

DEFORMATION HISTORY OF THE COAST STEEP ZONE, PRINCE RUPERT, BRITISH COLUMBIA

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INTRODUCTION

The Coast Steep Zone (formally referred to as the Coast shear zone) is a world-class, crustal-scale structure that extends for at least 800 km along the western boundary of an exhumed Cretaceous to early Tertiary magmatic arc in British Columbia and southeast Alaska (Fig. 1). At the latitude of Prince Rupert (54-55° N), the magmatic arc (Paleogene arc in Fig. 1) separates the Insular superterrane, accreted to North America in the Cretaceous, from Stikine and other previously accreted terranes. An outstanding question in Cordilleran tectonics is the latitudinal position of the Insular terrane at the time of collision (e.g. Cowen et al., 1997; Hollister and Andronicos, 1997). Mobilist models, based mainly on paleomagnetic data, suggest that the Insular terrane accreted at the latitude of present-day Baja, California and was translated 3000 km north along the coast between about 90 and 50 Ma (Bouge et al., 1995; Irving et al., 1996). However, many geologic studies suggest that coastwise displacements were minimal (e.g. Monger et al., 1994). As discussed by Cowen et al. (1997), if large scale northward translations took place in the North American Cordillera, then a structure, or set of structures, of the correct age should be present along the inboard margin of the Insular terrane. An obvious candidate for such a structure in British Columbia is the Coast Steep Zone (CSZ). However, Cowen et al. (1997) correctly points out that the relatively few kinematic studies of the CSZ show that the most recent motions within the zone are dip slip, and therefore incompatible with large strike-slip motions. In addition, ductile dip-slip motion within the CSZ near Prince Rupert post-dates the intrusion of the 58 Ma Quottoon pluton (Roth, this volume), making these structures too young to have accommodated much of the late Cretaceous strike slip motion. Therefore, if the Baja, British Columbia fault zone existed, it was either overprinted by later deformation along the CSZ, or is/was present in the core of the Paleogene arc between Stikine and the Insular terrane (Fig. 1).

REGIONAL GEOLOGY AND THE COAST STEEP ZONE

The Coast Mountains near Prince Rupert are defined by three tectonometamorphic units: the Western Metamorphic Belt (WMB) and associated Mid-Cretaceous plutons, the Central Gneiss Complex (CGC) and its associated Late Cretaceous and Paleogene plutons, and the low-grade metavolcanic and volcanoclastic rocks of the Stikine terrane (Figs. 1&2). The WMB contains well-foliated greenschist to upper amphibolite facies metamorphic rocks that dip moderately east. The metamorphic field gradient is inverted in that the lowest grade rocks occur in the west, below the high-grade rocks in the east (Crawford et al., 2000). In the east, the 91 Ma Ecstall pluton appears to have intruded these rocks during regional metamorphism and deformation (Crawford et al., 2000; Butler et al., in review).

The CGC is characterized by well-foliated upper amphibolite to granulite facies orthogneisses and paragneisses intruded by synkinematic tonalite and diorite plutons. Throughout the CGC, zones of gently to moderately north dipping foliation with down dip lineations are separated by steeply east-dipping to vertical zones with steep N-NW trending lineations (Andronicos et al., 1999; Hollister and Andronicos, 2000). The Coast Steep Zone (described below) and 58 Ma Quottoon pluton define the western margin of the CGC. The Shames River detachment zone marks the eastern margin of the CGC which is intruded and obscured by 55-53 Ma plutons (Heah, 1991).

The Coast Steep Zone (CSZ) is a 2-5 km thick zone of well-foliated steeply east dipping to vertical upper amphibolite facies rocks that separates the Western Metamorphic Belt from the Central

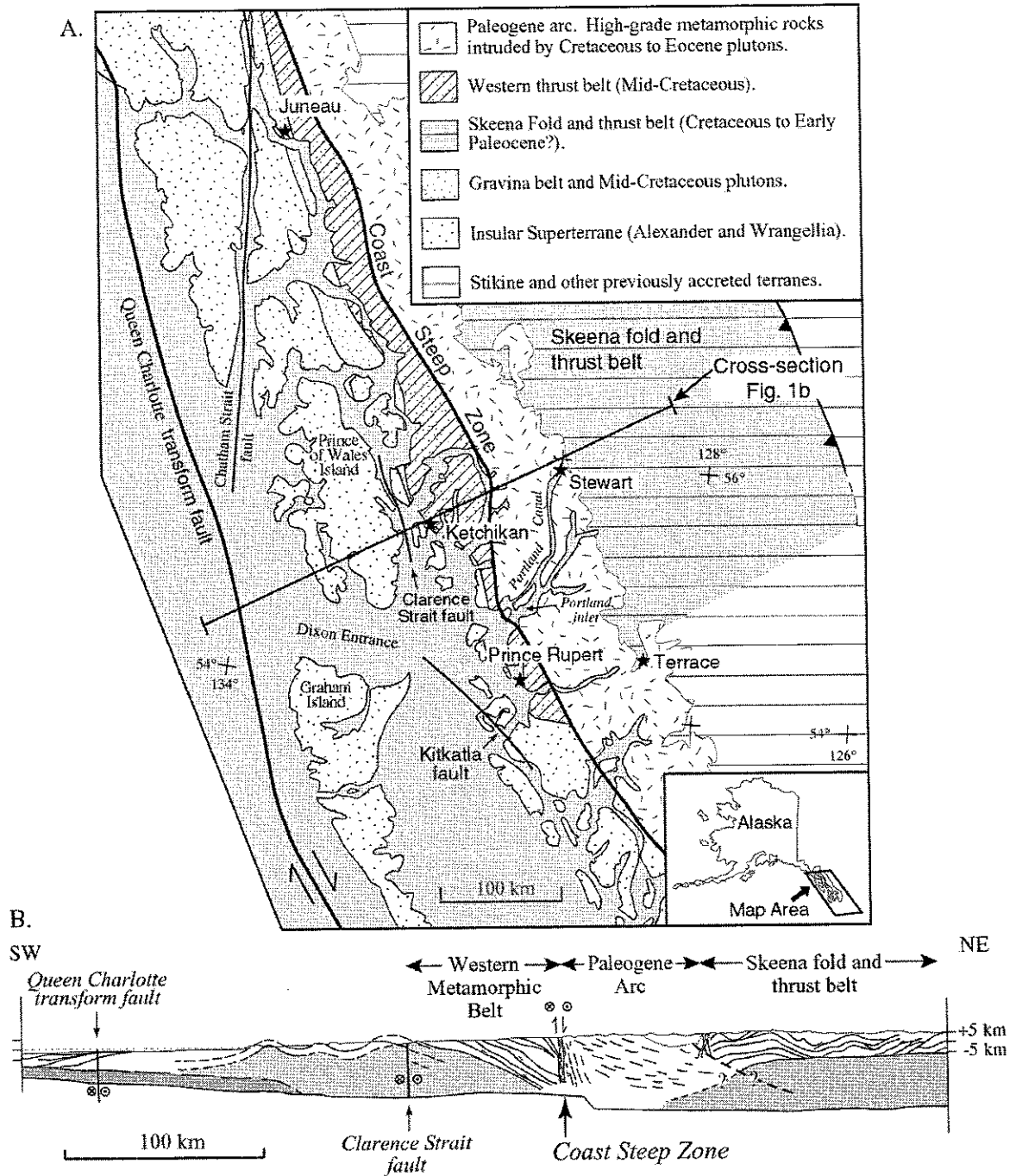


Figure 1. a) Tectonic map of southeastern Alaska and northwestern British Columbia. b) Simplified cross-section showing the major tectonometamorphic and tectonostratigraphic units of the Coast Mountains.

Gneiss Complex (Fig. 2). Nomenclature of this enigmatic structure has evolved over the past 23 years since Brew and Ford (1978) used the term “Coast Range Megalineament” to describe an obvious geomorphic lineament that can be traced from north of Juneau, Alaska into southern British Columbia (Fig. 1). More recently, Klepeis et al. (1998), Andronicos et al. (1999), and most of the contributions in Stowell and McClelland (2000) use the genetic term “Coast shear zone.” This implies that a strain gradient is present across this zone of steeply dipping rocks, with the highest strains recorded in the shear zone. However, there are no obvious strain markers or consistent strain gradients in these rocks that show that the rocks in the “Coast shear zone” record high strains relative to rocks on either side of the structure. Therefore, we propose using the non-genetic term “Coast Steep Zone” to describe this zone of well foliated steeply dipping paragneisses, orthogneisses and amphibolites that that strike consistently NW (~330°) and define the trace of the geomorphic feature described by Brew and Ford (1978). This proposed change in nomenclature is reinforced by Roth (this volume), where she shows that an apparent strain gradient is present in the Quottoon pluton north of the Skeena River as you approach the steep zone; however, south of the Skeena River, no apparent strain gradient is present (Fig. 2).

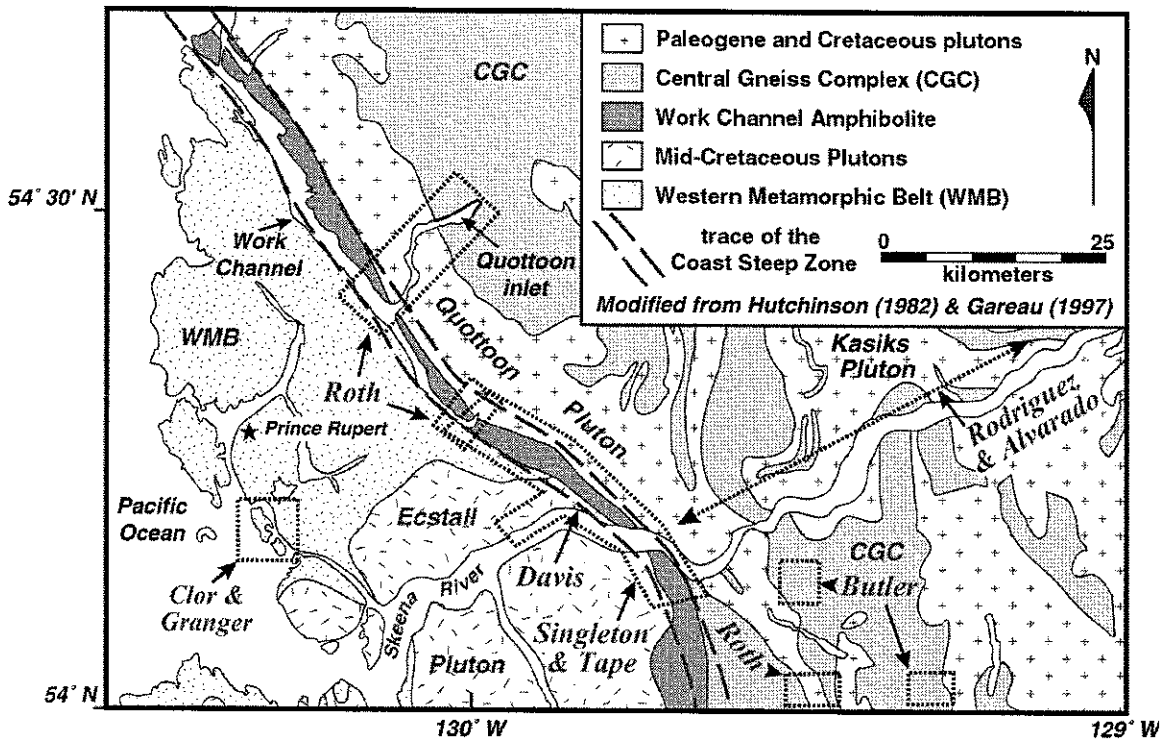


Figure 2. Geologic map of the Prince Rupert area. Dashed polygons show the approximate mapping areas of the nine students in the project. Rodriguez and Alvarado mapped along Highway 16 in the Central Gneiss Complex and associated Late Cretaceous and Paleogene plutons.

The CSZ has a long complex history and appears to be an important crustal-scale feature. Reflection (MCS) and refraction seismic data (Morozov et al., 1998) show a 2 km step in the Moho across the steep zone separating significantly different seismic velocities in the deep crust and upper mantle. This suggests that the CSZ might mark the boundary between two pieces of lithosphere with different geologic histories. Klepeis et al. (1998) show that the CSZ north of Portland Canal (Fig. 1) experienced high-temperature ductile east-side-up shearing between 65 Ma and 57 Ma, followed by a narrower 1-2 km thick ductile west-side-up shearing from 57 to 55 Ma. Near Wrangell, Alaska, McClelland and Mattinson (2000) show that the CSZ contains several alternating zones of ductile deformation that preserve west-side-up dip slip, dextral strike slip, and east-side-up dip slip motions. They suggest that the west-side-up fabrics are Late Cretaceous in age and the dextral strike slip and east side up fabrics are Late Cretaceous (?) and Tertiary in age.

RESEARCH PROJECTS

The primary goal of BC 2000 project was to complete a number of detailed studies along a narrow E-W corridor across the Coast Steep Zone to help constrain its metamorphic and structural history at the latitude of Prince Rupert, British Columbia. We had nine students and four faculty members working in groups of two and three distributed across the Western Metamorphic Belt, through the Coast Steep Zone, and into the Central Gneiss Complex.

Laura Clor (The College of Wooster) and **Nicole Granger** (Bates College) mapped two islands in the Mid-Cretaceous Western Metamorphic Belt south of Prince Rupert (Fig. 2). Most of their work was completed using a 14-foot inflatable boat to access the near 100% exposed shorelines. They produced an excellent 1:10,000 geologic map of the area, recorded macroscopic structural data, and collected oriented samples for later detailed kinematic analysis and P-T work. In her study, Clor focuses on defining the mineral assemblages for the units they mapped in the field, and determining the conditions of metamorphism from mineral chemistry. Granger concentrates on the microstructures present in these beautiful rocks and uses vorticity analysis to help constrain the deformation path.

Ken Davis (The College of William and Mary), **John Singleton** (Pomona College), and **Carl Tape** (Carleton College) worked together in an effort help define the nature and timing of brittle deformation along the trace of the Coast Steep Zone (Fig. 2). Together, they recorded orientation and slip kinematic data from over 300 brittle fault surfaces! Davis focuses on an apparently unique occurrence of pseudotachylyte found in an old road mettle quarry along Highway 16. He uses $^{40}\text{Ar}/^{39}\text{Ar}$ step-heating data from the pseudotachylyte “glass” to constrain the age of dextral (?) brittle faulting along the CSZ at 30 Ma. Singleton and Tape focus on the interpretation of fault data and use different approaches to the same data set to show that a majority of the brittle faults formed in a stress regime with near E-W tension (σ_3 horizontal) and with σ_1 either vertical (normal faults) or horizontal (dextral strike slip faults).

Deborah Roth (Colorado College) mapped and collected oriented samples along three transects through the Quottoon pluton and into the CSZ (Fig. 2). She uses image analysis to quantify the three-dimensional fabrics present in magmatically and subsolidus deformed tonalite and quartz diorite from the Quottoon pluton and shows that an apparent strain gradient is present in the pluton as you approach the CSZ north of the Skeena River, but absent south of the river.

Eric Butler (Beloit College) mapped and collected samples in the high-grade metamorphic rocks of the Central Gneiss Complex (Fig. 2). In his study, Butler uses garnet inclusion assemblages, reaction textures, and mineral chemistry to constrain the P-T path of these rocks. He also tests the feasibility of using elemental abundances of U, Th, and Pb in metamorphic monazite measured on an electron microprobe for dating metamorphic events in the CGC.

Daniel Alvarado (Trinity University) and **Kate Rodriguez** (St. Norbert College) worked together along Highway 16 to map and measure the orientation of felsic and mafic dikes found throughout the Central Gneiss Complex. Alvarado focuses on the felsic, leucogranitic dikes that typically cross cut fabrics in the CGC and shows that the orientation of these dikes vary systematically with the thinner dikes (<10 cm) forming two sets dipping steeply WSW and ENE, and the thicker dikes (> 1 m) dipping moderately SW. Rodriguez shows that the orientation of the mafic dikes are near vertical with a consistent NNW strike. She collected over 40 samples for detailed petrographic analysis and obtained whole rock geochemistry on 25 samples. Using discrimination diagrams, Rodriguez shows that these dikes are alkalic basalts derived from low degrees of partial melting in the mantle. Preliminary $^{40}\text{Ar}/^{39}\text{Ar}$ data suggest that these dikes were emplaced into relatively cold rocks before 46 Ma.

BELOIT COLLEGE BC 2000 WORKSHOP

The BC 2000 project participants held a workshop in Beloit, Wisconsin February 2-4, 2001. The primary goal of the workshop was to bring the participants together to discuss and share our research findings up to that point, and to help define what we had left to do before the symposium in April. Laura Clor (The College of Wooster) arrived three days early to use the Beloit College SEM/EDS to collect mineral chemistry for P-T work. The students gave 15-30 minute presentations on Saturday morning, and we spent the rest of the day and late into the night working together in small groups. This work included collecting data on the SEM/EDS, plotting structural data, petrography, and making figures. On Sunday, we

reconvened as a group to discuss our plans for the symposium, then the faculty met with students in small groups to discuss with each student what they needed to get done. I felt that this was particularly effective for everyone in defining their role in the project and what they had to do in the weeks leading up to the symposium. Overall the workshop was a great success and will contribute in a significant way toward the successful completion of our project.

ACKNOWLEDGEMENTS

This research was funded by the Keck Geology Consortium and National Science Foundation grant EAR-9526562 to Davidson. All the participants are greatly indebted to Peter Freeman for his assistance in the field and for finding Tim Flood a guitar. We also thank Lincoln Hollister for loaning us the inflatable boat that was used throughout the study. Allen Dobson, Dykstra Eusden, Tim Flood, and Steve Weaver are gratefully acknowledged for taking the time to visit us in the field and offer their expertise.

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