Structural and kinematic evolution of the Yukon-Tanana upland tectonites, east-central Alaska: A record of late Paleozoic to Mesozoic crustal assembly: Discussion and Reply

Discussion

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We welcome the efforts of Hansen and Dusel-Bacon (1998) in synthesizing sparse and apparently inconsistent structural data sets from widely separated areas of the poorly exposed Yukon-Tanana Uplands. However, we consider that credible extrapolation of such a synthesis southward to include a 300 × 800 km region of the Canadian Cordillera is unwarranted. We clarify here points of terrane definition and discuss the implications for tectonic models for the Yukon-Tanana terrane in the Canadian Cordillera.

TERRANE AND ASSEMBLAGE CLARIFICATIONS

The emplacement of allochthonous terranes (upper plate) over parautochthonous North America (lower plate) has been known for decades from the recognition of obvious klippen of Slide Mountain and Yukon-Tanana terranes resting on North American strata (e.g., Sylvester allochthon and St. Cyr and Stewart Lake klippen, Fig. 1). The Hansen and Dusel-Bacon's paper proposed a similar upper–lower plate relationship in the Yukon-Tanana Uplands. A strength of the paper is that it attached L-S tectonite-derived kinematic data to previous lithotectonic, geochronologic, and thermobarometric information to allow a refined interpretation of the nature and assembly of part of the Yukon-Tanana terrane that the authors and others have studied. However, the data that Hansen and Dusel-Bacon presented for east-central Alaska did not support extending their conclusions to the eastern and southern parts of the Yukon-Tanana terrane in the Yukon, northern British Columbia, and southeast Alaska. Complete structural analysis throughout the Yukon-Tanana terrane is needed before regional comparisons can be drawn. The model that they presented suffers from improper terrane definition, and from the omission or biased interpretation of recent structural, geochemical, and geochronological data sets in parts of the Yukon-Tanana terrane outside the study area of the Yukon-Tanana Uplands.

The metamorphic-structural focus of the Hansen and Dusel-Bacon study diverts attention from the fundamental geological criteria of terrane definition: rock types and protoliths, ages and contact relationships. Ideas of Hansen and Dusel-Bacon (1998) appear to be an outgrowth of those presented by Hansen (1990) and Hansen et al. (1991), although Hansen and Dusel-Bacon apparently recognized the weakness of terrane definition "first and foremost on the basis of metamorphic cooling ages and apparent structural position" advocated in those earlier papers. The approach used in Hansen and Dusel-Bacon's paper, i.e., the substitution of "assemblage" for "terrane," remains unsatisfactory. Their focus is the "crustal level of deformation" and the age and grade of metamorphism; these criteria determine the assemblage name applied to a rock succession. However, it is highly improbable that a portion of the crust the size of California would be affected everywhere by dynamothermal events with consistent style, geometry, and kinematics. Hence, correlations on this basis are of little probative value. For example, the Windermere Supergroup in the southern Canadian Cordillera exhibits Jurassic ductile deformation in some parts and Cretaceous and Tertiary fold-and-thrust deformation in others. Using the criteria espoused by Hansen and Dusel-Bacon, this stratigraphic unit would be split into different assemblages and/or terranes.

A metamorphic-structural focus led Hansen and Dusel-Bacon into difficulty with the Slide Mountain terrane. They spent considerable effort in determining the assemblage to which Slide Mountain terrane "equivalent protoliths" should be assigned (Taylor Mountain, Teslin, Anvil, or Seventymile), when in most cases the important issue is whether to include such successions in the Slide Mountain terrane at all. Part of their problem stems from an inaccurate definition of the Slide Mountain terrane. The suggestion by Hansen and Dusel-Bacon that the Slide Mountain terrane includes

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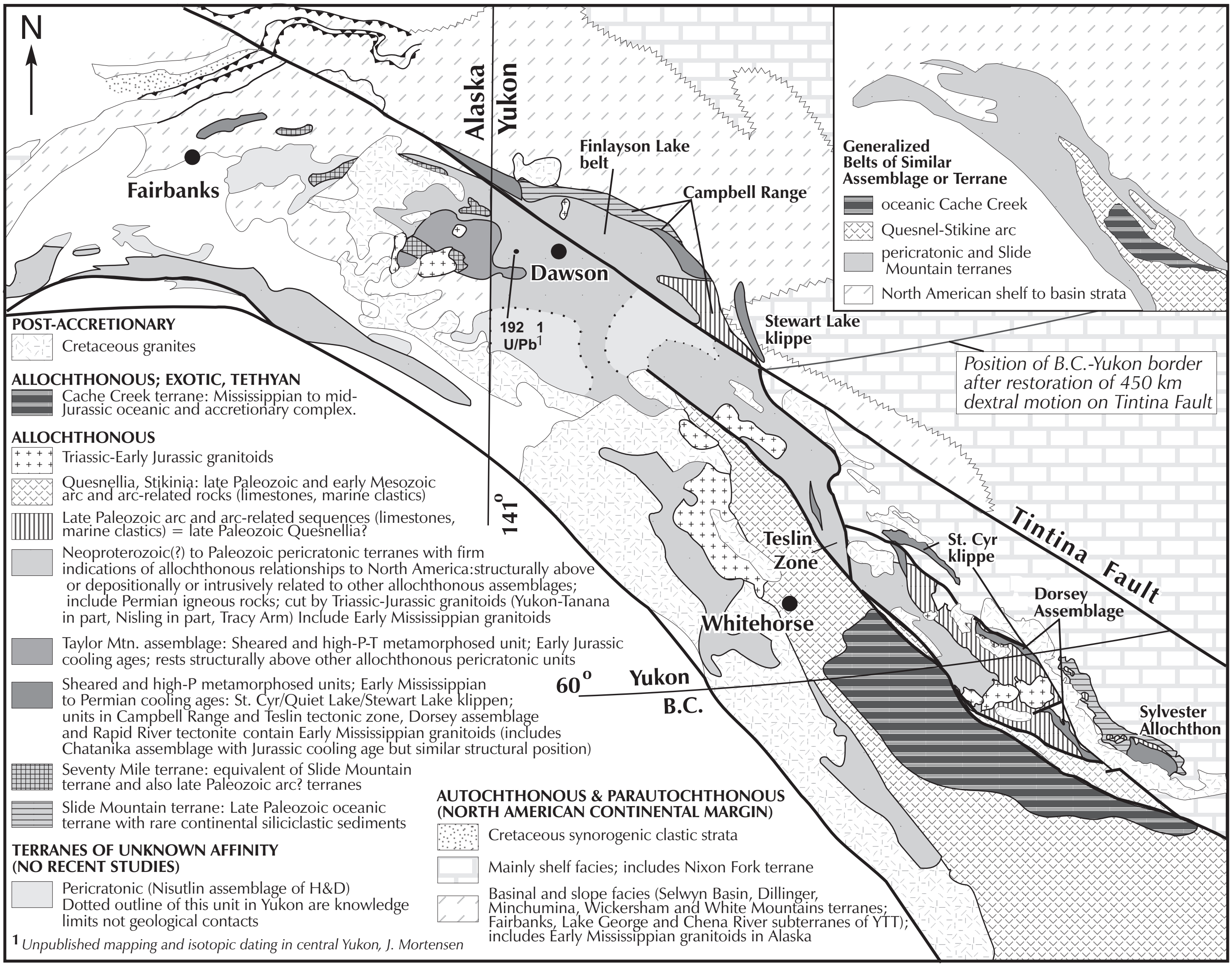

Figure 1. Distribution of terranes and assemblages in northern British Columbia, Yukon and eastern Alaska, after Figure 1 of Hansen and Dusel-Bacon (1998). Modifications include incorporation of recent published mapping in the Yukon-Tanana and adjacent terranes (see text) and definition of major autochthonous and parautochthonous units, a revised distribution of Slide Mountain terrane rocks, and a late Paleozoic arc origin for the Dorsey terrane. Geology northeast of the Tintina fault and northwest of Fairbanks is in part from an unpublished compilation by D. Murphy and G. Abbott. Inset shows highly generalized geology that highlights an oroclinal geometry.

Paleozoic arc rocks is misleading. They cited an abstract in which Nelson et al. (1989) proposed this. However, Nelson (1993) subsequently excluded arc rocks from the Slide Mountain terrane because of the absence of such rocks at both the Slide Mountain terrane type locality and other localities in British Columbia, where protolith textures are well preserved and the volcanic rocks are mid-oceanic-ridge basalt (MORB) with no interbedded arc rock types (Ferri, 1997; Schiarizza and Preto, 1987; Roback et al., 1994). Significant thicknesses of metabasite and ultramafic rocks within the Yukon-Tanana terrane of the Yukon and northern British Columbia were originally interpreted as tectonic fragments of Slide Mountain terrane when there were few detailed studies. However, many if not all later studies of these so-called Slide Mountain terrane allochthons within the Yukon-Tanana terrane have concluded that they are not MORB (Creaser et al., 1997, in the Teslin area), and that in the majority of cases they are not structural slices, but stratigraphic or intrusive units integral to the Yukon-Tanana terrane (Stevens et al., 1995, in the Teslin-Laberge area; Mihalynuk et al., 1998, in the Jennings River Area; Murphy, 1998, and Hunt and Murphy, 1998, in the Finlayson Lake area; and Oliver and Mortensen, 1998, in the Little Salmon Lake area). It is difficult to see how Hansen and Dusel-Bacon can comment authoritatively on terrane stacking order if they are unable to identify terranes accurately within the stack.

The use of inappropriate terrane-defining criteria also led Hansen and Dusel-Bacon (1998) into difficulty when interpreting the rocks of the Teslin tectonic zone. They clung to the hypothesis that the zone is a fossil accretionary prism. The results of recent structural and stratigraphic mapping in the Teslin tectonic zone are clearly inconsistent with a trench mélange origin (de Keijzer and Williams, 1996, 1998; Gallagher et al., 1998; Brown et al., 1995, 1998, and references therein). In addition, a coherent layered stratigraphy has been recognized recently (Oliver and Mortensen, 1998) at the Little Salmon Lake locality that Hansen and Dusel-Bacon used as an example of subduction zone tectonites. Can Hansen and Dusel-Bacon credibly claim evidence for a middle Permian through Early Jurassic subduction zone when detailed mapping of the Teslin tectonic zone has confirmed neither the existence of mélange nor the occurrence of subduction-zone kinematic indicators?

Hansen and Dusel-Bacon claimed that, in the Yukon, Early Jurassic manifestations of subduction are provided by the Stikinia arc granitoids of the Aishihik and Klotassin plutonic suites. However, the Aishihik batholith is a mid-crustal, magmatic-epidote–bearing granodiorite with no clear ties to Stikinia (Johnston and Erdmer, 1995), and the Klotassin batholith is mostly, if not entirely, Cretaceous in age (Godwin, 1975; C. J. R. Hart, 1998, personal commun.). Hansen and Dusel-Bacon correctly stated that eclogite and blueschist occurrences in the Teslin tectonic zone and other parts of the Yukon-Tanana terrane and Slide Mountain terrane record evidence of subduction and collision, but all available isotopic data show that subduction had ceased and cooling had taken place by Middle Triassic time (Erdmer et al., 1998).

The cooling of high-pressure rocks in the Yukon took place at different times (in the Early Carboniferous, Early to middle Permian, and Middle Triassic periods; Erdmer et al., 1998). The proposal by Hansen and Dusel-Bacon that the oldest eclogite and blueschist dates record the start of subduction while younger high-pressure metamorphism can be interpreted as the product of later closure of a single ocean basin is arbitrary. While continuous exhumation above a single subduction zone is possible, the growing body of age data from high-pressure rocks in the Yukon equally hints at a record of several subduction episodes and (or) zones, a possibility not addressed by Hansen and Dusel-Bacon. The statement by Hansen and Dusel-Bacon that Erdmer and Armstrong (1988) interpreted cooling dates to "reflect initial mid-Permian subduction" is an inaccurate citation.

Tectonic variability is a characteristic of the Yukon-Tanana terrane, adding to its appeal as a subject of geological study. Contrary to the assertion of Hansen and Dusel-Bacon (1998), this variability is well recognized, and few workers treat the Yukon-Tanana terrane as a "uniform assemblage with a simple geologic history." In a pragmatic and comprehensive Yukon-Tanana terrane synthesis, Mortensen (1992) presented evidence for an upward-younging succession of rocks formed during successive episodes of magmatism in a continental arc setting. He defined lower, middle, and upper units (not formations) to emphasize distinctive continental, epicontinental, and arc characteristics of the Yukon-Tanana terrane. This huge terrane displays significant lateral stratigraphic variations, especially in volcanic arc strata, which most workers tacitly acknowledge. This variability was recognized early in the terrane analysis of the Cordillera by Coney et al. (1980), who used the name "Yukon-Tanana (composite)" terrane, and by Churkin et al. (1982), who initially recognized four subterranes.

IMPLICATIONS FOR EXISTING MODELS

Hansen and Dusel-Bacon dismissed the oroclinal model (Nelson and Mihalynuk, 1993; Mihalynuk et al. 1994) on the basis of four arguments; these are partly based upon misinformation, are inconsistent with facts that they presented, and are subject to alternative interpretation. Hansen and Dusel-Bacon offered no data that explicitly contradict the oroclinal model. Instead, they supported a modification of the "collapse of a rifted continental margin" model originally proposed by Churkin (1974) and applied to the Yukon by Tempelman-Kluit (1979). This single subduction-zone model does not work well north of lat 60°N for reasons outlined above, and breaks down entirely to the south for several additional reasons (see Mihalynuk et al., 1994, p. 576). It is untenable because it requires that the oceanic Slide Mountain and Cache Creek terranes be equivalent, which they are not. Not only are their age range, stratigraphy, structural style, geochemistry, and faunas different, so too are their high-pressure metamorphic histories, with Cache Creek blueschists exhibiting Late Triassic (Ghent et al., 1996) and Middle Jurassic (Mihalynuk and Archibald, unpublished data) cooling ages. By disregarding the problematic Cache Creek and Quesnel terranes in their analysis, Hansen and Dusel-Bacon ignored a key tectonic problem in the Canadian Cordillera. That is, how did the exotic Tethyan Cache Creek terrane come to be enveloped by the less exotic arc terranes of Quesnellia and Stikinia, and then by pericratonic terranes (Fig. 1), (i.e., Kootenay, Nisutlin and Nisling terranes of Wheeler and McFeely, 1991; lower, middle, and upper units of the Yukon-Tanana terrane of Mortensen, 1992; etc.)? Contrary to the statements of Hansen and Dusel-Bacon, Mihalynuk and Nelson did not invent the problem, although we did name it the "oroclinal paradox" because the map pattern of related arc segments and pericratonic rocks suggests that they fold around the northern end of the Cache Creek terrane (Fig. 1). This map pattern is echoed by initial strontium isopleths, residual paleomagnetic rotations, detrital zircons, neodymium isotope ratios, etc. (Mihalynuk et al., 1994). Regardless of whether the oroclinal model is correct, and of what order assemblages within the Yukon-Tanana terrane are stacked in, the Cache Creek problem exists. Even if one is to disregard the pericratonic rocks entirely, the problem exists. It is rooted in work on Permian fusulinid assemblages in the Tethyan Cache Creek and adjacent less exotic terranes reported by Monger and Ross (1971) and Monger et al. (1972), and numerous subsequent workers in the Canadian Cordillera have contributed observations that bear on it. We simply cannot take credit for having fabricated the Cache Creek problem—one that any comprehensive model of Cordilleran assembly must address, but which is ignored by Hansen and Dusel-Bacon.

We have recast Figure 1 of Hansen and Dusel-Bacon (1998) to remove some of the ambiguity introduced by their Nisutlin assemblage of equivocal upper- or lower-plate origin and to show more accurate terrane assignments. In our Figure 1, we have included results of recent mapping in the Finlayson and Campbell Range belts and the Teslin tectonic zone, thesis mapping in the Aishihik Lake area (Johnston, 1993), unpublished mapping near Dawson (J. K. Mortensen, 1998, personal commun.) and an unpublished compilation of data for the Selwyn Basin and its extension into Alaska (D. C. Murphy and G. Abbott, 1995). These data sources show that the Nisutlin assemblage as defined by Hansen and Dusel-Bacon contains Permian arc and plutonic rocks and Jurassic plutons not found in the North American continental margin (the "lower plate"). These rocks are reassigned to allochthonous units, and the extent of the equivocal Nisutlin assemblage is reduced by almost two thirds in size (restricted south of Dawson to two areas known only from reconnaissance mapping). Our Figure 1 clearly shows an oroclinal geometry.

Hansen and Dusel-Bacon criticize the oroclinal model of Mihalynuk et al. (1994) because it does not address the deformation, timing, and crustal conditions that they document. Once again, Hansen and Dusel-Bacon assume that deformational events must be displayed by all parts of the Yukon-Tanana terrane equally. In the oroclinal model, deformation between about 185 and 175 Ma resulted from interlimb collision south of the hinge zone, but in the hinge zone (which includes the Yukon–Tanana Uplands), deformation must have occurred prior to 185 Ma to accommodate limb rotation. Unfortunately, there are few examples of oroclinal hinges to help guide our predictions of hinge deformation in an oroclinal model or to facilitate comparisons with structures found in the Yukon–Tanana Uplands. One possible analogue is the Carpathian orocline of Romania (Ratschbacher et al., 1993). There, material from the central zone was transferred toward the outer, convex margin of the orocline. K-Ar cooling dates from syntectonic mica record progressive deformation that lasted nearly 30 m.y. Stretching lineations in the Carpathian orocline are parallel to the precursor thrust belt. The lineations may have formed in a manner similar to the top-to-the-northwest "D2" lineations in upland tectonites studied by Hansen and Dusel-Bacon. In both cases, orogen-parallel lineations and shear-sense indicators record material transfer toward the unconstrained convex margin of the orocline. In the Cordilleran orocline, this process may have preceded collision of the limbs by 20 to 30 m.y., accommodating the age range of "D2" in Hansen and Dusel-Bacon and the well-constrained ca. 185 Ma onset of collision (e.g. Mihalynuk et al., 1994) that heralded the terminal stage of orocline formation.

We present the Carpathian analogue with reservations, because we believe that deformation of the Yukon-Tanana terrane is far too complex to attribute entirely to a simple tectonic model. We consider that efforts directed toward fine-tuning a tectonic model are, at this stage, largely misspent. A better understanding of the assemblages that comprise the Yukon-Tanana and Slide Mountain terranes, and of their stratigraphy, contact relationships, and structural histories is needed before durable models can be developed.

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Reply

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Mihalynuk et al. purport that Hansen and Dusel-Bacon (1998) suffer from improper terrane identification and omission of recent data. First, Hansen and Dusel-Bacon focused on geologic history rather than terrane analysis. Terrane analysis does not result in testable, predictive models, nor does it follow the scientific method (Şengör and Dewey, 1990). Terrane terminology is well entrenched in Cordilleran literature, yet comparison of text and terrane maps of Mihalynuk et al. and Erdmer et al. (1998) illustrates that terrane definitions and boundaries are non-unique and seemingly chimerical. To avoid these pitfalls, Hansen and Dusel-Bacon instead integrated lithological, structural, kinematic, metamorphic, *P-T* (pressure-temperature), and thermochronologic data. Second, Hansen and Dusel-Bacon did not disregard recent available data but in fact incorporated data from numerous journal publications. In comparison, Mihalynuk et al. cite sources that were either released as unpublished reports or published after Hansen and Dusel-Bacon (1998), or both. We consider it prudent to reserve judgement with respect to data within unpublished reports until formal publication. Similarly, although models should be predictive, they need not be clairvoyant with respect to unpublished data. We address other specific comments below.

TERRANES AND GEOLOGIC HISTORIES

Mihalynuk et al. are concerned with terrane names rather than geologic history, as illustrated by the following examples. (1) Whether Nelson et al. associated all Sylvester allochthon rocks with the Slide Mountain terrane (Nelson et al., 1989) or not (Nelson, 1993) is irrelevant. The Sylvester allochthon resides on North American margin strata and preserves, from structurally low to high levels: oceanic crust, volcanic arc rocks, and continental margin rocks (Nelson, 1993). These lithologies, tectonic environments, and stacking order are all accommodated in Hansen and Dusel-Bacon's model (1998, Fig. 8 and text). (2) Mihalynuk et al. state that the Aishihik batholith represents a mid-crustal plutonic body with no clear ties to Stikinia, yet the Aishihik batholith intrudes continental rocks (Nisling; Johnston and Erdmer, 1995), and Nisling, together with oceanic crust, form the subcrustal roots to the supracrustal volcanic arc (Stikinia) (Currie and Parrish, 1993; Rubin and Saleeby, 1991; Jackson et al., 1991). (3) Mihalynuk et al. assert that the Klotassin batholith is mostly, if not entirely, Cretaceous in age. However, Mortensen (1992, p. 847) clearly states (with 15 citations, not included here due to space constraints) that "The 'Klotassin Suite' which comprises most of the northern extension of the Stikine terrane in southwestern Yukon and eastern Alaska is lithologically identical to the Triassic–Jurassic plutons which intrude Yukon-Tanana terrane and yields the same crystallization age range (185–210 Ma), average age of inherited zircon, and Sr isotopic character. Lithologically similar intrusive rocks of Late Triassic to Early Jurassic age also occur within Nisling terrane in southwestern Yukon, in Dorsey terrane in southern Yukon and northern British Columbia, and in Slide Mountain terrane and Cache Creek terrane in south-central Yukon and northern British Columbia."

Comparison of Mihalynuk et al. and Erdmer et al. (1998) highlights serious terrane ambiguity even among papers with common authors. Mihalynuk et al. state that "Significant thickness of metabasite and ultramafic rocks within the Yukon-Tanana terrane…were originally interpreted as tectonic fragments of the Slide Mountain terrane when there were few detailed studies. However…later studies…concluded that they are not MORB, and that in the majority of cases they are not structural slices, but stratigraphic or intrusive units integral to the Yukon-Tanana terrane." Erdmer et al. (1998) state that occurrences of high *P* rocks of the Yukon Tanana terrane "near Stewart Lake and in the St. Cyr klippe are within mafic and ultramafic rocks assigned to the Slide Mountain terrane and are inferred to be in tectonic contact with surrounding units," and high *P* rocks at Last Peak and in the Simpson Range "are surrounded by rocks of the Yukon-Tanana terrane but are petrographically similar to Slide Mountain terrane occurrences and have ambiguous contacts." These statements by Mihalynuk et al. and Erdmer et al. (1998) are contradictory. Further ambiguity appears in terrane maps. East of the Tintina fault (1) Mihalynuk et al. show as Quesnel (arc?) what Erdmer et al. (1998) call Slide Mountain (oceanic?), and (2) Mihalynuk et al. show as Slide Mountain (oceanic?) what Erdmer et al. (1998) show as Yukon-Tanana. West of the Tintina fault, (3) Mihalynuk et al. show as Quesnel (arc?) what Erdmer et al. (1998) show as Dorsey (pericratonic?), and (4) Mihalynuk et al. show as Dorsey (pericratonic?) what Erdmer et al. (1998) call Slide Mountain (oceanic?). (5) Significant discrepancy also exists between the regional extent of Cache Creek; Mihalynuk et al. end Cache Creek ~100 km south of Whitehorse, whereas Erdmer et al. (1998) extend it >250 km northwest of Whitehorse. How does one decide which terrane configuration is correct? We prefer to abandon terrane names in favor of geologic history. Studies focused on geologic history allow geologists to examine multiple clues to tectonic assembly processes.

TESLIN SUTURE ZONE DATA

Mihalynuk et al. refer to the Teslin suture zone as the "Teslin tectonic zone." The Teslin suture zone historically refers to a north-northwest–trending, steeply dipping, 15–20-km-thick structural sequence of L-S tectonites derived from sedimentary and volcanic strata, basalt, peridotite, and granitoids (Tempelman-Kluit, 1979). It is bounded to the west by post-accretionary faults that juxtapose Teslin suture zone tectonites with low-grade to unmetamorphosed strata, and to the east by the d'Abbadie fault, which juxtaposes Teslin suture zone tectonites with L-S tectonites of North American affinity (Tempelman-Kluit, 1979). How does replacing the word "suture" with "tectonic" improve our understanding of this zone or crustal assembly processes?

Despite Mihalynuk et al.'s assertions, a multitude of published data (cited by Hansen and Dusel-Bacon, 1998) support the interpretation that Teslin suture zone tectonites represent the deep-seated portion of an an-

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cient accretionary complex. The structural style of deformation within a subduction zone depends on lateral position and structural depth within and across a convergent margin (Cowan, 1985; Cloos and Shreve, 1988; Bebout et al., 1996). Mihalynuk et al.'s requirement of preserved "trench mélange" to fingerprint ancient subduction complexes disqualifies most fossil subduction zones. Trench mélange materials occur only at shallow crustal levels and only at the leading edge of a subduction complex, whereas a host of other structural styles, including coherent ductile tectonite formation, occur at depth (Platt, 1986). Documented high *P-T* synkinematic metamorphism of Teslin suture zone tectonites and correlative rocks provides robust evidence of ancient subduction (Erdmer, 1987, 1992; Erdmer and Helmsteadt, 1983; Hansen, 1992a, 1992b; Erdmer et al., 1998). Furthermore, L-S tectonites record deformation within this high *P-T* environment, and thus provide an excellent record of deep-subduction processes. Over 50 quartz petrofabric diagrams illustrate that Teslin suture zone lineation is an elongation lineation (Hansen, 1989; Oliver, 1996), and that *P-T* conditions correlate with the kinematic record—facts ignored by unpublished reports cited by Mihalynuk et al. Detailed, integrative structural and kinematic, quantitative geothermobarometric, and thermal analysis of Teslin suture zone L-S tectonites support deformation and metamorphism within a deep-seated subduction zone environment (Hansen, 1989, 1992a, 1992b; Hansen et al., 1989, 1991). The data are all consistent with underplating to the hanging-wall plate during subduction backflow and downflow with the subduction channel (Hansen, 1992a), with variations in *P-T-t* (time) displacement histories consistent with subduction theory (e.g., Cloos and Shreve, 1988).

Contrary to assertions by Mihalynuk et al., Oliver and Mortensen (1998) caution that results from the Little Salmon Lake area of the Teslin suture zone constrain only the protolith age and stratigraphic relations in the eastern, structurally high part of the Teslin suture zone and should not be extrapolated across the entire zone. In fact, the eastern and western parts of the Teslin suture zone at Little Salmon Lake record dissimilar geologic histories based on protolith, deformation intensity, kinematics, and cooling ages—all of which provide clues to tectonic assembly. The eastern, structurally high region comprises part of the hanging-wall plate, whereas the western, structurally low region includes subduction zones tectonites (Oliver, 1996; Oliver and Hansen, 1997).

Mihalynuk et al. also gravely misrepresent thermochronologic data. $^{40}Ar/^{39}Ar$ data from numerous white mica samples indicate that at least some Teslin suture zone tectonites cooled through ~350 °C at 195 Ma (Hansen et al., 1991; Oliver, 1996); thus, cooling across the Teslin suture zone was not everywhere complete by Middle Triassic time, as Mihalynuk et al. assert. Curiously, Mihalynuk et al. cite Erdmer et al. (1998) for this statement, rather than the original publication, but, Erdmer et al. (1998) state that Hansen et al. (1991) obtained Middle Jurassic cooling ages for Teslin suture zone tectonites. Although geologic time scales fluctuate with new relative and absolute age constraints, a recent comparison of Mesozoic time scales (Gradstein et al., 1995), indicates an absolute age range from 213 to 205 Ma for the Triassic-Jurassic boundary. Thus, Teslin suture zone mineral ages in fact indicate Sinemurian to Pliensbachian cooling ages in Early Jurassic time (Hansen et al., 1991).

Mihalynuk et al. state that Hansen and Dusel-Bacon disregard new age data found in Erdmer et al. (1998) (published three months after Hansen and Dusel-Bacon, 1998). Although new age data extend the maximum age for Teslin suture zone subduction from 250 Ma to 269 Ma, this is easily accommodated in the Hansen and Dusel-Bacon model. Erdmer et al. (1998) favor two-step subduction with cooling, uplift, and subduction cessation at ~236 Ma, and renewed subduction that ceased at ~195 Ma. Hansen and Dusel-Bacon favor continuous subduction. Both interpretations are consistent with the new age data.

OROCLINAL PARADOX

A paradox may signal an inadequacy in the way one looks at a question, thereby suggesting a new and more fruitful way of approaching it (Ferris, 1991). Paradoxes are commonly defined by their assumptions or axioms (Anderson, 1998), and the oroclinal model of Mihalynuk et al. (1994) is no exception. By assuming that less exotic crystalline rocks wrap around the northern end of the more exotic Cache Creek terrane, Mihalynuk et al. (1994) presented a paradox. However, how robust is their assumption given that interpretations of map relations are inherently non-unique? For example, each of the following are viable explanations for northern Cordilleran map patterns: (1) Cache Creek terrane could be a klippe, and thus not be "enclosed" at all; (2) many combinations of lateral transport (strike-slip faults) and/or horizontal transport (thrust or normal faults) could have contributed to the present pattern; or (3) less exotic rocks on either side of Cache Creek could have quite different histories, and thus represent different tectonic units (e.g., Hansen and Dusel-Bacon, 1998). The oroclinal paradox exists only if one assumes that Cache Creek rocks are "enclosed" by continental rocks of shared geological history; such an assumption essentially assumes a solution, and hence, is paradoxical (Anderson, 1998).

Hansen and Dusel-Bacon's analysis dispels the oroclinal paradox with hypothesis (3) above. Although not the focus of their contribution, Hansen and Dusel-Bacon (1998) offered an explanation for northern Cordilleran orogen-scale map patterns, including the Cache Creek distribution. Hansen and Dusel-Bacon (p. 226) state that "in Late Permian through Early Jurassic time, the (east-facing) Stikinia arc and associated upper plate rocks were located at about the same latitude that they are today... Thus Stikinia apparently collided with North America at about the same location that it is today, and after collision, Stikinia (built locally on crust of continental affinity) was translated south (west of Cache Creek) during Jurassic–Cretaceous time, and translated north again in Cretaceous time." Quesnel and Cache Creek terranes likely represent a late Paleozoic–early Mesozoic west-facing arc and subduction complex formed generally south of the east-facing Stikinia arc. Thus, rocks of continental affinity that border Cache Creek rocks to the east (North America) and the west (local basement to Stikinia) differ in their respective geologic histories. Contrary to Mihalynuk et al.'s assertion, the Hansen and Dusel-Bacon model in no way requires, nor does it suggest, equivalence between Slide Mountain and Cache Creek terranes; nor does it require or suggest equivalence between Stikinia and Quesnel, which Mihalynuk et al. combine without justification on their map (Fig. 1).

Finally we take this opportunity to correct two errors in Hansen and Dusel-Bacon (1998). The first is a typographical error (page 223, column 3, line 20): "Nisutlin" should be Nisling (following Currie, 1995). The second is a graphical error in Figure 1; rocks of continental affinity (Nisling) shown immediately south and east of Whitehorse were inadvertently duplicated.

We thank Mihalynuk et al. for the opportunity to clarify data and methodology used to postulate a viable tectonic model aimed at understanding late Paleozoic to Mesozoic crustal assembly of an extensive part of the northern North American Cordillera. The model incorporates a wide range of data sets collected by an equally broad range of workers, and attempts to sidestep terrane analysis. Tempelman-Kluit (1979) put forward the general tectonic framework; we have added specific, but possibly important, modifications. Tempelman-Kluit's (1979) original synthesis stemmed from more than 10 years of mapping a large part of the Yukon, including most of the areas we discuss. Hansen and Dusel-Bacon also benefited immensely from Helen Foster's work in Alaska. Mapping by Foster and Tempelman-Kluit focused on geologic relations and geologic histories, not on terrane analysis—for this we are extremely thankful.

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