

# PRELIMINARY STRUCTURAL AND KINEMATIC ANALYSIS OF MYLONITIC ROCKS OF THE TESLIN SUTURE ZONE, 105 E, YUKON

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HANSEN, V.L., 1986. *Preliminary structural and kinematic analysis of mylonitic rocks of the Teslin Suture Zone, 105 E, Yukon*; in *Yukon Geology, Vol. 1; Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada*, p. 119-124.

## INTRODUCTION

The Teslin suture zone (TSZ), first described by Tempelman-Kluit (1979) forms the fundamental boundary between rocks formed along the ancient western margin of North America and the easternmost allochthonous terrane in northern British Columbia and Yukon. The suture zone is exposed along a north-northwest-trending belt in the Big Salmon Range of the Pelly Mountains within the Laberge map area (105 E), and it is also preserved to the east in klippen within the Quiet Lake (105 F) and Finlayson (105 G) map areas. The TSZ is truncated to the south by younger faults and intrusive rocks, and broadens to the northwest where it merges with the Yukon-Tanana cataclastic terrane in Alaska.

The TSZ comprises variably mylonitized sedimentary and volcanic strata, peridotite, basalt, gabbro, and granodiorite which record upper greenschist to epidote-amphibolite facies metamorphism. Within the TSZ a pervasive, penetrative mylonitic foliation dips steeply and trends north-northwest parallel to the regional TSZ trend, whereas mylonitic foliation preserved in the eastern klippen are subhorizontal, approximately parallel to the basal thrusts (Tempelman-Kluit, 1977, 1978a, 1978b, 1979; Gordey, 1981). TSZ rocks were metamorphosed during synchronous ductile deformation in Late Triassic to mid-Jurassic time and thrust eastward above cratonal sediments during Cretaceous time (Tempelman-Kluit, 1979; Stevens *et al.*, 1982; Metcalfe and Clark, 1983).

An understanding of structural and metamorphic development of the TSZ is of importance to models of early Mesozoic Cordilleran evolution, and is also of economic interest as TSZ rocks appear to be structurally and metamorphically equivalent to rocks of the Klondike area (Ruth Debicki, pers. comm.). Previous structural and petrologic analysis of the TSZ by Erdmer (1981; 1982), and Erdmer and Helmstaedt (1983) provided correlation of three distantly separated portions of the TSZ based on lithology, mylonitic textures, metamorphic grade, and hysteretic metamorphic P-T paths of enclosed eclogite.

The present study is an integrated research project to investigate the structural and metamorphic development of the TSZ within the Laberge map area, eastern half. The goal of this project is to better understand kinematics, P-T conditions, fluid compositions, and timing of deformation of this fundamental boundary. This report summarizes preliminary structural and kinematic interpretations of this portion of the TSZ.

## Methods

The TSZ is well exposed along the eastern edge of the Laberge map area, where it is preserved in a 15 km wide vertical zone within the Big Salmon Range of the Pelly Mountains. Geologic mapping and structural analysis, including microstructural analysis, of rocks along three ridge transects perpendicular to the trend of the TSZ form the basis of this report.

Field work consisted of geologic mapping coupled with emphasis on mesoscopic structural data collection and detailed sampling for microscopic kinematic analysis. Samples collected will also be used in later phases of this project for P-T analysis, and fluid inclusion analysis. Approximately two weeks were spent along each of the three east-west-trending ridges approximately 20 km apart: 1) south of Teraktu Creek (TC); 2) north of Dycer Creek (DC); and 3) south of Livingstone Creek (LV) (Fig. 1).

The LV transect crosses the entire width of the TSZ. Due to poor exposure, the TC and DC transects traverse only the eastern three-quarters of the TSZ. The author intends to extend these two transects westward with field work along the Teraktu Creek, Big

Salmon River, and Dycer Creek drainage during the summer of 1985. These transects, parallel to the ridges and perpendicular to the trend of the TSZ, were mapped in reconnaissance in two kilometre-wide strips at a scale of 1:50,000. Within each transect, lithologic units in general are continuous along strike. Lithologic units of the TSZ described by Tempelman-Kluit (1978, 1979) were further subdivided into the following lithologic units. The Nisutlin Allochthonous Assemblage, PPK1, is divided into: 1) chlorite-quartz phyllitic schist; 2) pale green micaceous quartzite; 3) mica-quartz schist; 4) orthoquartzite, and 5) graphitic quartzite. The Anvil Allochthonous Assemblage, CPav and CPaub, is divided into: 1) medium-grained, compositionally layered amphibolite; 2) finely laminated amphibolite; 3) massive, poorly foliated greenstone with possible relict flow breccia and pillow structures; 4) quartz-rich foliated greenstone; 5) fine-grained foliated granodiorite; 6) calc-silicate and white marble; 7) dunite, peridotite, pyroxenite (CPaub); and 8) augen-bearing granodiorite gneiss (Pn of Tempelman-Kluit, 1978). OSQqcl is further divided into: 1) graphitic phyllite; 2) pale green muscovite quartzite; 3) graphitic quartzite; and 4) white marble.

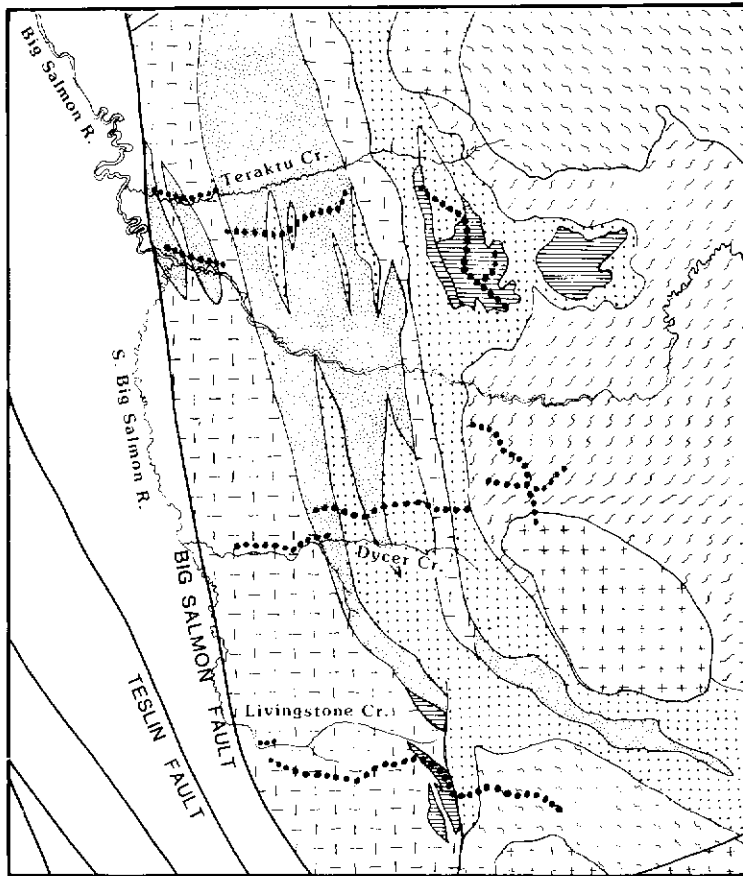
Each lithology is variably mylonitized (usage after Bell and Etheridge, 1973; White, 1976; Sibson, 1977) with a steep south-southwest-dipping foliation and elongation lineation described below. Limiting mineral assemblages indicate middle greenschist to epidote-amphibolite facies metamorphism.

Some 250 sites, at a density of 5-7 stations per km, locate approximately 600 oriented samples. Various rock types were sampled at several stations in order to optimize collateral kinematic and P-T interpretive tools. Petrographic and kinematic data presented in this report stem from preliminary study of over 400 samples.

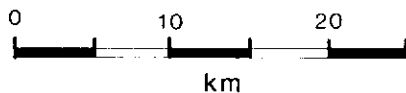
## STRUCTURES

TSZ rocks crop out as flaggy, gneissic to schistose rocks dotting the ridge tops along the three traverses. The flaggy character of these rocks results from a penetrative mylonitic foliation and variably developed elongation lineation. Layers rich in quartz interspersed with layers of mica, feldspar, carbonate, or amphibole define a moderately well-developed, planar, compositional foliation. Within the foliation plane, streaks of quartz, biotite, plagioclase, carbonate, or amphibole define a penetrative mylonitic lineation, Lm. Although Lm is observed in essentially all TSZ rock types, and the orientation of Lm in adjacent lithology is parallel, the character of the lineation is a function of host lithology. Axes of small scale folds, common throughout the TSZ, parallel Lm.

Geologic mapping and structural analysis along the three transects delineate two differently oriented populations of elongation lineations in the north-northwest-trending, steeply-dipping mylonitic foliation. Relationships of these two populations of Lm are best expressed within the LV transect (Fig. 2). In the western portion of the TSZ, Lm plunges moderately to steeply west and is referred to as Lm1. In the eastern portion of the TSZ, Lm plunges gently north-northwest to south-southeast and is here termed Lm2. Fractures are locally present normal to Lm2. Cross-cutting relations in the central portion of the TSZ may indicate that Lm2 locally post-dates Lm1, although no metamorphic or deformational hiatus is recognized. It is unclear at the writing of this report if Lm1 and Lm2 form distinct populations of lineations, or if they represent two end members in a gradual change in orientation from west to east across the TSZ. Continued field work should distinguish which of these two interpretations is correct. The structural characteristics of Lm1 and Lm2 are indistinguishable except for their orientations.



eastern Laberge-western Quiet Lake Map Area



61°45'

UNITS

- Kg post-TSZ granites
- TR-JR volcanic and related rocks
- NISUTLIN ALLOCHTHON**
- PMN mu-quartzite, phyllite
- ODN graphitic quartzite, carbonate, quartz schist
- ANVIL ALLOCHTHON**
- CPA amphibolite, metabasalt, diorite gneiss
- CPAU dominantly ultramafic rocks
- NORTH AMERICAN AUTOCHTHON**
- Pns mu-bi granodiorite gneiss
- PICs gt-mica schist, mu-quartzite, marble
- transects of this study

61°15'

133°45'

Generalized from Tempelman-Kluit 1978, 1984

Figure 1. Generalized geologic map of the Laberge area, eastern half. Mapping and sample transects shown as dotted lines. TC = Teraktu Creek DC = Dycer Creek; LV = Livingstone Creek. See text for TSZ lithologic units. Modified from Tempelman-Kluit, 1978b.

The mylonitic fabric of TSZ rocks is dominantly monoclinic, although locally orthorhombic symmetry is observed. This discussion focuses on the monoclinic fabrics which are more pervasive and record more details of the TSZ's structural history. Within the monoclinic fabric, the plane of symmetry is perpendicular to foliation and contains Lm; the 2-fold axis is perpendicular to Lm and parallel to mylonitic foliation (Fig. 3). TSZ fabrics generally consist of: 1) mylonitic foliation; 2) elongation lineation, Lm; and 3) open to isoclinal folds with axes parallel to Lm.

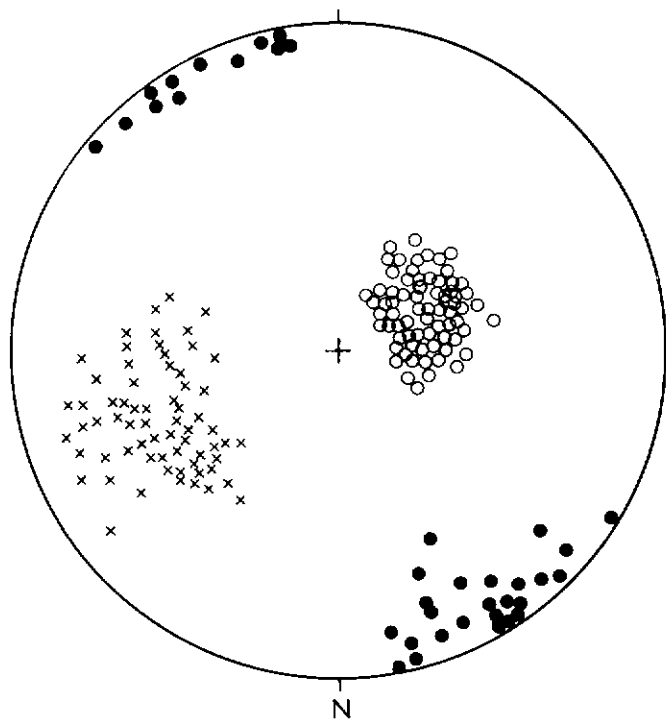
The mylonitic foliation is itself composed of two foliations: a) a penetrative schistosity, S, and b) a spaced, non-penetrative foliation, C (S = "schistosity" and C = "cisaillement," French for "shear;" after Berthe et al., 1979a, 1979b). S and C planes are best observed in the augen granodiorite gneiss unit. The microstructures of the augen granodiorite are described as an example of the monoclinicity of TSZ fabrics. Layers rich in quartz interspersed with layers of biotite and feldspar define a moderately well-developed, penetrative, planar, compositional mylonitic foliation, S. Within the foliation plane, streaks of quartz, biotite, and plagioclase define a unidirectional penetrative lineation, Lm. Blocky and elongate K-feldspar megacrysts commonly display quartz-filled fractures oriented normal to Lm within the plane of foliation. This relationship, along with observed quartz rodding, and quartz grain and subgrain elongation observed in this section, suggest Lm formed as an extensional lineation. This interpretation is important when evaluating bulk movement direction (see kinematic interpretation below). In sections normal to S and parallel to Lm, a weakly- to moderately-developed, non-penetrative crenulation cleavage-type plane, C, intersects S, defining a fabric asymmetry (Fig. 3). The intersection of S and C is normal to Lm. Aligned and smeared, very fine-grained mica coats

C-planes and marks a second slickenside-type, non-penetrative lineation parallel in trend to Lm. The asymmetry defined by the intersection of S and C planes within the plane of symmetry is extremely useful in interpreting the kinematic development of TSZ fabrics (Berthe et al., 1979a, 1979b; Simpson and Schmid, 1983; Lister and Snoke, 1984). Kinematic interpretations are discussed below.

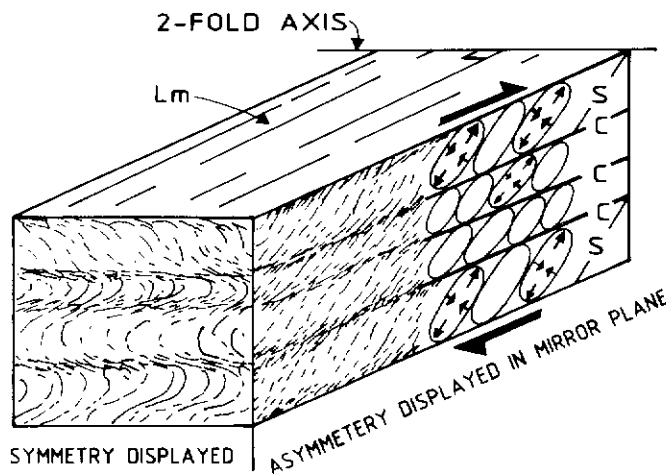
S and C planes are most easily seen in the granodiorite as a result of its relatively coarse-grained nature. Most other TSZ rocks are extremely fine-grained; hence, S and C planes and other developed asymmetries, when present, are distinguished only in thin section. Mylonitic foliation, as mapped in the field, is a combination of these two synchronously developed foliations.

The elongation, or stretching lineation marked most commonly by quartz rodding and mineral alignment, parallels the direction of bulk tectonic transport (Anderson, 1948; Ramsay and Graham, 1970; Lister and Price, 1978; Ramsay, 1980; White et al., 1980). Intersection lineations and crenulation lineations are also locally present within the TSZ rocks. These lineations are generally less well-developed, and exhibit greater variation in orientation from one plane of mylonitic schistosity to the next. Although these lineations may be important in understanding the tectonic development of the TSZ, they are not discussed in this report. Intersection and crenulation lineations result, at least in part, from the interference of small scale folds whose axes parallel mylonitic lineation.

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**Figure 2.** Equal area stereonet of poles to mylonitic foliation (x), Lm1 (o) and Lm2 (•). Structural data taken from approximately 40 stations along the LV transect.



**Figure 3.** Sketch of mylonitic fabrics in granodiorite gneiss. Plane of symmetry is parallel to Lm and perpendicular to mylonitic foliation; 2-fold axis is normal to Lm. Asymmetric mylonitic fabrics are often composed of two foliations. S planes are planes of penetrative schistosity, composed of numerous quartz subgrains which can be interpreted as tiny qualitative strain ellipses indicating shortening and elongation (arrows). C planes are marked by non-penetrative, spaced cleavage planes dominated by shear mechanisms. The asymmetry described by the relationship of these two surfaces indicates shear direction (Berthe *et al.*, 1978a, 1978b; Simpson and Schmid, 1983; Lister and Snoke, 1984).

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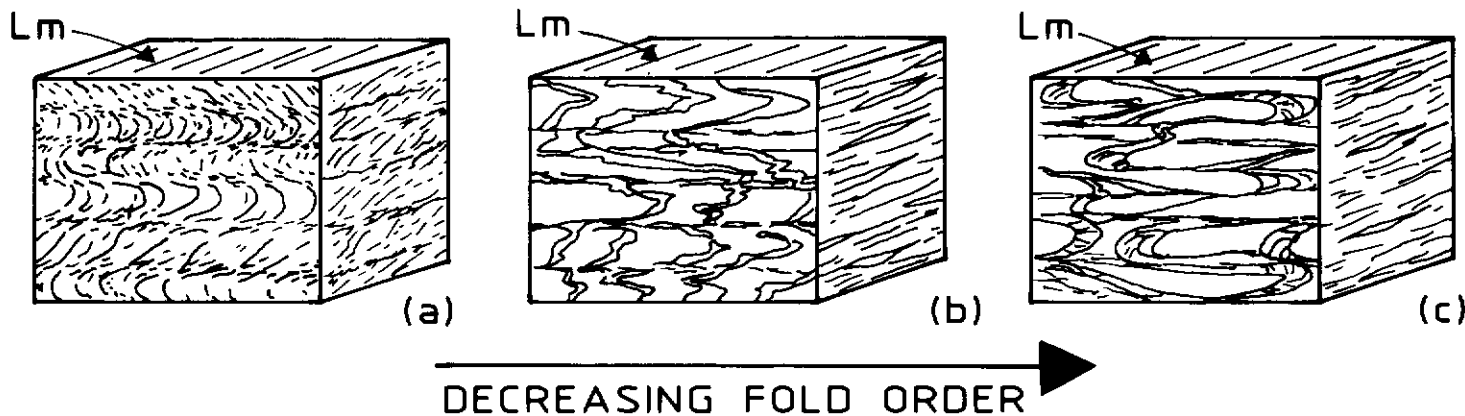
quartz-filled fractures oriented normal to Lm within the plane of foliation. This relationship, along with observed quartz rodding, and quartz grain and subgrain elongation observed in this section, suggest Lm formed as an extensional lineation. This interpretation is important when evaluating bulk movement direction (see kinematic interpretation below). In sections normal to S and parallel to Lm, a weakly- to moderately-developed, non-penetrative crenulation cleavage-type plane, C, intersects S, defining a fabric asymmetry (Fig. 3). The intersection of S and C is normal to Lm. Aligned and smeared, very fine-grained mica coats C-planes and marks a second slickenside-type, non-penetrative lineation parallel in trend to Lm. The asymmetry defined by the intersection of S and C planes within the plane of symmetry is extremely useful in interpreting the kinematic development of TSZ fabrics (Berthe *et al.*, 1979a, 1979b; Simpson and Schmid, 1983; Lister and Snoke, 1984). Kinematic interpretations are discussed below.

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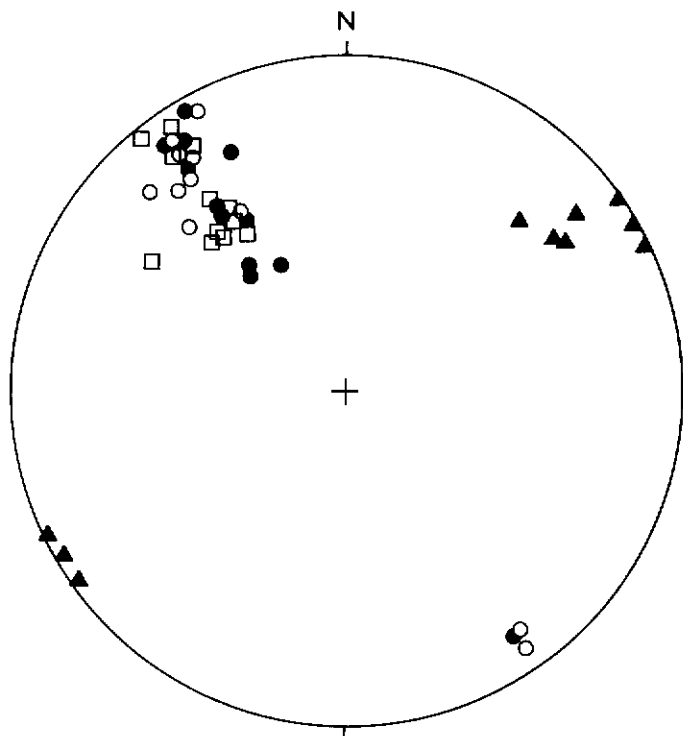
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Minor folds are observed in essentially all rock types which comprise the TSZ. Fold axes parallel Lm; therefore, fold axial profiles are observed in sections cut normal to both mylonitic foliation and lineation. In contrast to the section showing S and C planes described above, these sections display no apparent fabric asymmetry. Although folds within different host lithology vary in their interlimb angle and lengths of their preserved limbs, the folds share three important characteristics: 1) fold axes are parallel to Lm; 2) folds deform mylonitic foliation, yet display axial planar structures coplanar with mylonitic foliation; and 3) spaced foliations, coplanar with fold axial planes and mylonitic foliation, truncate and offset fold limbs with no resultant fold asymmetry. Both folds and mylonitic foliation which display varying degrees of fold limb attenuation, truncation, and offset within different host lithology appear to be the result of refolded and "tectonic kneading" (Fig. 4). For example, granodiorite mylonite gneiss and muscovite quartzite display open style folds with no apparent limb truncation (Fig. 4a). Phyllitic quartzite and graphitic quartzite display multiple refolded folds characterized by attenuated and truncated limbs and apparently thickened fold hinges (Fig. 4c). Amphibolite gneisses contain structures transitional between these two end members; spaced foliation planes parallel to fold axial planes attenuate the long limbs of tight to isoclinal folds, but limbs are rarely truncated along these planes (Fig. 4b).

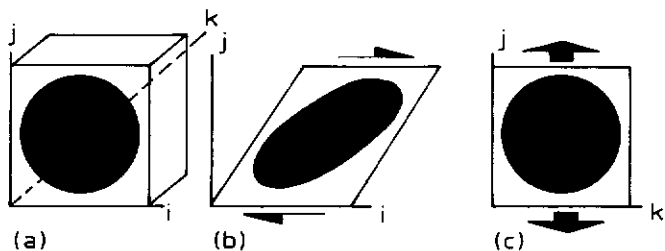
Parallelism of stretching lineation and minor fold axes is commonly reported from large scale shear zones (Christie, 1963; Eisbacher, 1970; Bell, 1978; Bell and Hammond, 1984), yet mechanisms of fold formation within shear zones are not clearly understood (Bell and Hammond, 1984). Several workers (Bryant and Reed, 1969; Rhodes and Gayer, 1977; Bell, 1978; Williams, 1978) propose that pre-existing, or early-formed folds, rotate into parallelism with elongation lineation with increasing shear deformation. Rotation of folds during shear deformation implies that folds initiate as open folds with axes at an angle to lineation, and become isoclinal folds as they rotate into parallelism with lineation. Minor folds in the TSZ (e.g., in mica quartzite and granodiorite gneiss) are commonly open style folds with axes statistically parallel to Lm (Fig. 5). This relationship indicates that TSZ folds initiated as open folds with axes originally parallel to Lm, and did not rotate into parallelism with continued deformation.



**Figure 4** Axial profiles of variably attenuated and "tectonically kneaded" open to isoclinal folds with axes parallel to  $L_m$ ; (a) granodiorite gneiss and mica quartzite; (b) amphibolite gneiss; and (c) phyllitic quartzite and graphitic quartzite.



**Figure 5** Equal area stereonet of poles to mylonitic foliation (▲);  $L_m2$  (●); axes of small scale open style folds (○); and axes of large scale ( $\lambda = 1$  to  $1/2$  m) open style folds (□), from mica quartzite of DC traverse.



**Figure 6** Textural asymmetries develop parallel to bulk movement directions. Consider a cube in  $ijk$  coordinates and apply simple shear parallel to  $i$  (a). Post-shearing cross-sections  $ij$ , parallel to shear direction (b) and  $jk$ , normal to shear direction (c) display resultant asymmetry and symmetry respectively. In TSZ rocks, asymmetric textures are expressed in sections cut parallel to  $L_m$ , whereas symmetric textures are observed in section cut normal to  $L_m$ . Therefore, movement during the formation of TSZ fabrics paralleled  $L_m$ .

Models of fold mechanisms in which folds initiate with fold axes parallel to a mylonitic lineation are discussed by Bell and Hammond (1984). Thus, it appears that TSZ folds formed progressively during mylonitization with synchronously developing, multiple generations of mylonitic foliation, and they do not record a later folding event.

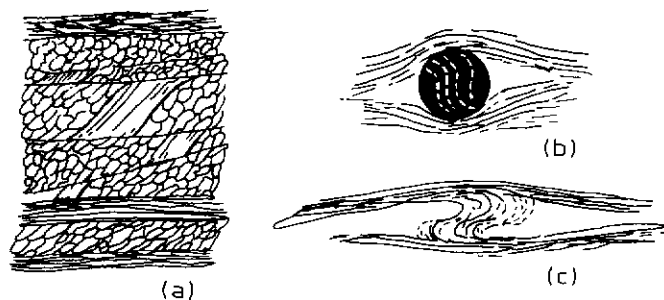
The fold styles described above are observed at both mesoscopic and microscopic scales. Field relationships indicate similar fold geometries may be present megascopically within the TSZ. Continued field work will help to clarify these relationships.

In summary, TSZ fabrics are characterized by four structural features: 1) mylonitic foliation; 2) elongation lineation,  $L_m$ ; 3) minor open to isoclinal folds with axes parallel to  $L_m$ ; and 4) fractures perpendicular to  $L_m$ .

#### KINEMATICS

Thin sections cut parallel to the plane of fabric symmetry, that is, parallel to  $L_m$  and normal to mylonitic foliation, often display asymmetries. The expression of textural asymmetry in sections parallel to  $L_m$  supports the conclusion that  $L_m$  parallels the bulk movement direction (Fig. 6). Further, textural asymmetries are useful in interpreting the direction of shear during mylonitization (Bouchez et al., 1983; Simpson and Schmid, 1983; Lister and Snoke, 1984). Indicators of shear zone kinematics include: 1) S and C planes; 2) mica and feldspar "fish;" 3) rotated clasts and minerals; and 4) preferred elongation of quartz grains (Fig. 7). Rarely preserved intrafolial folds, with fold axes normal to  $L_m$ , when present, are useful kinematic indicators (Ramsay, 1967).

Asymmetric textures described by S and C planes (Fig. 3), mica fish, quartz subgrain elongation, and rotated garnets in sections from the LV and DC traverses, cut normal to mylonitic foliation and parallel to  $L_m2$  consistently record right-lateral movement parallel to  $L_m2$ . Local intrafolial folds and rotated clasts observed in impure marble units in the field, also indicate right-lateral movement parallel to  $L_m2$ .



**Figure 7** Sketches of microstructural kinematic indicators exhibited in sections cut parallel to  $L_m$ ; (a) mica "fish" and elongate quartz grains; (b) rotated garnet with inclusion trails; (c) intrafolial fold with fold axis normal to  $L_m$ . Each sketch indicates dextral movement.

Kinematic interpretations of sections cut normal to mylonitic foliation and parallel to Lm1 are in preliminary stages. However, research to date indicates dominantly normal movement parallel to Lm1, or west-side-down. The author stresses the preliminary nature of kinematic interpretations of sections parallel to Lm1. Petrofabric analysis of quartz c-axes and calcite c-axes, as well as continued interpretation of textural asymmetries will clarify the kinematic picture.

## SUMMARY

The TSZ is a Late Triassic to mid-Jurassic subduction complex and forms the fundamental boundary between rocks deposited along the ancient western margin of North America, and allochthonous terranes to the west. The north-northwest-trending TSZ in the Big Salmon Range includes sedimentary and volcanic strata, basalt, peridotite, and granodiorite metamorphosed to middle greenschist to epidote-amphibolite facies and variably mylonitized. Petrochemical study of co-existing phases now being initiated should allow the assignment of P-T limits attending the recrystallization. Geologic mapping and structural analysis along three 10-15 km transects normal to the trend of the TSZ delineates two populations of stretching lineations, Lm1 and Lm2, in north-northwest-trending, steeply-dipping mylonitic foliation. Lm1, best developed in the western portion of the TSZ, plunges moderately to steeply west. Tight to isoclinal fold axes parallel Lm1. Lm2, best

developed to the east, plunges gently north-northwest and south-southeast. Open to isoclinal fold axes parallel to Lm2, and fractures are locally present normal to Lm2. Folds initiated during mylonitization as open structures with axes parallel to Lm, and do not record unrelated pre- or post-mylonitic fold events. Crenulation and intersection lineations vary in orientation between schistosity planes in the shear zone. The stretching lineations, Lm1 and Lm2, formed parallel to their bulk movement directions. Kinematic indicators consistently record right-lateral movement parallel to Lm2. Preliminary interpretation of Lm1 kinematics indicate dominantly normal movement parallel to Lm1, or west-side-down.

## ACKNOWLEDGEMENTS

This project was inspired by Dirk Tempelman-Kluit who has provided much encouragement and enthusiasm. I would like to thank Jim Morin, Grant Abbott, and Rob McIntyre for their "bush" expertise and hospitality, and a special thanks to Dan Spencer for his assistance and company in the field. This work was supported by the Exploration and Geological Services Division of DIAND, Whitehorse, and a grant from the Department of Earth and Space Sciences, UCLA (Chevron Funds). Many thanks to Ram Alkaly for prolific and careful thin section preparation. John Goodge and W. Gary Ernst greatly improved the manuscript.

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