3-DIMENSIONAL FOLIATION ANALYSIS OF THE QUOTTOON PLUTON AS A PROXY FOR CHARACTERIZING THE EFFECTS OF THE COAST STEEP ZONE, BRITISH COLUMBIA

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INTRODUCTION

In the past 30 years, the coast of British Columbia has become a hotspot for the study of the interplay between accretionary and postaccretionary tectonic processes. Here, westward convergence and terrane accretion, in conjunction with associated plate margin magmatism, has thickened a portion of the crust that was later uplifted to become the present day Coast Mountains (Stowell, H.H., and McClelland, W. C., 2000). Because the magmatism is syntectonic, the intrusions hold excellent structural records of past tectonics. As a result, it is possible to use them to research postaccretionary activity.

In the area around 54-55° north latitude (near Prince Rupert, BC), the principal dispute is over the exact location of the convergence margin during Mesozoic times: did terrane accretion occur at the latitude of present day Baja California with subsequent 3000 km translation NW along the Baja-BC fault system, or were the modern tectonic elements accreted directly onto the coast of British Columbia?

The problem is that researchers have been unable to distinguish a plate boundary structure that could be responsible for the large scale Mesozoic translation. The Coast Steep Zone, due to its position striking NW parallel to the coast and its age ~57-55 Ma (Klepeis et al., 1998), has been labeled as a possible player. Did it have a role as part of the Baja-BC fault system, and if so, what was its role?

REGIONAL GEOLOGY

Around Prince Rupert there are four NW-SE trending accretionary belts (Crawford, et al., 1999). One of these belts, the central belt, or Central Gneiss Complex, is composed of 80-49 Ma plutons of the Coast Plutonic Complex and associated high-grade metamorphic rocks that coincide with the Coast Mountains. The region experienced crustal thickening, and formation of major faults, such as the Coast Steep Zone, during convergent tectonics in Cretaceous time (Klepeis et al., 1998).

The Coast Steep Zone is a crustal scale structure forming the border between the western and central belts. It trends NW-SE for nearly 800 km along the coasts of British Columbia and Alaska and is characterized by vertically foliated mylonites and augen gneisses with near vertical lineations. The zone itself sits within the Work Channel, a topographic feature corresponding with the steep zone, and is therefore poorly exposed. However, it can be studied by examining its effects on the surrounding rock, such as the Quottoon Pluton (58-55 Ma).

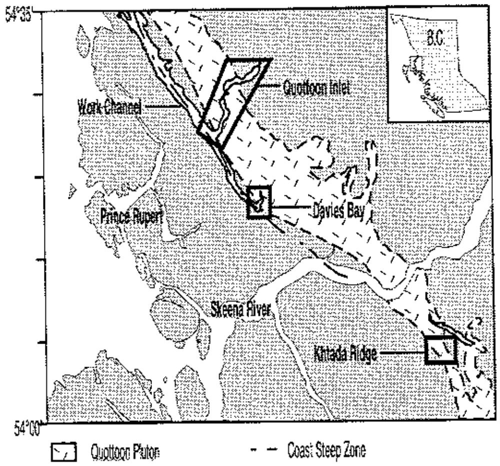


Figure 1. Regional map indicating study traverses in northwest British Columbia.

The Quottoon Pluton, which sits within the Central Gneiss Complex, was intruded along the NE boundary of the Coast Steep Zone. It parallels the Work Channel and continues south of the Skeena River.As of yet, the surface expression of the steep zone has not been identified directly south of the Skeena River, but it is known to continue through that area. Due to the pluton's elongate form and petrologic homogeneity, it provides an excellent source for study to further understand the Coast Steep Zone.

METHODS

Field work for this project included examining the Quotton Pluton along 3 cross-strike traverses, and noting changes in foliation intensity and geometry, and grain size across strike (Fig. 1). The first site was Quottoon Inlet, off of the Work Channel. Because the inlet runs perpendicular to the strike of the Quottoon Pluton, it provides excellent access for a transect across the entire pluton. At this location the Quottoon Pluton borders on the Coast Steep Zone, and thus in traversing across strike, it is possible to note changes in the rock fabric most likely caused by deformation in the steep zone. The second site was Davies Bay. Because this entire inlet is within the area of the pluton most affected by the steep zone, it provides supplemental information to that collected near the steep zone in Quottoon Inlet. The third site was a ridge south of the Skeena River by Khtada Lake. Because this ridge is within the Quottoon Pluton and along strike with the Coast Steep Zone, it was a good place to search for the continuation of the steep zone south of the Skeena River (Hutchison, 1971). Oriented samples were collected, and foliation and lineation attitudes were recorded. The foliations striked mostly NW and were steeply dipping to the NE, and the lineations were steeply plunging.

In the field I observed that the Quottoon Pluton changed from bands of elongate, aligned amphiboles and biotites near the steep zone, to more distributed, equant amphibole and biotite crystals showing a preferred orientation farther away from the steep zone. In the lab, I attempted to quantify these changes in foliation intensity, as well as changes in grain size, through the use of an NIH Imaging program (e.g. Davidson, et al., 1996). NIH Image enables one to calculate the autocorrelation function (ACF), which provides the data needed to calculate quantitave foliation intensities. The ACF represents the degree to which the minerals are aligned with one another, and can be used to determine foliation intensity. A best fit ellipse is then fitted to the ACF diagram and can be used to calculate the ellipticity and grain size (ellipticity = minor axis/major axis; grain size = sqrt.(major axis*minor axis). In order to get a 3-dimensional view of the regional foliation, each sample was cut along two orthogonal planes. One was cut parallel to lineation and perpendicular to foliation, and the other was cut perpendicular to lineation and perpendicular to foliation. I then used a table scanner to enter the samples into the program and calculated the ACF to support my findings in the field.

RESULTS

Foliation Intensity

The ACF ellipticity can be used as a proxy to quantify foliation intensity. With the calculations, the ellipticity will fall between 0 and 1, 0 meaning complete correlation (strong fabric), and 1 indicating no correlation (weak fabric). The foliation in Quottoon Inlet and Davies bay at the orientation parallel to lineation, shows a definite trend from low ellipticity (high intensity) to high ellipticity (low intensity) within the first 4 km of the steep zone (Fig. 2a). Values are ~.6 closest to Work Channel and ~.9 at about 4 km away. At 4 km the fabric ellipticity plateaus at around .8 and continues as such throughout the rest of the pluton. This confirms field observations that the area closest to the steep zone was more strongly foliated than the areas farther away from the steep zone. On Khtada Ridge, however, the foliation intensity parallel to lineation shows no trends. It varies between .25 and .8 (Fig. 2a).

In the orientation perpendicular to lineation, the ellipticity in Quottoon Inlet and Davies Bay remains high (low intensity) ~.8 (Fig. 3). At about 1.5 km from the steep zone, however, this value jumps down to .5, indicating an area of stronger foliation intensity. On Khtada Ridge, once again, there is no obvious trend.

Total Foliation Intensity

The total foliation intensity in three dimensions can be examined with a D value. The D value equals: $[(\ln x - \ln y)^2 + (\ln y - \ln z)^2]^{1/2}$. It can be calculated from the Flinn Diagram by measuring the distance between the plots and the origin: the further the plots are from the origin (higher D values), the greater the intensity. In Quottoon Inlet and Davies Bay the intensity shows a general decrease moving away from the steep zone, while on Khtada Ridge the intensity varies across the transect.

a

2a

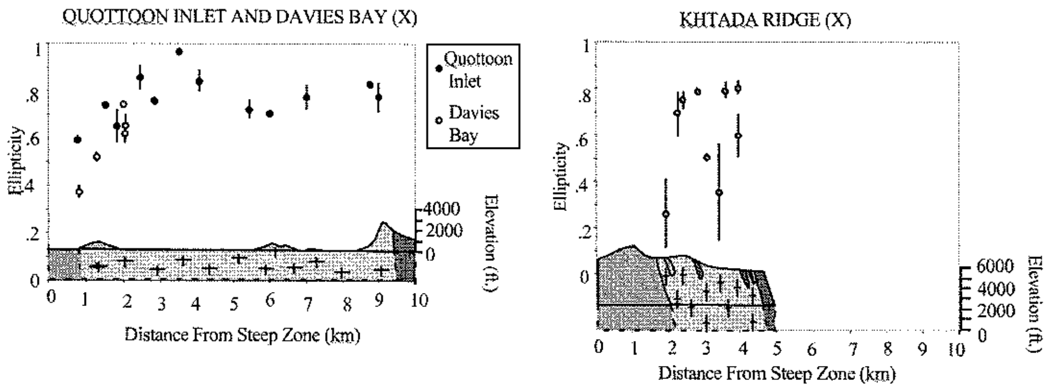
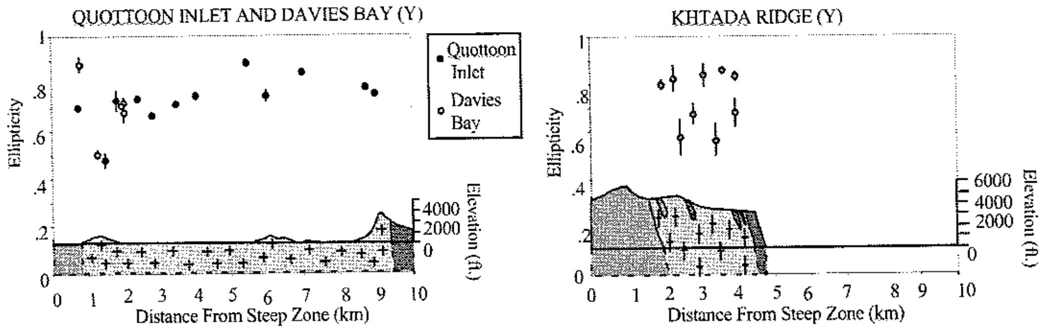


Figure 2a,b. Graphs showing ACF ellipticity as a function of distance from the steep zone in the directions a) parallel to lineation and perpendicular to foliation, and b) perpendicular to lineation and perpendicular to foliation. As ellipticities increase, foliation intensity decreases. Cross sections are of Quottoon Inlet and Khtada Ridge.

2b.



GEOMETRY

The geometry of the strain recorded along the Coast Steep Zone can be evaluated through the use of Flinn Diagrams. Flinn Diagrams allow for three dimensions to be plotted in two-dimensional fields by using ratios of the principal strain axes. The region of the graph that the data plot falls into to will determine whether the strain can be attributed to flattening, plane strain, or constriction. These diagrams can also be represented in terms of K values. The K value is equal to: $\ln (x/y)/\ln (y/z)$, where x equals the maximum strain axis, y equals the intermediate strain axis, and z equals the minimum strain axis. When the K values are between 0 and around 1, the type of strain is flattening, around 1, it is plane strain, and from greater than 1 to infinity represents constriction. On Khtada Ridge, the strain is mostly in the field of plane strain and constriction (Fig. 4). Moving northward to Quottoon Inlet and Davies Bay, the strain shifts towards flattening. There are a few samples that show evidence of more constriction, but for the most part all strain was flattening strain. This finding is consistent with the virtual absence of kinematic steep sense indicators in the field.

CONCLUSION

In map view the Quottoon Pluton is elongate in shape, bounded on its western margin by the Coast Steep Zone. Having preferentially intruded along this regional structure, it was subsequently deformed in response to steep zone movement. The flattening fabric of the Quottoon rocks adjacent to the Work Channel, intense near and diminishing away from the Coast Steep Zone, suggests that the foliation developed in response to deformation.

In the northwest along the Work Channel there is an obvious macroscopic change in foliation from mafic and felsic bands of aligned minerals in the SW to distributed, preferentially oriented, mafic minerals within a more homogeneous rock mass in the NE. The fabric analysis supports the field observations with highest calculated intensities near the steep zone. More distal portions of the Quottoon intrusion have moderately weak foliation intensities, but their development through flattening strain suggests they are also related to regional deformation along the Coast Steep Zone.

Comparable intensities of foliation existed throughout the Khtada Ridge traverse, but neither field observations nor quantitative calculations showed a systematic increase in foliation intensity on the SW side. Rather, the intensities are somewhat uniform and comparatively low. Furthermore, Flinn diagram analysis shows the fabric to have developed by constriction. While we know the Coast Steep Zone continues south of this area, these findings suggest that its effects on the surrounding rock are discontinuous along strike of the Quottoon Pluton.

Overall, it can be determined that the Coast Steep Zone may be characterized by steep foliations which vary in intensity along strike, or may have translated deformation to a parallel system in the area just south of the Skeena River.

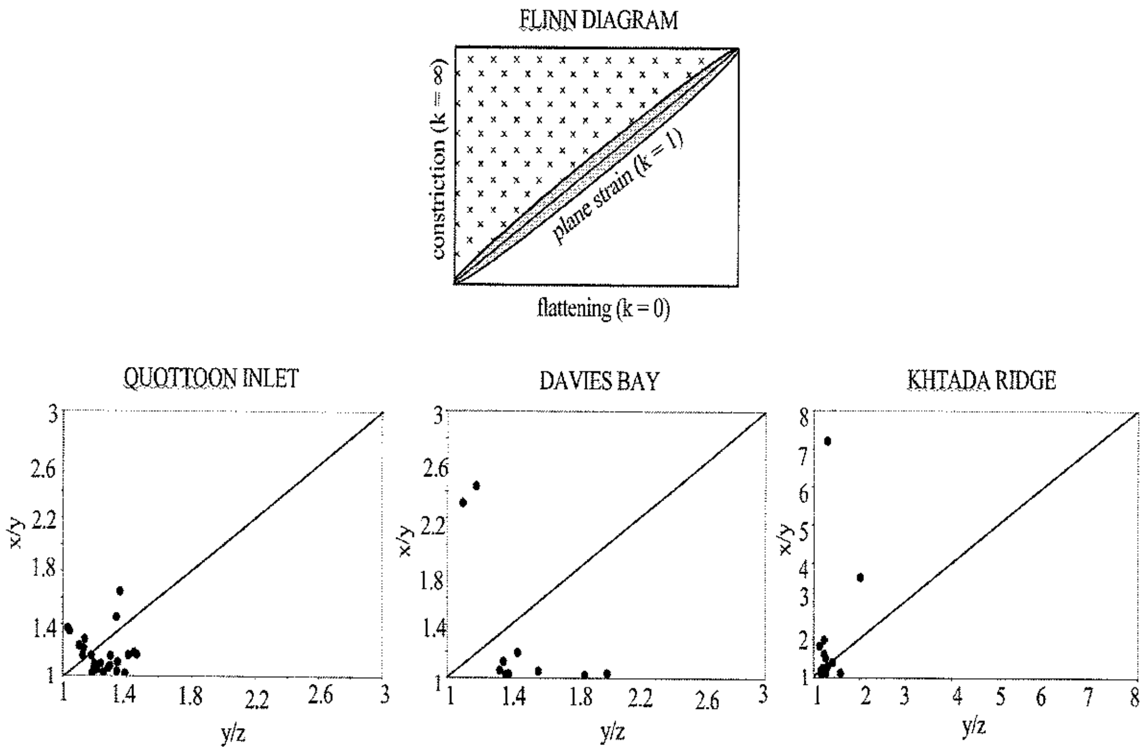


Figure 4. Flinn diagrams representing geometry of foliation deformation for each transect. All values between k = 0 and k < 1 represent a flattening regime, values around k = 1 are plane strain, and values between k > 1 and k = infinity represent constriction.

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

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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