STRUCTURAL ANALYSIS IN THE FOOTWALL OF THE UCHI-ENGLISH RIVER SUBPROVINCE BOUNDARY, RED LAKE REGION, NORTHWESTERN ONTARIO

by

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Abstract

Results of detailed structural mapping in two greenstone masses at Chase and Longlegged Lakes, near the Uchi-English River subprovince boundary, suggest that the late-stage, dextral Sydney Lake fault zone (SLFZ) could not have greatly affected the present structure. At Chase Lake, NW-SE striking lithological units and boudins would have been buckled had they been deformed by distributed dextral shear. Two tectonic scenarios account for the regional structure at Chase Lake. In scenario 1, an overturned anticline is refolded by a second WNW trending fold. In scenario 2, NW-SE ductile dislocations following the shore of Chase and Midway lakes produce the present lithologic pattern.

The displacement history of the Uchi-English River subprovince boundary, particularly the dip-shear component, is poorly known. From geophysical modelling, the subprovince boundary is interpreted to dip gently 30°S in the vicinity of the SLFZ. An accretion hypothesis for the Superior Province was tested by utilizing a new technique which determines the angular range of resolved shear strain within the footwall of the subprovince boundary. The local sense of shear strain on the footwall is dextral reverse or sinistral reverse in the Chase and Longlegged Lake areas. The varying sense of boundary-parallel displacement suggests that strike shear is insignificant on the scale of several kilometres.

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INTRODUCTION

An accretionary tectonic scenario, similar to widely accepted models for modern collisional orogens, is proposed by previous workers for the northern Superior Province (Williams *et al.* 1991, Davis *et al.* 1994). In this scenario, greenstone belts are aggregates of allochthonous and autochthonous masses (tectonic assemblages). The amalgamation of the subprovinces postdated the assembly of greenstone belts, but deformation continued into the Phanerozoic.

Information about the long tectonic history of Superior Province rocks has mainly been obtained in boundary zones between the subprovinces. Subprovince boundaries are typically structural and metamorphic transition zones between the subprovinces with contrasting lithological character (Williams *et al.* 1991). Variable amounts of late-stage strike-slip faulting and igneous intrusions occurred along these boundaries, for example, granitoid intrusions along the western section of the Uchi-English River subprovince boundary, in part obliterating earlier structural features including those indicative of dip-slip faulting and recumbent folding. Where subprovince boundaries have not been affected by later strike-slip motions, thrust faults with a north over south shear-sense and recumbent folding have been inferred (e.g., at the Wawa-Quetico and Wabigoon-Quetico subprovince boundaries). These "thin-skinned" dip-slip motions and accompanying upright folding were followed by "thick-skinned" thrust faulting, perhaps accompanied with greenstone belt-parallel strike-slip motions, such as in the Beardmore-Geraldton Belt at the Wabigoon-Quetico and Uchi-English River subprovince boundaries (Stone

1980, Kamineni *et al.* 1990). These motions have been attributed to transpression (Sanborn-Barrie *et al.* 1990, Stott *et al.* 1987), a widely accepted strain pattern in modern orogens.

The Uchi-English River subprovince boundary is the locus of south over north displacement (Campion *et al.* 1986, Breaks 1991, p.264). This is an exception among dislocations between subprovinces in Ontario (Williams *et al.* 1991, p.1280). Estimates of vertical throw on the Uchi-English River subprovince boundary vary greatly, and the kinematic history of displacement, particularly the dip-shear component, is poorly known. Also poorly known is the manner of boundary-parallel (= tangential) displacement, *i.e.* the proportion between boundary slip and broadly distributed, tangential shear.

The purpose of the present study is to further the structural knowledge of the Uchi-English River subprovince boundary in the Red Lake region. Attention is focused on the footwall, *i.e.* the north side of the boundary (Uchi greenstone and associated rocks). Here detailed structural field work was undertaken in two areas, (1) Chase Lake and vicinity and (2) southern Longlegged Lake and vicinity. The work was conducted under the umbrella of LITHOPROBE (Western Superior Transect) and with additional support from the Ontario Geological Survey.

One of the objectives of the project was to test the accretion hypothesis (Williams *et al.* 1991, Davis *et al.* 1994) on the Uchi-English River subprovince boundary by utilizing a method by Schwerdtner (in press, 1998) and Schwerdtner *et al.* (in press, 1998), which determines the shear sense and angular range of resolved shear strain directions in the stretched walls of a lithotectonic boundary (LTB). The attitude of the subprovince boundary was obtained from two-dimensional modeling and vertical profiles based from vertical second derivative maps of the gravity field in the Longlegged Lake area (Runnals 1978). A second method, taken from Bau

(1977) and Lin & Williams (1992), assumes monoclinic symmetry relationships between the lineation, foliation and the shear plane attitude to predict the fault zone attitude and is a special case of the geometry treated in Schwerdtner's (in press) new technique.

Foliation, mineral and shape lineation attitudes were collected from various locations in the Chase and Longlegged Lake areas for the purpose of shear sense analysis. A petrographic study was also undertaken in an attempt to clarify the structural relationships in the Chase and Longlegged Lake areas and to better define the metamorphic conditions at the subprovince boundary. Rock chip samples were collected from various localities across both greenstone masses. Mineral assemblages and metamorphic facies were interpreted from thin sections.

CHAPTER I

BACKGROUND INFORMATION

I. BACKGROUND INFORMATION

1.0 Introduction

This chapter provides geological information on the field area and surrounding region. Summaries are presented of the regional geology, tectonic history, geophysical data, age dates and metamorphic zones in the Uchi and English River subprovinces.

1.1 Previous work

The first geological mapping in the Rice Lake greenstone belt was undertaken by E.M. Burwash in 1923. Work was concentrated along the Manitoba-Ontario border. Four years later, a reconnaissance survey was completed by G. Gilbert. In 1938, Stockwell mapped the Rice Lake series and San Antonio formation (now the Rice Lake group) in the Rice Lake area. In 1945, R. Thomson investigated and compiled mineral occurrences in the Rice Lake belt.

By 1960, the first regional gravity interpretation was completed by Innes. Parkinson (1962) concluded from air photographs that the linear discontinuity he interpreted as a fault was the boundary between the Uchi and English River subprovinces. Also in 1962, Davies *et al.* subdivided the Rice Lake group in Manitoba into a lower volcanic series and upper sedimentary series. In 1963, Shklanka drew the first detailed map of the Rice Lake greenstone belt.

Bouguer anomaly maps of the Red Lake and Birch-Uchi belt were completed in 1965 by the Earth Physics branch in Ottawa. Grant *et al.* (1965) suggested a 7.6 km depth extent for the metavolcanic rocks in the Red Lake area from gravity work. In 1971, an abrupt change in magnetic patterns was observed at the subprovince boundary by Wilson. During the same year, McRitchie and Weber (1971) studied the Sydney Lake fault zone (SLFZ) and surrounding area in Manitoba. In this study, a dioritic pluton was noted to be dextrally offset by another fault north of the SLFZ.

Reconnaissance mapping of the entire fault zone by Breaks and Bond (1974-1978) showed that the boundary was coincident with an abrupt change in rock type, grade and intensity of deformation (Breaks *et al.* 1974). The SLFZ was observed to cut into the metavolcanics northeast of the Uchi subprovince near Pakwash Lake. U/Pb dates obtained from diatexites in the English River subprovince indicated that migmatization occurred at 2.68 Ga (Breaks *et al.* 1978). In 1978, Runnalls completed an M.Sc. thesis including two and three dimensional gravity modelling of the Red Lake and Dixie Lake area. In 1980, Stone completed a Ph.D. thesis on the Sydney Lake fault zone and concluded that it was a dextral transcurrent fault. In 1996, Hanes *et al.* did 40Ar/39Ar age dating in the English River subprovince and the SLFZ to determine the post-orogenic tectonothermal history.

1.2 Regional Geology

1.2.1 The Uchi & English River Subprovinces

The Uchi subprovince is an 80km-wide, east trending tract of meta-igneous rocks and greenstone, which extends from Lake Winnipeg to the Paleozoic cover to the east (Figures 1, 2, Corfu & Stott 1993). The greenstone belts consist of low pressure, subgreenschist to lower amphibolite metamorphic grade metavolcanic-metasedimentary sequences and associated granitoid plutons (Ermanovics & Froese 1978, Ayres 1978). The sediments of the Uchi subprovince are interpreted to be coeval with the oldest volcanic rocks and produced by the

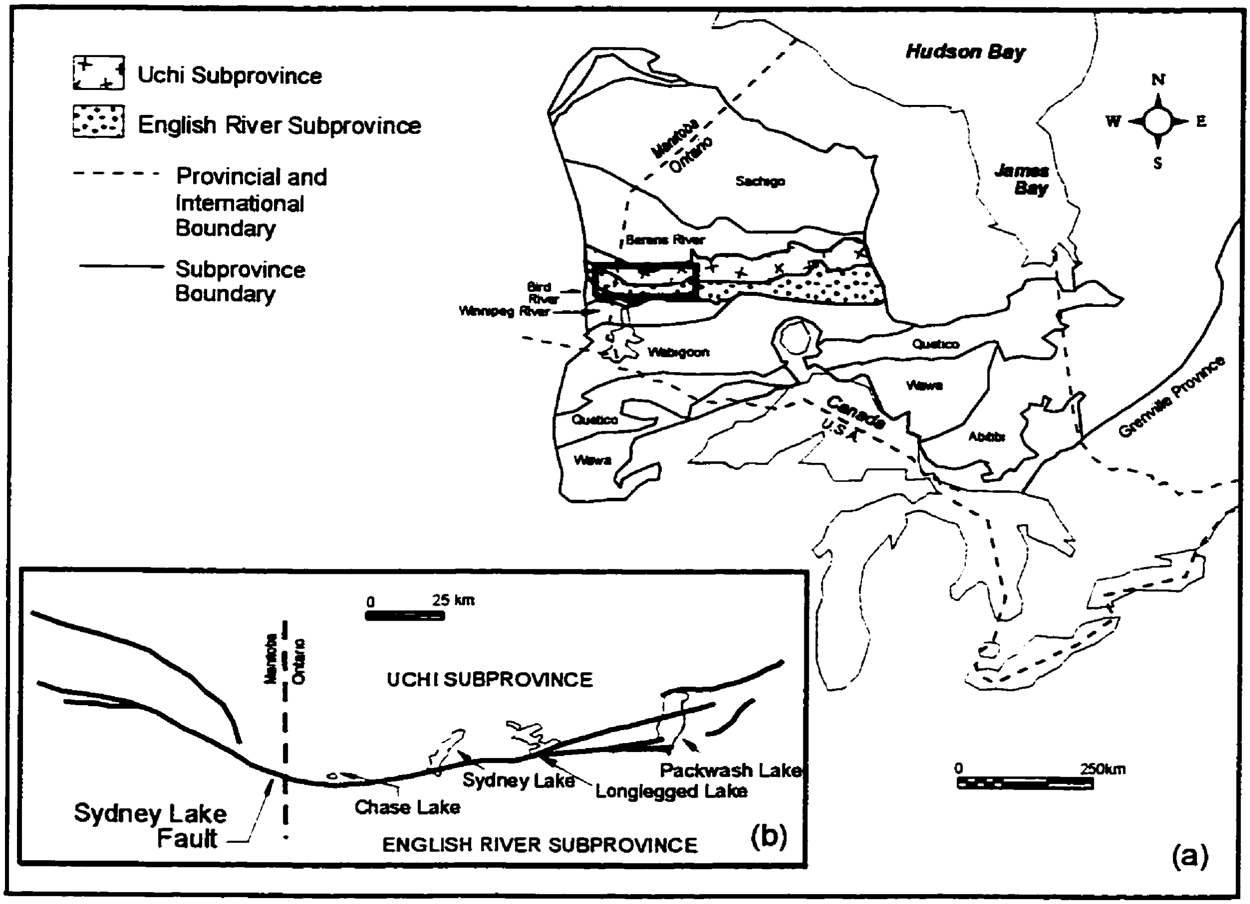


Figure 1. The location of the Sydney Lake Fault Zone. (a) Location of the Uchi and English River subprovinces in the Superior province, northwestern Ontario. (b) An enlargement of the western Uchi-English River subprovince boundary area showing the extent of the Sydney Lake Fault Zone (modified from Thurston & Breaks 1978, Stone 1981).

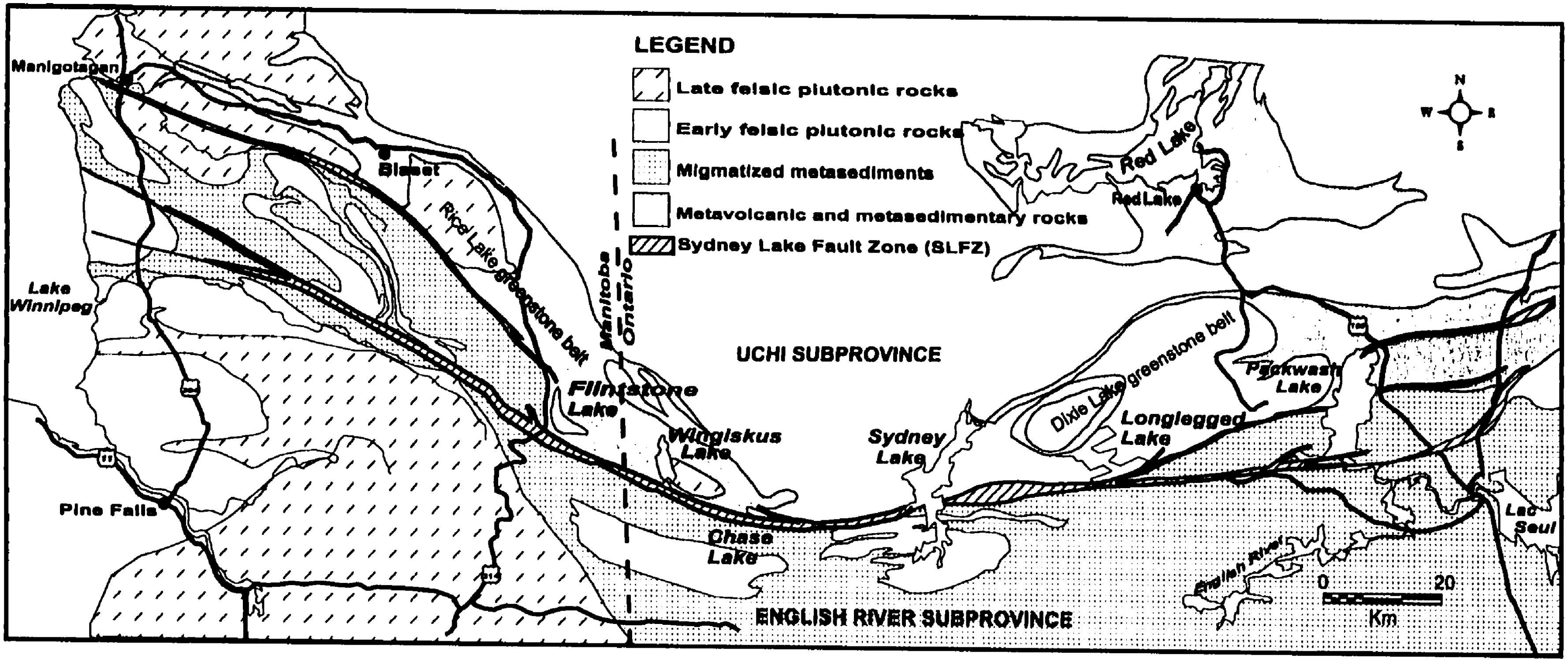


Figure 2. The regional setting of the Sydney Lake Fault Zone (modified from Stone 1980).

degradation of the flanking greenstone belts and rocks of the Wabigoon subprovince (Beakhouse 1985). A more recent study by Davis & Corfu (1990) suggests, from detrital zircon grain ages, that quartzite units within greenstone belts of the Uchi and Sachigo subprovinces were derived locally rather than from multiple cratonic sources. The English River metasediments to the south may have been deposited in a more distal environment (Ojakangas 1985).

The Uchi subprovince has been interpreted as a remnant of a deformed linear volcanic island chain, consisting of an early oceanic phase in an arc and/or back-arc environment, followed by an orogenic phase (Wilson *et al.* 1965, Ayres 1978, Stott & Corfu 1991, Davis *et al.* 1994). The southern part of the Uchi subprovince is characterized by the episodic addition of crustal units during compressional events of the Kenoran orogeny, approximately 2,700 Ma, and spanning a time period of over 300 my (Stott & Corfu 1991, Corfu & Stott 1993).

Large synclinal structures in the Uchi subprovince are comprised of upright, gently plunging, isoclinal folds which are concentrated near plutons and the subprovince boundary (Stone 1981, Stott & Corfu 1991). The generally steep foliation and shallow, east plunging lineation in the greenstone belts parallel the upright folds (Corfu *et al.* 1995). The upright folds are interpreted to be the result of refolded early, steeply plunging folds (Stott & Corfu 1991). The early subhorizontal major folds may have been initiated by subsidence during volcanism.

Overturned and possibly recumbent folds of the English River subprovince were produced either by diapiric compression due to the intrusion of domical bodies of tonalite-granodiorite and later granodiorite-quartz monzonite batholiths, or by regional orogenic shortening (Ramsay 1975, Thurston & Breaks 1978, Schwerdtner *et al.* 1979, West 1980, Beakhouse *et al.* 1983, Ayres & Thurston 1985, Stott & Corfu 1991). Some workers suggest that the tightening of the synclines was due to the growth of diapirs rather than the emplacement of granitic batholiths. The upper part of the sequence would, therefore, have been subjected to horizontal compression (Schwerdtner *et al.* 1978, Krogh *et al.* 1984, Ayres & Thurston 1985). Others workers hold that the deformation of greenstone may be due to horizontal stress unrelated to diapirism (Ayres & Thurston 1985).

The English River subprovince, characterized by high metamorphic grades, narrows from 50km wide at its east and west ends to 1.5km in its central region (Goodwin 1978, Breaks & Bond 1993). It extends for approximately 800 km from Lake Winnipeg to the Paleozoic sediments to the east (Figures 1, 2). The English River subprovince has been interpreted to represent a linear turbidite basin which developed between two volcanic island chains, the Uchi and Separation Lake belts, spanning at least 500 Ma (Ayres 1978, Beakhouse 1985, Breaks & Bond 1993, Davis *et al.* 1994). The metasediments may unconformably overlie the orthogneisses of the Winnipeg River subprovince (Harris and Goodwin 1976) and therefore represent a sedimentary basin between the Uchi and Wabigoon subprovinces (Ayres 1978). The sediments underwent little chemical alteration prior to metamorphism and the provenance of the detrital material was interpreted to be dacitic volcanics (Van de Kamp & Beakhouse 1979). Work by Davis *et al.* (1988) suggests, from zircon ages, that the sediments were at least partly derived from older material within the English River subprovince itself, and that the overlying calc-alkaline volcanic sequences are at least 30Ma older.

Two domains were formerly distinguished in the English River subprovince, the northern supracrustal and the southern plutonic domains. It was later subdivided into the English River, Winnipeg River and Bird River subprovinces (Breaks & Bond 1993). The northern domain (English River subprovince proper) is dominated by wacke-pelite metasedimentary rocks and derived migmatites interrupted by numerous intra-belt granitoid stocks and batholiths

(Beakhouse 1977, Breaks *et al.* 1978, Beakhouse 1985, Breaks & Bond 1993). Metasediments near Ear Falls and Manigotagan are mainly of volcanic origin and could be equivalent to the metavolcanics of the Uchi subprovince (van de Kamp 1973, Beakhouse 1974b, Breaks & Bond 1977). To the south, the southern domain (Winnipeg River subprovince) is underlain mainly by granitic intrusive rocks (Breaks & Bond 1993). The northeast striking Miniss River fault, with a dextral strike slip component of approximately 10 km, only partly follows the boundary between the English River and Winnipeg River subprovinces. The boundary is based on the southward disappearance of metasedimentary units against granitic intrusion (Breaks & Bond 1993).

1.2.2 The Rice Lake greenstone belt (Bee Lake belt)

The ESE-WNW trending Rice Lake greenstone belt, located in the Uchi subprovince, extends southeast from Lake Winnipeg in Manitoba to the Chase Lake area in Ontario (Figure 2). The Rice Lake belt is thought to have experienced subhorizontal regional shortening caused by a northwest axis of transpression (Stott & Corfu 1991). The structure of the Rice Lake belt was originally interpreted as a synclinal or steeply-dipping monoclinal succession produced by syntectonic intrusion (Gilbert 1927, Shklanka 1967). Other structural interpretations include a southeastward-plunging, generally northward dipping antiformal syncline and an antiformal fragment of a nappe (Weber 1971a, Thurston & Breaks 1978, Stott & Corfu 1991).

Widespread felsic magmatism occurred during the Kenoran Orogeny, between 2,710 - 2,690Ma and is represented by granodiorite bodies (Figure 2). The Rice Lake belt contains a central quartz diorite pluton called the Ross River pluton. Pre-tectonic basic intrusions have also been identified and may correspond to pre-Kenoran orogenic events (Shklanka 1967, Stott &

Corfu 1991). Quartz monzonite bodies in the Chase Lake area appear to be late or post-tectonic (Shklanka 1967).

The deposition of strata preserved in the Rice Lake belt is thought to have taken place within a basin of volcano-tectonic origin (Shklanka 1967). The sedimentary rocks have a dominantly granodioritic source area (Shklanka 1967). The stratigraphic sequence thickens from east to west and is comprised of interbedded basic to acid volcanic flows, pyroclastics and sediments metamorphosed to the greenschist and amphibolite grades, and contains numerous lateral facies changes (Shklanka 1967, Stott & Corfu 1991). On the basis of age, the rocks of the Rice Lake belt are put into the Confederation assemblage (Beakhouse 1985). The Rice Lake belt is part of the Rice Lake group, and is further subdivided into the Bidou Lake and Gem Lake subgroups (Stott & Corfu 1991).

The Rice Lake greenstone belt is pervaded by west-northwest folds and axial plane schistosity, parallel to the elongation of the belt (Shklanka 1967). Top directions point toward the southeast, indicating that the youngest rocks are located in the southern part of the belt (Shklanka 1967, Thurston & Breaks 1978, Stott & Corfu 1991). The southern boundary of the greenstone belt is marked by zones of mylonitization (Turek *et al.* 1989). Scattered volcanic remnants occur near, or along the junction between, the Uchi and English River subprovinces (Breaks *et al.* 1978).

Based on detailed structural mapping, I have outlined in *Chapter IV* two kinematic scenarios to account for the structure of the Chase Lake area. In the first scenario, an overturned tight anticline is refolded by a second fold. The second scenario envisages NW-SE dislocations along the south shore of Chase Lake and along Midway Lake.

1.2.3 The Dixie Lake greenstone belt

The Dixie Lake greenstone belt, composed of mafic to intermediate volcanic flows, branches into several arms which extend from a central mass (Figure 2). Two isolated remnants of greenstone are located at Longlegged Lake and probably represent a relict of an originally larger Dixie Lake greenstone belt (Breaks & Bond 1993). The Longlegged Lake dome, located in the center of the Dixie Lake greenstone belt (Figure 3) is composed of a metamorphosed, weakly to moderately foliated, tonalite and granodiorite (Muir 1991, Breaks & Bond 1993). The Dixie Lake belt is separated from the Red Lake belt by the granite and quartz monzonite Gullrock Lake batholith (Muir 1991).

1.2.4 The Sydney Lake Fault Zone

The arcuate Sydney Lake Fault Zone (SLFZ) coincides with a strip of mylonitic rocks between the Uchi and English River subprovinces (Figures 1, 2). The dip of the fault zone remains to be determined by geophysical methods. The SLFZ extends for approximately 250 km eastward from Lake Winnipeg into Ontario and may be connected with the Lake St. Joseph fault. According to Stone (1980), the SLFZ is finite and splays near its ends. The fault splays are characterized by a combination of abrupt, faulted contacts of metavolcanics of the Uchi Subprovince and the migmatites of the English River subprovince (Breaks & Bond 1993). The arcuate SLFZ changes strike by approximately 80° between its termini, and is regarded as a late fault system whose development may have been guided by the change in lithology at the subprovince boundary (Breaks *et al.* 1978, Stone 1980, Breaks & Bond 1993). The SLFZ, approximately 1-2 km wide, was active from 2.685 to 2.665 Ga and consists of mylonitic, protomylonitic and cataclastic rocks (Stone 1977, 1980, Breaks *et al.* 1978, Breaks & Bond 1993). The mylonitization in the most prominent segment of the SLFZ, between the Ontario/Manitoba border and Sydney Lake, was most severe at the contact between the English River metasediments and the Uchi metavolcanics or granitic rocks (Stone 1980).

Stone (1980) found evidence of 30 km strike slip and 2.3 km dip slip in the Sydney Lake area. McRitchie and Weber (1971) documented, south of Wanipigow Lake in Manitoba, a 16 km dextral displacement of a quartz diorite unit by the fault zone. South of Red Lake, Stone (1980) documented a minimum of 27 km dextral displacement and 4 km vertical displacement (Thurston & Breaks 1978). Within the SLFZ horizontal slickensides, mineral lineation, Z-folds, isolated feldspar, offset features and porphyroclasts with sigmoidal tails support a right-handed horizontal displacement (Breaks *et al.* 1978, Stone 1980). On a regional scale, two rock units of the Uchi subprovince were traced into the SLFZ (Stone 1980). The first unit is the Pineneedle Lake pluton near Longlegged Lake. The second is a metavolcanic unit, in the Chase Lake area, interpreted by Stone (1980) to have been buckled then abruptly caught, folded back and attenuated by the fault. The unit was recognized 6 km to the west of where it initially entered the SLFZ and it was suggested that the displacement was due to simple shear that produced a minimum dextral displacement of 6 km (Stone 1977, Breaks *et al.* 1978). Other faults in the Uchi subprovince, for example the Wanipigow fault at Rice Lake in Manitoba, also show evidence of dextral displacement. Lineation trends deflect towards parallelism and plunge magnitudes decrease as the Wanipigow fault is approached from the south. The pattern of lineation and the steepening of foliation suggests that the fault is a dextral transcurrent structure, assuming that the fabrics predate and were originally oblique to the Wanipigow fault (McRitchie 1971, Poulsen *et al.* 1986).

Near the English River and Uchi subprovince boundary, the mineral lineation is typically steep on schistosity planes, but is shallow in the SLFZ and the Lake St. Joseph fault. The orientation of the lineation in the fault zone is parallel to the predominent lineation and fold axes in the English River subprovince. The lineation has been interpreted by previous workers to have evolved during the late Kenoran transpression by orogen-parallel displacement of ductile rock (Stott & Corfu 1991, Thurston *et al.* 1991).

Structural evidence accumulated by previous workers points to a change from dip shear to strike shear tectonics (Stone 1980). Stone (1980) suggests that the SLFZ first formed in the region of the mid segment and then propagated and curved under the influence of a northwesterly regional compression and the anisotropy of the rock. Accordingly, flattening (pure shear) dominated at the northeast segment of the SLFZ while the western segment was dominated by simple shearing. The obliquity of cataclastic foliation, Z-folds and rigid feldspar crystals supports the notion of clockwise rotation in the western segments of the SLFZ. A plane of flattening for the northeast section was deduced from the attitude of lithological contacts trending at high angles to mylonitic foliation, slickensides that are poorly developed, cataclastic foliation which is generally parallel to the trend of the fault and dominantly M-folds (Breaks *et al.* 1978). A 20% decrease in volume of the fault rocks, calculated by analyzing the strain and rock fabrics, resulted from simple flattening and is thought to have occurred during the early stages of deformation (Stone 1980). The above evidence suggests that the SLFZ was formed by a northwesterly regional compression (Breaks *et al.* 1978, Breaks & Bond 1993, Corfu *et al.* 1995).

Pseudotachylite is observed in the youngest shears in the SLFZ (Breaks *et al.* 1978) and has been dated at 2,183+/-74 Ma, much younger than the proposed age of the SLFZ at approximately 2,690Ma (Kamineni *et al.* 1990, Breaks & Bond 1993). Pseudotachylite is known to be typically confined to upper levels of a fault system (Sibson 1977, Grocott 1977) and tends to develop more readily in metawackes, granitoid gneisses and homogeneous diatexites (Breaks & Bond 1993). In the case of the SLFZ, the pseudotachylites may represent later Proterozoic reactivation signifying a change to brittle dextral sense faulting (Breaks & Bond 1993). In the English River subprovince, pseudotachylites developed in the fault systems post-date the mylonitic foliation (Breaks & Bond 1993).

1.3 Geophysical information

For the Red Lake region, results of several geophysical surveys have been published (seismic work by Hall and Hajnal 1968; gravity work by Barlow *et al.* 1976, Gupta and Wadge 1978, Runnals 1978, Hall and Brisbin 1982; and paleomagnetics by Khan 1982). In recent years the Western Superior Transect (WST) LITHOPROBE made preliminary refraction seismic studies along the Red Lake road and will undertake electromagnetic and vibroseismic surveys.

On the northern edge of the English River subprovince seismic data lend support to models of a two-layer crust. Accordingly, the greenstone belts are underlain by a thick upper crustal unit while the lower crust is attenuated. Seismic gradients are steep at the margins of the English River subprovince and the total crust is thinnest at the Uchi-English River subprovince boundary (Hall 1971, Beakhouse 1977, Stone 1977, Breaks & Bond 1993).

The Uchi subprovince is characterized by belts of supracrustal rocks which surround oval-shaped batholiths. This is the widely known granitic-greenstone pattern well imaged on aeromagnetic maps (Wilson 1971, Ermanovics & Froese 1978). Gravity highs (positive anomalies) occur over greenstone belts and are associated with high density mafic flows and terranes of lowest metamorphic grade. Gravity lows (negative anomalies) occur in the surrounding granitic rocks (Thurston & Breaks 1978, Gupta & Wadge 1986). The English River subprovince is characterized by a linear aeromagnetic pattern (Ermanovics & Froese 1978). Gravity values are high and exhibit an uniform, linear, east-west trend parallel to the subprovince boundaries. Diatexites concentrated in the SLFZ exhibit the least magnetic noise and therefore the SLFZ appears as a weak, magnetic high (Breaks & Bond 1993). Ovoid magnetic anomalies occur at the Sydney Lake - Rainfall Lake dome and Longlegged Lake dome (Breaks & Bond 1993).

Gravity contours are strongly aligned parallel to the SLFZ. A gravity survey done in Manitoba by Hall and Brisbin (1982) revealed that the plutonic-greenstone contacts observed at the surface extend to depths of 5-6 km. They also suggest that a belt of surface magnetization lies along the southern boundary of the Uchi subprovince.

Pole positions were calculated in a paleomagnetic study by Khan (1982) in the Uchi and English River subprovinces. A comparison was made between the paleomagnetic pole positions with the results of published paleomagnetic poles deduced from rocks of similar age in the Canadian Shield. The study showed that samples collected along the highway to Red Lake have an apparent polar wander path (APWP) which coincides with published poles (2580, 2650, and 2680 Ma are suggested ages from post-orogenic felsic plutons, metasediments/gneisses and metavolcanics, respectively). Therefore, the magnetization of the rocks from the English River subprovince was probably acquired during the cooling phase of the Kenoran orogeny. Any primary magnetization was most likely reset and overprinted by the metamorphic event which occurred at approximately 2680 Ma (Fahrig & Chown 1973, Khan 1982).

Two-dimensional gravity modelling was undertaken by Runnals (1978) using a Bouguer gravity anomaly map of the Red Lake region obtained from a detailed gravity study in 1975-76 (Figure 3, Gupta & Wadge 1986). A vertical second derivative map of the gravity field was used in the geological interpretation of the data. Quantitative 2D modelling of the graphically smoothed residual gravity field was carried out in various profiles in the Longlegged Lake area (see profile A, B, B1 in Figures 3, 4).

Profile B (Figure 3) transects the Longlegged Lake sliver and the SLFZ. The gravity field increases toward the English River subprovince and reflects steep gradients at the subprovince boundary, coinciding with the SLFZ (Gupta & Wadge 1986). In the vicinity of the SLFZ, Runnals (1978) obtained a model dip of the subprovince boundary of 30° south. He called it "a shoulder" to the English River subprovince basin which extends to a depth of approximately 4km. A few kilometres to the south of the SLFZ the main structure dips 77° to the south to a depth of approximately 12 km (Runnals 1978, Gupta & Wadge 1986).

Profile A and B (Figure 4a & b) illustrate the trend of the subprovince boundary (north is on the left of the diagram and south to the right). Mean sampled density of the granitic-migmatite-metasedimentary trough of the English River subprovince is 2.72 Mgm^{-3}, felsic metavolcanics are 2.62 - 2.76 Mgm^{-3}, intermediate metavolcanics are 2.67 - 2.90 Mgm^{-3}, and mafic to intermediate metavolcanics are 2.71 - 3.28 Mgm^{-3} (Runnals 1978, Gupta & Wadge 1986). The midpoint of the profile shows a 30° southerly dipping boundary between the English River and Uchi subprovinces. A few kilometres to the south the model boundary has a steep southerly dip. The 2D modelling also indicates that the greenstone belts generally have a broad basin-like shape, with 2.3 km thickness of the Dixie Lake belt and a 4 km thickness of the Red Lake belt. In the Red Lake belt, the bottom topography of the gravity models sometimes reflects typical synclinal, anticlinal or homoclinal structures whose vertical projection onto the surface

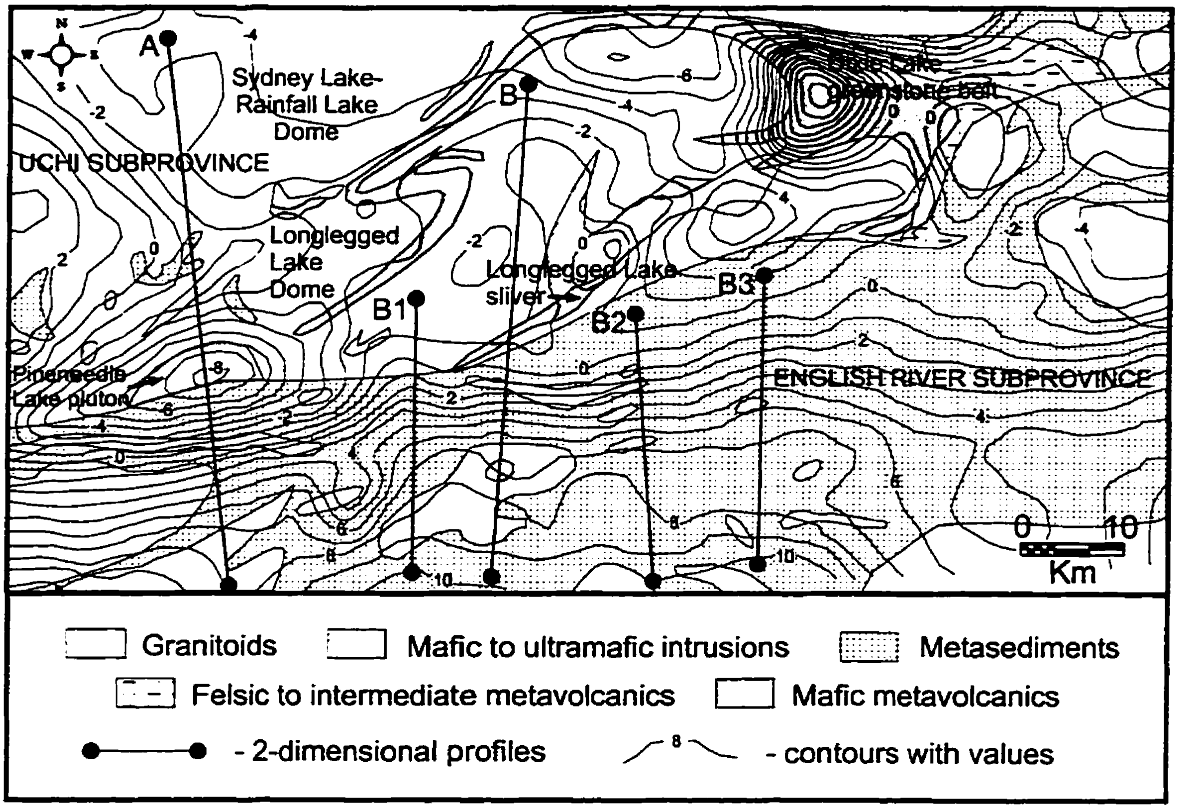
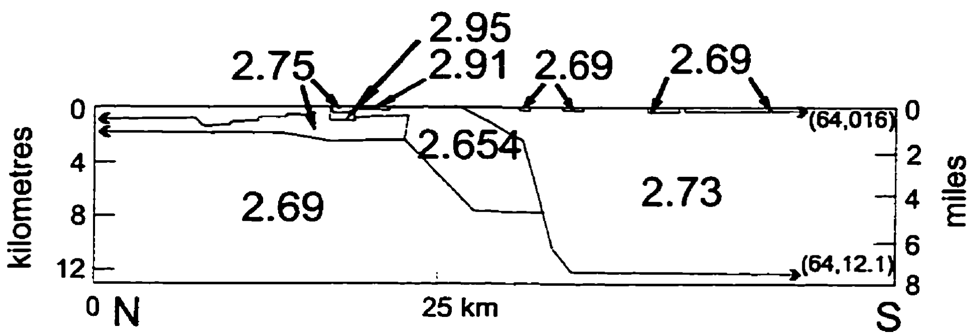
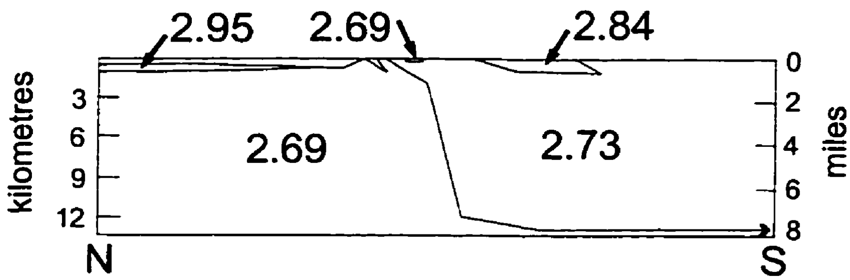


Figure 3. Geological compilation map and filtered Bouger map, showing 2-dimensional profiles used in modeling of the Dixie and Longlegged Lake areas. Residual between 0.6km and 16.1km upward continued maps. Contour interval 1mgal (modified from Runnalls 1978).



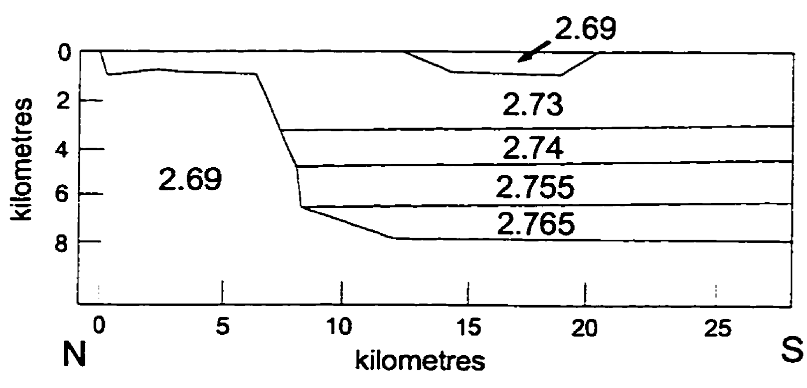
Profile A Baselevel - 6.5 mgal

(a)



Profile B Baselevel - 6.5 mgal

(b)



(c)

Figure 4. Two dimensional gravity modeling of the Uchi and English River subprovinces from profile A, B, and averaged profile of profiles B1,B2,B3 located in Figure 3 (modified from Runnalls 1978).

coincide with mapped structures. The modeling suggests that most granitic batholiths are relatively thin, sheet-like, or flat sill-like, usually between 4-7 km depth extent (Gupta & Wadge 1986).

The quartz monzonitic Pineneedle Lake pluton, located north of the SLFZ and east of Longlegged Lake (Figure 3), underlies the northern edge of the migmatites and follows the southerly dip of the boundary. The pluton extends south of the SLFZ to the west and is interpreted as evidence for dextral strike slip movement (Runnals 1978).

1.4 Age dates in the northwestern Superior province

The Rice Lake group, in the Uchi subprovince, has been dated at 2,445 and 2,435 Ma (Turek *et al.* 1989). The Ross River pluton, which intrudes the Rice Lake belt in Manitoba, yields an age of 2,728+/-8 Ma (Turek *et al.* 1989). By K-Ar methods, the granitic rocks that intrude the Rice Lake group have been dated at 2440 and 2670 Ma (Lowdon 1961, 1963). These age dates have been interpreted to correspond to the main period of metamorphism and intrusion in the Kenoran orogeny (Shklanka 1967). In Manitoba, Ermanovics & Wanless (1983) obtained U-Pb zircon ages of 2,900 to 3,000 Ma for early periods of plutonic activity and 2,715 to 2,735 Ma for a later period of volcanism and granitic intrusion. A Rb-Sr whole rock age of 2,674 Ma was obtained from a sample that yielded a zircon age more than 200 Ma older (Ermanovics & Wanless 1983).

In the English River subprovince the oldest rocks from the Lac Seul area occur in the Sen Bay plutonic gneisses, which have been dated at 3.0-3.1 Ga by Rb-Sr methods (Wooden & Goodwin 1980). Trondhjemitic-granodioritic gneisses have been dated at 2,780+/- 90Ma and granodioritic to granitic dykes and plutons were intruded between 2,660-2,560 Ma (Wooden &

Goodwin 1980). In the Miniss Lake area, an amphibolite unit was dated at 2,692+/-2 Ma.

Hanes *et al.* (1997) are currently determining 40Ar/39Ar curves to unravel the post-orogenic tectonothermal histories. Their study indicates that biotite age dates decrease toward the subprovince boundary with plateau dates of 2,480 Ma, while muscovite from the SLFZ yields dates between 2,455 and 2,490 Ma. "The biotite data imply uplift of the English River subprovince relative to the Uchi Subprovince ≤2,600 Ma" (Hanes *et al.* 1997).

Figure 5 shows the distribution of the dominant volcanic ages in the northwestern Superior province, modified from Thurston (1994). Age dates for the Chase Lake and Longlegged Lake areas are shown to be approximately 2,730 to 2,800 Ma for metavolcanic and plutonic rocks and 2,690 to 2,710 Ma for metasedimentary rocks (Stott & Corfu 1991). Felsic volcanic rocks in the Red Lake belt have been dated at 2,982, 2,830, 2,739 and 2,733 Ma (Thurston *et al.* 1981, Corfu and Wallace 1985, Wallace *et al.* 1986).

1.5 Metamorphic zones in the Uchi and English River subprovinces

Figure 6 illustrates the generalized distribution of the metamorphic zones in northwestern Ontario, modified from Thurston & Breaks (1978). A "jump" in metamorphic grade occurs across the subprovince boundary from low to medium grade rocks of the Uchi subprovince to medium to high grade rocks of the English River subprovince (Dwibedi 1966, McRitchie & Weber 1971, Jones 1973, Thurston & Breaks 1978, Breaks *et al.* 1978, Ermanovics & Froese 1978, Stone 1980, Breaks & Bond 1993).

The English River subprovince represents a deeper crustal level than the adjacent greenstone-granodiorite subprovinces (Ayres 1978). Kenoran migmatization occurred 2.6 Ga at

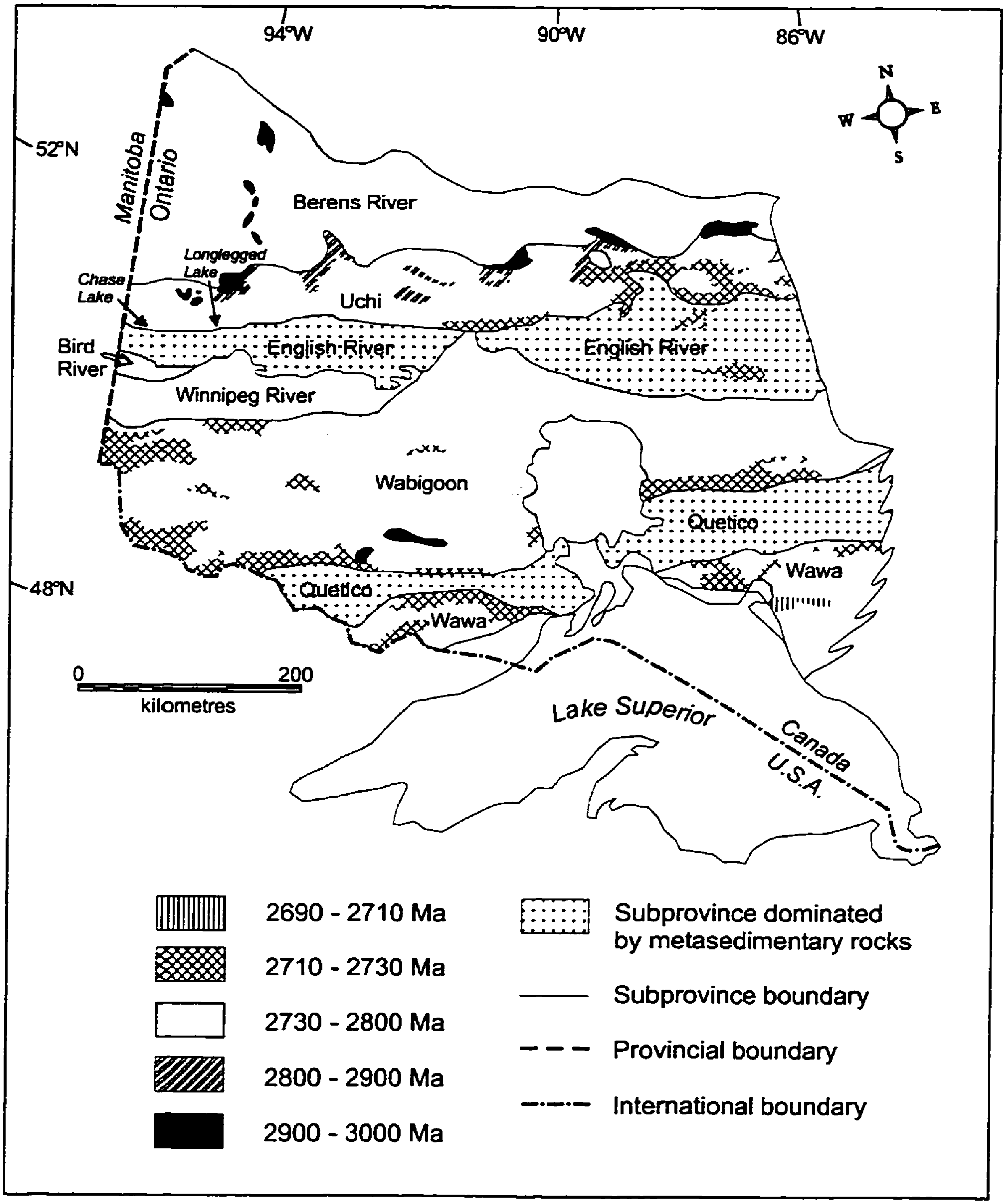


Figure 5. Dominant volcanic ages in the Superior Province in northwestern Ontario (modified from Thurston 1994).

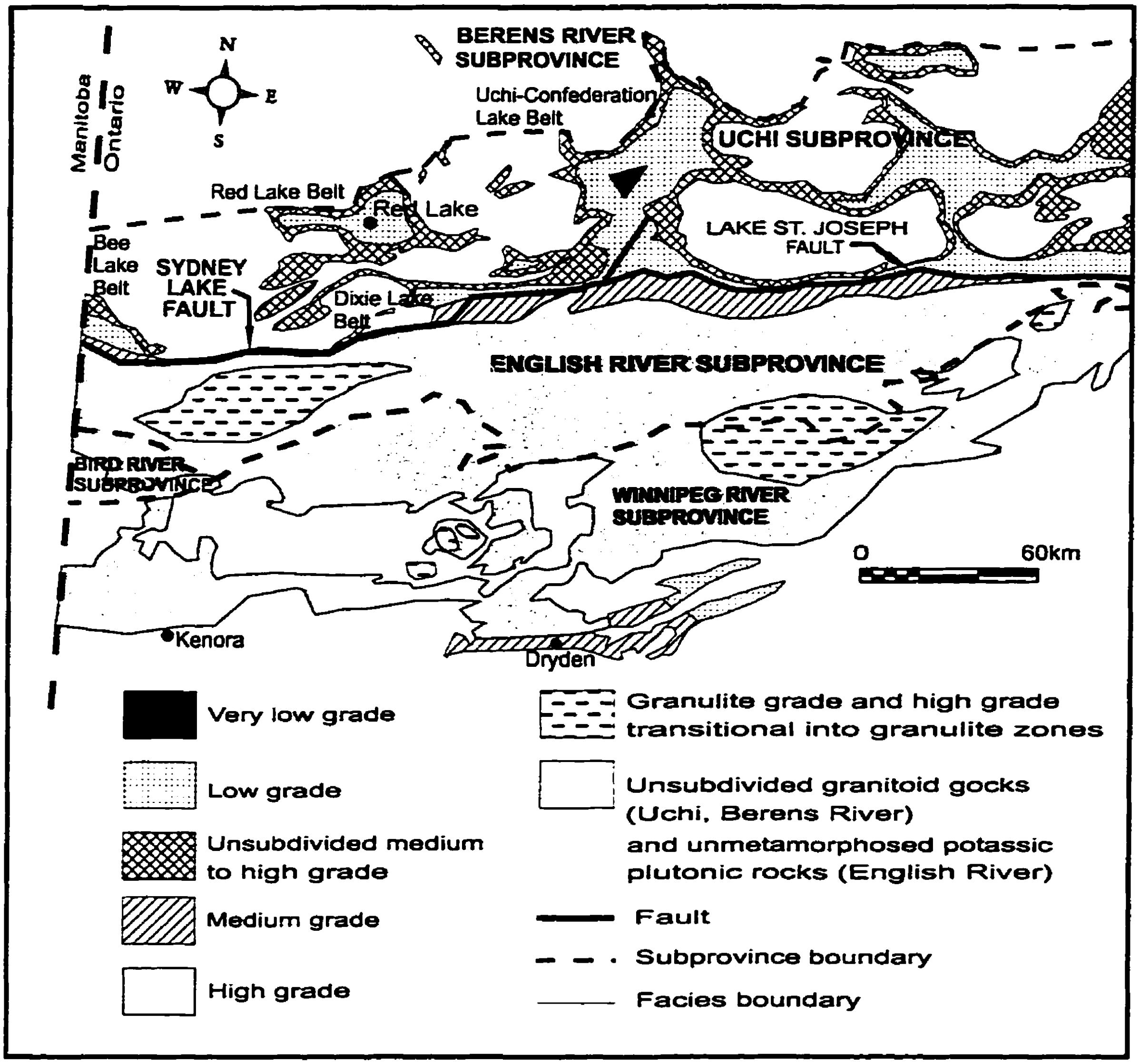


Figure 6. Generalized distribution of metamorphic zones within the English River, Uchi and Winnipeg River subprovinces (modified from Thurston & Breaks 1978).

low pressures of 0.4 to 0.6 GPa and temperatures that reached the granulite facies at a peak of 725°C (Corfu *et al.* 1995). The migmatization is coeval with the development of the main rock fabric throughout the subprovince. The greenstone-granite terrains did not reach high metamorphic grade, yet, metamorphism destroyed most primary structures except possibly for bedding (Corfu *et al.* 1995).

Chipera and Perkins (1988) found a "thermal anticline" preserved in the rocks of the English River subprovince. Temperatures of approximately 600°C occurred at the boundaries of the Uchi and Winnipeg River subprovinces and increased to approximately 725°C at the centre of the subprovince. At 650°C a garnet-cordierite 'in' isograd occurs and an Opx 'in' isograd occurs at approximately 700°C (Chipera & Perkins 1988).

An explanation for the discontinuity in metamorphic grade across the subprovince boundary is an uplift of the English River rocks in relation to the Uchi rocks (Breaks & Bond 1993). A block faulting model was originally developed to explain the rapid increase in metamorphic grade at the boundary, but, the model is too simplistic (Wilson 1971, McRitchie & Weber 1971). The English River and Uchi rocks are found to interleave in several localities along the SLFZ (Breaks & Bond 1993).

1.6 The tectonic history of the Uchi, English River and Winnipeg River subprovinces

Schwerdtner *et al.* (1979) recognized two possible overlapping periods of tectonic deformation, vertical and horizontal motion tectonics. The first period of tectonic deformation was thought to be related to the development of gigantic diapirs. The diapirs were responsible for the major folds within the greenstone belts. The second period of deformation was related to the northwest regional compression which developed major transcurrent faults and large-scale dextral shearing. Schwerdtner *et al.* (1979) also suggested that strike-slip faulting outlasted late plutonism leading to mylonitic zones which cut the Archean granitoid plutons.

A thrust hypothesis accounts for the "jump" in metamorphic grade across the subprovince boundary and the interleaving between English River migmatites and Uchi metavolcanics. Interleaving occurs, for example, in the Slate Lake-Papaonga Lake area of intermediate metavolcanics with English River subprovince metasediments (Breaks & Bond 1993). Another example occurs in Manitoba between the Rice Lake group and the Manigotagan Gneiss belt (Campbell 1971, Breaks & Bond 1993). Also, lenticular masses of Uchi subprovince metavolcanics occur as islands within the English River subprovince. (A short distance south of the boundary, at Otatakan and Whitemud Lakes, a thin metavolcanic unit is isolated in the English River subprovince (Breaks & Bond 1993)). The dextral Lake St. Joseph fault to the east is also discontinuous in places (Breaks & Bond 1977). The above evidence points to a structural connection between the two subprovinces (Breaks *et al.* 1978, Breaks & Bond 1993, Corfu *et al.* 1995), and agrees with the notion that the SLFZ and the Lake St. Joseph fault did not create the subprovince boundary and are not responsible for the change in rock types across the boundary (Schwerdtner *et al.* 1978, Stone 1980). Schwerdtner *et al.* (1979) also suggest that the structure of the Uchi subprovince had been established by the time of the onset of the SLFZ. However, they held that the SLFZ distorted the major folds in the greenstone belts and cut various massive plutons.

Northwest-southeast compression plays a large role in recent scenarios of the tectonic evolution of the subprovinces in the northwestern Superior province. Some workers suggest that at ~2,750 to 2,720 Ma, major arc magmatism occurred in the Uchi subprovince and, at ~2,710 Ma late stage volcanism in the Uchi subprovince was coincident with folding and thrusting and also with sedimentation of the English River subprovince (Corfu *et al.* 1995). At 2,700 Ma an extensive plutonic event occurred in all of the subprovinces. A modified diagram (Figure 7) from Corfu *et al.* (1995) depicts the evolution of the Wabigoon, Winnipeg River, English River and Uchi subprovinces at 2,690 Ma. It illustrates a high grade metamorphic event in the English River subprovince which was coeval with dextral shearing of the Sydney Lake fault zone at the subprovince boundary. Further compression led to continued faulting and thrusting throughout the subprovinces. A rapid transition from sedimentation to high-grade metamorphism occurred in the English River subprovince spanning 20 to 30 my. Migmatite and fabric development occurred at about 2,691 Ma for a brief time (Corfu & Stott 1993, Corfu *et al.* 1995).

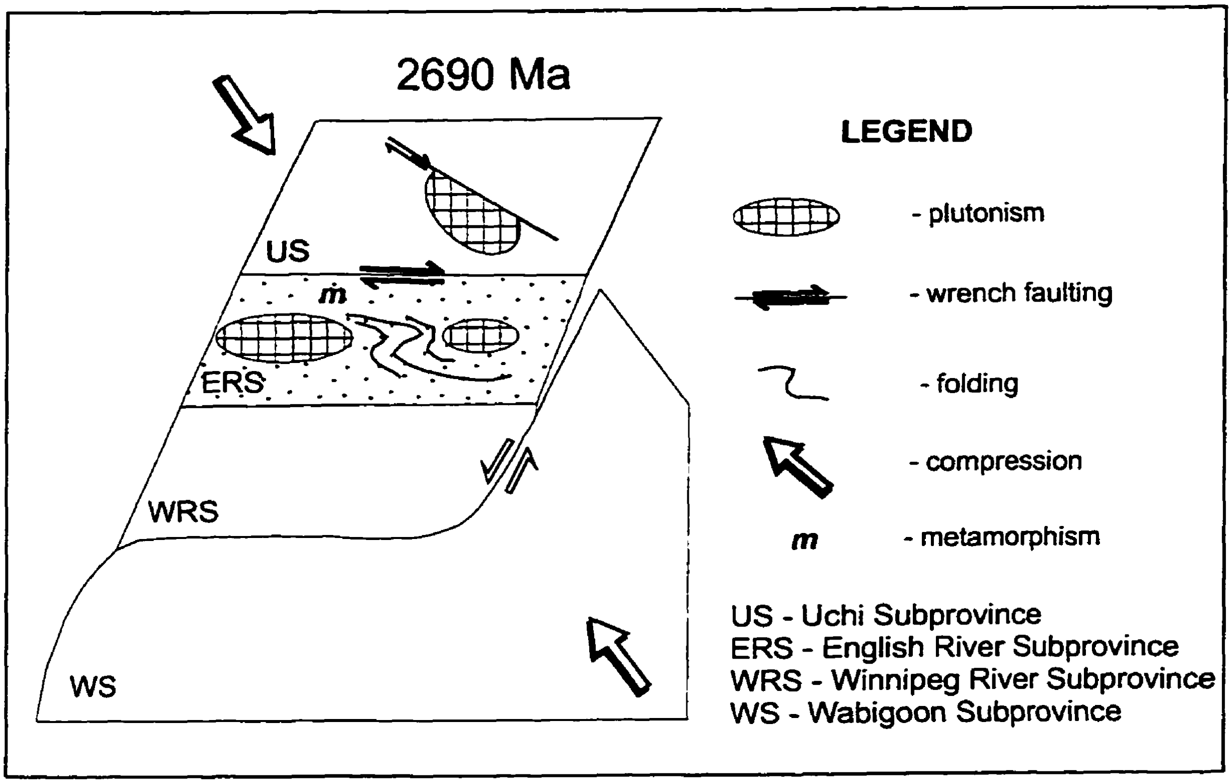


Figure 7. High-grade metamorphism in the English River Subprovince was coincident with migmatization and coeval with dextral movement at the Uchi-English River subprovince boundary at 2690Ma. Indentation of the Wabigoon-Winnipeg River superterrane into central English River subprovince (modified from Corfu et al. 1995).

CHAPTER II

LITHOLOGY AND STRUCTURAL MAP PATTERN

II. LITHOLOGY AND STRUCTURAL MAP PATTERN

2.0 Introduction

The present chapter describes lithological units found in the Chase Lake and Longlegged Lake areas. Knowledge of the areal distribution of different rock types is essential for understanding the kinematic history of the area.

The Rice Lake greenstone belt (Figure 2) in the Chase Lake area consists of mafic to intermediate metavolcanics, reworked felsic to mafic metavolcanics, metawackes, migmatites and quartz monzonite (Figure 8). The stratigraphic sequence consists of a basal mafic flow and overlying felsic and pyroclastic extrusions (Stone 1980). The mafic metavolcanic unit grades laterally into metawackes which are thought to be part of the English River subprovince metasediments (Stone 1980).

In the Chase Lake area, a main mafic metavolcanic unit, now largely amphibolite, is represented by a unit to the north of Chase Lake while a smaller unit is located south of Chase Lake (Figure 8). Both units are sandwiched by intermediate metavolcanic units consisting of reworked tuffs and tuff breccias. Reworked felsic to intermediate tuffs and tuff breccias occur north of the main mafic metavolcanic unit, between Chase and Eagle Lakes. Metawackes occur to the south of the main mafic metavolcanic unit, in the core of the Oiseau River synform, between the mafic metavolcanic units and on the south shore of Eagle Lake. A quartz monzonite pluton occurs in the western portion of the map between the mafic metavolcanics and metawackes, most of it in the area occupied by the map legend (Figure 8). Another quartz monzonite pluton is hosted by the mafic metavolcanic unit east of Chase Lake. Metatexitic and diatexitic metasedimentary migmatites are restricted to the east side of Chase Lake and to the

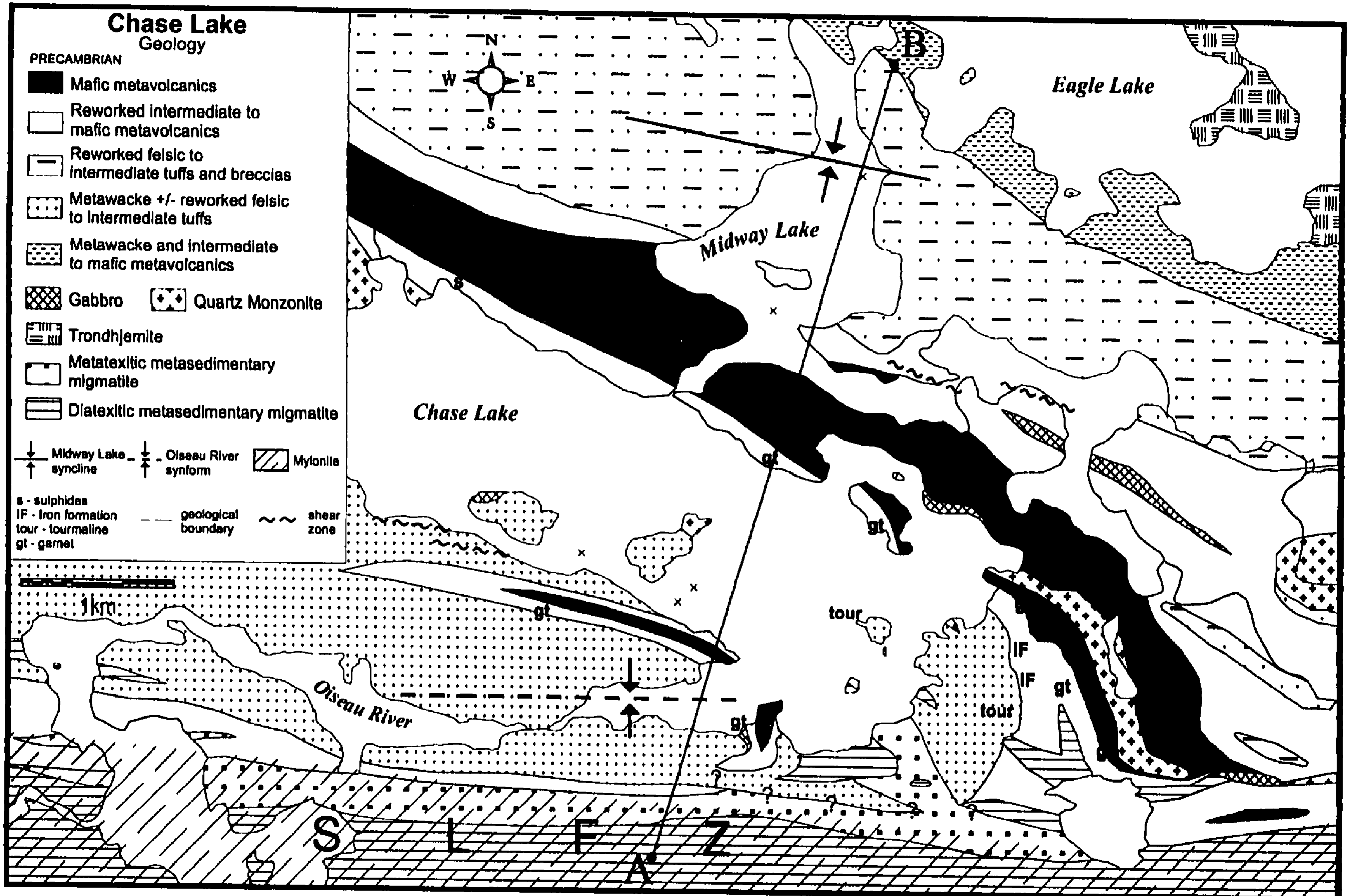


Figure 8. Geological map of the Chase Lake area, southeast Rice Lake greenstone belt. A-B is the trace of the vertical cross section (modified from Shklanka 1967, Breaks et al. 1978, Stone 1980).

south in the SLFZ and English River subprovince (Figure 8). The SLFZ is located at the southern portion of the map and consists predominantly of mylonitized metasedimentary migmatites and intermediate to mafic metavolcanics.

The Dixie Lake greenstone belt in the Longlegged Lake area (Figure 2), consists of mafic to intermediate pillows and flows, intermediate to felsic tuffs and breccias, and minor metawacke (Figure 9). The Longlegged Lake greenstone sliver, part of the Dixie Lake belt, has a northeasterly strike length of 15 km and a NW-SE width of ½ km to 1 km. Quartz monzonite, trondhjemite and gneissic trondhjemite occur to the north of the metavolcanic sliver, while diatexitic and metatexitic metasedimentary migmatites and trondhjemite occur to the south.

The SLFZ splays in the southwest portion of the metavolcanic sliver. One arm of the SLFZ follows the southern boundary of the Uchi subprovince metavolcanics and the English River subprovince migmatites. The main zone follows the east-west strike of the migmatites in the English River subprovince. The migmatites and metavolcanics in the SLFZ are typically mylonitic, protomylonitic and cataclastic.

The lithologic units in both the Chase and Longlegged Lake areas are detailed in the following sections, with an emphasis on the geology of individual outcrops. Examples are given and can be located by their station location number on a measurement station map of the Chase and Longlegged Lake areas in Appendices A.1 and B.1 (e.g. Station 2, A.1 = Appendix A, map 1, number 2).

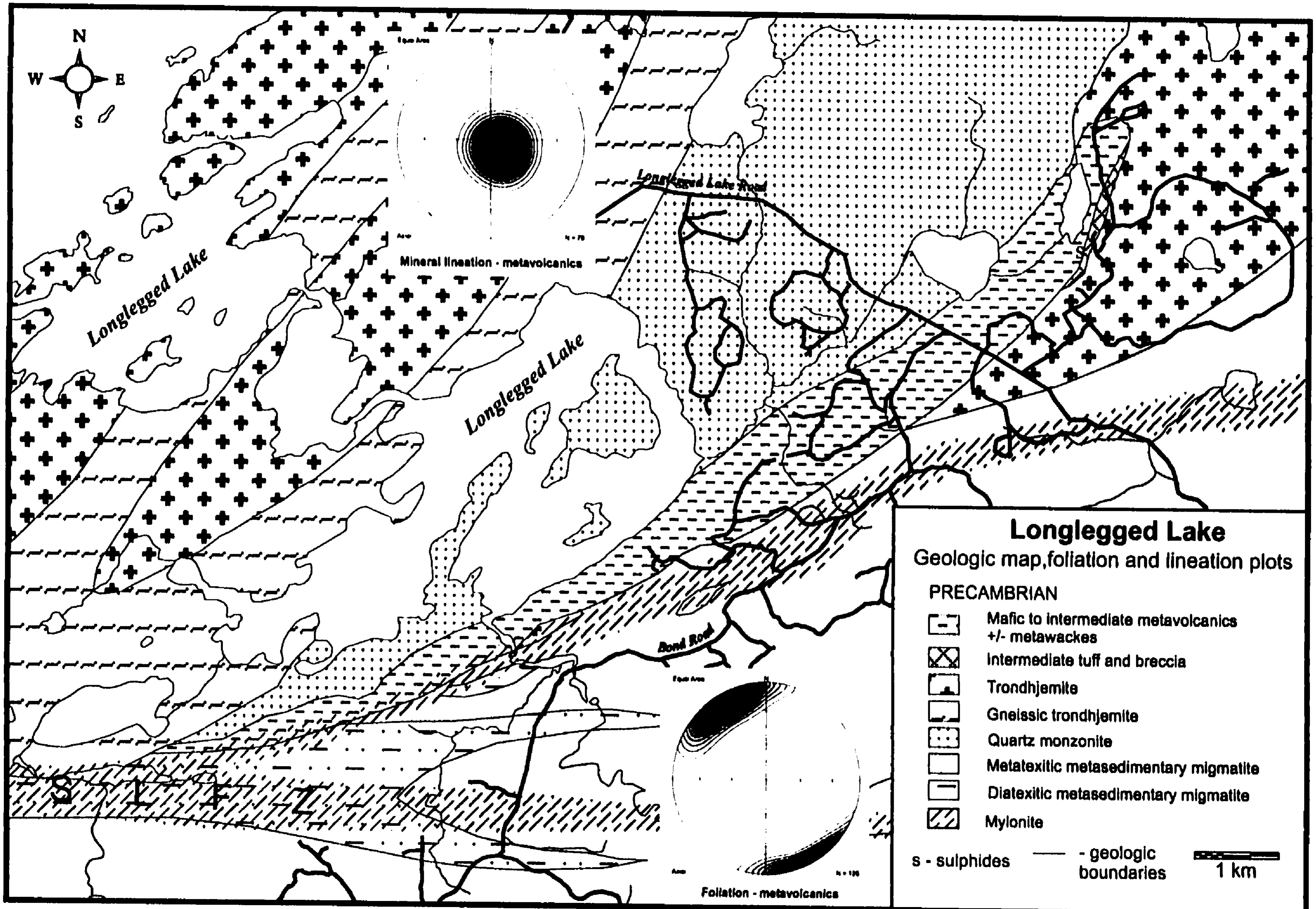


Figure 9. Geological map of the Longlegged Lake sliver, Dixie Lake greenstone belt, with stereoplots of contoured mineral lineation and normals to foliation in the mafic metavolcanics (modified from Shklanka 1963, Stone 1980).

2.1 Chase Lake Area

TABLE 1: Description of lithological units at Chase Lake.

Rock type	Mineralogy/clast composition	Weathering	Description
Mafic metavolcanics: **Amphibolite**	40-70% amphibole, plagioclase, micas, epidote	grey-brown, medium grey, grey-blue; fresh: dark grey	massive & cm to 1/2m layering/bedding; fine-to medium-grained; epidote, plagioclase, k-feldspar, quartz veinlets; cm->1m dykes; 1/2x3cm quartz & chlorite amygdules; 3mmx2cm varioles; garnet porphyroblasts.
Gabbro	40-60% amphibole & micas; 40-60% plagioclase	dark brown grey	massive; medium-, coarse-grained to pegmatitic; plagioclase-rich veinlets & dykes.
Reworked intermediate to mafic metavolcanics: **a) tuff and lapilli tuff (Plates 1a & 1b)** **b) reworked breccia (Plate 2a)**	a) plagioclase fragments in amphibole, plagioclase & mica matrix. Large garnet porphyroblasts with quartz pressure shadows (Plate 2b) b) ~30% mafic volcanic fragments	a) dark blue-green and light grey layers b) fresh: blue-grey	a) mm-5cm wide layers/beds; fine- to medium-grained matrix; 1/2cm wide & up to 7cm long plagioclase fragments comprise 50% of rock. Fine-grained mafic layers contain garnet. Coarse to pegmatitic quartz monzonite dykes. b) discernable bedding; felsic to mafic fragments up to 20x35cm, average 3x10cm; clast supported.
Reworked felsic to intermediate tuffs & breccias (Plates 3a & b)	Polymictic; <15% mafic fragments; large medium grained tonalite & granite fragments	dark brown to cream	~3000m thick unit (Shklanka 1967); graded bedding; weakly foliated, subrounded to rounded fragments.
Metawackes +/- reworked felsic to intermediate tuffs	micas, chlorite, quartz, plagioclase, epidote	dark brown to medium grey; fresh: pinkish grey to grey	massive; minor graded beds; fine- to medium-grained; abundant folds, dykes, crenulated foliation, quartz veins.
Quartz monzonite (Plates 4a & 4b)	10% quartz, plagioclase & K-feldspar; 10% mafic enclaves	cream to pinkish cream	up to 1/2m long mafic enclaves stretched along the foliation plane; crosscutting, medium-grained to pegmatitic, k-feldspar-rich dykes

2.1.1 Mafic metavolcanics

The mafic metavolcanic unit at Chase Lake (Figure 8) is predominantly composed of amphibolite. The unit is considered to be the oldest unit in the section and is interpreted by Stone (1980) to core two anticlines with one axis located in the larger mafic metavolcanic unit to the north of Chase Lake and the other in the mafic metavolcanics to the south (Stone 1980). Previous workers documented porphyritic basic metavolcanics which contain up to 30% relict plagioclase phenocrysts southeast of Eagle Lake and pillow and flow structures northwest of Chase Lake suggesting that the unit was built from submarine lava flows (Shklanka 1967, Stone 1980).

The typical amphibolite of the Chase Lake area (Table 1) consists of 40 - 70% amphibole (hornblende) while plagioclase, epidote, micas and accessory minerals comprise the remainder. The amphibolite is fine- to medium-grained, massive or contains cm- to 1/2-metre wide layering/bedding. In outcrop, amphibolite typically weathers grey-brown, medium grey and grey-blue and is medium to dark grey on fresh surfaces. Epidote-, plagioclase-, K-feldspar-, and quartz-rich veinlets are widespread features and crosscut the main foliation. Centimetre to >1 metre wide monzonite dykes are concordant and discordant to the foliation, folded and disrupted.

Other important features in the mafic metavolcanic unit are 1/2 cm x 3 cm quartz amygdules that occur in a medium-grained plagioclase- and amphibole-rich matrix on Midway Lake (Station 7, A.1). On the south shore of Chase Lake (Station 19, A.1) the mafic metavolcanic unit contains alternating, fine- to medium-grained, metre-scale layering/bedding which contain several quartz pods that parallel foliation. A 40 cm wide layer contains abundant plagioclase- and K-feldspar-rich varioles that range between 3 mm and 2 cm in size. The varioles are modestly strained and surrounded by a fine-grained, dark green mafic matrix containing coarse amphibole grains. Across the lake (Station 20, A.1), chlorite amygdules are found in the same fine-grained mafic metavolcanic unit. Garnet porphyroblasts, as large as a few centimetres wide, are visible in outcrop east of Chase Lake (Station 81, A.1) and south of Chase Lake (Station 181, A.1).

Gabbro units are found on the Midway Lake eastern extension, northeast and east of Chase Lake, on an island on western Chase Lake and at the fold nose of the Oiseau River synform (Figure 8). The gabbro is massive, medium- to coarse-grained and consists of 40 - 60% mafic minerals (amphibole and biotite) and 40 - 60% plagioclase (Table 1). The rock tends to weather to a darker brown-grey than the surrounding rock types. Several of the gabbro outcrops contain medium-grained to pegmatitic plagioclase-rich veinlets and dykes. The gabbro units appear to be relatively less deformed than the surrounding mafic metavolcanic unit.

2.1.2 Reworked intermediate to mafic metavolcanics

The intermediate to mafic metavolcanic unit (Figure 8) was described by Shklanka (1967) as consisting of metamorphosed tuffs, flows and agglomerates. He suggested that the fragments in the tuff breccias are derived mainly of acid volcanics surrounded by an arkosic or hornblende-biotite quartzitic matrix, locally rich in garnets. Subsequently, the unit was renamed as reworked intermediate to mafic metavolcanics (Breaks *et al.* 1978, Stone 1980). Such rock is essentially a volcaniclastic that shows sedimentary structures and is classified without regard to clast origin (Stone *pers. comm.* 1997). Reworked volcanics are usually bedded, intermediate to felsic rocks that were originally deposited by volcanic means followed by redeposition as a tuffaceous-rich sediment. They characteristically have diffusely defined bedding while the erosional types have sharply defined bedding planes (Breaks & Bond 1993). An intermediate reworked metavolcanic rock has been interpreted to consist of rounded felsic to intermediate fragments with <35% proportion of mafic fragments to the total amount of fragments. A felsic reworked metavolcanic rock contains <15% mafic fragments.

In the Chase Lake area, the medium to dark grey weathered, reworked tuff breccia unit is located between the main mafic metavolcanic unit north of Chase Lake and the felsic to intermediate reworked breccias on Midway Lake (Figure 8). Intermediate tuffs and lapilli tuffs are found south of the main mafic metavolcanic unit.

Examples of a typical reworked intermediate to mafic tuff are found on the northeast shore of Chase Lake. Plate 1a (facing west) shows an intermediate to mafic tuff and lapilli tuff on an island in the northeast portion of Chase Lake. It consists of mm to 5 cm wide, fine- and medium-grained, dark blue-green and light grey, amphibole- and plagioclase-rich layers (Table 1). Plagioclase fragments, up to ½ cm wide on the top surface, comprise 50% of the rock. Dark, fine-grained mafic layers contain visible garnet porphyroblasts. The crosscutting coarse-grained to pegmatitic quartz monzonite dyke strikes approximately 95° and is relatively undeformed. A close-up of the stretched feldspar fragments, up to 7 cm in length, is shown in Plate 1b.

Shklanka (1967) found isolated outcrops of metaconglomerate south and southwest of Midway Lake. The unit was subsequently interpreted as a reworked intermediate to mafic metavolcanic (Breaks *et al.* 1978, Stone 1980) and is located on southern Midway Lake and along the north shore of the Midway Lake eastern extension (Figure 8, Plate 2a, Station 3, A.1). Felsic to mafic fragments comprise the bulk of the rock and measure up to 20 cm x 35 cm in size, averaging ~3 cm x 10 cm (Table 1). The reworked intermediate to mafic metavolcanic unit consists of ~30% mafic metavolcanic fragments.

Other examples of the intermediate to mafic reworked metavolcanic unit can be found on the north side of the Midway Lake eastern extension (Figure 8, Stations 48 - 50, A.1). The outcrops consist of moderately to highly foliated tuff breccias (Table 1). Several of the outcrops contain fragments that have been weakly folded. Other outcrops in the area are highly magnetic, due to a high magnetite content, and contain small shear zones which continue to the south side of the extension (Figure 8).

Large garnet porphyroblasts are visible on clean outcrops on the north, northeastern and east shore of Chase Lake (Figure 8). The garnet porphyroblasts appear to mark (characterize) the contact between the mafic metavolcanics and reworked intermediate to mafic metavolcanics. The porphyroblasts are weathered reddish-brown and average a cm-wide, but several are up to six centimetres wide. East of Chase Lake (Station 91, A.1), garnet porphyroblasts are ornamented by quartz-filled pressure shadows (Plate 2b, facing 240°; Table 1) and arranged in cm-wide layers. Some pressure shadows appear to be asymmetrical but remain to be used as shear sense indicators. A large garnet porphyroblast in Plate 2b measures almost 8 cm in length. The outcrop is highly magnetic and iron formations were observed to the south.

The intermediate to mafic metavolcanic unit, south of Chase Lake, is comprised of a lapilli tuff. It contains 30% subrounded plagioclase fragments in a fine-grained, dark to medium grey matrix.

2.1.3 Reworked felsic to intermediate tuffs and breccias

The reworked to intermediate tuff and breccia unit has been described as an agglomerate or a granitic boulder breccia (Shklanka 1967), and as a reworked felsic to intermediate metavolcanic (Stone 1980). The reworked felsic to intermediate tuff and breccia unit is observed on Midway Lake and north of the Midway Lake eastern extension. It strikes northwesterly and is approximately 3000 metres thick (Shklanka 1967). The difference between the reworked intermediate to felsic metavolcanics and the reworked intermediate to mafic metavolcanics to the south is that the relatively weakly foliated felsic to intermediate breccia unit contains discernible graded bedding and a lower percentage of mafic fragments to the total fragment component (Table 1).

The source rocks for the reworked felsic to intermediate metavolcanic unit has been interpreted to be felsic volcanic rocks which were intruded by older and coeval granitic plutons and synvolcanic rocks (Goodwin & Schklanka 1967, Campbell 1971, Ojakangas 1985). A majority of the sedimentary rocks in the Archean contain felsic volcanic fragments plus intermediate to mafic fragments which supports the derivation of the sediment from volcanics (Ojakangas 1985). Ayres (1983) emphasized that the record of felsic volcanism includes the contemporaneous sedimentary sequences which are integral but condensed products of the volcanism, with the decrease in volume due to erosion, weathering, and abrasion of the pyroclastic debris (Ojakangas 1985).

An example of a typical reworked felsic to intermediate metavolcanic is shown in Plate 3a (way up is towards 245°). It is polymictic, consisting of felsic to mafic clasts in graded bedding (Table 1). The majority of the larger fragments are medium-grained tonalites and are subrounded to rounded. The remainder of the fragments are fine-grained, intermediate to mafic volcanics (Plate 3b, tops toward 315°).

At the mouth of Midway and Eagle Lakes, felsic breccias consist of medium- to coarse-grained, rounded, granitic clasts which comprise 40 to 50% of the rock. Larger fragments average 5 cm x 25 cm and smaller fragments average 5 x 5 cm. Fine-grained mafic fragments are stretched and comprise 15% of the total clast composition.

2.1.4 Metawackes with reworked felsic to intermediate tuffs

A problem in identifying the metasediments in the Uchi subprovince is the difficulty in distinguishing between an immature feldspathic greywacke and a fine-grained fragmental volcanics (Clifford & McNutt 1971). The metawackes and the reworked felsic to intermediate tuffs in the Chase Lake area are grouped into one unit because of the difficulty in differentiating between the two rock types in the field. One difference, observed in the Chase Lake area between the metawacke unit and the intermediate to mafic metavolcanic unit, is the typical brown weathered surface and "sandy" texture of the metawackes which display occasionally a pinkish-grey fresh colour. The metawacke and reworked felsic to intermediate tuff unit is located on either side of the mafic metavolcanic unit south of Chase Lake (Figure 8).

An example of a typical metawacke outcrop is located near the rapids at Oiseau River (Station 72, A.1). It is a fine- to medium-grained, medium-grey rock which contains abundant folds, dykes and crenulated foliation. Granitic dykes are concordant and discordant to foliation. Graded bedding is also discernible in places, however, the outcrops generally appear massive. Surrounding outcrops (Stations 199-203, A.1) consist of medium-grey weathered, medium-grained, quartz-rich metawacke with abundant quartz veins.

2.1.5 Quartz monzonite

Early granitoid rocks in the Rice Lake greenstone belt are composed of gneissic granodiorite with minor quartz diorite and quartz monzonite. The quartz monzonite in the Chase Lake area is a late granitic rock which intrudes early granitic rocks in numerous exposures along its contact and the mafic metavolcanic unit east of Chase Lake. The quartz monzonite in the Chase Lake area appears to be part of the Wingiskus Lake stock west of Chase Lake. Plate 4a (facing 190°) shows a typical quartz monzonite near the mafic metavolcanic/quartz monzonite contact east of Chase Lake. It contains ~10% mafic volcanic enclaves that are stretched along the foliation plane (Table 1). The enclaves suggest that the mafic metavolcanic unit was intruded by the quartz monzonite and subsequently shared the same deformation history. Another quartz monzonite outcrop is shown in Plate 4b (Station 79, A.1, viewing 240°). Fine- to medium-grained mafic enclaves are stretched, up to ½ metre long, along the foliation plane. The quartz monzonite unit contains medium-grained to pegmatitic, pink-weathered granitic dykes that parallel and crosscut (285°) the foliation (15°). The dykes exhibit the same deformation intensity as the host rock.

2.1.6 Migmatites

In the northern Superior province, migmatites have been interpreted to have formed by two different methods (Ayres 1978). In the first method, the migmatites are derived by the incorporation of granitoid material derived from a source area external to the host. The second is by in situ segregation of a granitoid component produced by partial melting or metamorphic differentiation of the host (Breaks & Bond 1993). In the English River subprovince migmatites are thought to have derived from the lit-par-lit injection of a magmatic melt into an older rock, commonly along existing anisotropies such as bedding and foliation (Breaks & Bond 1993).

Evidence for injection was identified by the lack of melanosome along the paleosome and leucosome interface, the presence of a relatively thick leucosome and a common presence of local discordancies to paleosome foliation or preserved bedding between leucosome and paleosome verifying an intrusive origin (Breaks & Bond 1993). Previous workers also favoured a magmatic origin due to the presence of rotated inclusions, dilationary wall rocks, sharp contacts and crosscutting relationships (Shklanka 1967). It was thought that the deformation coincident with the intrusion of early granitic rocks may have created the concordance of the foliation in migmatites with the foliation in the metasediments/metavolcanics and the early granitic rocks (Shklanka 1967). From observation, the migmatites at Chase Lake appear to have been derived from lit-par-lit injection of magmatic melt since preserved bedding and no melanosome were observed.

In the Uchi and English River subprovinces, Shklanka (1967) divided migmatitic rocks into two components, one granitic and the other metasedimentary or metavolcanic. However, a more recent classification was utilized for both study areas, which subdivided migmatites into metatexitic and diatexitic metasedimentary varieties based upon work by Scheumann (1936, 1937), Mehnert (1971), Brown (1973) and Breaks & Bond (1993). Migmatites are classified with increasing degree of partial melting as protometatexite, metatexite, inhomogeneous diatexite and diatexite (Breaks & Bond 1993). Even though the migmatites are thought to have formed by lit-par-lit injection, the migmatite classification was still utilized to remain consistent with the units used by Breaks & Bond (1993) and Stone (1980). The table below shows the description of migmatite stages and is modified from Breaks & Bond (1993):

TABLE 2. Description of Migmatite stages with increasing degree of partial melting (modified from Breaks & Bond 1993)

Migmatite stage	Leucosome content of migmatite	Field description
Protometatexite	<10%	locally migmatized medium grained to coarse grained porphyroblastic metapelitic units characterized by discontinous, podiform leucosome development. Intercalated with fine grained generally non-leucosome bearing metawacke
Metatexite	10 - 60%	conspicuously layered metasedimentary migmatite generally containing stromatically disposed leucosome
Inhomogeneous diatexite	60 - 90%	leucosome constituent begins to dominate such that between 5 and 40% of surviving metasedimentary sequence occurs as enclaves and/or schlieren
Homogeneous diatexite	>90%	complete domination of leucosome constituent, metasedimentary enclaves rare and usually <5%

Diatexites were distinguished from other granitic rocks from field characteristics identified by Breaks & Bond (1993), shown in the table below:

TABLE 3. Field characteristics of diatexitic migmatites. (modified from Breaks *et al.* 1978, Breaks & Bond 1993)

Diatexite: Means of identification
1) remnants of paleosome are nearly always present but vary in quantity.
2) evidence of varying degrees of mobility especially with respect to inhomogeneous diatexites. Rocks have 'turbulent' character with abundant contorted, plastically deformed enclaves are commonly notable.
3) wide range of grain size.
4) consist of distinctive earthy white-weathering, generally massive granitoid material, and usually exceeding 70% of a given outcrop.
5) sporadic presence of accessory minerals uncommon in most granitic rocks such as garnet, cordierite or sillimanite.
6) absence of stromatic structure

The most common type of migmatite in the English River subprovince is the metatexite and two surviving types of paleosome in the English River subprovince are wacke and pelite, corresponding to greywackes and mudstones (Breaks & Bond 1993). Both types of paleosome are found in the Chase and Longlegged Lake migmatites (Table 4). The wacke paleosome tends to be finer grained, relatively less foliated and contain a higher quartz and Al_2O_3 content and lower colour index than pelitic units (Breaks *et al.* 1978). The wacke and pelite paleosomes weather brown and sometimes exhibit a fresh medium bluish-grey colour. Breaks & Bond (1993) showed that potassic leucosomes, such as granite and quartz monzonite, are associated with pelite paleosomes, while sodic leucosomes, such as granodiorite and trondhjemite, are associated with feldspathic wacke paleosomes.

Metatexitic and diatexitic metasedimentary migmatites are located east of Chase Lake and in the SLFZ to the south where they have been mylonitized, cataclastized and Z-folded. East of Chase Lake the migmatites have been deformed along with the surrounding rocks (Plates 5a & 5b). The leucosome, in both plates, shows the typical earthy-white weathering while the wacke paleosome is weathered a dark reddish-brown colour (Table 4). Relict bedding is preserved and parallels the stromatic layering. Diatexites are comprised of <10% paleosome. The leucosome is a coarse-grained to pegmatitic quartz monzonite (Stone 1977). Plate 6a shows a mylonitized diatexite with folded stromatic layering in the SLFZ. The diatexites have been observed to crosscut metatexites to the south (Stone 1977).

2.1.7 Mylonites

Mylonitic rocks are produced at depths of greater than 10 km under ductile deformation

TABLE 4. Description of migmatites in the Chase Lake area.

Type of migmatite	Paleosome	Leucosome	Weathering	Description
Metatexitic metasedimentary migmatite	wacke & pelite	10-60% leucosome; potassic leucosome - pelite paleosome; sodic leucosome - wacke paleosome (Breaks & Bond 1993)	dark reddish brown paleosome; earthy-white leucosome	stromatic layering, occasionally folded; mylonitized & cataclastized in SLFZ
Diatexitic metasedimentary migmatite	wacke & pelite	>90% coarse-grained to pegmatitic quartz monzonite leucosome	earthy-white leucosome; brown paleosome	mylonitized, cataclastized & Z-folded in SLFZ (Plate 6a)

(Davis 1984). Deformation increases and the proportion of visible fragments decreases from protomylonites to mylonites to ultramylonites until a 'mylonitic' schist or gneiss is produced. Cataclastic rocks are formed under more brittle conditions within the first 10 km of the surface and have no visible fabric.

Mylonitized rocks in the Chase Lake area occur in the SLFZ and are shown as a broken line pattern in the southern portion of the geological map (Figure 8). Intermediate metavolcanics and metatexitic and diatexitic metasedimentary migmatites are affected by the SLFZ. They are mainly protomylonites and mylonites but also exhibit an overprinting cataclastic deformation. In the SLFZ, rotated rigid feldspar grains and oblique mylonitic foliation to the right of the fault strike has been documented (Stone 1977). Plate 6b shows a close-up of a protomylonitized leucosome layer in a metatexite on the Oiseau River in the southwest portion of the map area.

2.1.8 Dykes, sheets and veins

Four compositional varieties of dykes are found in the Chase Lake area (Table 5). The dykes are medium-grained to pegmatitic and occur on scales of centimetres to 7 metres wide. The most common type of dyke or sheet in the Chase Lake area is a medium-grained, cream and beige weathered, tonalite dyke (type 1, Table 5). It is concordant and discordant with the foliation, folded and disrupted. However, only the concordant and slightly discordant sheets are boudinaged. It was observed that a majority of the discordant dykes in the Chase Lake mass are oriented 10 - 30° counterclockwise from the strike of the foliation. An example is found in the intermediate to mafic metavolcanic unit on an island on northeast Chase Lake. The tonalite dykes strike 95° and the foliation strikes 122°, a difference of 27° counterclockwise to the foliation. Another example of the tonalitic dykes is shown in Plate 7a (Station 100, A.1, facing 195°) and is located in the metawackes and metavolcanics east of Chase Lake. The tonalite dykes are folded perpendicular to the foliation and boudinaged concordant with foliation.

The second variety of dyke (type 2, Table 5) is the granitic dyke. The medium-grained to pegmatitic, K-feldspar-rich and plagioclase and quartz megacrystic dykes are oriented concordant and perpendicular to the foliation in the quartz monzonite and exhibit a similar deformation intensity. Examples of the granitic dyke are shown in Plate 2d (in quartz monzonite, facing 240°), Plate 7b (Station 91, A.1, facing 320°) and Plate 8a (viewing 290°), which is an example of a boudinaged discordant dyke, oriented ~19° counterclockwise from the foliation plane. Plate 8b (viewing 300°) is another example of a discordant dyke oriented 10-20° counterclockwise from the foliation, however this example contains a type 2 granitic dyke instead of a type 1 tonalite dyke. A 25° counterclockwise angle exists between the concordant sheets and the discordant dykes. Plate 9a (viewing 250°) shows a dextrally offset, granitic disrupted sheet in the mafic metavolcanic unit south of Chase Lake. An outcrop east of Chase Lake contains a granitic dyke that crosscuts a concordant tonalite dyke (Station 87, A.1) at an angle of 25°. The granitic dyke is weakly folded and coarser-grained than the tonalite dyke and may be a later generation than the tonalite dyke.

The third type of dyke (type 3, Table 5) observed in the Chase Lake area contains large "books" of mica in a medium-grained quartz and plagioclase matrix. It is relatively weakly foliated and has been observed east of Chase Lake primarily in the metawackes and metatexites. It is similar to the tonalite dyke in composition but is coarse-grained. A subtype of type 3 is a K-feldspar-rich dyke that contains biotite and epidote. Examples of both types are found near the round lake east of Chase Lake (Stations 99, 109, 112, and 115, A.1) and are discordant and concordant to foliation.

The last type of dyke (type 4, Table 5) is the late-stage quartz vein which is relatively undeformed. Quartz veins are oriented perpendicular to the foliation and crosscut the granitic dykes in a metatexitic outcrop, southeast of Chase Lake (Station 256, A.1). The majority of dykes (types 1-3, Table 5), in the Chase Lake area are earlier crosscutting features that were deformed with the surrounding rock. The quartz-rich veins appear to be a later feature and are relatively undeformed.

TABLE 5. Description of dykes and sheets in the Chase Lake area

Type	Name	Plate	Description
1	tonalite dyke	7a	medium-grained, cream & beige weathered, concordant & discordant (10-30° counterclockwise from foliation), folded & boudinaged.
2	granitic dyke	2a,7b,8a,9a	concordant, medium-grained to pegmatitic, K-feldspar phenocrysts with quartz and plagioclase megacrysts.
3	tonalitic dyke	-	concordant, medium- to coarse-grained; biotite megacrysts, quartz, plagioclase
4	quartz vein	-	relatively undeformed

2.2 Longlegged Lake Area

2.2.1 Metavolcanics and metawackes

The greenstone sliver in the Longlegged Lake area, part of the Dixie Lake greenstone belt, strikes northeasterly and thins near the SLFZ (Figure 9). The rock types found in the Longlegged Lake sliver are mainly fine- to medium-grained, dark greyish-green amphibolites, with minor felsic to intermediate metavolcanics and metawackes. Plate 9b shows a typical intermediate to mafic metavolcanic outcrop. Rafts or xenoliths of the mafic metavolcanic unit are found in the mylonite zone, between two small lakes in the southwest portion of the map area (Figure 9). The mafic rafts may have formed from the intrusion of the granitic plutons or they may have been disrupted by the SLFZ.

The northeast portion of the greenstone sliver is the most geologically complex. From northwest to southeast one encounters the main mafic metavolcanic unit, followed by a ~2 metre wide gossanous zone and finally into an intermediate to felsic tuff and tuff breccia unit. The mafic metavolcanic unit is mainly massive or consists of mafic bands with thin felsic layers, but in one locality it consists of highly stretched pillows (Station 350, B.1). The gossan appears to be hosted by mafic metavolcanics. The breccias contain mafic metavolcanic clasts in a felsic matrix which comprise ~30 - 40% of the outcrop, averaging 1 cm x 5 cm in size. The gabbroic clasts weather brown and are stretched along the foliation plane. Several clasts are fine-grained, dark grey and highly magnetic. Quartz veins are abundant in the outcrop. The intermediate to felsic tuff and tuff breccia unit consists of a fine- to medium-grained matrix and the fragments, which comprise >50% of the outcrop and average 3 cm x 10 cm, are composed of finer and coarser versions of the matrix. Minor amphibolite fragments are highly stretched.

2.2.2 Quartz monzonite and trondhjemite

The quartz monzonite observed in the Longlegged Lake area is similar to the quartz monzonite unit encountered in the Chase Lake area. It consists of up to 30% coarse K-feldspar phenocrysts (up to 4 cm x 1cm), 50% plagioclase, 10% quartz and 10% mafics. The quartz monzonite is coarse-grained to pegmatitic and the coarse K-feldspar phenocrysts are aligned parallel to the foliation. The quartz monzonite outcrops contain cross-cutting granitic dykes. The dykes vary in strike direction and offset each othe both dextrally and sinistrally. Small mafic rafts are sporadically found in the quartz monzonite unit.

The trondhjemite unit consists of 50 - 60% plagioclase, 10 - 20% medium to coarse quartz phenocrysts and 20 - 30 % mafics. It weathers brown and cream in colour and fine-grained mafic enclaves are occasionally encountered.

2.2.3 Migmatites

Quartz monzonite leucosomes are present in all migmatites but trondhjemite varieties are found between the two branches of the fault and tonalitic varieties occur only in the main fault zone and in areas further south (Table 6). Migmatites which consist of a brown-weathered, "sandy", mica-rich paleosome and cream weathered monzonitic leucosome (type A, Table 6), are present in all areas. Between the main SLFZ and its splay (Station 388, B.1), the migmatites (type B, Table 6) consist of medium- to coarse-grained bands of cream-weathered trondhjemitic leucosomes and paleosomes that are < ½ metre wide. The coarse paleosome bands consist mainly of feldspars with minor quartz and mafics. The finer bands have a similar composition but contain a larger amount of mafics. The paleosome appears to be a wacke with a possible mafic volcanic or pelitic component. Pods of highly foliated, fine-grained mafic metavolcanics are found in minor amounts. Late stage, coarse-grained to pegmatitic dykes, consisting of mainly quartz, micas and epidote, crosscut the foliation and are also cataclastically deformed. The feldspar porphyroclasts reach lengths of up to ~10 cm.

In the main SLFZ and to the south a third type of migmatite is observed (Type C, Table 6). The medium- to coarse-grained granitic leucosomes are weathered pink and the grey paleosome is tonalitic in composition. In the SLFZ, the migmatites are mainly stromatic, mylonitized and leucosomes are occasionally boudinaged.

TABLE 6. Migmatites in the Longlegged Lake area.

Type	Locality	Description
A	All areas	-brown weathered, sandy texture, mica-rich paleosome -cream weathered monzonite leucosome
B	Between the northern splay & the main SLFZ	-cream weathered trondhjemite leucosome -medium- to coarse-grained, <1/2m wide bands of paleosome composed of feldspar, quartz & mafics. Finer bands contain abundant mafics. Late stage coarse to pegmatitic dykes (quartz, micas, epidote) crosscut foliation.
C	Main SLFZ and to the south	-medium- to coarse-grained granitic leucosome -grey tonalitic paleosome.

Plate 1a Intermediate to mafic tuff and lapilli tuff, with a crosscutting pegmatite dyke, on an island in the northeast area of Chase Lake (facing west).

Plate 1b A close-up in the foliation plane, at the outcrop shown in Plate 1a, of a strong, moderately plunging shape fabric (stretched fragments) in intermediate to mafic metavolcanics, Chase Lake (facing north).

Plate 1a

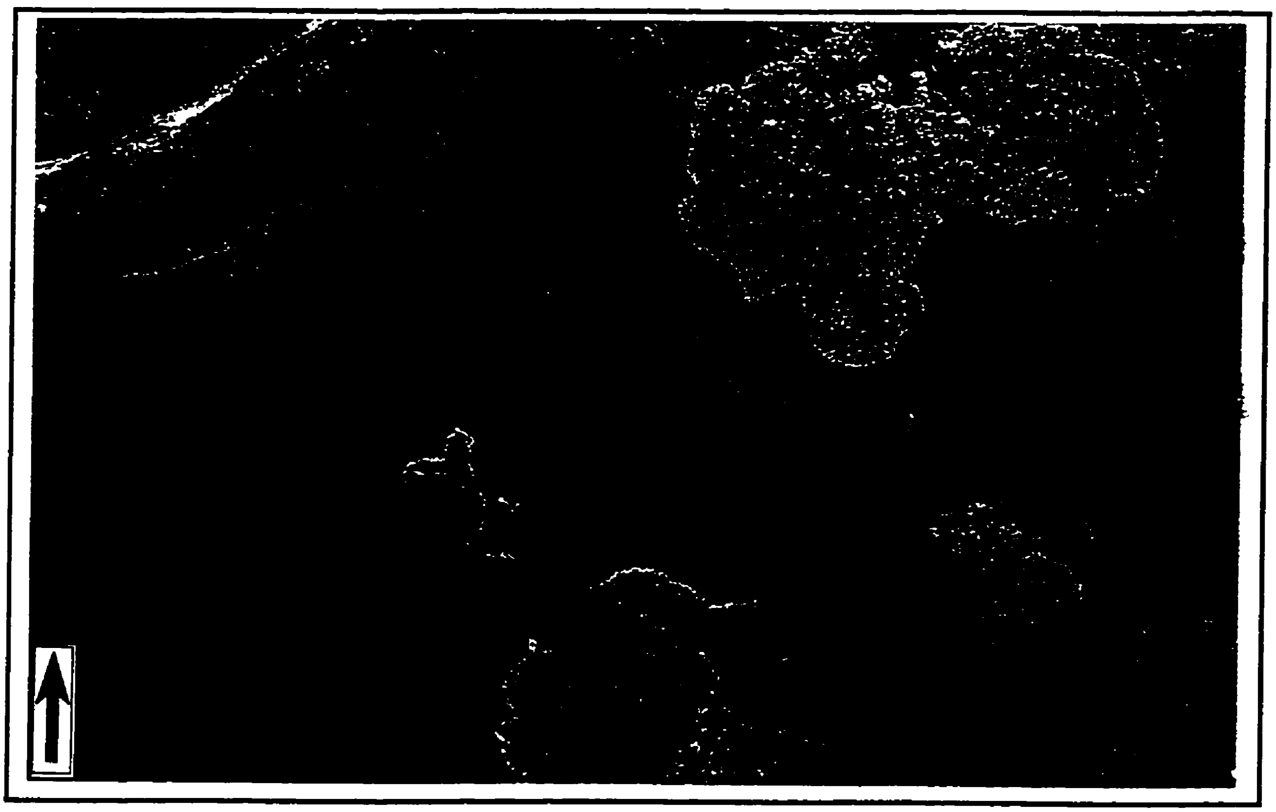


Plate 1b

Plate 2a	Intermediate to mafic breccia located on an island on Midway Lake near the Chase Lake narrows.
Plate 2b	Garnet porphyroblasts, with quartz-filled pressure shadows, in an intermediate metavolcanic (facing 240°).

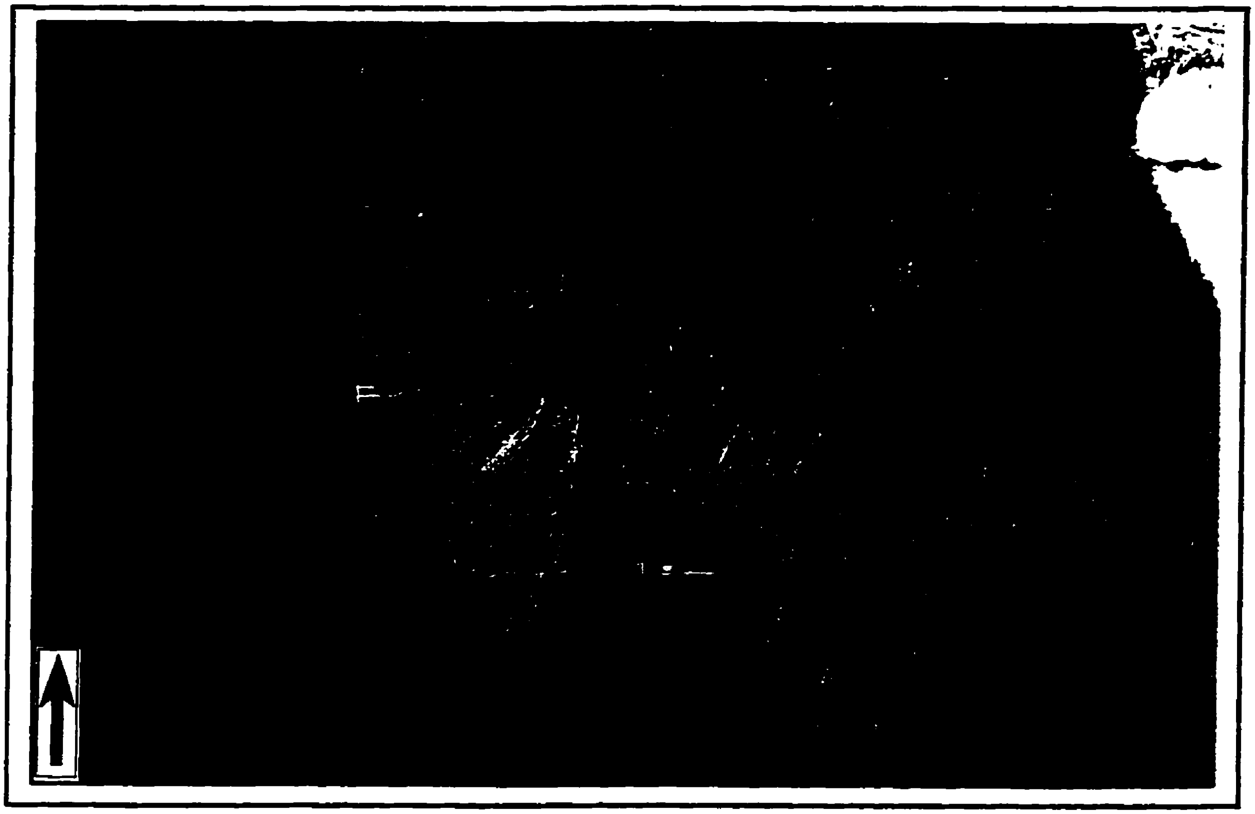


Plate 2a

Plate 2b

Plate 3a A reworked felsic to intermediate metavolcanic showing graded bedding and crosscutting foliation on Midway Lake (way up is towards 245°).

Plate 3b A reworked felsic to intermediate metavolcanic showing graded bedding and crosscutting foliation. The mafic fragments are stretched along the foliation plane, Midway Lake (tops toward 315°).

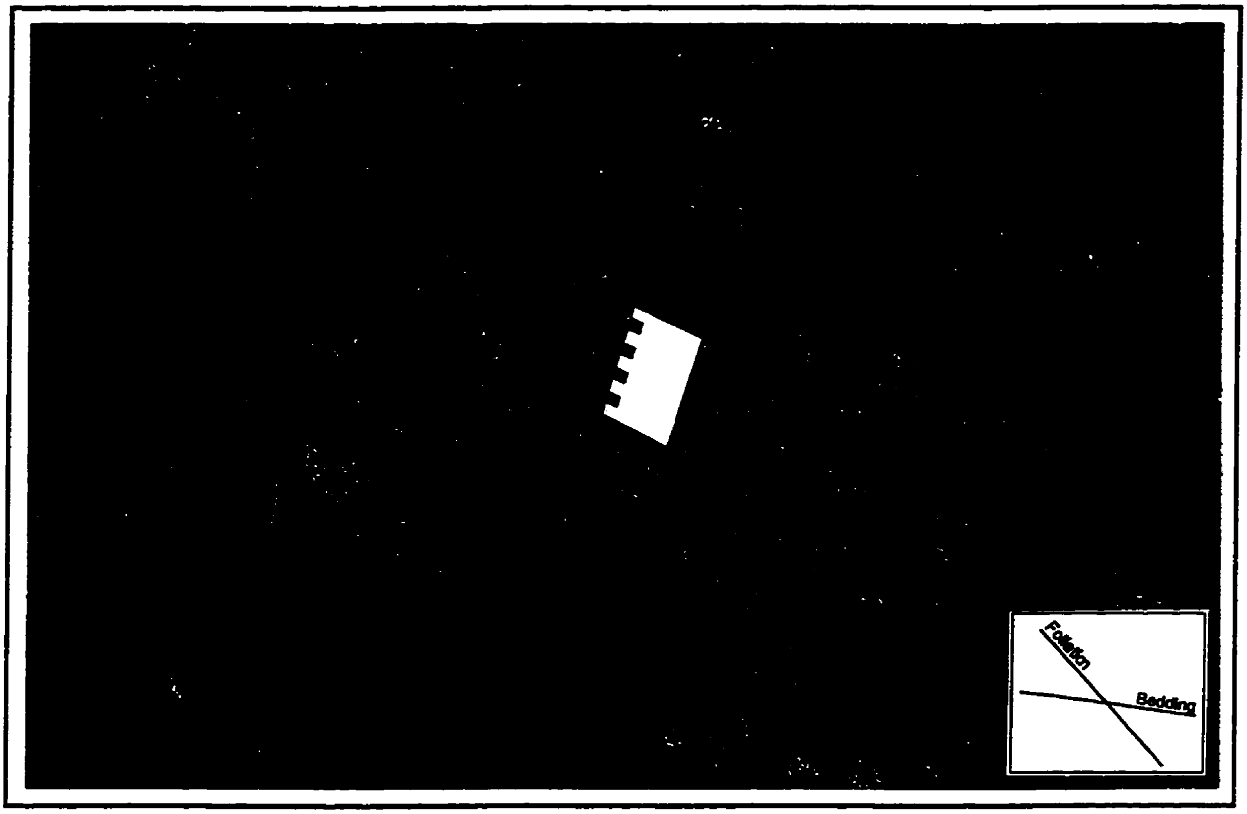


Plate 3a

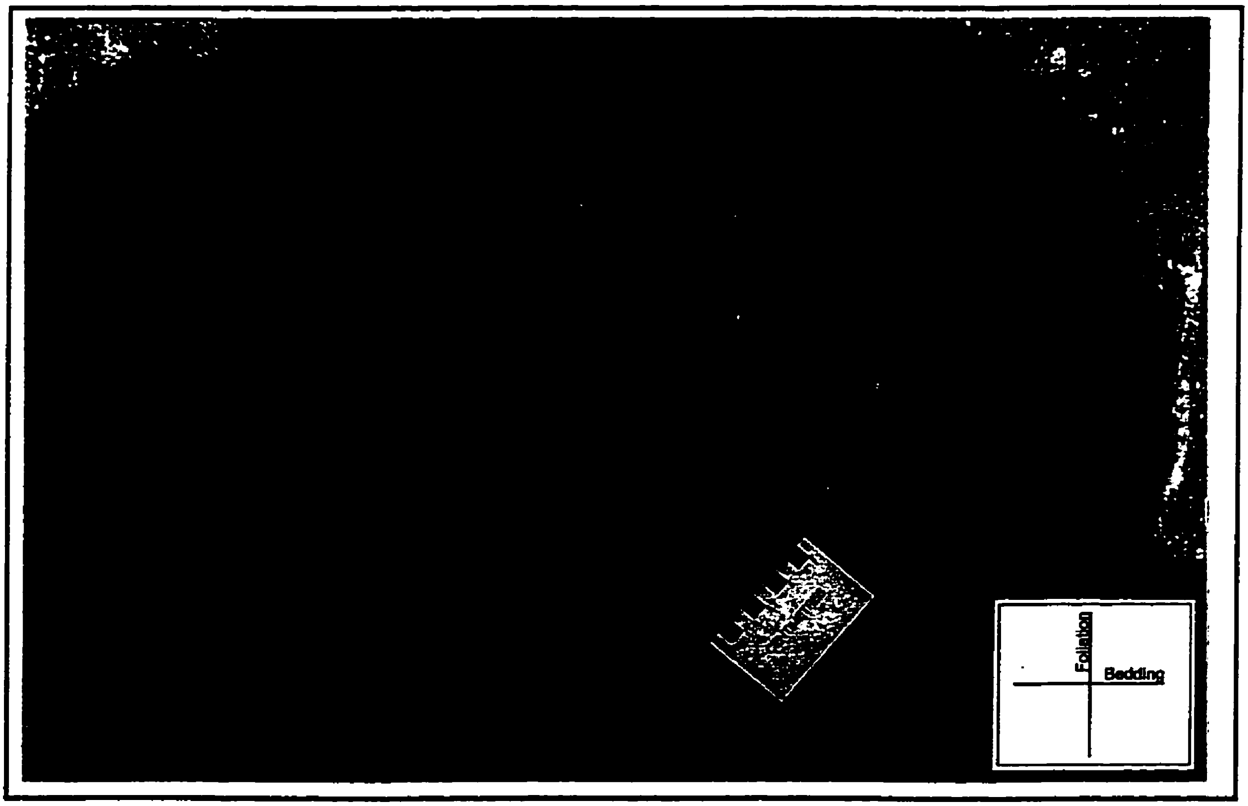


Plate 3b

Plate 4a	Mafic enclaves in quartz monzonite, found at the contact between the mafic metavolcanic unit and the quartz monzonite unit, east Chase Lake (facing 190°).
Plate 4b	Quartz monzonite with crosscutting granitic dykes. Foliation strikes 15° and crosscutting dykes strike 285° (facing 240°), Chase Lake.

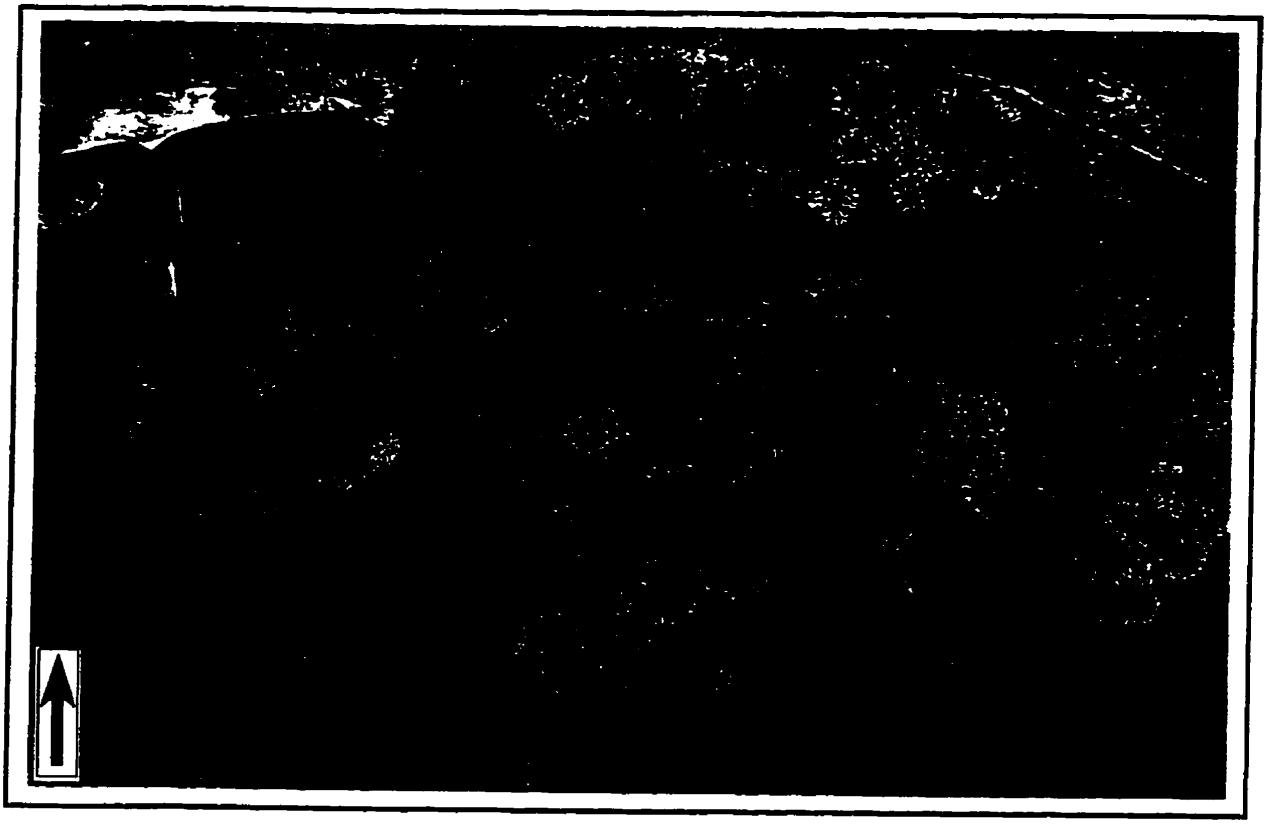


Plate 4a

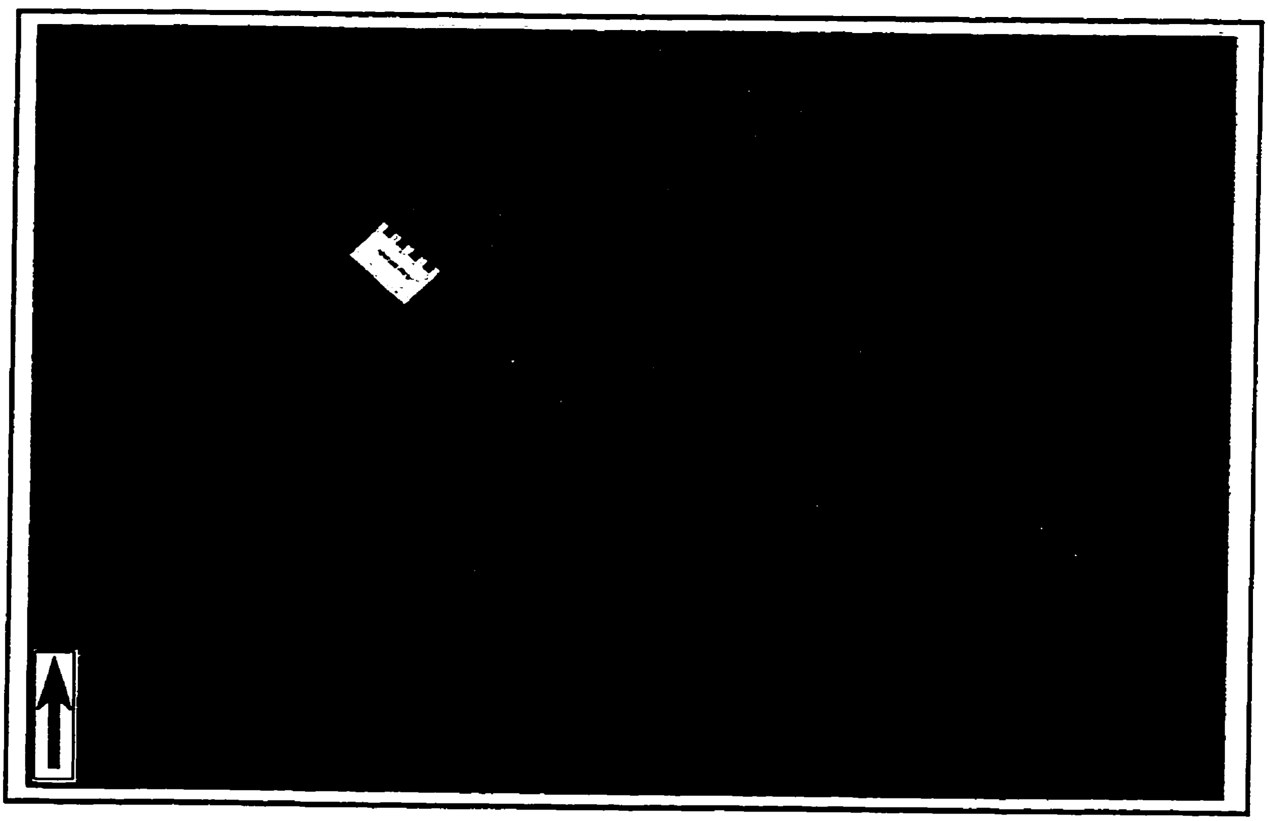


Plate 4b

Plate 5a	S-folded metatexitic metasedimentary migmatite. Leucosome shows earthy-white weathering while the wacke paleosome is weathered brown. Relict bedding is preserved and is parallel to the stromatic layering, east Chase Lake.
Plate 5b	Folded metatexitic metasedimentary migmatite, east Chase Lake.

Plate 5a

Plate 5b

Plate 6a A close-up of a protomylonitized leucosome layer in a metatexitic metasedimentary migmatite, southwest Chase Lake.

Plate 6b Mylonitized Z-folded diatexitic metasedimentary migmatite in the SLFZ.

Plate 6a

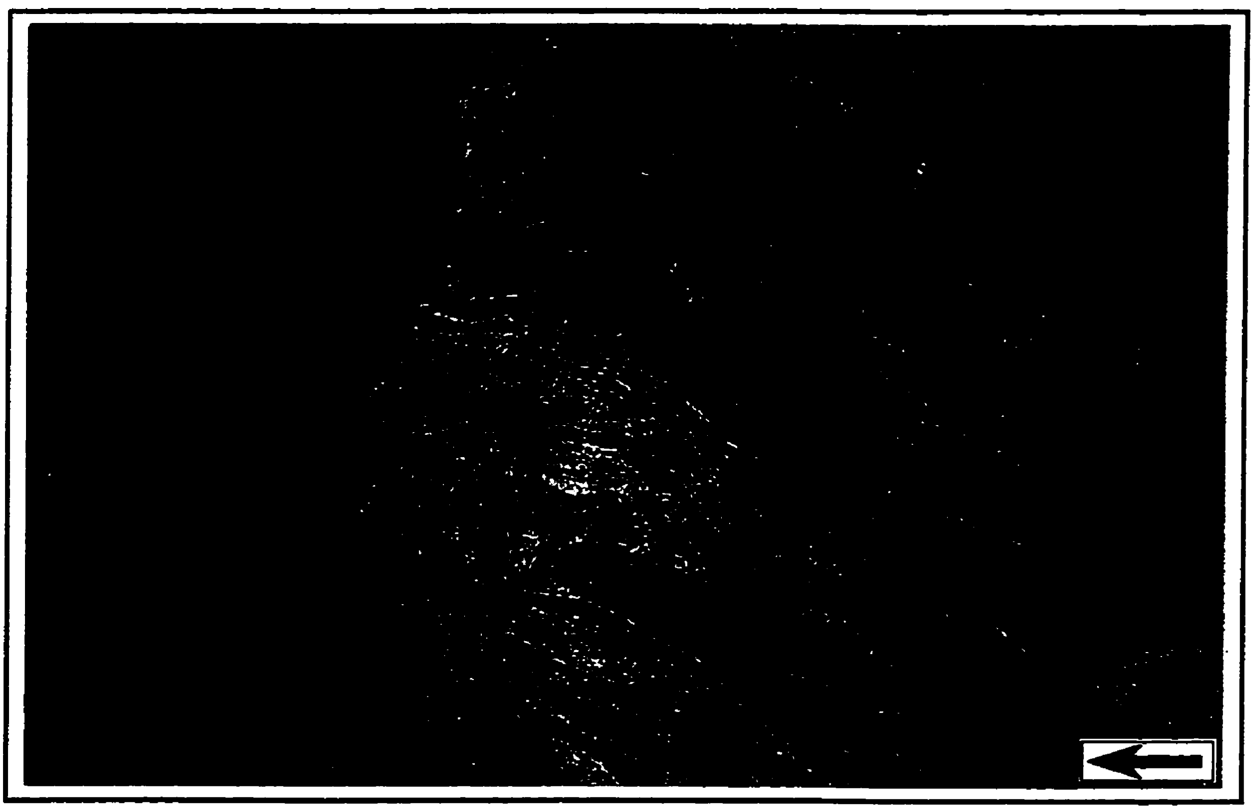


Plate 6b

Plate 7a Tonalite dykes, folded perpendicular to foliation and boudinaged concordant with foliation, in metawackes, east of Chase Lake (facing 195°).

Plate 7b Weakly foliated and ductilely folded pegmatite dyke in intermediate metavolcanics, east of Chase Lake (facing 320°).

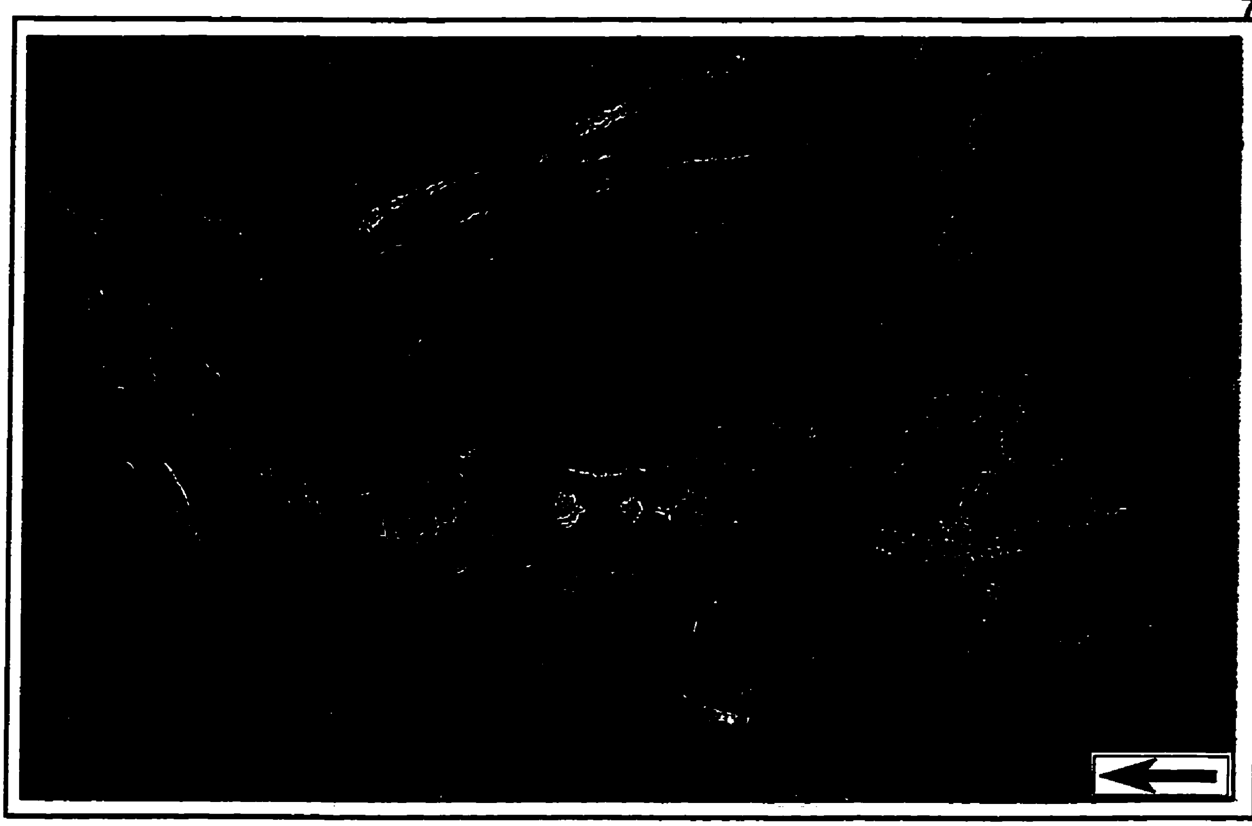


Plate 7a

Plate 7b

Plate 8a	A coarse-grained to pegmatitic granitic dyke hosted by intermediate to mafic metavolcanics. It is an example of a boudinaged discordant dyke oriented 19° counterclockwise from the foliation plane, Chase Lake (facing 290°).
Plate 8b	Discordant granitic dyke, oriented 10 - 20° counterclockwise from the foliation plane, Chase Lake (facing 300°).

Plate 8a

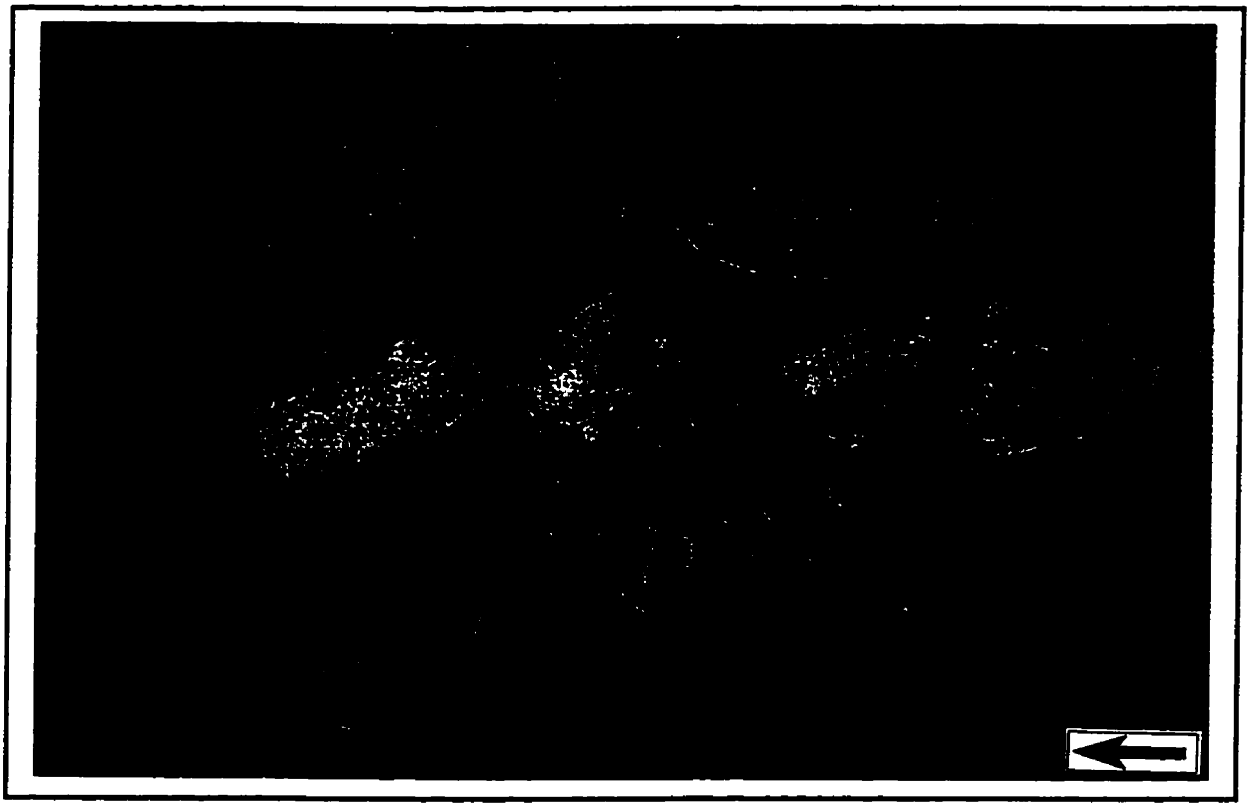


Plate 8b

Plate 9a A dextrally offset, granitic disrupted sheet in the mafic metavolcanic unit south of Chase Lake (facing 250°).

Plate 9b A typical intermediate to mafic metavolcanic outcrop in the Longlegged Lake area.

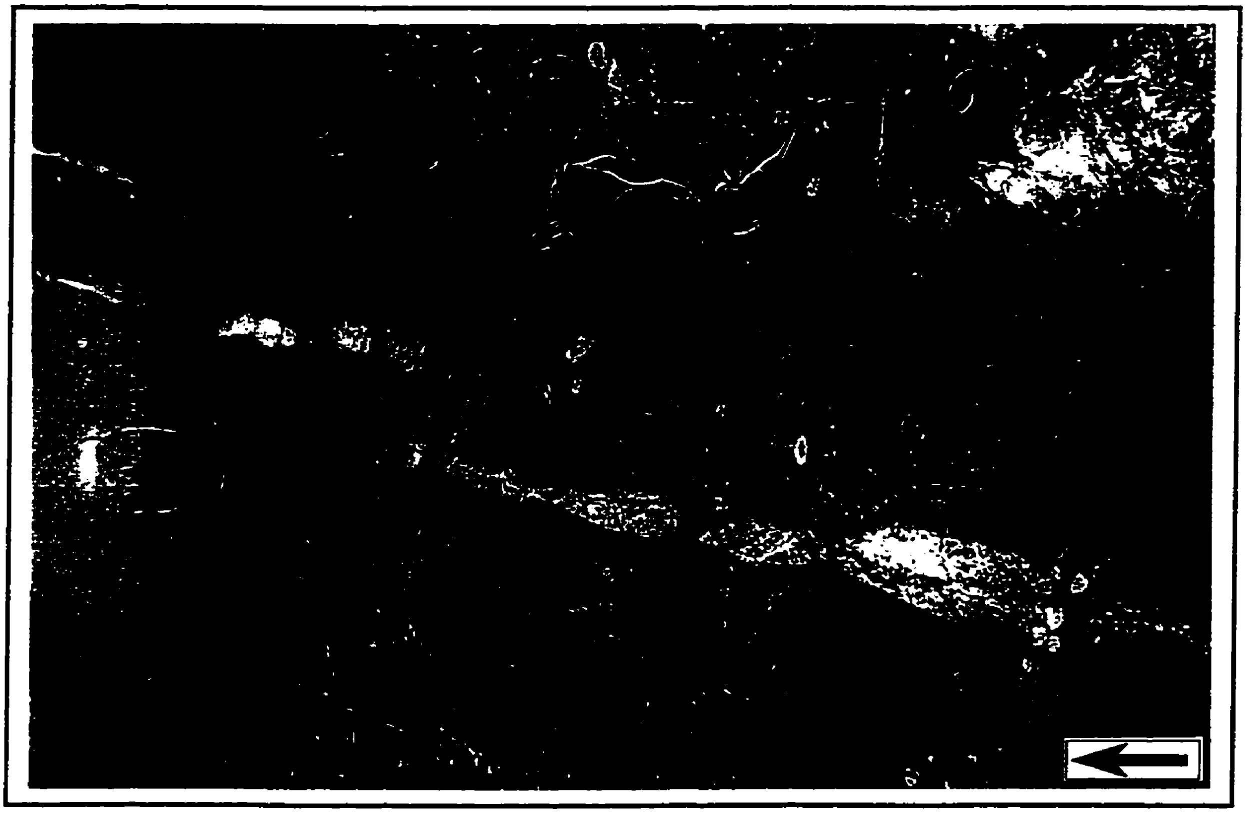


Plate 9a

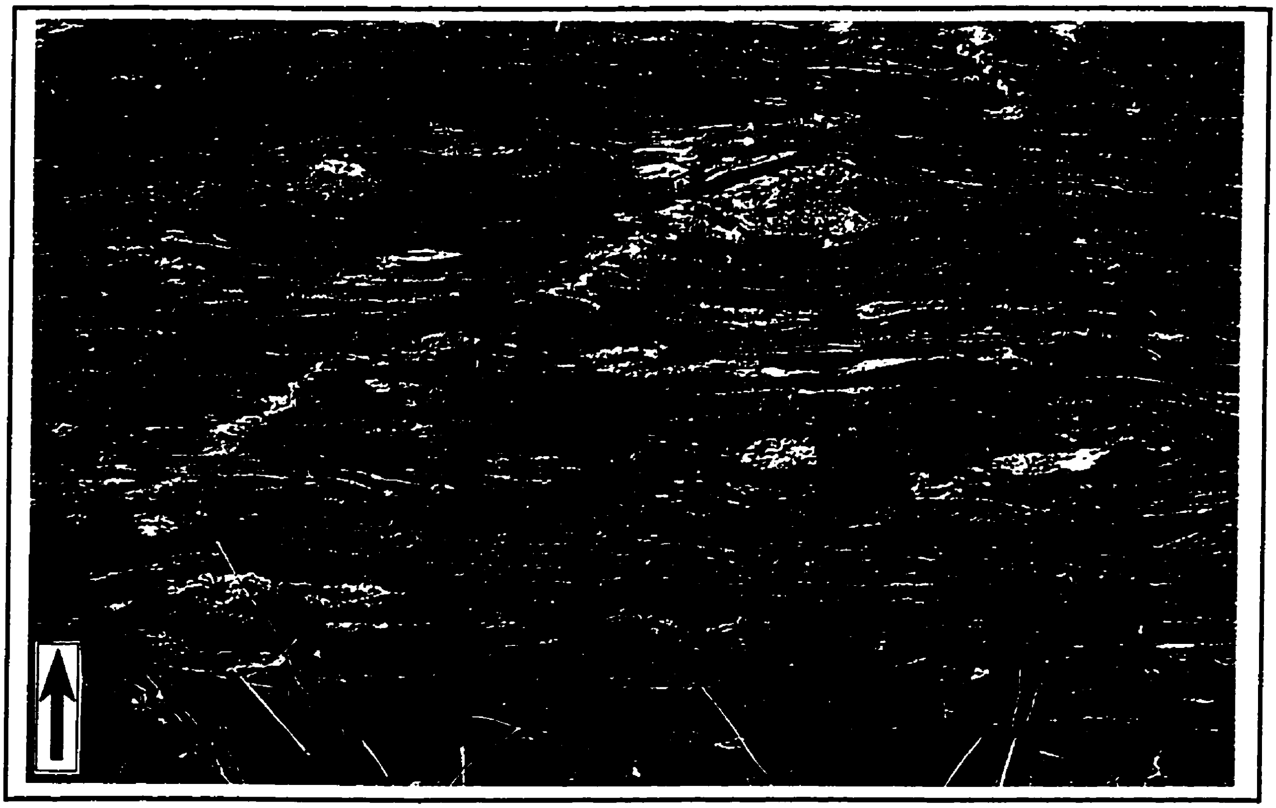


Plate 9b

CHAPTER III

PETROGRAPHY

III. PETROGRAPHY

3.0 Introduction

A petrography study was undertaken in rocks of the Chase and Longlegged Lake areas in order to clarify the structural relationships and to better define the metamorphic transition at the subprovince boundary.

3.1 Background

Thurston (1978) identified several metamorphic events in the English River and Uchi subprovinces. The first event was regionally significant and formed staurolite, biotite, andalusite, cordierite and garnet porphyroblasts. Subsequent retrograde metamorphism produced widespread sericitization of andalusite, chloritization of biotite, garnet and amphiboles, and pinitization of cordierite. The last metamorphic event was associated with fault movement along the Uchi-English River subprovince boundary and included formation of hematite, carbonate and epidote, and recrystallization of muscovite and chlorite (Breaks & Bond 1993).

In the Uchi subprovince, mineral assemblages in the greenstone belts indicate pressures of 3 to 4.7 kbar corresponding to a depth of 10.5 to 16 km (Thurston & Breaks 1978). The metamorphic grades in the Red Lake region have been recognized by the following mineral assemblages (modified from Thurston & Breaks 1978):

Low grade:	chlorite- biotite zone	Greenschist facies
Medium grade:	staurolite-chlorite-biotite zone sillimanite-muscovite zone	Lower amphibolite facies
High grade:	sillimanite-K feldspar zone cordierite-almandine-K feldspar zone	Upper amphibolite/ granulite facies

Pelitic rocks of the greenschist facies in the Uchi subprovince typically contain chlorite and sericite and are replaced at higher temperatures by almandine and biotite. Chlorite-epidote-actinolite mineral assemblages reflect the upper greenschist facies for basic rocks, while epidote-almandine-hornblende assemblages represent the lower amphibolite facies (Ermanovics & Froese 1978). The following three reactions have been used by Ermanovics & Froese (1978) in pelitic rocks to define the lower boundary of the amphibolite facies to higher pressures:

1) chlorite + almandine + muscovite → biotite + staurolite + quartz + H_2O.

2) chlorite + staurolite + muscovite + quartz → biotite + Al silicate + H_2O

3) chlorite + muscovite + quartz → biotite + Al silicate + cordierite + H_2O

In the Rice Lake belt, epidote-chlorite-carbonate mineral assemblages are common, but appear to be products of retrograde metamorphism (Shklanka 1967).

The anorthite content of plagioclase has been used by various authors to define metamorphic grade. Blewett (1976) stated that the lower limit of the amphibolite facies begins with a plagioclase composition of An15. He documented that plagioclase compositions in amphibolites at Sydney Lake range from An10 to An43-45 (Blewett 1976).

Mineral assemblages noted above have been used to define metamorphic facies in the study area, supplemented by sequences of assemblages defined by Bucher & Frey (1994, pp. 205, 263).

3.2 Chase Lake Area

Thirty rock chip samples were prepared for thin section analysis from various localities in the Chase Lake area. Mineral assemblages and percentages, textures, metamorphic facies and sample locations are listed in Appendix C.1. Figure 10 shows the number and location of thin section descriptions and Figure 11 shows the metamorphic mineral assemblages and locations in the Chase Lake area. Table 8 gives the location number, rock type and metamorphic grade of each sample. Brief descriptions of the thin sections by outcrop type and sample number follow.

The two mafic metavolcanic units in the Chase Lake area (Figure 8) consist dominantly of amphibole (hornblende)-epidote-plagioclase-quartz and biotite-chlorite-sericite-apatite-sphene-opaques metamorphic mineral assemblages (Figure 11). Typically, hornblende comprises 40 to 60% of the rock, however, actinolite is present in one sample (Sample 105) north of Chase Lake. Actinolite may be present in the reworked intermediate metavolcanic outcrop(Sample 105) which contains 30 to 40% quartz and was previously mapped as a mafic metavolcanic. A migmatite unit (Sample 129) sandwiched between the two main mafic metavolcanic units east of Chase Lake contains monzonite leucosomes and up to 80% amphibole in the paleosome.

The amphibolite and intermediate to mafic reworked metavolcanic units, north of the Midway Lake eastern extension, consist of metamorphic grades that change frequently across strike (Samples 40-46, Figure 10). At location 40, the rock consists of biotite zone greenschist facies mineral assemblages. A short distance north, at location 41, the outcrop contains amphibolite facies assemblages (Figure 11) and is highly foliated and magnetic, with cubes of magnetite visible in thin section. At location 42, the greenschist facies is encountered once again. Shear zones occur at and between the three localities and it is possible that most rocks in the area may have undergone retrograde metamorphism.

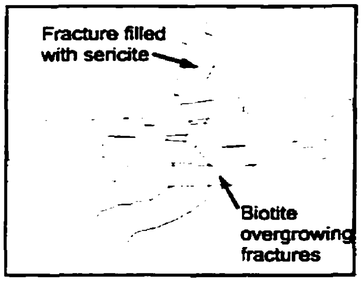


Figure 12. Sericite-filled fractures overgrown by biotite in metavolcanic at AB31.

Sample 31 (Figures 10 & 11), on the south shore of the Midway Lake eastern extension, consists of biotite zone mineral assemblages and may be a reworked metavolcanic rock. In thin section, evidence for retrograde metamorphism is present in the form of a sericite-filled fracture that crosscuts the foliation. The biotite and amphibole foliation postdates the formation of the sericite (Figure 12).

Garnets (Plate 2b, Chapter II) are visible in many outcrops east of and along the north shore of Chase Lake. At location 69 (Figure 10), 10% of the thin section consists of garnet porphyroblasts which occur in layers and are, on average, one centimetre wide. Another example occurs at locality 27 (Figure 10), on the north shore of Chase Lake, which contains light pink garnets in thin section that may be spessertine. Sample 91 (Figure 10) contains garnet porphyroblasts hosted by a mafic metavolcanic unit which contains moderate foliation defined by amphibole grains, however, it is evident in thin section that several amphibole grains are oriented perpendicular to foliation.

Mafic metavolcanics at locality 19 (Figure 10) contain varioles that comprise up to 50% of the outcrop. In thin section, the amphibole grains appear to be more strained than at locality 3 in the mafic metavolcanic unit to the north of Chase Lake.

An intermediate lapilli tuff at locality 77 (Figure 10), consists of 60%, large, plagioclase and quartz lapilli within a chlorite-epidote-sericite matrix. The outcrop is located close to the

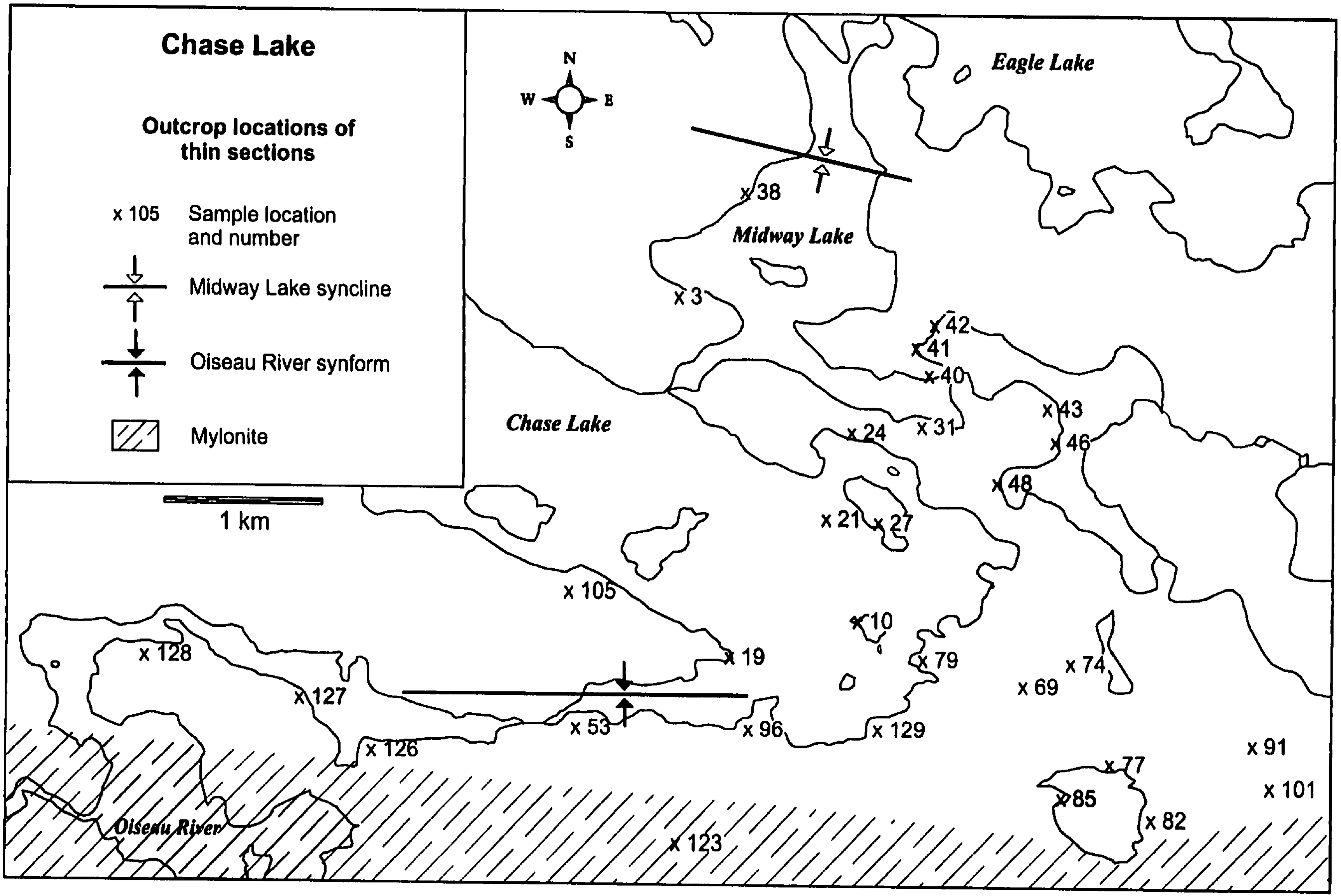


Figure 10. Sample location of thin sections from the Chase Lake area (see Appendix C for thin section descriptions).

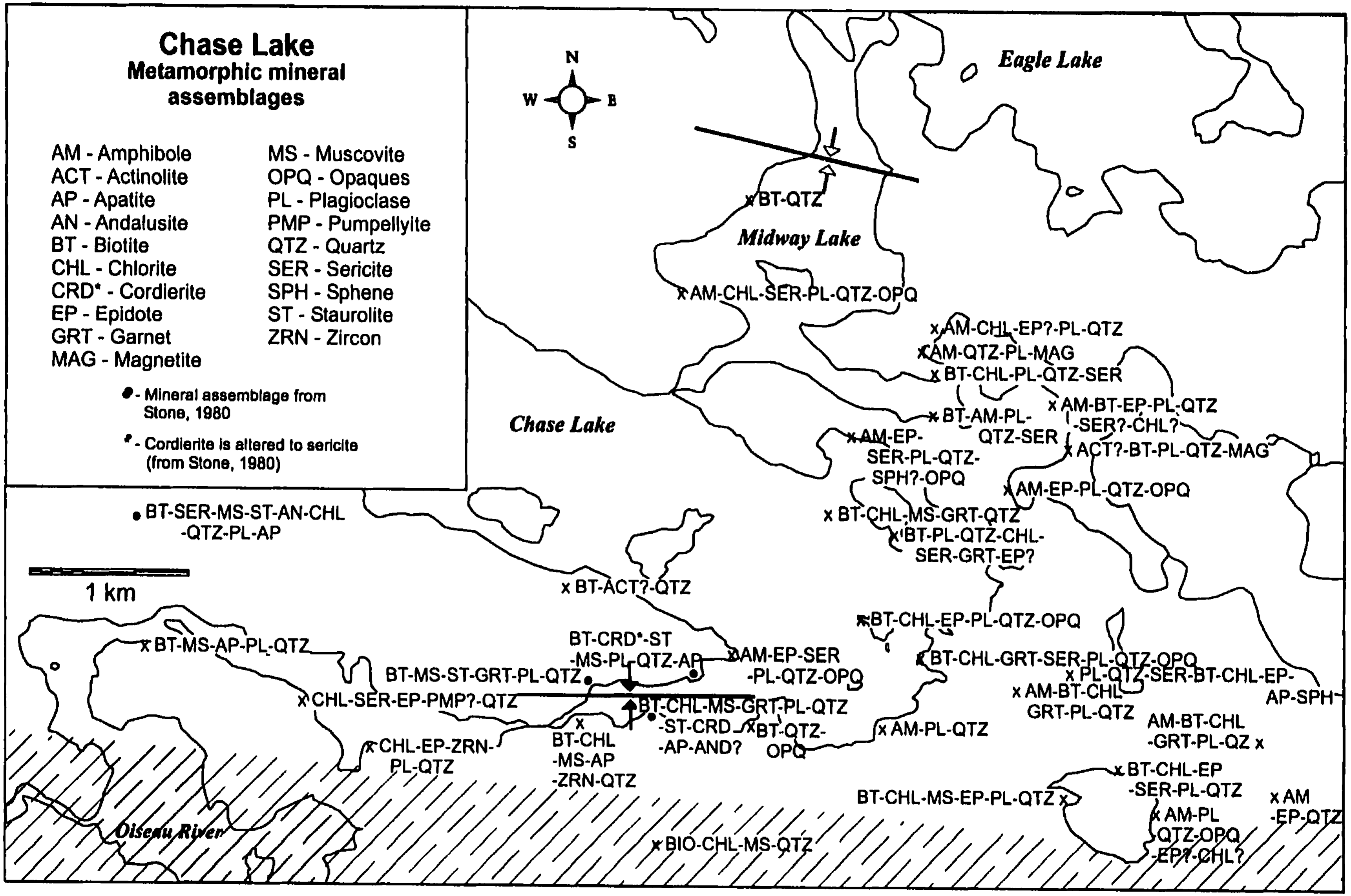


Figure 11. Metamorphic mineral assemblages in the Chase Lake area.

SLFZ and yet only reaches greenschist facies metamorphism (Figure 11). Also near the SLFZ, at locality 82 (Figure 10), amphibolite facies reworked intermediate to mafic metavolcanics contain ½ metre wide, concordant, pegmatite dykes and small Z-folds. The rock is weakly foliated with a relatively small grain size plus epidote- and chlorite-filled microfractures. Another amphibolite facies intermediate to mafic reworked metavolcanic located near the SLFZ, Sample 101 (Figure 10), is a moderately to highly strained and contains epidote-rich/amphibole layers and minor quartz-rich layers.

Biotite zone intermediate to mafic reworked metavolcanics are located at 85 (Figure 10). The rock consists of quartz and plagioclase with minor muscovite, biotite, chlorite and epidote. Granitic dykes comprise 20% of the outcrop.

Metawackes and reworked felsic to intermediate metavolcanics near the SLFZ are grouped into biotite or chlorite zones. Samples 53, 96 and 128 are located in the biotite zone, while Samples 126 and 127 are part of the chlorite zone (Figures 10 & 11, Table 8). Sample 53 (biotite zone) is composed of 60 to 70% quartz with biotite, muscovite, chlorite and minor apatite and zircon (Figure 11) and contains abundant ½ metre wide isoclinal folds. In thin section the chlorite and biotite define the comparatively weak foliation. Sample 96, a felsic reworked metavolcanic and/or metawacke, consists of 60% quartz and 40% biotite. The rock has a similar mineralogy and texture as Sample 53. Biotite and quartz define the foliation with biotite grains "wrapping" around larger quartz grains. Samples 126 and 127, located nearer to the SLFZ in the chlorite zone (Figure 10), contain no biotite and at least 30% chlorite in thin section. Both thin sections contain sericite and Sample 127 contains pumpellyite. Sample 128, to the west, is part of the biotite zone. It contains 50% quartz/plagioclase and 40% biotite with minor muscovite and apatite. Higher percentages of muscovite and quartz are found in Sample

TABLE 7. Location numbers, rock type and metamorphic grade of thin sections in the Chase Lake area.

Location	Rock type	Metamorphic grade
3	amphibolite	amphibolite facies
10	metawacke	biotite zone
19	amygdular amphibolite	amphibolite facies
21	reworked intermediate to mafic metavolcanic	biotite zone
24	amphibolite	amphibolite facies
27	reworked intermediate to mafic metavolcanic	biotite zone
31	metawacke or reworked intermediate metavolcanic	biotite zone
38	felsic to intermediate reworked breccia	biotite zone
40	intermediate metavolcanic	greenschist facies
41	intermediate metavolcanic	amphibolite facies
42	intermediate metavolcanic	greenschist facies
43	reworked intermediate to mafic metavolcanic	amphibolite facies
46	reworked intermediate to mafic metavolcanic	greenschist facies (?)
48	mafic metavolcanic	amphibolite facies
53	metawacke	biotite zone
69	reworked tuff or wacke	lower amphibolite
74	intermediate lapilli tuff	greenschist facies
77	intermediate lapilli tuff	greenschist facies
79	metawacke	biotite zone
82	reworked intermediate to mafic metavolcanic	amphibolite facies
85	metawacke	biotite zone
91	mafic metavolcanic	amphibolite facies
96	reworked felsic metavolcanic or metawacke	biotite zone
101	reworked intermediate to mafic metavolcanic	amphibolite facies
105	reworked intermediate to mafic metavolcanic	greenschist facies
123	metawacke	biotite zone
126	metawacke	chlorite zone
127	metawacke	chlorite zone
128	metawacke	biotite zone
129	mafic metavolcanic	amphibolite facies

53 compared to Samples 126 and 128. No cordierite or staurolite was observed.

Samples 10 and 79 (Figure 10) are located further from the SLFZ than the previous metawacke sample locations. Sample 10 contains 50% quartz and 30% biotite and is located in the biotite zone. The intergrowth of biotite and chlorite is crenulated. Nearby sample 79, also part of the biotite zone, contains minor garnet while sericite and chlorite define the foliation. Larger muscovite grains are occasionally oriented perpendicular to foliation.

3.3 Longlegged Lake

Seven thin sections were analyzed from various outcrop localities in the metavolcanic unit at Longlegged Lake. Figure 13 shows the sample locations and Figure 14 shows the metamorphic mineral assemblages and locations in the Longlegged Lake area. Table 9 shows the location number, rock type and metamorphic grade of each sample in the Longlegged Lake area.

All samples are located in the greenstone sliver at Longlegged Lake. The intermediate to mafic metavolcanics are composed mainly of amphibole (~70%) with quartz, plagioclase, garnet and occasionally pyroxene. Many of the outcrops contain disrupted layers. Sample 176 (Figure 13) contains disrupted, garnetiferous, intermediate metavolcanic layers and sample 171 contains disrupted epidote-rich layers hosted by incompetent amphibolite layers (Plates 10a & b, Chapter IV).

The intermediate to mafic metavolcanic rocks show a strong amphibole lineation and abundant epidote and sericite alteration. Sample 130 (Figure 13), located on the northeastern tip of the metavolcanics near the intermediate to mafic/felsic to intermediate metavolcanic boundary, has a strong mineral lineation, which consists of amphibole, quartz and biotite. Sample 137

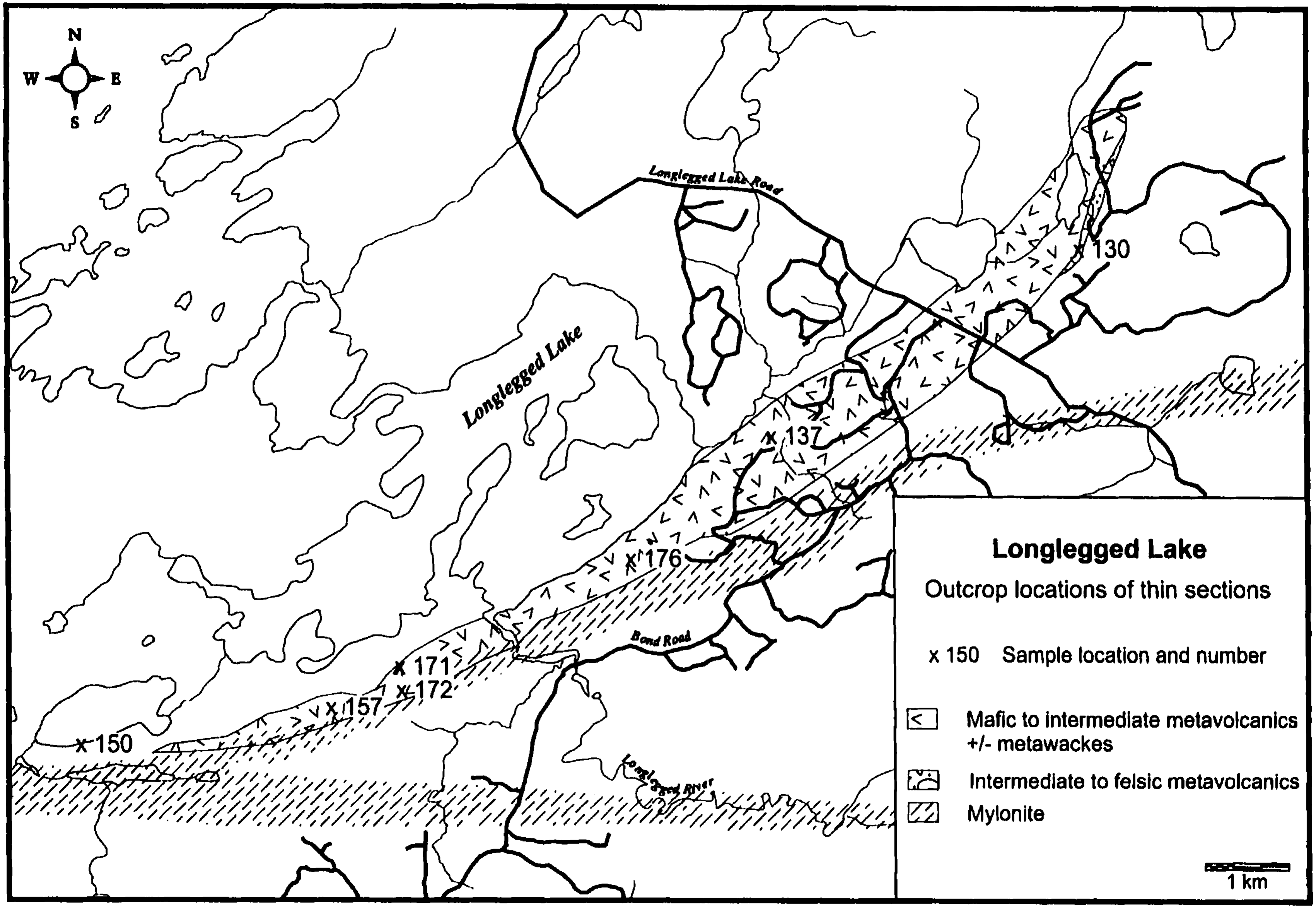


Figure 13. Sample locations of thin sections from the Longlegged Lake area (see Appendix C for thin section descriptions).

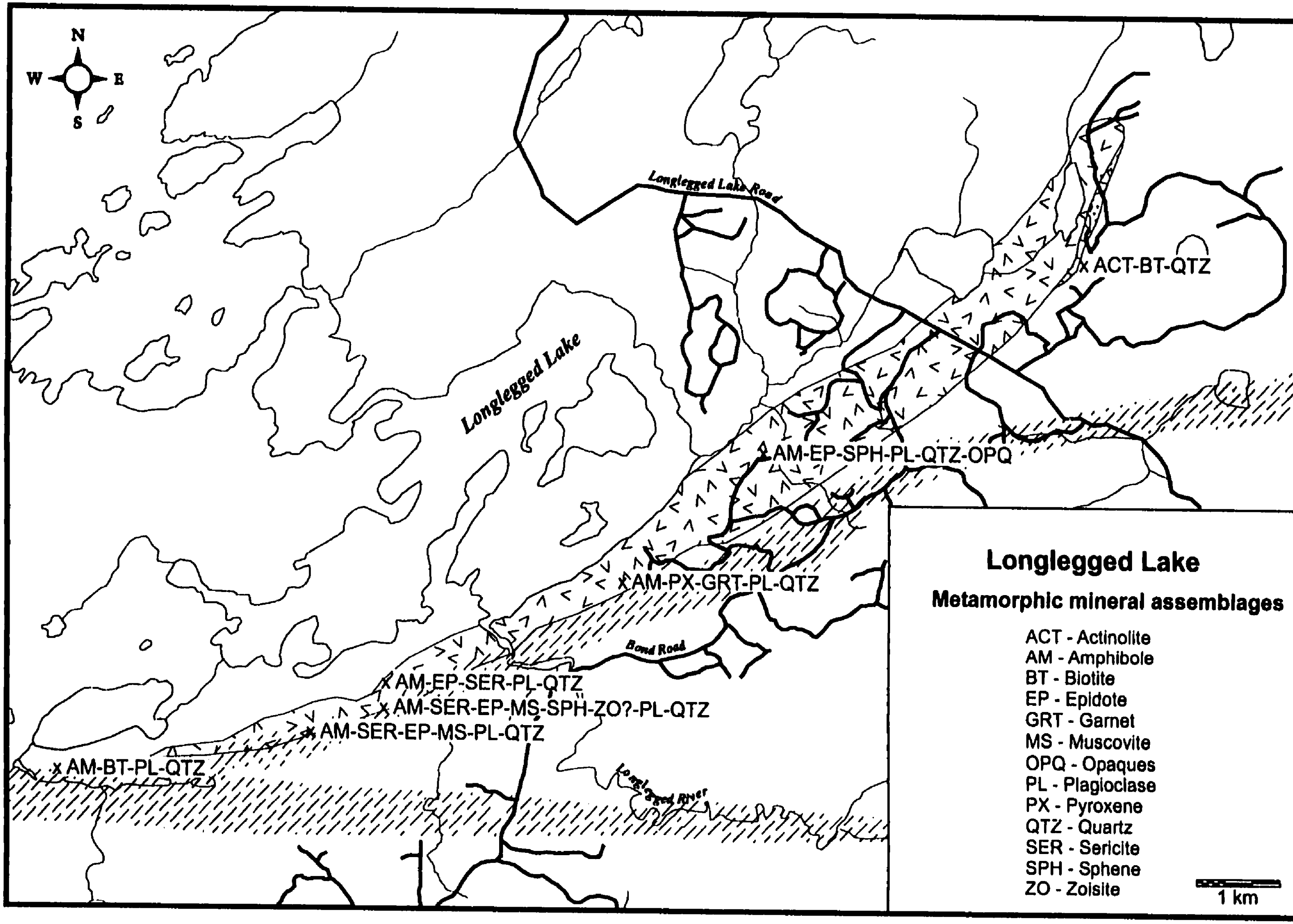


Figure 14. Metamorphic mineral assemblages in the Longlegged Lake area.

contains abundant epidote lenses while 157 and 172 contain 10% sericite/epidote and epidote veinlets.

Sample 150 (Figure 13), located in the southwest portion of the sliver, is taken from a large metavolcanic enclave. The enclaves or rafts are weakly foliated, medium-grained mafic metavolcanics hosted by mylonitized, white-weathered trondhjemite. Consisting of up to 70% amphibole, the sample has a larger grain size than any other sample taken in the greenstone sliver.

TABLE 8. Location numbers, rock type and metamorphic grade of thin sections in the Longlegged Lake area.

Location	Rock type	Metamorphic grade
130	intermediate to felsic metavolcanic	greenschist facies
137	intermediate to felsic metavolcanic	amphibolite facies
150	mafic to intermediate metavolcanic	amphibolite facies
157	mafic to intermediate metavolcanic	amphibolite facies
171	mafic to intermediate metavolcanic	amphibolite facies
172	mafic to intermediate metavolcanic	amphibolite facies
176	mafic to intermediate metavolcanic	amphibolite facies

3.4 Summary and Conclusions

The metawacke unit in the Chase Lake area appears to be low grade and is divided into chlorite and biotite zones, the former located nearer to the SLFZ. Blewett (1976) suggested that the rocks in the area lack the required bulk composition, specifically Al_2O_3, to produce cordierite and staurolite and could simply be paragneisses or even orthogneisses. He did not observe staurolite, sillimanite, kyanite or cordierite at Sydney Lake, but documented abundant chlorite, epidote and sericite, and attributed them to retrograde metamorphism. However, other workers (Stone 1980) identified metamorphic mineral assemblages in metawackes, adjacent to the mafic metavolcanic unit south of Chase Lake (Figure 9, mineral assemblages starting with a black dot "•" rather than an "x") that contain staurolite, garnet, cordierite and andalusite thus indicating a higher grade than observed by Blewett (1976). However, Stone (1980) also showed that cordierite had been altered to sericite which strengthens the hypothesis of retrograde metamorphism in the area near the SLFZ. Therefore, the metawackes near the SLFZ might have undergone retrograde metamorphism and therefore lack cordierite or staurolite in their mineral assemblages while containing abundant sericite, chlorite and epidote.

The amphibolite facies mafic metavolcanic unit in the Oiseau River synform appears to be sandwiched by the lower grade metawacke unit, supporting the idea that the metawacke units were indeed higher grade. Retrograde metamorphism could be related to the SLFZ and may have occurred after the fold event that produced the Oiseau River synform or during the formation of the synform. However, more samples need to be analyzed from the metawacke unit to support either theory.

Recrystallization of the metawackes, by regional metamorphism, has made identification of original textures difficult; however, the high quartz and biotite content of the metawackes in the Chase Lake area is consistent with the rocks being metamorphosed argillaceous sedimentary rocks (Blewett 1976). Metawackes with abundant sand-size detrital quartz have traditionally been interpreted to indicate a plutonic or cratonic source (Thurston *et al.* 1985, Ojakangas 1985).

In the Longlegged Lake area, the metavolcanic unit is composed almost entirely of amphibolite grade mineral assemblages. Mafic rafts in the southwest portion of the metavolcanic sliver may have developed prior to the SLFZ, during the greenstone sliver development or due to the SLFZ since the trondhjemites and rafts are mylonitized.

CHAPTER IV

RESULTS OF FIELD-BASED STRUCTURAL ANALYSIS

IV. RESULTS OF FIELD-BASED STRUCTURAL ANALYSIS

4.0 Introduction: Structural data and geometric analysis

The structure of mafic to intermediate metavolcanic units in the Chase Lake and Longlegged Lake areas was carefully analysed while other units were studied in less detail. The attitudes of mineral and shape lineations, foliation, bedding, fold axes, enveloping surfaces, dykes and boudin axes were measured on outcrop surfaces, wherever possible, and the data analysed in the laboratory. Structural data complement the available geological evidence and aids in the interpretation of the structural history of rocks in both study areas. The following section describe the geometry of structures seen in the Chase and Longlegged Lake areas, along with structural maps and fabric diagrams.

4.1 Chase Lake Area

4.1.1 Bedding attitudes

Bedding trajectories with dip values in the Chase Lake area are shown in Figure 15. On Midway Lake, graded beds in felsic to intermediate reworked metavolcanics (Plates 3a & 3b) define a large syncline (Shklanka 1967, Stone 1980). The axial trace of the Midway Lake syncline, shown as a blue line in Figure 15, trends west-northwest at 282° and plunges 21°. The moderate dip of bedding becomes steep on the extreme south limb of the fold. In the same unit to the east, along the Midway Lake eastern extension, steep bedding surfaces strike easterly. It appears that only the south limb of the Midway Lake syncline may be exposed in this part of the study area. The contoured normals to bedding in the Midway Lake syncline are shown on the

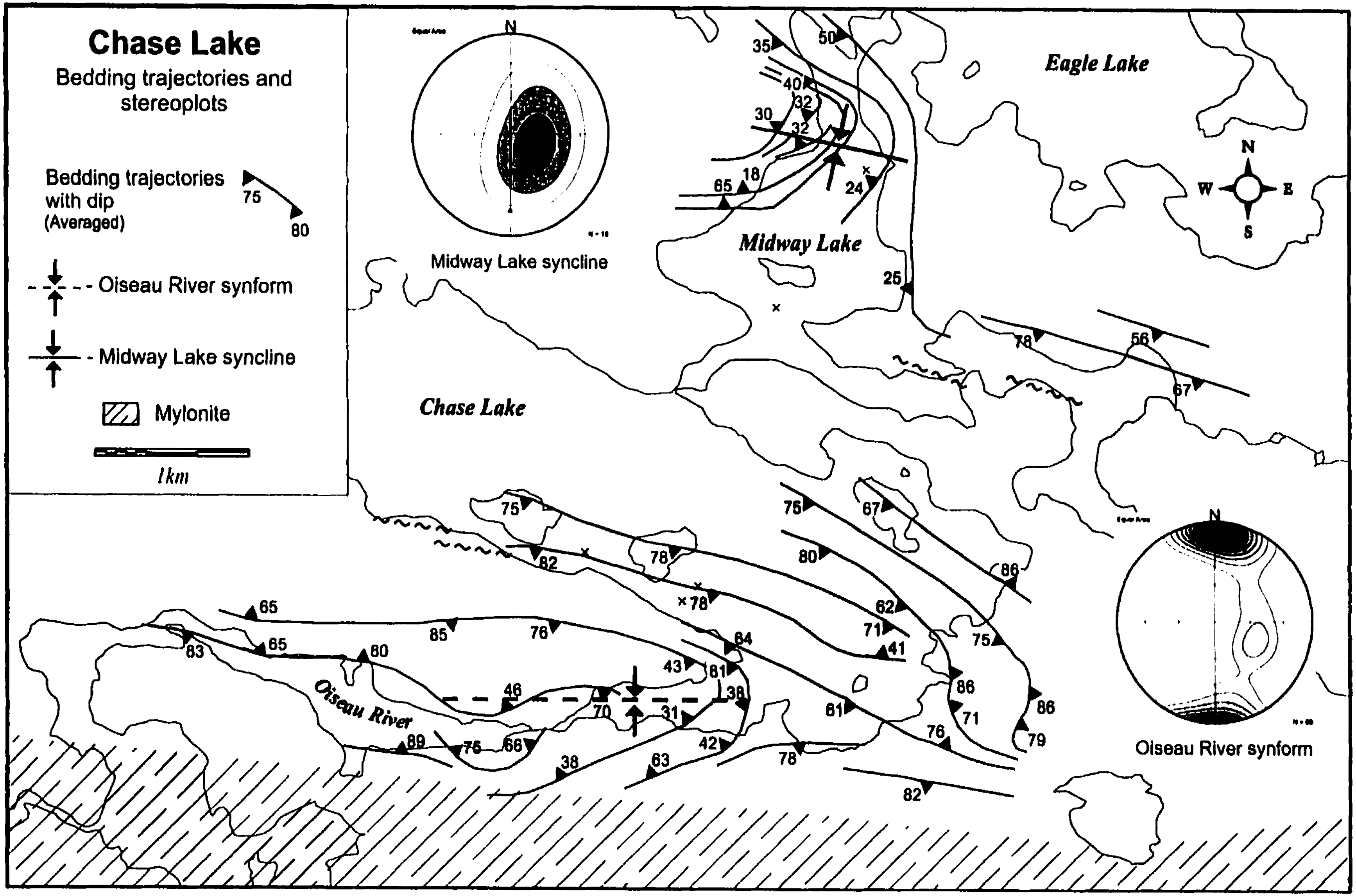


Figure 15. Averaged bedding trajectories with dip and stereoplots of the normals to bedding in the Midway Lake syncline and Oiseau River synform.

stereonet in the upper left corner of Figure 15. Contoured bedding normals define a crude heterogeneous girdle. A cross section of the Midway Lake syncline is shown in Figure 16. On the right-hand side of the graphic fold line is the map view of bedding trajectories while the left-hand side shows the cross section. The Midway Lake syncline turns out to be a shallow and open fold.

Figure 15 also shows the trajectories and dip values of bedding in the metawacke and metavolcanic units on Chase Lake and along the Oiseau River to the south. The metawacke unit is typically composed of interbedded pelite and wacke layers. Graded beds have been described by Shklanka (1967) and Stone (1980), but, were only rarely observed in this study. Bedding in the metawacke unit on Chase Lake strikes northwesterly and is typically steep. East of Chase Lake the strike of bedding changes direction to north-south.

At Oiseau River the bedding trajectories in the metawackes and metavolcanics form a synform. The northern limb of the synform strikes easterly with steep dips to the south. At the fold nose, northerly striking trajectories become shallow. The south limb of the Oiseau River synform contains easterly striking bedding surfaces with shallow to steep dips to the north. The Oiseau River synform is represented by a stereoplot of normals to bedding in the lower right corner of Figure 15, concentrated in a partial girdle with non-uniform point distribution.

Figure 17 depicts the down-plunge projection of the Oiseau River synform, whereby the right-hand side of the red fold line shows the map pattern of bedding trace trajectories with dip values from the metawacke and metavolcanic units. The red arrow represents the axial trace of the upright fold. To the left of the red fold line is the cross section of bedding (blue traces). It is evident that the Oiseau River synform is a close fold. The magenta fold line and arrow show the cross section and fold axis of a second order synform within the Oiseau River synform, with a

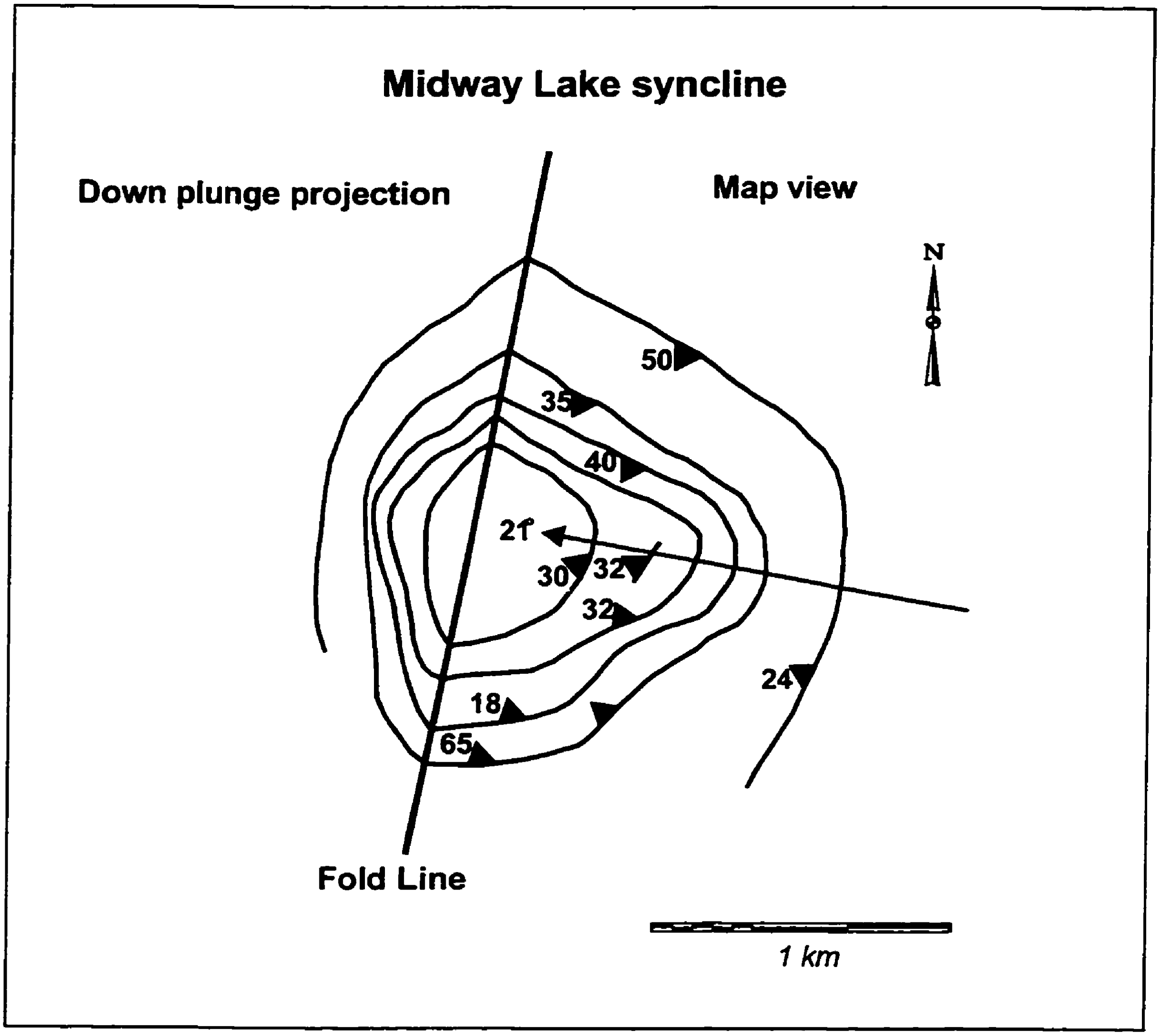


Figure 16. A down-plunge projection of the Midway Lake syncline. Fold axis trends 282° and plunges 21° .

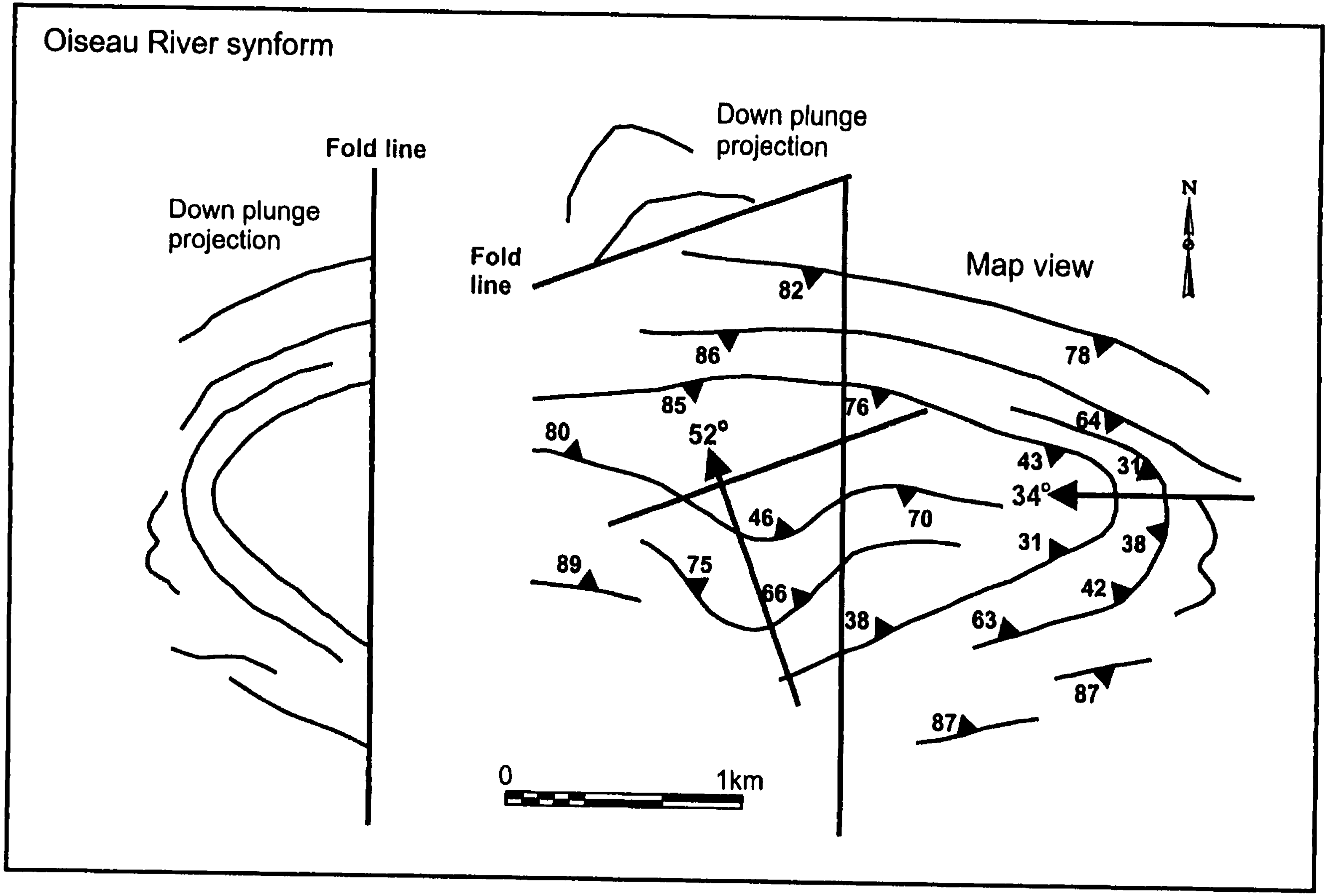


Figure 17. A down-plunge projection of the Oiseau River synform. Main fold axis trends 270 ° and plunges 34° , minor fold axis trends NNW with a 52° plunge.

fold axis trending approximately NNW and plunging 52°. The trace of the bedding surfaces in the second order fold is shown on the north side of the magenta fold line.

4.1.2 Foliation pattern

Figure 18 shows the foliation trajectories with dip values and domainal stereoplots. The line A-B is the trace of the vertical cross-section discussed in *subchapter 3.1.5.* At Midway Lake, in the reworked felsic to intermediate unit, the foliation strikes approximately west-northwest with moderate to steep dips. The stereoplot in the upper left corner of Figure 18 shows the contoured normals to foliation in the Midway Lake syncline. It has a moderately developed cluster with a partial girdle and non-uniform distribution. A majority of the foliation attitudes dip southerly (Figure 18). Bedding trajectories at Midway Lake are folded with an axial planar foliation, as befits a first-generation fold.

The mafic metavolcanic unit and surrounding units north of, and on, Chase Lake have NW-SE striking foliation with moderate to steep dips. However, east of Chase Lake the foliation trajectories have southerly strikes. Change in strike direction can be seen in the quartz monzonite which is sandwiched by mafic metavolcanics east of Chase Lake. Mafic enclaves are found in the quartz monzonite, east of Chase Lake (Plates 4a & 4b), and are stretched in the WNW striking foliation. Foliation and enclaves abruptly assume a north-south attitude across the small narrow lake east of Chase Lake (Figure 21). Disrupted granitoid sheets in the metawackes and metavolcanics also abruptly change direction and bear north-south in this area. The foliation traces resemble a large open Z, which we assume to reflect folding.

At Oiseau River the foliation trajectories are folded by the Oiseau River synform (Figure 18). Normals to foliation are shown on the stereoplot in the upper right hand corner of Figure 18, which shows a moderately developed girdle with non-uniform point distribution.

Intermediate to mafic metavolcanic units north of Chase Lake are moderately to highly foliated while the metawacke unit to the south exhibits only a weak foliation. Small shear zones are found north of the Midway Lake eastern extension, at the boundary between the mafic metavolcanic and intermediate to felsic reworked volcanic units, and southwest of Chase Lake in the metawacke unit. Both sets of shear zones strike approximately WNW.

4.1.3 Attitudes of mineral and shape lineations

Mineral and shape lineations are represented on three different maps. The first map, Figure 19, shows the traces of averaged lineation trend lines with contoured plunge values. The mineral and shape lineations in the Chase Lake mass are averaged and contoured using Spheristat v.1.1. On the second map (Appendix A.5) the trend and plunge values of the lineation are represented by different sizes of arrows. The longer arrows signify shallow plunges and shorter arrows signify steeper plunges. The third map is a hand-contoured rake diagram (Figure 20). (Rake is the angle between the horizontal and the lineation on the plane of the foliation.)

Lineation trend lines and the variation in plunge are shown in Figure 19. The plunge direction is indicated by an arrow, and plunge values are contoured in 10° intervals. The darkest shades represent high values while the lighter shades represent low values. The geometry of lineation trend line in the Chase Lake mass resembles an "S", but it is unclear whether foliation northeast of the Oiseau River synform has actually been folded.

The attitudes of mineral and shape lineations in the Midway Lake syncline are concentrated in an unimodal cluster with non-uniform distribution (Figure 19). Shape and mineral lineations trend west to WNW with shallow to moderate plunges, similar to the trend of the fold axis. Shape lineation is represented by stretched fragments in the reworked tuff breccias.

Moderate to steep mineral lineation in the mafic to intermediate metavolcanics and metawackes, north and east of Chase Lake, plunge southwesterly (see stereoplot in Figure 19, labelled 'mafic to intermediate metavolcanics'). Shape lineation is developed in the intermediate to mafic metavolcanics on an island on northeastern Chase Lake (Plate 1b). Here volcanic fragments are highly stretched and define a strong shape lineation. The mineral lineation in the metavolcanics and metawackes becomes shallower near shear zones on the Midway Lake eastern extension (Figure 8) and changes direction from southwest to southeast.

The trend of the mineral lineation varies between southeast to west in the Oiseau River synform. In the core and south limb of the synform, mineral lineation plunges to the west at shallow to moderate angles. Mineral lineation is represented also in a stereoplot, located on the left side of Figure 19, labelled 'Oiseau River synform'. It displays a partial girdle and internal clusters with non-uniform distribution. The contoured high trends 249° and plunges 48°, which is similar to the orientation of the Oiseau River synform fold axis. The north limb of the Oiseau River synform contains of a steep mineral lineation that trends south to southwest. The mineral lineation may be related to shear zones located on the south shore of Chase Lake. The SLFZ to the south contains shallow to moderate plunging, east and west trending mineral lineation. However, several steep mineral lineations have been documented by other workers (Stone 1980) but remain to be explained.

A mineral and shape lineation map in Appendix A.5 represents the plunge of lineation with various sizes of arrows. It is apparent from this map that mineral lineation shallows at the boundary between reworked metavolcanics and mafic to intermediate metavolcanics north of

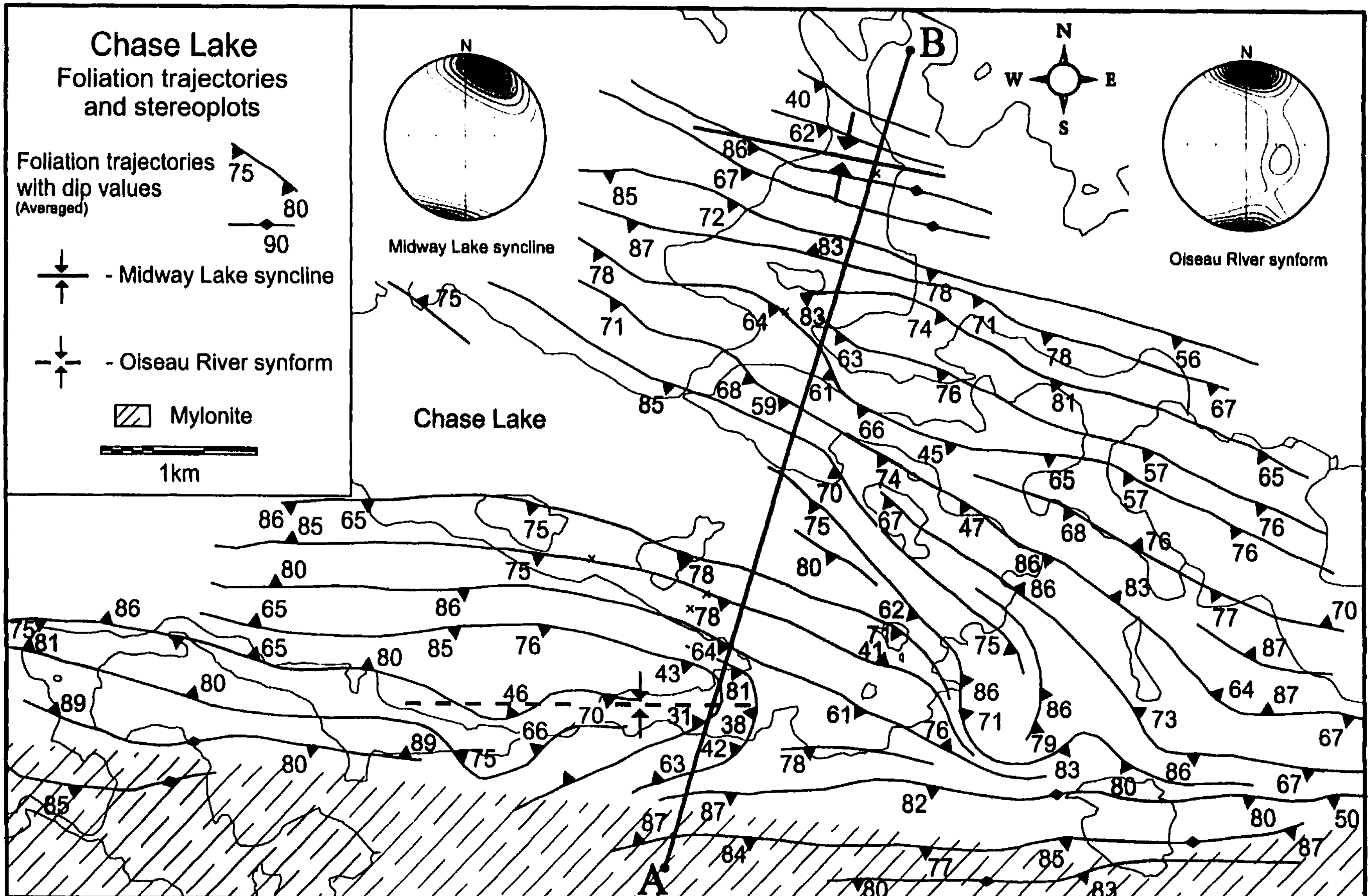


Figure 18. Averaged foliation trajectories with dip values and stereoplots of normal to foliation plane in the Midway Lake syncline and Oiseau River synform, Chase Lake. A-B is the trace of the vertical cross section.

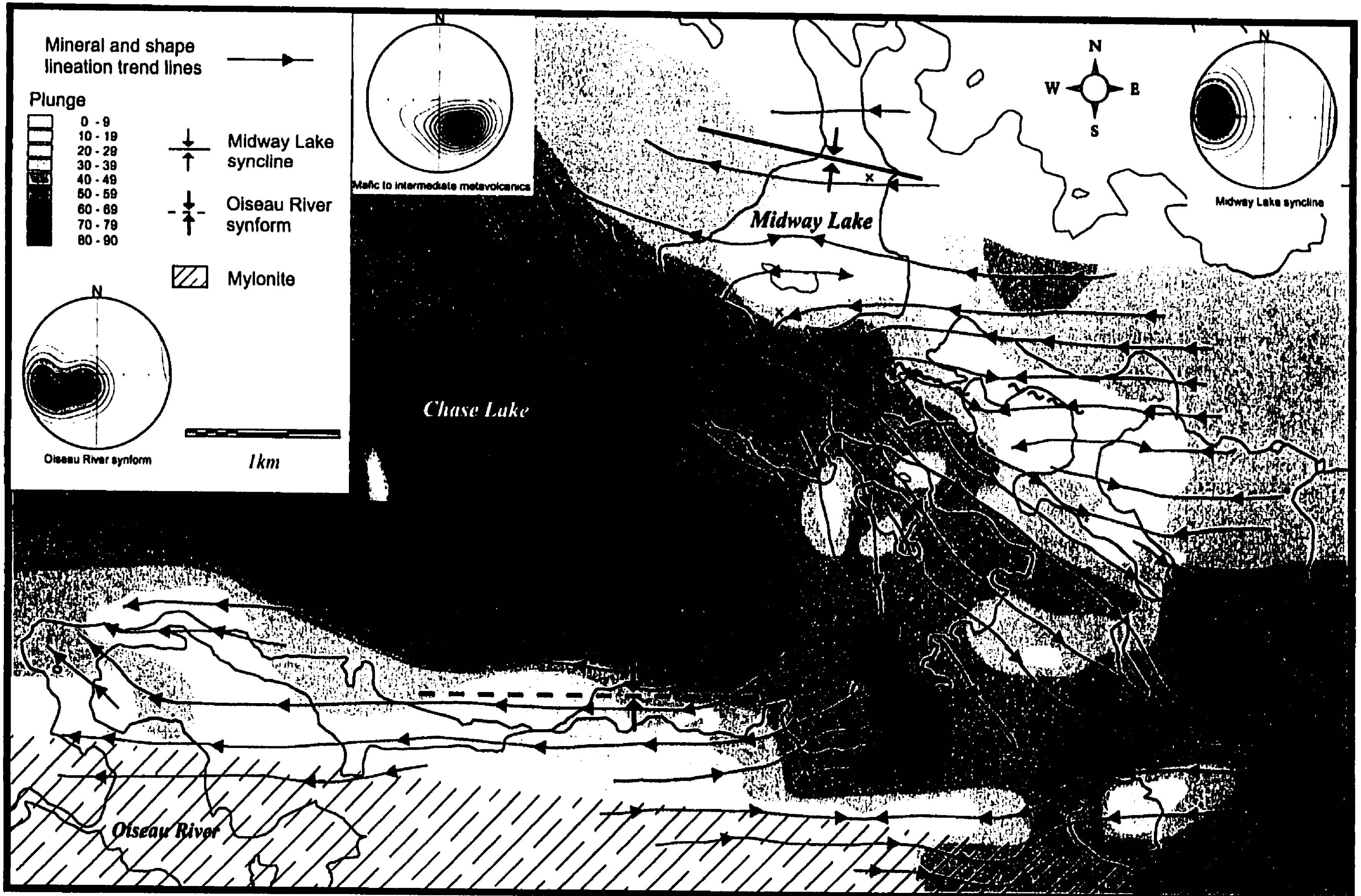


Figure 19. Mineral and shape lineation trend lines with contoured plunge values and stereoplots of mineral lineation in the Midway Lake syncline, Oiseau River synform and mafic to intermediate metavolcanics, Chase Lake.

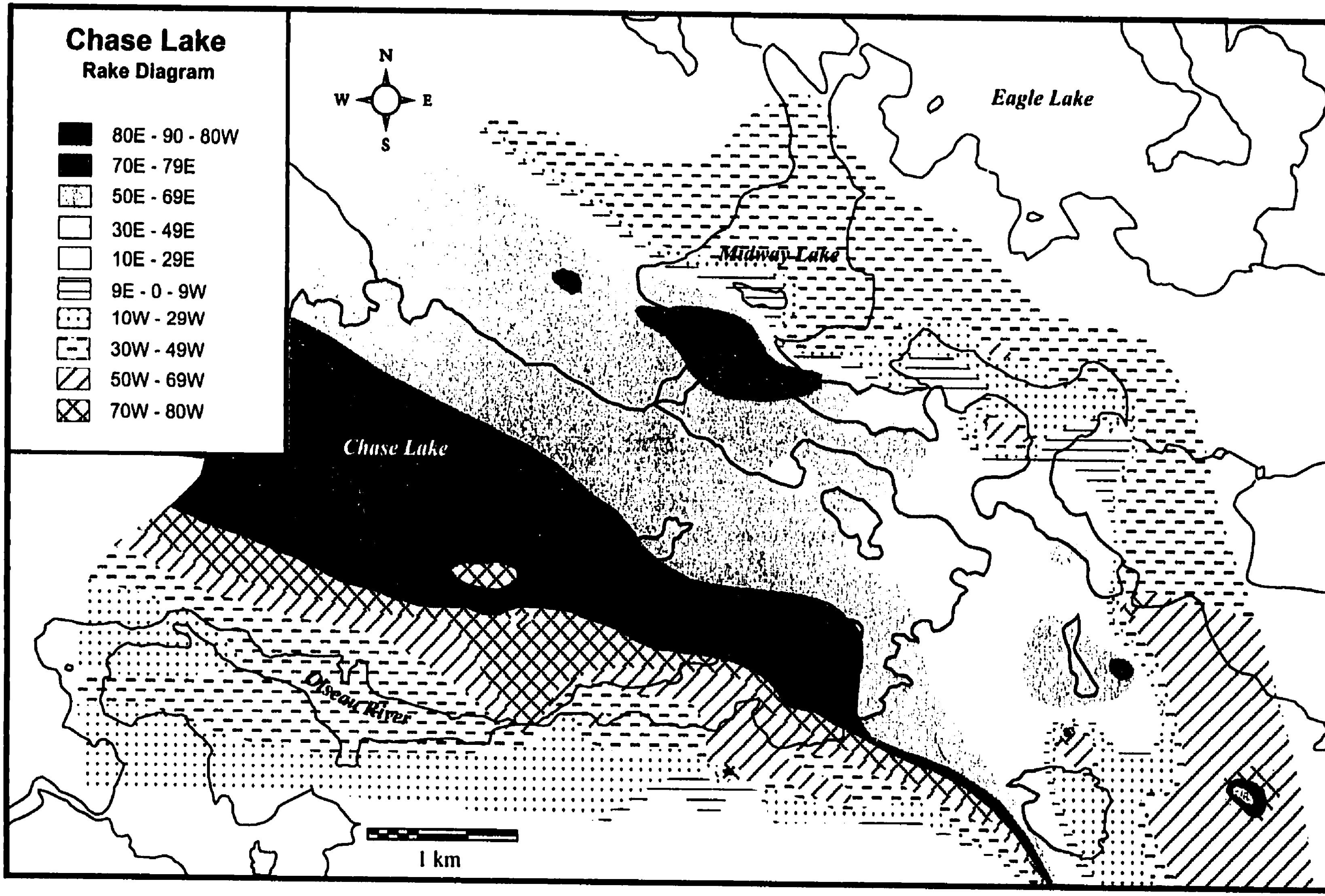


Figure 20. Contoured rake diagram of the Chase Lake area. The purple shades represent rake angles east of the strike line of foliation and blue shades indicate westerly rake angles.

Chase Lake. The shallow lineation may relate to shear zones on the Midway Lake eastern extension. It is also apparent that steep lineation south of Chase Lake is possibly related to shear zones observed at this locality.

Contoured rake values in the Chase Lake area are shown in Figure 20. Rake values are grouped into westerly and easterly intervals. Mineral lineation with trends to the west or WNW, for example at Midway Lake and Oiseau River, are contoured with blue shades. Darker colours represent larger angles between the horizontal and the mineral lineation on the foliation plane. Magenta colours represent easterly and southeasterly trending mineral lineation. Some ambiguity is encountered when contouring east of Chase Lake, where foliation strikes approximately north-south and rake angle are relatively small.

4.1.4 Geometry of folds, dykes, sheets and boudins

The geometry of folds, dykes, sheets and boudins of the Chase Lake area is depicted in Figure 21. Foliation traces are represented by fine lines while thicker lines represent sheets or dykes. S-, Z-, U- and M-folds are shown as well as several recumbent folds which are shown in blue. U-folds are partly exposed folds whose shape (monoclinicity sense) is uncertain. Mafic enclaves, hosted by quartz monzonite, are represented as black ellipses. Folds, enclaves and disrupted sheets with adjacent letters, A to G, are shown in plates in Chapter II.

Quasi-cylindrical boudins are developed in 5 cm to ½ metre thick granitoid sheets that parallel foliation in the mafic to intermediate metavolcanics, metawackes and migmatites. The disrupted granitoid sheets or boudins are oriented northwest-southeast in the mafic to intermediate metavolcanics north of Chase Lake. East of Chase Lake, however, the local strike of the boudins conforms to the outline of a large, open Z-fold. Disrupted granitoid sheets (Figure 21, Plate 7a) strike approximately north-south while folded granitoid dykes are oriented perpendicular to the sheets. Disrupted granitoid sheets south of Chase Lake are folded by the Oiseau River synform and strike northeasterly. Plate 9a (facing west) shows a dextrally offset, disrupted granitic sheet, hosted by mafic metavolcanics, located in the fold nose of the Oiseau River synform. The extension in the sheet is small (~200%).

Several boudin axes were observed on Chase Lake. The axis of one boudin, on an island on eastern Chase Lake, trends SSW with a 63° plunge. Another boudin axis, on eastern Chase Lake, trends northerly and plunges 83°. The axis of a third boudin, southeast of Chase Lake trends WSW and plunges 50°.

Mafic enclaves are hosted by the quartz monzonite unit east of Chase Lake. North and east of Chase Lake the stretched enclaves strike northwesterly, however, the enclaves abruptly change direction across the small narrow lake and strike northerly. The change of orientation across Chase Lake follows a pattern similar to that of the boudin attitudes.

M-, S-, U- and Z- fold axes north of Chase Lake trend approximately NW-SE with shallow to moderate plunge angles. Folds and boudins, east of Chase Lake, vary in orientation. Fold axes trend southwesterly with a moderate plunge, while disrupted sheets strike ENE. Fold axes and disrupted sheets, in the metawacke unit on Chase Lake, trend southeasterly. The fold pattern is more complicated southeast of Chase Lake in metawackes and migmatites. Fold axes vary in orientation and appear to adhere to the large Z-structure in lineation trend lines east of Chase Lake. The boudins and enclaves pre-date the fold event which produced the Z-structure. The folding of the large open Z-structure appears to have affected all of the units in the area, including migmatites that are thought to be derived from the English River subprovince. An S-

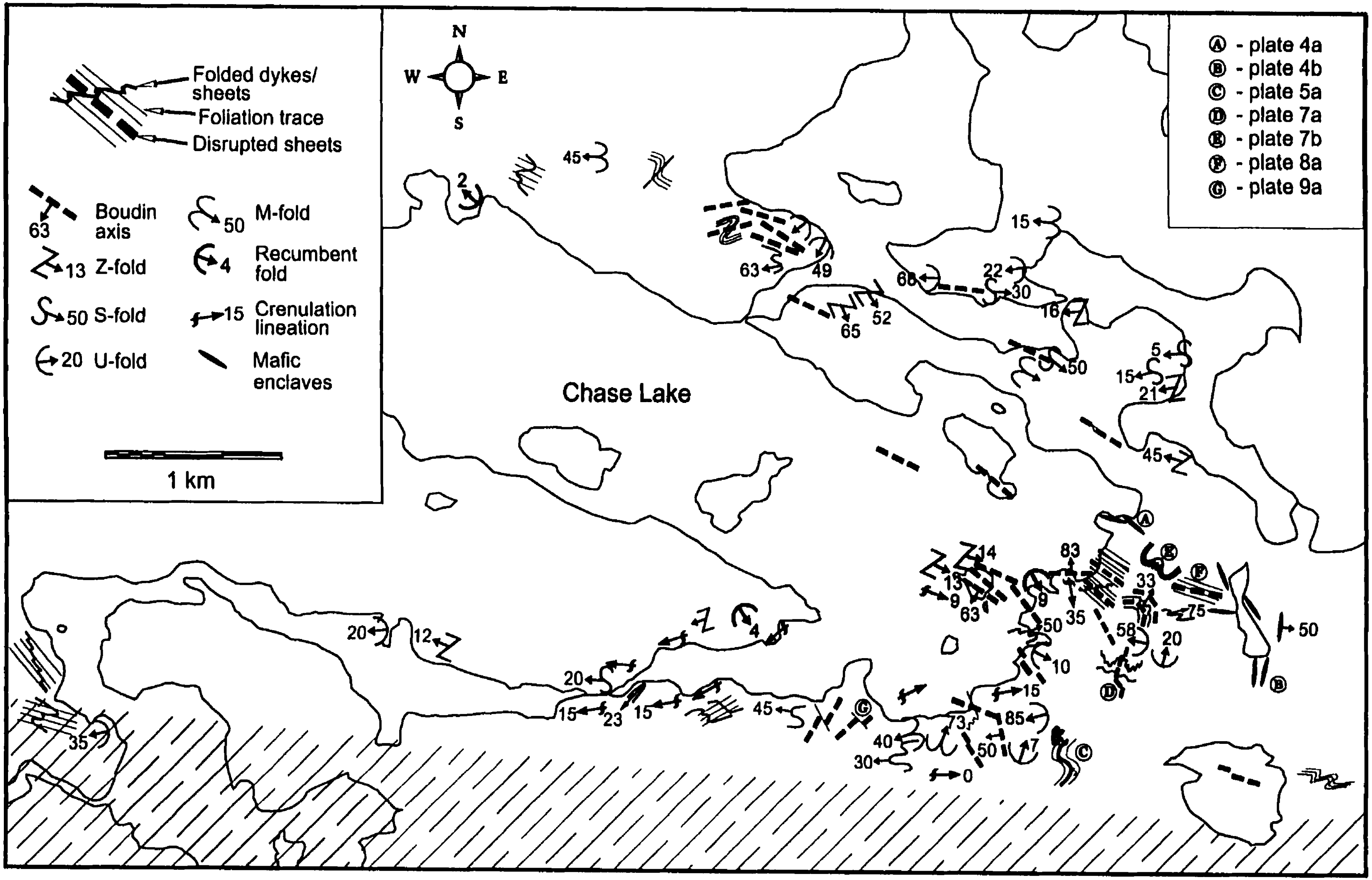


Figure 21. Disrupted layers, enclave and fold attitudes at Chase Lake (symbols not to scale). Symbols with adjacent letters, A to G, are shown in plates in chapter II.

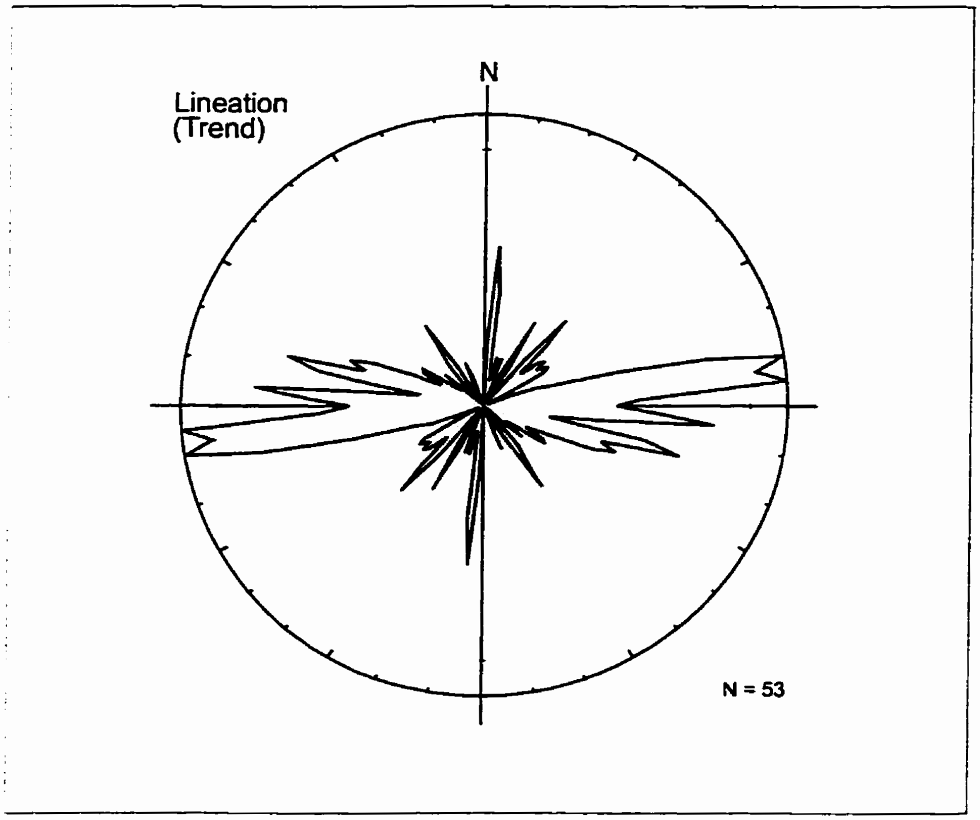


Figure 22. Rose diagram for the direction of fold axes (S-, Z-, M- and U-folds) in the Chase Lake area (see text for explanation).

folded metatexite in the area is shown in Plate 5a and Figure 21 at 'C'.

The Oiseau River synform contains westerly trending, shallow, small-scale folds that were probably coeval. The small folds are similar in orientation to the large Oiseau River synform fold axis and judged to be high-order structures. Small S- and Z-folds are found in equal abundance across the synform and on the outcrop scale. Z-folds tend to be more common in mylonites of the SLFZ to the south.

A rose diagram of all fold trends in the Chase Lake area is shown in Figure 22. The prominent WSW spike represents fold hinge lines typically seen in the Oiseau River synform. The second spike (WNW) is due to the fold axes north of, and up on, the islands of Chase Lake. The third spike (NNE) represents fold axes directions east of Chase Lake, in the Z-structure. Other spikes are minor local disturbances at various localities on Chase Lake.

4.1.5 Vertical cross section A-B

A vertical cross section, A-B, of the Chase Lake area is shown in Figure 23 ("A" is oriented towards the south). The trace of the cross section is shown in Figure 8. In the cross-section, magenta lines are parallel traces of foliation and bedding in the Oiseau River synform, while red lines are traces of foliation and black lines are traces of bedding for the Midway Lake syncline. Blue lines are traces of contacts, assumed to be steep, between rock types. The cross-section shows an open syncline on Midway Lake which contains axial planar foliation. The Oiseau River synform to the south folds bedding and foliation. Therefore, the Midway Lake syncline may predate the Oiseau River synform.

4.1.6 Discussion & Summary

The open Midway Lake syncline folds graded beds which are transected by an axial planar foliation. The syncline may predate the tight Oiseau River synform to the south, defined by the folded bedding and folded foliation. Therefore mineral and shape lineations in the syncline and synform probably formed during their respective folding events because the lineation and fold axis are approximately parallel at all localities. Between these two large folds, moderately plunging mineral lineation in mafic to intermediate metavolcanics trends southeasterly.

Two kinematic scenarios account for the structure of the Chase Lake area. In the first, an overturned tight anticline (Figure 24) is refolded by a second fold in the Rice Lake belt (Shklanka 1967). The second scenario envisages NW-SE dislocations along the south shore of Chase Lake and along Midway Lake to the north, where shear zones are developed (Figure 23).

The first scenario accounts for the intermediate to mafic metavolcanic unit south of Chase Lake now sandwiched by the metawacke unit. The thinning of the metavolcanic units toward the SLFZ could be explained by stretching of the metavolcanic unit as it was overturned and folded. Also, the metavolcanic units could be thicker than shown in Figures 23 & 24, an uncertainty created by the lack of rock outcrop south of the metawacke unit. The Midway Lake syncline, to the north, has then escaped the second folding.

The second scenario emphasizes the role of NW-SE dislocations in the Chase Lake area. A possible thrust fault along the south shore of Chase Lake explains the repetition of high grade metavolcanics and low grade metawacke units across Chase Lake. Another possible dislocation between the rocks of the Midway Lake syncline and intermediate to mafic metavolcanics, separates weakly deformed, lower grade rocks from relatively highly deformed, higher grade

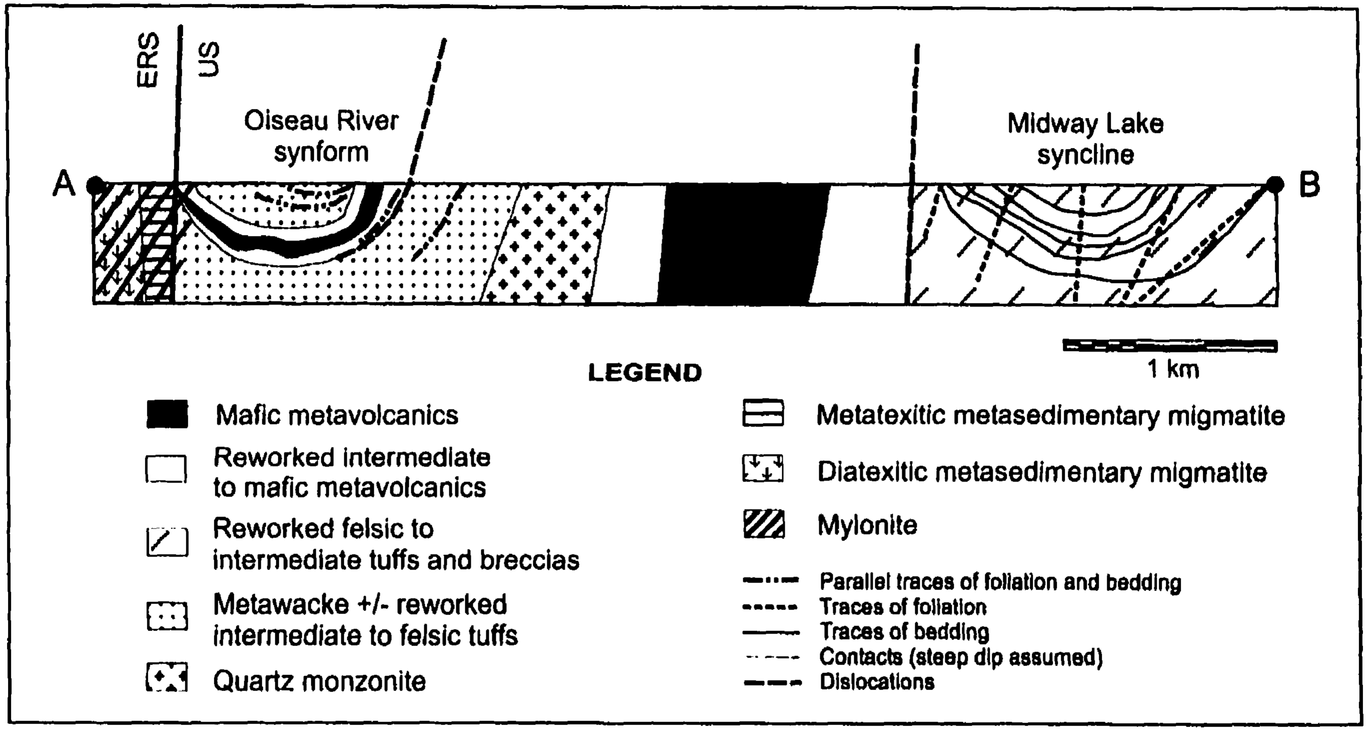


Figure 23. Conventional vertical cross section through the Chase Lake area. The trace of the A-B section is shown in Figure 8. A is towards the south.

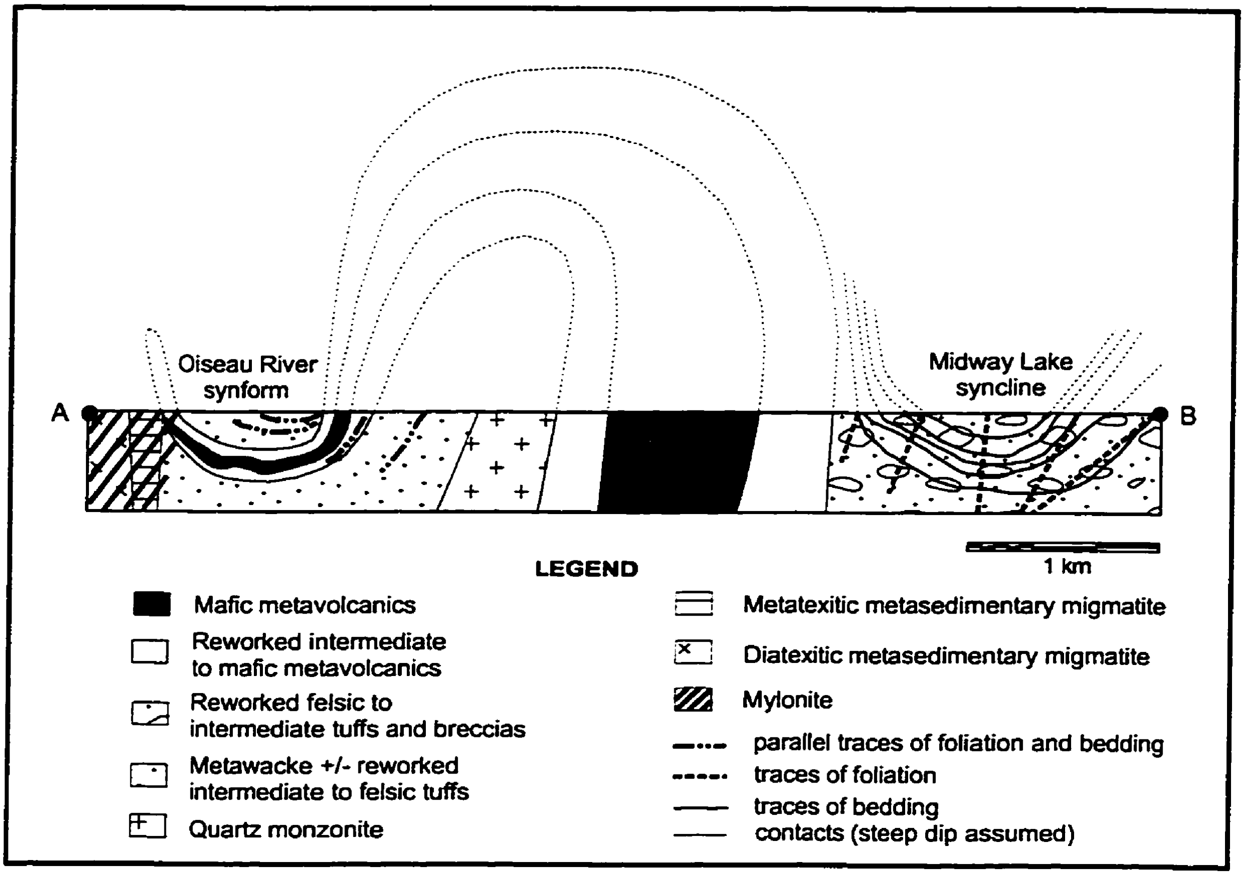


Figure 24. Chase Lake: Vertical cross-section A-B, and envisaged refolding of lithological contacts in the Oiseau River synform.

rocks.

The structure in the Chase Lake area could not have been produced by deformation similar to that in the late-stage dextral SLFZ. In particular, foliation and disrupted sheets north of Chase Lake would have been buckled by the dextral movement and could not have assumed their present orientation by clockwise rotation without being folded. Disrupted granite sheets in metawackes and metavolcanics probably originated early in the structural history of the area, and were subsequently folded by the Oiseau River synform and Z-type structure east of Chase Lake. The extension due to boudinage does not appear to be high, and a conservative estimate would be less than 200%. The axis of the boudins is a direction of small longitudinal strain, but is locally parallel to the mineral elongation lineation in the host rocks. This suggests that most boudins postdate the inception of the mineral lineation.

The orientation of boudins and the trend of the lithological units are compatible with north-south regional shortening (pure shear). It is possible that the SLFZ could have affected or formed the Oiseau River synform (Stone 1980) and the large open Z-structure in lineation trend lines or foliation trajectories east of Chase Lake, due to the transverse deformation gradient toward the SLFZ. However, the structures in all probability, predate the SFLZ.

English River subprovince migmatites are found to interleave with Uchi subprovince rocks at several localities north of the boundary thereby further complicating the history of the SLFZ (Breaks & Bond 1993). Migmatites, north of the SLFZ in the Chase Lake area, may be English River rocks which are affected by the large open Z-structure in lineation trend lines or foliation trajectories east of Chase Lake. A possibility exists that the dextral movement of the SLFZ could have formed the Z-structure at a later stage. The envisaged interleaving of the subprovinces complicates the idea that the English River subprovince rocks were uplifted with respect to the Uchi subprovince, accounting for the change in metamorphic grades across the subprovince boundary.

4.2 Longlegged Lake Area

Foliation and mineral lineation attitudes in the Longlegged Lake area are shown in the stereoplots of Figure 9 (Chapter II). The foliation generally strikes northeasterly with steep dips to the southeast. The SLFZ to the south strikes easterly, while its splay strikes northeasterly. S- and Z-folds occur throughout the sliver and their axes trend northeasterly with shallow to moderate plunges.

Amphibole and mica lineations in the metavolcanic sliver plunge steeply towards the southeast. A small portion of the metavolcanics near the SLFZ are mylonitized but still contain steep mineral lineation. In the SLFZ, the mineral lineation shallows as the trend lines approach the subprovince boundary. Steep mineral lineation has also been found in the SLFZ, but remains to be explained. S- and Z-fold axes trend northeasterly with shallow to moderate plunge. A mineral lineation map of the Longlegged Lake area is shown in Appendix B.5. Long arrows represent shallow plunges while shorter arrows signify steep plunges.

Disrupted granite sheets strike northeasterly in the Longlegged Lake sliver. A boudin chain in an oriented rock specimen, from the southwest area of the greenstone sliver (AB171), was cut and examined in detail. The boudins are composed entirely of epidote, while the adjacent incompetent layers are composed of 50% amphibole, 30% epidote and 20% plagioclase/quartz. The axis of principal extension, a, and intermediate axis, b, are shown on the stereoplot in Figure 25. Two boudin sections are shown in Plates 10a and b. Plate 10a shows the "a/c" section, which contains the maximum extension and shortening directions, while Plate 10b shows the "b/c" section, the minimum extension and shortening directions. The maximum extension, a, is shallow to the southwest while the intermediate axis is steep towards the ESE, similar in orientation to the hornblende lineation. The foliation in the greenstone sample strikes northeasterly and dips steeply to the south (Figure 25). The extension is approximately 190% in the b-direction and apparently larger for the a-direction. Therefore, stretching was most prominent in a horizontal, rather than a vertical, direction. The foliation, boudin orientation and mineral lineation at Longlegged Lake could have formed during a northwest compressional event.

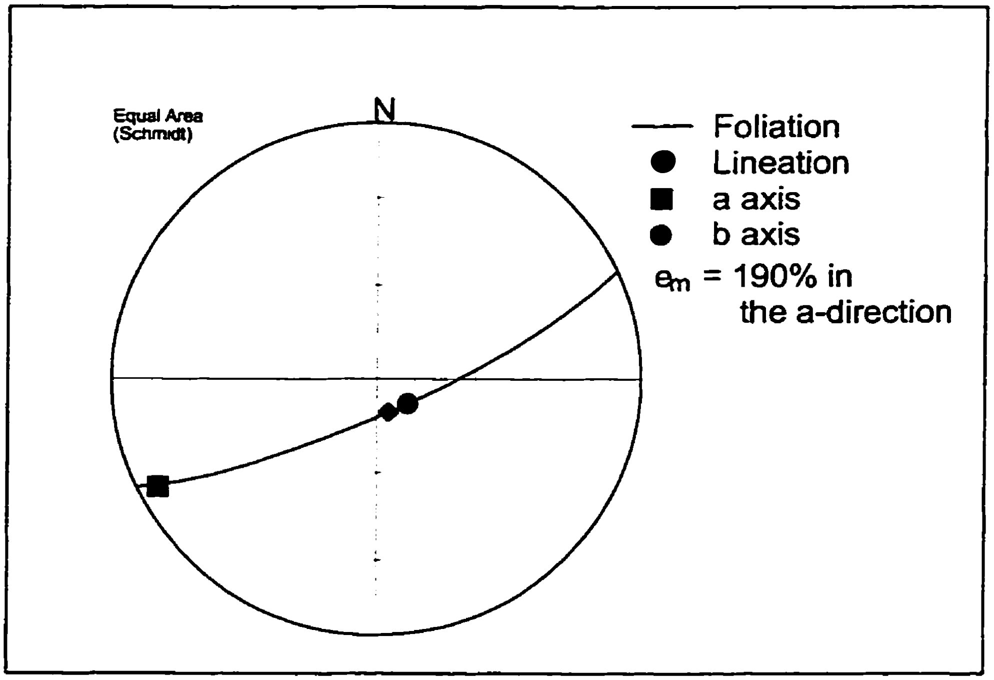


Figure 25. Stereoplot of foliation, mineral lineation, and boudin axes of disrupted epidote layers in amphibolite, station AB171, Longlegged Lake (e_m = extension).

Plate 10a	The minimum extension direction/shortening direction section of a boudin in sample AB171, Longlegged Lake (see text for explanation). The competent material is epidote.
Plate 10b	The maximum extension direction/shortening direction section of a boudin in sample AB171, Longlegged Lake (see text for explanation).

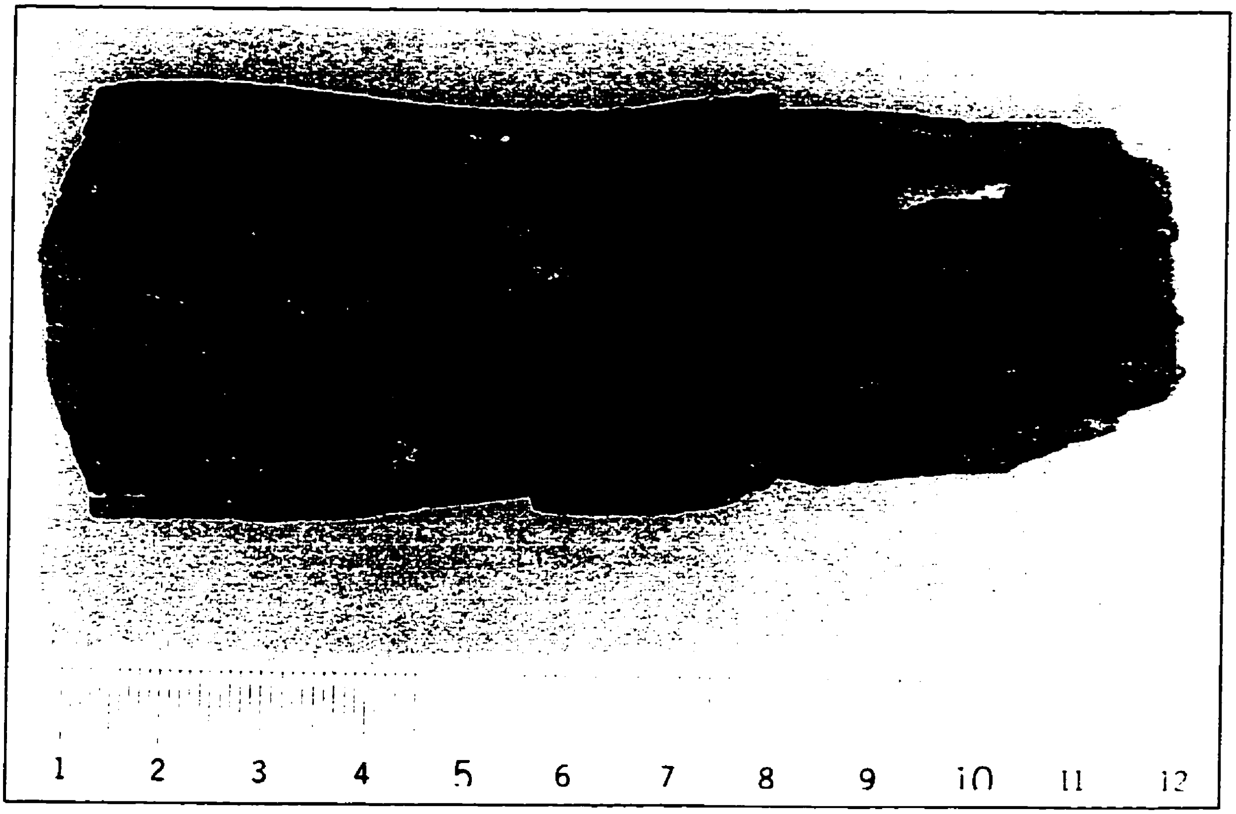


Plate 10a

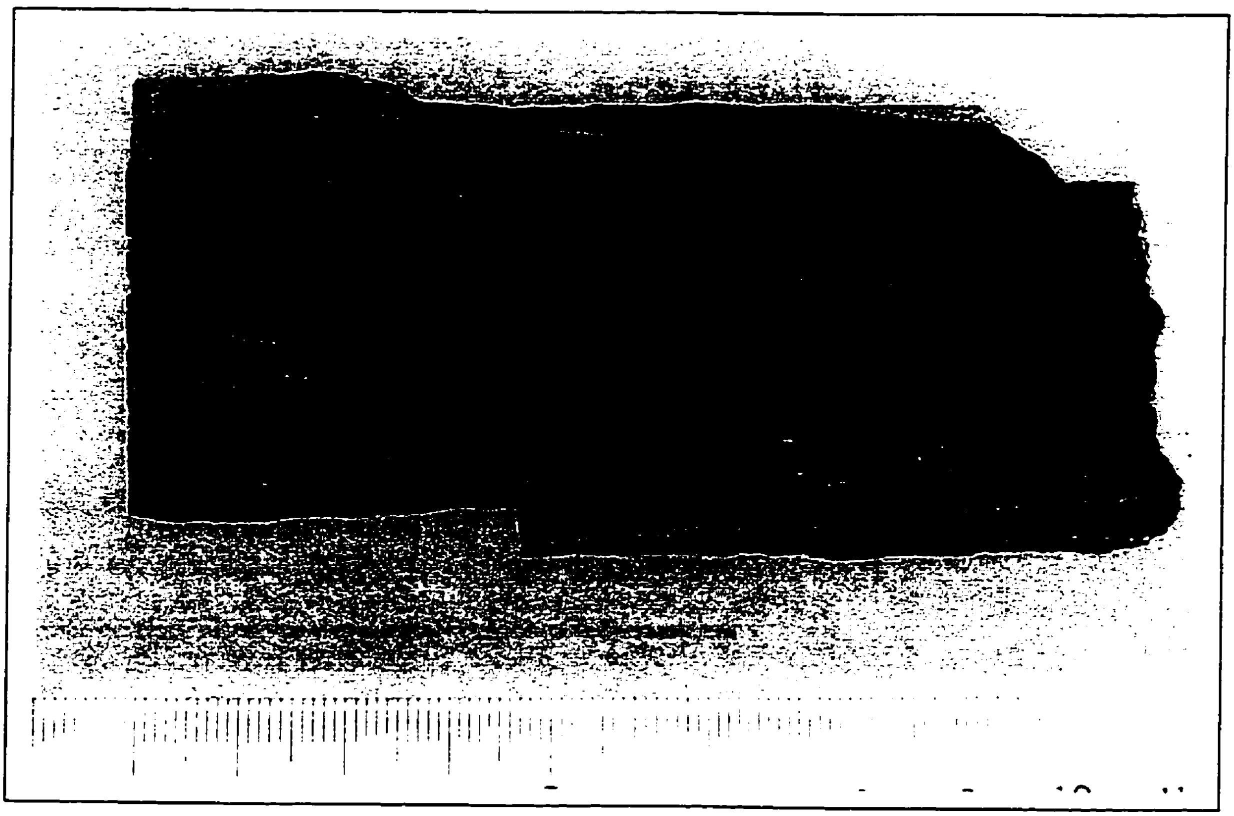


Plate 10b

CHAPTER V

LOCAL SENSE OF RESOLVED SHEAR STRAIN IN THE FOOTWALL OF THE SUBPROVINCE BOUNDARY

V. LOCAL SENSE OF RESOLVED SHEAR STRAIN IN THE FOOTWALL OF THE SUBPROVINCE BOUNDARY

5.0 Introduction

In the greater Red Lake region, the trace of the Uchi-English River subprovince boundary is marked by mylonites and tectonites of the dextral Sydney Lake fault zone (SLFZ). In this chapter we apply to the subprovince boundary a new technique of shear sense determination along a lithotectonic boundary (LTB), a technique developed by W.M. Schwerdtner (Schwerdtner, 1998, in press). Previous workers concluded that the Uchi-English River subprovince boundary has the same attitude as the SLFZ (Stone 1980, Breaks & Bond 1993). Structural geologists inferred that the SLFZ is subvertical (Schwerdtner *et al.* 1979, Stone 1980). However, the dip of the SLFZ remains to be determined by geophysical methods.

Two-dimensional gravity modelling of the subprovince boundary in the Longlegged Lake region by Runnals (1978) shows a shallow, south-dipping subprovince boundary (northern limits of contiguous English River rocks) in N-S vertical sections. Therefore the boundary may be transected by the SLFZ. This shows that a clear distinction needs to be made between the attitude of the subprovince boundary surface and that of the late-tectonic SLFZ.

5.1 W.M. Schwerdtner's graphic method to determine 'resolved shear strain' along a lithotectonic boundary

5.1.1 'Resolved shear strain' problem

The graphic technique by Schwerdtner (in press, 1998) uses L-S mineral fabrics to determine the local sense of shear strain in stretched walls of LTBs. "Lithotectonic boundary (LTB) is the family name of coherent and incoherent structural surfaces that govern the deformation of rock masses" (Schwerdtner, 1988, in press). Examples of LTBs are interfaces between sheared strata, thrust sheets or sutured microcontinents. During heterogeneous straining of wall rock, incoherent LTBs are loci of translational and/or rotational slip. Unfortunately, the local sense of translational slip need not correspond to the sense of tangential shear at the LTB (Schwerdtner, 1998, in press).

In a simple case of a monoclinic boundary surface, the intermediate principal strain direction (Y) lies within the LTB plane and the direction of resolved shear strain is easily obtained. Figure 26 shows the direction of resolved shear strain and the Y direction on an LTB plane and corresponding stereonet. The x_n plane contains the lineation and LTB normal, while the z_n plane contains the foliation normal and LTB normal. In this case, the x_n and z_n planes (x_n = z_n plane shaded grey in Figure 26) coincide and their common trace on the LTB gives the direction of resolved shear strain. However, the local direction of intermediate principal strain (Y) is commonly oblique to an LTB plane (Figure 27), which invalidates the practice of deducing the sense of tangential shear in the plane containing the lineation and foliation normal (Figure 26).

In a general 'oblique' case, the intermediate principal strain direction (Y) does not lie within the LTB plane (Figure 27). The x_n and z_n planes do not coincide and their traces on the LTB plane give two separate directions, j and m. In the end member case in which the strain ellipsoid is uniaxial prolate (ie. "pure lineation"), j would be the direction of resolved shear strain. In the other end member case in which the strain is uniaxial oblate, m would be the direction of resolved shear strain. The angle between j and m thus shows the range within which

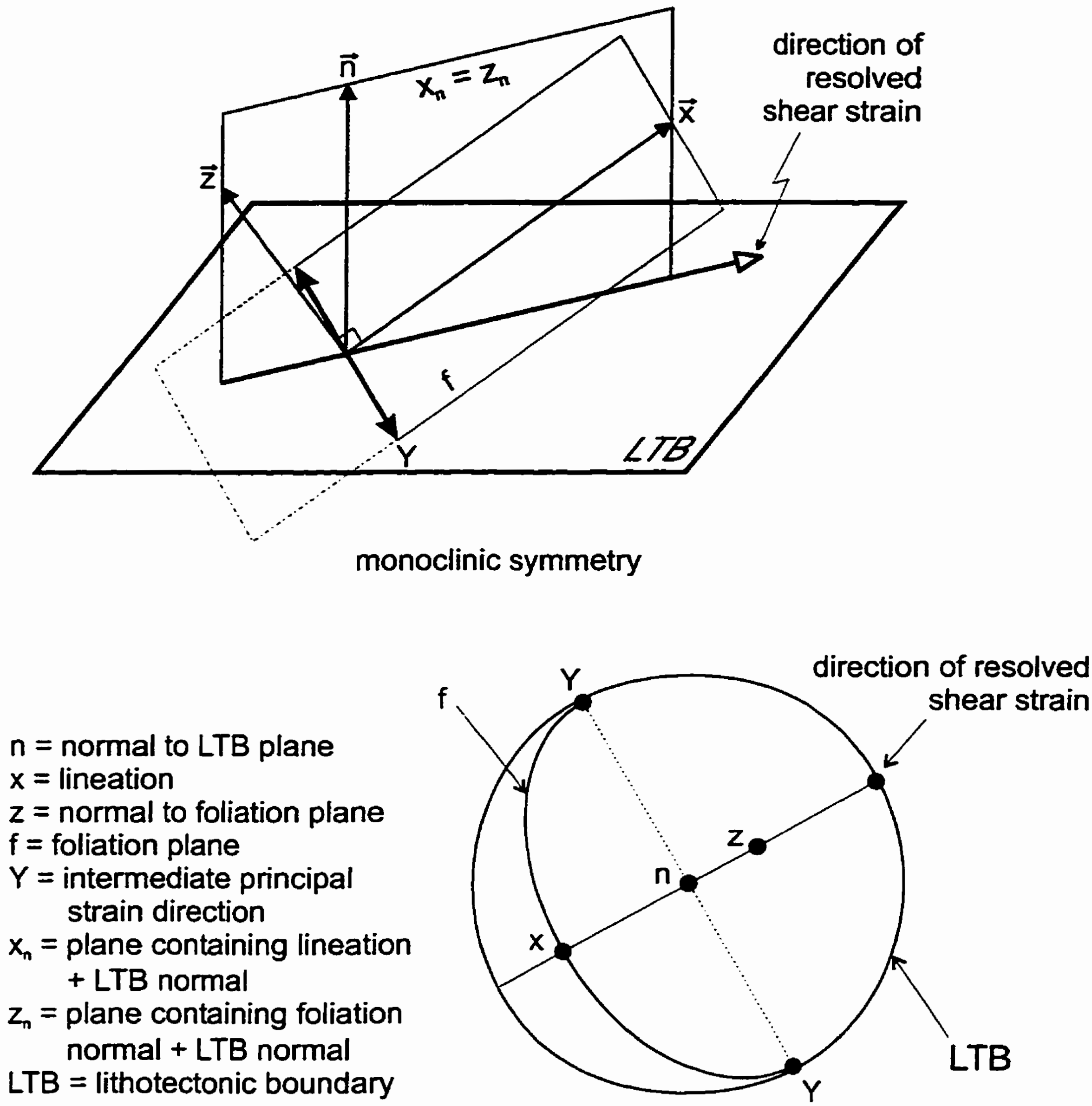


Figure 26. The direction of resolved shear strain on an LTB in which the intermediate principal strain direction (Y) lies on the LTB plane (monoclinic case). Planes x_n and z_n coincide and their common trace on the LTB plane gives the direction of resolved shear strain.

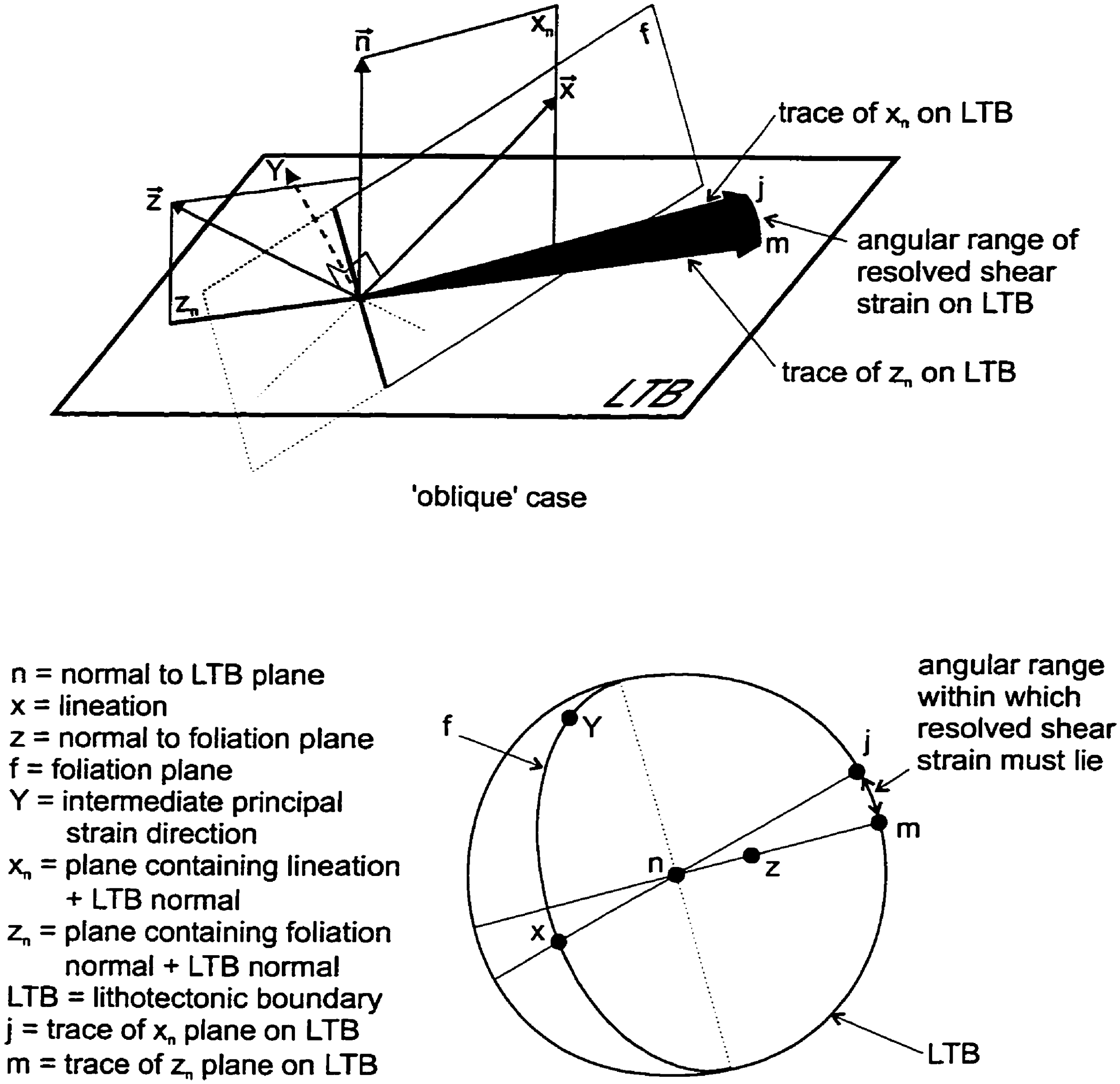


Figure 27. An 'oblique' case where the intermediate principal strain direction (Y) does not lie on the LTB plane. The traces of the x_n and z_n planes on the LTB plane gives the angular range of the resolved shear strain direction.

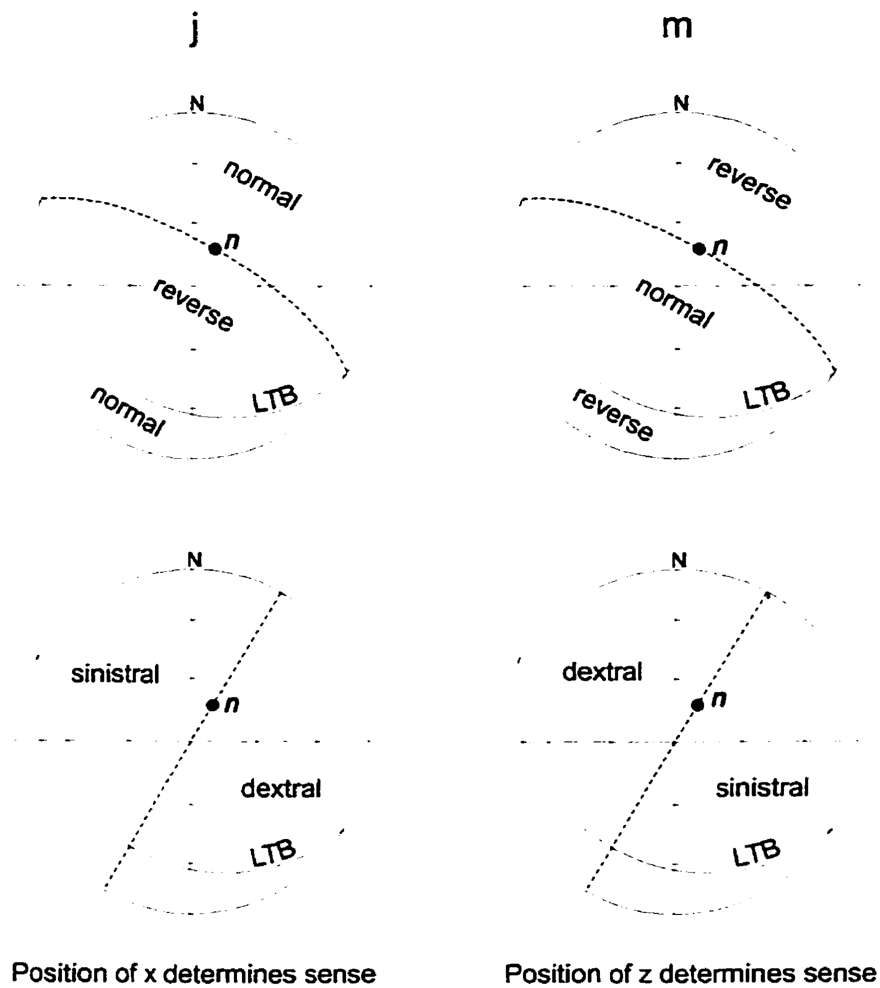


Figure 28. Fields of different shear-strain sense for principal directions in lower hemisphere stereographic projection (modified from Schwerdtner, in press, 1998).

the resolved shear strain must lie. Figure 28 applies to general LTBs and shows the fields of different shear-strain sense in lower hemisphere stereographic projection depending on the position of x and z with respect to the LTB attitude.

The new technique was thus devised specifically for the general 'oblique' case, when the Y direction does not lie within the LTB plane. The technique does not require the shape of the section ellipses on the x_n and z_n planes to determine the range of possible directions of the resolved shear strain. However, "the effectiveness of the technique depends critically on knowledge of (*i*) the present attitude of the local LTB surface on the scale of kilometres and (*ii*) the principal directions of incremental or total wall-rock strain" (Schwerdtner, 1998, in press).

The attitude of L-S hornblende fabrics were measured in the Chase and Longlegged Lake areas, north of the SLFZ, to assess the local sense of pre-SLFZ resolved shear strain in the footwall of the subprovince boundary. Locations of measurements are found in Figures 31 and 32 for the Chase and Longlegged Lake areas, respectively. In the Chase and Longlegged Lake areas, an assumption is made for the use of the new technique to assess the pre-SLFZ role of the subprovince boundary. It is assumed that the Uchi-English River subprovince boundary be pegged to a material surface while Flinn type L-S fabrics developed throughout the footwall, near peak metamorphism. (Support for such premise is provided by similar L-S fabrics in diatexites on both sides of the boundary.) In the Chase Lake area, second-order faults may have been active in the footwall before and during L-S fabric development (cf. second kinematic scenario in Chapter 4.1.6), but potential effects of such faults will be disregarded in the present chapter.

5.1.2 Attitude of the subprovince boundary

Two-dimensional gravity modelling was undertaken by Runnals (1978) using a Bouguer gravity anomaly map of the Red Lake region obtained from a detailed gravity study in 1975-76 (Figures 29 & 30). Quantitative 2D modelling of the graphically smoothed residual gravity field was carried out in several profiles in the Longlegged Lake area (see profiles A, B, B1 in Figure 30, Runnals 1978).

Profile B (Figure 30b) transects the Longlegged Lake greenstone sliver and the SLFZ. In the vicinity of the SLFZ, the subprovince boundary is interpreted to dip gently 30° to the south (Runnals 1978). A few kilometres downdip from the trace of the subprovince boundary on the surface, the boundary dips steeply 77°S to a depth of ~12 km (Runnals 1978, Gupta & Wadge 1986). Therefore, from the geophysical models a dip value of 30°S was utilized in the Longlegged Lake area for local shear sense determinations. The dip of the subprovince boundary at Chase Lake is also assumed to be 30°S even though it is unlikely to be similar over an extensive surface. In this case, the late-stage, vertical SLFZ most likely transects the subprovince boundary, and appears not to have affected the rocks beyond the fault zone, making it possible to use the new technique.

5.2 Shear sense determination in the Chase Lake area

The local sense of resolved shear strain in the Chase Lake area was determined for five locations assuming a subprovince boundary attitude of 90/30S, obtained by geophysical modelling outlined in section 5.1.2. Figure 33a and b shows two of the examples, at localities #19 and #318 (Figure 31), of the method used to obtain the angular range of the resolved shear

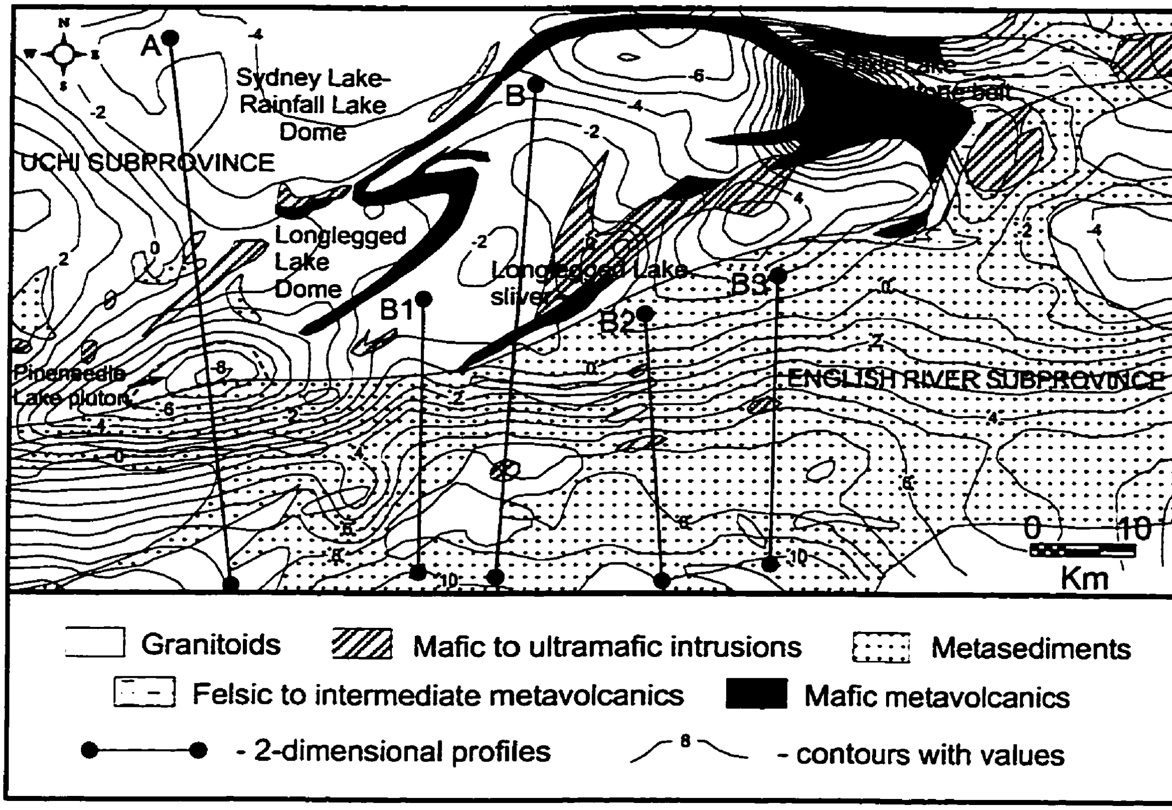
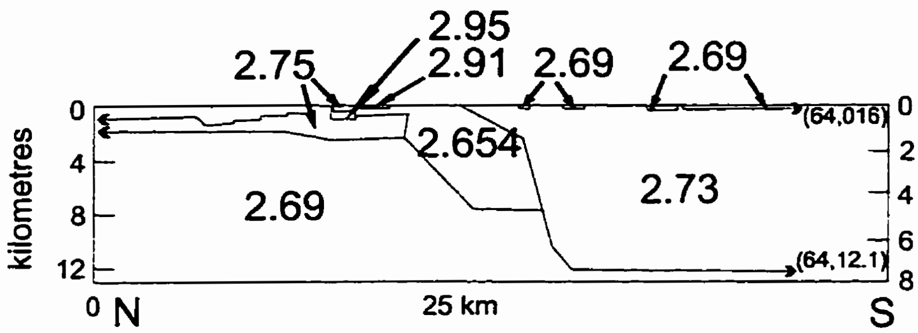
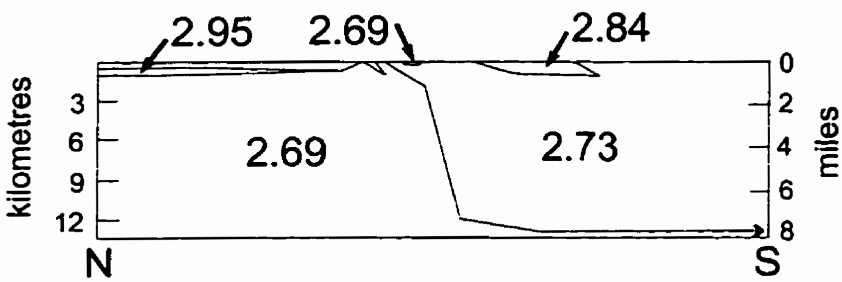


Figure 29. Geological compilation map and filtered Bouger map, showing 2-dimensional profiles used in modeling of the Dixie and Longlegged Lake areas. Residual between 0.6km and 16.1km upward continued maps. Contour interval 1mgal (modified from Runnalls 1978).



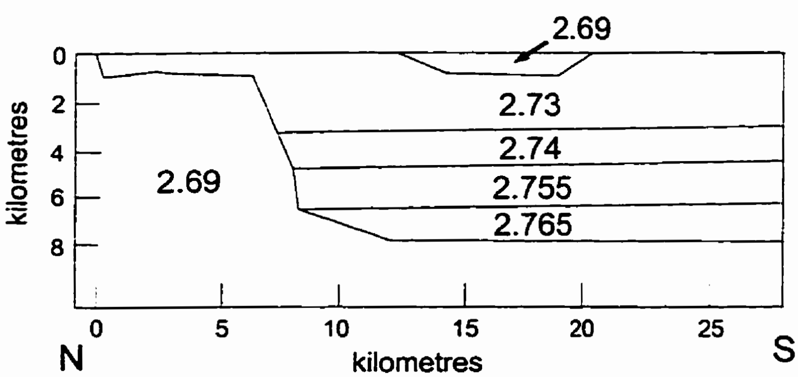
Profile A Baselevel - 6.5 mgal

(a)



Profile B Baselevel - 6.5 mgal

(b)



(c)

Figure 30. Two dimensional gravity modeling of the Uchi and English River subprovinces from profile A, B, and averaged profile of profiles B1,B2,B3 located in Figure 29 (modified from Runnalls 1978).

strain direction. The stereoplots show the orientation of the mineral lineation, subprovince boundary attitude, foliation, respective normals, long axes of schematic section ellipses and the directions of j and m (the traces of planes x_n and z_n, respectively, on the subprovince boundary plane (Figure 27)). The corresponding sectional strain ellipses on the x_n and z_n planes in Figure 27 show the shear strain sense of j and m. Points j and m are plotted on the hanging wall of the subprovince boundary and the angular range between them gives the resolved shear strain direction (grey shaded area). In the cases shown in Figure 33a and b, the shear strain sense corresponds to that of sinistral reverse faults. The angular range of resolved shear strain from the two examples in Figure 33 and other examples found in Appendix D.1 are shown on a map of the Chase Lake area in Figure 34. The shear strain sense corresponds mainly to that of sinistral reverse faults in the entire map area.

5.3 Shear sense determination in the Longlegged Lake area

The local sense of resolved shear strain in the Longlegged Lake area was determined for 11 locations assuming a subprovince boundary attitude of 65/30S or 85/30S, depending on the location near the SLFZ, obtained from geophysical methods (see subchapter *5.1.2*). Figure 33c, d and e shows three examples, at localities #378, #424 and #441 (Figure 32), of the method used to obtain the angular range of the resolved shear strain direction. The stereoplots in Figure 33 show the orientation of the mineral lineation, subprovince boundary, foliation, respective normals, long axes of section ellipses on x_n and z_n planes and directions j and m. The corresponding schematic sectional strain ellipses show the shear sense of j and m, shown also on the hangingwall of the subprovince boundary. The grey shaded area gives the angular range of resolved shear strain. In

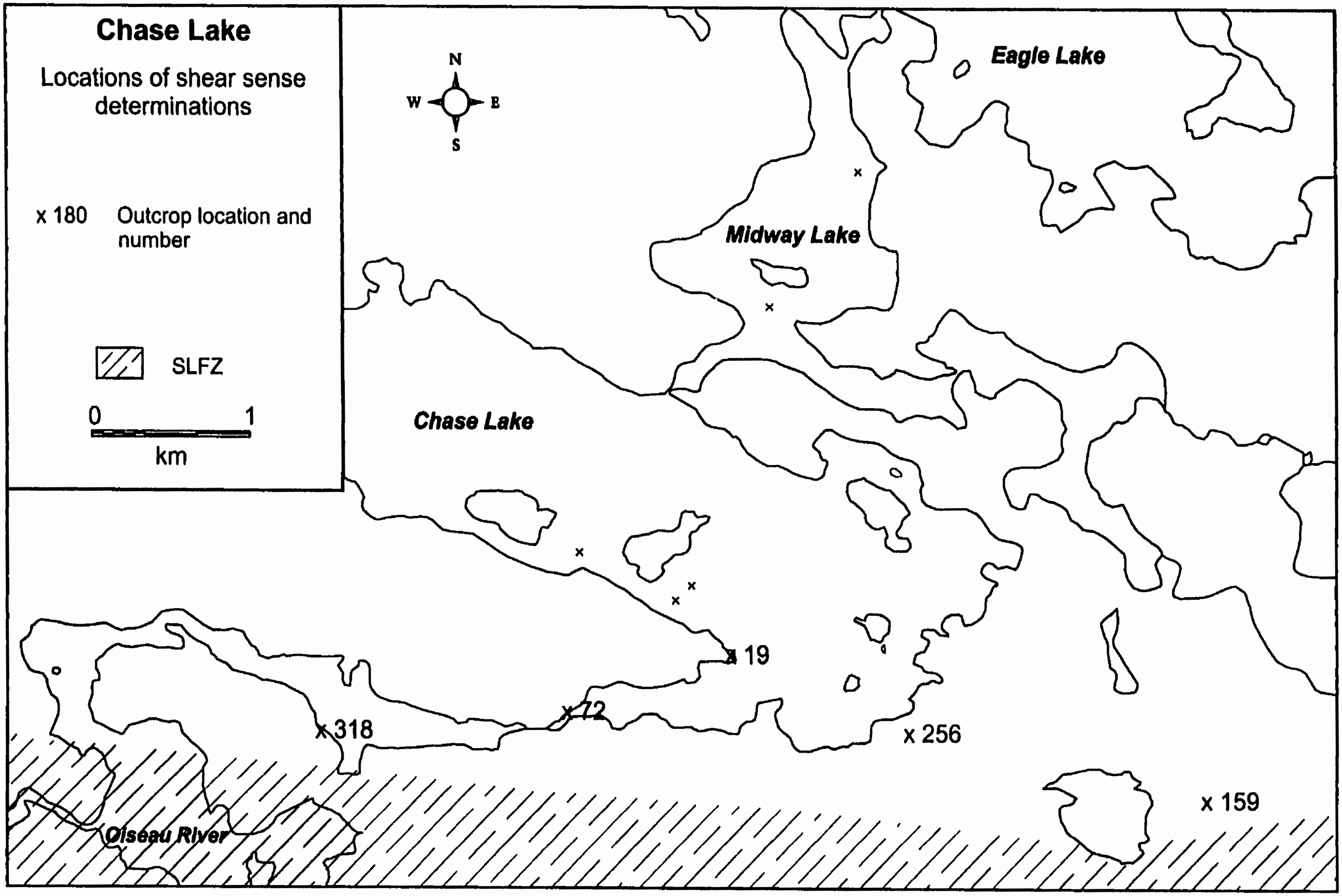


Figure 31. Number and location of local resolved shear strain determinations at the subprovince boundary, Chase Lake.

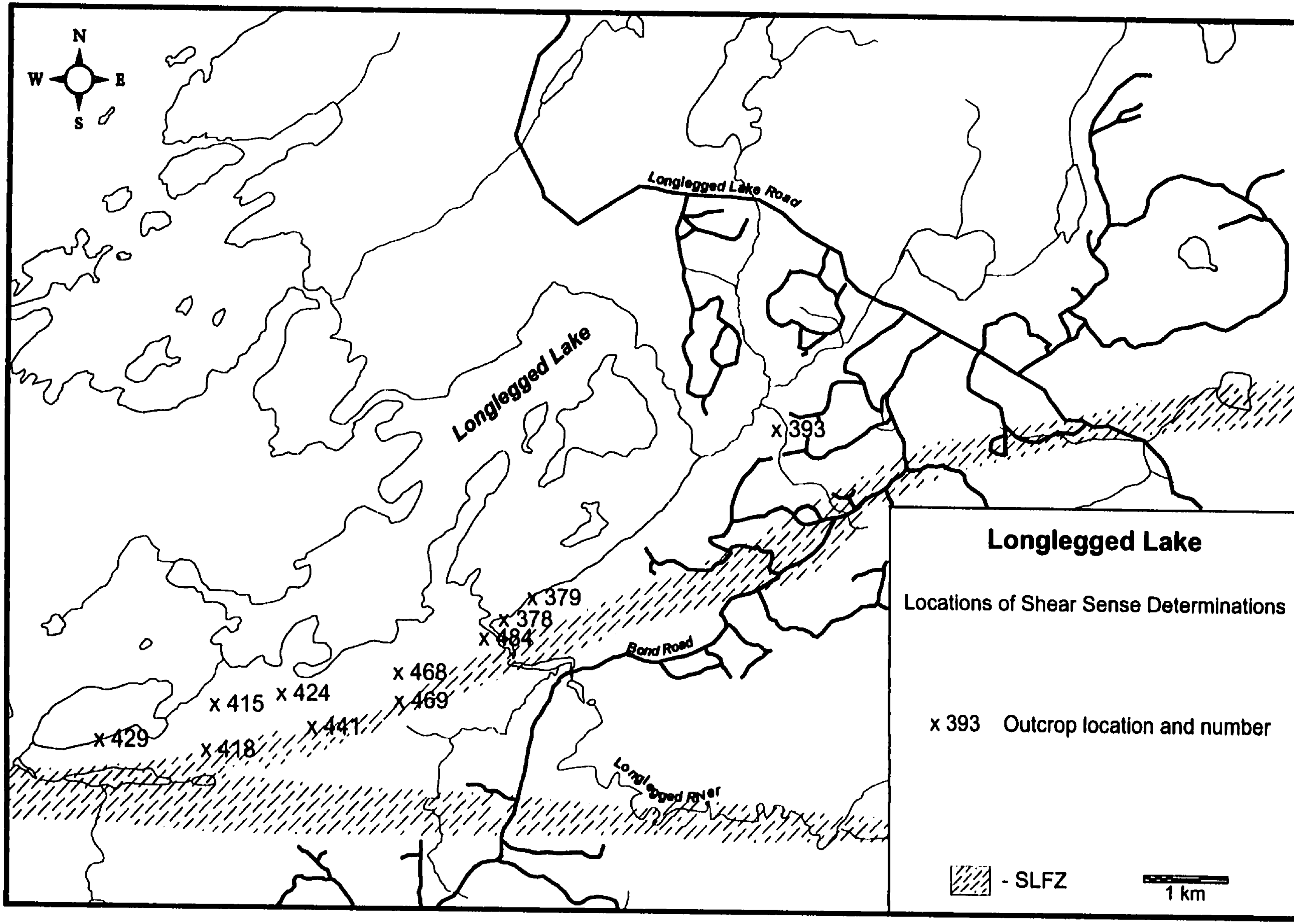
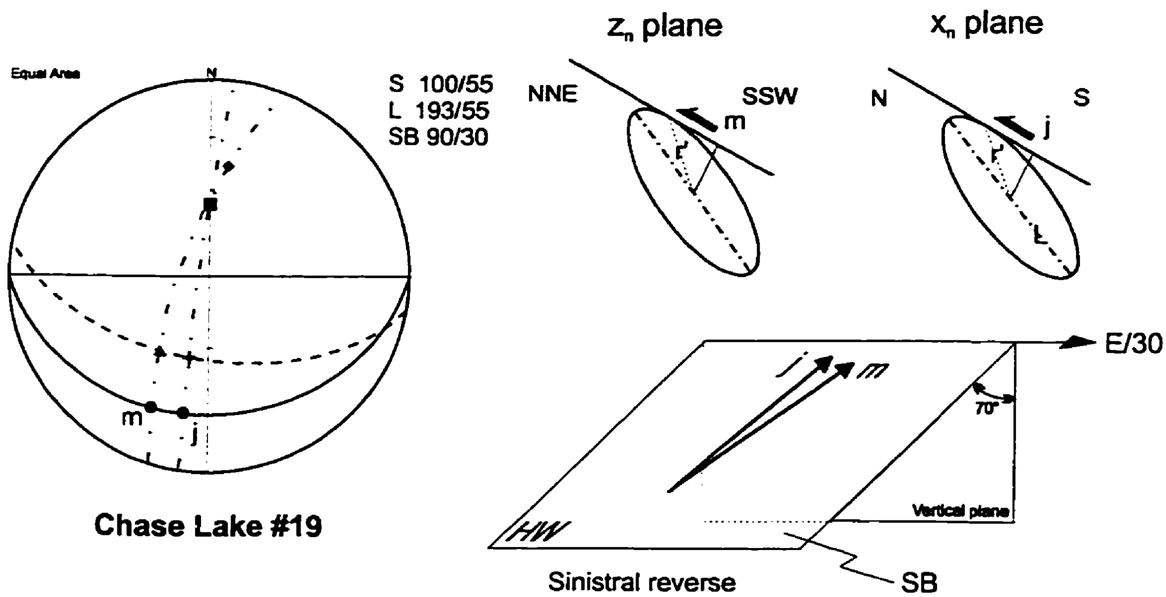


Figure 32. Number and location of determinations of the local sense of shear strain components at the subprovince boundary, Longlegged Lake.



(a)

Legend for stereoplots

- - Foliation (s)	■ LTB normal (n)
— subprovince boundary (SB)	▲ Long axis of section ellipse on z_n plane
✚ Lineation (x)	● j,m - traces of x_n and z_n planes on SB
◆ Foliation normal (z)	

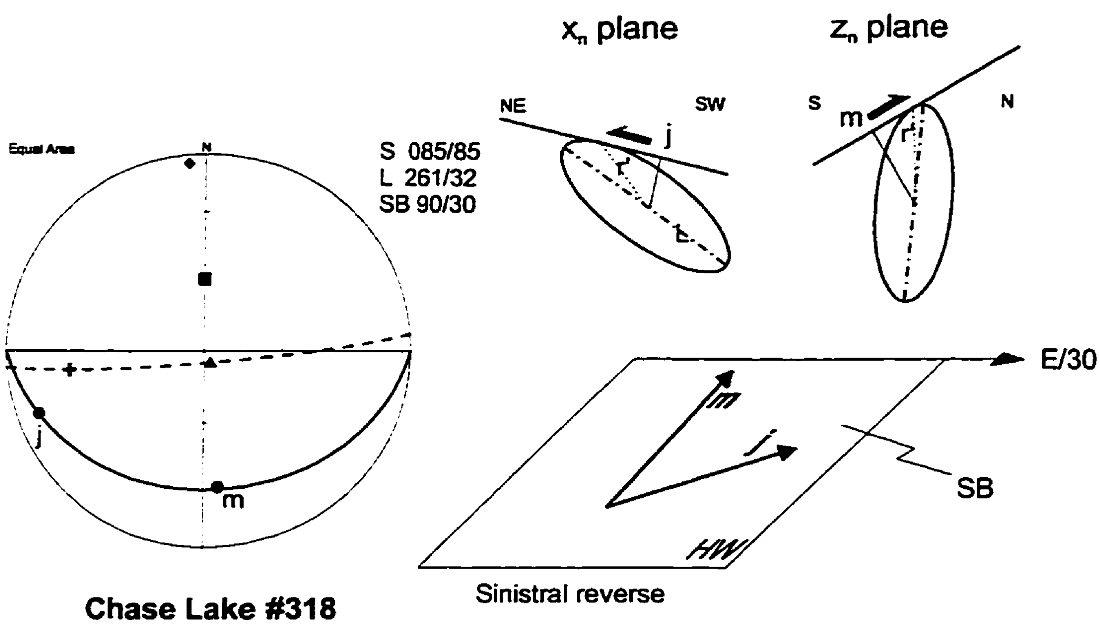
Legend for strain ellipses

normal to subprovince boundary	L lineation direction
long axis to sectional ellipse	j trace of x_n plane on SB
oblique radius of sectional strain ellipse on x_n & z_n planes	m trace of z_n plane on SB
	sense of shear

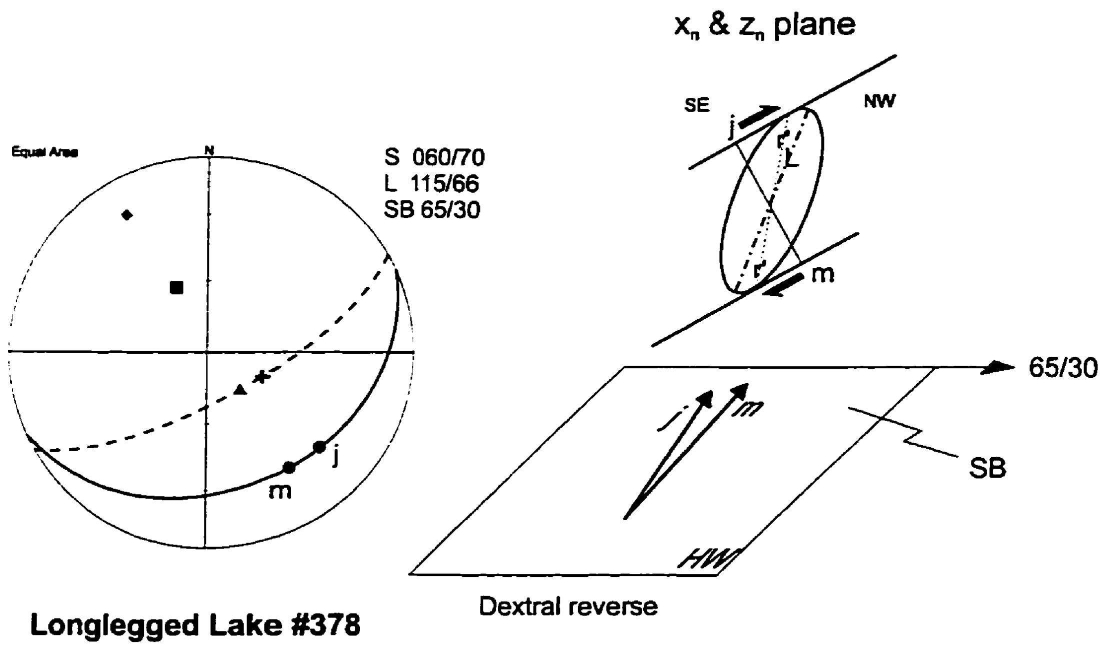
Legend for SB

Angular range of resolved shear strain on SB	HW Hanging Wall
	SB Subprovince Boundary

Figure 33. Angular range of local resolved shear strain in the subprovince boundary from various localities in the Chase and Longlegged Lake areas. Locations are shown in Figures 31 & 32. Grey shading in the hangingwall shows the angular range of the resolved shear strain with subprovince boundary attitudes of 90/30S, 65/30S and 85/30S.

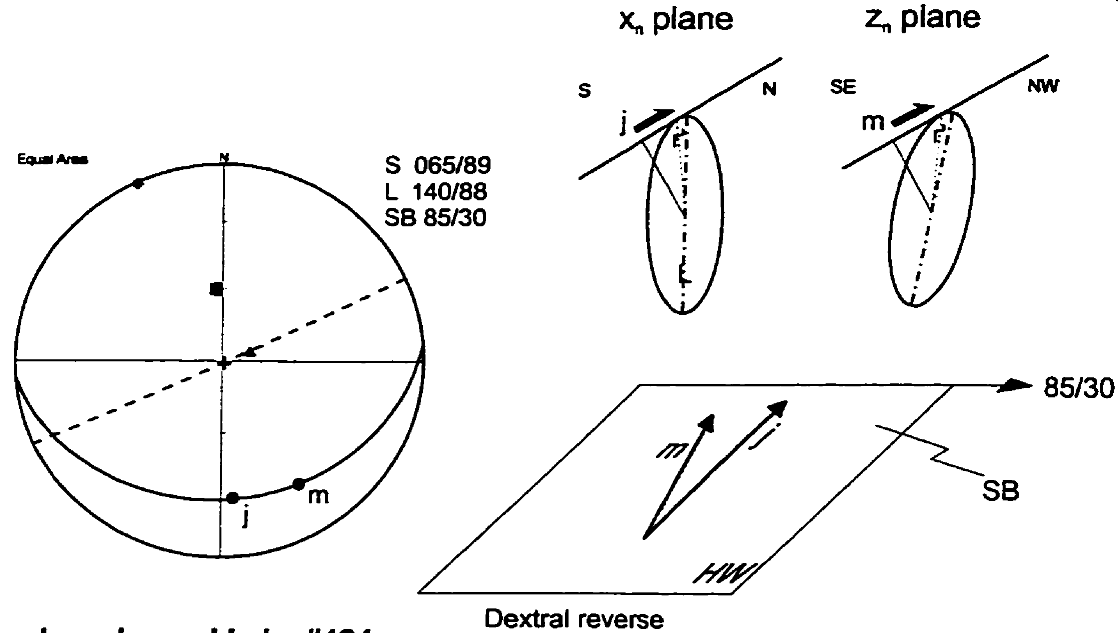


(b)



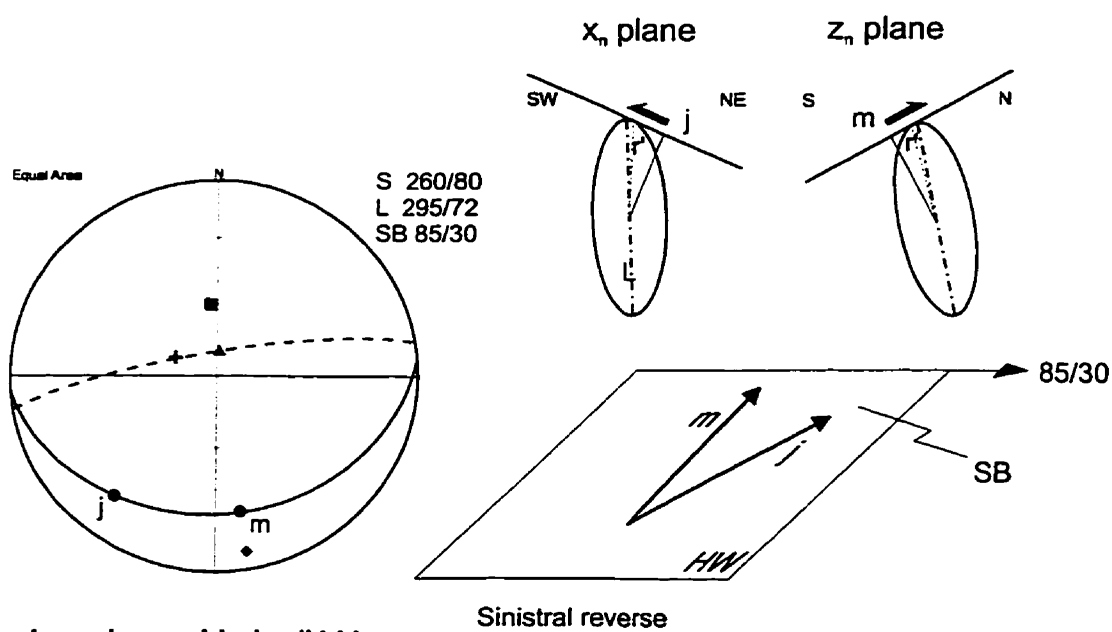
(c)

Figure 33 (cont.)



Longlegged Lake #424

(d)



Longlegged Lake #441

(e)

Figure 33 (cont.)

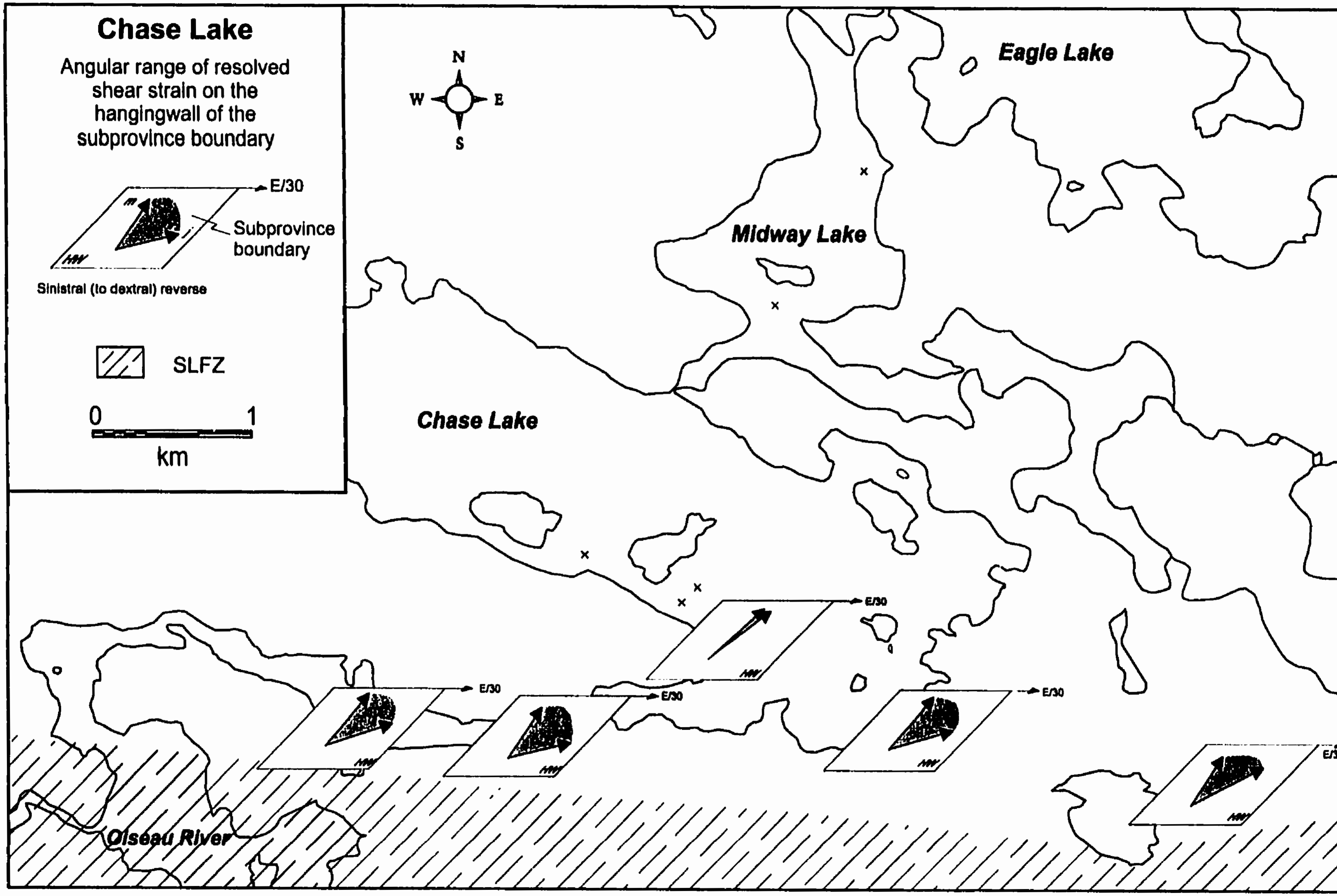


Figure 34. Angular range of resolved shear strain on the hangingwall with a 90/30S subprovince boundary attitude.

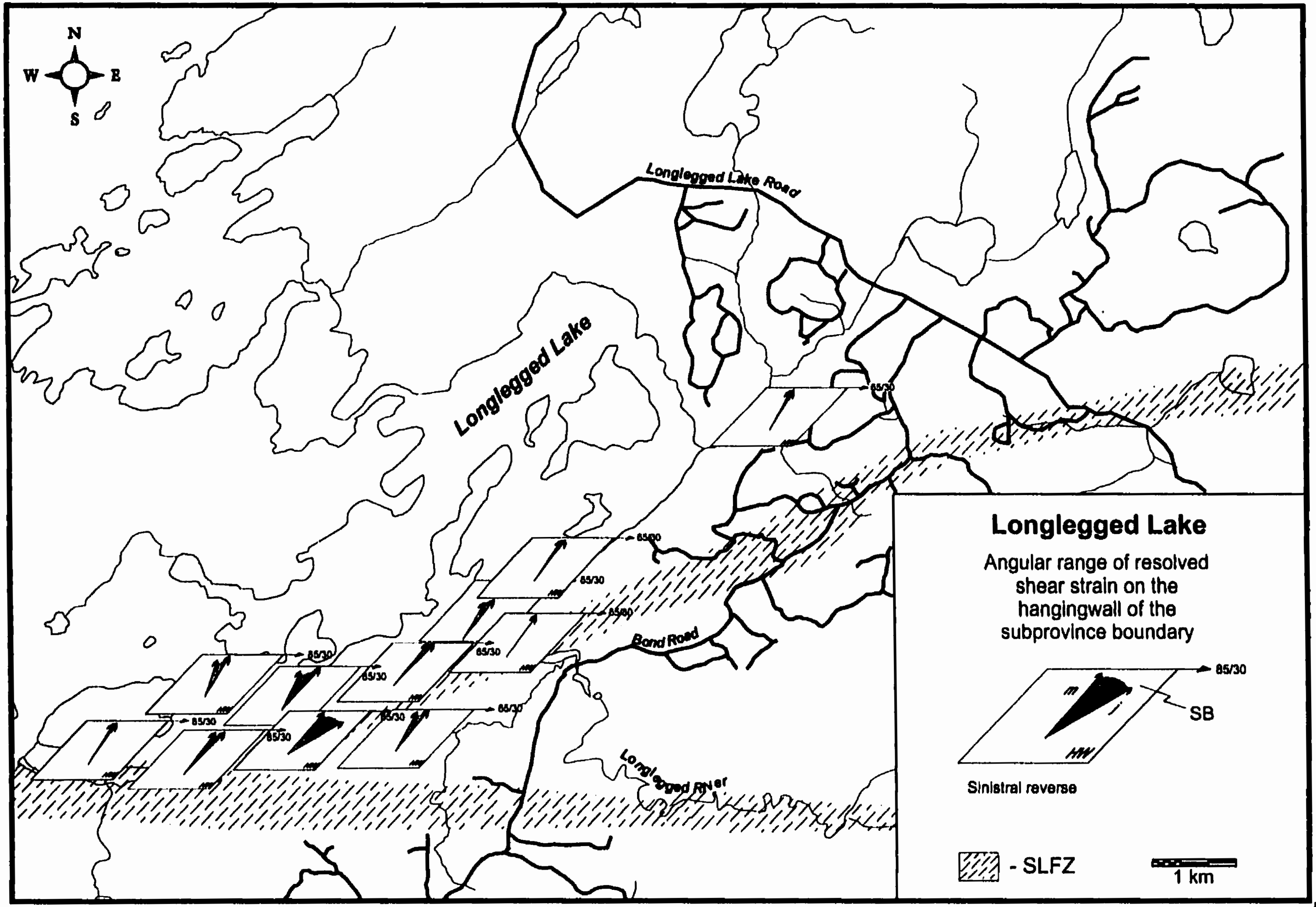


Figure 35. Angular range of resolved shear strain on the hangingwall of a 30 dipping subprovince boundary in the Longlegged Lake area.

the case of Figure 33c, d and e, the shear sense corresponds to sinistral or dextral thrusting. The angular range of resolved shear strain (grey shaded area) from the three examples in Figure 33 and other examples found in Appendix D.2, are shown on a map of the Longlegged Lake area in Figure 35. The shear sense corresponds to sinistral and dextral reverse faults throughout the area.

5.4 Using Bau's method for determining the SLFZ attitude

The method, which was devised by P.-Y.F. Robin and published by Bau (1977), is similar to a technique published by Lin & Williams (1992). Accordingly, the dip of the SLFZ is determined by assuming that the axis of intermediate principal strain (Y) lies on the fault zone (monoclinic symmetry). The dip of the SLFZ can be determined assuming that it coincides with the trace of the subprovince boundary on the surface and trends 90° at Chase Lake and 65° or 85° at Longlegged Lake. Within the SLFZ, the stretching lineation is parallel to the X direction of the finite strain ellipsoid on the foliation (Coté 1996). The intersection between the foliation and C-plane, Y, is oriented at 90° from the stretching lineation along the foliation plane (Figure 29, Y is shown as a '▲' in the stereoplot). The great circle of the SLFZ connects Y and the strike direction, in this case 65°, 85° or 90° depending where measurements were taken along the trace of the subprovince boundary. (Foliation and lineation measurements in the SLFZ are taken from geological maps of the SLFZ by Stone (1980)). SLFZ attitudes obtained by the Bau method produce trivial results if used for the new technique by Schwerdtner (in press). (This is because Bau's method assumes structural monoclinicity).

Local attitudes of mineral lineation, foliation, SLFZ and respective normals are shown on stereoplots in Figures 36 and 37. Figure 36 shows the determinations of the SLFZ attitude for eight localities in mylonitized, diatexitic metasedimentary migmatites in the Chase Lake area.

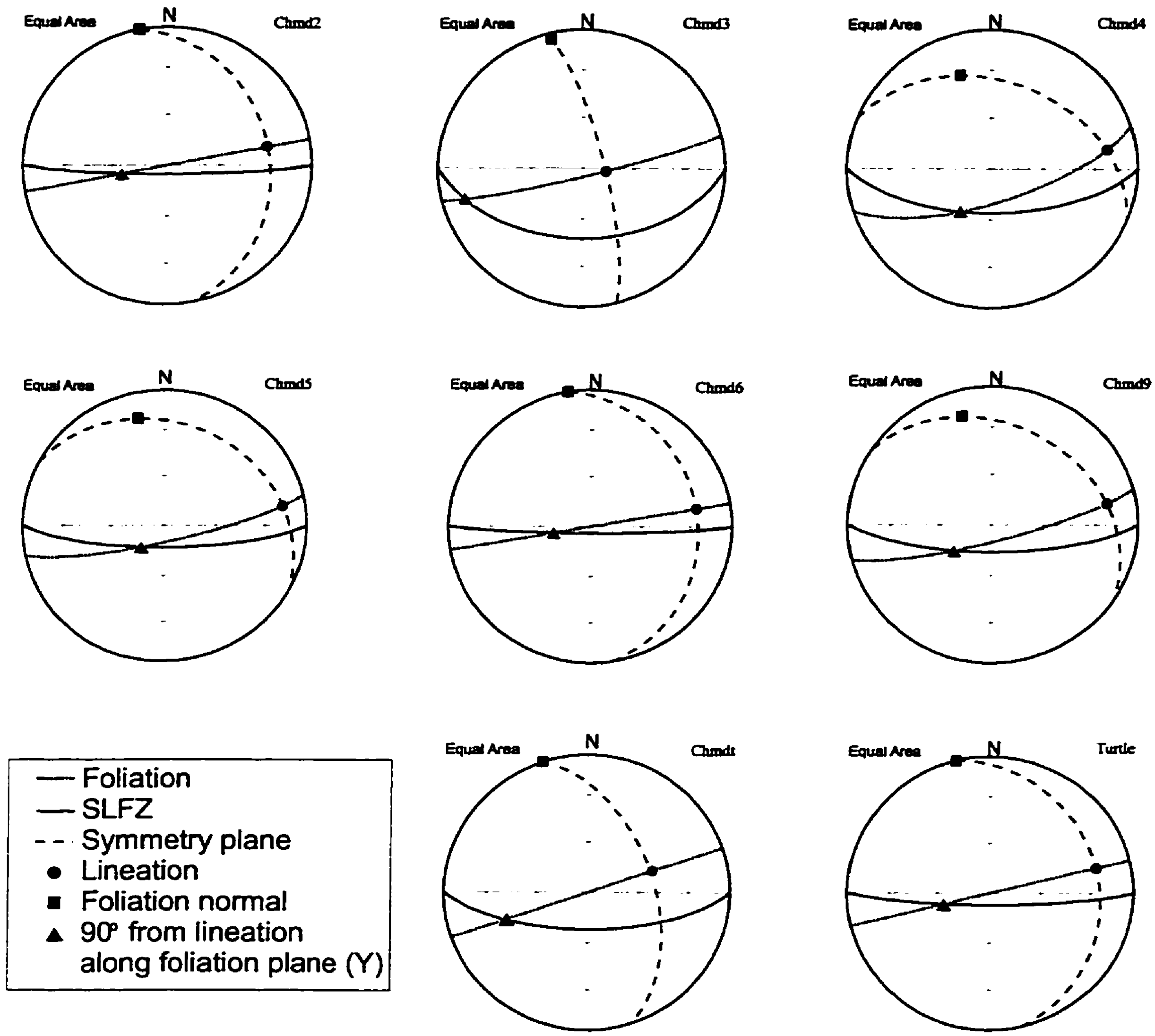


Figure 36. SLFZ dip determinations for various localities south of Chase Lake in mylonitized diatexitic metasedimentary migmatites using an E-W strike for the fault zone (method from Bau 1977).

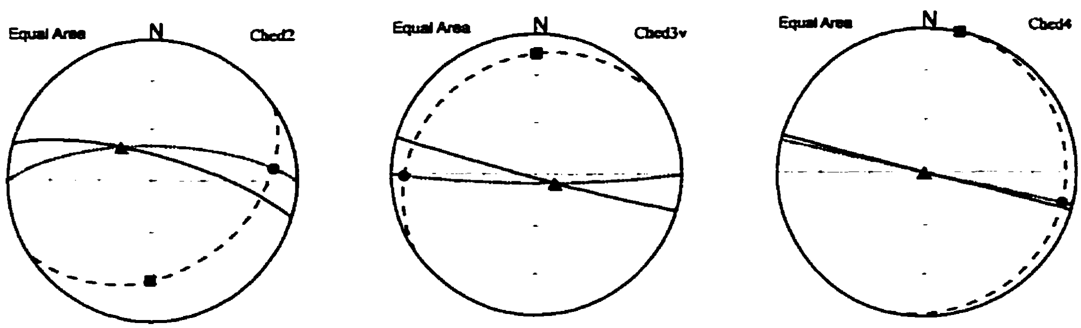


Figure 37a. SLFZ dip determinations for various localities west of Chase Lake in mylonitized diatexitic metasedimentary migmatites using 105°strike of the fault zone (method from Bau 1977)

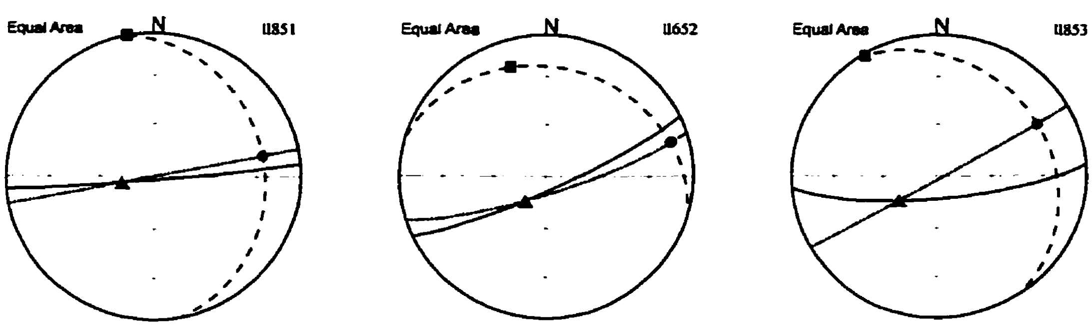
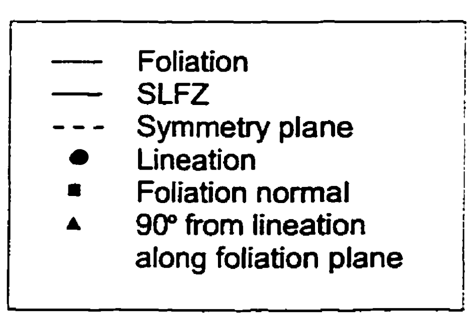


Figure 37b. SLFZ dip determinations for various localities south of Longlegged Lake in mylonitized diatexitic metasedimentary migmatites using 85° and 65° strike for the fault zone (method from Bau 1977)



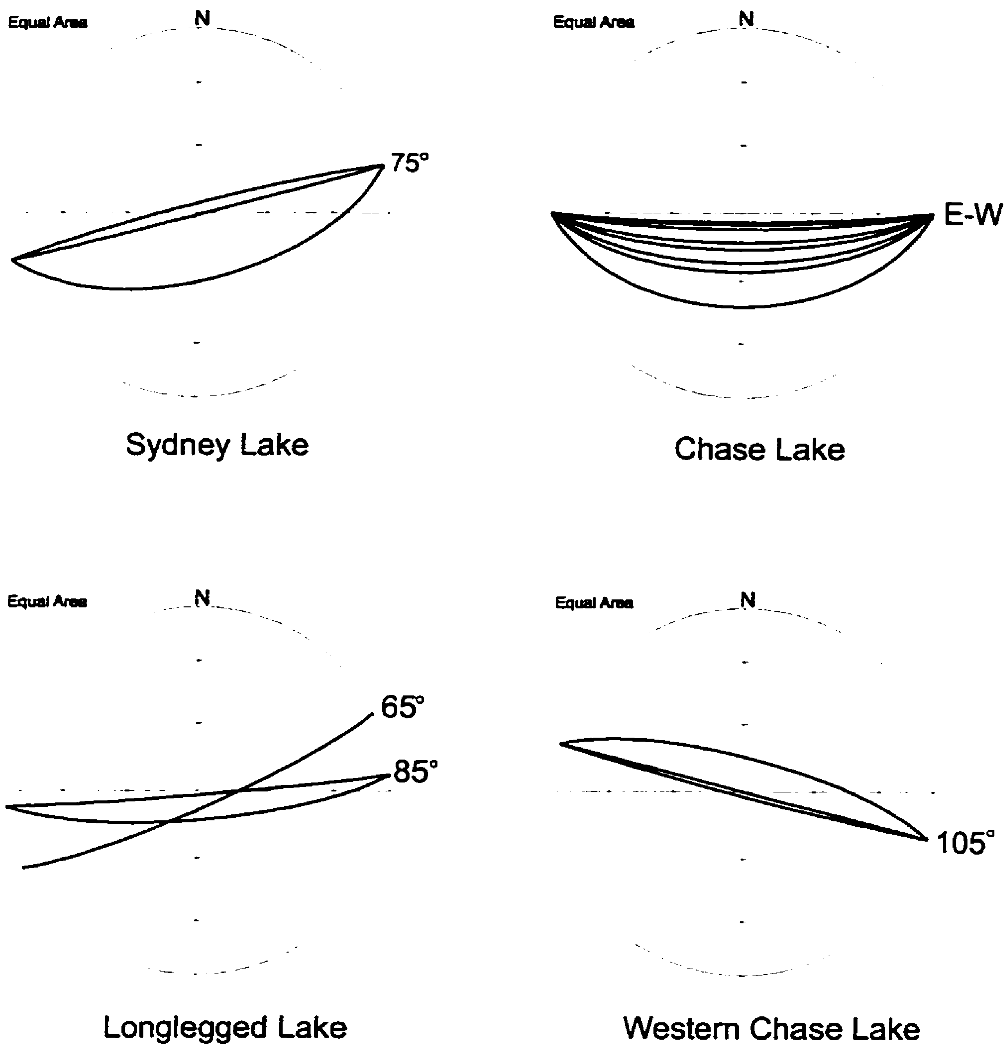


Figure 38. SLFZ dips found using the Bau method (1977) for Sydney Lake, Chase Lake, Longlegged Lake and western Chase Lake.

The SLFZ trends east-west at Chase Lake and the dip, using the Bau method, ranges from 45° to 85° southerly dips. Figure 38 shows all eight localities on one stereoplot, labelled 'Chase Lake'.

Figure 37a & b shows the SLFZ dip determinations for western Chase Lake diatexites which strike 105°. The SLFZ dips range from 75°NW to 85°S (Figure 37a). All three SLFZ attitudes are plotted on a stereonet, labelled 'western Chase Lake', in the bottom right corner of Figure 38. Figure 37b shows dip determinations for the SLFZ using an 85° strike where its splay changes orientation at the greenstone sliver. The dip estimates of 88°S and 74°S are obtained for the 85° striking SLFZ and 75°S for the SLFZ striking 65° (Figure 37b, centre stereoplot). Figure 38 shows all of the SLFZ dip determinations for the Longlegged Lake area on the stereoplot, labelled 'Longlegged Lake', in the bottom left corner .

The attitude of the SLFZ was also analysed at localities near Sydney Lake, in mylonitized metatexitic and diatexitic metasedimentary migmatites, using a 75° strike. Determinations gave 60°S, 88°S and 85°N dips for the SLFZ (Figure 38, upper left stereoplot labelled 'Sydney Lake').

5.5 Applying Schwerdtner's technique to steep subprovince boundary attitudes

The new technique by Schwerdtner (in press) depends on the knowledge of the present attitude of the subprovince boundary surface on the scale of kilometres. For this reason it is important to obtain correct results. The attitude of the subprovince boundary obtained from gravity modelling by Runnals (1978) may be questionable. The possibility exists that the subprovince boundary is steep near the surface. Assuming a steep attitude of the subprovince boundary, a different set of shear sense determinations are obtained. Appendix D.3 and D.4

show local shear sense determinations for the Chase and Longlegged Lake areas, respectively, with a steep subprovince boundary attitude and assuming that the Y direction does not lie within its surface.

The local sense of shear strain at Chase Lake is dextral normal and sinistral normal on the hangingwall of a 68° and 85° dipping subprovince boundary, a complete contrast to shear sense determinations made with a 30°S dipping subprovince boundary. Appendix D.4 shows the range of resolved shear strain directions in the Longlegged Lake area with subprovince boundary attitudes of 65/82S, 65/75S, 85/80S, 85/88S and 85/74S. Local sense of shear changes markedly within the Longlegged Lake area with steep subprovince boundary attitudes.

5.6 Discussion & Summary

Structural geologists have inferred that the SLFZ is subvertical, but the dip has not been determined by geophysical methods. The low dip value for the subprovince boundary obtained by gravity modelling (Runnals 1978) suggests that the SLFZ may cut the subprovince boundary. Using a new technique developed by Schwerdtner (in press, 1998) local shear sense determinations were obtained along a shallow dipping subprovince boundary. The local shear strain sense beneath a 30°S dipping subprovince boundary, in the Chase and Longlegged Lake areas, is dextral reverse or sinistral reverse. This result agrees with requirements of metamorphic petrology and regional models of the subprovince evolution. The varying sense of the subhorizontal shear strain component (m) suggests that the strike shear is regionally insignificant.

The Chase and Longlegged Lake areas appear not to be affected by the late-stage dextral SLFZ which therefore does not complicate the shear sense determinations. In the Chase Lake area, structural complexity increases towards the subprovince boundary and may attest to a strain gradient that predates dextral faulting and large folds near the SLFZ. Distributed dextral simple shear in the footwall on Chase Lake would have buckled NW-SE planar structures. This lends credence to the interpretation of L-S fabrics in terms of a pre-SLFZ field of ductile deformation. The Longlegged Lake greenstone sliver is asymptotic to the SLFZ, but its curvature need not be due to dextral shearing. The hornblende fabric most likely pertains to an earlier strain accumulated under conditions of midcrustal ductile deformation (Schwerdtner *et al.*, in press).

The shear sense obtained under the assumption of a steep subprovince boundary, in both study areas, differs from that determined for a shallow subprovince boundary. Accordingly, the sense of shear strain in the Chase Lake area has dextral or sinistral normal sense, while at Longlegged Lake, no pattern is discernible.

The relative strength of L and S (k value) is important in inferring the direction of resolved shear (Schwerdtner, in press). The application of the new technique would benefit from k values since the technique gives only an approximate range of resolved shear strain. In other words, in the case of pure lineation the resolved shear strain would equal the j direction within the LTB plane. However, no k values are available in either study area.

Using Bau's method on fabric attitudes from mylonites and migmatites (English River subprovince), moderate to steep attitudes were obtained for the subprovince boundary and SLFZ. However, Bau's method presupposes that, at any locality within the wall rock, the direction of intermediate strain lies in the plane of a shear zone or fault and therefore does not require use of the new technique for finding the resolved shear strain direction. It is evident that shear sense analysis will greatly benefit from vibroseismic profiling across the Uchi/English River subprovince boundary, which will be completed by western Superior Transect of LITHOPROBE in 1997/98.

SUMMARY & CONCLUSIONS

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The Uchi-English River subprovince boundary is thought to be a locus of south-over-north thrust displacement (Campion *et al.* 1986, Breaks 1991). However, the kinematic history of tangential displacement, particularly the dip shear component in wall rocks of the subprovince boundary is poorly documented. An important objective of the thesis project was to test modern accretion hypotheses by Williams *et al.* (1991) and Davis *et al.* (1994) at the Uchi-English River subprovince boundary by utilizing a new graphic technique by Schwerdtner (in press) which determines the local sense of tangential shear strain within stretched walls of a lithotectonic boundary (LTB). The technique uses L-S mineral fabrics to determine the local sense of shear strain and is taylored to situations in which the intermediate principal strain direction (Y) does not lie on the LTB surface. Two planes, one containing the lineation and LTB normal (x_n plane) and the other the foliation normal and LTB normal (z_n plane), are oblique to each other if Y does not lie on the LTB surface. The traces of the planes on the LTB surface define the angle of resolved shear strain.

In the thesis project, attention was focused on two areas in the footwall of the subprovince boundary, which is composed of Uchi greenstone and associated granitoid rocks. The subprovince boundary is marked by the late tectonic, dextral Sydney Lake Fault zone (SLFZ), generally regarded as subvertical. Metamorphic mineral assemblages are low to medium grade in the Chase Lake area and medium grade at Longlegged Lake. In the Chase Lake metawacke unit, cordierite and staurolite have been observed by previous workers (Shklanka 1967, Stone 1980), however, near the SLFZ it appears that staurolite and cordierite are absent. The mineral assemblages consist of biotite, chlorite, muscovite, sericite and accessory minerals. Therefore, the area may have undergone retrograde metamorphism possibly related to the SLFZ.

Two-dimensional gravity modeling of the subprovince boundary in the Longlegged Lake area by Runnals (1978) shows a shallow, south dipping subprovince boundary in N-S vertical sections. Therefore, the subprovince boundary may not coincide with the discordant SLFZ. To use Schwerdtner's new technique to determine the shear sense in the footwall of the subprovince boundary at Chase and Longlegged Lake, several assumptions were made. First, the Uchi-English River subprovince boundary was pegged to a material surface while L-S fabrics developed in the footwall. Second, it was assumed that the late stage SLFZ did not greatly affect the structure of the greenstone and associated rocks in the Chase and Longlegged Lake areas.

The Chase Lake and Longlegged Lake areas were mapped in detail to assess the potential affects of the SLFZ. The Chase Lake mass consists of metawackes and felsic to mafic metavolcanics and reworked metavolcanics (Shklanka 1967, Stone 1980). Large folds occur at Midway Lake and at the Oiseau River near the SLFZ. The Midway Lake syncline folds graded beds and consists of reworked felsic to intermediate metavolcanics. The foliation is approximately axial planar while the fold axis trends WNW and plunges 21°. Mineral and shape lineations plunge at shallow to moderate angles toward the WNW. The Oiseau River synform to the south consists of mafic metavolcanics, felsic to intermediate reworked metavolcanics and metawackes. Both bedding and foliation are folded, therefore, the synform may postdate the Midway Lake syncline. The majority of the mineral and shape lineations have a shallow to moderate plunge and a westerly trend. Lineation, however, is steep on the north limb of the fold in the mafic metavolcanic unit. Numerous small-scale S- and Z-folds are found in the core of the fold and their hinge lines plunge at shallow to moderately steep angles to the west. The fold axis of the Oiseau River synfrom plunges 34° to the west.

Mineral and shape lineations in the intermediate to mafic metavolcanic unit north of

Chase Lake plunge at moderate to steep angles and trend southeasterly. This region lies between the two larger folds which contains a mineral lineation that trends westerly. Mineral and shape lineations shallow as the Sydney Lake fault zone is approached and in the fault zone are typically shallow with east-west trends. Steep lineations are present in the fault zone, but this remains to be interpreted.

The geometry of greenstone east of Chase Lake defines a large Z structure affecting all lithological units which are located near the Sydney Lake fault zone. The metawackes and migmatites contain numerous small-scale S- and Z-folds with varying trends of fold axes. Mafic enclaves in quartz monzonite and disrupted felsic sheets in the metawackes and migmatites are also folded by the Z structure which appears to have formed in the latest period of ductile deformation. Disrupted granitoid sheets at Chase Lake typically strike northwesterly with an exception east of Chase Lake where the strike is north-south and at Oiseau River where the sheets are folded by a synform.

The Midway Lake syncline appears to predate the Oiseau River synform. The rocks of the syncline are modestly strained and exhibit axial planar foliation. Mineral lineation in both structures is parallel to the fold axis. The structural complexity at Chase Lake increases toward the subprovince boundary, possibly indicating a gradient of deformation predating the SLFZ. NW-SE striking boudins at Chase Lake do not fit a northwesterly regional compression model proposed by others for the orogenic evolution of the subprovinces (Stone 1980, Corfu *et al.* 1995, & others). Boudins also could not have been formed by the dextral distributed shear, which would have buckled lithological units now trending NW-SE.

At Chase Lake, two pre-SLFZ tectonic scenarios account for the regional structure. In scenario one, an overturned tight anticline is refolded by a second WNW trending fold, the

Oiseau River synform. This accounts for *i)* the intermediate to mafic metavolcanic unit sandwiched by a metawacke unit, *ii)* stretching and thinning of the metavolcanic units during overturning and folding, and *iii)* the Midway Lake syncline escaping the second folding event. In scenario two, northwest-southeast ductile dislocations along the south shore of Chase Lake and along Midway Lake, govern the deformation of the metavolcanic-metasedimentary rocks. Thrusting explains the repetition of high grade metavolcanics with low grade metawackes at Chase Lake and juxtaposition along Midway Lake of weakly deformed, low grade rocks with highly deformed, higher grade rocks.

The Longlegged Lake greenstone mass consists of medium grade, intermediate to mafic metavolcanics with minor metawacke. A narrow unit of felsic to intermediate tuffs and breccias is found at the northern tip. Foliation is steep with a NE-SW strike and mineral lineation is steep towards the southeast. Locally, at the southern boundary, the amphibolite is mylonitized and contains a mineral lineation that is steep towards the southeast as well. Upon entering the migmatite unit in the Sydney Lake fault zone to the south, mineral lineation becomes shallow with E-W trends. Disrupted felsic sheets strike northeasterly in the Longlegged Lake sliver.

Since the SLFZ did not greatly affect the greenstone in the Chase and Longlegged Lake areas, the new technique for determining shear sense can be utilized without further complications. In the Chase and Longlegged Lake areas, the angular range of resolved shear strain beneath a 30°S dipping subprovince boundary is dextral reverse or sinistral reverse. The varying sense of boundary-parallel displacement (m) suggests that strike shear is insignificant on the scale of several kilometres.

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APPENDIX A

A.0 INTRODUCTION

Appendix A contains measurement station maps
and structural data maps of the Chase Lake area.

Linear and planar structures are used in Chapter IV to assess the structure in the Chase Lake area. Mineral lineation and foliation attitudes are used in Chapter V to determine the local sense of shear strain components in the footwall of the subprovince boundary. Appendix C contains measurement stations with sample localities of thin sections studied. Measurement stations and sample localities are also referred to in several chapters.

A.1 Measurement stations

A.2 Sample localities

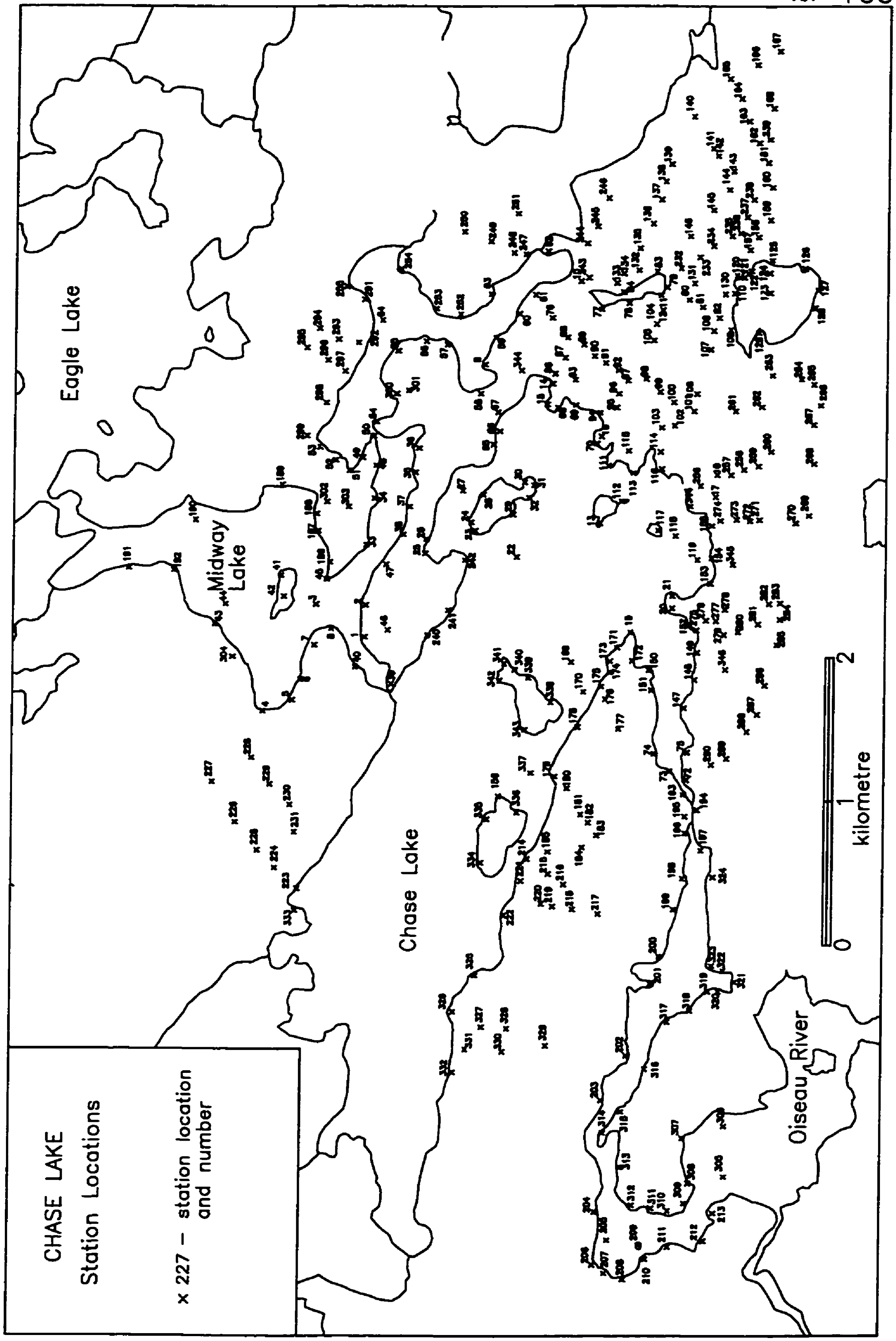
A.3 Photo localities

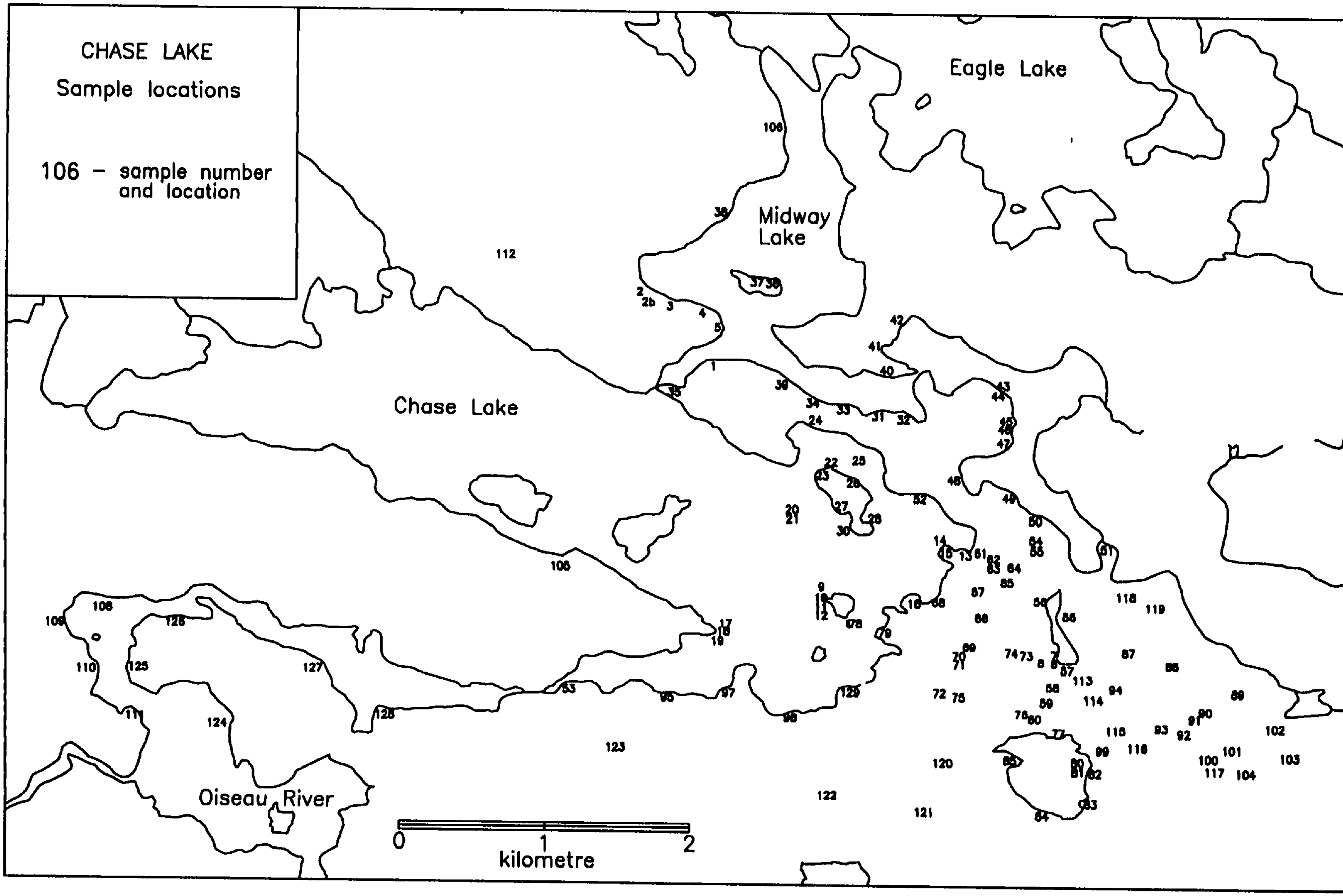
A.4 Foliation attitudes

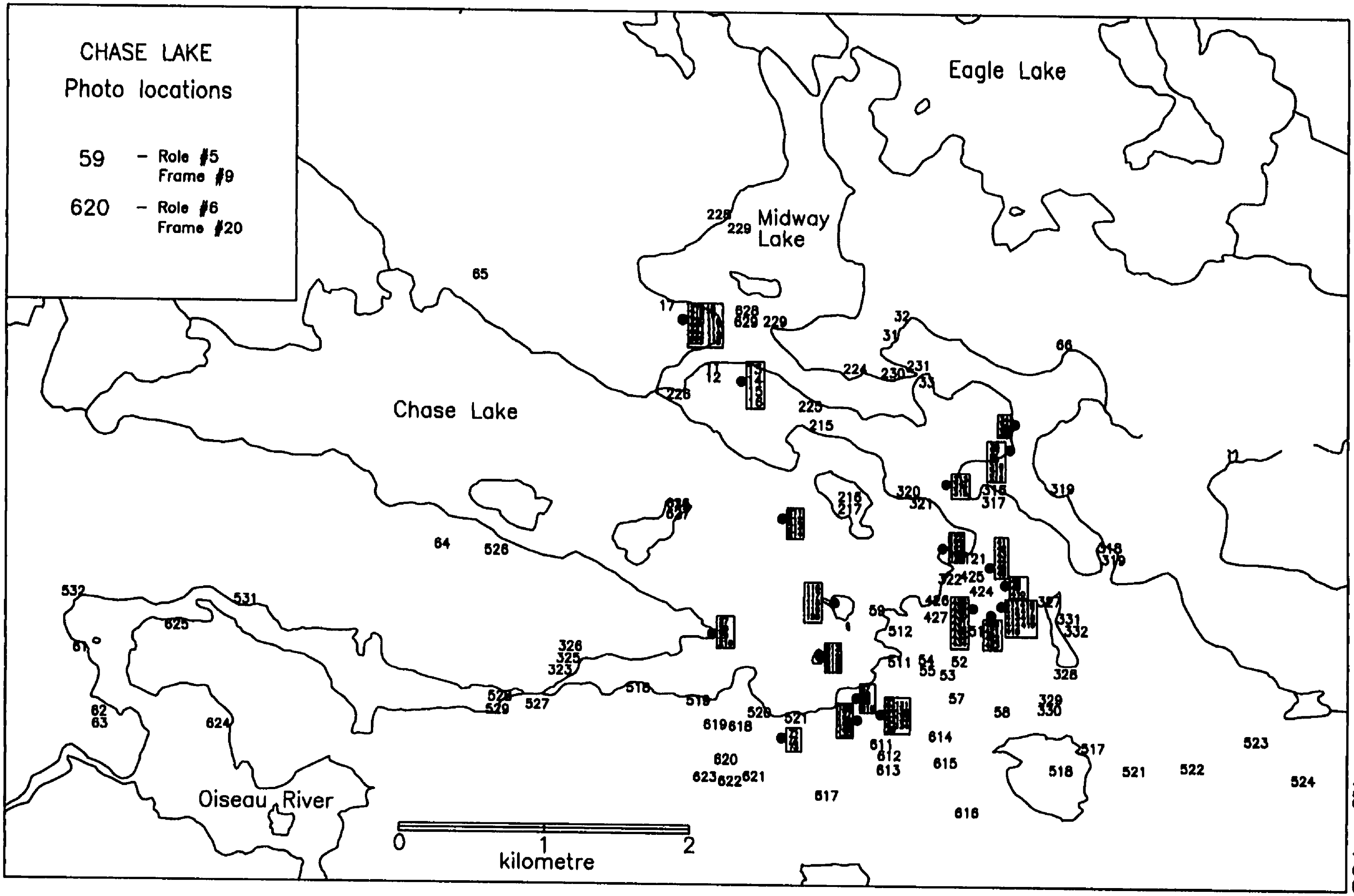
A.5 Mineral and shape lineation attitudes

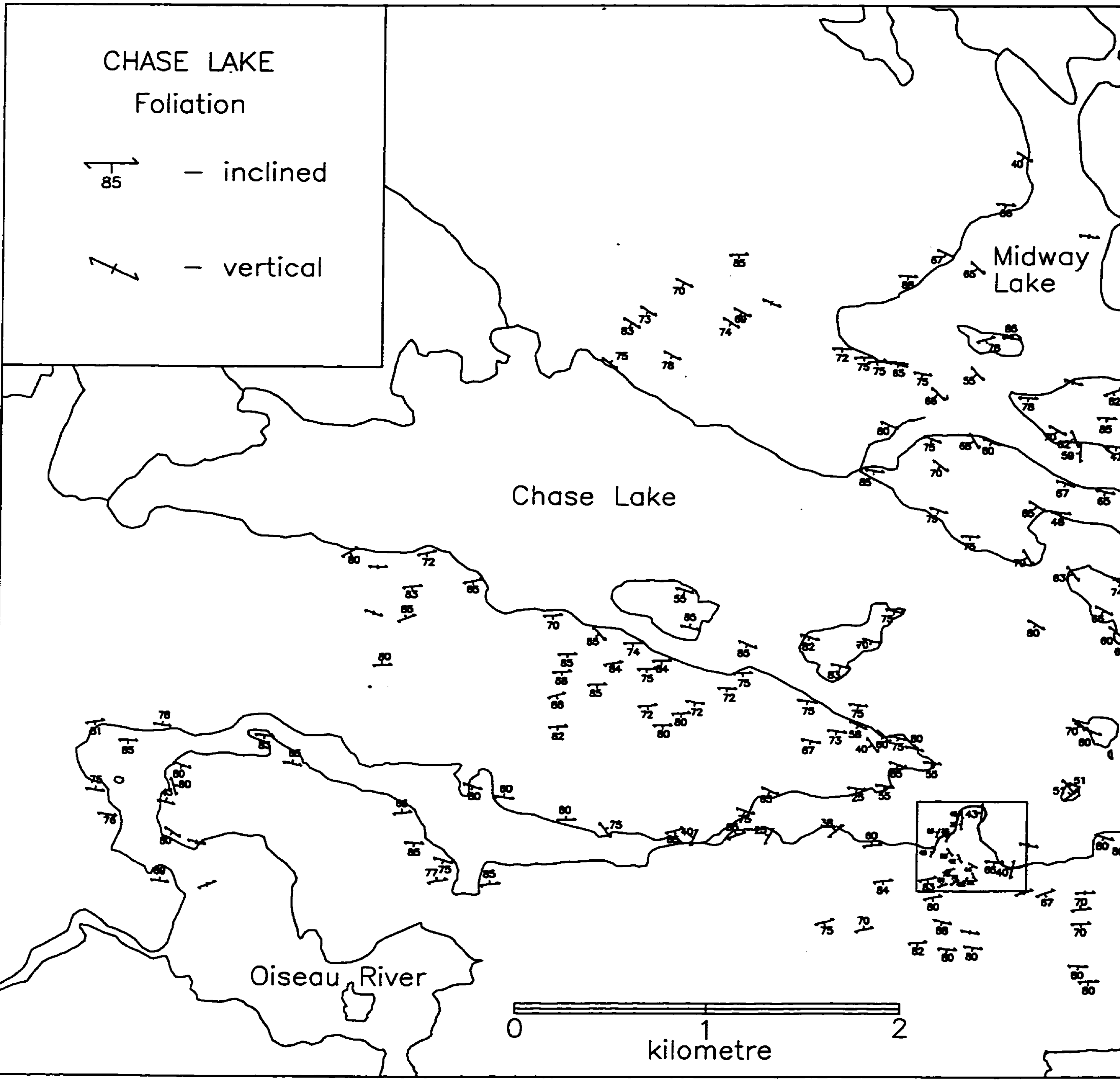
A.6 Linear structures (mineral, stretching, crenulation, slicken striae)

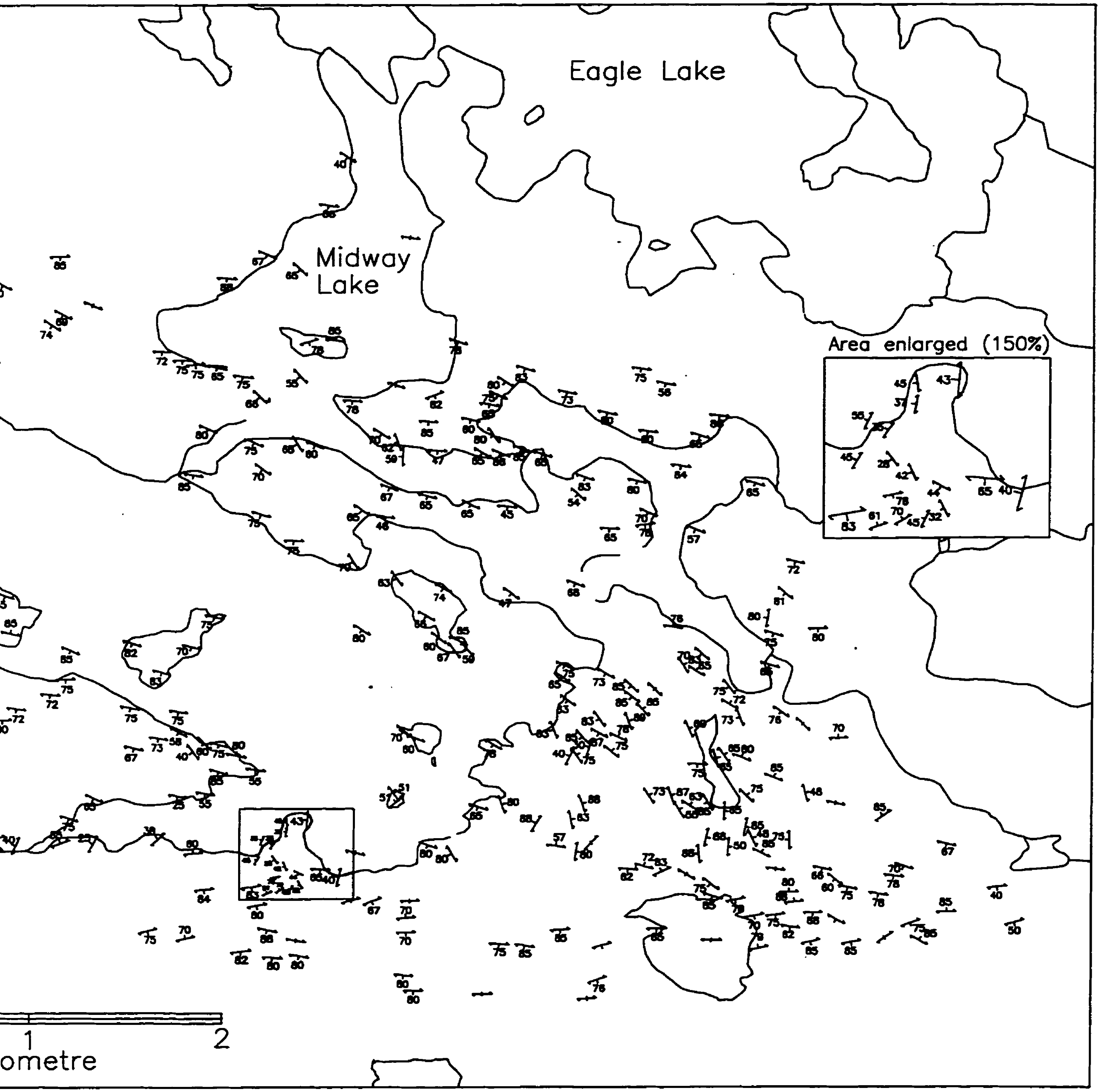
A.7 Fold geometry (crenulation lineation, S-, Z-, U- and M-folds)

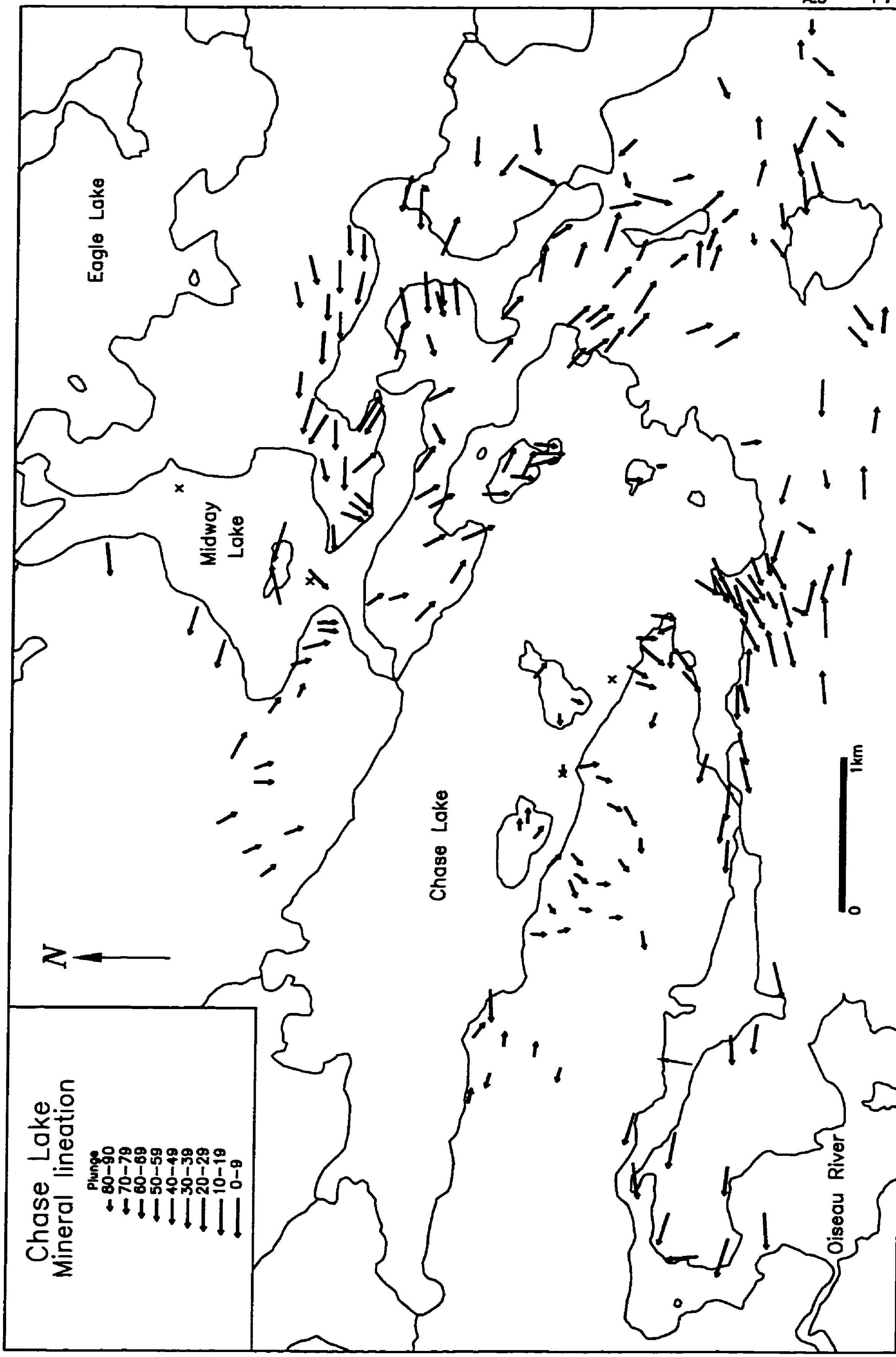

CHASE LAKE
Station Locations
x 227 - station location
and number
Eagle Lake
Midway Lake
Chase Lake
Oiseau River
0
1
2
kilometre

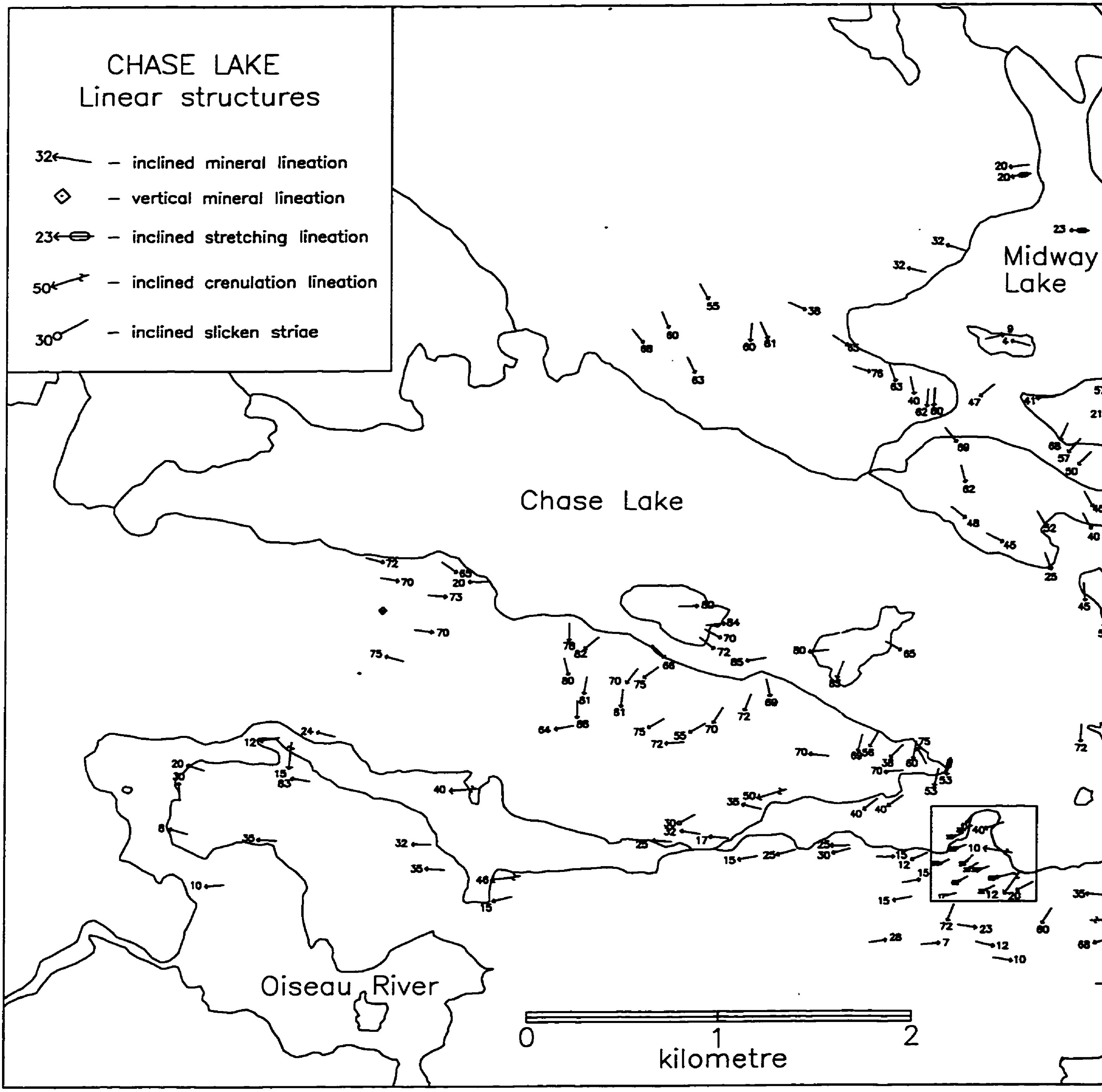

CHASE LAKE
Sample locations
106 – sample number and location
Eagle Lake
Midway Lake
Chase Lake
Oiseau River
0 1 2
kilometre


CHASE LAKE
Photo locations
59 - Role #5 Frame #9
620 - Role #6 Frame #20
Eagle Lake
Midway Lake
Chase Lake
Oiseau River
0
1
2
kilometre

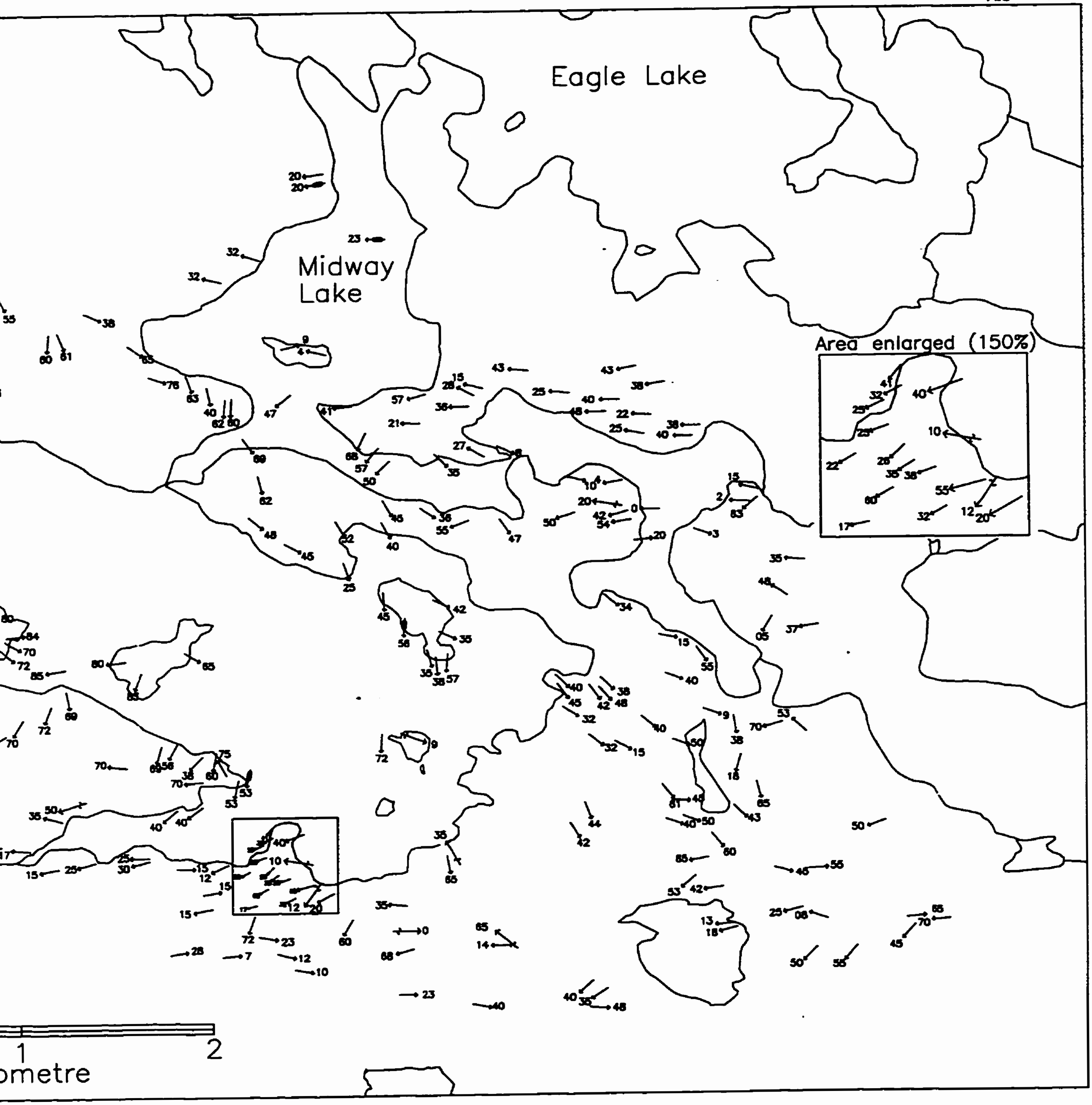

CHASE LAKE
Foliation
85
— inclined
— vertical
Midway Lake
Chase Lake
Oiseau River
0
1
2
kilometre

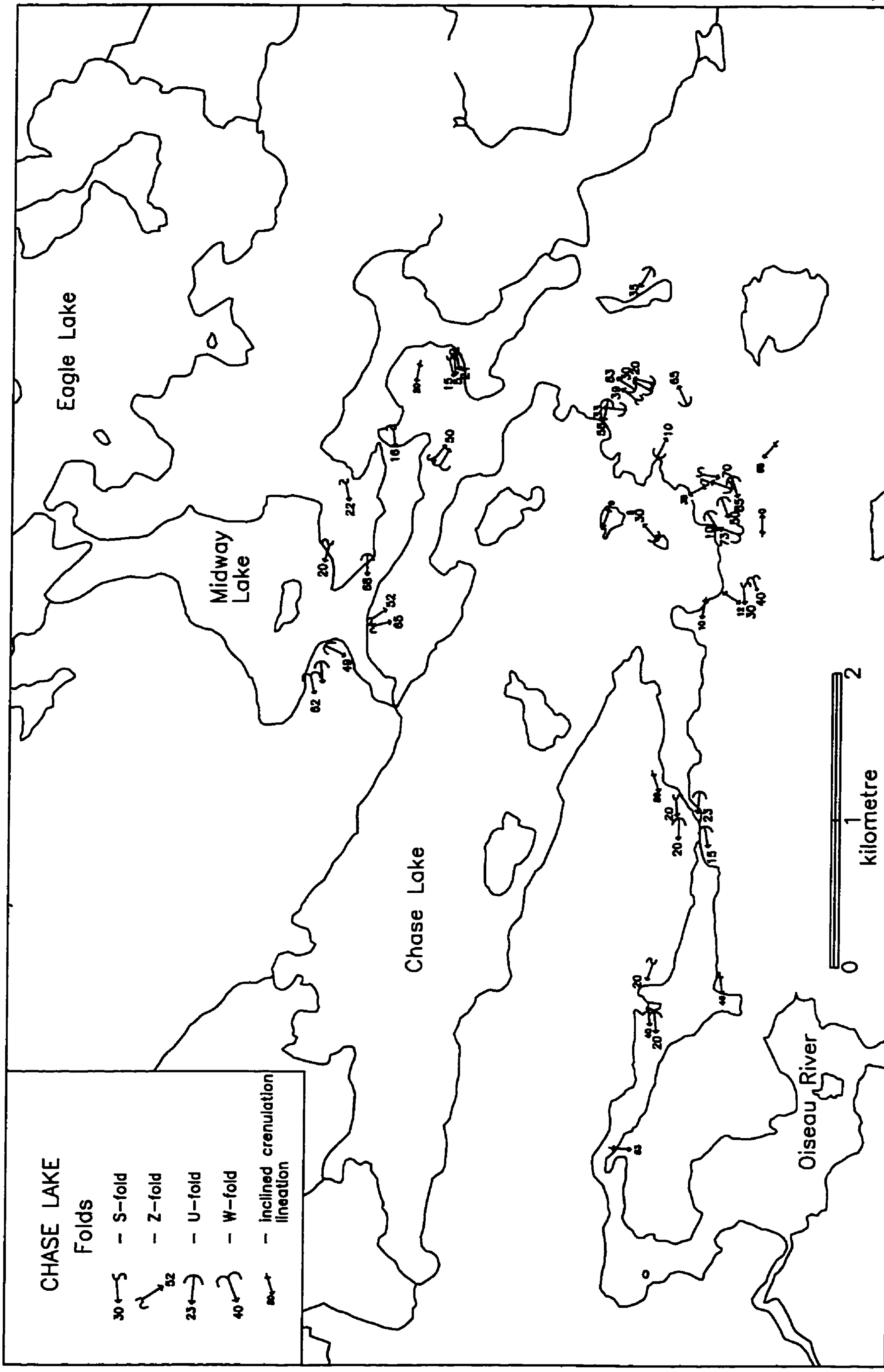

Eagle Lake
Midway Lake
Area enlarged (150%)
1
2
ometre


Chase Lake
Mineral lineation
Plunge
80–90
70–79
60–69
50–59
40–49
30–39
20–29
10–19
0–9
N
Eagle Lake
Midway Lake
Chase Lake
Oiseau River
0
1km



CHASE LAKE
Linear structures
32 – inclined mineral lineation
– vertical mineral lineation
23 – inclined stretching lineation
50 – inclined crenulation lineation
30 – inclined slicken striae
Midway Lake
Chase Lake
Oiseau River
0
1
2
kilometre


Eagle Lake
Midway Lake
Area enlarged (150%)
1
2
ometre


Eagle Lake
Midway Lake
Chase Lake
Oiseau River
0 1 2
kilometre
CHASE LAKE
Folds
– S-fold
– Z-fold
– U-fold
– W-fold
– inclined crenulation lineation

APPENDIX B

B.0 INTRODUCTION

Appendix B contains measurement station maps and structural data from the Longlegged Lake area

Linear and planar structures are used in Chapter IV to assess the structure in the Longlegged Lake area. Mineral lineation and foliation attitudes are used in Chapter V to determine the local sense of shear strain components in the footwall of the subprovince boundary. Appendix C contains measurement stations with sample localities of thin sections studied. Measurement stations and sample localities are also referred to in several chapters.

B.1 Measurement stations

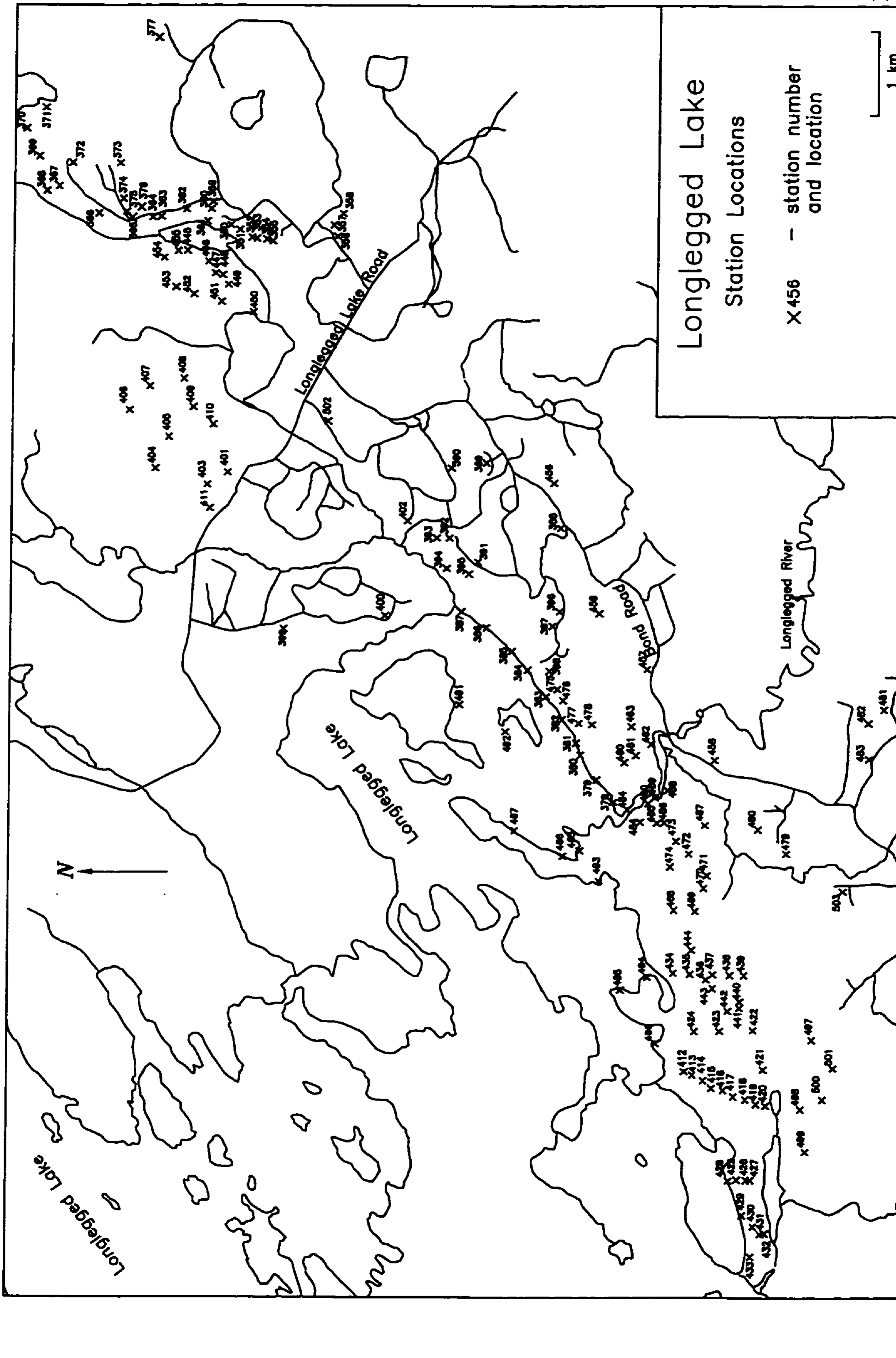
B.2 Sample localities

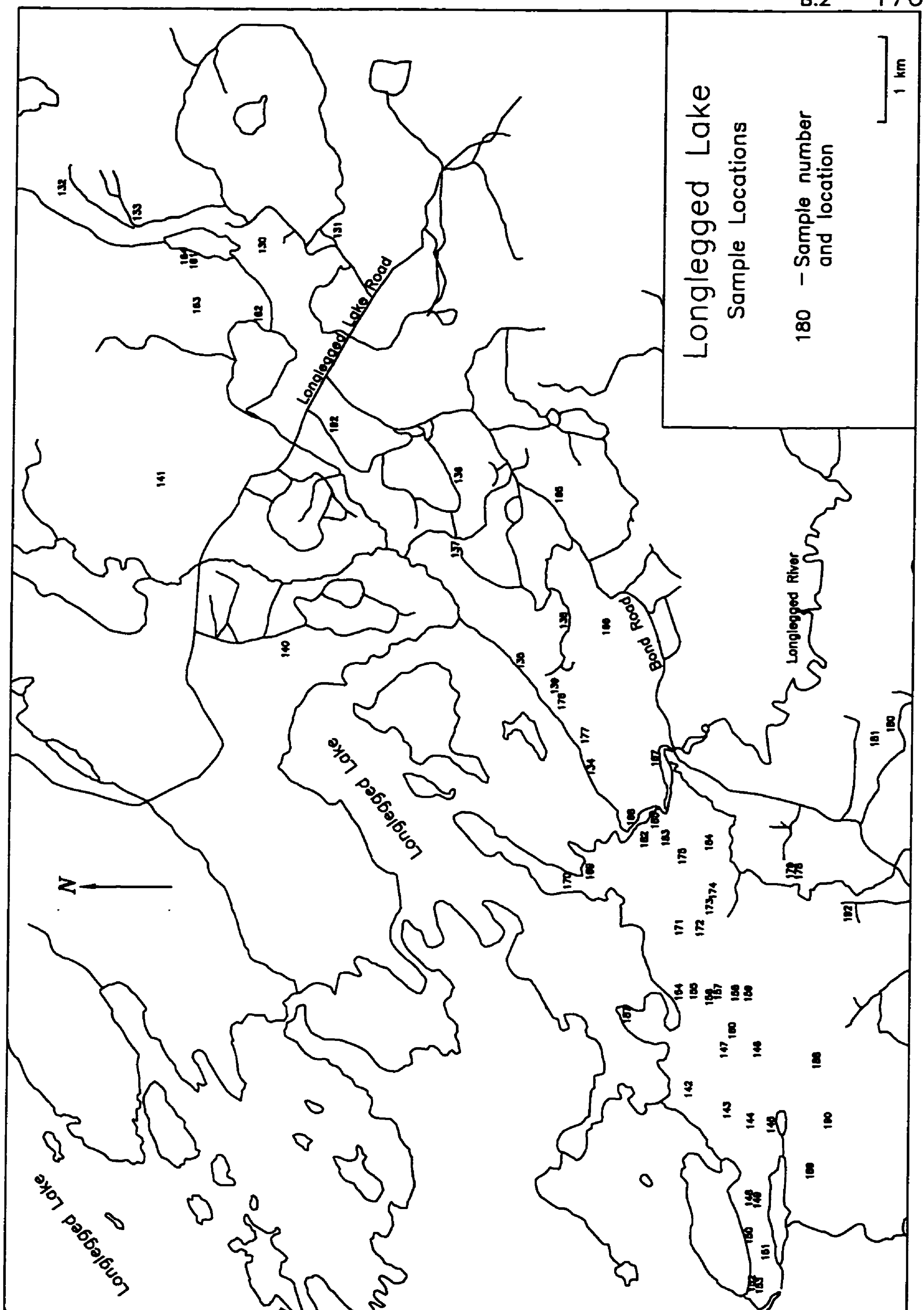
B.3 Photo localities

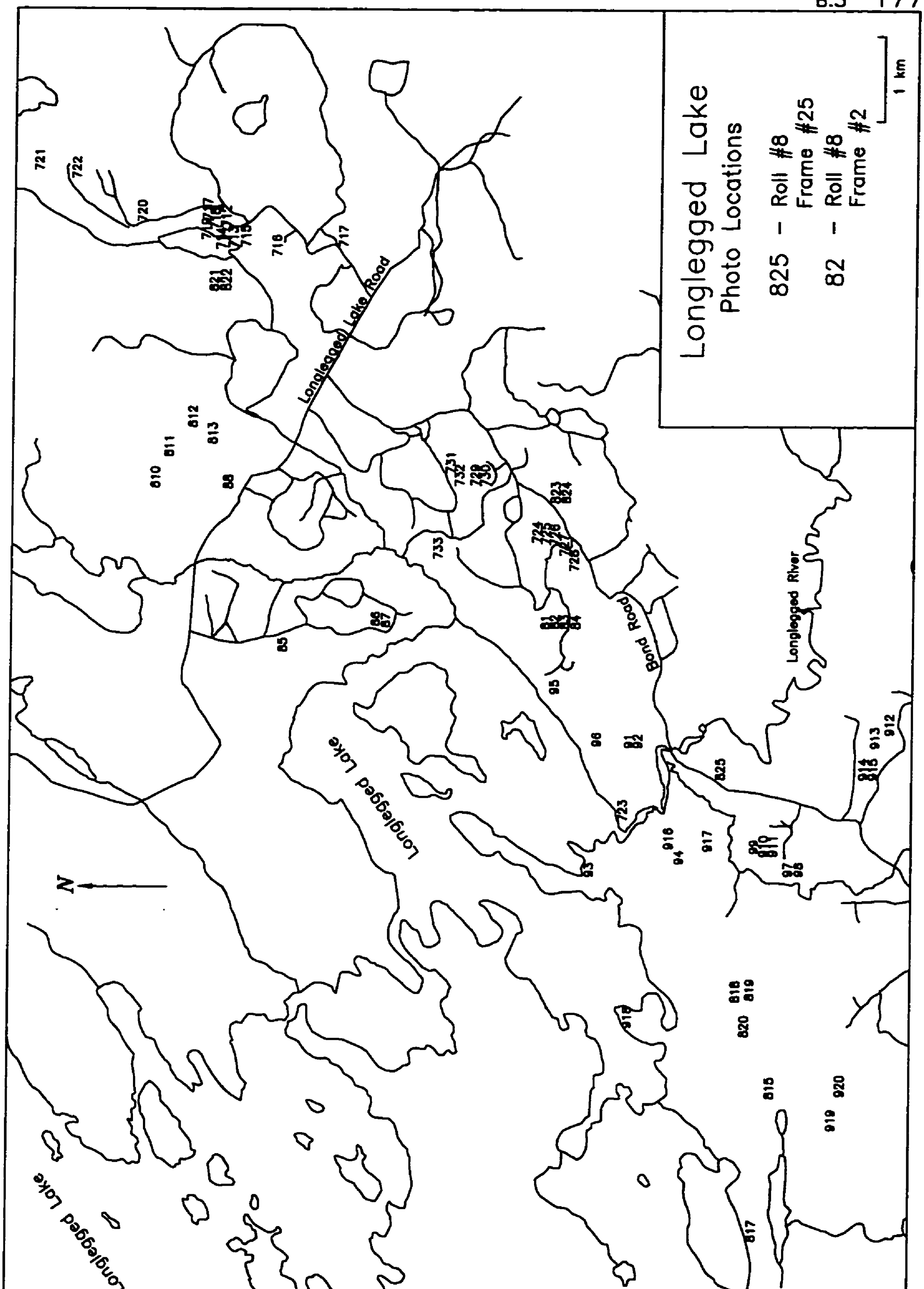
B.4 Foliation attitudes

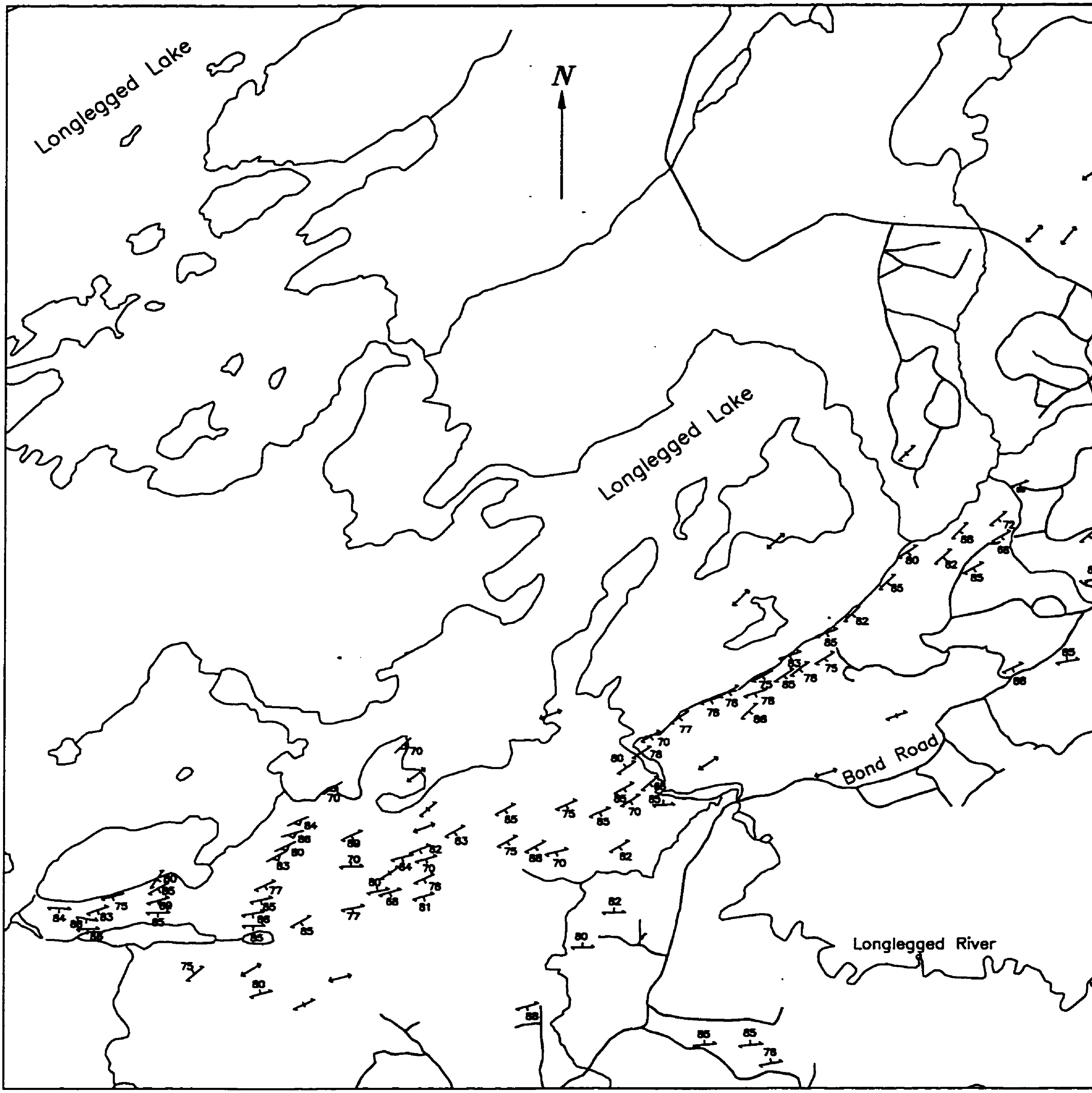
B.5 Mineral and shape lineation attitudes

B.6 Linear structures (mineral, stretching, crenulation, slicken striae)

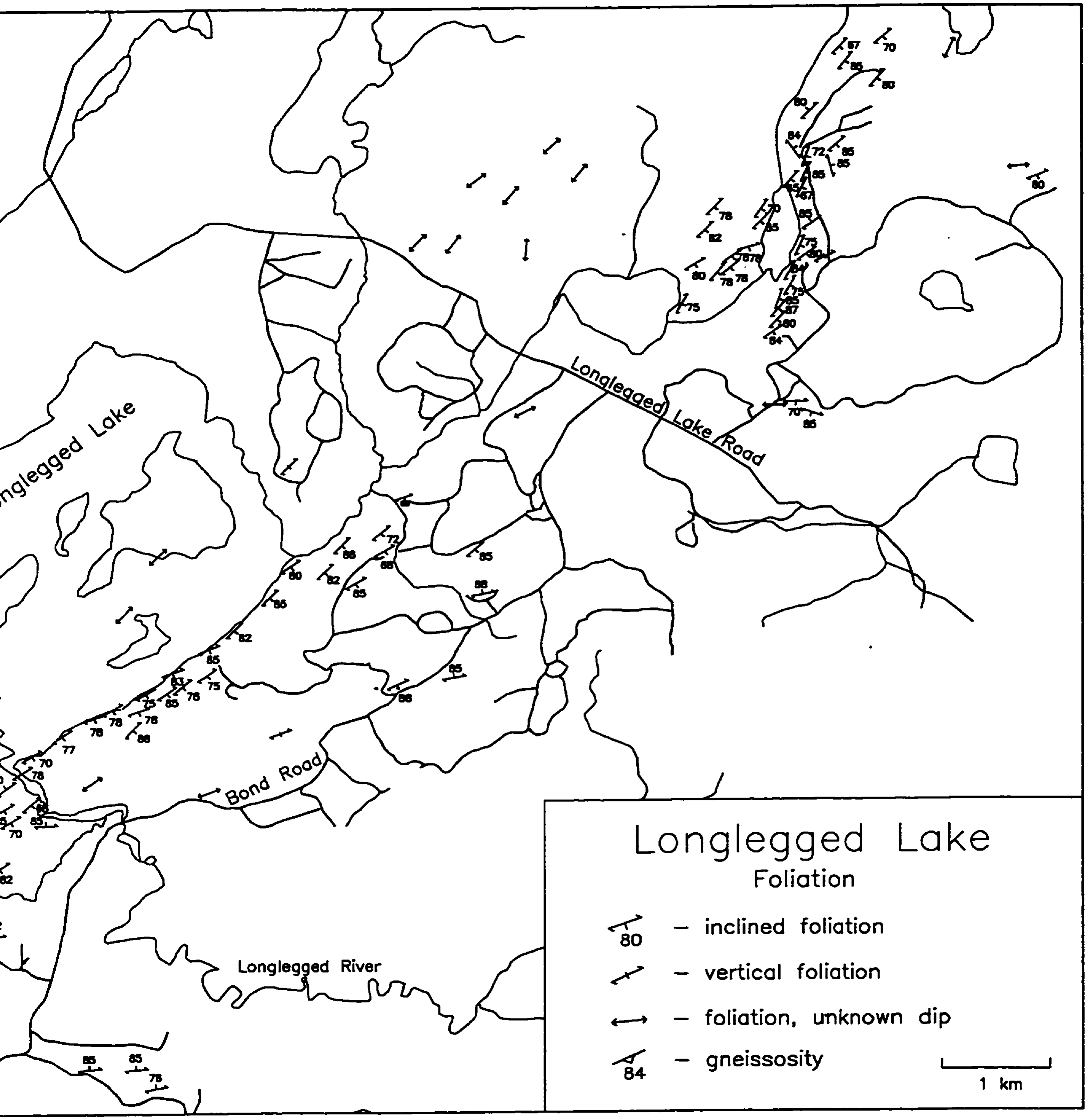

Longlegged Lake
Station Locations
X456 – station number and location
1 km
N
Longlegged Lake Road
Bond Road
Longlegged River
Longlegged Lake
Longlegged Lake

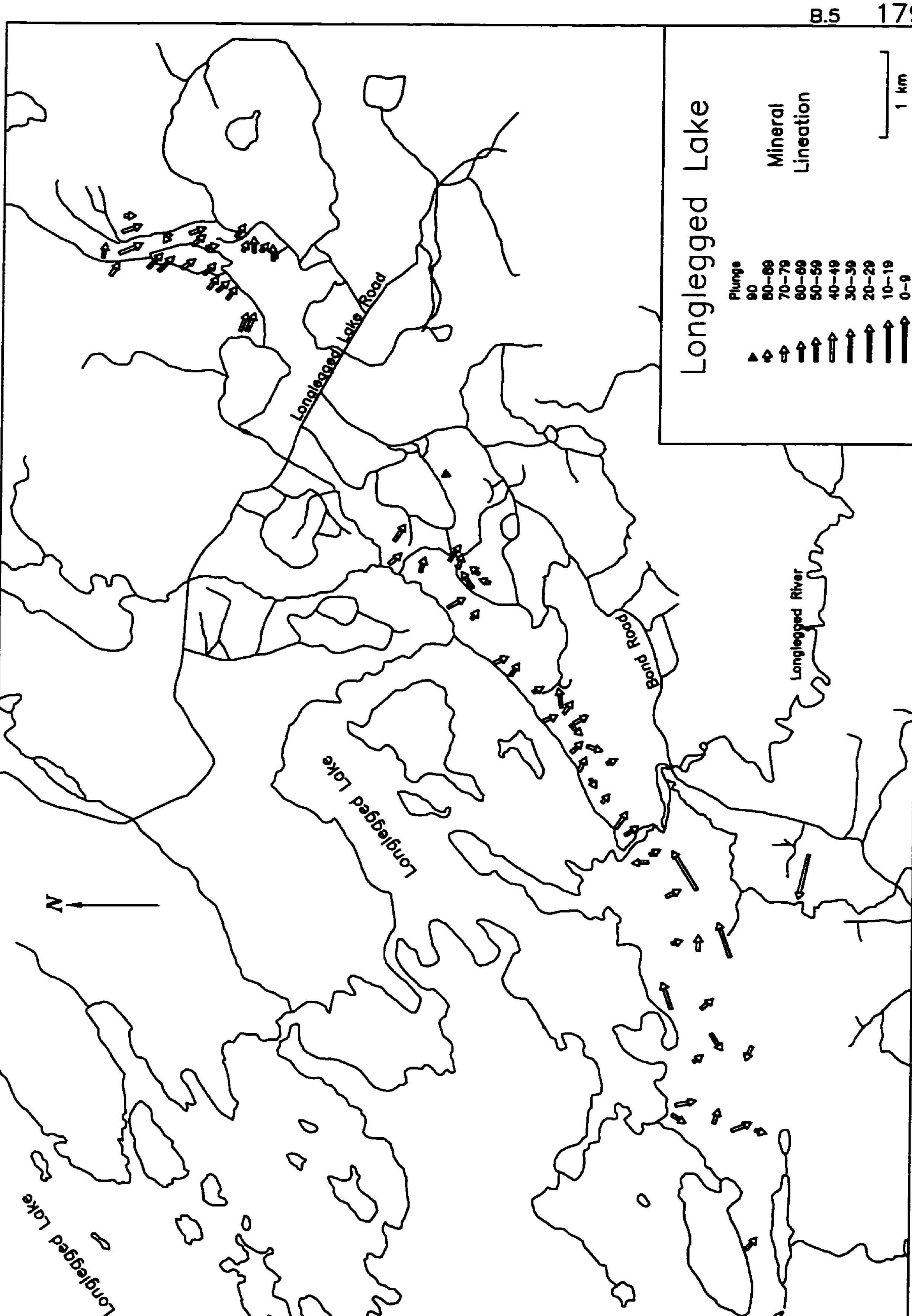

Longlegged Lake
Sample Locations
180 —Sample number
and location
1 km
N
Longlegged Lake Road
Bond Road
Longlegged River
Longlegged Lake
Longlegged Lake

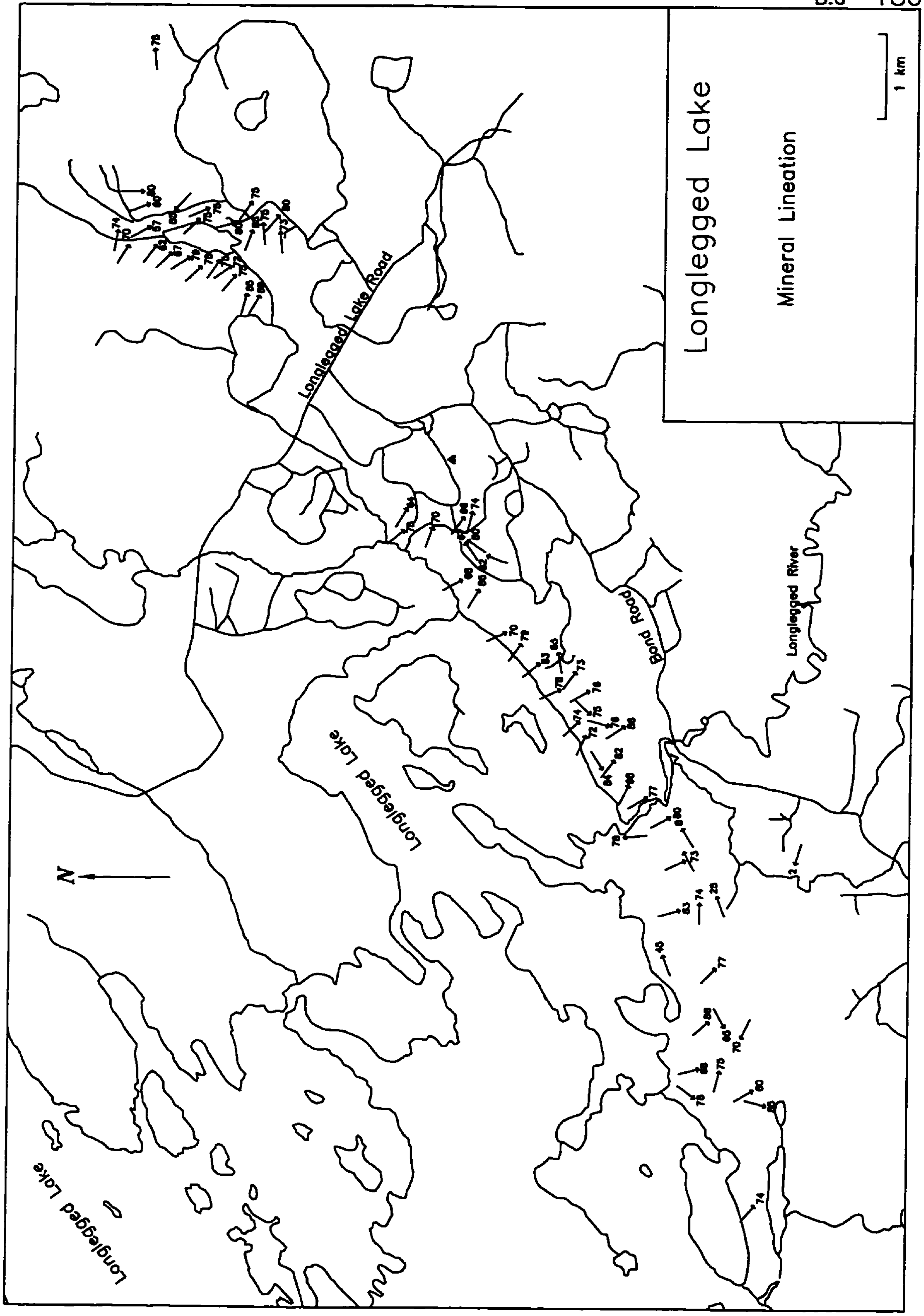

Longlegged Lake
Photo Locations
825 - Roll #8
Frame #25
82 - Roll #8
Frame #2
1 km
N
Longlegged Lake Road
Bond Road
Longlegged River
Longlegged Lake
Longlegged Lake



N
Longlegged Lake
Longlegged Lake
Bond Road
Longlegged River


Longlegged Lake
Longlegged Lake Road
Bond Road
Longlegged River
Longlegged Lake
Foliation
inclined foliation
vertical foliation
foliation, unknown dip
gneissosity
1 km


Longlegged Lake
Mineral Lineation
Plunge
90
80–89
70–79
60–69
50–59
40–49
30–39
20–29
10–19
0–9
1 km
Longlegged Lake Road
Bond Road
Longlegged River
Longlegged Lake
Longlegged Lake
N


Longlegged Lake
Mineral Lineation
1 km
N
Longlegged Lake Road
Bond Road
Longlegged River
Longlegged Lake
Longlegged Lake

APPENDIX C

C.0 INTRODUCTION

Appendix C contains a summary of thin section petrography for the Chase Lake and Longlegged Lake areas.

C.1 Chase Lake area

C.2 Longlegged Lake area

C.1 CHASE LAKE: SUMMARY OF THIN SECTION PETROGRAPHY

Rock sample localities are shown in Figure 10, Chapter III.
All thin sections view the XZ plane

Sample 3 - station AB06.

40% amphibole, 25% plagioclase, 25% quartz, 15% sericite, 5% chlorite, minor opaques.

- Amphibolite Facies

Chlorite defines the foliation. Approximately 40% of the thin section is hornblende. Hornblende is the peak metamorphic mineral and does not define the foliation. Therefore, the deformation is simultaneous with retrogression, not with peak metamorphism. Outcrop is mafic metavolcanics with 5cm wide cross-cutting K-feldspar dykes and concordant plagioclase rich sheets. Disrupted and Z-folded sheets and dykes occur on a small-scale.

Sample 10 - station AB13

50% quartz, 30% biotite, 10% plagioclase, 10% epidote, 5% chlorite, <5% apatite, 1% opaques.

- Biotite Zone

Biotite and chlorite are intergrown and crenulated. Metawacke outcrop contains disrupted, cream-weathered granitoid sheets. Cm- to m-scale folds, crenulation cleavage and mm- to cm-scale bedding.

Sample 19 - station AB19.

35-40% amphibole, 50% quartz, 10% plagioclase, 5% sericite, minor epidote, opaques.

- Amphibolite Facies

Mafic metavolcanic outcrop contains 50% varioles and layering on metre scale. Amphibole and quartz define the foliation.

Sample 21 - station AB22.

Layer A: 40% plagioclase/quartz, 30% muscovite, 25% biotite, 5% chlorite, minor garnet.
Layer B: 60% plagioclase/quartz, 40% biotite.

- Biotite Zone

Highly strained outcrop. One layer (relatively more highly strained of the two layers) contains muscovite/biotite/quartz where biotite and muscovite define the foliation. The other layers do not contain muscovite. A thin layer, composed mostly of larger muscovite grains, separates higher strain layers from lower strain layers.

Sample 24 - station AB26.

50-60% amphibole, 40% plagioclase/quartz, minor sericite, epidote, opaques, sphene(?).

- Amphibolite Facies

The outcrop is a mafic metavolcanic that is weakly altered (minor sericite) and foliated. AB24 and AB46 have a similar grain size but AB46 contains a stronger foliation.

Sample 27 - station AB29.

~70% quartz/plagioclase, 30% biotite, minor garnet, chlorite, sericite, opaques, epidote(?).

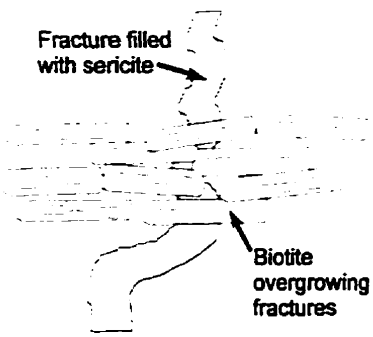
- Biotite Zone

The thin section contains a thin layer of very light pink garnets (spessartine?) with large quartz and plagioclase grains. Fractured garnets contain inclusions of quartz and chlorite. Thin section shows quartz/plagioclase layers with quartz/plagioclase/biotite layers and several thin chlorite layers. Thin section is similar to AB21. The outcrop is an intermediate reworked volcanic or semi-pelite.

Sample 31 - station AB35.

60% plagioclase/quartz, 30% biotite, 10% amphibole, minor sericite.

- Biotite Zone



The reworked metavolcanic or metasediment contains disrupted felsic sheets. In thin section, quartz grains are recrystallized and "strung out". Biotite and amphibole define the foliation. This section is similar to AB43. Evidence for retrograde metamorphismbiotite is a sericite-filled fracture that crosscuts the foliation and has been overgrown by biotite which parallels foliation (see diagram, above).

Sample 38 - station AB43.

60% quartz, ~40% biotite, minor sericite(?).

- Biotite Zone

The weakly deformed outcrop contains approximately 20% large fragments (>6.4cm long; lensoid) and remainder lapilli size fragments. Fragments are felsic to intermediate in composition. Matrix is fine-grained and medium grey. In thin section, biotite defines the foliation and wraps around quartz-rich fragments.

Sample 40 - station AB48.

60% plagioclase/quartz, 40% biotite/chlorite, minor epidote, zircon, allanite.

- Greenschist Facies

The outcrop is an intermediate metavolcanic. The tuff consists of cm-wide layers that are weakly magnetic and contain trace sulphides. The outcrop contains abundant small S- and Z-folds. In thin section, lapilli-size fragments are composed of plagioclase and minor quartz. Biotite and minor chlorite encompass the lapilli. Allanite is a brown roundish mineral surrounded by epidote (metamict state).

Sample 41 - station AB51.

60% amphibole, 40% quartz/plagioclase, minor magnetite.

- Amphibolite Facies

The outcrop is a highly foliated, magnetic, intermediate metavolcanic with abundant metre-scale folds.

Sample 42 - station AB52.

Plagioclase, quartz, chlorite, epidote(?).

- Greenschist facies

Z-folds and minor offsets of quartz veinlets found in outcrop. Thin section is fine-grained, crenulated and "mucky" and it is hard to determine mineral percentages.

Sample 43 - station AB55.

50-70% plagioclase/quartz, 30 - 40% amphibole (layer 1), 40 - 50% biotite (layer 2), chlorite (?), sericite (?), minor opaques.

- Amphibolite Facies

Amphibole and biotite define the foliation and wrap around the quartz grains. Alternating deep green amphibole and brown biotite layers. Also looks like C-S fabric in parts of the thin section. The outcrop is an intermediate to mafic reworked metavolcanic that is schistose with sections that contain "clumps" of amphibole. S- and Z-folds also found in outcrop.

Sample 46 - station AB56.

amphibole (both hornblende and actinolite?), biotite, magnetite.

- Greenschist Facies?

Gabbro? Possibly two different amphiboles. AB46 is similar to Samples 24 and 41. Outcrop is weakly magnetic.

Sample 48 - station AB58.

60% amphibole, 20% quartz/plagioclase, 20% epidote, 1% opaques.

- Amphibolite facies

Outcrop consists of mainly cm-layered mafic metavolcanic with a >1m wide fine-grained felsic layer. Epidote- and quartz-filled fractures. Rock is moderately strained.

Sample 53 - station AB72.

60-70% quartz, 15% biotite, 10% muscovite, 5% chlorite, minor apatite, zircon.

- Biotite Zone

The rock is a metawacke with abundant ½ metre scale isoclinal folds. In thin section, the chlorite and biotite define the comparatively weak foliation. Higher muscovite content and more pelitic in this section compared with Samples 126 to 128. Quartz content is high.

Sample 69 - station AB99.

35% amphibole, 20% plagioclase, 20% quartz, 10% garnet, 10% chlorite, 5% biotite.

- Lower Amphibolite Facies

The outcrop contains disrupted sheets. In thin section inclusions of hornblende, quartz, biotite and plagioclase are found in the garnet (poikilitic). Chlorite-filled fractures in the garnet. Chlorite and biotite define the foliation and wrap around garnet porphyroblasts. Alternating chlorite/biotite bands with hornblende/biotite/chlorite. Possibilities are a reworked tuff or metawacke.

Sample 74 - station AB105.

55% plagioclase/quartz, 35% chlorite/biotite, epidote, minor sericite, apatite, sphene.

- Greenschist Facies

The rock is an intermediate lapilli-tuff (~10-20% plagioclase fragments). Outcrop also contains small-scale S-folds. The thin section shows that epidote is fine-grained and widespread.

Sample 77 - station AB110.

~ 60% plagioclase occurs as larger lapilli (some quartz), chlorite, biotite, epidote, sericite.

- Greenschist Facies

Rocks at this outcrop are intermediate lapilli tuffs. Fragments are plagioclase and some quartz. Chlorite and biotite wrap around the fragments. Outcrop contains pegmatite dykes.

Sample 79 - station AB113.

40% quartz/plagioclase, 25% biotite, 20% chlorite, 15% muscovite, 1% garnet, minor sericite, opaques.

- Biotite Zone

Biotite, chlorite, and muscovite define the foliation. One section also has quartz defining the foliation. A few larger grains of garnet are found. Micas "wrap" around garnet grains. Muscovite has a larger grain size then chlorite and biotite, and sometimes is oriented perpendicular to the foliation. The outcrop is a metawacke with crosscutting granitoid dykes. Abundant small Z-folds and disrupted sheets.

Sample 82 - station AB125.

50% amphibole, 50% quartz/plagioclase, minor opaques.

- Amphibolite Facies

Microfractures filled with epidote and chlorite. Amphibole defines the foliation. This thin section is located near the fault and yet the rock is not highly foliated. Relatively small grain size. The outcrop is an intermediate to mafic reworked metavolcanic with ½ metre wide, concordant pegmatite dykes and small Z-folds.

Sample 85 - station AB129

45% quartz/plagioclase, 30% muscovite, 10% biotite, 10% chlorite, 5% epidote.

- Biotite Zone

Rocks at the outcrop are highly foliated with ~20% or less neosome (felsic sheets). Micas and quartz define the foliation. "Pods" of quartz layers.

Sample 91 - station AB142.

50% plagioclase/quartz, 35% amphibole, 5-10% garnet, minor biotite, opaques.

- Amphibolite Facies

The outcrop is a fine-grained mafic metavolcanic that contains approximately 10% folded dykes and sheets. Tourmaline is found in quartz veins. Moderate foliation is defined by the amphibole, however some grains are almost perpendicular to foliation. Quartz grains are on average smaller than amphibole grains.

Sample 96 - station AB149.

60% quartz, 35-40% biotite, minor opaques.

- Biotite Zone

Rocks at this outcrop are felsic reworked metavolcanics or metawackes and contain a 10 m wide S-folded felsic dyke. Similar to Sample 53. Biotite and relatively large quartz grains define the foliation.

Sample 101 - station AB162.

~50% amphibole, 30% epidote, 20% quartz.

- Amphibolite Facies

The thin section is moderately to highly strained and contains epidote- and quartz-rich layers. The outcrop is an intermediate to mafic reworked metavolcanic.

Sample 105 - station AB180

40% amphibole (actinolite?), 30-40% quartz, 20% biotite.

- Greenschist Facies (?)

Intermediate to mafic reworked metavolcanic. Biotite and amphibole define the foliation and wrap around quartz grains in quartz-rich layers.

Sample 123 - station AB288.

40% quartz, 35% biotite, 20% chlorite, 5% muscovite.

- Biotite Zone

The weakly foliated outcrop is a light grey metawacke with felsic dykes.

Sample 126 - station AB313.

50% quartz/plagioclase, 30% chlorite, 20% epidote, minor zircon.

- Chlorite Zone

The outcrop is a fine-grained, medium greenish-grey, metawacke. Relatively weakly foliated. Small offset felsic dykes in outcrop.

Sample 127 - station AB317.

Chlorite, sericite, epidote, pumpellyite, quartz.

- Chlorite Zone

The thin section is "mucky" and therefore hard to visually estimate mineral percentages. The outcrop is a fine-grained, light grey metawacke that contains K-feldspar-rich dykes.

Sample 128 - station AB323. **C.1**

50% quartz/plagioclase, 40% biotite, minor muscovite, apatite.

- Biotite Zone

The outcrop is a metawacke. Some biotite grains are oriented perpendicular to the foliation.

Sample 129 - station AB344.

80% amphibole, 20% quartz/plagioclase.

- Amphibolite Facies

Weakly foliated mafic metavolcanic. Contains a few quartz/plagioclase rich bandsin thin section. Small-scale Z- and S-folds of quartz-rich sheets/dykes found in the outcrop.

C.2 LONGLEGGED LAKE: SUMMARY OF THIN SECTION PETROGRAPHY

Rock sample localities are shown in Figure 12, Chapter III.
All thin sections view the XZ plane

Sample 130 - station AB351.

50% quartz, 40% actinolite, 10-20% biotite.

- Greenschist Facies

Both actinolite and biotite define the foliation. Too much quartz and biotite to be a mafic metavolcanic. The sample is taken near a gossan. The outcrop contains a strong mineral lineation.

Sample 137 - station AB392.

55% amphibole, 35% quartz/plagioclase (andesine range), 10 % epidote/sphene/opaques.

- Amphibolite Facies

Intermediate to felsic metavolcanic. Abundant quartz and amphibole layers. Smaller grain size than Samples 157 and 172. Lenses of epidote in the outcrop. Poor, small outcrop.

Sample 150 - station AB429.

70% amphibole, 20% quartz/plagioclase, 10% biotite.

- Amphibolite Facies

The outcrop exhibits rafts or lenses of weakly foliated, medium-grained mafic metavolcanics in a mylonitized white trondhjemite. Larger grain size at this outcrop than the previous thin section, AB137.

Sample 157 - station AB437

~60% amphibole, 20-30% quartz/plagioclase, sericite, epidote, minor muscovite.

- Amphibolite Facies

A mafic metavolcanic outcrop with abundant pink-weathered, granitic sheets/dykes. Amphibole defines the foliation. Muscovite found in quartz-rich bands. Small epidote veinlets.

Sample 171 - station AB468.

50% amphibole, 30% epidote, 20% plagioclase/quartz.

- Amphibolite Facies

This small, flat outcrop is a mafic metavolcanic. The sample contains disrupted epidote-rich layers.

Sample 172 - station AB469

~60% amphibole, 30% plagioclase/quartz, 10% sericite/epidote/sphene, minor zoisite(?).

- Amphibolite Facies

The mafic metavolcanics at this outcrop contain a strong mineral lineation and epidote alteration. Amphibole defines the foliation. A twinned mineral with blue birefringence may be zoisite. Abundant Z-folded, k-feldspar-rich sheets are present in outcrop. Migmatites are found approximately 20 metres east of this outcrop.

Sample 176 - station AB475

70% amphibole, quartz, plagioclase, garnet, pyroxene.

- Amphibolite Facies

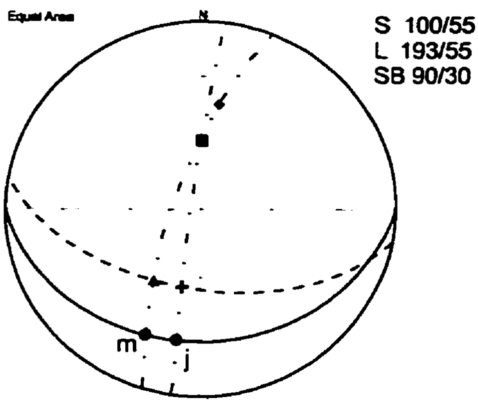
Mafic to intermediate metavolcanic outcrop with disrupted intermediate layers. Garnet porphyroblasts visible in outcrop.

APPENDIX D

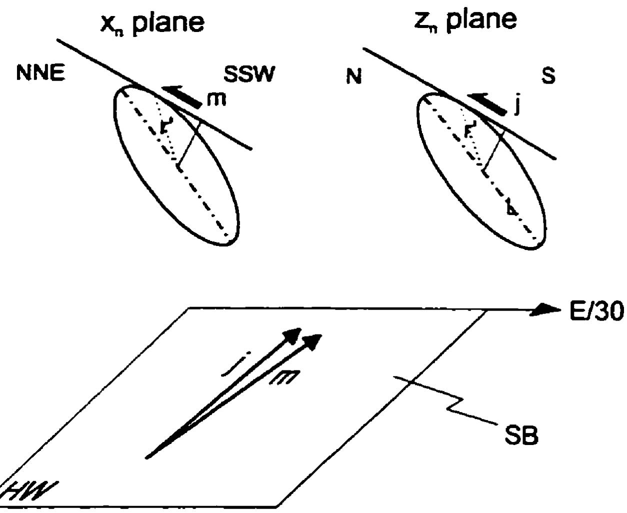
D.0 INTRODUCTION

Appendix D contains figures that depict the derivation of the local sense of resolved shear strain within the subprovince boundary for the Chase and Longlegged Lake areas (Chapter V). The shallow subprovince boundary attitude (30° dip, D.1 & D.2) was obtained from gravity modeling by Runnalls (1978). D.3 and D.4 assumes several steep subprovince boundary attitudes represented by SB1, SB2 and SB3 for the Chase and Longlegged Lake areas.

D.1 Chase Lake: 30° subprovince boundary dip



Chase Lake #19



Sinistral reverse

Legend for stereoplots

- -- Foliation (z)
- — Subprovince boundary (SB)
- ✚ Lineation (x)
- ● Foliation normal
- ■ LTB normal
- ▲ Long axis of section ellipse
- ● j, m - traces of x_n & z_n planes on SB

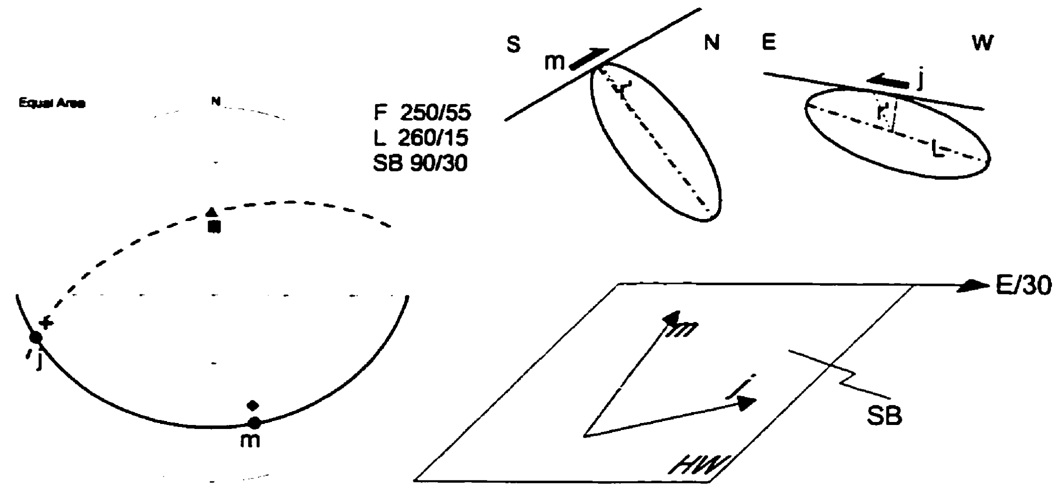
Legend for strain ellipses

- normal to subprovince boundary
- long axis to sectional ellipse
- oblique radius of sectional strain ellipse
- L lineation direction
- j, m traces of x_n & z_n planes on SB
- sense of shear

Legend for LTB

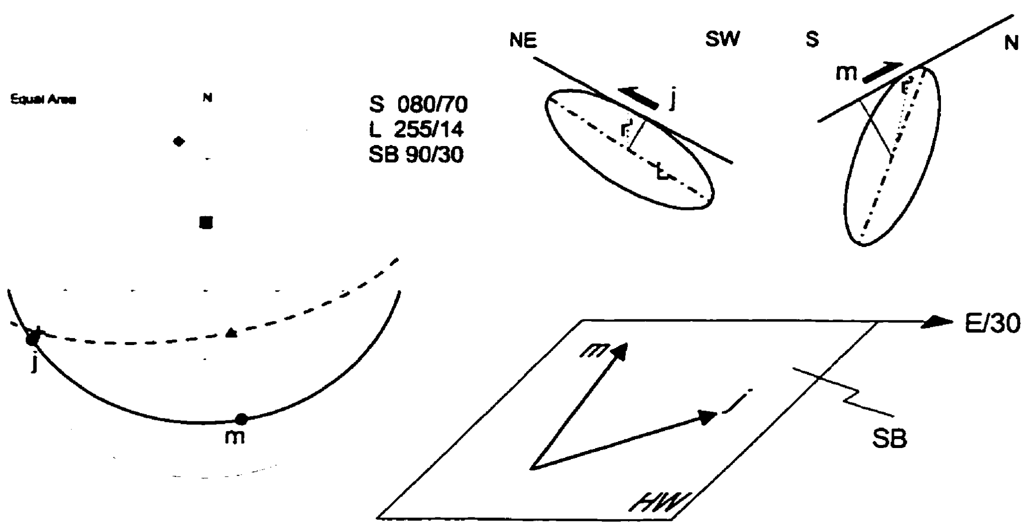
- j, m Angular range of resolved shear strain
- HW Hanging Wall
- SB Subprovince Boundary

D.1 Chase Lake



Sinistral (to dextral) reverse

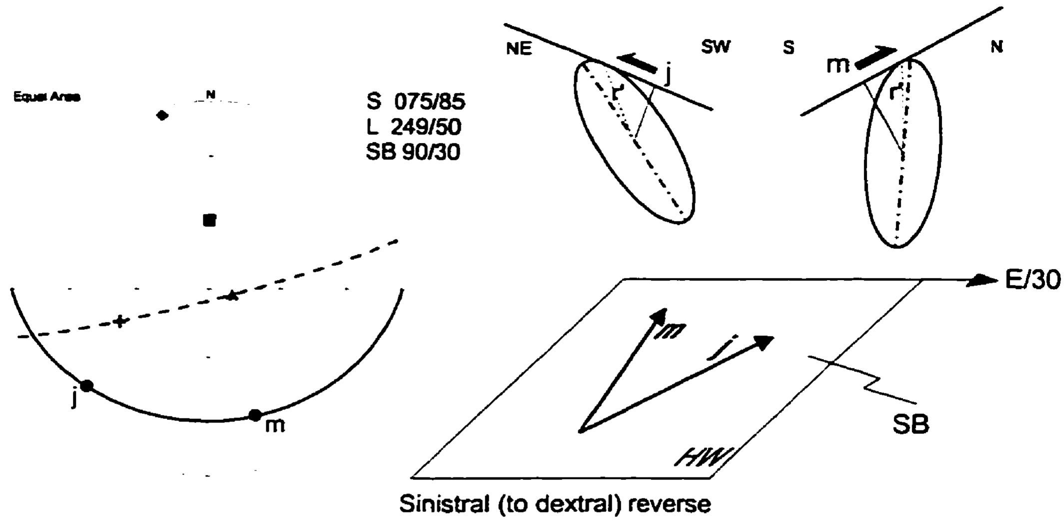
Chase Lake #72



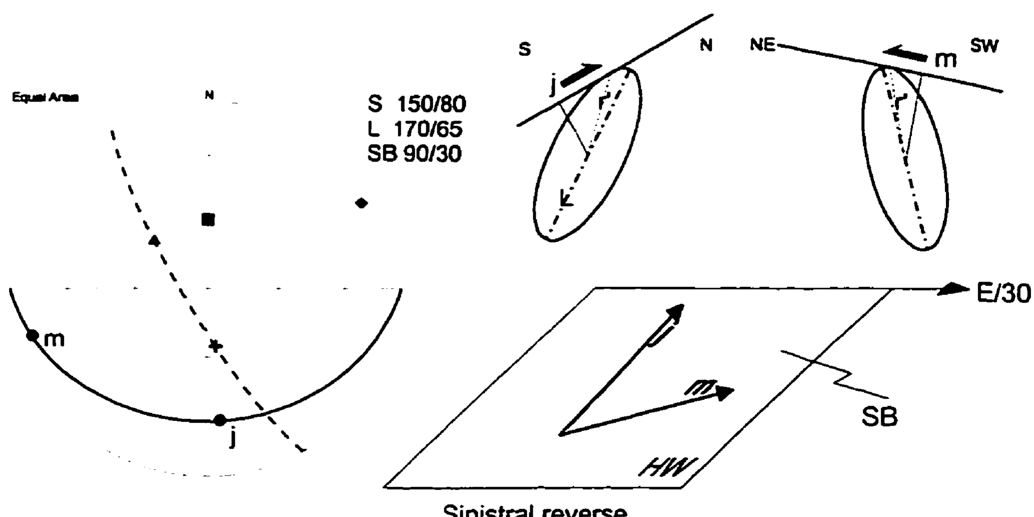
Chase Lake #122

Sinistral reverse

D.1 Chase Lake

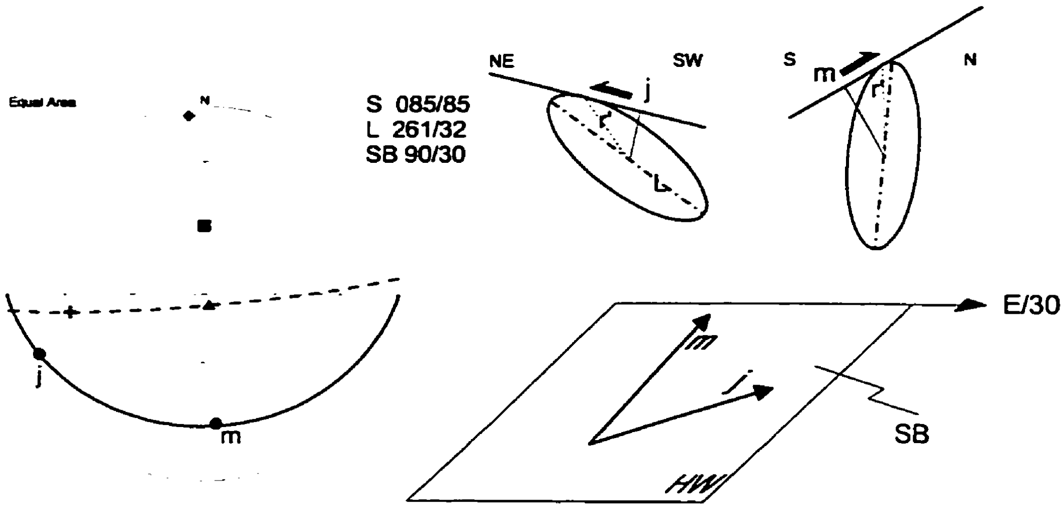


Chase Lake #159



Chase Lake #256

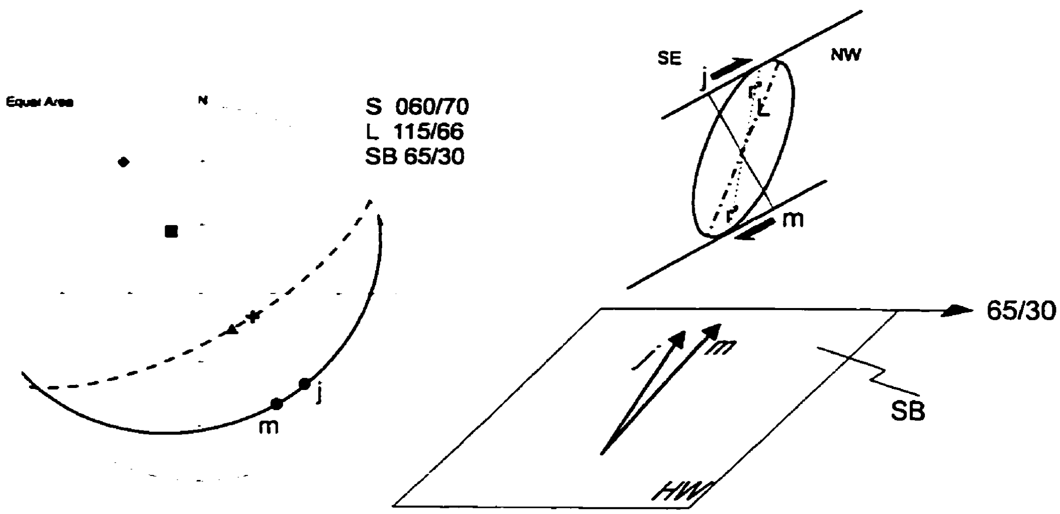
D.1 Chase Lake



Sinistral reverse

Chase Lake #318

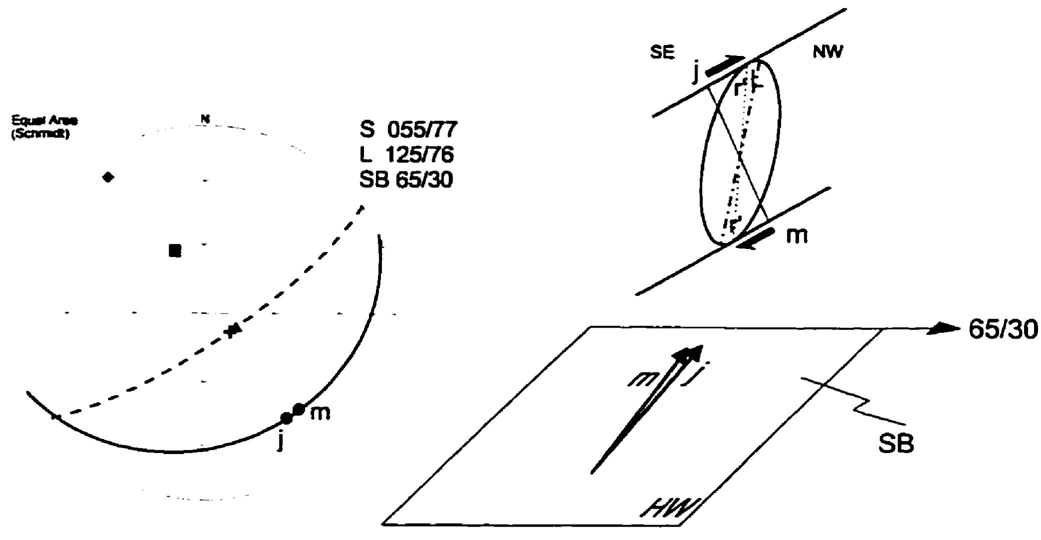
D.2 Longlegged Lake (30° subprovince boundary dip)



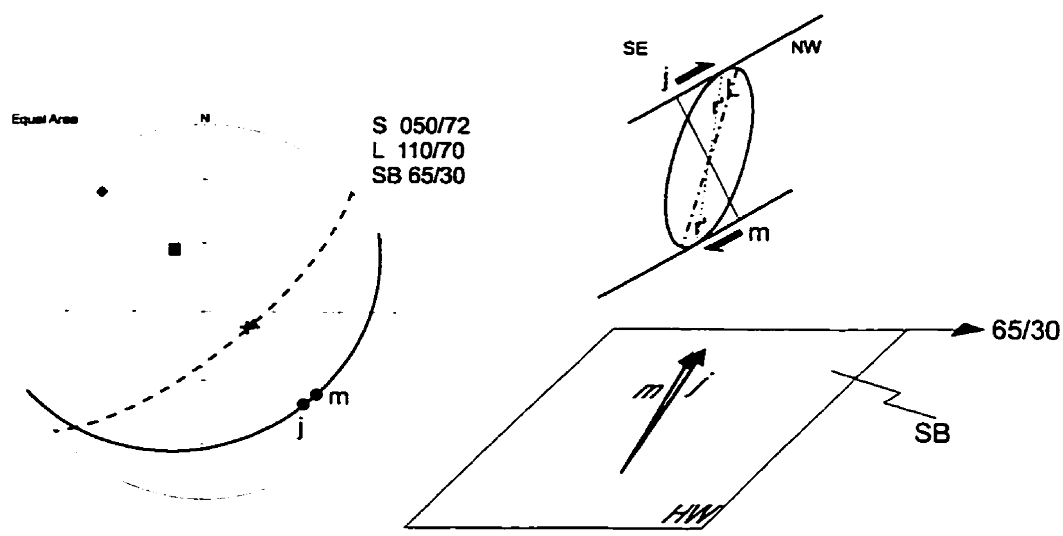
Dextral reverse

Longlegged Lake #378

D.2 Longlegged Lake

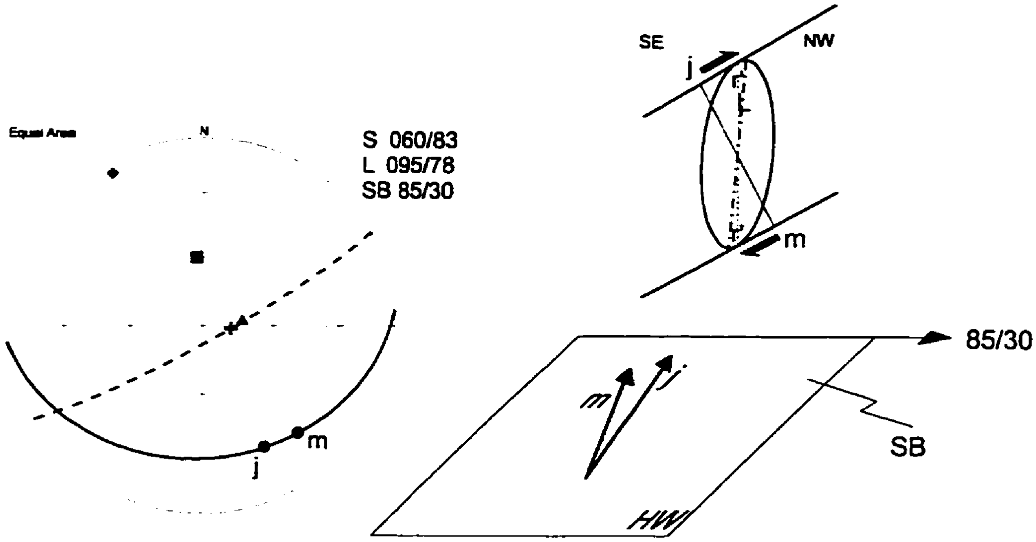


Longlegged Lake #379



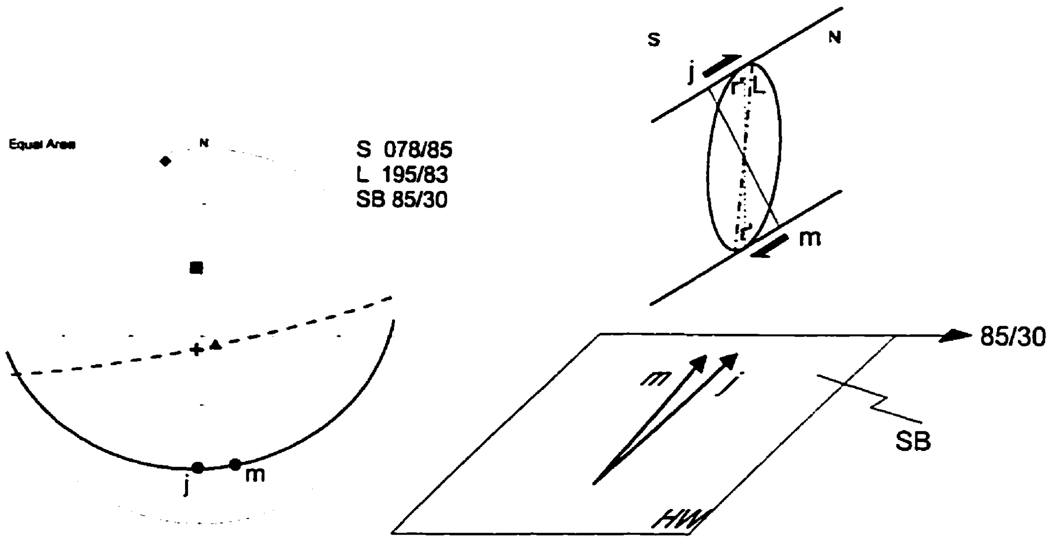
Longlegged Lake #393

D.2 Longlegged Lake



Longlegged Lake #415

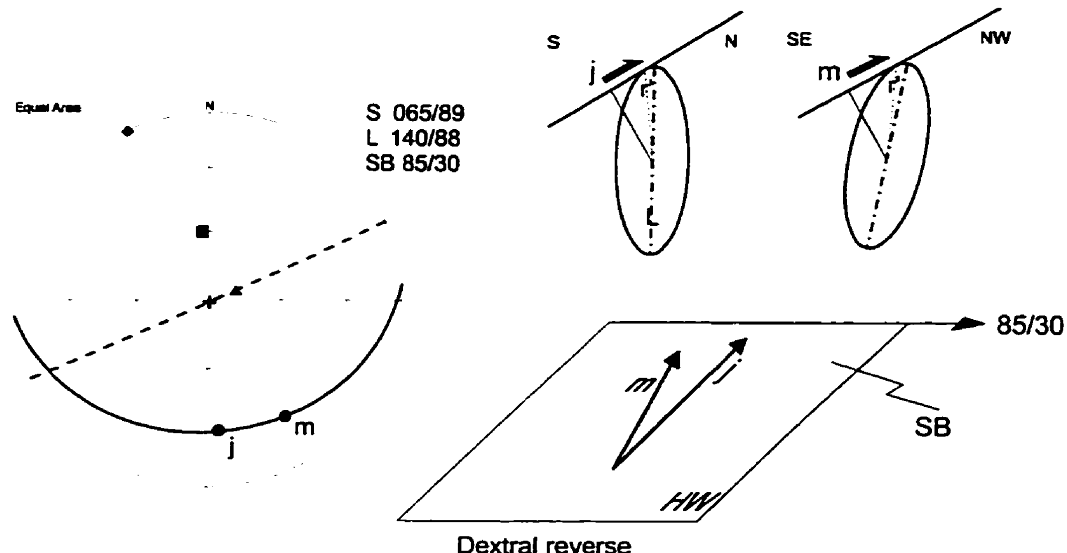
Dextral reverse



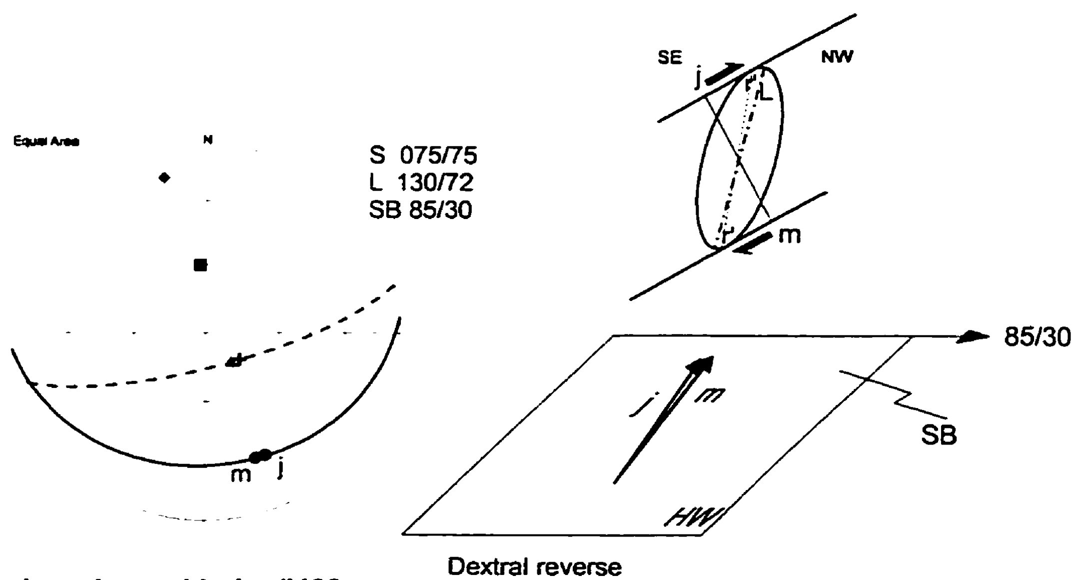
Sinistral reverse

Longlegged Lake #418

D.2 Longlegged Lake

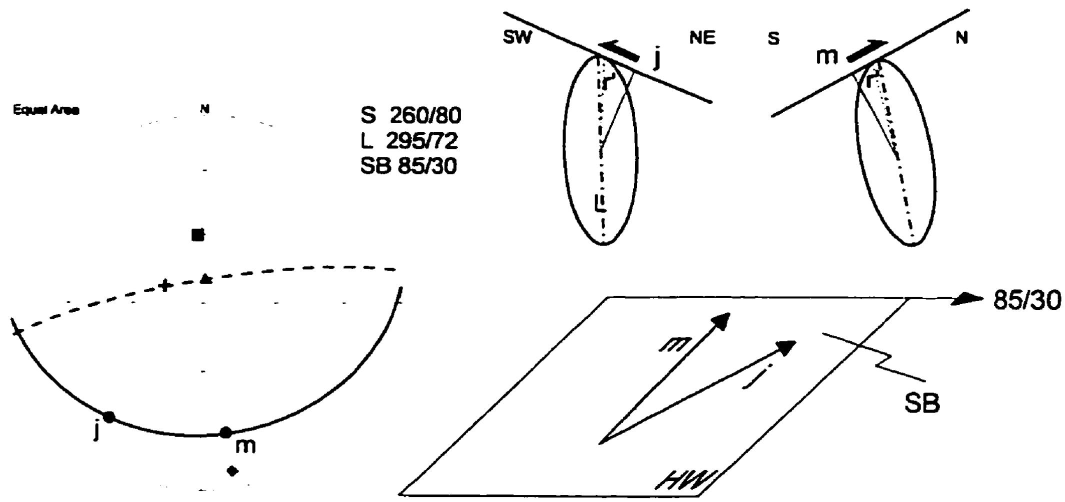


Longlegged Lake #424



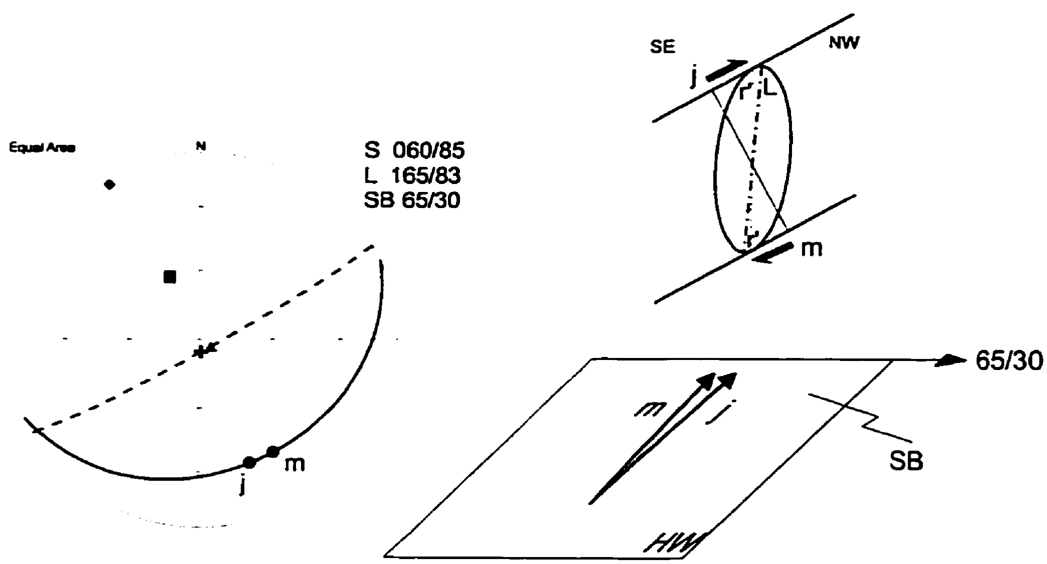
Longlegged Lake #429

D.2 Longlegged Lake



Sinistral reverse

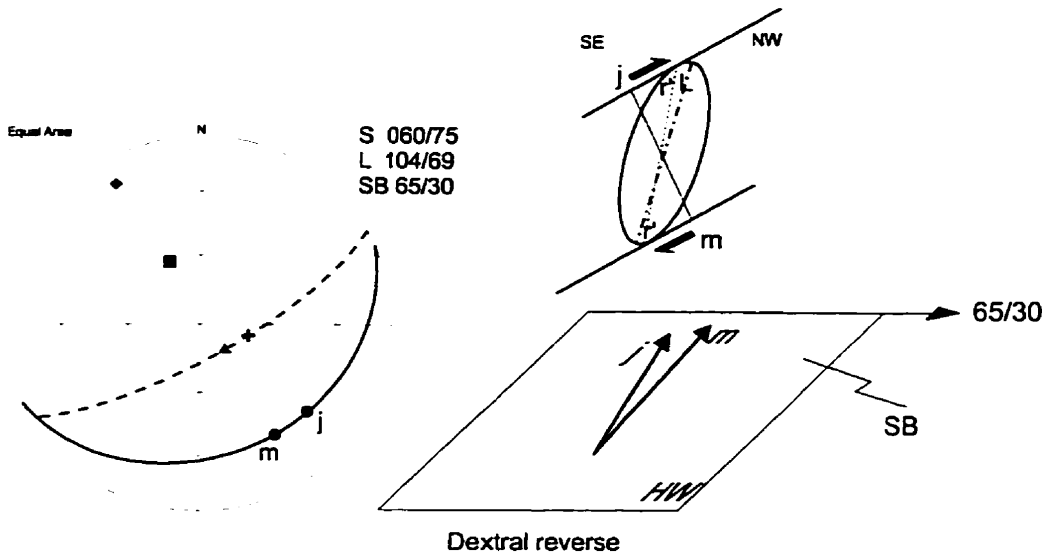
Longlegged Lake #441



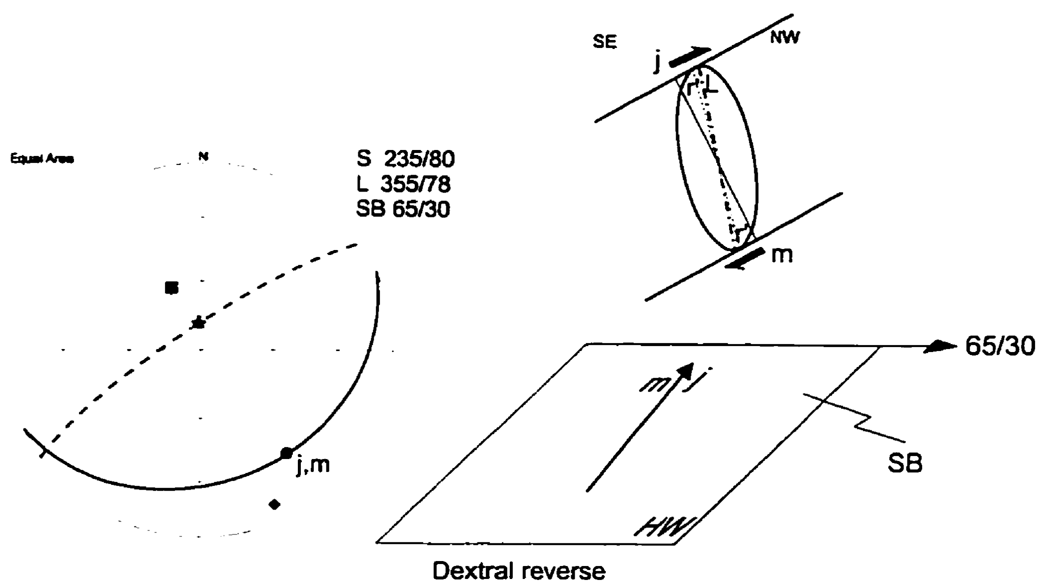
Dextral reverse

Longlegged Lake #468

D.2 Longlegged Lake



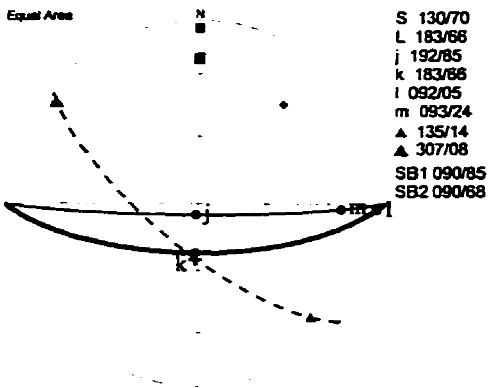
Longlegged Lake #469



Longlegged Lake #484

D.3 Chase Lake: steep subprovince boundary dips

Chase Lake - #13

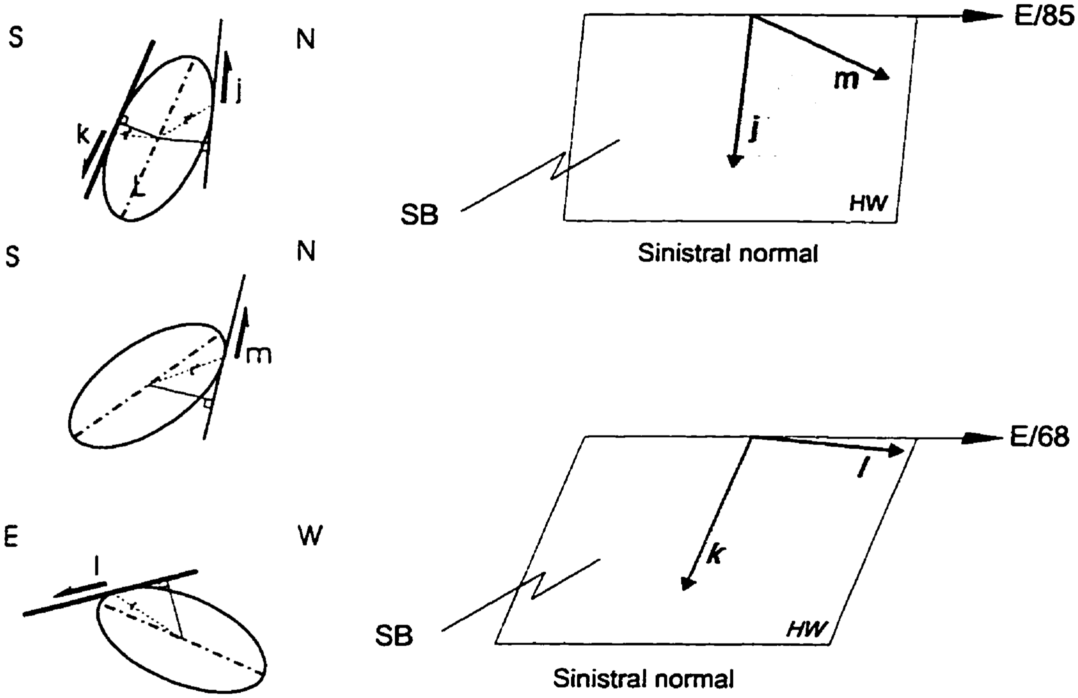


Legend for stereoplot

— Foliation	● SB1 normal
— SB1	■ SB2 normal
— SB2	▲ Long axis of section ellipse (1)
✚ Lineation	▲ Long axis of section ellipse (2)
● Foliation normal	● j, m & k, l traces of x, & z, planes on SB1 & SB2

Legend for SB

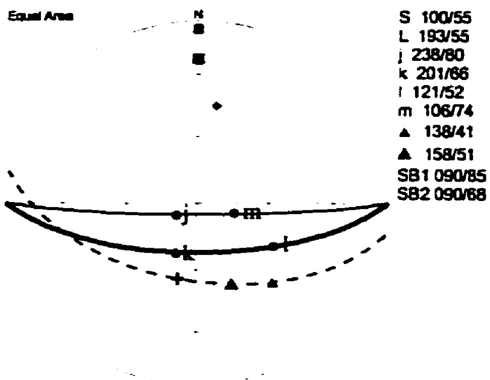
m(l), j(k): angular range of resolved shear strain	HW hangingwall SB subprovince boundary



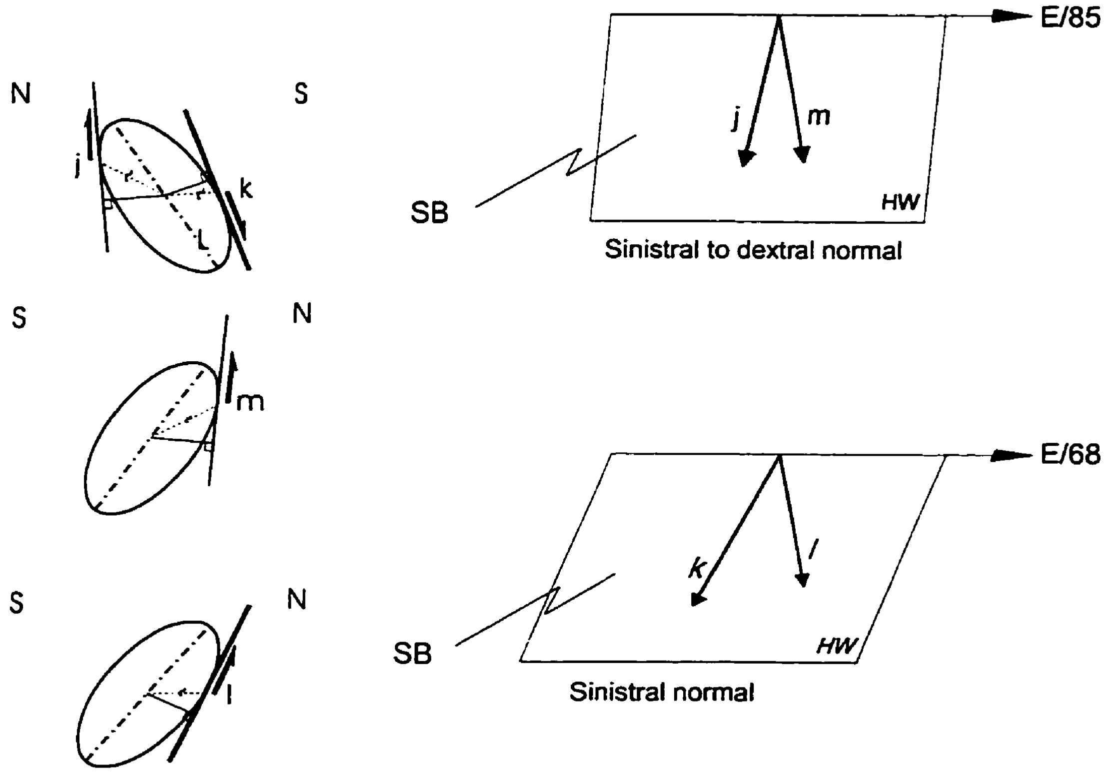
Legend for strain ellipses

normal to subprovince boundary (SB)	L lineation direction
long axis to sectional ellipse	j, m trace of xn & zn planes on SB
oblique radius of sectional strain ellipse	sense of shear

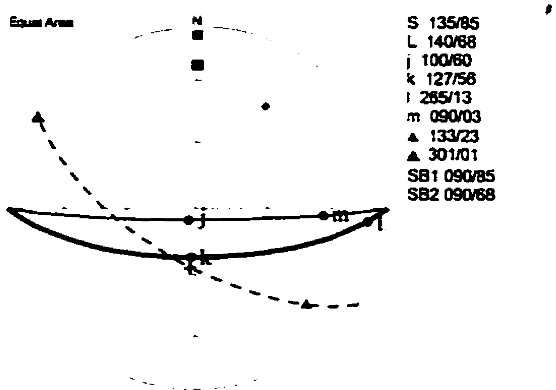
D.3 Chase Lake



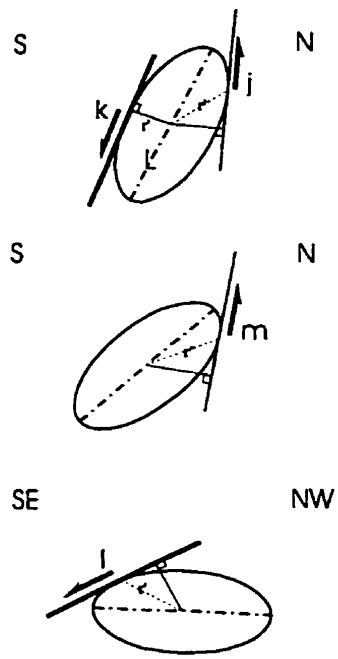
Chase Lake - #19

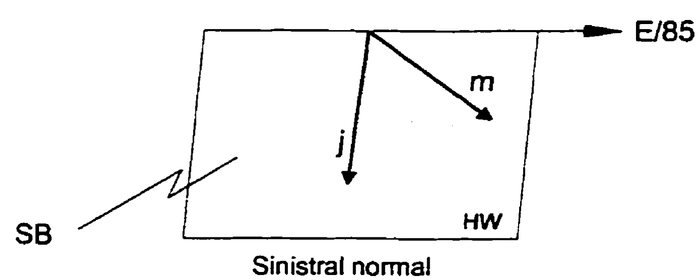


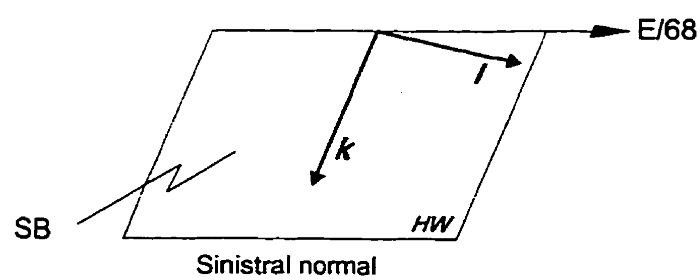
D.3 Chase Lake



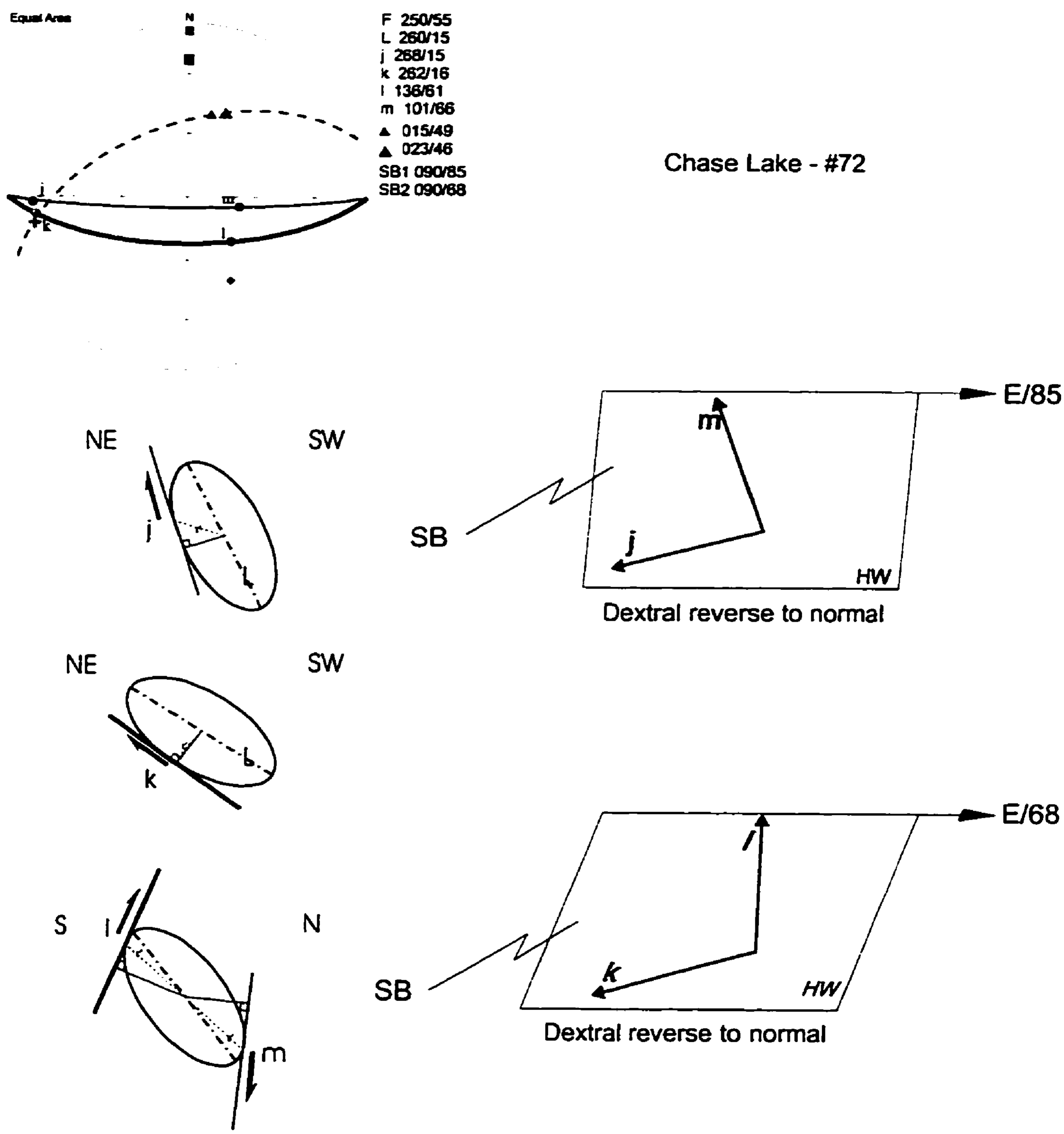
Chase Lake - #29



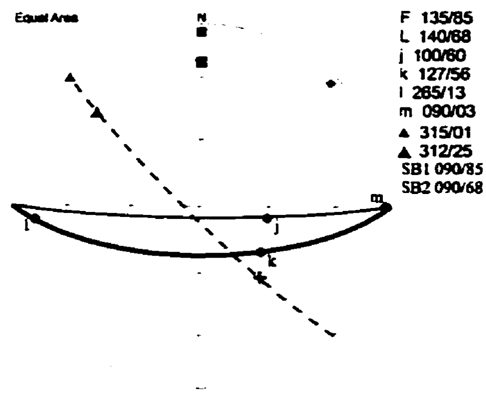




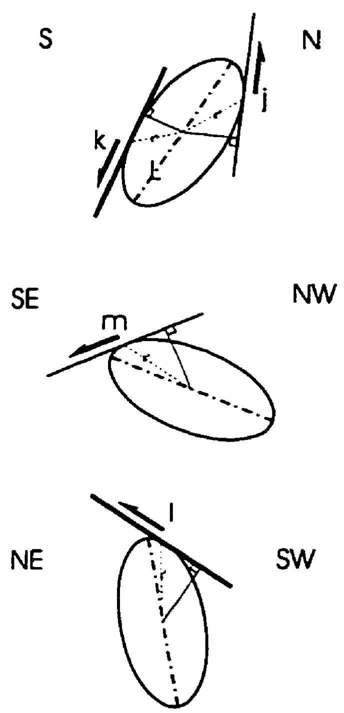
D.3 Chase Lake

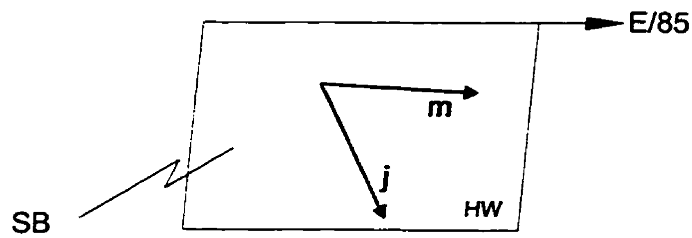


D.3 Chase Lake

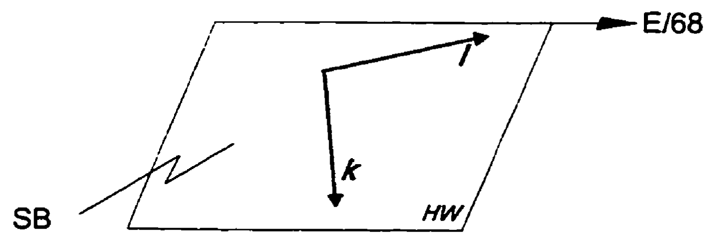


Chase Lake - #87



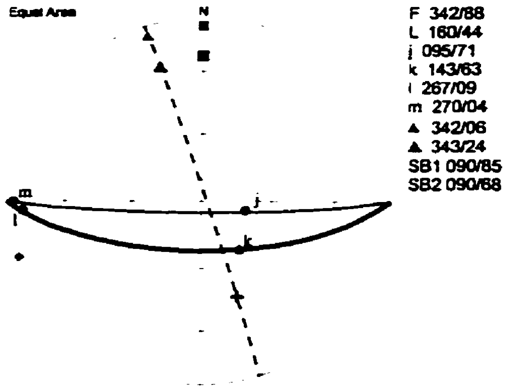


Sinistral normal

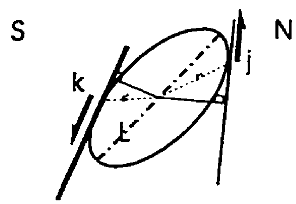


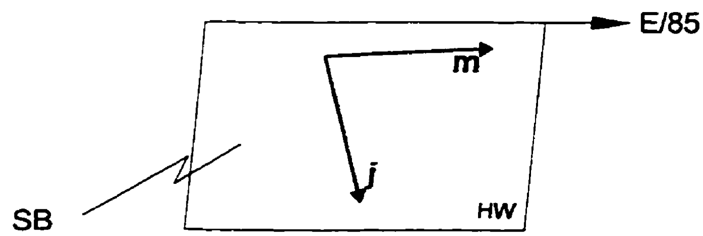
Sinistral normal to reverse

D.3 Chase Lake

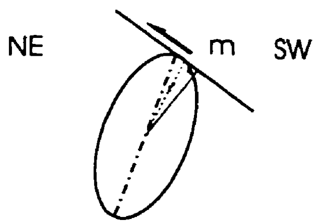


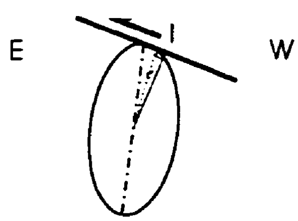
Chase Lake - #99

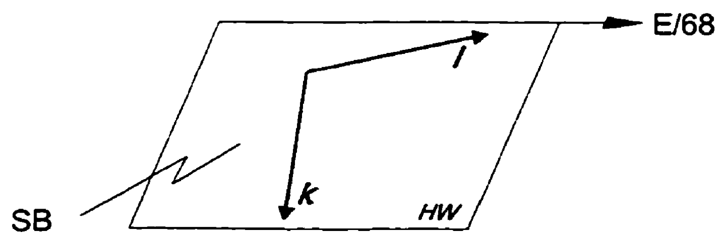




Sinistral normal to reverse

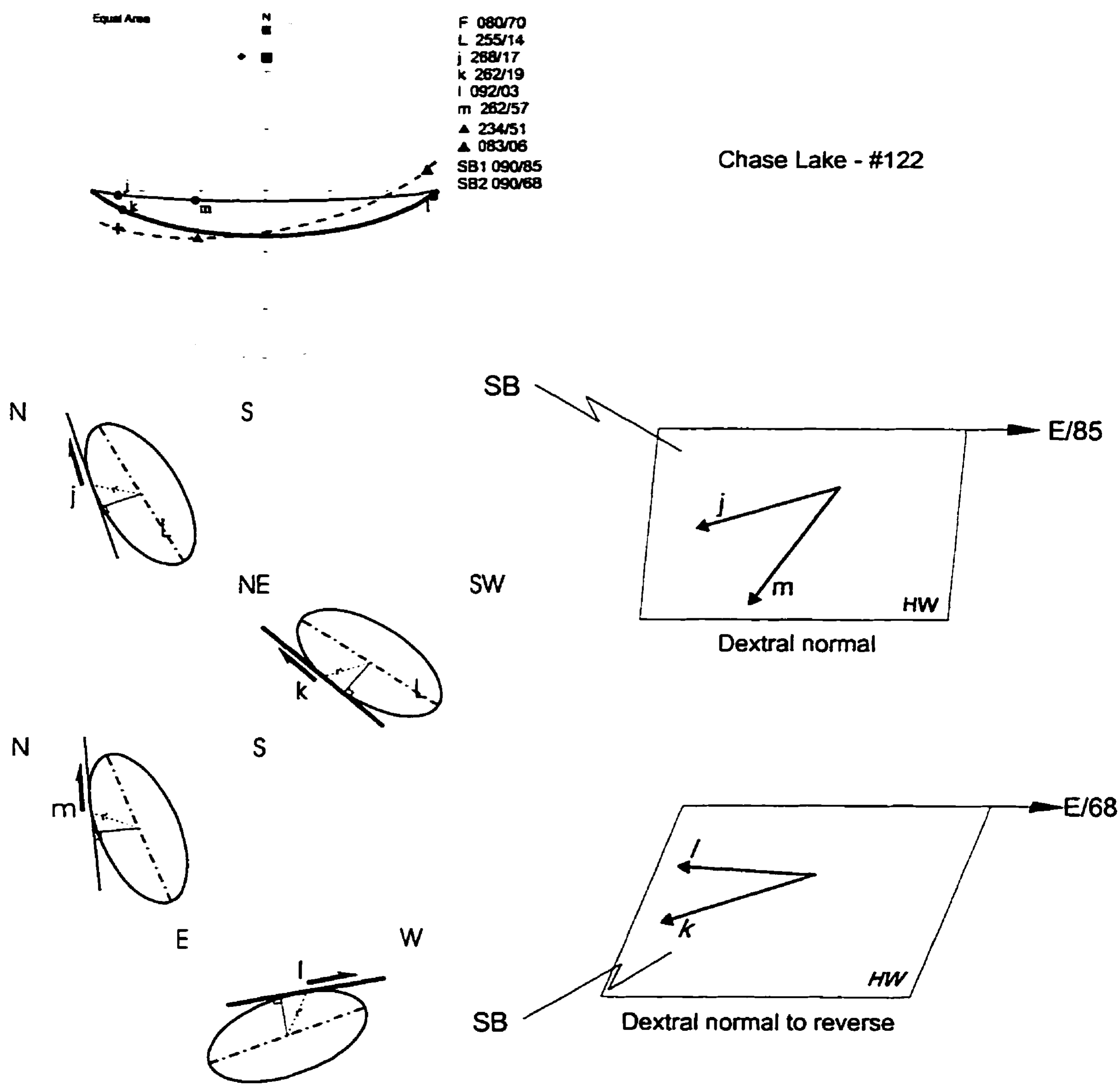




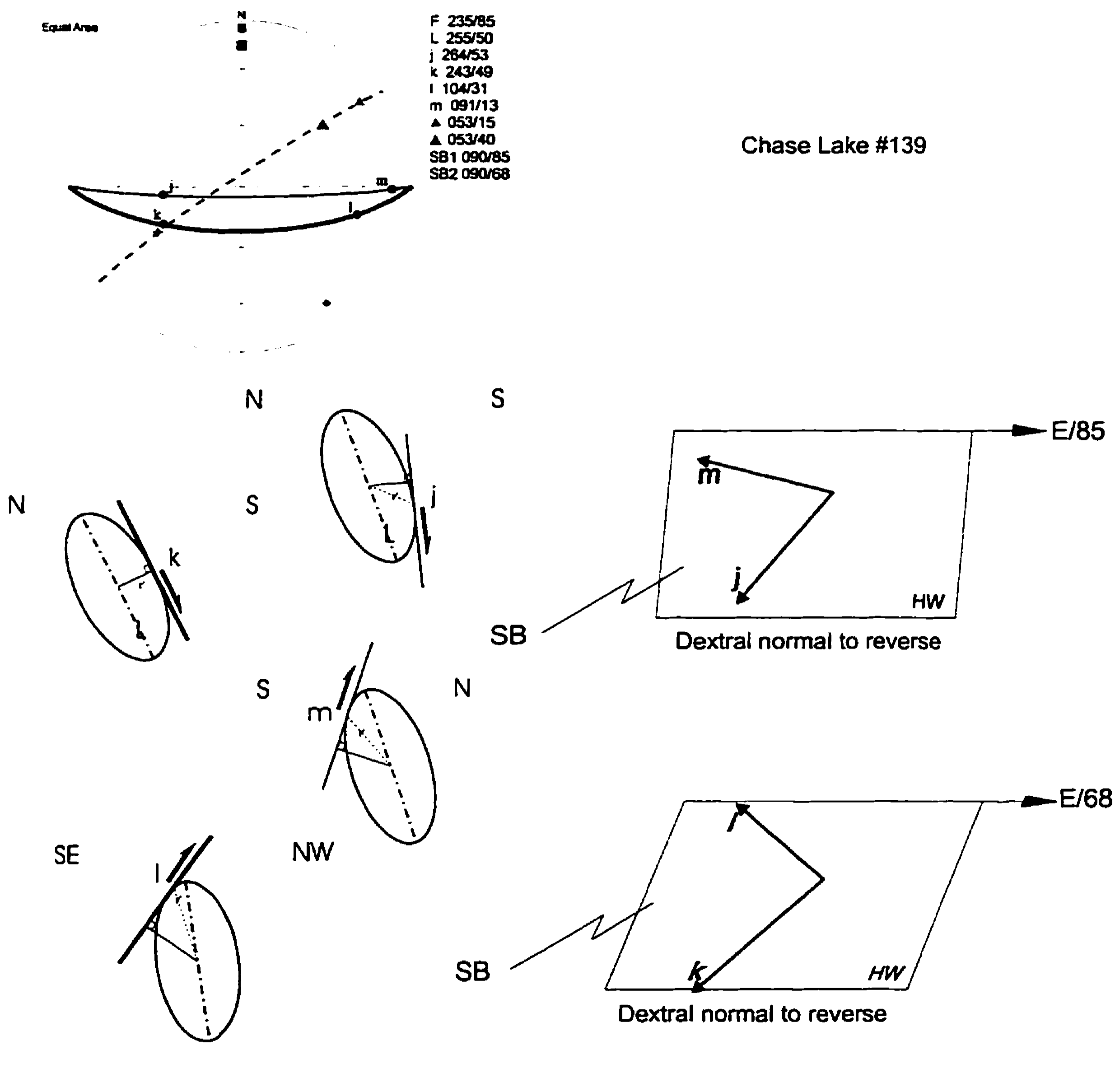


Sinistral normal to reverse

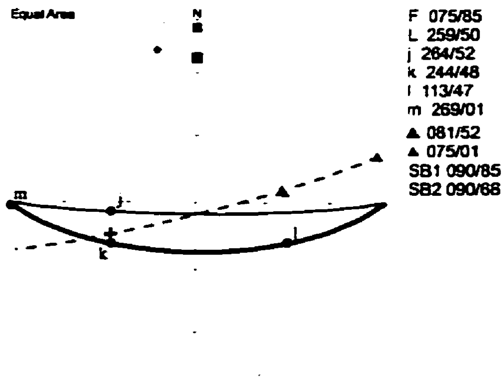
D.3 Chase Lake



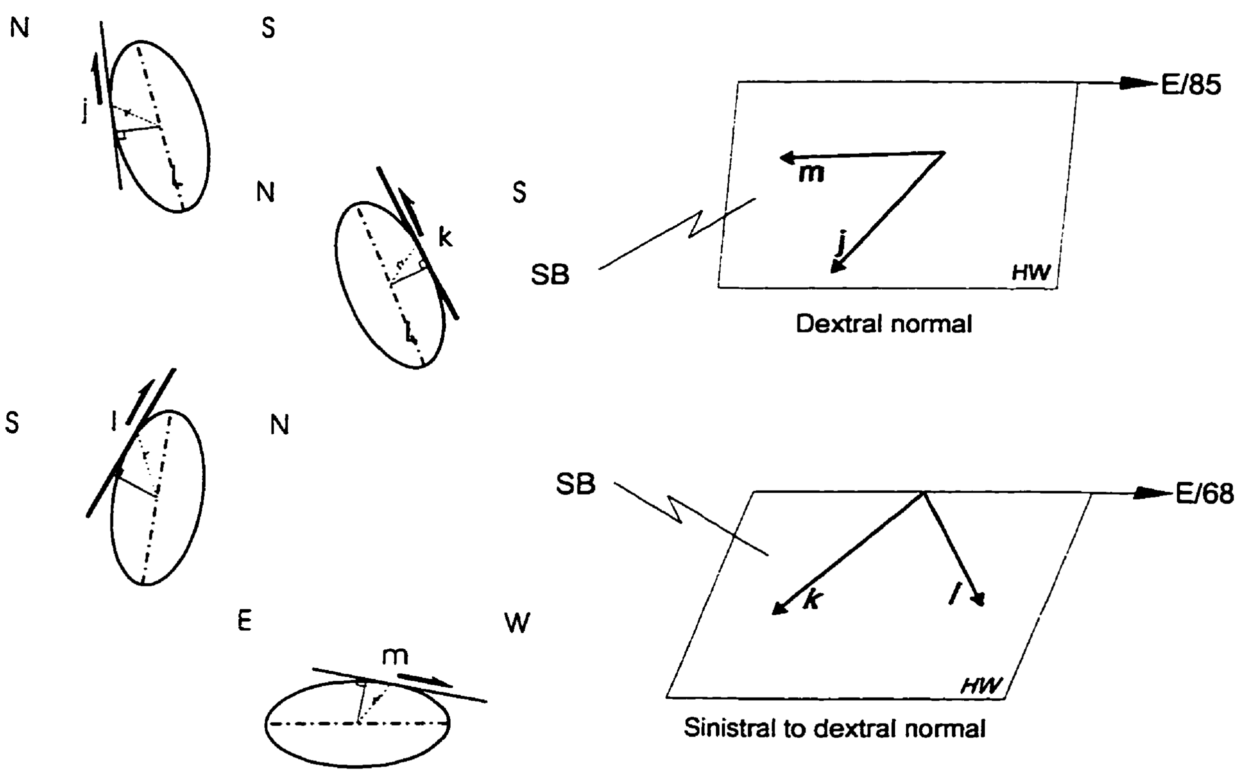
D.3 Chase Lake



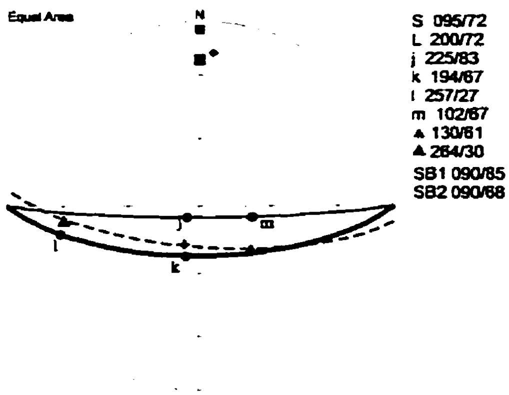
D.3 Chase Lake



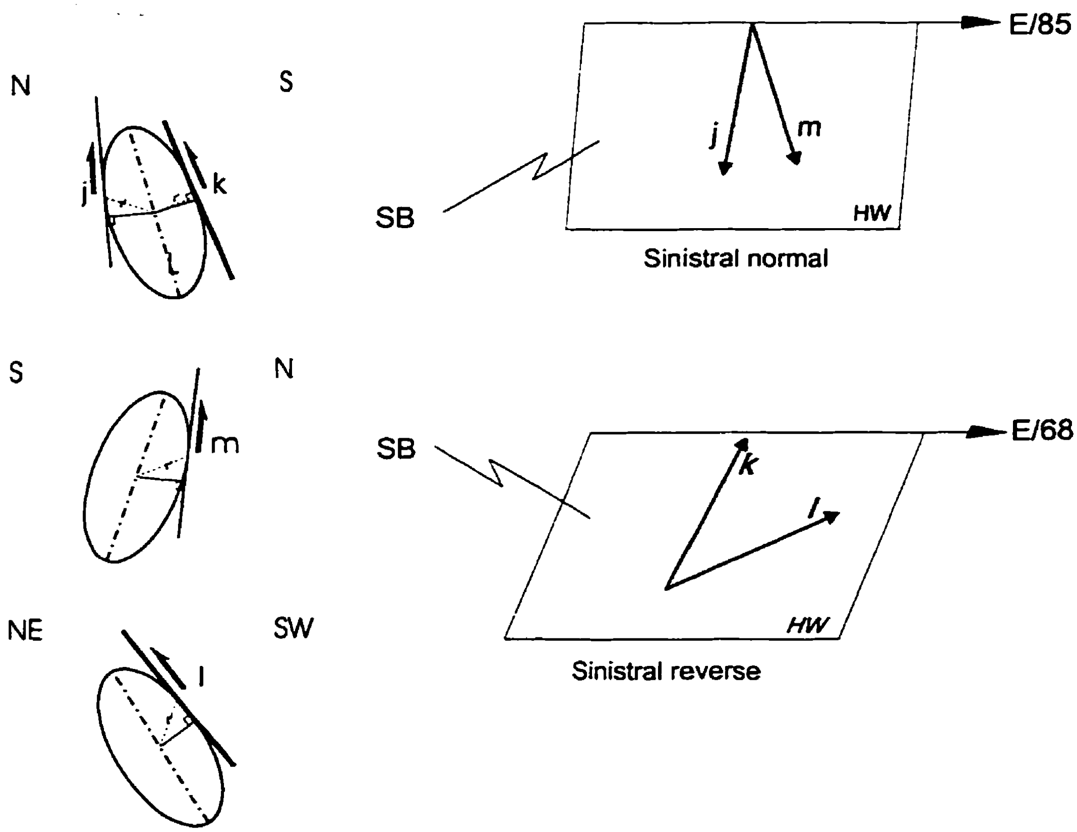
Chase Lake - #159



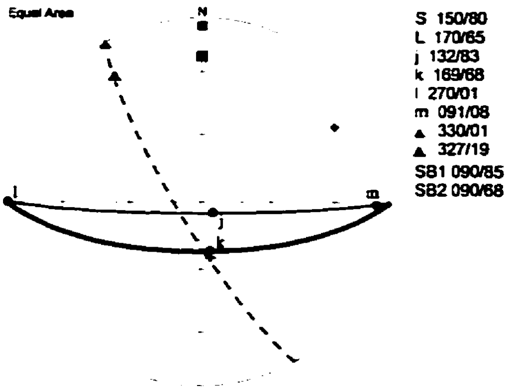
D.3 Chase Lake



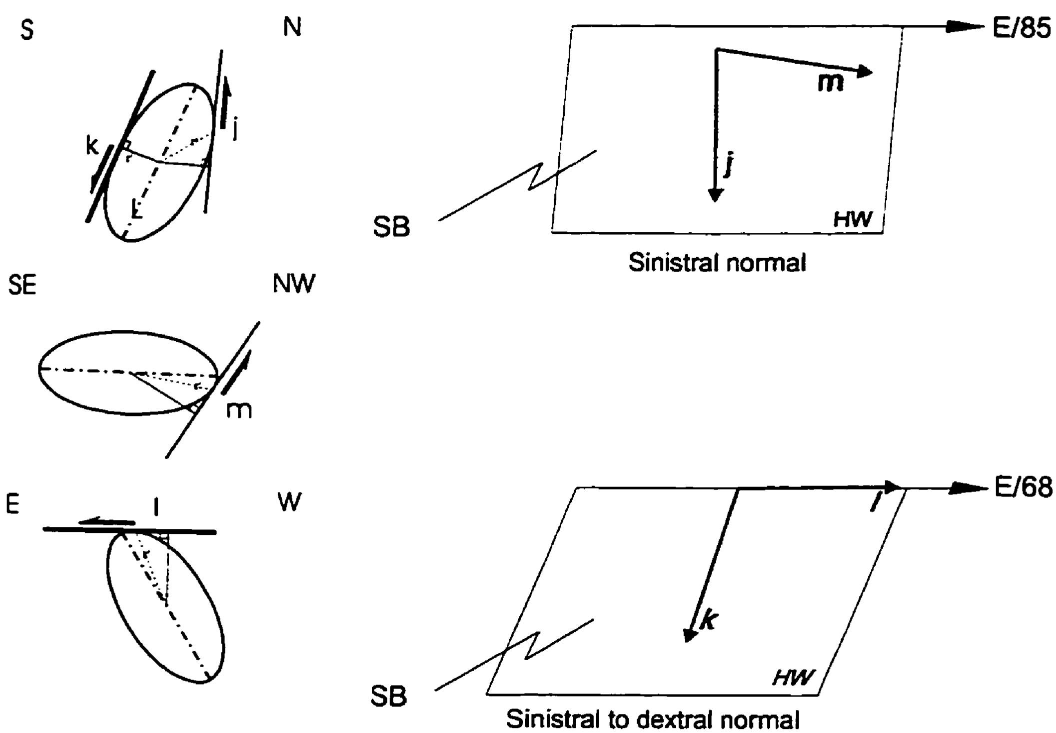
Chase Lake - #180



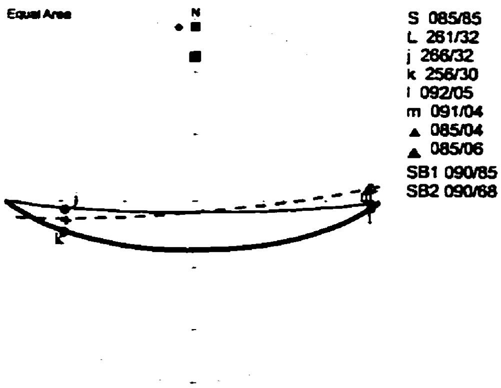
D.3 Chase Lake



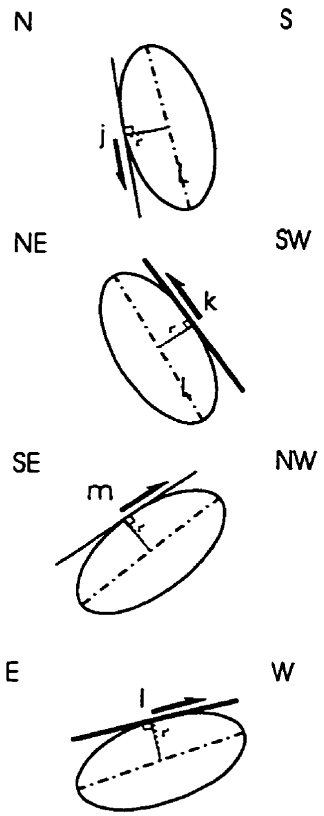
Chase Lake - #256

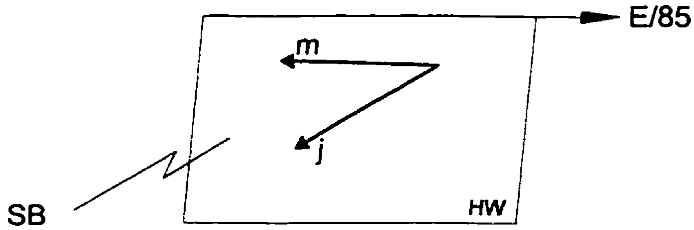


D.3 Chase Lake

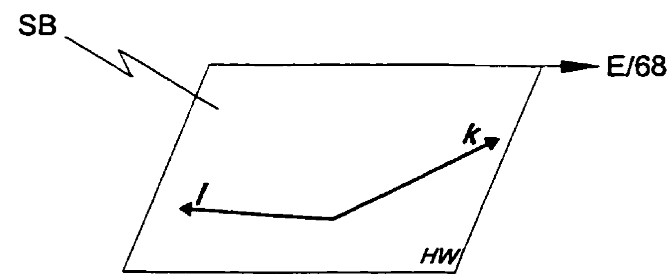


Chase Lake - #318



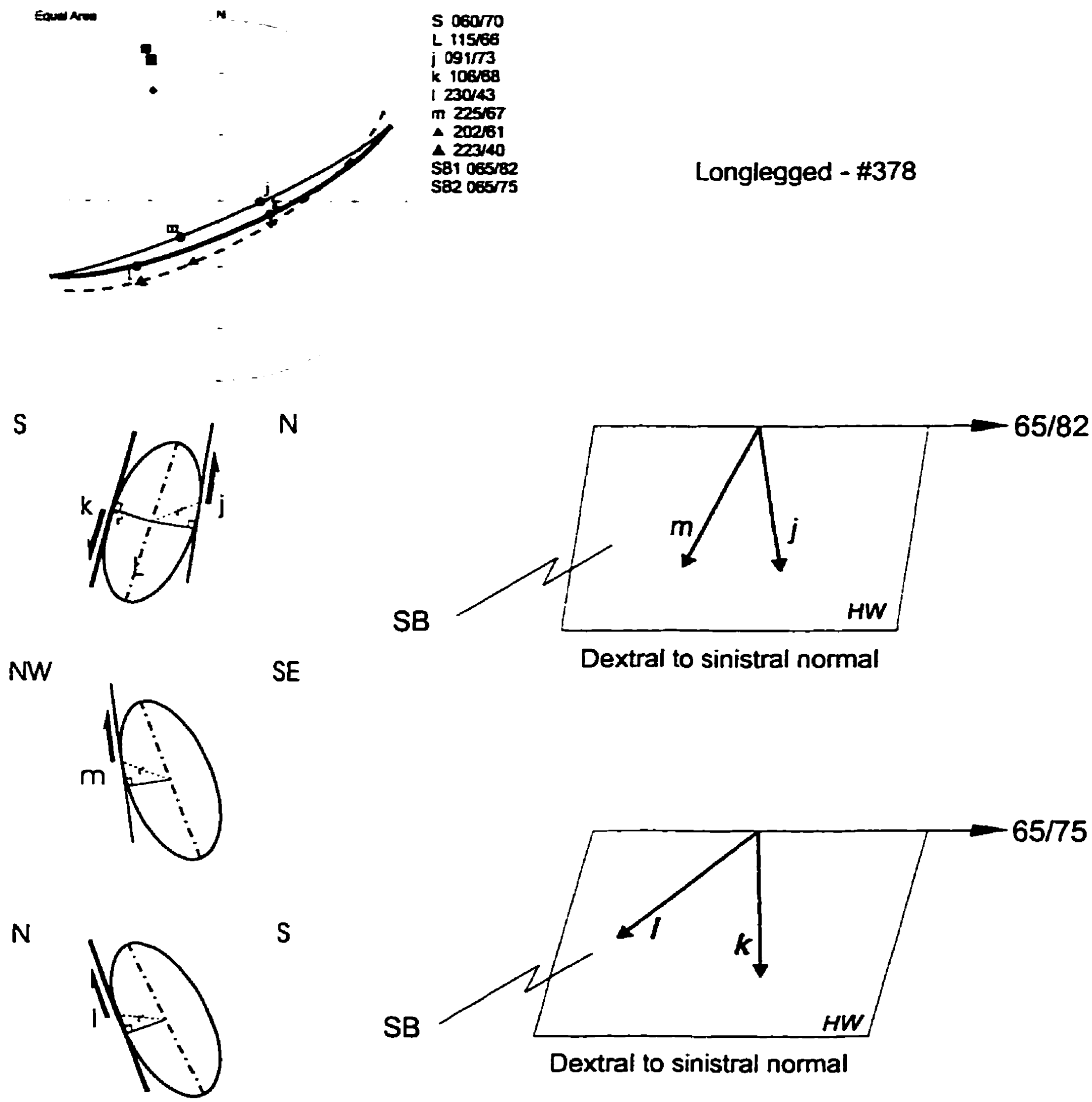


Dextral normal

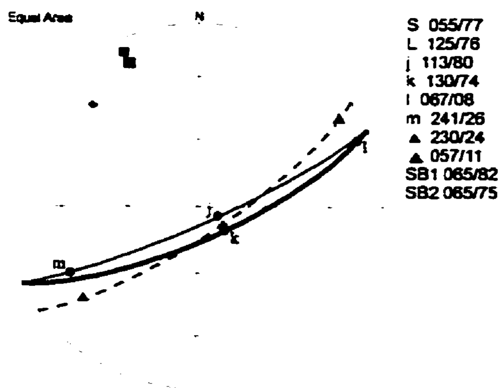


Dextral to sinistral reverse

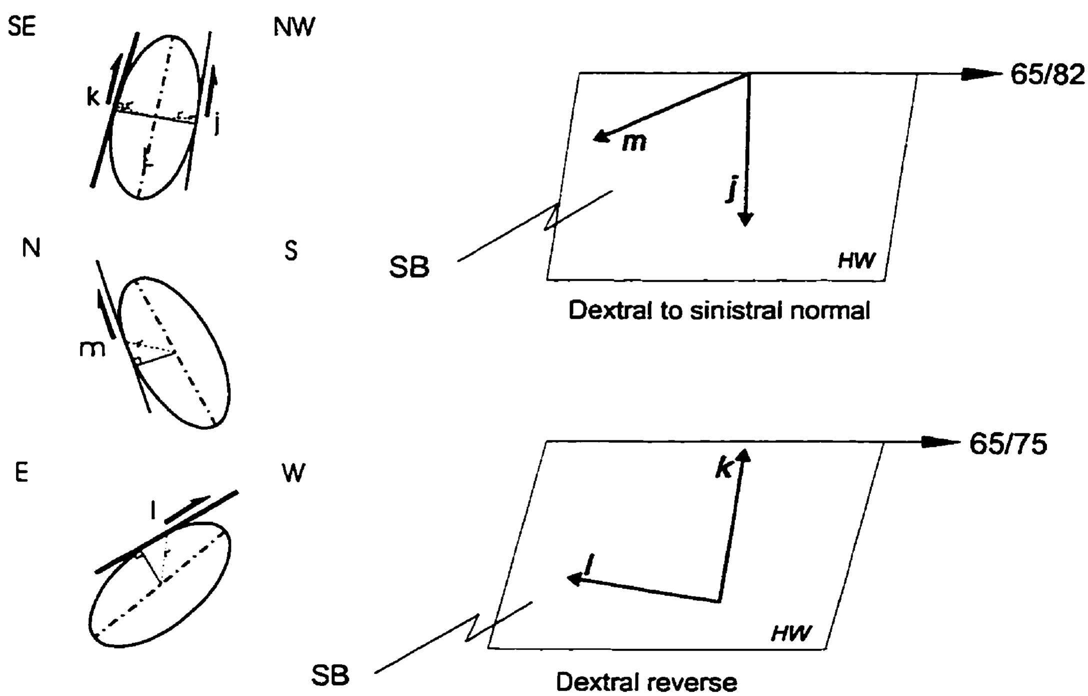
D.4 Longlegged Lake: steep subprovince boundary dips



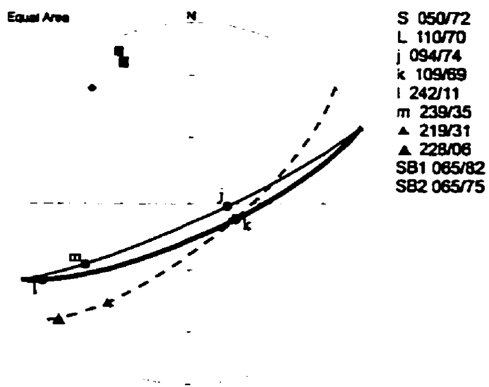
D.4 Longlegged Lake



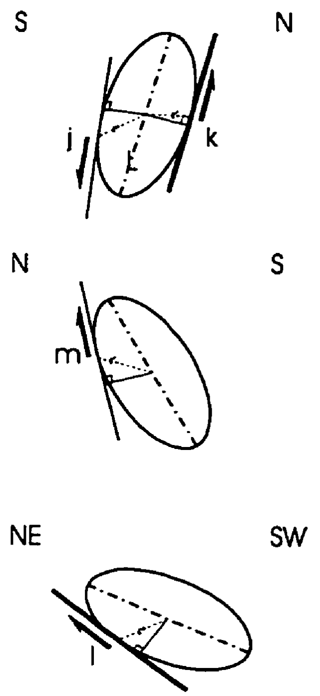
Longlegged - #379

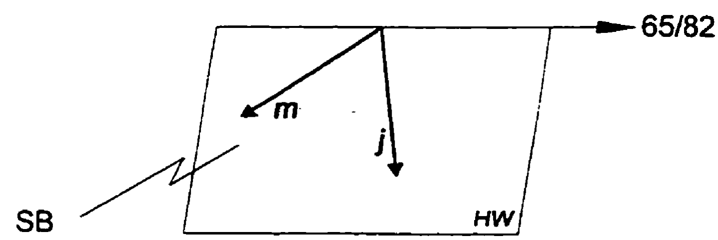


D.4 Longlegged Lake

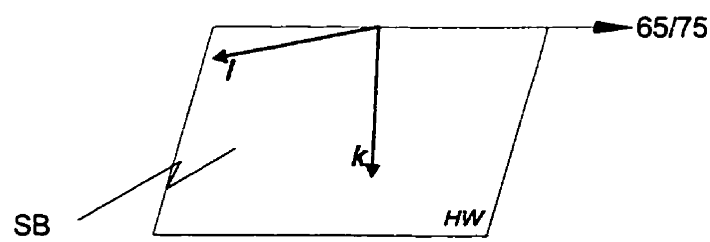


Longlegged - #393



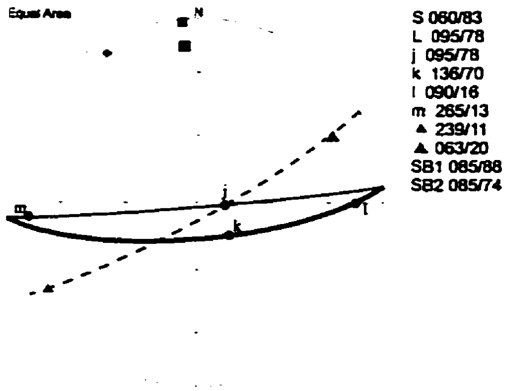


Dextral to sinistral normal

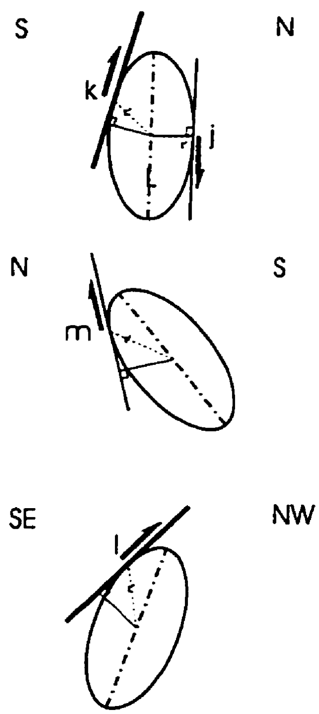


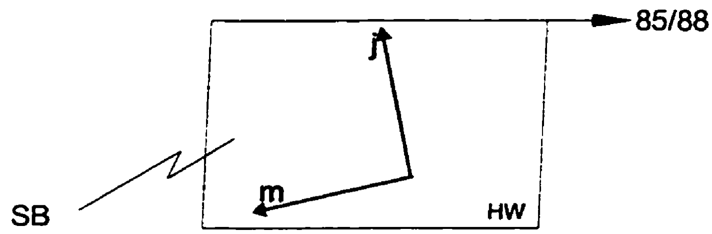
Dextral to sinistral normal

D.4 Longlegged Lake

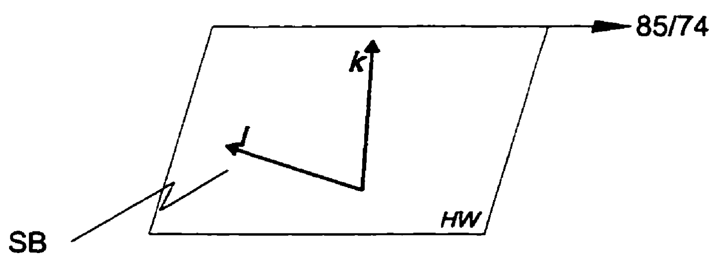


Longlegged - #415



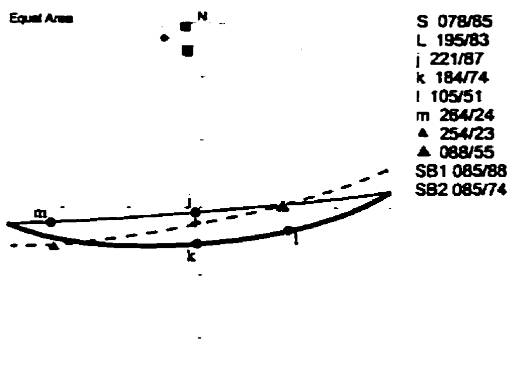


Dextral reverse to normal

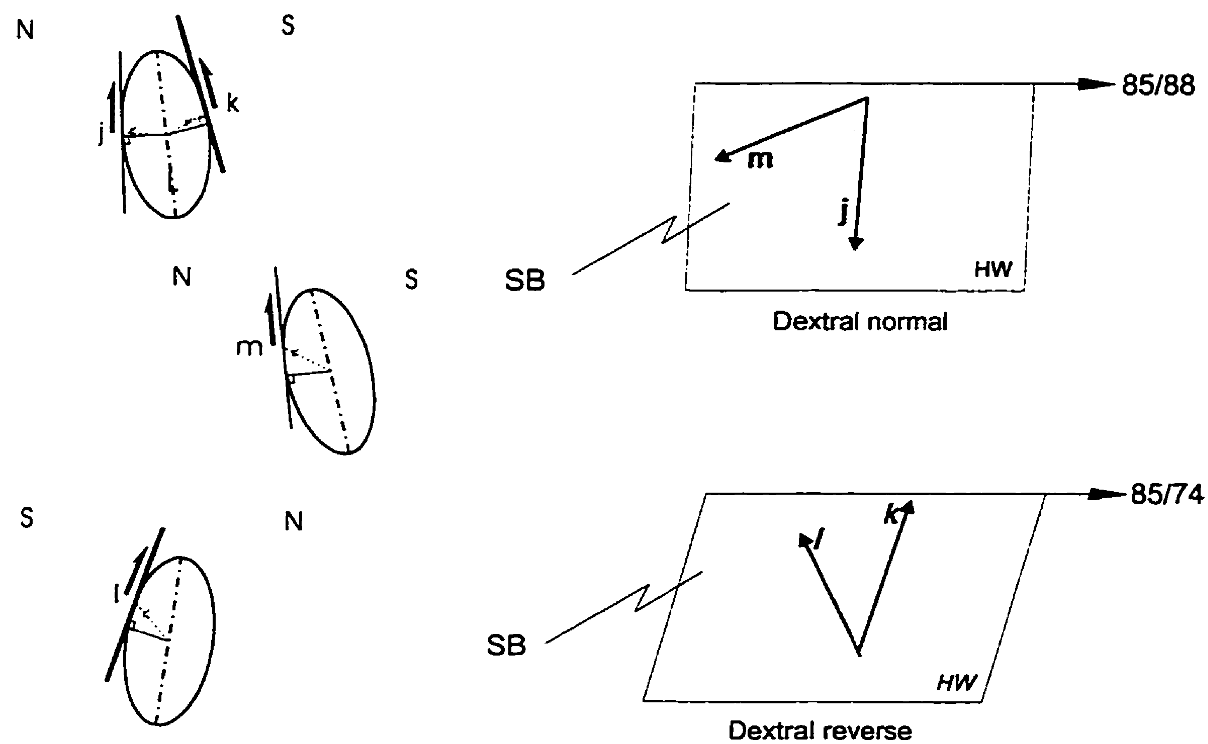


Dextral reverse

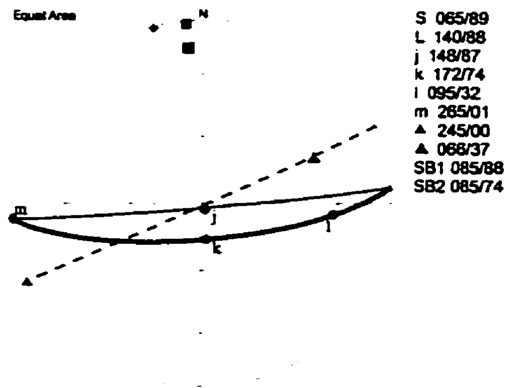
D.4 Longlegged Lake



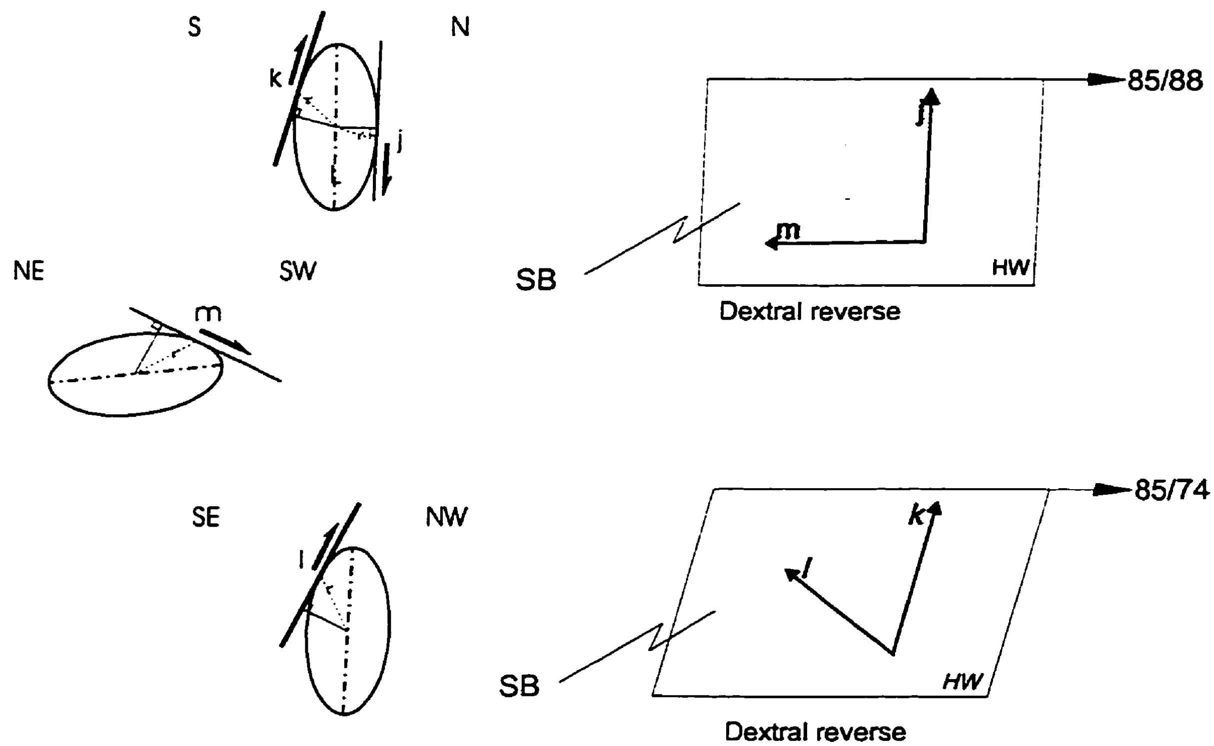
Longlegged - #418



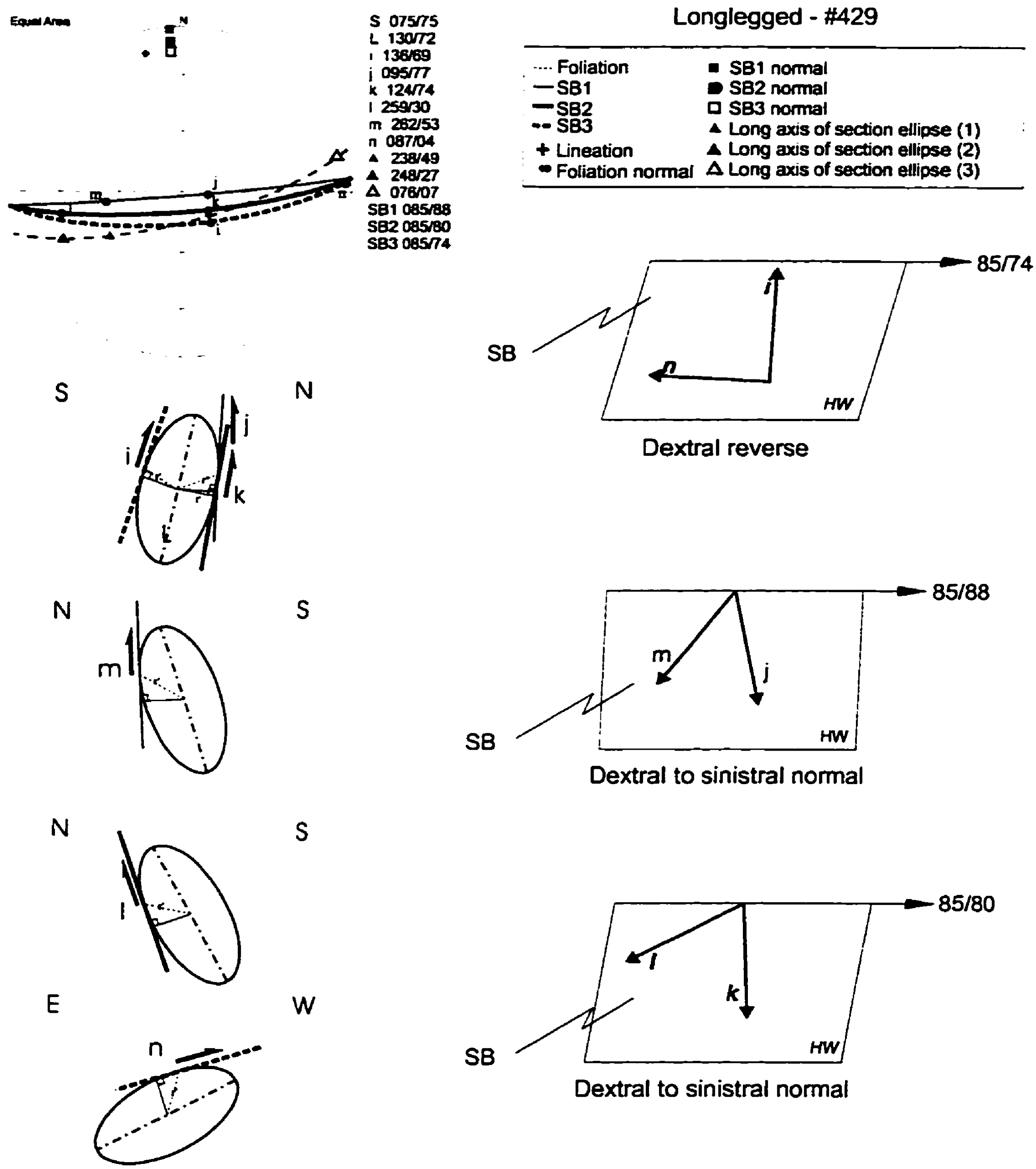
D.4 Longlegged Lake



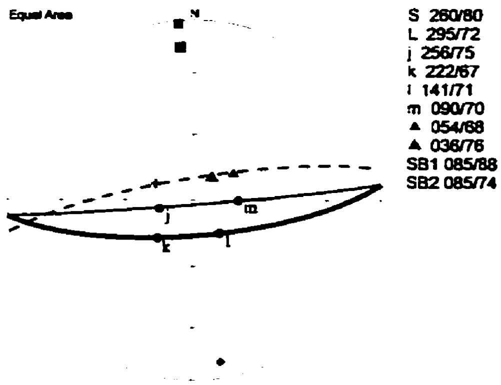
Longlegged - #424



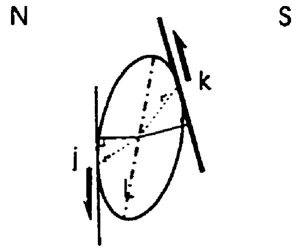
D.4 Longlegged Lake

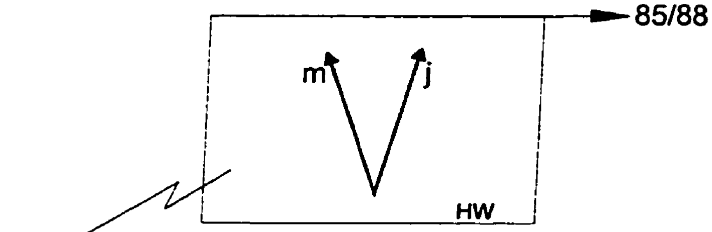


D.4 Longlegged Lake

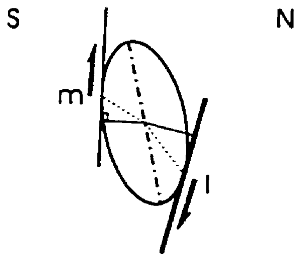


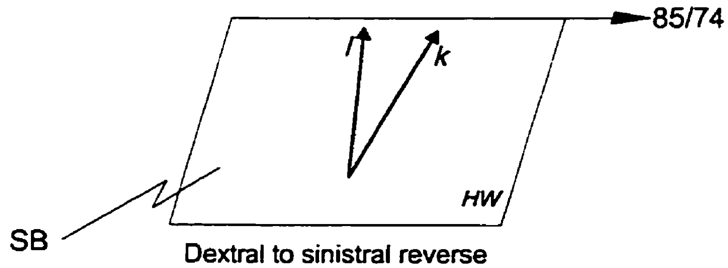
Longlegged - #441





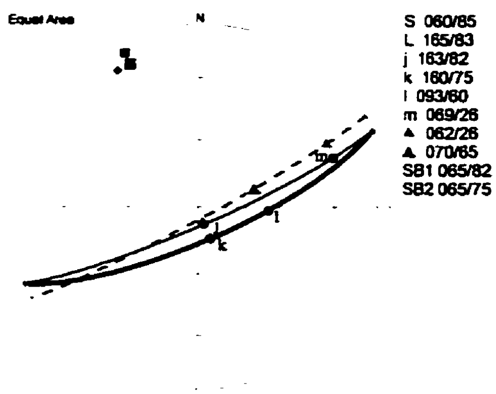
Dextral to sinistral reverse



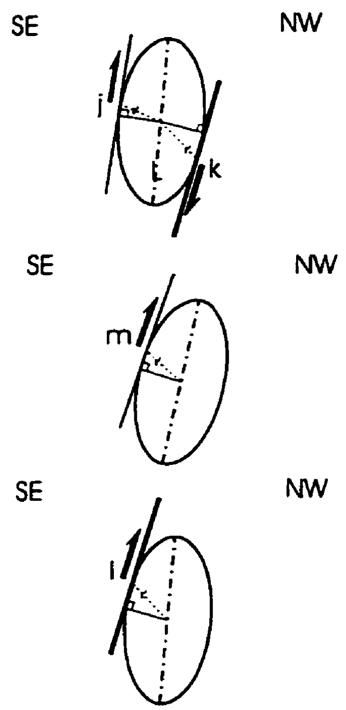


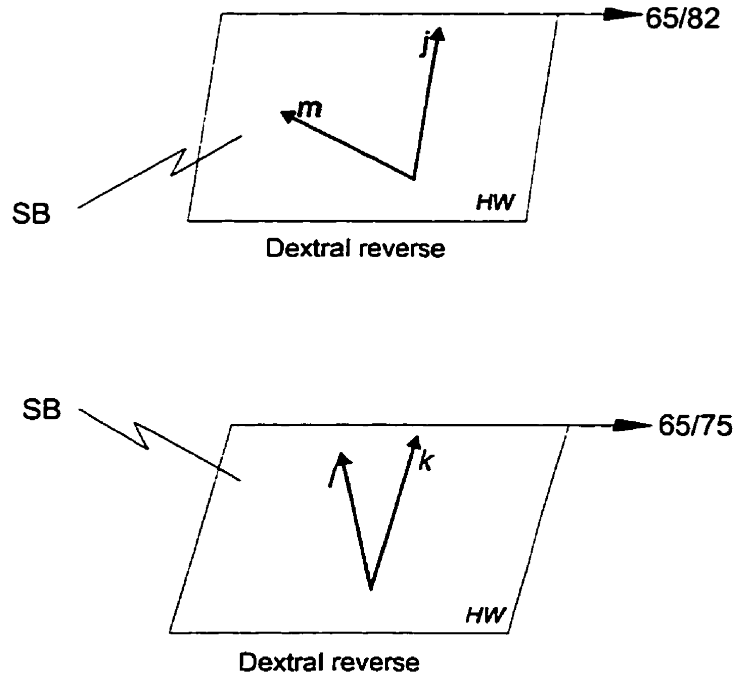
Dextral to sinistral reverse

D.4 Longlegged Lake

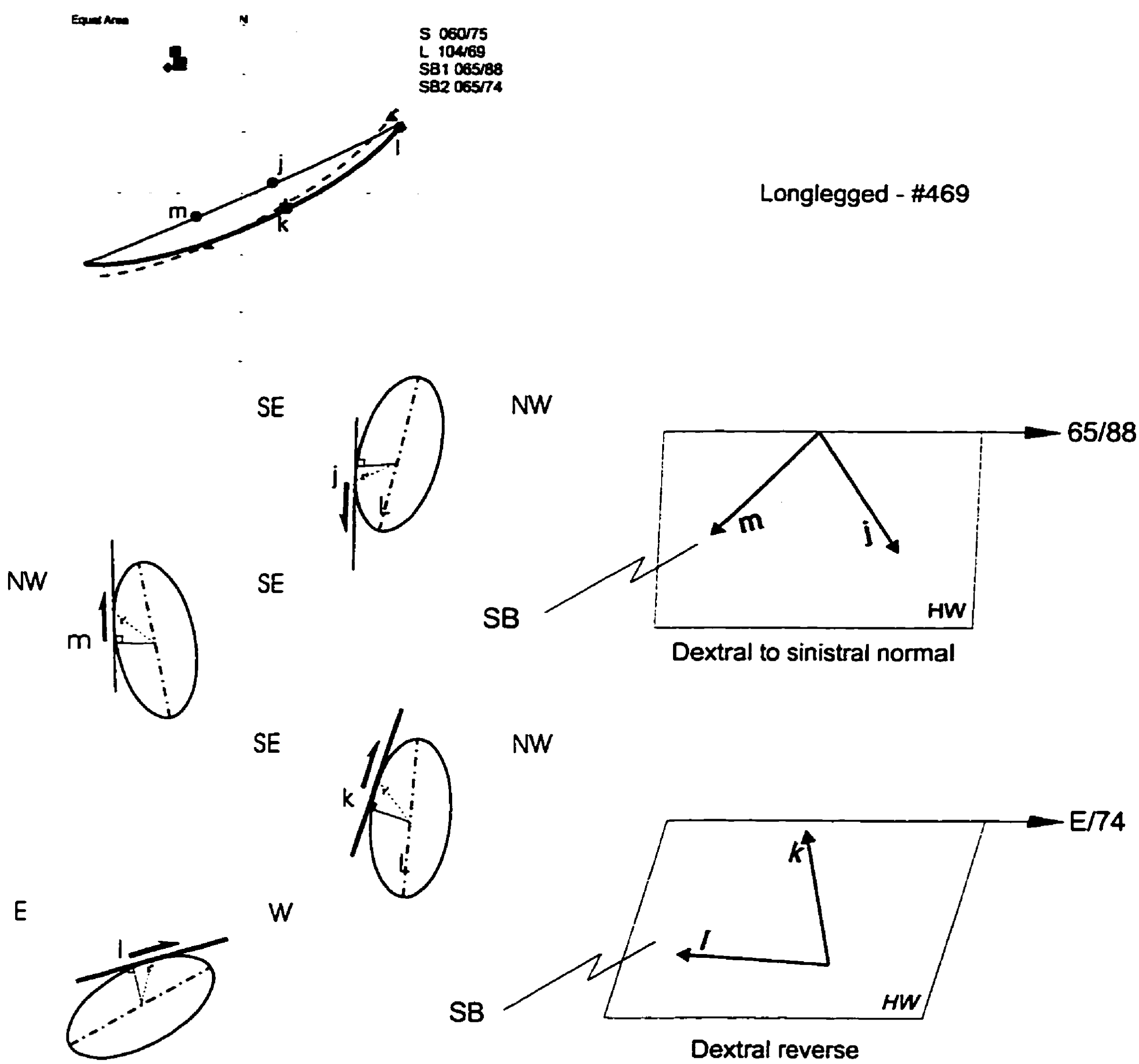


Longlegged - #468

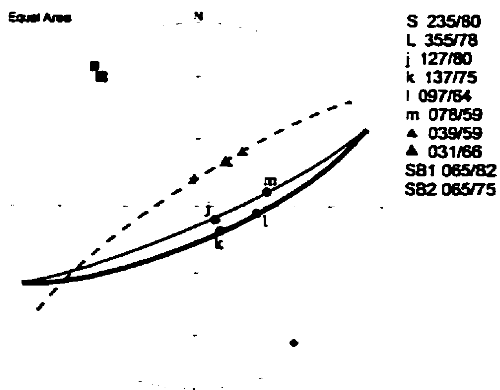




D.4 Longlegged Lake



D.4 Longlegged Lake



Longlegged - #484

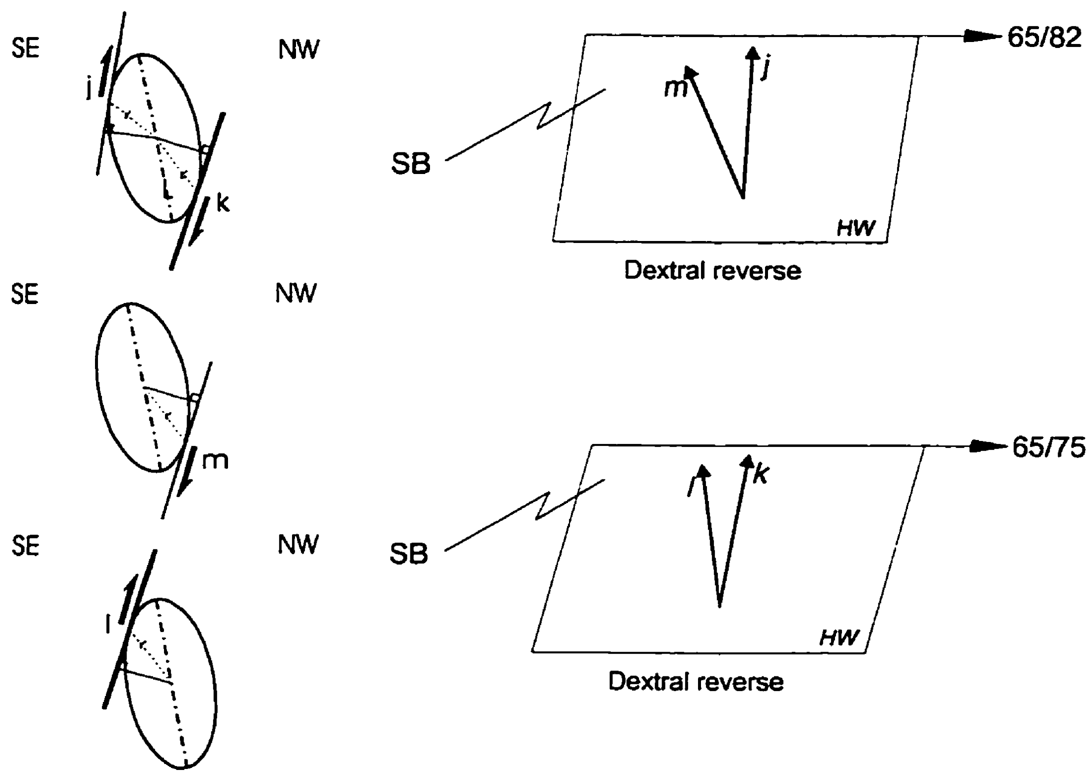
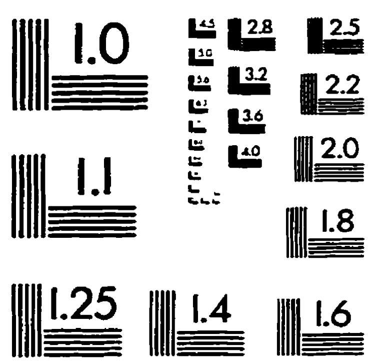


IMAGE EVALUATION TEST TARGET (QA-3)



150mm

6"

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