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MESOZOIC THERMAL EVOLUTION OF THE YUKON-TANANA COMPOSITE TERRANE: NEW EVIDENCE FROM $^{40}Ar/^{39}Ar$ DATA

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Abstract. The Yukon-Tanana composite terrane (YT) in the northern North American Cordillera records a complex polyphase history. Twenty-three new $^{40}Ar/^{39}Ar$ dates from YT tectonites of Yukon and eastern Alaska form the basis for subdivision of the YT into different cooling packages. These data, together with structural and kinematic interpretations presented elsewhere, enable us to define four spatially, kinematically, and temporally distinct, yet overlapping, deformation events. The Teslin-Taylor Mountain and Nisutlin terranes are distinguished herein on the basis of cooling history, from the orthogneiss assemblage. Divisions of the YT into these terranes is consistent with division based on structural, kinematic, and metamorphic criteria. Metamorphic minerals of the Teslin-Taylor Mountain and Nisutlin terranes give Early Jurassic cooling dates. Hornblende and white mica from high-P/T Teslin-Taylor Mountain and Nisutlin tectonites in Yukon yield isochron dates of ~195 Ma; similarly, two Teslin-Taylor Mountain hornblende-biotite (hb-bi) mineral pairs from eastern Alaska yield isochron dates of 188 (hb) and 186 (bi), and 187 (hb) and 185 Ma (bi), respectively. Near-coincident mineral pair dates suggest cooling rates of ~100°C/Ma through 500°-300°C from both regions. Rocks of the orthogneiss assemblage (here Cassiar terrane) record Late Jurassic to dominantly mid-Cretaceous cooling ages. Orthogneiss in southern Yukon yields discordant $^{40}Ar/^{39}Ar$ mineral pair dates indicative of slow cooling (~5°C/Ma), from Late Jurassic to mid-Cretaceous time (hb ~147 Ma; muscovite ~117 Ma; bi ~110 Ma). Low-angle, east-vergent ductile shear deformation predated cooling of orthogneiss assemblage rocks in this region. In easternmost Alaska, two white mica-biotite mineral pairs recovered from the orthogneiss assemblage yield concordant $^{40}Ar/^{39}Ar$ plateau dates of ~109 Ma. These dates, taken together with an Early Cretaceous metamorphic hornblende cooling date reported from the same region by others, indicate that YT orthogneiss assemblage tectonites in eastern Alaska cooled during the Early Cretaceous at a rate of ~20°C/Ma through 500°-300°C. We interpret that these differences in cooling dates and cooling rates determined for the Teslin-Taylor Mountain and orthogneiss terranes of the YT reflect important differences in the structural and tectonic evolution of these two terranes. We propose a model in which the Teslin-Taylor Mountain, Nisutlin, and Slide Mountain terranes comprise the leading edge of the upper plate of a convergent margin which overrode North American parautochthonous strata in early Jurassic time. While this upper plate package was uplifted, the rocks cooled through at least 300°C; as a result of overthrusting, lower plate parautochthonous strata were tectonically buried and metamorphosed. Lower plate rocks cooled through 300°C, only after overthrusting, as a result of erosion in southern Yukon, and as a result of top-to-the-northwest and top-to-the-southeast directed crustal extension in eastern Alaska. Through this model we suggest that the orthogneiss assemblage of the YT represents parautochthonous North American strata overridden by the easternmost accreted terranes. High-angle, northwest striking dextral shear zones cut all YT packages and Cassiar parautochthonous shelf strata in southern Yukon in Late Cretaceous time. Muscovite and biotite from tectonites of one such ductile shear zone, the d'Abbadie fault, yield concordant cooling dates of ~97 Ma. Other subparallel shear zones cut, or are cut by, northwest striking Late Cretaceous plutons.

INTRODUCTION

The Yukon-Tanana composite terrane (YT) is an extensive, heterogeneous metamorphic-plutonic assemblage of variably deformed ductile tectonites exposed over thousands of square

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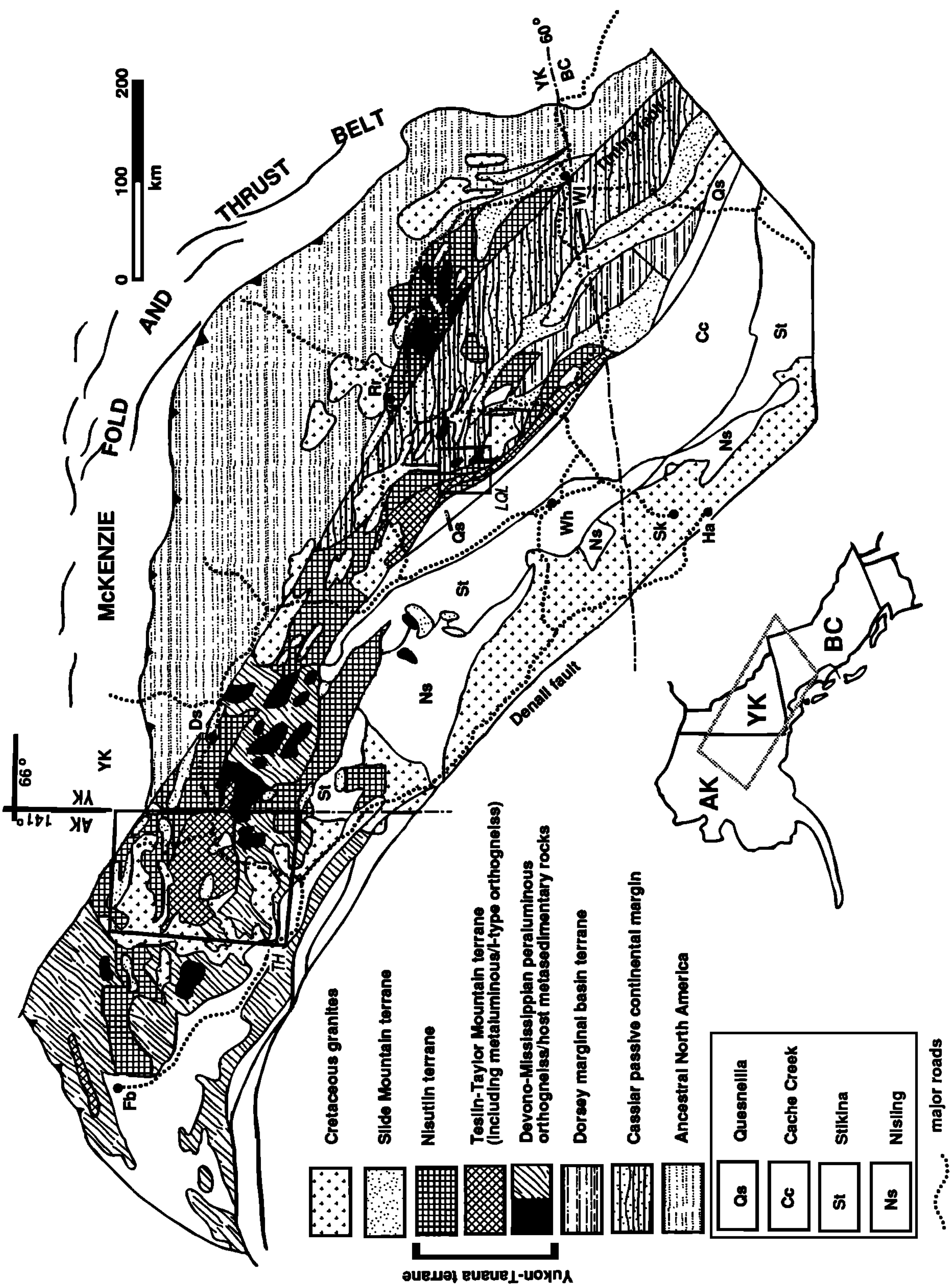
McKENZIE FOLD AND THRUST BELT
0 100 200
km
YK
BC
60°
AK
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66°
Denali fault
Tintina fault
Ns
St
Cc
Qs
Wh
Sk
Ha
Ds
Fb
TH
LQL
Wl
Rr
AK
YK
BC
Yukon-Tanana terrane
Cretaceous granites
Slide Mountain terrane
Nisutlin terrane
Teslin-Taylor Mountain terrane (including metaluminous/I-type orthogneiss)
Devono-Mississippian peraluminous orthogneiss/host metasedimentary rocks
Dorsey marginal basin terrane
Cassiar passive continental margin
Ancestral North America
Qs Quesnellia
Cc Cache Creek
St Stikina
Ns Nisling
major roads

kilometers in east central Alaska and western and southern Yukon (Figure 1) [Monger and Berg, 1987; Jones et al., 1987]. The YT records a polyphase history which is an inevitable source of confusion; ages of metamorphism and ductile deformation within the YT are not presently well defined [Foster et al., 1987; Dusel-Bacon, in press]. A review of isotopic data from the western Yukon crystalline terrane [Wilson et al., 1985], of which the YT makes up a large part, revealed five possible igneous events and four possible thermal (metamorphic?) events from Mississippian to early Tertiary time. Because the tectonothermal history of this terrane is complex, it is important that isotopic dates determined for YT tectonites are evaluated within a structural framework.

Study of the YT is further hampered by poor exposure, yet the YT is relatively well exposed along the Taylor Highway in eastern Alaska and within the Laberge-Quiet Lake area in southern Yukon (Figure 1). We have completed twenty-three $^{40}Ar/^{39}Ar$ age spectrum analyses on YT tectonites from these two areas. In this paper we present these data and propose a twofold division of the YT on the basis of cooling dates, tectonite fabrics, and structural level. The twofold division is broadly consistent with previously defined YT subdivisions [e.g., Churkin et al., 1982], although the former were not supported by metamorphic cooling dates. $^{40}Ar/^{39}Ar$ dates, taken together with results from structural and metamorphic studies presented elsewhere [Hansen, 1986, 1987, 1989], allow us to recognize four kinematically, spatially, and temporally distinct ductile deformation events. From these data we reinterpret the assembly of YT elements in eastern Alaska and southern Yukon, which in turn leads to a new interpretation of the evolution of the YT.

GEOLOGICAL RELATIONSHIPS

The YT represents a broad band of metamorphic rocks, between the Tintina and Denali faults in eastern Alaska and Yukon (Figure 1). A sliver of the YT is offset by approximately 450 km of Cretaceous dextral shear along the Tintina fault [Roddick, 1967; Tempelman-Kluit, 1979; Gabrielse, 1985].

In Alaska, workers have divided the YT north of the Tanana River into four subterranes, Y_{1-4}, on the basis of lithology, metamorphic grade and isotopic data [Churkin et al., 1982; Foster et al., 1985; Aleinikoff et al., 1987]. Subterranes Y_1 and Y_2 consist of peraluminous orthogneiss (340-360 Ma, U-Pb zircon dates with Proterozoic inheritance as reported by Dusel-Bacon and Aleinikoff [1985] and Aleinikoff et al. [1986]) and related aluminous metasedimentary rocks, quartzites, metacarbonates, and amphibolite. Subterranes Y_3 and Y_4 consist of metavolcanic and metasedimentary rocks including argillite, phyllite, graphitic quartzite, amphibolite, metabasalt, marble, and metachert. Y_3 and Y_4 subterranes may preserve a north to south compositional change from more siliceous to more mafic-rich rocks, as well a change in metamorphic facies, from greenschist facies in the north to albite-epidote amphibolite facies in the south [Dusel-Bacon et al., in press; (V. L. Hansen, unpubl. mapping, 1987)]. Eclogite exists locally in Y_4 (V. L. Hansen, unpubl. mapping, 1987). Y_3 and Y_4 subterranes are juxtaposed along a 1-3 km wide Mesozoic age thrust zone [Cushing, 1984; Cushing et al., 1984a, b; Foster et al., 1984, 1985].

In Yukon, the YT has been divided into five assemblages [Tempelman-Kluit, 1979; Mortensen and Jilson, 1985]. An augen orthogneiss suite, consisting of Devonian-Mississippian peraluminous orthogneiss (340-360 Ma, U-Pb zircon dates with Proterozoic inheritance) and related metasedimentary rocks, consistently crops out at the lowest exposed structural level within the YT and is correlative with the Y_1 and Y_2 subterranes on the basis of U-Pb, initial strontium and Sm-Nd isotopic data [Aleinikoff et al., 1986; Mortensen and Jilson, 1985; Bennett and Hansen, 1988; Mortensen, 1988b; Hansen et al., 1989]. Greenschist to albite-epidote amphibolite facies metasedimentary and metavolcanic rocks, and rare eclogites and blueschists, of the mafic-rich Anvil and the siliceous Nisutlin assemblages [Tempelman-Kluit, 1979], are broadly correlative with the Y_4 and Y_3 subterranes, respectively, defined in Alaska. The YT in Yukon also contains a Permian orthogneiss assemblage (Sulphur Creek orthogneiss, 256 Ma, U-Pb zircon with no inheritance [Mortensen, 1986; Wheeler and McFeeley, 1987; Wheeler et al., 1988]) and a Mississippian I-type granitoid assemblage (340-360 Ma, U-Pb zircon, no inheritance), the Simpson plutonic suite [Mortensen, 1988a, b]. Both of these granitoid suites consistently occupy high structural levels within the YT relative to adjacent assemblages [Tempelman-Kluit, 1979; Mortensen, 1988b]. To date, neither of these plutonic assemblages have been identified in Alaska. However, this may be due to a sampling problem with respect to the Permian assemblage, as Permian orthogneiss appears lithologically identical to the older peraluminous orthogneiss [Mortensen, 1988b]. The YT in Alaska and Yukon also includes Late Triassic-Early Jurassic granitoids (e.g., the Taylor Mountain batholith in east central Alaska [Foster, 1970, 1976; Foster et al., 1987] and intrusions in southern and south central Yukon [Tempelman-Kluit, 1984; Mortensen and Jilson, 1985]) that predominantly postdate ductile deformation of their host rocks [Mortensen, 1988b].

The lithology of the YT has historically been differentiated from adjacent rocks on the basis of penetrative deformation fabrics. Generally all YT rocks, with the exception of the YT south of the Tanana River and the Upper Triassic-Lower Jurassic plutons discussed above, exhibit penetrative ductile deformation fabrics. Rocks of the Slide Mountain terrane, which are adjacent to rocks of the YT in Yukon and Alaska, were originally differentiated from YT rocks because they lack ductile tectonite fabrics and a regional metamorphic overprint (for example, within the Teslin suture zone (Figure 1), rocks of the Anvil allochthon [Tempelman-Kluit, 1979] are ductiley deformed and metamorphosed, and therefore considered as part of the Yukon-Tanana terrane [Coney and Jones, 1985], yet these L-S tectonites are lithologically correlative with rocks

Fig. 1. Simplified terrane and subterrane map of the northern Canadian and Alaskan Cordillera compiled from Dusel-Bacon and Aleinikoff [1985], Foster et al. [1987], Mortensen and Jilson [1985], Hansen [1987], Jones et al. [1987], Monger and Berg [1987], Wheeler and McFeely [1987], Wheeler et al. [1988]. Towns include Ds, Dawson; Fb, Fairbanks; Ha, Haines; Rr, Ross River; Sk, Skagway; Wh, Whitehorse; and Wl, Watson Lake. The Taylor Highway area (TH) and Laberge-Quiet Lake areas (LQL) are indicated with boxes. The Teslin suture zone is the part of the Teslin-Taylor Mountain and Nisutlin terranes in the Laberge-Quiet Lake area. The approximate location of map is shown by box on inset map.

exposed in the Anvil and Campbell ranges east of the Tintina fault which are not ductiley deformed or metamorphosed, and hence considered to be part of the Slide Mountain terrane [Monger and Berg, 1987]. We believe that these two rocks packages are correlative as suggested by Hansen [1988, 1990a, b] and as discussed below).

Despite differences in the structural and metamorphic character of the YT Teslin-Taylor Mountain and Slide Mountain terranes, they share important lithologic similarities [Hansen, 1988, 1990a, b]. First, the Slide Mountain terrane includes Devonian to Upper Triassic chert, argillite, sandstone, conglomerate, basalt, carbonate rocks, and ultramafic rocks. The YT Teslin-Taylor Mountain terrane comprises metavolcanic rocks, metabasalt, marble, metachert, amphibolite, and ultramafic rocks. The YT Nisutlin terrane consists of metamorphosed and tectonized felsic and quartz-rich sedimentary, volcanic, and intrusive rocks of Late Proterozoic, Paleozoic, and possible early Mesozoic age [Wheeler et al., 1988]. Second, rocks mapped as Teslin-Taylor Mountain record coherent high-P/T metamorphic conditions in the Teslin suture zone [Hansen, 1987], and in east central Alaska [Dusel-Bacon and Douglass, 1990]; this same package contains eclogites included as tectonic lenses [Erdmer, 1985, 1987; (Hansen, unpubl. mapping,1987)]. Nisutlin tectonites also record high-P/T metamorphic conditions in the Teslin suture zone [Hansen, 1987; (V. L. Hansen, P-T evolution of the Teslin suture zone, Yukon: Implications for deep-seated subduction zone processes, submitted to *Journal of Metamorphic Geology*, 1990; herein referred to as Hansen, submitted manuscript, 1990)], east of the Tintina fault near Ross River and north of Watson Lake, Yukon [Erdmer, 1987], and even rocks included with the Slide Mountain terrane locally preserve evidence of high-P/T metamorphic conditions east of the Tintina fault, Yukon [Erdmer, 1987].

We propose that the Teslin-Taylor Mountain terrane, as described herein, is lithologically correlative with the Slide Mountain terrane, though it records tectonism at a different crustal level than the generally brittley deformed and unmetamorphosed Slide Mountain terrane. Although not explicitly stated, Wheeler et al. [1988] make a similar correlation, as they include rocks which are herein distinguished as the Teslin-Taylor Mountain terrane with the Slide Mountain terrane. On previous terrane assemblage maps these rocks have been included with the YT [Monger and Berg, 1987; Coney and Jones, 1985]. Although we believe these rocks are lithologically correlative, we retain a distinction between Teslin-Taylor Mountain and Slide Mountain terranes (Figure 1). Within the Teslin-Taylor Mountain terrane we include Slide Mountain terrane rocks of Wheeler et al. [1988] that have previously been considered to be part of the YT or the Slide Mountain terrane and that (1) comprise rock types consistent with the definition of the Slide Mountain terrane [Wheeler et al., 1988]; (2) have a documented coherent high-P/T metamorphic history; or (3) display penetrative L-S tectonite fabrics, although P-T conditions have not yet been documented. Our definition of the Nisutlin terrane follows that of Wheeler et al. [1988], although we locally reassign terrane names in east central Alaska in better accordance with terrane definitions outlined by Wheeler at al. [1988]. Considered in this light, the Teslin-Taylor Mountain and Nisutlin terranes of the YT have more in common with the Slide Mountain terrane than they have with the YT orthogneiss assemblage with which they have been correlated in terrane definitions [Coney and Jones, 1985].

In addition, the Teslin-Taylor Mountain and Nisutlin terranes can be differentiated from orthogneiss assemblage tectonites on the basis of structural and kinematic histories and metamorphic cooling dates. Thus, the YT is herein divided into two parts, the Teslin-Taylor Mountain and Nisutlin terranes, and the orthogneiss assemblage. The Teslin-Taylor Mountain and Nisutlin terranes include subterranes Y_4 and Y_3, respectively, in Alaska, and the Anvil assemblage (usage of Tempelman-Kluit [1979]) and the Nisutlin terrane, respectively, in Yukon. The Teslin-Taylor Mountain terrane may also include Permian orthogneiss and the Simpson plutonic suite although this correlation is not yet documented on the basis of metamorphic cooling ages. The orthogneiss assemblage includes Y_1 and Y_2 subterranes in Alaska, and the augen orthogneiss suite in Yukon. Orthogneiss assemblage tectonites are exposed at the lowest structural levels within the YT in Yukon [Mortensen, 1988a], and, as we argue below, they also occupy a lower plate position in Alaska.

Teslin-Taylor Mountain and Nisutlin tectonites record greenschist to moderately high-P/T albite-epidote amphibolite facies metamorphism, with blueschist and eclogite facies rocks preserved locally. Within the Teslin suture zone, Yukon, these rocks preserve albite-epidote amphibolite facies in the west and greenschist facies assemblages in the east; in eastern Alaska albite-epidote amphibolite assemblages are preserved to the south with greenschist assemblages are preserved to the north [Hansen, 1989]. These tectonites record Early Jurassic metamorphic mineral cooling dates. Lower Jurassic granitoids associated with the YT intrude Teslin-Taylor Mountain and Nisutlin tectonites but do not intrude rocks of the orthogneiss assemblage.

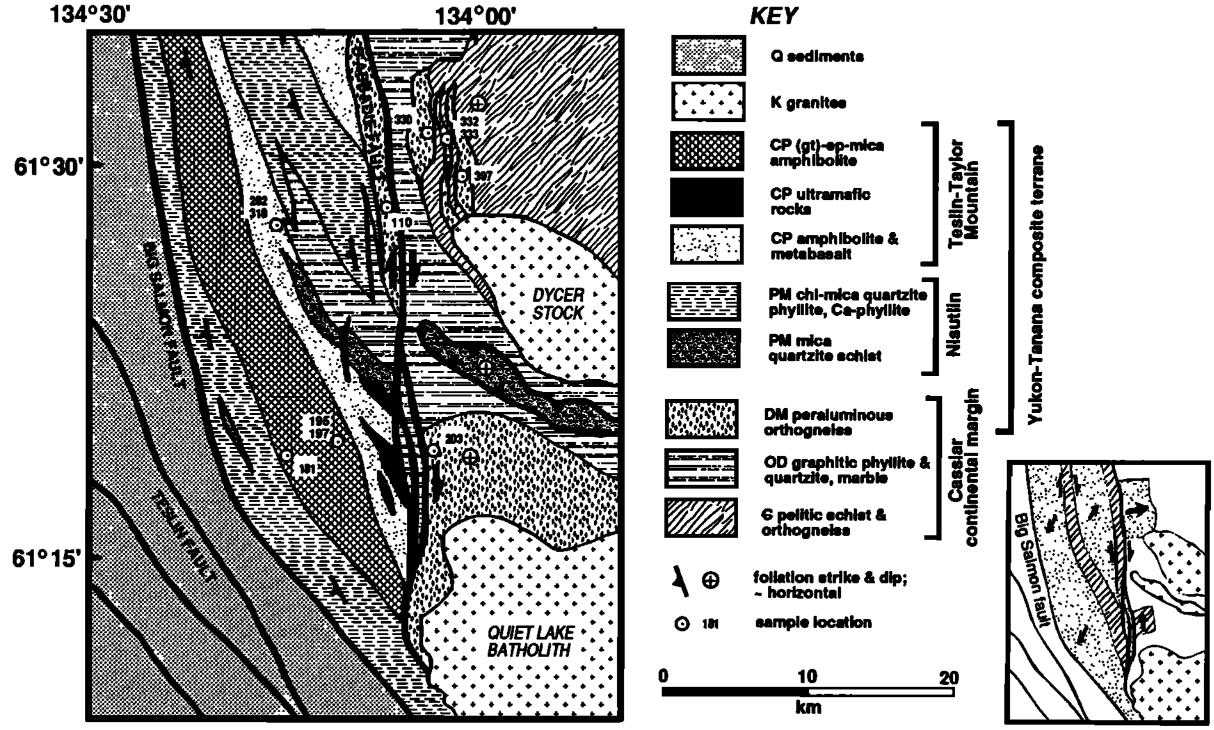
The orthogneiss assemblage is characterized by Devonian-Mississippian peraluminous orthogneiss and host metasedimentary rocks. Peraluminous orthogneiss records Proterozoic U-Pb inheritance [Aleinikoff et al., 1981, 1986; Mortensen, 1983, 1988b; Mortensen and Jilson, 1985] and Sm-Nd model ages consistent with North American cratonal basement values (ε_{Nd} [340 Ma] is -14 to -16, and depleted mantle model ages are 2.0-2.3 Ga [Bennett and Hansen, 1988]). Metamorphic mineral cooling dates consistently yield latest Late Jurassic to Cretaceous values. Although structural level of the orthogneiss assemblage is generally unconstrained in Alaska due to poor exposure [Foster et al., 1987; H. L. Foster, personal communication, 1987], Cretaceous cooling dates, metamorphic grade, and contact relations with adjacent Teslin-Taylor Mountain and Nisutlin rocks are consistent with a lower plate position as discussed below.

THERMOCHRONOMETRY

Analytical Techniques

Samples were collected for $^{40}Ar/^{39}Ar$ analysis from the Teslin-Taylor Mountain and Nisutlin terrane, and orthogneiss assemblage in the Laberge-Quiet Lake area, Yukon (Figure 2 and Table 1), and the Taylor Highway area, Alaska (Figure 3 and Table 2). The structural and kinematic history of each sample was either previously documented or is presented herein. Chronometric data are discussed together with geological and structural relationships observed within each of the field areas.

High-purity mineral separates (>99%) were prepared from crushed and sized rock powders using conventional heavy liquid and magnetic separation techniques. The minerals were wrapped in Sn foil and irradiated in evacuated, flat-bottomed quartz vials for 60 hours in the H-5 position of the Ford



a) *LABERGE/QUIET LAKE MAP AREA, YUKON*

b)

Fig. 2. (a) Simplified geologic map of the Laberge-Quiet Lake area showing location of samples for $^{40}Ar/^{39}Ar$ analysis [Tempelman-Kluit, 1977, 1978, 1984; Hansen, 1987]. The Teslin suture zone includes northwest striking, steeply dipping tectonites between the Big Salmon and the d'Abbadie faults. (b) Simplified structural domain map showing distribution and shear sense of dip-slip (stippled pattern), D_{ds}, and strike-slip (lined pattern), D_{ss}, fabrics in the Laberge-Quiet Lake map area. Half arrows indicate dextral shear, and whole arrows indicate displacement of structurally higher rocks relative to structurally lower rocks as interpreted from L-S tectonite fabrics [Hansen, 1989].

Reactor at the University of Michigan, Ann Arbor. Samples of flux monitor Fe-mica (307.3 Ma) were placed above and below the unknowns in order to monitor the neutron dose. K/Ca ratios for each sample were calculated from measured $^{39}Ar/^{37}Ar$ isotopes and knowledge of the flux monitor K/Ca (~24). Ar was extracted from each sample in a double-vacuum, resistance-heated furnace with temperature accuracy of better than ± 5°C. Gas clean-up was accomplished by SAES getter pumps. Ar isotope analyses were performed using an automated Nuclide 4.5—60-RSS mass spectrometer equipped with an on-line data reduction program. (Blank-corrected (~1 x 10^{-14} moles ^{40}Ar) $^{40}Ar/^{39}Ar$ results and correction factors used to account for interfering nuclear reactions on Ca and Kavailable from the authors upon request.) Age spectra are shown in Figures 4-6, 8 and 9. Stated precisions are based on errors associated with peak height regressions and are quoted at the 1σ level. All ages are calculated using decay constants and isotopic abundances recommended by Steiger and Jager [1977]. Additional experimental information is given by Harrison and FitzGerald [1986].

Nearly all samples display well-behaved flat age spectra and yield well-correlated isochron data, thus greatly reducing the need for detailed discussion of each sample interpretation. Deviation from plateau-type age spectra generally results from incorporation of trapped argon with a higher than atmospheric (295.5) $^{40}Ar/^{36}Ar$ ratio. Because isochron analysis makes no assumption of the trapped argon component, unlike the calculated apparent ages on the age spectrum, the age defined by the isochron is considered the best estimate for the sample age. Complete discussion of isochron analysis is given by Heizler and Harrison [1988]. All isochron ages and trapped components are calculated from intercepts yielded by regression of the data using the method of York [1969].

Closure temperatures for argon in various minerals can be calculated with the use of equations given by Dodson [1973]. The kinetic parameters needed to solve the closure temperature equation have been estimated experimentally and generally limit closure temperatures to ± 50°C. We recognize that compositional effects, diffusion grain size, and cooling rate bear on the closure temperature, but we assign closure temperatures as follows: hornblende, 500°C [Harrison, 1981]; muscovite-white mica, 350°C [Robbins, 1972; Purdy and Jager, 1976]; and biotite, 300°C [Harrison et al., 1985].

Several samples (i.e., TH-39 biotite) have gaps in their age spectra due to gas loss during argon extraction. An estimate has been made of the amount of ^{39}Ar lost in a given step through knowledge of the mineral degassing behavior and K concentrations.

Laberge-Quiet Lake Area, Yukon

The Laberge-Quiet Lake area is divisible into three north striking belts (Figure 2). West of the Big Salmon fault a belt

TABLE 1. Localities and $^{40}Ar/^{39}Ar$ Data of Samples Analyzed From the Eastern Laberge-Western Quiet Lake Area, Yukon

Sample	Rock Type	Terrane	Deformation	Latitude	Longitude	Minerals	Isochron Age, Ma	$^{40}Ar/^{36}Ar_{initial}$
LV-195	gt-clz-ab amphibolite gneiss	TTM	N-ds	61°18.83'	134°11.11'	hb	188 ± 13	696 ± 119
LV-197	gt-clz-mu-ab mylonitic gneiss	TTM	N-ds	61°18.96'	134°10.36'	wm	195.3 ± 0.9	320 ± 16
LV-181	ab-mu mylonitic qtzt	TTM or NT?	N-ds	61°18.64'	134°14.01'	wm	195.2 ± 0.4	344 ± 14
DW-318	gt-mu-ab mylonite gneiss	TTM	RL-ss	61°26.46'	134°17.57'	wm	194.6 ± 1.9	382 ± 56
DW-282	gt-clz-bi-mu-ab mylonitic gneiss	TTM	RL-ss	61°26.46'	134°04.69'	wm	191.3 ± 0.3	282 ± 14
DE-333	gt-hb-mu-bi schist	OA	TTE-ds	61°30.68'	143°03.19'	hb	146.8 ± 2.43	295.1 ± 17
DE-332	gt-mu-bi schist	OA	TTE-ds	61°30.68'	134°03.19'	mu	115.1 ± 0.6	308 ± 7
DE-330	2-mica granitic orthogneiss	OA	TTE-ds	61°30.80'	134°03.36'	bi	109.5 ± 0.3	308 ± 3
DE-397	2-mica granitic orthogneiss	OA	TTE-ds	61°29.14'	134°02.91'	mu	117.7 ± 0.2	298 ± 3
						bi	108.5 ± 0.1	303 ± 8
LV-203	2-mica grano-diorite orthogneiss	OA?	RL-ss	61°18.98'	134°04.69'	bi	98.1 ± 0.6	321 ± 17
DC-110	2-mica grano-diorite orthogneiss	OA?	RL-ss	61°26.06'	134°06.98'	mu	97.1 ± 0.2	301 ± 5

Abbreviations are ab, albite; bi, biotite; clz, clinozoisite; gt, garnet; hb, hornblende; mu, muscovite; wm, white mica; N, normal displacement; RL, right-lateral displacment; TTE, top-to-the-east shear; ds, dip-slip shear; ss, strike-slip shear; TTM, Teslin-Taylor Mountain; NT, Nisutlin; OA, orthogneiss assemblage.

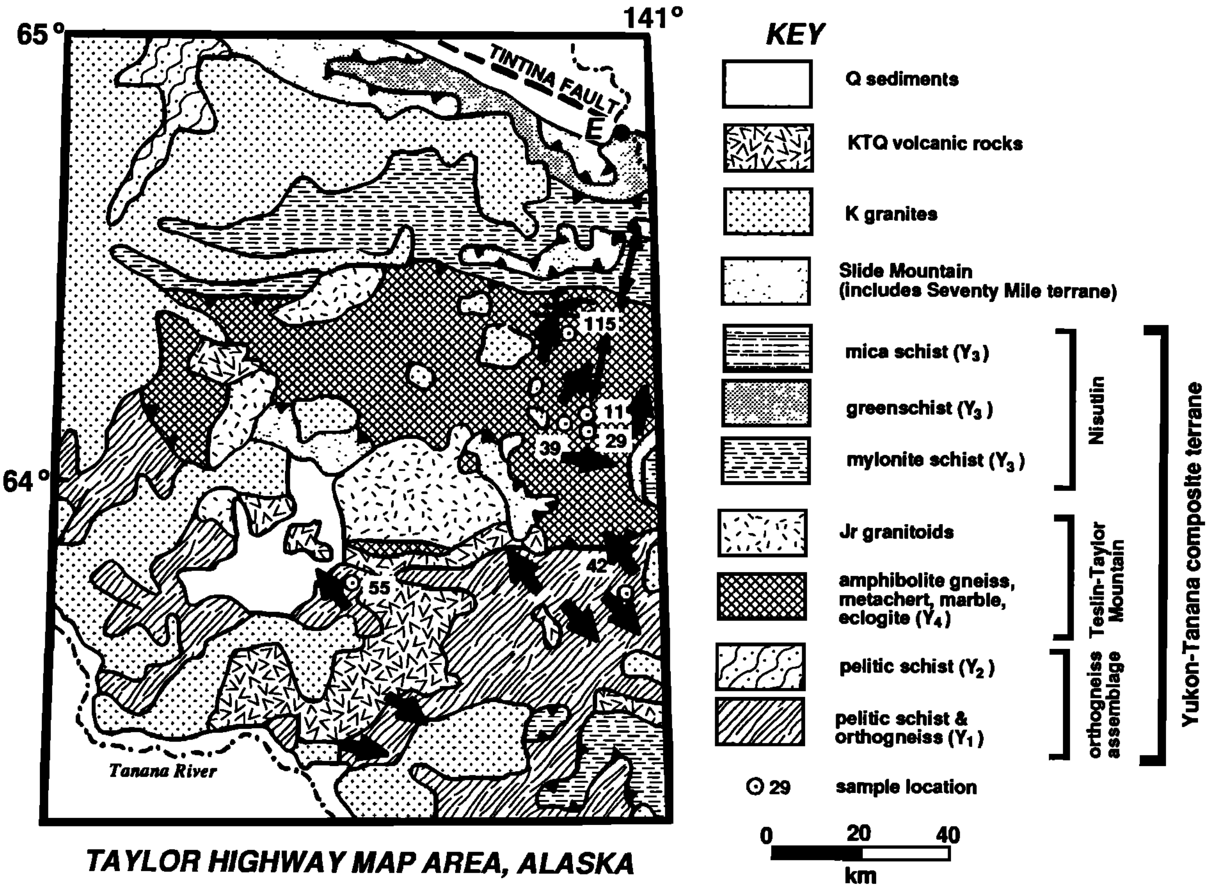


Fig. 3. Simplified geologic map of the Taylor Highway area showing location of samples for $^{40}Ar/^{39}Ar$ analysis (Tanacross and Eagle 2 degree sheets) [Foster, 1970, 1976; Foster et al., 1987]. Double-headed arrows indicate the orientation of common elongation lineations in Teslin-Taylor Mountain terrane rocks; single headed arrows depict the displacement direction of structurally higher rocks relative to structurally lower rocks as interpreted from shear sense indicators in L-S tectonites (V. L. Hansen, unpubl. data, 1988).

of non-metamorphosed to low-grade volcanic, volcaniclastic, and sedimentary rocks of mainly Pennsylvanian age assigned to Quesnellia [Wheeler et al., 1988] cut by extensive north-northwest striking high-angle faults crops out beneath extensive Quaternary alluvial deposits. Between the Big Salmon and the d'Abbadie faults, siliceous to mafic-rich L-S tectonites of the Teslin suture zone [Tempelman-Kluit, 1979; Hansen, 1988, 1989] form the steeply dipping segment of the YT. These tectonites include rocks of the Teslin-Taylor Mountain and Nisutlin terranes, and the orthogneiss assemblage. East of the west dipping d'Abbadie fault, Teslin-Taylor Mountain and Nisutlin L-S tectonites lie in klippen above peraluminous orthogneiss and metasedimentary rocks that display gently dipping foliation; tectonite foliation within the klippen also dips gently. Orthogneiss bodies parallel tectonite foliation and metasedimentary compositional layering.

Greenschist to amphibolite facies metasedimentary rocks east of the d'Abbadie fault are mapped as Paleozoic continental margin strata of the Cassiar terrane [Tempelman-Kluit, 1977, 1978, 1984; Wheeler et al., 1988]. Recent detailed mapping and radiometric dating within this package have identified Devonian-Mississippian [Hansen et al., 1989] orthogneiss sills which are lithologically and isotopically (U-Pb; Rb-Sr; K-Ar; Sm-Nd; and $^{40}Ar/^{39}Ar$ as shown below) correlative with peraluminous orthogneiss of the YT orthogneiss assemblage [Bennett and Hansen, 1988; Hansen, 1990a, b]. L-S tectonite fabrics are concordant across lithologic boundaries [Hansen, 1989]. These relationships indicate that peraluminous granitoids, at least locally, intruded parautochthonous North American Paleozoic strata (e.g., the Cassiar terrane) prior to ductile deformation. Further evidence for this conclusion is documented to the east where another body of peraluminous orthogneiss intrudes Cassiar strata (Figure 1) [Tempelman-Kluit, 1984; (V. L. Hansen, unpubl. mapping, 1988)]. Sm-Nd values from each of these orthogneiss bodies east of the d'Abbadie fault are correlative with YT orthogneiss assemblage values [Bennet and Hansen, 1988]. U-Pb isotope analysis in progress (J. K. Mortensen, personnal communication, 1990) will confirm whether the easternmost body is correlative with Devonian-Mississippian orthogneiss of the YT orthogneiss assemblage on this basis.

The Teslin suture zone is truncated by steep faults to the south, and it broadens to the northwest where tectonite foliation shallows into parallelism with regionally horizontal foliation of the YT [Tempelman-Kluit, 1979]. The d'Abbadie

TABLE 2. Localities and $^{40}Ar/^{39}Ar$ Data of Samples Analyzed From the Taylor Highway Area, Alaska

Sample	Rock Type	Terrane	Deformation	Latitude	Longitude	Minerals	Isochron Age, Ma	$^{40}Ar/^{36}Ar_{initial}$
TH-39	gt-bi amphibolite gneiss	TTM	TTESE	64°10.09'	141°25.11'	hb	188.3 ± 0.3	294 ± 1
						bi	186.1 ± 1.0	291 ± 8
TH-115	clz-wm-plag gneiss	TTM	TTNNE	64°21.08'	141°23.66'	wm	109.8 ± 0.8	300 ± 2
TH-29	gt-bi amphibolite gneiss	TTM	WNW Le	64°10.09'	141°19.62'	hb	187.0 ± 0.2	312 ± 5
						bi	185.4 ± 0.3	296 ± 2
TH-11	ky-wm-bi schist	TTM	TTENE	64°11.11'	141°21.29'	wm	185.0 ± 0.6	324 ± 6
						bi	188.2 ± 1.0	314 ± 16
TH-55	2-mica granitic orthogneiss	OA	TTNW	64°49.32'	142°31.29'	mu	110.1 ± 0.4	323 ± 17
						bi	111.0 ± 0.6	311± 25
TH-42	2-mica granitic orthogneiss	OA	TTSE	64°49.31'	141°35.08'	mu	109.2 ± 0.1	299 ± 4
						bi	109.2 ± 0.4	371 ± 24

Abbreviations are ky, kyanite; plag, plagioclase; TTNNE, top-to-the-north-northeast shear; TTWNW, top-to-the-west-northwest shear; TTESE, top-to-the-east-southeast shear; TTSE, top-to-the-southeast shear; TTNW, top-to-the-northwest shear; other abbreviations are the same as those used in Table 1.

fault, which separates steeply west dipping tectonites to the west from gently dipping to horizontal tectonites to the east, is marked by brittle deformation, although L-S tectonite fabrics in orthogneiss on either side of the fault provide evidence of an earlier ductile history [Hansen, 1989]. Massive Cretaceous granitic plutons which show no evidence of ductile deformation intrude tectonites east of the d'Abbadie fault, as well as the fault zone itself. Therefore these bodies place an upper bound on the time of displacement associated with horizontal foliation and on displacement along the d'Abbadie fault.

Rocks on either side of the d'Abbadie fault display L-S tectonite fabrics. Hansen [1989] conducted a detailed structural and kinematic analysis of these tectonites which is summarized here. West of the d'Abbadie fault within the Teslin suture zone, L-S tectonite foliation dips steeply in the west and flattens to the east. Elongate, north-northwest striking structural domains within the Teslin suture zone, marked by differently oriented but coplanar elongation lineations (Le) of dip-slip (D_{ds}) and strike-slip (D_{ss}) orientation, define a regionally coherent structural pattern within the Teslin suture zone (Figure 2b). A zone of D_{ss} bisects two D_{ds} zones, and a second D_{ss} zone strikes subparallel to the d'Abbadie fault.

In the northern part of the map area east of the d'Abbadie fault, Le within the gently dipping foliation of the peraluminous orthogneiss and metasedimentary tectonites of the Cassiar terrane strike west to west-southwest. To the south, Le in flat-lying peraluminous orthogneiss foliation strike northward. Both to the east and west of the d'Abbadie fault, tectonite fabrics cross lithologic boundaries; they are not related to the distribution of orthogneiss or any other lithology.

West of the d'Abbadie fault, dip-slip tectonic movement (D_{ds}) progressively evolved to dominantly dextral strike-slip shear (D_{ss}) parallel to the strike of the Teslin suture zone. D_{ds} fabrics within the western part of the Teslin suture zone record apparent normal shear, or down-to-the-west-southwest displacement, whereas D_{ds} fabrics within the eastern part of the Teslin suture zone (also west of d'Abbadie fault) record dominantly thrust-style, or top-to-the-east-southeast shear (Figure 2b). East of the d'Abbadie fault tectonites record top-to-the-east-northeast ductile shear in the northern part of the map area; to the south peraluminous orthogneiss records top-to-the-north-northwest ductile shear. Orthogneiss L-S tectonite fabrics that parallel the d'Abbadie fault record dextral displacement. The sense or amount of displacement associated with brittle deformation along the d'Abbadie fault is not defined. Similarly, shear sense or amount of displacement along the Big Salmon and Teslin faults is unknown.

Within the hanging wall block of the d'Abbadie fault D_{ds} and D_{ss} rocks display mineral assemblages indicative of the albite-epidote amphibolite to greenschist facies, with a possible eastward decrease in metamorphic grade [Hansen, 1987, submitted manuscript, 1990]. Quantitative geothermobarometric study reveals significant P-T changes during L-S tectonite formation, as recorded by progressive change from pervasive D_{ds} fabrics to localized D_{ss} shear zones [Hansen, 1987, submitted manuscript, 1990]. Westernmost D_{ds}-bearing tectonites record P-T conditions of 575°-675°C and 12 ± 4 kbar, whereas westernmost D_{ss} mineral assemblages record 425°-550°C and 5-8 kbar metamorphic conditions. Rb-Sr whole rock + muscovite isochrons and K-Ar (bi) dates indicate that D_{ss} and D_{ds} tectonites fabrics in the western part of the Teslin suture zone formed prior to 182-213 Ma [Hansen et al., 1989].

Tectonites selected for $^{40}Ar/^{39}Ar$ analysis from each of the structural domains outlined above (Table 1) include (1) D_{ds}- and (2) D_{ss}-bearing Teslin-Taylor Mountain and Nisutlin tectonites west of the d'Abbadie fault, (3) D_{ds}-bearing orthogneiss and paragneiss tectonites east of d'Abbadie fault, and (4) D_{ss}-bearing orthogneiss tectonites which parallel the d'Abbadie fault. One of the D_{ds}-bearing tectonites from the Teslin suture zone, an albite-white mica quartzite (LV-181), may represent a lense of Nisutlin rocks surrounded by Teslin-Taylor Mountain rocks; tectonic interleaving of lensoids is a common structural style throughout the Teslin suture zone [Erdmer, 1985; Hansen, 1987, 1989].

Five samples of Teslin suture zone tectonites were analyzed by the $^{40}Ar/^{39}Ar$ method. Three of the tectonites display D_{ds} fabrics (LV-195, hb; LV-197, wm; LV-181, wm), and two display D_{ss} fabrics (DW-318, wm; DW-282, wm). Age spectra are shown in Figure 4.

The age spectrum for hornblende derived from D_{ds}-bearing amphibolite (LV-195) exhibits a complex age pattern (Figure 4a). Low-temperature steps correspond to relatively young ages and high K/Ca values, whereas high temperature steps correspond to older ages and lower and constant K/Ca values. The final 70% of gas released is derived from mainly the hornblende (as portrayed by the low and constant K/Ca ratios), but it also suggests an argon concentration gradient due to the monotonic increase in age from ~200-220 Ma. Ages decrease over the final 15% of argon released and may reflect ^{39}Ar recoil [Huneke and Smith, 1976]. The lack of excess ^{40}Ar in the initial steps suggests that the entire sample is not highly contaminated with excess ^{40}Ar. Isochron data cluster and thus yield ambiguous intercepts with respect to age and trapped argon. Our interpretation is that the age gradient corresponding to the gas evolved with a constant K/Ca reflects a $^{40}Ar^*$ concentration gradient resulting from slow cooling or reheating of an older hornblende (~225 Ma?), followed by fast uplift at ~195 Ma. The young ages over the first 30% of release reflect degassing of a less retentive (probably micaceous) phase.

The LV-197 white mica age spectrum and isochron is shown in Figure 4b and yields an isochron date of 195.3 ± 0.9 Ma. D_{ds}-bearing LV-181 white mica yields an isochron date of 195.2 ± 0.4 Ma (Figure 4c).

Figures 4d and 4e illustrate the release spectra and isochrons for white mica from D_{ss}-bearing DW-282 and DW-318. These samples have isochron dates of 191.3 ± 0.3 Ma and 194.6 ± 1.9 Ma, respectively. P-T constraints derived from D_{ss} tectonites west of the d'Abbadie fault are 425-550°C and 5-8 kbar [Hansen, 1986, 1987]; therefore these dates are interpreted as a minimum estimate for the timing of these metamorphic conditions. The concordance in hornblende and white mica dates for D_{ds}-bearing and D_{ss}-bearing tectonites west of the d'Abbadie fault suggests that there was no significant variation in cooling history along strike and that the D_{ds} and D_{ss} tectonites packages cooled synchronously through 350°C.

Five samples were analyzed from amphibolite grade D_{ds}-bearing Cassiar tectonites east of the d'Abbadie fault (Figure 2 and Table 1). The age spectrum for hornblende derived from DE-333 shows a complex release pattern (Figure 5a). The apparent age gradient for the first 30% of gas released is probably related to outgassing of less retentive K-rich inclusions or exsolution lamellae during slow cooling. The plateau at ~147 Ma can be regarded as the time at which hornblende cooled below 500°C. The age spectrum and isochron for muscovite from orthogneiss DE-332 which is adjacent (< 1 m) to DE-333 is shown in Figure 5b. The sample has an isochron date of 115.1 ± 0.6 Ma. Figure 5c illustrates the release spectrum and isochron for biotite of orthogneiss DE-330. A 109.5 ± 0.3 Ma date is indicated from the isochron. Release spectra and isochron plots for muscovite and biotite from orthogneiss DE-397 are shown in Figure 5d. The isochrons yield discordant dates of 117.7 ± 0.2 Ma and 108.5 ± 0.1 for muscovite and biotite, respectively. The discordant mineral dates presented in Figure 5 illustrate that D_{ds}-bearing tectonites east of the d'Abbadie fault cooled slowly through 500-300°C during latest Late Jurassic to mid-Cretaceous time.

Release spectra and isochron plots for muscovite and biotite from orthogneiss with well-developed S-C fabrics parallel to the d'Abbadie fault are shown in Figure 6. Muscovite from orthogneiss DC-110 has a 97.1 ± 0.2 Ma isochron date (Figure 6a). LV-203 biotite has a similar isochron date of 98.1 ± 0.6 Ma. We interpret these data as indications that this segment of the d'Abbadie fault was active as a dextral ductile shear zone as recently as 97 Ma. The Quiet Lake batholith, which yields a K-Ar biotite date of 85.3 ± 3.1 Ma (Tempelman-Kluit as cited by Wanless et al. [1978]) intrudes the d'Abbadie fault (Figure 2).

Each of the cooling dates presented above are consistent with K-Ar muscovite and Rb-Sr whole rock and mineral dates determined by Hansen et al. [1989], but the data presented here reflect a larger range of closure temperatures and greater analytical precision which allow us to more carefully differentiate the three ductile deformation events recorded by tectonites within the Laberge-Quiet Lake map area (Figure 7). (1) Pre-middle Early Jurassic (>194 Ma) dip-slip and strike-slip ductile shear preserved within Teslin-Taylor Mountain and Nisutlin terrane rocks of the Teslin suture zone, and accompanied by moderately high-P/T metamorphic conditions, is interpreted as deformation within the deep-seated part of a subduction complex [Hansen, 1989, 1990a, b, submitted manuscript, 1990] prior to collision with Cassiar strata. (2) Pre-Late Jurassic to mid-Cretaceous (147-109 Ma) low-angle, top-to-the-east shear of Cassiar tectonites, which include YT peraluminous orthogneiss, is interpreted to result from collision and top-to-the-east thrusting of the Teslin suture zone tectonites over Cassiar strata, which is itself involved in this deformation. We interpret that the fast cooling of Teslin suture zone tectonites in middle Early Jurassic time records uplift of Teslin suture zone tectonites as a result of initial collision with Cassiar strata to the east. Upper plate Teslin-Taylor Mountain and Nisutlin tectonites within the Teslin suture zone, and those preserved in flat-lying klippen, cooled though 500°-300°C at this time, whereas lower plate Cassiar (and locally Nisutlin?) strata were tectonically buried, and hence heated, as a result of this collision. These rocks did not cool through 500°-300°C until latest Late Jurassic to mid-Cretaceous time. (3) Mid to Late Cretaceous (97 Ma) postaccretion ductile deformation along the high-angle dextral d'Abbadie shear zone cuts YT and North American strata. Brittle deformation along the d'Abbadie fault postdates dextral ductile shear deformation, and the fault itself is crosscut by Late Cretaceous plutons.

Taylor Highway Area, Alaska

The Taylor Highway area in Alaska (Figure 3) exposes the four subterranes of the YT as defined by Churkin et al. [1982] as well as rocks of the Seventy Mile terrane [Churkin et al., 1982; Foster et al., 1987], which is correlative with the Slide

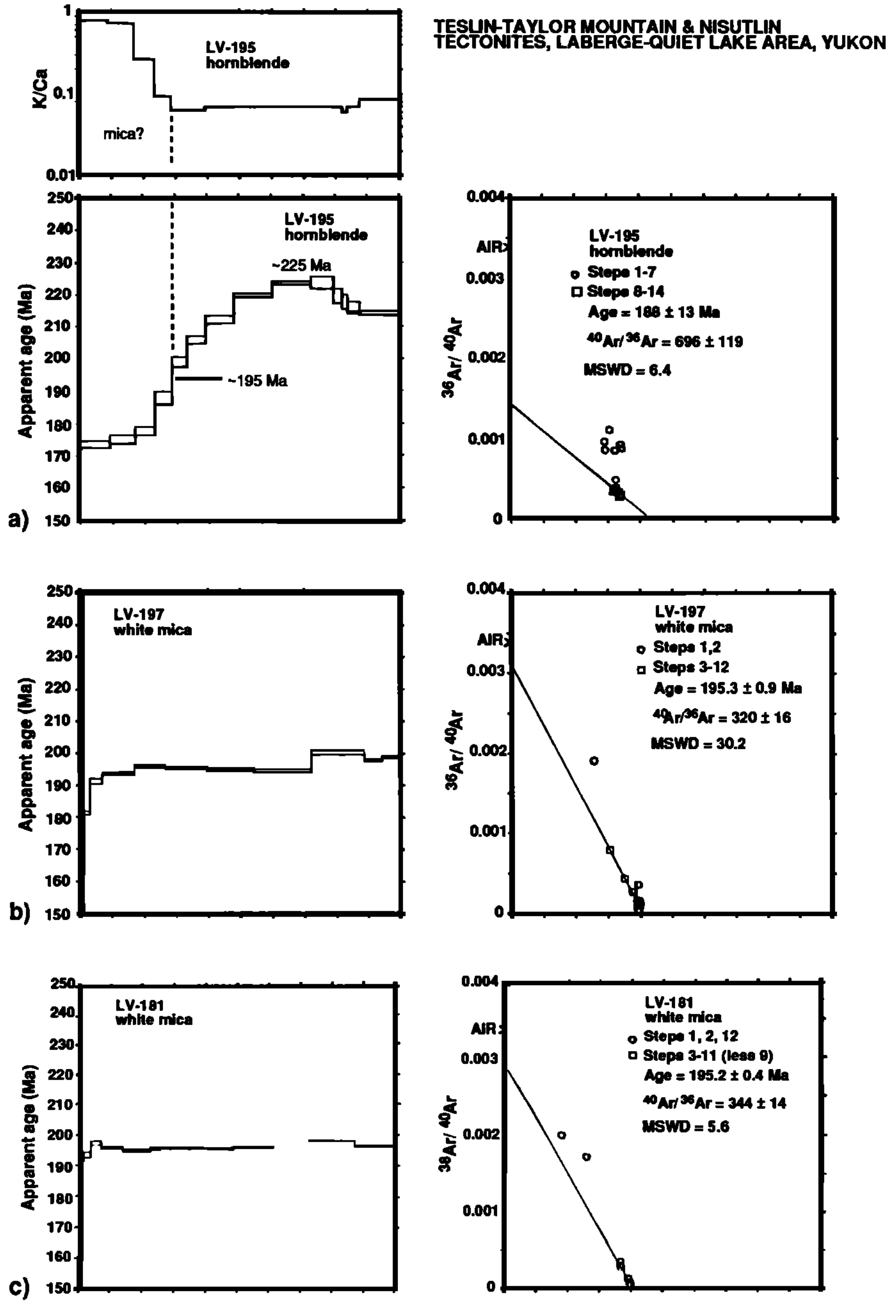


Fig. 4. $^{40}Ar/^{39}Ar$ incremental release date spectra and isochron diagrams for Teslin-Taylor Mountain and Nisutlin terrane tectonites from the Teslin suture zone west of the d'Abbadie fault, Laberge-Quiet Lake area, Yukon (Figure 2). (a) D_{ds}-LV-195 hornblende spectrum; steps 8-14 yield a date of 188± 13 Ma and a $^{36}Ar/^{40}Ar$ component of 696 ± 119 with MSWD = 6.4. (b) D_{ds}-LV-197 white mica; steps 3-12 yield a date of 195.3 ± 0.9 Ma and a $^{36}Ar/^{40}Ar$ component of 320 ± 16, and MSWD = 30.2. (c) D_{ds}-LV-181 white mica; steps 3-11 (less 9) yield a date of 195.2 ± 0.4 Ma and a $^{36}Ar/^{40}Ar$ component of 344 ± 14 with MSWD = 5.6. The minor hole in the age spectrum at step 9 results from accidental gas loss. (d) D_{ss}-DW-282 white mica; steps 3-10 (less 9) yield a date of 191.3 ± 0.3 Ma and a $^{36}Ar/^{40}Ar$ component of 282 ± 14 with MSWD = 1. The hole in the age spectrum at step 9 results from accidental gas loss.

Fig. 4. (continued) $^{40}Ar/^{39}Ar$ incremental release date spectra and isochron diagrams for Teslin-Taylor Mountain and Nisutlin terrane tectonites from the Teslin suture zone west of the d'Abbadie fault, Laberge-Quiet Lake area, Yukon (Figure 2). (e) D_{ss}-DW-318 white mica; steps 3-9 yield a date of 194.6 ± 1.9 Ma and a $^{36}Ar/^{40}Ar$ component of 382 ± 5 with MSWD = 14.

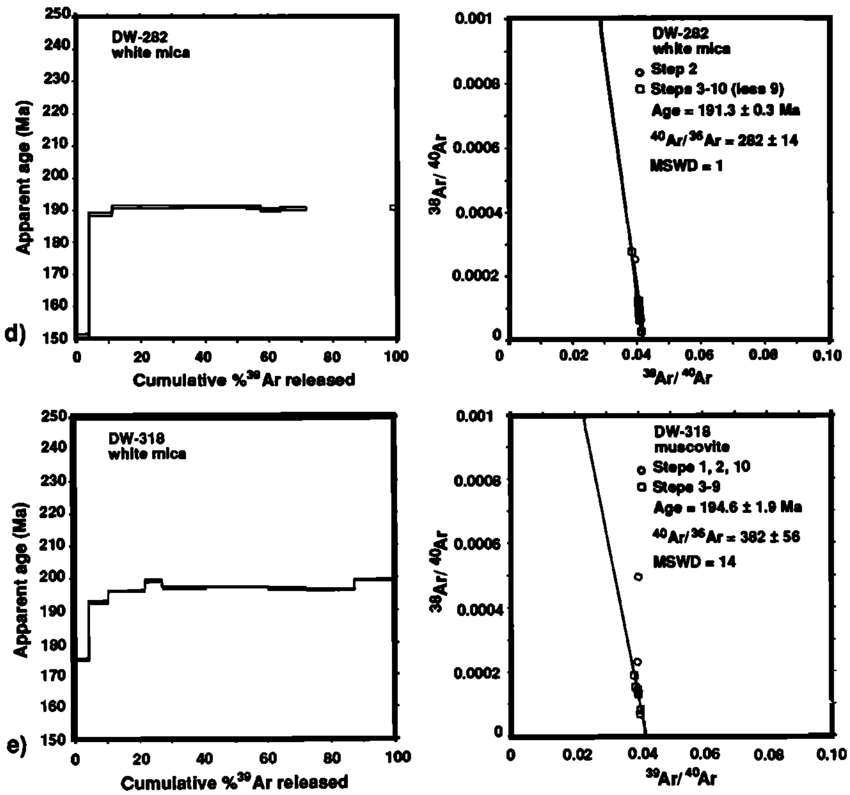
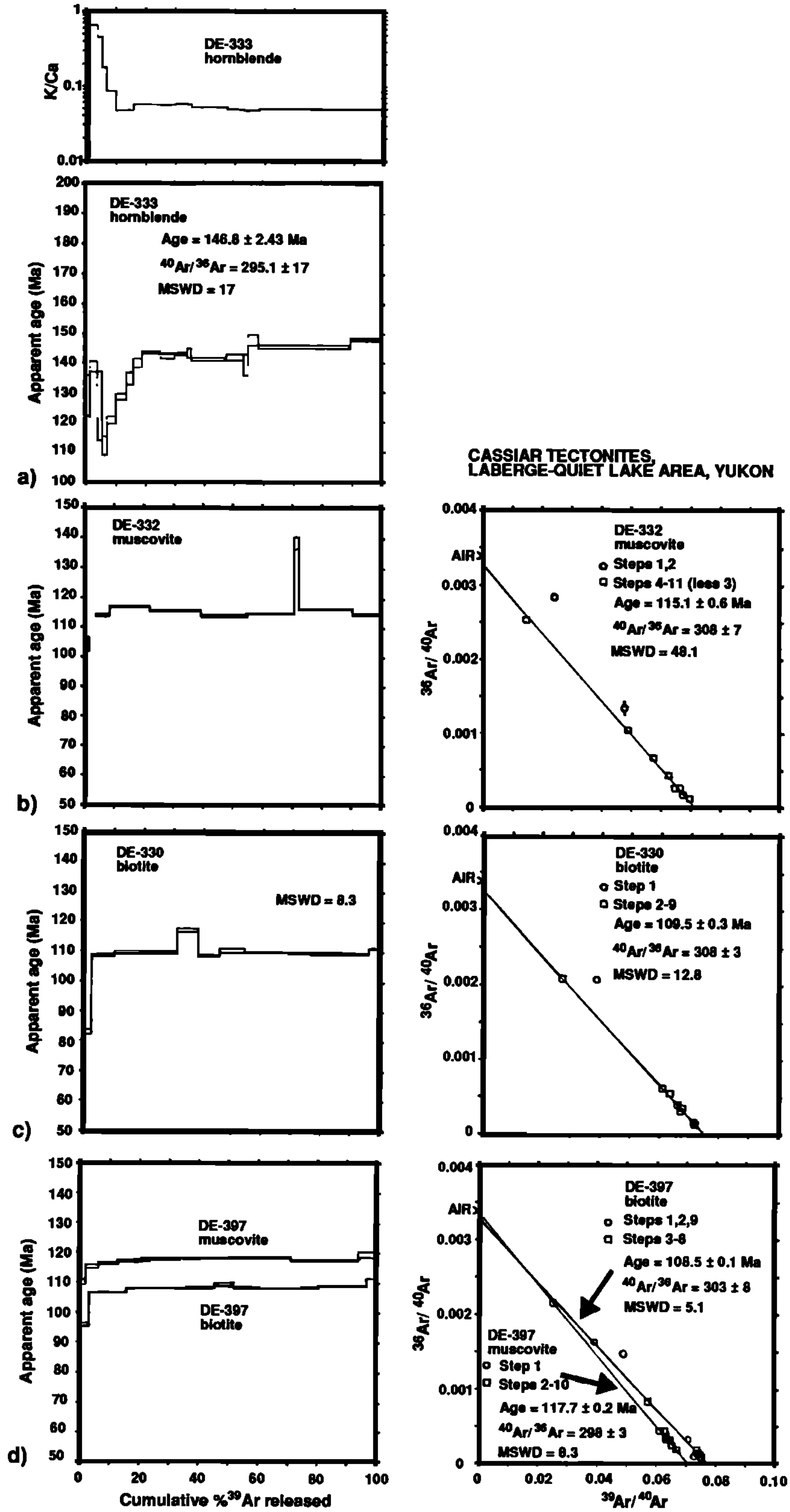


Fig. 4. (continued)

Mountain terrane [Harms et al., 1984; Coney and Jones, 1985]. Within this region, YT foliation is relatively flat-lying and gently deformed in regional warps [Cushing et al., 1984b; Foster, 1970, 1976; Foster et al., 1985, 1987]. L-S tectonites of the Teslin-Taylor Mountain and Nisutlin terranes (Y_4 and Y_3 as defined above) generally crop out in the northern part of the area, and orthogneiss assemblage L-S tectonites (Y_1 and Y_2) are exposed in the south and northwest. The region is extensively intruded by Upper Cretaceous plutons, which, unlike Upper Cretaceous northwest striking elongate plutons which intrude the YT in central and southern Yukon, have no apparent preferred shape orientation (Figures 1 and 3). These bodies are considered to be wholly post tectonic and place an upper limit on the timing of final juxtaposition of the tectonic slivers of the YT subterranes and Slide Mountain terrane rocks in this region.

The Teslin-Taylor Mountain and Nisutlin terranes are juxtaposed along a complex 1-3 km wide (map view), east-southeast striking, north-vergent thrust zone [Cushing et al., 1984a; Foster et al., 1984]. Greenschist facies Nisutlin tectonites display tight to isoclinal folds with east-southeast trending, gently plunging fold axes, whereas albite-epidote amphibolite facies Teslin-Taylor Mountain tectonites preserve tight to isoclinal folds with north-northeast trending, gently plunging fold axes [Cushing, 1984]. This discordance in fold orientations and the complex thrust contact led workers to postulate separate structural histories for rocks of the Teslin-Taylor Mountain and Nisutlin terranes [Cushing et al., 1984b; Foster et al., 1984, 1985].

Despite a difference in the orientation of fold axes in these two terranes, recent examination of Teslin-Taylor Mountain and Nisutlin tectonites along the Taylor Highway reveals a general north-northeast concordance in the trend of moderately developed elongation lineations, although east-west orientations are preserved locally (V. L. Hansen, unpubl. mapping, 1987) (Figure 3). Nisutlin structures are typically not well behaved, a possible result of the lower grade and less ductile character of deformation. Microstructures and quartz c-axis fabrics record both top-to-the-northeast and top-to-the-southwest shear sense in Teslin-Taylor Mountain and Nisutlin L-S tectonites, although north-vergent fabrics dominate ([V. L. Hansen, unpublished data0, 1989). The generally consistent trend of elongation lineations within Teslin-Taylor Mountain and Nisutlin rocks suggests that they share, at least in part, a common structural history. The difference in the orientation of the fold axes preserved within these two packages may reflect the crustal level at which each of these assemblages were deformed. Fold axes of the higher-grade Teslin-Taylor Mountain tectonites parallel the dominant elongation lineation; fold axes and elongation lineation are commonly parallel in highly strained rocks of high-grade terranes [see Bell and Hammond, 1984]. In contrast, fold axes in the greenschist facies Nisutlin rocks are commonly perpendicular to elongation lineations. Fold axes are commonly oriented normal to transport direction at shallow crustal levels consistent with greenschist facies metamorphic conditions [Sibson, 1977]. Therefore Teslin-Taylor Mountain and Nisutlin packages may have shared a structural history dominated by deformation associated with north-northeast to northeast tectonic transport, and they were juxtaposed along an east-southeast striking, 1-3 km wide, thrust zone late in their shared history. In either case, deformation of both of these packages must have occurred prior to, or during, their juxtaposition along an Early Jurassic thrust zone [Cushing, 1984; Cushing et al., 1984a].


DE-333
hornblende
K/Ca
DE-333
hornblende
Age = 146.8 ± 2.43 Ma
$^{40}Ar/^{36}Ar$ = 295.1 ± 17
MSWD = 17
Apparent age (Ma)
a)
CASSIAR TECTONITES,
LABERGE-QUIET LAKE AREA, YUKON
DE-332
muscovite
b)
DE-332
muscovite
Steps 1,2
Steps 4-11 (less 3)
Age = 115.1 ± 0.6 Ma
$^{40}Ar/^{36}Ar$ = 308 ± 7
MSWD = 48.1
AIR
$^{36}Ar/^{40}Ar$
DE-330
biotite
MSWD = 8.3
c)
DE-330
biotite
Step 1
Steps 2-9
Age = 109.5 ± 0.3 Ma
$^{40}Ar/^{36}Ar$ = 308 ± 3
MSWD = 12.8
DE-397
muscovite
DE-397
biotite
d)
Cumulative %^{39}Ar released
DE-397
biotite
Steps 1,2,9
Steps 3-8
Age = 108.5 ± 0.1 Ma
$^{40}Ar/^{36}Ar$ = 303 ± 8
MSWD = 5.1
DE-397
muscovite
Step 1
Steps 2-10
Age = 117.7 ± 0.2 Ma
$^{40}Ar/^{36}Ar$ = 298 ± 3
MSWD = 6.3
$^{39}Ar/^{40}Ar$

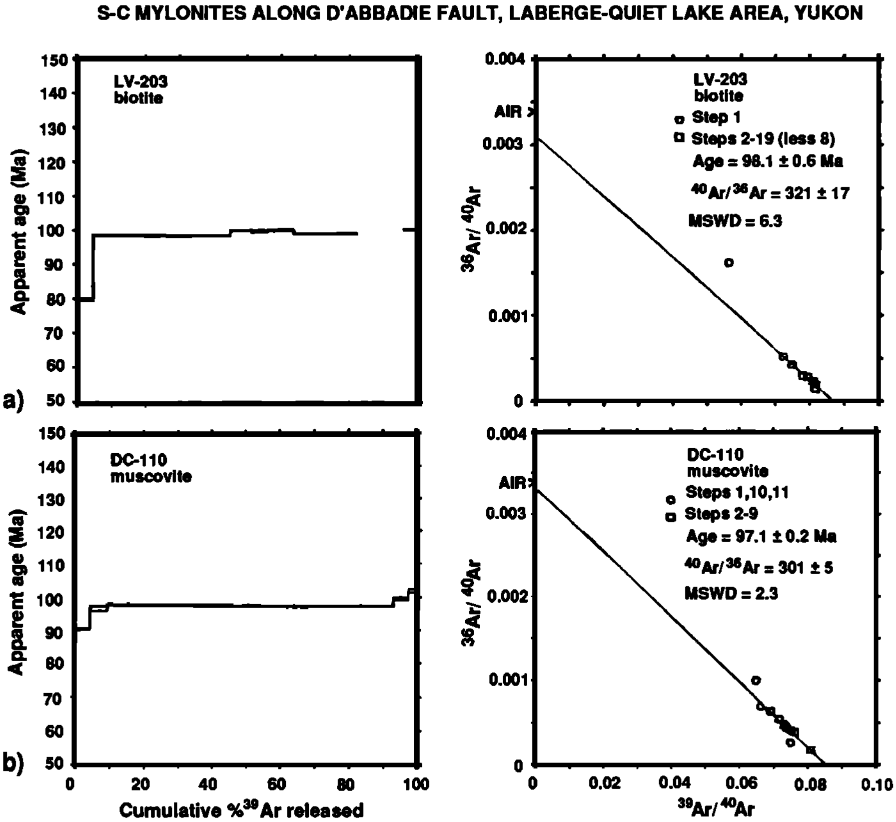


Fig. 6. ^{40}Ar/^{39}Ar incremental release spectra and isochron diagrams for S-C mylonites parallel to the dextral d'Abbadie fault, Laberge-Quiet Lake area, Yukon (Figure 2). (a) LV-203 biotite from peraluminous orthogneiss; steps 2-19 (less 8) yield a date of 98.1 ± 0.6 Ma and a ^{36}Ar/^{40}Ar component of 321 ± 17 with MSWD = 6.3. The minor hole in the age spectrum at step 8 results from accidental gas loss. (b) DC-110 muscovite from peraluminous orthogneiss; steps 2-9 yield a date of 97.1 ± 0.2 Ma and a ^{36}Ar/^{40}Ar component of 301 ± 5 with MSWD = 2.3.

Greenschist to amphibolite grade orthogneiss assemblage L-S tectonites preserve generally southeast to northwest trending, gently plunging elongation lineations; locally east-southeast lineations are preserved. Orthogneiss assemblage tectonites record top-to-the-southeast and top-to-the-northwest shear (Figure 3). Recent field study has documented an east-northeast axis north of which orthogneiss assemblage tectonites record top-to-the-northwest shear, and south of which they record top-to-the-southeast shear [Hansen, unpubl. data]. Locally, evidence of high-P/T metamorphic conditions is preserved; preliminary geothermobarometric analysis of paragneiss located near the axis of opposing shear sense yield peak metamorphic conditions of 600°-750°C at 8.2-12.4 kbar [Dusel-Bacon and Douglass, 1990].

Although contact relations between YT subterranes in this region are not well exposed, several important relationships with regard to these contacts can be gleaned from examination of the generalized geologic map (Figure 3). Weakly metamorphosed rocks of the Slide Mountain terrane lie in fault contact above greenschist facies Nisutlin rocks (Y_3), above greenschist to amphibolite facies (Y_2) rocks, and above epidote-amphibolite facies Teslin-Taylor Mountain rocks (Y_4) within the Taylor Highway area (Figure 3). In addition, north of Fairbanks, eclogite of the Chatanika terrane, here correlated

Fig. 5. ^{40}Ar/^{39}Ar incremental release spectra and isochron diagrams for Cassiar terrane tectonites east of the d'Abbadie fault, Laberge-Quiet Lake area, Yukon (Figure 2). (a) DE-333 hornblende; the apparent age gradient for the first 30% of gas released is probably related to outgassing of less retentive K-rich inclusions or exsolution lamellae during slow cooling. We regard the plateau at ~147 Ma as the time at which hornblende cooled below 500°C. (b) DE-332 muscovite; steps 4-11 (less 3) yield a date of 115.1 ± 0.6 Ma and a ^{36}Ar/^{40}Ar component of 308 ± 7, and MSWD = 48.1. The minor hole in the age spectrum at step 2 results from accidental gas loss. (c) DE-330 biotite from peraluminous orthogneiss; steps 2-9 yield a date of 109.5 ± 0.3 Ma and a ^{36}Ar/^{40}Ar component of 308 ± 3 with MSWD = 12.8. (d) DE-397 muscovite and biotite from peraluminous orthogneiss; steps 2-10 yield a date of 117.7 ± 0.2 Ma and a ^{36}Ar/^{40}Ar component of 298 ± 3 for muscovite with MSWD = 8.3, and steps 3-8 yield a date of 108.5 ± 0.1 Ma and a ^{36}Ar/^{40}Ar component of 303 ± 8 for biotite with MSWD = 5.1.

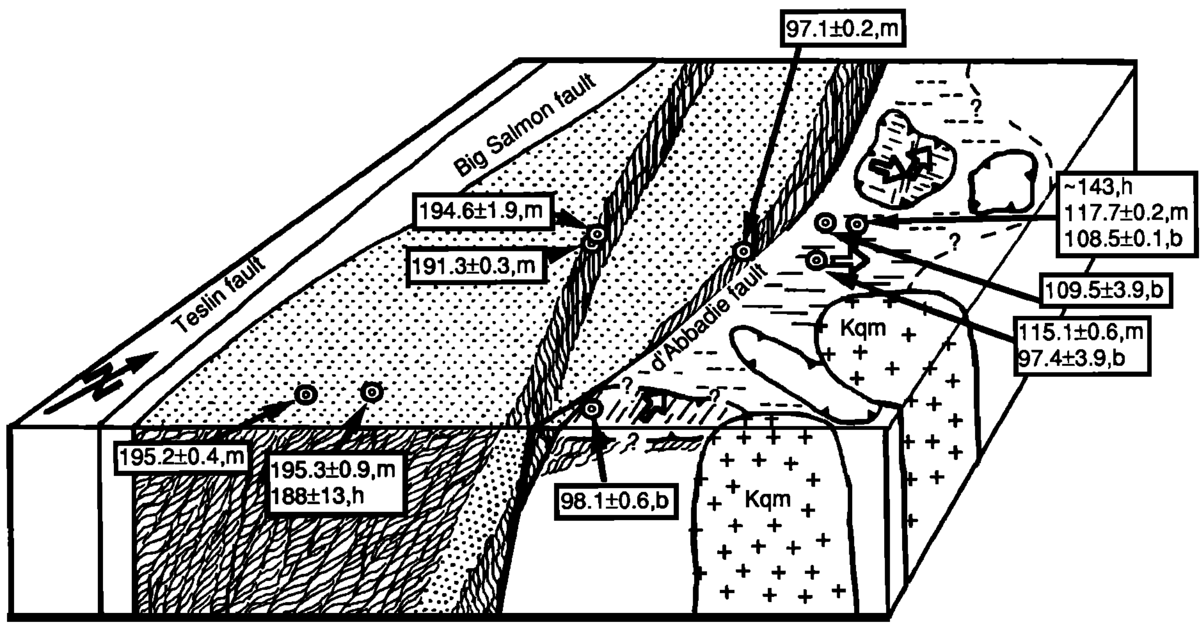


Fig. 7. Block diagram of the Laberge-Quiet Lake map area with $^{40}Ar/^{39}Ar$ dates. Abbreviations are b, biotite, h, hornblende, m, white mica, and Kqm, Cretaceous quartz monzonite.

with the Teslin-Taylor Mountain terrane on the basis of lithology and metamorphic grade, structurally overlies Fairbanks schist tectonites (Y_2) (Figure 1) [Laird and Foster, 1986]. Similarly, greenschist facies Nisutlin (Y_3) rocks are in fault contact with amphibolite facies rocks of the orthogneiss assemblage (Y_1) in the southern Taylor Highway map area, and epidote-amphibolite facies Teslin-Taylor Mountain (Y_4) rocks are in fault contact with the orthogneiss assemblage in the central part of the map area. Foster et al. [1987] interpret this as an imbricate north-vergent thrust stacking of Y_1 rocks above Y_4 rocks, which are in turn thrust above Y_3 rocks. Y_3 rocks are interpreted to be exposed as a structural window beneath Y_1 rocks in the south. $^{40}Ar/^{39}Ar$ data presented and discussed below are inconsistent with this interpretation.

Contractional thrust faults generally place deep crustal rocks on top of shallow crustal rocks, or high-grade above low-grade metamorphic assemblages. In contrast, extensional faults generally place low-grade rocks in abrupt contact above higher-grade rocks. We present here structural and thermochronological data that lead us to propose that the tectonic contacts between orthogneiss assemblage tectonites and Teslin-Taylor Mountain and Nisutlin tectonites within the Taylor Highway area, and by extrapolation elsewhere in Alaska and western Yukon, may be extensional fault contacts.

We conducted $^{40}Ar/^{39}Ar$ step-heating gas release experiments on seven mineral separates from four Teslin-Taylor Mountain tectonites and four mineral separates from two orthogneiss assemblage tectonites. Age spectra and isochron diagrams for these samples are shown in Figures 8 and 9, respectively. The $^{40}Ar/^{39}Ar$ dates determined through this study, and previous studies in this region, are shown in Figure 10.

The hornblende, biotite, and white mica samples from the Teslin-Taylor Mountain terrane (TH-11, 29, 39, and 115) exhibit very well correlated isochron data (Figure 8). Dates range from ~185 to 190 Ma for all of the samples with hornblende-biotite pairs discordant by ~2 Ma (Table 2). These data indicate that this package was cooled through 300°C by middle Early Jurassic time (~185 Ma), and the slight discordance in hornblende-biotite dates indicates a cooling rate of ~100°C/Ma, which corresponds to an uplift rate of ~4 mm/yr assuming a 25°C/km geotherm. These data are consistent with $^{40}Ar/^{39}Ar$ data of Cushing [1984], but the data presented here have greater analytical precision.

Orthogneiss assemblage tectonites yield significantly different cooling dates, as expected based on Cretaceous K-Ar ages determined for Y_1 and Y_2 subterrane rocks [Wilson et al., 1985, and references cited therein]. Muscovite and biotite pairs extracted from two peraluminous orthogneiss samples (TH- 42 and 55) yield well-constrained, concordant mid-Cretaceous isochron dates of ~110 Ma (Figure 9). Sample TH-55 displays well-developed penetrative S-C fabrics which record top-to-the-northwest shear, whereas sample TH-42 records top-to-the-southeast shear. We suggest that orthogneiss TH-55 acquired its L-S tectonite fabric as structurally higher rocks were shed in a northwesterly direction during mid-Cretaceous crustal extension and that orthogneiss TH-42 acquired its similar fabric as structurally higher rocks were displaced to the southeast during the same extensional episode. Muscovite and biotite cooling ages (350°-300°C at 110-109 Ma) taken together with the $^{40}Ar/^{39}Ar$ hornblende date of 119 Ma (cooling through 500°C) from an adjacent lithology [Dusel-Bacon et al., in press], indicate cooling (~20°C/Ma) of these tectonites from 119 Ma to 110 Ma. We interpret that cooling resulted from uplift of this part of the orthogneiss assemblage during regional mid-Cretaceous crustal extension. Lower plate orthogneiss assemblage tectonites acquired their characteristic northwest-southeast trending elongation lineation during this extensional episode.

In line with earlier suggestions [Duke et al., 1988; Hansen et al., 1988; Hansen, 1990a, b; Pavlis et al., 1988; Pavlis,

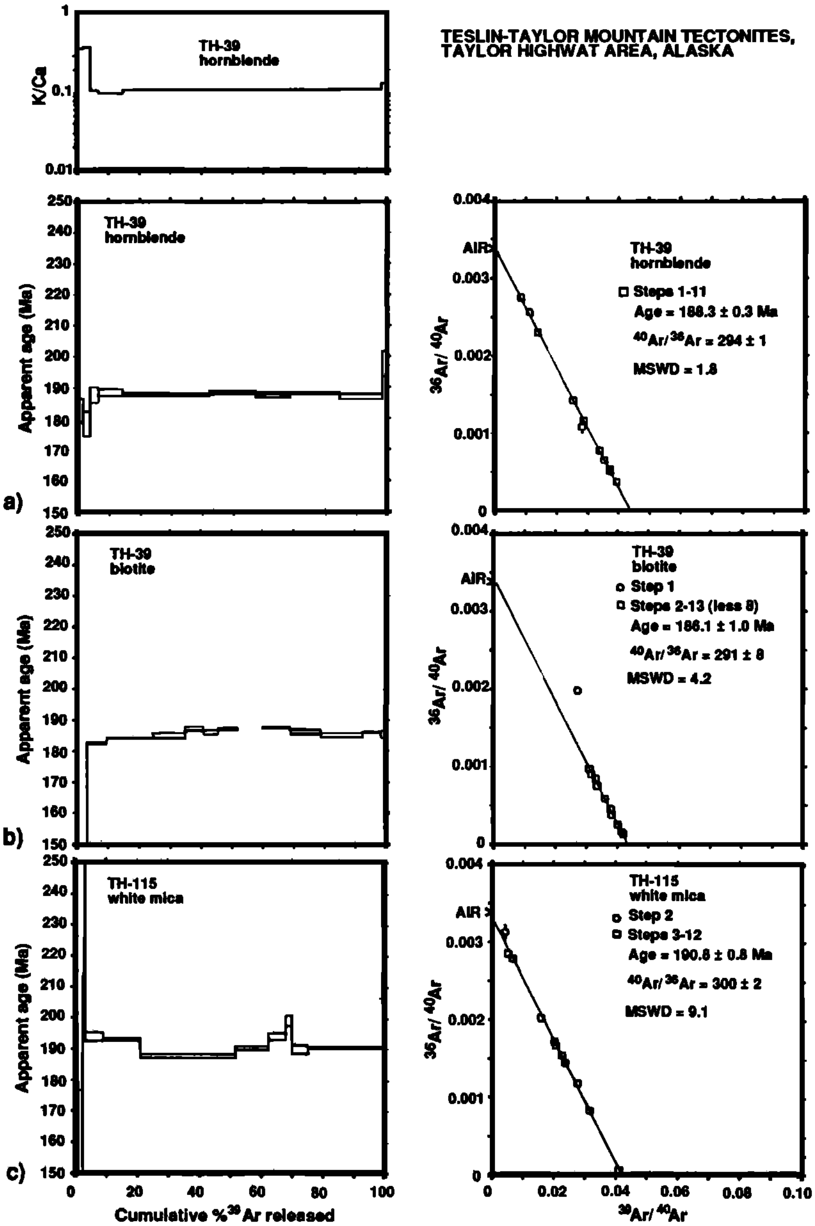


Fig. 8. $^{40}Ar/^{39}Ar$ incremental release spectra and isochron diagrams for Teslin-Taylor Mountain terrane tectonites from the Taylor Highway area, Alaska (Figure 3). (a) TH-39 hornblende; steps 1-11 yield a date of 188.3 ± 0.3 Ma and a $^{36}Ar/^{40}Ar$ component of atmospheric composition with MSWD = 1.8. (b) TH-39 biotite; steps 2-13 yield a date of 186.1 ± 1.0 Ma and a $^{36}Ar/^{40}Ar$ component of 291 ± 8, and MSWD = 4.2. (c) TH-115 white mica; steps 3-12 yield a date of 190.8 ± 0.8 Ma and a $^{36}Ar/^{40}Ar$ component of 300 ± 2 with MSWD = 9.1.

1989], we propose that many of the contacts between YT orthogneiss assemblage tectonites and rocks of the Slide Mountain, Teslin-Taylor Mountain, or Nisutlin terranes may be extensional shear zones reflecting mid-Cretaceous crustal extension in which structurally higher Slide Mountain, Teslin-Taylor Mountain, and Nisutlin terrane rocks were down dropped and juxtaposed against tectonically denuded orthogneiss assemblage rocks. This interpretation is consistent with the bimodal character of the cooling dates recorded in the Teslin-Taylor Mountain terrane and the orthogneiss assemblage, with structural and kinematic data, and with the metamorphic discordance between higher-grade orthogneiss assemblage rocks and lower-grade rocks of the Slide Mountain, Nisutlin, and Teslin-Taylor Mountain terranes. By this interpretation the YT orthogneiss assemblage forms the lowest structural level of the YT which was uplifted

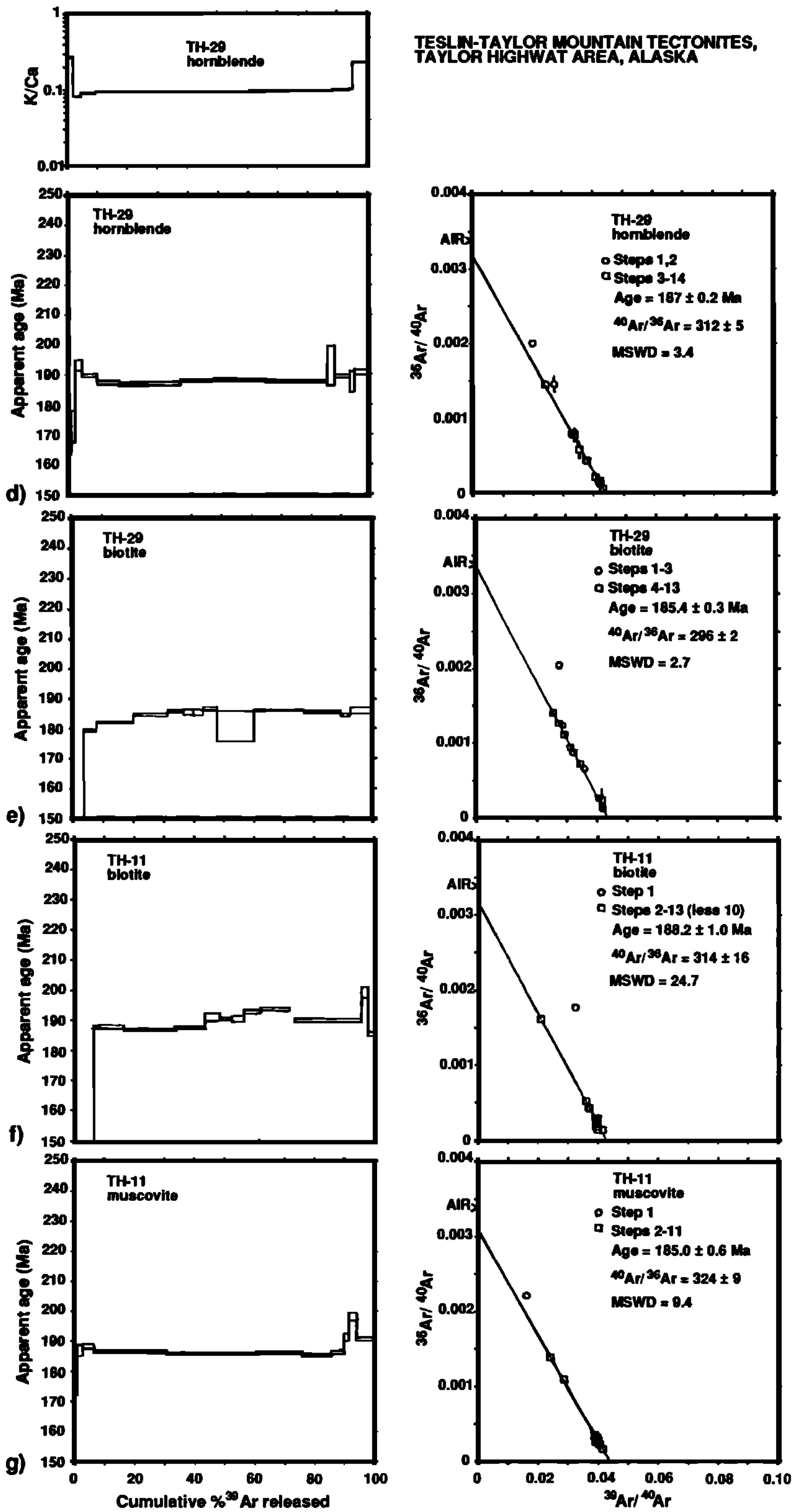


Fig. 8. (continued) $^{40}Ar/^{39}Ar$ incremental release spectra and isochron diagrams for Teslin-Taylor Mountain terrane tectonites from the Taylor Highway area, Alaska (Figure 3). (d) TH-29 hornblende; steps 3-14 yield a date of 187 ± 0.2 Ma and a $^{36}Ar/^{40}Ar$ component of 312 ± 5, and MSWD = 3.4. (e) TH-29 biotite; steps 4-13 yield a date of 185.4 ± 0.3 Ma and a $^{36}Ar/^{40}Ar$ component of atmospheric composition with MSWD = 2.7. (f) TH-11 biotite; steps 2-13 (less 10) yield a date of 188.2 ± 1.0 Ma and a $^{36}Ar/^{40}Ar$ component of 314 ± 16 with MSWD = 24.7. (g) TH-11 white mica; steps 2-11 yield a date of 185.0 ± 0.6 Ma and a $^{36}Ar/^{40}Ar$ component of 324 ± 9 with MSWD = 9.4.

as a result of northwest-southeast directed mid-Cretaceous crustal extension. The lower plate orthogneiss assemblage cooled at this time, but not before. In contrast, upper plate Teslin-Taylor Mountain rocks record Early Jurassic or older cooling dates which greatly predate crustal extension. These dates could record precollision deformation with uplift and cooling resulting from to collision with North American rocks, or the cooling dates could record cooling synchronous with collision-related deformation. We believe that these tectonites were deformed dominantly prior to uplift and cooling and that the deformation represents dominantly precollision, or preterrane accretion deformation.

YT DUCTILE DEFORMATIONS

On the basis of the structural, kinematic, and thermochronometric data presented above we can distinguish four spatially, kinematically, and temporally distinct ductile deformation events which are variably recorded in YT tectonites. The regional distribution, structural and kinematic vergence, P-T conditions, as summarized below, and timing of each of these events must be incorporated into any model of Mesozoic YT tectonic evolution.

Preearly Early Jurassic Preaccretion(?) Deformation

Preearly Early Jurassic deformation and high P/T metamorphism of Teslin-Taylor Mountain and Nisutlin terrane tectonites is recorded in Alaska and Yukon. In Yukon this deformation and associated metamorphism is best documented within the Teslin suture zone [Hansen, 1987; 1989]. Teslin suture zone fabrics record initial dip-slip penetrative deformation (D_{ds}) which progressively evolved into dextral translation along a 1-3 km wide anastomosing shear zone (D_{ss}). D_{ds} hornblende and white mica and D_{ss} white mica all yield $^{40}Ar/^{39}Ar$ plateau ages of ~194 Ma, indicating rapid cooling of these rocks.

Similarly, in east central Alaska, Teslin-Taylor Mountain and Nisutlin tectonites record dominantly orogen-normal (north-northeast) elongation lineations, and hence tectonic transport, and local orogen-parallel (east) elongation lineations. Teslin-Taylor Mountain tectonites record peak high-P/T metamorphic conditions [Dusel-Bacon and Douglass, 1990], and hornblende and biotite $^{40}Ar/^{39}Ar$ dates of ~188 and 186 Ma, respectively. These data provide a minimum age for ductile deformation and indicate rapid cooling in Early Jurassic time. Teslin-Taylor Mountain cooling dates from both Alaska and Yukon indicate cooling through 500-300°C in 2 Ma, which corresponds to an uplift rate of ~4 mm/yr, assuming a 25°C/km geotherm. These dates corroborate previously determined Rb-Sr and K-Ar cooling dates (Yukon [Hansen et al., 1989]; Alaska [Cushing, 1984; Cushing et al. [1984a]). Calculated uplift rates are similar to those determined for the Himalayan Pliocene uplift [Copeland et al., 1988]. Teslin-Taylor Mountain and Nisutlin tectonites are the only YT rocks that record moderately high-P/T deformation and that consistently yield > 180 Ma cooling ages (through 300°C). These terranes lack a Cretaceous age cooling signature (except where these rocks are adjacent to Cretaceous plutons), which is characteristic of the orthogneiss assemblage.

Uplift is interpreted as the result of subduction-related collision of Teslin-Taylor Mountain and Nisutlin rocks with North American strata [Hansen, 1988, 1990a, b]. We interpret that rapid cooling in Early Jurassic time was the result of emplacement of Teslin-Taylor Mountain above North American-Cassiar strata. This interpretation implies that the structural fabrics preserved in the Teslin-Taylor Mountain and Nisutlin tectonites record pre-Early Jurassic preaccretionary to synaccretionary deformation.

Early Jurassic (?) to Mid-Cretaceous Synaccretion(?) Deformation

$^{40}Ar/^{39}Ar$ analyses from Devonian-Mississippian orthogneiss and host metasedimentary rocks of the Cassiar terrane east of the d'Abbadie fault yield Jurassic-Cretaceous cooling ages. Hornblende, white mica, and biotite from ductiley sheared rocks which record top-to-the-east sense of shear yield $^{40}Ar/^{39}Ar$ dates of 150, 117, and 110 Ma, respectively. These data indicate that ductile deformation may have begun prior to 150 Ma. These data also indicate slow cooling of ~5°C/Ma, which corresponds to an uplift rate of ~0.2 mm/yr, assuming a 25°C/km geotherm.

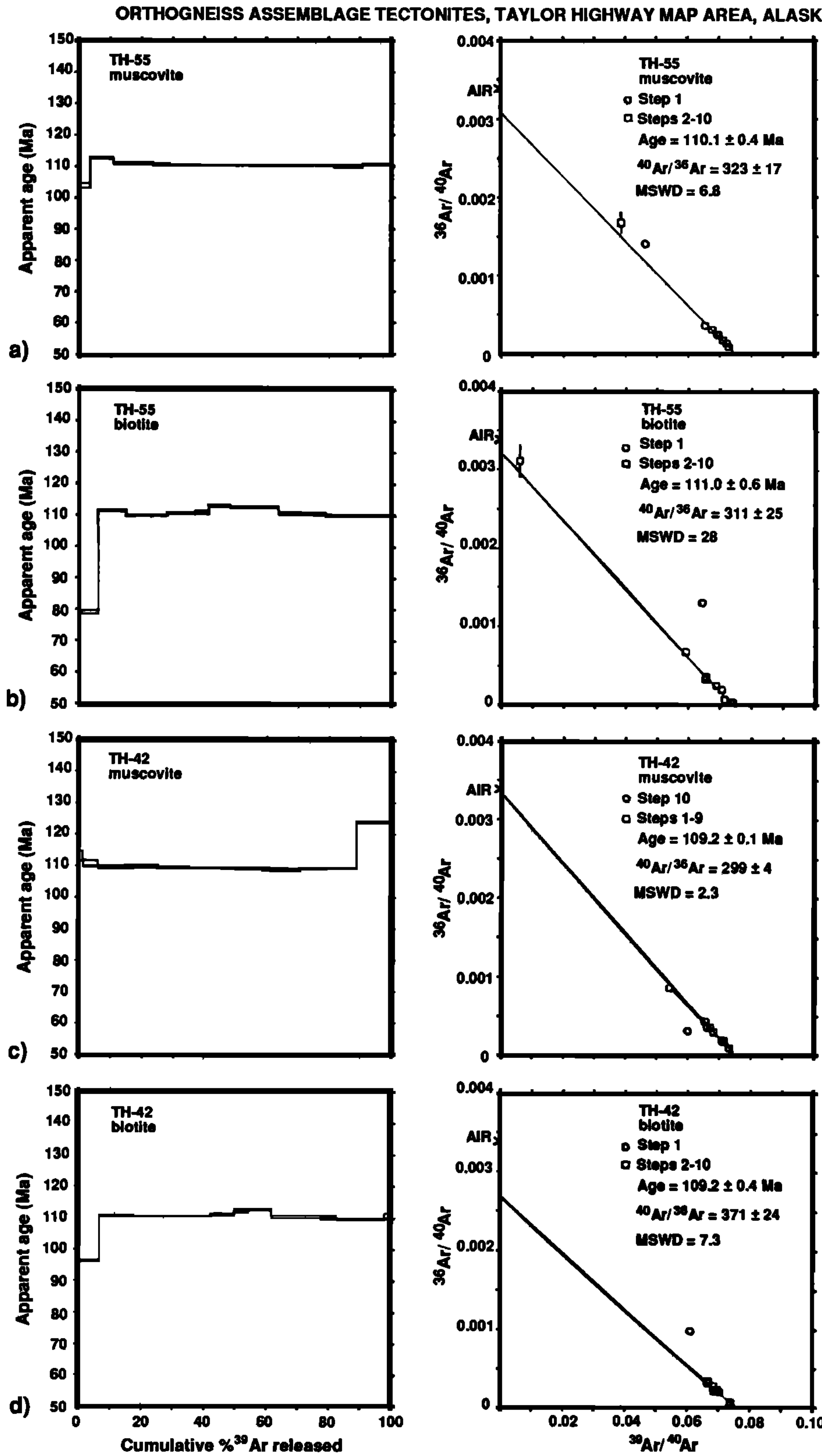
Pre-mid-Cretaceous thrust imbrication of North American continental strata has long been recognized in Yukon [e.g., Tempelman-Kluit, 1977]. However, this deformation has typically been described in upper crustal rocks represented by low-grade to unmetamorphosed Triassic or older strata; neither North American basement nor ductile roots of these thrust faults have been previously described. We interpret that Cassiar tectonites discussed here may preserve the ductile roots of pre-mid-Cretaceous thrusts within the Laberge-Quiet Lake area, Yukon.

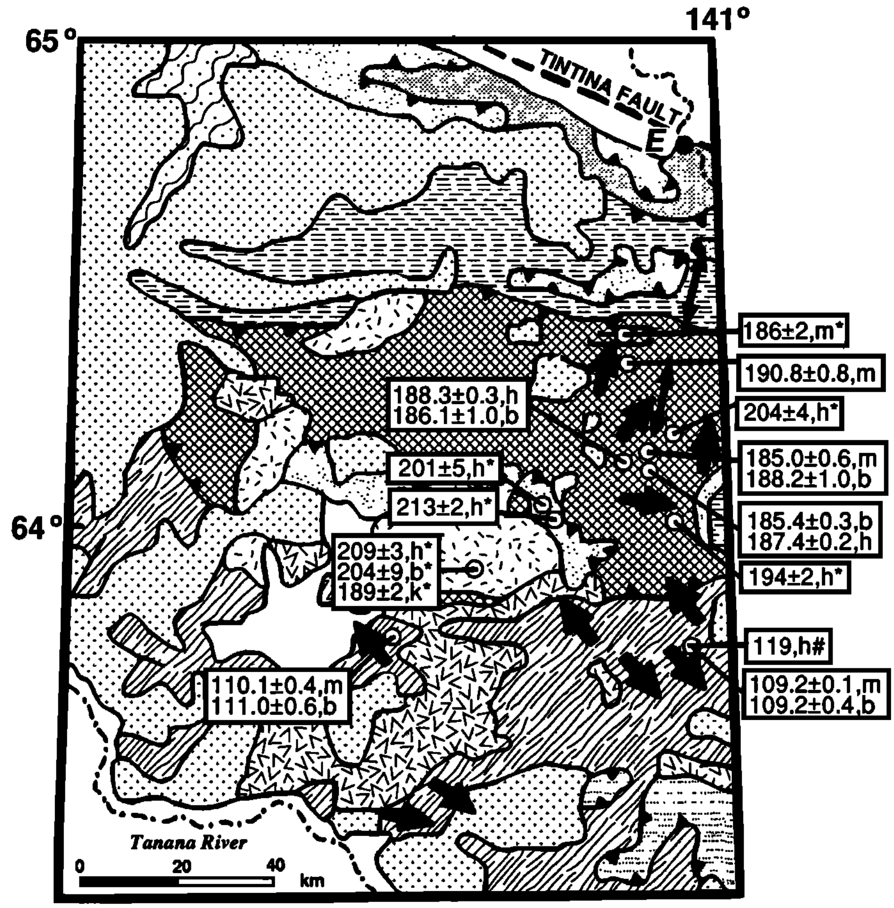
We interpret the discordance of Cassiar tectonite mineral cooling dates to reflect uplift and cooling of these rocks following overthrusting of Teslin-Taylor Mountain allochthons at ~190 Ma. This interpretation contrasts with suggestions of reheating by Upper Cretaceous plutons [e.g., Armstrong, 1988]. Although Cretaceous plutons may be responsible for localized resetting of isotopic systems in tectonites adjacent to the pluton, ongoing study of the Big Salmon and Nisutlin batholiths and their wall rocks in the eastern Quiet Lake map sheet indicates that intrusion of these large bodies resulted in limited thermal effects of their wall rocks [Spicuzza and Hansen, 1989].

Rocks affected by this newly recognized ductile deformation are correlated with North American (Cassiar) Paleozoic strata on the basis of lithology and field relationships [Tempelman-Kluit, 1977], although they include orthogneiss which is correlative with peraluminous orthogneiss of the YT orthogneiss assemblage on the basis of lithology and U-Pb (zircon), Sm-Nd, and initial strontium isotopic data [Bennett and Hansen, 1988; Hansen et al., 1989]. Therefore these data are consistent with an interpretation that the YT orthogneiss assemblage is correlative with Precambrian to Triassic parautochthonous North American strata as suggested by Hansen [1990a, b].

Mid-Cretaceous Crustal Extension

Orthogneiss assemblage tectonites in eastern Alaska yield mid-Cretaceous metamorphic cooling dates, in strong contrast to Early Jurassic cooling ages recorded in adjacent Teslin-Taylor Mountain and Nisutlin rocks. In addition, the structurally lower orthogneiss assemblage tectonites locally record higher metamorphic facies than adjacent Teslin-Taylor Mountain rocks or Slide Mountain terrane assemblages as documented northeast of Fairbanks [Laird and Foster, 1986], within the Dawson area [Mortensen, 1988a], in central and southern Yukon [Tempelman-Kluit, 1979], and elsewhere in


ORTHOGNEISS ASSEMBLAGE TECTONITES, TAYLOR HIGHWAY MAP AREA, ALASKA
a)
TH-55 muscovite
TH-55 muscovite
Step 1
Steps 2-10
Age = 110.1 ± 0.4 Ma
40Ar/36Ar = 323 ± 17
MSWD = 6.8
b)
TH-55 biotite
TH-55 biotite
Step 1
Steps 2-10
Age = 111.0 ± 0.6 Ma
40Ar/36Ar = 311 ± 25
MSWD = 28
c)
TH-42 muscovite
TH-42 muscovite
Step 10
Steps 1-9
Age = 109.2 ± 0.1 Ma
40Ar/36Ar = 299 ± 4
MSWD = 2.3
d)
TH-42 biotite
TH-42 biotite
Step 1
Steps 2-10
Age = 109.2 ± 0.4 Ma
40Ar/36Ar = 371 ± 24
MSWD = 7.3
Apparent age (Ma)
36Ar/40Ar
AIR
Cumulative %39Ar released
39Ar/40Ar



TAYLOR HIGHWAY MAP AREA, ALASKA

Fig. 10. Map of the Taylor Highway area, Alaska, showing the location of $^{40}Ar/^{39}Ar$ ages from this study and previous studies. Symbols are * [Cushing, 1984] and # [Dusel-Bacon, 1990]. Abbreviations are h, hornblende, m, white mica, b, biotite. Units and other symbols are the same as in Figure 3.

Alaska [Coney and Jones, 1985]. Similar discordant metamorphic relationships have been documented in the Brooks Range [Miller, 1987] and the Seward Peninsula [Miller et al., 1990]. In east central Alaska, orthogneiss assemblage tectonites record northwest-trending elongation lineations, whereas Teslin-Taylor Mountain and Nisutlin tectonites preserve dominantly north-northeast trending elongation lineations.

Mid-Cretaceous crustal extension, recently documented in eastern Alaska in the western [Pavlis et al., 1988], southern [Duke et al., 1988] and eastern [Hansen, 1989] parts of the YT, could explain the juxtaposition of lower-grade Teslin-Taylor Mountain rocks on higher-grade orthogneiss assemblage rocks, the difference in elongation lineation orientation in the two terranes, and their contrasting cooling histories. This mid-Cretaceous juxtaposition of upper plate Teslin Taylor Mountain-Nisutlin-Slide Mountain rocks with lower plate orthogneiss assemblage rocks may locally obliterate evidence of earlier interterrane relationships and therefore contribute to the difficulty in defining the time of "terrane emplacement". Crustal extension has been proposed to explain similar geological relationships in the similar age

Fig. 9. $^{40}Ar/^{39}Ar$ incremental release spectra and isochron diagrams for Nisling terrane tectonites from the Taylor Highway area, Alaska (Figure 3). (a) TH-55 muscovite from peraluminous orthogneiss; steps 2-10 yield a date of 110.1 ± 0.4 Ma and a $^{36}Ar/^{40}Ar$ component of 323 ± 17 with MSWD = 6.8. (b) TH-55 biotite from peraluminous orthogneiss; steps 2-10 yield a date of 111.0 ± 0.6 Ma and a $^{36}Ar/^{40}Ar$ component of 311 ± 25 with MSWD = 28. (c) TH-42 muscovite from peraluminous orthogneiss; steps 1-9 yield a date of 109.2 ± 0.1 Ma and a $^{36}Ar/^{40}Ar$ component of 299 ± 4 with MSWD = 2.3. (d) TH-42 biotite; steps 2-10 yield a date of 109.2 ± 0.4 Ma and a $^{36}Ar/^{40}Ar$ component of 371 ± 24 with MSWD = 7.3.

tectonites of the Brooks Range [Miller, 1987] and the Seward Peninsula [Miller et al., 1990]. We postulate that essentially all rocks of the orthogneiss assemblage in the hinterland of the McKenzie fold and thrust belt (Figure 1) represent metamorphosed North American strata. These rocks were structurally overridden by the Teslin-Taylor Mountain, Nisutlin, and Slide Mountain terranes in Late Triassic to Early Jurassic time and exposed as a result of mid-Cretaceous crustal extension. High-P metamorphic conditions documented locally in orthogneiss assemblage tectonites in the Taylor Highway map area [Dusel-Bacon and Douglass, 1990] may reflect tectonic burial of these rocks during overthrusting. Mid-Cretaceous crustal extension was complete by the time of intrusion of early Late Cretaceous age plutons, which are undeformed and cross cut all terrane contacts.

Mid to Late Cretaceous Strike-Slip Translation and Plutonism

The d'Abbadie fault experienced dextral displacement under ductile crustal conditions as late as 97 Ma, as evidenced by muscovite and biotite cooling ages from dextrally sheared orthogneiss which parallels the strike of the fault. The sense of later displacement along the fault under brittle crustal conditions is not known. However, brittle deformation probably predated intrusion of the Quiet Lake batholith which truncates the fault [Tempelman-Kluit, 1977]. In central and southern Yukon, between the d'Abbadie and Tintina faults, elongate granitoids parallel northwest striking dextral Cretaceous shear zones [Gabrielse, 1985]. Dextral shear is broadly synchronous with the emplacement of Cretaceous granitoids, although it can be shown to predate and postdate plutonism locally [Gabrielse, 1968, 1985; Gabrielse and Dodds, 1982]. The strike of mid to Late Cretaceous shear zones and elongate plutons reflect a major transcurrent strain regime in this segment of the northern Cordillera [Gabrielse, 1985].

It appears that deformation related to transcurrent tectonism dominantly (or perhaps completely) postdates mid-Cretaceous cooling and uplift of Cassiar tectonites in the Laberge-Quiet Lake area away from strike-slip shear zones. Cassiar tectonites that are intruded by Cretaceous granitoids yield muscovite and biotite $^{40}Ar/^{39}Ar$ cooling dates of >109 Ma, whereas granitoids generally yield K-Ar cooling dates of 100-70 Ma [Tempelman-Kluit, 1977, 1979; Gabrielse, 1985].

WORKING TECTONIC MODEL

The structurally, kinematically, and temporally distinct ductile deformation events discussed above can be explained by a comprehensive tectonic model of oblique convergence and resultant terrane collision and accretion. The model builds on those proposed by Tempelman-Kluit [1979] and Hansen [1990a, b].

Beginning in Devonian-Mississippian time, peraluminous granitoids were emplaced into North American continental strata (Figure 11a). U-Pb and Sm-Nd data reflect the continental crustal affinity of these rocks, and their significantly younger cooling histories are consistent with a lower plate structural position. These data can be explained by a relationship in which orthogneiss assemblage protoliths are (para)autochthonous with respect to North America. The origin of the granitic magmas is beyond the scope of this discussion and lacks general consensus; magmatism may have resulted from subduction [Mortensen, 1988b; Rubin et al., 1989, in press], crustal thickening, or rifting (M. Churkin, personal communication, 1987). Following, or perhaps related to, plutonism, a basin formed outboard of western North America (present-day coordinates) (Figure 11b). The basin may have formed as a result of rifting of the westernmost margin of North America that resulted in isolation of a fragment of North American continental crust, which hosts Devonian-Mississippian peraluminous granites, to form the western boundary of that basin (possibly Nisling rocks, as illustrated in Figures 1 and 11). The basin was built at least in part on oceanic crust locally preserved as ophiolite assemblages within the Slide Mountain terrane. Neither the size of this basin nor the orientation of spreading centers is known. The basin may have been a large paleo-Pacific ocean [Harms, 1986; Anvil ocean of Tempelman-Kluit, 1979] or a narrow marginal basin, similar to that forming the Gulf of California today [Nelson et al., 1989]. Ocean-type crust formation probably continued through Mississippian and Permian time, as suggested by exhalites of these ages within the Slide Mountain terrane [Nelson and Bradford, 1987; Nelson et al., 1988].

In Permian time, southwest-dipping, right-oblique subduction outboard of western North America began to close the basin (Figure 11c). Permian (Rb-Sr mineral cooling ages [Erdmer & Armstrong, 1988]) eclogite and blueschist, interpreted to be from the Teslin-Taylor Mountain and Nisutlin terranes, place a minimum age on subduction initiation. The Permian age Sulfur Creek orthogneiss near Dawson [Mortensen, 1988b] and Permian dikes in Slide Mountain rocks [Harms, 1986] may represent plutonism resulting from this subduction. The basin continued to close during right-oblique subduction, as determined from pre-Early Jurassic dextral shear zones (D_{as}) within the Teslin suture zone [Hansen, 1989]. The western overriding plate was composed of an arc complex (possibly Stikine, built in part on Nisling rocks (?) (North American strata before rifting?) and, in part, on oceanic crust) and an accretionary complex. Moderate to deep crustal levels of the accretionary complex are represented by ductiley deformed Teslin-Taylor Mountain and Nisutlin tectonites, which record coherent to localized high-P/T metamorphism, and higher crustal levels by the Slide Mountain terrane. The accretionary complex incorporated progressively more autochthonous strata, at structurally lower levels, as the basin closed, as reflected in the stacking order of the Sylvester allochthon [Nelson et al., 1988, 1989].

This tectonic package overrode North America earlier to the south along the Cordillera (Figure 11d), consistent with right-oblique subduction and older cooling dates of the Teslin-Taylor Mountain and Nisutlin terranes in Yukon relative to Alaska. Where along the Cordillera North American continental crust began to underthrust the (Nisling-Stikine-)Teslin-Taylor Mountain-Nisutlin-Slide Mountain composite terrane is not known; however, initial crustal thickening related to terrane emplacement was probably not great in northern British Columbia and southern Yukon (Figures 1 and 11e), where Slide Mountain rocks of the Sylvester allochthon lie structurally above unmetamorphosed Cassiar rocks [Harms, 1986]. Within the Laberge-Quiet Lake map area, Cassiar rocks appear to be involved in ductile deformation related to terrane emplacement. With continued subduction, North American continental crust was underthrust farther beneath the accreting terrane; it shortened along intracontinental shear zones and thickened as a result of imbrication and terrane obduction (Figure 11f). Following emplacement of (Nisling-Stikine-)Teslin-Taylor Mountain-Nisutlin-Slide Mountain composite terrane onto North American continental crust, we postulate that subduction polarity changed to the east beneath

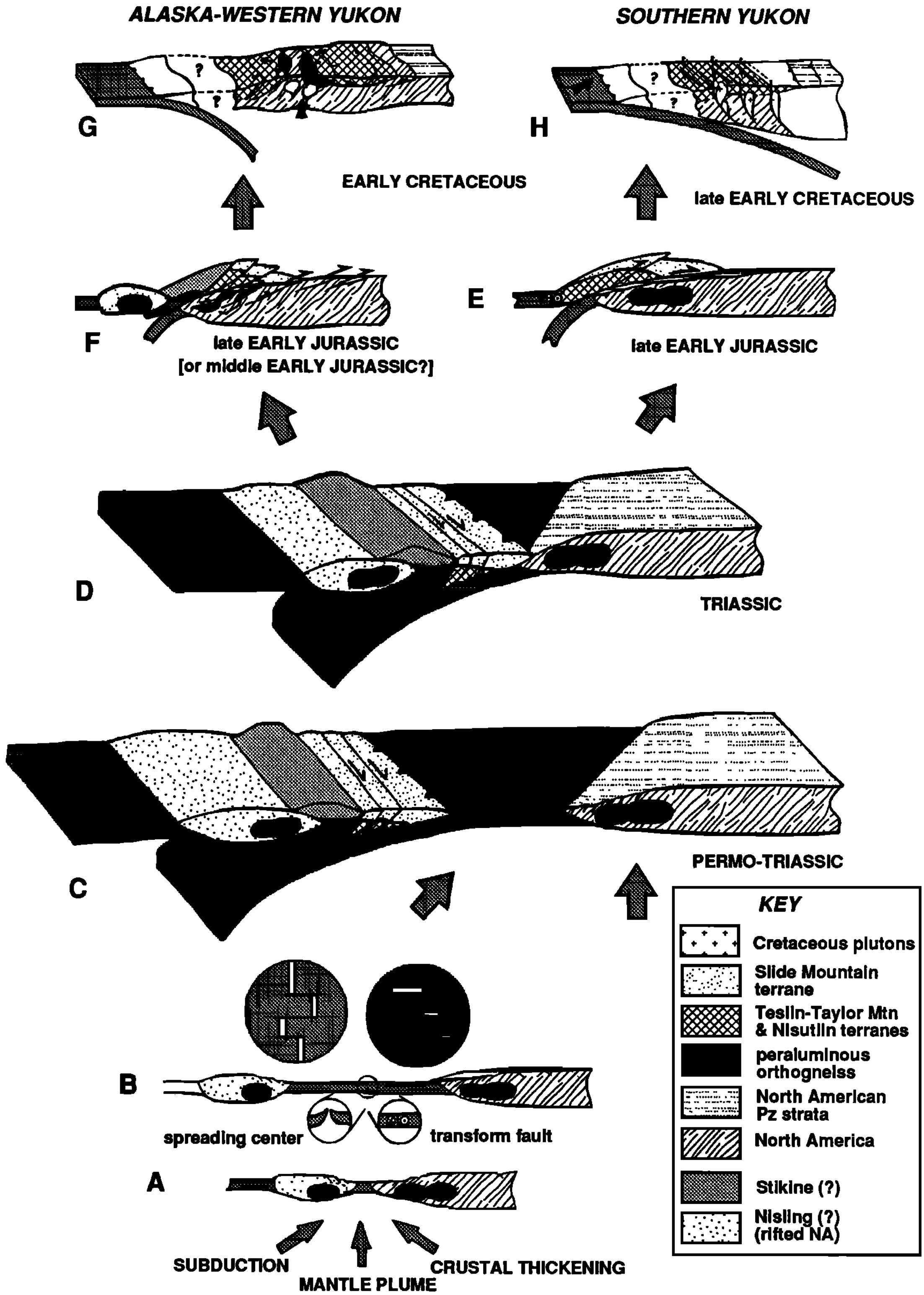


Fig. 11. Tectonic model for late Paleozoic to Mesozoic evolution of Teslin-Taylor Mountain, Nisutlin, and Slide Mountain terranes and the orthogneiss assemblage and adjacent Cassiar-North American strata. In stages G and H, the upper plate terrane is shown as a single unit for simplicity. See text for explanation. Modified from Hansen [1990b].

North America (Figures 11g and 11h), although this is not constrained by the data presented here.

Northwestern North American crust was not everywhere overridden to the same extent, or shortened as a result of composite terrane collision; hence it was not everywhere equally thickened. It appears the North American crust was dominantly overthickened in the hinterland to the McKenzie fold and thrust belt, western Yukon and eastern Alaska. As a result of this crustal overthickening, North American crust underwent gravitational collapse and resultant crustal extension (Figure 11g) [e.g., Dewey, 1988; Pavlis, 1989]. Mid-Cretaceous extension resulted in tectonic unroofing and exposure of previously underthrust North American strata (orthogneiss assemblage). Regions that were not thickened to the point of tectonic instability, in northern British Columbia and southern Yukon, did not collapse due to extension (Figure 11e); rather, they were uplifted at rates consistent with erosional denudation. Right-oblique subduction beneath North America in Cretaceous time [Engebretson et al., 1985; Debiche et al., 1987] resulted in dextral translation of tectonic slivers of North American crust (including now accreted Teslin-Taylor Mountain, Nisutlin, and Slide Mountain rocks) along subduction-related (?) margin-parallel shear zones such as the d'Abbadie fault (Figure 11h) [e.g., Beck, 1986]. Magma following margin-parallel crustal weaknesses in Yukon intruded as elongate northwest striking bodies in Cretaceous time.

This tectonic scenario can serve as a working model in which to view the evolution and accretion of the easternmost terranes in the northern Cordillera. This set of hypotheses explains some of the data not adequately explained in previous models of YT evolution: (1) the continental character of the orthogneiss assemblage, and U-Pb inheritance and Sm-Nd model ages consistent with North American cratonal values; (2) the low structural position of the orthogneiss assemblage with respect to the Teslin-Taylor Mountain, Nisutlin, and Slide Mountain terranes; (3) Teslin-Taylor Mountain-Nisutlin and orthogneiss assemblage diachronous cooling ages; (4) the location of orthogneiss assemblage rocks within the hinterland of the McKenzie fold and thrust belt; (5) local differences in metamorphic grade between the orthogneiss assemblage and Teslin-Taylor Mountain-Nisutlin, and the metamorphic gradient within Teslin-Taylor Mountain-Nisutlin tectonites; and (6) the stacking order within the Slide Mountain Sylvester allochthon with increasing autochthonous character of the structurally lower, and eastward, packages.

In addition, this model makes several predictions with respect to Nisling and Stikine terrane rocks west of the YT. Gehrels et al. [1990a] suggest that Stikine rocks may lie depositionally, at least locally, above Nisling strata. The Nisling terrane could represent a fragment of rifted North America in Devonian-Mississippian time (Figures 11c and 11d). This suggestion explains (1) the continental character of Nisling rocks, and the association of Devonian-Mississippian peraluminous orthogneiss with these rocks [Gehrels et al., 1990a, c; McClelland et al., 1990; Saleeby and Rubin, 1990; Samson et al., 1990]; (2) the dominant primitive character of Stikine [Samson et al., 1990], yet with an indication of continental isotopic contamination [Bevier, 1990]; (3) the observation that Nisling rocks are included as roof pendents in Stikine granitoids [Doherty and Hart, 1988]; and (4) Permian-Triassic lower-intercept U-Pb ages of Nisling rocks interpreted as cooling ages [Gehrels et al., 1990b]. The model can also accommodate both the continental and oceanic affinity of the Slide Mountain terrane, which has been documented by various workers. (J. K. Mortensen, personal communication, 1990].

The model proposed here, modified from Hansen [1990a, b], purposely does not identify any particular volcanic arc that may have been associated with the accretionary complex represented by the Teslin-Taylor Mountain-Nisutlin-Slide Mountain composite terrane because there are simply too many unknowns. It is possible that Quesnellia was the arc, although it has been suggested that Quesnellia and the Cache Creek terrane formed a west facing arc-accretionary complex pair. It may also be that the unidentified terrane is no longer recognized in the Cordillera. However, the model does outline a coherent structural, thermal, and temporal evolution of each of the tectonic elements considered, and it has important implications for the Paleozoic and Mesozoic tectonic evolution of the northern Cordillera. Several aspects of this interpretation warrant critical evaluation, but future tectonic models for this part of the Northern Cordillera must also account for the structural, kinematic, and temporal constraints summarized below.

CONCLUSIONS

The package of variably ductilely deformed and metamorphosed rocks known as the YT composite terrane is divisible into two distinct packages. The Teslin-Taylor Mountain and Nisutlin terranes comprise an allochthonous upper plate, and the lower plate consists of the autochthonous orthogneiss assemblage. These packages are distinguished on the basis of their lithology, structural and kinematic evolution, and cooling histories.

The allochthonous Teslin-Taylor Mountain, Nisutlin, and Slide Mountain terranes regionally form an upper-plate suite that was thrust over orthogneiss assemblage rocks in Late Triassic to Early Jurassic time. The Teslin-Taylor Mountain and Slide Mountain terranes encompass dominantly ocean crust components, and they represent deep and shallow crustal levels of an accretionary complex. Teslin-Taylor Mountain rocks were metamorphosed to the albite-epidote amphibolite facies and enclose eclogites. Quantitative geothermobarometric studies indicate that these rocks underwent high-P/T metamorphism [Hansen, 1986, 1987; Dusel-Bacon and Douglass, 1990], similar to P-T conditions derived from eclogites enclosed within these rocks [Erdmer and Helmsteadt, 1983; Erdmer, 1987]. The Nisutlin terrane consists of marginal basin volcanic and sedimentary rocks imbricated during basin closure. Teslin Taylor Mountain and Nisutlin tectonites locally record eclogite and blueschist facies mineral assemblages that cooled through 300°C by Late Permian to Early Triassic time [Erdmer and Armstrong, 1988]. High-P/T conditions recorded in Teslin-Taylor Mountain and Nisutlin tectonites are consistent with metamorphism and deformation of these rocks within the deep-seated part of a subduction complex [see Pavlis and Bruhn, 1983; Cloos and Shreve, 1988a, b]. Teslin-Taylor Mountain and Nisutlin tectonites preserve preaccretion to synaccretion orogen-normal, and, locally, orogen-parallel, structures in Yukon and Alaska. Teslin-Taylor Mountain and Nisutlin tectonites in Yukon and Alaska cooled quickly through 500°-300°C in Early Jurassic time (~194 Ma in southern Yukon and ~185 Ma in eastern Alaska).

Rocks of the orthogneiss assemblage locally record orogen-normal top-to-the-east underthrusting(?) in Yukon; in Alaska these rocks record top-to-the-northwest and top-to-the-southeast shear associated with crustal extension. In southern Yukon orthogneiss assemblage, tectonites cooled slowly through 500°-300°C from latest Late Jurassic (~147 Ma) to mid-Cretaceous (~110 Ma) time; uplift and cooling probably resulted from erosion. Uplift of the lower plate orthogneiss assemblage was followed by, but not directly related to, Late Cretaceous dextral displacement along localized northwest striking shear zones, and spatially and temporally related plutonism. In east central Alaska, and probably in western Yukon, orthogneiss assemblage rocks began cooling through 500°C by 119 Ma [Dusel-Bacon et al., in press] and cooled through 300°C by 109 Ma. Uplift and cooling of orthogneiss assemblage tectonites in this region resulted from regional crustal extension. Late Cretaceous plutonism postdates crustal extension.

We identify four distinct ductile shear deformations in YT L-S tectonites in Yukon and Alaska. (1) Pre-middle Early Jurassic dip-slip and strike-slip shear in Yukon and Alaska is related to preaccretion margin-normal contraction and margin-parallel strike-slip deformation and early accretion deformation. (2) Late Jurassic to pre-mid-Cretaceous, synaccretion(?), low-angle, thrust-style(?) ductile shear deformation is recognized only in southern Yukon. Evidence of this deformation may be preserved locally in Alaska where it has not been obliterated by regionally penetrative mid-Cretaceous extension fabrics. (3) Low-angle, top-to-the-northwest and top-to-the-southeast, postaccretion ductile shear related to crustal extension exposes lower plate orthogneiss assemblage tectonites in eastern Alaska. Similar uplift and cooling as a result of crustal extension is postulated for orthogneiss assemblage tectonites in western Yukon. (4) High-angle, Late Cretaceous, postaccretion, dextral shear displaces Teslin-Taylor Mountain, Nisutlin, Slide Mountain, and orthogneiss assemblage (Cassiar) strata along the Tintina fault in eastern Alaska and Yukon and along subparallel shear zones west of the Tintina fault in central and southern Yukon.

Each of these spatially or temporally distinct ductile deformation events represents one stage in the pre-, syn- and postaccretion tectonic history of the inboard suspect terranes and North America. The first two events are probably related to southwest-dipping (present day coordinates), Permian-Triassic subduction of ocean crust of the North American plate beneath, and subsequent obduction accretion of, an east facing arc and associated subduction complex onto North American continental crust. Teslin-Taylor Mountain, Nisutlin, and Slide Mountain rocks represent the accretionary complex of this arc. The Stikine terrane and Nisling terrane may represent the east facing volcanic arc and basement. Crustal extension, which culminated in east central Alaska in mid-Cretaceous time, may be related to over thickened crust resulting from earlier accretion of the Teslin-Taylor Mountain-Nisutlin-Slide Mountain superterrane [see Dewey, 1988; Pavlis, 1989]. Mid to Late Cretaceous dextral strike-slip deformation in Yukon may result from right-oblique subduction of the Farallon plate beneath North America as postulated by plate motion studies [Engebretson et al., 1985].

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REFERENCES

Aleinikoff, J. N., C. Dusel-Bacon, H. L. Foster, and K. Futa, Proterozoic zircon from augen gneiss, Yukon-Tanana Upland, east-central Alaska, *Geology, 9*, 469-473, 1981.

Aleinikoff, J. N., C. Dusel-Bacon, and H. L. Foster, Geochronology of augen gneiss and related rocks, Yukon-Tanana terrane, east-central Alaska, *Geol. Soc. Am. Bull., 97*, 626-637, 1986.

Aleinikoff, J. N., C. Dusel-Bacon, H. L. Foster, and W. J. Nokleberg, Lead isotopic fingerprinting of tectono-stratigraphic terranes, east-central Alaska, *Can. J. Earth Sci., 24,* 2089-2098, 1987.

Armstrong, R. L., Mesozoic and Early Cenozoic magmatic evolution of the Canadian Cordillera, *Spec. Paper Geol. Soc. Ameri. 218*, 55-91, 1988.

Bell, T. H., and R. L. Hammond, On the internal geometry of mylonite zones, *J. Geol., 92*, 667-686, 1984.

Beck, M. E., Jr., Model for late Mesozoic-early Tertiary tectonics of coastal California and western Mexico and speculations on the origin of the San Andreas fault, *Tectonics, 5*, 49-64, 1986.

Bennett, V. C., and V. L. Hansen, Neodymium isotopic similarities between the Yukon-Tanana Terrane, Yukon Territory and continental North America, *Geol. Soc. Am. Abstr. Programs, 20,* A111, 1988.

Bevier, M. L., New U-Pb and K-Ar ages for igneous rocks, Iskut River map area, British Columbia, *Geol. Assoc. Can. Abstr. Programs, 15*, A10, 1990.

Churkin, M., Jr., H. L. Foster, R. M. Chapman, and F. R. Weber, Terranes and suture zones in east-central Alaska, *J. Geophys. Res., 87*, 3718-3730, 1982.

Cloos, M., and R. L. Shreve, Subduction-channel model of prism accretion, melange formation, sediment subduction, and subduction erosion at convergent plate margins: 1. Background and description, *Pure Appl. Geophys., 128,* 455-500, 1988a.

Cloos, M., and R. L. Shreve, Subduction-channel model of prism accretion, melange formation, sediment subduction, and subduction erosion at convergent plate margins: 2. Implications and discussion, *Pure Appl. Geophys., 128,* 501-545, 1988b.

Coney, P. J., and D .L. Jones, Accretion tectonics and crustal structure in Alaska, *Tectonophysics, 119,* 265-283, 1985.

Copeland, P., K. V. Hodges, T. M. Harrison, P. LeFort, and A. Pecher, Rapid Pliocene uplift associated with the Main Boundary thrust, Central Nepal, *Geol. Soc. Am. Abstr. Programs, 20*, A321, 1988.

Cushing, G. W., The tectonic evolution of the eastern Yukon Tanana Upland, Alaska, M. Sc. thesis, 255 pp.,State University of New York, Albany, 1984.

Cushing, G. W., H. L. Foster, and T. M. Harrison, Mesozoic age of metamorphism and thrusting in the eastern part of east-central Alaska, *Eos Trans. AGU, 65*, 290-291, 1984a.

Cushing, G. W., H. L. Foster, T. M. Harrison, and J. Laird, Possible Mesozoic accretion in the eastern Yukon-Tanana

Upland, Alaska, *Geol. Soc. Am. Abstr. Programs, 16*, 481,1984b.

Debiche, M. G., A. Cox, and D., Engebretson, The motion of allochthonous terranes across the North Pacific basin, *Spec. Pap. Geol. Soc. Am 207*, 49 pp., 1987.

Dewey, J. F., Extensional collapse of orogens, *Tectonics, 7*, 1123-1140, 1988.

Dodson, M. H., Closure temperature in cooling geochronological and petrological systems, *Contrib. Mineral. Petrol., 40*, 259-274, 1973.

Doherty, R. A., and C. J. R. Hart, Preliminary geology of Fenwick Creek (105D/3) and Alligator Lake (105D/6) map areas, *Indian North. Aff. Can. Yuk. reg. Open File, 1988-2, 80 pp., 1988*

Duke, N. A., C. R. Nauman, and S. R. Newkirk, Evidence for Late-Cretaceous extensional uplift of the Yukon-Tanana crystalline terrane, Eastern Alaska Range, *Geol. Soc. Am. Abstr. Progs., 20*, A113, 1988.

Dusel-Bacon, C., Metamorphic history of Alaska: Yukon-Tanana Upland and Alaska Range north of McKinley and Denali faults, *in Decade of North American Geology, in pres.*

Dusel-Bacon, C., and J. Aleinikoff, Petrology and tectonic significance of augen gneiss from a belt of Mississippian granitoids in the Yukon-Tanana terrane, east-central Alaska, *Geol. Soc. Am. Bull., 96*, 411-425, 1985.

Dusel-Bacon, C., and S. Douglass, New thermobarometric evidence for high pressure, medium temperature metamorphism of two subterranes of the Yukon-Tanana composite terrane (YTT) in easternmost Alaska, *Geol. Ass.oc Can. Abstr. Progs.., 15*, A35, 1990.

Dusel-Bacon, C., B. Csejtey, H. L. Foster, E. F. O'Rourke, W.J. Nokleberg, and G. Plafker, Distribution, facies, ages, and proposed tectonic associations of regionally metamorphosed rocks in east- and south-central Alaska, *U.S. Geol. Surv. Prof. Pap. 1497-C*, 1990.

Engebretson, D. C., A. Cox, and R. G. Gordon, Relative motions between oceanic and continental plates in the Pacific Basin, *Spec. Pap. Geol. Soc. Am. 206*, 59 pp., 1985.

Erdmer, P., An examination of the cataclastic fabrics and structures of parts of Nisutlin, Anvil and Simpson allochthons, central Yukon: Test of the arc-continent collision model, *J. Struct. Geol., 7*, 57-72, 1985.

Erdmer, P., Blueschist and eclogite in mylonitic allochthons, Ross River and Watson Lake areas, southeastern Yukon, *Can. J. Earth Sci., 24*, 1439-1449, 1987.

Erdmer, P. and R. L. Armstrong, Permo-Triassic isotopic dates for blueschist, Ross River area, Yukon, *Yukon Geol. Can. Dept. Indian North. Aff., 2*, 33-36, 1988.

Erdmer, P., and Helmsteadt, H., Eclogite from central Yukon: A record of subduction at the western margin of ancient North America, *Can. J. Earth Sci., 20*, 1389-1408, 1983.

Foster, H. L., Reconnaissance geologic map of the Tanacross Quadrangle, Alaska, *U.S. Geol. Surv. Map, I-593*, scale 1:250,000, 1970.

Foster, H. L., Geologic map of the Eagle Quadrangle, Alaska, *U.S. Geol. Surv. Map, I-922*, scale 1:250,000, 1976.

Foster, H. L., J. Laird, and G. W. Cushing, Thrust faulting in the Eagle quadrangle, Alaska, and its implications for the tectonic history of the Yukon-Tanana Upland, *Eos Trans. AGU, 65*, 291, 1984.

Foster, H. L., G. W. Cushing, and T. E. C. Keith, Early Mesozoic tectonic history of the Boundary Area, east-central Alaska, *Geophys. Res. Lett., 12*, 553-556, 1985.

Foster, H. L., T. E. C. Keith, and W. D. Menzie, Geology of East-Central Alaska, *U.S. Geol. Surv. Open File Rep., 87-188*, 59 pp., 1987.

Gabrielse, H., Geology of the Jennings River map-area, British Columbia (104-O), *Pap. Geol. Surv. Can., 68-55*, 37 pp., 1968.

Gabrielse, H., Major dextral transcurrent displacements along the Northern Rocky Mountain Trench and related lineaments in north-central British Columbia, *Geol. Soc. Am. Bull., 96*, 1-14, 1985.

Gabrielse, H. and C. J. Dodds, Faulting and plutonism in northwestern Cry Lake and adjacent map areas, British Columbia, *Curr. Res. Geol. Surv. Can.., 82-1A*, 321-323, 1982.

Gehrels, G. E., W. C. McClelland, S. D. Samson, and P. J. Patchett, Geologic relations along the west flank of the Coast Mountain batholith between Cape Fanshaw and Taku Inlet, SE Alaska, *Geol. Assoc. Can. Abstr. Programs, 15*, A45, 1990a.

Gehrels, G. E., W. C. McClelland, S. D. Samson, and P. J. Patchett, U-Pb geochronology of detrital zircons from the Yukon crystalline terrane along the west flank of the Coast Mountain batholith, *Geol. Assoc. Can. Abstr. Programs, 15*, A45, 1990b.

Gehrels, G. E., W. C. McClelland, S. D. Samson, P. J. Patchett, and J. L. Jackson, Ancient continental margin assemblage in the northern Coast Mountains, southeast Alaska and Northwest Canada, *Geology, 18*, 208-211, 1990c.

Hansen, V. L., Metamorphic and structural evidence of a Mesozoic transpressional North American margin, *Geol. Soc. Am. Abstr. Programs, 18*, 627, 1986.

Hansen, V. L., Structural, metamorphic, and geochronologic evolution of the Teslin suture zone, Yukon: Evidence for Mesozoic oblique convergence outboard of the northern Canadian Cordillera, Ph.D. thesis, Univ. of Calif., Los Angeles, 221 pp, 1987.

Hansen, V. L., A model for terrane accretion: Yukon-Tanana and Slide Mountain terranes, northwest North America, *Tectonics, 7*, 1167-1177, 1988.

Hansen, V. L., Structural and kinematic evolution of the Teslin suture zone, Yukon: Rrecord of an ancient transpressional margin, *J. Struct. Geol., 11*, 717-733, 1989.

Hansen, V. L., Mesozoic evolution of the Yukon-Tanana terrane, *Geol. Soc. Am. Abstr. Programs, 21*, 90, 1990a.

Hansen, V. L., The Yukon-Tanana terrane: A partial acquittal, *Geology, 18*, 365-369, 1990b.

Hansen, V.L., M. T. Heizler, and T. M. Harrison, Mesozoic thermal evolution of the Yukon-Tanana terrane, Yukon and Alaska: New evidence from $^{40}Ar/^{39}Ar$ data, *Geol. Soc. Am. Abstr. Programs, 20*, A111-A112, 1988.

Hansen, V. L., J. K. Mortensen, and R. L. Armstrong, Pre-Jurassic ductile deformation and synchronous metamorphism of the Yukon-Tanana terrane: Geochronologic constraints from the Teslin suture zone, Yukon, *Can. J. Earth Sci., 26*, 2224-2235, 1989.

Harms, T. A., Structural and tectonic analysis of the Sylvester allochthon, northern British Columbia: Implications for paleogeography and accretion, Ph.D. thesis, 80 pp., Univ. of Ariz., Tucson, 1986.

Harms, T. A., P. J. Coney, and D. L. Jones, The Sylvester allochthon, Slide Mountain terrane, British Columbia: A correlative of oceanic terranes of northern Alaska, *Geol. Soc. Am. Abstr. Programs, 16*, 288, 1984.

Harrison, T. M., Diffusion of ^{40}Ar in hornblende, *Contrib. Mineral. Petrol., 78,* 324-331, 1981.

Harrison, T. M, and J. D. FitzGerald, Exsolution in hornblende and its consequences for ^{40}Ar/^{39}Ar age spectra and closure temperatures, *Geochim. Cosmochim. Acta, 50,* 247-253, 1986

Harrison, T. M., I. Duncan, and I. McDougall, Diffusion of ^{40}Ar in biotite: Temperature, pressure, and compositional effects, *Geochim. Cosmochim. Acta, 49,* 2461-246, 1985.

Heizler, M. T., and T. M. Harrison, Multiple trapped argon isotope components revealed by ^{40}Ar/^{39}Ar isochron analysis, *Geochim. Cosmochim. Acta, 52,* 1295-1303, 1988.

Huneke, J. C., and S. P. Smith, The realities of recoil: ^{39}Ar recoil out of small grains and anomalous patterns in ^{40}Ar-^{39}Ar dating, *Geochim. Cosmochim. Acta, 7, suppl.* 1987-2008, 1976.

Jones, D. L., N. J. Silberling, P. J. Coney, and G. Plafker, Lithotectonic terrane map of Alaska (west of the 141st Meridian), *U.S. Geol. Surv. Misc. Field Stud. Map, MF-1874-A,* scale 1:2,500,000, 1987.

Laird, J., and H. L. Foster, Petrologic evidence for a terrane boundary in south-central Circle quadrangles, Alaska, *Geophy. Res. Lett., 13,* 1035-1038, 1986.

McClelland, W. C., G. E. Gehrels, S. D. Samson, and P. J. Patchett, Geologic structural relations along the western flank of the Coast Mountains batholith: Stikine River to Cape Fanshaw, central Alaska, *Geol. Assoc. Can. Abstr. Programs, 15,* A86, 1990.

Miller, E. L., Dismemberment of the Brooks Range orogenic belt during middle Cretaceous extension, *Geol. Soc. Am. Abstr. Programs, 19,* 433, 1987.

Miller, E. L., A. T. Calvert, and T. A. Little, Metamorphic core complexes on the Seward Pennisula, Alaska?, *Geol. Soc. Am. Abstr. Programs, 22,* 68, 1990.

Monger, J. W .H., and H. C. Berg, Lithotectonic terrane map of western Canada and southeastern Alaska, *U.S. Geol. Surv. Misc. Fiels stud. Map, MF-1874-B,* scale 1: 2,500,000, 1987.

Mortensen, J. K., Age and evolution of the Yukon-Tanana terrane, southeastern Yukon Territory, Ph.D. thesis, Univ. Calif., Santa Barbara, 155 pp., 1983.

Mortensen, J. K., U-Pb ages for granitic orthogneiss from western Yukon Territory: Selwyn Gneiss and Fiftymile Batholith revisited, *Pap. Geol. Surv. Can., 86-1B,* 141-146, 1986.

Mortensen, J. K., Geology of the southwestern Dawson map area, Yukon Territory, *Pap. Geol. Surv. Can., 88-1E,* 73-78, 1988a.

Mortensen, J. K., Significance of episodic magmatism in Yukon-Tanana terrane, Yukon and Alaska, *Geol. Soc. Am. Abstr. Programs, 20,* A111, 1988b.

Mortensen, J. K., and G. A. Jilson, Evolution of the Yukon-Tanana terrane: Evidence from southeastern Yukon Territory, *Geology, 13,* 806-810, 1985.

Nelson, J., and J. Bradford, Geology of the area around the Midway deposit, northern British Columbia (104O/16), *Pap. Minist. Energy Mines Pet. Resour. B. C.,* 1987.

Nelson, J., J. A. Bradford, K. C. Green, and H. Marsden, Geology and patterns of mineralization, Blue Dome map area, Cassiar district (104P/12), *Pap. Minist. Energy Mines Pet. Resour. B. C.,* 1988.

Nelson, J., J. A. Bradford, F. Ferri, and P. Schiarizza, Marginal basin and island arc elements in the Slide Mountain terrane: Evidence for early North American affinities, *Geol. Soc. Am. Abstr. Programs, 21,* 121, 1989.

Pavlis, T. L., Middle Cretaceous orogenesis in the northern Cordillera: A Mediterranean analog of collision-related extensional tectonics, *Geology, 17,* 947-950, 1989.

Pavlis, T. L., and R. L., Bruhn, Deep-seated flow as a mechanism for the uplift of broad forearc ridges and its role in the exposure of high P/T metamorphic terranes, *Tectonics ,2,* 473-497, 1983.

Pavlis, T. L., V. B. Sisson, W. J. Nokleberg, G. Plafker, and H. Foster, Evidence for Cretaceous extension in the Yukon Crystalline terrane, East-Central Alaska, *Eos Trans. AGU, 69,* 1543, 1988.

Purdy, J. W., and E. Jager, K-Ar ages on rock-forming minerals from the Central Alps, *Mem. Ist Geol. Min. Univ. Padova, 30,* 31 pp., 1976.

Robbins, G. A., Radiogenic argon diffusion in muscovite under hydrothermal conditions, M. S. thesis, Brown Univ., Providence, R. I., 42 pp., 1972

Roddick, J. A., Tintina Trench, *J. Geol., 5,* 23-33, 1967.

Rubin, C. M., G. Smith, and M. M. Miller, The geologic evolution and tectonic setting of mid-Paleozoic arc basement in the North American Cordillera, *Geol. Soc. Am. Abstr. Programs, 21,* 137, 1989.

Rubin, C. M., M. M. Miller, and G. Smith, Tectonic development of Cordilleran mid-Paleozoic volcano-plutonic complexes: Evidence for convergent margin tectonism, *Spec. Pap. Geol. Soc. Am.* , in press.

Saleeby, J. B., and C. M. Rubin, The East Behm gneiss complex (southern Southeast Alaska) and some insights into basement tectonics along the insular suture belt, *Geol. Assoc. Can. Abstr. Programs, 15,* A116, 1990.

Samson, S. D., P. J. Patchett, W. C. McClelland, and G. E. Gehrels, A detailed isotopic investigation of the Taku and Yukon crystalline terranes, S.E. Alaska: Ancient continental material between juvenile crust of the Canadian Cordillera, *Geol. Assoc. Can. Abstr. Programs, 15,* A117, 1990.

Sibson, R. H., Fault rocks and fault mechanisms, *J. Geol. Soc. London, 133,* 191-213, 1977.

Spicuzza, M. J., and V. L. Hansen, Constraints on Mesozoic evolution of south-central Yukon: Structural and metamorphic data from the Late Cretaceous Nisutlin batholith and host rocks, *Geol. Soc. Am. Abstr. Programs, 21,* 147, 1989.

Steiger, R. H., and E. Jager, Subcommission on geochronology: Convention on the use of decay constants in geo- and cosmochronology, *Earth Planet. Sci. Lett., 36,* 359-362, 1977.

Tempelman-Kluit, D. J., Quiet Lake (105F) and Finlayson Lake (105G) map area, Yukon, *Geol. Surv. Can. Open File, 486,* scale 1:250,000, 1977.

Tempelman-Kluit, D. J., Laberge map area (NTS 105E), *Geol. Surv. Can. Open File ,578,* scale 1:250,000, 1978.

Tempelman-Kluit, D. J., Transported cataclasite, ophiolite and granodiorite in Yukon: evidence of arc-continent collision, *Pap. Geol. Surv. Can., 79-14,* 27 pp., 1979.

Tempelman-Kluit, D. J., Geology, Laberge (105E) and Carmacks (115I), Yukon Territory, *Geol. Surv. Can. Open File, 1101,* scale 1:250,000, 1984.

Wanless, R. K., R. D. Stevens, G. R. Lachance, and R. N. Delabio., Age determinations and geological studies: K-Ar isotopic ages, report 13, *Geol. Surv. Can. Pap. 77-2,* 67p., 1978

Wheeler, J. O., and P. McFeely, Tectonic assemblage map of the Canadian Cordillera and adjacent parts of the United States of America (revised edition), *Geol. Surv. Can. Open File, 1565*, scale 1:12,000,000, 1987.

Wheeler, J. O., Brookfield, A. J., Gabrielse, H., Monger, J. W. H., Tipper, H. W., and G. J. Woodsworth, Tectonic assemblage map of the Canadian Cordillera and adjacent parts of the United States of America (revised edition), *Geol. Surv. Can.Open File, 1894*, scale 1:2,000,000, 1988.

Wilson, F. H., J. G. Smith, and N. Shew, Review of radiometric data from the Yukon Crystalline Terrane, Alaska and Yukon Territory, *Can. J. Earth Sci., 22*, 525-537, 1985.

York, D., Least squares fitting of a straight line with correlated errors, *Earth Planet. Sci. Lett., 13*, 973-075, 1969.

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