PETROTECTONIC STUDY OF THE TESLIN SUTURE ZONE, YUKON: A PROGRESS REPORT

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ABSTRACT

The Teslin suture zone (TSZ) forms the fundamental boundary between rocks deposited along the ancient margin of North America and allochthonous terranes to the west. Both North American and allochthonous rocks were ductilely deformed and concurrently metamorphosed under upper greenschist to amphibolite facies conditions at temperatures of 450-650°C and pressures greater than or equal to 6 kbars, probably during Late Triassic to mid-Jurassic time. North-northwest-striking foliation dips steeply in the western portion of the TSZ, but flattens to the east in North American autochthonous rocks.

The TSZ in the combined eastern Laberge/western Quiet Lake map area is divisible into three distinct elongate structural domains parallel to the NNW-trending TSZ. Domains are identified by the distribution of differently oriented stretching lineations, Le1 and Le2, which formed during non-coaxial ductile deformation, and their associated "motion planes." Le1 trends westward and plunges down dip, whereas Le2 trends NNW-SSE and plunges shallowly. Le1 and Le2 are associated with the same mineral assemblages and formed under similar metamorphic conditions. Silicate mineral assemblages record temperatures up to 625°C, and pressures to 8 kbars; carbonate assemblages record temperatures in the range 350-500°C. The difference in temperature suggested by these assemblages may reflect lower temperatures of ductile flow and recrystallization in carbonate rocks.

Elongate lensoidal domains of Le1 are separated from each other by narrower NNW-trending zones of Le2, forming a regional-scale anastomosing shear zone. Two western domains of Le1 are comprised chiefly of allochthonous rocks, or rocks of uncertain affinity; however, the eastern domain comprises North American autochthonous rocks, previously considered to be unaffected by TSZ metamorphism and deformation. Macroscopic and microscopic kinematic indicators consistently record right-lateral, or top-to-the-north movement parallel to Le2. Kinematics associated with Le1 are more complex. To the west kinematic indicators record west-side-down (normal) movement parallel to Le1; elsewhere, both reverse and normal movement are recorded. Field relations suggest Le1 began forming earlier than Le2, followed by a period during which both Le1 and Le2 formed, and ended with movement parallel only to Le2. These geometries and movement histories indicate that rocks of the TSZ and structurally associated autochthonous rocks record a history of right-lateral transpression along this portion of the North American margin during Triassic-Jurassic time. Movement consisted of early tectonic shortening at a high angle to the ancient margin, followed by a period of right-lateral translation approximately parallel to the Mesozoic margin of western North America.

INTRODUCTION

The Teslin suture zone (TSZ), initially described by Tempelman-Kluit (1979), forms the fundamental boundary between rocks deposited along the ancient western margin of North America and the eastern-most accreted terrane in northern British Columbia and Yukon. Rocks of the TSZ consist of metamorphosed sedimentary and volcanic strata, peridotite, basalt, gabbro, and granodiorite which were ductilely deformed and concurrently metamorphosed under greenschist to amphibolite facies conditions, probably during Late Triassic to mid-Jurassic time (Tempelman-Kluit, 1979; Metcalfe and Clark, 1983; Stevens et al., 1982). The TSZ probably represents rocks deformed and metamorphosed within the deep-seated portion of the Late Triassic to mid-Jurassic convergent plate margin. It is the purpose of this on-going research to study the structural/metamorphic development of a portion of the TSZ in order to better understand the nature of late Mesozoic plate convergence along this portion of the western North American margin. In this report, the author outlines structures present throughout the TSZ within the eastern Laberge and western Quiet Lake map areas, discusses geometries and kinematics of TSZ deformation, and outlines constraints which structural relations place on models of the tectonic evolution of this ancient western margin.

Data presented in this report summarizes field work from two summer seasons in the Big Salmon Range of the Pelly Mountains, eastern Laberge-western Quiet Lake map area. Field work during the 1985 summer consisted of extending geologic mapping and detailed sampling, begun in 1984, along three transects normal to the trend of the TSZ (Hansen, 1985, 1986a). Mapping along these three transects south of Teraktu Creek (TC), north of Dycer and Mendicino Creeks (DC), and south of Livingstone Creek (LV) (Fig. 1), emphasized mapping of mylonitic elongation lineations (Le) and interpretation of megastructures and microstructures associated with Le. Through mapping the author was able to: 1) document the distribution of two elongation lineations; Le1, generally east-west-trending, and Le2, generally north-south-trending, throughout the TSZ; 2) document the nature of the transition and timing between Le1 and Le2; 3) identify narrow alternating elongate structural domains of Le1 and Le2 parallel to the trend of the TSZ; and 4) provide evidence that rocks of the North American autochthon, previously interpreted to lack evidence of TSZ deformation (Tempelman-Kluit, 1979; Erdmer, 1981, 1985), share the same structural, kinematic and metamorphic signature as TSZ rocks. Data presented and discussed in this report results from detailed field study as well as petrographic analysis and the kinematic interpretation of petrofabrics and micro-textures.

GEOLOGIC SETTING

Yukon comprises autochthonous and allochthonous tectonic elements with distinctive internal stratigraphy. The NW-trending Tintina fault zone separates dominantly autochthonous elements to the northeast from dominantly allochthonous elements to the southwest. The northeastern assemblages include strata deposited on the Paleozoic to Mesozoic North American continental margin. The southwestern tectonic province includes miogeosynclinal rocks deposited in a Palezoic ocean (Monger, 1977; Monger and Price, 1979) and continental and oceanic terranes of unknown paleogeography. These two distinctive tectonic assemblages collided in Late Triassic to Early Jurassic time and were juxtaposed along the Teslin suture zone.

The TSZ is most simply divided into three assemblages (Tempelman-Kluit, 1979): 1) the Nisutlin allochthon comprises an

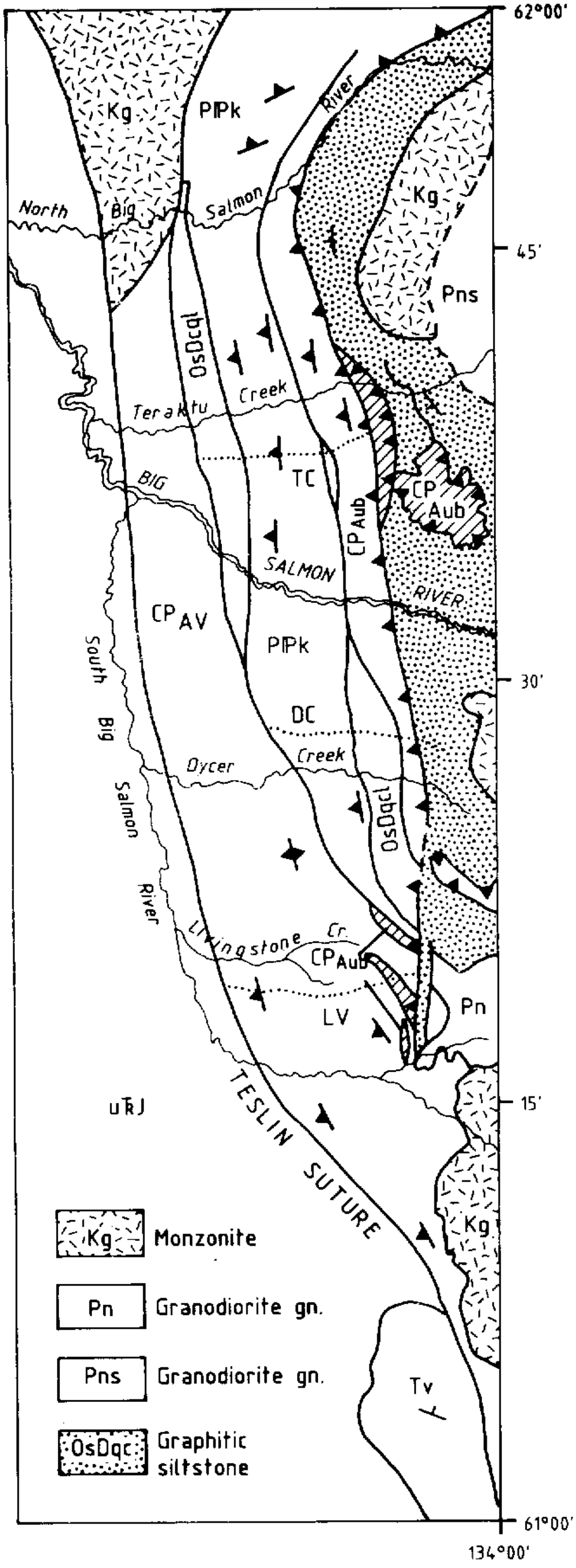

Figure 1. Generalized geologic map of the Teslin suture zone, eastern Laberge-western Quiet Lake map area. Mapping and sampling transects, shown as dotted lines, from north to south are: Teraktu Creek, TC; Dycer Creek, DC; and Livingstone Creek, LV.

assemblage of siliceous tectonites derived from sedimentary and volcanic protoliths, and siliceous melange; 2) the Anvil allochthon encompasses an assemblage of sheared ophiolite containing basalt, gabbro and periodotite; and 3) the Simpson allochthon includes mylonitic granitic gneiss. Lithologies within these assemblages have poorly constrained formational ages ranging from late Devonian to mid-Permian (Tempelman-Kluit, 1979; Tempelman-Kluit and Wanless, 1980; Aleinikorr et al., 1981; Mortensen, 1985; Mortensen and Jilson, 1985).

Within the suture zone, in plan, the three allochthonous assemblages or structurally-bound lenses 3-4 km wide and 20-30 km long, elongate parallel to the NNW-trend of the TSZ. The allochthonous assemblages are not chaotically mixed within the suture zone; generally siliceous melange, ophiolite, and granodiorite are exposed successively from northeast to southwest. However, within any one allochthon, lithologies of the other two allochthons may be locally interleaved (Erdmer, 1981, 1985; Erdmer and Helmstaedt, 1983; Hansen, 1985, 1986a; Mortensen, 1985).

TSZ rocks were metamorphosed during synchronous ductile deformation in Late Triassic to mid-Jurassic time (Tempelman-Kluit, 1979; Sevens et al., 1982; Metcalfe and Clark, 1983). These rocks record greenschist- to amphibolite-facies metamorphism (Erdmer, 1981; Hansen, 1986b). Tectonic blocks of eclogite are reported within the Nisutlin siliceous melange assemblage (Tempelman-Kluit, 1970, Erdmer, 1981). Erdmer and Helmstaedt (1983) documented that the basaltic and eclogites record metamorphic pressures to 10 kbars.

Tertiary right-lateral strike-slip deformation characteristic of the North American Cordillera from Mexico to Alaska is localized along the Tintina fault zone to the east and the Denali fault zone to the west. Therefore, the TSZ, although locally offset 450 km by the dextral Tintina fault (Roddick, 1967), does not appear to be internally disrupted by Tertiary-age right-lateral offset within the study area.

Eastern Laberge/Western Quiet Lake Map Area

The geology of the Laberge and Quiet Lake map sheets was first mapped at 1:250,000 in the early 1960's (Bostock and Lees, 1961; Wheeler et al., 1960). Most recent mapping has been completed by Tempelman-Kluit (1977b, 1978a, b), also at 1:250,000 and by Erdmer (1981) at a scale of 1:50,000.

The TSZ is exposed in the eastern half of the Laberge map sheet as a regionally-extensive sub-vertical NNW-trending zone greater than 15 km wide and is preserved in klippen within the Quiet Lake and Finlayson map areas to the east. The TSZ is truncated to the south by faults and intrusive rocks, and it broadens to the northwest where it merges with the "Yukon cataclastic complex" in northern Yukon and Alaska. To the west within the map area the high-angle NNW-trending Big Salmon fault places nonmetamorphosed to low-grade volcanic and volcaniclastic sedimentary rocks against high- to moderate-grade rocks of the TSZ (Tempelman-Kluit, 1978b).

METAMORPHIC AND STRUCTURAL RELATIONS OF TSZ

Metamorphic Environment of TSZ

Petrographic investigation to date TSZ metamorphism in the epidote-amphibolite to amphibolite facies is in progress. Mineral assemblages present in TSZ rocks which are useful for P-T estimates include: 1) garnet-biotite; 2) garnet-muscovite; 3) garnet-hornblende; 4) plagioclase-biotite-garnet-muscovite; 5) calcite-dolomite; 6) muscovite composition; 7) plagioclase-amphibole composition; 8) amphibole composition; and 9) coexisting feldspars. Preliminary P-T-ometry constrains metamorphic temperatures at 450-625°C, and pressures greater than or equal to 6 kbars. Coexisting calcite-dolomite mineral pairs (Anovitz and Essene, 1982; Powell et al., 1984) yield values of T = 450-550°C, whereas garnet-biotite, garnet-muscovite, and garnet-hornblende mineral pairs (Ferry and Spear, 1978; Graham and Powell, 1984; Green and Hellman, 1982; Hodges and Spear, 1982; Krogh and Raheim, 1978) indicate temperatures of 550-625°C. Carbonate rocks deform ductilely at lower temperatures than silicate rocks (REF); it is possible that the lower apparent temperature of metamorphism recorded by the carbonate rocks records ductile deformation of these rocks to a lower temperature than the silicate rocks. It is also possible that these temperature differences reveal a metamorphic gradient. Regionally distributed data and more P-T calculations are necessary to substantiate the suggested P-T conditions and place constraints on a tectonic model of TSZ formation. In addition, P-T paths will be studied by examining mineral inclusions in porphyroblasts displaying sieve structures.

Although metamorphic temperatures are quite well constrained in the range 550-625ºC for silicate rocks, pressure calculations are less than satisfactory at this time. It is possible that fluid inclusion study will shed light on this problem, by permitting construction of isochores (lines of equal density in P-T space) which, together with temperature data, may further constrain metamorphic pressure.

Structural Environment of TSZ

The TSZ is well-exposed along the eastern edge of the Laberge map sheet where it is preserved in a greater than or equal to 15 km wide belt within the Big Salmon Range. It is bounded to the west by the high-angle, NNW-trending Big Salmon fault. Northward in the Laberge sheet the TSZ broadens to the east, merging with isolated klippen from the south. Within this broad zone rocks of the TSZ are variably ductilely deformed and mylonitized. They crop out as NNW-trending, flaggy, gneissic to schistose rocks dotting the ridge tops throughout the study area. The rocks contain a variably-developed, penetrative mylonitic foliation and lineation (Hansen, 1985, 1986a). Geologic mapping in 1984 delineated two differently oriented elongation lineations, Le1 and Le2, in the steeply-dipping mylonitic foliation. Continued field work in 1985 extended geologic mapping and detailed sample collection along the three transects normal to the TSZ trend. Along the northernmost transect, TC, mapping was extended westward to the Big Salmon fault and eastward to the Dunite klippe area of Erdmer (1981). The central transect, DC, was also extended west to the Big Salmon fault and eastward to the westernmost Quiet Lake area, including rocks of the North American autochthon (Tempelman-Kluit, 1979). The author also revisited the Livingstone transect in order to study details of megascopic structural geometries.

Through mapping and detailed kinematic analysis the author is able to: 1) document the distribution of two distinct elongation lineations, Le1 and Le2, throughout the TSZ; 2) document the nature of the geometric transition and timing relations between Le1 and Le2; 3) identify three NNW-trending structural domains, delineated by the distribution of Le1 and Le2; and 4) provide evidence that rocks of the North American autochthon, previously considered to be unaffected by TSZ deformation and metamorphism (Tempelman-Kluit, 1979; Erdmer, 1981, 1985), bear important structural and metamorphic similarities to TSZ rocks.

Le1 and Le2 are both elongation lineations, as marked by rodded quartz, smeared micas, and aligned minerals, and they formed parallel to the direction of tectonic transport during simple-shear dominated ductile deformation (Hansen, 1985, 1986a). The two lineations are distinguished in the field, in part, by their structural trend. Le1 trends westward and plunges down dip at a high angle to the strike of mylonitic foliation, whereas Le2 trends NNW-SSE and plunges shallowly approximately parallel to the strike of foliation (Hansen, 1985, 1986a).

Other structures geometrically related to Le include 1) small-scale, open to isoclinal folds with axes parallel to Le and axial planes parallel to mylonitic foliation; and 2) mesoscopic fractures perpendicular to Le. These structures are most commonly observed in association with Le2; however, they are also locally preserved with Le1. Folds colinear with Le display no apparent preferred vergence, and they formed synchronously with mylonitization, apparently initiating with fold axes parallel to Le (Hansen, 1985, 1986a). Most importantly, these folds are not useful as kinematic indicators because they formed with their axes parallel to Le.

Valid kinematic indicators must display fabric asymmetry within the motion plane of ductilely deformed rocks. A motion plane is that plane in a sheared rock which contains both the elongation lineation and the pole to foliation (Arthaud, 1969), and it allows us to consider, in three dimensions, the plane in which the movement of a shear zone may be viewed (Fig. 2).

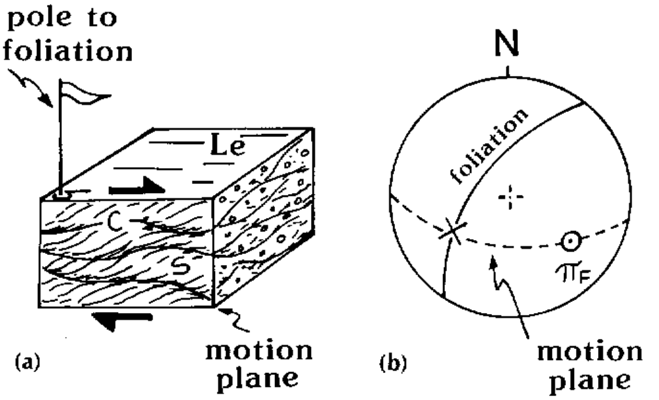

Figure 2. a) S and C planes (Berthe et al., 1979a), b) observed in "motion plane." b) Motion planes as plotted on a stereogram. Note that the motion plane is that plane which contains both Le and the pole to foliation (Athaud, 1969).

Kinematics associated with Le1 and Le2 were studied in the field and in thin section. Useful kinematic indicators include: 1) S-C fabrics; 2) mica fish; 3) asymmetric quartz strain shadows; 4) quartz subgrain preferred orientations; 5) preferred orientation to quartz c-axes; and 6) asymmetric vergence of folds with axes normal to Le and axial planes approximately parallel to mylonitic foliation (Berthe et al., 1979a, b; Bouchez et al., 1983; Hanmer, 1982; Lister and Snoke, 1984; Simpson and Schmid, 1984). Megascopic and microscopic kinematic indicators associated with Le2 consistently record right-lateral, or top-to-the-north movement parallel to Le2. However, tectonic movement associated with Le1 is more complex: to the west, kinematic indicators consistently record west-side-down (normal) movement parallel to Le1; elsewhere, both reverse and normal movement are recorded (Fig. 3). It appears that thrust-style, or top-to-the-east, movement is dominant parallel to Le1 further to the east; however, a simple pattern of Le1 kinematics has not yet emerged from the present data. In general, Le1 and Le2 are interpreted to record dip-slip and strike-slip movement, respectively. Le1 and Le2 are associated with the same metamorphic mineral assemblages and formed under similar metamorphic conditions. Therefore it appears that the stuctural-tectonic environment changed during the formation of Le1 and Le2, although the metamorphic environment remained essentially the same.

Megascopic and microscopic structural relations constrain the relative timing of Le1 and Le2 formation locally. The relative timing between Le1 and Le2 are inferred from: 1) Le1 deformed around folds whose axes are colinear with Le2; 2) rotation of quartz pressure shadows on euhedral pyrite cubes within the plane of the foliation (Fig. 4); 3) the observation that Le2 is locally much more strongly developed than Le1; and 4) strained quartz grains and subgrains associated with Le2 appear to be less annealed than those fabrics associated with Le1. Generally, Le1 can be shown to pre-date Le2 at specific locations where they either occur together, or where Le1 is mapped into regions containing Le2. It is possible that Le1 remained active in one region while Le2 was beginning to form elsewhere. The author interprets the intimate spatial relationship betwen Le1 and Le2, the similarity in associated metamorphic mineral assemblages, and the similar structural style of Le1 and Le2 to indicate that Le1 and Le2 formed in a similar geologic environment and therefore were probably not separated by a distinct break in time. Le1 probably formed predominantly before Le2, but changes in the regional tectonic regime perhaps led first to a period during which both Le1 and Le2 formed simultaneously, and finally to the cessation of Le1 formation and solely formation of Le2.

The geographic distribution of Le1 and Le2 as mapped in the field outlines distinct structural domains. These domains are most easily illustrated in a diagram of motion planes throughout the study area. A regional plot showing trends of elongation lineations does not distinguish the structural domains because the dip of foliation is near vertical in the west and decreases significantly to the east, and the orientation of the foliation is not considered in such a projection. It is therefore necessary to plot the motion planes associated with Le1 and Le2 in order to consider the three dimensional orientation of the lineations. Stereoplots of poles to motion

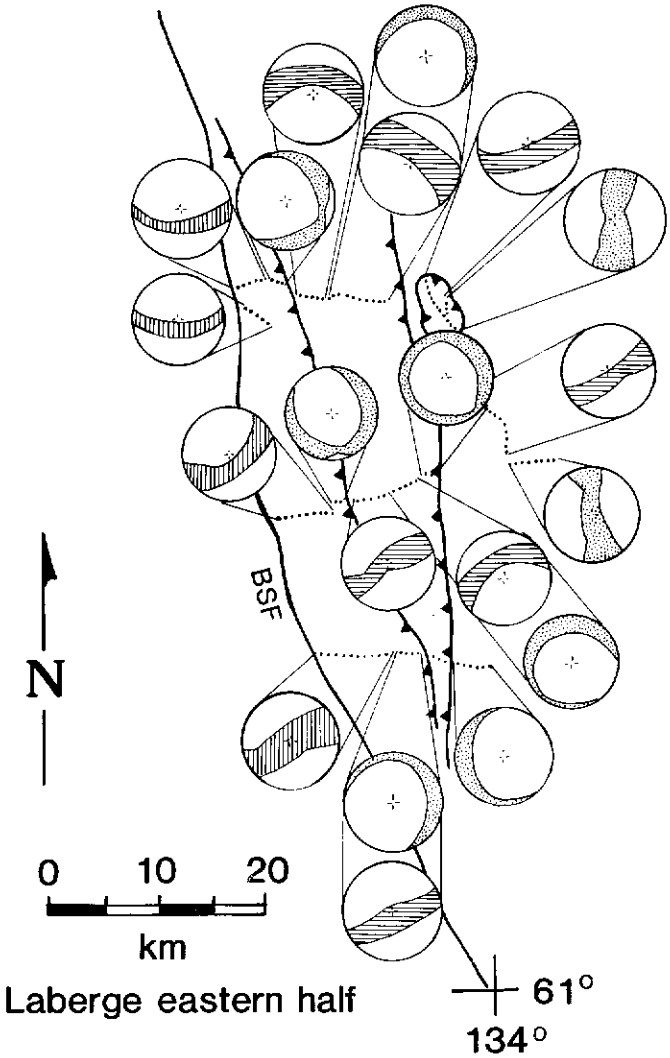

Figure 3. The distribution of Le1 and Le2 and their associated motion planes mark elongate structural domains parallel to the regional trend of the TSZ. Steeply-dipping, east-west-trending motion planes are associated with Le1 (lined pattern); whereas Le2 is associated with gently-dipping horizontal planes or north-south-trending vertical planes (stippled pattern). Pattern girdles on stereoplots represent all motion planes. Horizontally lined pattern indicated normal, or west-side-down movement within the motion planes parallel to Le1; vertically lined pattern indicates either/both normal and thrust-style (top-to-the-east) movement parallel to Le1 within the motion plane; and stippled pattern indicates right-lateral or top-to-the-north movement parallel to Le2 within the motion plane.

planes and Le are plotted in Figure 3.

The domains are delineated by the presence of Le1 or Le2 and the orientation of their associated motion planes (Fig. 3). Motion planes associated with Le1 are steep east-west-striking planes, whereas motion planes associated with Le2 are either subhorizontal, gently-dipping planes, or nearly vertical, north-south-oriented planes depending on the local orientation of foliation. Alternating zones of fabrics dominated by Le1 and Le2 define several lensoidal structural domains elongated parallel to the regional trend of the TSZ. Three NNW-trending zones of Le2 separate domains of Le1 in the west to Le2 in the east vary from gradational to sharp. The domains of Le2 appear to correlate in a general way with lineaments defined by topographic lows. Based on timing relations outlined above, the distribution of Le2, and consistent right-lateral kinematics interpreted from Le2, it appears that the deformation which formed the Le2 fabrics occurred in a regional scale anastomosing shear zone which overprinted older Le1 deformation features and displaced TSZ rocks right-laterally along the ancient Mesozoic margin (Fig. 5).

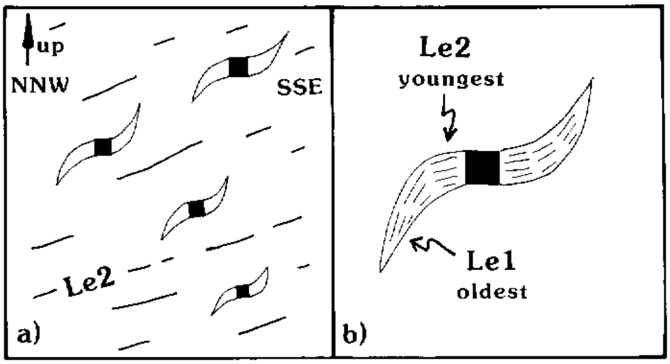

Figure 4. Quartz strain shadows on pyrite looking on to the plane of foliation of a carbonate-rich rock. Tails of strain shadows plunge steeply parallel to Le1; strain shadows closest to the pyrite cube plunge gently parallel to Le2. b) Timing is interpreted from the relative proximity of the quartz fibres to the pyrite cube. The youngest fibres form against the pyrite crystal (Choukroune, 1971). Hence Le2 post-dates Le1.

Both allochthonous, or "suspect,'" and autochthonous rocks record Le1 and Le2 structures. The two western domains of Le1 are comprised of chiefly allochthonous rocks, or rocks of uncertain origin; however, the eastern domain comprises rocks which are autochthonous with respect to North America (Tempelman-Kluit, 1979; Erdmer, 1981, 1985), it displays metamorphic foliation and variably developed elongation lineations wich are structurally continuous and consistent with TSZ geometries (Fig. 3). Therefore, rocks which are autochthonous with respect to North America have experienced at least a part of the same structural deformation and associated metamorphic history as rocks of the TSZ.

In conclusion, the TSZ forms the fundamental boundary between rocks deposited along the ancient margin of North America and allochthonous terranes to the west. Structurally, this boundary is a transpressional suture affecting both eastern autochthonous rocks and western allochthonous or "suspect" rocks. Rocks within the suture zone were deformed and simultaneously metamorphosed under upper-greenschist to amphibolite facies conditions during a changing structural-tectonic regime. Early collapse of an ocean basis to the west and collision of western allochthonous terranes is recorded by structures associated with Le1. Initial convergence occurred at a high angle to the western continental margin. With continued collision the tectonic regime changed from overall shortening to right-lateral translation approximately parallel to the ancient margin as recorded in the transition from Le1 to Le2.

Future Work

Rb-Sr whole-rock and mineral dating, to be carried out at the University of British Columbia, should allow the author to place metamorphic and deformation episodes in a quantitative time frame. They may, for instance, enable a chronological distinction of dominantly compressional-age tectonics, Le1, from translation-age tectonics, Le2; or such data may indicate that conclusions with respect to the intimate timing of Le1 and Le2 are incorrect, and in fact that these two lineations may represent distinctly different deformational events. Such time constraints would greatly constrain models of early Mesozoic Cordilleran evolution. Establishment of a quantitative time frame coupled with interpreted P-T constraints may also allow construction of P-T-time paths.

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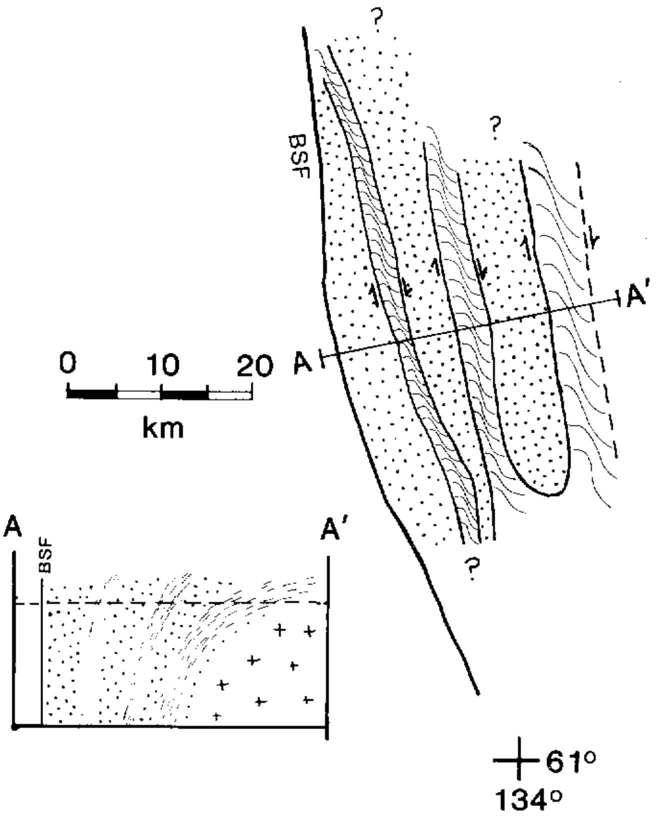

Figure 5. Elongate structural domains are marked by alternating zones of Le1 (dotted pattern) and Le2 (shear pattern). Zones of Le1 record early tectonic shortening overprinted by zones of Le2 which form a regional-scale anastomosing shear zone. Zones of Le2 consistently record right-lateral or top-to-the-north movement parallel to Le2. Cross section displays flattening of foliation to the east and resultant top-to-the-north movement indicated by Le2 kinematic interpretations.

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