases on the western margin of the pluton, those nearer to the Loukes Lake shear zone typically contain large, euhedral epidote crystals. Some of the less well-formed epidote crystals are elongate in the direction of the primary foliation.

Less deformed phases of the Gants Lake batholith have a similar mineralogy to their strongly deformed counterparts, but differ in that there is less alteration, and only a weak to moderate foliation as defined by an alignment of biotite phenocrysts. Muscovite is present in all phases in trace amounts, but unlike in the more deformed phases, where it occurs within plagioclase phenocrysts, in the less deformed areas it is often present between larger phenocrysts of plagioclase, quartz and hornblende, exhibiting a radiating pattern. Euhedral epidote crystals are still common in the less deformed areas of the batholith, but they are typically smaller than seen elsewhere.

The Gants Lake batholith contains abundant evidence for multiple episodes of essentially comagmatic felsic intrusive phases. In a well-exposed area northwest of Loukes Lake, and away from the Loukes Lake shear zone, five different comagmatic intrusive pulses were recognized. Lithologically similar, these phases are recognizable only on the basis of textural and grain size variations. Where all five phases coexist they exhibit complex crosscutting inter-relationships, suggesting that all units intruded at approximately the same time. Mafic schlierien in this area are variable in size and their contacts are wispy to moderately sharp. While lithologic contacts crosscut the fabric, schlierien are preferentially aligned parallel to the NNE-trending fabric (Plate 2c). Where these lithologies are present on the west shore of an unnamed lake north of Loukes

Lake, the Loukes Lake shear zone has obliterated all crosscutting relationships. The evaluation of lithologies and structures in this area was aided by a 1989 forest fire, which cleared the exposure of the northern portion of the Gants Lake batholith.

Recognizable comagmatic mafic lithologies are not common in the Gants Lake batholith. This may be more a function of deformation intensity than the lack of these magmas in the generation of the batholith, as these lithologies are likely to be less competent than felsic varieties. Where comagmatic diorite is found in granodiorite, particularly in the northeastern portion of the batholith it occurs as a large lenticular zone. These lozenges can be as wide as 30 m, and are discontinuous from one outcrop to the next. Because of the lack of evidence for faulting in the immediate area, this is taken to represent large mafic lenses intruded into the host granodiorite. The nature of the contact suggests that they were approximately comagmatic. On outcrop and hand specimen scales these lithologies typically have a sharp contact, although mixtures of the two lithologies are occassionally apparent. Evidence for a comagmatic origin for these rocks includes a 15 cm wide zone of intermediate composition rock, representing the mixing of these two lithologies, the incorporation of potassium feldspar into the diorite, and the cuspated and lobate nature of the mafic lenses. In this location, both lithologies are very fresh, and have a weak contact-subparallel foliation, indicating that the mafic magma imprinted a fabric on both lithologies when it was emplaced. A second fabric, apparent only in the diorite, may be due to regional tectonic stresses and may not be significant in the felsic lithology due to its competency.

On the eastern margin of the batholith, the West Reed-North Star shear zone separates the Gants Lake batholith from the Reed Lake gabbro, and mafic volcanic rocks (Figure 9). Two large xenolith-rich zones on the margin of the batholith suggest that the Gants Lake batholith intruded into both mafic volcanic rocks and gabbros. These zones, one of which is fault-bounded, consist of large (up to 10 m wide) angular xenoliths of both mafic lithologies within a quartz-porphyritic granodiorite, indicating that the batholith was not transported to its present location along faults. Xenoliths in both areas occupy 50-80% of the outcrop area. Another complexity within the granodiorite east of the Loukes Lake shear zone includes the presence of two approximately 150-200 m wide blocks of mylonitized intrusive rock, with no north-south spatial continuation (see Figure 10). These blocks retain the north-northeast-trending fabric seen within shear zones and elsewhere in the batholith, but their origin and orientation are suspect.

Juxtaposing the Gants Lake batholith and the Elbow Lake tonalite is a zone of banded mylonite. Although provenance is equivocal, the presence of mafic sheets, interpreted as mafic intrusive lithologies, in this thin mylonite belt suggests that pluton emplacement may be the mechanism for activation of this shear zone. This further highlights the question of the timing of the West Reed-North Star shear zone, which juxtaposes wall rock and batholith lithologies. The zone contains mylonitic mafic and felsic sheets, which are interpreted as representing equivalents of the two proximal lithologies (Plate 3a). Does this represent shearing related to the emplacement of the Gants Lake batholith, or is the shear zone an early feature which caught up both lithologies in the later deformation? Garnet porphyroblasts, presumed to be related to peak metamorphic conditions in the Flin Flon belt, are somewhat rotated within the felsic units, and in thin section they are typically anhedral, foliations bending around them. This suggests that shearing continued post-peak metamorphism, and the West Reed-North Star shear zone had continued deformation after pluton emplacement. This is similar to the protracted deformation history proposed for other structures in the map sheet (*ie.* the Elbow Lake and West Reed-North Star shear zones).

2.5.1 Little Swan Lake pluton

At the northern margin of the map sheet the late, ovoid Little Swan Lake pluton intrudes into the Gants Lake batholith (Figures 8 and 9). The northern half of the pluton, located in the Elbow Lake sheet (map units 9n to 9s of Whalen (1993a)), yielded an U-Pb titanite age of 1828±5 Ma, significantly younger than the 1876+7/-6 Ma U-Pb zircon age obtained on its plagioclase-porphyritic granodiorite wall rock (Whalen and Hunt, 1994). Consistent with the apparent age gap, north and northeast-trending structures within the elongate Gants Lake batholith terminate at the Little Swan lake pluton contact (Figure 10). A secondary foliation overprints the primary NNE-trending fabric in the Gants Lake batholith parallel to its contact with the Little Swan lake pluton. Intensity of this overprinting rapidly decreases away from the contact. The Little Swan lake pluton is moderately deformed, foliations being subparallel to the margin of the pluton and

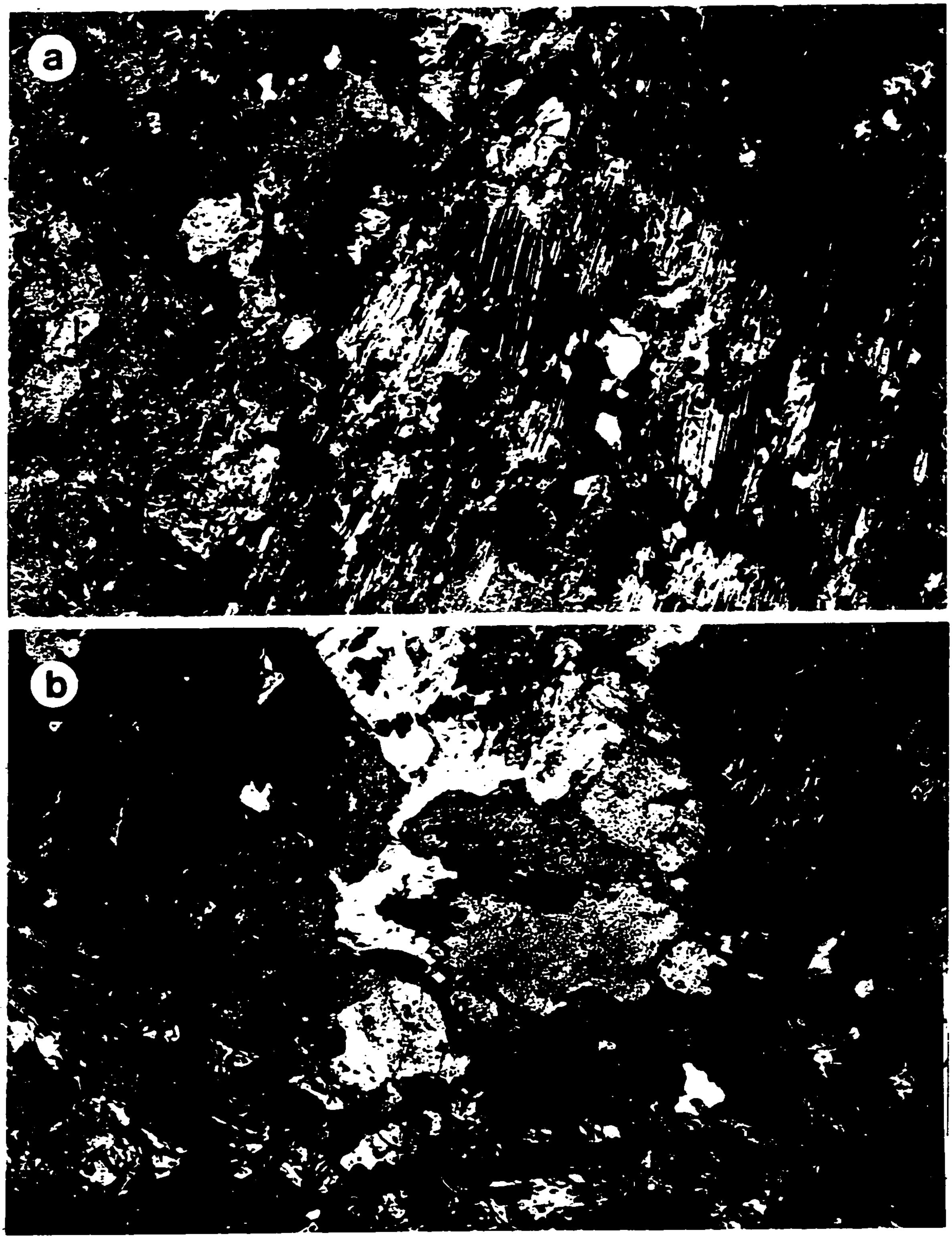


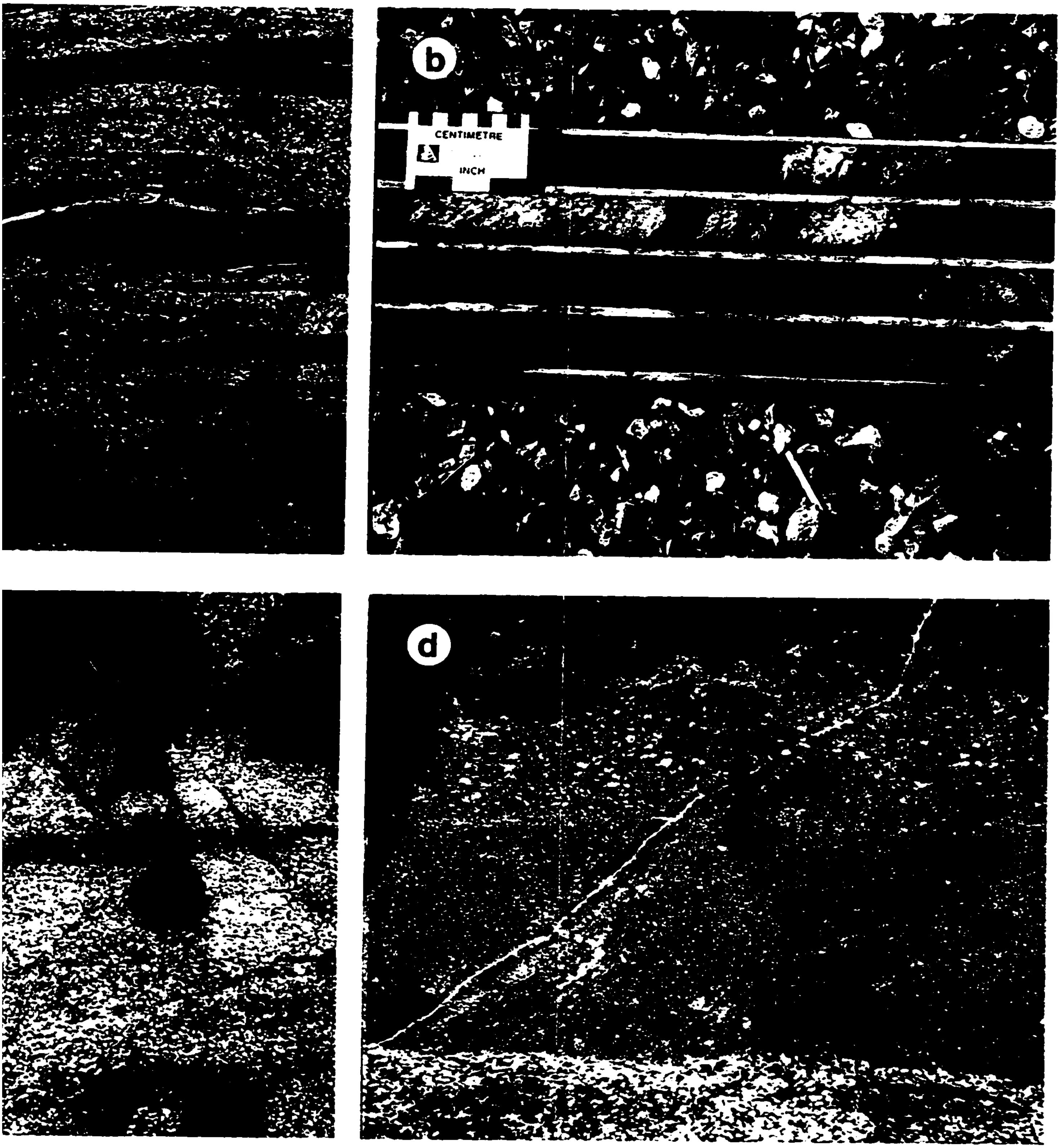
Plate 5. *Photomicrographs of; (a) Warped lamellae in a large plagioclase phenocryst. Deformation is typical of Gants Lake batholith rocks away from the Loukes Lake shear zone; (b) Large, anhedral-subhedral epidot phenocryst (bright green, orange and yellow in the photomicrograph) from the Gants Lake batholith, on the east shore of Iskwasum Lake. This is similar in mineralogy to Namew Gneiss rocks. Both photomicrographs under crossed polars.*

Plate 6. *(a) Mafic-felsic gneiss on the eastern shore of Iskwasum Lake. The rock is interpreted as being the sheared equivalents of granodioritic and quartz dioritic lithologies of the Gants Lake batholith, possible formed as a result of shearing on the East Iskwasum shear zone. Notice the similarity to Namew gneiss core (plate 6(b)), both units being heterogeneous mixtures of mafic and felsic lithologies.*

(b) Hetrogeneous gneiss of the Namew gneiss complex, south of the Iskwasum Lake sheet. The Namew gneiss is not exposed, and has been mapped by Leclair et. al. (1993, 1994) based on drillcore, magnetic signature and gravity surveys.

(c) Mafic schlierien in the Gants Lake batholith. Photograph taken from unit P6f. Contacts between comagmatic felsic lithologies in this unit are sharp irregardless of their relationship to foliation directions. Although this unit is characterized as one of only moderate deformation in the Gants Lake batholith, mafic schlierien are variably strung out. Larger schlierien (above the hammer) are dense, and do not exhibit strong assimilation into the felsic rock. Thinner schlierien (to the right of the hammer) have wispy contacts with the granodiorite, and are more difficult to recognize.

(d) Contact between comagmatic(?) gabbro and plagioclase porphyritic granodiorite of the Gants Lake batholith. Photograph taken from the northeast corner of the batholith. Notice the large zone of partially assimilated material between the gabbro (top of photo) and the granodiorite (bottom of photo). Cuspated, gradational margins are apparent nearer the gabbro, but the contact with the hybrid rock and the granodiorite appears to be sharp. An intermediate dioritic phase is apparent between the two end members, and plagioclase has been incorporated into the hybrid rock.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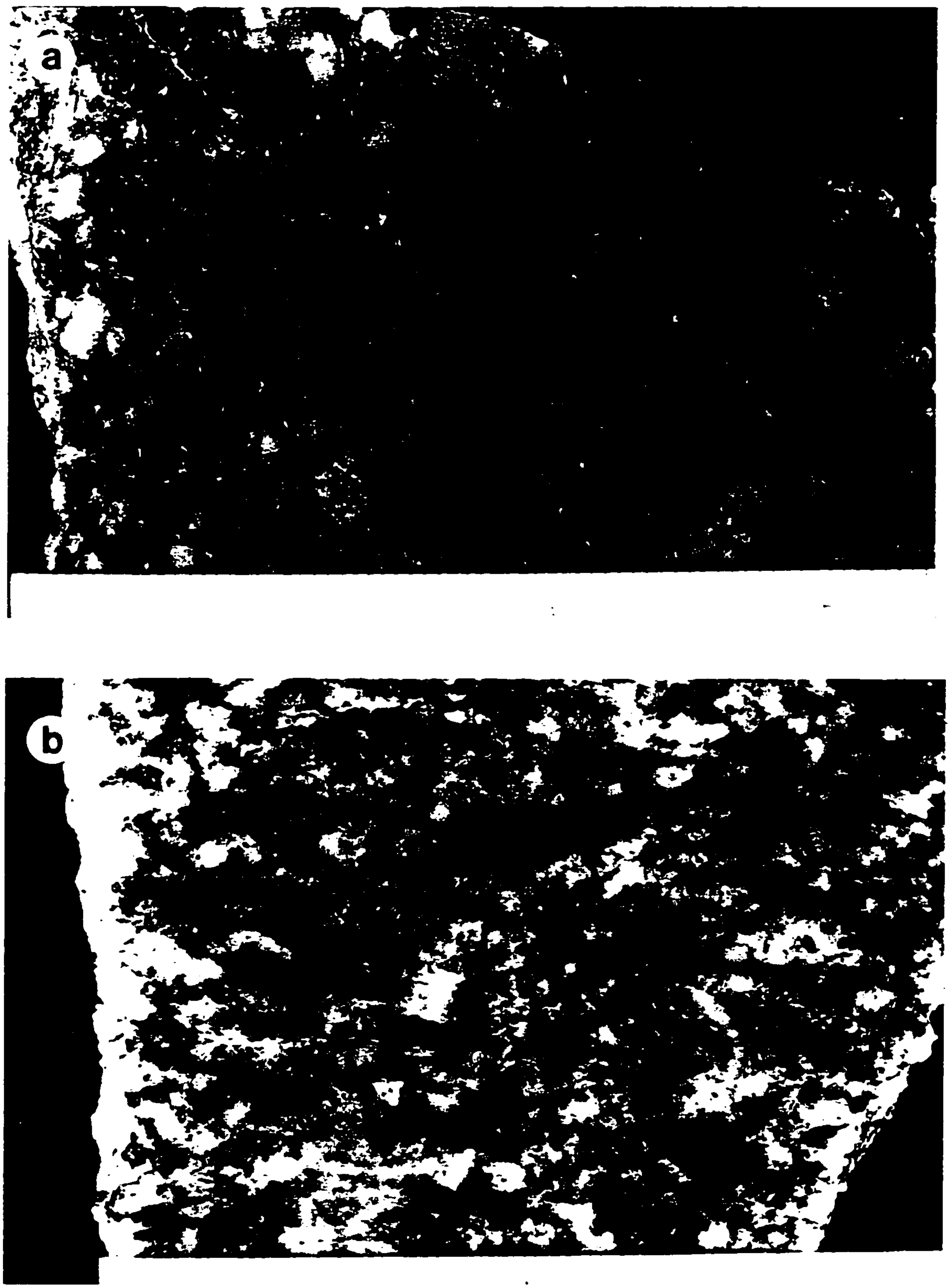


Plate 7. *(a) Feldspar porphyritic granodiorite of the Gants Lake batholith. This is the main phase of the batholith. Both potassium and plagioclase feldspar show a pinkish color, and occur as 0.2-0.8 cm phenocrysts (b) Rare, unaltered plagioclase porphyritic phase of the Gants Lake batholith. A strong fabric is defined by the alignment of biotite. Scale shown is in centimeters.*

increasing in intensity towards the margin. Fabrics are typically defined by a weak alignment of mafic minerals, but toward the margin of the pluton some compositional banding is present.

Coarse-grained hornblende- and biotite-bearing granodiorite is the dominant lithologies, but quartz diorite, diorite and gabbro is present. The main units of the pluton contain equigranular phases, but the vast majority is plagioclase porphyritic. The mineralogy of the more felsic phases is similar, consisting of quartz, plagioclase, biotite, hornblende and potassium feldspar.

Small (cm-scale), lobate mafic lithologies within granodiorite are indicative of coexisting mafic and felsic magmas (Plate 8b) (see also Whalen, 1993a, b). A large zone of fine-grained equigranular quartz diorite, consisting predominantly of plagioclase, biotite, and hornblende is found in the center of the pluton. Hornblende is often poikilitic with inclusions of plagioclase, while quartz occurs only in minor amounts as small rounded phenocrysts. Muscovite is present as an alteration of biotite and chlorite. Biotite, muscovite and chlorite are often oriented in a radiating pattern. The large zone of quartz diorite is similar in mineralogy and texture to the small comagmatic quartz diorite lobes located immediately south. The significant difference between the two lithologies is that the smaller quartz diorite lobes appear to have encorporated plagioclase phenocrysts into them, giving them a plagioclase-porphyritic appearance.

Alteration in the Little Swan Lake pluton is typically less pronounced than in other plutons of the Iskwasum Lake sheet, consisting of chlorite, epidote, muscovite and sericite. Petrographically, the Little Swan Lake pluton differs from the Gants Lake batholith in a number of ways. including the degree to which deformation and alteration has taken place. Like the Gants Lake batholith epidote crystals are euhedral, but in contrast they are much smaller.

2.6 The Wedge Lake pluton.

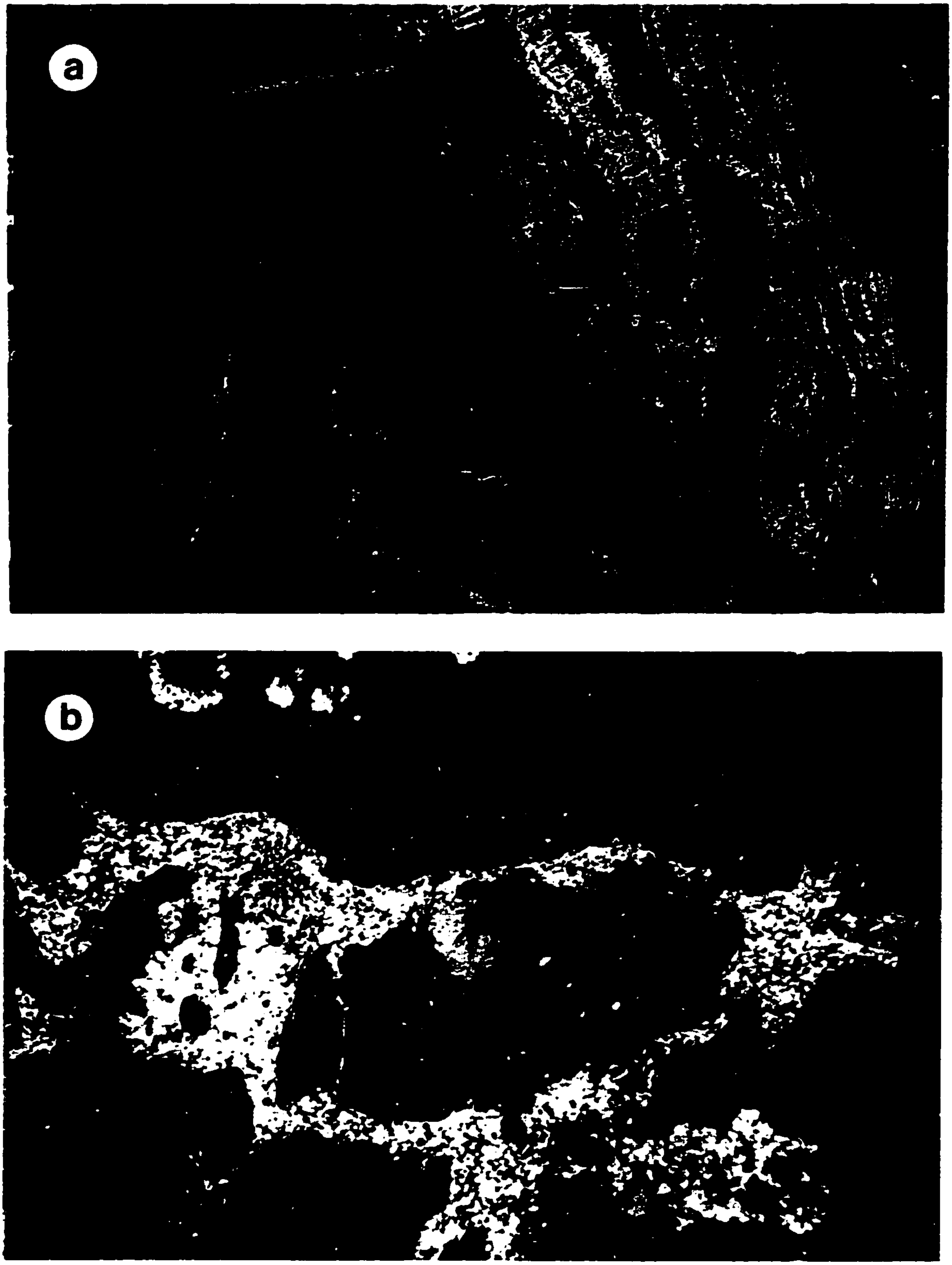
The Wedge Lake pluton is located west of the South Iskwasum Lake pluton (Figures 8 and 9), and only about 10 km^2 of the pluton is located within the Iskwasum lake map sheet. The Wedge Lake pluton is more structurally and lithologically complex than the nearby South Iskwasum Lake pluton. It contains, at its southern margin, a small zone of potassium feldspar-porphyritic granodiorite with poikilitic potassium feldspar megacrysts up to 3 cm, containing quartz and biotite inclusions. This unit, which is volumetrically more significant in the adjoining Cranberry Portage sheet to the west, grades to the north into equigranular biotite-hornblende granodiorite. Further north, this unit grades into hornblende quartz-monzonite, and finally, near its northernmost wall-rock contact, into hornblende-biotite granodiorite. At the northern contact with mafic tectonite is a thin (150 m wide) zone of intrusive breccia, which contains xenoliths of no less than seven different lithologies. Enclaves in this zone include mafic tectonite and moderately deformed to massive mafic volcanic xenoliths, several different intrusive lithologies of unknown providence and cognate xenoliths. Mafic tectonite xenoliths consist of banded mafic mylonites, similar in appearance to those from the Elbow Lake shear zone. Mafic intrusive xenoliths range in composition from diorite to gabbro, and are generally coarse-grained. Cognate xenoliths include medium-grained, equigranular biotite leucogranodiorite and coarse-grained quartz-porphyritic and plagioclase-porphyritic hornblende-biotite granodiorite. The southern margin of the pluton is overlain by an outlier of Ordovician dolomite, while the eastern margin is in intrusive contact with moderately deformed pillow basalt.

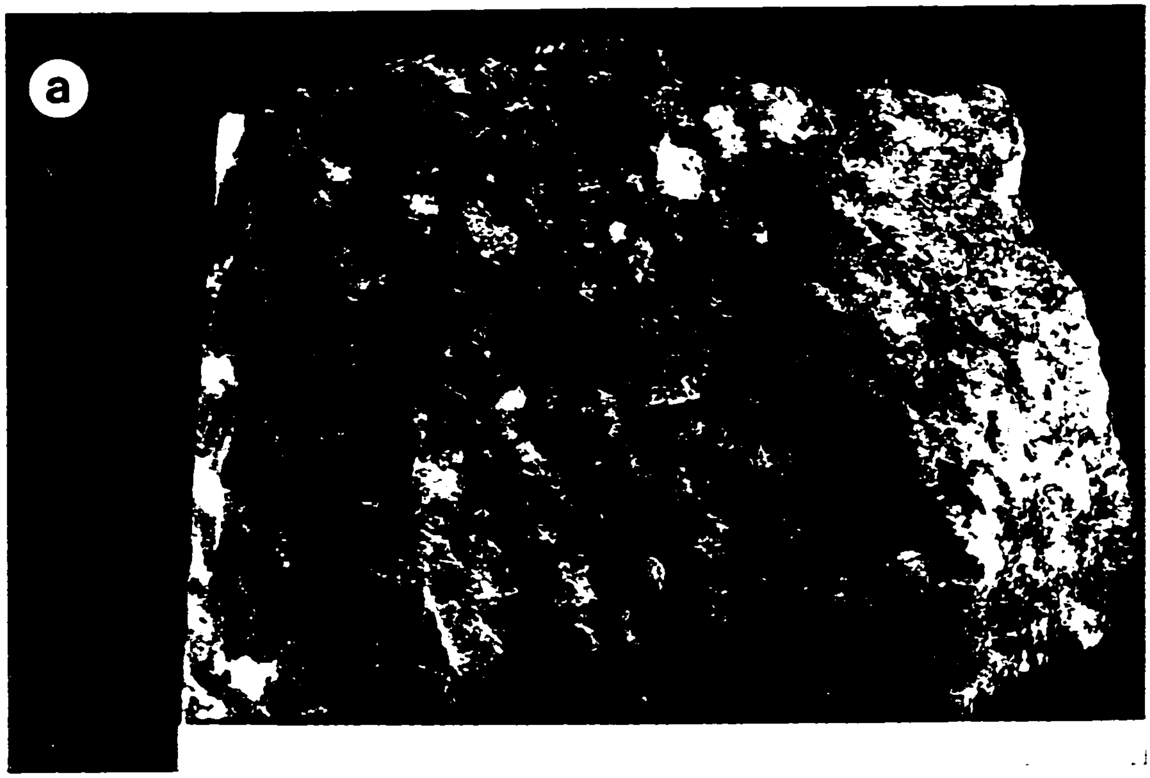
All phases of the Wedge Lake pluton contain quartz, plagioclase, potassium feldspar and biotite. Hornblende, the dominant mafic mineral in only one phase, becomes more abundant in the east-center of the pluton, where the rocks are more mafic. Accessory zircon and titanite are common, but crystals are generally small. Although alteration is weak, it includes sericite, chlorite and epidote, and is most significant in the most mafic phases of the pluton. Plagioclase phenocrysts are generally zoned, often showing oscillatory pattern. Sericitic alteration is common along the zones within the plagioclase. Other plagioclase phenocrysts have a myrmekitic texture with plagioclase in vermicular quartz, while potassium feldspar is most often poikilitic with variable amounts of quartz and biotite.

The Wedge Lake pluton differs from the South Iskwasum Lake pluton in the complexity of the structures within it. A shear zone which forms the northeastern contact with mafic volcanic rocks, crosscuts the pluton in the south, and cuts off the breccia zone in the north. Within the pluton, this structure is 150-200 m wide.

Plate 8. *(a) Felsic-mafic tectonite of the Flag Lake shear zone. Banding is characteristic of the shear zone, which juxtaposes the Gants Lake batholith granites to the west with mafic volcanic rocks to the east at this location. Photograph taken from near the rapids on the Grass River between Loukes and Flag Lakes. Note the constant thickness of the bands which continue in parallelism over large distances, disregarding lateral offsets along late brittle structures. Note that shear sense indicators are rare at the hand specimen scale. Hammer for scale.*

(b) Lobate, comagmatic inclusions of quartz diorite in porphyritic granodiorite of the Little Swan Lake pluton. Photo is from unit P10Ag and quartz diorite lobes are correlated with unit P10Ae; note the incorporation of plagioclase phenocrysts into the quartz diorite from the granodiorite.


a
b



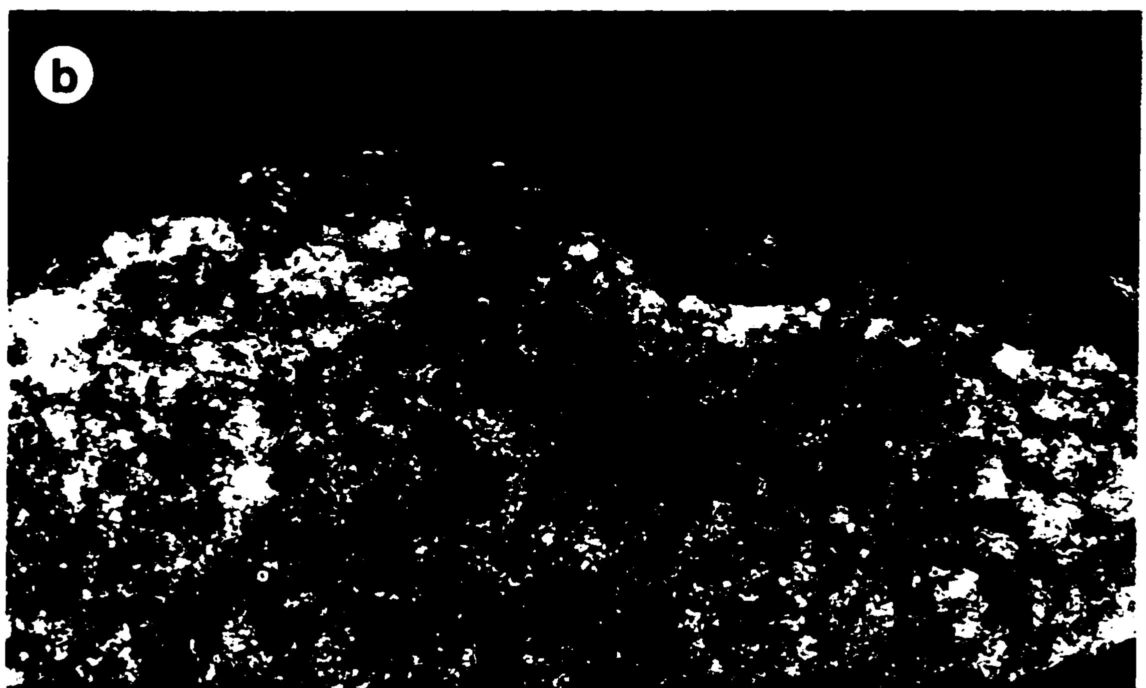


Plate 9. *(a) Very fresh, quartz porphyritic granodiorite of the Little Swan Lake pluton. Note the weak fabric, and lack of alteration; (b) Potassium feldspar porphyritic granodiorite of the Wedge Lake pluton. Orange mineral surrounding biotite, plagioclase and quartz in the top 2/3 of the photo is two or three poikilitic potassium feldspar phenocrysts. Scale shown is in centimeters.*

Although lithologies within the shear zone may include mafic sheets, rocks at its margins are recognizable as sheared equivalents of South Iskwasum lake pluton units. Strain in the Wedge Lake pluton is highlighted by elongate quartz phenocrysts which have extensive "strain shadows" and an alignment of biotite phenocrysts, particularly in the southeastern portions of the pluton.

Comagmatic(?) diorite in the center of the pluton is in sharp contact with granodiorite. Mafic enclaves are subangular to rounded, and occupy 0-15 % of the outcrop area. The diorite contains large, fresh plagioclase phenocrysts within a fine- to medium-grained matrix of hornblende, plagioclase and biotite. The mafic enclave is subangular to rounded, and has what appears to be a chilled margin. There is a gradational change in grain size and mineralogy towards the granodiorite, but it is not certain whether this represents the contact between comagmatic phases or the interaction between a hot felsic magma and a cold xenolith.

2.7 Summary

Felsic intrusive rocks of the Iskwasum Lake sheet are generally lithologically restricted to tonalites and granodiorites. Subordinate quartz diorites and gabbros are present in only moderate amounts. However, each pluton is lithologically and texturally variable, and subdivision of these differrent phases is possible. Most plutons are porphyritic, but equigranular phases are not uncommon. Older plutons in the map sheet are characterized by discontinuous lithologic variations, usually controlled by late brittle deformation. Although lithologic units are typically terminated by faults, there is ample evidence for gradational as well as sharp intrusive contacts in all plutons. Although sharp intrusive contacts are normally only seen where mafic units have intruded into existing felsic units, this is not always the case, and in the Gants Lake batholith at least five comagmatic, generally felsic lithologies are distinguished by textural rather than lithologic variations. Lobate comagmatic quartz diorites and diorites are common in the Little Swan Lake pluton, and similar lithologies are present in the northeast corner of the Gants Lake batholith.

Gradational lithologic contacts have also been recognized within all plutons, but the mapping of these contacts is typically hampered by the extent of brittle deformation, particularly within the oldest plutons. However, even in the Elbow Lake tonalite, where brittle deformation is typically so intense that lithologic units cannot be traced from outcrop to outcrop, gradational contacts have been recognized. This suggests that the entire pluton may consist of numerous similar units, disarranged during brittle deformation. It is also noted that in general this pluton has a contact sub-parallel foliation pattern, but internal zones appear to have concentric patterns within this (particularly in the northwest corner of the pluton) (see Figure 13). This may refelct multiple pulses of similar tonalitic magma, a feature not previously recognized. Clearly a more detailed structural analysis of the pluton is required to shed further light on these features.

Individual plutons are characterized by distinct lithologically and texturally variability. Unlike the Gants Lake batholith, units in intrusions such as the South Iskwasum Lake and Big Rat Lake plutons, and the Iskwasum Lake stock are only distinguished by textural and alteration differences, and the number of units is correspondingly small. In plutons such as the Elbow Lake tonalite, the lack of easily recognizable or mappable compositional or textural variants makes it difficult to resolve the structural complexity within the pluton.

3.0 Structural Geology

3.1 Introduction

Felsic intrusive rocks of the Iskwasum Lake sheet allow for qualitative and quantitative interpretation of the structures and deformation events within the area. Major faults and shear zones, both within and adjacent to plutons, aid in determining the timing of deformation events, and constrain the timing of tectonic events which shaped the geology of the area. When combined with precise geochronological data, the crosscutting relationships between plutonic rocks and the structures in the area will quantify and constrain limits on timing of deformation.

In the Elbow Lake sheet, immediately north of the Iskwasum Lake sheet, U-Pb geochronology by Whalen and Hunt (1994) aids in the interpretation of the Elbow Lake shear zone and associated structures. The extrapolation of dated lithologic units into the Iskwasum Lake sheet allows for bracketing the age of structures in the study area. This section will deal primarily with faults and shear zones of felsic intrusive rocks in the Iskwasum Lake sheet. In most cases these features also affect the surrounding supracrustal packages, suggesting that they are related to regional deformation rather than internal fabrics related to pluton emplacement.

In his structural interpretation of the western half of the map sheet Syme *et al.* (1994) delineated eight deformation events in the area (see Table 1). Deformation includes brittle, ductile and brittle-ductile features, but the most pronounced features in the area are ductile and brittle-ductile shear zones. These include the Elbow Lake, Loukes Lake and Flag Lake/West Reed-North Star (herein reffered to as the West Reed-North Star shear zone) shear zones and the Berry Creek fault (figure 10). Brittle deformation is pervasive, but in general does not produce such spectacular features as the ductile shear zones. The most significant brittle feature in the Iskwasum Lake sheet is the Barb Lake fault (see figure 10). Of the main deformational features in the Iskwasum Lake sheet, the Barb Lake fault and the Loukes Lake shear zone have the greatest effect on felsic intrusive bodies. The Elbow Lake shear zone is contained entirely within supracrustal rocks, while the Flag Lake shear zone contains felsic and mafic intrusive lithologies and mafic supracrustal rocks. Recent work by Syme *et al.*

Table 1. *Summary of main fabric generations in the Iskwasum Lake sheet (modified after Syme, 1994). a "*" indicates the main structural feature, if present.*

Generation	Trend	Structures, fabrics, age relationships
D_0	N-NNE	* primary ***bedding and flow contacts*** in McDougall's Point basalt
D_1	N-NNE	- weak ***bedding-parallel foliation*** in McDougall's Point basalt, - N-trending foliation in Iskwasum mafic complex, Center Lake mafic tectonite,
D_2	Folded: NE, WNW, NW, NNE	* ***Elbow Lake shear zone*** on Iskwasum Lake; West Reed-North Star/Flag Lake shear zone? - juxtaposes McDougall's Point basalt against Center Lake mafic tectonite and Iskwasum mafic-ultramafic complex - dominant mylonite/tectonite fabric on Iskwasum Lake - associated penetrative foliation extends >1 km into wall rocks
D_2-D_3?	N-NNE	* ***Barb Lake fault***; brittle deformation in plutons and supracrustal rocks - age relationships particularly apparent by the offset of the Barb Lake fault by the D_2 Elbow Lake shear zone, and the D_3 East Iskwasum shear zone
D_3	NNW, N	* N-trending ***East Iskwasum shear zone*** - crenulation cleavage to mylonitic foliation, mainly in Iskwasum mafic complex - D_3 cleavage overprints D_2 foliation
D_4	N	* ***S-trending faults***, Grass River area - dextral and sinistral offset of folded Elbow Lake shear zone - shear fabric within and adjacent to some faults, locally overprinted by S_6 spaced cleavage
D_5	W	* ***Berry Creek fault*** - dextral fault\shear zone - dextral deflection of Elbow Lake shear zone, Loukes Lake shear zone and Gants Lake batholith into a westerly trend - associated ENE-trending F_5 folds in Loukes Lake mylonite, D_6 axial planar spaced fractures - S_5 ultramylonite zones adjacent to the Berry Creek fault on southern Iskwasum Lake - W-trending spaced fabric in Gants Lake batholith within 2 km of the Berry Creek fault, overprinting D_2 structures
D_6	NE	- ***NE-trending regional cleavage*** - spaced chlorite crenulation cleavage, spaced fracture cleavage, spaced quartz-filled cleavage; - minor penetrative foliation, includes cm-m scale ductile shear zones on southern Iskwasum Lake; - overprints D_2, D_3 and D_4 fabrics on central and northern Iskwasum Lake, Grass River - same generation as D_8?
D_7	NE	* ***NE-trending shear zone***, southern Iskwasum Lake - truncates S_3 East Iskwasum shear zone. S_7 tectonite/mylonite fabric overprints and re-orients D_3 cleavage, and is axial planar to F_7 folds in D_3 cleavage - anastomosing dextral shears developed in and coplanar with S_2 shear zone, southern Iskwasum Lake
D_8	N	* ***East Iskwasum fault*** - truncates NE-trending S_7 shear zone, southern Iskwasum Lake - cuts across the S portion of the Gants Lake batholith reoriented into the S_5 Berry Creek direction - well developed shear fabric within and adjacent to the fault, including in the S_7 zone - spaced cleavage and minor shear zones in Gants Lake batholith, locally overprinting W-trending D_5(?) structures, within 1 km of the fault

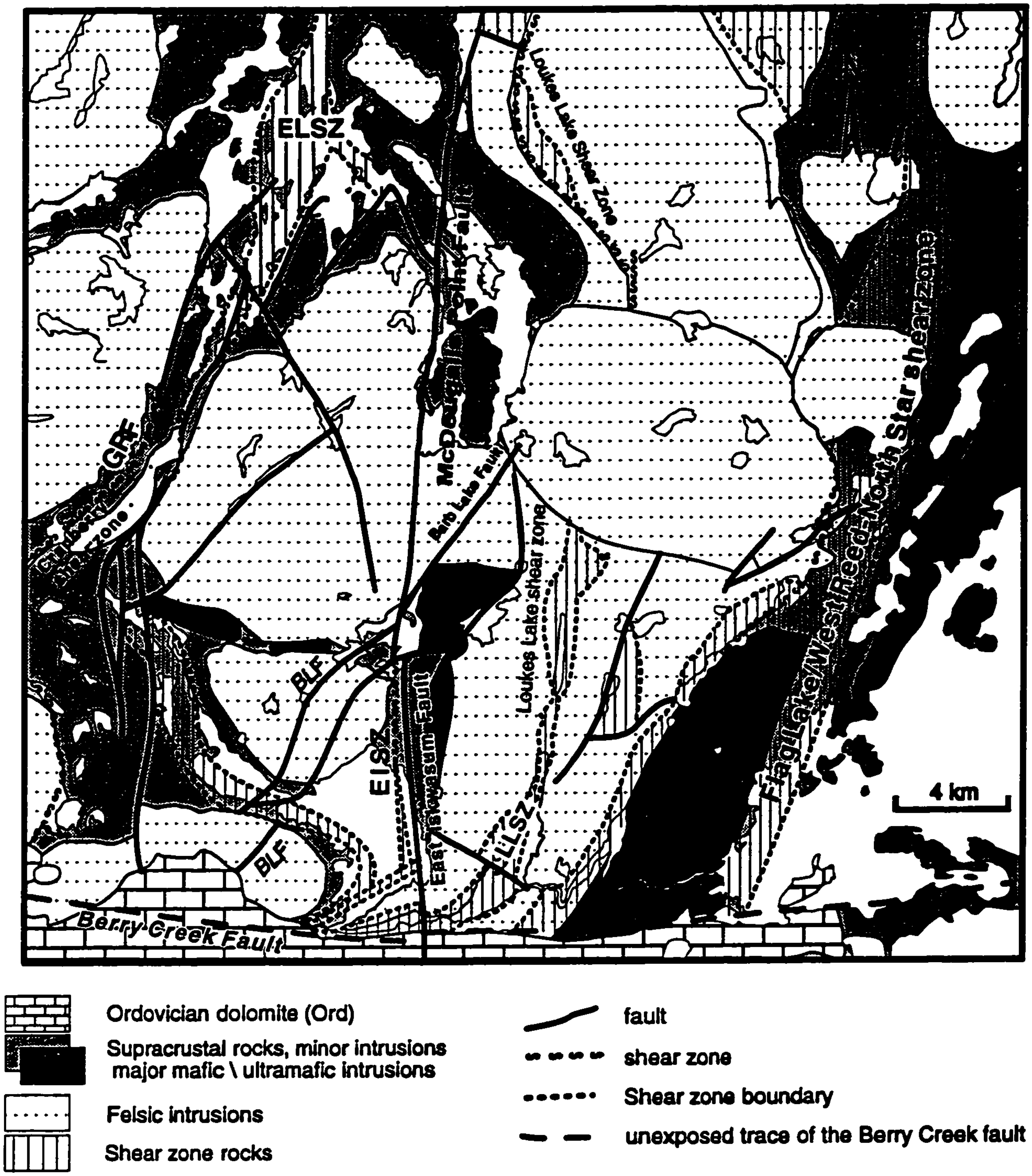


Figure 10. *Names of major structural features within the Iskwasum (NTS 63K\10) and southern Elbow (NTS 63K\15) Lake sheets. Abbreviations: BLF=Barb Lake Fault; LLSZ=Loukes Lake Shear Zone; ELSZ=Elbow Lake Shear Zone; EISZ=East Iskwasum Shear Zone; GRF=Grass River Fault. All fault and shear zone names are from Syme et. al., 1995, Syme, 1994 and Morrison and Whalen, 1994. The locations of the Loukes and Flag Lake/West Reed-North Star shear zones in the northern portion of the map is only suggested based on similarities in lithology, texture and macroscopic appearance. No attempt has been made to look at the structural similarities between them. For simplicity many of the faults have been omitted from this diagram. For more detailed geology of the Iskwasum Lake area see map 1 in the pocket. For more detailed geology of the Elbow Lake sheet see Whalen, 1993a (map 2 in the pouch). (Modified after Morrison and Whalen, 1994).*

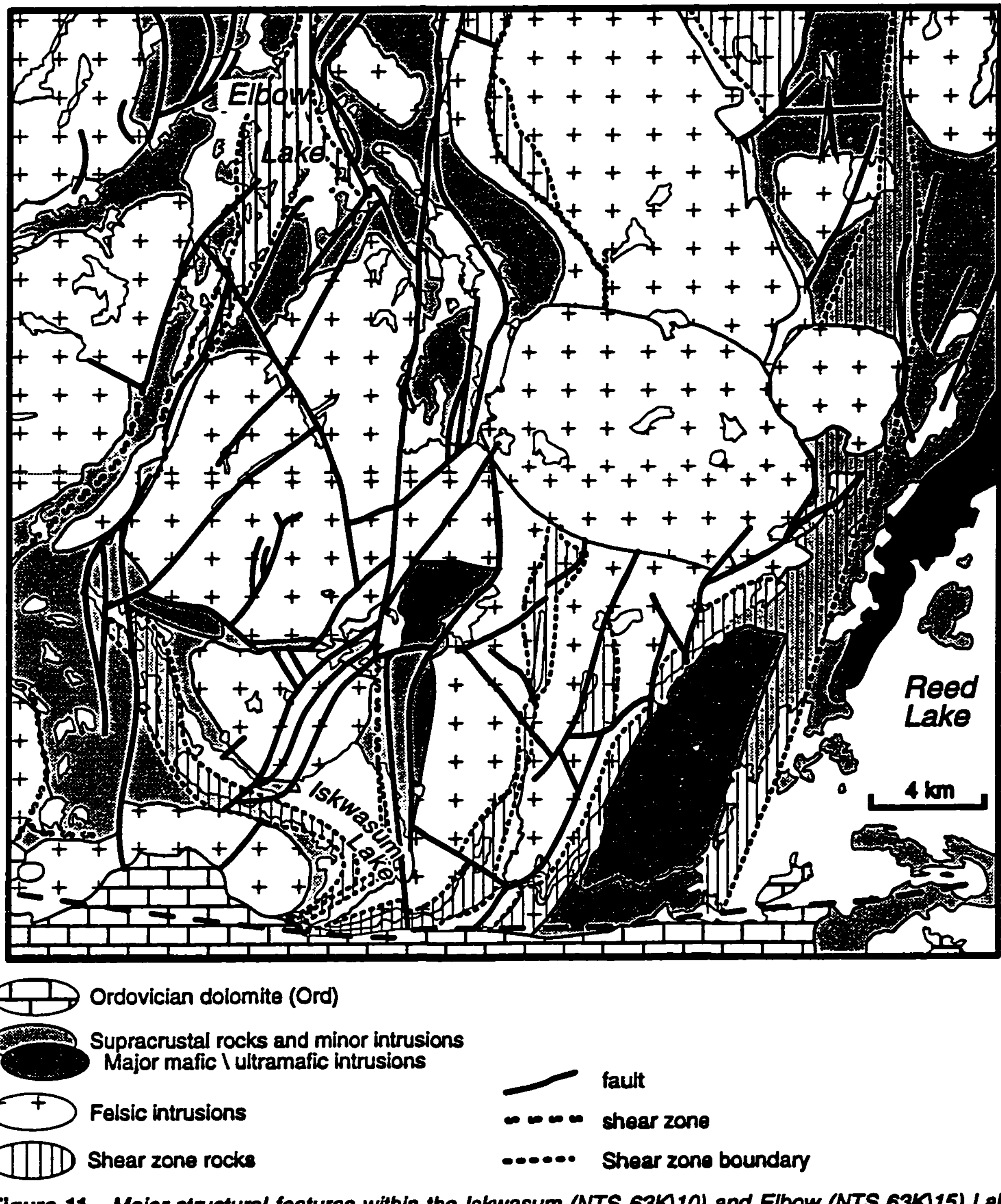


Figure 11. *Major structural features within the Iskwasum (NTS 63K\10) and Elbow (NTS 63K\15) Lake sheets. Subdivision of the geology is into supracrustal, felsic intrusive, mafic intrusive and Ordovician dolomite. Note the relationship between shear zones (including felsic-mafic tectonite) to the felsic intrusive rocks in the area. This diagrams illustrates the propensity for brittle deformation within felsic intrusive rocks, but also shows that ductile deformation is also present, dominantly in the Gants Lake batholith. The diagram also shows the continuation of many of the structural features in the Iskwasum Lake sheet into the Elbow Lake sheet to the north. For the names of the shear zones and major faults see figure 9. For a more detailed geology of the Iskwasum Lake area see map 1 in the pocket. For a more detailed geology of the Elbow Lake sheet see Whalen, 1993a (map 2 in pouch). (Modified after Morrison and Whalen, 1994).*

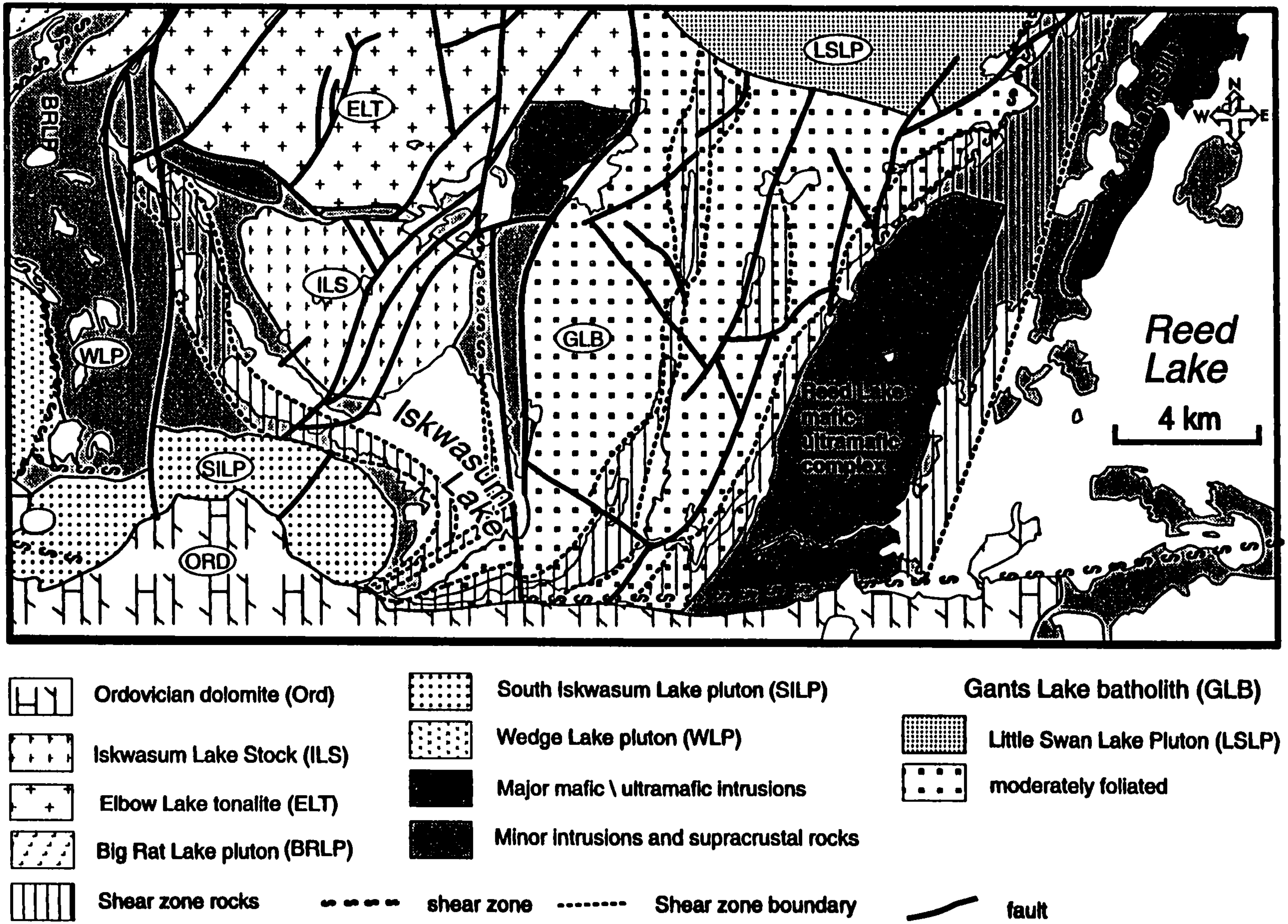


Figure 12. *Major structural elements in the Iskwasum Lake sheet. For a more detailed structural framework refer to map 1 in the pocket. For shear zone names refer to figure 9.*

(1995) on the supracrustal rocks and structures in the eastern half of the map sheet has delineated five dominant structural fabrics east of the Gants Lake batholith. Correlation of structures across the east and west portions of the map sheet has at present not been undertaken, and will be mentioned only briefly in the following sections.

3.2 Ductile deformation

Ductile deformation in the Iskwasum Lake sheet has produced four major shear zones; the Loukes Lake, Elbow Lake, and the West Reed-North Star shear zones, and the Berry Creek fault (figures 10 and 11). This deformation is responsible for much of the fabric within the Gants Lake batholith, as well as the supracrustal rocks in the area. These structures, which allow for analysis of the tectonic and structural history of the area, are dicscussed separately below.

3.2.1 Elbow Lake shear zone

The Elbow Lake shear zone is a significant feature within both the Elbow Lake (Syme, 1992; Ryan and Williams, 1993, 1994, 1995) and Iskwasum Lake sheets (Syme, 1994; Morrison and Whalen, 1995) (figures 10 and 11). Ryan and Williams (1993, 1994) interpret the shear zone as a complex and long-lived structure which was activated prior to the emplacement of the 1864 Ma Elbow Lake tonalite (Whalen and Hunt, 1994) and outlasted peak metamorphism in the area (1830-1805 Ma, Gordon *et al.*, 1990; David *et al.*, 1993). Evidence for this is the presence of tectonite fragments within the Elbow Lake tonalite, and the structure offsetting metamorphic isograds. Geochemical investigations by Stern *et al.* (1995a) show that the Elbow Lake shear zone juxtaposes oceanic island basalts to the east and volcanic arc assemblagesto the west in the Elbow Lake sheet.

In the Elbow Lake sheet, the Elbow Lake shear zone narrows to the north and south, from 2200 m wide within Elbow Lake to 50 m wide in the Grass River outlet (Syme, 1991). Reconnaissance geology by Syme (1994), and Ryan and Williams (1995) suggests that the Elbow Lake shear zone extends south into the Iskwasum Lake sheet. In the northern part of the Elbow Lake map sheet, folding within the shear zone is interpreted as reflective of N-S shortening due to sinistral transpression in the Elbow and Cranberry Lake sheets (Ryan and Williams, 1995).

In the south, the shear zone has been dextrally-rotated in proximity to the Berry Creek fault, creating a large-scale drag fold. On Iskwasum Lake, it is localized within various mafic rocks, forming a 60-900 m wide corridor of tectonically laminated basalts and gabbros with minor felsic sheets (Syme, 1994). In most locations the shear zone marks the boundary between the Center Lake mafic-ultramafic complex and McDougall's Point basalt. At the north end of Iskwasum Lake a discrete fault splays off from the Elbow Lake shear zone in a more northerly direction, forming the same boundary (Syme, 1994).

The shear zone has been studied in more detail in the Elbow Lake sheet, but is similar in style, and intensity and complexity of deformation within the Iskwasum Lake sheet. The reader is referred to Syme (1991, 1994) and Ryan and Williams (1993, 1994) for a more detailed description of the shear zone in both of these locations. In the Iskwasum Lake sheet, Syme (1994) has interpreted the Elbow Lake shear zone as a D_2 structure. This is based on relationships between the shear zone, primary bedding and bedding-parallel foliations, and post-D_2 structures. Felsic intrusive rocks at the margins of the shear zone are not deformed to the same extent that the supracrustal rocks are, and this may be attributed to competency contrasts between the two lithologies or as D_2 deformation being constrained entirely to the period before emplacement of the intrusions. Lack of deformation due to competency contrasts is not likely to be the only factor, given the timing of deformation features in the Elbow Lake sheet, and a combination of competency contrasts and deformation timing is proposed. This supports the hypothesis put forth by Syme (1991, 1994) and Ryan and Williams (1993, 1994) that the Elbow Lake shear zone has had a protracted deformation history.

Further evidence for a protracted deformation history for the Elbow Lake shear zone is shown by the presence of xenolith-rich zones at the margins of the Elbow Lake tonalite and the Iskwasum Lake stock. In these zones, where the intrusions are in close proximity to shear corridors, previously sheared xenoliths of proximal wall-rock lithologies predominate. In general, the larger xenoliths in these zones (some xenoliths are up to 20 m wide) have retained their original orientation, suggesting that they did not sink far into the magma chamber. Smaller xenoliths however, rotated from their original orientation. Folding within the xenoliths is common, but there is none within the pluton. In addition, the foliation within the pluton is terminated at xenolith margins. Although the marginal phase of the pluton is strongly foliated, it may be no stronger than would be expected to have formed due to the emplacement of the intrusion, and is consistent even where sheared rocks are not in close proximity (a contact-subparallel mineral foliation throughout the pluton). The foliation is subparallel to the pluton margin, and is consistent with its derivation during pluton emplacement. It is interpreted as having intruded into already deformed mafic supracrustal rocks. This does not however, preclude a protracted deformation history for the Elbow Lake shear zone, but rather suggests that significant deformation took place prior to emplacement of the pluton, but did not have a significant effect on it.

Based on age constraints from the Elbow Lake sheet, timing of the Elbow Lake shear zone is broadly constrained as having been active prior to 1869 Ma (emplacement of the Elbow Lake tonalite, Whalen and Hunt, 1994) to post 1830-1805 Ma (peak metamorphic conditions, Ryan and Williams, 1993, 1994; Gordon *et al.*, 1990). Although timing of peak metamorphism has not been determined in the Iskwasum Lake sheet, it is presumed to be similar to that found elsewhere in the Flin Flon belt, suggesting similar timing relationships as in the Elbow Lake sheet. Within the Iskwasum Lake sheet, the shear zone affects the 1901 Ma mafic volcanic and intrusive package (based on U-Pb geochronologic data on mafic synvolcanic intrusions (Stern *et al.*, 1995), but is intruded by 1869 Ma plutons intrusions (Elbow Lake tonalite and Iskwasum Lake stock; (*note- there is no geochronologic data available for the Iskwasum Lake stock, but the petrologic and textural similarities to the Elbow Lake tonalite suggests that they are of similar age). This confirms the oldest age constraint on the initiation of deformation on the Elbow Lake shear zone to a period between 1901 and 1869 Ma.

3.2.2 Loukes Lake shear zone

The previously unrecognized Loukes Lake shear zone is represented by a zone of variably mylonitized granitoid rocks (figures 10 and 11). Only one thin (150 m wide) sliver of mafic tectonite was recognized within the 1500 m wide shear zone on the southeast shore of Loukes Lake (figure 12). The Loukes Lake shear zone, which separates eastern and western portions of the Gants Lake batholith in the Iskwasum Lake sheet, anastomoses in a broadly north-south direction. To

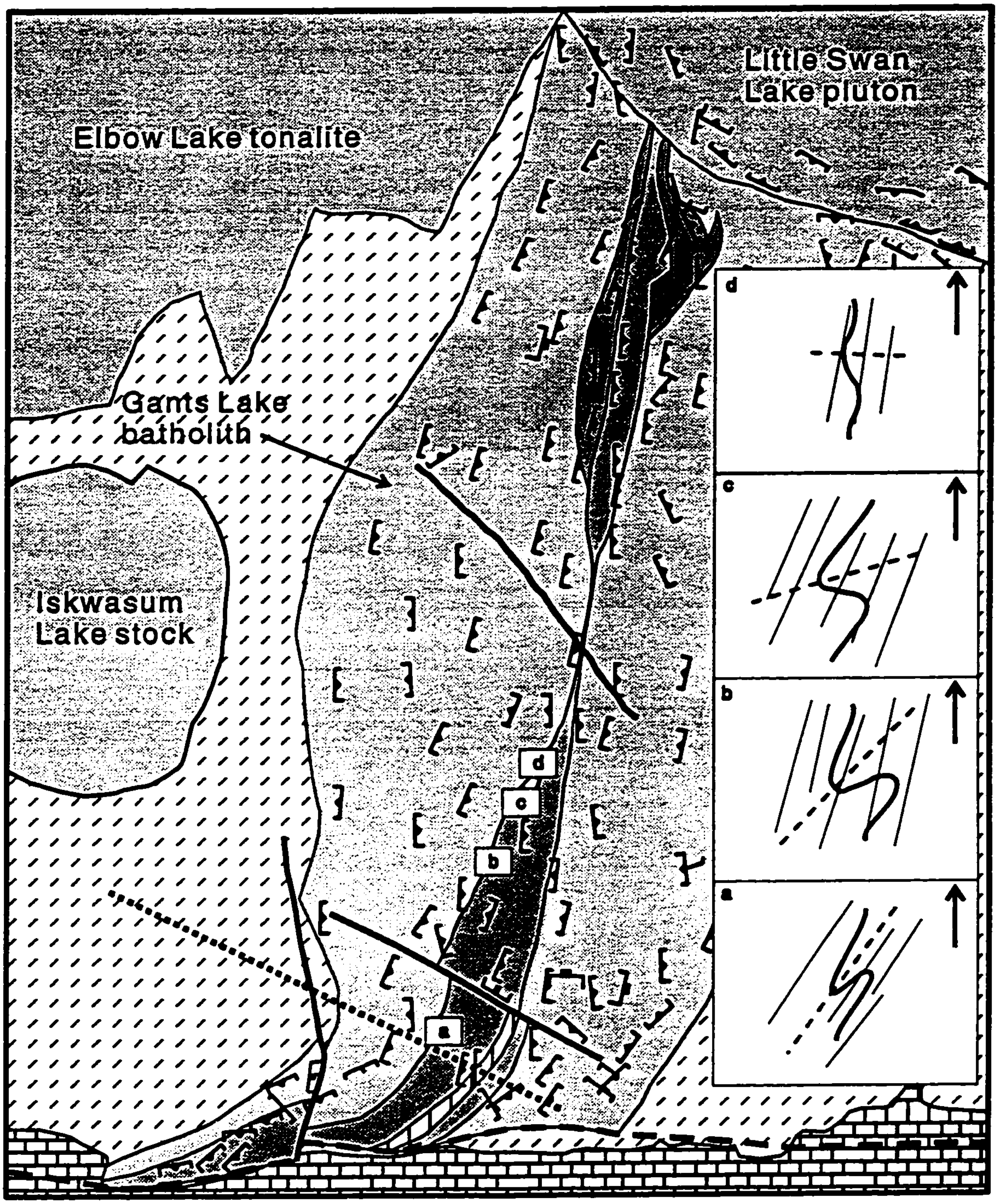


Figure 13. *Structural features in the Gants Lake batholith and Loukes Lake shear zone. Structural features in the Gants Lake batholith host and other granitic intrusions are omitted. Insets a) to d) represent a schematic summary of fold characteristics from south to north; Thin continuous lines=main mylonitic fabric; heavy continuous lines=pegmatite veins; thin dashed lines=fold axial trace. For reference, the axial plane of the fold generated by the dragging of the Loukes Lake shear zone into the Berry Creek fault is shown in the main diagram as a thick, dotted line. Notice that folds generally become more open further from the Berry Creek fault, and axial planes to these folds rotate into the folded Gants Lake batholith and Loukes Lake shear zone axial plane. Key to diagram in Table 2.*

Table 2. *Key to structural symbols and lithologies in Figure 12. Symbols are modified from the NATMAP symbol library.*

	FOLIATION, generation unknown.
	FOLIATION, first generation (relative to unknown generation).
	FOLIATION, second generation (relative to unknown generation)
	SHEAR ZONE (outcrop scale) sense unknown
	JOINT
	FOLD AXIAL PLANE, generation unknown
	FOLD AXIAL PLANE, second generation
	Fault
	Berry Creek fault
	Mafic supracrustal rocks, synvolcanic intrusions and minor felsic intrusions
	Granitic intrusions
	Felsic mylonite of the Loukes Lake shear zone
	Felsic-mafic tectonite of the Loukes Lake shear zone
	Gneissic component of the Loukes Lake shear zone
	Ordovician dolomite

the north it first pinches out, then reappears on an unnamed lake north of Loukes Lake, and to the south it is deformed into a dextral drag fold near the Berry Creek fault. Intensity of deformation generally decreases away from the center of Loukes Lake. An abrupt change from mylonitic to strongly foliated granitoid rock is marked to the west by a long linear swamp, and is attributed to late north-northeast brittle structures along the western margin of the shear zone. Granitoid rocks east of the shear zone are strongly deformed only at the extreme northern end of Loukes Lake; other exposures on the south and central east side are much less deformed.

As the Loukes Lake shear zone thins to the north, it grades into a gneissic unit. Further north, on the aforementioned unnamed lake, the mylonite reappears and continues north until it is transected by the Little Swan Lake pluton near the northern margin of the map sheet. Deformation intensity gradually decreases from

Table 3. *Summary of main fabrics seen in the Gants Lake batholith; 1. Ryan and Williams, 1995.*

Generation	*Trend*	*Structures, fabrics, age relationships*
D_1	NNE to N	Loukes Lake shear zone Flag Lake shear zone -compositional banding and mineral alignment
D_2	E-W, ENE	Berry Creek fault - E-W orientation of the Gants Lake batholith on the Grass River between Iskwasum and Loukes Lakes * dextral dragging of the Gants Lake batholith and Loukes Lake shear zone into an E-W orientation * kink band axial planes and related fractures with a 110° orientation, axial planar to the fold in the batholith and created by the dragging of structures and lithologies into the Berry Creek fault (north of Loukes Lake) * D_2 mineral alignment at 110° overprinting the E-W Berry Creek fault fabric
D_3	ENE	Berry Creek fault - macroscopic isoclinal S-folding of the Berry Creek fault fabric on Iskwasum Lake related to late sinistral shear on the structure[1]
D_4 (D_2-D_5?)	ENE, NNE	Brittle faults - brittle deformation throughout the Gants Lake batholith - pre D_3 - post D_5?
D_5?	NNE	Little Swan Lake emplacement - ductile deformation related to emplacement. - mineral alignment subparallel to the pluton contact, immeadiately south of the pluton

mylonitic to strongly foliated within 500 m east and west of the lake. Further north in the Elbow Lake sheet, the shear zone is correlated with a major mylonite zone within the Gants Lake batholith, as outlined by Whalen (1993a, b) (figures 10 and 11). Except for a few minor east-west offsets, the shear zone continues in a north-south-direction, from the north side of the Little Swan Lake pluton to the northern edge of the Elbow Lake sheet.

The Loukes Lake shear zone postdates or is contemporaneous to emplacement of the Gants Lake batholith. The shear zone cuts across lithologic boundaries, including quartz diorite, tonalite and granodiorite from south to north. Regardless of timing of initiation of the shear zone, it is apparent that continued deformation was significant after these units of the pluton were intruded. It is possible however, that the shear zone was initiated prior to emplacement of the batholith, and continued deformation or reactivation of the shear zone occurred after emplacement. Further work is needed to evaluate this hypothesis. Porphyritic granodiorite, which is the primary lithology west of Loukes Lake, resembles a major plutonic unit on the northwest side of the Gants Lake batholith in the Elbow Lake sheet, where it is bounded on its western side by what is interpreted as a continuation of the Loukes Lake shear zone (Morrison and Whalen, 1994). This granodiorite unit, dated at 1876+7\-6 Ma (Whalen and Hunt, 1994), places a maximum age constraint on the shear zone. A minimum age constraint on the shear zone is obtained because an the 1828±5 Ma Little Swan Lake pluton (Whalen and Hunt, 1994) intrudes into the Gants Lake batholith and all structures within it.

Pegmatite dikes are emplaced into the Loukes Lake shear zone and are variably deformed, with the larger ones being typically less deformed than smaller varieties. Smaller pegmatite dikes (typically 1-3 cm wide) have been deformed in the shear zone to the point where single potassium feldspar porphyroclasts are strung out 1-10 cm apart. These porphyroclasts appear to be both fragmented and non-fragmented phenocrysts which have been dismembered from the original dike.

Although unambiguous shear sense indicators are seldom seen, winged porphyroclasts are observed on occasion. In general these indicate dextral shear, although some indicate sinistral shear (see Plate 10a). The complexity of deformation history is easily recognized when oriented thin sections of the Loukes Lake shear zone are viewed. Both dextral and sinistral shear sense indicators are present on a horizontal plane even in a single thin section, and overprinting relationships between the two are typically non-existent. The presence of opposite shear sense indicators may reflect a combination of oblique slip movement on the shear zone (the dip-slip component is best seen on a vertical plane), as well as being due to episodic movement directions. A second generation of deformation is recorded by the presence of mineral alignments (typically biotite) overprinting D1 structures. D_2 structures consistently trend at 110° in the southern portion of the shear zone (on Loukes Lake) regardless of their proximity to the Berry Creek fault, and are axial planar to the fold generated by the dragging of the Loukes

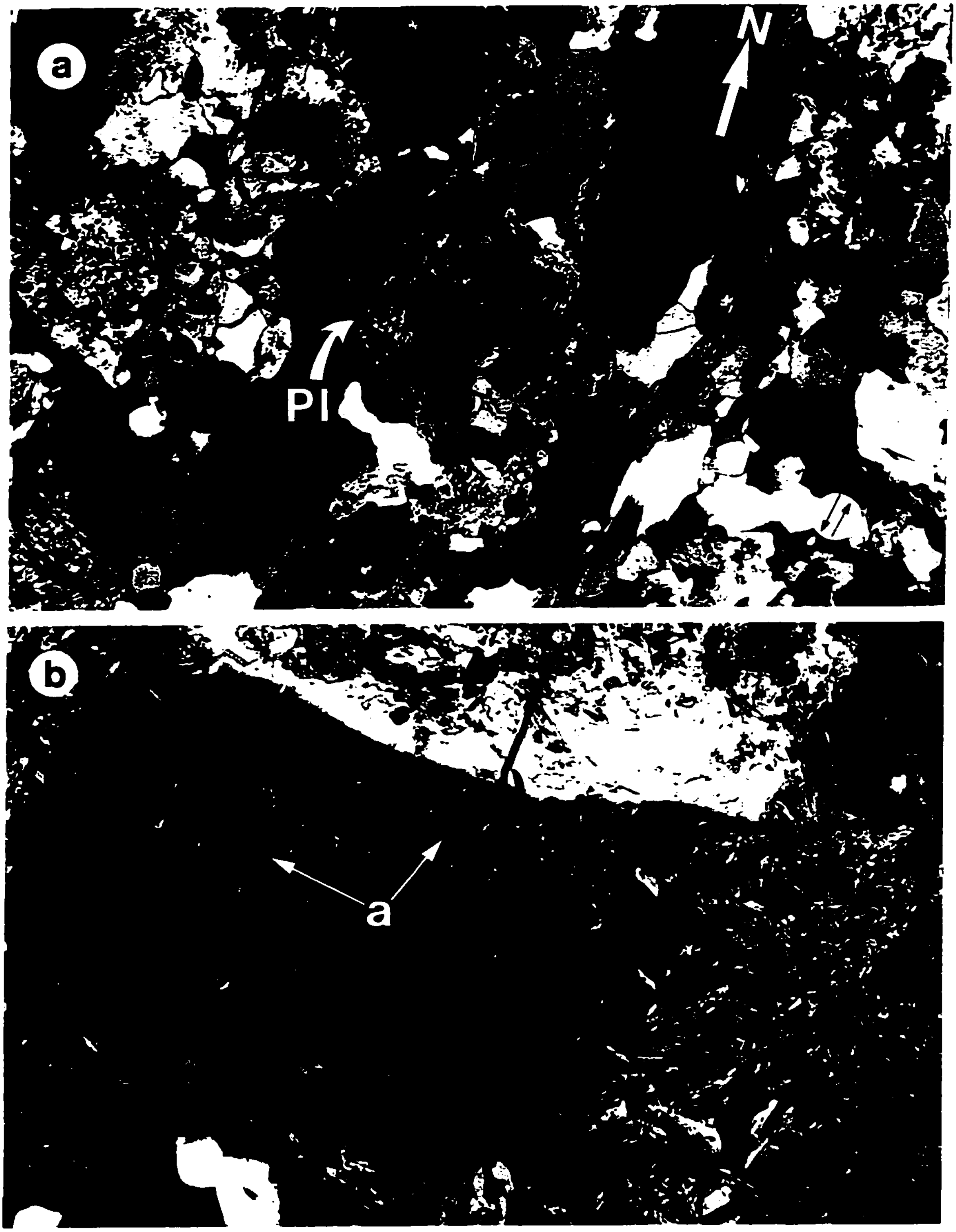


Plate 10. *Photomicrographs of; (a) Large, highly altered plagioclase (Pl) phenocryst in the Loukes Lake shear zone, towards the north end of Loukes Lake. Pressure fringes of muscovite and biotite help define a sinistral shear sense; (b) Oscillatory zoning in a large plagioclase phenocryst from the South Iskwasum Lake pluton. Notice the preferential alteration to sericite around the core of the phenocryst (shown as an a). Field of view is 2 mm.*

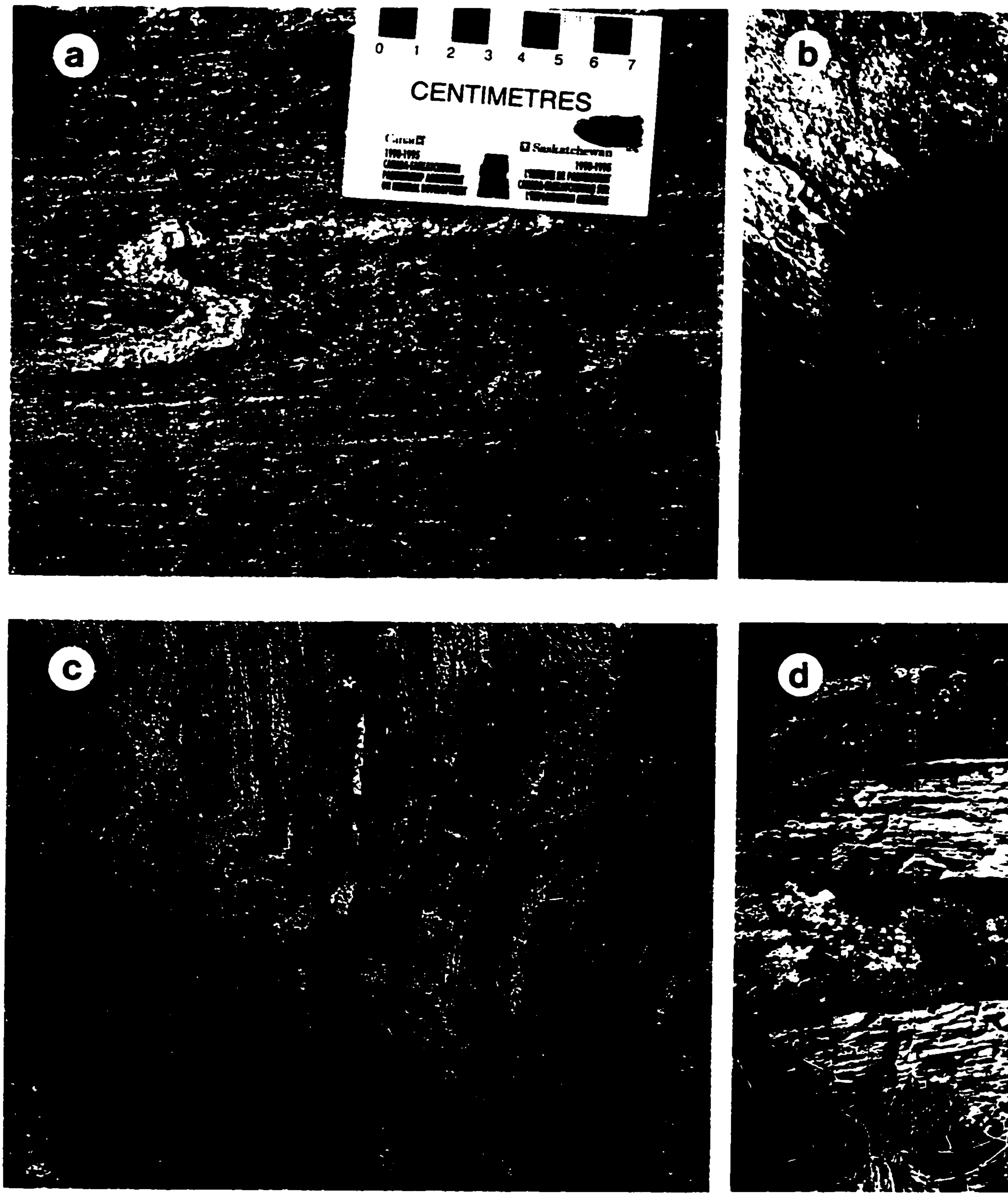
Lake shear zone into the Berry Creek fault. Kink fold axial planes, as well as fractures and mineral alignments have this orientation, but their relation to the primary compositional banding depends on proximity to the Berry Creek fault. Nearest to the fault, on the Grass River between Loukes and Iskwasum lakes the S_2 mineral alignment is at a low oblique angle to the generally east-west orientation of the S_1 compositional banding. Further north on the west shore of Loukes Lake, kink fold axes are at a high oblique angle to the general north-south orientation of the compositional banding.

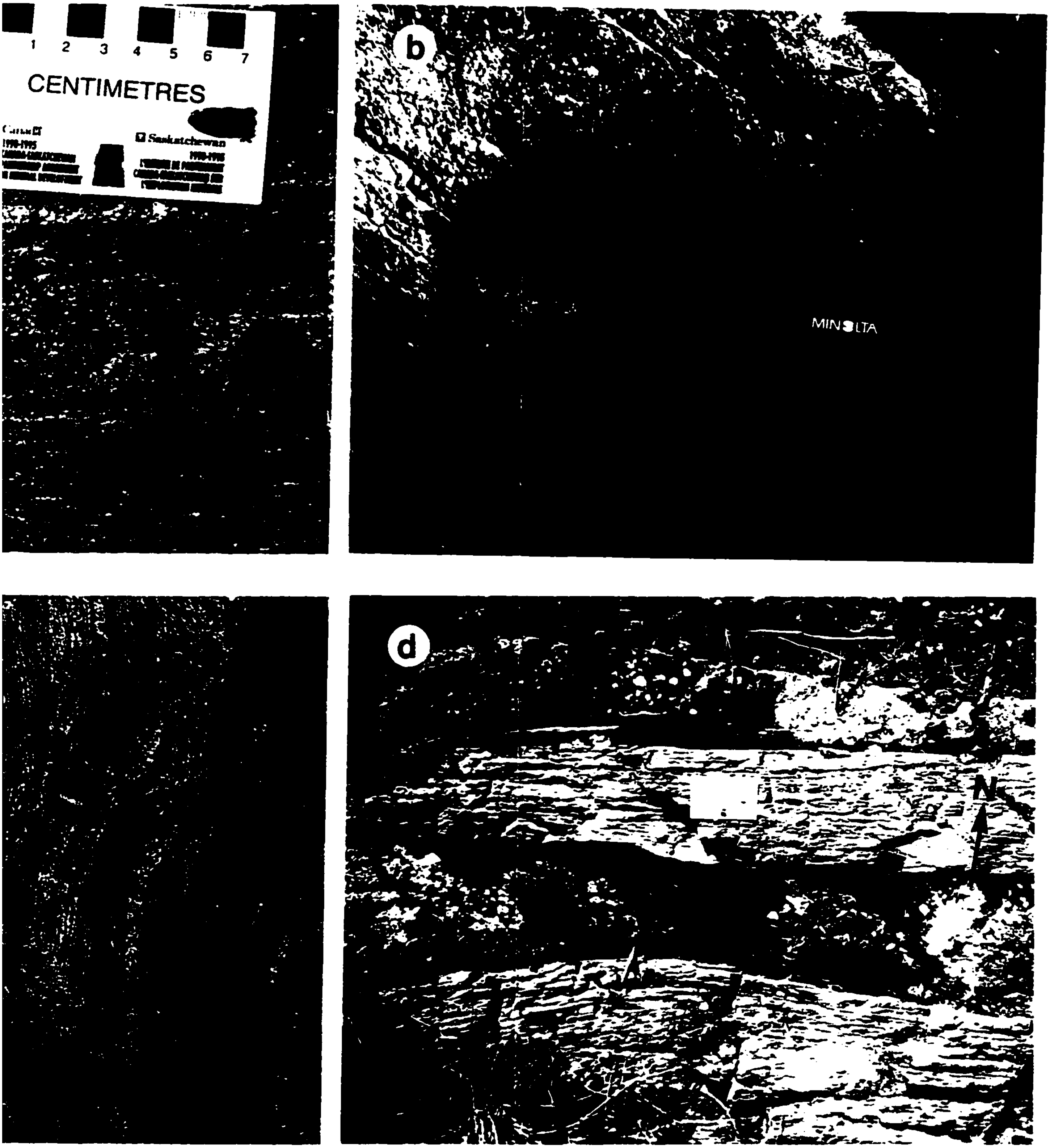
Effects of the Berry Creek fault are subsequently lost further north on an unnamed lake north of Loukes Lake and are replaced by an S_3 mineral alignment related to the emplacement of the Little Swan Lake pluton. This overprinting foliation contrasts the D_2 structural features recognized further south in that it is oriented at 022°, and roughly parallels the contact of the Little Swan Lake pluton immediately north.

On Loukes Lake there is a change in the style of folding of pegmatite dikes from south to north (see figure 13). In the south tight to isoclinal S-folds, with axial planes subparallel to the main mylonitic fabric give way to more open S- and Z-folds to the north. The axial planes of these folds rotate into the axial plane of the large fold in the Gants Lake batholith and Loukes Lake shear zone created by their being dragged into the Berry Creek fault, northwards (Plate 11a and 11b). Z-folds are tighter than S-folds in the north, but appear to be almost entirely related to late shear zones crosscutting the mylonite (Plate 11c). These shear zones are also subparallel to the large fold in the Gants Lake batholith and Loukes Lake shear zone created by the Berry Creek fault.

3.2.3 West Reed-North Star/Flag Lake shear zone

The Flag Lake shear zone, as defined by Morrison and Whalen (1995), is a north-northeast-trending zone of banded mafic-felsic mylonites on the western margin of Flag Lake, separating the Gants Lake batholith to the west from the Reed Lake mafic-ultramafic complex and mafic volcanic rocks to the east (figures 11 and 12). Reconaissance geology east of the Gants Lake batholith by Syme *et al.* (1995) indicates that this is a part of a much larger structure termed the West Reed-North Star shear zone. Although the interpretation of protoliths of the rocks


a
b
c
d
0 1 2 3 4 5 6 7
CENTIMETRES
Saskatchewan


1 2 3 4 5 6 7
CENTIMETRES
Saskatchewan
1990-1995
b
d
N

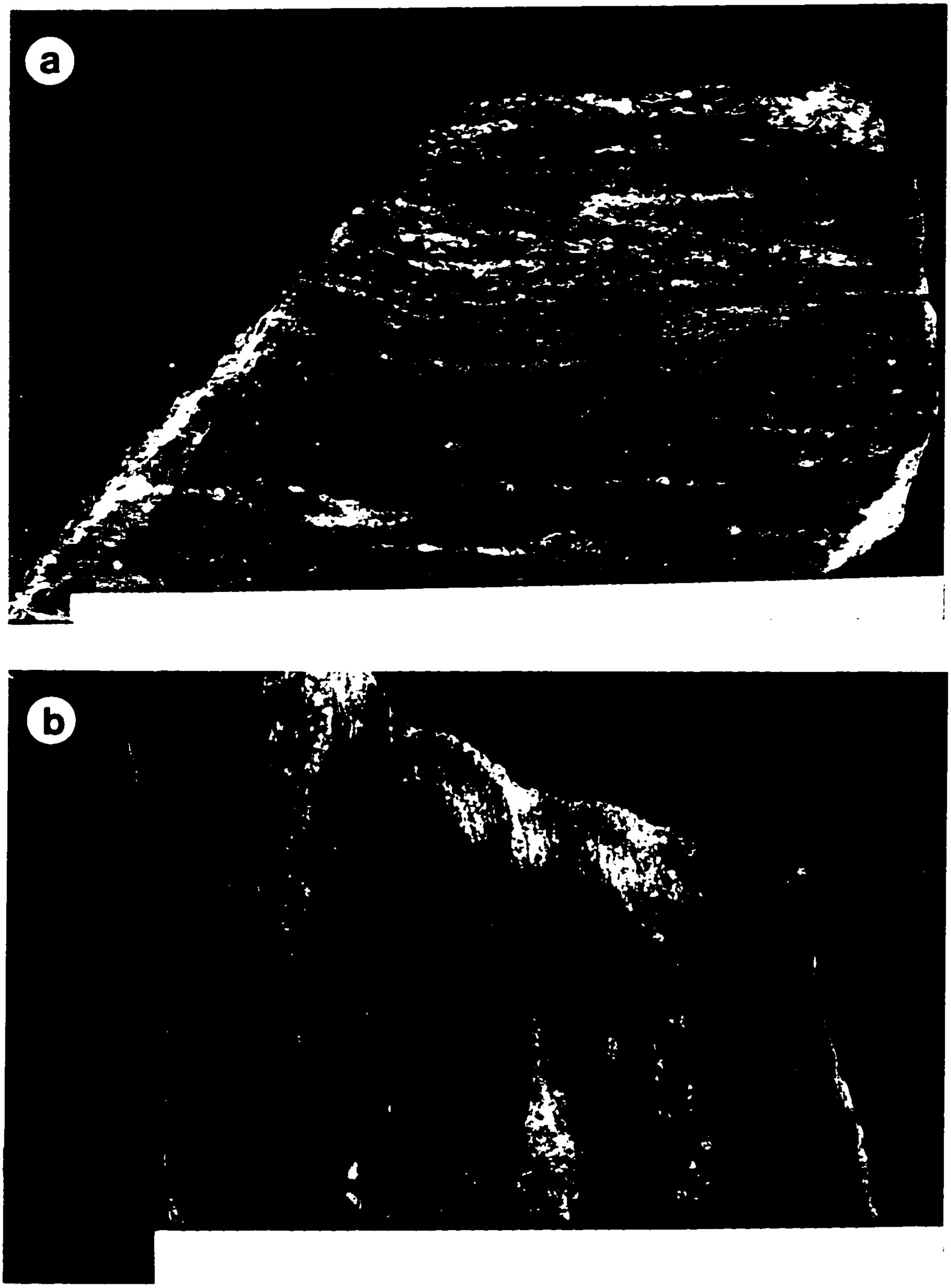


Plate 12. *(a) Fine-grained mylonite of the Loukes Lake shear zone. Pegmatite veins are extremely attenuated, and gentle folding of the fabric is attributed to movement on Berry Creek fault; (b) Banded mafic-felsic mylonite of the West Reed-North Star shear zone. Boudinaged and attenuated felsic layers and garnet porphyroblasts dominantly show symmetric relationships. Scale shown is in centimeters.*

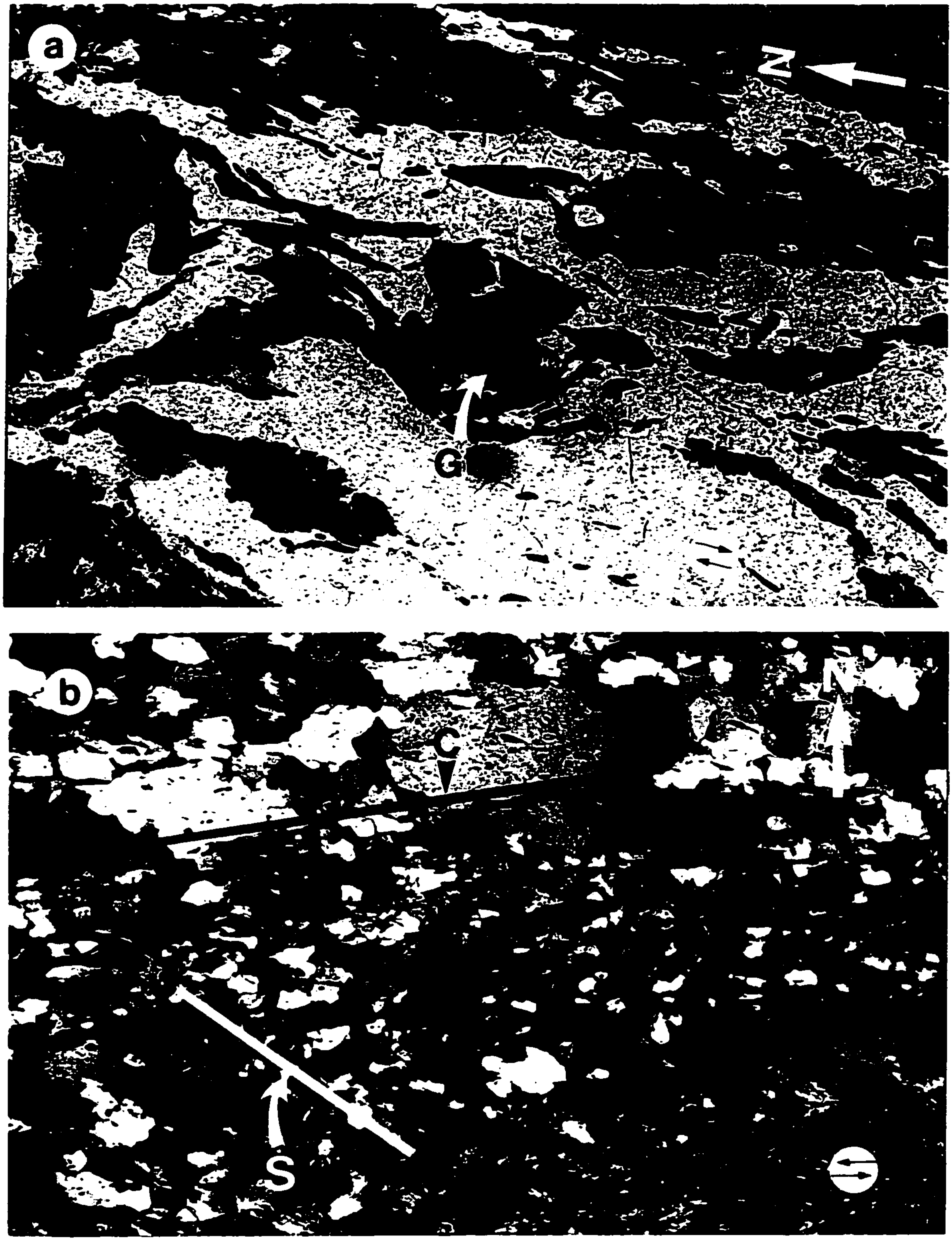


Plate 13. *Photomicrographs of (a) Dextrally rotated garnet (Gt) in banded mylonite of the West Reed-North Star shear zone, in plane-polarized light; (b) C-S fabric in mylonite of the Loukes Lake shear zone, near the Berry Creek fault. C and S fabrics are indicated by arrows. North direction and shear sense are shown in both photographs. Both photomicrographs are under crossed polars.*

at the eastern margin of the Gants Lake batholith is equivocal, this tectonite zone may represent a sheared mixture of the Gants Lake batholith and Reed Lake mafic-ultramafic complex. The shear zone is overlain in the south by Ordovician dolomite, and passes along strike to a felsic mylonite to the north, where it is eventually truncated by a north-northwest-trending fault. The shear zone is typically a fine-grained unit with a dominant banded appearance on Flag Lake, and no shear sense indicators were discerned in the field (Plate 11d). In thin section garnet porphyroblasts, presumably related to peak metamorphic conditions in the area, are consistently rotated with a sinistral sense of shear. They are partially replaced by opaque minerals and chlorite, and appear to have formed prior to, or during the dominant deformational period which created the Flag Lake shear zone.

The eastern portion of the Gants Lake batholith contains two fault-bounded blocks of felsic mylonite, situated between relatively undeformed granodiorite (figure 10). These mylonitic 150-900 m wide blocks have no clear relationship with respect to large scale structures in the area for they do not extend along strike, but do have a similar fabric orientation as other north-northeast trending structures in the area. They may represent fragmented parts of the Flag Lake shear zone, or of an earlier similarly orientated structure, for they are similar in appearance to mylonites seen further south on Loukes Lake.

The intensity of deformation in the West Reed-North Star shear zone wanes towards the western contact with relatively undeformed granitic rocks of the Gants Lake batholith. Like the Loukes Lake shear zone, shearing may have begun prior to the emplacement of the Gants Lake batholith. If this is true, it would suggest that the shear zone had a long and episodic deformation history, possibly recording numerous generations of deformation during reactivation events. This is consistent with many of the structures in the Iskwasum Lake sheet (Elbow Lake shear zone; Ryan and Williams, 1993, 1994, 1995; West Reed-North Star shear zone; Syme *et al.*, 1995). Conversely, evidence for an early initiation of the shear zone prior to emplacement of the pluton is lacking, possibly due to the effects of later episodes of deformation overprinting earlier fabrics.

Syme *et al.* (1995) have determined the West Reed-North Star shear zone to be a 5.5 km wide north-trending structure. Syme *et al.* (1995a) suggest the shear zone is a D_1 zone which was subsequently reactivated during D_{3a} deformation, and may correlate in time with the Elbow Lake shear zone, as it is similar in style and appearance. In the east the shear zone is compositionally banded, and has rare mylonitic belts which are typically overprinted by later deformation. This is similar to that described on the western margin of the shear zone. Since these intrusive sheets are in all cases layer parallel regardless of the bulk strain, and occur only in the shear zone, Syme *et al.* (1995a) suggest that they were emplaced during the initial phases of deformation. The shear zone is located on the eastern margin of the Reed Lake mafic-ultramafic complex, and although deformation has an effect on some of the mafic intrusive lithologies, it dominantly occurs in mafic supracrustal rocks.

The tectonic significance of this structure in the east is that it effectively transposes arc volcanic assemblages (Fourmile Island assemblage) to the east with ocean floor assemblages (Reed Lake mafic-ultramafic complex) to the west.

3.2.4 Berry Creek fault

The Berry Creek fault is a major E-W-trending shear zone which extends from Athapapuskow Lake through to Tramping and Wekuso Lakes (see figure 10 for the location of the Berry Creek fault in the Iskwasum Lake sheet). Though it is entirely overlain by Phanerozoic rocks and swamp in the western half of the Iskwasum Lake sheet, deformation associated with this fault has been recognized up to 5 km north of it. The Berry Creek fault is better exposed in the eastern half of the map sheet, where it is located north of the Phanerozoic cover. The fault has a north-side-down normal dip-slip component in this location (Syme, 1992; Lucas *et al.*, 1994), and in the Cranberry Lake area a sinistral sense of shear with a strong brittle component (Syme, 1993). This is not the case in the western half of the Iskwasum Lake sheet, where large-scale north-northeast-trending structures as well as the Gants Lake batholith are dragged into the shear zone with dextral asymmetry, showing strong ductile characteristics.

On a hand-specimen scale, fabrics of the Berry Creek fault overprint earlier fabrics within the Gants Lake batholith. This overprinting is so intense that, nearest to the fault it is difficult to separate the earlier fabric from the Berry Creek fault fabric. For up to 5 km northward, fabrics related to the fault continue to be seen, recognized as minor open to isoclinal folds, an axial planar foliation and late axial-planar brittle faults (see figure 13; Plates 11a to 11c). Based on thin section evidence from near the northern tip of Loukes Lake, a late kink banding parallel to the axial plane of the folded Loukes Lake shear zone overprints the earlier compositional banding of the Loukes Lake shear zone. At this location the axial planes of kinks are at a high angle to the compositional banding, but further south have lower angles with respect to it.

The Berry Creek fault almost completely transposes the original Loukes Lake shear zone fabrics in the southern portion of the shear zone, dragging the shear zone into an east-west orientation (Plate 11d). A second foliation is still apparent however, roughly axial planar to the larger folded shear zone. This suggests that there was not a complete transposition of the earlier Loukes Lake shear zone into the Berry Creek fault.

Isoclinal folds are commonly located nearer to the Berry Creek fault, and typically have an east-northeast orientation with S-fold asymmetry. These S-folds are attributed to sinistral shear after the early dextral shear which transposed structures and lithologic units in the south (Ryan and Williams, 1995). In the east, where the fault is better exposed, both brittle and ductile characteristics are recognizable (Syme *et al.*, 1995a). However, it is not certain whether shearing corresponds to a single deformational episode, or whether it represents a long-lived event initially related to collision with the Superior province. In the east, the shear zone is 1 km wide, and is dominated by finely laminated phyllonite, cataclasite seams, brittle fractures and pseudotachylite bands. The heterogeneity of structural types is indicative of a ductile-brittle transition in the fault zone (Syme *et al.*, 1995a), and is suggestive of a long-lived zone of deformation, including reactivation during post-Superior collision. In addition, the fault trace corresponds to a topographic discontinuity in much of the Iskwasum Lake area. High-standing Ordovician dolomites form up to 10 m high cliffs in the west half of the map sheet, and correspond to the inferred fault trace. Syme *et al.* (1995a) suggest that this may be due to reactivation of the shear zone during the Phanerozoic.

Although evaluation of the relationship between the exposed Precambrian rocks and structures north and south of the fault is hindered by the presence of overlying Ordovician dolomite in the west, vertical gradient aeromagnetic signatures on either side are significantly different. This may suggest that the Berry Creek fault forms the boundary between the Namew Gneiss complex in the south and exposed Precambrian lithologies in the north. It must be noted however, that gneissic phases of the Gants Lake batholith, particularly on the eastern shore of Iskwasum Lake are similar in appearance, mineralogy and texture to those seen in the Namew Gneiss complex, suggesting that these two packages of rocks are possibly the same.

Although the fault trace corresponds to a strong linear feature on vertical gradient aeromagnetic maps in both the west (where Precambrian rocks are not exposed south of the fault), and east halves of the map sheet (where Precambrian rocks north and south of the fault zone are exposed) there may not be significant movement along the zone. In the eastern half of the map sheet there is a continuity of lithologies across the fault. Syme *et al.* (1995a) note a continuation of many of the Fourmile Island assemblage units across the fault, while further east the fault juxtaposes west-facing basaltic units north of the fault with east-facing basalts to the south. In addition gneissic units of the Reed Lake pluton are juxtaposed with relatively undeformed units of the same pluton. Given the heterogeneous movements recorded along the shear zone, and the change from ductile to brittle deformation recorded in the east half of the map sheet, it is likely that the Berry Creek fault represents a structure initiated early in the tectonic history of the area, and was reactivated over a long period of time (possibly into the Phanerozoic).

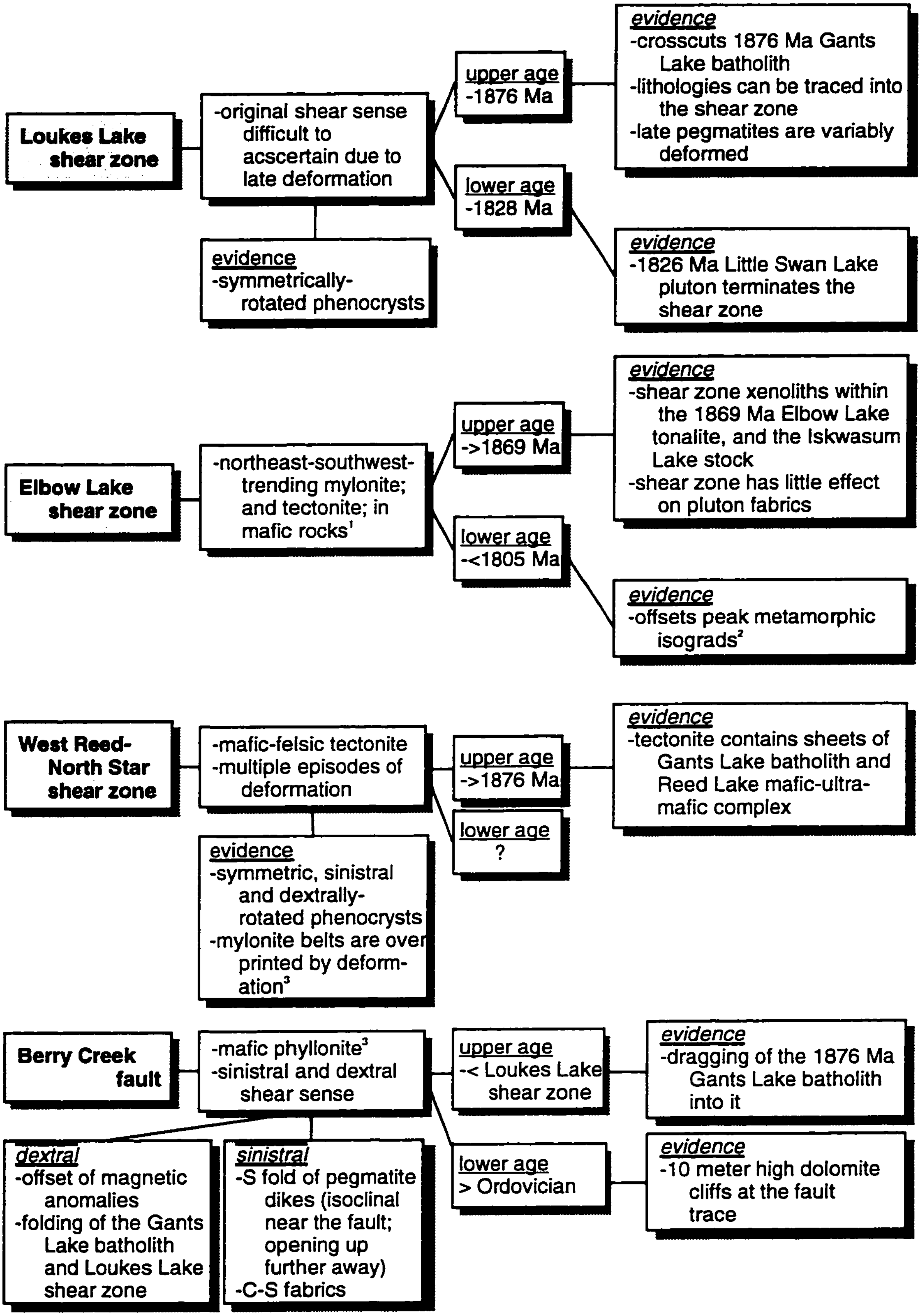


Figure 14. *Summary of shear zone characteristics in the study area; 1. Syme (1994); 2. Ryan and Williams (1994); 3. Syme et al. (1995). All geochronologic data is from Whalen and Hunt (1994) from correlative units in the Elbow Lake sheet.*

3.2 Brittle deformation

3.2.1 Introduction

North-northeast brittle deformation is prevalent in the granitoid rocks of the Iskwasum Lake sheet. Older plutons (i.e. the Elbow Lake tonalite, Iskwasum Lake stock, Gants Lake batholith and South Iskwasum Lake pluton) have significant brittle deformation features, typically recognizable by the presence of lithologic offsets and occasional fault-parallel fracture sets. These features, along with aerial photographic interpretation permit identification of these structures. However, the extent of brittle deformation is not always mapable at the 1:50 000 scale, and it is often apparent that more deformation exists.

In the Elbow Lake tonalite brittle deformation is so intense that mafic dikes and quartz stockworks can not be traced from one outcrop to the next, and often results in textural, compositional and alteration inconsistencies from outcrop to outcrop. In the Elbow Lake tonalite, parallel fracture sets are most significant in a series of discontinuous fault splays east of Barb Lake (figure 10). In this area a grain size reduction is also present. Rocks nearest the fault exhibit a fine-grained appearance rather than the quartz-biotite-porphyritic texture typical of the pluton.

Although the Iskwasum Lake stock is lithologically and compositionally similar to the Elbow Lake tonalite, there is a significant difference in the extent and style of brittle deformation present in each body. Brittle deformation in the Iskwasum Lake stock is dominated by a number of large structures, including the Barb Lake fault (figure 9 and 10), while the Elbow Lake tonalite is dominated by more abundant smaller-scale faults and fractures. In general, shear zones in these bodies are rare.

In the Iskwasum Lake stock, brittle deformation is concentrated predominantly along three north-northeast trending faults. The larger of these, the Barb Lake fault, is a significant feature transecting the pluton, supracrustal host rocks, and the South Iskwasum Lake pluton. In the Iskwasum Lake stock, the fault juxtaposes relatively unaltered and altered equivalents of plutonic phases. Based on Syme's (1994) structural interpretation of the western half of the map area, this fault is offset by the early Elbow Lake shear zone in the south, continuing into the south Iskwasum Lake pluton to the southeast. Parallel faults within the Iskwasum Lake stock east of the Barb Lake fault are however, truncated by it.

Since Syme (1994) and Ryan and Williams (1993, 1994) have interpreted the Elbow Lake Shear zone as an early (D_2) structure with a protracted deformation history, it is plausible that the Barb Lake fault crosscut the Elbow Lake shear zone during a period of hiatus. The D_3 East Iskwasum shear zone offsets the Barb Lake fault in Barb Lake. Thus the timing of brittle deformation in the pluton must therefore be constrained to post-D_2 and pre-D_3 deformation. In most cases north-northeast trending brittle faults truncate similar northwest-trending structures, but this is not always the case. This suggests that the multiple orientations of brittle faults in the Iskwasum Lake sheet granitoid plutons were approximately coeval, or that these are results of a conjugate fracture system.

The dominant deformation in the Gants Lake batholith is ductile, consisting of deformation related to the Loukes Lake, Flag Lake and East Iskwasum shear zones. Brittle deformation is similar to that seen within other plutons in the area, but associated parallel fracture sets and grain size reduction are not apparent. Brittle deformation may be responsible for the rapid decrease in strain at the western margin of the Loukes Lake shear zone, where a long, 50-200 m wide linear swamp marks the boundary between gneissic to mylonitic Loukes Lake shear zone rocks and moderately deformed Gants Lake batholith lithologies. This is not present on the eastern margin of the shear zone. Because lithologic variations within the batholith can be traced into the shear zone, it is presumed that lateral movement on the fault is minimal. This suggests a similar predominant dip-slip sense of movement as that seen on the Barb Lake fault (see section 3.2).

Younger plutons in the map sheet have generally escaped the brittle deformation which is prevalent in the older plutons. The 1845 Ma (Whalen and Hunt, 1994) Big Rat Lake pluton does not contain significant brittle deformation in the Iskwasum Lake or Elbow Lake sheet portions of the pluton (see Whalen, 1993a), nor does the 1828 Ma (Whalen and Hunt, 1994) ovoid Little Swan Lake pluton (Morrison and Whalen, 1994), which is emplaced into the older Gants Lake batholith in the northern portion of the map sheet This pluton is not only less altered than the Gants Lake batholith, but cuts north-northeast-trending structures that are predominant in it. This relationship applies to both brittle and ductile features, except on the eastern margin of the Little Swan Lake pluton where a north-northeast-trending fault passes through it (figure 10). This fault is later than others in the area, and is the only evidence that there was some tectonic deformation after the intrusion of the pluton. The same fault juxtaposes Little Swan Lake pluton lithologies to the west with Gants Lake batholith and gabbroic lithologies to the east. These features, as well as structural relationships between the Barb Lake fault and other deformation events in the area suggest that brittle deformation in the Iskwasum Lake sheet began early (post D_2 and pre-D_3), and continued until after the emplacement of the Little Swan Lake pluton.

3.2.2 Barb Lake fault

Brittle deformation in the Iskwasum Lake sheet is rarely as pronounced as near the Barb Lake fault. This fault is significant in that it transects three plutons; the Elbow Lake tonalite, Iskwasum Lake stock, and South Iskwasum Lake pluton. The importance of the structure is further delineated by the fact that it juxtaposes the Elbow Lake tonalite and the Iskwasum Lake mafic-ultramafic complex, as well providing constraints on timing of other deformational features in the area (figure 10). The Barb Lake fault is one of the north-northeast-trending structures that characterize the brittle deformation within the map sheet. It is a continuous fault from the southern margin of the shield to the northern margin of the map sheet, and is only offset by the D_2 Elbow Lake shear zone and the D_3 East Iskwasum shear zone (figure 10).

The Elbow Lake shear zone has been determined to represent a long-lived structure that initiated prior to emplacement of the pluton in the Elbow Lake sheet (Ryan and Williams, 1994), and since the Barb Lake fault was obviously initiated after emplacement of the Elbow Lake tonalite, Iskwasum Lake stock and South Iskwasum Lake pluton, This implies that the Barb Lake fault formed during a break in deformation along the Elbow Lake shear zone. These relationships constrain the Barb Lake fault to post-pluton emplacement, but prior to D_3 deformation.

In the South Iskwasum Lake pluton the fault juxtaposes fine- to medium-grained, and medium- to coarse-grained granodiorites. In the Elbow Lake tonalite, it forms a linear feature on the aerial photograph. However, the effects of the fault are best seen within the Iskwasum Lake stock, particularly at the pluton-wall rock contact.

The Barb Lake fault is not only more recognizable on both the map and the outcrop scale in the Iskwasum Lake stock, but the nature of movement on the fault can be determined. A long north-northeast trending swamp delineates the fault trace through all of the map sheet, but evidence for the presence and nature of the fault in the Iskwasum Lake stock is less equivocal. East and west of the fault, large cliff faces (up to 20 m high) are evidence for the presence of a significant structure. Fault-parallel fracture sets can be recognized up to 1 km from the fault and are most pronounced nearest the fault, where it results in a stair step appearance to the outcrop. Further from the fault, the fractures become less pronounced, until eventually they, and the stair step appearance die out. Fractures are generally parallel to subparallel to the fault, striking from 010°- 020°, and dipping steeply to the east. A weak conjugate fracture set is present near the fault. Conjugate fractures are much less pronounced than the parallel fracture set, and trend at approximately 075°, dipping steeply to the north. Although the fracture set weakens away from the fault, these orientations are consistent for up to 1 km from the fault..

The Barb Lake fault juxtaposes highly and moderately altered equivalents of Iskwasum Lake stock lithologies. East of the fault fracture-related alteration is pronounced, while pervasive alteration is more apparent to the west. Lithologic variations across the fault simply reflect juxtaposition of similar lithologies with varying degrees of alteration. Lateral offset of wall rock lithologies with respect to the pluton is minimal. Assuming that the pattern noted above reflects the lower and higher levels of the intrusion respectively, the fault is presumed to have an east side up movement. This, as well as the lack of a significant lateral offset of the pluton-wall rock contact, suggests a predominant dip-slip component

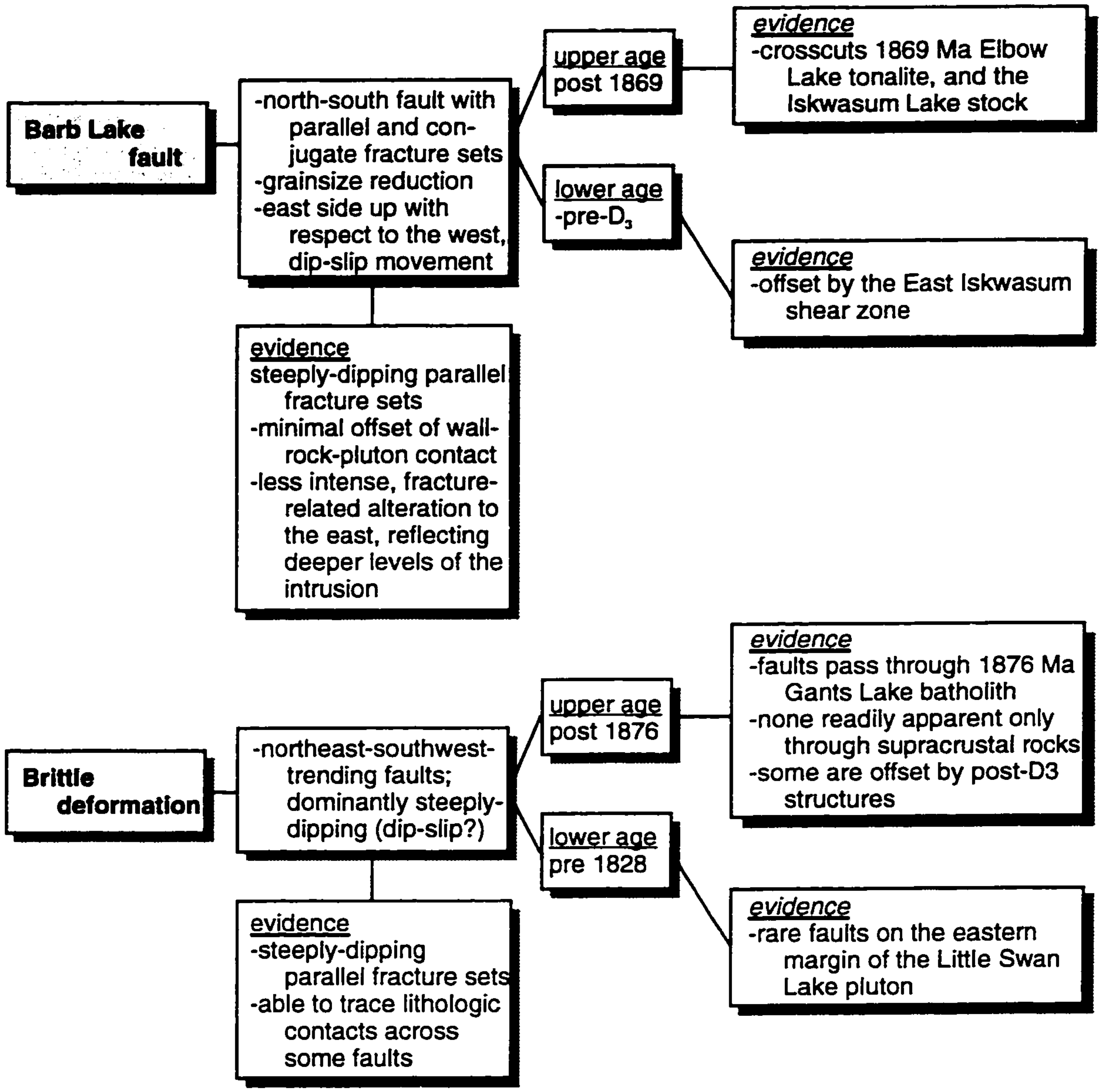


Figure 15. *Summary of shear zone characteristics in the study area. All age dates are in millions of years, and are from Whalen and Hunt (1994) for correlative units in the Elbow Lake*

of movement. This is consistent with other movement on brittle faults in the area (i.e. at the western margin of the Loukes Lake shear zone).

3.4 Summary

The geology of the Iskwasum Lake sheet is structurally complex, with at least eight episodes of deformation recorded. Although most of these structures are contained within mafic supracrustal packages, they are not restricted to them. The dominant fabric in the area trends NNE, but this is generally disrupted by multiple orientations of brittle structures. The most significant structures in the map sheet, based on the extent that they affect the rocks they pass through, are ductile shear zones. Of the five major shear zones, only the Loukes Lake shear zone cuts across granitic rocks in the Iskwasum Lake sheet.

The Loukes Lake shear zone is a structure which passes through the center of the Gants Lake batholith from its southern extension at the Berry Creek fault to its northern termination by the Little Swan Lake pluton. It records both sinistral and dextral oblique slip, but folding of the mylonite appears to be related in the south to movement along the Berry Creek fault. This is indicated by the gradual opening of folds away from the fault, and the rotation of the axial plane of those folds into a subparallel orientation with the large fold created by the dragging of the Gants Lake batholith into it.

Based on crosscutting relationships there is not a strong correlation between brittle or ductile deformation and time. However, ductile deformation began prior to emplacement of the Elbow Lake tonalite, and continued to post-peak metamorphic conditions. This suggests that the plutons in the map sheet may have stitched these structures, and were reactivated after emplacement. This is generally consistent with the complex nature of movement on the shear zones. Brittle deformation appears to be constrained to a period of time after emplacement of the plutons, and the extent of brittle deformation wanes significantly towards the time of emplacement of the Little Swan Lake pluton, possibly reflecting a decrease in compression. There is no evidence for ductile movement along shear zones after the emplacement of the Little Swan Lake pluton.

Multiple subparallel shear zones in the Iskwasum Lake sheet may represent steeply dipping transpressive shear zones initiated during early accretion of

Table 4. *Summary of pluton data, and critical relationships. All geochronological data is from Whalen and Hunt (1994) for correlative units in the Elbow Lake sheet.*

pluton	rock type (lithology)	age (Ma)	fabric	critical relationships
Wedge Lake pluton	granodiorite, monzongranite		-contact subparallel -late shear zone through eastern margin	-late potassium feldspar, indicating that it is late in the petrogenetic history -indicates there is definitely some late shearing in the study area
South Iskwasum Lake pluton	granodiorite		-contact subparallel	-weak internal fabric -apparently terminated in the south by the Berry Creek fault (subphanerozoic; based on offset of aeromagnetic signatures) -strongly deformed wall rocks are within 50 meters of weakly deformed pluton
Gants Lake batholith	tonalite, granodiorite, quartz diorite, gabbro	$1876^{+7}/_{-6}$	-NNE-SSW -parallels Loukes Lake shear zone	-south and southwest margins structurally controlled -intrsuion breccias along the margins indicate the batholith was emplaced in its present location -crosscutting relationships in less-deformed areas indicate that foliation orientation is due to tectonic forces, not to emplacement -Loukes Lake shear zone transects the batholith -southwest margin of the batholith is similar in texture lithology and alteration as the Namew Gneiss in the subphanerozoic -batholith and Loukes Lake shear zone are dextrally-folded into the Berry Creek fault -sinistral movement along the Berry Creek fault resulted in the formation of S folds in the batholith
Iskwasum Lake stock	tonalite (leucocratic)		-contact subparallel -dominant feature is the Barb Lake fault, and associated fracture sets	-fracture-related and stronger pervasive alteration east and west of the Barb Lake fault is evidence for east-side up movement with respect to the west -limited offset of the pluton-wall rock contact is evidence for dip slip movement -dragging of the wall rock into the pluton contact indicates some lateral movement during emplacement

tectonic elements. If this is true, these shear zones would then have been reactivated during post-acretion subduction-related tectonic activity, and stitched by plutons in the area. Syn-magmatic shearing may have been common. It must be noted that there is no evidence has yet been collected for shearing prior to emplacement of the Gants Lake batholith, as it does not crosscut any of the older volcanic rocks in the area. At most it can be postulated that deformation was underway during emplacement of the batholith.

Table 4 (cont.). *Summary of pluton data, and critical relationships. All geochronological data is from Whalen and Hunt (1994) for correlative units in the Elbow Lake sheet.*

pluton	rock type (lithology)	age (Ma)	fabric	critical relationships
Elbow Lake tonalite	tonalite, quartz diorite	1864 $^{+5}/_{-4}$	-roughly contact subparallel -disrupted by brittle deformation -distinct concentric zones within	-concentric zones of foliations within the pluton may indicate multiple magma pulses -intrusion breccia on the western margin of the pluton indicats shearing was initiated prior to emplacement -contact with the Gants Lake batholith is a banded gneiss; interpreted a result of pluton emplacement -Barb Lake fault transects the pluton, bearing on the timing of the structure
Big Rat Lake pluton	granodiorite-granite	1845 +/-3	-contact subparallel	
Little Swan Lake pluton	granodiorite, tonalite, quartz diorite, gabbro	1828 +/-5	-contact subparallel	-intruded into the Gants Lake batholith, crosscutting the fabric and structures in it -bears on timing of the Loukes Lake shear zone, and of brittle faulting in the study area -emplacement resulted in a second foliation overprinting the NNE-SSW Gants Lake batholith fabric; is recognizeable up to 1 kilometer from the contact

4.0 Geochemistry

4.1 Introduction

The geochemical evaluation of granitoid rocks in the Iskwasum Lake sheet involved major, trace and rare earth element (REE) analysis. A limited amount of high-precision data is available for granitoid rocks in the Iskwasum Lake sheet, but evaluation of these data is enhanced by comparison with the significant data set that exists for granites in the Elbow Lake sheet to the north (Whalen, unpublished data). Access to these data allows for evaluation of the representativeness of Iskwasum Lake sheet geochemistry.

Geochemical data are valuable as a means of characterizing and identifying similarities and differences between map units. They will be used in this study to compare and correlate plutonic units across map sheets, compare and contrast these rocks with those from other well-studied granitoid suites in the Circum-Pacific, and to identify some of their possible tectonomagmatic characteristics.

Compostional and tectonic discrimination of granitoid rocks based on the proportions of major element oxides is useful, but care must be extended when utilizing this type of data. It is apparent that agreement between discrimination diagrams is not necessarily possible, even for those that attempt to discriminate the same factors. The field geologist must rely on all available data including geophysics, geochronology and petrology as an aid to the interpretation of granitoid rocks. In addition, observations made in the laboratory must concur with those obtained from the field.

Given the need for corroborative studies in the interpretation of granitoid terranes, geochemical data may be used as a tool in defining rock lithology, emplacement and crystallization history, and tectonic environment. They may also aid in the correlation of units over large areas, and outlines the significant differences and similarities in them. Care must be taken however, as the processes involved in the generation of a pluton and its subsequent emplacement are often difficult to ascertain. Certainly the degree to which fractional crystallization, pluton ascent history, source region composition, assimilation and influx of new magma into the system (to name a few) are involved in the generation of the pluton is important. Determining the effects of these processes can be quite difficult, and requires a wholistic and multidisciplinary approach to the study of granites.

In the Iskwasum Lake sheet, samples were carefully selected to be representative of the most volumetrically significant plutonic units in the area. The objective was to obtain a representative geochemical database which could be employed as a tool for correlation with plutonic units previously recognized by Whalen (1993a) in the Elbow Lake sheet to the north. Additionally, it allows for a comparison of more units within plutons, highlighting the similarities and differences between them, and providing clues to their inter-relationships.

4.2 Geochemical characteristics of granitoid rocks

This section provides a brief overview of the geochemical characteristics of granitoid rocks in the Iskwasum Lake area. In general these granites exhibit remarkably similar geochemical characteristics. Within and between pluton discrepancies in the data will be discussed in more detail in sections 4.3, 4.4 and 4.5.

As initial field names for granitoid compositions are subjective, it is often useful to use other means to classify the rocks. Determination of composition can be done in numerous ways; based on modal mineralogy (*i.e.,* Streckheisen, 1976) or major element geochemistry (*i.e.,* Debon and LeFort, 1983). The latter uses discrimination diagrams (QBF and QP, Debon and LeFort (1985) (figures 16 and 17)) to classify granites based on major-element composition. Other means of classifying granites include the CIPW normative ternary albite-anorthite-orthoclase plot (figure 18a), and the mesonormative quartz-alkali feldspar-plagioclase ternary plot (LeMaitre, 1989) (figure 18b).

The QP diagram is a ternary plot of albite-orthoclase-quartz and is based on the normative quartz-feldspar ratio of a rock sample. The QBF diagram adds a mafic mineral component B, and plots samples in a ternary plot of Q=quartz, B=dark minerals, F=feldspars. Each of these two diagrams discriminates between 12 rock types based on the sample's geochemical characteristics. The ternary plot of normative anorthite-albite-orthoclase is another means of evaluating rock compositions (Barker, 1979). Based on mesonormative calculations, LeMaitre (1989) discriminates 17 rock types, and granitoid rocks of the Iskwasum Lake sheet are plotted on this diagram in figure 18b. The advantage to this type of

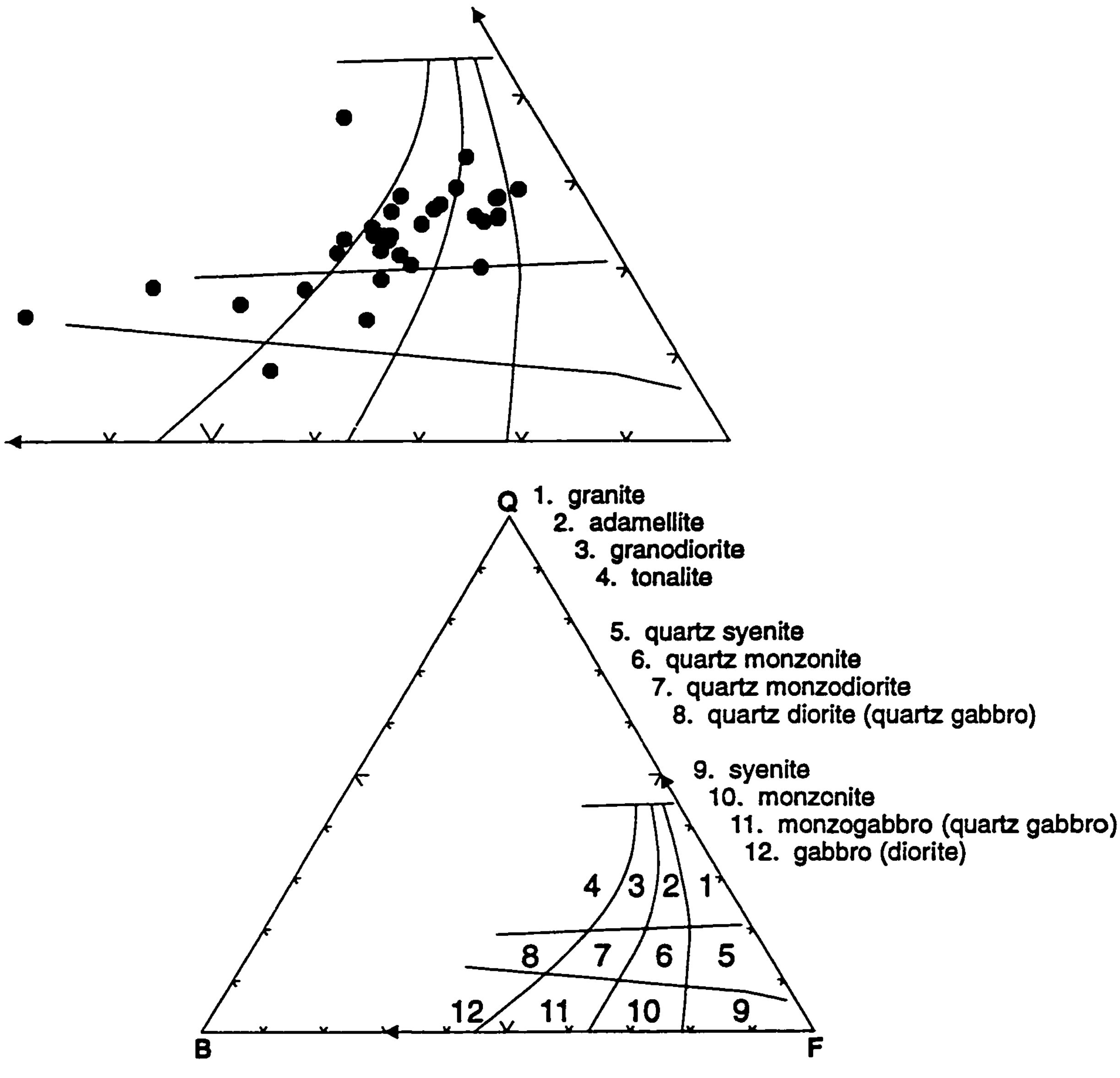


Figure 16. *Distribution of granites in the Iskwasum Lake sheet in the QBF plot of Debon and Le Fort (1983). Q = quartz (Si/3-(K + Na +2Ca/3)); B = dark minerals (Fe + Mg + Ti); F = feldspar + muscovite (555 - (Q + B)). Each field represents a petrographic type as labelled in the diagram above. The three parameters are in gram-atoms X 10^3 in 100 grams of rock or mineral.*

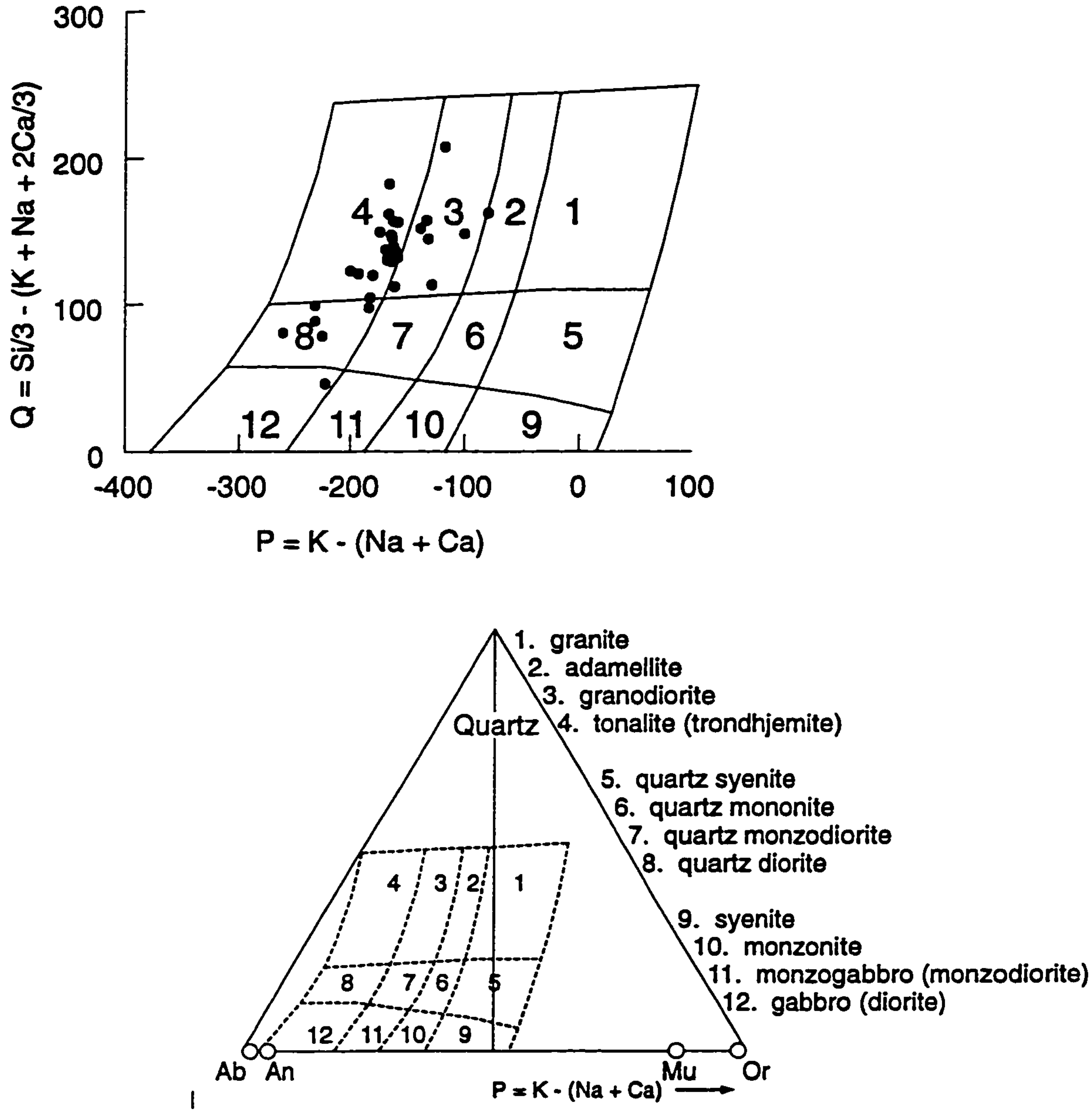


Figure 17. *Distribution of granites in the Iskwasum Lake sheet, in the 'nomenclature' (Q-P) diagram of Debon and Le Fort (1983). Petrographic type corresponding to each zone is given in the diagram above.*

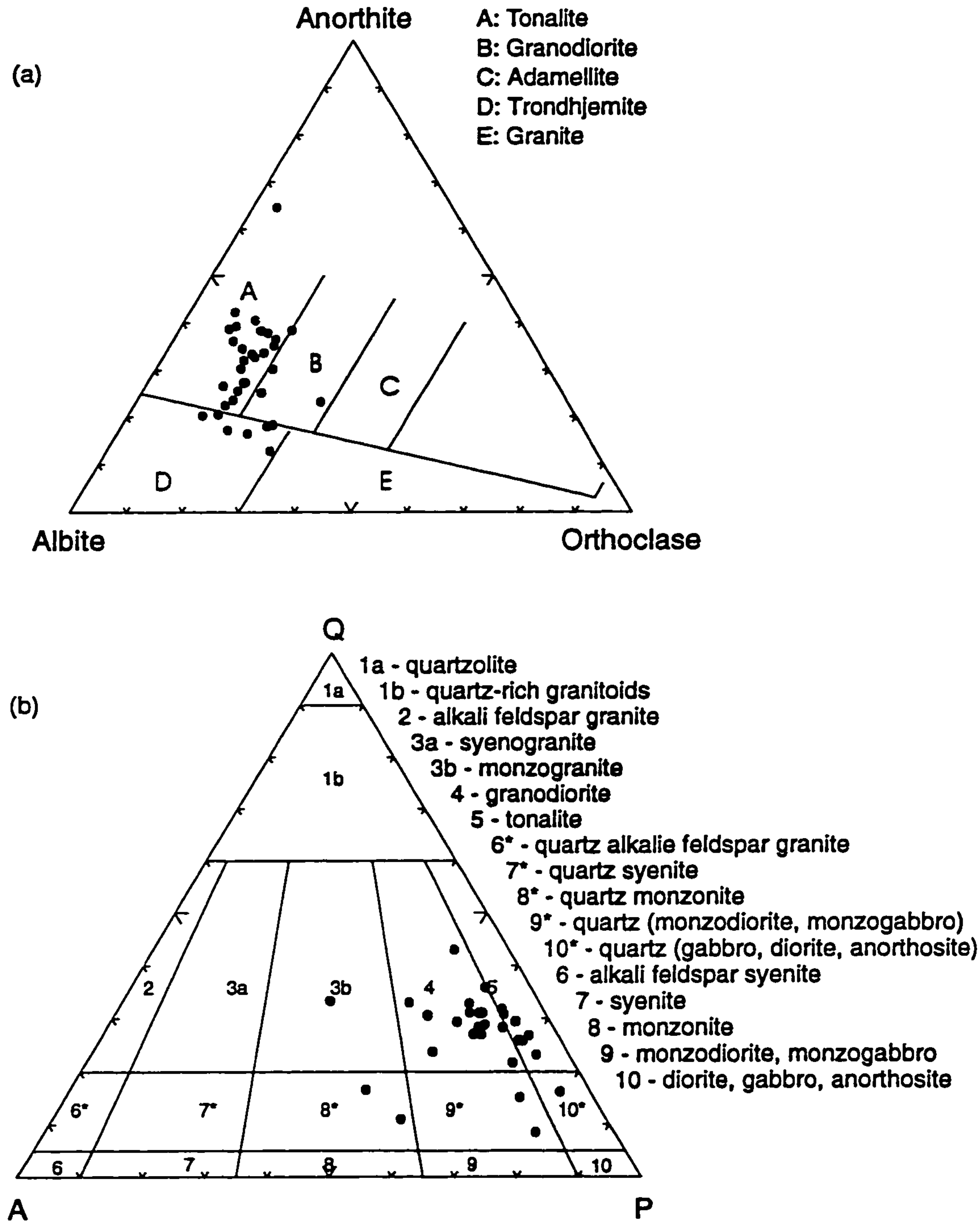


Figure 18. *Iskwasum Lake area plutonic units in; (a) CIPW normative anorthite-albite-orthoclase ternary plot. Fields are described to the right. After Barker (1979) (b) Mesonormative quartz-alkali feldspar-plagioclase ternary plot. Fields from LeMaitre (1989).*

geochemical composition determination is the ease with which it can be undertaken. Large numbers of samples can be analyzed to provide a "statistical" approach to classifying lithology. By plotting samples in the geochemical diagrams, a general nomenclature is determined. It becomes evident however, that the petrographic type is strongly influenced by which means of discrimination is used, as different methods provide different results (figures 16, 17 and 18).

In general, all granitoid rocks of the Iskwasum Lake sheet range in compositions from quartz diorite to tonalite and granodiorite. Most granites fall within the tonalite and granodiorite fields of all diagrams, but the range is most restricted in the CIPW normative plot.

Ternary AFM diagrams, with A=Na_2O + K_2O, F=FeO(T) and M=MgO (wt%) can be used to define trends in magmatic suites. Irvine and Baragar (1971) defined a dividing line between samples of calc-alkaline and tholeiitic affinities. All Iskwasum Lake sheet samples plot in the calc-alkaline field (figure 19a).

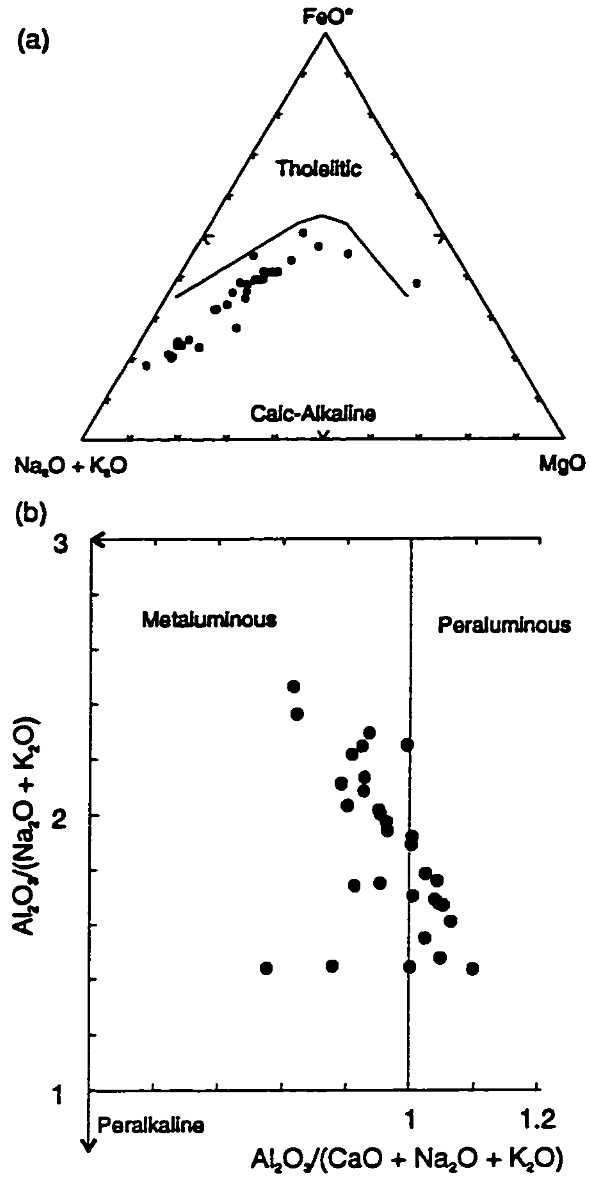


Figure 19. *Characterization of granites in (a) an AFM diagram. Fields for calc-alkaline and tholeiitic rocks from Irvine and Baragar (1971); (b) Shand's aluminous index.*

Based on aluminosity (A/CNK index), granitoid rocks in the Iskwasum Lake sheet are predominantly metaluminous, with more leucocratic units shifting towards the peraluminous field (figure 19b). All samples have A/CNK <1.1 (Al_2O_3/Na_2O + K_2O + CaO<1.1), and are alkali-undersaturated based on an alkali saturation index ($Al_2O_3/(Na_2O + K_2O)$) greater than 1.

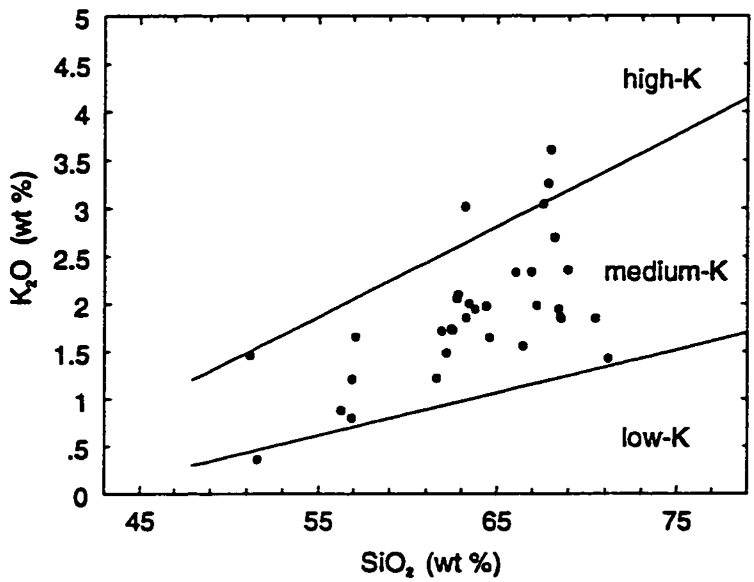


Figure 20. *Harker diagram comparing K_2O vs SiO_2 for granites in the Iskwasum Lake sheet. After Peccerillo*

Harker diagrams can be used to characterize plutonic suites. One method of using these diagrams is to plot major element oxides versus one another. On a K_2O vs SiO_2 Harker diagram, most granitoid rocks have K_2O contents from 1-3. More mafic rocks (SiO_2<55 wt%) have low K_2O contents. Almost all plot within the medium-K field (figure 20).

Discrimination of tectonic environments of both volcanic and plutonic rocks has been aided by the use of trace elements. Two diagrams of Pearce *et al.* (1984) have been used here to discriminate granitoid rocks in the Iskwasum Lake sheet.

The Rb versus (Nb + Y) plot is a good plot for discriminating between volcanic-arc and syn-collisional granites, as it separates the two geotectonic domains (figure 21a). Granites plotted in this diagram show the same general pattern as in the Nb versus Y diagram (figure 21b), except most samples fall entirely within the volcanic-arc granite field.

In the Nb versus Y tectonic discrimination diagram, fields for volcanic-arc + syn-collisional granites are presented along with those for within-plate and ocean-ridge granites (figure 21b). In addition, a transitional zone between the within plate and ocean ridge granites is presented. Most of the samples from the Iskwasum Lake sheet plot well within the volcanic-arc + syn-collisional field.

Granitoid rocks of the Iskwasum Lake study area have a broad range in REE contents, but in general show a heavy rare earth element (HREE) depleted pattern

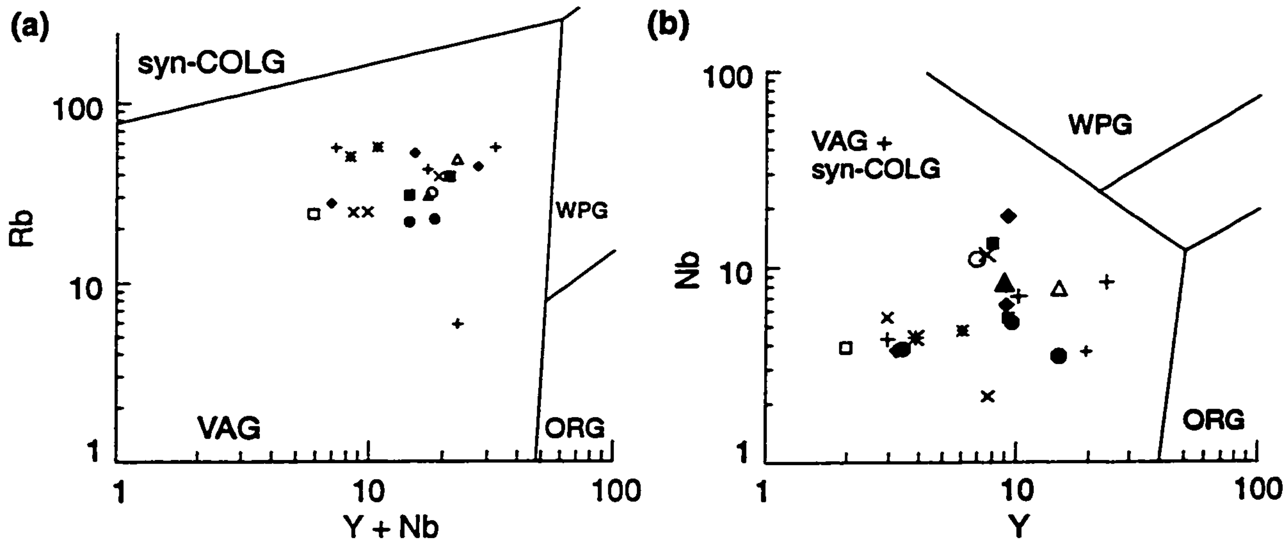


Figure 21. (a) *Rb vs. (Y+Nb) tectonic discrimination diagram of Pearce et al. (1984). All values are in parts per million (ppm). (b) Y vs Nb tectonic discrimination diagrams of Pearce et al. (1984). Symbols include; volcanic arc (VAG), syn-collisional (syn-COLG), within plate (WPG), and ocean ridge (ORG) granites. Data plotted are for samples with visible quartz.*

when normalized to chondritic values (figure 22a). The REE abundances vary from approximately 10 to 100 times chondrite. Few samples show any single-element anomalies, although significant samples exhibit a distinct negative Eu anomaly. Extended trace element plots, normalized to primitive mantle values of Taylor and McLennan (1985) show a similar pattern. These diagrams show that granites from the Iskwasum Lake area have distinct light lithophile element enrichments, and distinct negative Nb and Ti anomalies (figure 22b).

4.3 Geochemical comparison with the Elbow Lake sheet

An extensive geochemical database for granitoid rocks of the Elbow Lake sheet (Whalen, unpublished data) north of the study area has made better evaluation of granitoid rocks of the Iskwasum Lake possible. In the following section, major, trace and rare element data for plutonic units as defined by Whalen (1993a) will be compared to those in the Iskwasum Lake area.

4.3.1 Aluminous content

Samples of the Gants Lake batholith in both the Iskwasum and Elbow

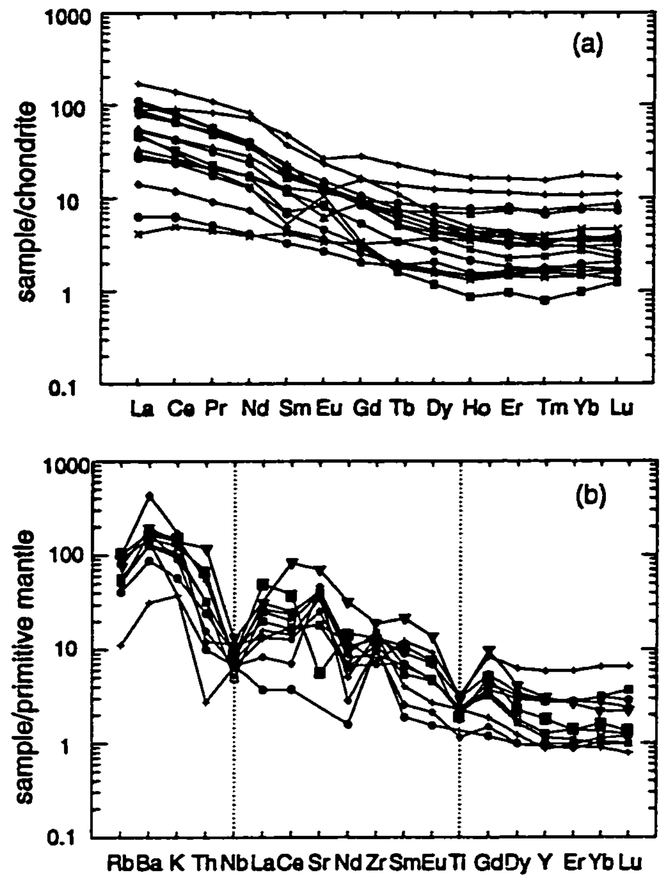


Figure 22. *Broad distribution of Iskwasum Lake sheet granites in (a) chondrite-normalized REE plot, normalized to the values of Sun (1982); (b) primitive mantle-normalized extended trace element diagram, normalized to the values of Taylor and McLennan (1985). Note the consistent negative Nb and Ti anomalies. Symbols do not correspond to plutons, or plutonic units in either figure.*

Lake sheets circumscribe a broad area on the A/CNK diagram, but cluster around the peraluminous-metaluminous boundary (figure 23). Only one sample from the Iskwasum Lake sheet plots entirely within the peraluminous field. Samples from the Elbow Lake sheet generally correlate well with those of the Iskwasum Lake sheet.

Samples of the Elbow Lake tonalite from the Elbow Lake sheet are more tightly clustered than those of the Iskwasum Lake sheet. It is not surprising, given the lithologic complexities in the Iskwasum Lake sheet in comparison to the Elbow Lake sheet, that samples from the Iskwasum Lake sheet show a broader range of compositions. As a whole however, they fall within the same area as Gants Lake batholith samples. Elbow Lake sheet samples plot entirely within the metaluminous field, while Iskwasum Lake sheet samples span the peraluminous-metaluminous boundary (figure 23).

Of all the plutons in the map sheet, the Little Swan Lake pluton has the broadest range of $Al_2O_3/(Na_2O + K_2O)$ values, from 1.3 to 3.0 (figure 23). Samples from the Iskwasum Lake sheet show less variability, possibly because of the limited number of samples taken. A difference between the two data sets is that those samples taken from the Elbow Lake sheet plot almost entirely within the metaluminous field, while half of those from the Iskwasum Lake sheet are slightly

Table 5. *Iskwasum Lake area map units and their Elbow Lake sheet equivalents. Symbols are those used for some diagrams in the text. A * beside the Iskwasum Lake sample indicates that the plutonic unit is not present in the Elbow Lake sheet, a - indicates that correlation is not possible.*

Iskwasum Lake pluton	Map unit	Representative sample(s) of the Iskwasum Lake sheet	symbol	Elbow Lake sheet equivalent	Comments
Gants Lake batholith	P6c	DWM4050	■	9j	-samples plot well-within the pattern defined by unit 9j of the Elbow Lake sheet
		DWM0174a	○		
		DWM0183	□	9g	-similar, but has lower overall REE abundances, and a positive Eu anomaly
	P6i	DWM0197	△	9b	-correlates with a subset of unit 9b which has a steeper slope and no Eu anomaly
	P6h	DWM0203	X	9b,9c?	-correlates with a subset of unit 9b which has a flatter slope and -ve Eu anomaly
		DWM0197(?)			-unit 9c is similar, but does not have the same negative Eu anomaly
	P6a	DWM0390	▲	9h	-most closely resembles this unit, with a somewhat less steep slope
	P6e	-DWM0118	◆		
	P6e	-DWM0221	✻		
	P6g	-DWM0124	+		
Elbow Lake tonalite	P9Ac	DWM0211	✻	6	-almost all samples of the Iskwasum Lake sheet correlate well
		DWM0034	■		-exceptions include a sample with a slightly concave-up REE pattern
	P9Ab	-DWM0077	▲		
	P9Ab	-DWM6268b	◆		
	P9Ad	-DWM0317	X		
	P9Ae	-DWM0024	●		
Iskwasum Lake stock	P9Ba	*DWM0150	X		-has a similar REE pattern as the Elbow Lake tonalite, but lower overall abundances
	P9Ba	*DWM0304	✻		
	P9Bc	*DWM0125	+		
	P9Bd	*DWM0324	◆		
Little Swan Lake pluton	P10Ab	DWM0007	+	9s	-has a flat REE slope, and a negative Eu anomaly
	P10Ag	DWM0421a	✻	9p,9q,9r	-comagmatic quartz diorite that correlates with P10Ae, and more mafic units of the pluton in the Elbow Lake sheet
		DWM0421b	●		
	P10Af	-DWM0395	X		-has an anomalous REE pattern
Big Rat Lake pluton	P10B			14f, 14g	-correlates with both units
Wedge Lake pluton	P8b	*DWM0165	✻		
	P8d	*DWM0262	+		
South Iskwasum Lake pluton	P10Ca	*DWM4200	+		
	P10Cb	*DWM4039	✻		

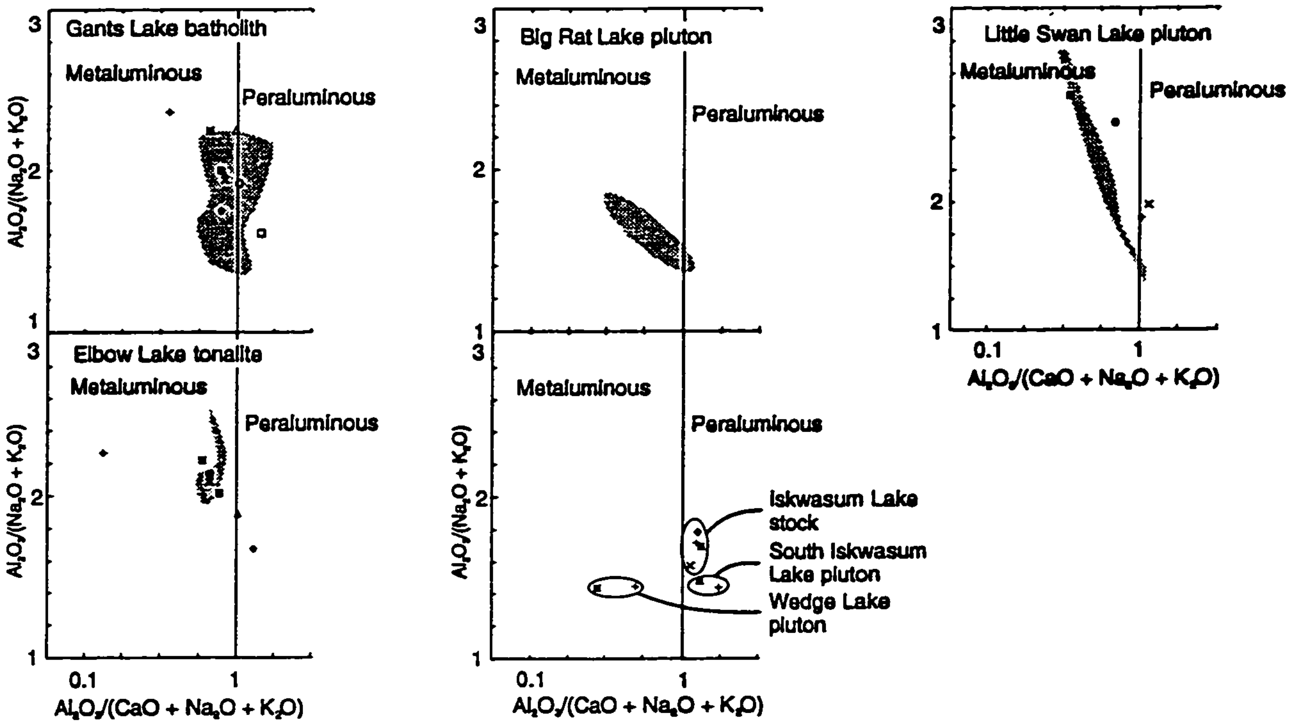


Figure 23. *Distribution of granites in the Iskwasum Lake sheet by pluton, in Shand's aluminous index. Key to symbols in Table 4. Shaded areas correspond to samples of Whalen (unpublished data) in the Elbow Lake sheet.*

peraluminous.

Petrography, alteration patterns and structural style suggest that the Elbow Lake tonalite and Iskwasum Lake stock are broadly coeval, with a similar source and emplacement history. Despite these similarities, Elbow Lake tonalite granites of the Iskwasum Lake stock plot in a very limited area on the diagram; slightly within the peraluminous field. This may reflect a greater degree of alteration. Although only two samples were taken from the South Iskwasum Lake pluton, they plot in the same area as samples of the Iskwasum Lake stock. Both samples of the Wedge Lake pluton plot within the metaluminous field (figure 23).

4.3.2 AFM diagrams - Alkalinity

AFM diagrams are used to define trends in magmatic suites. It is not surprising that granitoid rocks from the Iskwasum and Elbow Lake sheets correlate well when plotted on these diagrams, all defining a calc-alkaline trend. In addition, all plutons generally show the same trend. This diagram is not useful for map unit correlation (figure 24).

4.3.3 The rare earth elements

The rare earth elements (REE) are the group of elements from La to Lu that have similar chemical and physical properties. In the following text LREE will refer to the elements from La to Sm, HREE to those from Gd to Lu, and MREE broadly to those elements from approximately Sm to Ho.

REEs concentrate in the silicate rather than the sulfide phases of a melt, and are therefore characterized as lithophile. Many REEs are concentrated in accessory minerals (*e.g.*, zircon, titanite, garnet and apatite), but can also be significantly partitioned into the major rock-forming minerals (*e.g.*, biotite, hornblende, plagioclase and pyroxene).

Because a significant aspect of this study is the correlation of map units across map sheets, this section will deal with comparing REE patterns of units in granitic rocks from the Iskwasum and Elbow Lake sheets.

Extensive geochemical sampling in the Elbow Lake sheet by Whalen (unpublished data) provides an adequate base for comparison. In the Iskwasum Lake sheet geochemical samples were chosen in order to delineate and characterize as many plutonic units as possible, and for this reason there was not a preferential sampling of any one particular unit in the map sheet. Only a specific subset of the Iskwasum Lake sheet geochemical data set was analysed for trace and rare earth elements.

Some attempt has been made in section 4.3.1 and 4.3.2 to compare lithologic units in the Iskwasum Lake sheet with those in the Elbow Lake sheet based on major element geochemistry. Results obtained were often ambiguous, probably due to the overall lithologic heterogeneity of plutons. The rare earth elements provide another means of tackling this comparison. Differences in total REE concentration, individual element abundances relative to the other REEs, and the overall pattern allows for a detailed comparison.

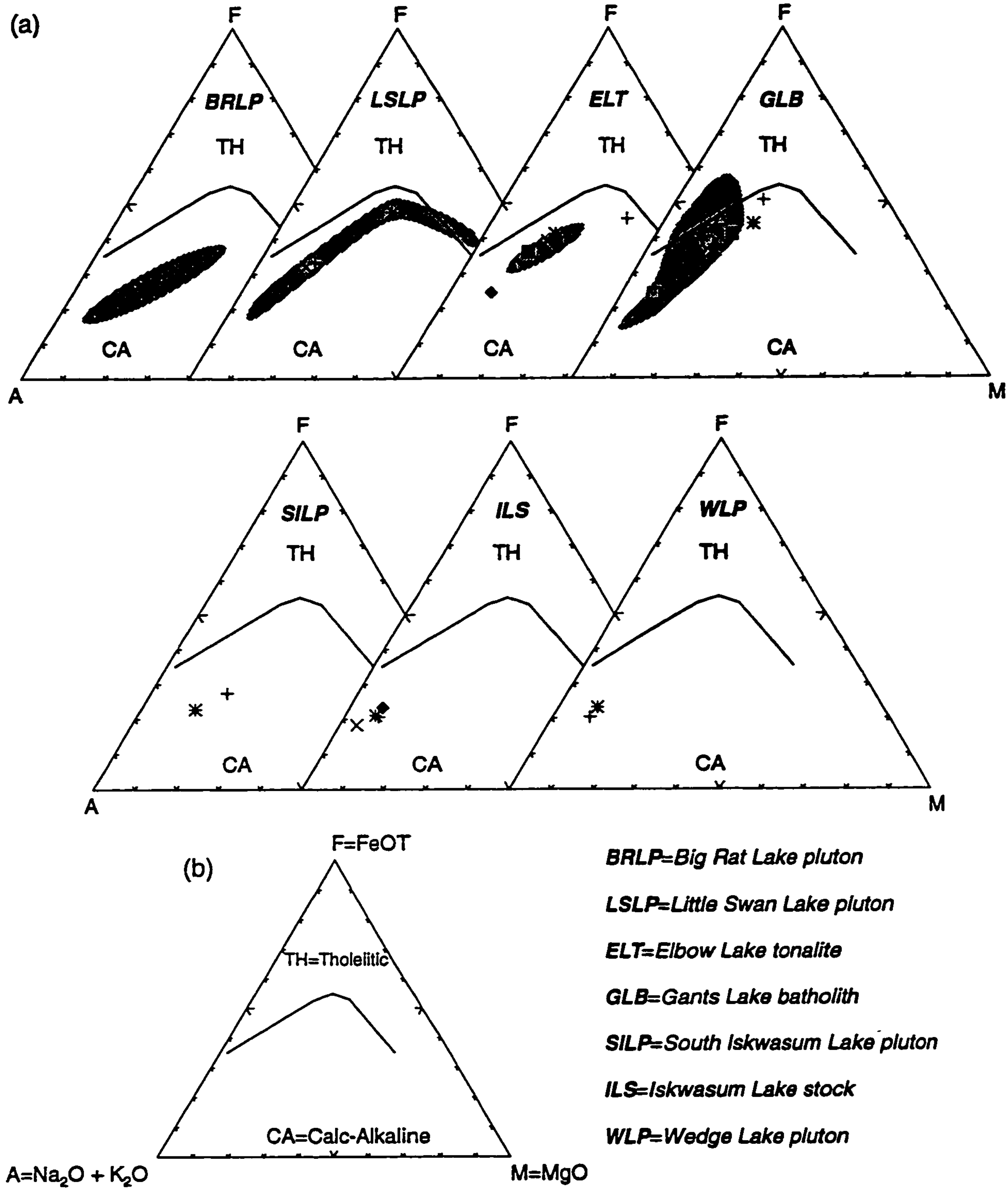


Figure 24. *(a) AFM diagrams for DWM geochemical samples in the Iskwasum Lake sheet, grouped by pluton. Division between tholeiitic and calc-alkaline fields is from Irvine and Baragar (1971). Symbols and corresponding sample numbers are given in table 4. Shaded areas correspond to samples of Whalen (unpublished data) in the Elbow Lake sheet; (b) Legend to codes used in (a).*

4.3.3.1 Gants Lake batholith

As the Gants Lake batholith is lithologically and texturally heterogeneous, this section will attempt to compare only lithologic units in both map sheets which are texturally and compositionally similar.

Figure 25 shows five chondrite normalized REE diagrams of plutonic units in the Gants Lake batholith, normalized to the values of Sun (1982).

At first glance REE patterns of rocks from the Iskwasum Lake sheet do not compare well those of the the Elbow Lake sheet. Although samples of the Gants Lake batholith from the Elbow Lake sheet show a broad range of overall REE abundances, three categories of patterns exist;

1 *strongly HREE depleted patterns with slightly concave-down appearances, and without single-element anomalies* (units 9j and 9g). *These show a broad range in total REE abundances, with two distinct patterns emerging (both with similar slopes, but slightly different total REE contents)*

2 *moderately HREE-depleted patterns with slightly concave-up appearances, and without single-element anomalies* (units 9f and 9b).

3 *moderate HREE-depleted patterns with negative Eu anomalies* (unit 9b).

Correlation of units from both areas is often possible by first comparing samples of the Iskwasum Lake sheet with the above patterns, and then concentrating on the details of each pattern. Iskwasum Lake sheet plutonic units will be discussed individually in the following order; unit P6c, units P6i and P6j, and unit P6a.

@BULLET ONE = Unit P6c

Volumetrically the most significant unit of the Gants Lake batholith in the Iskwasum Lake sheet is unit P6c. Four geochemical samples were taken from this unit. Two distinct patterns emerge when these samples are plotted on chondrite normalized REE plots, these will be discussed below in relation to Elbow

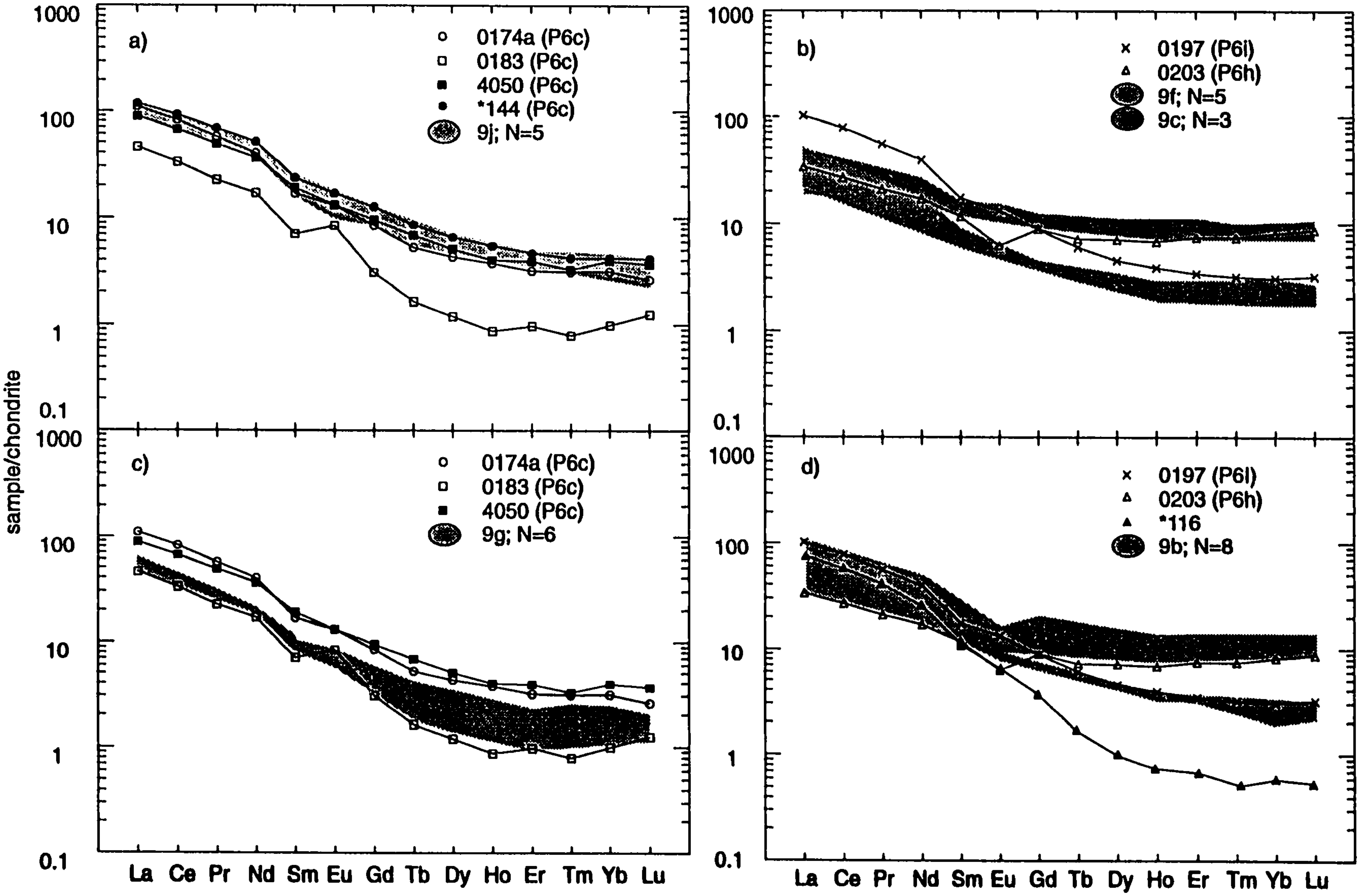


Figure 25. *REE abundances for Gants Lake batholith units in the Iskwasum Lake sheet compared to those from the Elbow Lake sheet. All Elbow Lake data, and Iskwasum Lake sheet samples delineated by * are from Whalen (unpublished data). Data is normalized to the chondritic values of Sun (1982). N=the number of samples from the unit.*

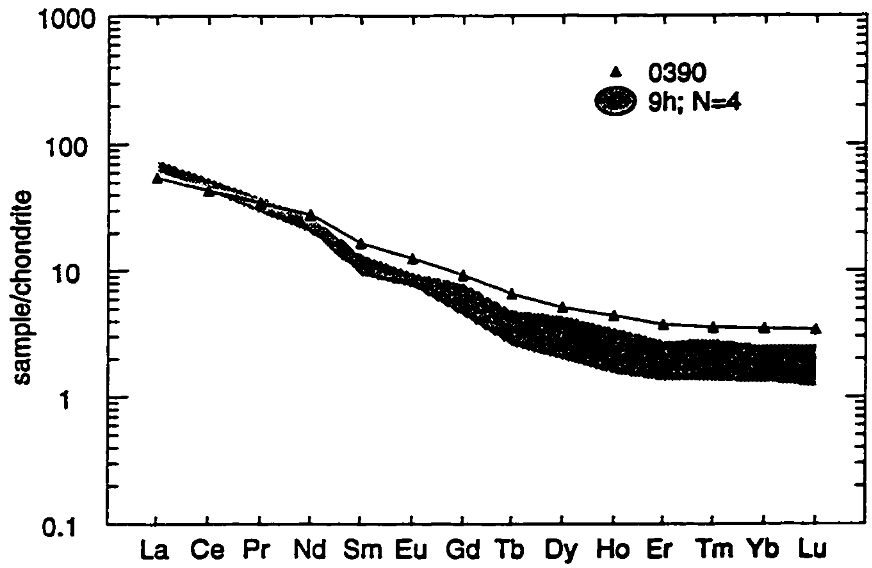


Figure 25 (cont.). *REE abundances for Gants Lake batholith units in the Iskwasum Lake sheet compared to those from the Elbow Lake sheet. All Elbow Lake data, and Iskwasum Lake sheet samples delineated by * are from Whalen (unpublished data). Data is normalized to the chondritic values of Sun (1982). N=the number of samples from the unit.*

Lake sheet units. Spatially, texturally and compositionally the unit is correlatable with units 9j and 9g of Whalen (1993b), which fall into category 1 above. The REE patterns (figure 25a and 25b) of samples from both sheets have similar shapes, but there is a dichotomy in the overall abundances of the rare earth elements between units 9j and 9g. Unit 9g has total REE abundances lower than unit 9j, and the two patterns do not overlap. Three samples from the Iskwasum Lake sheet plot almost entirely within the pattern defined by unit 9j (figure 25a). The fourth sample, 0183, most closely resembles unit 9g of Whalen (1993b) (figure 25b), but has slightly lower total REE abundances. Although it has a similar pattern shape as other samples of the Gants Lake batholith, it exhibits a moderate positive Eu anomaly which is not apparent in other samples from the Elbow Lake sheet.

- *Units P6i and P6h*

The REE patterns of units P6i and P6h do not appear to correlate well with those of units from the Elbow Lake sheet. Based on field descriptions, the two units are similar to units 9f, 9b and 9c of Whalen (1993b).

Unit 9c falls in category two of the patterns defined above, and most closely resembles unit P6h (sample 0203) in the Iskwasum Lake sheet. However, sample 0203 has a greater concave-up HREE pattern than seen in unit 9c, a slight depletion in the MREEs and a distinct negative Eu anomaly. This is similar to a subset of unit 9b, which exhibit these same geochemical properties. Unit 9b appears to be a mixture of categories 2 and 3 with one subset exhibiting a steep negative slope, and the other a flatter pattern. The latter more closely resembles unit 9c (with a negative Eu anomaly). P6i appears to more closely resemble the flatter of the two patterns, but total REE abundance are slightly lower. Unit P6h (sample 0197) from the Iskwasum Lake sheet most closely resembles category 2 REE patterns, and correlate well with the steeper REE pattern of unit 9b from the Elbow Lake sheet.

Sample *116 has a steep negative slope, and a concave-up-LREE and concave-down HREE pattern. There are no single element anomalies, and its REE pattern does not closely resemble that for any unit in the Gants Lake batholith. Having said this, it is notable that the overall shape of the pattern is similar to units 9b and P6h, but with lower overall REE abundances and greater HREE depletion.

- *Unit P6a*

The final unit of the Gants Lake batholith to be discussed is P6a. Only one sample of this unit was taken from the Iskwasum Lake sheet (sample 0390). Lithologically and texturally P6a closely resembles unit 9h in the Elbow Lake sheet (figure 25e). The REE patterns of these units in the two map sheets have similar negative slopes and overall REE abundances. The significant difference between the two units is in the overall slope of the patterns, with sample 0390 being somewhat less HREE depleted.

4.3.3.2 The Elbow Lake tonalite and Iskwasum Lake stock

The Elbow Lake tonalite has not been subdivided in the Elbow Lake sheet, primarily because extensive faulting and fracturing have disrupted lithologic units to such an extent that correlation is impossible from one outcrop to the other. Although the comparison of units in the two map sheets is hampered by this difference, it does allow for evaluation of compositional and textural variations in the Iskwasum Lake sheet.

REE patterns of the Elbow Lake tonalite from the Elbow Lake sheet are all very similar (figure 26a). They exhibit a moderate negative, slightly concave-up pattern. Samples of the Elbow Lake tonalite in the Elbow Lake sheet have HREE concentrations two to eight times and LREE abundances 20-50 times that of chondrite. Most samples from the Iskwasum Lake sheet plot within the zone defined by Elbow Lake sheet REE patterns, particularly those from the main unit of the pluton. Two samples depart from this zone, however. Sample 0034 is a fine- to medium-grained equigranular tonalite from the northwest corner of the pluton in the Iskwasum Lake sheet. It has a more concave-up HREE pattern than its counterparts. Sample 6268 is from a very coarse-grained unit within the main quartz-biotite porphyritic unit of the pluton. It has MREE and HREE abundances greater than those seen in other samples from the pluton, and a striking concave-up pattern in the LREEs from La to Nd.

The Iskwasum Lake stock is similar to the Elbow Lake tonalite in deformation intensity, alteration and composition, and the geochemical characteristics of these plutons will be compared, and as previously mentioned, are considered to be of similar petrogenesis. Since they are similar petrographically, it is important to consider their geochemical properties, particularly the REEs. Samples of the Iskwasum Lake stock show a much broader range in REE patterns than those of the Elbow Lake tonalite (figure 26b). They have a similar concave-up HREE patterns, but have up to ten times lower total REE abundances. Like most Elbow Lake tonalite samples, most have a slight negative slope.

4.3.3.3 The Little Swan Lake pluton

The Little Swan Lake pluton is a compositionally heterogeneous pluton that intrudes into the Gants Lake batholith in the northern part of the map sheet. This section will attempt to correlate map units within the Iskwasum Lake sheet portion of the Little Swan Lake pluton with units in the Elbow Lake sheet immediately north.

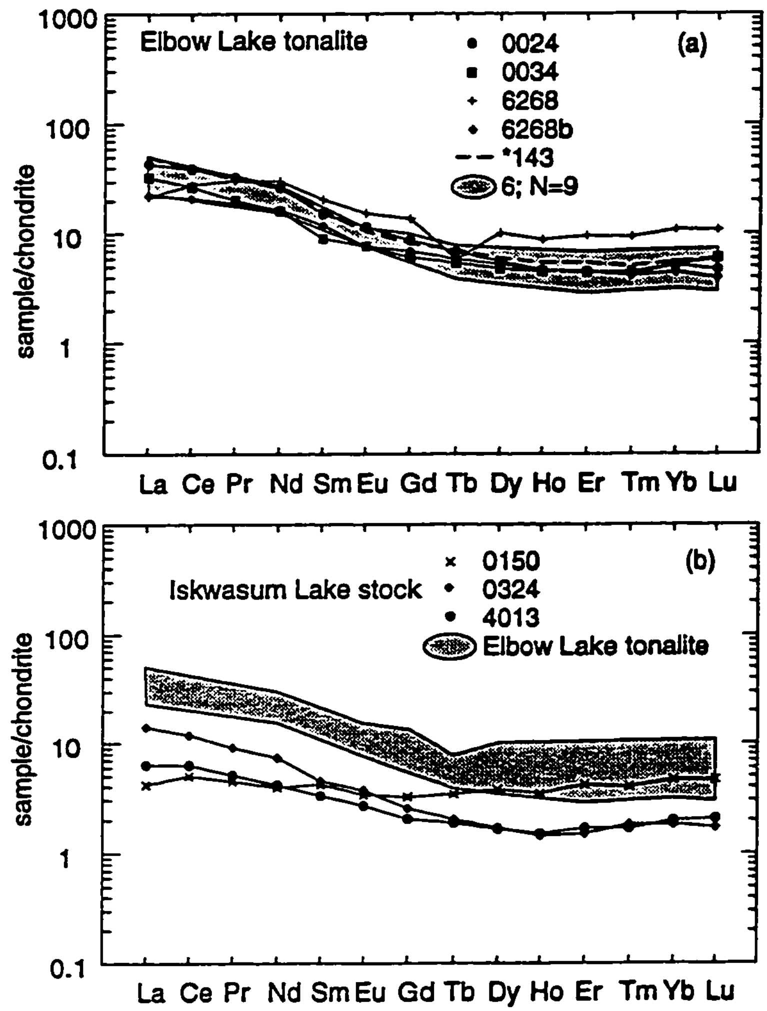


Figure 26. *Comparison of chondrite normalized REE abundances for (a) Elbow Lake tonalite rocks in the Iskwasum Lake sheet (symbols) and the Elbow Lake sheet (shaded). N=number of samples in the unit (b) Elbow Lake tonalite rocks from the Elbow and Iskwasum Lake sheets (shaded), and the Iskwasum Lake stock (symbols). Elbow Lake sheet data is from Whalen (unpublished data). A * prefix indicates a geochemical sample of Whalen (unpublished data) of an Iskwasum Lake sheet granitoid. Normalizing values are from Sun (1982).*

Figure 27a is a chondrite normalized REE plot for three Iskwasum Lake sheet samples and units 9q, 9r and 9p of Whalen (1993b) from the Elbow Lake sheet. Two mafic intrusive units have been defined by Whalen (1993b) in the Elbow Lake sheet (units 9q and 9r), one of which is correlateable with comagmatic quartz diorites in the Iskwasum Lake sheet. Sample 0421b is of the comagmatic quartz diorite, and geochemically it correlates well with unit 9q. Both rocks have REE

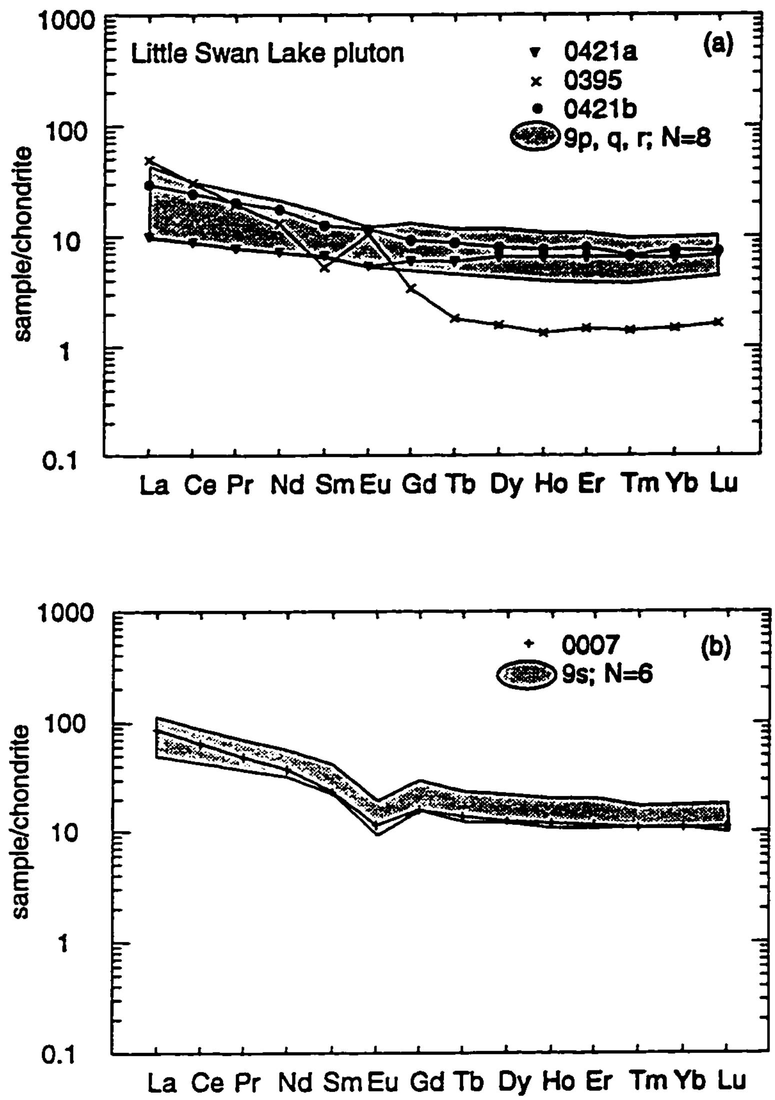


Figure 27. *Chondrite normalized REE plots for Little Swan Lake pluton granitoids in the Iskwasum Lake sheet (symbols), compared to Elbow Lake sheet unites (shaded), normalized to the values of Sun (1982). Elbow Lake sheet data from Whalen (unpublished data).*

patterns with slight negative slopes and a concave-up appearance. In addition, they have similar total REE abundances. What is somewhat surprising is the similarity in the REE patterns between both these units and unit 9p of Whalen (1993b). This is a hybrid unit of quartz diorite and mafic extrusive rocks which has not been correlated into the Iskwasum Lake sheet. This would suggest that these rocks are of the same origin as the quartz diorite in the center of the pluton.

Sample 0395 is an anomaly. It has a strongly fractionated, concave-down HREE pattern and a distinct positive Eu anomaly (figure 27a). The sample is taken nearer to the Gants Lake batholith contact than all others, and may represent a cumulate phase of the Little Swan Lake pluton, since plagioclase retains Eu in its structure.

Sample 0007, taken from the hornblende-biotite granodiorite portion of the pluton has a similar HREE pattern as more mafic samples, but higher LREE concentrations, and a distinct negative Eu anomaly. It closely resembles the pattern defined by samples of unit 9s (figure 27b) (Whalen, 1993a) of the Elbow Lake sheet.

4.3.3.4 The Big Rat Lake pluton

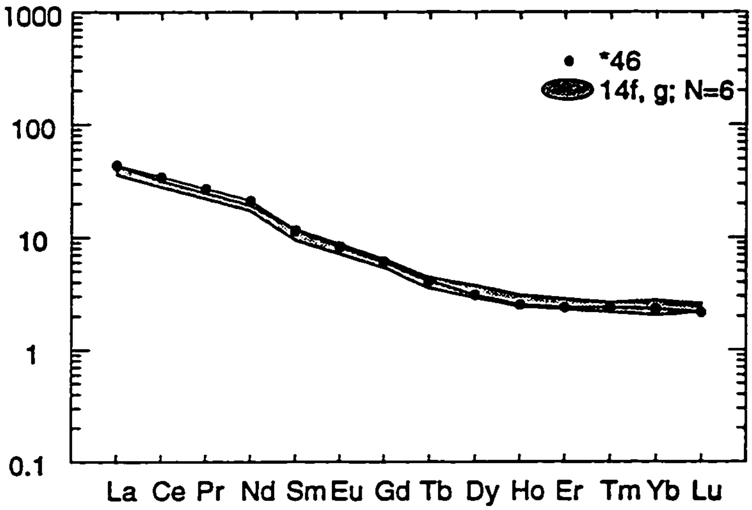


Figure 28. *Chondrite normalized REE pattern for Big Rat Lake pluton granitoids in the Iskwasum Lake sheet (symbol), compared to correlateable units in the Elbow Lake sheet (shaded). All data is from Whalen (unpublished data), and N refers to the number of samples from the unit. Normalizing values are from Sun (1982).*

The Big Rat Lake pluton underlies a small area in the northwest corner of the Iskwasum Lake sheet. Only one sample was taken from this area. The REE pattern of this sample correlates well with those of units 14g and 14f in the Elbow Lake sheet (figure 28). These two units are correlateable compositionally and in alteration and deformation intensity, and texturally differ only in grain size variations. The REE patterns are slightly HREE depleted, and concave-up.

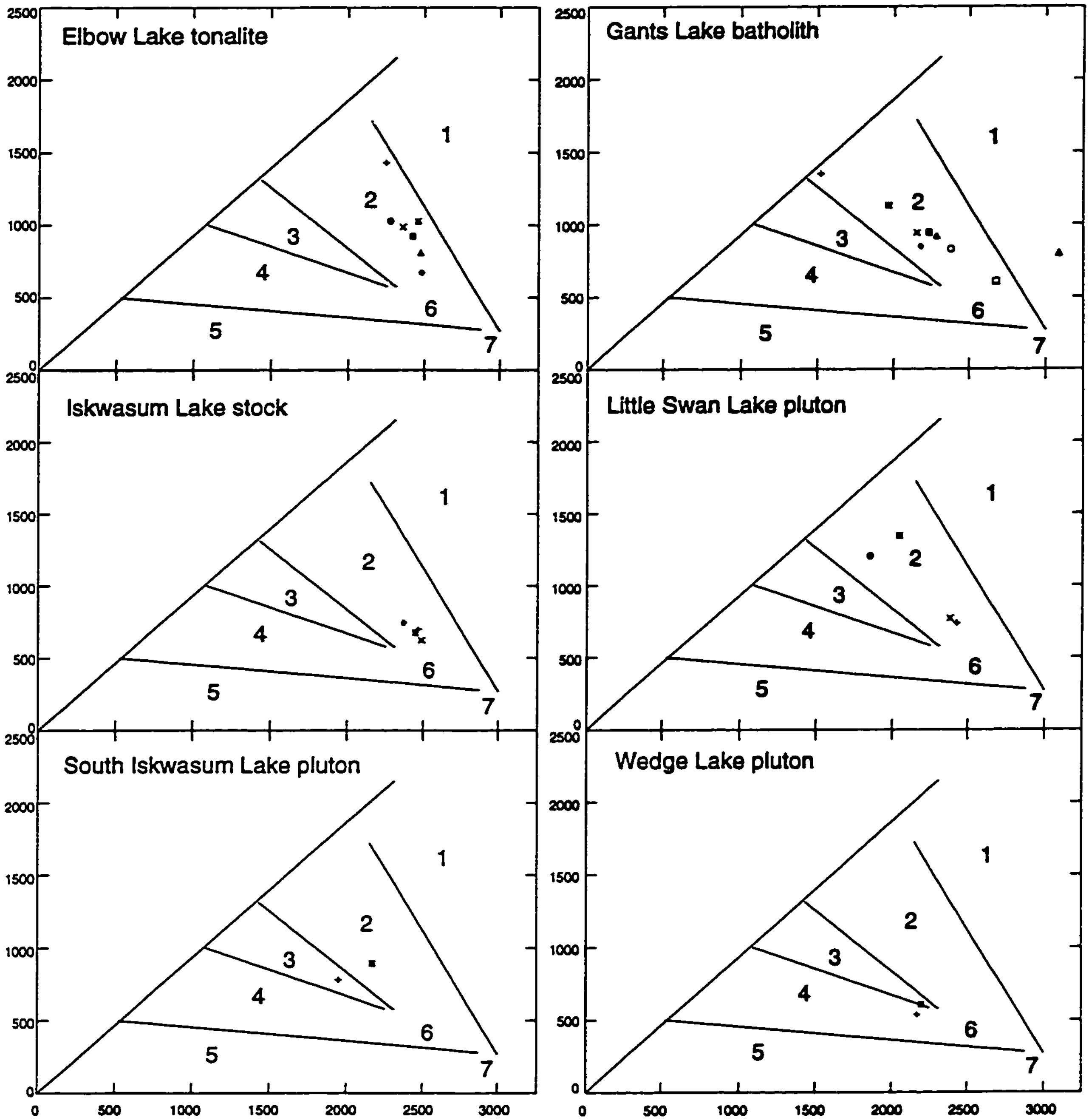
4.4 Tectonomagmatic characteristics of granites

The granitoid plutons of the Iskwasum Lake area are important indicators of tectonic conditions during their formation. As the dominant magmatic feature from

1.87 to 1.83 Ga, these plutons provide the only significant means of evaluating the tectonic processes that occurred during that time.

A number of authors have suggested ways of determining the tectonic environment in which granites were formed, based on geochemical characteristics. Multicationic plots have been proposed as a means of discriminating granite types and genesis. The generally accepted value of this type of plot lies in perceived inadequacies of bivarient oxide, and other discrimination diagrams that use oxide weight percents for accurately discriminating geotectonic origins. The reasoning behind these inadequacies is cited as the inability of these oxide weight percent discriminants to represent true cationic distribution of the elements in a sample (Batchelor and Bowden, 1985). A further problem is the inability of oxide weight percent diagrams in discriminating between variations of I-type granites. The discrimination diagram of Batchelor and Bowden (1985) aims at dealing with these problems by plotting R1 (4Si - 11(Na + K) -2(Fe + Ti)) versus R2 (6Ca + 2Mg + Al) (figure 29).

A diagram of this nature disregards the oxide weight percents, and relies on the balance of the given elements in the sample. It allows for the distinction of units as well as providing information on geotectonic environments. Further, it provides clues on the method by which granitic magmas were generated. Batchelor and Bowden have delineated 7 groups, each of which represents a particular geotectonic environment. It is of particular relevance in that it suggests a set of parameters by which to place plutons or plutonic phases in relation to an orogenic cycle. Groups II through IV represent such a cycle, with the earliest phases plotting in the group II series, and the latest phases in the group IV. This represents a progression through pre-plate collision, post-collisional uplift, and finally late orogenic granites. This progression is characterized by an increase in K and Na from an initial source, and ideally would form a linear trend from the upper right of the diagram to the lower left. Possible explanations for an enrichment of these elements over time include; 1) contamination of a mafic magma by K-and Al-rich phases, 2) initial bulk compositions which lie somewhere along the proposed trajectory, and 3) fractional crystallization of a mafic melt. Group I granites, found in the uppermost portions of the diagram are from a fractionated mantle source; these are the plagio-orthogranites. Group VI series



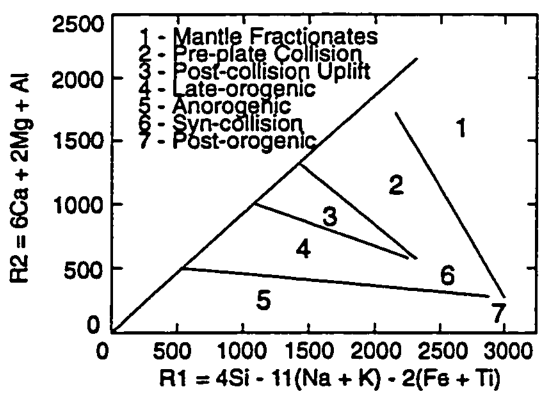


Figure 29. *Distribution of granites from the Iskwasum Lake sheet by pluton, in the multicationic R1-R2 discrimination diagram of Batchelor and Bowden (1985). Parameters and fields are given in the diagram to the left. Key to symbols is given in table 4.*

are indicative of syn-collisional granites and are characterized by higher R1 values than all other genetic types.

Variations within series or groups requires further explanation, given that the ideal situation through an orogenic cycle would be along the upper right to lower left trajectory in the diagram. This may include the derivation of the magma from slightly different source materials, magma mixing or fractional crystallization processes, to name a few.

Samples from the Iskwasum Lake sheet plot predominantly in the orogenic cycle defined as groups II through IV (figure 29). Only one sample, from the Gants Lake batholith plots outside these parameters. This sample falls in the Group I field, suggesting a mantle-derived protolith.

As mentioned previously, group II granites which are formed at a destructive plate margin, dominate the Iskwasum Lake sheet. All samples of the Elbow Lake tonalite, Iskwasum Lake stock and Little Swan Lake pluton plot in this field, and this generally corresponds to structural and geochronological evidence suggesting they are early plutons. Samples of the South Iskwasum and Wedge Lake plutons plot in fields II through IV, suggesting that at least some of the intrusive phases in the Iskwasum Lake sheet were emplaced later in the orogenic cycle. This is supported by the lack of deformation in these two plutons compared to others in the map sheet. Somewhat surprisingly, granitoid rocks of the 1828 Ma Little Swan Lake pluton plot within the pre-plate collisional regime. As this is the youngest known phase in the Iskwasum Lake sheet, it would be expected to plot later in the orogenic cycle, being more closely related to the South Iskwasum Lake and Wedge Lake plutons.

Tectonomagmatic characterization of granitoid rocks of the Iskwasum Lake sheet depends on the parameters with which the geochemical and petrographic criteria is evaluated. Discrimination of tectonic environment of formation of both volcanic and plutonic rocks has been aided by the use of trace elements. As noted in section 4.2, granitoid rocks from the Iskwasum Lake sheet are metaluminous to slightly peraluminous (see figure 19b), plot in the volcanic arc field of Pearce *et al.* (1984) (see figure 21a), are calc-alkaline (see figure 19a), and have a restricted range of compositions (see figures 16, 17 and 18). They are dominantly of medium-K tonalite to granodiorite, and have hornblende as a mafic phase in most units. These characteristics are indicative of the I-type granites of Chappell and White (1974, 1992). This will be discussed further in the following section.

4.5 Geochemical comparison with other granitoid suites

Similarities exist between granites in oceanic island arc and continental arc systems, particularly with respect to major element geochemistry. This is most probably due to a similar set of processes acting on the magma during its genesis. This includes, but is not limited to partial melting of the upper mantle, dehydration, and contamination by crustal material (Brown, Thorpe and Webb, 1984).

The traditional I-S terminology of Chappell and White (1974, 1992) does not convey the significant different tectonic environments in which I-type magmas may be emplaced, and Pitcher (1983) proposed an M-type to distinguish essentially mantle-derived melts from the I-type or infracrustal magmas. In addition, he proposed that I-type granites be further subdivided into two distinct types based on genetic differences. These include those formed in a setting similar to the Caledonides, and those from the Cordilleran.

In this section, the geochemical composition of rocks from the study area is compared to those of well-documented tectonic settings. Three suites of rocks were chosen for this comparison; Uasilau-Yau Yau intrusive complex, Coastal batholith and the Peninsular Ranges batholith. The Uasilau-Yau complex was chosen because it is characteristic of juvenile granitoid rocks formed in an oceanic island arc regime. The Coastal and Peninsular Ranges batholiths were chosen as representatives of continental subduction-related magmatism.

The Uasilau-Yau Yau intrusive complex was emplaced ca. 28 Ma ago into an active oceanic island arc on New Britain, a small island off the coast of Papua, New Guinea. Whalen (1985) used geochemical data of granitoids on the island to determine that these rocks are of juvenile arc origin, and have the same protolith as the volcanic rocks in the arc (*i.e.,* a mixture of subducted oceanic crust and suboceanic mantle). They are characterized as M-type granites.

To accurately depict the similarities and differences between granitic rocks in the Iskwasum Lake sheet and Uasilau-Yau Yau intrusive complex, major element data are plotted on four diagrams (figures 30 through 33). In addition, trace and REE data are plotted on chondrite and primitive mantle normalized plots respectively (figures 34 and 35).

The similarity in major element geochemistry is readily apparent. Uasilau-Yau Yau intrusive complex rocks are all metaluminous (figure 30) and have a calc-alkaline trend (figure 31). Iskwasum Lake sheet granites have a broader range of compositions on both these plots but are also calc-alkaline.

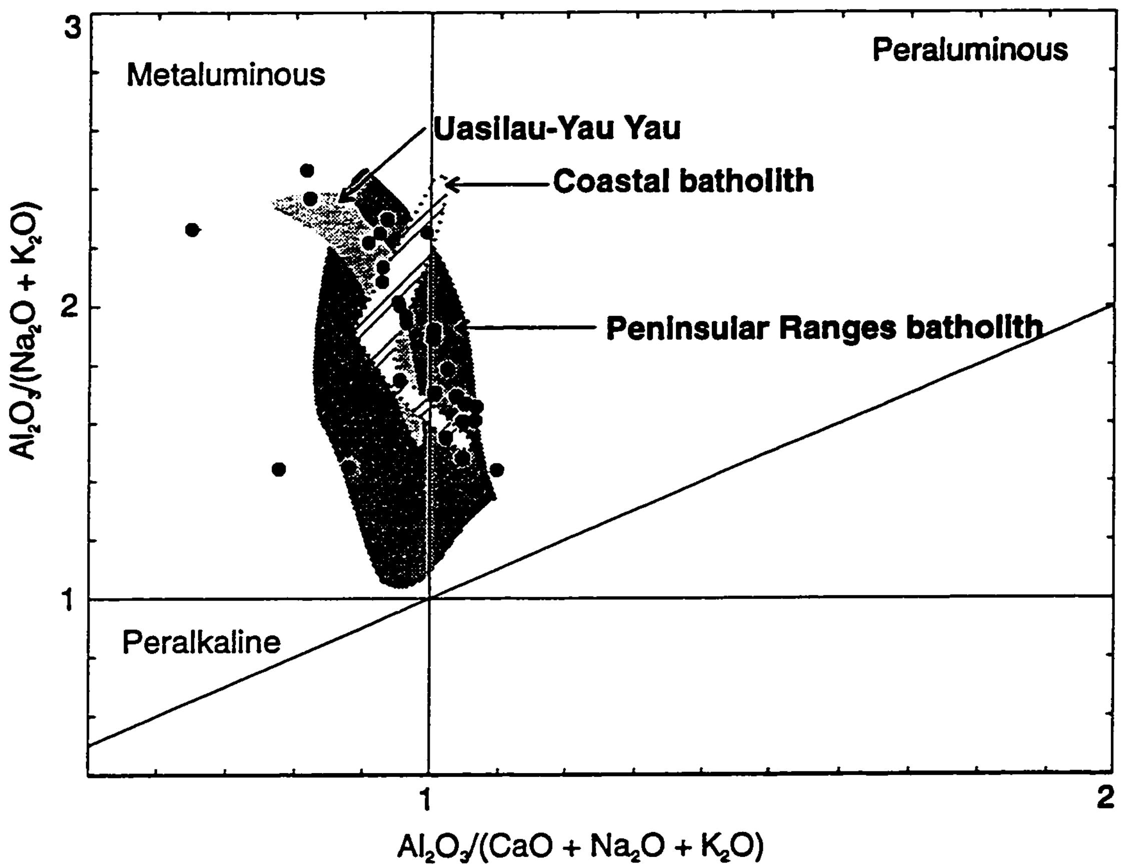


Figure 30. *Distribution of granites in the Iskwasum Lake sheet compared to Circum-Pacific plutonic suites; the Uasilau-Yau Yau intrusive complex of New Britain, Papua, New Guinea (Whalen, 1985); the Coastal batholith of Peru (Pitcher et al., 1985); the Peninsular Ranges batholith of Southern California (Baird and Miesch, 1984), in Shand's aluminous index. Filled circles are for granites in the Iskwasum Lake sheet.*

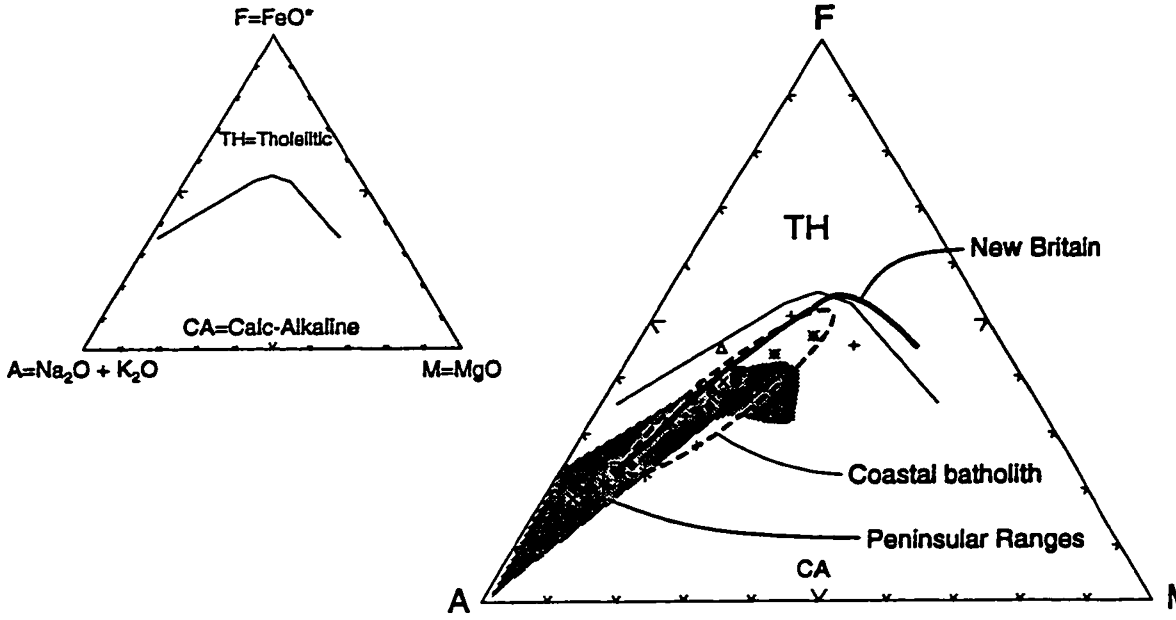
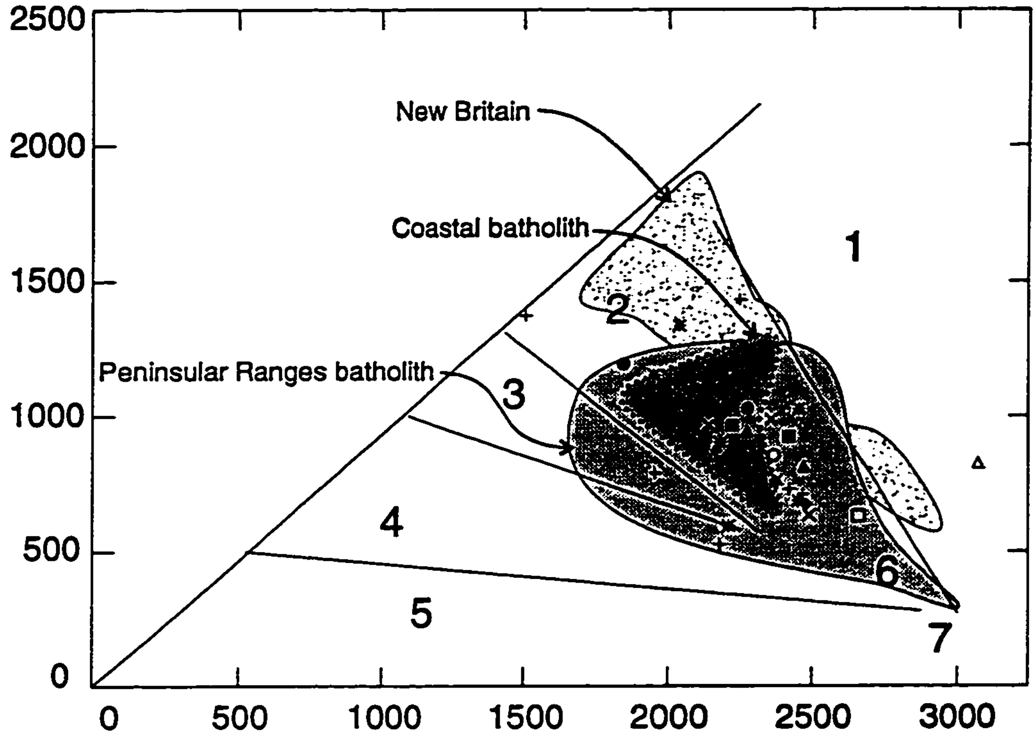


Figure 31. *AFM diagrams for DWM geochemical samples in the Iskwasum Lake sheet (symbols) compared to the Uasilau-Yau Yau intrusive complex of New Britain, Papua, New Guinea (Whalen, 1985); the Peninsular Ranges batholith (Baird and Miesch, 1984); and the Coastal batholith (Pitcher et al., 1985). AFM dviding line between tholeiitic and calc-alkaline fields from Irvine and Baragar (1971). Symbols do not correspond to particular units of plutons.*

In the R1-R2 multicationic diagram of Batchelor and Bowden (1985) rocks of the Iskwasum Lake sheet also show a broader chemical signature (figure 32). In this diagram granites of the Uasilau-Yau Yau intrusive complex cluster near the field 1 and 2 boundary, with nearly equal distribution in both fields. Conversely, granites of the Iskwasum Lake sheet encompass fields 1 through 4, and cluster dominantly in the middle of field 2.

On a Na_2O vs. K_2O Harker diagram (figure 33a) New Britain granites generally have lower K_2O contents over a large range of Na_2O contents. Granites of the Iskwasum Lake sheet have Na_2O contents of approximately 3 for all but the most K-poor samples, and a much broader range of K_2O contents. On a K_2O vs. SiO_2 Harker diagram Uasilau-Yau Yau intrusive complex rocks are lower in K_2O for a given SiO_2 content than samples of the Iskwasum Lake sheet, and particularly at high SiO_2 contents (figure 33b). They dominantly plot in the lower portion of the medium-K field, with a small portion in the low-K field. Geochemical samples from the study area show a much broader range over the full spectrum of SiO_2 contents, ranging from low- to high-K, most plotting within the middle of the medium-K field.



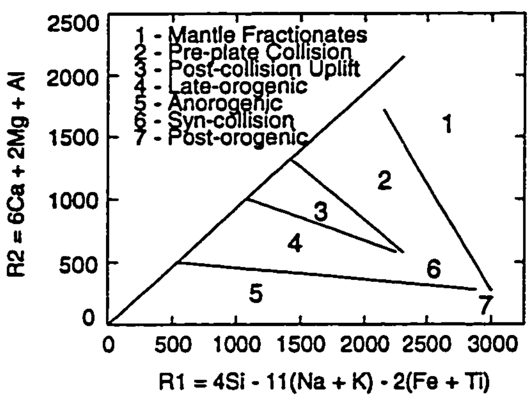


Figure 32. *Distribution of granites in the Iskwasum Lake sheet (symbols) compared to well known calc-alkaline granites in the multicationic R1-R2 discrimination diagram of Batchelor and Bowden (1985). Parameters and fields are given in the diagram at the top. Symbols do not correspond to individual units or plutons. Data for the Coastal batholith from Pitcher et al. (1985); the Peninsular Ranges batholith from Baird and Miesch (1984), and New Britain samples from Whalen (1985).*

Chondrite normalized REE plots for granites of the Uasilau-Yau Yau intrusive complex exhibit three slightly different patterns; these are plotted along with Iskwasum Lake sheet units. Of these three patterns, one probably reflects cumulate plagioclase-bearing gabbros (flat REE patterns with positive Eu anomalies) (Whalen, 1985). Immediately apparent in figure 34 is the relatively flat pattern exhibited by Uasilau-Yau Yau granitoids, compared to the Iskwasum Lake sheet granitic rocks. The latter generally have LREE relative to HREE enriched patterns, with Gd to Lu being relatively flat. The greatest similarity in patterns is between sample 0150 from the Iskwasum Lake stock and trend b; however, REE abundances in this sample are 3-4 times lower than those from New Britain. The

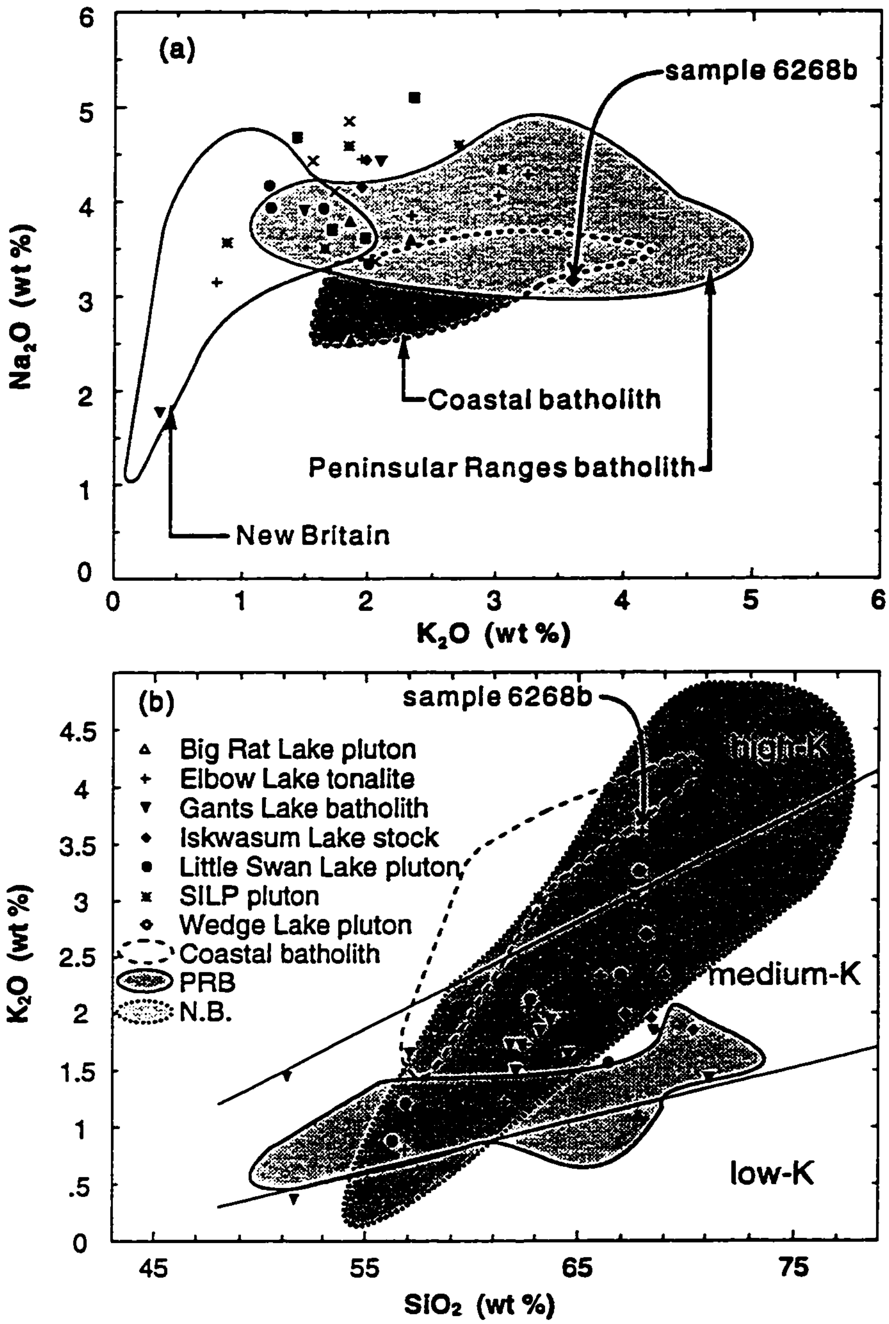


Figure 33. *Harker diagrams comparing; **(a)** Na_2O vs K_2O for Iskwasum Lake sheet granites compared to other granite terranes; **(b)** K_2O vs SiO_2 for granites in the Iskwasum Lake sheet compared to other granites of known tectonic environment. SILP=South Iskwasum Lake pluton; PRB=Peninsular Ranges batholith; N.B.=New Britain. High-K, late magmatic pegmatitic segregation from the Elbow Lake tonalite is indicated (sample 6268b). Data for New Britain granites are from Whalen (1985), Coastal batholith from Pitcher et al. (1985), and Peninsular Ranges batholith from Baird and Miesch (1984).*

only other similarity is that there is a distinct positive Eu anomaly in samples 0183 (Gants Lake batholith), 0395 (Little Swan Lake pluton), and trend c of the Uasilau-Yau Yau intrusive complex, a feature noted previously to probably reflect cumulate plagioclase.

Primitive mantle normalized extended element patterns show similar relationships to figure 35, but indicate Iskwasum Lake plutons contain higher overall abundances of the light lithophile elements (Rb, Ba, K), plus Th, and to a lesser extent Nb. Similarities include negative Nb, Nd and Ti anomalies, and positive Sr anomalies.

Like the Uasilau-Yau Yau intrusive complex, strong similarities exist between granitoid rocks of the Iskwasum Lake sheet and those from other Circum-Pacific granite terranes. All show a calc-alkaline trend (figure 31), and a concentration of samples in the medium-K field of figure 33b. Geochemical samples of the Peninsular Ranges batholith are most similar to those of the Iskwasum Lake sheet, encompassing a much broader range of compositions, and having an overall increase in K_2O with decreasing SiO_2 content. The significantly broader range in K_2O contents for Peninsular Ranges batholith may be a reflection of the inclusion of western zone granites into the database. These granites have compositions which more closely resemble New Britain granites. In contrast, Coastal batholith rocks exhibit a much higher K_2O content at lower SiO_2 contents. In the Na_2O vs. K_2O Harker diagram in figure 33a, Peninsular Ranges batholith granites encompass a similar range in Na_2O content at a given K_2O, but some have higher K_2O contents. Granites of the Coastal batholith encompass a narrower range of compositions than those from either the Peninsular Ranges batholith or Iskwasum Lake sheet.

Distribution of samples in the R1-R2 multicationic diagram of Batchelor and Bowden reveals a similar correlation of Peninsular Ranges batholith and Iskwasum Lake sheet rocks (figure 32). Both plot predominantly in field 2, extending into fields 1,3 and 4, and exhibit a general decrease in R1 values with increasing R2 values. Rocks of the Coastal batholith are clustered more tightly within field 2.

Of the three arc granitoid complexes compared in major element

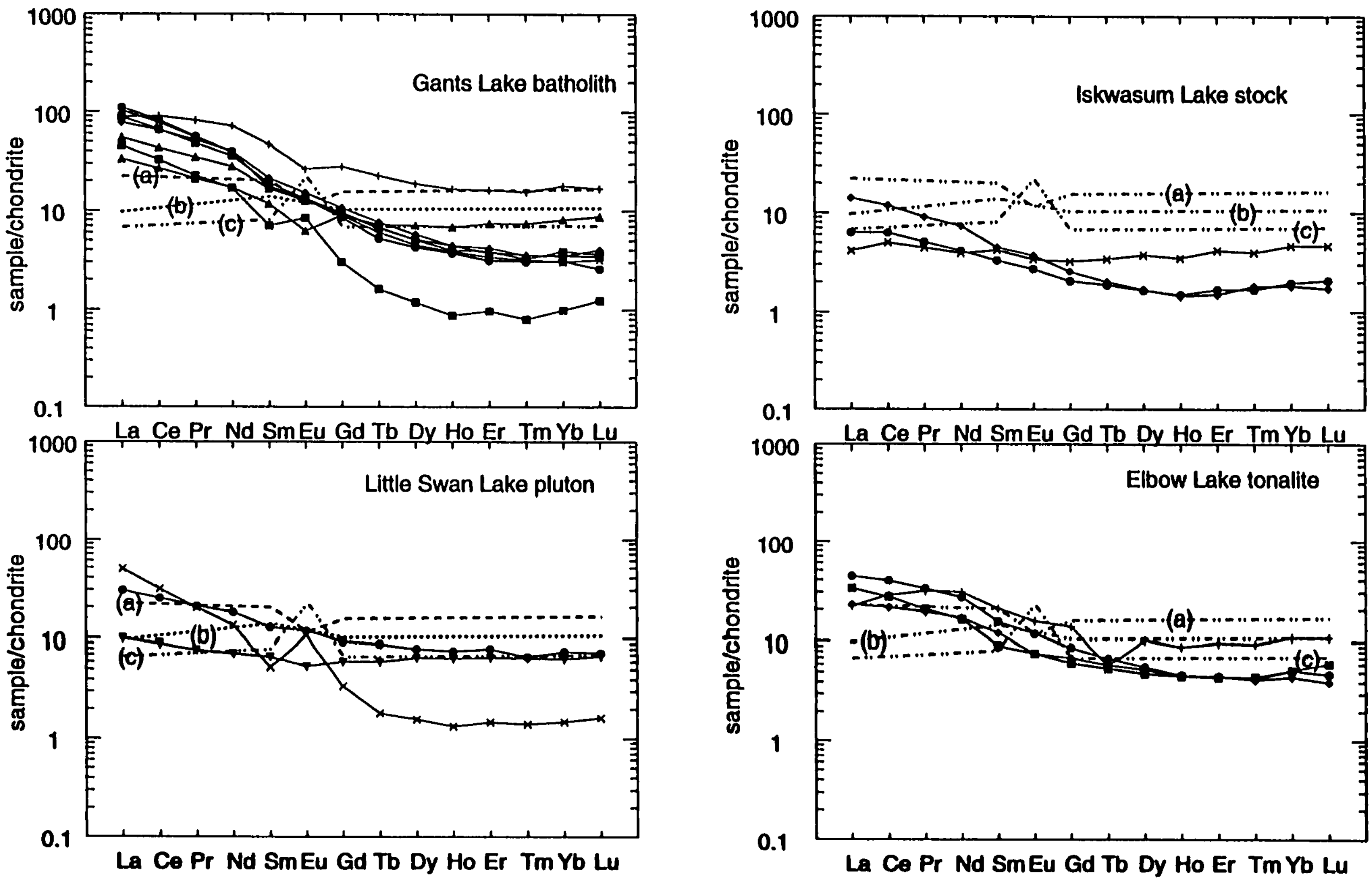


Figure 34. ***Rare earth element plots for granites from the Iskwasum Lake sheet, compared to those from New Britain, Papua, New Guinea (shaded area), normalized to chondritic values of Sun (1982). All New Britain data are from Whalen (1985).***

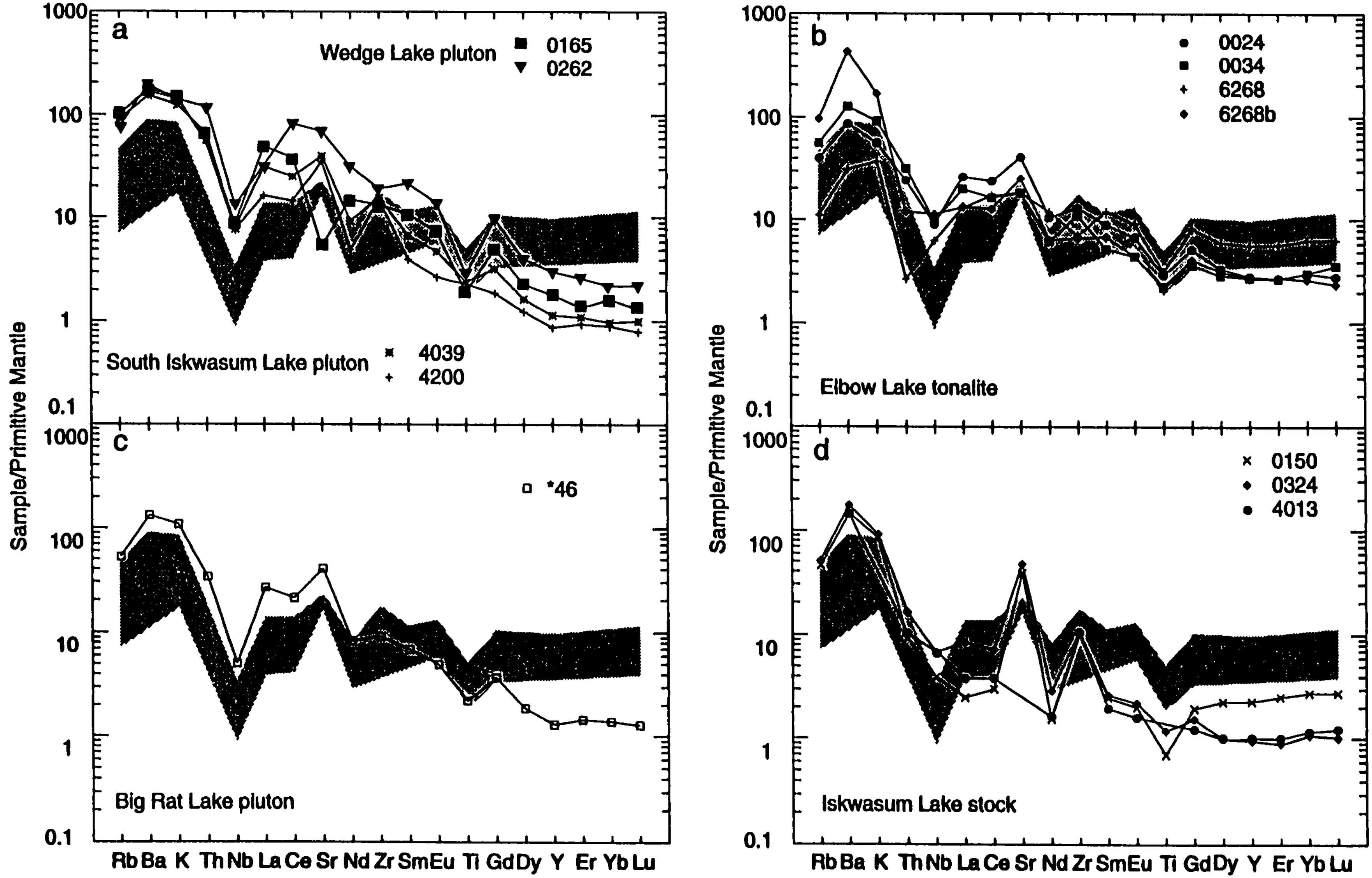


Figure 35. *Extended trace element diagrams for granites from the Iskwasum Lake sheet and those from New Britain, Papua, New Guinea (shaded area), normalized to the primitive mantle values of Taylor and McLennan (1985). A sample number preceded by * indicates an Iskwasum Lake sheet granite from Whalen (unpublished data). All New Britain data are from Whalen (1985).*

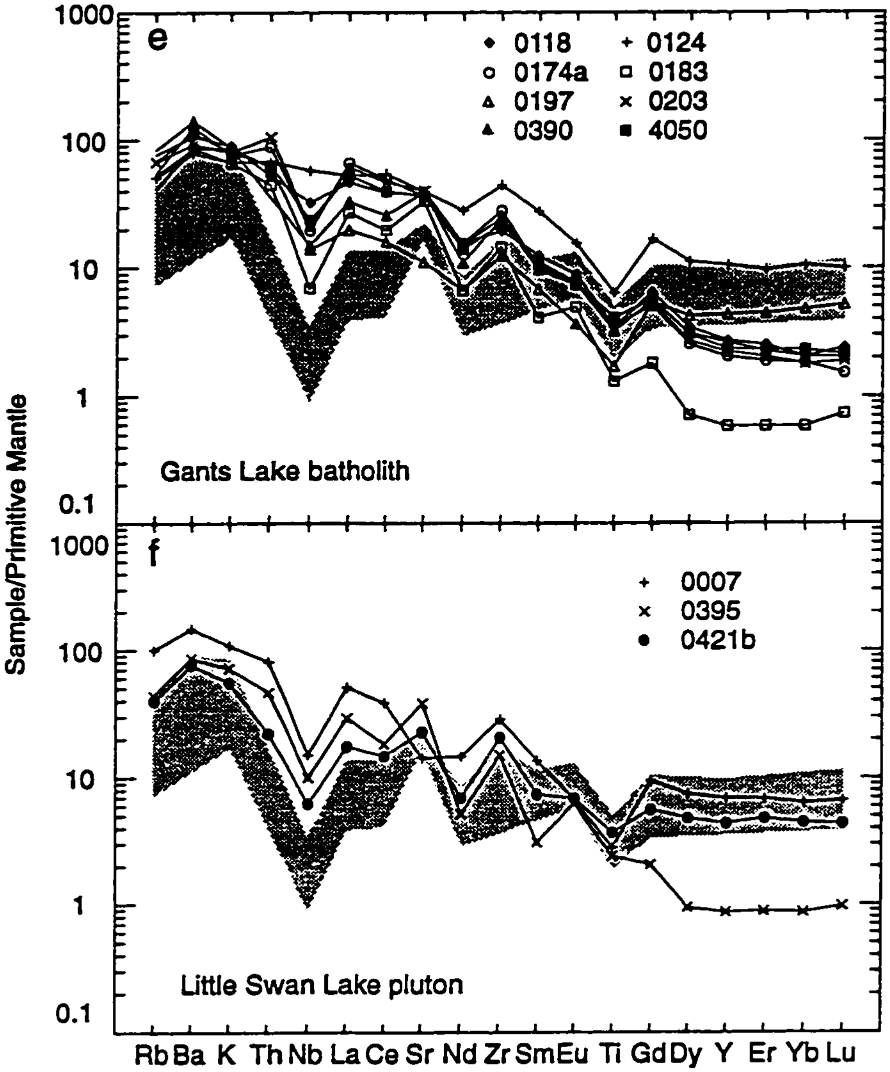


Figure 35 (cont.). *Extended trace element diagrams for granites from the Iskwasum Lake sheet, compared to those from New Britain, Papua, New Guinea (shaded area), normalized to the primitive mantle values of Taylor and McLennan (1985). A sample number preceded by * indicates an Iskwasum Lake sheet granite from Whalen (unpublished data). All New Britain data are from Whalen (1985).*

discrimination diagrams above, the Peninsular Ranges batholith appears to correlate with Iskwasum Lake sheet granites best. Not surprisingly, REE patterns also show many similarities. The Peninsular Ranges batholith is unique in that there is a systematic change in the REE patterns from west to east (Gromet and Silver (1987) and Silver and Chappell (1988)). Granites of the western zone typically have flat REE patterns which appear to be similar to juvenile oceanic island arc granites of the Uasilau-Yau Yau intrusive complex. The central and eastern zones of the Peninsular Ranges batholith have a depletion of the heavy

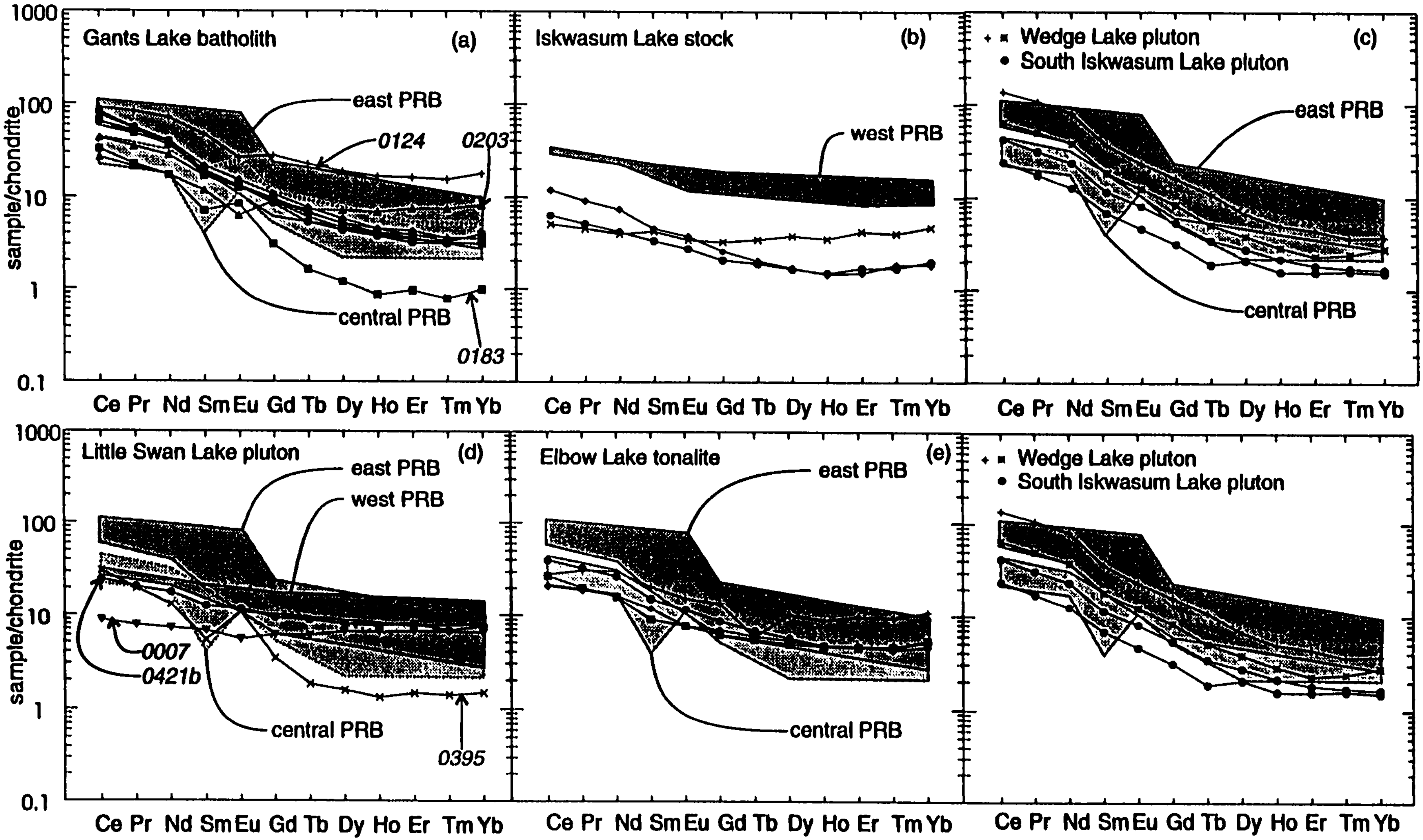


Figure 36. *Rare earth element diagrams for granites from the Iskwasum Lake sheet, compared to those from Peninsular Ranges batholith (PRB) (shaded areas), normalized to chondritic values of Sun (1982). PRB data is subdivided into spatial zones. All PRB data are from Gromet and Silver (1987).*

REEs and are closely comparable to most granites from the Iskwasum Lake sheet (figure 36).

Granitic rocks in the Iskwasum Lake sheet which have flat REE patterns are rare (figure 36b). They typically have slight heavy REE depletions, and 3 to 10 times lower overall REE abundances than granites of the western Peninsular Ranges batholith. The closest correspondance in REE patterns between Iskwasum Lake sheet granites and the western Peninsular Ranges batholith is in the Iskwasum Lake stock (figure 36b), with these rocks lieing between the western and central zones in REE abundances. In addition, two samples of the Little Swan Lake pluton also show flat REE patterns (figure 36d). Sample 0421b, a comagmatic quartz diorite, plots in the lower part of the field defined by the western Peninsular Ranges batholith, and retains the same pattern. Sample 0007, a sample of the main granodioritic phase of the pluton, has a similar pattern with lower overall REE abundances.

In general, samples of the eastern Peninsular Ranges batholith have higher overall REE abundances than those of the Iskwasum Lake sheet, but patterns are similar. In the central Peninsular Ranges batholith, rocks have an intermediate REE composition between the west and east, and most closely resemble the majority of granites from the Iskwasum Lake sheet (figs. 36a to 36e). The exception is the South Iskwasum Lake pluton which has a steeper pattern than all others, with sample 4200 having greater LREE abundances than any of the Peninsular Ranges batholith (figure 36c).

Anomalous samples from the Iskwasum Lake sheet include 0183 (figure 36a; Gants Lake batholith) and 0395 (figure 36d; Little Swan Lake pluton). These REE patterns exhibit much steeper slopes and greater depletion of the HREEs than any others in either area. In general granites of the Gants Lake batholith have REE patterns that more closely resemble those from the eastern zone of the Peninsular Ranges batholith.

4.6 Magma source and temporal variations in arc magmatism

Granitic plutons in the Flin Flon domain of the Trans-Hudson orogen are important indicators of the tectonic processes which operated during the evolution of the orogen. Temporal subdivision of granitic rocks in the Iskwasum Lake sheet includes 1.88-1.84 Ga post accretionary arc magmatism and 1.84-1.83 Ga late arc magmatism. Although both periods of granite emplacement are considered to represent arc magmatism, their different geochemical properties point to significant differences in the source of these magmas. This has implications for the tectonic evolution of the Flin Flon domain. Spatial correlation of these rocks in the Iskwasum Lake sheet is impossible, but this may reflect the small size of the study area relative to the Flin Flon belt.

The predominance of intermediate magmas and the uniform calc-alkaline character is indicative of an arc setting. Other evidence includes distinct negative Nb and Ti anomalies on primitive mantle-normalized extended trace plots, and a broad range in compositions from gabbro to tonalite and granodiorite. All rocks plot within the volcanic arc field of Pearce *et al.* (1984) and are predominantly metaluminous in character. In addition, these rocks consistently show geochemical characteristics which are comparable to younger arc-related magmas (*i.e.,* the Peninsular Ranges batholith of southern California). Although isotopic data is not available for granites in the Iskwasum Lake sheet for comparison, they all exhibit characteristics which are consistent with their derivation from igneous sources, including amphibole as a mafic phase, and a preponderance of igneous microgranitoid enclaves. A mantle-derived component to arc magmatism is indicated by the presence of mafic intrusive rocks throughout the time span during which granites were emplaced in the Iskwasum Lake sheet.

Stern *et al.* (1995a) suggest that the change from a collisional to subduction-related tectonic regime around 1.88-1.87 Ga is shown by the change from a subaqueous volcanic-dominated sequence, to that of arc-related magmatism and rare subaerial volcanic rocks, and that this may be due to an increase in the thickness of the continental crust. Because of the predominance of granites during that period of the evolution of the Flin Flon domain, their geochemical signature allows for an evaluation of this model.

4.6.1 1.88 to 1.84 Ga arc magmamatism

Steep, HREE-depleted REE patterns and no Eu anomalies characterize

1.88-1.84 Ga magmatism in the Iskwasum Lake sheet (see figures 25 and 26). This may be due to derivation of the granites by partial melting of a material with garnet in the residue, but not significant plagioclase (or alternatively subequal proportions of plagioclase and hornblende). If this is the case, the magma must have been generated within the garnet stability field.

Magma source also has tectonic implications. The generally moderate potassium content and high Mg# (30) of these high-Mg andesitic composition granites are compatible with a source of mafic to intermediate composition. Geochemical attributes of the granitoids are consistent with derivation of these magmas from the basaltic portion of the subducted slab, including (requirements for a slab-derived melt from Drummond and Defant (1990), and Defant and Drummond, (1990)) (figure 37);

- *Al_2O_3>15 wt%*
- *Yb<1.9 ppm*
- *Y <15 ppm*
- *Nb<10 ppm*
- *K/Rb<550*
- *Rb/Sr<0.15*
- *Sr>300 ppm*
- *La/Yb>20*
- *little or no Eu anomaly*

Slab-derived melts require hot, young oceanic crust being subducted (Drummond and Defant (1990), and Defant and Drummond, (1990)). To satisfy this parameter, the granites in the Iskwasum Lake sheet would likely have been formed from basalts derived in a recently active oceanic environment. This may have included basalts formed in a back-arc basin, or alternatively in a rapidly closing oceanic basin. Both are consistent with the current tectonic interpretation of the Flin Flon belt. An alternative is that these melts were derived from a LREE-enriched mantle source. Not all granites have complete slab-derived characteristics and a combination of processes, including derivation from the mantle (or incorporation of mantle melts) is likely. It is difficult to discern the relative proportions of these components with the given data. If a combination of the two components is reflected in the geochemical signature, early slab-derived melts may have been ponded at the base of the crust, effectively melting the

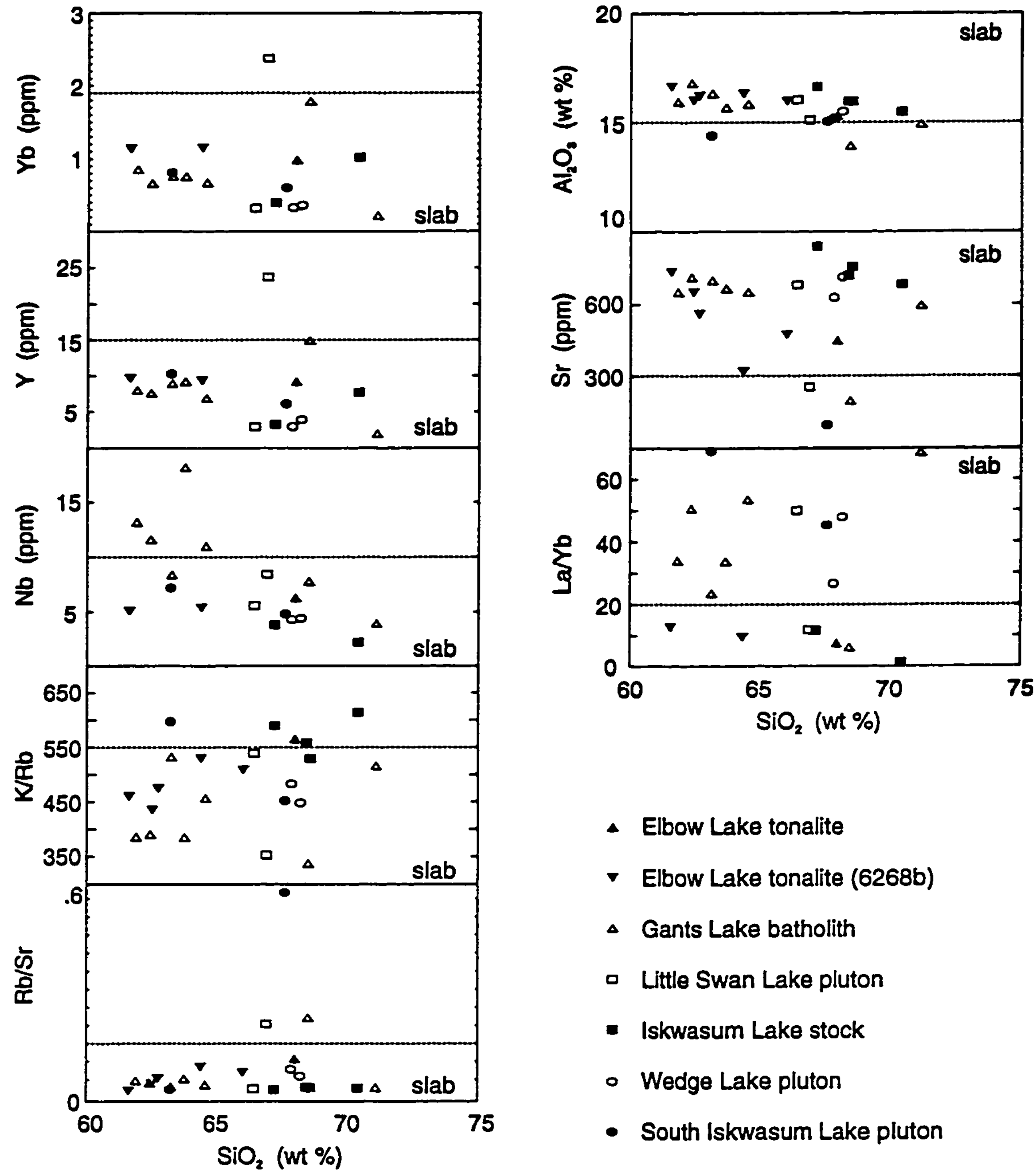


Figure 37. *Major and trace element Harker diagrams for granites of the Iskwasum Lake study area. Fields for slab-derived melts (from Drummond and Defant (1990) and Defant and Drummond (1990)) are shown.*

mantle wedge and creating hybrid melts.

4.6.2 1.84-1.83 Ga arc magmatism

Late arc magmatism (1.84-1.83 Ga) in the study area has a different geochemical signature, and correspondingly different tectonic implications than early arc magmatism. These rocks generally have flatter primitive mantle-normalized REE patterns than the earlier granites, and distinct negative Eu anomalies (figure 27b). The Little Swan Lake pluton provides an ideal means of evaluating the implications of these geochemical differences. Absolute age determinations show this pluton to be one of the youngest in the Flin Flon belt, within the 1.84-1.83 Ga time frame. The REE characteristics of these granites are consistent with their derivation via partial melting of basalt under lower pressure conditions (*i.e.*, the depths at which partial melting occurred evidently decreased from that seen for 1.88-1.84 Ga magmatism). Later arc magmatism shows few slab-derived characteristics, and its geochemical signature may represent remelting of the collage crust (the amalgamated tectonic terranes which would have formed the continental crust at the time of pluton emplacement) due to crustal thickening towards the end of the arc, or alternatively an increase of the geothermal gradients within this crust.

The Big Rat Lake pluton, dated at 1.845 Ga, is the next youngest pluton in the Iskwasum Lake sheet, and it does not exhibit the same REE pattern characteristics of the Little Swan Lake pluton. However, similar REE patterns to those from the Little Swan Lake pluton, although rare, do exist in other plutons.

Samples of the Little Swan Lake pluton have relatively flat REE patterns and negative Eu anomalies. These patterns contrast the HREE depleted pattern of the 1876 Ma dated phase of the Gants Lake batholith. These two granite bodies are ideal for comparison because they respectively represent some of the youngest and oldest arc-related granites in the Flin Flon belt. It becomes apparent when comparing REE patterns for these intrusive bodies that the Gants Lake batholith has granite phases with similar geochemical signatures to those from the Little Swan Lake pluton.

When samples with negative Eu anomalies are removed from the Gants Lake batholith, the average REE content of the remaining samples shows a HREE depleted pattern without a negative Eu anomaly. The average REE pattern for those with a negative Eu anomaly is almost identical to the Little Swan Lake pluton granites (figure 38). This suggests that 1.84-1.83 Ga magmas may have been injected into the composite Gants Lake batholith. Because sharp intrusive contacts between the two temporal extremes are nowhere apparent in the Gants Lake batholith, the geochemical signatures may reflect a gradational change in the tectonic conditions during arc magmatism.

Felsic magmas of the Little Swan Lake pluton are similar in their REE characteristics, and deviations from the REE pattern are best explained individually. In the Iskwasum Lake sheet one anomalous sample has a steep negative REE pattern. The large positive Eu anomaly suggests cumulate plagioclase in the melt, and the LREE-enriched pattern may be attributed to cumulate phases (*e.g.*, allanite?). Mafic units within the Little Swan Lake pluton generally have similar REE patterns, but do not exhibit the negative Eu anomaly that is characteristic of the felsic varieties. This may be attributed to subequal amounts of plagioclase and pyroxene in the residue. Again, the presence of these magmas in the Iskwasum Lake sheet probably reflect a mantle source, and thus indicate multiple, or mixed granite sources for the spectrum of compositions in the study area.

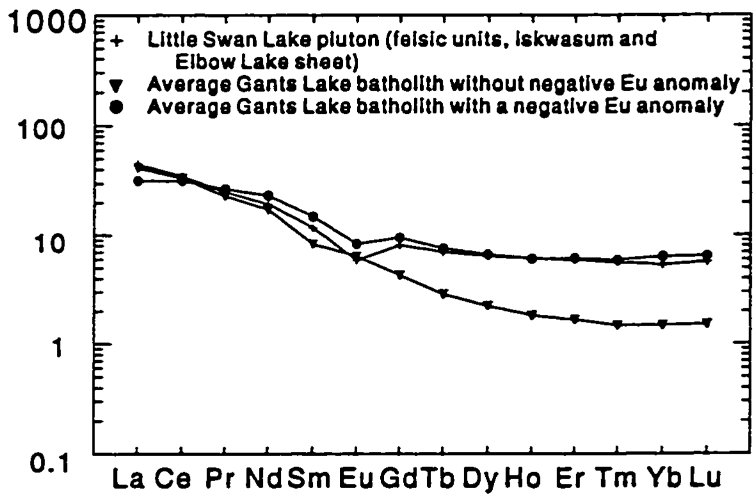


Figure 38. *REE plot comparing Little Swan Lake pluton granites with the Gants Lake batholith. Note that Gants Lake batholith granites with negative Eu anomalies have REE patterns similar to those from the Little Swan Lake pluton. Normalized to the values Sun (1982). Geochemical data from the Little Swan Lake pluton in the Elbow Lake sheet from Whalen (unpublished data).*

4.7 Summary

The previous sections illustrate how comparitive geochemistry can help in the mapping of granite-greenstone terranes by establishing regional correlation of granioid rock units. In addition, the geochemistry of these granioid rocks places constraints on their tectonic environment and the processes which led to their emplacement.

In the Iskwasum Lake sheet, felsic intrusive rocks are calc-alkaline, metaluminous to slightly peraluminous volcanic-arc granites. They have a range of compositions from quartz diorite to tonalite and granodiorite, but are predominantly intermediate in composition. On the multicationic plot of Batchelor and Bowden (1985) granites predominantly plot within groups II, III and IV, which defines a progression through an orogenic cycle. They have moderate potassium contents, and have Na_2O contents typically 3 wt% and Na_2O/K_2O ratios around 2.

Major element geochemistry illustrates the limited range of compositions of granites from the Iskwasum Lake sheet. Although there is some variation between diagrams discriminating compositions of granites from the study area, they are generally consistent in plotting samples in a tight cluster around the tonalite and granodiorite fields.

Trace and rare earth element data can also be used to compare units and tectonic regimes. Based on petrographic, structural and textural similarities, a general correlation of map units is possible, but trace and rare earth element data provide a means for more detailed correlation. This is particularly important in large bodies such as the Gants Lake batholith, which is subdivided into numerous units, many of which are subdivided based solely on textural criteria.

A comparison with those granites from generally well-understood volcanic arc terranes may provide a model for the genesis of Iskwasum Lake sheet granites. The oceanic island arc granites of the Uasilau-Yau Yau intrusive complex, New Britain do not correlate well with those from the study area, and the best correlation appears to be with the continental subduction-related magmatism of the Peninsular

Table 6. *Summary of the geochemical attributes of granitoid rocks in the Iskwasum Lake sheet. Data compiled from diagrams in the text, and appendix 5. La/Lu ratios were chosen as an indicator of the steepness of the rare earth element patterns.*

		South Iskwasum Lake pluton	*Wedge Lake pluton*	*Iskwasum Lake stock*	*Elbow Lake tonalite*	*Gants Lake batholith*	*Little Swan Lake pluton*
Silica Range (weight percent)		63-68	67-79	67-71	57-68	51-71	56-67
Alkali-lime index		CA	CA	CA	CA	CA TH (minor)	CA TH(minor)
Shand's index		metaluminous	peraluminous (slightly)	peraluminous (slightly)	metaluminous peraluminous (slightly)	metaluminous peraluminous (slightly)	metaluminous peraluminous (slightly)
Na_2O/K_2O (weight percent)		0.99 (avg.)	2.38 (avg.)	1.44 (avg.)	0.65 (avg.)	0.79 (avg.)	0.76 (avg.)
	range	0.88-1.15	2.37-2.39	1.37-1.72	0.38-1.05	0.47-1.79	0.47-1.21
Na_2O/K_2O (weight percent)		1.38 (avg.)	1.51 (avg.)	2.40 (avg.)	2.14 (avg.)	2.25 (avg.)	3.00 (avg.)
	range	1.34-1.42	1.31-1.70	2.23-2.62	0.88-3.94	1.35-3.27	1.65-4.06
Na_2O (weight percent)		4.2 (avg.)	4.44 (avg.)	4.58 (avg.)	3.44 (avg.)	3.78 (avg.)	4.01 (avg.)
Al_2O_3/Na_2O+K_2O+CaO (molar)		<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
La/Lu (chondrite-normalized)		41.2 (avg.)	24.3 (avg.)	4.0 (avg.)	4.8 (avg.)	22.6 (avg.)	15.5 (avg.)
	range	35.6-46.83	17.5-30.0	0.9-8.1	2.1-9.4	5.3-41.8	4.0-34.7
Total rare earth elements		191.7 (avg.)	79 (avg.)	21.96 (avg.)	64.7 (avg.)	119.47 (avg.)	83.61 (avg.)

CA: calk-alkaline; TH: tholeitic: Chondritic values of Taylor and McLennan, 1985

Ranges batholith.

Because of its well-documented geochemical characteristics and tectonic significance, the Peninsular Ranges batholith provides a valuable basis for comparison with granitoid rocks of older orogens. The Peninsular Ranges batholith shows a systematic change in the REE patterns eastward. In the western zone, granites typically have flat REE patterns, similar in appearance to those of the oceanic island arc of New Britain. From the west to the central zone there is a disappearance of the moderate negative Eu anomaly and a fractionaltion of the HREEs. From the central to the eastern zone there is an enrichment of the LREEs resulting in an overall steeper negative slope to the REE pattern.

An important aspect to come out of the geochemical studies of the peninsular Ranges batholith is the general lack of correlation between rock type and REE pattern, suggesting that these patterns are representative of the source material, and not products of high-level fractionation.

Plots of major-element data show that the central and eastern zones of the Peninsular Ranges batholith are most similar to Iskwasum Lake sheet granites. Unlike New Britain granites, which have Na/K ratios>3, and a broad range in Na contents, granites of the Peninsular Ranges batholith and Iskwasum Lake sheet generally have Na/K ratios around 1.0-1.5, and Na contents>3 wt% for all but the most K-rich samples. REE data confirm the similarities, but also point to some minor differences. Many of these differences are best explained by the presence of minor unique conditions during the time of emplacement. As the area covered in this study is small, the spatial relation to REE content in the Peninsular Ranges batholith is not seen in the Iskwasum Lake sheet. Iskwasum Lake sheet samples span the range of REE contents of granites from the east and central zones of the Peninsular Ranges batholith.

Rare earth and trace element data are consistent with two temporal associations for arc magmatism in the Iskwasum Lake sheet. Granites of 1.88-1.84 Ga age are presumed to reflect derivation from a basaltic source (slab?) at depths within the garnet stability field. Alternatively, they could reflect derivation from a LREE-enriched mantle source. The presence of mafic intrusive rocks in the plutons suggests that the magmatism received direct mantle-derived contributions, and a combination of the two models is probable. Late arc (1.84-1.83 Ga) magmatism is distinct from earlier magmatism, and is consistent with partial melting at lower pressure conditions. Protoliths are poorly constrained, but on the basis of major element chemistry recycling of the collage crust is judged as a likely scenario. If this scenario is correct, thickening of the collage crust and rising of the geothermal gradients into it may have resulted in an increase in the crustal component. It may also have been due to partial melting of the mantle wedge with pyroxene and plagioclase in the residue. Again, a mantle component is evidenced by the presence of gabbroic to quartz dioritic rocks.

The presence of REE patterns with negative Eu anomalies in the Gants Lake batholith suggests that there was a gradational change in the conditions that led to the formation of late arc magmas. Although there are a diverse set of processes which could lead to such a transformation, it is important to recognize that there are tectonic implications, many of which must be dealt with in the future.

5.0 Summary and Tectonic Significance

Granitoid plutons of the Iskwasum Lake sheet are metaluminous to peraluminous quartz diorites to tonalites and granodiorites. Although there is a considerable range of compositions, these rocks are dominantly tonalitic to granodioritic in composition. They are predominantly medium-K, have moderate Na and generally high Ca contents, and show a strong calc-alkaline trend. Hornblende is most common in the more mafic units, in some instances being the predominant mafic mineral. Although muscovite is common in almost all rocks, it is not a primary mineral as it occurs as a late alteration of feldspar. In general alteration of granites in the Iskwasum Lake sheet is strong but variable from outcrop to outcrop. It includes the crystallization of epidote, sericite, muscovite and chlorite. The subdivision of plutonic units within the map sheet, and their correlation with units in the Elbow Lake sheet can be successfully accomplished on the basis of lithology, structure, texture and geochemistry.

Plutons are compositionally variable, ranging from gabbro to tonalite and granodiorite. Pegmatite and aplite dikes are rare, and emplaced predominantly at the margins of plutons and in high strain zones. Mafic dikes are less abundant and do not appear to be preferentially emplaced in high- or low-strain zones. Although evidence for compositional zonation is rare, it is apparent in areas where brittle and ductile structures are not prevalent (*ie.* the Big Rat Lake pluton). All plutons show evidence for contact-subparallel foliations. Evidence for comagmatic felsic and mafic magmas includes lobate quartz diorite lenses in granodiorite and complicated cross-cutting relationships. Evidence for magma mixing includes a thin zone of hybrid rocks at the contact between comagmatic gabbro and granodiorite.

Fabrics throughout the Iskwasum Lake sheet are strongly influenced by ductile shear zones. These structures are located dominantly within the mafic supracrustal rocks, but are not limited to them. The Loukes Lake shear zone is located entirely within the Gants Lake batholith, and structures within it are affected by later movement along the Berry Creek fault. These structures may be the trace of sutures created during the amalgamation of the Flin Flon collage which were subsequently reactivated during emplacement of calc-alkaline granites. All appear to be long-lived structures with protracted deformation histories.

Granites from the Iskwasum Lake sheet are geochemically similar to some more "evolved" granite terranes such as the Peninsular Ranges batholith. They contrast strongly with the more "juvenile" oceanic subduction terranes such as the Uasilau-Yau Yau intrusive complex of New Britain in both major and trace element characteristics. Because the intrusive rocks in the Iskwasum Lake sheet span a time interval within the history of the Flin Flon belt where volcanism was rare, they provide the best record of the tectonic evolution of the belt during this period.

Indications of the processes occurring during the emplacement of granitic plutons in the Iskwasum Lake sheet is important for the understanding of the evolution of the Trans Hudson orogen. As all these plutons have similar major and trace element signatures, they are considered to have formed by similar means and within similar tectonic environments. All geochemical samples plot within the volcanic arc field of Pearce *et al.* (1984) (figure 21), show a strong, uniform calc-alkaline trend (figure 19), and have similar trace and rare earth element patterns regardless of composition (figure 22). The moderate to strong depletion of the HREEs in all samples is attributed to derivation of the magma by partial melting of eclogite with garnet in the residue. Deviations in the REE patterns may be explained by high level fractionation, but a simpler approach would be to explain them by variable amounts of garnet, plagioclase and hornblende remaining in the residue.

The tectonic history of the Flin Flon greenstone belt is complex, involving the juxtaposition of five distinct tectonostratigraphic assemblages, followed by the creation of a new (successor) arc, and finally post-collisional tectonics. Although granite plutons in the Iskwasum Lake sheet are part of "successor" arc magmatism, it is important to consider the earlier amalgamation and formation of the Flin Flon accretionary collage, as it forms the host to granite intrusions.

Lucas *et al.* (1995) suggest that juvenile lithologic regimes were tectonically juxtaposed by 1.88 to 1.87 Ga. This was then followed by a change in the tectonic regime from dominantly collisional to subduction, and successor arc magmatism from 1.87 to 1.83 Ga. This theory suggests that during the period from 1.92 to 1.88 Ga distinct lithologic terranes were formed separately in different tectonomagmatic environments. These distinct terranes were then amalgamated into one collage of crust during the period from 1.88 to 1.87 Ga and during the waning stages of this accretionary process a predominantly collisional orogen was transformed into one of subduction-related magmatism. Initial magmatism was related to partial melting of the basaltic slab, a LREE-enriched mantle, or more likely a combination of the two until 1.84 Ga, when this gradually gave way to magmatism reflecting recycling of the collage crust. This may have been due to an increase in the crustal thickness. Subduction continued until 1.83 Ga, when collisional tectonics presumably became the dominant tectonic regime affecting the area. Obviously the basis of the change from a collisional to subduction-related tectonic environment must be supported by the 1.87 to 1.83 Ga calc-alkaline plutons, as they are the dominant magmas formed during this time.

What becomes important when considering the geochemical signature of these rocks is that they do not exhibit "juvenile" ocean arc subduction characteristics (*e.g.,* flat REE patterns, low Na/K ratios) but rather are more consistent with well known oceanic-continental subduction related magmatism such as the Peninsular Ranges batholith. There are significant differences between the Peninsular Ranges batholith and granitoid rocks of the study area. As the study area is small relative to the Peninsular Ranges batholith, no a spatial association of the REE patterns of granites in the Iskwasum Lake sheet would be expected. The overall change in composition is similar to that seen in the Peninsular Ranges batholith, however, and a temporal rather than spatial correlation of granites may be possible. The extreme flat REE patterns of the western Peninsular Ranges granites are not found in the Iskwasum Lake rocks, but 1.84-1.83 Ga granites show flatter REE patterns and have distinct negative Eu anomalies that are not apparent in the older granites. The lack of a distinct spatial change in REE patterns may not be recognizeable at the scale of this study, and it may be more appropriate to look at granites in the entire width of the Flin Flon domain to determine if the there is some spatial continuity beween them. While the Peninsular Ranges batholith is emplaced into relatively simple packages of volcanic and sedimentary rocks, this is not the case in the Flin Flon domain, where granites are emplaced into rocks that have been tectonically juxtaposed. This may

Table 7. *Summary of the tectonic events that shaped the Iskwasum Lake sheet.*

1). "1.92 - 1.88 Ga" ***FORMATION OF DISTINCT LITHOTECTONIC DOMAINS***
- -eruption of 1904 Ma ocean floor basalts to the west
- -eruption of volcanic arc basalts to the east
- -emplacement of "synvolcanic" mafic-ultramafic intrusions into the ocean floor basalts

2). "1.88 - 1.87 Ga" ***ACCRETION OF LITHOTECTONIC DOMAINS INTO THE FLIN FLON ACCRETIONARY COLLAGE***
- -juxtaposition of ocean floor and arc volcanic suites of rocks
- -initiation of the Elbow Lake shear zone
- -initiation of the Flag Lake and Loukes Lake shear zones?

3). "1.87 - 1.84 Ga" ***FORMATION OF A SUCCESSOR ARC***
- -change from a compressional to subduction regime
- -NE?-dipping subduction under the Flin Flon accretionary collage
- -emplacement of calc-alkaline volcanic arc granites into the collage crust, predominantly stitching existing shear zones and faults
- -continued compression and reactivation of shear zone, possibly where emplacement had already began (*i.e.*, the Loukes Lake shear zone)

4). "1.84 - 1.83 Ga" ***LATE SUCCESSOR ARC MAGMATISM***
- -continued subduction
- -thickening of the continental crust
- -partial melting of that crust above the garnet stability field
- -closing of the back-arc basin?, and the cessation of subduction

5). "Post 1.83 Ga" ***POST-COLLISIONAL TECTONICS***
- -dominantly brittle deformation, the appearance of this stage of evolution of the Flin Flon belt is not readily apparent in the Iskwasum Lake sheet, but may include late movement on the Berry Creek fault

have allowed granites to be emplaced where it is easiest for them to do so, typically along existing faults. In this way where they are emplaced is as much a result of the tectonic environment during accretion as the tectonic forces during subduction.

Although Nd isotopic data for granites in the Iskwasum Lake sheet is not available, other granites in the Flin Flon belt (see Lucas *et al.*, 1995) of similar age and calc-alkaline affinity have juvenile εNd values, suggesting that older crust was not a volumetrically significant source component. This corresponds well with the ideas put forth earlier that the geochemical characteristics of granites in the Iskwasum Lake sheet represent their source. A brief summary of the tectonic processes important in generating what rocks we see in the Iskwasum Lake sheet today is given in Table 7. Figure 39 shows a cartoon illustrating these tectonic events.

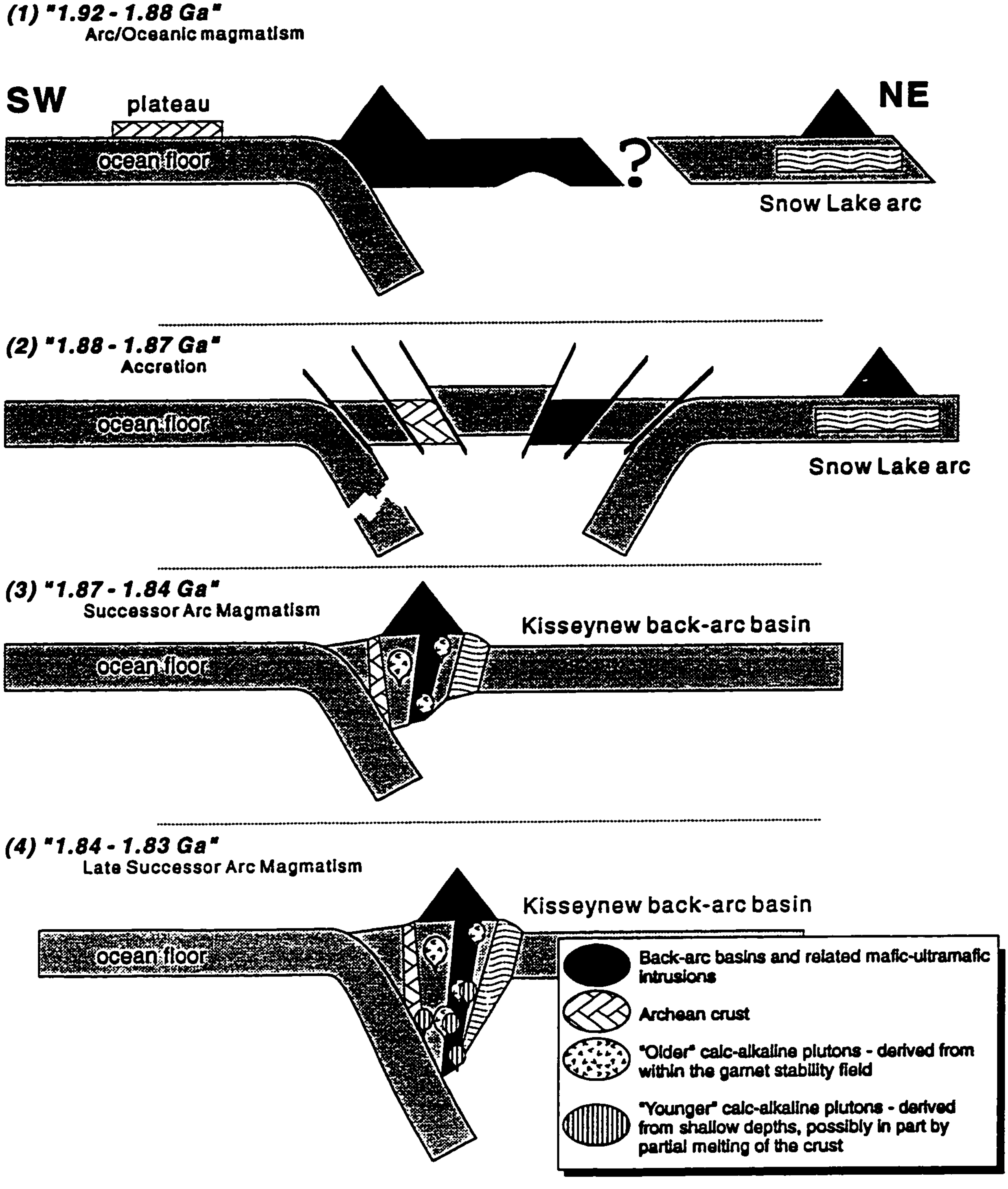


Figure 39. *Cartoon illustrating the tectonic history of the Flin Flon greenstone belt. Thickening of the crust in (d) may be responsible for derivation of granitic magmas with flatter REE patterns and negative Eu anomalies. Heavy lines in (b) indicate major faults separating tectonically juxtaposed stratigraphic assemblages. Modified after Lucas et al. (1995).*

The classification of the granites in the Iskwasum Lake sheet depends entirely on which method is used, but regardless of the classification scheme, the granites from the Iskwasum Lake sheet appear to be emplaced into a continental margin, dominantly along pre-existing faults (stitching plutons) They are the product of a subduction-related magmatic event that follows a period of compressional tectonics in the Flin Flon belt. Because they are the strongest evidence for such a tectonic setting (volcanic rocks of the same age are rare), they are crucial to the evaluation of the tectonic history of the area.

Because of the size of this study, and the limited data available, only a cursory look at the importance of these bodies has been undertaken. Suggestions for future work include:

- *Closer evaluation of the structures outside the Gants Lake batholith and Loukes Lake shear zone to better determine whether they were indeed the locus of magmatism, or whether there was large-scale rotation of blocks which allowed for the emplacement of some plutons.*

- *Closer evaluation of the structures at the margins of the plutons - may allow for a better determination of the effects that emplacement had on the host rocks, and allow for the determination of mechanisms of pluton emplacement. This would in turn be a significant indicator on the importance of the plutons in the history of the Flin Flon belt.*

- *Closer evaluation of the structures related to all shear zones in the map sheet - this may provide answers as to the timing and history of the structures and allow an evaluation of the importance of these structures in the tectonic history of the greenstone belt.*

- *Detailed geochronologic work to better constrain plutonism and the timing of deformation in the map sheet. May also better evaluate the idea that older granite bodies, such as the Gants Lake batholith, have younger (ie., 1.84-1.83 Ga) phases.*

- *Geobarometry on plutons on either side of major structures (e.g.,, Loukes Lake shear zone) - this may allow for a better determination of their structural history, particularly if they are early thrusts in which the fabrics related to them are obliterated by late movement.*

- *Geochronology of mafic supracrustal rocks to the east - this will allow for a comparison of tectonic domains to the west and may allow for a better evaluation of the Gants Lake batholith and the structures between the two tectonic domains.*

- *Detailed, precise geochemical study of significant plutonic units - singling out, and sampling suitable plutonic units would allow for a better evaluation of the genesis of granites in the Iskwasum Lake sheet. It would also allow for detailed modelling of the REE data to determine the origin and evolution of the granites. It may also provide clues as to whether younger plutonic phases are present in older granite bodies, and whether there is a spatial relationship between them.*

- *Geochemical evaluation of plutons throughout the entire Flin Flon belt - this would allow for a systematic study of all granites in the evolution of a granite-greenstone belt. Similar studies in the Peninsular Ranges batholith of southern California and the Coastal batholith of Peru have revealed systematic changes in the chemistry of granites in these areas, which has in turn revealed specific conditions at the time of their emplacement and led to hypothesis on the tectonic setting, state of the mantle and petrographic evolution of the granites at that time. Similar studies in the Flin Flon domain may reveal the true origin of the late arc granite geochemical signature.*

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Appendix 1. Characteristics of granitic plutons in the Iskwasum Lake sheet (NTS 63K\10), Manitoba.

This table summarizes features of felsic plutons in the Iskwasum Lake map sheet. The structure of the table is described below. Numbers correspond to individual headings in the table. Empty spaces indicate data is not available at this time.

1. Pluton name; **ILS=** *Iskwasum Lake stock*; **ELT=** *Elbow Lake tonalite*; **BRLP=** *Big Rat Lake pluton*; **WLP=** *Wedge Lake pluton*; **SILP=** *South Iskwasum Lake pluton*; **GLB=** *Gants Lake batholith*; **LSLP=** *Little Swan Lake pluton.*

2. Map unit used on the geologic map.

3. Approximate area of plutons in the Iskwasum Lake sheet (in km^2).

4. Nature of internal contacts, in order of decreasing importance or abundance. **g=** *gradational intrusive*; **sh=** *sharp intrusive*; **st=** *structural.*

5. Age of plutons, in Ma. All geochronological data is for correlative pluton in the Elbow Lake sheet (NTS 63K\15) north of theIskwasum Lake sheet, and is taken directly from Whalen and Hunt (1994). All dates are U-Pb zircon ages, except where indicated by *, which is an U-Pb titanite age.

1	2	3	4	5
pluton	**map unit**	**area (km^2)**	**contact**	**age (Ma)**
BRLP	P10B	10	g	1845±3
ELT	P9A	60	g, st	1864+5/-4
WLP	P8	10	g, st	
ILS	P9B	25	g, st	
SILP	P10C	20	g, st	
LSLP	P10A	30	g, sh,st	*1828±5
GLB	P6	110	st, sh	1876+7/-6

Appendix 2. Petrography of granitic rocks in the Iskwasum Lake sheet.

This is a summary of the petrography of the major plutonic units in the Iskwasum Lake sheet. Data was obtained during the 1994 field season, as well as subsequent laboratory studies. Empty space indicates the absence of a feature, or that data is currently unavailable. Terms and structure of the table are described below, numbered to correspond to individual headings in the table.

1. "*pluton*" is the name used to refer to felsic plutons in the Iskwasum Lake sheet, refered to in the text, and on the geological map. Refer to appendix 1 for the codes used in this section. **SZRS**=shear zone related rocks, and where possible lithologic protolith is also indicated.

2. "*map unit*" refers to individual pluton phases, and is the same as that used on the geological map. Letters occurring in brackets indicate pluton units, while those outside the brackets refer to the pluton it belongs to (refer to appendix 1 for pluton codes).

3. "*grsz*" is the typical grain size, or grain size variation in each unit. **vfg**=very fine-grained; **fg**=fine-grained; **mg**=medium-grained; **cg**=coarse-grained; **vcg**=very coarse-grained; **mc**=megacrystic.

4. "*texture*" refers to macroscopic textural features present in the unit. **eq**=equigranular; **Qtz-porp**=quartz porphyritic; **Qtz-Bt-porp**=quartz-biotite porphyritic; **Bt-porp**=biotite porphyritic; **Pl-porp**=plagioclase porphyritic; **Kf-porp**=potassium feldspar porphyritic; **Kf-clast**=potassium feldspar porphyroclastic; **feld-porp**=feldspar porphyritic; **Hbl-porp**=hornblende porphyritic.

5. "*mafics*" is the mafic minerals present in the unit, in order of decreasing abundance. Minerals in brackets indicate only an occassional presence. **Hbl**=hornblende; **Bt**=biotite; **px**=pyroxene (orthopyroxene and clinopyroxene).

6. "*access*" is the accessory minerals present, in order of decreasing abundance. **Ttn**=titanite; **Aln**=allanite; **op**=opaques, **Zrn**=zircon.

7. "*alteration*" is the dominant alteration products in the unit, in order of decreasing abundance. Thin section analysis is used wherever possible, except where indicated by *, which is based on field observations. Empty spaces indicate that thin section analysis is not availabe, and field observations do not reflect significant alteration. **Chl**=chloritic alteration; **ser**=sericitic alteration; **Ep**=epidote; **carb**=carbonate; **(f)**=fracture-related; **(d)**=disseminated; **Ms**=muscovite;

8. "*lith*" is the dominant lithology, as determined in the field. Where geochemical analysis is available a * is indicated (bracketed lithologies indicate ocassional presence). **g**=granite; **gd**=granodiorite; **mg**=monzogranodiorite; **md**=monzodiorite; **t**=tonalite; **qd**=quartz diorite; **di**=diorite; **gb**=gabbro; **ap**=granitic aplite; **peg**=granitic pegmatite; **ms**=mafic sheets; **fs**=felsic sheets; **ib**=intrusion breccia; **qm**=quartz monzonite.

9. "*inclusion*" is the dominant inclusion or enclave lithology. **i**=intrusive; **v**=volcanic; **m**=mafic; **f**=felsic; **x**=xenolith; **c**=comagmatic; **t**=tectonite.

10. "*struc*" is the dominant internal structure in the unit. **m**=massive; **wf**=weakly foliated; **mf**=moderately foliated; **stf**=strongly foliated; **gn**=gneissic; **myl**=mylonite; t=tectonite.

1	2	3	4	5	6	7	8	9	10
pluton	***map unit***	***grsz***	***texture***	***mafics***	***access***	***alteration***	***lith***	***inclusions***	***struc***
ILS	P9B(a)	fg	eq	Bt,	Ttn, Aln	Ep (f), ser (f), Chl (f), Ms	gd		mf-wf
ILS	P9B(b)	fg-mg	Bt-porp	Bt,	Ttn, Aln	* Ep (d), ser (d), Chl (d), Ms	gd		wf
ILS	P9B(c)	fg	eq	Bt,	Ttn, Aln	Ep (d), ser (d), Chl (d), Ms	gd		mf
ILS	P9B(d)	fg-mg	Bt-porp	Bt,	Ttn, Aln	* Ep (f), ser (f), Chl (f), Ms	gd		w-mf
ILS	P9B(e)	mg	eq	Bt,	Ttn, Aln	Ep (f,d), ser (f,d), Chl (f,d), Ms	gd	mtx, mvx, mlx	mf-stf
ELT	P9A(a)	mg-cg	Qtz-Bt-porp	Bt	Ttn, Aln	Ep (d), Chl (d), ser (d)	tn	mtx, mvx	mf-stf
ELT	P9A(b)	mg-cg	Qtz-Bt-porp	Bt, (h)	Ttn, Aln	Ep (d), Chl (d), ser (d)	tn	mtx, mvx, mlx	wf-stf
ELT	P9A(c)	mg	eq	Bt	Ttn, Aln	Ep (d), Chl (d), ser (d)	tn	mvx, mvc	mf
ELT	P9A(d)	mg-cg,	Qtz-Bt-porp	Bt, (h)	Ttn, Aln	* Chl	gd	mvx	mf
ELT	P9A(e)	mg-cg	Qtz-Bt-porp	Hbl, Bt	Ttn, Aln	* Chl	tn		mf
ELT	P9A(f)	mg-cg	Qtz-Bt-porp	Bt	Ttn, Aln	Ep (d), Chl (d), ser (d)	tn	mtx, mvx	mf-stf
BRLP	P10B(a)	fg-mg	eq	Bt	Aln	* Ep, Chl	gd-g		wf-mf
BRLP	P10B(b)	mg-cg	eq	Bt	Aln	* Ep, Chl	gd-g		wf-mf
SILP	P10C(a)	fg-mg	eq	Bt, (Hbl)			gd		wf-mf
SILP	P10C(b)	mg-cg	eq	Bt, (Hbl)			gd, (ms)		wf-mf
WLP	P8(a)	mg-vcg	Hbl-porp	Hbl, Bt			gd	mvx	wf-stf
WLP	P8(b)	mg	Kf-poik	Bt			gd	mvx	wf-
WLP	P8(c)	mg-vcg	eq	Bt, Hbl		Ep (d), Chl (d)	gd		mf-stf

1	2	3	4	5	6	7	8	9	10
pluton	***map unit***	***grsz***	***texture***	***mafics***	***access***	***alteration***	***lith***	***inclusions***	***struc***
WLP	P8(d)	mg-mc	Hbl-porp	Hbl, (Bt)	Ttn	carb (d), Ep (d)	mg-qm		mf-stf
WLP	P8(e)	mg	eq	Hbl, Bt			gd, lb	mtx, mlx, mvx, flx	stf
GLB	P6(a)	fg-mg	Pl-porp	Bt, Hbl			gd		gn
GLB	P6(b)	mg	Pl-porp	Bt, (Hbl)		Ms (d), carb (d), Chl (d)	gd	mtx, mlx, mvx	stf
GLB	P6(c)	mg-cg	Pl-porp	Bt,(Hbl)	Ttn, op	Ep (d), Chl (d), Ms (d), carb (d)	gd		stf
GLB	P6(d)	mg	Pl-porp	Hbl, Bt	Ttn, op	Ep (d), Chl (d), Ms (d)	gd		mf
GLB	P6(e)	mg	Pl-porp	Hbl, Bt	op, Ttn,Zrn	Chl (d), Ep (d), carb (d), Ms (d)	gd-t		mf-stf
GLB	P6(f)	g, mg, cg	eq, Qtz-porp, Pl-porp	Bt, (Hbl)			gd, tn, ap peg, qd,	flc, mvx	
GLB	P6(g)	fg-mg	eq	Bt			tn		stf
GLB	P6(h)	fg-mg	eq	Bt, Hbl			tn, ms		gn
GLB	P6(i)	mg	Pl-porp	Bt, (Hbl)			gd, ms		mf-gn
GLB	P6(j)	mg-cg	eq - Pl-porp	Bt, (Hbl)	Zrn, Aln	carb (d), Ep (d), Ms	gd		stf
GLB	P6(k)	fg-mg	eq - Qtz-porp	Bt, Hbl			gd		stf
LSLP	P10A(a)	mg-cg	Qtz-porp	Bt, Hbl		Ep (d), Ms (d), Chl (d)	gd		mf
LSLP	P10A(b)	mg-cg	Qtz-porp	Hbl, Bt	Zrn	Ep (d), Ms (d), Chl (d)	gd		mf
LSLP	P10A(c)	fg	eq	Hbl, (Bt)			gd		wf
LSLP	P10A(d)	mg-cg	eq	Hbl			gb		wf

1	2	3	4	5	6	7	8	9	10
pluton	***map unit***	***grsz***	***texture***	***mafics***	***access***	***alteration***	***lith***	***inclusions***	***struc***
LSLP	P10A(e)	cg	Qtz-porp	Bt, Hbl	Zrn		gd		gn
LSLP	P10A(f)	fg-mg	eq-Qtz-porp	Bt, Hbl			tn		gn
LSLP	P10A(g)	cg	Qtz-porp	Hbl-Bt			gd	mic	wf

Appendix 3. Geochemical sample locations and descriptions.

Listed below in order of sample number (sample #) are locations of geochemical samples in eastings (east), and northings (north) (UTM grid zone 14u). Also included is the pluton (pluton) and pluton phase (unit) and sample description (description). Refer to Appendix 2 for pluton phase descriptions, and codes used in "pluton" and "description".

sample #	*east*	*north*	*pluton*	*unit*	*description*
DWM0007	393916	6066475	LSLP	(P10Ab)	cg-meg;eq;Hbl-Bt;gd
DWM0024	375454	6068426	ELT	(P9Ae)	-mg;Hbl-Bt;tn -strongly altered
DWM0034	376739	6067556	ELT	(P9Ac)	-mg;eq;Bt;tn -weakly altered
DWM0077	379738	6067633	ELT	(P9Ab)	-mg-cg;Qtz-Bt-porp; tn -moderately altered (Chl and Ep)
DWM0118	383466	6052795	GLB	(P6e) west side	-fg-mg;Pl-porp;Hbl-Bt;qzdi-tn -moderate deformation -weakly altered
DWM0124	384521	6056299	GLB west side	(P6g)	-mg;Pl-porp;Hbl-Bt;tn -moderately altered
DWM0125	382097	6057677	ILS	(P9Bc)	-fg;eq;Bt;gd -has pegmatitic fracture
DWM0150	377624	6059705	ILS	(P9Ba)	-mg;eq;Bt;gd -strongly altered
DWM0165	371031	6054118	WLP	(P8b)	-mg;Bt;Kf-porp -Kf poikilitic -weakly altered
DWM0174a	386929	6052470	GLB west side	(P6c)	-cg;Pl-porp; Bt;tn-gd -strongly altered
DWM0183	387857	6056409	GLB east side	(P6c)	-cg;Pl-porp;Bt;gd -weakly altered
DWM0197	388265	6054924	GLB east side	(P6i)	-fg-mg;Pl-porp;Bt;tn -very weakly altered
DWM0203	386017	6054620	GLB west side	(P6h)	-mg;Pl-porp;tn -moderately altered

sample #	*east*	*north*	*pluton*	*unit*	*description*
DWM0211	377116	6063355	ELT	(P9Ac)	-mg;eq;Bt;tn -strongly altered
DWM0221	384474	6054014	GLB west side	(P6e)	-fg;Pl-porp;Bt;qzdi-gd -strongly altered (chlorite)
DWM0262	371100	6054946	WLP	(P8d)	-fg;eq;Bt-Hbl;gd -very little alteration
DWM0304	381710	6061645	ILS	(P9Bc)	-fg-mg;eq;Bt;gd -strongly atlered (plagioclase)
DWM0317	384357	6066274	ELT	(P9Ab)	-mg;Qz-Bt-porp;tn-gd
DWM0324	381530	6061567	ILS	(P9Bd)	-mg;Bt-subporp;gd -weakly altered
DWM0390	389739	6064754	GLB northeast side	(P6a)	-mg;Pl-porp;Hbl-Bt;gd-gn -weakly altered
DWM0395	390656	6066059	LSLP	(P10Af)	-fg-mg;eq;Bt;tn-gd -weakly altered (chlorite)
DWM0421	392296	6066748	LSLP	(P10Ag)	-fg;eq;Bt-Hbl;di-gb -contact between comagmatic qzdi and gd
DWM0421b	392296	6066748	LSLP	(P10Ag)	-fg;eq;bt-Hbl;di-gb -strongly altered (chlorite and epidote)
DWM4013	380242	6057127	ILS	(P9Ab)	-mg;Bt-porp;gd -strongly altered
DWM4039	380766	6052010	SILP	(P10Cb)	-mg-cg;eq;Bt; gd -strongly altered (epidote)
DWM4050	387653	6058622	GLB west side	(P6c)	-mg;Pl-porp; Bt;gd -strongly altered
DWM4200	378505	6054807	SILP	(P10Ca)	-mg;eq;Bt;gd -strongly altered (chlorite)
DWM6268b	380285	6067872	ELT	(P9Ab)	-cg;Bt-porp;tn -phase in a fracture in the regular tonalite
DWM6268c	380285	6067872	ELT	(P9Ab)	-cg;Qtz-Bt-porp;Bt-Hbl;gd -fresh, very mafic mafic

Appendix 4. Petrographic locations and descriptions.

Listed below are the location of thin sections studied. Included in the table is the pluton, map unit (see appendix 2 for pluton names), eastings (east) and northings (north). Also included is sample number (sample #), thin section type (type), mafic minerals (mafic mins), felsic minerals (felsic mins), and thin section description (description).

Key to abreviations used in "thin section type"

o=oriented	n=non-oriented

Key to abreviations used in "mafic minerals"

Bt=biotite	Grt=garnet
px=pyroxene	Chl=chlorite
Hbl=hornblende	(alt)=alteration product

Key to abreviations used in "felsic minerals"

Pl=plagioclase	Qtz=quartz	ser=sericite
Kf=potassium feldspar	Ep=epidote	(a)=accessory mineral
feld=feldspar	carb=carbonate	(alt)=alteration product

Key to abreviations used in "description"

Kf=potassium feldspar	Bt=biotite	myl=mylonite
Pl=plagioclase	Ms=muscovite	porps=porphyroblasts
Qtz=quartz	Ep=epidote	
Hbl=hornblende	Grt=garnet	

sample #	***pluton***	***map unit***	***type***	***mafic mins***	***felsic mins***	***east***	***north***	***description***
0007	LSLP	P10Ab	n	Chl (alt), Bt, Hbl	Ep (alt), ser (alt), Pl, Qtz, Kf	393916	6066475	-euhedral Pl, elongate Qtz -fresh
0024	ELT	P9Ac	n	Chl (alt), Bt	Ep (alt), ser (alt), carb (alt), Qtz, Pl	375454	6068426	-strongly altered (mostly Chl and Ms)
0034 inclusions	ELT	P9Ab	n	Bt	Ep (alt), ser (alt), carb (alt), Qtz, Pl-unzoned Pl have random ser	376739	6067556	-oscillatory zoned Pl, ser along zones -Qtz phenocrysts have shadowy extinction
0077	ELT	P9Ab	n	Chl (alt), Bt	Ep (alt), ser (alt), carb (alt), Qtz, Pl	379738	6067633	-euhedral Pl -e longate Qtz -accessory titanite and zircon
0118	GLB	P6c	n	Bt, Chl (alt)	Ep (alt), ser (alt), Ms (alt), Qtz, Pl, Kf	383466	6052795	-banded -accessory titanite (partially replaced by opaque minerals) -Ms within Pl
0124	GLB	P6e	n	Chl (alt), Bt, Hbl (a)	Qtz, Pl, Kf, Ms (alt), ser (alt)	384521	6056299	-strongly foliated, and fabric bends around larger Pl and Qtz phenocrysts -distinct abundant large Ep
0150	ILS	P9Ba	n	Chl (alt), Bt	Qtz, Pl, Kf, Ms (alt), Ep (alt)	377624	6059705	-accessory titanite and opaques -strong fracture-related alteration -weak fabric -very few mafic minerals
0151	ILS	P9Bc	n	Bt, Chl (alt)	Kf, Pl, Ep (alt)	376639	6060866	-fresh, except some Chl -banded
0165 cores	WLP	P8b	n	Bt, Chl (alt)	Qtz, Kf, Pl, Ep (alt), Ms (alt)	371031	6054118	-accessory titanite (euhedral) -weakly altered, moderately foliated -rarely poikilitic Kf with Bt and Qtz -oscillatory zoned Pl, with sericitic

sample #	pluton	map unit	type	mafic mins	felsic mins	east	north	description
0174a	GLB	P6d	n	Bt, Chl (alt)	Qtz, Kf, Pl, Ep (alt)	388265	6054924	-accessory titanite and opaques -"warped Pl -pressure shadows around Qtz -strong banding -large euhedral Ep
0176	LLSZ	P12b	o	Chl (alt)	Qtz, Kf, Pl, Ep (alt)	386825	6054363	-myl with compositional "banding" -accessory Grt in Qtz "bands" -moderate alteration -predominantly symetric shear sense indicators (rarely sinistral sense of shear)
0178a	LLSZ	P12b	o	Bt	Qtz, Pl, Kf, Ep (alt), Ms (alt)	386300	6054029	-accessory titanite and opaques -few mafic minerals -kink folding of D_1 myl "banding" -sinistral and dextral shear sense
indicators								
0178b	LLSZ	P12b	o	Bt	Qtz, Pl, Kf, Ms (alt), Ep (alt)	386300	6054029	-sericitized feldspars -strong myl compositional "banding" -no shear sense indicators
0181b	LLSZ	P12b	o	Bt	Qtz, Pl, Kf, Ms (alt)	384454	6051581	-Bt altered to Ms -strong myl compositional "banding" -D_1 E-W compositional "banding" overprinted by D_2 mineral alignment at a low oblique angle (110^o)
0197	GLB	P6j	o	Bt	Qtz, Kf, Ms (alt), Ep (alt)	388265	6054924	-accessory allanite and zircon -fairly fresh -Ms random, but not in Pl
0211	ELT	P9Af	n	Bt, Chl (alt)	Qtz, Pl, Ep (alt), ser (alt)	377116	6063355	-oscillatory zoned Pl -elongate Qtz

sample #	pluton	map unit	type	mafic mins	felsic mins	east	north	description
0221	GLB	P6e	n	Bt, Chl (alt)	Qtz, Kf, Pl, ser (alt), Ms (alt)	384474	6054014	-accessory opaques and titanite -Kf is concentrically altered to musc -large Ep, and strongly sericitized -banded
0262	WLP	P8d	n	Bt	Qtz, Kf, Pl, ser (alt)	371100	6054946	-accessory titanite -moderate foliation -oscillatory zoned Pl with ser along zone boundaries -rare vermicular texture in Pl with Qtz -occassional perthitic Kf, rarely poikilitic with Qtz and Bt
0266	WLP	P8a	n	Hbl, Bt	Qtz, Kf, Pl, Ep (alt)	371382	6058242	-accessory zircon -gradational contact between felsic and mafic comagmatic? phases -felsic phase coarser-grained, less epidote, Bt>Hbl -mafic phase Hbl>Bt
0276a	FLSZ	J14b	o	Hbl	Qtz, feld	388580	6052937	-accessory Grt and opaques -Grt altered to Chl and opaques -sinistral sence of shear indicated by rotated Grt porps
0317	ELT	P9Ab	n	Bt, Chl (alt)	Qtz, Pl	384357	6066274	-Bt larger than Qtz and planar -Qtz is elongate
0324	ILS	P9Br	n	Bt	Qtz, Pl, Ep (alt), Ms (alt)	381530	6061567	-large, euhedral epidote -accessory titanite -large (<0.5cm) Qtz phenocrysts
0341	LLSZ	P12d	o	Bt, Chl (alt)	Qtz, Pl, Kf, Ms (alt), Ep (alt)	388232	6062544	-accessory titanite and opaques -boudined feld indicate sinistral shear -D_2 alignment of fabric at low oblique angle (022^{o}) to N-S D_1 orientation, possibly due to emplacement of Little Swan Lake pluton immeadiately north?

sample #	pluton	map unit	type	mafic mins	felsic mins	east	north	description
0383	GLB	P6c	n	Bt, Hbl, Chl (alt)	Qtz, Pl, Kf, Ep (alt)	385562	6066920	-highly altered -large Pl phenocrysts -moderate fabric
0390	GLB	P6c	n	Bt, Hbl (a)	Qtz, Pl, Kf, Ep (alt)	389739	6064754	-weak fabric, and Bt is concentrated around Pl phenocrysts
0395	LSLP	P10Af	n	Bt, Chl (alt), Hbl	Qtz, Pl, Kf, Ep (alt)	390073	6066484	-accessory opaques and zircon -weak fabric and alteration
0421a	LSLP	P10Ag	n	Hb, Bt	Pl, Ms (alt), Qtz	392296	6066748	-accessory zircon and opaques -poikilitic Hbl with Pl -weak fabric, radial micas
4013	ILS	P9Bc	n	Bt, Chl (alt)	Qtz, Pl, Ep (alt), ser (alt)	380242	6057127	-accessory titanite -extreme sericitization -few mafic minerals
4039	SILP	P10Cb	n	Bt, Chl (alt)	Qtz, Pl, Kf, Ms (alt), Ep (alt)	380766	6052010	-accessory titanite and zircon -strongly altered -replacement of titanite, Bt and Chl by opaques
4050	ELT	P9Ab	n	Bt, Chl (alt)	Qtz, Pl, Kf, Ep (alt), ser (alt)	387653	6058622	-accessory titanite and zircon -extensive alteration
4200	SILP	P10Ca	n	Bt, Hbl, Chl (alt)	Qtz, Pl, Kf, Ep (alt), Ms (alt), ser (alt)	378505	6054807	-accessory zircon, titanite and opaques -oscillatory zoned Pl -strongly altered -small, euhedral titanite and Ep
6268a	ELT	P9bAb	n	Bt, Chl (alt)	Qtz, Pl	380285	6067872	-accessory titanite, opaques, zircon -contact between mafic and felsic comagmatic? phases of the pluton -alteration in mafic > felsic phase
6268c	ELT	P9Ab	n	Bt, Hbl	Qtz, Pl	380285	6067872	-twinned Hbl, with good crystal shape -very mafic

Appendix 5. Granite geochemical data

Tabulated below are major element, trace element, and rare earth element data collected during the summer of 1994 (prefix DWM) and from Whalen (unpublished data) in the Elbow Lake sheets (prefix WXMS). Information on accuracy and analytical methods is given in Appendix 6. Pluton name is given below each sample number (pluton), followed by the map unit (code) used on the geological map (map 1 in back pouch) below that. Major elements data is in weight percent, trace element and REE data in parts per million. Legend: **BRLP**=Big Rat Lake pluton; **ELT**=Elbow Lake tonalite; **GLB**=Gants Lake batholith; **LSLP**=Little Swan Lake pluton; **SILP**=South Iskwasum Lake pluton; **WLP**=Wedge Lake pluton; **ILS**=Iskwasum Lake stock. A dash indicates that geochemical data is not available; <DL indicates that the data is below detection limits.

Number	WXMS-46	WXMS-43	WXMS-143	WXMS-144	WXMS-142	WXMS-145	DWM-0024	DWM-0034	DWM-0077	DWM-0211	DWM-0317	DWM-6268d	DWM-6268c
Pluton	BRLP	ELT	ELT	GLB	GLB	GLB	ELT	ELT	ELT	ELT	ELT	ELT	ELT
Code	14g	6	6	9j	9n	9r	P9Ae	P9Ac	P9Ab	P9Ac	P9Ab	P9Ab	P9Ab
SiO_2	68.94	62.50	63.40	62.15	51.60	62.80	61.61	64.40	66.04	62.50	62.73	56.88	68.02
TiO_2	0.35	0.45	0.39	0.69	0.34	0.55	0.48	0.36	0.29	0.39	0.38	0.51	0.36
Al_2O_3	15.78	17.73	16.20	16.35	15.25	16.65	16.64	16.32	15.97	16.00	16.21	13.68	15.29
Fe_2O_3*	2.33	4.72	5.37	6.21	7.97	5.96	5.30	4.44	3.73	5.47	5.32	8.96	2.83
MnO	0.04	0.12	0.13	0.10	0.15	0.11	0.09	0.10	0.08	0.11	0.11	0.33	0.05
MgO	0.90	1.69	2.12	2.57	9.41	2.16	2.17	1.45	1.19	2.02	1.98	5.70	1.04
CaO	2.65	5.83	5.78	5.55	11.85	4.77	5.56	4.97	4.11	5.72	5.34	8.23	3.02
Na_2O	5.10	4.23	3.35	3.91	1.77	4.43	3.94	3.62	3.60	3.25	3.37	3.15	3.17
K_2O	2.36	1.52	2.01	1.49	0.37	2.10	1.22	1.98	2.33	1.73	2.06	0.80	3.61
P_2O_5	0.10	0.14	0.17	0.31	0.05	0.16	0.16	0.12	0.09	0.17	0.15	0.10	0.08
LOI	0.62	1.28	0.68	0.85	0.90	0.68	1.60	1.30	1.40	1.10	1.40	0.80	1.00
Total	99.17	100.21	99.58	100.16	99.66	100.37	98.77	99.06	98.82	98.45	99.05	99.14	98.47
Mg#**	43	42	44	45	70	42	45	39	39	42	42	56	42
Trace Elements													
Cr	<DL	17	26	44	550	30	45	38	18	24	29	318	8
Ni	<DL	<DL	<DL	15	224	15	7	3	3	8	6	45	3
Sc	<DL	8	13	17	41	21	.	.	.	.	.	.	.
V	32	73	95	90	155	69	91	59	48	89	89	173	43
Cu	6	<DL	20	27	113	20	.	.	.	.	.	.	.
Pb	9	6	7	6	<DL	<DL	.	.	.	.	.	.	.
Zn	40	38	57	70	43	72	63	49	46	58	66	118	40
S	28	46	125	248	527	161	.	.	.	.	.	.	.
K	0	0	0	0	<DL	<DL	10136	16437	19342	14361	17101	6641	29968
Rb	29	24	33	23	6	37	22	31	38	33	36	6	53
Ba	675	570	752	542	99	709	440	642	.	.	.	158	2151
Sr	715	559	601	740	126	303	734	320	474	650	560	322	449
Ga	20	16	18	22	13	21	.	.	.	.	.	.	.
Ta	2.52	2.46	0.03	0.02	0.03	0.19	0.21	0.24	.	.	.	.07	.07
Nb	2.81	4.99	6.04	12.61	1.50	9.89	5.10	5.40	.	.	.	3.60	6.30
Hf	2.86	2.73	2.32	5.40	0.81	4.74	2.50	2.19	.	.	.	1.74	1.74
Zr	76	71	94	202	32	170	107	91	.	.	.	59	56
Ti	0	0	0	0	0	.	2860	2146	1715	2350	2272	3081	2176
Y	4.4	12.9	10.9	9.6	12.4	32.3	9.7	9.4	.	.	.	19.5	9.2
Th	2.1	1.7	3.4	3.7	0.6	1.7	1.5	2.0	1.0	1.0	<DL	0.2	0.2
U	.	.	.	.	.	.	5.0	3.0	5.0	5.0	4.0	<DL	<DL
La	14.5	11.2	17.5	38.7	3.3	15.1	14.5	10.9	.	.	.	7.2	7.4
Ce	29.8	25.3	36.6	79.5	7.7	37.7	34.2	23.3	.	.	.	24.4	18.1
Pr	3.5	3.2	4.3	8.8	1.0	5.4	4.3	2.6	.	.	.	4.0	2.5
Nd	13.4	13.4	17.0	31.7	4.5	23.8	16.8	10.1	.	.	.	19.1	10.4
Sm	2.37	2.88	3.36	4.72	1.36	6.02	3.11	1.84	.	.	.	4.17	2.42
Eu	0.64	0.88	0.88	1.29	0.41	1.12	0.90	0.59	.	.	.	1.19	0.59
Gd	1.68	2.60	2.43	3.50	1.65	6.04	2.41	1.69	.	.	.	3.78	1.91
Tb	0.20	0.40	0.36	0.43	0.30	1.00	0.34	0.27	.	.	.	0.29	0.30
Dy	1.06	2.47	2.17	2.25	2.24	6.07	1.93	1.66	.	.	.	3.50	1.82
Ho	0.19	0.51	0.45	0.41	0.50	1.25	0.36	0.35	.	.	.	0.68	0.35
Er	0.54	1.51	1.26	1.04	1.48	3.56	1.02	1.00	.	.	.	2.17	1.03
Tm	0.08	0.22	0.19	0.14	0.23	0.52	0.15	0.16	.	.	.	0.33	0.15
Yb	0.51	1.56	1.26	0.90	1.41	3.33	1.14	1.15	.	.	.	2.39	0.99
Lu	0.07	0.24	0.21	0.14	0.23	0.48	0.16	0.21	.	.	.	0.37	0.14

* is total Fe_2O_3 ** Mg# is calculated as 100*(MgO/MgOMW)/((*FeO/FeOMW) + (MgO/MgOMW)), where *FeO=FeO + Fe2O3*0.89981

Name Pluton Code	DWM-0174a GLB (East) P6c	DWM-0183 GLB (East) P6c	DWM-0197 GLB (East) P6i	DWM-0118 GLB (West) P6e	DWM-0124 GLB (West) P6g	DWM-0203 GLB (West) P6h	DWM-0221 GLB (West) P6e	DWM-0390 GLB (West) P6a	DWM-4050 GLB (West) P6c	DWM-0125 ILS P9Bc	DWM-0150 ILS P9Ba	DWM-0304 ILS P9Bc	DWM-0324 ILS P9Bd
SiO_2	64.58	71.15	68.53	63.76	51.20	62.43	57.10	63.24	61.88	68.45	70.44	68.59	67.22
TiO_2	0.58	0.21	0.28	0.56	1.02	0.55	0.74	0.52	0.65	0.17	0.11	0.19	0.19
Al_2O_3	15.83	14.89	13.92	15.67	17.69	16.79	17.02	16.31	15.94	15.95	15.48	15.95	16.63
Fe_2O_3*	4.99	2.41	5.28	4.84	9.83	4.97	7.28	5.14	6.00	2.07	1.76	2.11	2.42
MnO	0.05	0.02	0.10	0.06	0.15	0.06	0.00	0.07	0.08	0.04	0.04	0.05	0.05
MgO	1.56	0.71	1.36	2.06	3.54	1.96	3.17	1.83	2.35	0.77	0.37	0.68	0.76
CaO	4.13	2.61	4.29	4.10	7.72	4.81	5.96	4.76	4.80	3.25	2.82	3.08	3.57
Na_2O	3.93	4.68	2.53	4.16	3.59	4.11	3.51	3.80	3.71	4.45	4.85	4.59	4.44
K_2O	1.65	1.43	1.87	1.95	1.46	1.74	1.66	1.86	1.72	1.95	1.85	1.85	1.99
P_2O_5	0.19	0.06	0.06	0.26	0.61	0.21	0.36	0.19	0.28	0.06	0.04	0.06	0.07
LOI	1.30	0.60	0.90	1.60	2.00	1.20	2.30	1.10	1.80	1.10	0.90	1.00	1.30
Total	98.79	98.77	99.11	99.02	98.81	98.83	99.09	98.82	99.22	98.27	98.66	98.15	98.64
Mg#**	38	37	34	46	42	44	46	41	44	42	29	39	38
Trace Elements													
Cr	37	25	6	42	48	35	55	28	41	12	18	2	26
Ni	<DL	2	5	14	16	14	20	9	18	2	.	3	2
Sc	.	.	.	.	.	.	.	.	.	.	.	.	.
V	70	21	79	77	152	77	116	89	93	24	14	27	39
Cu	.	.	.	.	.	.	.	.	.	.	.	.	.
Pb	.	.	.	.	.	.	.	.	.	.	.	.	.
Zn	70	44	49	64	98	69	83	64	79	43	25	43	43
S	.	.	.	.	.	.	.	.	.	.	.	.	.
K	13697	11871	15523	16188	12120	14444	13780	15440	14278	16188	15357	15357	16520
Rb	30	23	46	42	28	37	31	29	37	29	25	29	28
Ba	649	438	720	548	404	473	.	438	583	.	741	.	895
Sr	650	594	198	665	702	712	736	698	650	720	682	756	840
Ga	.	.	.	.	.	.	.	.	.	.	.	.	.
Ta	0.49	0.30	0.77	1.29	0.98	0.49	.	.	0.81	.	0.12	.	0.20
Nb	11.00	3.90	7.80	18.20	32.20	11.60	.	8.40	13.20	.	2.20	.	3.80
Hf	4.45	2.79	2.70	3.29	6.50	4.32	.	.	3.37	.	2.18	.	2.06
Zr	233	120	104	162	366	204	.	204	182	.	84	.	88
Ti	3453	1265	.	3357	6127	3267	4406	3111	3897	1049	677	1151	1139
Y	6.9	2.0	14.9	9.2	35.9	7.6	.	9.0	8.0	.	7.7	.	3.2
Th	5.7	2.9	3.9	3.4	4.3	6.8	.	<DL	4.0	.	0.6	.	1.0
U	2.0	5.0	5.0	2.0	1.0	3.0	3.0	4.0	2.0	5.0	5.0	3.0	1.0
La	36.3	15.0	10.9	25.7	29.1	33.6	.	18.1	29.1	.	1.4	.	4.7
Ce	70.9	28.3	23.1	55.9	77.8	67.2	.	37.2	57.1	.	4.3	.	10.3
Pr	7.3	2.9	2.7	6.8	10.7	7.1	.	4.5	6.3	.	0.6	.	1.2
Nd	24.9	10.7	10.8	25.1	45.3	24.5	.	17.6	22.5	.	2.5	.	4.7
Sm	3.43	1.43	2.38	4.31	9.56	3.55	.	3.39	3.85	.	0.85	.	0.91
Eu	1.01	0.65	0.48	1.17	2.03	1.03	.	0.97	1.02	.	0.26	.	0.29
Gd	2.34	0.83	2.46	2.95	7.69	2.45	.	2.55	2.63	.	0.89	.	0.70
Tb	0.26	.08	0.36	0.38	1.12	0.30	.	0.33	0.34	.	0.17	.	0.10
Dy	1.46	0.41	2.42	1.97	6.42	1.54	.	1.76	1.73	.	1.29	.	0.58
Ho	0.28	0.07	0.52	0.34	1.28	0.30	.	0.34	0.30	.	0.27	.	0.11
Er	0.70	0.22	1.67	0.94	3.65	0.76	.	0.85	0.87	.	0.94	.	0.34
Tm	0.11	0.03	0.26	0.12	0.55	0.11	.	0.13	0.11	.	0.14	.	0.06
Yb	0.68	0.22	1.78	0.76	3.90	0.67	.	0.76	0.86	.	1.02	.	0.40
Lu	0.09	0.04	0.30	0.14	0.57	0.11	.	0.12	0.12	.	0.16	.	0.06

* is total Fe_2O_3 ** Mg# is calculated as 100*(MgO/MgOMW)/((*FeO/FeOMW) + (MgO/MgOMW)), where *FeO=FeO + Fe2O3*0.89981

Name	DWM-4013	DWM-0007	DWM-0395	DWM-0421a	DWM-0421b	DWM-4039	DWM-4200	DWM-0186	DWM-0262
Pluton	ILS	LSLP	LSLP	LSLP	LSLP	SILP	SILP	WLP	WLP
Code	P9Bb	P10Ab	P10Af	P10Ag	P10Ag	P10Cb	P10Ca	P6b	P6d
SiO_2	-	66.93	66.45	56.29	56.90	67.63	63.19	68.23	67.88
TiO_2	-	0.45	0.38	0.78	0.59	0.31	0.46	0.38	0.37
Al_2O_3	-	15.11	16.03	16.81	18.74	15.04	14.40	15.49	15.18
Fe_2O_3*	-	4.30	3.83	8.55	6.34	2.91	3.98	2.79	2.43
MnO	-	0.05	0.05	0.12	0.08	0.05	0.06	0.03	0.03
MgO	-	1.57	1.28	4.09	2.78	1.49	2.38	0.99	0.93
CaO	-	3.38	3.66	7.57	6.52	4.91	3.54	2.36	1.79
Na_2O	-	3.85	4.43	3.57	4.17	4.34	4.06	4.60	4.28
K_2O	-	2.34	1.56	0.88	1.21	3.05	3.02	2.70	3.26
P_2O_5	-	0.11	0.11	0.12	0.14	0.13	0.26	0.12	0.12
LOI	-	0.80	0.40	0.50	0.80	0.60	<DL	<DL	0.80
Total	-	98.89	98.18	99.28	98.27	100.45	95.35	97.70	97.06
Mg#**	-	42	40	49	46	50	54	41	43
Trace Elements									
Cr	-	36	21	40	37	58	72	-	20
Ni	-	16	3	27	21	18	52	-	6
Sc	-	-	-	-	-	-	-	-	-
V	-	55	58	155	84	53	81	41	41
Cu	-	-	-	-	-	-	-	-	-
Pb	-	-	-	-	-	-	-	-	-
Zn	-	61	62	82	65	48	64	<DL	58
S	-	-	-	-	-	-	-	-	-
K	-	19425	12950	7305	10045	25319	25070	22414	27062
Rb	-	55	24	13	22	56	42	50	56
Ba	736	752	436	-	390	847	984	769	886
Sr	-	256	681	329	407	97	1243	712	627
Ga	-	-	-	-	-	-	-	-	-
Ta	0.20	0.36	0.31	-	0.16	0.29	0.37	0.24	0.25
Nb	3.87	8.44	5.60	-	3.50	4.80	7.20	4.40	4.30
Hf	1.90	5.89	2.52	-	3.48	2.33	3.56	3.00	2.83
Zr	90	237	125	-	172	110	157	127	122
Ti	-	2698	2302	4676	3537	1828	2776	2308	2188
Y	3.4	23.7	2.9	-	14.9	6.1	10.3	3.9	3.0
Th	0.7	5.2	3.0	-	1.4	3.7	7.7	4.3	3.4
U	-	2.0	4.0	-	1.0	6.0	6.0	5.0	6.0
La	2.1	28.1	16.1	-	9.7	27.4	56.1	17.3	8.9
Ce	5.5	55.3	26.3	-	21.2	55.6	118.7	36.2	20.6
Pr	0.7	6.3	2.5	-	2.7	6.5	14.0	4.1	2.3
Nd	2.6	23.4	8.4	-	11.2	23.9	51.0	14.9	8.1
Sm	0.67	4.70	1.07	-	2.58	3.74	7.44	2.36	1.39
Eu	0.21	0.88	0.82	-	0.90	0.97	1.80	0.63	0.35
Gd	0.56	4.35	0.94	-	2.58	2.34	4.49	1.47	0.86
Tb	0.09	0.69	0.09	-	0.44	0.25	0.55	0.17	0.09
Dy	0.56	4.27	0.54	-	2.75	1.31	2.31	0.94	0.71
Ho	0.12	0.91	0.10	-	0.59	0.22	0.38	0.17	0.12
Er	0.38	2.58	0.33	-	1.80	0.51	0.98	0.41	0.35
Tm	0.06	0.38	0.05	-	0.24	0.08	0.13	0.06	0.06
Yb	0.43	2.38	0.32	-	1.66	0.61	0.81	0.36	0.33
Lu	.07	0.38	0.05	-	0.25	0.08	0.13	0.06	0.05

* is total Fe_2O_3

** Mg# is calculated as 100*(MgO/MgOMW)/((*FeO/FeOMW) + (MgO/MgOMW)), where *FeO=FeO + Fe2O3*0.89981

Appendix 6. Geochemical sampling and analysis techniques.

Sampling proceedures and preparation

Material for analysis was collected using sledge hammer, typically in areas of easy access. About 800 cm^3 of the freshest material possible was collected, care being taken to discard any weathered surfaces. This material was reduced in size in a jaw crusher, producing approximately 1 liter of crushed material. A 50 milliliter split of this material was furthered crushed to a powder in a tungsten-carbide swing mill. Care was taken between each sample to clean the equipment using detergent and then acetone.

Major and Trace element analysis

Geochemical analysis was undertaken at both Memorial University of Newfoundland and the University of Ottawa. Random duplicates and triplicates were taken, and based on these analyses, the results are of high quality. All major element data was obtained from the X-ray fluorescence (XRF) technique at the University of Ottawa, while some trace element (Li, Ta, Hf, Th, U) and all rare earth element data was produced at Memorial University of Newfoundland using the inductively coupled plasma-mass spectrometry (ICP-MS) method of Jenner (1990).

Appendix 7. C.I.P.W. normative mineralogy for DWM geochemical samples in the Iskwasum Lake sheet.

sample	0024	0034	0077	0211	0317	6268	6268b	0174a	0183	0197	0118	0124	0203	0221
Q	19.8	23.5	25.8	22.8	21.8	13.8	27.7	24.59	31.83	35.5	21	5.93	19.2	14.1
C	0	0	0.21	0	0	0	0.65	0.4	0.93	0	0	0	0	0
Z	0.02	0.02	0	0	0	0.01	0.01	0.05	0.02	0.02	0.03	0.07	0.04	0
Or	7.23	11.7	13.8	10.2	12.2	4.73	21.4	9.76	8.46	11.07	11.5	8.64	10.3	9.82
Ab	33.3	30.6	30.5	27.5	28.5	26.7	26.8	33.25	39.6	21.41	35.2	30.4	34.8	29.7
An	24.2	22.5	20	24	23	20.8	15.2	19.68	12.92	21.15	18.4	27.9	22.3	25.8
Lc	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ne	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kp	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nc	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ac	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Di	1.11	0.65	0	2.02	1.39	14.7	0	0	0	0	0	2.99	0	0
Hy	4.89	3.31	2.96	4.1	4.29	7.38	2.59	3.89	1.77	3.39	5.13	7.43	4.88	7.89
Ol	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cs	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mt	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cm	0.01	0.01	0	0.01	0.01	0.07	0	0.01	0.01	0	0.01	0.01	0.01	0.01
Hm	5.3	4.44	3.73	5.47	5.32	8.96	2.83	4.99	2.41	5.28	4.84	9.83	4.97	7.28
Il	0.19	0.21	0.16	0.23	0.24	0.67	0.12	0.11	0.04	0.21	0.12	0.32	0.14	0
Tn	0.93	0.61	0	0.67	0.62	0.4	0	0	0	0	0.45	2.1	0.43	1.19
Ru	0	0	0.2	0	0	0	0.3	0.52	0.19	0.16	0.31	0	0.3	0.25
Ap	0.39	0.28	0.21	0.4	0.36	0.25	0.19	0.45	0.13	0.15	0.62	1.44	0.5	0.85
To	97.3	97.9	97.5	97.5	97.7	98.5	97.8	97.69	98.31	98.34	97.6	97	97.8	96.9

sample	0390	4050	0125	0150	0304	0324	0007	0395	0421a	0421b	4039	4200	0165	0262
Q	21.6	20.7	27.1	28.5	27.3	25	26.2	25.13	12.2	10.79	20.6	18.3	24.8	25.4
C	0	0	0.68	0.34	0.85	0.68	0.26	0.56	0	0	0	0	0.86	1.5
Z	0.04	0.04	0	0.02	0	0.02	0.05	0.03	0	0.03	0.02	0.03	0.03	0.02
Or	11	10.2	11.5	10.9	11	11.8	13.9	9.23	5.21	7.16	18.1	17.9	16	19.3
Ab	32.2	31.4	37.7	41	38.8	37.6	32.6	37.48	30.21	35.28	36.7	34.4	38.9	36.2
An	22	21.8	16	14.2	15.2	17.8	16.4	17.8	27.26	28.89	12.6	12.2	11.4	8.57
Lc	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ne	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kp	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nc	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ac	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Di	0	0	0	0	0	0	0	0	5.79	0.85	8.02	2.32	0	0
Hy	4.56	5.85	1.92	0.92	1.69	1.89	3.91	3.19	7.5	6.53	0.01	4.86	2.47	2.32
Ol	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cs	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mt	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cm	0.01	0.01	0	0	0	0.01	0.01	0	0.01	0.01	0.01	0.02	0	0
Hm	5.14	6	2.07	1.76	2.11	2.42	4.3	3.83	8.55	6.34	2.91	3.98	2.79	2.43
Il	0.15	0.18	0.09	0.07	0.1	0.1	0.12	0.1	0.27	0.18	0.09	0.13	0.07	0.06
Tn	0.52	0.38	0	0	0	0	0	0	1.56	1.22	0.63	0.97	0	0
Ru	0.23	0.4	0.13	0.07	0.14	0.14	0.39	0.33	0	0	0	0	0.35	0.33
Ap	0.45	0.67	0.15	0.1	0.15	0.16	0.25	0.27	0.28	0.33	0.31	0.63	0.3	0.29
To	97.9	97.6	97.3	97.9	97.3	97.6	98.3	97.94	98.84	97.6	100	95.7	97.9	96.5

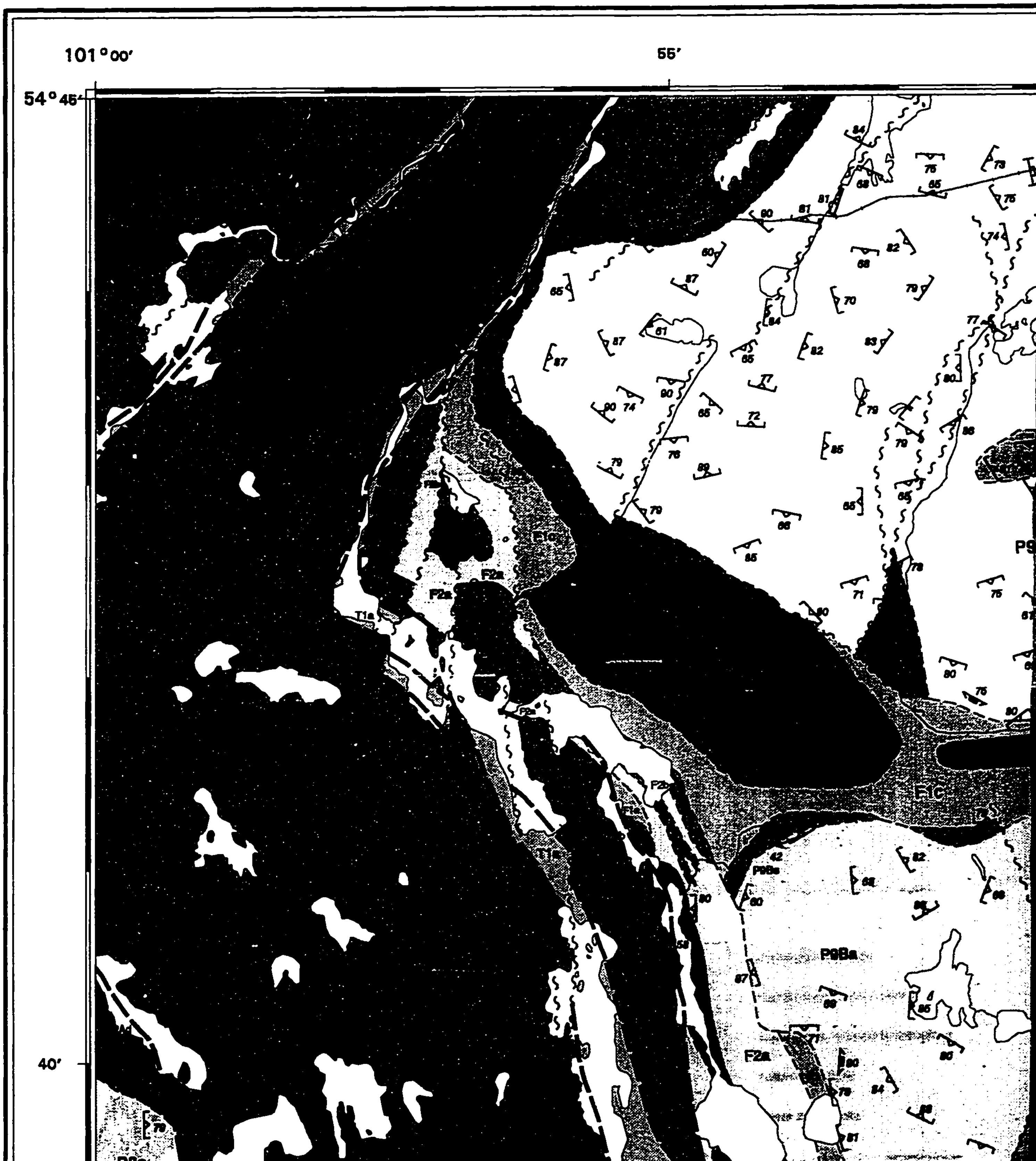
Appendix 8. Current research paper.

Granitoid plutons and major fault structures in the Iskwasum Lake map area, Manitoba: A portion of the Flin Flon domain of the Trans-Hudson orogen.

by Morrison, D.W. and Whalen, J.B.

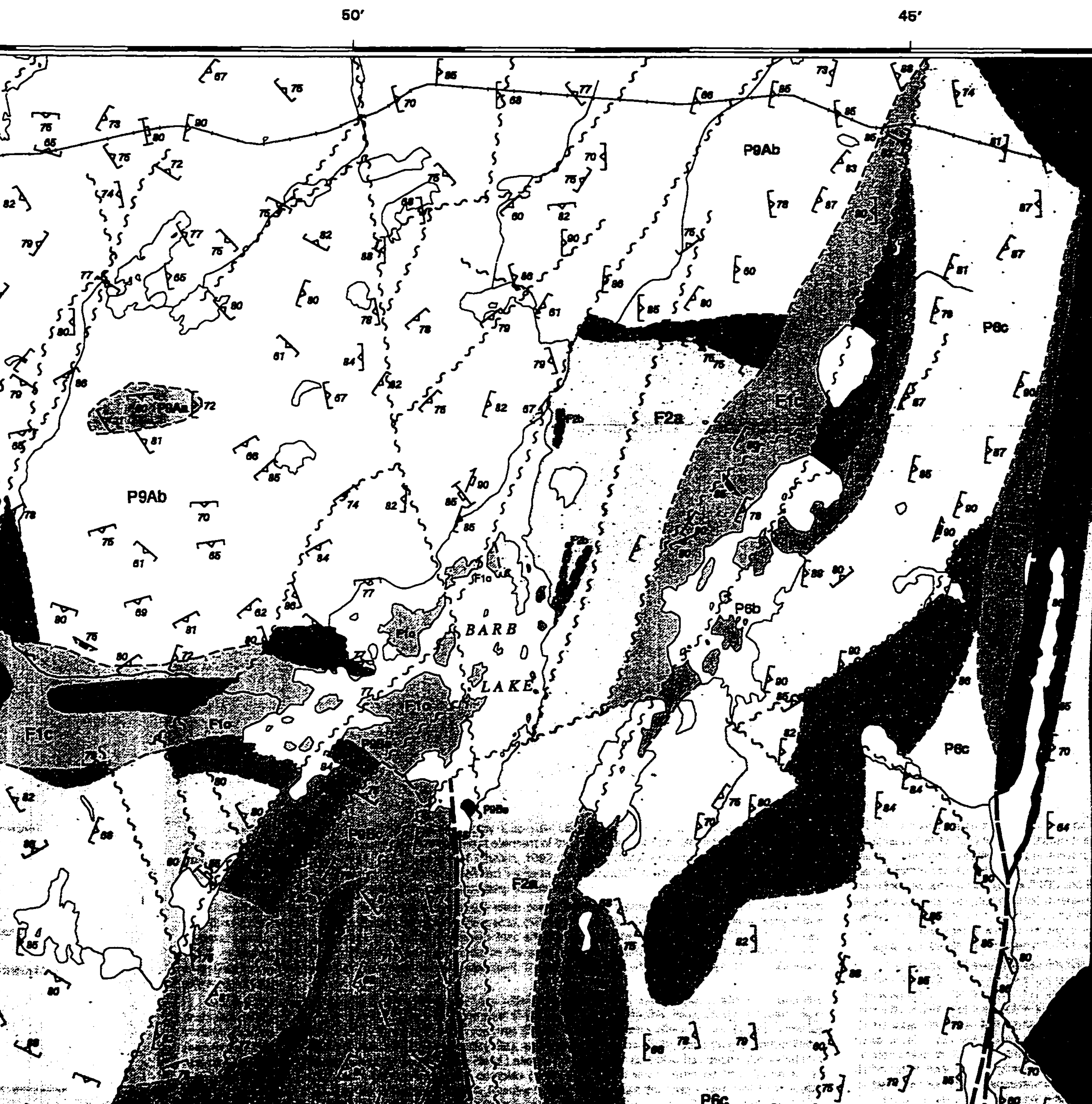
in Geological Survey of Canada, Current Research 1994-C, p.225-234.

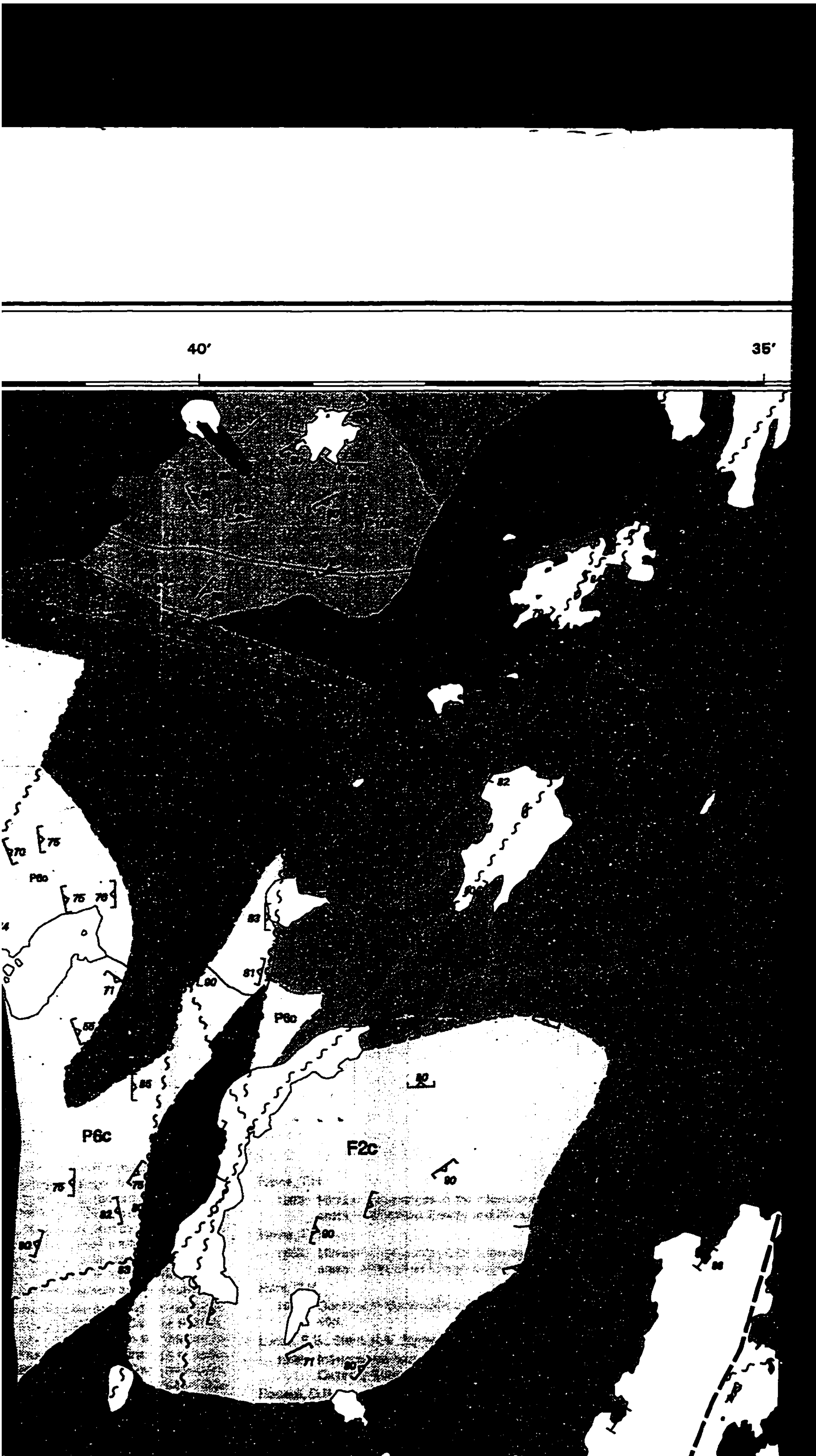
Natural Resources Canada   Ressources naturelles Canada



GEOLOGICAL SURVEY OF CANADA

COMMISSION GÉOLOG





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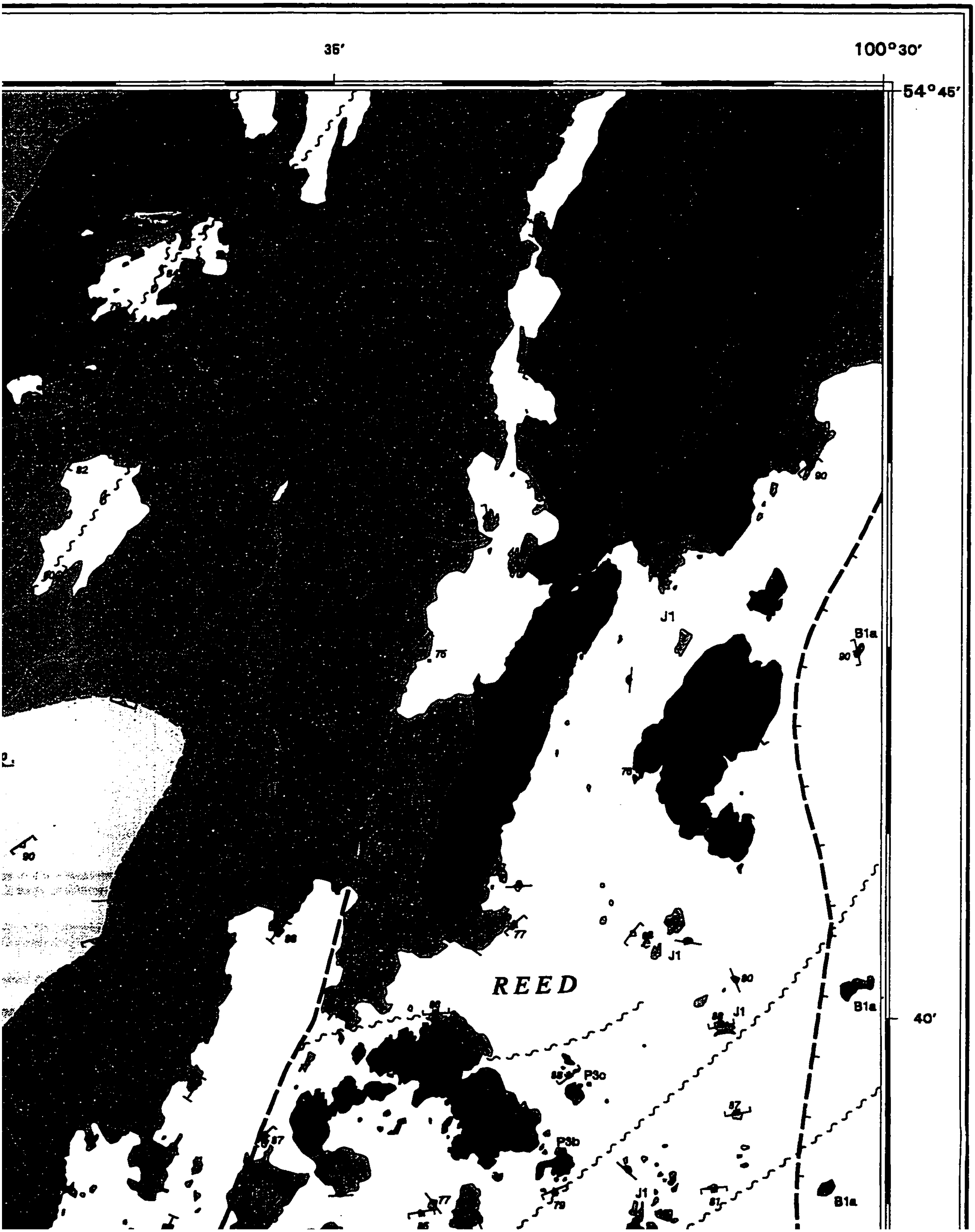
NATMAP
CARTNAT
Canada's National Geoscience Mapping Program
Le Programme national de cartographie géoscientifique du Canada



NATMAP
CARTNAT
National Geoscience Mapping Program
...ional de cartographie géoscientifique du Canada

LEGEND

PHANEROZOIC
ORDOVICIAN

O1 — *Red River Formation dolomite*

Burntwood suite
- a *greywacke siltstone,mudstone,derived gneisses and migmatites*

PALEOPROTEROZOIC
(1.88-1.83 Ga intrusions, and intrusions of unknown age)

Felsic mylonite, felsic tectonite
- a *porphyroclastic quartz-diorite; includes mafic dykes and plagioclase phenocrysts. Mylonitic equivalent to unit* 9e
- b *quartz diorite to tonalite mylonite. Incudes K-feldspar porphyritic, and porphyroclastic pegmatite veins and dykes, and mafic dykes. Mylonite equivalent of unit* 9h
- c *plagioclase porphyroclastic granodiorite mylonite. Includes porphyroclastic granitic pegmatite veins and dykes*
- d *felsic mylonite of multiple or unknown origin. Includes fault-bounded blocks of felsic mylonite with no lithologic equivalents. Also contains mylonites composed of multiple felsic intrusive phases*

MAFIC-FELSIC SHEAR ZONE ROCKS
- a *mafic tectonite, phyllonite, mylonite*
- b *mafic tectonite±variably mylonitized felsic sheets*
- c *mafic-felsic ribbon mylonite*

Little Swan Lake pluton (1826 ± 5 Ma)
- a *medium-grained quartz subporphyritic to porphyritic biotite-hornblende granodiorite*
- b *medium- to coarse-grained quartz porphyritic hornblende-biotite granodiorite*
- c *fine-grained equigranual hornblende-biotite quartz diorite.*
- d *medium- to coarse-grained equigranular hornblende-gabbro.*
- e *coarse-grained quartz-porphyritic biotite-hornblende granodiorite gneiss.*
- f *fine- to medium-grained equigranualar to quartz-porphyritic biotite-hornblende tonalite gneiss*
- g *coarse-grained quartz porphyritic hornblende-biotite granodiorite. This unit is characterised by small (<10 cm) lobate comagmatic inclusions of unit* P10Ac

Big Rat Lake pluton (1845 ± 3 Ma)
- a *medium- to coarse-grained equigranual biotite granodiorite to granite*
- b *fine- to medium-grained equigranular biotite granodiorite to granite*

South Iskwasum Lake pluton
- a *medium-grained equigranular biotite granodiorite*
- b *medium- to coarse-grained equigranular biotite granodiorite*

P9Ab

Elbow Lake tonalite (1864+5/-3 Ma)
- a *fine- to medium-grained equigranular to quartz-porphyritic hornblende biotite quartz diorite to tonalite*
- b *medium- to coarse-grained quartz biotite porphyritic tonalite*
- c *fine- to medium-grained equigranular biotite tonalite to quartz diorite*
- d *coarse-grained quartz biotite porphyritic tonalite to granodiorite*
- e *medium-grained quartz biotite porphyritic tonalite intrusion breccia. Includes blocks (up to 10mm wide) of proximal mafic tectonite. Wall rock lithologies locally constitute >80% of outcrop area. A moderate fabric in the granodiorite crosscuts the pre-*

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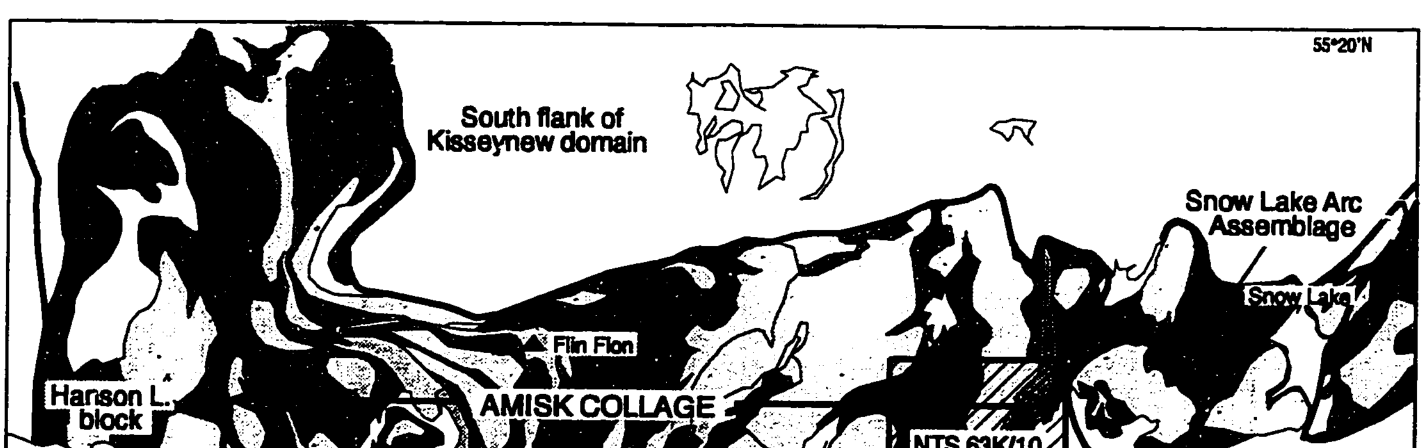

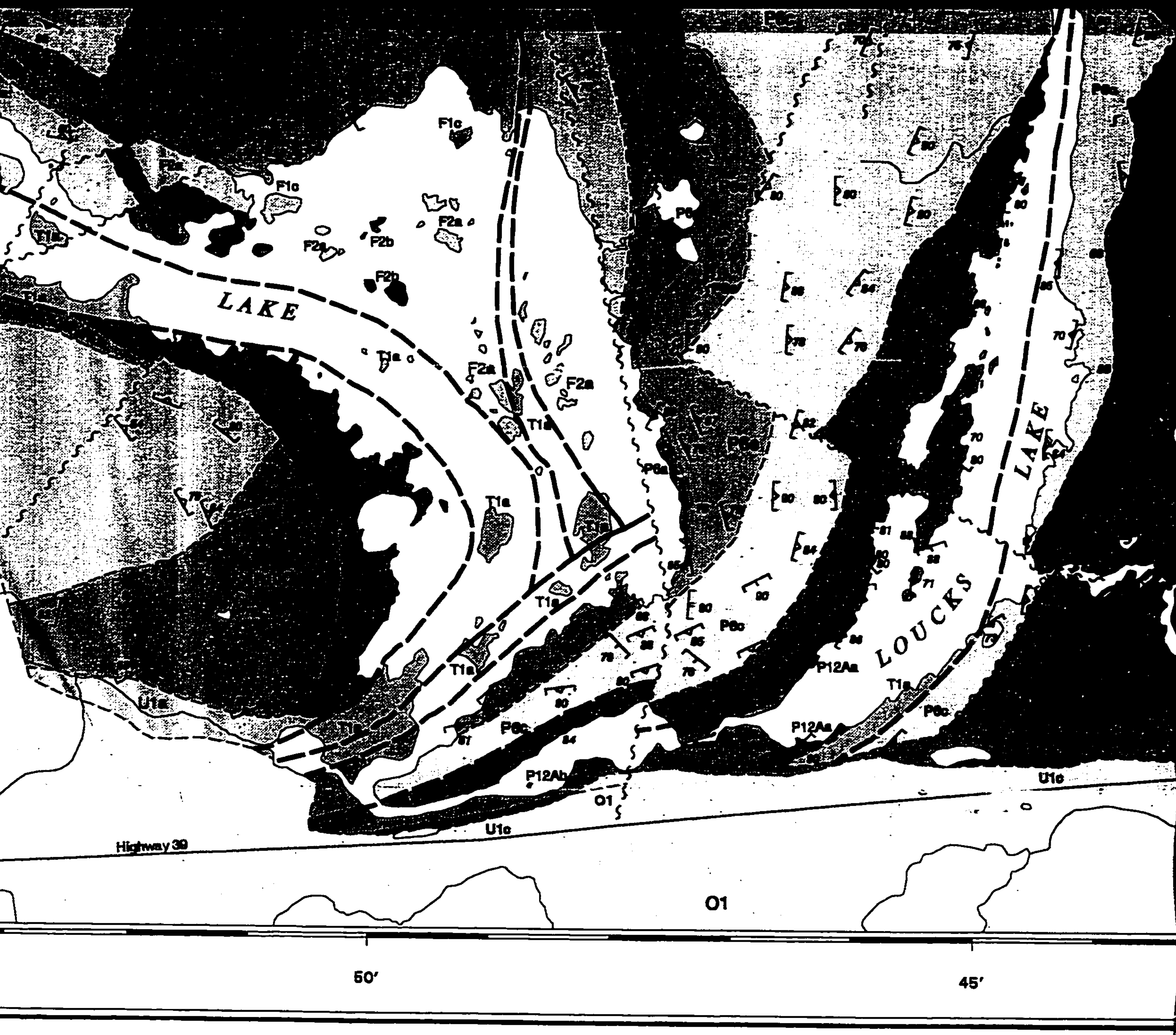

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GEOLOGY

ISKWASUM LAKE

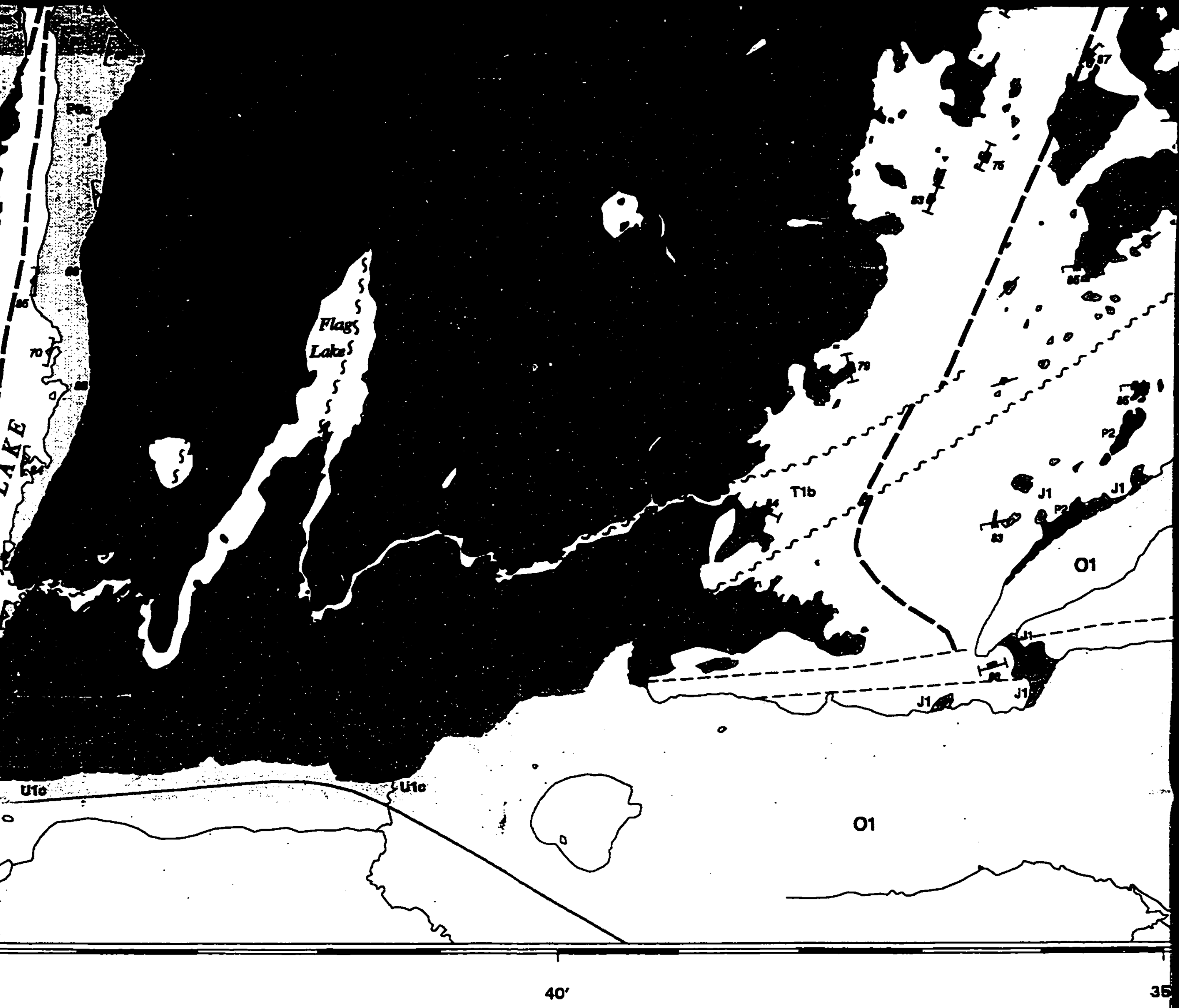
MANITOBA

Scale 1:50 000 --Échelle 1/50 000

Kilometres 1 0 1 2 3

Universal Transverse Mercator Projection

Projection transverse universe



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Geology of plutonic rocks by D.W. Morrison, 1994; assisted by T.Bohay, J.W
and A. Lalonde; geology of supracrustal rocks by E. Syme, 1994 (west ha
and E. Syme, A. Bailes and S. Lucas, 1995 (east half); additional
information compiled from Hunt (1970) and Rousell (1970)

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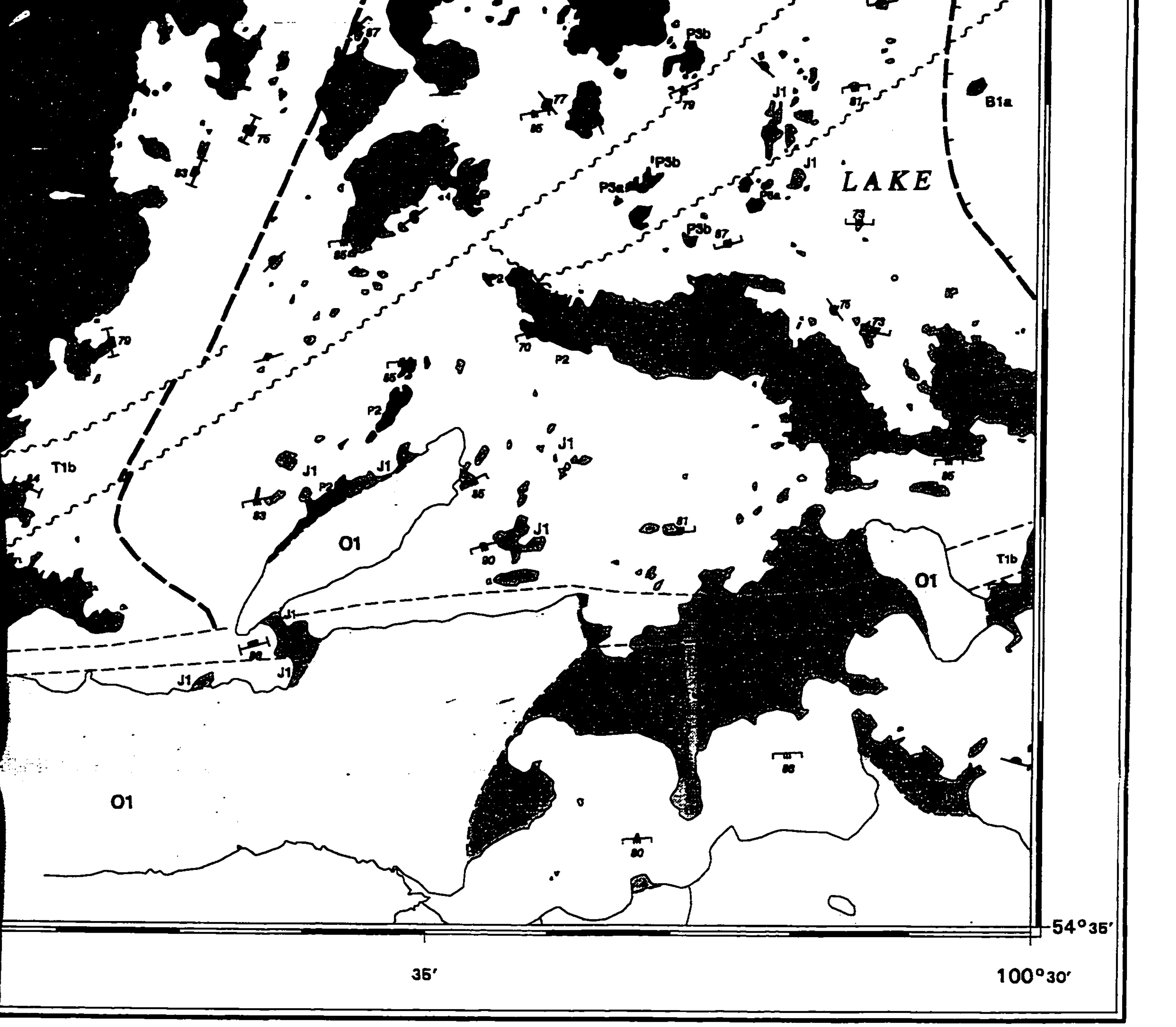

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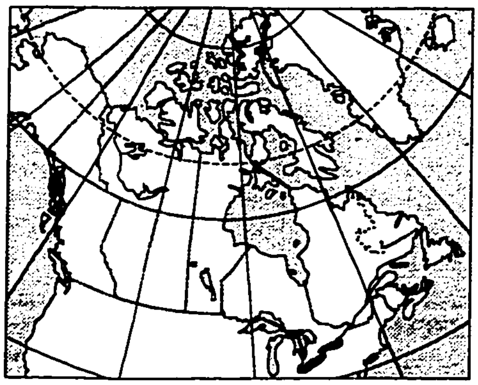

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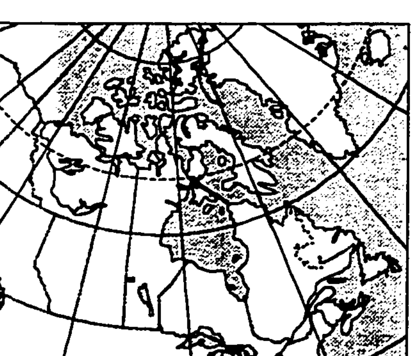

d coarse-grained quartz biotite porphyritic tonalite to granodiorite
e medium-grained quartz biotite porphyritic tonalite intrusion breccia. Includes blocks (up to 10mm wide) of proximal mafic tectonite. Wall rock lithologies locally constitute >80% of outcrop area. A moderate fabric in the granodiorite crosscuts the pre-existing tectonite fabric and folding in the xenoliths
f fine- to coarse grained quartz-biotite subporphyritic quartz diorite to tonalite

P6a

Iskwasum Lake stock
a fine- to medium-grained equigranular biotite porphyritic tonalite to granodiorite. Includes fracture-related epidote alteration of plagioclase
b medium-grained biotite porphyritic tonalite to granodiorite. Includes fracture-related epidote alteration of plagioclase
c fine- to medium-grained equigranular biotite tonalite to granodiorite. This unit is the pervasively-altered equivalent of unit 9Ba, and includes extensive epidote, sericitic, and chloritic alteration
d medium- to coarse-grained biotite porphyritic tonalite to granodiorite. This unit is the pervasively-altered equivalent of unit 9Bc, and includes strong sericitic, chloritic and epidote alteration
e medium-grained equigranular to biotite porphyritic tonalite to granodiorite intrusion breccia. Includes up to 80% proximal wall rock xenoliths. Xenoliths vary in size (0.5 cm to 6 m) and concentration, but in all cases the fabric within them is crosscut by intrusive offshoots

P6a
P6c

Wedge Lake pluton
a medium-grained equigranular hornblende granodiorite
b medium-grained K-feldspar porphyritic biotite tonalite to granodiorite. This unit is characterized by 2-3 cm poikilitic K-feldspar porphyroblasts with quartz and mafic mineral inclusions
c medium-grained equigranular to hornblende porphyritic hornblende ± biotite monzogranodiorite. This unit grades from the east into a less mafic equivalent, possibly quartz monzonite in composition
d medium-grained equigranular biotite granodiorite
e medium-grained hornblende-biotite granodiorite intrusion breccia. Included in this unit are fragments of proximal wall rock lithologies, including mafic tectonite and variably deformed mafic volcanic rocks, as well as cognate xenoliths and mafic and felsic xenoliths of unknown origin

P6c
P6a

Gants Lake batholith (1876+7/-6 Ma)
a fine- to medium-grained plagioclase subporphyritic quartz diorite to tonalite to granodiorite gneiss. This is the gneissic equivalent of units P6a and P6c, probably related to formation of structures on the western margin of the pluton
b medium-grained plagioclase porphyritic tonalite to granodiorite intrusion breccia. Includes sheets and xenoliths of proximal wall rock lithologies, including mafic tectonite and minor gabbro
c medium- to coarse-grained plagioclase porphyritic biotite-hornblende granodiorite
d medium-grained plagioclase porphyritic hornblende-biotite granodiorite
e medium-grained plagioclase porphyritic hornblende-biotite quartz diorite to tonalite
f multiple felsic and mafic lithologies. Is predominantly composed of medium-grained plagioclase porphyritic quartz diorite to granodiorite, but also includes fine-grained equigranular biotite granodiorite, fine-grained equigranular quartz diorite to tonalite, very fine-grained aplitic granite and coarse-grained plagioclase porphyritic biotite-hornblende granodiorite. Cross-cutting relationships suggest that all phases are approximately cogmagmatic
g fine- to medium-grained equigranular biotite tonalite
h fine- to medium-grained equigranular tonalite-gneiss. Quartz diorite sheets are ubiquitous in this unit, occupying 10 to 20% of outcrop area
i medium-grained plagioclase porphyritic biotite±hornblende granodiorite. This package of rocks is variably deformed, from moderately deformed to gneissic, but mafic sheets and dykes are ubiquitous
j medium- to coarse-grained equigranular to plagioclase-porphyritic biotite ± hornblende granodiorite
k fine- to medium-grained equigranular to quartz-porphyritic biotite-hornblende granodiorite

JOSLAND SILLS
a gabbronorite, gabbro
b ferrogabbro

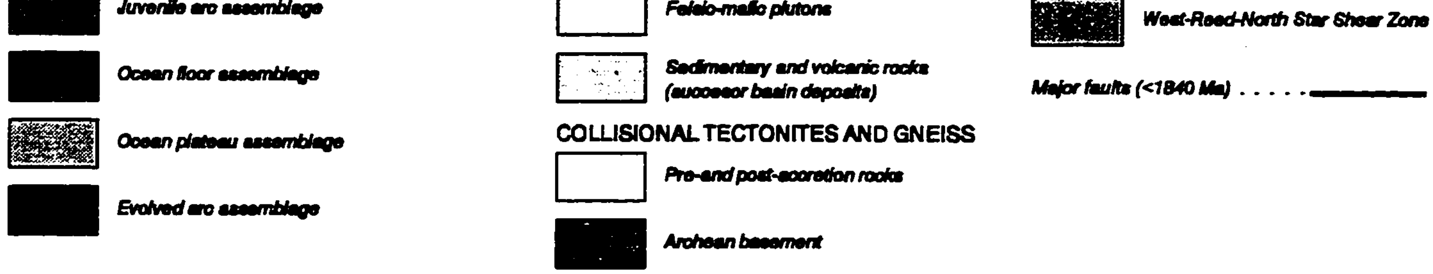

Figure 1: Location of the Iskwasum Lake sheet (NTS 63K/10) in the central portion of the Flin Flon greenstone belt of the Trans Hudson Orogen

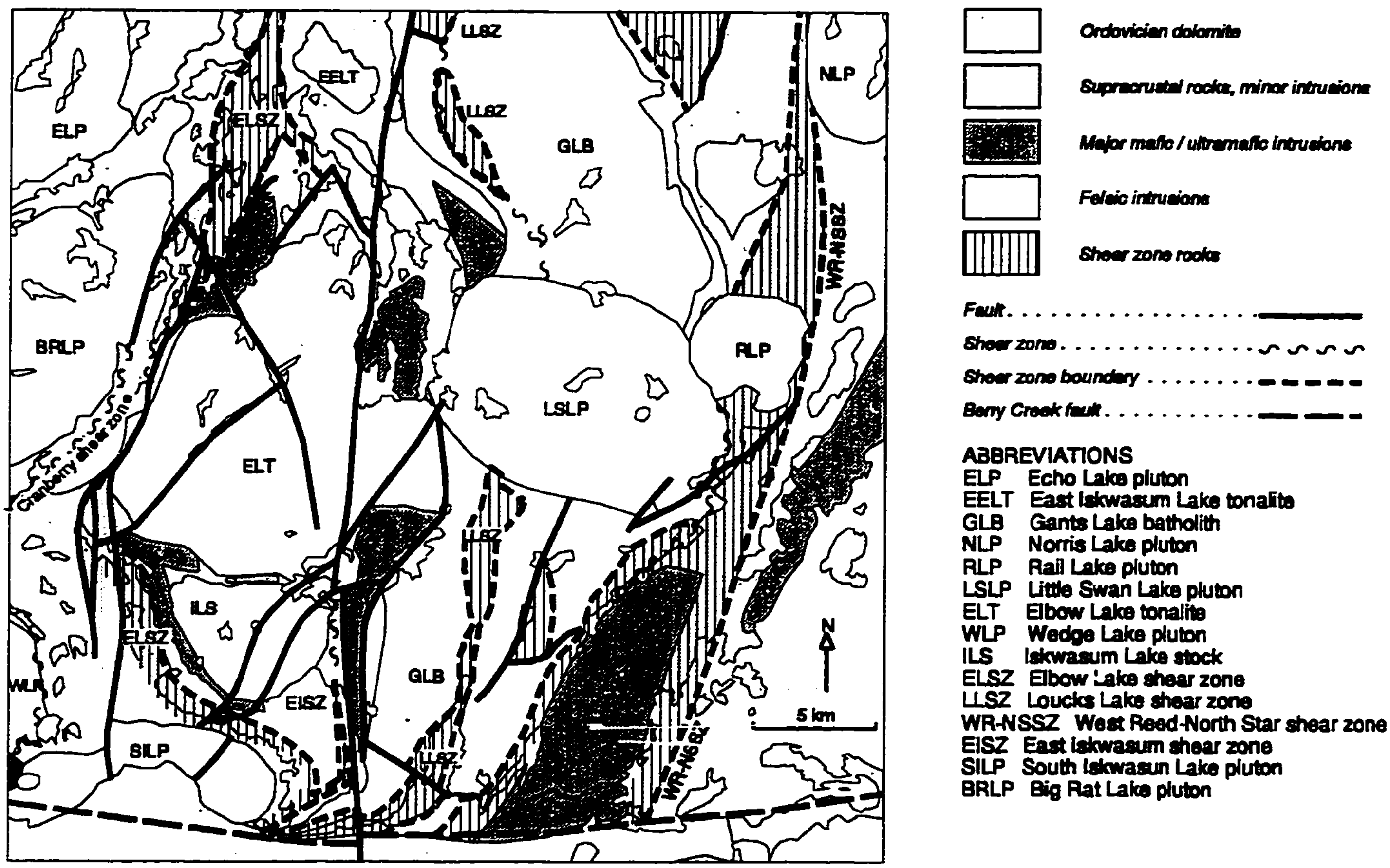

Figure 2: Major structural features and pluton names within the Iskwasum (NTS 63K/10) and Southern Elbow (NTS 63K/15) lake sheets

Canada

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DESCRIPTIVE NOTES

The Iskwasum Lake sheet (63K/10), bounded by latitudes 54°30' and 54°45' and longitudes 100°30' and 101°00', is located approximately 50 km east-southeast of Flin Flon and 45 km west-southwest of Snow Lake (Fig. 1). It lies entirely within the Grass River Provincial Park. The southern portion of the map area is accessable via lakes (e.g. Iskwasum and Reed lakes) and logging roads adjoining provincial highway 39. The northern half is accessable via an abandoned rail line. Float plane access was required only in the north-central portion of the map sheet. Outcrop exposure of intrusive rocks was in general good, although it was better in the north, due to a forest fire in 1989, than the south, where a thick blanket of moss obscures exposures.

This geological map is the result of field work undertaken in the summer of 1994. Supracrustal rocks in 63K/10 were mapped or compiled by E.C. Syme and A.H. Bailes (Manitoba Geological Services Branch) and S.B. Lucas (G.S.C.). The project forms part of a M.Sc. thesis by D. Morrison on the granitoid plutons at the University of Ottawa, supervised by A. Lalonde and J.B. Whalen. It was carried out under the auspices of the NATMAP Shield Margin Project (S.B. Lucas) and the Canada-Manitoba Partnership Agreement on Mineral Development 1990-1995 (J.B. Whalen).

The Iskwasum Lake sheet is located within the central part of the Flin Flon domain of the Paleoproterozoic Trans-Hudson Orogen. Recent interpretation by Lucas et. al. (1995) has suggested that this area formed by an amalgamation of oceanic and arc assemblages (1.92-1.88 Ga; Amisk collage) which was subsequently stitched by 1.88-1.84 Ga granitic intrusions, and overlapped by 1.85-1.84 Ga sedimentary rocks. Granitic plutons, which occupy about 60% of the area, represent an important element of the Flin Flon domain. Recent work in the Elbow Lake sheet (63K/15) to the north (e.g., Syme and Whalen, 1992; Whalen, 1993; Whalen and Hunt, 1994; Ryan and Williams, 1994, 1995) (see Fig. 2) has defined various supracrustal, plutonic and tectonic units or assemblages, and examined the significance of boundary structures.

Supracrustal rocks in the Iskwasum Lake sheet were compiled from Syme (1994), Rousell (1970), Hunt (1970) and Syme et al. (1995). Syme (1994) and Stern et al. (1995) defined the Elbow-Athapapuskow ocean-floor assemblage (unit F1). These are correlatives of ocean-floor affinity supracrustal units within the Elbow Lake map sheet to the north (Syme, 1992). Supracrustal rocks in the east half of the Iskwasum Lake sheet, which were simplified from Syme et al. (1995), include tectonites (unit T1b) and volcanic rocks interpreted to be island-arc affinity (unit J1).

Mafic-ultramafic complexes in the Iskwasum Lake sheet (units F2a,b,c,d and e) occur within, or spatially associated with, ocean-floor assemblages, west and east of the Gants Lake batholith, respectively. Smaller mafic intrusive bodies also occur within the west half of the map (F2e). The Iskwasum Lake mafic-ultramafic complex (see Syme, 1994) has been divided into a gabbro unit (F2a), and a composite unit (F2b), consisting of serpentinite, talc-carbonate-hematite schist and pyroxenite. The Reed Lake mafic-ultramafic complex has been subdivided into a gabbro body (unit F2c) and a gabbro-ultramafic complex (unit F2d), which were compiled from Syme et. al. (1995). It has been described by Williamson (1994). Smaller bodies throughout the map sheet (unit P2) consist of gabbro, diorite, quartz diorite and diabase. The Josland Sills (units P3a, P3b, and P3c) are located in the northeast corner of the map sheet, and have been subdivided into gabbronorite-gabbro (P3a), ferrogabbro (P3b), and quartz ferrodiorite-ferrotonalite (P3c)

Seven major granitoid bodies intrude into mafic tectonites, volcanic rocks and older intrusive suites (see Fig. 2). These granitic plutons vary in relative age, lithologic and structural complexity, and degree of alteration. Two of these plutons are confined to the map area, four others are continuous with plutons of the Elbow Lake sheet (63K/15) to the north (Whalen, 1993a), and two extend into the Cranberry Portage sheet (63K/11) to the west.

The **Gants Lake batholith** is compositionally variable, ranging from quartz diorite to tonalite (units P6e, P6g, and P6h), and to granodiorite (units P6a, P6c, P6d, P6i and P6j). Subdivisions are based on composition, grain size and textural variations, the presence of mafic sheets, and deformation state. In general, the Gants Lake batholith is moderately to strongly foliated, and intrusive units, as well as the dominant foliation and structures, trend north-northeast. In the south these features appear to be dragged into a westerly orientation by the Berry Creek fault. The dominant Gants Lake batholith lithology, a strongly foliated medium- to coarse-grained, plagioclase porphyritic granodiorite (unit P6c), closely resembles the granodiorite unit within the Elbow Lake sheet which yielded an U-Pb zircon age of 1876+7/-6 Ma (Whalen and Hunt, 1994). Central and eastern portions of units P6c and P6d may include equivalents of relatively younger granodioritic units 9g and 9h mapped by Whalen (1993a) in the Elbow Lake sheet to the north. Although the deformation state of granitoid phases generally decreases in intensity away from major shear zones, all portions are moderately to strongly foliated. There are, however, late (?) faults bounding areas of mylonites (unit P12d) which bear no apparent relationship to major shear zones. Northwest of Loucks Lake, in an area where penetrative north-northeast- trending deformation is less intense, five texturally distinct, but comagmatic, felsic plutonic lithologies (grouped as unit P6f) were distinguished. Cross-cutting relationships between these lithologies become obliterated as the Loucks Lake shear zone is approached. The Gants Lake batholith is bounded on the east and west by shear zones (Fig. 2). In the west, an unnamed fault separates a zone of intrusion breccia (unit P6b) from supracrustal rocks, while in the east, the West Reed-North Star shear zone (unit J14b; Syme et al. (1995)) separates the batholith from Fourmile Island arc assemblage rocks. The presence of intrusive breccia zones (unit P6b) with mafic tectonite xenoliths of proximal shear zone rocks at these margins indicate that the batholith post-dates some, but not necessarily all,deformation.

The **Wedge Lake pluton** (unit P8) is a structurally and lithologically complex body. Less than 15 km^2 of this pluton is located in the Iskwasum Lake sheet; the majority lies in the Cranberry Lake sheet (63K/11). A small zone of K-feldspar porphyritic granodiorite (unit P8b) at its southern end is a volumetrically more important unit in the adjacent Cranberry Portage sheet. It is characterised by poikiolitic K-feldspar with quartz and mafic mineral inclusions. This unit grades northward into biotite-hornblende granodiorite (unit P8d), hornblende quartz monzonite (unit P8c), and hornblende-biotite granodiorite (unit P8a). The northern margin of the pluton is in probable intrusive contact with mafic tectonite. A xenolith-rich zone (unit P8e) containing variably deformed mafic volcanic and intrusive rocks, cognate xenoliths and intrusive rocks of unknown origin, separates the pluton from the tectonite. Sheared equivalents of Wedge Lake pluton lithologies, and probably younger mafic intrusive sheets

have been recognized in, and adjac

The **Elbow Lake tonalite** (unit P
southwestern part of the Elbow Lake
from the Elbow Lake portion of this p
of medium-grained, quartz-biotite po
between outcrops can be conside
stockworks, even between outcrops,
Although this faulting has largely de
recognized. In the northwest corner
equigranular tonalite (unit P9Ac); at
its western margin, the presence o
tectonite (up to 10 m) and variably de
contact is intrusive rather than struct
batholith, characterized by a thin zon

The ovoid **Iskwasum Lake stoc**
fine-grained, leucocratic, biotite tona
tectonite, mafic volcanic and intrusive
lithologies (up to 75% wallrock inclu
pluton, often cross-cutting the pre-ex
less deformed aplite dykes are comm
from the eastern portion (units P9Bb
epidote alteration of plagioclase, whe
a biotite porphyritic unit, similar to u
and have been altered almost entire
equigranular biotite tonalite, with 5-1

The **South Iskwasum Lake plu**
subdivided into fine- to medium-g
respectively). The weak to modera
mylonitic mafic tectonite within to th
deformation in the pluton compared
Lake pluton was emplaced after m
concentrated in the less competent
deformation near the margins of othe
of the shear zone in the Iskwasum La
The southern portion of this pluton is

The **Big Rat Lake pluton** (unit P
(see Fig. 2). The main part of this intr
much more lithologic variation has b
into the map sheet from the Elbow
granodiorite phase; unit P10Ba is f
microgranitoid enclaves, which are c
phases of the pluton, as are mafic d
(Whalen and Hunt, 1994), combined
P10Bb intrude a phase of the Big Ra

The ovoid **Little Swan Lake plu**
Gants Lake batholith (see Fig. 2). Fie
and an U-Pb titanite age of 1826+/-
1994), demonstrate that this is a rela
rocks are strongly foliated to gneissi
typically sub-parallel to the margins.
secondary foliation subparallel to the
from the contact, and is presumed to
Lake pluton is predominately quartz p
and P10b, respectively). Field relation
are comagmatic with the granodiorite
occurs as small (<10 cm) lobate inclu

Shear zone rocks in the Iskwasu
with variable mylonitized felsic sheets
zone rocks are described by Syme (1
zone consists of mylonitic equivalen
P12Ac), as well as various unknown
reappearing on an unnamed lake im
gradually away from the shear zo
granodiorite. Banded felsic-mafic te
batholith in the west from the Reed
stratigraphic packages (unit J1) to the
Reed Lake mafic-ultramafic complex
dominantly confined to supracrustal r
the Berry Creek fault is not expose
Structures and lithologic units, includ
indicating an apparent dextral sense

Ottawa, Ontario, K1A 0E9

Mean magnetic declination 1996, 9°29' E, decreasing 7.8' annually

een recognized in, and adjacent to, a thin (150-200 m) shear zone which cuts the east side of this pluton.

e **Elbow Lake tonalite** (unit P9A) dominates the northwestern portion of the Iskwasum Lake sheet and the astern part of the Elbow Lake sheet (Whalen, 1993a). An U-Pb zircon age of 1864+5/-4 Ma was obtained e Elbow Lake portion of this pluton (Whalen and Hunt, 1994). Although the pluton predominantly consists um-grained, quartz-biotite porphyritic tonalite (unit P9Ab), textural and compositional variation in this unit n outcrops can be considerable. This variation, and the inability to trace mafic dykes and quartz orks, even between outcrops, is a result of predominant north-northeast-trending faulting within the pluton. h this faulting has largely destroyed evidence for internal zonation, some undisrupted portions have been zed. In the northwest corner of the pluton, an ovoid zone of granodiorite (unit P9Ad) grades outward to nular tonalite (unit P9Ac); at the center of the pluton is a zone of hornblende-rich tonalite (unit P9Aa). At ern margin, the presence of an intrusion breccia (unit P9Af), consisting of large fragments of mafic e (up to 10 m) and variably deformed mafic volcanic rocks cut by tonalitic dykes, suggests that this plutonic is intrusive rather than structural (Ryan and Williams, 1994, 1995). Its eastern contact with the Gants Lake h, characterized by a thin zone (<50 m wide) of banded gneiss and mylonite, is interpreted as tectonic.

e ovoid **Iskwasum Lake stock** (unit P9B), located near the centre of the map area, consists primarily of a ined, leucocratic, biotite tonalite that contains less than 15% mafic minerals. The pluton intrudes mafic e, mafic volcanic and intrusive rocks; portions of its outer margin (unit P9Be) are rich in fragments of these ies (up to 75% wallrock inclusions). Foliation in this marginal unit is typically stronger than the rest of the often cross-cutting the pre-existing foliation in the fragments, but on occasion deflected around them. Late, ormed aplite dykes are common. The western half of the pluton (units P9Ba and P9Bd), which is separated e eastern portion (units P9Bb and P9Bc) by the Barb Lake fault (Fig. 2), is characterised by fracture-related alteration of plagioclase, whereas units P9Bb and P9Bc have a much more pervasive alteration. P9Bd is e porphyritic unit, similar to unit P9Bb east of the fault. Biotite phenocrysts are rarely larger than 3-4 mm, ve been altered almost entirely to chlorite. Unit P9Ba, the main lithology within this pluton, is a fine-grained nular biotite tonalite, with 5-15% mafic minerals, while unit P9Bc is its more pervasively altered equivalent.

e **South Iskwasum Lake pluton** (unit P10C), a homogenous biotite-hornblende granodiorite, has been ided into fine- to medium-grained, and medium- to coarse-grained phases (P10Ca and P10Cb, tively). The weak to moderate foliation which characterizes this pluton contrasts with the foliated to c mafic tectonite within to the Elbow Lake shear zone to the north. This contrast, and the lack of brittle ation in the pluton compared to most others in the map sheet suggests that either the South Iskwasum luton was emplaced after much of the deformation that had affected the area, or deformation was trated in the less competent mafic host rocks (cf. Ryan and Williams, 1994, 1995). Given the lack of ation near the margins of other plutons in the area, and Ryan and Williams (1995) assessment of the timing hear zone in the Iskwasum Lake sheet, this contrast is likely a result of a combination of the two scenarios. uthern portion of this pluton is overlain by Ordovician dolomite (unit O1a).

e **Big Rat Lake pluton** (unit P10B) occupies less than 10 km^2 at the northwestern margin of the map sheet g. 2). The main part of this intrusion is located in the Elbow Lake and Cranberry Portage map sheets, where nore lithologic variation has been documented (see Whalen, 1993a, 1993b). The two phases that extend e map sheet from the Elbow Lake sheet are textural variants of a compositionally similar granite to iorite phase; unit P10Ba is fine- to medium-grained, unit P10Bb is medium-to coarse-grained. Mafic ranitoid enclaves, which are common in other plutons in the area, are conspicuously absent from these of the pluton, as are mafic dykes and late veins. Recent geochronologic work in the Elbow Lake sheet n and Hunt, 1994), combined with field relations (Whalen, 1993a, 1993b), suggest that units P10Ba and intrude a phase of the Big Rat Lake pluton that yielded an U-Pb age of 1845±3 Ma.

e ovoid **Little Swan Lake pluton** (unit P10A), at the northeastern margin of the map area, crosscuts the ake batholith (see Fig. 2). Field relations, which include termination of north-northeastern trending fabric, U-Pb titanite age of 1826+/-5 Ma obtained from the northern portion of this pluton (Whalen and Hunt, demonstrate that this is a relatively late intrusion. Deformation is strongest at the pluton margin, where the re strongly foliated to gneissic. Internal foliations, presumably related to emplacement of the pluton, are sub-parallel to the margins. Near the margin of the pluton, host Gants Lake batholith rocks record a ary foliation subparallel to the contact between the two intrusions. This fabric weakens in intensity away e contact, and is presumed to be a result of emplacement of the Little Swan Lake pluton. The Little Swan uton is predominately quartz porphyritic biotite-hornblende and hornblende-biotite granodiorite (units P10a 0b, respectively). Field relationships suggest that large zones of quartz diorite (unit P10c) within this pluton nagmatic with the granodiorite. In a small, oval zone in the center of the pluton (unit P10g), quartz diorite as small (<10 cm) lobate inclusions within granodiorite, suggesting comingling of mafic and felsic magmas.

ear zone rocks in the Iskwasum Lake sheet include mafic tectonite, mafic-felsic tectonite, mafic tectonite iable mylonitized felsic sheets and felsic varieties (units T1a, T1b, T1c and P12, respectively). Mafic shear cks are described by Syme (1994), and include tectonite, phyllonite and mylonite. The Loucks Lake shear onsists of mylonitic equivalents of mapped Gants Lake batholith lithologies (units P12Aa, P12Ab and , as well as various unknown lithologies (unit P12Ad). North of Loucks Lake, the shear zone pinches out, aring on an unnamed lake immediately to the north. On this lake the intensity of deformation decreases lly away from the shear zone, grading to gneissic (unit P6a) and then strongly foliated (unit P6c) orite. Banded felsic-mafic tectonites of the West Reed-North Star shear zone separate the Gants Lake h in the west from the Reed Lake mafic-ultramafic complex (unit F8e) and Fourmile Island volcanic arc aphic packages (unit J1) to the east. The tectonite zone probably contains sheared equivalents of both the ake mafic-ultramafic complex and the Gants Lake batholith where it juxtaposes these two intrusions, but is ntly confined to supracrustal rocks east of the Reed Lake mafic-ultramafic complex. Although the trace of ry Creek fault is not exposed in the Iskwasum Lake sheet (see Fig. 2), effects are readily apparent. es and lithologic units, including major shear zones and faults, are dragged into a westerly orientation, ng an apparent dextral sense of shear. At the outcrop scale, Berry Creek fault fabrics overprint earlier

fabrics within the Gants Lake batholith. Adjacent to the fault zone, this fabric is transpose earlier fabrics. The Barb Lake fault (see Fig. 2) is a large brittle structure, fracture set (190 /80 to 200 /80). Assuming that late-stage hydrothermal fluids have portions of the pluton, and given the fact that there can only be a limited amount steeply-dipping wall-rock contacts, this fault is interpreted as having predomina movement.

Mineral prospecting in the Iskwasum Lake area has resulted in the discovery o occurrences, including gold, platinum group elements, sulphides and talc (Heine, 1 gold showings in Reed Lake are associated with sheared tonalite, the previously unre zone (unit P12) within the Gants Lake batholith may merit exploration for gold. The in the northern half of the map area, due to a 1989 forest fire, has revealed previous sulphide-bearing veins within the Elbow Lake pluton (unit P9A). In addition, as indica pluton contains late fracture-related potassic alteration, a characteristic which also m exploration. The mineral potential of existing showings has been summarized by Hei

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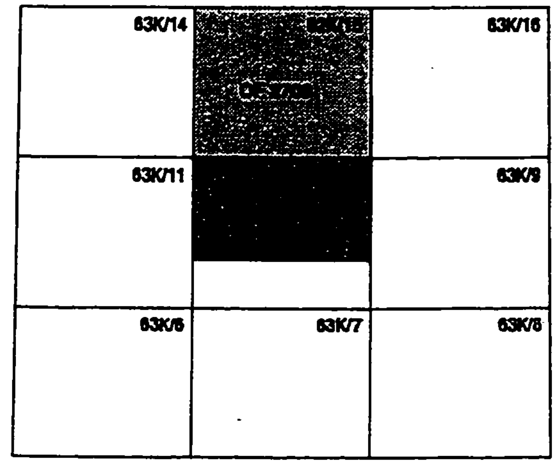
LOCATION MAP

agnetic declination 1996, 9°29' E, decreasing 7.8' annually

Gants Lake batholith. Adjacent to the fault zone, this fabric is so strong as to completely abrics. The Barb Lake fault (see Fig. 2) is a large brittle structure, with an associated parallel 0 to 200 /80). Assuming that late-stage hydrothermal fluids have a greater effect on the upper uton, and given the fact that there can only be a limited amount of lateral displacement on all-rock contacts, this fault is interpreted as having predominantly dip slip (west-side-up)

ecting in the Iskwasum Lake area has resulted in the discovery of approximately 100 mineral ding gold, platinum group elements, sulphides and talc (Heine, 1994). Because some known eed Lake are associated with sheared tonalite, the previously unrecognized Loucks Lake shear hin the Gants Lake batholith may merit exploration for gold. The increased outcrop exposure in f the map area, due to a 1989 forest fire, has revealed previously unrecognized quartz- and eins within the Elbow Lake pluton (unit P9A). In addition, as indicated by Whalen (1993b), this e fracture-related potassic alteration, a characteristic which also makes it a candidate for gold ineral potential of existing showings has been summarized by Heine (1993 and 1994).



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Manitoba
PARTNERSHIP ASSOCIATION
ENTENTE DE PARTENARIAT SUR L'EXPLOITATION MINÉRALE 1990 - 1995
PARTNERSHIP AGREEMENT ON MINERAL DEVELOPMENT 1990 - 1995
Canada

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COMMISSION GÉOLOGIQUE DU CANADA
OTTAWA
09/1996

LOCATION MAP

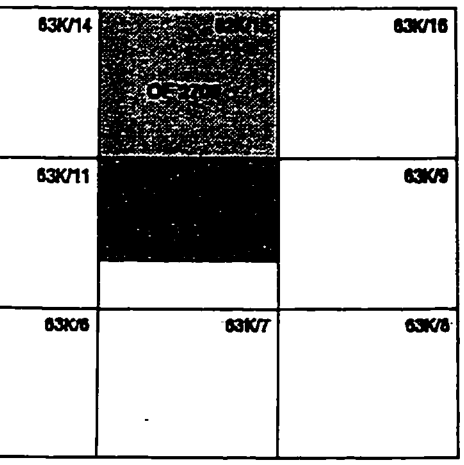
b *ferrogabbro*
c *quartz ferrodiorite, ferrotonalite,*

MINOR MAFIC INTRUSIONS
a *gabbro, diorite, quartz diorite and diabase*

FOURMILE ISLAND ARC ASSEMBLAGE
a *pillowed and massive basalt, basaltic andesite, rhyolite, volcaniclastic rocks*

ELBOW-ATHAPAPUSKOW OCEAN-FLOOR ASSEMBLAGE
Mafic-ultramafic Complexes
a *Iskwasum Lake gabbro*
b *Iskwasum Lake ultramafic rocks, serpentinite, hematite-talc schist*
c *Reed Lake gabbro*
d *Reed Lake gabbroic + ultramafic rocks*

Basalt, diabase, related mafic volcaniclastic rocks, and derived tectonite
a *McDougall's Point basalt*
b *Athapapuskow basalt*
c *Centre Lake mafic tectonite*



NATIONAL TOPOGRAPHIC SYSTEM REFERENCE

ROCKS OF UNKNOWN AFFINITY

MAFIC ROCKS AND MINOR FELSIC INTRUSIVE ROCKS
a *biotite schist, hornblende schist, minor felsic and mafic intrusions and mafic intrusions*
b *fine-grained tonalite*
c *supracrustal rocks, and Namew Gneiss (not exposed), interpreted from aeromagnetic signature*

Geological contact, inferred ....
Flow contact (top known, overturned) ....
Pillowed flow (top known, overturned) ....
Foliation (generation unknown) ....
Foliation (generation known)
1st, 2nd, 3rd, 3rd-shearing ....
Stretching lineation (generation unknown) ....
Fold axial plane (generation unknown);
axial plane, s fold, z fold ....
Fault ....
Fault (sense unknown, dextral, sinistral) ....
Shear zone boundary ....
Morton Lake fault zone ....
Shear zone (sense unknown) ....

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Energy, Mines and Resources, Canada   Énergie, Mines et Ressources, Canada

DESCRIPTIVE NOTES

The Elbow Lake map area (NTS 63K/15) comprises 865 km2, bounded by latitudes 54° 45' and 55° 00' and longitudes 101° 00' and 100° 30'. It is located within the Early Proterozoic Flin Flon metavolcanic belt, 65 km east of Flin Flon and 40 km west of Snow Lake. The geological context of this area has been outlined by Syme (1991; 1992). The area was burnt in the summer of 1989, an event which greatly improved the quality and quantity of bedrock exposure. This map is a follow-up to the cooperative Elbow Lake project in which detailed (1:15 840) geological mapping was divided between Manitoba Energy and Mines (supracrustal rocks: Syme, 1992) and the Geological Survey of Canada (granitoid rocks: Whalen, 1992) (Syme and Whalen, 1992). Upon completion of the cooperative Elbow Lake project area, mapping of granitoid rocks within the remainder of NTS 63K/15 was carried out at 1:50 000 scale during 1992 and 1993. In this map, the geology of the area covered in the cooperative Elbow Lake project, has been greatly simplified, in particular the supracrustal rocks, major mafic intrusions and minor intrusions mapped by E. Syme, Manitoba Energy and Mines.

Supracrustal rocks in the area belong to the Amisk Group (**unit 1**) and consist mainly of mafic metavolcanic rocks and related high level intrusions. Within the area he has mapped, Syme (1992; pers. com. 1993) has subdivided these rocks into sequences with arc, back-arc and ocean island basalt affinity (**units 1a, b,** and **c**). Elsewhere in the map area, the Amisk Group is undivided (**unit 1d**). In the eastern portion of the map area, the supracrustal rocks were compiled from McGlynn (1959). In the northwestern portion of the sheet, data was compiled from Schledewitz (1992b; 1993 pers. com.). Detailed descriptions of the supracrustal rocks are given by Syme (1991, 1992) and Schledewitz (1992a).

Gneissic supracrustal rocks of possible Amisk Group affinity (**unit 2**) are exposed in the northeast portion of the map area. In large part **unit 2** was compiled from McGlynn (1959). Adjacent to the Gants Lake batholith (**unit 9**), this unit is a heterogeneous mixture of equal portions of migmatitic paragneiss and amphibolite, considered to represent a deformed and metamorphosed supracrustal package. The presence of a major proportion of probable metavolanic rocks suggest an affinity with the Amisk Group.

Numerous small, high level intrusions into the Amisk Group were mapped along with the supracrustal rocks by Syme (1991;1992). In this map, these have been grouped into two units; a felsic to intermediate group (**unit 3a**) and a mafic to intermediate group (**unit 3b**). Each group contains intrusive phases of diverse relative ages, some of which may be equivalent to phases of the major mafic/ultramafic and granitoid intrusions. A similar variety of minor intrusions is probably present within the undivided Amisk Group (**unit 1d**) elsewhere in the map area.

A number of large mafic/ultramafic intrusions (**unit 4**) occur within the map area. The Long Bay, East Claw Lake and Elbow/Claw Lake gabbro complexes (**units 4a, 4b** and **4c**), mapped and described by Syme (1991; 1992), include a spectrum of mafic lithologies such as layered and massive gabbro units. In this map, these complexes compiled from Syme and Whalen (1992) are not subdivided. The other group of major mafic intrusions (**unit 4d**) was mainly compiled from McGlynn (1959). The name, Josland gabbro complex, was adopted from equivalent rocks described in the adjacent File Lake sheet (NTS 63K/16) by Bailes (1980). The major mafic intrusions have been interpreted as relatively early (syn- to slightly post-volcanic) intrusions (Bailes, 1980; Syme, 1991; 1992).

The East Elbow Lake, Elbow Lake, Webb Lake, and Rail Lake intrusions (**units 5** through **8**) are quartz phyric to quartz megacrystic tonalitic intrusive rocks which may belong to an early (>1860Ma), potassium-poor intrusive suite. Lithologically similar plutons near Flin Flon (Cliff Lake) and Snow Lake (Sneath Lake and Richard Lake) have been interpreted as being subvolcanic bodies which are genetically related to massive sulphide mineralization (Gordon et al., 1990).

The East Elbow Lake stock (**unit 5a**) is an oval intrusion which covers an area of 10 km^2 just east of the northeast corner of Elbow Lake. Preliminary U-Pb results from this body indicate it is pre-Missi in age (1864+/-3 Ma; Whalen and Hunt, unpublished data). This intrusion consists of white weathering, coarse- grained quartz megacrystic (1-2.5 cm), biotite-hornblende tonalite which locally contains euhedral biotite books. Foliation is generally weak and orientated east to northeast. Similar quartz megacrystic to quartz phyric tonalite sills (**units 5b** and **5c**) occur within and northwest of Claw Lake.

The Elbow Lake tonalite (**unit 6**) covers an area of 250 km^2, only about 25% of which is located within the map-area. Portions of the Elbow Lake pluton outside the map-area have been described by Baldwin (1980) and Hunt (1970). Unit 6 is generally quartz phyric rather than quartz megacrystic. Preliminary U-Pb zircon results from this pluton suggest that it is pre-Missi in age (1869+20/-7 Ma; Hunt and Whalen, unpublished data). A remarkable feature of the mapped portion of this large intrusion is a lack of distinctive compositional or textural phases. However, there is some variation at the outcrop scale in the size and abundance of euhedral biotite phenocrysts

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'E NOTES

The southern end of the Gants Lake batholith consists of an ovoid, bimodal intrusion (**units 9n** through **9s**), only the northern half of which lies within the map area. The eastern part of this body consists of poorly exposed fine to coarse grained gabbroic to dioritic rocks (**units 9o** and **9n**). On its west side, adjacent to Claw Lake, there is a heterogeneous mixture of gneissic to massive, fine- to medium-grained, gabbroic to tonalitic intrusive and basaltic volcanic rocks (**unit 9p**). This agmatite zone is cut by numerous dykes of equigranular to quartz-eye porphyritic tonalite to granodiorite related to **unit 9s**. To the east, similar mafic intrusive rocks, without the volcanic lithologies, form irregularly spaced, north-south orientated screens (**unit 9q**) within a major granodiorite to granite phase (**unit 9s**). The northern end of the intrusion consists of an area of quartz diorite to tonalite (**unit 9r**) that is texturally similar to **unit 9s**. Contact relationships between **units 9n** to **9s** suggest comagmatic intrusion of mafic and felsic magmas with hybridization to produce intermediate compositions (**unit 9r**). A sample of granodiorite unit 9s yielded a poorly defined U-Pb zircon age of 1845+27/-12 Ma, compatible with all phases at this end of the batholith being contemporaneous with the various zoned plutons in the map area (**units 12** through **14**).

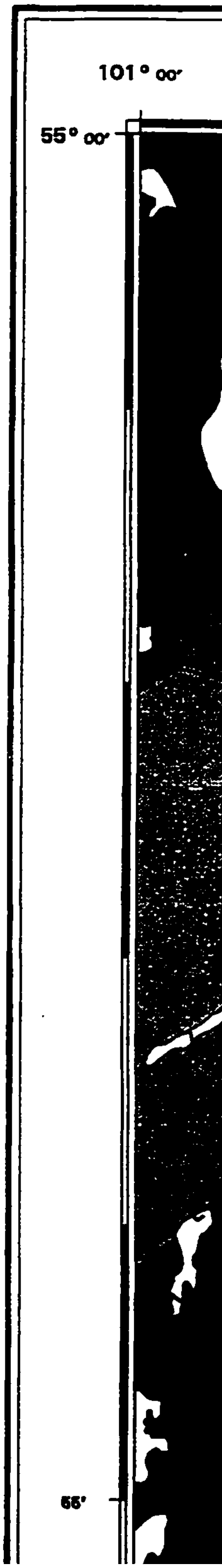
A couple of small (1 to 2 km^2) ovoid, only slightly foliated biotite phyric (**unit 9t**) and quartz phyric granite bodies intrude well foliated portions of **unit 9g** and **9d** just southwest of Gants Lake. Their relationship to other intrusive phases is unknown.

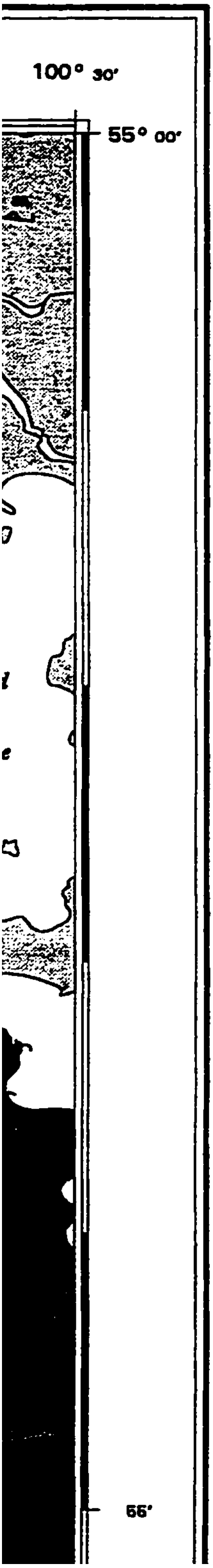
The North Star Lake pluton (**unit 10**) is a small (10 km2) intrusion exposed on the west side of North Star Lake. Contacts of this pluton were compiled from Norquay et al. (1991). Unit 10a, a strongly foliated, medium to coarse grained quartz and plagioclase phyric biotite granodiorite to tonalite, and **unit 10b**, a very fine to fine grained biotite felsic aplite, may be metamorphosed equivalents of phases 9g and 9h of the Gants Lake batholith. If so, there is marked increase in metamorphism and deformation east of this batholith, comparable to the contrast described above between **units 9g** and **9f**.

The composite Echo Lake pluton (**unit 11**) covers an area of about 48 km^2 on the northwest side of the map-area. In the northwestern portion of this pluton, there is a massive and apparently undeformed oval plug (**unit 11e**), that may be equivalent in age (1847 Ma; Gordon et al., 1990) to plutons such as the Lynx Lake pluton south of Flin Flon, which postdate regional D2 deformation. Sharp contacts have been observed between this massive, feldspar-amphibole porphyritic granodiorite (**unit 11e**) and well-foliated, coarse-grained, hornblende-biotite granodiorite (**unit 11d**). Matrix grain size in **unit 11e** varies from very fine-grained near margins to medium-grained in its interior. Textures exhibited by this unit, together with the presence of cross-cutting amygdaloidal mafic dykes, suggest that it was intruded at a relatively high-level. Minor areas of equigranular, coarse-grained, hornblende-biotite granite occur at a number of localities near the edge of **unit 11e**. The older, tectonically foliated portion of the Echo Lake pluton has been subdivided into a number of compositional variants which become more felsic and more lithologically homogeneous toward the interior of the pluton. The most eastern **unit 11b** exhibits textural variation from fine- to coarse- grained and compositional variation from melagabbro to diorite and quartz diorite. Included in this unit are areas of diorite which contain a high portion (10 to 40%) of pyroxenitic inclusions. Coarse- grained pyroxenite occurs both as bands or schlieren and as massive zones (**unit 11a**). It is thought that some of the abrupt compositional and textural variations in this unit could be due to left-lateral faulting and shearing with displacements varying from a few meters to a number of kilometres. There is a close textural resemblance between the two more western phases. The split into two units is based on quartz content and the fact that the diorite to quartz diorite **unit 11c** commonly contains mafic (basaltic or gabbroic) inclusions. In contrast, such inclusions are less common in the quartz diorite to granodiorite **unit 11d** and biotite is more abundant than hornblende. Various compositional and textural types of dykes are most common in the eastern portion of this pluton and include grey to beige feldspar-quartz rhyolite porphyry, dark pink granitic aplite and basaltic to diabasic dykes. Due to later deformation, these dykes generally can not be followed for any distance along strike. In contrast, only one generation of amygdaloidal basaltic dykes cuts the western massive granodiorite **unit 11e**. These dykes can often be followed for up to 500 meters.

The Gauthier Lake, Norris Lake and Big Rat Lake plutons (**units 12** through **14**) are composite, compositionally zoned, generally unaltered and only slightly deformed. This relatively late suite of intrusions are probably all of similar age to the Big Rat Lake pluton from which an U-Pb age of 1845+/-3 Ma was obtained (Whalen and Hunt, unpublished data).

The Gauthier Lake pluton (**unit 12**), an ovoid body covering an area of about 30 km^2 in the north central portion of the map area, is zoned from a monzodiorite or quartz monzonite rim (**unit 12a**), through granodiorite (Unit 12b) to a granite core (**unit12c**). All internal contacts appear to be gradational. Contacts are displaced by late north-south trending, narrow, fault zones. Evidence for a vertical movement component on these faults is given by the presence of high-level porphyritic textures and stockwork quartz veins with sericitic alteration within the central portion of the granite core to this pluton.





Tectonites in shear zones and faults. Brit
in shear zones; includes fault breccia, my
and mafic and felsic phyllonites

BIG RAT LAKE PLUTON

Subunits 14a to 14e are similar in age a
subunits 14f to 14g; contacts are gradatio
14a - 14e and 14f - 14g

Heterogeneous "hybrid" intrusive rocks: un
(>40%) mafic igneous plutonic and volcan

Grey, foliated, medium grained, equigranu
biotite diorite to quartz diorite

14c

Beige to grey, foliated, medium grained, e
hornblende-biotite quartz diorite to granodi

Medium pink, foliated, medium grained, po
hornblende-biotite granodiorite (1845 +/- 3
Hunt and Whalen, unpublished data)

Dark pink to red, foliated, coarse grained,
to subporphyritic, hornblende-biotite granod

Dark pink, foliated, equigranular, fine to m
biotite +/- hornblende granite (intrudes 14c

Dark pink, foliated, equigranular, medium
grained, biotite granite

NORRIS LAKE PLUTON

Subunits 13a to 13d are similar in age w
between 13a to 13c; 13d intrudes 13b an
pluton are lithologically similar to units 14c

Grey, foliated, fine to medium grained, eq
hornblende +/- biotite diorite to quartz dior
common rafts and inclusions of fine to co
plutonic rocks including pyroxenite, gabbro

Grey to pink, foliated, medium grained, eq
hornblende-biotite quartz diorite to granodi

Pink, foliated, medium grained, equigranula
biotite granodiorite

Pink, foliated, fine to medium grained, equ

LEGEND

and faults. Brittle deformation
fault breccia, mylonite, diorite,
lonites

similar in age and older than
acts are gradational within

trusive rocks: unit 14b with abundant
tonic and volcanic inclusions

ained, equigranular, hornblende-
orite

edium grained, equigranular,
iorite to granodiorite

dium grained, porphyritic,
rite (1845 +/- 3 Ma;
shed data)

coarse grained, equigranular
de-biotite granodiorite

anular, fine to medium grained,
ite (intrudes 14c)

anular, medium to coarse

similar in age with gradational contacts
intrudes 13b and 13c; phases of this
ilar to units 14a to 14e

ium grained, equigranular,
e to quartz diorite containing
es of fine to coarse grained mafic
roxenite, gabbro and quartz gabbro

lium grained, equigranular,
orite to granodiorite

ned, equigranular, hornblende-

um grained, equigranular,

Grey to black, slightly foliated to massive, equigranular, very fine to medium grained, hornblende gabbro to quartz diorite

Black, massive to slightly foliated, medium to coarse grained, hornblende-biotite gabbro to diorite

Heterogeneous "hybrid" intrusive rocks; mixture of foliated, fine to medium grained, hornblende-biotite diorite to quartz diorite and mafic volcanic rocks in a matrix of, and cut by dykes of, medium to coarse grained, dark pink granodiorite to quartz diorite equivalent to subunit 9s

9q — Grey to black, massive to foliated, fine to coarse grained, hornblende-biotite diorite to quartz diorite; cuspated, pillowed contacts with subunit 9s suggest comagmatic intrusion

Grey to beige, coarse grained, equigranular, hornblende-biotite quartz diorite to tonalite

Dark pink to grey, coarse grained, foliated, hornblende-biotite granodiorite to granite; includes quartz phyric portions and dykes (1845+27/-12 Ma; Hunt and Whalen, unpublished data)

9t — Beige, massive to slightly foliated, coarse grained, biotite phyric granite

9u — Beige, massive to slightly foliated, coarse-grained, quartz phyric biotite granite

RAIL LAKE PLUTON

Subunits 8a to 8c are thought to be similar in age

8a — Pink to beige, foliated, coarse to very coarse grained, quartz megacrystic hornblende-biotite tonalite

Beige, foliated, coarse to very coarse grained, biotite megacrystic tonalite (intrudes 8a)

Beige, foliated, fine to medium grained, quartz phyric biotite-hornblende tonalite (intrudes 8a)

WEBB LAKE PLUTONIC COMPLEX

Subunits 7b to 7f are similar in age and lithologically similar to Elbow Lake tonalite (unit 6); contacts are both gradational and intrusive; subunits 7b and 7c are interpreted as high level roof zone equivalents of 7e and 7f; subunit 7d is intruded by unit 11c

7e — Grey, fine grained, foliated, plagioclase phyric, biotite-within the map-area. Portions of the Elbow Lake pluton outside the map-area have been described by Baldwin (1980) and Hunt (1970). Unit 6 is generally quartz phyric rather than quartz megacrystic. Preliminary U-Pb zircon results from this pluton suggest that it is pre-Missi in age (1869+20/-7 Ma; Hunt and Whalen, unpublished data). A remarkable feature of the mapped portion of this large intrusion is a lack of distinctive compositional or textural phases. However, there is some variation at the outcrop scale in the size and abundance of euhedral biotite phenocrysts and in the degree and nature of alteration. Also, the northeastern portion of the pluton contains more prominent quartz phenocrysts or eyes. Within the central portion of this pluton, there are areas of potassic alteration spatially associated with healed vein stockworks. These veins have 1-3 cm selvages containing pink feldspar and large euhedralsecondary biotite books. Also, the foliation in these areas is arently because alteration has overgrown or obscured the original foliation.

The name Webb Lake plutonic complex (**unit 7**) is used to refer to a texturally diverse group of mainly tonalitic plutonic rocks covering an area of about 35 km^2 near Webb Lake. Portions of this complex mapped by Schlediwitz (1992a) and Syme and Whalen (1992) were previously included within the Echo Lake and Webb Creek plutons. Phases resemble the Elbow Lake tonalite (**unit 6**), in being quartz phyric (**units 7b** to **7e**) or biotite phyric (**unit 7f**) rather than quartz megacrystic and in being affected by similar hydrothermal alteration. In general, this complex appears to preserve a higher level of exposure than seen in the Elbow Lake tonalite, with **units 7b** and **7c** probably representing a subvolcanic roof zone. Textural and compositional diversity within these high level units has been mapped in detail and described by Schledewitz (1992a and 1992b).

The Rail Lake pluton (**unit 8**) is a small (18 km^2) ovoid body in the southeastern portion of the map area. One phase (**unit 8a**) is quartz megacrystic (1 to 2.5 cm), another (**unit 8b**) is biotite megacrystic (1 to 3 cm) and a third phase (**unit 8c**) is quartz phyric, similar to portions of **unit 6** and **unit 7**.

The Gants Lake batholith (**unit 9**) is an elongate, north-south trending body which extends for over 54 km from beneath the Shield margin to within the Kisseynew belt. Of the 550 km^2 it occupies, over 60% is located in the map area. McGlynn (1959) described this batholith as consisting simply of gneissic biotite granodiorite. However, remapping, indicates this to be a composite batholith which contains the oldest (>1870 Ma) granitoid rocks in the map area and intrusive phases which are equivalent in age to the younger (<1850 Ma) zoned plutons (**units 12** to **14**). A sharp difference in metamorphic grade and penetrative deformation exists across this batholith. In the northeast it consists of orthogneisses (**units 9a** to **9d**) bounded further east by heterogeneous paragneisses and amphibolites (**units 2** and **1d**). This is in marked contrast to its western side where slightly to moderately foliated homogeneous plutonic phases intrude easily recognizable metavolcanic lithologies. Further work, in particular U-Pb dating, is required to resolve whether this batholith stitches a major tectonic boundary or whether it may juxtapose equivalent rocks of contrasting erosional levels.

Compositionally banded to migmatitic gneisses exposed on the northeastern side of the Gants Lake batholith have been roughly subdivided into various mappable components. This includes a number of coarse grained amphibole-garnet gabbro bodies (**unit 9a**) which have sheared contacts with their host gneisses. A major phase, grey tonalitic to quartz dioritic gneiss containing abundant sheets of earlier deformed tonalitic to mafic orthogneisses (**unit 9b**), is particularly well exposed on the shores of Gants Lake. Just northeast of here, there is an area consisting mainly of K-feldspar phyric migmatitic granodioritic gneiss (9c). Extensions of **unit 9b** further to the northeast are based on airphoto interpretation and compilation from McGlynn (1959). To the west, the easily identifiable older orthogneiss component in **unit 9b** decreases and the abundance of foliation parallel sheets of younger biotite granodiorite and granite increases (**unit 9d**). The younger component in **unit 9d** is probably equivalent to **units 9f** and **9h**. Further west there is an area (**unit 9e**) in which outcrop scale rafts of older orthogneisses (probably equivalent to **units 9b** and **9c**) are included within less deformed granodiorite to granite (equivalent to **units 9f** to **9h**). The older plutonic rafts frequently preserve foliation directions which contrast with that of their younger host rocks. Due to their compositional similarly, it is only in areas of good exposure that the two ages of granodiorite can be separated. The central portion of the Gants Lake batholith consists of a number of fine to coarse grained, biotite+/-amphibole granodioritic phases (**units 9f** to **9h**). Unit 9f is characterized by a 'sugary' recrystallized gneissic texture which is lacking in **unit 9e**. Unit 9h is texturally and compositionally more variable than **units 9e** and **9f**. Exposures of **unit 9h** in the southern part of the batholith are homogeneous finer grained equivalent of **unit 9g**. The more northern exposures of this unit can be gneissic and include compositionally banded portions. It is thought that the south to north contrasts in **units 9f** to **9h** reflect a progressive northward metamorphic and local tectonic overprinting rather than the presence of different ages of granodiorites.

The northwestern portion of the Gants Lake batholith consists of a group of probably comagmatic phases (**unit 9i** to **9m**). The U-Pb age of 1871+/-3 Ma obtained from granodiorite **unit 9j** (Hunt and Whalen, unpublished data) indicates that these phases are among the oldest in the map area. A body of diverse mafic intrusive rocks (**unit 9l**) exhibits both contacts which suggest it is comagmatic with the host granodiorite (**unit 9j**) and others which suggest that the gabbro is older. Unit 9j consists of slightly to well-foliated, buff, coarse-grained, plagioclase porphyritic (1-2 cm), biotite-hornblende granodiorite. Adjacent to this units' contact with Unit 1, there is a narrow sheet of strongly foliated to mylonitic, dark pink, aplitic to pegmatitic, biotite granite (**unit 9k**). This phase was probably intruded at the contact between **unit 1** and **unit 9j**. The northwestern edge of the batholith includes a couple of more mafic phases (**units 9l** and **9m**) considered to be comagmatic with the main granodiorite phase (**unit 9j**). Portions of **unit 9j** adjacent to **units 1** and **9h** grade to feldspar augen schist and its contacts with **units 9h** and **9g** are believed to be faults. Where exposed, this contact consists of a 100 m wide zone of ribbon mylonites, including sheets of tectonized mafic supracrustal rocks. This mylonite zone has been traced southward within the batholith east of Claw Lake where it appears to be truncated by phases of a younger intrusive suite (**units 9n** to **9s**). It is possible that the narrow elongate wedge of **unit 9j**, east of Claw Lake may have tectonically emplaced from the northwest, rather than being intruded into its present location.

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The Gauthier Lake pluton (**unit 12**), an ovoid body covering an area of about [illegible] in the north-central portion of the map area, is zoned from a monzodiorite or quartz monzonite rim (**unit 12a**), through granodiorite (Unit 12b) to a granite core (**unit12c**). All internal contacts appear to be gradational. Contacts are displaced by late north-south trending, narrow, fault zones. Evidence for a vertical movement component on these faults is given by the presence of high-level porphyritic textures and stockwork quartz veins with sericitic alteration within the central portion of the granite core to this pluton.

The oval Norris Lake pluton (**unit 13**), covers an area of 24 km2 at the east-central edge of the map area. The western half of this intrusion, which lies in the map area, is zoned from a mafic inclusion-rich dioritic rim (**unit 13a**), through quartz diorite and granodiorite (**units 13b and 13c**) to minor areas of late granite (**unit 13d**). Contacts between 13a to 13c are gradation, whereas **unit 13d** intrudes **unit 13c**.

The Big Rat Lake pluton (**unit 14**) covers an area of about 32 km^2 on the southwest side of the map-area. Granitic **units 14f** and **14g** cut more mafic phases (**units 14a** to **14e**) and appear not to be cut by dykes which intrude the more mafic phases. This suggests that there could be an age gap between granitic and dioritic to granodioritic phases. The older, more mafic phases appear to be consanguineous components of a pluton which is zoned from a granodioritic rim to a dioritic core. The medium to dark pink, foliated biotite granite of **units 14f** and **14g** is remarkably uniform in composition, lacks mafic enclaves and is only cut by some probably comagmatic granitic aplite dykes. Based on consistent variations in grain size, it has been subdivided into fine- to medium- (14g) and medium- to coarse-grained (14f) portions. The eastern margin of **unit 14f** is more biotite-rich, quartz-poor and hornblende-bearing. This zone, which is also characterized by the presence of ovoid to stretched (4 to 50 cm) fine-grained, hornblende-biotite granodioritic inclusions, may reflect marginal contamination or assimilation of older quartz diorite to granodiorite. Sharp intrusive contacts were observed between **unit 14f** and older **unit 14c**. Two gradational textural subtypes of a relatively compositionally homogeneous granodiorite form the outer zones of the northeastern portion of this pluton.The outer, coarser grained, more equigranular phase (**unit 14e**) is variably foliated and sheared such that it is difficult to distinguish primary feldspar phyric texture from feldspar-augen texture. There is a gradation from coarse-grained, equigranular **unit 14e** through subporphyritic to porphyritic **unit 14d** from the margin inward. As no intrusive contacts were observed between these granodiorite units and other phases of this pluton, contacts are thought to be gradational. Other subunits in the northeast portion of this pluton are uniformly medium-grained equigranular but compositionally variable. There is variation from more felsic (quartz diorite to granodiorite)(**unit 14c**) to more mafic (quartz diorite to diorite)(**unit 14b**) towards the core. Mapped boundaries, based on field estimates of quartz and mafic mineral content, are apparently gradational over short distances rather than intrusive. Areas of hybrid intrusive rocks (**unit 14a**) consist of mainly rounded mafic igneous inclusions (5 cm to >3 m) in a matrix of diorite to quartz diorite. Inclusions form about 40 to 60% of this subunit and include mafic metavolcanic rocks, which were deformed prior to their incorporation, and cognate mafic intrusive rocks. Various dykes including basalt to diabase, grey granodioritic feldspar-hornblende porphyry and composite basalt - dacite dykes are common cutting the **units 14a** to **14e** north of Separation Creek. The presence of a right-lateral fault in Separation Creek, is indicated by offsets in approximately north-south trending intrusive boundaries. Compositional contrasts between phases across this creek could be due to some normal displacement on this fault.

Tectonites in major shear zones and faults zones (**unit 15**) include the products of both brittle and ductile deformation. These rocks, compiled from Syme and Whalen (1992) and described by Syme (1992), occur within the major north-south Elbow Lake and Claw Bay shear zones.

In general, the vastly improved quality of outcrop resulting from the 1989 burn greatly facilitates prospecting for mineral deposits in the Elbow Lake sheet. The setting of gold mineralization and potential for VMS deposits in the map area has been reviewed by Syme (1991 and 1992) and Schledewitz (1991). Gold occurrences in the Elbow Lake area are epigenetic and localized within intense deformation zones within and adjacent to the Elbow Lake shear zone. Though known gold showings occur mainly within supracrustal units, granitoid units may be equally good hosts. The burn has provided extensive new exposures of plutonic rocks cut by quartz and sulphide-bearing veins, major faults and shear zones. In contrast to the supracrustal rocks, which have been intensely prospected since the early 1930's, such zones in granitoid rocks generally bear no evidence of having been prospected. Though such zones are frequently not exposed, mapped displacements of or juxtapositioning of plutonic phases indicate the location of major faults and shear zones.

Comparison to mineralization in the Phantom Lake stock, west of Flin Flon (Galley and Franklin, 1989; Thomas, 1990) and the Star Lake pluton in the La Ronge belt (Poulsen et al., 1986), suggests that Elbow Lake area plutons also have potential for late magmatic - hydrothermal gold and porphyry-type mineralization. Portions of the Webb Lake complex (**units 7b, 7c** and **7d**) probably represent a subvolcanic roof zone. Texturally diverse very fine to fine grained intrusive phases in these units are cut by sulphide-bearing quartz vein systems which have potential for gold mineralization (Schledewitz, 1993 pers. com.). The presence of late magmatic, fracture-controlled, potassic alteration in portions of the Elbow Lake tonalite (**unit 6**) make it a possible target for gold prospecting. A couple of the younger zoned plutons contain areas of fracture-related alteration with associated sulphides. The larger fault bounded block on the east side of the granite core (**unit 12c**) to the Gauthier Lake pluton has outcrop scale areas of quartz vein related sericitic alteration. This block of **unit 12c** exhibits porphyritic textures absent in adjacent portions of this phase, suggesting that it may represent a down faulted higher level zone of the pluton. Within the core of the Norris Lake pluton (**unit 13**) there are a number of small late bodies of granite (**unit 13d**). Exposures of granodiorite **unit 13c** adjacent to **unit 13d** are cut by stockworks of sulphide-bearing veins which die out within the granite, suggesting a genetic tie between veins and granite. The map area contains a number of both early (**units 3a, 4** and **9a**) and late (**units 9o, 9p** and **11a**) mafic to ultramafic intrusions. The potential of these bodies for nickel and platinum group metals merits evaluation. For example, at the northeast edge of the Gants Lake batholith, an extensive gossan zone was noted within a 5 km^2 body of gabbro (**unit 9a**) at its contact with granodioritic gneisses (**unit 9c**).


5a
5b
5c
1a
1b
3a
3b
CLAW

Pink, foliated, fine to medium graine
biotite-hornblende granite

GAUTHIER LAKE PLUTON

Subunits 12a to 12c are similar in s

Beige to grey, foliated, fine to coars
hornblende-biotite monzodiorite to qu

Pink to grey, foliated, medium to co
equigranular, hornblende-biotite granc

Pink, foliated, medium to coarse grai
phyric, biotite-hornblende granite to g

ECHO LAKE PLUTON

Subunits 11b to 11d have gradationa
age; subunit 11b intrudes 11a and a

Black, massive, coarse grained, pyro

Grey to black, foliated, medium to co
hornblende +/- biotite gabbro to quar
(>30%) mafic plutonic inclusions, incl
(intrudes 11a)

Grey to beige, foliated, medium to co
hornblende +/- biotite diorite to quartz

Pink to grey, foliated, medium to coa
hornblende-biotite granodiorite to quar

Grey, massive, feldspar porphyritic, ho
granodiorite; minor equigranular coars
adjacent to unit 11d (intrudes 11d)

NORTH STAR LAKE PLUTON

Subunits 10a and 10b are similar in
to units 9g and 9h, respectively

50'

Grey to beige, well foliated, medium
quartz phyric biotite granodiorite

Dark grey to pink, well foliated, very
equigranular, biotite granodiorite (intru

GANTS LAKE BATHOLITH

Phases within this batholith range in
to 1871 Ma (subunit 9j) or older (sub
within the following groupings are tho
9f to 9h; 9i to 9m; 9n to 9s; 9t to 9

Black, medium to coarse grained, folia
hornblende-pyroxene +/- garnet gabbro

Grey, medium to coarse grained, equi
hornblende, tonalitic to quartz dioritic
(>30%) rafts of older compositionally-h

m grained, equigranular,

imilar in age with gradational contacts

to coarse grained, equigranular,
rite to quartz monzonite

um to coarse grained,
tite granodiorite

oarse grained, K-feldspar
anite to granodiorite

gradational contact and are similar in
11a and subunit 11e intrudes 11d

ined, pyroxenite and melagabbro

dium to coarse grained, equigranular,
ro to quartz diorite with abundant
sions, including pyroxenite

dium to coarse grained, equigranular,
to quartz diorite

um to coarse grained, equigranular,
te to quartz diorite

phyritic, hornblende-biotite,
ular coarse grained granite
les 11d)

'ON
similar in age and maybe equivalent
tively

, medium to coarse grained,
liorite

ated, very fine to fine grained,
iorite (intrudes 10a)

range in age from 1845 (subunit 9e)
older (subunits 9a to 9h); subunits
ge are thought to be of similar age:
9e; 9t to 9u

rained, foliated, equigranular,
rnet gabbro

ained, equigranular, biotite-
rtz dioritic gneiss with abundant
ositionally-banded garnet-bearing
eisses

7a — *Grey, fine grained, foliated, plagioclase phyric, biotite-hornblende quartz diorite*

Beige to pink, slightly to strongly foliated, very fine to medium grained, quartz phyric biotite leucotonalite porphyry containing abundant (>30%) mafic to felsic supracrustal inclusions

Beige to pink, slightly to strongly foliated, very fine to medium grained, quartz phyric biotite leucotonalite porphyry with areas of abundant (>30%) comagmatic, fine grained, hornblende-biotite diorite inclusions

Pink, foliated, fine to medium grained, quartz phyric, biotite-hornblende tonalite to quartz diorite

Pink to grey, foliated, medium to coarse grained, quartz phyric, biotite-hornblende tonalite to quartz diorite

Pink to grey, foliated, medium to coarse grained, biotite phyric, biotite-hornblende tonalite

ELBOW LAKE TONALITE

6 — *Beige to pink, medium to coarse grained, equigranular to quartz-biotite megacrystic, biotite-hornblende tonalite (1860+20/-7 Ma; Hunt and Whalen, unpublished data)*

EAST ELBOW LAKE TONALITE STOCK AND RELATED SILLS

5 — *5a: Beige, coarse grained, quartz megacrystic, biotite-hornblende tonalite (1864+/-3 Ma; Hunt and Whalen, unpublished data)*
5b: Beige, equigranular to weakly quartz megacrystic biotite-hornblende hornblende tonalite; minor quartz diorite
5c: Beige to greenish, fine to medium grained, equigranular to quartz phyric, biotite-hornblende tonalite, locally gneissic; diabase dykes; local intrusions; locally contains an older grey-green phase and a younger leucocratic phase

MAJOR MAFIC/ULTRAMAFIC INTRUSIONS

4a: Long Lake gabbro complex
4b: East Claw Lake gabbro complex
4c: Elbow Lake/Claw Lake gabbro complex
4d: Josland gabbro complex

MINOR INTRUSIONS

3a — *Felsic to intermediate intrusions: quartz porphyry, fine grained leucotonalite, rhyolite, quartz diorite*

Mafic to intermediate intrusions: diabase, gabbro diorite, pyroxenite, mafic agmatite

GNEISSIC SUPRACRUSTAL ROCKS OF POSSIBLE AMISK AFFINITY

2 — *Mixture of compositionally banded amphibolitic gneiss and granodioritic migmatite and paragneiss cut by abundant dykes and sheets of tonalitic to granodioritic orthogneisses (equivalent to units 9b and 9c)*

AMISK GROUP
Mainly mafic, with minor felsic, volcanic and volcaniclastic rocks, minor sedimentary rocks and high-level intrusive rocks

may have tectonically emplaced from the northwest, rather than being intruded into its present location.

gossan zone wa
gneisses (unit 9

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Syme, E.C.
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Energy a

1992: Elbow La
Minerals

Syme, E.C., and W
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Thomas, D.J.
1990: New pers
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Whalen, J.B.
1992: Elbow La
Minerals

veins which die out within the granite, suggesting a genetic tie between veins and granite. The map area contains a number of both early (**units 3a, 4 and 9a**) and late (**units 9o, 9p and 11a**) mafic to ultramafic intrusions. The potential of these bodies for nickel and platinum group metals merits evaluation. For example, at the northeast edge of the Gants Lake batholith, an extensive gossan zone was noted within a 5 km^2 body of gabbro (**unit 9a**) at its contact with granodioritic gneisses (**unit 9c**).

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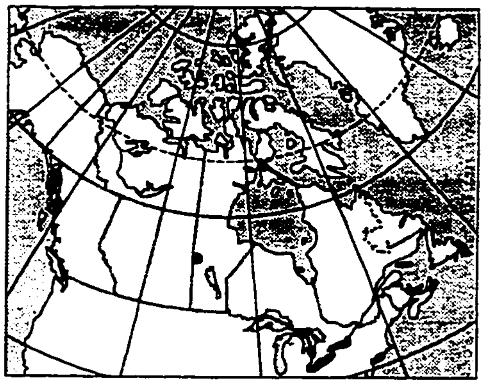
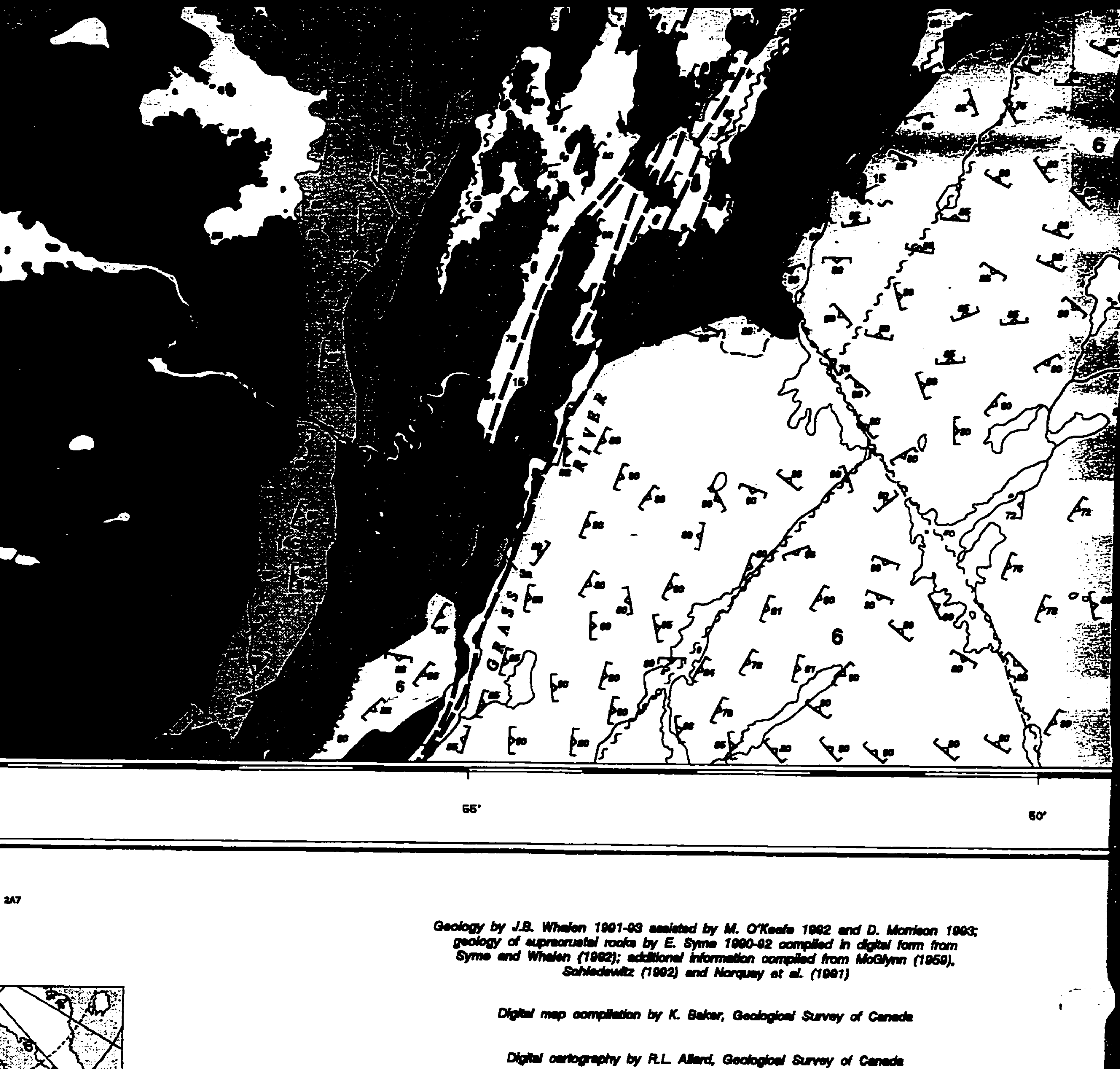
OTTAWA
1993



LOCATION MAP



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Geology by J.B. Whalen 1991-93 assisted by M. O'Keefe 1992 and D. Morrison 1993; geology of supracrustal rocks by E. Syme 1990-92 compiled in digital form from Syme and Whalen (1992); additional information compiled from McGlynn (1959), Schledewitz (1992) and Norquay et al. (1991)

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Any revisions or additional information known to the user would by welcomed by the Geological Survey of Canada

Digital base map from Surveys, Mapping and Remote Sensing published at the same scale. Generalized and modified by the Geological Survey of Canada

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GEOLOGY

ELBOW LAKE

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Scale 1:50 000 - Échelle 1/50 000

Kilometres 1 0 1 2 3 4 Kilomètres

Transverse Mercator Projection
CM 100°45', Scale Factor 1

M.C. 100°45', facteur d'échelle 1
Projection transverse de Mercator

40'

35'

Kilomètres

Copies of the topographical edition of this map may be obtained from the Canada Map Office, Department of Energy, Mines and Resources, Ottawa, Ontario, K1A 0E9

Mean magnetic declination 1993, 9° 53' East, decreasing 9.9' annually. Readings vary from 9° 35' East in the SE corner to 10° 11' in the NW corner of the map

Coordinated through the auspices of the NATMAP Shield Margin Project

Contribution to Canada-Manitoba Partnership Agreement on Mineral Development (1990-1995), a subsidiary agreement under the Canada-Manitoba Economic and Regional Development Agreement

Published 1993

to 1871 Ma (subunit 9j) or older (subunits 9a to 9h); subunits within the following groupings are thought to be of similar age: 9f to 9h; 9l to 9m; 9n to 9s; 9t to 9u

Black, medium to coarse grained, foliated, equigranular, hornblende-pyroxene +/- garnet gabbro

Grey, medium to coarse grained, equigranular, biotite-hornblende, tonalitic to quartz dioritic gneiss with abundant (>30%) rafts of older compositionally-banded garnet-bearing tonalitic and amphibolitic gneisses

Pink to grey, fine to coarse grained, equigranular to K-feldspar phyric, biotite-hornblende granodioritic gneiss

As subunit 9b with abundant dykes and sheets of younger fine to medium grained, biotite granodiorite to granite and granitic pegmatite equivalent to subunits 9g and 9h

Heterogenous sheeted mixture of older, foliated to gneissic, medium to coarse grained, biotite tonalite to granite (probably equivalent to subunits 9b and 9c) and younger, massive to foliated, fine to coarse grained, biotite granodiorite to granite (equivalent to subunits 9f and 9h)

Pink to beige, medium to coarse grained, gneissic, quartz porphyritic, biotite granite to granodiorite (maybe equivalent to subunit 9g)

Medium to coarse grained, biotite granite to granodiorite

Grey to pink, foliated, fine to medium grained, equigranular to plagioclase phyric, biotite +/- hornblende granodiorite to granite; includes compositionally banded gneissic portions with a sugary recrystallized texture

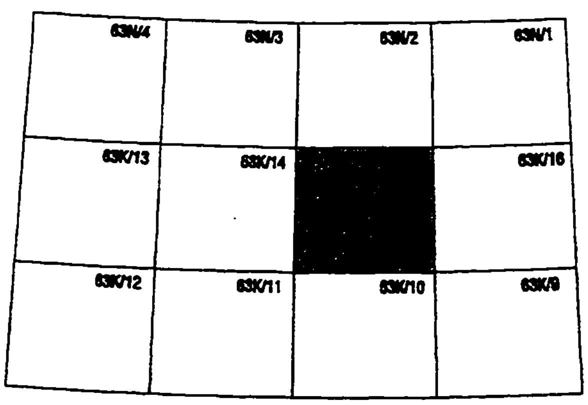
Mafic intrusive complex; includes diabase, medium grained hornblende diorite, coarse to very coarse grained equigranular hornblende gabbro and minor pyroxenite

Grey to beige, coarse grained, plagioclase phyric to equigranular, hornblende-biotite granodiorite to quartz diorite (1871 +/- 3 Ma; Hunt and Whalen, unpublished data)

Pink, foliated to mylonitic, leucocratic granite pegmatite and/or aplite

Grey, medium grained, equigranular to plagioclase phyric, hornblende-biotite quartz diorite to granodiorite

Grey, foliated, fine to coarse grained, equigranular, hornblende-biotite quartz diorite to diorite



NATIONAL TOPOGRAPHIC SYSTEM REFERENCE

oarse grained, foliated, equigranular,
+/- garnet gabbro

arse grained, equigranular, biotite-
to quartz dioritic gneiss with abundant
r compositionally-banded garnet-bearing
olitic gneisses

coarse grained, equigranular to
otite-hornblende granodioritic gneiss

abundant dykes and sheets of younger fine
biotite granodiorite to granite and granitic
to subunits 9g and 9h

d mixture of older, foliated to gneissic,
rained, biotite tonalite to granite (probably
ts 9b and 9c) and younger, massive to
se grained, biotite granodiorite to
subunits 9f and 9h)

m to coarse grained, gneissic, quartz
anite to granodiorite (maybe equivalent

rained, biotite granite to granodiorite

d, fine to medium grained, equigranular
, biotite +/- hornblende granodiorite to
npositionally banded gneissic portions with
d texture

lex; includes diabase, medium grained
oarse to very coarse grained equigranular
nd minor pyroxenite

e grained, plagioclase phyric to
nde-biotite granodiorite to quartz
a; Hunt and Whalen, unpublished data)

nitic, leucocratic granite pegmatite

d, equigranular to plagioclase phyric,
rtz diorite to granodiorite

coarse grained, equigranular,
rtz diorite to diorite

Mixture of compositionally banded amphibolitic gneiss and granodioritic migmatite and paragneiss cut by abundant dykes and sheets of tonalitic to granodioritic orthogneisses (equivalent to units 9b and 9c)

AMISK GROUP

Mainly mafic, with minor felsic, volcanic and volcanoclastic rocks, minor sedimentary rocks and high-level intrusive rocks

Arc assemblage

Ocean floor assemblage

Ocean island basalt assemblage

Undivided

Geological contact (observed, inferred) . . . .

Bedding, top known (inclined) 80

Bedding, top unknown (inclined) 80

Pillows, top known (inclined,overturned) 35 80

Pillows, top unknown (inclined) 80

Flow contact, top known (inclined) 80

Flow contact, top unknown (inclined) 80

Foliation, inclined (generation unknown, 1st, 2nd) 80 75 85

Igneous layering, top known (inclined,overturned) 35 80

Igneous layering, top unknown (inclined) 80

Lineation, generation unknown (inclined) 35

Fault, sense unknown (outcrop scale) 80

Fault . . . .

Shear zone, sense unknown (inclined) 80

Narrow shears and shear zones . . . .

Boundary of shear zones . . . .

Recommended Citation:
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1993: Geology, Elbow Lake, Manitoba; Geological Su
of Canada, Open File 2709, scale 1:50 000

Granitoid plutons and major structures in the Iskwasum Lake sheet, Manitoba: a portion of the Flin Flon Domain of the Trans-Hudson Orogen[1]

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Abstract: Six major granitoid plutons intrude mafic volcanic rocks, mafic tectonites and older plutonic rocks within the Iskwasum Lake sheet of Manitoba (NTS 63K/10). Three of these plutons are contiguous with plutons of the adjoining Elbow Lake sheet, which range in age from 1.876 Ga to 1.826 Ga, and in composition from granodiorite to quartz diorite. The Iskwasum Lake sheet is structurally complex, containing four major shear zones and many minor faults. Except for the late east-west-trending Berry Creek fault in the south, most of these structures are apparently early and long-lived, north-northeast-trending structures. Based on geochemical studies of correlative volcanic assemblages bounding these structures to the north, some probably represent important internal boundaries or sutures within the Flin Flon Domain of the Paleoproterozoic Trans-Hudson Orogen.

Résumé : Six plutons granitoïdes importants recoupent des volcanites mafiques, des tectonites mafiques et des plutonites plus anciennes dans la région cartographique du lac Iskwasum, au Manitoba (SNRC 63K/10). Trois de ces plutons sont contigus aux plutons de la région cartographique adjacente du lac Elbow, dont l'âge varie entre 1,876 Ga et 1,826 Ga, et dont la composition va de granodiorite à diorite quartzique. La région cartographique du lac Iskwasum est structuralement complexe et contient quatre zones de cisaillement majeures et de nombreuses failles mineures. À l'exception de la faille tardive de Berry Creek à orientation est-ouest dans le sud, la plupart de ces structures semblent être des structures précoces de longue durée, à orientation nord-nord-est. Selon des études géochimiques des assemblages volcaniques corrélatifs limitant ces structures au nord, certaines représentent probablement d'importantes frontières ou sutures internes au sein du Domaine de Flin Flon de l'orogène trans-hudsonien paléoprotérozoïque.

[1] Contribution to the Shield Margin NATMAP Project and Canada-Manitoba Partnership Agreement on Mineral Development (1990-1995), a subsidiary agreement under the Canada-Manitoba Economic and Regional Development Agreement.

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INTRODUCTION

The central part of the Flin Flon Domain of the Paleoproterozoic Trans Hudson Orogen, interpreted as an amalgamation of 1.91-1.88 Ga oceanic and arc tectonostratigraphic assemblages, termed the Flin Flon tectonic collage, is stitched together by 1.87-1.84 Ga granitoid plutons, and overlain by 1.85-1.84 Ga sedimentary rocks (Lucas and Stern, 1994: Lucas et al., in prep.) (Fig. 1). Critical evaluation of this model requires a better understanding of key elements, such as the volumetrically significant (>60%) granitoid plutons and major structures separating portions of the collage. Recent studies in the Elbow Lake sheet (63K/15) (e.g., Syme and Whalen, 1992; Syme, 1992; Whalen, 1993a,b; Ryan and Williams, 1993; Whalen and Hunt, 1994) have provided a better understanding of some of these elements. Geochemical and structural studies of volcanic and plutonic rocks, within and adjacent to the Elbow Lake shear zone (Fig. 1), show that it represents a long-lived deformation zone, separating ca. 1.9 Ga tectonostratigraphic assemblages (Syme, 1992; Stern et al, 1994; Ryan and Williams, 1993; Stern et al., in prep.).

This study in the Iskwasum Lake map sheet (NTS 63K/10), which forms part of a M.Sc. thesis at the University of Ottawa, was initiated in 1994 with the objective of extending geological mapping and the study of granitoid plutons southward from the Elbow Lake sheet to the Shield Margin. Mapping was undertaken jointly with E.C. Syme (Manitoba Geological Services Branch), who was responsible for reconnaissance mapping of the supracrustal rocks in the Iskwasum Lake sheet (Syme, 1994). Geochronology of the granitoid plutons is part of a collaborative project with N. Machado (GEOTOP, Université du Québec à Montréal).

The study area is located 50 km east-southeast of Flin Flon and 45 km west-southwest of Snow Lake, lying entirely within the Grass River Provincial Park. Geological mapping during the summer of 1994, at a scale of 1:50 000, outlined six major granitoid bodies (Fig. 2), three of which are correlative with plutons in the Elbow Lake sheet. These plutons together comprise approximately 60 per cent of the Precambrian bedrock in the map area. The southern portion of the area is underlain by Paleozoic cover rocks. Some of the major shear zones and faults from the Elbow Lake sheet were mapped through the study area (cf. Syme, 1994), and a previously unrecognized major shear zone was identified. Future field and laboratory studies will better constrain age relationships between important structural/tectonic events and pluton emplacement mechanisms and their tectonic setting.

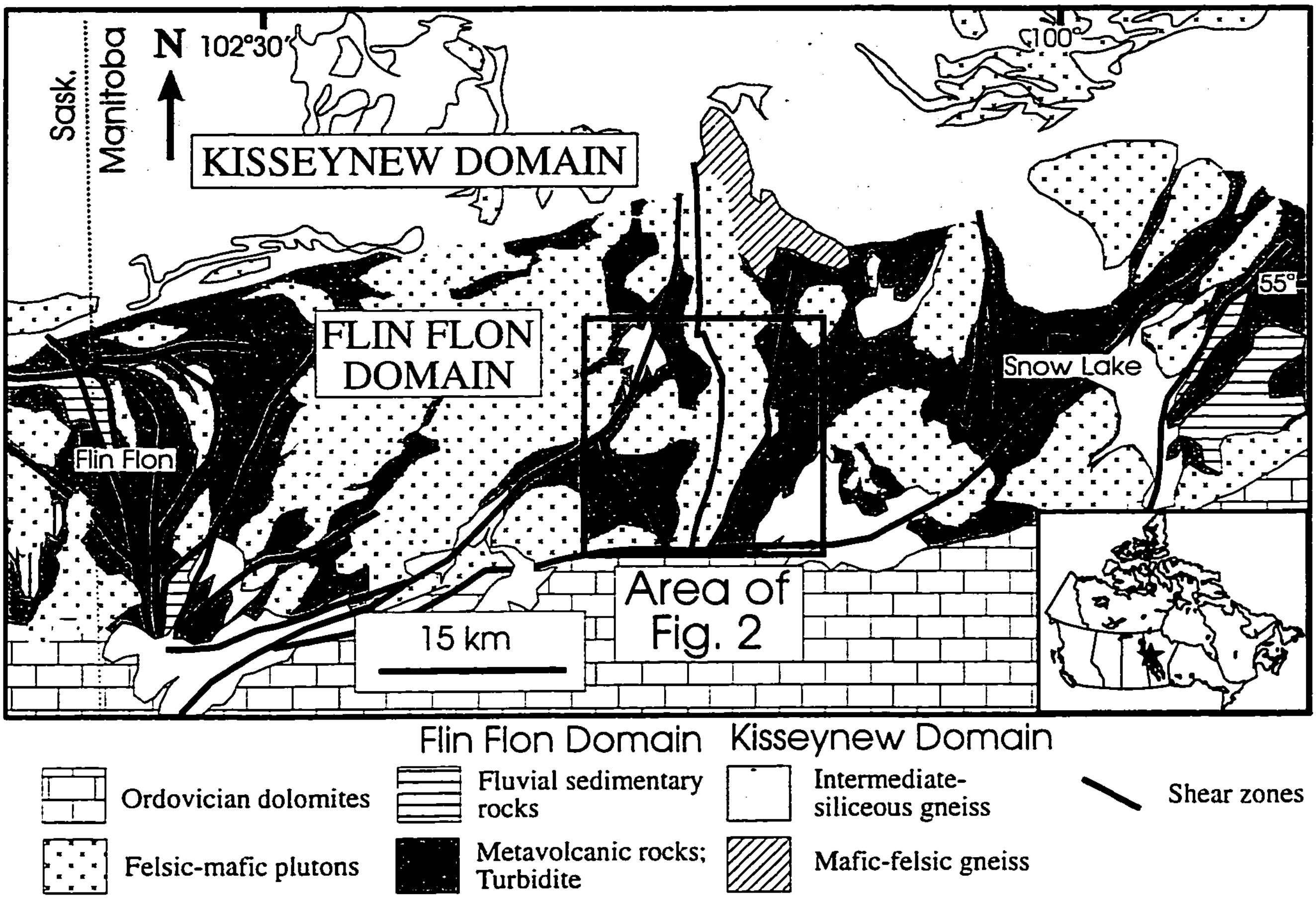


Figure 1. Location of the Iskwasum Lake sheet (NTS 63K/10), Manitoba, in the Flin Flon Domain of the Paleoproterozoic Trans-Hudson Orogen.

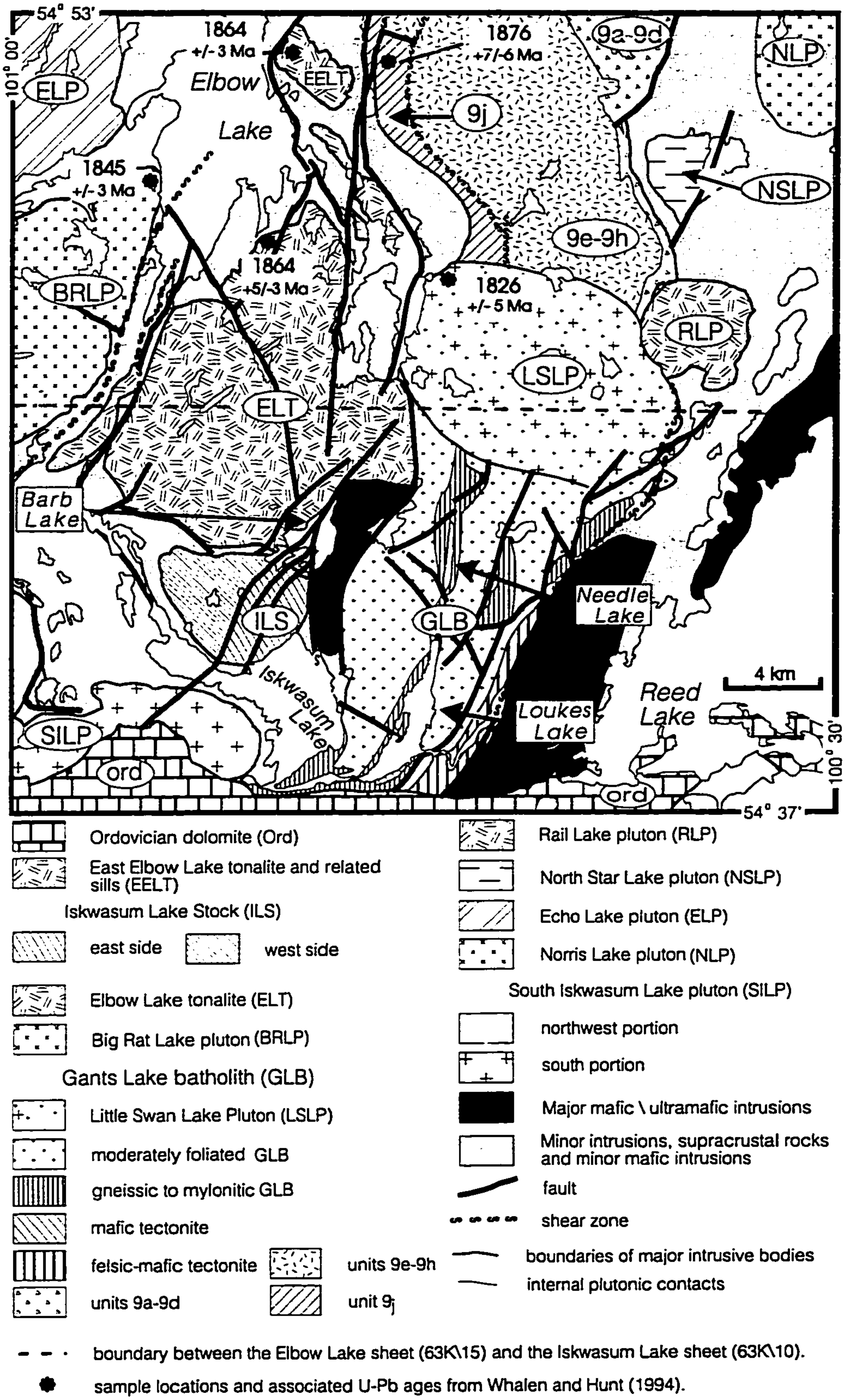


Figure 2. Simplified geological map of the Iskwasum Lake (NTS 63K/10) and the adjoining Elbow Lake (NTS 63K/15) sheets showing major granitoid intrusions. Abbreviations for plutons used in figure and text are given in legend. Elbow Lake sheet portion modified after Whalen (1993b) and Whalen and Hunt (1994); unit numbers within the Gants Lake batholith refer are map units of Whalen (1993a).

PETROGRAPHY OF GRANITOID PLUTONS

1. Iskwasum Lake stock

The ovoid Iskwasum Lake stock (ILS) consists mainly of leucocratic, biotite tonalite. Mafic minerals generally make up <10 per cent, and locally <5 per cent of the rock. Pervasive and fracture-related epidote alteration of plagioclase occur east and west of the Barb Lake fault, respectively. The Iskwasum Lake stock lithologically resembles the Elbow Lake tonalite. Pluton host rocks include mafic tectonite and mafic volcanic rocks. The western and northern edges of the pluton consist of a 100-200-m-wide zone of tonalite rich (up to 75%) in wallrock inclusions. The fabric in mafic tectonite inclusions was folded prior to incorporation in the tonalite. A later moderate foliation in the Iskwasum Lake stock is oriented concentric to the margins of the pluton.

2. Elbow Lake tonalite

The Elbow Lake tonalite (ELT) straddles the boundary between the Elbow Lake and Iskwasum Lake sheets (Fig. 2). The northern portion, which was described by Whalen (1992, 1993a,b), yielded the U-Pb zircon age of 1864+5/-4 Ma (Whalen and Hunt, 1994). Although this pluton can be compositionally, texturally, and structurally variable at the outcrop scale, at the map scale it is predominantly a quartz-biotite porphyritic, biotite±hornblende tonalite. Locally, the pluton varies from quartz diorite to granodiorite, and from porphyritic to equigranular. Quartz and biotite phenocrysts range from 2-20 mm.

The Elbow Lake tonalite is cut by mafic dykes and quartz stockworks which cannot be traced from one outcrop to the next, suggesting discontinuous preservation of primary features within the pluton. Brittle north-northeast-trending faults which crosscut the Elbow Lake tonalite are the dominant structural features within the pluton. These faults, typically recognizable as topographic lineaments and as areas with distinct fracture patterns, are associated with a relative decrease in grain size.

In portions of the Elbow Lake tonalite, compositional zoning appears to have escaped disruption by the prevalent, north-northeast-trending brittle faults. At the pluton's western margin, an ovoid granodiorite unit grades outwards to equigranular tonalite, and finally to quartz-biotite porphyritic tonalite. At the pluton's centre, a hornblende-rich tonalite unit has been outlined.

In general, the margins of the Elbow Lake tonalite appear to be intrusive rather than structural. The best evidence in support of this is the presence of abundant wall rock xenoliths. Two distinct xenolith-rich zones contain large, angular fragments of proximal wall-rock lithologies. However, the contact between the Elbow Lake tonalite and Gants Lake batholith (Fig. 2, 3) is interpreted as a sheared contact. It is marked by a thin (<50 m) zone of banded gneisses and mylonites probably derived from felsic intrusive and mafic supracrustal rocks.

3. Big Rat Lake pluton

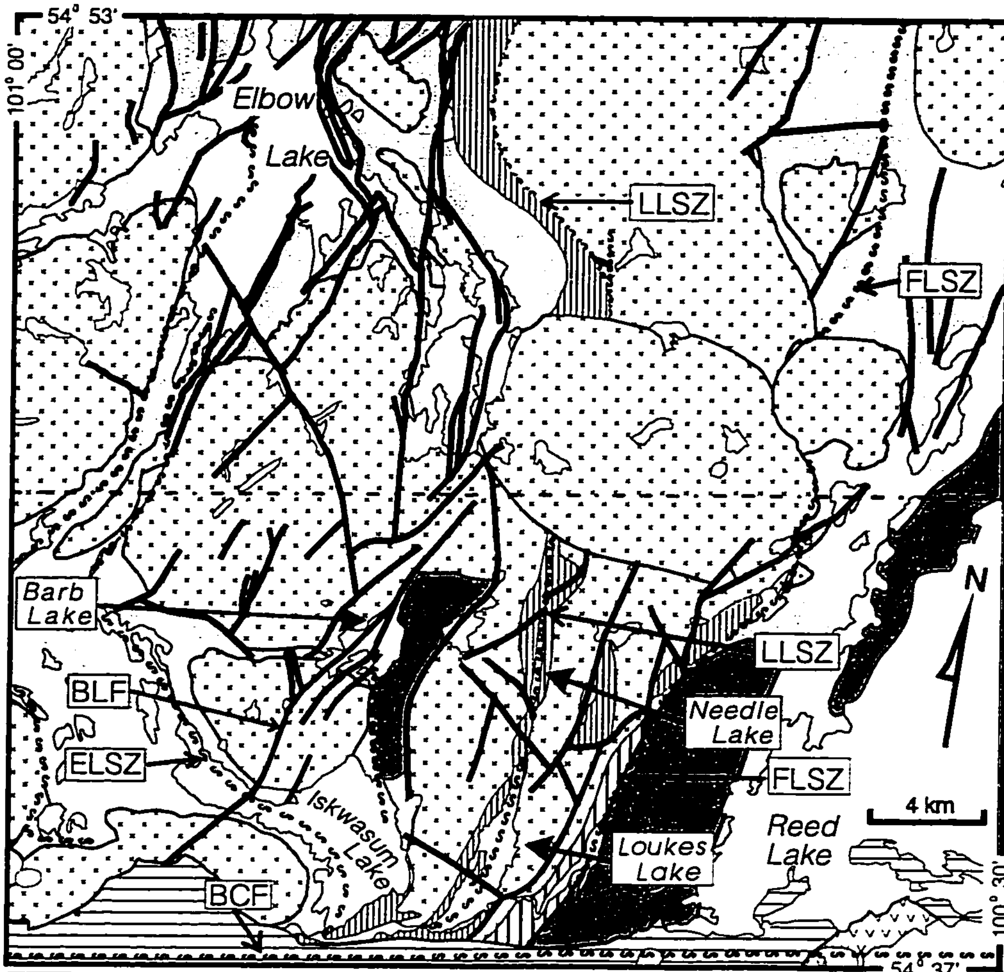
The Big Rat Lake pluton (BRLP) occupies only about 10 km^2 in the northwest corner of the Iskwasum Lake sheet (Fig. 2). Only two of the phases mapped in the Elbow Lake sheet by Whalen (1993a) continue into the Iskwasum Lake sheet. These consist of a fine- to medium-grained biotite granite to granodiorite, and a medium- to coarse-grained, biotite granite to granodiorite. Based on field relationships in the Elbow Lake sheet (Whalen, 1993a,b) these units intrude into a Big Rat Lake pluton unit that has an U-Pb zircon age of 1845 ± 3 Ma (Whalen and Hunt, 1994).

4. South Iskwasum Lake pluton

The exposed South Iskwasum Lake pluton (SILP) is separated into lithologically distinct southern and northwestern portions (Fig. 2). Its southern end is overlain by Paleozoic rocks. Its southern portion, located south of Iskwasum Lake, consists of homogeneous, moderately foliated, biotite-hornblende granodiorite. South of Iskwasum Lake, relatively undeformed granodiorite of the South Iskwasum Lake pluton and mafic tectonite occur in close proximity. It is notable that north-northeast-trending brittle faults and shear zones, ubiquitous in other plutons, are relatively rare in this body. However, the Barb Lake fault is a notable exception (Figs. 2, 3). This suggests that either the South Iskwasum Lake pluton was emplaced after much of the deformation, or that deformation was concentrated in less competent mafic host rocks. Given the low state of deformation in other plutons in the area adjacent to deformed supracrustal rocks, we favour the latter suggestion.

The northwestern portion of the South Iskwasum Lake pluton is lithologically more complex than the southern portion (Fig. 2). At its southern end, it contains a small zone of K-feldspar-porphyritic granodiorite. K-feldspar is poikilitic with quartz and mafic mineral inclusions. This unit, which is volumetrically more significant in the adjoining Cranberry Portage sheet, grades towards the north into equigranular biotite-hornblende granodiorite. Farther north, this unit grades into hornblende quartz-monzonite and, finally, near its northernmost wall-rock contact, into hornblende-biotite granodiorite. The northern contact with mafic tectonite is characterized by a thin (<150 m wide) zone of intrusive breccia which contains at least seven different xenolith lithologies. Xenoliths include mafic tectonite, moderately deformed to massive mafic volcanic rock, various intrusive rocks, and cognate xenoliths. The southern margin of the northwestern portion of the pluton is overlain by an outlier of Ordovician dolomite. The eastern margin is in intrusive contact with moderately deformed pillow basalt.

The northwestern portion of the South Iskwasum Lake pluton also differs from its southern counterpart in its structural complexity. A shear zone, which forms its northeastern contact with mafic volcanic rocks, crosscuts the pluton to the south (Fig. 3). This ductile shear zone is 150-200 m wide within the pluton, and appears to truncate the zone of intrusive breccia in the north. Rocks at the margins of the shear zone



Ordovician dolomite (Ord)

Major felsic intrusive rocks (see Fig. 2 for details)

Major mafic \ ultramafic intrusions

Variably deformed mafic extrusive and intrusive rocks, and minor felsic intrusions

Gneissic to mylonitic GLB lithologies

Felsic-mafic tectonite of the FLSZ

Mafic tectonite of the LLSZ

boundary between the Elbow Lake sheet (63K\15) and the Iskwasum Lake sheet (63K\10).

Major intrusive boundaries (see Fig. 2 for pluton names, and lithologic contacts)

fault — shear zone

ELSZ - Elbow Lake shear zone — LLSZ - Loukes Lake shear zone

FLSZ - Flag Lake shear zone — BLF - Barb Lake fault

BCF - Berry Creek fault

Figure 3. Simplified structural map of the Iskwasum Lake (NTS 63K/10) and the adjoining Elbow Lake (NTS 63K/15) sheets. Abbreviations of faults and shear zones used in figure and text are given in the legend.

are recognizable as sheared equivalents of South Iskwasum Lake pluton units, but there is some evidence that mafic sheets have also been deformed within the shear zone.

5. Gants Lake batholith

The bulk of the Gants Lake batholith (GLB) crops out in the Elbow Lake sheet, where it was mapped and subdivided by Whalen (1993a,b). Two or three main intrusive units appear to continue into the Iskwasum Lake sheet. Significant structural complexities, within and at the margins of the GLB, are mainly related to the north-northeast-trending Loukes Lake (LLSZ) and Flag Lake (FLSZ) shear zones and the east-west-trending Berry Creek fault (BCF) (Fig. 3). These structural features are described below.

The southern portion of the Gants Lake batholith is dominated by plagioclase porphyritic, hornblende-biotite granodiorite. A similar plagioclase- porphyritic granodiorite phase mapped in the Elbow Lake sheet (map unit 9j of Whalen, 1993a,b) (Fig. 2), yielded an U-Pb zircon age of 1876+7/-6 Ma (Whalen and Hunt, 1994). The deformation state of this phase varies from slightly foliated to gneissic, and may reflect proximity to the Loukes Lake shear zone (Fig. 3). At present, however, the age of phases bounding the shear zone is not known.

In a well-exposed area northwest of Loukes Lake, and away from deformation related to the Loukes Lake shear zone, five texturally different intrusive lithologies were recognized in the Gants Lake batholith. Crosscutting relationships, where all five phases coexist, suggest that all phases were approximately comagmatic. Where these lithologies are present on the west shore of Needle Lake, the Loukes Lake shear zone has obliterated all crosscutting relationships. East of the Loukes Lake shear zone, the Flag Lake shear zone separates the Gants Lake batholith from the Reed Lake mafic/ultramafic complex and mafic intrusive and extrusive rocks to the south and north, respectively. Two large xenolith-rich zones suggest that the Gants Lake batholith intruded both mafic volcanic rocks and gabbros. These zones, one of which is fault-bounded, consist of large (up to 10 m wide) angular fragments of both mafic intrusive and extrusive lithologies within quartz-porphyritic granodiorite. Fragments in both areas occupy 50-80 per cent of the outcrop area. The Gants Lake batholith granodiorite east of the Loukes Lake shear zone includes one ~150-200m wide block of mylonitic felsic intrusive rock within relatively undeformed granodiorite. Two of the three sides of this block are faulted bounded (see Fig. 2).

At the northern margin of the map sheet, the ovoid Little Swan Lake pluton (LSLP) intrudes the Gants Lake batholith. The northern half of this pluton, located in the Elbow Lake sheet (map units 9n to 9s of Whalen (1993a), yielded a U-Pb titanite age of 1826 ± 5 Ma (Whalen and Hunt, 1994), significantly younger than the 1876 +7/-6 Ma U-Pb zircon age obtained for its plagioclase porphyritic granodiorite wall rock. Consistent with this apparent age gap, north-trending structures within the elongate Gants Lake batholith terminate at the Little Swan Lake pluton contact (Fig. 3). The Little

Figure 4. *Lobate, comagmatic inclusions of quartz diorite in porphyritic granodiorite of the Little Swan Lake pluton; note the incorporation into the quartz diorite of plagioclase phenocrysts from the granodiorite. (GSC 1994-743E)*

Swan Lake pluton typically exhibits a moderate foliation, parallel to the margin of the pluton. A second, similarly oriented, foliation is developed within the Gants Lake batholith parallel to its contact with the Little Swan Lake pluton. Intensity of this second foliation in the Gants Lake batholith increases toward its contact with the Little Swan Lake pluton.

The Little Swan Lake pluton is dominanted by coarse grained, hornblende-biotite granodiorite, but also includes quartz diorite, diorite, and gabbro. Field relations, such as small (<10 cm) lobate mafic inclusions (Fig. 4) as well as much larger (1500 m wide) mafic zones within granodiorite, indicate coexisting mafic and felsic magmas (see also Whalen, 1993a,b).

STRUCTURAL GEOLOGY

The Iskwasum Lake sheet is dominated by three northerly trending shear zones (the Loukes Lake shear zone (LLSZ) (Syme, 1994), Flag Lake shear zone (FLSZ), and the Elbow Lake shear zone (ELSZ) (Syme, 1994)), and a late east-west-trending shear zone (the Berry Creek fault (BCF); Syme, 1993, 1994)) (Fig. 3). In addition, smaller faults, with a dominant north-northeast-trending orientation, are common throughout the area. These north-northeast-trending structures typically truncate earlier NW trending faults, but this is not always the case. Of these brittle features, the Barb Lake fault (BLF) is an important feature and will be discussed further.

1. Elbow Lake shear zone

The Elbow Lake shear zone (ELSZ) is a prominent structure in the Elbow Lake sheet (Syme, 1991, 1992). Ryan and Williams (1993) interpreted it as a complex and long-lived structure, which began to form prior to the 1864 Ma emplacement of the Elbow Lake tonalite and which outlasted peak metamorphic conditions at 1820 to 1805 Ma (David et. al., 1993; Ansdell and Norman, in press). Mapping by Syme (1991,1992) and Syme and Whalen (1992) and geochemical investigations by Stern et al. (in press, in prep.) have shown that the Elbow Lake shear zone juxtaposes various ocean floor and arc tectonostratigraphic assemblages.

In the Elbow Lake sheet, the Elbow Lake shear zone narrows to both the north and south, from its maximum width of about 2.2 km in the middle of Elbow Lake, to approximately 50 m at the Grass River outlet at the lake's southwest end (Syme, 1991). Reconnaissance geology by Syme (1994) suggests that the Elbow Lake shear zone continues southward from Elbow Lake to Iskwasum Lake and is eventually dragged into, and terminated against the Berry Creek fault. On Iskwasum Lake, the Elbow Lake shear zone is localized primarily within various mafic extrusive and intrusive units. Although often strongly foliated/gneissic, granitoid rocks exposed on the northeast shore of Iskwasum Lake (the only granitoid rocks to outcrop on Iskwasum Lake) are not as deformed as the mafic rocks within the Elbow Lake shear zone. Deformation on the margin of the Gants Lake batholith can be attributed to the shear zone, as the intensity of deformation rapidly decreases away from the shore of the lake (Fig. 3). The Elbow Lake shear zone does not appear to affect other large granitoid plutons (i.e., Elbow Lake tonalite, Iskwasum Lake stock, South Iskwasum Lake pluton) in the area to the same degree as the Gants Lake batholith.

2. Loukes Lake shear zone

Previously unrecognized, the Loukes Lake shear zone is a ≤1500 m wide zone of variably mylonitic granitoid rocks. Only one thin (<200 m wide) sliver of mafic tectonite was recognized within the shear zone on the southeast shore of Loukes Lake. The Loukes Lake shear zone, which separates eastern and western portions of the Gants Lake batholith, is an anastomosing shear zone. To the north it first pinches out, then reappears on Needle Lake, and to the south it is dragged into the Berry Creek fault (Fig. 3). Intensity of deformation generally decreases away from the centre of Loukes Lake. An abrupt westward change from mylonitic to strongly foliated granitoid rocks is attributed to late north-northeast brittle structures along the edge of the Loukes Lake shear zone. These brittle structures, as well as primary strain deviations, may account for the anastomosing nature of the shear zone. Granitoid rocks east of the Loukes Lake shear zone are mylonitic only at the extreme northern end of Loukes Lake, and other exposures of the Gants Lake batholith on the east shore are less deformed (see Fig. 3).

As the Loukes Lake shear zone thins to the north, it becomes gneissic rather than mylonitic. Farther north on Needle Lake, the mylonite reappears, and continues north until it is cut by the Little Swan Lake pluton at the northern margin of the map sheet. Deformation intensity gradually decreases laterally, from gneissic to strongly foliated 500 m east and west of Needle Lake. To the north in the Elbow Lake sheet, the Loukes Lake shear zone is correlated with a mylonite zone within the Gants Lake batholith outlined by Whalen (1993a,b). Except for a few minor east-west offsets, the Loukes Lake shear zone appears to continue in a north-south-direction, from the north side of the Little Swan Lake pluton to the northern edge of the ELbow Lake sheet (see Fig. 3), where it was mapped as a mylonite belt by Whalen and Syme (1992).

The Loukes Lake shear zone appears to postdate Gants Lake batholith emplacement, as the shear zone cuts across lithological boundaries, including quartz diorite, quartz diorite to tonalite and granodiorite from south to north. The porphyritic granodiorite, which occurs on the western side of the Loukes Lake shear zone near Loukes Lake, resembles a major plutonic unit on the northwest side of the Gants Lake batholith in the Elbow Lake sheet (unit 9j) (Fig. 2). In the Elbow Lake sheet, this unit is bounded on its eastern side by the proposed continuation of the Loukes Lake shear zone. The granodiorite unit with a dominant north-northeast-trending orientation yielded an U-Pb zircon age of 1876+7/-6 Ma (Whalen and Hunt, 1994), which puts a maximum age constraint on the Loukes Lake shear zone. A 1826 ± 5 Ma U-Pb titanite age was obtained on the crosscutting Little Swan Lake pluton (Whalen and Hunt, 1994), which cuts off the Loukes Lake shear zone. This places a minimum age constraint on the Loukes Lake shear zone, for the Little Swan Lake pluton is only moderately foliated and truncates all major structures in the Gants Lake batholith.

Pegmatite dykes and veins intrude the Loukes Lake shear zone and are variably deformed, suggesting that they have been syntectonically emplaced. Narrow pegmatite veins (1-3 cm wide) have been deformed in the shear zone to the point where they consist of K-feldspar porphyroclasts strung out 1-10 cm apart (Fig. 5). Although unambiguous shear sense indicators are relatively rare, locally present winged porphyroclasts generally indicate dextral shear, although some are sinistral. Thin section study of the Loukes Lake shear zone mylonite will attempt to validate such field observations and further identify shear sense indicators.

3. Flag Lake shear zone

The Flag Lake shear zone, a north-northeast-trending zone of banded mafic-felsic mylonite on the Grass River east of Loukes Lake, separates the Gants Lake batholith to the west from the Reed Lake layered mafic-ultramafic complex to the east (Fig. 2, 3). Although interpretation of protoliths is equivocal, this 500-750 m wide belt of tectonite probably contains sheared equivalents of both intrusive bodies. The Flag Lake shear zone is unconformably overlain to the south by Paleozoic cover, and passes along strike into a felsic mylonite to the north, where it is eventually truncated by a north-northwest-trending fault. Tectonites along the Flag Lake shear zone are typically fine grained with a dominant banded appearance. No shear sense indicators were identified in the field. The Flag Lake shear zone is predominately concentrated in supracrustal rocks, but immediately north of the northwest-trending fault, which truncates the tectonite belt, is an area of mylonitic felsic intrusive rock. Although this unit is along strike with the tectonite, it is not certain whether deformation in this unit was due to the Flag Lake shear zone, or whether it is an unrelated fault-bounded block.

The eastern portion of the Gants Lake batholith contains two fault-bounded blocks of felsic mylonite, juxtaposed against relatively undeformed granodiorite (Fig. 2). The mylonitic blocks (~0.15-0.9 km) have no context with respect to large-scale structures in the area and do not continue along strike. However, the mylonitic fabric generally has a similar orientation to the north-northeast-trending structures in the area. The blocks may represent fragmented parts of the Flag Lake shear zone or an earlier, similarly orientated structure. The Flag Lake shear zone may continue north-northwest into the Elbow Lake sheet, linking with a shear zone which crosses North Star Lake and continues northward west of the Norris Lake pluton (see Fig. 3).

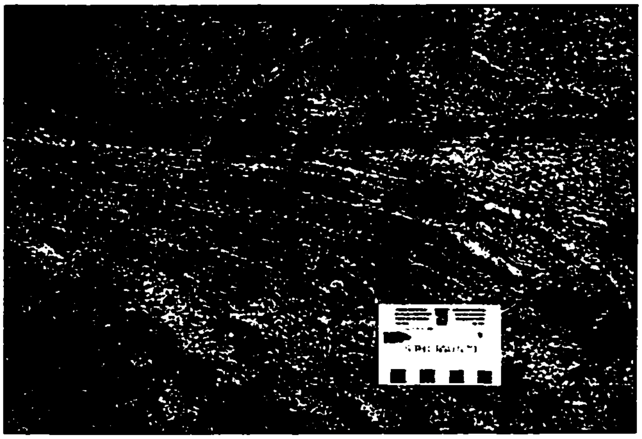


Figure 5. Folded and strung out pegmatite veins near the margin of the Loukes Lake shear zone; note the extremely attenuated nature of the veins, some are folded, others form strung out lines of K-feldspar porphyroclasts. (GSC 1994-743C)

4. Berry Creek fault

The Berry Creek fault is a major west-east trending structure which extends from Athapapuskow Lake to the west shore of Wekusko Lake. Although it is entirely covered by Palaeozoic rocks in the Iskwasum Lake sheet, associated deformation has been recognized up to 5 km to the north of it. The Berry Creek fault has a north-side-down or normal dip slip component south of Athapapuskow Lake (Syme, 1992) and, in the Cranberry Lake area, an apparent sinistral sense of displacement associated with brittle deformation (Syme, 1993). However, in the map area, ductile deformation has transposed north-northeast-trending structures and lithologies into a westerly orientation, suggesting a dextral sense of horizontal shear. The Berry Creek fault is, therefore, a complex structure with an apparently long-lived deformational history, and further work is required to integrate observations along strike length.

On a hand-specimen scale, fabrics of the Berry Creek fault overprint earlier fabrics within the Gants Lake batholith, and its shear zones (Elbow Lake shear zone, Loukes Lake shear zone, Flag Lake shear zone). This overprinting is so intense that, adjacent to the fault, earlier fabrics are completely transposed into the Berry Creek fault fabric (Fig. 6). Farther away, for up to 5 km north, the Berry Creek fault foliation can be recognized as an axial planar foliation to minor open to isoclinal folds of earlier foliations and compositional layering. Late brittle faults also appear to be axial planar to the Berry Creek fault-related folds (see Fig. 7). Isoclinal folds are commonly located nearer to the Berry

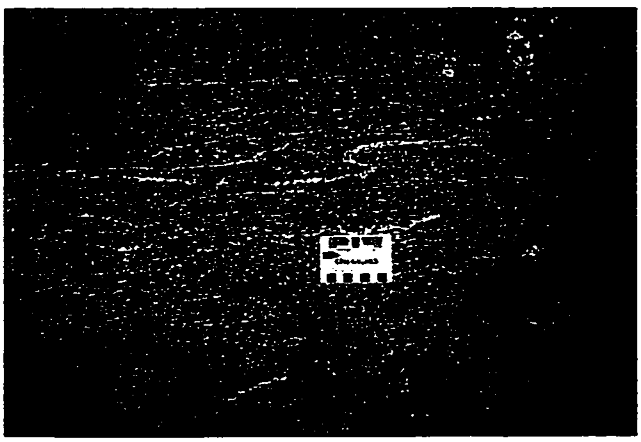


Figure 6. Complex folds of a thin pegmatite vein in the Loukes Lake shear zone. Folds are tight to isoclinal, and appear to show some signs of polyphase folding. Shear zone fabric trends approximately north, while Berry Creek fault fabric can be seen as late brittle fractures. (GSC 1994-743G)

Figure 7. Sheet of ultramafic rock within the Loukes Lake shear zone, near the Berry Creek fault; note that the felsic host rock is so extremely attenuated that few kinematic indicators are preserved. Although the Loukes Lake shear zone is a north-northwest-trending structure, the fabric at this location is east-west-trending due to the later east-west Berry Creek fault. (GSC 1994-743H)

Creek fault and typically have an east-northeast orientation with Z-fold asymmetry (Fig 7), consistent with the map-scale relations.

5. Barb Lake fault

The Barb Lake fault, one of the most significant north-northeast-trending brittle faults, is a large structure with associated distinct fracture sets. These structures are best recognized on aerial photographs and can be recognized by mapping of lithological offsets. The Barb Lake fault cuts the Iskwasum Lake stock (ILS), extends north through Barb Lake, and south through Iskwasum Lake, where it cuts the Elbow Lake shear zone (Syme, 1994) and the South Iskwasum Lake pluton (Fig. 2, 3). The Barb Lake fault is best seen within the Iskwasum Lake stock, where it separates highly altered rocks from less altered equivalents. Large cliff faces are found on either side of the fault, and associated fracture patterns are recognizable up to 1 km away. These fractures trend parallel to the fault (010-020°) and dip east at about 80°. Such brittle deformation is common throughout the Iskwasum Lake sheet but is rarely as pronounced. The eastern portion of the Iskwasum Lake stock has fracture-related alteration of plagioclase to epidote while alteration on the west side is much more pervasive. This is thought to reflect shallow- (east-side) and deeper- (west-side) level exposures of the Iskwasum Lake stock, assuming that late-stage hydrothermal alteration is due to fluids which have had a greater effect on the upper portions of the pluton. Because the juxtaposition of these two different alteration patterns requires that the east side be moved up with respect to the west, this fault is interpreted as having a predominantly dip-slip component. Lateral offset on the Barb Lake fault appears minimal, given the minor displacement of the steeply dipping contact between the Iskwasum Lake stock and host rocks.

DISCUSSION

Correlatives of both main plutonic rock units and major structures, which are well defined in the Elbow Lake sheet to the north (e.g., Syme and Whalen, 1992; Syme, 1992; Whalen, 1993a,b), have been mapped in the Iskwasum Lake sheet. The Iskwasum Lake sheet probably represents a similar complex and tectonically important portion of the Flin Flon Domain.

The Elbow Lake shear zone, which juxtaposes diverse volcanic assemblages, is interpreted as an early structure (pre-1864 Ma) with a protracted movement history (Syme, 1992; Ryan and Williams, 1993). The Loukes Lake shear zone is localized almost entirely within plutonic rocks of the Gants Lake batholith in both the Iskwasum and Elbow Lake sheets. Geochemical characterization of volcanic rocks (E.C. Syme, 1994, pers. comm.) indicates that the Gants Lake batholith is bounded by ocean-floor assemblages to the west and arc-type assemblages to the east. Based on this evidence, Whalen and Hunt (1994) suggested that the Gants Lake batholith may be localized along a significant tectonic boundary. The Loukes Lake shear zone, like the Elbow Lake shear zone, may represent the reworked trace of such a boundary. More detailed investigation is required to determine the age, tectonic significance, and relationship of shear zones in the Iskwasum-Elbow Lake area to other map scale structures in the Flin Flon Domain.

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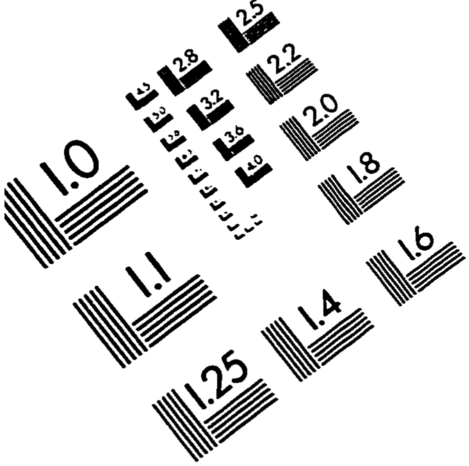

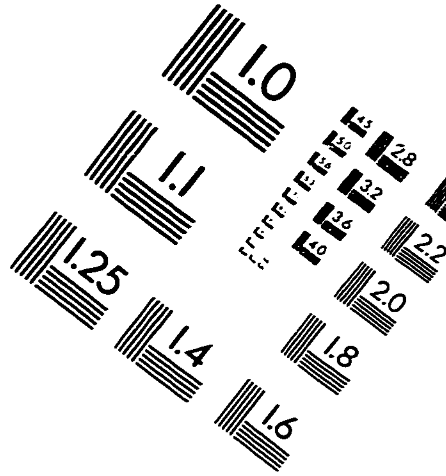

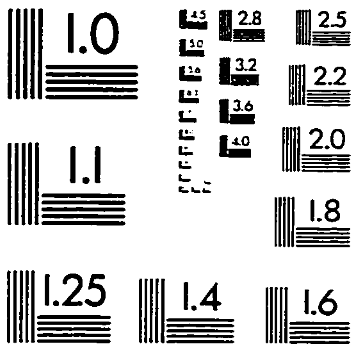

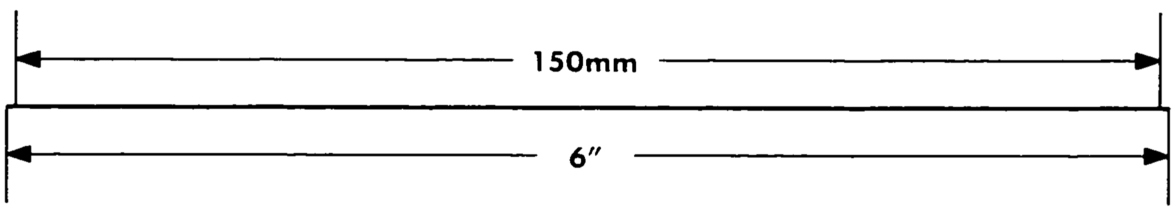

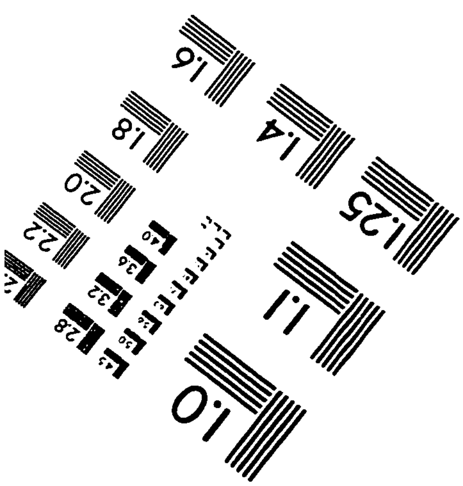

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