KINEMATICS AND STRUCTURAL HISTORY OF BRITTLE DEFORMATION ALONG THE COAST STEEP ZONE NEAR PRINCE RUPERT, BRITISH COLUMBIA

JOHN SINGLETON
Dept. of Geology, Pomona College
Faculty Sponsor: Linda Reinen

INTRODUCTION

The Coast Steep Zone (CSZ) in northern British Columbia and southeast Alaska is a crustal scale, high strain area that underwent ductile shear in the late Cretaceous to early Tertiary. Previous work along the CSZ has focused on high temperature ductile deformation, yet along the trace of the CSZ near Prince Rupert there is also abundant evidence of brittle deformation. Features such as slickenside surfaces, cataclastic rock, and pseudotachylyte suggest that brittle faulting represents an important component of the deformational history in the region. In this study I characterize this brittle deformation based upon paleostress regimes, geographic trends, and fault rock analysis.

GEOLOGIC SETTING

The CSZ to the east of Prince Rupert displays strong, steeply dipping foliation and is defined topographically by the glacially eroded Work Channel lineament (Fig. 1 in Davidson et al., this volume). At the latitude 54-55° N, the CSZ near Prince Rupert lies approximately 240 kilometers east of the Queen Charlotte transform fault and is at the northern end of the offshore Queen Charlotte basin. Carl Tape (Carleton College), Ken Davis (College of William and Mary), and I focused our field work on three main rock units in and around the CSZ: the mid-Cretaceous Ecstall pluton along and to the west of the CSZ, the early Tertiary Quottoon pluton bordering the CSZ to the east, and the early Tertiary Work Channel amphibolite within the CSZ (Fig. 2 in Davidson, et al., this volume).

METHODS

Using a Brunton compass, we measured the strikes and dips of over 300 slickenside surfaces. As a criterion for shear fracture data collection, we only measured surfaces that showed a definable slickenline lineation. The rakes of slickenlines were measured with a protractor. We determined the slip senses of surfaces using slickenside textures and shear steps. The sense of displacement was questionable or unknown on just under half of all the shear surfaces. In addition to the fault surface data collection, we measured the host rock foliation and took a GPS reading at each outcrop. I determined the pressure (P) and tension (T) axes of our entire shear fracture data set with the program "Fault Kin" (Allmendinger, R.W., 1990). P and T-axes are mutually perpendicular to each other and oriented 45° from a slickenline lineation. These orientations roughly correspond to σ_1 and σ_3 directions, respectively. In this study I use P and T-axes to determine the paleostress and thus the kinematic compatibility of the brittle faults in the study area.

OBSERVATIONS AND FAULT KINEMATICS

Brittle deformation is concentrated along the CSZ. Outcrops along the Work Channel Road have a shear fracture density that is roughly five times greater than that observed in the Quottoon pluton (Fig. 1). Outcrops in the Ecstall pluton to the west of the CSZ, where exposure is substantially better than along the Work Channel Road, have less than half amount of faults per meter than outcrops from the Work Channel Road.

Our fault data can be broken down into four principle sets that are kinematically incompatible with each other. The P-axes are particularly important in defining each of these sets. All the fault data show a fairly consistent T-axis orientation that is indicative of an east-northeast and west-southwest trending

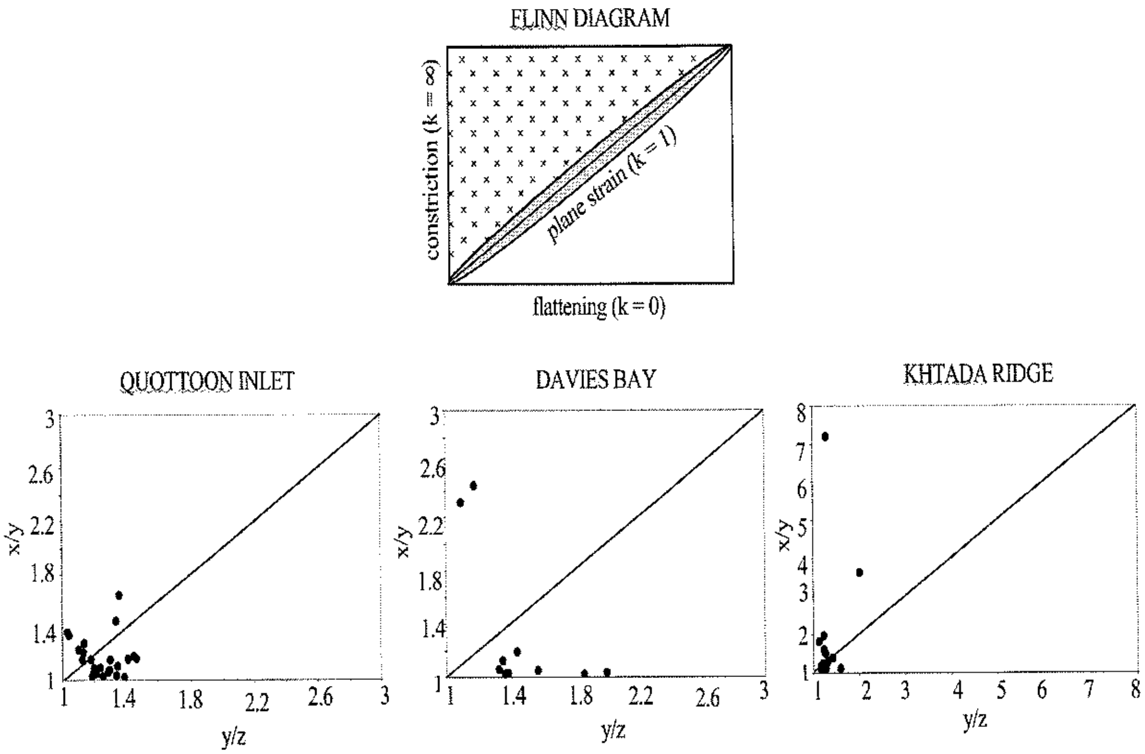

Figure 4. Flinn diagrams representing geometry of foliation deformation for each transect. All values between k = 0 and k < 1 represent a flattening regime, values around k = 1 are plane strain, and values between k > 1 and k = infinity represent constriction.

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minimum compressive stress direction (Fig. 6 in Tape, this volume). Northwest striking, steeply dipping felsic and mafic dikes in the study area (Alvarado, Rodriguez, this volume) indicate a σ_3 direction that is consistent with the T-axes from the fault data.

The most well-defined pattern of brittle deformation can be seen in the set of dextral faults along the CSZ (N=24-33). These faults strike to the northwest, typically dip steeply to the southwest, and show slickenline lineations indicative of dextral to dextral/east-side-up displacement (Fig. 2). Many of these fault surfaces are parallel to foliation planes and are present in at least three different rock types along the CSZ. The dextral movement corresponds to north trending, shallowly plunging P-axes (Fig. 3). We found several dextral/oblique dextral faults within the metamorphosed plutonic rocks in the Work Channel Road and within the Work Channel amphibolite outcrops south of the Skeena River. Along the Work Channel Road the dextral faults commonly have trace lengths of several meters. At the outcrop containing pseudotachylyte (Davis, this volume), almost all the fault surfaces show strike-slip movement. Kinematic indicators at this particular location are poor, but a few faults show clear dextral displacement, suggesting that most of the other strike-slip surfaces are also right-lateral. It is important to note that these dextral faults are found almost exclusively along the trace of the CSZ and are virtually absent in well-exposed outcrops to the east and west of the CSZ.

A second set of brittle faults (N=50-61) is characterized by high angle, west-side-up displacement. These faults strike north to northwest, dip steeply to the southwest, and are found in the rocks along the CSZ and in outcrops in the Ecstall pluton to the west of the CSZ. In outcrops with a strong foliation these faults usually strike along foliation planes to the northwest, most likely representing slip along a pre-existing surface. In outcrops with a less developed fabric, the faults have a more northerly strike. The steeply dipping displacements correspond to west to southwest trending, moderately plunging P-axes (Fig. 4).

A third group of faults (N=54-78) are northwest to northeast striking normal faults. In terms of quantity and size, these structures represent the most important set west of the CSZ. Most of the normal faults strike N ± 20°, dip between 40-70° E, and show steeply plunging P-axes, indicating a near vertical σ_1 direction. Many of the fault zones containing cataclasite and gouge show similar attitudes and normal slip senses, suggesting that the formation of cataclastic rock is related to normal faulting.

A fourth group of faults strike north to northwest, dip moderately to steeply to the northeast, and show reverse (east-side-up) displacements. These faults correspond to a paleostress regime that is opposite of the steeply dipping, west-side-up faults. We found 10-14 of these faults scattered throughout the Quottoon pluton and 5-10 more at one site within the Ecstall pluton. In terms of quantity this set appears to be minor compared to the other groups but represents the only consistent fault data from the Quottoon pluton.

The fault sets described above constitute the majority of the brittle structures we measured, but there are still several shear fracture surfaces that do not fall into these sets. Among the faults not described are sinistral faults of various attitudes, northeast striking reverse/northwest-side-up faults, and low angle normal faults.

FAULT ROCK PETROGRAPHY

In thin section, the rocks from brecciated fault zones show clear evidence of cataclastic flow. These cataclasites are most common in normal fault zones in the Ecstall pluton. Our samples consist of angular fragments of various sizes supported by a fine-grained matrix (Fig. 5). Sharp boundaries between cataclastic zones of differing matrix sizes and clast to matrix ratios suggest multiple episodes of cataclasis occured in these fault zones. Dark, very fine-grained matrices are most likely rich in clays. Broken grains of quartz, feldspar, and epidote are present throughout the zones. Epidote and idocrase are particularly common, most likely occurring as low temperature hydrothermal products. The angularity and wide range of grain sizes exhibited by these minerals suggests that much of the hydrothermal activity was synkinematic with faulting. Small tensional veins filled with interlocking quartz are also common within the fault zones. Along the host rock wall y-shears are often present. Substantial grain size reduction along these y-shears suggests shear was concentrated within these zones.

DISCUSSION AND CONCLUSIONS

The dextral faults along the CSZ represent the clearest pattern of brittle deformation in the region. This zone accommodated dextral, strike-slip faulting sometime after ductile deformation occurred. Although we cannot be certain, it is likely that the formation of pseudotachylyte within the CSZ (Davis, this volume) is related to this dextral motion. Davis (this volume) dated the pseudotachylyte at 30 Ma, so dextral faulting was probably active along the CSZ around this time. This movement is most likely related to the right-lateral, transcurrent plate regime to the west of the study area. Several studies indicate that that this regime was present from the mid-Eocene and on with little change in plate direction (Hyndman and Hamilton, 1991).

There are two possible timeframes during which normal faulting may have taken place. Extension in the early to middle Miocene resulted in the formation of the nearby Queen Charlotte basin (Rohr and Currie, 1997). Widespread normal faulting associated with the basin subsidence accompanied this east-west extension, but many of the basement-involved faults show variable geometries and dips (Rohr and Dietrich, 1991). The normal faults in the Ecstall pluton might be related to this early to middle Miocene extension. An observation that supports this model is that in our study area the normal faults appear to become more important in terms of quantity and size towards the west.

A second possible timeframe for the normal faulting is much more recent. Farley et al. (2001) indicate that intense glacial erosion after 2.5 Ma may have triggered isostatic rebound resulting in the majority of the Coast Mountains uplift. The normal faults observed in the Ecstall pluton may have resulted from this uplift. However, this model fails to explain the lack of normal faulting in the Quottoon pluton. Since the Quottoon is mechanically similar to the Esctall pluton, there is no apparent reason that broad, isostatic uplift would cause brittle deformation in only one of the plutonic bodies. In either scenario, it is likely that the normal faults are younger than the 30 Ma pseudotachylyte.

The relative timing of the major brittle deformation episodes is unclear due to the lack of crosscutting relationships. At a site in the Ecstall pluton east-side-up reverse faults truncate at least three other shear fractures, including a normal fault that strikes to the northwest and dips 45° E. This suggests that the east-side-up faults may have formed after the truncated faults. At an outcrop in the Work Channel amphibolite there is a slickenside surface along a mafic dike that indicates similar east-side-up displacement. The mafic dikes in the region are from the early Eocene (Rodriguez, this volume). These crosscutting relations imply that the east-side-up reverse faults may have formed after the mafic dikes and possibly after the normal faults.

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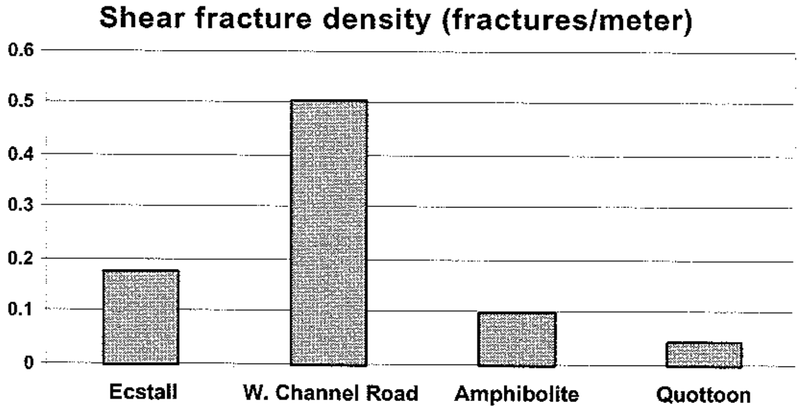

Figure 1. Shear fracture densities in study area. Ecstall = 88 fractures/ 490 meters. Work Channel Road = 71 fractures/140 meters. Amphibolite = 47 fractures/460 meters. Quottoon = 34 fractures/775 meters.

Figure 2. Slickenside surface near CSZ showing oblique dextral displacement.

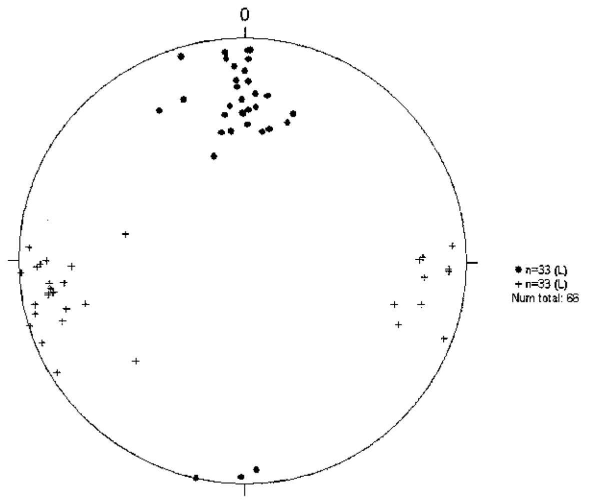

Figure 3. P and T-axes of dextral faults along CSZ. Circles represent P-axes, and crosses represent T-axes.

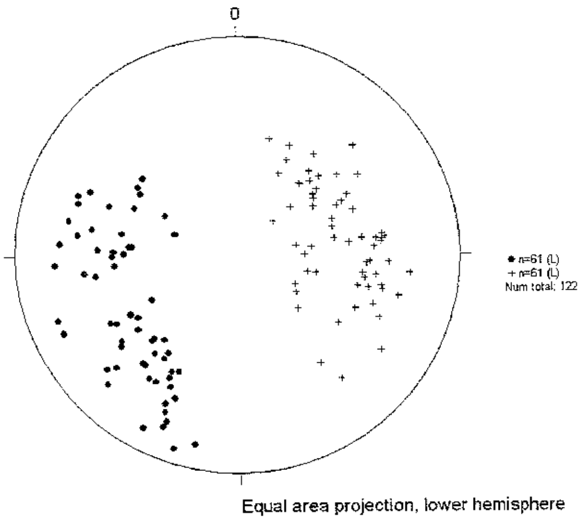

Figure 4. P and T-axes of all west-side-up faults. P-axes (circles) show N and NW striking set.

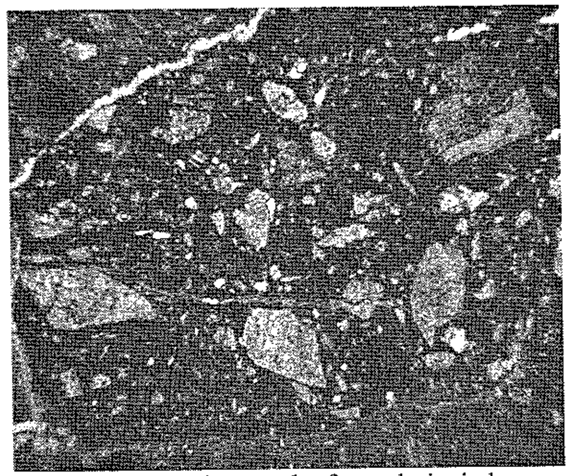

Figure 5. Photomicrograph of cataclasite in low power, plane-polarized light. Angular fragments consist of feldspar, quartz, and epidote.