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Structural investigation of an exposure of the Teslin Fault, northwestern British Columbia[1]

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Abstract: In the Teslin Lake map area (NTS 104-O), northwestern British Columbia, the steeply oriented Teslin Fault juxtaposes Cache Creek Terrane ribbon chert and wacke against mafic metavolcaniclastic and meta-intrusive greenstone of the Yukon-Tanana Terrane. A section ~250 m wide of washed, almost continuous, exceptional exposure along the Jennings River is oriented at high angle to the southeasterly trending steep fault zone. Structural analysis reveals two episodes of shearing. Dominantly transcurrent, sinistral ((?)transpressive) motion (D_1), indicated by a variety of shear-sense and sense-of-vorticity indicators, was associated with pervasive (ultra)mylonitization in the greenstone package. A younger set of more localized, dominantly brittle(-ductile) structures overprinting D_1 fabrics probably formed during dextral transpression (D_2). D_1 deformation was penetrative in the Yukon-Tanana rocks; however, it did not (significantly) affect the currently exposed Cache Creek rocks. Juxtaposition of these differently D_1-strained rock packages is attributed to D_2.

Résumé : Dans la région cartographique du lac Teslin (SNRC 104-O), dans le nord-ouest de la Colombie-Britannique, la faille de Teslin fortement inclinée juxtapose du chert rubané et du wacke du terrane de Cache Creek à des roches volcanoclastiques mafiques métamorphisées et des roches vertes intrusives métamorphisées du terrane de Yukon–Tanana. Un affleurement exceptionnel presque continu, érodé par l'eau, d'environ 250 m de largeur, se rencontre le long de la rivière Jennings; il est orienté suivant un angle presque droit par rapport à la zone de faille fortement inclinée à orientation sud-est. L'analyse structurale indique qu'il y a eu deux épisodes de cisaillement. Le mouvement (D_1), principalement un coulissage senestre ((?)transpression), dont témoigne une gamme d'indices de la direction du cisaillement et de la vorticité, a été associé à une (ultra)mylonitisation pénétrative de l'assemblage de roches vertes. Un ensemble de structures plus jeunes, plus localisées et surtout cassantes(-ductiles), en surimpression sur les fabriques D_1, aurait été formé au cours d'un épisode de transpression dextre (D_2). La déformation D_1 s'est manifestée de façon pénétrative dans les roches du terrane de Yukon-Tanana, mais elle n'a pas touché de manière significative les roches du terrane de Cache Creek qui affleurent actuellement. La juxtaposition de ces ensembles de roches déformées différemment par l'événement D_1 est attribuable à la déformation D_2.

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[1] Contribution to the Ancient Pacific NATMAP Project

INTRODUCTION

Large-scale, (post-)Late Cretaceous (<85 Ma), orogen-parallel, dextral displacements in the Canadian Cordillera are prediction from known plate motion (Engebretson et al., 1985); significant dextral translation of the outboard portions of the ancient western margin of North America presumably resulted from partial coupling with the adjacent, north-moving, oceanic Kula plate. Orogen-parallel dextral displacements of the order of hundreds of kilometres along the Tintina and Denali faults (e.g. Gabrielse, 1985; Fig. 1) provide independent confirmation for significant dextral translations.

Displaced flood basalts probably derived from the Yellowstone hotspot give an indication of potentially even larger displacements (of the order of thousands of kilometres). During the Cretaceous, North America moved west in the hotspot reference frame (Engebretson et al., 1985), migrating over the Yellowstone hotspot. Mantle-plume-generated flood basalts erupted above the hotspot about 70 Ma (believed to be the Carmacks Group; Johnston et al., 1996), providing a pinning point for measuring subsequent orogen-parallel displacement. Carmacks Group volcanic rocks overlying the Cache Creek Terrane west of the Teslin Fault were subsequently displaced at least 1900 ± 700 km north of the hotspot track (Marquis and Globerman, 1988; Johnston et al., 1996), consistent with anomalously low magnetic inclinations recorded by the flood basalts (Johnston et al., 1996; Wynne et al., 1998). The paleolatitude and paleolongitude of probable Carmacks Group volcanic rocks overlying the Yukon-Tanana Terrane east of the Teslin Fault are currently unclear.

The far-traveled nature of the Cache Creek Terrane and other (more) outboard terranes requires that one or more large-displacement dextral transcurrent faults separate these terranes from autochthonous North American rocks to the east. The Tintina, d'Abbadie, and Teslin faults are the only faults between crust overlain by the Carmacks Group and autochthonous North American rocks that potentially have accommodated large transcurrent displacement (Fig. 1). Net dextral displacement over approximately 450 km has been documented along the Tintina Fault (Roddick, 1967; Gabrielse, 1985); no evidence exists for regionally significant transcurrent motion along the d'Abbadie Fault (de Keijzer et al., 1999; Gallagher, 1999). This leaves the Teslin Fault as the prime candidate to have accommodated most, if not all, of the apparently 'missing' dextral displacement. Its strike length (*see* Fig. 1) also makes it a potentially regionally important transcurrent fault.

A well exposed section ~250 m wide below the high-water line of the Jennings River, Teslin Lake map area (NTS 104-O), shows part of the Teslin Fault (Fig. 2) and provides an excellent opportunity to constrain the fault's kinematic history by 'direct' ground observations. Preliminary structural observations indicate two main episodes of shearing (D_1 and D_2), described below.

RESULTS

Rock types

At the Jennings River exposure, orange- to rusty-weathering, grey ribbon chert and subordinate wacke of the northern Cache Creek Terrane (~120 m structural thickness exposed) are separated from greenstone (~130 m structural thickness exposed) of the Yukon-Tanana Terrane to the east by a tectonically mixed contact zone ~25 m wide containing rocks from both terranes (Fig. 2b). The mixed contact zone comprises ~85% greenstone and ~15% ribbon chert. The ribbon

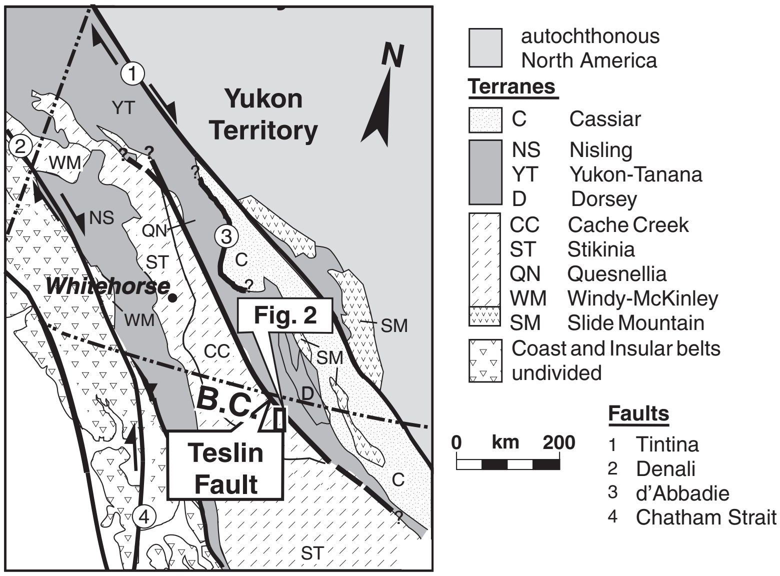

Figure 1. *Generalized terrane map of the Yukon Territory and northern British Columbia.*

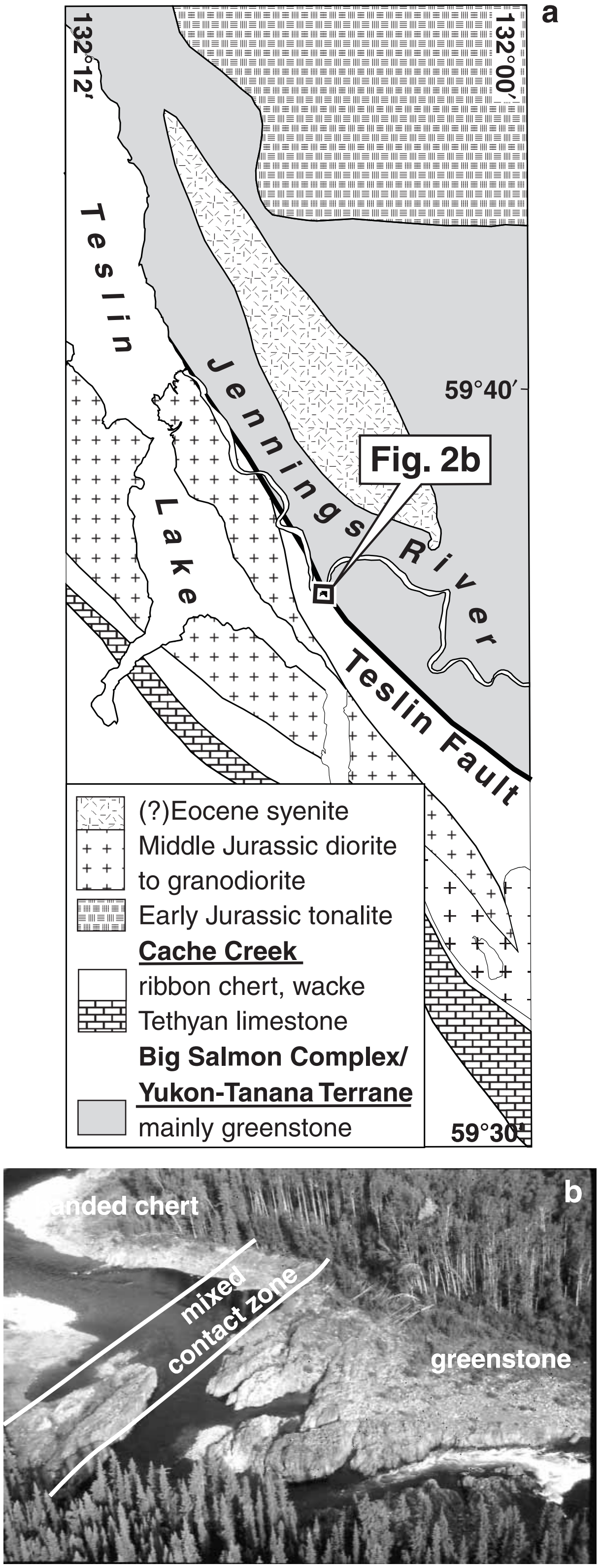

*Figure 2. **a**) Location and regional geology map. **b**) Aerial view of the Jennings River exposure looking 35° down towards 280°. Top left to bottom right field of view is ~225 m.*

chert is made up of 1–4 cm wide chert layers alternating with up to ~1 cm thick argillaceous partings. Pervasive mylonitization (*see* below) generally hampers protolith identification in the greenstone. Nevertheless, protolith textures are preserved in low-strain domains where bright green aquagene lithic lapilli tuff, basalt, and subordinate ash and pyroxene crystal tuff can be identified. Near the eastern limit of the exposure, the greenstone is intruded by a 50–65 cm wide, laterally extensive, weakly foliated, porphyritic quartz-diorite sill. Feldspar and quartz phenocrysts are up to 1 cm and 0.4 cm in diameter, respectively. The sill has discrete and locally somewhat irregular boundaries with surrounding mylonitic greenstone and does not show a visible increase in foliation intensity towards its margins. A strongly foliated, 40 by 80 cm serpentine lens is of uncertain origin. A transposed and dismembered, ~15 cm thick, tan- to pink-weathering, foliated granodiorite body occurs within the greenstone close to the boundary with the mixed contact zone. Variably deformed veins occur throughout the exposure, but are concentrated in the mixed contact zone. They are filled principally with quartz and may also contain carbonate and/or ankerite.

Structure

Mylonitic and ultramylonitic structures (D_1)

Field evidence for pervasive mylonitization and ultramylonitization of greenstone is best seen by the profound grain-size reduction of feldspar porphyroclasts; in many high-strain zones, centimetre- to decimetre-scale, low-strain lenses with a high proportion of commonly angular feldspar porphyroclasts or augen up to 1 cm in diameter are bounded by distinctly finer grained, darker green, more strongly foliated rock with fewer and smaller feldspar augen (Fig. 3a). Some of the smaller augen show leucocratic tails of apparently dynamically recrystallized material (feldspar and/or (?)feldspar breakdown products). Centimetre- to decimetre-scale isoclinal folds are conspicuous where outlined by centimetre-wide leucocratic layers; they display strongly attenuated limbs due to intense transposition (Fig. 3b). Compared with mylonitic greenstone, grains in ultramylonitic greenstone are more strongly comminuted and macroscopic, submillimetre feldspar augen (and/or other minerals) are only sporadically preserved. Ultramylonite zones up to 5 m wide occur throughout the greenstone package and are characterized by straight, millimetre- to decimetre-thick layers of various shades of green (Fig. 3c), many of which can be traced across the entire strike length of the outcrop. The ultramylonite fabric is (nearly) parallel to the mylonitic foliation (together referred to as 'S_m') and its orientation is interpreted as representing the flow plane. On average, S_m in the greenstone strikes towards 130° and dips 75–85° to the southwest (Fig. 4). The spread in the orientation of S_m (Fig. 4) is attributed to back-rotation of S_m about steep axes during D_1 and D_2, C′-type, shear-band formation (*see* Berthé et al., 1979) (e.g. Fig. 3c, e) and to (further) dispersion during D_2 brittle faulting (*see* below).

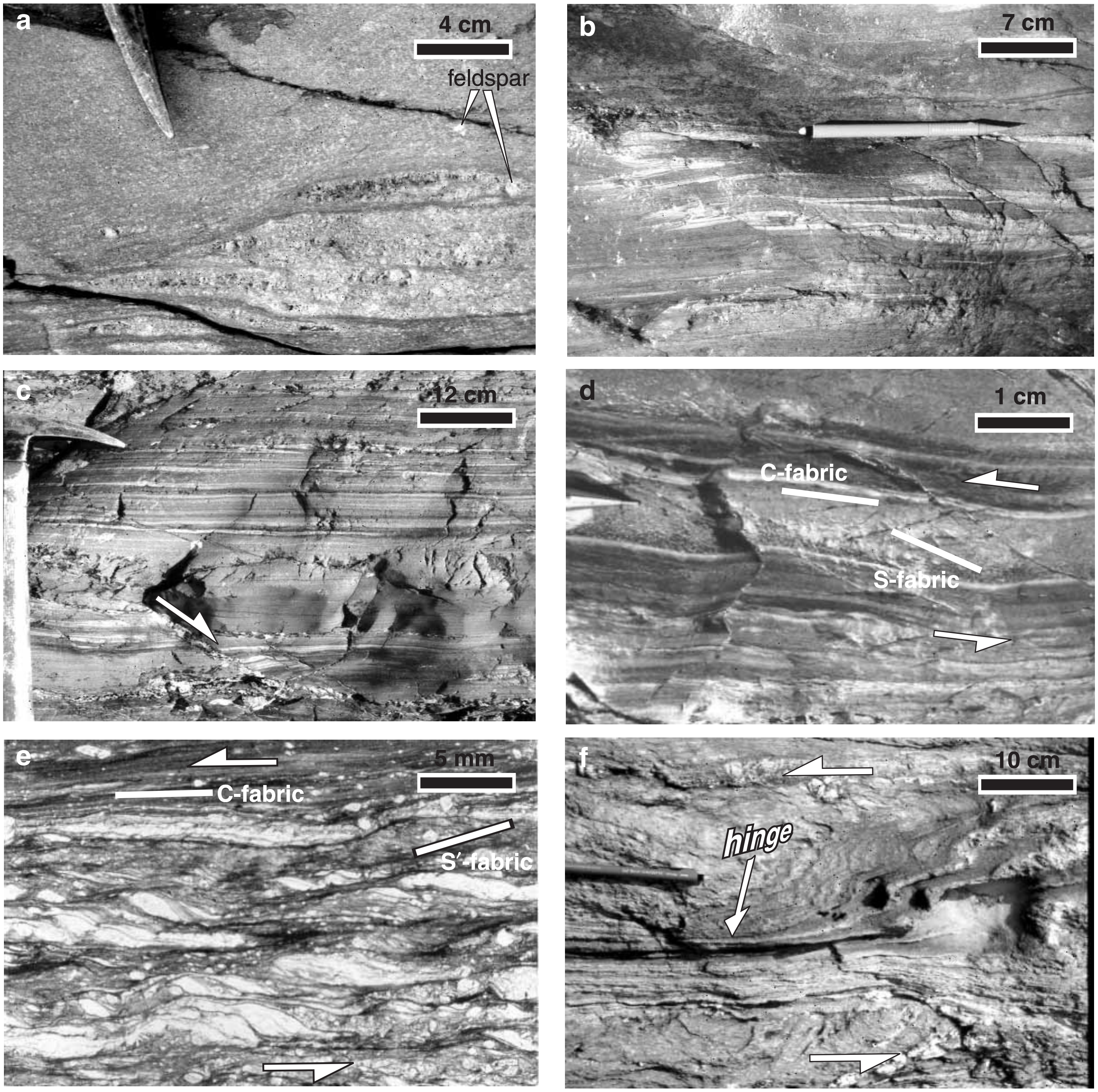

Figure 3. *Mesoscopic (**a–d, f**) and microscopic (**e**) (ultra)mylonitic D_1 structures in the greenstone. Top view; left–right corresponds to ~130°–310°. See text for explanation.*

Mylonite and ultramylonite both preserve a shallowly southeasterly plunging mineral and stretching lineation (L_{sh}), best outlined by amphibole and elongated porphyritic feldspar grains, and a distinctly more steeply plunging mineral and stretching lineation (Fig. 4), defined in some places by the same minerals that outline L_{sh} and in others by elongated lapilli (L_{st}). Both L_{sh} and L_{st} occur in various parts of the greenstone package; however, the detailed spatial distributions of both lineations is not well constrained because of the relatively small number of measurements. L_{sh}, poles to S_m, and poles to various asymmetric planar structures such as sinistral shear bands (described below) plot roughly in a great-circle girdle and define approximately monoclinic fabric symmetry (with the hinges of steep drag folds oriented close to the pole of the girdle). The kinematic significance of L_{st}, and of some lapilli and pyroxene grains that are flattened but do not define a lineation, is unclear at present (*see* ‘Discussion’).

The presence of a variety of macroscopic and ‘hand-lens-scale’ vorticity and shear-sense indicators is consistent (*see* ‘Discussion’) with an interpretation of bulk sinistral movement associated with mylonitization. These include: submillimetre- to centimetre-scale C/S fabrics (Berthé et al., 1979), the S-fabric being defined principally by elongated feldspar and amphibole grains (and locally lithic lapilli) aligned 8–10° clockwise with respect to bounding ultramylonite layers (C-planes; Fig. 3d); submillimetre to 5 m

C′-type shear bands (Fig. 3e; some filled with secondary quartz) oriented at relatively low angles (~5–20°) anticlockwise with respect to S_m; relatively rare, centimetre- to decimetre-scale, intrafolial, steeply plunging, sinistral drag folds of S_m (Fig. 3f) and sinistrally folded quartz veins; quartz veins oriented subparallel to S_m that show asymmetric pinch-and-swell structures (some veins geometrically resemble trails of mica fish); and dextral shears in elongated feldspar grains that are interpreted as antithetic shears formed during bulk sinistral shearing, with anticlockwise rotation of the extending feldspar grains towards the flow plane (*see* Hanmer and Passchier, 1991, Fig. 24). These features have been observed across the entire greenstone exposure. However, they are best preserved in the easternmost ~80 m of the outcrop, which largely escaped D_2 brittle-ductile to brittle deformation.

High (shear) strains similar to those recognized in the greenstone have not been recorded in the Cache Creek ribbon-chert unit. Ductile strain of ribbon chert is recorded by transposition (which involved dismemberment) of bedding in the eastern part of the ribbon chert and wacke exposures. Millimetre-sized phyllitic ‘intraclasts’ in these wackes show a consistent low-angle relationship to transposed bedding surfaces and resemble the geometrical relationship of mica fish and mylonitic fabric (Lister and Snoke, 1984). Away from the mixed contact zone, however, indications of high ductile strains are absent (e.g. no C/S fabrics). Instead, localized brittle-ductile and brittle (D_2) structures predominate (*see* below).

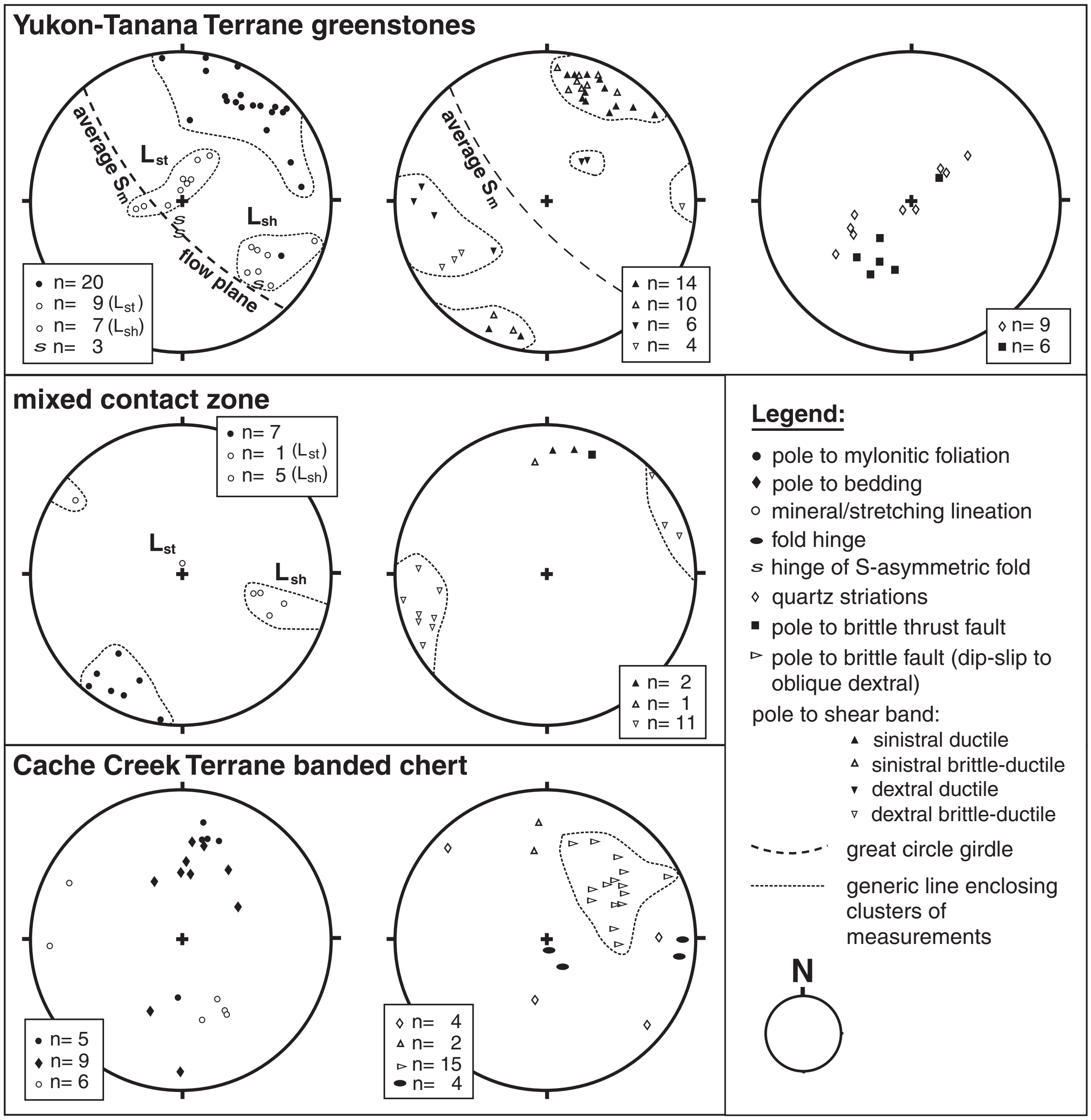

Figure 4. *Lower-hemisphere, equal-angle projections of Teslin Fault structural data.*

Brittle-ductile and brittle deformation (D_2)

A network of discrete brittle-ductile shears, discrete brittle faults, and cataclasite zones, grouped as D_2 structures, is extensively developed in the mixed contact zone and for about 50 m into the greenstone, where it overprints the D_1 (ultra)mylonitic structures (e.g. brittle-ductile, C´-type shear bands overprinting 'ultramylonites (Fig. 3c) with 'sinistral C/S fabrics' (Fig. 3d)). Similar 'more brittle' structures also occur in the easternmost 5 to 20 m of the ribbon-chert unit are best interpreted as belonging to D_2. The intensity of D_2 deformation diminishes abruptly to the northeast and southwest away from this zone. However, discrete faults occur in the ribbon-chert unit up to at least 200 m from the mixed contact zone.

Significant dismemberment/boudinage of the various types of pre-existing layering, observed at scales of up to at least 10 m, took place during D_2 in the greenstone package and the mixed contact zone. There, the most prominent D_2 structures are steeply oriented, brittle-ductile to brittle dextral shear bands (Fig. 5a) and discrete, moderate to vertical dipping, top-to-the-southwest thrusts (Fig. 5b). Thrust faults and abundant late quartz veins spatially associated with these faults preserve well developed, steeply plunging, nearly down-dip striations (Fig. 5c, d). Locally, intricate networks of conjugate sets of shear bands (Fig. 5e) predominate.

The D_2 structures in the ribbon-chert unit are similar to those in the greenstone package and mixed contact zone. However, some differences are apparent: dextral, brittle-ductile shears and brittle faults are typically less planar (Fig. 5f, g) and dip moderately rather than steeply (Fig. 4); striations on (oblique-)dextral, brittle-ductile faults commonly have shallower plunges (Fig. 4); and disharmonic folds and kinks are common in attenuated tips/wedges of fault-bounded lenses (Fig. 5g). Open through isoclinal folds, with decimetre- to metre-scale wavelengths and a well developed axial-plane foliation, occur in the banded-chert unit, but not in the greenstone package. It is unclear whether these folds are a consequence of regional deformation in the Cache Creek Terrane (i.e. 'inherited' structures) or whether they are unique to the Teslin Fault (i.e. presumably D_2).

DISCUSSION

Crustal-scale faults are commonly zones of weakness that may record a complex kinematic history as a result of reactivation (e.g. White et al., 1986). Such is the case for the Teslin Fault. Structural data from the Jennings River exposure are interpreted as recording a change in kinematic frame from largely transcurrent, sinistral, ductile movement (D_1) (probably sinistral transpression with a large component of boundary-parallel motion; *see* below) to oblique-dextral transpression with a substantial boundary-normal shortening component (D_2).

The Teslin Fault — a zone of transpression

Given that the movement vector of most convergent plate boundaries is oblique (e.g. Dewey, 1975) and that complete partitioning of strain into pure dip-slip and pure strike-slip components is uncommon (Jiang and Williams, 1998), the kinematics of steep, orogen-parallel faults is generally expected to be transpressional/transtensional in nature (i.e. expected to follow triclinic deformation paths) (e.g. Fossen and Tikoff, 1998; Jiang and Williams, 1998). Assuming that more outboard plate-boundary forces can be effectively transmitted towards the Cordilleran interior, the Teslin Fault is expected to be a zone of transpression given the oblique movement between the Pacific and North American plates in the Mesozoic (Engebretson et al., 1985, 1992).

D_2 oblique-dextral transpression

Top-to-the-southwest thrusts and the various sets of D_2 brittle-ductile shear bands are interpreted as having formed simultaneously within the same kinematic frame on the basis of the following observations. First, both dextral and sinistral, brittle-ductile shear bands root in discrete thrust surfaces (i.e. continuity exists between them rather than a structural break; Fig. 5d). Second, a spatial relationship exists between the thrusts and the various sets of D_2 shear bands. Third, conjugate sets of shear bands indicate a large component of coaxial shortening (e.g. Williams and Price, 1990), consistent with significant boundary-normal thrusting. D_2 fabrics are interpreted as recording oblique-dextral transpression with slip-partitioning into boundary-parallel, dextral shear, manifested by a predominance of dextral shear bands, and boundary-normal compression, manifested by top-to-the-southwest thrusts and, locally, by brittle-ductile conjugate shears.

Top-to-the-southwest thrusts are not unique to the Jennings River exposure; similar thrusts formed throughout the northern Cache Creek Terrane during emplacement of the Cache Creek Terrane onto the Stikinia Terrane (Gabrielse, 1998). If D_2 thrusts in the Jennings River exposure and the other thrusts are kinematically linked, then the former have to be older than ~172 Ma, the age of plutons that crosscut thrusts along the western margin of the Cache Creek Terrane (Mihalynuk et al., 1992). This, however, is improbable since the Teslin Fault probably truncates Eocene plutons and Late Cretaceous Carmacks Group volcanic rocks to the north. Further, if the D_2 thrusts are the expression of a regional thrusting event, Yukon-Tanana rocks should somewhere overlie Cache Creek rocks west of the Jennings River exposure, but this has not been documented. The D_2 thrusts are more likely part of a transpressive flower structure, especially given the dominance of steep to vertical fault surfaces.

The marked contrast in D_1 strain between the highly strained greenstone and the lesser strained ribbon chert is not believed to be the result of rheological differences. Chert in the westernmost parts of the Jennings River exposure shows a similar degree of strain as chert elsewhere in the Cache Creek Terrane, substantiating the interpretation that the former did not experience the (intensity of) D_1 deformation recorded in the greenstone package. It is proposed that uplift/(?)extrusion

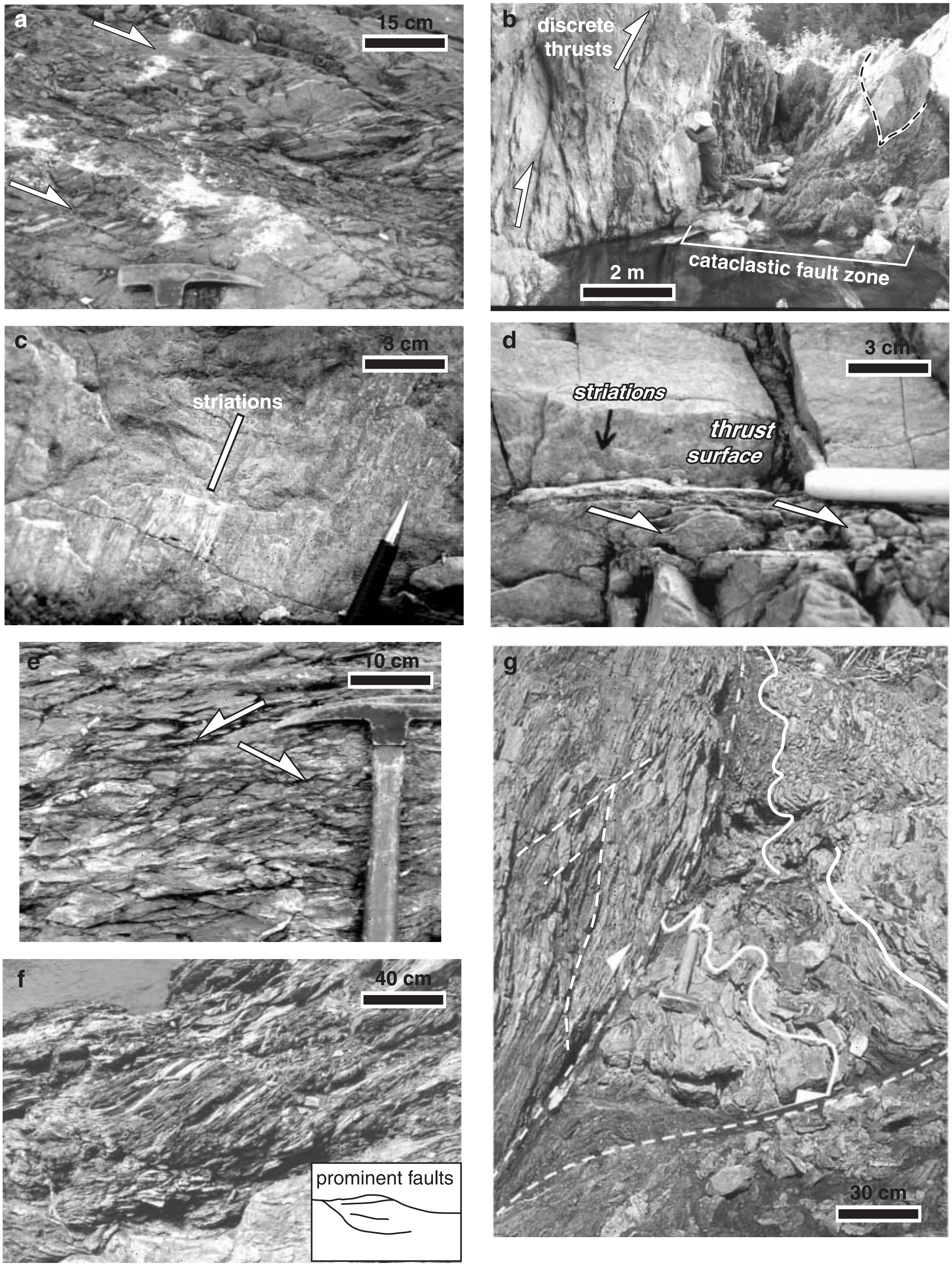

Figure 5. *Mesoscopic D_1 structures in the greenstone (**a–e**) and chert unit (**f, g**). **a, e**) Top view. Left to right corresponds to ~130°–310°. **b**) View looking southeast. **c, d**) View looking northeast. **f, g**) View looking southwest. See text for explanation.*

of highly strained greenstone during D_2 transpression resulted in these rocks being juxtaposed, along steep D_2 faults, against higher crustal level and lower strained Cache Creek chert.

Probable D_1 sinistral transpression

Block rotation at various scales may have occurred in the fault zone during D_2 transpression. Consequently, the current orientations of L_{sh} and L_{st} may differ from their initial orientations. However, L_{sh} and L_{st} are proximal to one another within structurally coherent mylonite zones. This argues against a simple interpretation of L_{sh} and L_{st} being the result of variable rotation of a single D_1 lineation during D_2.

A characteristic of steep transpression zones is the presence of multiple linear fabrics that are typically oriented (nearly) horizontally and (nearly) vertically (defining triclinic symmetry) (e.g. Fossen and Tikoff, 1998; Jiang and Williams, 1998; Lin et al., 1998). These orientations roughly coincide with the pitches of L_{sh} and L_{st}, allowing for some rotation during D_2. If L_{st} formed during D_1, the bulk finite symmetry of the fault zone is triclinic and the deformation path during D_1 may well have been transpressional. It is realized that if L_{sh} and L_{st} formed in a transpressional environment, neither L_{sh} nor L_{st} need coincide with the movement direction of the simple shear component; for example, switching or progressive reorientation of lineation directions is expected to occur during transpression (e.g. Sanderson and Marchini, 1984; Fossen and Tikoff, 1998; Jiang and Williams, 1998; Lin et al., 1998). Nevertheless, it is reasonable to assume that the boundary-parallel displacement vector presumably was close to horizontal (i.e. close to the orientation of L_{sh}), assumming that S_m parallels the boundaries of (this strand of) the Teslin Fault. This is because the steep intersection of the various finite-strain foliations (S_m or C-planes, S- and C´-planes), which approximately defines the vorticity vector in a thinning or transpression zone (Jiang and Williams, 1998), is at high angle to the boundary-parallel displacement vector (e.g. Jiang and Williams, 1998, Fig. 5).

Resolving the flow kinematics and the sense of shear in (transpressional) shear zones is not straightforward (*see* Jiang and Williams (1998, 1999) for general discussion). With our current knowledge, the boundary-parallel shear component during D_1 is reasonably interpreted as (shallowly oblique) sinistral, from the interpretation of a shallow to horizontal, boundary-parallel displacement vector and the predominance of sinistral, mesoscopic, kinematic and vorticity indicators (Fig. 3).

One possible explanation (e.g. Lin et al., 1998) for the presence of two lineations in the greenstone package is that during the initial stages of D_1, a steep lineation (L_{st}) was more dominant (low strains and/or low simple to pure shear ratio). Lineation L_{st} was then reoriented during progressive shear into a more shallow orientation (L_{sh}), perhaps accompanied by new mineral growth, in zones that experienced higher sinistral shear strains and a higher ratio of simple shear to pure shear.

If L_{st} formed during D_2 and is excluded from D_1 fabrics, D_1 fabrics exhibit monoclinic symmetry. However, monoclinic symmetry may also have resulted from sinistral transpression, with triclinic rather than monoclinic movement, if the ratio of simple shear to pure shear was high (>10; Lin et al., 1998).

Unfortunately, only a small portion of the Teslin Fault is exposed and the nature of presumably lesser strained greenstone in the marginal domains of the fault is unknown (e.g. does overall triclinicity of D_1 fabrics, similar to that in the Roper Lake shear zone (Lin et al., 1998), exist?). Interpretation of the overall flow kinematics during D_1 is therefore necessarily speculative.

Regional significance of the structural data

The Teslin Fault penetrates the mantle and juxtaposes crust and mantle provinces of different chemical character, as demonstrated by contrasting isotope characteristics of plutons (Morris and Creaser, 1999) and contrasting mantle xenoliths in Holocene volcanic rocks (Francis et al., 1999). Mylonites and ultramylonites in the fault have a total thickness >100 m. This indicates accommodation of potentially very large transcurrent displacements. The recognition of high-strain D_1 *sinistral* motion, irrespective of whether it was transcurrent or transpressional, has important tectonic consequences. First, it demonstrates that postaccretionary, orogen-parallel faults in the Intermontane and Omineca belts of the northern Canadian Cordillera do not have a ‘simple’ history of dextral transcurrent motion, as has been assumed in the past (e.g. Gabrielse, 1985; Struik, 1993). Second, D_1 documents southward movement of the Cache Creek Terrane relative to the Yukon-Tanana Terrane. This supports results from paleomagnetic studies, which require complex histories of terrane movement (both southward and northward), and therefore the expectation of both sinistral and (subsequent) dextral fault motions.

In contrast to D_1 structures, D_2 structures in the Jennings River exposure do not show the intensity and pervasiveness of fabric development expected with a fault having >1000 km of displacement. However, other conceivably narrow and unexposed strands of the Teslin Fault probably occur in the area, given 1) the strain partitioning during, and localized nature of, D_2 deformation, and 2) the large amount of glacial cover in the region. Consequently, cumulative dextral displacement during D_2 could be large.

Timing of D_1 and D_2 deformation

Timing of D_1 and D_2 deformation is unresolved. The Teslin Fault postdates the deposition of banded chert, which is Toarcian or older elsewhere in the Cache Creek Terrane, but is undated at the Jennings River exposure. The timing of sinistral and dextral transpressive/transcurrent motion along the Teslin Fault must be resolved before the structural data can provide concrete answers to outstanding tectonic questions in the region. For example, do both D_1 and D_2 deformation predate deposition of the Carmacks Group? This is probably the case, given that 1) the Deadman Creek batholith

(~109 Ma) cuts the Teslin Fault in the Teslin Lake map area to the north, providing a minimum age of displacement on the fault (Gordey et al., 1998), and 2) probable Carmacks Group rocks are present on either side of the Teslin Fault (*see* Fig. 1 of Johnston et al. (1996) for detailed distribution). Nearly orthogonal and oblique sinistral convergence occurred between North America and the Pacific plate between the Early Jurassic and the middle Cretaceous (Engebretson et al., 1985). This presumably occurred together with southward displacement (relative to the craton) of certain terranes (e.g. Ave-Lallement and Oldow, 1988; Irving and Wynne, 1991) and is consistent with sinistral motion in the crustal-scale Llewellyn fault zone to the west (Mihalynuk, in press).

Overall dextral oblique convergence between the Pacific plate and the continent took place in Late Cretaceous and Tertiary times (Engebretson et al., 1985) and may have coincided with dextral displacement on the Tintina (Gabrielse, 1985) and Teslin faults (this study). However, south-southwest-directed overthrusting of the Cache Creek Terrane onto the Stikinia Terrane (Thorstad and Gabrielse, 1986; Mihalynuk et al., 1992) points to a period of dextral transpression that began in the Late Toarcian (~180 Ma; e.g. Ricketts et al., 1992), peaked between 174 and 172 Ma, and had ended by 172 Ma (Mihalynuk et al., 1999).

To constrain the timing of motion along the Teslin Fault, two samples were collected for isotopic dating, a transposed, 15 cm wide, granodioritic body that underwent most or all of the sinistral D_1 shearing and a foliated, feldspar-porphyritic, quartz-diorite sill that is believed to postdate at least the high-strain part of D_1 and to have been affected by D_2.

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