Arc and intraplate volcanism in the Spences Bridge Group: Implications for Cretaceous tectonics in the Canadian Cordillera

Derek J. Thorkelson
Department of Earth Sciences, Carleton University, Ottawa-Carleton Geoscience Centre, Ottawa, Ontario K1S 5B6, Canada
Alan D. Smith
Département de Géologie, Université de Montréal, Montreal, Quebec H3C 3J7, Canada

ABSTRACT

The Spences Bridge Group, a late Albian (100 Ma) age volcanic succession built on the western margin of Superterrane I, comprises two stratigraphic units with contrasting geochemistry. The lower unit, the Pimainus Formation, represents a set of stratovolcanoes with calc-alkaline character. Lavas of the overlying Spius Formation, deposited as a shield volcano, are hybrids between Pimainus arc magma and "Spius-type" melts of intraplate affinity. Integration of regional geology suggests that the Pimainus Formation was produced by short-lived, easterly dipping subduction beneath Superterrane I. That convergence closed a narrow oceanic basin, now represented by the Methow-Tyaughton trough, bringing Superterrane II into collision with Superterrane I. Accretion in the latest Albian resulted in cessation of Pimainus arc volcanism, the eruption of Spius lavas, and easterly directed deformation of Methow-Tyaughton strata. Early to middle Cretaceous arc volcanism of the Gambier Group on Superterrane II was produced by a separate, concurrently active subduction zone.

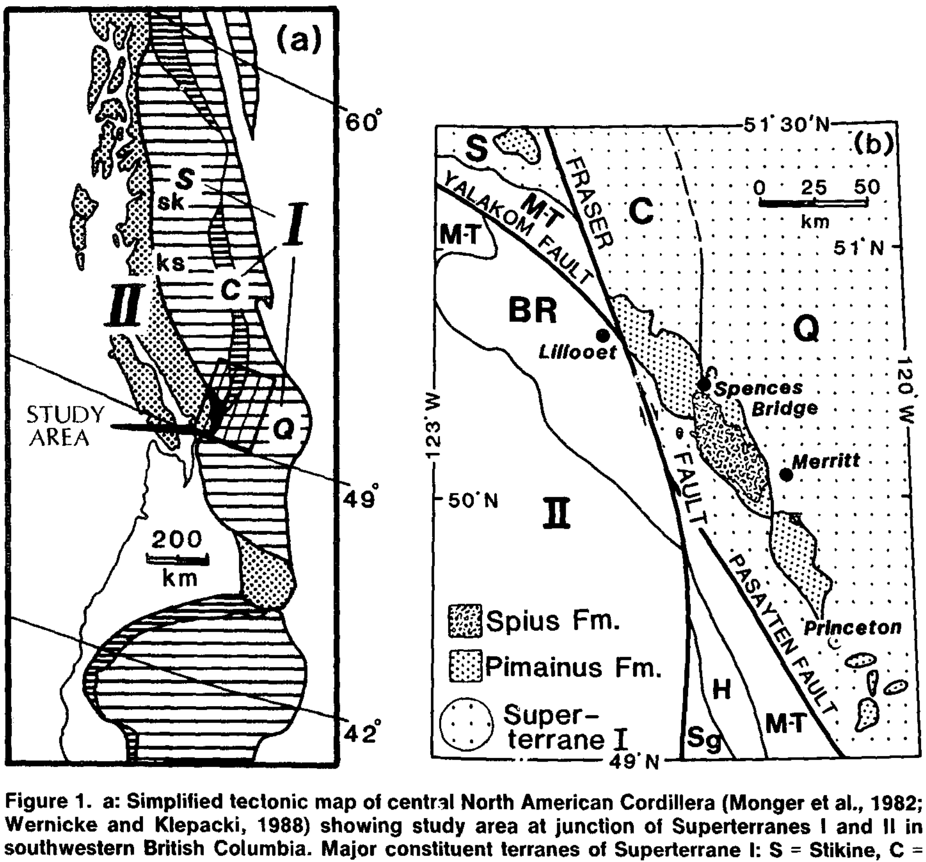


Figure 1. a: Simplified tectonic map of central North American Cordillera (Monger et al., 1982; Wernicke and Klepacki, 1988) showing study area at junction of Superterranes I and II in southwestern British Columbia. Major constituent terranes of Superterrane I: S = Stikine, C = Cache Creek, Q = Quesnel; ks = Kasalka volcanics, sk = Skeena volcanics. b: Distribution of Spences Bridge Group with respect to principal geologic elements in southwestern British Columbia. M-T = Methow-Tyaughton trough; BR = Bridge River terrane; H = Hozameen terrane; Sg = Skagit terrane; other abbreviations as in a (after Kleinspehn, 1985; Monger, 1985; Thorkelson and Rouse, 1989).

INTRODUCTION

Controversy surrounds the nature and timing of collision between Superterrane I (Intermontane Superterrane) and Superterrane II (Insular Superterrane) in the Canadian Cordillera (Monger et al., 1982). Several workers have argued that amalgamation of Superterranes I and II (Fig. 1a) occurred in Middle Jurassic to Early Cretaceous time. For example, Anderson (1976), on the basis of the distribution of early Mesozoic oceanic and volcanic arc rocks, suggested that collision occurred in the Middle Jurassic. Similarly, Tipper (1984) cited stratigraphic similarities among the Wrangell, Stikine, and Quesnel terranes and concluded that the superterranes were juxtaposed by Callovian time. Kleinspehn (1985) used regional correlations of Lower Cretaceous strata of the Methow-Tyaughton basin in southwestern British Columbia to support an Early Cretaceous time of accretion. Armstrong (1988) concurred, stating that superterrane linkage was accomplished prior to 130 Ma. More recently, Van Der Heyden (1989) described metamorphic and plutonic events in and around the central Coast Plutonic Complex that imply suturing by the Middle Jurassic.

Other researchers, however, concluded that collision occurred later, in the middle Cretaceous. For example, Tennyson and Cole (1978) used paleocurrent data from the Methow basin, consistent with subsequent data of Kleinspehn (1985), to suggest that Superterrane II did not collide with Superterrane I until the middle Albian. Monger et al. (1982) agreed, citing voluminous middle Cretaceous magmatism in the Coast Plutonic Complex as evidence for accretion. A similar conclusion was reached by Crawford et al. (1987), who modeled 100–110 Ma deformation and metamorphism in the central Coast Plutonic Complex as the first stage of middle Cretaceous, westerly vergent superterrane collision.

In their reconstructions, most authors did not consider the role of the Spences Bridge Group, a *mid*-Cretaceous volcanic succession that overlaps the Quesnel, Cache Creek, and Stikine terranes on the southwestern margin of Superterrane I. Notable exceptions are Monger (1986) and Souther (1990), who related middle Cretaceous arrival of Superterrane II and closure of the Methow-Tyaughton trough to genesis of the Spences Bridge Group. Our volcanological, geochemical, and isotopic investigations of the Spences Bridge Group support a late Albian time of accretion, consistent with Souther's (1990) depiction of imbricate, east-dipping subduction beneath both superterranes in middle Cretaceous time.

SPENCES BRIDGE GROUP

The Spences Bridge Group is exposed in a northwest-trending Cretaceous structural depression extending for 115 km from near the British Columbia–Washington border almost to lat 51° (Fig. 1b) (Monger, 1985; Thorkelson and Rouse, 1989). In Paleogene time, correlative rocks to the northwest were displaced about 90 km to the north by dextral wrench motion along the Fraser fault system (Mathews and Rouse, 1984; Kleinspehn, 1985; Monger, 1985).

The Spences Bridge Group is divided into two stratigraphic units (Thorkelson and Rouse, 1989). The lower unit, the Pimainus Formation, comprises a 2.5-km-thick sequence of basaltic to rhyolitic lavas intercalated with pyroclastic and epiclastic rocks and is present throughout the Spences Bridge Group belt. The overlying Spius Formation comprises a relatively homogeneous, 1-km-thick succession of amygdaloidal andesite, scoria, and minor tuff, but is restricted to a 50 × 15 km area in the center of the belt. A late Albian age for the Pimainus Formation, indicated by fossil leaves and palynomorphs (Thorkelson and Rouse, 1989), is generally supported by previous fossil collections (Bell, 1956) and by an array of K-Ar and Rb-Sr determinations ranging from Aptian to Cenomanian (Preto, 1979; Thorkelson, 1986; Smith, 1986). As indicated by early angiosperm palynomorphs and corroborated by K-Ar whole-rock determinations, the Spius Formation was deposited in the latest Albian, just prior to Cenomanian time (Thorkelson and Rouse, 1989). Preto's (1979) K-Ar hornblende (96.8 ±2.6 Ma) and biotite (96.7 ±2.1; 98.2 ±2.6 Ma) dates from crosscutting granitic plutons apparently give an upper age limit for the volcanism.

TABLE 1. MAJOR AND TRACE ELEMENT ANALYSES OF MAFIC LAVAS FROM THE SPENCES BRIDGE GROUP

	Pimainus Fm.		Spius Fm.	
	370B	2-101F	134B	97B
SiO_2	54.57	48.70	53.86	57.94
Al_2O_3	17.23	15.64	17.81	18.03
FeO	8.36	11.22	8.34	7.15
MgO	6.06	9.18	5.28	5.86
CaO	9.55	9.36	8.07	4.79
Na_2O	2.24	3.47	3.29	2.67
K_2O	0.66	0.63	1.45	1.71
TiO_2	0.94	1.30	1.17	1.20
P_2O_5	0.22	0.31	0.59	0.51
MnO	0.17	0.19	0.14	0.14
Nb	4	6	14	12
Zr	76	91	218	200
Y	23	15	29	30
Ba	252	289	341	530
Sr	786	580	732	527
Rb	6	16	17	27
Ni	33	79	82	101
Cr	78	200	138	131
V	257	-	160	173

Note: Major oxides recalculated to 100 wt% on volatile-free basis; trace elements in ppm (Smith, 1986; Thorkelson, 1986).

Pimainus Formation

As determined by major- and trace-element studies (Thorkelson, 1985, 1986, 1987; Smith, 1986), Pimainus Formation lavas are calc-alkaline and subduction-generated. Lavas have silica contents ranging from 48% to 75%, are moderately aluminous, and are weakly to moderately potassic (Table 1). Their trace-element spidergrams (Thompson et al., 1984) slope downward to the right and show deep Nb anomalies (Fig. 2). On most discriminant diagrams they plot in the fields of arc-related rocks. Consistent with these chemical trends are time-corrected (100 Ma) $^{87}Sr/^{86}Sr$ isotopic ratios that range from 0.70316 to 0.7040; those of $^{143}Nd/^{144}Nd$ vary from ϵ_{Nd} (100 Ma) = +5.0 to +7.8 (Preto, 1979; Smith, 1986). Consequently, on a Sr-Nd isotope correlation diagram, the Pimainus data cluster along the mantle array, in the field of primitive island arcs.

Profound lateral changes in volcanic facies and subtle geochemical variations indicate that the Pimainus was erupted from several centers. Locally abundant rhyolitic flows and fluvial-lacustrine beds within a volcanic pile dominated by mafic lava and felsic volcaniclastic rocks suggest that this unit formed a set of coalescing composite volcanoes.

Spius Formation

The style of Spences Bridge Group volcanism changed drastically with the onset of Spius deposition. Eruption of rhyolitic magma ceased, and the dense, thick, mafic lava flows of the Pimainus Formation gave way to thin, highly vesicular flows of Spius and andesite. These changes reflect a transition from stratovolcano to shield morphology.

Despite major element geochemistry similar to that of the Pimainus (Table 1), the Spius is slightly more alkaline and characterized by higher levels of high-field-strength elements (HFSE), notably Nb, Zr, Y, and P (Fig. 2). However, in contrast to most volcanic suites including the Pimainus, the highest concentrations of HFSE in the Spius are found in the most mafic flows. This distribution results in a positive correlation between HFSE and compatible elements such as Ni and Cr, a trend that cannot be explained by fractional crystallization.

On the basis of these chemical trends, and the occurrence in Spius lavas of corroded xenocrysts similar to Pimainus phenocrysts, Thorkelson (1986, 1987) argued that Spius lavas were hybrids between Pimainus magma and "Spius-type" magma, a hypothetical end member richer in HFSE. Because of its higher HFSE contents and higher Ti/V ratios, the Spius-type magma was identified as having intraplate or rift affinity. This hypothesis is supported by time-corrected isotopic ratios, which range as low as 0.70298 for Sr and as high as ϵ_{Nd} (100 Ma) = +8.8 for Nd (Smith, 1986 and unpub. data), suggesting derivation from mantle that was less affected by subduction.

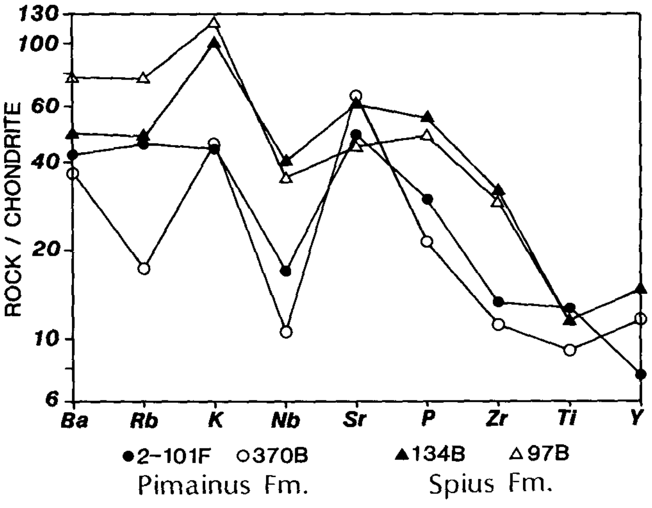


Figure 2. Chondrite-normalized spider diagram (Thompson et al., 1984) for Spences Bridge Group samples of Table 1, showing less arc character in Spius Formation than in Pimainus.

TECTONIC MODEL

According to the stratigraphic record, no subduction-related volcanic rocks were erupted onto Superterrane I between the end of Hazelton Group deposition in the Middle Jurassic and genesis of the Spences Bridge Group in the middle Cretaceous. We suggest that during most of this 70 m.y. interval, when plutonism also reached a minimum (Armstrong, 1988), subduction did not occur beneath Superterrane I. The intense burst of magmatism and resultant deposition of the Pimainus Formation along the southwestern margin of Superterrane I indicate renewal of subduction in the late Early Cretaceous and are interpreted to mark the onset of the accretion of Superterrane II.

Pimainus eruption appears to have been synchronous with generation of the mid-Cretaceous Kasalka and Skeena volcanic groups (Armstrong, 1988) in west-central British Columbia (Fig. 1a). As with the Pimainus, these units were deposited near the western margin of Superterrane I. Although possible correlation among these successions is obscured by faults, Tertiary cover, and crosscutting plutons, they may have originally formed a nearly continuous magmatic arc extending from near the Washington border to lat 55°N. This arc may have extended still farther to the northwest, where it could now be represented by metamorphic and plutonic rocks of the Coast Plutonic Complex. Similarly, the arc may also have extended southeast of present Pimainus exposures into northern Washington, where its plutonic roots might be exposed as part of the Remmel batholith.

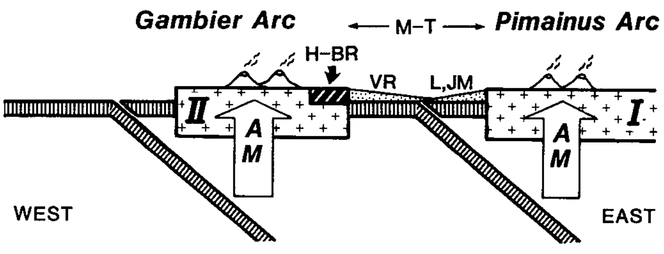
In Alaska, the approach and accretion of Superterrane II is constrained to Albian and post-Cenomanian time, respectively, by deformation and uplift of the Kahiltna and Manley flysch terranes (Jones et al., 1986). Similarly, contraction of the Methow-Tyaughton basin, to the west of the Spences Bridge Group, records convergence between the southern parts of Superterranes I and II. The Methow-Tyaughton trough, apparently underlain by Triassic ocean floor of the Spider Peak Formation (Ray, 1986), can be divided into two broad sedimentary cycles. The first, as indicated by the Ladner, Thunder Lake, Jackass Mountain, and equivalent groups, generally represents a Lower Jurassic to middle Albian, west-facing, marine clastic wedge (O'Brien, 1986; McGroder and Miller, 1989), apparently bounded on the east by Superterrane I (Monger, 1986). During the second cycle, beginning in the mid-Albian, the basin was uplifted and for the first time acquired a western margin, as demonstrated by fluvial and deltaic deposition of chert-rich sediments (Virginian Ridge Formation, Pasayten Group, and "Kingsvale" group of Kleinspehn, 1985) with easterly directed paleocurrents (Tennyson and Cole, 1978; Kleinspehn, 1985; Trexler and Bourgeois, 1985). Progradation of these westerly derived deposits across the basin and onto Superterrane I (Cordey, 1986) occurred in the late Albian and Cenomanian, during which time basin closure produced easterly directed folds and thrust faults (Coates, 1974; McGroder and Miller, 1989). Synvolcanic deformation within the Spences Bridge Group (Monger, 1985; Thorkelson and Rouse, 1989) was probably cogenetic.

The source of chert in the westerly derived deposits is the Hozameen–Bridge River terrane (Figs. 1 and 3), a melange and dismembered ophiolite unit faulted against the western margin of the basin. The youngest rocks of this terrane are Middle Jurassic, suggesting that it was emergent by the Late Jurassic and not an abyssal equivalent to much of the Methow-Tyaughton strata. This observation conflicts with depictions of this terrane as ocean floor during the Early Cretaceous (Monger, 1986) but is consistent with an interpretation by Rusmore et al. (1988) in which the Bridge River terrane was amalgamated with another outboard terrane (Cadwallader) in the Middle Jurassic. However, because of the history of the Methow-Tyaughton trough, we reject suggestions (e.g., Rusmore et al., 1988) of Middle Jurassic superterrane collision. Instead, we suggest that following its Middle Jurassic obduction, the Hozameen–Bridge River terrane was amalgamated with Superterrane II in the Early Cretaceous, an event that may be related to 120–130 Ma metamorphism and deformation in the Shuksan suite of northwestern Washington (Brown, 1987). Subsequently, in Albian time, eastward subduction beneath the southwestern margin of Superterrane I (Monger, 1986; Souther, 1990) closed a marginal basin and generated arc magmas that erupted to form the Pimainus Formation (Fig. 3). The existence of a narrow seaway rather than a major ocean basin separating the superterranes prior to late Albian time is consistent with paleomagnetic (Irving et al., 1985) and fossil evidence (Smith and Tipper, 1986) which implies that constituent terranes of both superterranes were at similar latitudes since the Triassic, and in the eastern Pacific basin by the Early Jurassic.

On Superterrane II, Early to middle Cretaceous arc volcanism is represented by the Gambier Group and correlative rocks (Heah et al., 1986; Armstrong, 1988). This volcanism, in part coeval with the Spences Bridge Group, is inferred to have been generated by a second, concurrently active subduction zone (Fig. 3) (Souther, 1990). Synchronous subduction beneath each of the superterranes is analogous to the pair of arc-trench systems now bounding the Philippine plate. After closure of the marginal basin, subduction outboard of Superterrane II continued, leading to Late Cretaceous and Cenozoic magmatism across both superterranes.

Cessation of the Pimainus arc and the transition to intraplate magmatism of the Spius Formation signaled the accretion of Superterrane II. Genesis of Spius-type magma may have been caused by decompressive melting of upwelling asthenosphere following detachment and sinking of an overthickened lithospheric root (Thompson et al., 1984). Similarly, mantle upflow may have occurred in response to detachment of the subducted slab (Rehrig, 1986) from the inboard edge of accreted Superterrane II. Both these mechanisms might be expected to produce extensional tectonism and widespread eruption of a distinct unit of lavas with intraplate signatures. The Spius Formation, however, is restricted to the center of the arc and was erupted during a period of regional compression. Its origin may be related more reasonably to deformation of the lower crust and lithospheric

(a) late Albian



(b) latest Albian

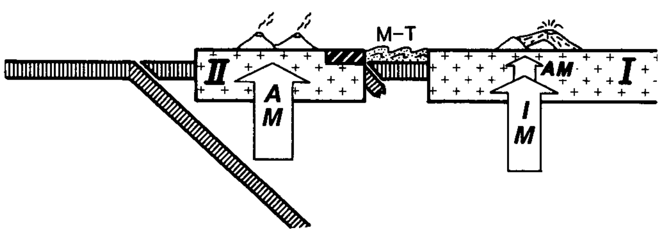


Figure 3. Tectonic conditions during genesis of Spences Bridge Group. a: Late Albian: Pimainus arc is initiated by subduction of marginal basin separating Superterranes I and II (Monger, 1986). Concurrent subduction produces Gambier Group magmatism (Souther, 1990). H-BR = Hozameen–Bridge River terrane; VR = Virginian Ridge Formation and correlative rocks; L,JM = Ladner, Jackass Mountain, and equivalent groups; AM = arc magma; M-T = Methow-Tyaughton. b: Latest Albian: contraction of Methow-Tyaughton basin, cessation of subduction and termination of Pimainus volcanism. "Spius type" intraplate magma (IM) mixes with remnant arc magma and erupts as Spius lava. Subduction outboard of Superterrane II continues.

mantle of Superterrane I during accretion, facilitating a local incursion of asthenosphere. Alternatively, mantle diapirism may have developed along a tear in the downgoing slab, possibly a transform fault reactivated by jamming of the subduction zone during collision.

The foregoing model of superterrane convergence is consistent with many of the geologic relations observed in the Canadian Cordillera, especially the inversion of the Methow-Tyaughton basin, the distribution of Mesozoic volcanic-arc rocks, the deformation in the central Coast Plutonic Complex (Crawford et al., 1987), the timing of collision in Alaska (Jones et al., 1986), and the marked change in regional stress orientation in Albian time (Gabrielse, 1985). It conflicts mainly with the interpretations of stratigraphic and plutonic similarities between the superterranes (e.g., Tipper, 1984; Armstrong, 1988; Van Der Heyden, 1989). In attempts to reconcile these apparently conflicting groups of data, models were proposed suggesting time-transgressive accretion that progressed either southward (Armstrong, 1988) or northward (Wernicke and Klepacki, 1988). However, the middle to Late Cretaceous timing of accretion in Alaska apparently negates the possibility of a southward-progressing collision. Both models of diachronous accretion have difficulty explaining the paucity of magmatism on both superterranes during the Late Jurassic and Early Cretaceous.

REFERENCES CITED

Anderson, P., 1976, Oceanic crust and arc-trench gap tectonics in southwestern British Columbia: Geology, v. 4, p. 443–446.

Armstrong, R.L., 1988, Mesozoic and early Cenozoic magmatic evolution of the Canadian Cordillera, *in* Clark, S.P., Jr., Burchfiel, B.C., and Suppe, J., eds., Processes in continental lithospheric deformation: Geological Society of America Special Paper 218, p. 55–91.

Bell, W.A., 1956, Lower Cretaceous floras of western Canada: Geological Survey of Canada Memoir 285, 331 p.

Brown, E.H., 1987, Structural geology and accretionary history of the Northwest Cascades system, Washington and British Columbia: Geological Society of America Bulletin, v. 99, p. 201–214.

Coates, J.A., 1974, Geology of the Manning Park area, British Columbia: Geological Survey of Canada Bulletin 238, 177 p.

Cordey, F., 1986, Radiolarian ages from the Cache Creek and Bridge River complexes and from chert pebbles in Cretaceous conglomerates, southwestern British Columbia, *in* Current research, part A: Geological Survey of Canada Paper 86-1A, p. 595–602.

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.

Gabrielse, H., 1985, Major dextral transcurrent displacements along the Northern Rocky Mountain Trench and related lineaments in north-central British Columbia: Geological Society of America Bulletin, v. 96, p. 1–14.

Heah, T.S.T., Armstrong, R.L., and Woodsworth, G.J., 1986, The Gambier Group in the Sky Pilot area, southwestern Coast Mountains, British Columbia, *in* Current research, part B: Geological Survey of Canada Paper 86-1B, p. 685–692.

Irving, E., Woodsworth, G.J., Wynne, P.J., and Morrison, A., 1985, Paleomagnetic evidence for displacement from the south of the Coast Plutonic Complex, British Columbia: Canadian Journal of Earth Sciences, v. 22, p. 584–598.

Jones, D.L., Silberling, N.J., and Coney, P.J., 1986, Collision tectonics in the Cordillera of western North America: Examples from Alaska, *in* Coward, M.P., and Ries, A.C., eds., Collision tectonics: Geological Society of London Special Publication 19, p. 367–387.

Kleinspehn, K.L., 1985, Cretaceous sedimentation and tectonics, Methow-Tyaughton Basin, southwestern British Columbia: Canadian Journal of Earth Sciences, v. 22, p. 154–174.

Mathews, W.H., and Rouse, G.E., 1984, The Gang Ranch–Big Bar area, south-central British Columbia: Stratigraphy, geochronology, and palynology of the Tertiary beds and their relationship to the Fraser fault: Canadian Journal of Earth Sciences, v. 21, p. 1132–1144.

McGroder, M.F., and Miller, R.B., 1989, Geology of the eastern North Cascades, *in* Joseph, N.L., et al., eds., Geologic guidebook for Washington and adjacent areas: Washington Division of Geology and Earth Resources Information Circular 86, p. 97–111.

Monger, J.W.H., 1985, Structural evolution of the southwestern Intermontane belt, Ashcroft and Hope map areas, British Columbia, *in* Current research, part A: Geological Survey of Canada Paper 85-1A, p. 349–358.

——1986, Geology between Harrison Lake and Fraser River, Hope map area, southwestern British Columbia, *in* Current research, part A: Geological Survey of Canada Paper 86-1B, p. 699–706.

Monger, J.W.H., Price, R.A., and Tempelman-Kluit, D.J., 1982, Tectonic accretion and the origin of the two major metamorphic and plutonic welts in the Canadian Cordillera: Geology, v. 10, p. 70–75.

O'Brien, J.A., 1986, Jurassic stratigraphy of the Methow Trough, southwestern British Columbia, *in* Current research, part B: Geological Survey of Canada Paper 86-1B, p. 749–756.

Preto, V.A., 1979, Geology of the Nicola Group between Merritt and Princeton: British Columbia Ministry of Energy, Mines and Petroleum Resources Bulletin 69, 90 p.

Ray, G.E., 1986, The Hozameen fault system and related Coquihalla serpentine belt of southwestern British Columbia: Canadian Journal of Earth Sciences, v. 23, p. 1022–1041.

Rehrig, W.A., 1986, Processes of regional Tertiary extension in the western Cordillera: Insights from the metamorphic core complexes, *in* Mayer, L., ed., Extensional tectonics of the southwestern United States: A perspective on processes and kinematics: Geological Society of America Special Paper 208, p. 97–122.

Rusmore, M.E., Potter, C.J., and Umhoefer, P.J., 1988, Middle Jurassic terrane accretion along the western edge of the Intermontane superterrane, southwestern British Columbia: Geology, v. 16, p. 891–894.

Smith, A.D., 1986, Isotopic and geochemical studies of Terrane I, south-central British Columbia [Ph.D. thesis]: Edmonton, University of Alberta, 195 p.

Smith, P.L., and Tipper, H.W., 1986, Plate tectonics and paleobiogeography: Early Jurassic (Pliensbachian) endemism and diversity: Palaios, v. 1, p. 399–412.

Souther, J.G., 1990, Volcanic regimes, *in* Gabrielse, H., and Yorath, C.J., eds., The Cordilleran orogen: Canada (Geology of Canada, Volume 4): Ottawa, Ontario, Geological Survey of Canada and Geological Society of America, The Geology of North America, v. G-2 (in press).

Tennyson, M.E., and Cole, M.R., 1978, Tectonic significance of upper Mesozoic Methow-Pasayten sequence, northeastern Cascade Range, Washington and British Columbia, *in* Howell, D.G., and McDougall, K.A., eds., Mesozoic paleogeography of the western United States: Society of Economic Paleontologists and Mineralogists, Pacific Section Symposium, v. 2, p. 499–508.

Thompson, R.N., Morrison, M.A., Hendry, G.L., and Parry, S.J., 1984, An assessment of the relative roles of crust and mantle in magma genesis: An elemental approach: Royal Society of London Philosophical Transactions, ser. A, v. 310, p. 549–590.

Thorkelson, D.J., 1985, Geology of the mid-Cretaceous volcanic units near Kingsvale, southwestern British Columbia, *in* Current research, part B: Geological Survey of Canada Paper 85-1B, p. 333–339.

——1986, Volcanic stratigraphy and petrology of the mid-Cretaceous Spences Bridge Group near Kingsvale, southwestern British Columbia [M.S. thesis]: Vancouver, University of British Columbia, 119 p.

——1987, Magma mixing and alteration of tectonic affinity in the Spences Bridge Group, southwestern British Columbia: Geological Association of Canada Programme with Abstracts, v. 12, p. 96.

Thorkelson, D.J., and Rouse, G.E., 1989, Revised stratigraphic nomenclature and age determinations for mid-Cretaceous volcanic rocks in southwestern British Columbia: Canadian Journal of Earth Sciences.

Tipper, H.W., 1984, The allochthonous Jurassic–Lower Cretaceous terranes of the Canadian Cordillera and their relation to correlative strata of the North American craton, *in* Westermann, G.E.G., ed., Jurassic-Cretaceous biochronology and paleogeography of North America: Geological Association of Canada Special Paper 27, p. 113–120.

Trexler, J.H., and Bourgeois, J., 1985, Evidence for Mid-Cretaceous wrench faulting in the Methow Basin, Washington: Tectonostratigraphic setting of the Virginian Ridge Formation: Tectonics, v. 4, p. 379–394.

Van Der Heyden, P., 1989, Jurassic magmatism and deformation: Implications for the evolution of the Coast Plutonic Complex: Geological Society of America Abstracts with Programs, v. 21, p. 153.

Wernicke, B., and Klepacki, D.W., 1988, Escape hypothesis for the Stikine block: Geology, v. 16, p. 461–464.

ACKNOWLEDGMENTS

Supported by the Geological Survey of Canada through J.W.H. Monger, and by Natural Science and Engineering Research Council of Canada grants to W. H. Mathews, R. StJ. Lambert, J. N. Ludden, R. L. Armstrong, G. E. Rouse, and grant #A1877 to R. P. Taylor. We thank J. N. Ludden and C. Greig for their comments on an earlier version of the manuscript; M. L. Bevier and J. G. Souther for thoughtful reviews; and J. G. Souther for providing a copy of his Decade of North American Geology contribution (in press).

Manuscript received April 17, 1989
Revised manuscript received July 10, 1989
Manuscript accepted July 19, 1989