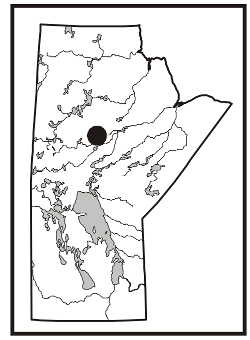
MYSTERY LAKE HIGH-STRAIN ZONES: SINISTRAL AND DEXTRAL, EAST-SIDE-UP DISPLACEMENTS, THOMPSON NICKEL BELT

by H.V. Zwanzig



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SUMMARY

A regional syncline, which was traced northeast along Mystery Lake in previous mapping, has a core of Ospwagan Group metasedimentary and metavolcanic rocks with large ultramafic intrusions. The Archean basement gneiss on the limbs of the syncline contains high-strain zones that feature kinematic indicators interpreted, in this report, to be the result of northwest shortening with sinistral east-side-up displacement and, locally, less clearly defined dextral east-side-up displacement. With respect to a structural history proposed by Bleeker (1990a, b) and modified by Zwanzig (1998), the large fold and the high-strain zones developed mainly during D_3 sinistral transpression. The Mystery Lake data suggest that northwest compression and vertical extension were dominant but that mega-boudinage may have caused local concentration of the shear component and rare reversals in the horizontal shear component. The results do not support a model involving only dextral transpression (A. Potrel, D. Peck, N. Machado and C. Wegleitner, work in progress, 2000). However, they are consistent with the structural style of undisrupted, long sinuous folds that has been identified during preparation of a compilation map of the Thompson Nickel Belt (Macek and McGregor, 1998).

INTRODUCTION

The complex, long-lived structural evolution of the Thompson Nickel Belt (TNB) has lead to a variety of tectonometamorphic interpretations. Bleeker (1990a, b) proposed early nappe tectonics, followed by intrusion of 1.88 Ga dykes and late (ca. 1.77 Ga) sinistral transpression. Zwanzig (1998, 1999) presented a revision to the model of Bleeker (1990a, b), citing from his work in the Setting Lake region 1) the apparent absence of early, large-scale, stratigraphic repetitions in the Ospwagan Group; and 2) the presence of large recumbent folds, formed ca. 1.81 Ga, during the time of peak metamorphism of the Kisseynew gneiss. Potrel et al. (work in progress, 2000) have proposed that the TNB structure formed as a result of dextral transpression alone. Whereas final interpretation of the structural fabrics at Setting Lake awaits the completion of the regional compilation map (Macek and McGregor, 1998), a known pattern of major map units at Mystery Lake provides the critical framework for a kinematic analysis in the northern part of the TNB.

Mesoscopic structural data were collected on Mystery Lake over a period of 10 days in spring, before the cresting Burntwood River had flooded the critical outcrops. The Mystery Lake shoreline has a varied relief and provides clean subhorizontal exposures, cleavage surfaces and south faces, produced by glacial abrasion and plucking. Consequently, the various planar and linear fabric elements were measured, and kinematic indicators were commonly recorded from observations on the three principal surfaces. In this report, the structural measurements from various types and ages of fabrics are analyzed and related to structures that are several kilometres long. These are related, in turn, to the regional structure of the TNB. A special effort was made to analyze the movement pattern around the large ultramafic bodies hidden under the lake (Coats et al., 1972).

STRATIGRAPHIC AND STRUCTURAL FRAMEWORK

Mystery Lake is underlain by steeply dipping sedimentary and volcanic rocks of the Ospwagan Group, exposed on several islands and, locally, on the shore (Fig. GS-5-1). Archean basement gneiss occurs on much of the east and west shores and forms small outrops on the adjacent high ground. The gneiss is overlain by the lower part of the Ospwagan Group (mainly Manasan Formation quartzite and Pipe Formation semipelite). The upper formations in the Ospwagan Group (Setting quartzite with thin pelite, and Bah Lake mafic flows and sills) occur on the central islands. Consequently, stratigraphic facing is toward the centre of the lake, inward from both sides, defining a large syncline. A west-facing angular unconformity at the base of the Ospwagan Group in the northeast corner of the lake is consistent with this interpretation (Fig. GS-5-2; *see* 'U' on Fig. GS-5-1). The large, differentiated, North Mystery Lake ultramafic intrusion, which occupies much of the east limb of the syncline, also faces west (H.V. Zwanzig, work in progress, 2000). The Mystery Lake granodiorite batholith lies directly west of the syncline.

The dip of the layering is subvertical everywhere, indicating that the fold is isoclinal. The supracrustal units pinch and swell along strike; slightly downward-diverging dips on the limbs of the syncline are taken as an indication that the Ospwagan Group also pinches and swells on a large scale about a shallow-plunging axis in the core of the fold.

Small-scale folding is prominent in strongly layered (stromatic) basement gneiss and, locally, in well bedded Ospwagan Group sedimentary rocks. Curvilinear hinges occur in some areas but they curve through less than 90°, which suggests an origin by superposed folding, as at Setting Lake (Zwanzig, 1998), rather than sheath folding.

The structural style and fabric elements at Mystery Lake are similar to those along strike at Setting Lake (Zwanzig, 1998). The deformational history is therefore also considered to be the same, and the main Proterozoic high-temperature foliation is interpreted as composite S_2-S_3 schistosity with coplanar elements that are distinguished in F_3 fold hinges at Setting Lake (Ducharme and Zwanzig, 1999). At Mystery Lake, the basement rocks show a strong early gneissosity (S_A) and stromatic layering, both of which are assumed to be Archean because they are not present in the Ospwagan Group. The Proterozoic biotite schistosity (S_2-S_3) is generally coplanar with S_A but cuts it in some of the early (?Archean) fold hinges. In much of the Mystery Lake area, as elsewhere in the TNB, the intense late fabric development (S_3, L_3) obliterated or transposed the earlier fabrics. Weakly developed crenulation in S_2-S_3 has a variable plunge and an uncertain origin. The S_4 foliation, containing fine-grained muscovite and chlorite or carbonate, is associated with late shear zones.

HIGH-STRAIN ZONES

High-strain zones occur 1) close to the contact between the Ospwagan Group and the basement gneiss, 2) along the east margin of the Mystery Lake granodiorite, and 3) at the west margin of a uniform granitoid gneiss that is part of the basement on the east side of the 'northeast area' (Fig. GS-5-1). These zones feature strong planar fabrics and moderately well developed lineations. They comprise high-temperature protomylonitic to mylonitic foliations and stretching lineations that overprint the Archean gneissosity (S_A) in the basement and the schistosity (S_2) in the supracrustal rocks. They are thus interpreted to represent mainly S_3. Lens-shaped bodies, such as boudins, pods of leucosome (Fig. GS-5-3) and porphyroclasts within the highly planar fabric, are predominantly symmetric and indicate a large component of coaxial strain: northwest compression, at a high angle to the regional strike (Fig. GS-5-1). Most lineations plunge subvertically down dip. They are

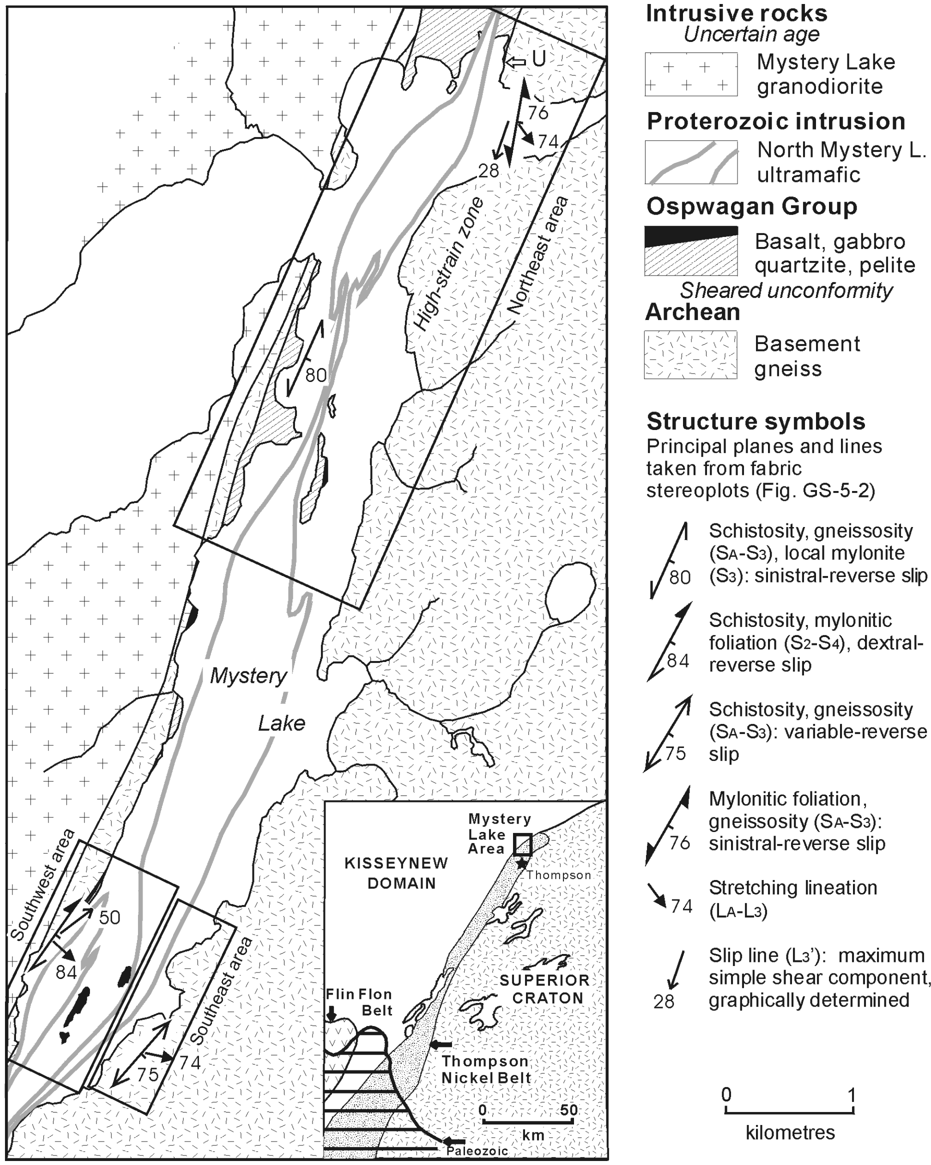

Figure GS-5-1: Geological sketch map of the Mystery Lake area with the outline of the North Mystery Lake ultramafic intrusion (after Coats et al., 1972), and showing the principal planar and linear fabric orientations (for three structurally distinctive areas) as determined on Figure GS-5-8.

Figure GS-5-2: Unconformity at the base of the Ospwagan Group, showing the angular relationship between 1) Archean foliation (S_A) in the basement gneiss, which is overprinted by weak Proterozoic schistosity (S_2-S_3), and 2) thin bedding with coplanar schistosity (S_0-S_3) in the overlying quartzite.

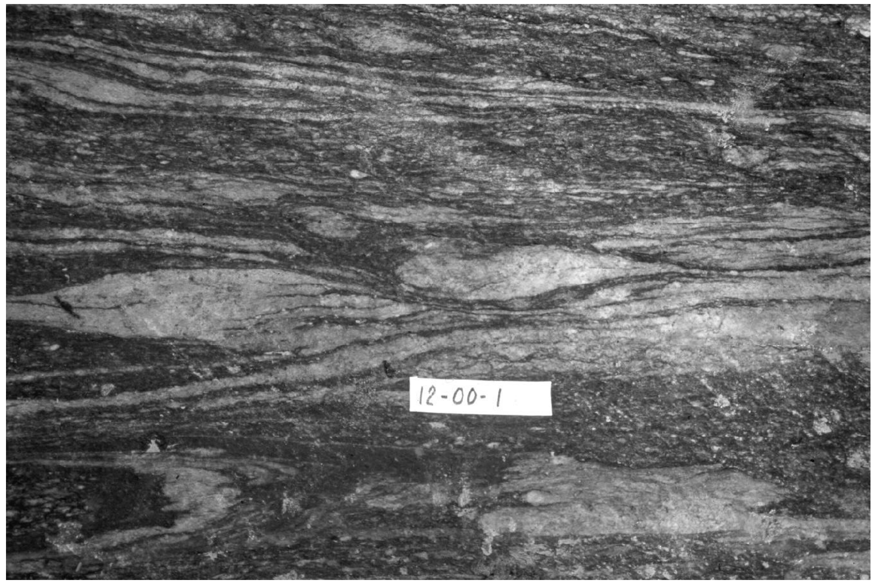

Figure GS-5-3: Lenses and folded layers of granitoid leucosome in layered (stromatic) basement gneiss. The slight dextral asymmetry of the larger sigmoidal pods (above the tape) are analogous to the structural style of the North Mystery Lake ultramafic intrusion (see Fig. GS-5-1). Tape is 10 cm long.

dominated by stretching lineations that indicate a high degree of coaxial vertical extension, because asymmetrical structures are absent or subdued on vertical rock faces perpendicular to the foliation.

The most prominent mylonite zone occurs in the Archean granitoid gneiss in the eastern part of the 'northeast area'. However, the highest strain in the basement may be recorded in the strongly gneissic to schistose, multicomponent stromatic rocks along the shores of Mystery Lake in the 'southeast area' and 'southwest area' (Fig. GS-5-1). This unit contains a sedimentary component and is similar to Ospwagan Group semipelite injected by granitic veins. Consequently, the origin of some of the strongly foliated rocks on the west side of the lake is uncertain. Zones with even higher strain may occur in the incompetent pelite units under the lake. In contrast, well preserved, weakly foliated to massive rocks occur in the interior of the Mystery Lake granodiorite and on the central islands. Well preserved basalt, ultramafic rock and quartzite appear to occupy low-strain domains that are probably lens-shaped, though not fully exposed. The high-strain zones around them are probably anastomosing but only exposed along the shore. The strain gradient on the margin of the well preserved domains implies that the local strain was noncoaxial (Hanmer and Passchier, 1991).

Noncoaxial shear-sense indicators occur sporadically along the west shore of Mystery Lake and consistently in the high-strain zone in the northeast area. The mylonite contains S-C fabrics (S_3-C_3; Fig. GS-5-4), and more discrete shear bands (C_3'), which formed sequentially during progressive deformation (Hanmer and Passchier, 1991), occur in the protomylonite gneiss (Fig. GS-5-5, -6). Asymmetrical structures, such as winged sigma porphyroclasts and back-rotated boudins, generally show the same sense of shear as the planar structures. Rolled (delta) porphyroclasts are rare or absent. Discrete narrow shear zones (Fig. GS-5-7) and small faults containing ultramylonite and pseudotachylite do not all have a consistent sense of shear. They are considered to be relatively young (S_4), but their relationship to the main high-strain zones is uncertain. Late shear zones on Setting Lake have greenschist-facies retrograde mineral assemblages in amphibolite-grade rocks, a relationship that will be tested in the rocks from Mystery Lake.

MESOSCOPIC FABRIC ANALYSIS

All planar fabrics in the Mystery Lake area strike northeast to north and are vertical or have a steep easterly dip (Fig. GS-5-8). Overturning of layering and axial surfaces of folds, or vergence, is consistently to the northwest. Overall, the area shows a slight curvature, with the more northerly strikes being in the northeast. The distribution of subvertical foliation and steeply plunging stretching lineations defines strong central maxima, typical of strongly preferred orientations of L-S fabrics with random variations (Fig. GS-5-8). This fabric data and the generally poor development of asymmetrical shear-sense indicators suggest that all rock units at Mystery Lake have undergone northwest compression and vertical stretching. The dispersion of poles and lineations is interpreted to be the result of local variations in the movement pattern around competent bodies. This is particularly evident in the 'southwest area', where boudins of gabbro and elongate lenses of leucogranite are present.

Asymmetrical fabric elements, which are indicative of noncoaxial strain, developed locally around Mystery Lake, but measurements have been concentrated in areas where they occur. The study area is subdivided into three domains (northeast, southeast and southwest areas) based on consistent changes in the shear sense from sinistral to dextral and to mixed (Fig. GS-5-1, -8). All of these domains show a component of reverse displacement (i.e. southeast-side-up). Independent measurements of the S and C fabric elements, as well as schistosity and mylonitic foliation with more discrete shear bands (C'), were taken on the same parts of the outcrops, and these data were used to approximate the vector of maximum shear strain (slip line). The C-planes are generally not exposed, and fine striations (Lin and Williams, 1992) were not observed. The 'slip' lines in Figure GS-5-8 are given by the normal to the S-C intersection in the plane of the main foliation (either S or C). They are determined with reasonable accuracy only in the 'northeast area', where eight pairs of measurements provided a tight cluster of lines that plunge south-southwest at about 30° (*see* lower right diagram in Fig. GS-5-8). An approximate direction of slip is suggested by the symmetries on several outcrops, where strongly asymmetrical sinistral indicators on a horizontal surface are matched by weakly asymmetrical but consistent indicators for reverse displacement on subvertical exposures normal to the foliation. All relevant data indicate that the slip line plunges southwest throughout the 'northeast area'.

In the 'southwest area', the sense of slip appears to be dextral and a single pair of surfaces suggests a moderately northeast-plunging slip line. Again, this was predicted by comparing horizontal and steep faces, but here the asymmetry is weak as viewed on the horizontal plane. The calculated vector is almost normal to that in the northeast. The greater dispersion of stretching lineations in this area (*see* upper left diagram in Fig. GS-5-8) may be related to the local variations in ductility (*see* above). This may reflect the partitioning of the simple shear component of strain into narrow zones in which the stretching lineations approach the slip line, whereas the shear-zone-normal shortening is reflected in the general steep plunge of the lineations (Lin et al., 1998). This is consistent with the spread of lineations in Figure GS-5-8. Future work will include a thorough search for and sampling of such zones.

Figure GS-5-4: Layered mylonitic basement gneiss with S-C fabric indicating east- side-up displacement; view looking northeast. Its protolith is interpreted to have been like the rock in Figure GS-5-3.

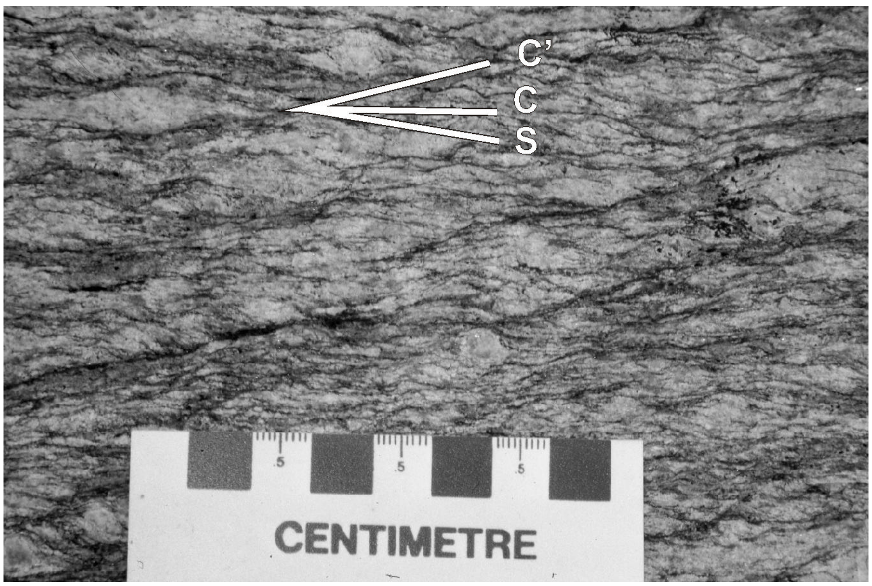

Figure GS-5-5: Archean granitoid gneiss overprinted by Proterozoic foliation (S-C) with shear bands (C'), as seen in plan view in the protomylonite zone in the 'northeast area' on Figure GS-5-1.

In the 'southeast area', dextral indicators tend to occur on shoreline promontories, close to the North Mystery Lake ultramafic intrusion. Sinistral indicators occur in the bays and suggest a reversal in the flow regime away from the intrusion. One outcrop featured indicators suggesting both shear senses. However, as on the southwest shore, the asymmetry is not pronounced on horizontal outcrops.

DISCUSSION

The shear-related fabrics are interpreted to be the result of the D_3 and D_4 deformation, which occurred during the development and tightening of the F_3 major syncline at Mystery Lake. The strong, vertical, coeval stretching is consistent with the northwest compression that resulted in the folding. A component of noncoaxial strain produced oblique, sinistral, southeast-side-up displacement throughout the northern half of the lake. Clearly, the competent southeast basement block was uplifted and moved northeast, starting to override the northwest bock that contained the Mystery Lake granodiorite. The incompetent pelitic gneiss in the core of the large syncline at Mystery Lake acted as a ductile zone, probably with partitioning of oblique simple shear into zones around low-strain domains.

Relatively shallow-plunging oblique displacement with vertical stretching, as is described in this report, is a hallmark of transpression zones. However, several factors mitigate against a large component of transcurrent slip. These include: 1) a preponderance of structures indicating vertical extension and northwest compression, and the apparent absence of zones with horizontal striation; 2) generally weak development of C surfaces; 3) the lack of rotation of the stretching lineation into the calculated slip line in the largest high-strain zone in the northeast; and 4) a change in the movement direction around a large competent body that acted as a megaboudin and produced a reversal in the direction of the horizontal flow component from sinistral to dextral. Considerable transcurrent slip may be partitioned into pelites that are unexposed at Mystery Lake, but this is not apparent in pelite exposed in the Grass River linear northeast of Setting Lake.

An area of particular interest is located southeast Mystery Lake, where a reversal in horizontal flow suggests that a southward-widening basement wedge was expelled toward the southwest and upward. A ramp at the south side of this block would be a basement overthrust. A recumbent fold at the south side of the block would resemble a small, south-verging basement nappe. The area is accessible and warrants further mapping to test for such structures. A structural model that may be worthwhile to consider in the TNB is one of protracted northwest compression with a small regional component of oblique, sinistral, southeast-side-up displacement.

An important conclusion of this study of kinematic indicators on Mystery Lake is that the main part of the TNB is unlikely to represent a crustal-scale transcurrent zone. This is consistent with the structural

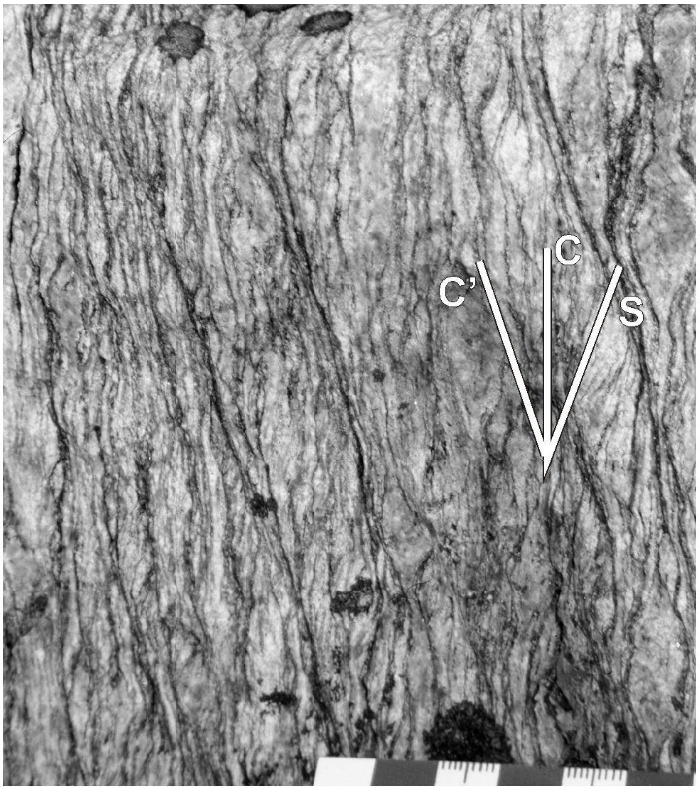

Figure GS-5-6: Archean granitoid gneiss overprinted by Proterozoic foliation (S-C) with shear bands (C'); view looking north, normal to and directly below the view in Figure GS-5-5.

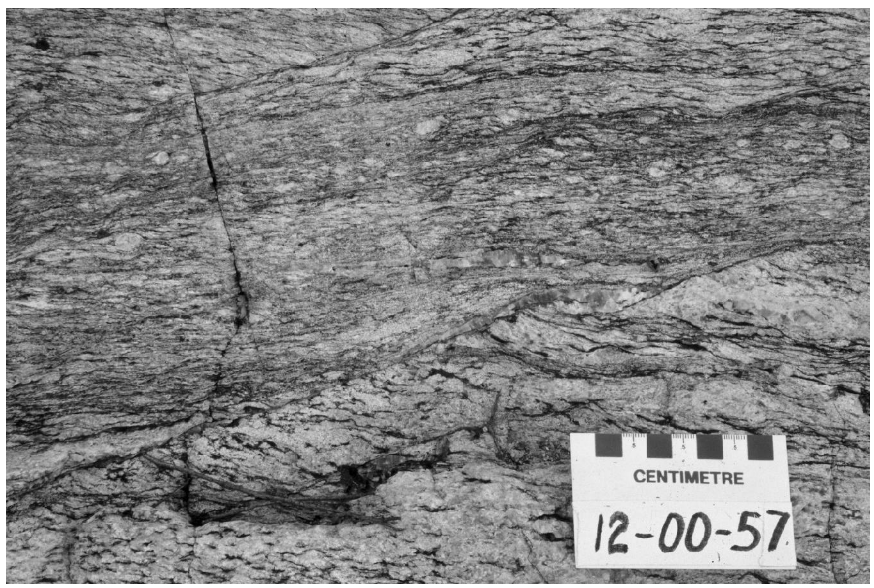

Figure GS-5-7: Archean granitoid gneiss, preserved in the lower right and cut by a late sinistral shear zone (?S_4). The abrupt increase in Proterozoic strain in the shear zone requires partitioning of considerable simple shear into the bounding fault.

style indicated by the regional map pattern (Coats, 1972; Macek and McGregor, 1998). Map units are continuous along strike, as well as across the strike of high-strain zones where these terminate or become highly curved. The units in the Ospwagan Group, not the high-strain zones, control the location of ultramafic intrusions and their associated nickel deposits in the TNB.

ACKNOWLEDGMENTS

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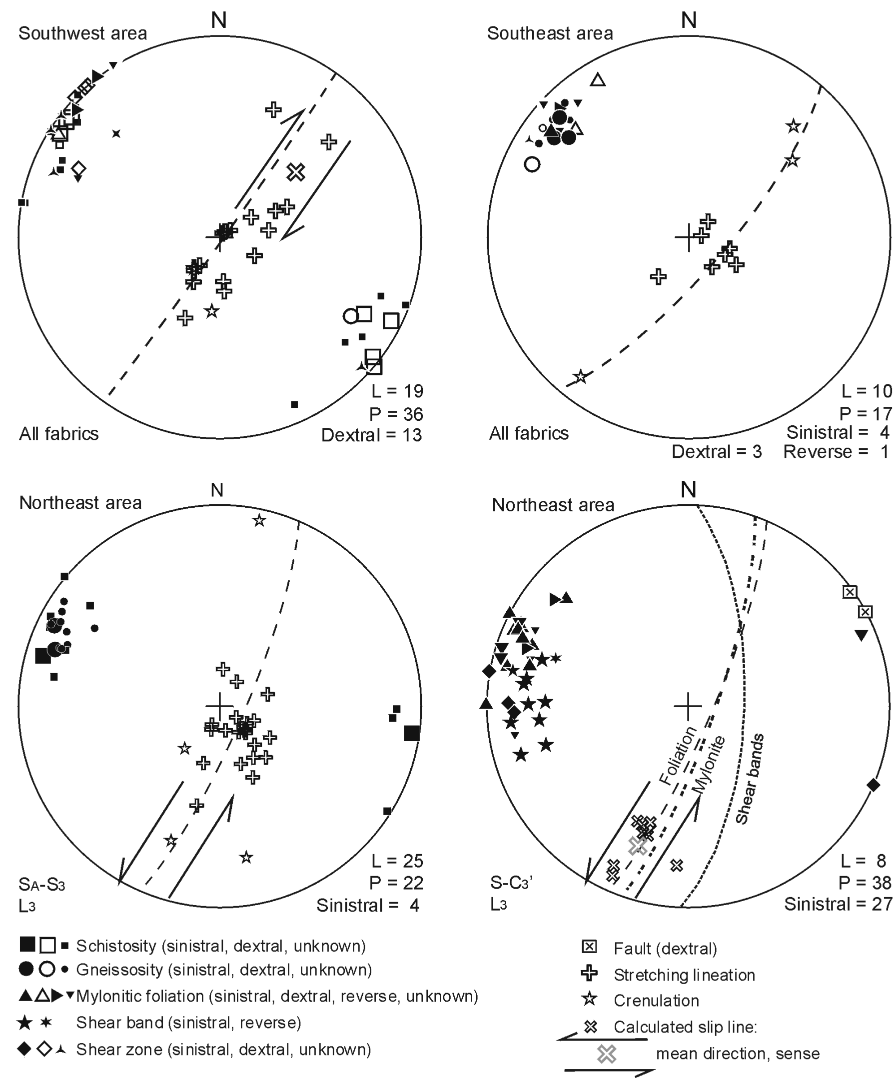

Figure GS-5-8: Equal-area stereoplots of various types and ages of fabric elements shown for three different areas on Mystery Lake. The 'slip lines' were determined as the normals to the S-C or C' intersections projected onto the main foliation (S or C). (This assumes rotation of earlier shear bands into S and may introduce a small error in the azimuth of the 'slip line'.)

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