KINEMATICS OF THE PRINCE RUPERT SHEAR ZONE, BRITISH COLUMBIA

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INTRODUCTION

The history of metamorphism and deformation for the Prince Rupert - Skeena area in British Columbia, Canada, has remained controversial for the past two decades. There are several discrepancies among researchers in terms of the local, as well as the regional geology. The purpose of this study is to provide an in depth kinematic analysis of four small islands off the coast of Prince Rupert (Figure 1). The metamorphism and deformation for these rocks is dated at 90 +/- 1 Ma, based on Argon dates obtained from hornblende in the adjacent Smith Island pluton, which cuts the surrounding metamorphic rock (Crawford et al, 1987). This project has developed a working model for the mechanisms of deformation within the rocks that will explain the local geology. This model is based upon interpretations of field work including an analysis of structure data, analysis of meso and micro scale kinematics, and a vorticity analysis.

The regional geology of the Prince Rupert - Skeena area has been divided into three separate belts based upon tectonic boundaries. These different divisions are defined as the Western Metamorphic Belt, the Central Belt, and the Eastern Belt (Crawford et al., 1987) (Figure 1). The area of focus for this study was the Prince Rupert Shear Zone, located within The Western Metamorphic Belt (Figure 1). Previous studies of this area stated that an inverted metamorphic sequence could be observed where the rocks occupying the structurally higher positions toward the east were of higher metamorphic grade (Crawford et al., 1987). This inverted metamorphic sequence was explained by tops to the west thrusting that brought packets of higher grade rocks from deep within the crust over the lower grade rocks (Crawford et al, 1987).

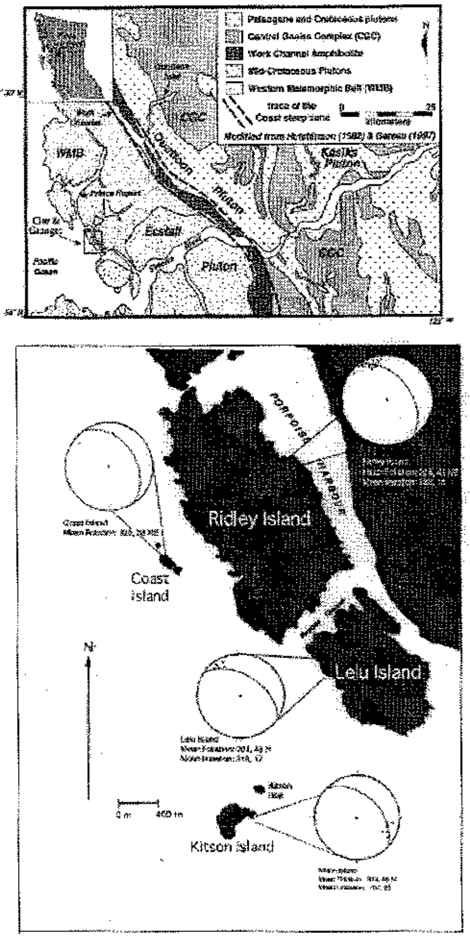
RESULTS

The four islands off the coast of Prince Rupert that were analyzed were, from west to east, Kitson Island, Coast Island, Ridley Island, and Lelu Island (Figure 2). Kitson Island is comprised of weakly foliated, interbedded mafic and felsic metavolcanics. These rocks have a mean strike and dip of 314, 45 N (Figure 2.) A mean amphibole lineation shows a trend and plunge of 107, 25 °. Coast Island is located approximately 500 m west of Ridley Island, and is comprised of strongly foliated marble units interbedded with rusty schists. The mean strike and dip for these foliation planes is 329, 38 NE (Figure 2.) A mean lineation value is not given due to inaccuracy of the measurements.

Ridley Island is the largest of the islands within the field site, covering roughly five square kilometers. It's orientation is parallel to the direction of the mean foliation, which strikes and dips 324, 45 NE. Several mineral lineations were measured, giving a mean lineation of 338, 16 °. Directly to the south east of Ridley is Lelu Island; the second largest island in the field site covering about 2.5 km^2. Lelu Island has a mean foliation that measures 304, 48 N, and a mean lineation of 318, 17 ° (Figure 2). Though these two islands are located parallel from northwest to southeast, the stereonet data shows a bending of the foliation planes so that the planes begin to dip to the north approaching the southeast tip of Lelu Island. These islands are composed of rusty weathering, muscovite +/- biotite +/- garnet +/- amphibole schists with minor zones of amphibolite and micaceous quartzite (Hutchison, 1982.)

The structure data for these four islands shows that there were strike slip motions with a small dip slip component, defined by the gentle plunge of the mineral lineations. Kinematic indicators observed in the field should be able to give a sinistral or dextral shear sense for the motion on the fault, however there were no left or right handed indicators that were visible on Kitson in either a meso or micro scale. Several instances of boudinage were seen in the field, however boudined quartz and epidote veins showed sigma 3 to be parallel to foliation. The thin section analysis also yielded no kinematic indicators.

The actual fault motions cannot be determined for Coast Island due to the lack of an accurate lineation measurement. Boudined quartz veins seen on an outcrop scale showed rotations to the left and to the right making a



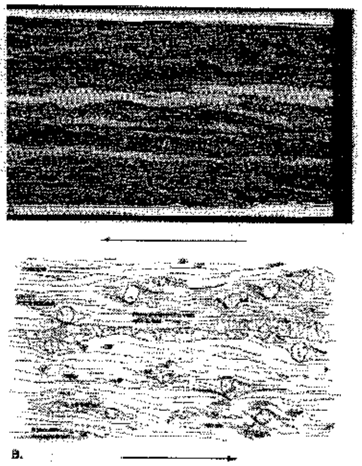
shear sense indeterminable. Similar kinematics were visible in thin section for the study of garnet porphyroblasts. The foliation is seen to wrap around the garnet porphyroblasts, and some grains show formation of pressure shadows. These pressure shadows are poorly developed and give indications of sinistral and dextral shear.

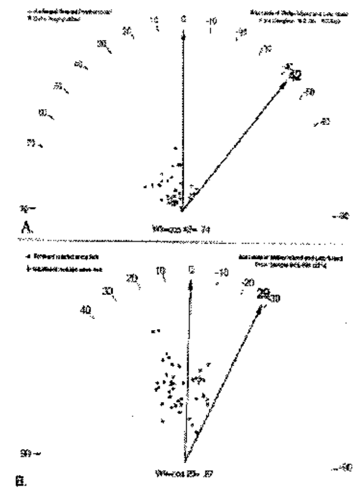
Kinematic indicators viewed in the outcrop scale on Ridley and Lelu Islands consistently showed sinistral

Figure 1(above). Location map and regional map of the Prince Rupert-Skeena area showing location of field site.

Figure 2(below). Map of Ridley, Lelu, Coast, and Kitson islands showing stereonet data. The great circle is the mean foliation, and the poles are the lineations.

shear. Boudinage of several quartz veins observed within the schists showed a stepping up to the left in comparison to the foliation. The individual quartz boudins and cm scale garnet porphyroblasts were rotated with sigma-like and delta-like tails showing sinistral shear. The thin section analysis showed a dominating trend of left handed indicators, however some antithetic indicators were visible. The rock layers containing mm-cm scale garnets showed syntectonic growth of garnet porphyroblasts with wrapping foliations and pressure shadows forming sigma and delta tails (Figures 3a.) The majority of the porphyroblasts have sinistral tails, however some of the garnet porphyroblasts do exhibit dextral tails, which are antithetic to the findings in the field (Figure 3b). Several other textures were observed in thin section, including mica fish, and S-C fabrics. The S-C fabrics are defined by the orientation of the biotites. The C-planes are parallel to the foliation, and the S-fabrics are inclined to the left





showing sinistral shearing. Large mica fish are located on the eastern side of Ridley and Lelu, and show left handed motions. The majority of mica fish are inclined toward the left and have some development of pressure shadows, yet some mica fish are inclined to the right which contradicts the findings of the field work.

Figure 3 (left) A) Scanned image of BCL-35 thin section in single polarized light. B) map of BCL-35 thin section showing foliation, and rotated garnet and staurolite porphyroblasts with a sinistral shear sense.

Figure 4 (right) A) Rf and theta values obtained from rotated garnet porphyroblasts for the west side of Ridley and Lelu Islands, plotted ona hyperbolic net. The angle between the two eigenvectors is 42 degrees; Wk=cos 42 = .74. B) Rf and theta values obtained from mica fish for the east of Ridley and Lelu Islands, plotted on a hyperbolic net. The angle between te two eigenvectors is 29; Wk=cos 29 = .87

VORTICITY ANALYSIS

The kinematics viewed in thin section from Ridley and Lelu show that the dominant trend for a shear sense is sinistral. However there were some indications of dextral structures evidenced by right handed sigma porphyroblasts and mica fish inclined to the right. The likely explanation for these discrepancies is inhomogeneous strain, or general shear. In order to quantify how much pure versus simple shear was exerted on the rocks, a vorticity analysis was done based on technique explained in Simpson and De Paor, 1997. Two separate analysis were performed; one for the west side of the islands and the other for the east. The analysis for the west side of the islands was done by measuring garnet porphyroblasts from thin sections. The distinction between forward (in the direction of the sense of shear) and backward (counter to the direction of the sense of shear) rotated clasts needed to be made in order to perform the analysis. The resulting voricity number for the west side of Ridley and Lelu was .74, showing that the rocks in fact have experienced general shear (Figure 4a.)

The vorticity analysis performed on the eastern side of Ridley and Lelu was done measuring mica fish. Analysis of garnets on the east of the islands was not possible since they have been defined as post-tectonic in nature with no kinematic implications. They therefore cannot be distinguished as being forward or backward rotated. The mica fish however demonstrated inclinations from foliation that were sinistral and dextral, and therefore could be used in the analysis. The resulting vorticity number for the east side of Ridley and Lelu was .87, showing that the rocks have experienced general shear (Figure 4b.)

Although the values obtained from the two vorticity analysis are different, the implications of both results support general shearing as the mechanism for deformation. The difference in vorticity number is likely due to the different crystal geometries of the biotite and garnet crystals, and how those geometries affect the response to shearing. The different vorticities do not necessarily support differences in shearing between the west and east sides of the islands. In order to determine the significance of the two vorticity values, further studies would need to be conducted in order to show the different ways in which garnets and biotites react to shearing. If they respond differently, the interpretation of the vorticity values can be accepted as showing general shear. If they respond similarly, then the vorticity values can be accepted as showing a changing trend in the general shear mechanism that is increasing in simple shear towards the east of the islands. This interpretation is not however supported by the results observed in thin section or in field work, and the accepted result for the vorticity analysis in this study is that the rocks have undergone deformation by general shear.

DISCUSSION AND CONCLUSIONS

The results of this study show that the rocks on the islands of Ridley, Lelu, Coast, and Kitson have been deformed by general shear. This is evidenced by the presence of a vast range of kinematic indicators showing both plane strain and inhomogenious strain. While the behavior of particle movements in a pure shear regime make the formation of asymetric tails possible, the consistency of sinistral kinematic indicators in the outcrop scale on Ridley and Lelu refute that explanation. The vorticity analysis provides a quantitative means of showing that the shearing is in fact general shear, with fairly equal proportions of pure and simple shear.

This model of general shear with oblique slip fault motions does not agree with the Crawford model of tops to the west thrusting. The lineation directions, taken into account with the kinematics indicate that the fault motions were sinistral oblique-slip normal faulting. The age dates provided for the formation of the inverted metamorphic sequence due to thrust faulting are based on Ar 40/ Ar 39 hornblende dates between 90-85 Ma (Stowell and Goldberg, 1997). The age dates for this deformational event are younger than the dates given for the metamorphism of the Prince Rupert area. The sinistral oblique-slip normal faulting that is present therefore disproves the theory of tops to the west thrusting for the area covered within this study. Had the dates given for the thrusting been older than the deformation recorded in the Prince Rupert area, the shearing could have been explained as overprinting the earlier deformational event. It does not however disprove the possibility of tops to the west thrusting within the western metamorphic belt. Future work will need to be done to cover a wider transect from west to east to determine if the inverted metamorphic sequence is a result of contact metamorphism from the extensive regional pluton emplacement, or if their are a series of westward thrusts.

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