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EVOLUTION OF THE CANADIAN CORDILLERA: A PLATE-TECTONIC MODEL

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ABSTRACT. The Canadian Cordillera consists of five distinct geological and physiographic belts, each with its own history and largely independent of neighboring belts until the Mesozoic. These are, from east to west: the (1) Rocky Mountain Belt, (2) Omineca Crystalline Belt, (3) Intermontane Belt, (4) Coast Plutonic Complex, and (5) Insular Belt.

The Cordillera is presumed to have been initiated by an episode of rifting in the mid-Proterozoic. Subsequently a miogeoclinal wedge developed along the western margin of the North American craton in the Rocky Mountain and Omineca Crystalline Belts. In late Devonian time the interaction between the North American plate and a Pacific plate resulted in the shedding of clastic detritus eastward from oceanic crust into the miogeocline and ultimately local overthrusting of oceanic crust on to miogeoclinal rocks. In the late Paleozoic, arc rocks represent the Omineca Crystalline Belt, oceanic crust the Intermontane Belt, arc rocks the Coast Plutonic Complex, and a mixture of arc rocks and mid-Paleozoic continental crust, the Insular Belt. One implication of this distribution is that all Paleozoic rocks west of the Omineca Crystalline Belt are allochthonous with respect to the North American craton. The Cordillera became consolidated in the Mesozoic with apparently physically continuous Upper Triassic units linking Coast, Intermontane, and Omineca Belts in the north. Similar continuity is not evident until the Cretaceous in the south. Definite linkages cannot be made between these three belts and the Rocky Mountain Belt (and thus the North American craton) to the east until the late Jurassic, and the Insular Belt to the west until the Cretaceous. During the Mesozoic the western Cordillera evolved from a system of island arcs in the Triassic and Early Jurassic, through an intermediate stage of marine troughs fed in part by detritus from actively uplifted granitic and metamorphic rocks of the Omineca Crystalline Belt and Coast Plutonic Complex, to a final stage in the Late Cretaceous and Eocene of a continental Cordillera, comparable with the present day Andes. Concomitantly there was a considerable amount of transcurrent movement within the Cordillera perhaps in response to a strong northerly component of motion of a Pacific plate. Finally, in Miocene time, crustal extension and emplacement of plateau basalts took place in much of the Cordillera.

INTRODUCTION

This paper attempts to interpret lithological assemblages in the Canadian Cordillera in terms such as island arcs, oceanic crust, and continental rise:slope:shelf assemblages and to synthesize these interpretations, using plate-tectonic concepts, to present a model of the tectonic history. Most previous detailed discussions of the evolution of the Canadian Cordillera have been within the context of geosynclinal theory (White, 1959; Roddick and others, 1967; Douglas and others, 1970), although there have been several brief plate-tectonic interpretations (Wilson, 1968; Danner, 1970; Souther, 1970a) and one more lengthy one comparing the Alpine chains of Greece with the Cordillera (Dercourt, 1970).

Hamilton (1969a) and Burchfiel and Davis (1972) have applied the approach used in this paper to interpretations of the United States Cordillera, following pioneering suggestions made by Gilluly (1965, p. 29). However the Canadian Cordillera is sufficiently different from the segment south of lat 47° N to warrant a separate discussion. The Canadian Cordillera between lats 50° and 60° N consists of five clearly defined physiographic and geological belts (fig. 1). From west to east

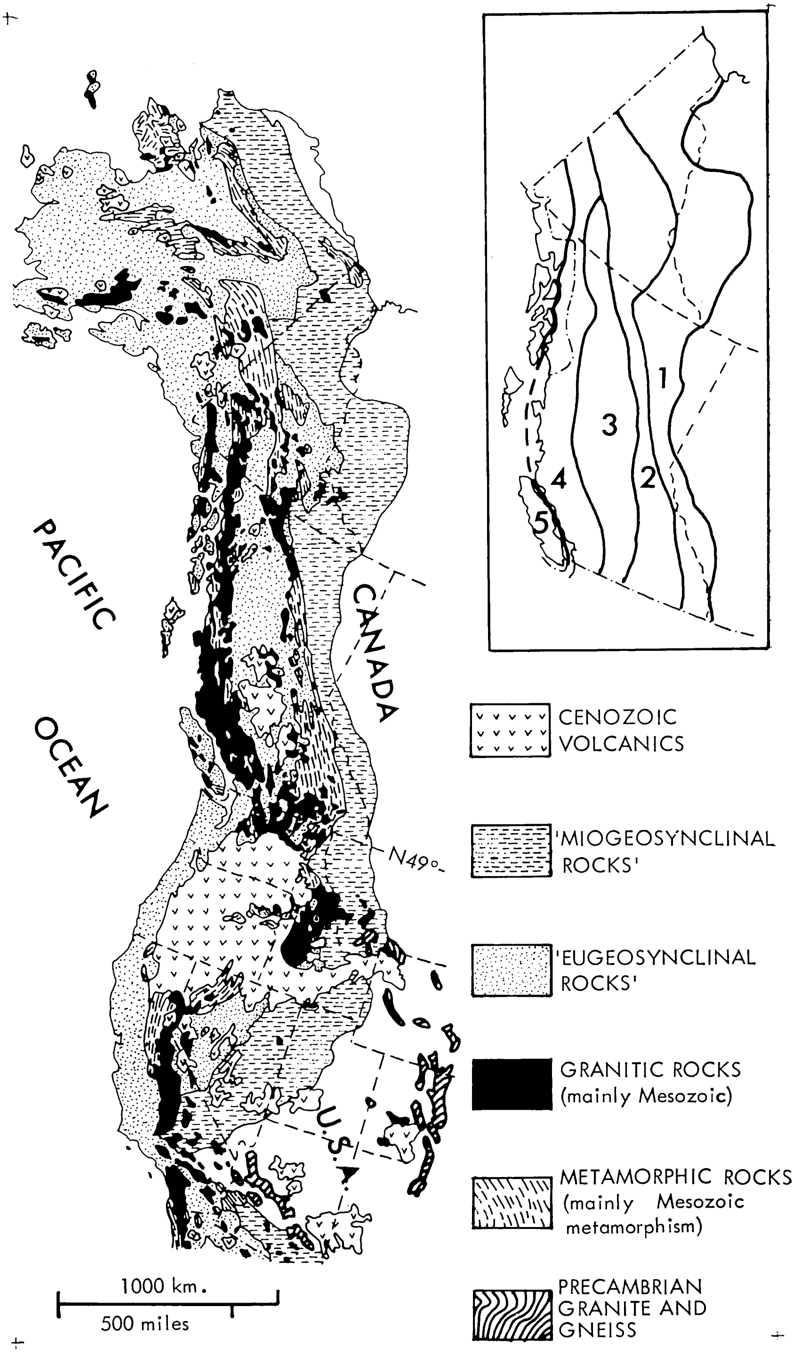

Fig. 1. Sketch map of the North American Cordillera (after King, 1969) showing differences between the Canadian and United States' segments of the Cordillera. "Eugeosynclinal" and "miogeosynclinal" rocks refer to stratified assemblages respectively with and without volcanic rocks. The inset map shows the location of the geological and physiographic belts of the Canadian Cordillera. These are (1) Rocky Mountain Belt, (2) Omineca Crystalline Belt, (3) Intermontane Belt, (4) Coast Plutonic Complex, and (5) Insular Belt.

are (1) sedimentary, "miogeosynclinal" strata in the Rocky Mountains Belt, (2) metamorphic and granitic rocks in the Omineca Crystalline Belt, (3) mainly unmetamorphosed and low-grade sedimentary and volcanic "eugeosynclinal" and "epieugeosynclinal" strata in the Intermontane Belt, (4) predominantly granitic rock in the Coast Range Plutonic Complex, and (5) largely unmetamorphosed and low-grade sedimentary and volcanic "eugeosynclinal" strata in the Insular Belt. These belts (south of 60° N) are roughly rectilinear and contrast with the complex, "z-shaped" pattern to the south in the United States (Wise, 1963). In Canada, there is no equivalent to the Colorado Rockies or Colorado Plateau. The Canadian Rockies are analogous to the south-southwesterly-trending belt of thrust faults passing through Wyoming and Idaho (Armstrong and Oriel, 1965), and extending southward into Nevada (Burchfiel and Davis, 1972). The Omineca Crystalline Belt is seemingly largely equivalent to the Sierra Nevada-Idaho Batholith granitic and metamorphic terrane, and the Intermontane Belt to some parts of the United States Cordillera west of the Sierra Nevada. There appear to be no direct counterparts to the Coast Plutonic Complex and Insular Belt south of about 47° N.

The distribution in time and space of the various lithological assemblages, interpreted as island arcs et cetera, is summarized in figure 2. This figure emphasizes (1) the different histories of the various belts,

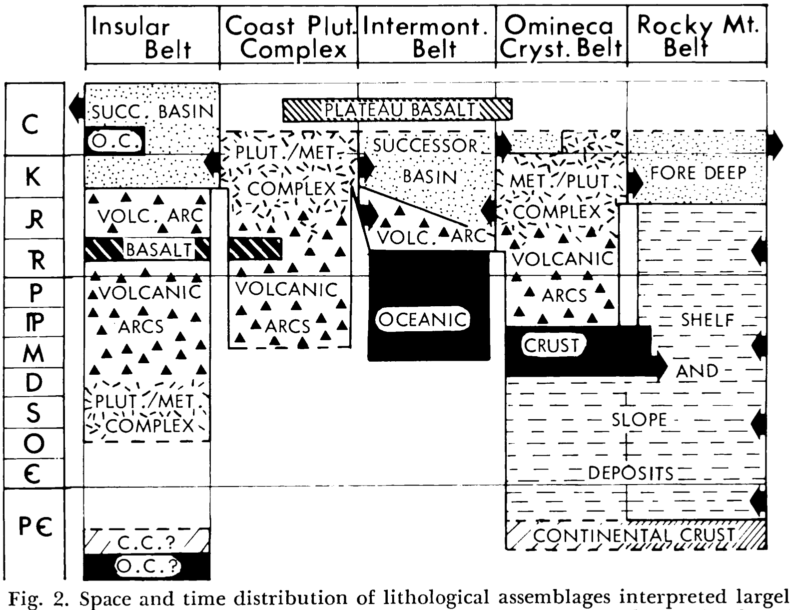

Fig. 2. Space and time distribution of lithological assemblages interpreted largely in actualistic terms within the various physiographic and geological belts of the Canadian Cordillera. Spaces between the vertical columns indicate that no linkages are known between the belts. These linkages take the form of detritus shed from one belt to another, shown by arrows that indicate the direction of clastic movement, or of stratigraphic units spanning two contiguous belts.

(2) the presence of oceanic crust in the Intermontane Belt with the inference that all pre-Mesozoic rocks in the Canadian Cordillera west of the Omineca Crystalline Belt may be allochthonous, and (3) the importance of recognizing linkages between the various belts. These linkages take the form of stratigraphic units common to contiguous belts or clastic detritus shed from one belt to the other. Formerly it was assumed tacitly that the relative geographic positions of these belts were fixed. Today, increased knowledge of the lateral mobility of the Earth's crust makes this concept untenable. From the record in the Canadian Cordillera there is evidence only that it attained its present configuration, with five geological belts, in late Mesozoic time.

Much of the information and data for distribution maps are summarized from Douglas and others (1970), to which the reader is referred for more precise information. The distribution maps are highly simplified and are intended to give a general impression only. For example, many details have been lost in combining under "lower Paleozoic" nine of Douglas' maps.

PROTEROZOIC AND LOWER PALEOZOIC HISTORY

Proterozoic and Lower Paleozoic (through Devonian) mainly sedimentary strata outcrop almost entirely in the Rocky Mountain and Omineca Crystalline Belts (figs. 3A, 3B). These rocks lie either on crystalline basement or can be linked with the North American craton by near physical continuity of stratigraphic units. In general, isopach trends in these rocks parallel the north-northwesterly trend of the Cordillera and crosscut markedly the predominant northeasterly trend of the partly(?) underlying crystalline basement.

The underlying basement, more than 1600 m.y. old (Burwash and others, 1962), can be traced westward under the Rocky Mountain Belt as far as the Rocky Mountain Trench, which bounds it on the west, but possibly extends for at least 80 km farther west under the Omineca Crystalline Belt. Ross (1970, p. 61) believed that the cores of gneiss domes in the Shuswap metamorphic terrane are reactivated basement rocks, but Reesor (1970, p. 85) suggested that they are metamorphosed Upper Precambrian and younger strata. Campbell (1970, p. 33) noted that granitic gneiss at Quesnel Lake (at the northern end of the Shuswap terrane) may be crystalline basement. Interpretation of available geophysical data (Berry and others, 1971) is in accord with Reesor's interpretation. North of 50° N the crystalline basement seemingly terminates below the Rocky Mountain Trench, but south of 50° N it may extend west of the Trench under the Purcell Mountains as suggested by Bally, Gordy, and Stewart (1966). West of the Omineca Crystalline Belt the only evidence for Precambrian basement is just south of the International Boundary in the Cascade Mountains, where Mattinson (1970, p. 116) obtained ages of 1600 to 2000 m.y. from zircons in reactivated gneiss. Misch (1966, p. 106) has speculated that mafic rocks in this gneiss complex are remains of primary oceanic crust subsequently

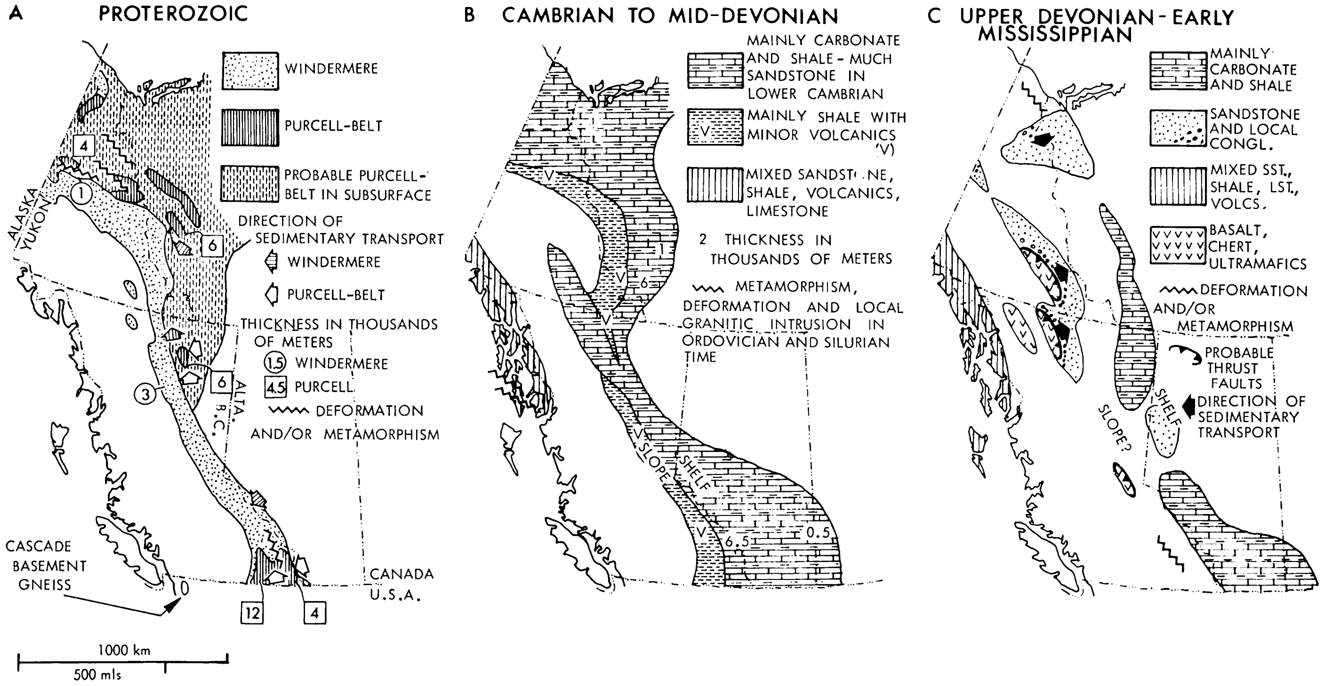

Fig. 3. Distribution maps for the (A) Proterozoic, (B) Cambrian to mid-Devonian, and (C) Upper Devonian to Early Mississippian of the Canadian Cordillera. Maps are generalized from Douglas and others, 1970.

converted into continental crust. It appears therefore as though the western limit of ancient crystalline rocks that are definitely part of the North American craton is either near the line of Rocky Mountain Trench or somewhere not too far to the west under the Omineca Crystalline Belt.

The Proterozoic consists of two great but mutually distinct sedimentary sequences of strata that occur throughout the length of the Cordillera (fig. 3A). These rocks include and are correlative with the Purcell (or Belt) and the overlying Windermere rocks of southeastern British Columbia and adjacent Alberta (Gabrielse, 1972).

Purcell rocks (approx 1400-900 m.y.) may represent the greatest volume of any single sequence in the Cordillera, even though they are somewhat restricted in outcrop to the southern Rocky and adjoining Purcell Mountains, to the northern Rocky Mountains, and to the core of the Mackenzie Mountains. Total thicknesses range from less than 3000 m in eastern exposures to more than 9000 m in western ones.

Purcell strata are predominantly argillite, siltstone, fine-grained sandstone, carbonate, and local, relatively rare, basalt flows, and probably related gabbroic dikes and sills. Characteristic of strata in eastern outcrops are shallow-water or intertidal structures such as mud cracks, desiccation breccias, and stromatolites, whereas equivalent strata to the west are in many cases turbidites of predominantly deep water origin (Price, 1965; Bell, 1968). In some western exposures the older, thickest, part of the succession is largely turbidite. These rocks grade upward into a shallow-water stromatolitic and carbonate-rich sequence at the top (Bishop, Morris, and Edmunds, 1970). In general, the Purcell sequence can be interpreted as a continental shelf:slope:rise assemblage fringing the western margin of the ancient North American craton. The margin may have been physiographically complex, with reentrants such as those suggested by Harrison and Peterman (1971) for the Belt Basin.

Purcell sedimentation was terminated by the deformation, low-grade metamorphism, and uplift referred to as the East Kootenay Orogeny in southeastern British Columbia (White, 1959) and the Racklan Orogeny (Gabrielse, 1967) in the Mackenzie Mountains. Ages of these "orogenies" are not precisely known, and their correlation is tentative.

Windermere rocks, late Proterozoic, 800 to 600 m.y., are, unlike the Purcell strata, almost continuously exposed along the Cordillera in the Omineca Crystalline and Rocky Mountain Belts. These rocks generally thicken but become finer grained to the west, reaching a maximum thickness of in excess of 4500 m. They are predominantly impure, poorly sorted, often coarse clastic rocks (grits) characterized locally by thin to extremely thick diamictite. In many places carbonate is common in the upper part of the sequence and basalt is present in a few localities. Much of the lower part of the Windermere sequence could represent deposition in relatively deep water with the periodic introduction of coarse grained material by turbidity current. The fairly widespread carbonates in the upper part reflect a shallow-water environment attained when deposition reached wave base. The site of maximum depositional thickness of Windermere rocks was generally to the west of that for the Purcell, suggesting that these sedimentary rocks were building out the western margin of the continent.

Cambrian to Middle Devonian strata are mainly in the Rocky Mountain and Omineca Crystalline Belts (fig. 3B). Ordovician, Silurian, and Devonian strata occur in southeastern Alaska, and Devonian rocks in the Saint Elias Mountains, southwestern Yukon. In addition small areas of Devonian rocks are in and just west of the Northern Cascade Mountains, south of lat 49° N. No pre-Mississippian strata are known from the Intermontane or Coast Crystalline Belts.

In the eastern Cordillera lower Paleozoic strata are at least locally conformable on the Windermere, but they are commonly finer grained and better sorted than the underlying rocks. With the exception of thick Lower Cambrian orthoquartzite, the strata contain only minor contributions of coarse clastic material from the craton and are mainly shales and carbonates. Lower Cambrian to Silurian rocks locally contain conspicuous basic volcanic members in their more western exposures. Distinct facies boundaries separate depositional environments representing shelf and deeper basins and are roughly parallel with the trend of the Cordillera. These strata are thick near the eastern margin of the deformed belt but are far thinner to the east, on the craton. For example, in southern British Columbia, cumulative thicknesses for Cambrian to Middle Devonian rocks are on the order of 7000 m, whereas to the east they are less than one-tenth of this. In northern British Columbia the comparable thicknesses are 5000 m and 500 m.

An anomaly in the relatively simple pattern is the Cassiar Platform of the northern Omineca Crystalline Belt, which appears as a tongue of carbonate west of shale facies in figure 3B. In this the facies are of shallow-water aspect and contrast with deeper water, shaley, facies to the northeast. The Cassiar Platform lies west of the Tintina and Northern Rocky Mountain trenches, along which there was probable right-lateral transcurrent movement in the Mesozoic, and possibly is displaced along these faults. An alternative suggestion is that the Platform represents a sialic block torn away from the North America craton during initial rifting (see below) but remaining close to it.

Ordovician through Devonian rocks in the western part of the Cordillera are confined to the Insular Belt. They typically contain conspicuous volcanics. Near the Northern Cascade Mountains are Middle Devonian fine-grained clastic rocks, carbonate, and basic volcanics (Danner, 1960). In southeastern Alaska, Ordovician and Lower Silurian assemblages include slate, graywacke, and associated andesite, with similar rocks plus notable carbonate in Late Silurian and Devonian time (Brew, Loney, and Muffler, 1966). This area provides good evidence for lower to mid-Paleozoic "orogeny" manifested by Ordovician granitic rocks and metamorphism, Silurian granitic rocks, and Devonian granite-bearing conglomerate (Lanphere, MacKevett, and Stern, 1964; Berg, 1970;

Brew, Loney, and Muffler, 1966). Finally, carbonate with interbedded argillite is present in southwestern Yukon (Wheeler, 1963; Muller, 1967).

Proterozoic and lower Paleozoic rocks of the eastern Cordillera can reasonably be interpreted as continental shelf:rise:slope assemblages composing a miogeoclinal wedge that accumulated along the western (trailing) margin of the North American craton at least in part on continental crust (figs. 4A, 4B). The orientation of this margin, which is nearly normal to the grain of the basement crystalline rocks, was controlled by the orientation of the spreading axis or transform fault that rifted apart an originally continuous plate of continental crust. The continental mass on one side (now east) of the rift became the North American craton, the source for Purcell sediments, and continued contributing sediment through Windermere and early Paleozoic time. The other mass left no recognizable record in succeeding sedimentation. An interruption in this simple history possibly came in post-Purcell, pre-Windermere time, when the Racklan and East Kootenay Orogenies may record reversal of the prevailing trailing-edge situation. Volcanic rocks are relatively minor in the eastern Cordillera and are predominantly basaltic. They may merely reflect local rifting in an overall tensional environment.

By contrast rocks in the western Cordillera seem to have formed mainly in island arcs, presumably above subduction zones of unknown polarity. A conservative view is that these rocks formed the arc component of an arc:marginal basin:rise:slope:shelf assemblage and were in essentially the same position as now. This is considered unlikely, not only as there is no direct reflection of the southeastern Alaska Ordovician-Silurian orogenic event in the eastern Cordillera, but also because of later history. In late Paleozoic time these rocks were separated from the eastern Cordillera by an island arc:oceanic crust complex, which makes their separation from the eastern Cordillera almost mandatory. Jones, Irwin, and Ovenshine (1972) have suggested that southeastern Alaska is a fragment from what is now California emplaced by latest Paleozoic or early Mesozoic right lateral transcurrent faulting. This suggestion is quite compatible with what is known of the later history of the Canadian Cordillera.

UPPER PALEOZOIC TO MIDDLE TRIASSIC HISTORY

The Devonian-Mississippian boundary is the first time in the history of the Canadian Cordillera that there is evidence for the presence of rocks west of the Omineca Crystalline Belt. This evidence takes the form of clastic detritus shed eastward onto rocks that can be linked physically with the North American craton (fig. 2). Also, after this time all five belts comprising the modern Cordillera are represented, as the oldest known rocks in the Coast Range Plutonic Complex and Intermontane Belt are Mississippian. However, only the upper Paleozoic rocks in the Omineca Crystalline and Rocky Mountain Belts, and possibly those of the Intermontane Belt, can be tied with some confidence to the North American craton as the oceanic aspect of rocks in the Intermontane Belt makes it probable that all rocks to the west are allochthonous.

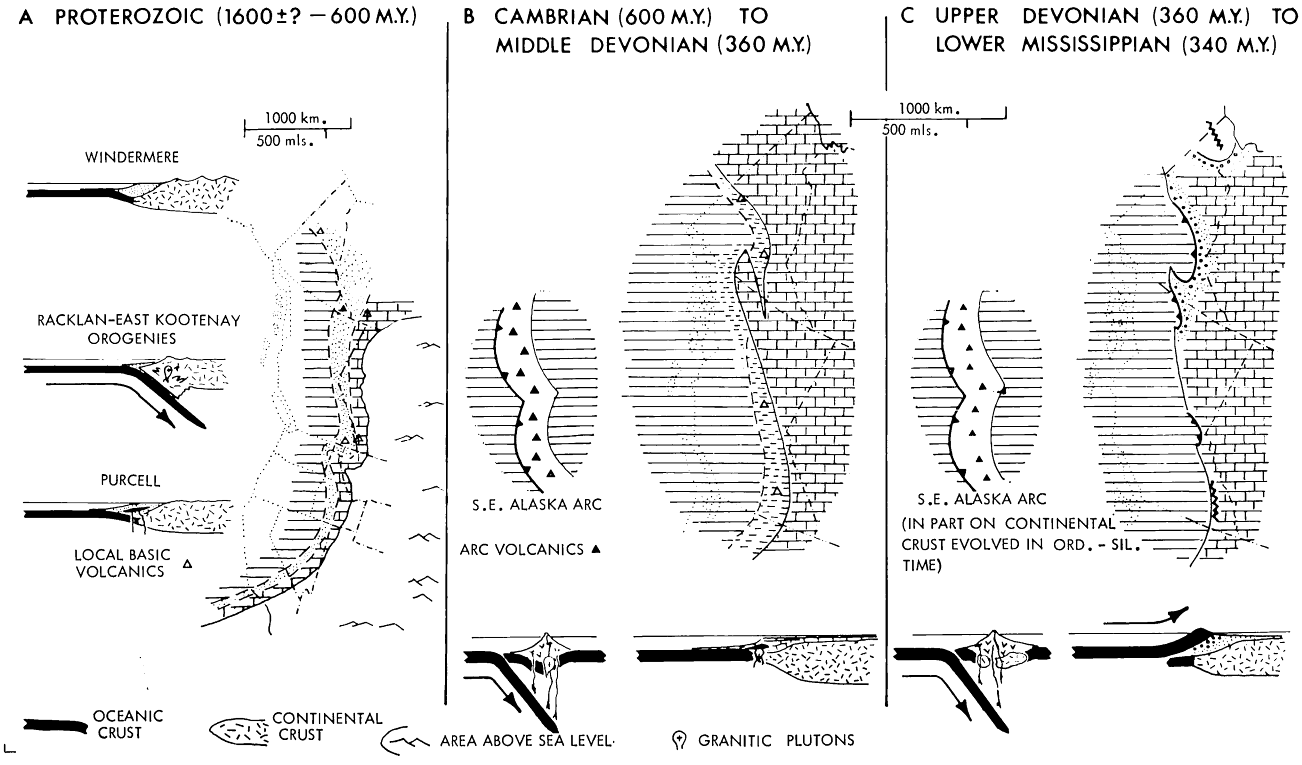

Fig. 4. Plate tectonic interpretations of the (A) Proterozoic, (B) Cambrian to Middle Devonian, and (C) Upper Devonian to Early Mississippian rocks of the Canadian Cordillera. The East Kootenay-Racklan section is hypothetical; an actual subduction zone may not have developed. Unknown also are the position of the southeastern Alaska arc relative to the continent and the polarity of the southeastern Alaska subduction zone.

The change is heralded by deposition in the northern Cordillera of large volumes of sedimentary rock, notably chert-pebble conglomerate, chert arenite, graywacke, and argillite that were derived from a source west of the Omineca Crystalline Belt (fig. 3C; Gabrielse, 1963, 1967; Douglas and others, 1970). In time and style these phenomena are comparable with the Antler Orogeny of the western United States (Roberts and others, 1959). An additional feature in the northern Canadian Cordillera is the presence above the clastic rocks of a thick assemblage of Upper Devonian(?) and Mississippian basalt, metabasalt, ultramafic rock, chert, and local gabbro, that can be interpreted as oceanic crust, underlying an area about 160 km long by 30 km wide, in the McDame synclinorium (Gabrielse, 1963). Rocks at the basal contact of this mass are highly deformed, and no feeders to it are known to cut the underlying Proterozoic to Middle Devonian shelf-like assemblage of carbonates and shale. A similar mass forms the Slide Mountain Group, about 650 km along trend to the south-southeast.

These features can be interpreted as the result of reorganization of lithospheric plates, perhaps in response to the closing of the Proto-Atlantic ocean on the opposite side of the North American craton, an event recorded by the Acadian Orogeny of the Appalachians (Bird and Dewey, 1970). The western margin of North America ceased to be an intraplate boundary and became a plate margin, interacting with a plate to the west (fig. 4C). Initially, oceanic crust was elevated, eroded, and shed clastic debris eastward over rocks on the margin of the craton. Oceanic crust was then thrust, or slid, over the detritus, in a manner analogous with that described from Papua by Davies (1968). Elsewhere, as in the southeastern part of the Omineca Belt, deformation and low-grade metamorphism, perhaps the result of plate collision, possibly took place at this time within rocks bordering the craton (*see* Wheeler, 1968).

Information on the distribution of Mississippian to Middle Triassic rocks indicates that in the Cordillera south of about 60° N there are at least four belts, each with a characteristic lithology (fig. 5A; Monger and Ross, 1971; Monger, in press). In the Rocky Mountains (1) is a belt of carbonate, predominantly fine-grained clastic rock toward the west, some craton-derived sandstone, and local chert. A somewhat poorly defined zone in the Omineca Crystalline Belt (2) is characterized by locally abundant pyroclastic rock, local acid and probable andesitic volcanic rock, sandstone, shale, and carbonate of Mississippian and Permian ages. In the northern Cordillera these rocks locally overlie or are infolded with Upper Devonian(?) and Mississippian basalt and ultramafic rock, noted above. In the Intermontane Belt (3), separated from the above rocks by the Teslin and Pinchi Faults (fig. 7A), are altered basalt, in many places associated with Alpine ultramafic rock and gabbro, ribbon chert, and pelite. In places thick, linear masses of shallow-water, Bahama-type, carbonate may range in age from the Upper Mississippian to Upper Permian within the same body. In the Coast Mountains and Insular Belts (4) are basalt, andesite, acid volcanic rock, sandstone, con-

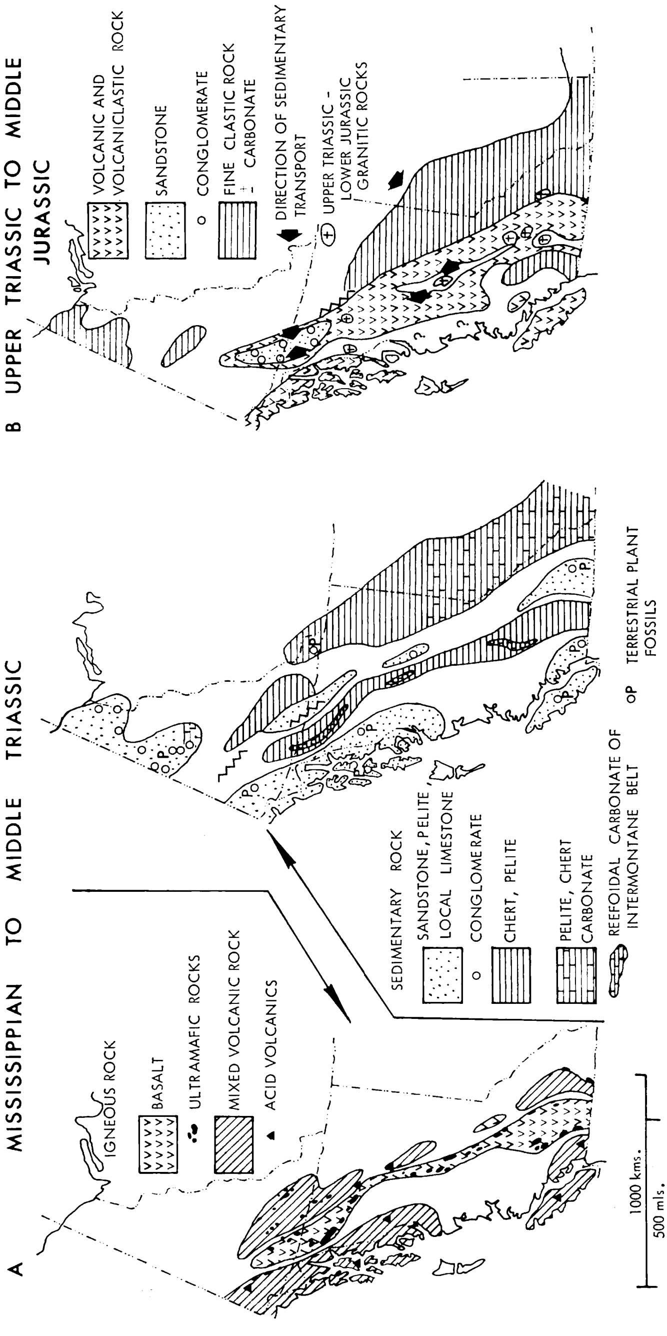

Fig. 5. Distribution maps for (A) Mississippian to Middle Triassic and (B) Upper Triassic to Middle Jurassic rocks.

glomerate, pelite, and carbonate of Mississippian, Pennsylvanian, and Permian ages, with ultramafic rocks locally along the Shakwak-Denali fault systems (figs. 5A, 7A).

These various assemblages can be interpreted as (1) a shelf:slope assemblage in the Rocky Mountains, (2) island arcs in the Intermontane Belt, (3) oceanic crust in the Intermontane Belt, and (4) island arcs in the Coast Plutonic Complex and Insular Belts (fig. 6A). Various models can be made because constraints are few. There is no positive information on the polarity of the arcs and little precise information on when they were active.

The island arc in the Omineca Crystalline Belt is poorly defined but appears to have been active in at least Mississippian and Permian time, as evidenced by pyroclastics and flow rocks of various compositions of these ages (for example, Lord, 1948; Roots, 1954). The arc appears to have developed at least partly on oceanic crust (some of which may have been overthrust in Devonian Mississippian time) and partly on craton-derived sedimentary rocks, yet must have been well removed from the Rocky Mountain Belt, for no tuffaceous material or other evidence of volcanism has been reported from this belt.

Rocks in the Intermontane Belt are mainly comparable with those in modern ocean basins, with the exception of the Mississippian to Permian linear masses of shallow-water carbonate. A similar association is found in the ophiolite belt of Oman where the carbonate has been explained by Reinhardt (1969) as forming on an oceanic ridge near sea level. Presumably carbonate deposition, once initiated, kept pace with subsidence as the substratum moved away and down from the ridge. If this model is applicable to the Canadian Cordillera (fig. 6A) and if we can assume a conservative but uniform spreading rate of 2 cm per year for the ridge, then the oldest carbonates could have migrated about 1800 km since initiation of sedimentation, as their deposition continued uninterrupted for about 90 m.y. (from the Upper Mississippian to the Upper Permian). The model of continuous subduction for this length of time, however, may be questioned (see below). The scarcity of clastic rocks coarser than pelites in the Intermontane Belt suggests that this assemblage was laid down far from the now contiguous, coeval assemblages in the Omineca Crystalline Belt and Coast Plutonic Complex, both of which contain abundant clastic material. An alternative model for the Intermontane Belt is that the thick carbonate represents a sedimentary arc developed on oceanic crust, complementary to the volcanic arc in the Omineca Crystalline Belt. This is considered less likely than the previous hypothesis partly because of the minor amount of coarse clastic material in the Intermontane Belt, whereas a considerable amount might be expected from the arc, and partly because blueschists are locally developed in these rocks (Monger and Hutchison, 1971), implying the existence of some kind of subduction between them and the volcanic arc to the east.

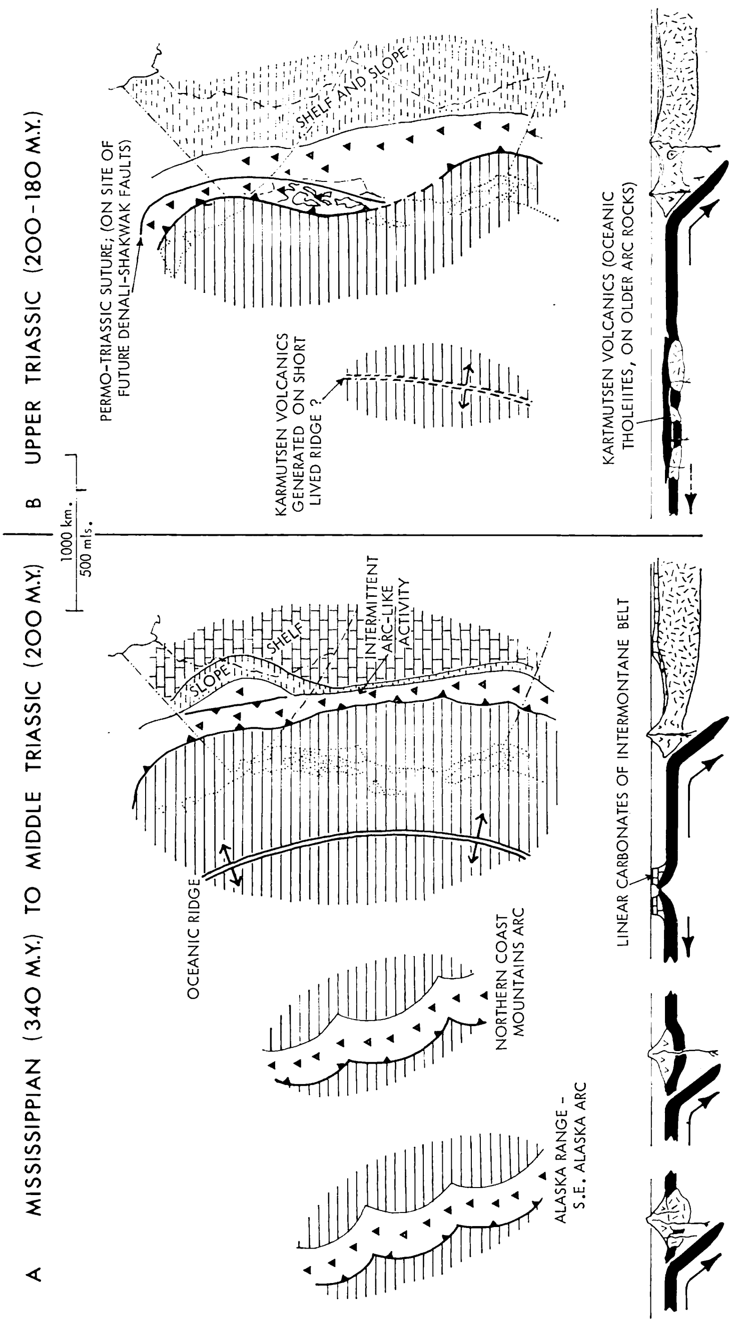

Fig. 6. Plate tectonic interpretations of (A) Mississippian to Middle Triassic and (B) Upper Triassic rocks. The relative positions and polarity of arcs in (A) are unknown; (B) does not show possible "internal" transcurrent faulting that may have occurred in part at this time.

Arc-type rocks in the Coast Plutonic Complex and Insular Belts may have developed at least partly on continental crust that evolved during Ordovician and Silurian "orogeny" in southeast Alaska. Terrestrial plant fossils there indicate the existence of land, probably volcanic islands, and the composition of sandstones and conglomerates suggests erosion of a volcanic terrane rather than crystalline basement. More than one arc system may be involved. Richter and Jones (1970) suggested that rocks southwest of the Shakwak-Denali Faults (fig. 7A) represent an old arc that was sutured to the continent in Permo-Triassic time along a subduction zone on the site of these faults. Their "continent" is the northerly extension of the Coast Plutonic Complex, itself probably an arc in upper Paleozoic time, as shown in figure 6A. The southward extension of this suture is not known, but from the relative continuity of southeastern Alaskan geology, it must seemingly separate the Insular Belt from the Coast Plutonic Complex. The only break interrupting this continuity is the cross-cutting Chatham Strait Fault, but the maximum movement given for this fault is 190 km right-lateral (Lathram, 1964), insufficient to make this a major transform fault related to a Permo-Triassic, Shakwak-Denali suture.

The eastward dip shown for subduction zones in the model in figure 6A is probably reasonable for a subduction zone located along the Teslin and Pinchi Faults (fig. 7A) but is purely surmise elsewhere. West of the Teslin and Pinchi Faults in rocks of oceanic type are blueschists best dated as Permo-Triassic (Monger and Hutchison, 1971), whereas there are coeval arc-type rocks to the east. Along the Tintina Fault zone in the Yukon (fig. 7A) southwest-dipping faults of probable Permo-Triassic age are associated with serpentinite and local blueschist and eclogite (D. J. Tempelman-Kluit, personal commun.). Possibly these faults represent a southwest-dipping Permo-Triassic subduction zone.

Oceanward stepping of subduction zones from Permian to Middle Triassic time may be recorded by a westward shift of juxtaposed oceanic basin:arc assemblages. Permian rocks near Kamloops, British Columbia, can be interpreted as an arc assemblage from abundant included sandstones and pyroclastic rocks, whereas those 80 km to the west near Cache Creek are the typical Intermontane Belt oceanic assemblage of chert, pelite, metabasalt, and carbonate (see Campbell and Tipper, 1971). Middle Triassic arc-like rocks (Pavilion Group, Trettin, 1961) overlie the older assemblage near Cache Creek, but a Middle Triassic oceanic assemblage (Fergusson Group, Cameron and Monger, 1971) is farther west, beyond the Fraser-Yalakom Fault zone (fig. 7A).

A serious objection to the model in figure 6A is that the amount of upper Paleozoic andesitic volcanism in the Omenica Crystalline Belt is relatively minor, and no granitic or regionally metamorphosed rocks of this age are known. If subduction was continuous from the Mississippian to the Permian (90 m.y.), then the volume of andesite would be expected to be much greater. This anomaly is very evident when compared with the Upper Triassic to Lower Jurassic volcanism (30 m.y. in-

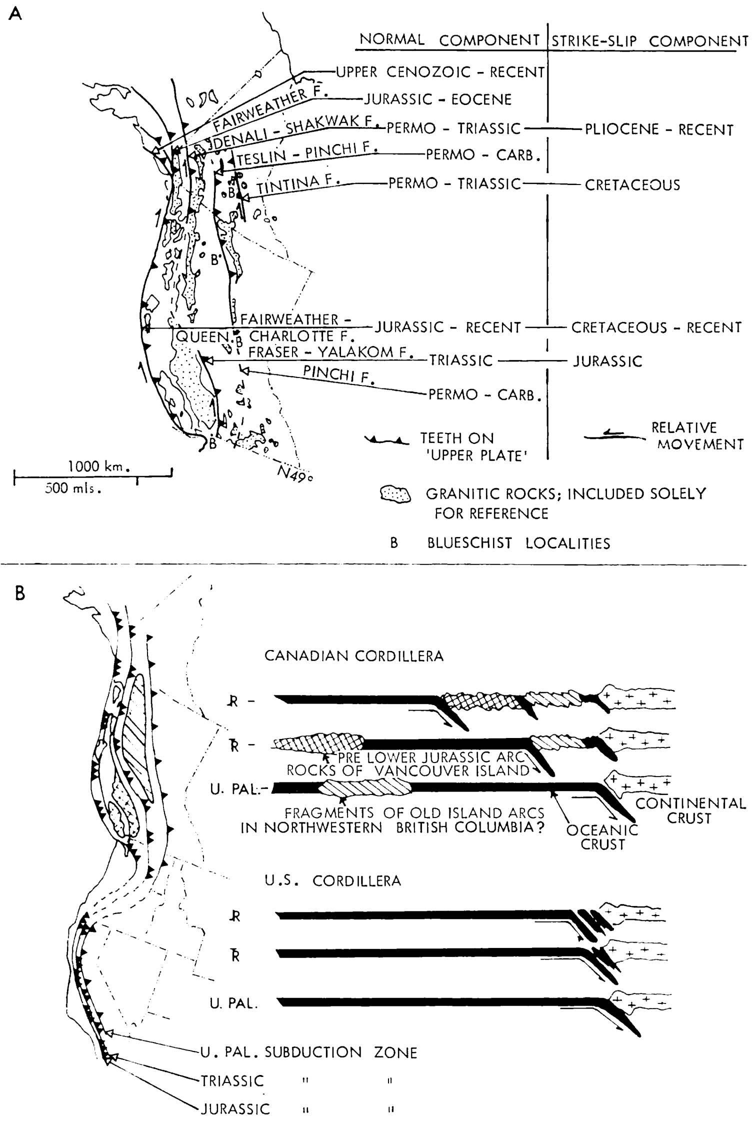

Fig. 7. A. Possible subduction zones in the Canadian Cordillera, inferred largely from juxtaposition of oceanic crust:arc assemblages. Most of these zones appear to be the sites of later transcurrent faults, and in places this movement overlaps in time with inferred normal movement suggesting that there was oblique subduction. Other possible strike slip faults, such as the northern Rocky Mountain Trench are not shown, as they show no evidence of having been subduction zones.

B. Comparison of the Canadian and United States segments of the North American Cordillera, explaining the "jumping-out" of subduction zones in the Canadian Cordillera as the result of incorporation of blocks of light crustal material. These blocks may have been brought in by transcurrent rather than normal plate movements.

terval), when vast amounts of volcanic rock were produced, accompanied by regional metamorphism and emplacement of granitic rocks. Possibly there was little interaction between the ocean floor and the craton for most of the upper Paleozoic. For short intervals the oceanic material may have been subduced below the Omineca Crystalline Belt with a major episode of subduction in Permo-Triassic time, which seems to be the best age for the blueschists on the Pinchi and Teslin faults.

Plate movements are shown normal to the continent. This probably was not so. In the Canadian Cordillera the most allochthonous rocks appear to be those of the Coast Plutonic Complex and Insular Belts, yet preliminary investigations of the fusulinid faunas in these belts suggests they have close affinities to faunas of the North American continent. Possibly these rocks were emplaced in post-Permian time by movement with a considerable transcurrent component, as suggested by Monger and Ross (1971) and Jones, Irwin, and Ovenshine (1972).

UPPER TRIASSIC TO OLIGOCENE HISTORY

The western Canadian Cordillera evolved from a system of island arcs in the Late Triassic and Early Jurassic, through an intermediate stage with deposition in increasingly restricted basins, to a continental cordillera in the Late Cretaceous and Early Tertiary (figs. 5B, 6B, 8, 9). The final stage was perhaps not very different from the present-day Andes and included almost all elements of the modern Cordillera. This evolution involved changes in the nature of the volcanism (Souther, 1967, 1970b), sedimentation (Wheeler, 1961), intrusion of vast volumes of granitic rock mainly in the Coast Mountain Belt (Gabrielse and Reesor, 1964; Roddick, 1966; Hutchison, 1970), and widespread regional metamorphism, most extensive in the Omineca Crystalline Belt (Monger and Hutchison, 1971). Most of this activity can readily be ascribed to processes above an eastward-dipping subduction zone (or zones) and stands in contrast with the upper Paleozoic, when elements of both oceanic crust and island arcs were involved. Again, possibly this change can be related to the opening of the North Atlantic in early Mesozoic time and consequent strong westward movement of the North American plate relative to a Pacific plate.

The greatest episode of volcanic activity known in the Cordillera occurred in late Middle and Late Triassic, Early and, locally, mid-Jurassic time (fig. 5B). This volcanism had somewhat different characteristics in the Insular Belt (and southern Coast Mountains?) than it did in the Intermontane, Omineca, and northern Coast Mountains Belts. In the Insular Belt (Vancouver Island, Queen Charlotte Islands) nearly 6000 m of pillow basalt and breccia of the Karmutsen Formation accumulated in Ladinian and Karnian time (Muller and Carson, 1969 and personal commun.). Chemically these rocks resemble oceanic basalts in both major and minor elements (Sutherland Brown, 1968 and personal commun.; Kuniyoshi, 1971). Composition of overlying volcanic rocks of the Bonanza Formation is very different. These rocks are calc-alkaline andesites, dacites, and pyroclastic strata as much as 2500 m thick, whose deposition was perhaps in part accompanied by intrusion of granitic plutons radiometrically dated as Middle Jurassic (Muller, 1971). Volcanic rocks comparable with the Karmutsen Formation are also present locally in the southern part of the Coast Plutonic Complex (H. W. Tipper, personal commun.). Upper Triassic, Lower Jurassic, and locally Middle Jurassic assemblages in the Intermontane Belt, western Omineca Belt, and Coast Plutonic Complex of northwestern British Columbia apparently do not show the marked change in composition of volcanic rocks from the Upper Triassic to Lower Jurassic seen in the Insular Belt, although there is considerable variation in composition within the succession. These rocks form the very thick (more than 10,000 m.y. according to Lord, 1948), areally extensive, stratigraphically complex assemblages known in part as the Nicola, Takla, and Hazelton Groups that comprise basaltic andesite, local basalt, and acid volcanic rock, abundant pyroclastic rock, and marine clastic rock and carbonate (for example, Lord, 1948; Tipper, 1959; Schau, 1970). Chemically these rocks belong to the calc-alkaline and alkaline suites (Souther, in press). Their extrusion and deposition was at least in part accompanied by granitic intrusion in Lower and Middle Jurassic time (fig. 5B) and, perhaps, widespread regional metamorphism best dated as mid- to Late-Jurassic. In northern British Columbia and Yukon this assemblage is apparently physically continuous from the Coast Plutonic Complex, across the Intermontane Belt to the west side of the Omineca Crystalline Belt, indicating that these three belts were linked together by Upper Triassic time.

The Nicola-Takla-Hazelton and Bonanza assemblages can readily be interpreted as old island arcs. The Karmutsen is problematical in that in chemistry it is very close to basalts formed on oceanic ridges. It differs from most of these assemblages in lacking gabbro and ultramafic rock and including only very minor chert. The Karmutsen stratigraphically overlies upper Paleozoic rocks that can best be interpreted as island-arc assemblages. Muller (1971) and Souther (in press) suggested that the Karmutsen volcanics are arc rocks. If so, the petrological differences between these and the contemporaneous Nicola-Takla assemblage can only be accounted for by making the site of extrusion of the former very close to a trench. Alternatively, the assemblage may have formed above a spreading center that partly broke up an upper Paleozoic arc in the ocean west of a subduction zone associated with the Nicola-Takla arc (fig. 6B). A possible modern analogue to the Karmutsen would be the volcanics of the eastern Canary Islands (Rothe and Schmincke, 1968; Sutherland Brown, personal commun.). In post-Karmutsen, pre-Bonanza time (Norian?) the zone jumped westward, from below the Nicola-Takla assemblages, perhaps as it was unable to absorb the old arc rocks (fig. 7B), and its activity in Lower Jurassic time produced the Bonanza Formation (fig. 9A).

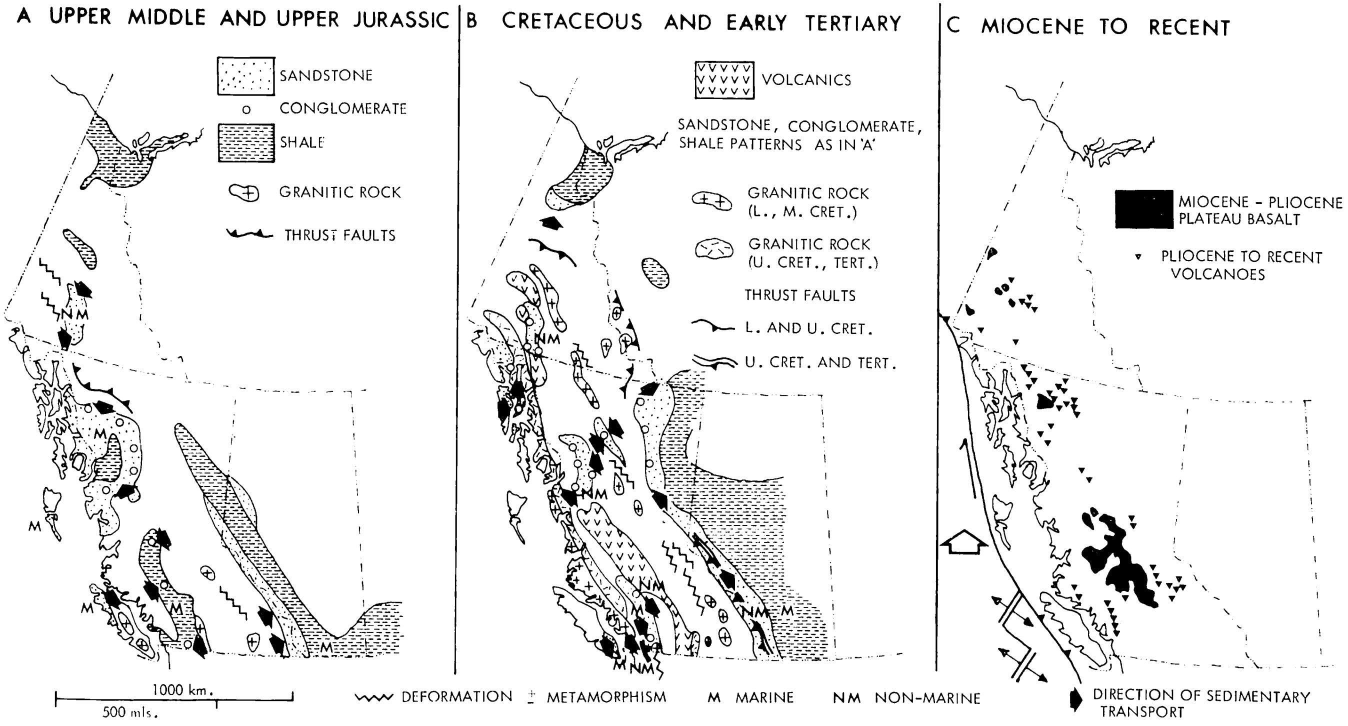

Fig. 8. Distribution of (A) Middle and Upper Jurassic, (B) Cretaceous and Early Tertiary, and (C) Miocene to Recent rocks. The movement directions of recent plates are shown on (C).

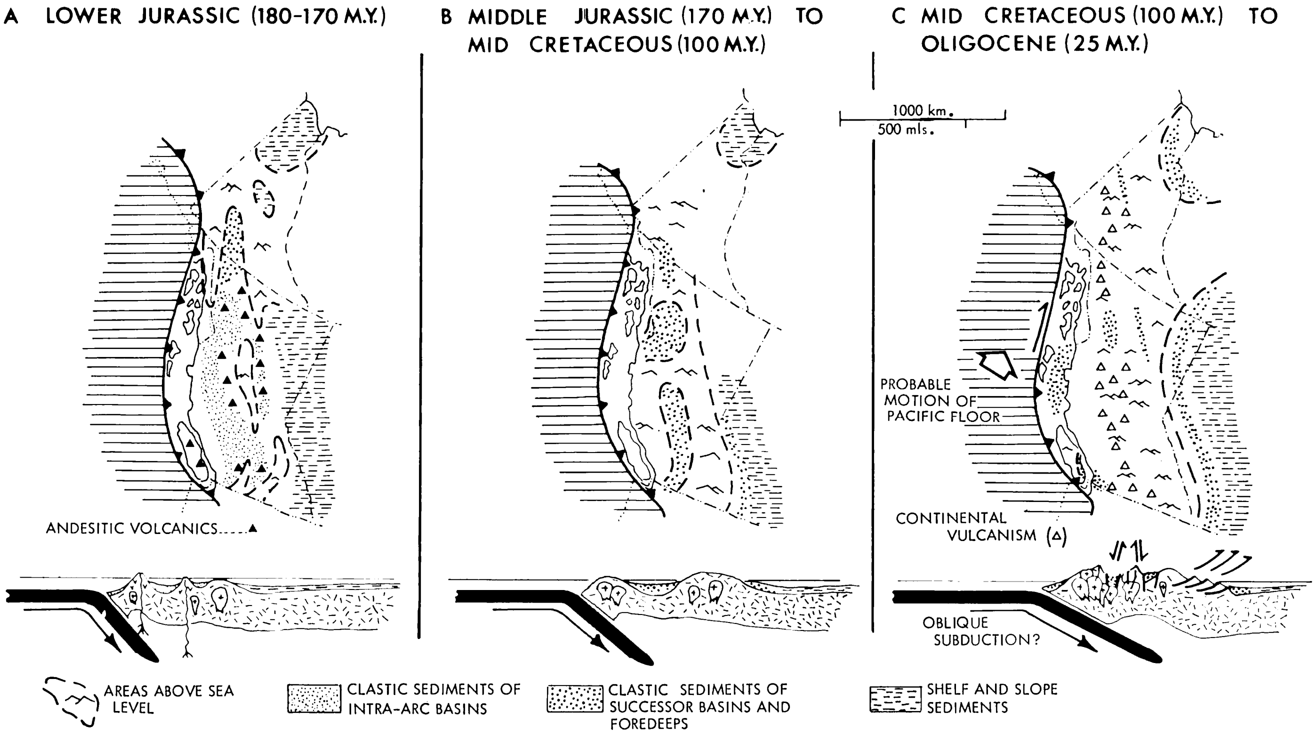

Fig. 9. Plate tectonic interpretations of (A) Lower Jurassic, (B) Middle Jurassic to Lower Cretaceous, and (C) Middle Cretaceous to Oligocene rocks. The clastic sediments of the successor basins and foredeeps are derived from actively uplifted crust and contain granite and metamorphic detritus, unlike the earlier intra-arc sediments that are largely volcaniclastic. "Internal" transcurrent movement is not shown on these diagrams.

Although all elements in the Canadian Cordillera seem to have been east of a subduction zone from the Early Jurassic until the Early Tertiary, there is evidence for considerable strike-slip faulting within the Cordillera in the Mesozoic (fig. 7A). Preliminary paleomagnetic latitudes for the Karmutsen Formation are about 50° south of those for southern Canada in the Late Triassic (Symons, 1971b; Irving and Yole, in press). By contrast, paleomagnetic latitudes from the mid-Jurassic plutons of Vancouver Island indicate there was little or no post-intrusion movement relative to the continent (Symons, 1971a). If these results are valid a great deal of movement took place in the Cordillera in post-Karnian to mid-Jurassic time. Evidence for such movement was put forward by Tozer (1970) who recognized that Upper Triassic faunas in the Intermontane Belt of the south-central Yukon were warmer water faunas than those in the Rocky Mountains Belt at similar latitudes. He suggested a considerable northward movement of the Cordillera west of the Rocky Mountains Belt in post-Triassic time. Tipper (1969) reported 225 km of dextral movement that probably took place mainly in Jurassic time, on the northwesterly extension of the Fraser-Yalakom Fault System. Roddick (1964) and Tempelman-Kluit (personal commun.) suggest considerable dextral movement on Tintina Fault, with nearly 400 km displacement, much of which was in Cretaceous time. This transcurrent movement, within the largely consolidated Cordillera, may have resulted from oblique movement with a strong northerly component of the plate west of the offshore subduction zone. The traces of the old subduction zones probably localized the "internal" transcurrent movement. The situation is perhaps analogous with that suggested by Atwater (1970, fig. 16) for movements *within* the western edge of the North American plate during the last 20 m.y.

During the Mesozoic and Early Tertiary the Intermontane, Rocky Mountain, and Insular Belts developed several troughs (respectively successor basins or epieugeosynclines and foredeeps or exogeosynclines) that were filled with clastic rocks derived from actively uplifted parts of the Cordillera. In the Intermontane Belt these troughs were located on the sites of arcs, interarc or possibly arc-trench basins containing volcanic rocks and mainly clastic rocks derived from them. By the Early Jurassic in the north and the Late Jurassic in the south the troughs received flysch-like sediments containing granitic and metamorphic detritus as well as volcanic clasts, derived from the flanking, actively rising, Coast Plutonic Complex and Omineca Crystalline Belts (fig. 9A, 9B, 9C; Gabrielse and Wheeler, 1961; Jeletzky and Tipper, 1968). During the Late Jurassic in the north and latest Early Cretaceous in the south, the troughs were non-marine and contained molasse-type rocks. The Rocky Mountain Belt in the early Mesozoic was the site of deposition of pelites and fine sandstone derived from the craton. These sedimentary rocks can perhaps be traced westward to similar rocks in the Omineca Crystalline Belt (Slocan Group). In the Late Jurassic this belt began receiving coarse clastic sediments from the rising Omineca Crystalline Belt to the west, the first record on the North American craton of activity to the west since deposition of the Devonian-Mississippian clastic rocks. This belt is non-marine as early as Late Jurassic in the west and as late as Campanian in the east. The southern part of the Insular Belt, on the west side of the Northern Cascade Mountains received granitic debris in Lower Cretaceous time (Crickmay, ms) and became non-marine by the Early Tertiary. To the north, the modern marine Queen Charlotte Basin, between the Queen Charlotte Island and the mainland, contains non-marine strata of Upper Cretaceous age (Shouldice, 1971).

In Late Cretaceous and Eocene time, the Cordillera with the exception of the Rocky Mountain Belt became the site of extensive, continental explosive acidic to intermediate volcanism (Souther, 1967, 1970b). In the north, extensive sheets of ignimbrite are associated with flows and pyroclastic rocks. Elsewhere there is a considerable range in composition, from rhyolite, through trachyte and trachyandesite, to phonolite. Extrusion of these rocks, accompanied by block faulting and local cauldron subsidence, was coeval with high-level quartz monzonite, granite, and syenite intrusion. The Andes in late Cenozoic to Recent time, with its vast volume of continental volcanic rock and subvolcanic intrusions (Hamilton, 1969b), is probably analogous. One exception to this type of volcanism is the Eocene basalt with associated gabbro on southernmost Vancouver Island. These rocks are the northerly continuation of the Olympic Province, considered to be a volcanic and sedimentary assemblage built on oceanic crust (Hamilton and Myers, 1966). The basalts are in fault contact with upper Paleozoic and younger rocks to the north.

The Canadian Cordillera, with its two belts of Mesozoic high-grade regional metamorphic and granitic rocks, contrasts markedly with its southern extension in the United States, where there is only one belt, the Sierra Nevada granitic and metamorphic terrane. The latter can be explained by the relatively simple process of nearly continuous subduction of oceanic crust beneath the North American plate (Hamilton, 1969a; Burchfiel and Davis, 1972). In the Canadian Cordillera metamorphism, granitic intrusion, and uplift are roughly coeval in the two belts and show greater differences along a single belt than they do between both. In the Omineca Crystalline Belt, high-grade regional metamorphism is best dated as Triassic in the north and Jurassic in the south (Monger and Hutchison, 1971). Granitic intrusion ranges from Triassic to Cenozoic but is probably most voluminous in the Cretaceous (Gabrielse and Reesor, 1964). Uplift is first apparent in the Late Jurassic. In the Coast Range, metamorphism appears to be mainly Jurassic and Cretaceous, in concert with the bulk of radiometric ages of the granitic rocks (Hutchison, 1970). Uplift took place during the Jurassic in the north but was Late Jurassic or Early Cretaceous in the south.

Perhaps the simplest explanation for the double system in the Cordillera is found in the pre-Mesozoic rocks now in the Coast Plutonic Complex and Insular Belts. If a subduction zone persisted below the

Omineca Crystalline Belt from the upper Paleozoic through the Mesozoic without interruptions, the result would presumably have been identical to the Cordillera in the United States, with its single belt of granitic and high grade metamorphic rocks. Instead, an interruption of the process in Canada was caused possibly by the arrival at the subduction zone in early Mesozoic time of low specific gravity material of the upper Paleozoic arc assemblage of the Coast Plutonic Complex and Insular Belt and possibly old continental crust formed by Ordovician-Silurian orogeny in southeastern Alaska. This material blocked off the late Paleozoic and Middle Triassic subduction zone, causing it to jump oceanward (fig. 7B). This jump presumably was in pre-Upper Triassic time in the north, as Upper Triassic arc assemblages can be traced from the Omineca Belt to the Coast Mountains, but in the south may not have been until latest Triassic time (post-Kamutsen, pre-Bonanza Formations).

MIOCENE TO RECENT HISTORY

Miocene and later volcanism generally was very different in character from that of the Eocene. Large areas (nearly 40,000 sq km) of flat-lying, late Miocene to early Pliocene alkaline olivine basalt ("Plateau basalt") (fig. 8C) occur in the Intermontane Belt. To the west, the lavas have been upwarped by post-Miocene uplift of the Coast Mountains and have been mainly eroded, although the presence of late Miocene basaltic dikes near Bella Coola indicates that the lavas probably extended at one time as far west as the Coast (Souther, 1970b). By the late Pliocene and through the Quaternary the style of volcanism changed somewhat, although most lavas still seem to belong to the alkali-olivine basalt suite. In contrast to the Miocene lava sheets, these are mainly small separate centers, some merely isolated cinder cones active as recently as about 200 years ago. Some centers comprise large composite volcanoes, such as Mount Edziza in northwestern British Columbia, where volcanics range from picrite basalt to rhyolite. In southwestern British Columbia the Mount Garibaldi Center (Mathews, 1958) is more andesitic in overall composition and perhaps is the northernmost center in the chain of volcanos in the Cascades of the northwestern United States.

The change from the Eocene calc-alkaline lavas associated with subvolcanic plutonic rocks to the Miocene and younger alkaline olivine basalts is a fundamental one. The Eocene (and older) volcanics can be interpreted as having formed above an east-dipping, offshore subduction zone (Souther, 1970a). The Miocene and younger lavas show no change in composition with distance from continental margin and could have been formed directly by partial melting of mantle material, probably unrelated to any subduction zone. This change can be related to changes along the boundary between the Pacific and North Atlantic plates (for example, Atwater, 1970). At about late Oligocene-early Miocene time the plate boundary changed from a consuming margin, in which the Pacific plate was being driven under the North American plate at some oblique angle (fig. 9C), to the present-day situation where most of the margin of the Canadian part of the North American plate is the transform Fairweather—Queen Charlotte Fault. Only in the south is there intermittent subduction of the small Juan de Fuca plate, causing formation of volcanic rocks of the Cascades and Mount Garibaldi. Within the margin of the North American plate, extension fracturing, perhaps related to the northward movement of the Pacific plate, taps the mantle and allows extrusion of these younger volcanics.

CONCLUSIONS

The geological evolution of the Canadian Cordillera can be explained by a plate-tectonic model, although many features remain obscure. The following generalizations appear valid:

1. The location of the Cordillera relative to the North American craton results from mid-Proterozoic rifting that transected the grain of an early Proterozoic crystalline basement.
2. The nature and distribution of upper Paleozoic rocks suggests that all pre-Mesozoic rocks west of the Omineca Crystalline Belt are allochthonous with respect to the North American craton.
3. The allochthonous terrane is probably not a fragment of Asia, as suggested by Wilson (1968) and Danner (1970). On the contrary it probably includes elements of diverse origin such as oceanic crust of unknown provenance in the Intermontane Belt, island arcs containing faunas with North American affinities in the Coast Plutonic Complex and Insular Belt, and continental crust in the Insular Belt of southeastern Alaska.
4. The addition, possibly in large part by early Mesozoic transcurrent faulting, of allochthonous elements that have not been subducted presumably because of their low density, has caused a major difference between the Canadian and United States segments of the Cordillera.

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REFERENCES

Armstrong, F. C., and Oriel, S. S., 1965, Tectonic development of Idaho-Wyoming thrust belt: Am. Assoc. Petroleum Geologists Bull., v. 49, p. 1847-1866.

Atwater, Tanya, 1970, Implications of plate tectonics in the Cenozoic tectonic evolution of western North America: Geol. Soc. America Bull., v. 81, p. 3513-3535.

Bally, A. W., Gordy, P. L., and Stewart, G. A., 1966, Structure, seismic data and orogenic evolution of southern Canadian Rockies: Canadian Petroleum Geology Bull., v. 14, p. 337-381.

Bell, R. T., 1968, Proterozoic stratigraphy of northeastern British Columbia: Canada Geol. Survey Paper 67-68, 75 p.

Berg, H. C., 1970, Paleozoic plutonism and contrasting metamorphic terranes, Annette Island, Alaska: Geol. Soc. America Abs. with Programs, v. 2, no. 2, p. 70.

Berry, M. J., Jacoby, W. R., Niblett, E. R., and Stacey, R. A., 1971, A review of geophysical studies in the Canadian Cordillera: Canadian Jour. Earth Sci., v. 8, no. 7, p. 788-801.

Bird, J. M., and Dewey, J. F., 1970, Lithosphere plate-continental margin tectonics and the evolution of the Appalachian orogen: Geol. Soc. America Bull., v. 81, p. 1031-1060.

Bishop, D., Morris, H. C., and Edmunds, F. R., 1970, Turbidites and depositional features of the lower Belt-Purcell Supergroup: Geol. Soc. America Abs. with Programs, v. 2, no. 7, p. 497.

Brew, D. A., Loney, R. A., and Muffler, L. J. P., 1966, Tectonic history of southeastern Alaska: Canadian Inst. Mining and Metallurgy Spec. v. 8, p. 149-170.

Burchfiel, B. C., and Davis, G. A., 1972, Structural framework and evolution of the southern part of the Cordilleran orogen, western United States: Am. Jour. Sci., v. 272, p. 97-118.

Burwash, R. A., Baadsgaard, H., Peterman, Z. E., and Hunt, G. H., 1964, Precambrian, *in* Geological History of Western Canada: Calgary, Alberta Soc. Petroleum Geologists, p. 14-19.

Cameron, B. E. B., and Monger, J. W. H., 1971, Middle Triassic conodonts from the Fergusson Group, northeastern Pemberton map area, British Columbia: Canada Geol. Survey Paper 71-1, pt. B, p. 94-96.

Campbell, R. B., 1970, Quesnel Lake map-area, British Columbia: Canada Geol. Survey Paper 70-1, pt. A, p. 32-35.

Campbell R. B., and Tipper, H. W., 1971, Geology of Bonaparte Lake map-area, British Columbia: Canada Geol. Survey Mem. 363, 100 p.

Crickmay, C. H., ms, 1925, The geology and paleontology of the Harrison Lake district, British Columbia, together with a general review of the Jurassic faunas and stratigraphy of western North America: Ph.D. thesis, Stanford Univ.

Danner, W. R., 1960, Paleozoic eugeosynclinal sequence of southwestern British Columbia and northwestern Washington [abs.]: Geol. Soc. America Bull., v. 71, p. 2055.

——— 1970, Paleontologic and stratigraphic evidence for and against sea floor spreading and opening and closing oceans in the Pacific Northwest: Geol. Soc. America Abs. with Programs, v. 2, no. 2, p. 84-85.

Davies, H. L., 1968, Papuan Ultramafic Belt: Internat. Geol. Cong., 23rd, Prague 1968, Proc., v. 1, p. 209-220.

Dercourt, J., 1970, L'éxpansion océanique actuelle et fossile, ses implications géotectoniques: Soc. géol. France Bull., ser. 7, v. 12, no. 2, p. 261-317.

Douglas, R. J. W., Gabrielse, Hubert, Wheeler, J. O., Stott, D. F., and Belyea, H. R., 1970, Geology of Western Canada, *in* Douglas, R. J. W., ed., Geology and Economic Minerals of Canada: Canada Geol. Survey Econ. Geology Rept. 1, p. 366-488.

Gabrielse, Hubert, 1963, McDame map-area, Cassiar District, British Columbia: Canada Geol. Survey Mem. 319, 138 p.

——— 1967, Tectonic evolution of the northern Canadian Cordillera: Canadian Jour. Earth Sci., v. 4, p. 271-298.

——— 1972, Younger Precambrian of the Canadian Cordillera: Am. Jour. Sci., v. 272, p. 521-536.

Gabrielse, Hubert, and Reesor, J. E., 1964, Geochronology of plutonic rocks in two areas of the Canadian Cordillera, *in* Osborn, F. F., ed., Geochronology in Canada, Royal Soc. Canada Spec. Pub. 8, p. 96-138.

Gabrielse, Hubert, and Wheeler, J. O., 1961, Tectonic framework of southern Yukon and northwestern British Columbia: Canada Geol. Survey Paper 60-24, 37 p.

Gilluly, James, 1965, Volcanism, tectonism and plutonism in the western United States: Geol. Soc. America Spec. Paper 80, 69 p.

Hamilton, Warren, 1969a, Mesozoic California and the underflow of Pacific mantle: Geol. Soc. America Bull., v. 80, p. 2409-2430.

——— 1969b, The volcanic central Andes—a modern model for the Cretaceous batholiths and tectonics of western North America: Oregon Dept. Geology and Mineral Industries Bull. 65, p. 175-184.

Hamilton, Warren and Myers, W. B., 1966, Cenozoic tectonics of the western United States: Rev. Geophysics, v. 4, no. 4, p. 509-549.

Harrison, J. E., and Peterman, Z. E., 1971, Belt-Windermere rocks and their correlatives in the western United States: Geol. Soc. America Abs. with Programs, v. 3, no. 7, p. 592.

Hutchison, W. W., 1970, Metamorphic framework and plutonic styles in the Prince Rupert region of the central Coast Mountains, B. C.: Canadian Jour. Earth Sci., v. 7, p. 376-405.

Irving, E., and Yole, R., in press, Paleomagnetic criteria for the recognition of ancient oceanic crust: Canada Earth Physics Branch Pub. (NAGGS/AGGG Geodynamics Symposium on the oceanic crust and the identification of ancient oceanic crusts in the continents).

Jeletzky, J. A., and Tipper, H. W., 1968, Upper Jurassic and Lower Cretaceous rocks of Taseko Lakes map-area and their bearing on the geological history of southwestern British Columbia: Canada Geol. Survey Paper 67-54, 218 p.

Jones, D. L., Irwin, W. P., and Ovenshine, A. T., 1972, Southeast Alaska—a displaced continental fragment? *in* Geological Survey Research 1972: U.S. Geol. Survey Prof. Paper 800B, p. B213-B219.

King, P. B., 1969, Tectonic map of North America: U.S. Geol. Survey.

Kuniyoshi, S., 1971, Chemical composition of the Karmutsen volcanics, Vancouver Island, British Columbia: Geol. Soc. America Abs. with Programs, v. 3, no. 7, p. 628-629.

Lanphere, M. A., MacKevett, E. M., and Stern, T. W., 1964: Potassium-argon and lead-alpha ages of plutonic rocks, Bokan Mountain area, Alaska: Science, v. 145, no. 3633, p. 705-707.

Lathram, E. H., 1964, Apparent right-lateral separation on Chatham Strait fault, southeastern Alaska: Geol. Soc. America Bull., v. 75, no. 3, p. 249-252.

Lord, C. S., 1958, McConnell Creek map-area, Cassiar District, British Columbia: Canada Geol. Survey Mem. 251, 72 p.

Mathews, W. H., 1958, Geology of the Mount Garibaldi map-area, southwestern British Columbia, Canada. Pt 2: Geomorphology and Quaternary volcanic rocks: Geol. Soc. America Bull., v. 69, p. 174-198.

Mattinson, J. M., 1970, Uranium-lead geochronology of the Northern Cascade Mountains: Geol. Soc. America Abs. with Programs, v. 2, no. 2, p. 116.

Misch, Peter, 1966, Tectonic evolution of the Northern Cascades of Washington State: Canadian Inst. Mining and Metallurgy Spec. v. 8, p. 101-148.

Monger, J. W. H., in press, Oceanic rocks in the Canadian Cordillera: Canada Earth Physics Branch Pub. (NAGGS/AGGG Geodynamic Symposium on the oceanic crust and the identification of ancient oceanic crusts in the continents).

Monger, J. W. H., and Hutchison, W. W., 1971, Metamorphic map of the Canadian Cordillera: Canada Geol. Survey Paper 70-33, 61 p.

Monger, J. W. H., and Ross, C. A., 1971, Distribution of fusulinaceans in the western Canadian Cordillera: Canadian Jour. Earth Sci., v. 8, no. 2, p. 259-278.

Muller, J. E., 1967, Kluane Lake map-area, Yukon Territory; Canada Geol. Survey Mem. 340, 137 p.

———— 1971, Chemistry and petrology of some volcanic rocks of Vancouver Island, British Columbia: Canada Geol. Survey Paper 71-1, pt. B, p. 5-10.

Muller, J. E., and Carson, D. J. T., 1969, Geology and mineral deposits of Alberni map-area, British Columbia: Canada Geol. Survey Paper 68-50, 52 p.

Price, R. A., 1965, Flathead map-area: Canada Geol. Survey Mem. 336, 221 p.

Reesor, J. E., 1970, Some aspects of structural evolution and regional setting in part of the Shuswap metamorphic complex: Geol. Assoc. Canada Spec. Paper 6, p. 73-86.

Reinhardt, B. M., 1969, On the genesis and emplacement of ophiolites in the Oman Mountains Geosyncline: Schweizer. Mineralog. Petrog. Mitt., v. 49, no. 1, p. 1-30.

Richter, D. S., and Jones, D. L., 1970, Structure and stratigraphy of Eastern Alaska Range: Am. Assoc. Petroleum Geologists Bull., v. 54, no. 12, p. 2502.

Roberts, R. J., Hotz, P. E., Gilluly, J., and Ferguson, H. G., 1958, Paleozoic rocks of north central Nevada: Am. Assoc. Petroleum Geologists Bull., v. 42, p. 2813-2857.

Roddick, J. A., 1964, Tintina Trench: Jour. Geology, v. 75, no. 1, p. 23-33.

———— 1966, Coast Crystalline Belt of British Columbia: Canadian Inst. Mining and Metallurgy Spec. v. 8, p. 73-82.

Roddick, J. A., Wheeler, J. O., Gabrielse, H., and Souther, J. G., 1967, Age and nature of the Canadian part of the Circum-Pacific orogenic belt: Tectonophysics, v. 4, no. 4-6, p. 319-337.

Roots, E. F., 1954, Geology and mineral deposits of Aiken Lake map-area, British Columbia: Canada Geol. Survey Mem. 274, 246 p.

Ross, J. V., 1970, Structural evolution of the Kootenay Arc, southeastern British Columbia: Geol. Assoc. Canada Spec. Paper 6, p. 53-65.

Rothe, P., and Schmincke, H.-U., 1968, Contrasting origin of the eastern and western islands of the Canarian Archipelago: Nature, v. 218, no. 5147, p. 1153-1154.

Schau, M., 1970, Stratigraphy and structure of the type-area of the Upper Triassic Nicola Group in south central British Columbia: Geol. Assoc. Canada Spec. Paper 6, p. 123-135.

Shouldice, D. H., 1971, Geology of the western Canadian Continental shelf: Canadian Petroleum Geology Bull., v. 19, no. 2, p. 405-436.

Souther, J. G., 1967, Acid volcanism and its relationship to the tectonic history of the Cordillera of British Columbia, Canada: Bull. volcanol., v. 30, p. 161-176.

——— 1970a, Tectonic implications of volcanism in the Cordillera of North America [abs.]: Univ. Alaska, Geophys. Inst., Inaugural Symposium Geophysics and Geology of Bering Sea region.

——— 1970b, Volcanism and its relationship to recent crustal movements in the Canadian Cordillera: Canadian Jour. Earth Sci., v. 7, no. 2, p. 553-568.

——— in press, Mesozoic and Tertiary volcanism of the western Canadian Cordillera: Canada Earth Physics Branch Pub. (NAGGS/AGGG Geodynamics Symposium on the oceanic crust and the identification of ancient oceanic crusts in the continents).

Sutherland Brown, A., 1968, Geology of the Queen Charlotte Islands: British Columbia Dept. Mines and Petroleum Resources Bull. 54, 226 p.

Symons, D. T. A., 1971a, Paleomagnetism of the Jurassic island intrusions of Vancouver Island, British Columbia: Canada Geol. Survey Paper 70-63, p. 1-17.

——— 1971b, Paleomagnetic notes on the Karmutsen basalts, Vancouver Island, British Columbia: Canada Geol. Survey Paper 71-24, p. 11-24.

Tipper, H. W., 1959, Revision of the Hazelton and Takla Groups of central British Columbia: Canada Geol. Survey Bull. 47, 51 p.

——— 1969, Mesozoic and Cenozoic geology of the northeast part of Mount Waddington map-area, Coast District, British Columbia: Canada Geol. Survey Paper 68-73, 103 p.

Tozer, E. T., 1970, Marine Triassic faunas, *in* Douglas, R. J. W., ed., Geology and Economic Minerals of Canada: Canada Geol. Survey Econ. Geology Rept. 1, p. 633-640.

Trettin, H. P., 1961, Geology of the Fraser River Valley between Lillooet and Big Bar Creek: British Columbia Dept. Mines and Petroleum Resources Bull. 44, 109 p.

Wheeler, J. O., 1961, Whitehorse map-area, Yukon Territory: Canada Geol. Survey Mem. 312, 156 p.

——— 1963, Kuskawulsh, Yukon Territory: Canada Geol. Survey Map 1134A.

——— 1968, Lardeau (west half) map area British Columbia: Canada Geol. Survey Pap. 68-1, pt. A, p. 56-58.

White, W. H., 1959, Cordilleran tectonics in British Columbia: Am. Assoc. Petroleum Geologists Bull., v. 43, no. 1, p. 60-100.

Wilson, J. Tuzo, 1968, Static or mobile Earth: the current scientific revolution: American Philos. Soc. Proc., v. 112, no. 5, p. 309-320.

Wise, D. U., 1963, An outrageous hypothesis for the tectonic pattern of the North American Cordillera: Geol. Soc. America Bull., v. 74, no. 3, p. 357-362.