DAVID BLOOM

Major dextral transcurrent displacements along the Northern Rocky Mountain Trench and related lineaments in north-central British Columbia

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ABSTRACT

The Northern Rocky Mountain Trench and a number of other prominent lineaments, along and east of the eastern margin of the Intermontane Belt, mark faults along which dextral transcurrent movements have been dominant. Offsets of shelf to off-shelf facies boundaries in lower Paleozoic rocks indicate a cumulative displacement of at least 750 km, and probably >900 km, within the system of faults related to those in the Northern Rocky Mountain and the Tintina Trenches. Farther west, another system of faults appears to offset plutons and stratigraphic assemblages along the eastern margin of the Intermontane Belt by as much as 300 km. These faults, including the Kutcho and the Pinchi, connect in part with the Teslin Suture Zone in Yukon Territory and probably with the Fraser River–Straight Creek fault zone in southern British Columbia. Although dextral transcurrent faulting may have taken place between the Middle Jurassic and early Cenozoic, the most convincing evidence points to middle Cretaceous and particularly to early Cenozoic (Eocene?) displacements. The Eocene(?) movements were temporally related to plutonism, volcanism, lamprophyre dike emplacement, high heat flow, sedimentation in grabens, and rapid uplift of northwesterly trending elongate ranges. Climactic episodes of granite emplacement, particularly in and near the northern Omineca Crystalline Belt, at ~100 m.y., 70 m.y., and 50 m.y. ago may have been facilitated by changes from dominantly compressional to dominantly transcurrent and related tensional strain.

INTRODUCTION

Regional, mainly northwest-striking faults are conspicuous elements in the geology of north-central British Columbia (Fig. 1). They are generally marked by prominent lineaments, across which lithology, stratigraphic sequence, grade of metamorphism, and structural style change abruptly. Preservation of Paleocene-Eocene nonmarine sedimentary and volcanic rocks in grabens or half-grabens along the major lineaments suggests late normal faulting, but offsets of a variety of geologic elements indicate earlier and probably in part contemporaneous dextral transcurrent faulting.

The faults described herein form an anastomosing network between the Northern Rocky Mountain Trench (N.R.M.T.) on the east and the Cordilleran Intermontane Belt on the west. To the east of the N.R.M.T., prominent lineaments in the Rocky Mountains appear to have resulted from erosion of relatively soft rocks parallel with regional fold structures. To the west, the distribution of strata in the Bowser and the Sustut basins of western British Columbia precludes significant transcurrent faulting there since Middle Jurassic time.

PHYSIOGRAPHIC EXPRESSION OF FAULTS

Most of the regional faults in north-central British Columbia lie along conspicuous lineaments tens to hundreds of kilometres long. Some of the lineaments are deeply incised, flat-bottomed, steep-walled valleys, whereas others comprise aligned, narrow notches on ridge crests. Faults, along which major movements may have ceased before Late Cretaceous time, are not everywhere coincident with obvious topographic lineaments. In general, faults, along which there have been significant Cenozoic displacements, show marked topographic expression.

SUMMARY OF REGIONAL GEOLOGY

A brief review of the stratigraphy and structure flanking the major faults emphasizes the degree to which they have disrupted paleogeographic elements (Figs. 1, 2, 3). In general terms, the region includes the western part of the Cordilleran miogeocline, represented by the Foreland Fold and Thrust Belt east of the N.R.M.T. The region also includes the Omineca Crystalline Belt, which at this latitude is considered herein to be a dextrally offset slice of the miogeocline, west of the N.R.M.T. Allochthonous oceanic and island-arc terranes locally overlie the miogeoclinal rocks west of the N.R.M.T.; to the west, they are in fault contact with oceanic and island-arc terranes of the Intermontane Belt.

The northern Rocky Mountains are underlain by upper Proterozoic rocks lying on basement granitoid gneiss (Evenchick, 1982; Gabrielse, 1975; Gabrielse and others, 1977) and lower Paleozoic strata. The latter show a well-defined, fairly narrow transition from carbonate and clean sandstone of stable-platform to subsiding-shelf facies on the east, to shale, siltstone, and local slide breccias of off-shelf facies on the west (Figs. 1, 2). These rocks are overlain by westerly derived shale and turbiditic sandstone, of Late Devonian to Mississippian age, with local Lower Mississippian limestone. Except for a narrow, complexly deformed zone flanking the N.R.M.T., the northern Rocky Mountains are characterized by easterly directed, fairly continuous thrust faults and folds with westerly dipping axial surfaces (Gabrielse, 1962a; Gabrielse and others, 1977).

On its west side, the N.R.M.T. acutely truncates a number of northwesterly trending, fault-bounded panels characterized by distinctive facies, thickness and sequence of strata, grade of metamorphism, the presence or absence of volcanic and granitic rocks, and structural style. In the Cassiar Mountains, lower Paleozoic strata exhibit a westward change in facies from platform to subsiding shelf (transitional) to off shelf. A narrow panel northeast of Burnt Rose fault (Fig. 1) is exceptional, for the region southwest of the N.R.M.T., in having graptolitic Ordovician and Silurian shale and siltstone of an off-

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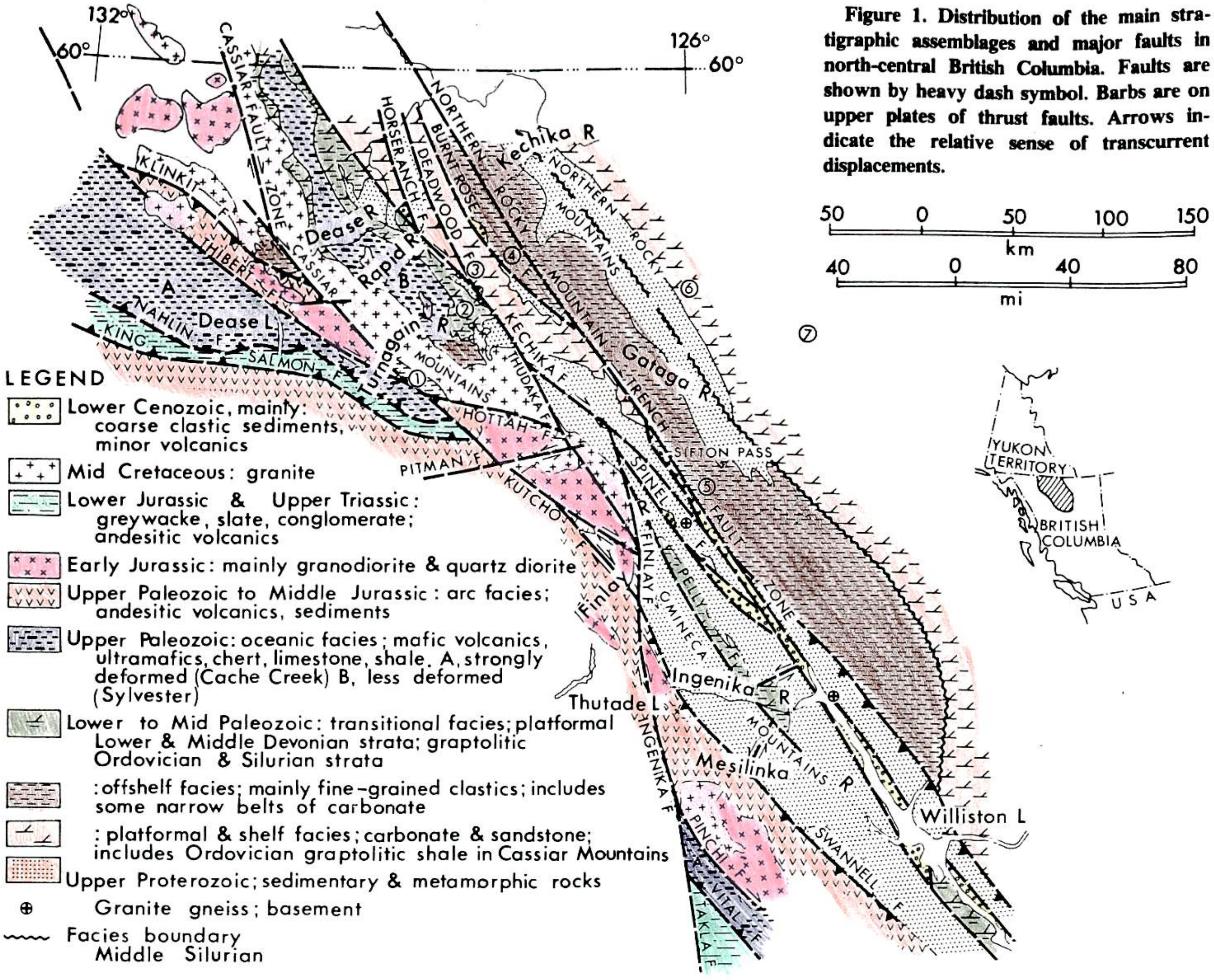


Figure 1. Distribution of the main stratigraphic assemblages and major faults in north-central British Columbia. Faults are shown by heavy dash symbol. Barbs are on upper plates of thrust faults. Arrows indicate the relative sense of transcurrent displacements.

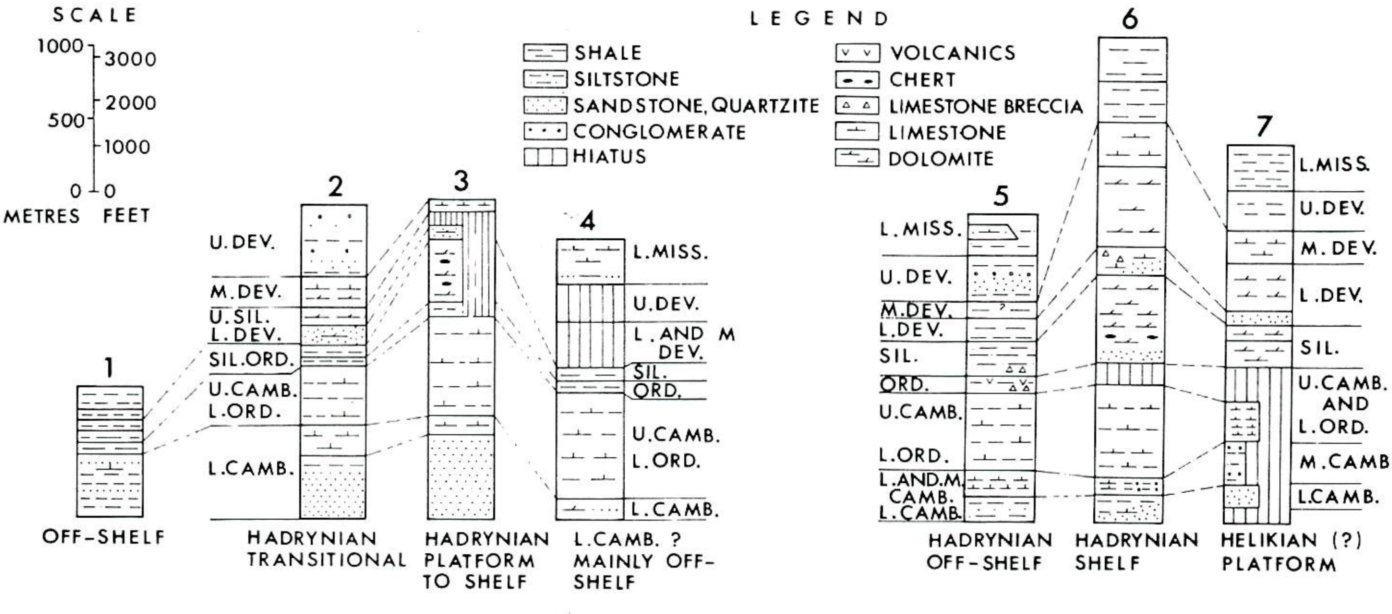


Figure 2. Generalized stratigraphic columns in Cassiar and northern Rocky Mountains showing thickness and facies changes. See Figure 1 for locations.

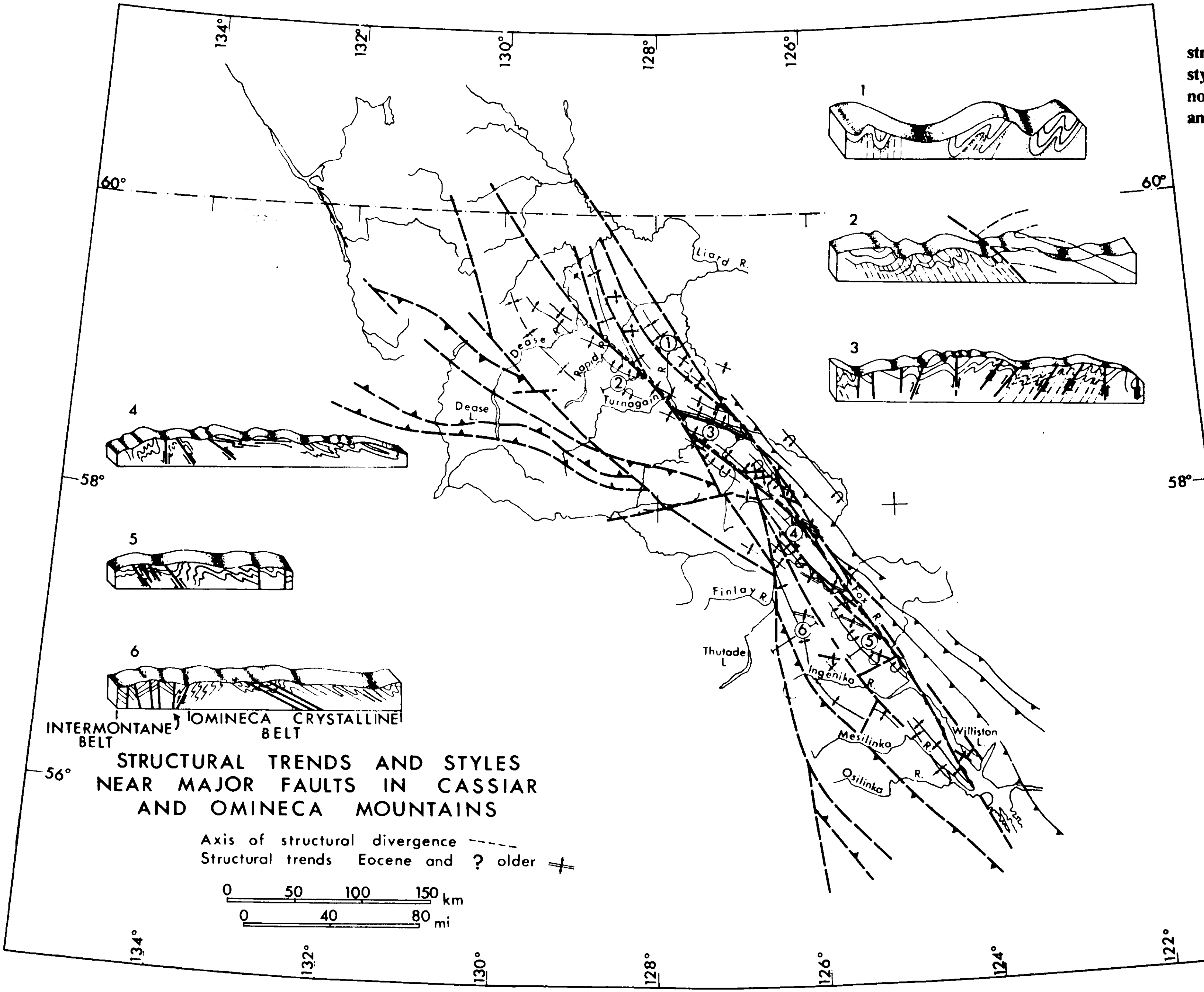


Figure 3. Summary of structures and structural styles near major faults in northern Rocky, Cassiar, and Omineca Mountains.

shelf facies overlain unconformably by Lower Mississippian limestone (Figs. 1, 2; Gabrielse, 1962b). Overlying the miogeoclinal strata, there is an allochthon of oceanic, mainly Mississippian to Permian rocks (Sylvester Terrane). Northeast of a zone of structural divergence along the Kechika fault (Fig. 1), most structures are eastward verging. Structures with an opposite sense of vergence occur southwest of the Kechika fault, southeast of Rapid River (Fig. 3). Structures west of the N.R.M.T. commonly trend more easterly than do those in the Rocky Mountains; in some places they trend almost east-west and are much less continuous.

The Omineca Mountains are underlain mainly by a thick succession of variably metamorphosed, miogeoclinal upper Proterozoic to Lower Ordovician strata assigned, for the most part, to the Omineca Crystalline Belt (Mansy and Gabrielse, 1978). Most regional structures verge westward and are locally characterized by nappes with gently dipping axial surfaces (C. A. Evenchick, 1982, personal commun.). Along the west side of the Cassiar and Omineca Mountains, there are Mesozoic arc terranes thrust northeastward (on the Klinkit, Hottah, and Swannell faults, for example) over older miogeoclinal rocks or juxtaposed against them along transcurrent faults (Gabrielse and Dodds, 1982). Faulted against western portions of the arc terranes along the Thibert and Pinchi faults in the northwestern and southern parts of the region, respectively, are oceanic terranes in part composed of tectonic mélange. They are bounded on the southwest by thrust faults (for example, King Salmon, Nahlin, and Vital), along which they have been emplaced southwestward onto another belt of arc rocks of late Paleozoic and early Mesozoic ages (Gabrielse and others, 1978, 1980; see also Fig. 1). All of the Mesozoic and Paleozoic arc and oceanic terranes are assigned to the Intermontane Belt. In terrane terminology, the arc rocks northeast of the Kutcho and Pinchi faults are referred to Quesnellia; the oceanic rocks, to Cache Creek; and the southwestern belt of arc rocks, to Stikinia.

The assemblages of rocks between the Thibert and King Salmon faults and between the Pinchi and Takla faults are of particular importance because they are not only similar but also unique. They comprise structurally complex sequences of dominantly upper Paleozoic and possibly minor early Mesozoic chert, argillite, limestone, volcanic, and ultramafic rock that is commonly in fault contact with, but locally overlain stratigraphically by, a distinctive Upper Triassic volcanic unit characterized by dacitic-quartz porphyry. Overlying the porphyry unit, there is a thick sequence of turbiditic shale, siltstone, graywacke, and conglomerate of Early Jurassic age. In some areas, an Upper Triassic limestone formation is present between the volcanic and turbidite units.

Middle Cretaceous granitic plutons are widespread in areas believed to be underlain by continental crust. Early Jurassic plutons are closely associated with volcanic rocks of the arc terranes.

Structurally complex, high-grade metamorphic rocks that yield Eocene K-Ar ages overlie granitoid basement gneiss northeast of the Spinel fault; a structurally complex area containing augen gneiss lies east of Horseranch fault (Gabrielse, 1963). A body of fresh, undeformed ultrabasic rock of probable Eocene age lies along the east side of the Horseranch fault.

Areally restricted but tectonically significant rocks occur in and along the fault zones. These include Upper Cretaceous, Paleocene and/or Eocene nonmarine conglomerate, sandstone, siltstone, and shale, locally with coal. They are most extensively developed in the N.R.M.T. near Sifton Pass (Fig. 1), but they are also present locally along the Kechika, Spinel, and Burnt Rose faults (Gabrielse, 1962a, 1963). A flora near the Turnagain River along the Kechika fault has been tentatively assigned a Late Cretaceous (Santonian-Campanian) age by W. A. Bell of the Geological Survey of Canada. Andesitic volcanics of Eocene age (Wanless and others, 1978) are exposed near the junction of the N.R.M.T. and Spinel faults and near Sifton Pass. Eocene rhyolitic volcanics underlie an area of ~35 km^2 along the east side of Kechika fault just north of the Turnagain River (Stevens and others, 1982). Finally, a swarm of northeasterly and northwesterly striking Eocene lamprophyre dikes cuts metamorphic and granitic rocks northeast of the Spinel fault and locally cuts Paleogene rocks in the Spinel fault zone.

The distributions of sedimentary facies and of domains of similar structural style (Figs. 1, 2, 3), as outlined above, show the degree to which the original paleogeographic and tectonic elements have been disrupted by faults. The same criteria demand that the faults be transcurrent and of regional importance. No evidence indicating that the facies distributions are the result of low-angle thrust faulting followed by dip-slip displacements has been recognized in the region.

STRUCTURES RELATED TO FAULTS

Structures in Fault Zones

A wide variety of structures occurs in and along the fault zones. Sedimentary rocks along the Kechika and Horseranch faults are intensely brecciated over widths of tens of metres. The Paleocene-Eocene sediments in the N.R.M.T. are gently to tightly folded, faulted, and locally brecciated. Numerous clasts in conglomerate have been systematically fractured and, although only local studies have been made, it appears that the strain is in accord with the orientation of folds which trend more westerly than does the N.R.M.T. (see area near lat. 58° in Fig. 3). Tight folds in Paleozoic strata near the mouth of the Turnagain River have steeply plunging axes, but similar steep plunges have not been noted elsewhere.

Along the Kechika and Spinel faults, there are spectacular folds, ranging from crinkles to those with amplitudes of >100 m, whose hinges trend more westerly than the regional fault and fold axes (Eisbacher, 1972). The hinges of tight, chevron-crinkle folds in lower Paleozoic rocks in the Spinel fault zone are parallel with the hinges of tight folds in Paleogene clastics.

Granitic rocks along the Kutcho, Cassiar, and Thudaka faults have been penetratively sheared and foliated over widths of as much as 2 km. Commonly, the deformation culminates in zones of ultramylonite <1 metre wide. Prominent, horizontal to gently plunging lineations in the shear-zone rocks are evident. Middle Cretaceous K-Ar ages from muscovites generated in the fault zones suggest that foliation developed during or not long after emplacement of the middle Cretaceous granitic rocks. Strongly foliated granitic rock in the N.R.M.T. east of the mouth of the Ingenika River locally contains spectacular cross-cutting veins of ultracataclasite (Evenchick, 1982).

Structures in Panels between Faults

In the Omineca Mountains northeast of the Swannell fault, a late penetrative crinkle lineation trends frm almost east-west to ~115 degrees. Similar trends are observed in folds and thrust faults in the panels northeast of the northern part of the Thudaka fault (Fig. 3). On the northeast side of the Kechika fault, westerly trending folds plunge moderately toward the fault.

The orientations of structures noted above are compatible with stress related to dextral transcurrent movements on the major faults, evidence for which is presented below. Indeed, the contrasting structural styles of the northern Rocky Mountains, characterized by low-plunging, uniformly trending fold axes and relatively continuous thrust faults, and the Cassiar-Omineca Mountains, characterized by local steeply plunging and variably trending fold axes, may be the consequence of an overprint west of the N.R.M.T. of structures related to dextral transcurrent faulting on earlier formed structures similar to those east of the trench (Fig. 3).

DISPLACEMENTS OF REGIONAL FAULTS

The best criteria for estimating displacements on regional faults are those that are least affected by depth of erosion. These include offsets of geologic units with considerable vertical extent, for example, batholiths, distinctive cylindrical folds that involve thick stratigraphic sequences and, particularly, paleogeographic elements, such as strand lines and shelf-to-basin transition zones. In the Northern Rocky, Cassiar, and Omineca Mountains, the criteria mentioned above occur singly or in combination and provide information on displacements for several of the major faults.

Northern Rocky Mountain Trench Fault Zone

The N.R.M.T. is the physiographic expression of a major structural discontinuity, across which there are abrupt changes in stratigraphy and paleogeographic trends. That the changes are not simply the result of original basin configurations is evident from an analysis of sedimentary facies and depositional polarity in lower Paleozoic rocks (Figs. 4, 5). In the northern Rocky Mountains, all lower Paleozoic rocks change facies westward (Fig. 2). In general, well-bedded carbonates of Middle Ordovician to Middle Devonian age to the east reflect stable platform or subsiding-shelf environments of deposition. To the west, the carbonates grade across well-defined, narrow transition zones into shale and siltstone, with local slide breccias derived from the carbonate banks. Clean, Lower Cambrian sandstone defines a narrow facies belt along the eastern margin of the subsiding shelf. To the west, siltstone, shale, impure sandstone, and local members of limestone are typical. Lower Devonian clean sandstone and dolomitic sandstone of the eastern platform facies are equivalents of a mixed carbonate sandstone and breccia facies of the subsiding shelf which, in turn, are correlative with off-shelf shale, siltstone, and debris flows to the west.

The distribution of all units described above clearly indicates that the rocks, in general, are of shallow-water facies to the east and deeper-water facies to the west as far as the N.R.M.T. The facies boundaries can be followed northward for hundreds of kilometres and are interpreted as marking the western limit of the broad carbonate platform of the lower Paleozoic continental shelf. This simple, general paleogeography is complicated locally by narrow, northwest-trending belts of Middle Cambrian and Devonian reefoidal carbonates, generally <100 km long, that may have been deposited on uplifted blocks bounded by rifts in the off-shelf region (Gabrielse, 1981; McIntyre, 1981). Facies boundaries associated with these blocks are commonly restricted to rocks representing a relatively short time span and easily separated from the much more fundamental boundaries noted above. Lower Cambrian clastic facies are not affected by the fault blocks.

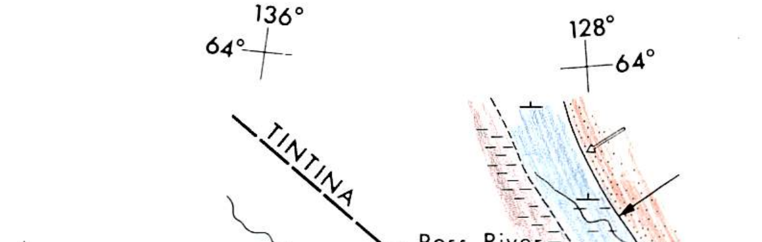
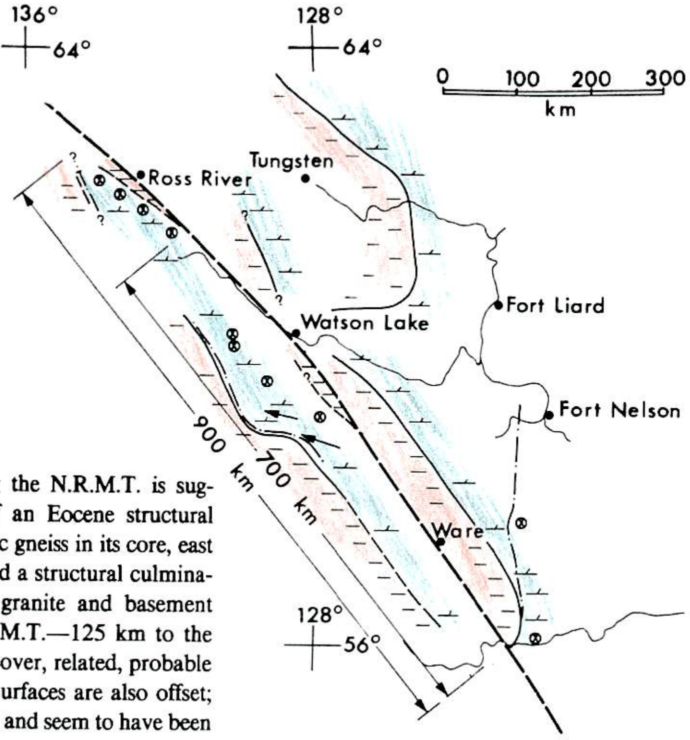


Figure 4. Facies distributions, paleocurrent directions (closed arrows), and fining directions (open arrows) of clastic Lower Cambrian strata in part of northern Cordillera.

Similar stratigraphy in the Cassiar and Omineca Mountains show the same kinds of facies changes in a westward direction as do those in the northern Rocky Mountains. Moreover, current directions indicate easterly source areas for shallow-water Lower Cambrian and Lower Devonian sandstones (Figs. 4, 5). Clearly, the clastic rocks could not have been carried through the off-shelf environment east of N.R.M.T. It appears, therefore, that lower Paleozoic strata have been displaced from their former position adjacent to platform and subsiding-shelf facies now exposed in the northern Rocky Mountains (Figs. 6A, 6B).

The magnitude of displacement is suggested by the location of the intersections of facies boundaries with the Tintina and Rocky Mountain Trenches. Offset of the Lower Cambrian clean-quartzite–facies belt is difficult to determine accurately. Intersection of the belt with the east side of the N.R.M.T. must be near, or south of, latitude 56°N. On the west side, it apparently lies near latitude 61°32′N (Read, 1980; Tempelman-Kluit and others, 1976), suggesting a minimum dextral offset of 750 km. Location of the lower to middle Paleozoic carbonate to shale boundary can be determined more precisely. The boundary is closely fixed east of the N.R.M.T. at about latitude 56°N. There, distinctive Silurian and Devonian carbonate strata, with diagnostic faunas including *Stringocephalus* sp. of late Middle Devonian (Givetian) age (Taylor and Mackenzie, 1970), are similar to rocks just west of the Tintina Trench, near latitude 61°15′N—about 700 km to the northwest (Fig. 5). The latter are found in a northwesterly trending belt as far north as latitude 62°N, but Tempelman-Kluit (1977) has suggested that they were deposited on a peninsula with off-shelf facies between them and the Tintina Trench (Fig. 5). Much greater apparent displacement—more than 900 km—is indicated

Figure 5. Facies distributions, *Stringocephalus* sp. localities, and paleocurrent directions in Upper Silurian, Lower and Middle Devonian strata.



if, alternatively, the off-shelf facies between the Tintina Trench and the platform facies west of Ross River is a faulted slice and has also been displaced dextrally (Fig. 5). Studies of sedimentary transport in clastic rocks of strata west of Tintina Trench would provide constraints on these options.

Not all of the displacement discussed above took place along the N.R.M.T. but was distributed between the Trench and several major faults farther west that connect with faults in the Tintina and N.R.M. Trenches.

Cenozoic offset along the N.R.M.T. is suggested by the match of an Eocene structural culmination, with granitic gneiss in its core, east of the Ingenika River and a structural culmination, cored by Eocene granite and basement gneiss, west of the N.R.M.T.—125 km to the northwest (Fig. 1). Moreover, related, probable early Cenozoic erosion surfaces are also offset; these flank the N.R.M.T., and seem to have been

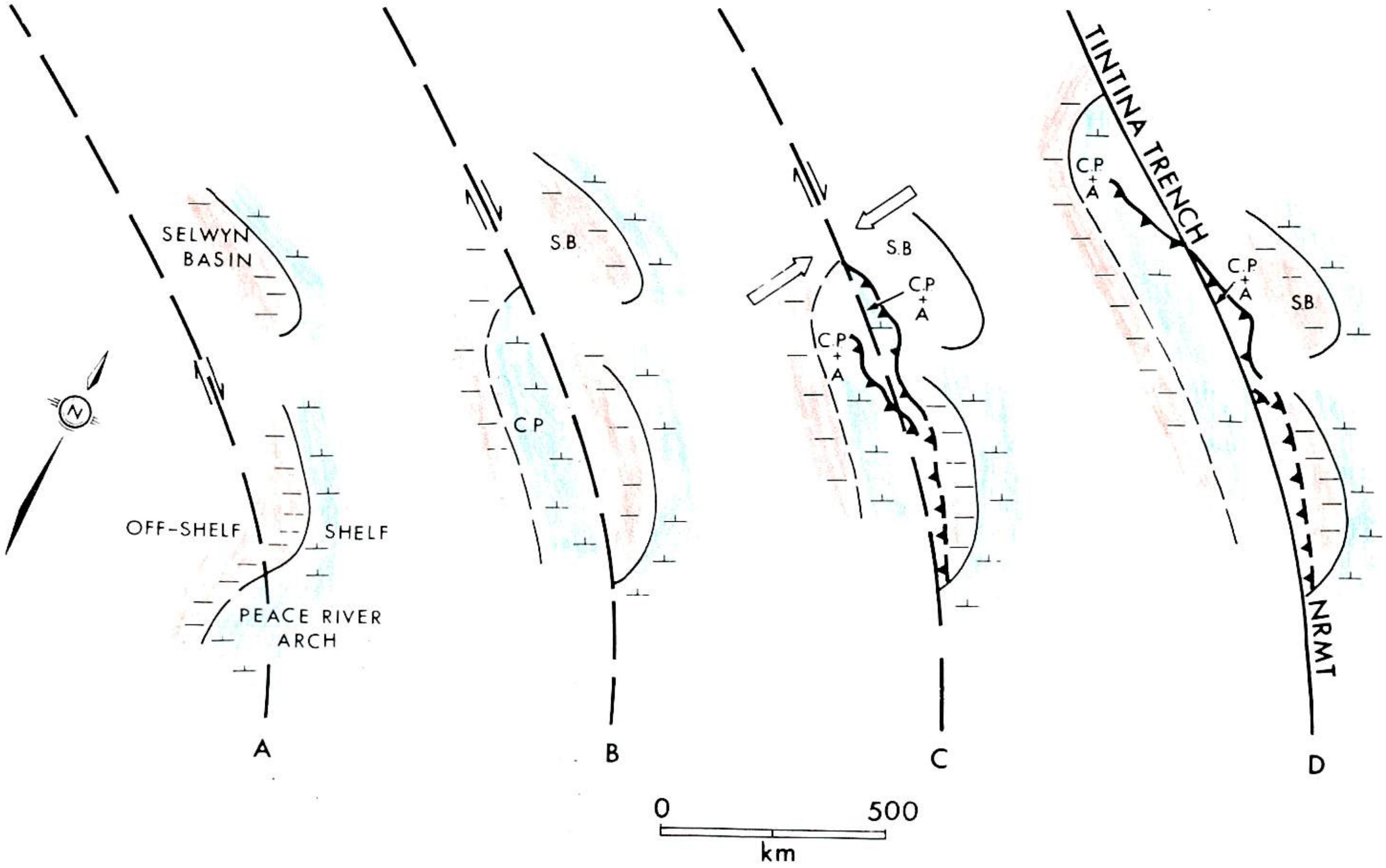


Figure 6. Interpretation of Cassiar Platform as a displaced part of the Peace River Arch (A, B) based on Figure 5. A possible explanation for the discrepancy in offsets, suggested by pre–Late Cretaceous contractional structures and early Paleozoic facies boundaries, is shown in 6C (regional contraction) and 6D (subsequent further dextral displacement). C.P. = Cassiar Platform; C.P. + A. = Cassiar Platform with allochthonous terranes. See text for further explanation.

upwarped on the culminations. The surfaces now slope to the north and south, away from the structural highs. It is possible, however, that the culminations represent independent Eocene uplifts, thus providing no information on the amount of transcurrent displacement.

Spinel Fault Zone

Lower Cenozoic conglomerate, deposited on the erosion surface west of the mouth of Fox River, includes boulders of foliated, megacrystic, muscovite-bearing granite as much as 2 m in diameter (Fig. 7). Muscovite from the boulders was dated by the K-Ar method at ~97 and 106 m.y. B.P. Granitic rocks nearby to the north are of markedly different character and have been dated by K-Ar method at ~42 m.y. B.P. The obvious source for the boulders is the middle Cretaceous Thudaka pluton, bounded on the west by Thudaka fault. It is foliated, muscovite-bearing, and has been dated by the K-Ar method at between 88 and 100 m.y. B.P. Similar rocks of the Whudzi pluton, probably displaced dextrally from the Thudaka pluton, lie along the east side of Finlay fault to the south. It is clear from the size of clasts that the boulders could not have been transported far, and it is improbable that they traveled the distance required by the present distribution of the conglomerate and source rocks. Most likely, the terrane west of Spinel fault was displaced to the northwest as much as 85 km, following deposition of the conglomerate.

Kechika and Thudaka Faults

West of Kechika fault near Rapid River, the southwesterly directed structures typical of the southern Cassiar Mountains and Omineca Mountains are replaced transitionally along structural trend to the northwest by northeasterly directed structures. These structures are typical of the northern Cassiar Mountains and the area northeast of Kechika fault. Restoration along the Kechika and Thudaka faults in the order of 60 km and a further minimum of 110 km along Kechika fault southeast of its intersection with Thudaka fault juxtaposes terranes of similar structural style (Fig. 8).

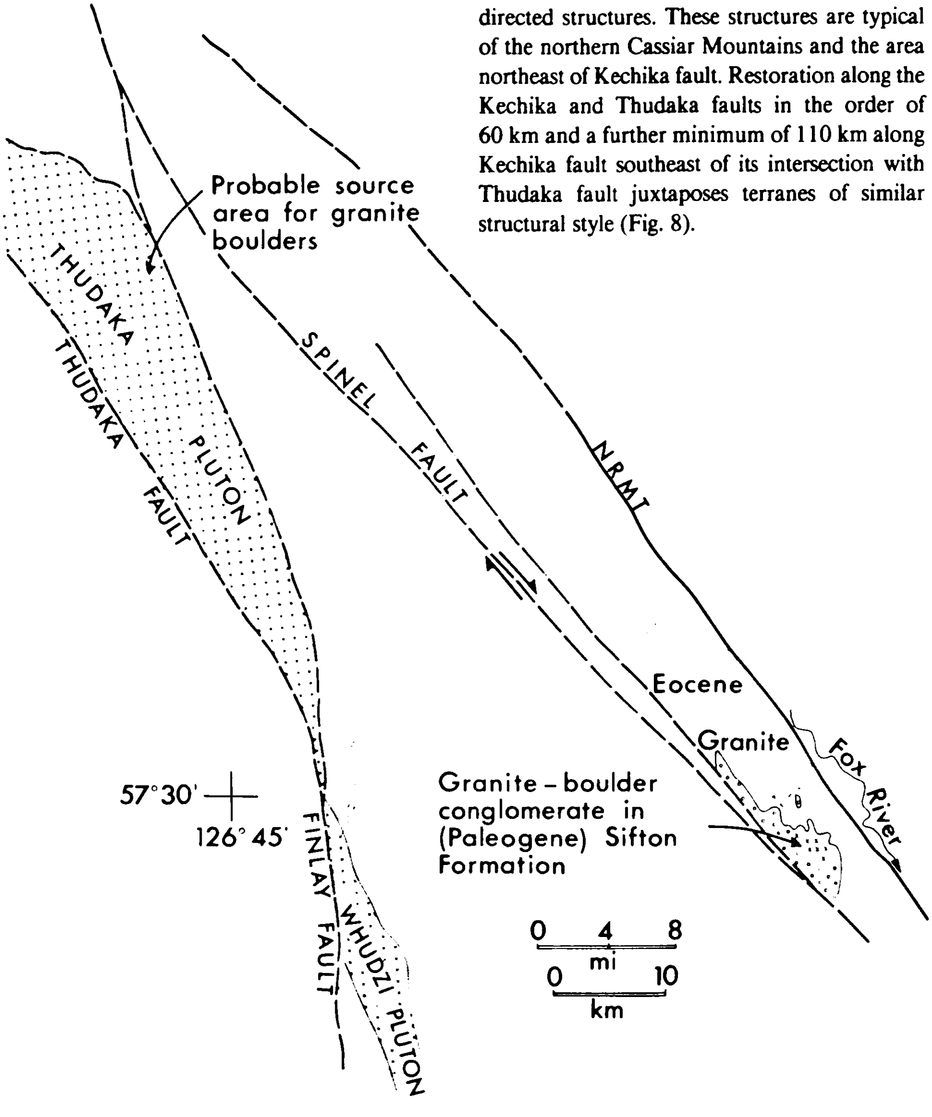


Figure 7. Diagram showing proposed dextral offset on Spinel fault zone following deposition of lower Paleogene conglomerate.

Horseranch and Deadwood Faults

The most obvious component of movement on these faults is vertical, and the intervening Proterozoic rocks are strongly uplifted. Stratigraphic throws probably exceed 2 km. The orientation of these faults suggests a tensional origin related to dextral movement on the Kechika fault.

Pelly Fault

North of the Ingenika River, the Pelly fault is marked by a straight lineament trending parallel with the N.R.M.T. A significant vertical component of movement is shown by the presence of upper Proterozoic strata to the west and Cambrian-Ordovician strata to the east. At its south end, this fault intersects two northeasterly striking faults, along which apparent transcurrent displacement has been sinistral. They offset the axes of two regional anticlinoria as much as 15 km (Fig. 3). If they are conjugate faults related to the Pelly fault, the compatible movement on the Pelly fault would be dextral. Farther south, the Pelly lineament along the Mesilinka River is crossed by a regional syncline, precluding the possibility of significant transcurrent faulting.

Thudaka, Finlay, Ingenika, and Kutcho Faults

The distribution of middle Cretaceous granite in the region between the Turnagain and Finlay Rivers strongly suggests that the southeast end of the Cassiar batholith has been offset dextrally by the Thudaka and Finlay faults (Figs. 1, 9A). Displacements on the Thudaka fault appear to have been in the order of 60 km and, judging from K-Ar ages on muscovite developed in the foliated granitic rocks, took place during late middle Cretaceous or early Late Cretaceous time. Displacement on the Finlay fault, indicated by offset of granitic rocks, was a minimum of 15 km and a maximum of 50 km. The latter amount is compatible with offsets along the Finlay fault farther south.

Further indication that considerable dextral movement took place on the Thudaka, Finlay, and Ingenika faults is given by the apparent displacement of ~125 km of an upper Paleozoic and Upper Triassic terrane in the hanging-walls of the Hottah and Swannell thrust faults (Figs. 9A, 9B). Similar dextral offset of ~110 km is suggested by the disposition of two belts of Upper Triassic(?) zoned intrusive ultramafic bodies (Figs. 9A, 9B). This amount may have been distributed about equally along the Thudaka fault and the Finlay fault, on the east side of the Thudaka pluton.

The Cassiar, Klinkit, Thibert, Nahlin, King

Salmon, and Hottah faults and bounding terranes are truncated by the Kutcho fault (Figs. 1, 9A). Monger and others (1978) suggested the possible dextral offset of 200 km to account for the distribution of Cache Creek oceanic rocks in the Omineca and Cassiar Mountains. Restoration of dextral offset of ~300 km along the Kutcho, Finlay, Ingenika, and Takla faults, however, juxtaposes the Nahlin and the Vital thrust faults and the unique stratigraphic assemblages associated with these structures (Fig. 9C, 9D; Paterson, 1977). It also brings together a complex batholith (Hogem) of Jurassic and Cretaceous granitic plutons east of the Takla fault with an equally complex batholith southwest of the Kutcho fault and east of Dease Lake. Indeed, the two batholiths and a similar one straddling the Pitman fault may have been one body originally. Displacement along the Kutcho fault of ~100 km is indicated by offset of the Klinkit and Hottah faults, which bound similar Upper Triassic and related granitic rocks. If this is the case, the remaining 200 km of displacement could have taken place along the Thibert and the Finlay-Thudaka fault systems, possibly ~75 km on the former and 125 km on the latter. Movement of this order of magnitude is consistent with suggested offsets described above for the Finlay, Thudaka, and Kechika faults. Also implied is that the Kutcho and Pinchi faults, two of the most important structures in northern British Columbia, are segments of a formerly continuous fault, offset by the Finlay fault zone, along the northeast side of the Cache Creek Terrane (Fig. 9).

Because the orientations of the Thibert, Kutcho, Thudaka, and Finlay faults are significantly different from one another, even the simplest restorations involve some rotation of geologic units. Fewer problems occur if it is assumed that all of the movement on the Finlay and Thudaka faults postdated movements on the Kutcho and Pinchi faults (Fig. 9B). It appears, however, that some movements on the Kutcho and Thudaka faults were contemporaneous (see below), and if restoration of the traces of the Nahlin and Vital faults is valid, then the total strain involved entails a complex geometry of dextral displacements coupled with rotations (Fig. 9D).

Cassiar Fault

Although stretching lineations in mylonitic rocks in the Cassiar fault zone (Fig. 1) suggest transcurrent movement (Gabrielse, 1969; Poole, 1956), no correlations across the zone have been made.

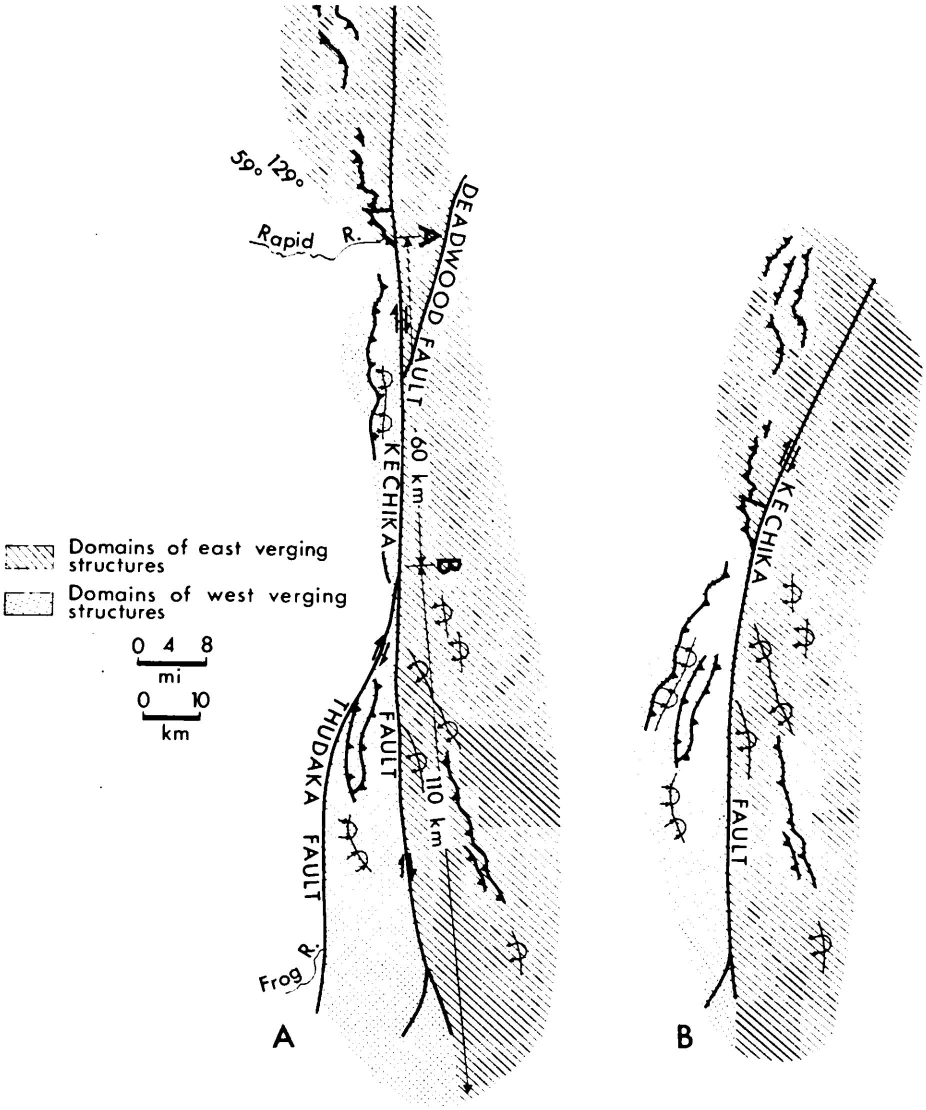


Figure 8. Apparent dextral offsets on Kechika and Thudaka faults showing displacements of distinctive structural domains. 8A. Present distribution of structural domains. 8B. Distribution after restoration on Kechika and Thudaka faults of ~50 km. Further restoration of >110 km on Kechika fault is required to juxtapose east-verging structural domains along the fault southeast of Thudaka fault.

Pitman and Related Faults

About 3 km of sinistral displacement, suggested by offsets of the Kutcho and Thudaka faults, is apparent on the east-northeast-trending Pitman fault, but the amount, if any, of vertical movement is difficult to assess. The sense of apparent vertical movement along the fault is indicated along its western part, where Upper Triassic volcanics in its southern wall are juxtaposed against Middle Jurassic sediments and volcanics to the north. East of the north end of Dease Lake, a fault of similar trend, one of a set of subparallel faults, offsets the Kutcho fault sinistrally ~4 km (Gabrielse and Dodds, 1982). There, however, striae and crinkle crenulations associated with the easterly striking fault indicate that important displacement has resulted in relative uplift of rocks to the south. The sinistral movement and orientation of the fault, east of Dease Lake and the Pitman fault, is compatible with their origin as antithetic shears related to the dominant northwest-striking dextral fault.

Klinkit and Hottah Faults

These thrust faults place younger rocks of the upper Paleozoic to Middle Jurassic arc terrane onto metamorphosed miogeoclinal strata (Gabrielse and Dodds, 1982). In some places, overlap of the terranes is probably >10 km. As noted above, the two structures may represent offset segments, along the Kutcho fault, of a formerly continuous thrust fault.

TABLE 1. SUMMARY OF AMOUNTS AND AGES OF DEXTRAL TRANSCURRENT DISPLACEMENTS ON SELECTED FAULTS IN THE NORTH-CENTRAL CANADIAN CORDILLERA

Fault	Displacement	Age	Criteria
Northern Rocky Mountain and Tintina Trenches fault zone	700 to >900 km	Pre-middle Cretaceous(?) to Eocene or Oligocene	Offsets of lower Paleozoic continental-shelf facies boundaries
Northern Rocky Mountain Trench	125 km	Late Eocene to Oligocene	Offset of Eocene structural culmination and erosion surface
Kechika fault	>170 km	Middle Cretaceous to Oligocene	Offset of pre-middle Cretaceous structures; generation of middle Cretaceous mica in associated Thudaka fault; fault zone contains Santonian-Campanian to Eocene rocks
Spinel fault	85 km	Late Eocene to Oligocene	Displaces Paleogene conglomerate from source area
Thudaka fault	60 km	Middle Cretaceous	Offsets middle Cretaceous granitic rocks with generation at middle Cretaceous micas in fault zone
Finlay fault, north of Thudaka fault	50 km	Middle Cretaceous and (?) younger	Offsets middle Cretaceous granite
Finlay fault, total	110 km	Middle Cretaceous and (?) younger	Offsets Kutcho and Pinchi faults, Hottah and Swannell faults, belt of Late Triassic ultrabasic intrusions; continuous with Thudaka and Finlay faults
Kutcho fault	100 km	Pre-Late Cretaceous	Offset of Klinkit and Hottah faults; fault zone involves middle Cretaceous granite; trace cut by Late Cretaceous granite
Thibert fault	75 km	Pre-Late Cretaceous	Linked to Kutcho and Finlay fault displacements

Thibert Fault

Where best exposed near Dease Lake, the Thibert fault appears to be steeply southwest-dipping, its southwest side up. Its trace to the northwest is truncated by an unfoliated, high-level, middle to Late Cretaceous granite pluton. If offsets postulated for displacements on the Kutcho and Finlay faults are correct, then as much as 75 km of dextral movement must have taken place along the Thibert fault.

King Salmon and Nahlin Faults

These are southwestward-directed thrust faults >300 km long. Distributions of rock units and structures within and near the fault zones show that the dominant movements along easterly striking segments of the faults have been parallel with the dip. Along northwesterly striking segments, however, the faults are commonly steeply dipping, and local steep, minor-fold axes suggest a component of transcurrent displacement.

The geometrical relationship between the Kutcho, King Salmon, and Nahlin faults is compatible with related dextral transcurrent strain on the Kutcho fault and with southerly directed thrusting on the other faults.

Cumulative Dextral Displacement

Based on estimates of displacements along transcurrent faults described herein (Table 1), it seems probable that the cumulative dextral displacement of terranes west of the faults relative to the terrane east of the N.R.M.T. was >1,000 km. Paleomagnetic data from Upper Triassic, Lower Jurassic, and Lower Cretaceous rocks west of the Ingenika and Takla faults (Monger and Irving, 1980) indicate northward displacement relative to cratonal North America in the order of 1,300 km. The distribution of Late Triassic (Karnian and Norian) faunas in the Cordillera suggests that those faunas of warmer-water habitats in the Intermontane Belt have been displaced northerly, compared with those of cooler-water habitats at comparable latitudes on the craton (Tozer, 1970). Early Jurassic (Pliensbachian) faunas show the same anomaly in distribution (Tipper, 1981). Several lines of evidence thus support the contention of large dextral strain between the Intermontane Belt and the North American craton.

AGES OF TRANSCURRENT DISPLACEMENTS

Data that constrain postulated ages or spans of ages for transcurrent displacements are meager. Although some faults appear to have been active as early as middle Cretaceous time, it is not known whether the entire system was initiated that early. Furthermore, the relative amounts of strain on various faults may have changed in response to alterations in directions of regional principal stress (see Fig. 12 below).

On a regional scale, it is clear that pre–middle Cretaceous structures (Figs. 1, 3, 7, 10) and middle Cretaceous granitic plutons (Figs. 1, 9) have been offset. Middle Cretaceous K-Ar ages have been obtained on muscovite generated in fault zones where they cut granitic rocks along the Cassiar, Kutcho, Thudaka, and Finlay faults. Where unstrained or little strained, the granitic rocks contain biotite, hornblende, and no muscovite. Fault movements of Late Cretaceous age are suggested by the presence of Santonian-Campanian(?) clastic rocks along the Kechika fault, near the Turnagain River, and by Maastrichtian to Danian sediments in the southern part of the N.R.M.T. south of Williston Lake (Rouse, 1967). The Thibert fault appears to be cut by a Late Cretaceous pluton. Many of the faults contain Paleocene and/or Eocene nonmarine clastic rocks, and Eocene volcanic rocks are present locally along the Kechika, Spinel, and N.R.M.T. faults. Northerly trends of Eocene dike swarms are compatible with dextral strain on bounding faults. Finally, the possible offset, along the N.R.M.T., of Eocene structural culminations and related erosion surfaces and of a postulated source area for Paleocene-Eocene conglomerate along the Spinel fault, shows the importance of Cenozoic movements—possibly as young as late Eocene or Oligocene.

In summary, several kinds of criteria indicate that major dextral transcurrent displacements took place along a system of faults along and west of the N.R.M.T. in an interval between middle Cretaceous and late Eocene or Oligocene time. Most, if not all, of the movement on the Thibert, Kutcho, and Pinchi faults may have been of pre–Late Cretaceous age. Indeed, the Kutcho fault may have been initiated during the Middle to Late Jurassic, the time of southerly thrusting along the King Salmon and Nahlin faults. The remaining faults may have had a history of displacements from middle Cretaceous to the Oligocene (Table 1).

REGIONAL IMPLICATIONS

Regional Continuation of Faults

The faults described above are continuous with specific faults or fault zones north and south of the Cassiar-Omineca region (Figs. 10, 11). Faults along or near the eastern margin of the Intermontane Belt, including the Kutcho and Thibert faults, connect northward with the Teslin Suture Zone (Tempelman-Kluit, 1979). To the south, they are continuous with two main faults, the northerly striking Takla fault and the northwesterly striking Pinchi fault, which fol-

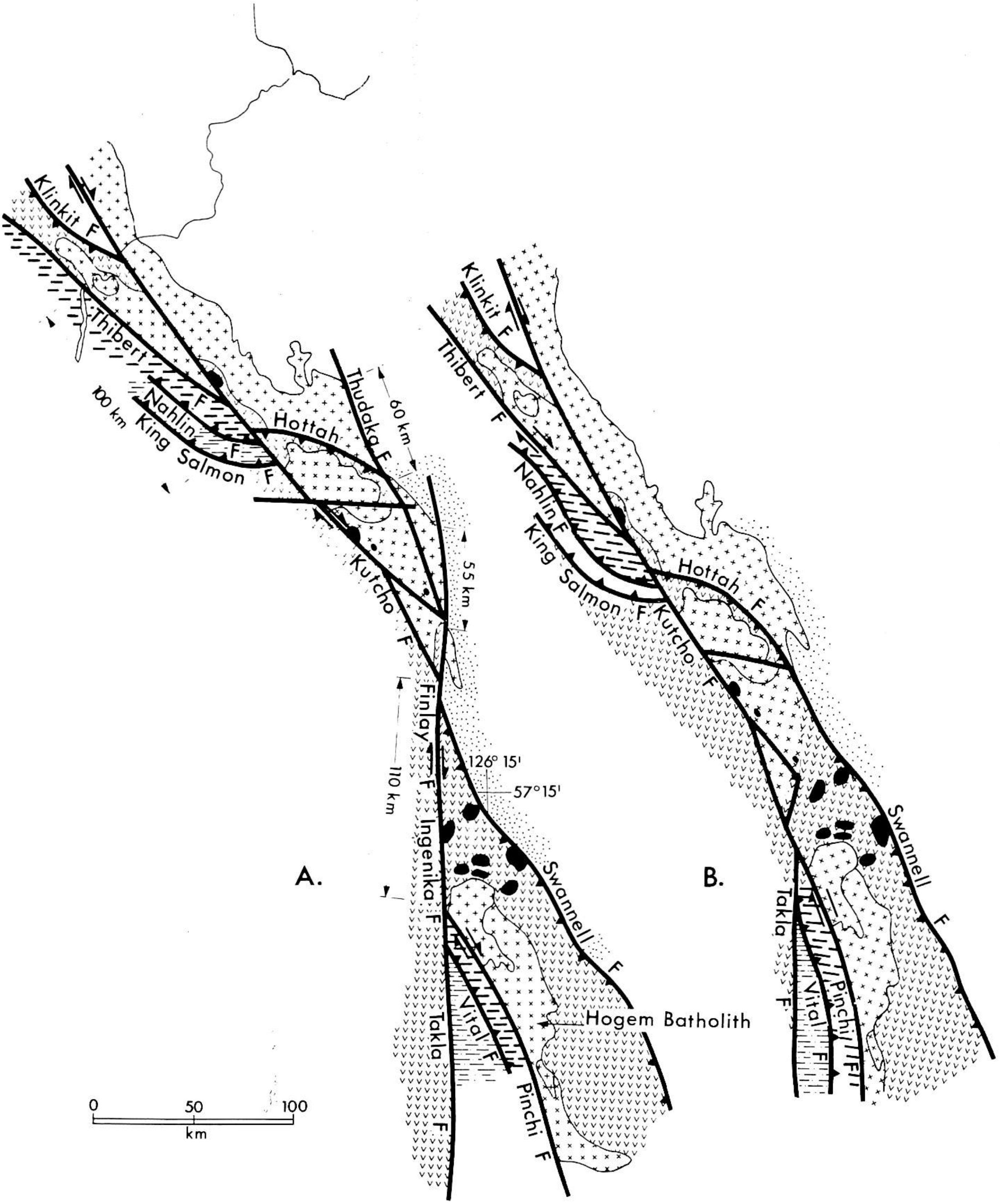


Figure 9. Proposed restoration of geologic elements along the Thudaka, Kutcho, Finlay, and Pinchi faults. See Figure 1 for legend. Solid black areas represent zoned, intrusive ultrabasic rocks of Late Triassic age. 9A. Generalized geology near faults. 9B. Restoration of 60 km on Thudaka fault and 50 km on Finlay and Ingenika faults. 9C. Further restoration of 100 km on Kutcho fault. 9D. Restoration juxtaposing Nahlin and Vital faults with displacements distributed on Thibert, Kutcho, Thudaka, Finlay, Ingenika, and Pinchi faults.

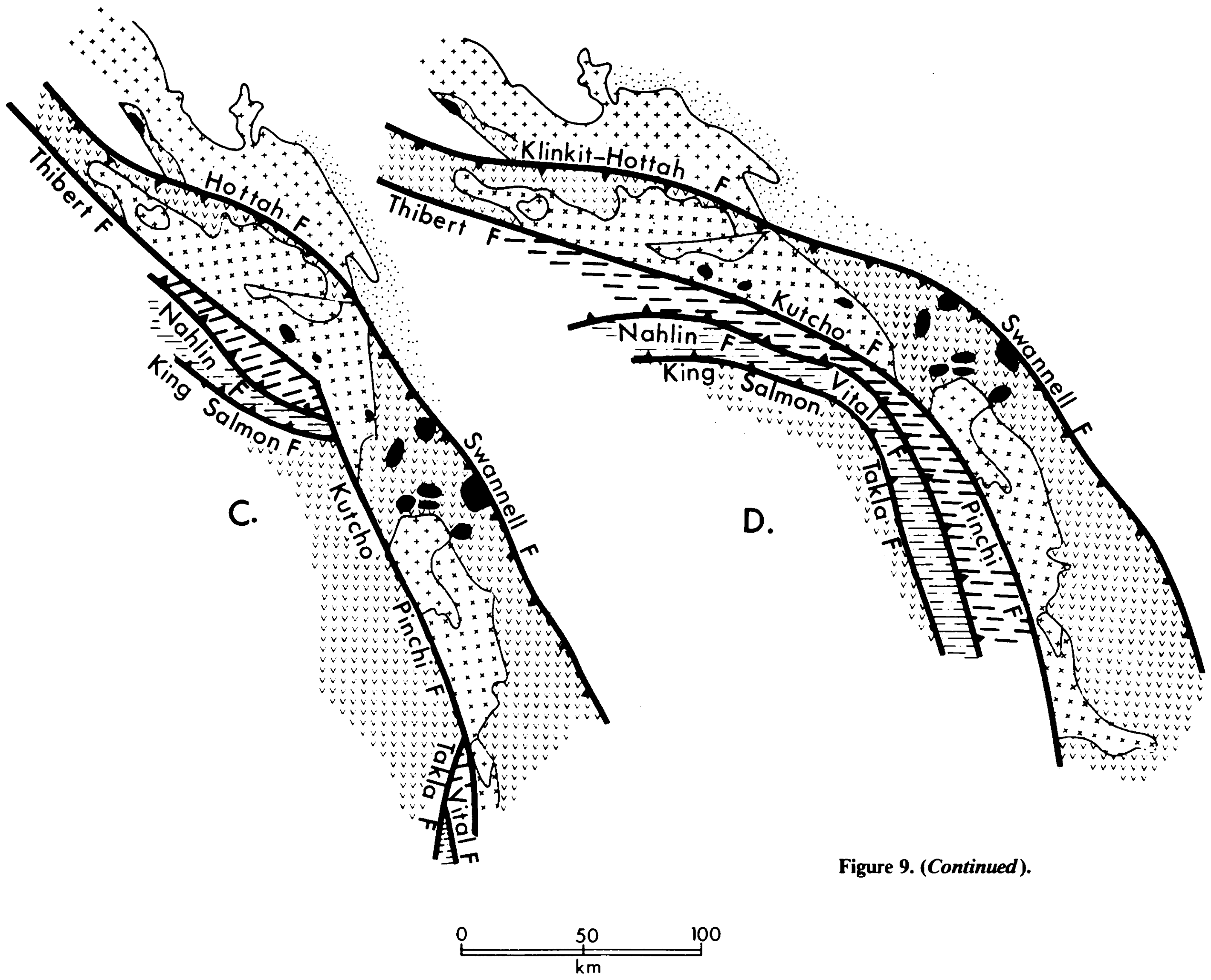


Figure 9. (*Continued*).

lows the northeast side of the Cache Creek Terrane (Richards and others, 1976). Farther south, the Takla fault probably connects with the Fraser River–Straight Creek fault zone. The relationship of the Takla, Finlay, and Thudaka faults to the more northwesterly trending structures is remarkably similar in geometry and scale to that of the Fraser River–Straight Creek fault zone and bordering structures (Kleinspehn, 1982). In each case, the northwesterly striking faults are offset by northerly striking faults.

The Thudaka, the northern part of the Finlay faults, and those faults farther east, including the N.R.M.T. fault zone (Figs. 10, 11), appear to be direct continuations of the Tintina and possibly related faults in the Yukon Territory (Tempelman-Kluit, 1979). The connections are obscured, however, by the drift cover of the Liard Plain in the region straddling the British Columbia–Yukon Territory boundary. The difference in estimates for total displacements along the Tintina Trench of ~450 km (Roddick, 1967; Tempelman-Kluit, 1979; Gordey, 1981) and along the N.R.M. and Tintina Trenches of ~900 km or more, as suggested in this paper, are difficult to reconcile. Criteria used for estimates of movements on the Tintina Trench involve middle to late Mesozoic structures, whereas displacements indicated herein relate to Paleozoic paleogeographic features. One possibility is that the discrepancy results from significant dextral movements that occurred before the major contractional deformation of the supracrustal rocks. If this had been the case, transported traces of the early fault zone might be expected in cover rocks east of the Tintina and N.R.M.T. faults (Fig. 6C), although they could have been removed by erosion. This kind of evidence would be difficult to recognize in rocks that have undergone significant folding and thrusting. Nonetheless, the location of the Cassiar Platform of Tempelman-Kluit (1977), east of the Tintina Trench, might be explained by this model (Figs. 6C, 6D). Another possibility is that the structures preserving the Jurassic-Cretaceous clastics (Roddick, 1967; Fig. 10) were dynamically related to transcurrent movement on the Tintina fault and were not continuous before decoupling of the terranes on either side of the fault. The magnitude of displacement, suggested by matching allochthonous terranes across the Tintina Trench (Tempelman-Kluit, 1977), is minimal because of reinterpre-

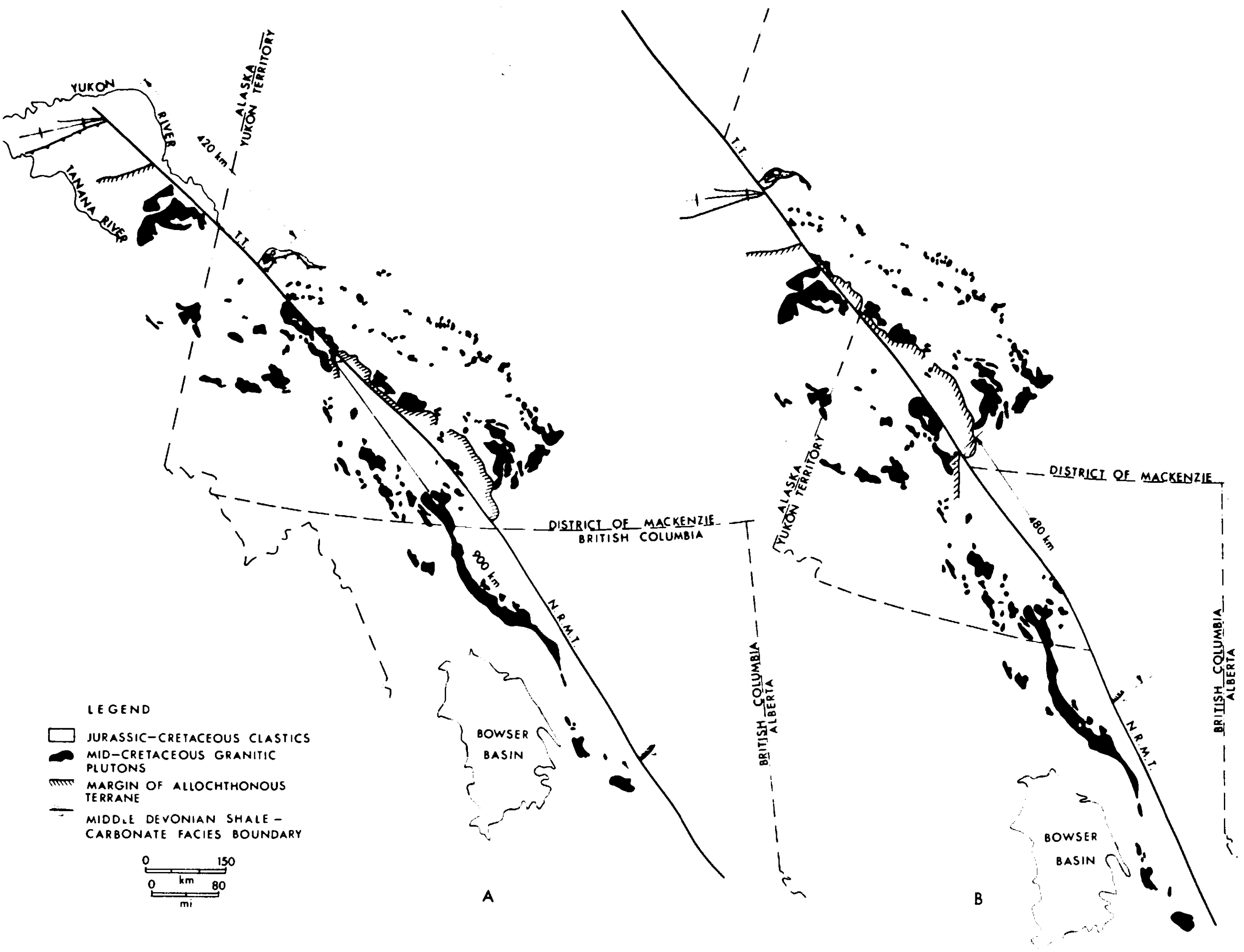


Figure 10. Reconstruction for offsets along the Tintina Trench and N.R.M.T. Data from Roddick, 1967; Tempelman-Kluit, 1977; Beikman, 1980; and Gordey, 1981. Note that the restoration of ~420 km, obtained by matching the Jurassic-Cretaceous clastics, still leaves the Middle Devonian facies boundaries 480 km apart.

tation of the geology on the northeast side by S. P. Gordey (1982, personal commun.). There, the northwest end of the allochthon is now believed to lie 180 km farther southeast than shown in Figure 10. In any event, the position of the intersection of allochthon boundaries with the Tintina Trench would be affected markedly by erosion because of their relatively shallow dip. Of the various possibilities suggested above, the hypothesis of dextral transcurrent displacements overlapping regional contractional deformation seems to best explain the disposition of parameters used to estimate offsets along the Tintina and N.R.M.T. faults.

The continuation of the Tintina fault in Alaska is a further problem. There, at least the late dextral displacement must be expressed in contractional and transpressive structures or in dextral strike-slip faults in the west-central part of the state. This region is characterized by southwesterly and westerly structural trends.

If, as suggested above, the transcurrent faults in the northern Cordillera have had a history of initiation and displacements during the interval between middle Cretaceous (or earlier) and late Eocene or Oligocene, then it is possible that early-formed faults may have been complicated or obscured by Cenozoic deformation. This is particularly important in the southeastern part of the Canadian Cordillera, perhaps accounting for the difficulty in tracing faults of the N.R.M.T. system to the south. Some idea of variations in principal stress directions in the Cordillera, from pre-Albian through Oligocene time, can be obtained from trends of regional fold axes and orientations of transcurrent faults coupled with their presumed ages (Fig. 12). For the north-central Cordillera, at least, there appears to have been a marked change in general orientations of principal stress from northeast in pre-Albian time to north or even north-northwest in the middle Cretaceous to north-northeast in Late Cretaceous and/or early Cenozoic time. The most conspicuous expression of this evolution is the offset of the Kutcho and Pinchi faults

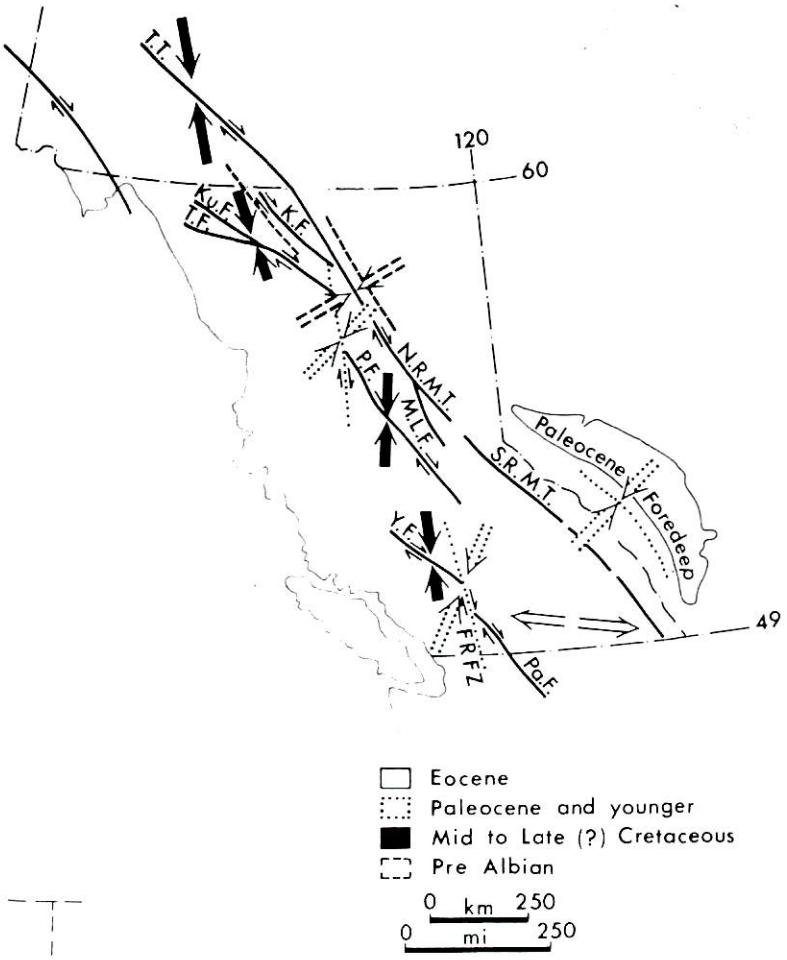


Figure 12. Approximate regional stress orientations compatible with structures of pre- middle Cretaceous (JK), middle to Late(?) Cretaceous (mK), and early Cenozoic ages (P = Paleocene; E = Eocene and (?)Oligocene). T.T. = Tintina Trench; N.R.M.T. and S.R.M.T. = northern and southern Rocky Mountain trenches. Faults: K = Kechika, Ku = Kutcho, T = Thibert, F = Finlay, P = Pinchi, M.L. = McLeod Lake, Y = Yalakom, FRFZ = Fraser River Fault Zone, Pa = Pasayten.

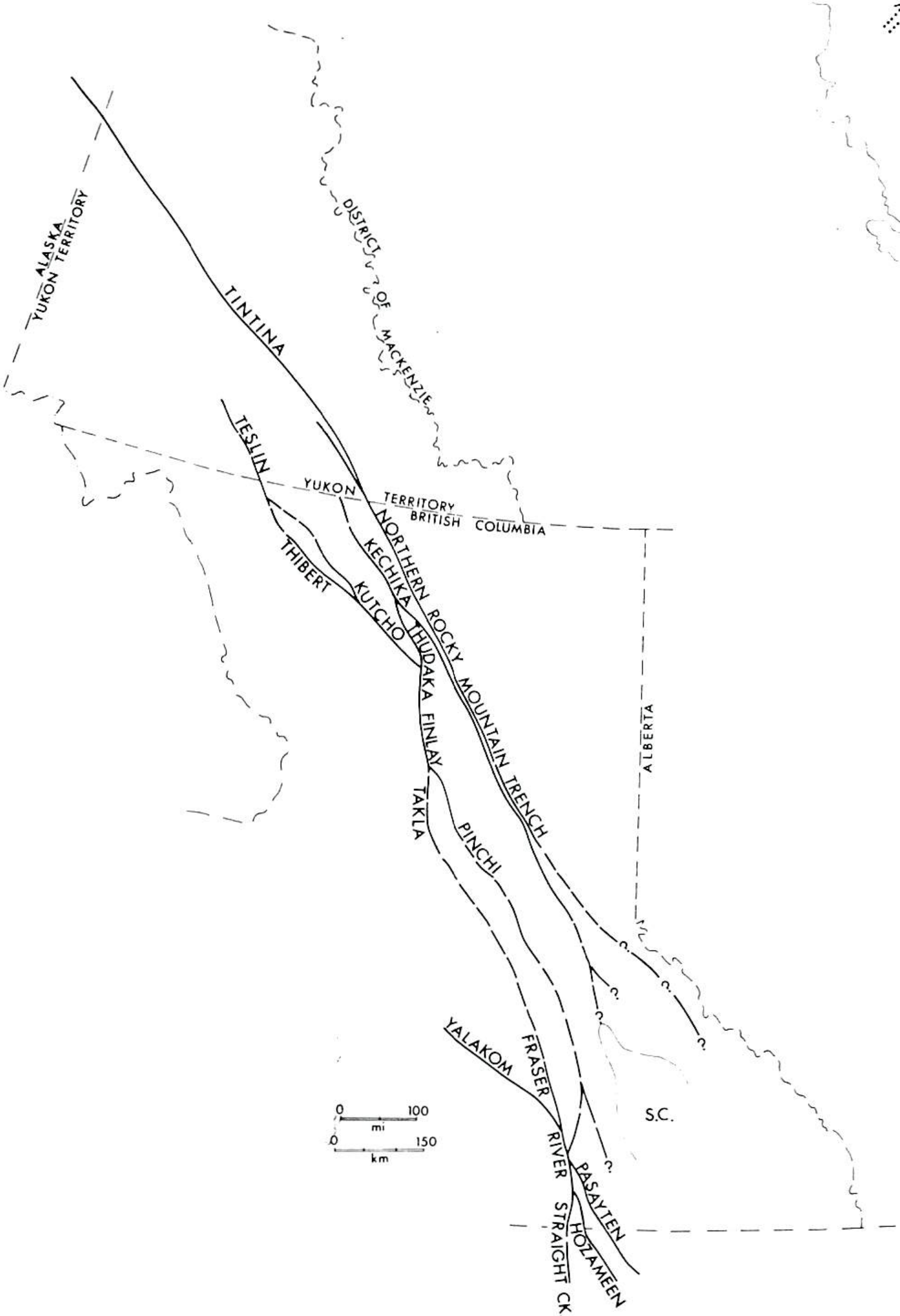


Figure 11. Regional continuation of faults in the Cordillera. S.C. = Shuswap Complex.

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along the Finlay, Ingenika, and Takla faults. The early-formed faults, representing zones of weakness, may have facilitated some later transcurrent movements, except where principal stresses were at too high an angle to their trends.

In the southern part of the Canadian Cordillera, the southern Rocky Mountain Trench has about the same orientation as the early-formed Pinchi, Yalakom, and Pasayten faults (Fig. 11). It traverses a region, however, that has undergone significant Paleocene compression directed almost at right angles to it. Considerable extension in the south-central part of the Canadian Cordillera took place in Eocene time. These Cenozoic deformations may have displaced the southerly continuation of faults that had pre-Cenozoic displacements. Perhaps the graben structure of the southern Rocky Mountain Trench has been superimposed on cover rocks thrust over the locus of an earlier transcurrent fault continuous with the N.R.M.T. If not, the southerly continuation of the N.R.M.T. fault zone must lie in the structurally complex region within or flanking the Shuswap Metamorphic Complex (Fig. 11).

Related Phenomena

Mention has been made of phenomena that are temporally and spatially associated with dextral transcurrent faulting in the north-central Cordillera. These include granitic plutonism during the middle and Late Cretaceous (circa 100 and 70 m.y. B.P.) and early Cenozoic (circa 50 m.y. B.P.); possible westerly striking, northerly directed thrusts and folds of middle Cretaceous and younger age; early Cenozoic volcanism and lamprophyre dike emplacement; early Cenozoic high heat flow followed by rapid uplift; and Late Cretaceous to Eocene nonmarine sedimentation in restricted, fault-bounded basins. Dynamic models have been proposed that link many of these processes (Ewing, 1980; Price, 1979), and they involve ductile spreading and thinning of the deep crust accompanied by high heat flow in a tensional and/or transcurrent strain regime. Coeval volcanism and plutonism are, however, commonly related to subduction zones (Ewing, 1980). The remarkable coincidence of early Cenozoic plutonism, volcanism, high heat flow, and rapid uplift with structures related to transcurrent faulting in the northern Cordillera raises the question as to whether these processes might have occurred in environments not directly associated with subduction. Thinning of continental crust, accompanied by a rapid rise in geothermal gradient, may have resulted in the plutonic and volcanic events. In the Cassiar and Omineca Mountains, the onset of granitic plutonism on a large scale in the middle Cretaceous coincided with transcurrent displacements and clearly postdated a major episode of regional compression. In the southeast, Paleocene compression was succeeded farther west by Eocene volcanism and plutonism. Perhaps the emplacement of plutons reflects the regional change in stress: from stress producing the characteristic Cordilleran compressional structural trends to one producing northwesterly striking dextral transcurrent faults. In this view, the initiation of tensional environments associated with transcurrent faulting either (1) facilitated the emplacement of plutons whose origin was dependent upon preceding crustal thickening and heating or (2) led directly to melting of crust that may or may not have been previously thickened.

CONCLUSIONS

Dextral transcurrent faults with cumulative offset of possibly more than 1,000 km along the N.R.M.T. and several prominent lineaments farther west in north-central British Columbia belong to a system of structures with a similar sense of displacement that have markedly disrupted the original distribution of paleogeographic elements in the northwestern Cordillera. The history of displacements on the faults dates from the middle Cretaceous, or earlier, to late Eocene or Oligocene. Attempts to reconcile offsets of ~450 km along the Tintina fault, based on pre–Late Cretaceous contractional structures, and offsets of >900 km along the Tintina and N.R.M.T. faults, based on early Paleozoic shelf to off-shelf facies boundaries, suggest the possibility of transcurrent displacements bracketing the time of the major regional thrusting and folding. Cenozoic deformation in the southern Cordillera greatly complicates attempts to trace the N.R.M.T. fault zone to the south. Early displacements may have occurred along the southern R.M.T., to be obscured later by overlying thrust sheets. Subsequent and possibly minor movements could have produced the present physiographic feature. The extent to which dextral displacements were distributed west of the southern R.M.T. is not known. If little or no dextral displacement has taken place along the southern R.M.T., major dislocations must have occurred within, or flanking, the Shuswap Metamorphic Complex.

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