Vol. 7, No. 11 November 1997

GSA TODAY

A Publication of the Geological Society of America

INSIDE

A Candidate for the Baja British Columbia Fault System in the Coast Plutonic Complex

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ABSTRACT

Results of part of ACCRETE, a multidisciplinary project to investigate the processes of crustal formation in the Coast orogen of British Columbia, suggest that a candidate for the Baja British Columbia fault zone, across which 1500 to 2000 km of displacement could have occurred between Late Cretaceous and early Tertiary time, is present in the Coast orogen. Evidence comes from new structural data that reveal a sequence of high-temperature deformational events. Early deformation consisted of partitioned transpression recorded by a broad zone of contemporaneous southwest-directed thrusting and dextral orogen-parallel strike-slip shearing. Subsequent uplift and exhumation of the high-grade core of the orogen accompanied by syntectonic plutonism produced fabrics that erased much of the evidence for earlier strike slip and thrust deformation. We suggest a cause-and-effect relation as to why Late Cretaceous to early Tertiary granodioritic to tonalitic plutons of the 2000-km-long Coast Plutonic Complex are restricted to the region of the Baja British Columbia fault. The cause is basaltic magma intruded into the crust from conduits produced by strike-slip faults passing into the mantle. These magmas provided the heat for the crustal melting that produced the tonalitic plutons. The result is that deformation is confined to regions softened by heating and melting. Continuing episodes of deformation and basaltic underplating and the consequent melting and recrystallization at high temperatures obscure evidence of prior deformation.

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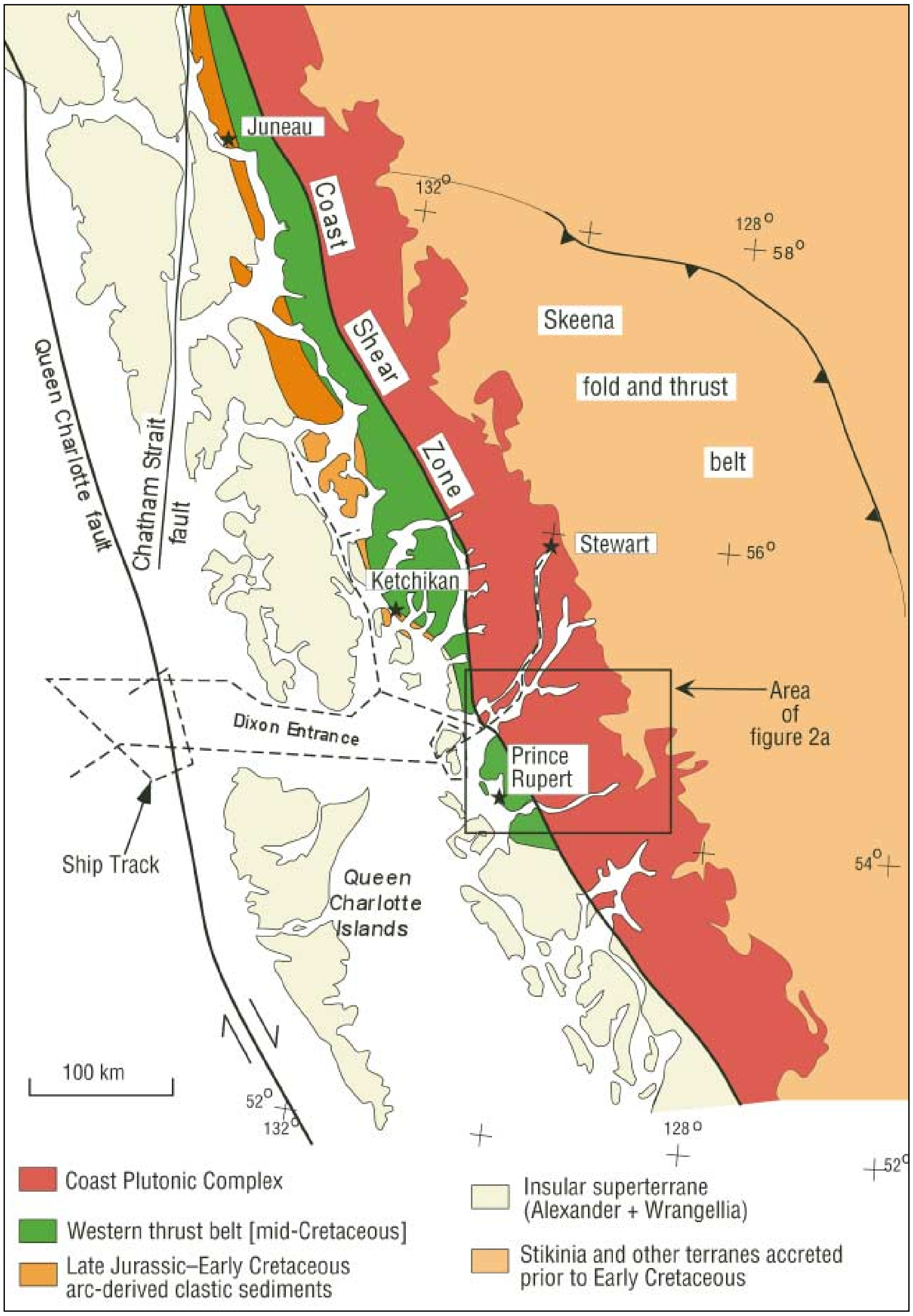

Figure 1. Simplified map showing terranes within Coast orogen in British Columbia. The red area is generally called the Coast Plutonic Complex, but within area of Figure 2a, where high-grade metamorphic rocks are dominant, it is called the Central Gneiss Complex. The western thrust belt is called the Coast Mountains orogen by Cowan et al. (1997). The Skeena fold and thrust belt is described by Evenchick (1991). Ship track for 1994 ACCRETE seismic experiment is approximate.

Editor's note: This paper illustrates the influence of 1997 GSA Day Medal winner Ted Irving, whose determinations of paleolatitudes showed thousands of kilometers of northward translation of the outer tectonic elements of the northwestern North American Cordillera.

GSA TODAY November 1997
Vol. 7, No. 11

GSA TODAY (ISSN 1052-5173) is published monthly by The Geological Society of America, Inc., with offices at 3300 Penrose Place, Boulder, Colorado. Mailing address: P.O. Box 9140, Boulder, CO 80301-9140, U.S.A. Periodicals postage paid at Boulder, Colorado, and at additional mailing offices. **Postmaster:** Send address changes to GSA Today, Membership Services, P.O. Box 9140, Boulder, CO 80301-9140.

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In Memoriam

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Salt Lake City, Utah
March 29, 1997

Wallace W. Hagan
Lexington, Kentucky
July 18, 1997

Dorothy Hill
Queensland, Australia
April 23, 1997
(correction of August *GSA Today* listing)

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Vernon Hill, Virginia
July 1997

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INTRODUCTION

One of the most intensely debated tectonic questions in Cordilleran tectonics (e.g., Cowan et al., 1997) is the latitude of accretion of the Insular superterrane, which is now along the west coast of Canada and southeast Alaska (Fig. 1). Mobilist models suggest that these terranes have traveled from the latitude of present-day Baja California since the Late Cretaceous. Stationary models suggest that these terranes have been more or less at their present location with respect to North America since the mid-Cretaceous. Arguments for large-scale strike-slip translation are based mainly on paleomagnetic data (Bogue et al., 1995; Wynne et al., 1995; Ague and Brandon, 1996); arguments against it have been mainly geological (Gehrels et al., 1991a; McClelland et al., 1992a, 1992b; van der Heyden, 1992; Monger et al., 1994).

The Coast shear zone (Fig. 1) is a prominent structural feature that extends along the western boundary of a line of Late Cretaceous to early Tertiary magmatic bodies known as the Coast Plutonic Complex. Attention has focused on this shear zone (e.g., Cowan, 1994) as a possible location for strike-slip translation. However, Cowan et al. (1997) reviewed studies reporting that kinematic indicators at the Coast shear zone indicate down-dip movement or flattening and, because these movements are younger than 65 Ma, they postdate the time of suspected strike-slip motion. Accordingly, Cowan et al. (1997, p. 133) concluded that the 1500–2000 km of displacement, if it occurred, would be within the Coast Plutonic Complex to the east. They named the suspected fault the Baja British Columbia fault. If the Coast Plutonic Complex contains such a strike-slip fault system, it would rank at the top of the world's longest known intracontinental transcurrent fault systems.

In this paper, we present geologic data for a segment of the Coast Plutonic Complex (see Fig. 1) to the east of the Coast shear zone. This segment, which is called the Central Gneiss Complex (Fig. 2a), is a 50–100-km-wide zone of gneiss and migmatite intruded by Late Cretaceous to early Tertiary plutons. Because of its high proportion of Mesozoic and older gneiss and migmatite, the Central Gneiss Complex presents an opportunity to study the dynamic setting into which Late Cretaceous to early Tertiary plutons intruded. On the basis of our studies, we conclude that large-scale orogen-parallel displacement probably occurred across the Coast Plutonic Complex between about 85 Ma and 60 Ma. This zone would be the proposed Baja British Columbia fault system.

The results summarized here are part of a collaborative endeavor among seismologists, geologists, geophysicists, and geochemists, begun in 1993, to study continental growth by accretion in the northeast Pacific. The project, called ACCRETE, aims to define and interpret the geologic and geophysical features of the crust, from surface to Moho, across the Coast orogen (see Fig. 1). Updates on progress are periodically posted on the ACCRETE Web site, at http://geo.princeton.edu/accrete/accrete.html. The activities and participants of the ACCRETE program are:

Crustal structure, crustal velocity models: John Diebold, Lamont Doherty Earth Observatory, Columbia University; Igor Morozov and Scott Smithson, University of Wyoming; Phil Hammer, Ron Clowes, and Bob Ellis, University of British Columbia; Nik Christensen, Purdue University; Kristan Rohr, Geological Survey of Canada; Anne Trehu, Oregon State University.

Geological studies: Lincoln Hollister, Princeton University; Maria Luisa Crawford, Bryn Mawr College; Cameron Davidson, Beloit College; Keith Klepeis, University of Sydney; Margi Rusmore, Occidental College; Glenn Woodsworth, Carol Evenchick, Lisel Currie, and Suzie Gareau, Geological Survey of Canada.

Detrital zircon studies; boundaries of accreted terranes: George Gehrels, University of Arizona.

U/Pb ages to constrain structural and plutonic histories: George Gehrels; Krishna Sinha, Virginia Polytechnic Institute.

Define zones of paleomagnetic anomalies: Robert Butler, University of Arizona.

Geochemistry of plutons, map source areas of plutons: Krishna Sinha.

Prior work directed at the question of large-scale strike-slip displacement was mainly concentrated along the Coast shear zone. Here, we first review some of this work, and then integrate our new results with other studies across the Central Gneiss Complex to define the geologic history for the period of possible northward transport of the Insular superterrane. Finally, we propose a cause-and-effect relationship of pluton generation and strike-slip faulting for the Coast Plutonic Complex.

Coast Shear Zone

The Coast shear zone (Fig. 1) marks the western boundary of the Coast Plutonic Complex (Brew and Ford, 1978), and truncates a top-to-the-west mid-Cretaceous thrust system that lies to its

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CALL FOR NOMINATIONS REMINDERS

PENROSE AND DAY MEDALS, AND HONORARY FELLOWSHIP

Nominations for 1998 Penrose and Day Medals and for Honorary Fellowship in the Society are due by **FEBRUARY 2, 1998.**

YOUNG SCIENTIST AWARD (DONATH MEDAL)

The Young Scientist Award was established in 1988 to be awarded to a young scientist (35 or younger during the year in which the award is to be presented) for outstanding achievement in contributing to geologic knowledge through original research that marks a major advance in the earth sciences. The award, consisting of a gold medal called the Donath Medal and a cash prize of $15,000, was endowed by Dr. and Mrs. Fred A. Donath.

For the year 1998, only those candidates born on or after January 1, 1963, are eligible for consideration. In choosing candidates for the Young Scientist Award, scientific achievement and age will be the sole criteria. Nominations for the 1998 award must include

- biographical information,
- a summary of the candidate's scientific contributions to geology (200 words or less),
- a selected bibliography (no more than 10 titles),
- supporting letters from five scientists in addition to the person making the nomination.

Deadline for nominations for 1998 is **FEBRUARY 2, 1998.**

OFFICERS AND COUNCILORS

The GSA Committee on Nominations requests your help in compiling a list of GSA members qualified for service as officers and councilors of the Society. The committee requests that each nomination be accompanied by basic data and a description of the qualifications of the individual for the position recommended (vice-president, treasurer, councilor).

Deadline for nominations for 1998 is **FEBRUARY 18, 1998.**

DISTINGUISHED SERVICE AWARD

The GSA Distinguished Service Award was established by Council in 1988 to recognize individuals for their exceptional service to the Society. GSA Members, Fellows, Associates, or, in exceptional circumstances, GSA employees may be nominated for consideration. Any GSA member or employee may make a nomination for the award. Awardees will be selected by the Executive Committee, and all selections must be ratified by the Council. Awards may be made annually, or less frequently, at the discretion of Council. This award will be presented during the annual meeting of the Society. Deadline for nominations for 1998 is **MARCH 2, 1998.**

JOHN C. FRYE ENVIRONMENTAL GEOLOGY AWARD

In cooperation with the Association of American State Geologists (AASG), GSA makes an annual award for the best paper on environmental geology published either by GSA or by one of the state geological surveys. The award is a $1000 cash prize from the endowment income of the GSA Foundation's John C. Frye Memorial Fund. The 1998 award will be presented at the autumn AASG meeting to be held during the GSA Annual Meeting in Toronto, Canada.

Nominations can be made by anyone, based on the following criteria: (1) paper must be selected from GSA or state geological survey publications, (2) paper must be selected from those published during the preceding three full calendar years, (3) nomination must include a paragraph stating the pertinence of the paper.

Nominated papers must establish an environmental problem or need, provide substantive information on the basic geology or geologic process pertinent to the problem, relate the geology to the problem or need, suggest solutions or provide appropriate land-use recommendations based on the geology, present the information in a manner that is understandable and directly usable by geologists, and address the environmental need or resolve the problem. It is preferred that the paper be directly applicable by informed laypersons (e.g., planners, engineers). Deadline for nominations for 1998 is **MARCH 30, 1998.**

NATIONAL AWARDS

The deadline is **April 30, 1998,** for submitting nominations for these four awards: William T. Pecora Award, National Medal of Science, Vannevar Bush Award, Alan T. Waterman Award.

Materials and supporting information for any of the nominations may be sent to GSA Executive Director, Geological Society of America, P.O. Box 9140, Boulder, CO 80301. For more detailed information about the nomination procedures, refer to the October 1997 issue of *GSA Today,* or call headquarters at (303) 447-2020, extension 140.

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west (Crawford et al., 1987; Rubin et al., 1990; McClelland et al., 1992b; Klepeis et al., 1996). Plutons younger than 85 Ma (most 75 to 50 Ma) occur east of the Coast shear zone. Plutons with ages of 100 to 90 Ma dominate to the west. Any discussion of the tectonic history of the Coast orogen must explain why *no* Late Cretaceous to early Tertiary plutons occur west of the Coast shear zone. This point is addressed in the last section.

Previous studies have found that the Coast shear zone: (1) may be a suture zone formed by near orthogonal collision between accreted terranes (Ingram and Hutton, 1994); abundant evidence of important flattening at the Coast shear zone has been documented (Ingram and Hutton, 1994; Klepeis et al., 1996); (2) may be the locus of postaccretion tilting of previously amalgamated crustal terranes west of the Coast shear zone (McClelland et al., 1992b; Cook and Crawford, 1994); (3) was the zone across which the high-temperature core of the orogen, the Central Gneiss Complex, was uplifted and exhumed (Hollister, 1982; Klepeis et al., 1996); (4) was an important strike-slip fault. Many workers have sought evidence for strike-slip displacement within the Coast shear zone without success. However, evidence for a major, dextral, high-temperature shear zone has been reported by Andronicos et al. (1996) about 10 km east of the Coast shear zone (Figs. 2a and 3). Klepeis et al. (1996) also described a component of late dextral displacement for the Coast shear zone at Portland Inlet and farther to the north.

A series of tabular, foliated tonalite plutons and dikes, collectively known as the "foliated tonalite sill" (Brew and Ford, 1978) occur within and along the entire eastern side of the Coast shear zone in southeastern Alaska. These plutons and dikes range in age from about 72 to about 58 Ma (Gehrels et al., 1991). They have nearly vertical western contacts and steeply northeast dipping eastern contacts as far south as the Skeena River (Fig. 2a). The Quottoon pluton (Hutchison, 1970), within the area of this study, is part of the "foliated tonalite sill" (Fig. 2). Gehrels et al. (1991b) reported an age of 58 Ma where this pluton crosses the Skeena River. The location of the Coast shear zone along the western boundary of the string of foliated tonalite plutons, and the great length of both, strongly imply that the plutons were intruded into a zone of weakness that extended into the mantle lithosphere (Ingram and Hutton, 1994). Because fabrics produced by deformation in the Coast shear zone affect the tonalite plutons and dikes (Klepeis et al., 1996), deformation along the Coast shear zone must overlap and postdate their intrusion.

When the tonalite plutons intruded the Coast shear zone, hot (>700 °C) migmatitic rocks within the Central Gneiss Complex were already juxtaposed against colder (~400 °C) rocks of the western thrust belt (Crawford et al., 1987; Hollister, 1982; Klepeis et al., 1996). Hollister (1982) considered that this juxtaposition occurred between about 60 and 50 Ma as the Central Gneiss Complex was being exhumed at a rate of 1–2 mm/yr. The Quottoon pluton was intruded during this uplift, as indicated by east-side-up, high-temperature fabrics within both the pluton and the Coast shear zone (Ingram and Hutton, 1994; Klepeis et al., 1996). The resulting steep thermal gradient implies a sharp rheological contrast across the Coast shear zone during uplift, when the Quottoon pluton was intruding.

We emphasize that the fundamental, crustal-scale break that controlled emplacement of the foliated tonalite sills existed prior to their intrusion. Most deformation described at the Coast shear zone was synchronous with or postdated these sills. The location and displacement history across this zone prior to the intrusion of the Quottoon pluton is not established.

We argue that because the uplift of the Central Gneiss Complex involved migmatitic rocks at temperatures of 600 to 700 °C, older kinematic indicators were overprinted by high-temperature penetrative deformation across the Coast shear zone associated with this uplift. Heat from the plutons and dikes intruded during this

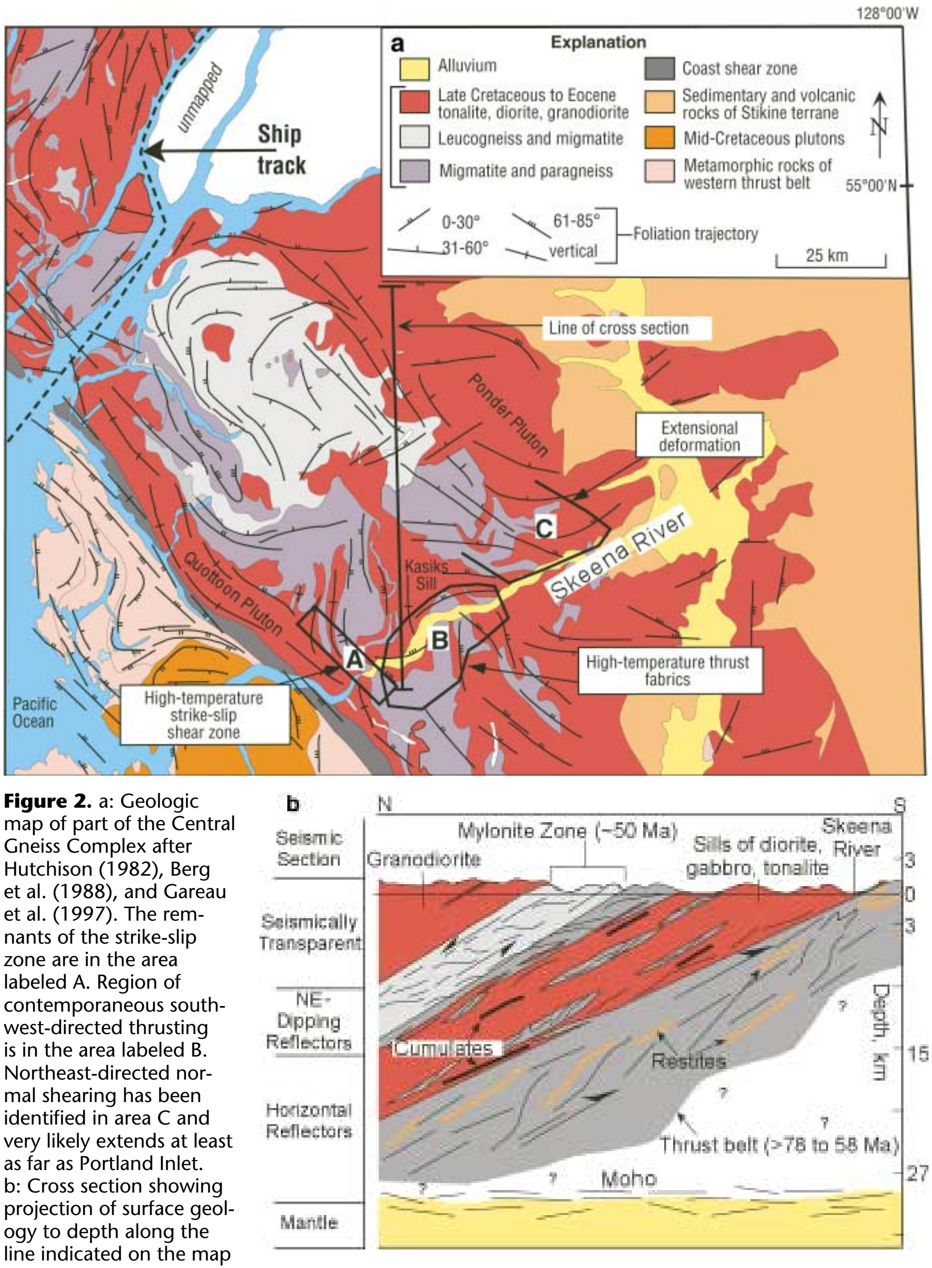

Figure 2. a: Geologic map of part of the Central Gneiss Complex after Hutchison (1982), Berg et al. (1988), and Gareau et al. (1997). The remnants of the strike-slip zone are in the area labeled A. Region of contemporaneous southwest-directed thrusting is in the area labeled B. Northeast-directed normal shearing has been identified in area C and very likely extends at least as far as Portland Inlet. b: Cross section showing projection of surface geology to depth along the line indicated on the map and correspondence of some reflectors on the ACCRETE seismic profile (along ship track) to the geology (see Hollister et al., 1996). The north end of the cross section is correlated with the seismic section at the end of the arrow along the ship track.

Figure 3. (looking down and northeast) of the high-temperature dextral shear zone in location A in Figure 2a. The amphibolite xenolith contains internal foliation at ~90° to external foliation, indicating clockwise rotation consistent with asymmetry of the tails. The amphibolite xenolith to the left of the coin is cut by synthetic shears filled with leucosome, indicating the presence of melt during shearing. An asymmetric calcsilicate nodule also indicates dextral shearing. Note the low-angle, melt-filled synthetic shear band cutting the foliation near the base of the photo. Courtesy of Cameron Davidson.

uplift intensified the effect. High temperatures promoted recrystallization and recovery, leading to further resetting of fabrics.

Whereas Cowan et al. (1997) argued against the Coast shear zone being a locus of strike-slip motion, they considered that strike-slip motion could have occurred to the east along a hypothetical Baja British Columbia fault system within the Coast Plutonic Complex. We accept this possibility, but we emphasize that the Coast shear zone cannot be excluded as part of the Baja British Columbia fault system.

Central Gneiss Complex

Andronicos et al. (1996) found evidence for dextral strike-slip motion across a northwest-trending shear zone in the Central Gneiss Complex (Figs. 2a and 3). This shear zone is at least 3 km thick and can be traced for ~25 km along the east side of the Quottoon pluton (area A in Fig. 2a). Lineations in the shear zone are northwest-trending and have gentle to moderate plunges. The structures recording dextral kinematics formed at high enough temperatures that leucosomes (melt patches) are concentrated in asymmetric boudin necks and shear bands (see photo). Medium to coarse grain sizes indicate initial recovery and grain growth after deformation when the rocks were still hot. The shear zone and associated kilometer-scale isoclinal folds are crosscut by the 58 Ma Quottoon pluton, which was itself affected by the final phases of dextral shearing. These relations suggest that the Quottoon pluton intruded an active dextral transpressive shear zone during the waning stages of deformation.

Within the part of the Central Gneiss Complex shown in Figure 2a, large regions of gently north to northeast dipping layering contain abundant kinematic (movement) indicators for apparent top-to-the-southwest thrusting (area B in Fig. 2a; Fig. 2b; Hollister et al., 1996). Rusmore et al. (1996) found similar features just south of this area. The sequence with high-temperature, penetratively deformed layering is over 3 km thick where it was defined in area B in Figure 2a. Tonalitic sills ranging from meters to kilometers in thickness are intruded mostly concordantly into the layering (Fig. 2b). Dates of 75 Ma from zircon inclusions in garnets, and of 65 Ma from zircons in the matrix of the layered sequence (Woodsworth et al., 1983) imply that thrusting began prior to the intrusion of the Quottoon pluton. Field relations (Andronicos et al., 1996) confirm that the Quottoon pluton intruded after thrusting was largely complete. Metamorphic *P-T* paths of the high-grade rocks containing the thrust fabric show that they were at

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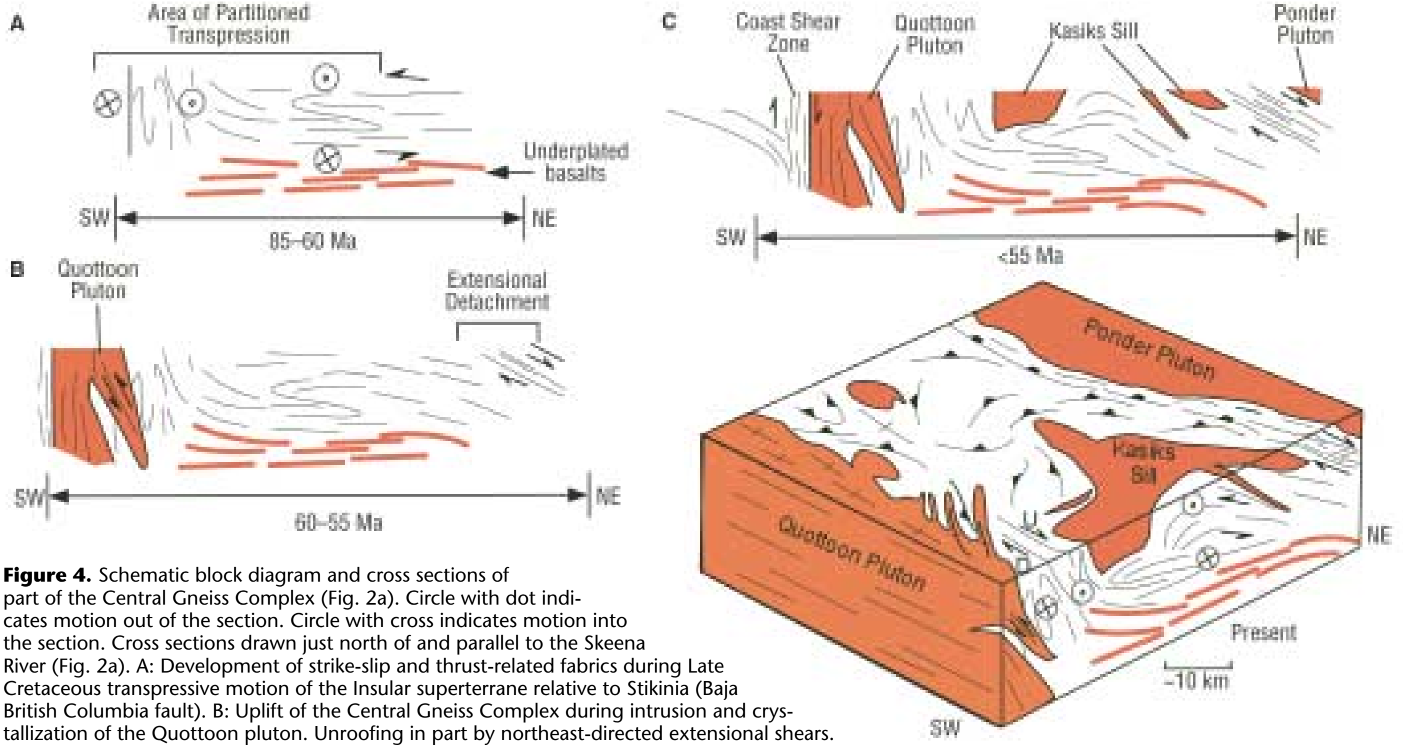

Figure 4. Schematic block diagram and cross sections of part of the Central Gneiss Complex (Fig. 2a). Circle with dot indicates motion out of the section. Circle with cross indicates motion into the section. Cross sections drawn just north of and parallel to the Skeena River (Fig. 2a). A: Development of strike-slip and thrust-related fabrics during Late Cretaceous transpressive motion of the Insular superterrane relative to Stikinia (Baja British Columbia fault). B: Uplift of the Central Gneiss Complex during intrusion and crystallization of the Quottoon pluton. Unroofing in part by northeast-directed extensional shears. C: Late deformation across Coast shear zone (Cook and Crawford, 1994) and intrusion of Kasiks sill and Ponder pluton (see Fig. 2).

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temperatures over 600 °C during thrusting between 85 and 60 Ma, at depths of at least 25 km between 70 and 60 Ma, and at depths of 10 to 5 km when cooled rapidly from over 600 °C down to 300 °C at 50 Ma (Hollister, 1982). Kilometer-scale folds within the thrust package that are deflected and refolded by the shear zone indicate that strike-slip deformation outlasted thrusting. Similar metamorphic conditions and kinematic and geometric compatibility suggest that the thrust and strike-slip zones formed a partitioned transpressive system in which displacements occurred synchronously on horizontal and vertical surfaces (Fig. 4A).

Farther east, along the eastern side of the Central Gneiss Complex (area C in Fig. 2a), the ductile thrust fabric is cut at a low angle by a moderately dipping (~30° east to northeast; Fig. 2b), 4-km-thick mylonite zone with top-to-the-east-northeast shear sense (Fig. 4B). This zone of normal shear sense was first recognized by Heah (1991), who constrained the age to be between 60 and 50 Ma. This is more or less the same time as the uplift and exhumation of the Central Gneiss Complex (Hollister, 1982). Microfabric analyses indicate that this lower temperature mylonitic fabric was superimposed on the higher temperature migmatitic thrust fabric.

In the strain history across the Central Gneiss Complex (Fig. 4), the earliest recorded strain was transpressive and was accommodated by partitioned thrust and strike-slip–related shearing that largely predated the intrusion of the Quottoon pluton. The top-to-the-southwest ductile thrusting predates and overlaps the dextral strike-slip deformation. Fabrics related to transpression and to the intrusion of the "foliated tonalite sill" are postdated by extensional fabrics related to shearing and emplacement of synextensional plutons (Fig. 4B). High temperatures persisted throughout the deformation history of the Central Gneiss Complex, leading to complex strain gradients and overprinting relations that are difficult to interpret.

Baja British Columbia Fault Zone

On the basis of our analysis of the structures in the area shown in Figure 2a, net large-scale northward displacement across the Central Gneiss Complex is likely. Significantly, the emplacement of the 83 to 50 Ma middle to lower crustal plutons and migmatites in this region overlaps the period when relative motions between the Kula and North America plates were predominantly transpressive (Engebretson et al., 1985). The orientation of the Coast shear zone was appropriate for strike-slip motion during this time period. Plutons deformed by the top-to-the-south thrusting have U/Pb dates ranging from 83 to 63 Ma. The 58 Ma Quottoon pluton at the Skeena River puts a younger limit on the transpressive stage. Pre–58 Ma southwest-directed thrusting could produce the uplift that is recorded by rapid Late Cretaceous to early Tertiary erosion in this area (Plafker et al., 1994). Eocene extension along the eastern side (Heah, 1991) contributed to exhumation.

This synthesis provides arguments for substantial cumulative strain throughout the Central Gneiss Complex. As shown in Figure 4, the complex pattern of structural fabrics can be attributed to strike-slip, normal, and thrust faulting complicated by local mobilization and upward flow of melt. Under the high-temperature (sillimanite stability field) conditions in the complex between 83 and 50 Ma, new ductile deformational fabrics should have formed continuously, overprinting and obliterating earlier fabrics. Cumulate amphibole in the Quottoon pluton indicates derivation from a tonalitic liquid intruded at a temperature over 1000 °C. Assuming that the Coast shear zone was a boundary to the Central Gneiss Complex during intrusion of the Quottoon pluton and subsequent uplift, preexisting kinematic indicators would not be preserved. Instead, the Coast shear zone records kinematics of pluton emplacement and the rapid uplift of the hot core of the Central Gneiss Complex which lasted until about 50 Ma.

Following collision of the Insular superterrane and formation of the 100 to 90 Ma imbricate thrust system and associated plutons, relative plate motions changed to oblique convergence across the northwest-trending coastline. This convergence was recorded by top-to-the-southwest thrusting and margin-parallel dextral strike-slip fabrics in rocks now at the latitude of the ACCRETE study area. By the time the foliated tonalite sill complex was intruded, the Kula (Pacific) plate had slowed and relative transcurrent motion across the Central Gneiss Complex had effectively stopped. This episode is recorded by rapid exhumation of the basement and by the normal detachment along the east side of the Central Gneiss Complex. The slowing and death of the Kula plate can be attributed to collision of the Insular superterrane with southern Alaska. This collision is recorded in the Chugach terrane at 58 to 55 Ma (Sisson and Pavlis, 1993).

Implications for Generation of the Tonalitic Plutons

A major piece of the puzzle is still missing. Why are Late Cretaceous–early Tertiary plutons *missing* west of the Coast shear zone? We offer our speculations.

The first question is the mechanism for generating the tonalitic plutons with batholithic proportions, given that some 1500 to 2000 km of orogen-parallel displacement occurred in the Coast orogen during their emplacement. If these plutons were generated above a subduction zone within an arc, or by melting at the base of tectonically overthickened crust during thermal relaxation, some magma should have leaked across the Coast shear zone. The fact that this did not happen calls for an alternative hypothesis.

Another consideration is that a large-scale strike-slip fault system causing thousands of kilometers of northward translation of the Insular superterrane must involve the mantle lithosphere. As such, a zone of fracture or weakness extending to the asthenosphere or a Benioff zone(?) could provide an access path to the crust for basaltic magma. Upon reaching the base of the crust, these magmas could pond, providing the exceptional heat source needed to generate the tonalitic melts that intruded the Coast Plutonic Complex at temperatures of >1000 °C. An important consequence of such melting and associated metamorphism is the maintenance of a softened and weakened crust. The continuous intrusion of basaltic magmas and thermal softening of the mantle lithosphere provides a feedback mechanism for confining strike-slip displacement to a single zone.

We suggest that the western edge of the weak part of the mantle shear zone coincided with the Coast shear zone. To account for the lack of Late Cretaceous–early Tertiary plutons west of the Coast shear zone, the crust and mantle in this area must have been cool enough that melt leaking into this region from the Central Gneiss Complex solidified very quickly. In essence, the Coast shear zone marked the edge of a thermal wall. A much stronger mantle and crust west of this wall caused deformation to be confined to the batholith complex.

Evidence for basaltic magmas intruding the Central Gneiss Complex during the orogenic episode comes from numerous synplutonic basaltic dikes in the tonalitic plutons and small intrusive ultramafic bodies. Synplutonic dikes occur as pillowed mafic layers within the tonalite plutons and as mafic enclaves. Ultramafic bodies occur as small sills within the layered metamorphic rocks and range in composition from pyroxenite to hornblendite. Secondary evidence for the involvement of basalt comes from the exceptionally high temperatures of the tonalite plutons. Such high temperatures require an exceptional heat source, and mafic magmas derived from the mantle are an obvious candidate.

An important implication of the Central Gneiss Complex containing the record of strike-slip motion in the ductile lower crust is that the roots of a former strike-slip fault can be observed and studied on the surface. We need not go 20 km below

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the surface to understand large strike-slip faults like the San Andreas. Understanding how displacements are transmitted from the asthenosphere through the mantle lithosphere and the lower crust to the earthquake zone requires the inductive reasoning of geologists who can identify and analyze the roots of ancient displacement zones. Such a place appears to exist in the Coast Mountains of British Columbia and southeast Alaska.

ACKNOWLEDGMENTS

Research supported by National Science Foundation grant EAR-9526531, the Kraus Memorial Fund, an NSF Graduate Fellowship (Andronicos), and a GSA research grant (Andronicos). We thank Keith Klepeis, Dominique Chardon, Darrel Cowan, Suzanne Kay, and an anonymous reviewer for constructive comments and suggestions. We especially thank C. Davidson (Beloit College) for the photo. Members of the ACCRETE team have contributed to the content of this paper, but the authors are responsible for errors and interpretations. The U.S. part of the ACCRETE project is funded by the NSF Continental Dynamics Program.

REFERENCES CITED

Ague, J. J., and Brandon, M. T., 1996, Regional tilt of the Mt. Stewart batholith, Washington, determined using aluminum in hornblende barometry: Implications for northward translation of Baja British Columbia: Geological Society of America Bulletin, v. 108, p. 471–488.

Andronicos, C. L., Davidson, C., and Hollister, L. S., 1996, A dextral orogen parallel transcurrent shear zone at the eastern margin of the Quottoon Pluton, Coast Orogen, British Columbia: Eos (Transactions, American Geophysical Union), v. 77, p. F651.

Berg, H. C., Eliott, R. L., and Koch, R. D., 1988, Geologic map of the Ketchikan and Prince Rupert quadrangles, southeastern Alaska: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-1807, scale 1:250 000.

Bogue, S. W., Gromme, S., and Hillhouse, J. W., 1995, Paleomagnetism, magnetic anisotropy, and mid-Cretaceous paleolatitude of the Duke island (Alaska) ultramafic complex: Tectonics, v. 14, p. 1133–1152.

Brew, D. A., and Ford, A. B., 1978, Megalineament in southeastern Alaska marks southwest edge of Coast Range batholithic complex: Canadian Journal of Earth Sciences, v. 15, p. 1763–1772.

Cook, R. D., and Crawford, M. L., 1994, Exhumation and tilting of the western metamorphic belt of the Coast orogen in southern southeastern Alaska: Tectonics, v. 13, p. 528–537.

Cowan, D., 1994, Alternative hypotheses for the mid-Cretaceous paleogeography of the Western Cordillera: GSA Today, v. 4, p. 181, 184–186.

Cowan, D. S., Brandon, M. T., and Garver, J. I., 1997, Geologic tests of hypotheses for large coastwise displacements—A critique illustrated by the Baja British Columbia controversy: American Journal of Science, v. 297, p. 117–173.

Crawford, M. L., Hollister, L. S., and Woodsworth, G. J., 1987, Crustal deformation and regional metamorphism across a terrane boundary, Coast Plutonic Complex, British Columbia: Tectonics, v. 6, p. 343–361.

Engebretson, D. C., Cox, A., and Gordon, R. G., 1985, Relative motions between oceanic and continental plates in the Pacific Basin: Geological Society of America Special Paper 206, 59 p.

Evenchick, C. A., 1991, Geometry, evolution, and tectonic framework of the Skeena fold and thrust belt, north-central British Columbia: Tectonics, v. 2, p. 527–546.

Gareau, S. A., Woodsworth, G. J., and Rickli, M., 1997, Regional geology of the northeastern quadrant of Terrace map area, west-central British Columbia: Geological Survey of Canada Current Research 1997-A, p. 47–55.

Gehrels, G. E., McClelland, W. C., Samson, S. D., and Patchett, P. J., 1991a, U-Pb geochronology of detrital zircons from a continental margin assemblage in the northern Coast Mountains, southeast Alaska: Canadian Journal of Earth Sciences, v. 28, p. 899–911.

Gehrels, G. E., McClelland, W. C., Samson, S. D., Patchett, P. J., and Brew, D. A., 1991b, U-Pb geochronology of Late Cretaceous and early Tertiary plutons in the northern Coast Mountains batholith: Canadian Journal of Earth Sciences, v. 28, p. 899–911.

Heah, T. S. T., 1991, Mesozoic ductile shear and paleogene extension along the eastern margin of the central gneiss complex, Coast belt, Shames River area, near Terrace, British Columbia [M.S. thesis]: Vancouver, University of British Columbia, 155 p.

Hollister, L. S., 1982, Metamorphic evidence for rapid (2 mm/yr) uplift of a portion of the Central Gneiss Complex, Coast Mountains, B.C.: Canadian Mineralogist, v. 20, p. 319–332.

Hollister, L. S., Andronicos, C., and Diebold, J., 1996, Correlation of deep crustal reflectors of the ACCRETE seismic section with subsurface exposures of rocks formed in the lower crust: Eos (Transactions, American Geophysical Union), v. 77, p. F651.

Hutchison, W. W., 1982, Geology of the Prince Rupert–Skeena map area, British Columbia: Geological Survey of Canada Memoir 394, 116 p.

Ingram, G. M., and Hutton, D. H. W., 1994, The Great Tonalite Sill; emplacement into a contractional shear zone and implications for Late Cretaceous to early Eocene tectonics in southeastern Alaska and British Columbia: Geological Society of America Bulletin, v. 106, p. 715–728.

Klepeis, K. A., Crawford, M. L., and Gehrels, G. E., 1996, Structural history of the coast shear zone near Portland Inlet, Ak/BC: Eos (Transactions, American Geophysical Union), v. 77, p. F651.

McClelland, W. C., Gehrels, G. E., Samson, S. D., and Patchett, P. J., 1992a, Protolith relations of the Gravina belt and Yukon-Tanana terrane in central southeastern Alaska: Journal of Geology, v. 100, p. 107–123.

McClelland, W. C., Gehrels, G. E., Samson, S. D., and Patchett, P. J., 1992b, Structural and geochronologic relations along the western flank of the Coast Mountains batholith: Stikine River to Cape Fanshaw, central southeastern Alaska: Journal of Structural Geology, v. 14, p. 475–489.

Monger, J. W. H., van der Heyden, P., Journeay, J. M., Evenchick, C. A., and Mahoney, J. B., 1994, Jurassic-Cretaceous basins along the Canadian Coast Belt: Their bearing on pre–mid-Cretaceous sinistral displacements: Geology, v. 22, p. 175–178.

Plafker, G., Moore, J. C., and Winkler, G. R., 1994, Geology of the southern Alaska margin, *in* The geology of Alaska: Boulder, Colorado, Geological Society of America, Decade of North American Geology, v. G-1, p. 389-451.

Rubin, C. M., Saleeby, J., Cowan, D. S., Brandon, M. T., and McGroder, M. F., 1990, Regionally extensive mid-Cretaceous west-vergent thrust system in the northwestern Cordillera: Implications for continent-margin tectonism: Geology, v. 18, p. 276–280.

Rusmore, M. E., Gehrels, G. E., and Shula, S., 1996, Evolution of the Central Gneiss Complex (CGC), 54°N lat., British Columbia: Eos (Transactions, American Geophysical Union), v. 77, p. F651.

Sisson, V. B., and Pavlis, T., 1993, Geological consequences of plate reorganization: An example from the Eocene southern Alaska fore arc: Geology, v. 21, p. 913–916.

van der Heyden, P., 1992, A Middle Jurassic to early Tertiary Andean-Sierran arc model for the Coast Belt of British Columbia: Tectonics, v. 11, p. 82–97.

Woodsworth, G. J., Loveridge, W. D., Parrish, R. R., and Sullivan, R. W., 1983, Uranium-lead dates from the Central Gneiss Complex and Ecstall pluton, Prince Rupert map area, British Columbia: Canadian Journal of Earth Sciences, v. 20, p. 1475–1483.

Wynne, P. J., Irving, E., Maxson, J. A., and Kleinspehn, K. L., 1995, Paleomagnetism of the Upper Cretaceous strata of Mount Tatlow: Evidence for 3000 km of northward displacement of the eastern Coast Belt, British Columbia: Journal of Geophysical Research, v. 100, p. 6073–6091.

Manuscript received May 5, 1997; revision received September 8, 1997; accepted September 12, 1997 ■

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