GEOLOGY OF TATLA LAKE (92N/15) AND THE EAST HALF OF BUSSEL CREEK (92N/14) MAP AREAS

By Peter S. Mustard[1] and Peter van der Heyden
Geological Survey of Canada
[1](now at: Earth Sciences, Simon Fraser University)

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INTRODUCTION

Geologic mapping at 1:50 000 scale of the Tatla Lake map area (NTS 92N/15), the east half of the Bussel Creek map area (92N/14), and a small part of northern Razorback map area (92N/10) was conducted in 1993, with minor additional fieldwork in 1994 (Figure 1). This paper summarizes the results of this mapping project, which redefined the structure and stratigraphy of the area; resulted in several new fossil collections (Haggart, 1995), eight new U-Pb zircon dates from plutons and volcanic rocks in the area, one set of U-Pb ages of detrital zircons obtained from the Late Cretaceous Silverquick formation exposed in this map area, and several $^{40}Ar/^{39}Ar$ ages from micas and hornblendes within igneous units or shear zones. The 1:50 000 scale geologic map for this area has been published (Mustard *et al.*, 1994a, b). Earlier reports on the results of this project are available in the Geological Survey of Canada current research publications (Mustard and van der Heyden, 1994, van der Heyden *et al.*, 1994).

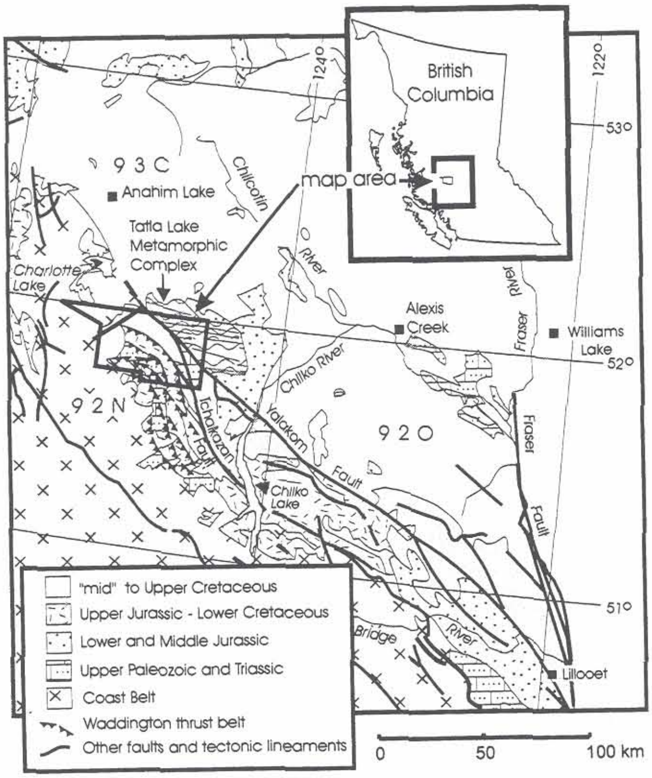

Figure 1. Regional location and geology. Geology modified and greatly simplified from Wheeler and McFeely (1991) with additions from Rusmore and Woodsworth (1993).

REGIONAL GEOLOGIC SETTING

Recent mapping south of the present study area (Rusmore and Woodsworth, 1988, 1989, 1991a, 1993) defined the Late Cretaceous (*ca.* 87-84 Ma) Eastern Waddington thrust belt (Figure 2), along which the Jura-Cretaceous Coast Belt magmatic arc was thrust northeastward over Mesozoic strata of the Tyaughton trough. Both Tipper (1969) and Rusmore and Woodsworth (1993) showed the thrust system projecting into the Tatla Lake and Bussel Creek map areas, but its northerly continuation, as well as contact relations and ages of most rock units and structures in the present study area, remained enigmatic until this study.

In the Anahim Lake (93C) map area, northwest of the present study, the eastern Coast Belt consists dominantly of Jura-Cretaceous plutonic and metamorphic rocks (van der Heyden, 1990, 1991, van der Heyden *et al.*, 1994); structures are dominated by steeply dipping, northeast-trending ductile fabrics, and the area is disrupted by steeply dipping brittle shear zones. Thrust faults that might correlate with the Eastern Waddington thrust belt, and rocks correlative with Tyaughton trough strata, are not present in the Anahim Lake map area.

The study area can be subdivided into several fault-bounded, west to northwest-trending domains (Figures 2 and 3). Rocks of the Jura-Cretaceous Coast Belt magmatic arc in the southwest are thrust over a strongly imbricated zone consisting of multiple thrust slices of Upper Triassic arc rocks. The arc rocks are thrust over Lower Cretaceous marine strata of the Tyaughton trough, which, in turn, are thrust over Upper Cretaceous nonmarine strata that record the final stages in the evolution of the trough. Further northeast, between the trend of the Tchaikazan and Yalakom faults, Upper Triassic strata are intruded by two newly dated Late Triassic to earliest Jurassic plutons. The

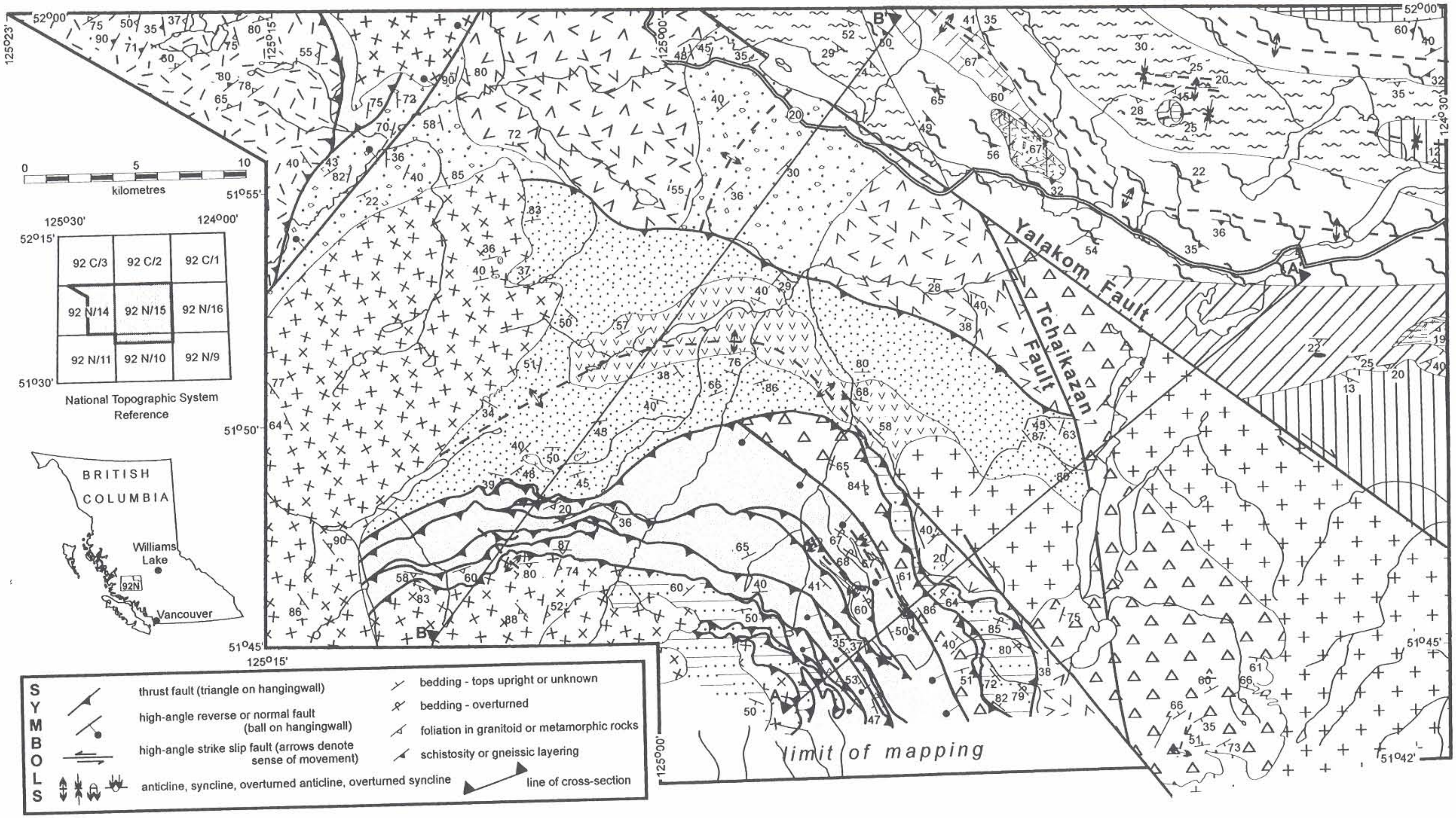

Figure 2. Simplified geology of the project area (modified from Mustard *et al.*, 1994b). Map legend is shown on facing page.

LEGEND

Southwest of Yalakom Fault

Sedimentary and Volcanic Rocks

CRETACEOUS

UPPER CRETACEOUS

CENOMANIAN - UPPER ALBIAN

POWELL CREEK volcanics: green, purple, grey, andesitic conglomerate and breccia, rare flows; interbedded carbonaceous siltstone and fine sandstone in lower 100 m

SILVERQUICK formation: sandstone; coarse to fine arkosic arenite, immature; interbedded pebble - boulder conglomerate of igneous clasts; carbonaceous silty mudstone in upper 100 m, rare plant fragments

UPPER ALBIAN and YOUNGER(?)

TAYLOR CREEK GROUP: sandstone, siltstone, carbonaceous mudstone, minor pebble conglomerate; common plant fragments;

volcanic subunit: felsic volcanic flows, breccia, intermediate flows, breccia, rare pillowed volcanics

LOWER CRETACEOUS

HAUTERIVIAN

CLOUD DRIFTER formation: sandstone, siltstone, minor conglomerate; sandstone commonly contains abundant detrital hornblende; conglomerate clasts dominantly felsic and intermediate volcanic rocks and quartzose granitoid rocks

UPPER JURASSIC(?) to LOWER CRETACEOUS

HAUTERIVIAN(?)

OTTARASKO formation: green volcanic breccia and tuff, rare flows, minor siltstone and shale; volcanic rocks are dacite and andesite with subordinate but locally abundant basalt and rhyolite; poorly stratified and poorly sorted

UPPER TRIASSIC

NORIAN

MOSLEY formation: red and grey volcaniclastic sandstone, red siltstone, limestone wackestone/packstone

mappable lenses up to 150 m thick of fossiliferous limestone wackestone and packstone

ANISIAN to LOWER NORIAN

MT. MOORE formation: maroon and green, basaltic to andesitic volcanic breccia, lesser volcanogenic sandstone and massive greenstone, rare carbonate; volcanic rocks commonly augite phyric

Intrusive Rocks

LATE CRETACEOUS - TERTIARY

Klinaklini Pluton (south map area) McClinchy Pluton (NW map area)

tonalite, granodiorite, quartz monzanite, quartz diorite

unnamed pluton (south of Perkins Peak): tonalite, minor quartz diorite

MIDDLE - LATE JURASSIC

Wilderness Mountain Pluton: tonalite

LATE TRIASSIC - EARLY JURASSIC

Sapeye Creek Pluton and unnamed plutons east of Tchaikazan fault: tonalite, minor quartz diorite

Northeast of Yalakom Fault

Tatla Lake Metamorphic Complex

LOWER PLATE - DUCTILELY SHEARED ASSEMBLAGE

JURASSIC AND CRETACEOUS

One Eye Tonalite: nonfoliated to weakly foliated biotite-hornblende tonalite

Biotite granodiorite sills

og — *Mylonitic orthogneiss: quartz diorite to granodiorite augen gneiss* (not present in map area)

Biotite tonalite augen gneiss

Biotite tonalite to granodiorite augen gneiss

Biotite - muscovite tonalite to granodiorite augen gneiss

Jms — *Foliated to mylonitic Jurassic (?) metasedimentary rocks* (not present in map area)

Quartzofeldspathic schist, minor amphibolite

Jmv — *Foliated to mylonitic Jurassic (?) metavolcanic rocks* (not present in map area)

Chlorite-actinolite-quartz-albite schist

Hornblende-quartz-oligoclase schist

LOWER PLATE - GNEISSIC CORE

CRETACEOUS AND (?)OLDER

Medium to coarse-grained hornblende-biotite granoblastic gneiss

Migmatitic gneiss

Figure 2. LEGEND

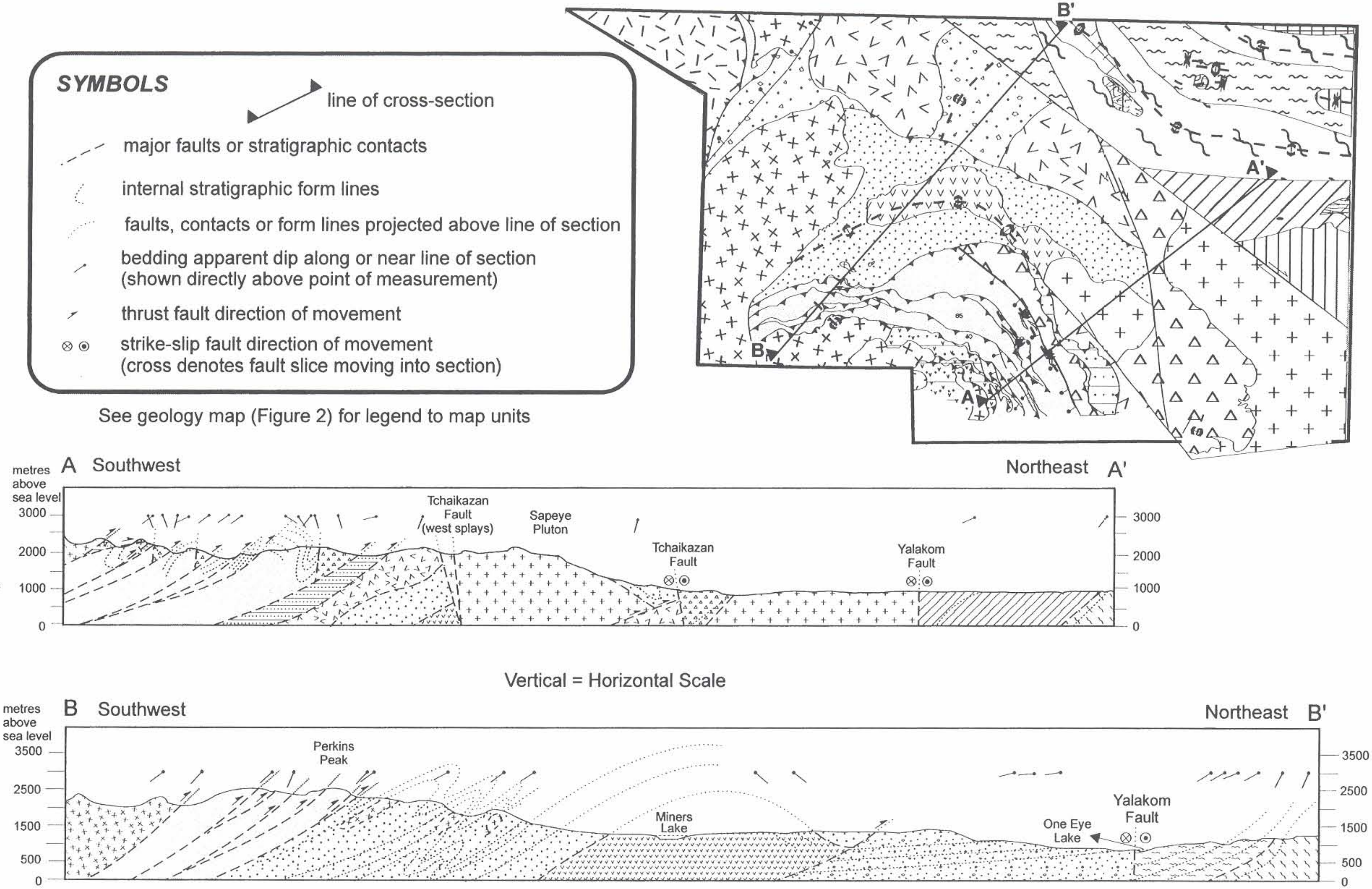

Figure 3. Simplified cross-sections through the study area (modified from Mustard *et al.* 1994b)

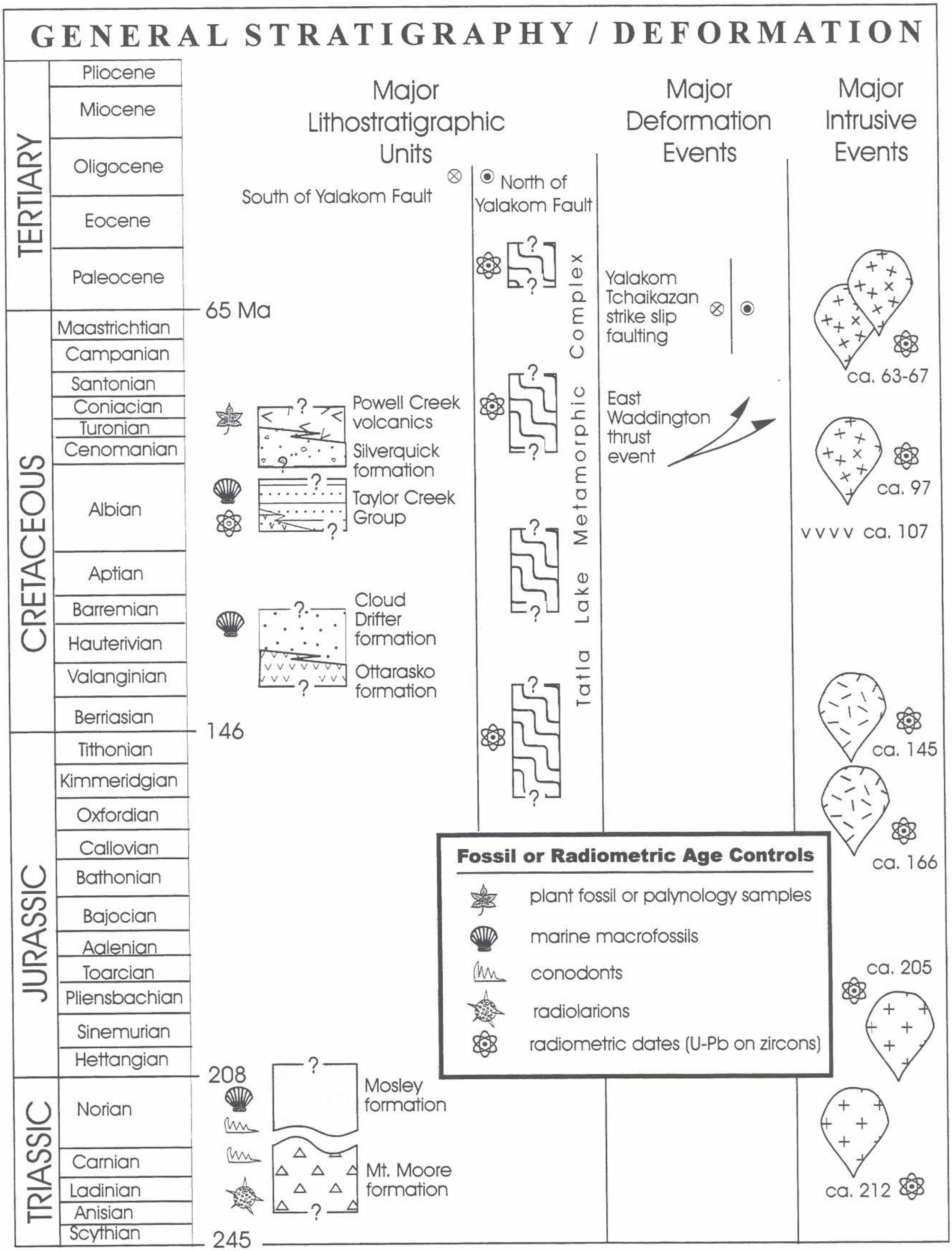

Figure 4. Schematic representation of major lithostratigraphic units, deformation, and intrusive events in the map area.

TABLE 1
SUMMARY OF FORMATIONS

PERIOD	STAGE	LITHO-STRATIGRAPHIC UNIT	MAP UNIT AND LITHOLOGY	DEPOSITIONAL ENVIRONMENT	MAXIMUM THICKNESS (METRES)
Cretaceous	Upper Albian-Cenomanian?	Powell Creek volcanics	**uKPC** green, purple, grey andesitic conglomerate and breccia, rare flows; interbedded carbonaceous siltstone and fine sandstone in lower 100 m	Subaerial to rarely subaqueous volcanic arc lahars, debris flows and reworked pyroclastic flows. Fluvial sandstone and mudstone in lower part of unit.	>500?
conformable - gradational over a few tens of metres					
Cretaceous	Upper Albian-Cenomanian?	Silverquick formation	**uKSQ** medium to light grey, coarse to fine-grained arkosic arenite, immature; interbedded pebble-boulder conglomerate of igneous clasts; carbonaceous silty mudstone in upper 100 m, rare plant fragments	Subaerial alluvial fan and lower fan to braidplain debris flow and braided fluvial deposits. First cycle, locally derived sediment from high-relief plutonic/volcanic source.	750-1000
contact not seen - probably unconformable					
Cretaceous	latest Valanginian to Albian	Taylor Creek Group	**KTC** dark to medium grey sandstone, siltstone, carbonaceous mudstone, minor pebble conglomerate; common plant fragments; **KTCv** volcanic subunit: felsic volcanic flows and breccia, intermediate flows and breccia; rare pillowed volcanics	Deep shelf to off-shelf marine turbidites. Rare chert grains in sandstone may suggest eastern provenance?	>500
contact not seen - probably unconformable					
Cretaceous	Hauterivian	Cloud Drifter formation	**lKCD** medium grey to brown-grey sandstone, siltstone, minor conglomerate; sandstone commonly contains abundant detrital hornblende; conglomerate clasts dominantly felsic and intermediate volcanic rocks and quartzose granitoid rocks	Outer shelf turbidites, sand waves and storm deposits. Immature volcanic lithic sand composition suggests first cycle derivation from volcanic arc (possibly eroded Ottarasko formation?)	>2000
conformable - gradational over about 200 metres, probably lateral intertonguing relationship					
Cretaceous (& Upper Jurassic?)	Hauterivian (or older?)	Ottarasko formation	**lKO** green-grey volcanic breccia and tuff, rare flows, minor siltstone and shale; volcanic rocks are dacite and andesite with subordinate, but locally abundant basalt and rhyolite; poorly stratified and poorly sorted.	Volcanic arc debris flows, reworked pyroclastics and locally abundant volcanic flows. Generally appears nonmarine but marine in upper part where grades into turbidites of overlying Cloud Drifter formation	>1000
contact not seen - major unconformity suspected					
Triassic (& possibly Lower Jurassic)	Norian (and younger?)	Mosley formation	**uTM** red and grey volcaniclastic sandstone, red siltstone; fossiliferous wackestone and packstone in distinctive discontinuous unit up to 150 m thick; lateral facies change to west to red and green-grey massive volcaniclastic breccia (Perkins Peak area).	pyroclastic debris in shallow marine bars, debris flows and channels. Laterally restricted but locally long lived carbonate reef and off-reef facies of bivalves and corals in shallow-marine setting. Changes laterally to west to subaerial volcanic ediface dominated by volcanic debris flows and lahars	>650
contact not seen - possibly conformable?					
Triassic	Anisian to mid-Norian?	Mt. Moore formation	**uTMM** maroon and green, basaltic to andesitic volcanic breccia; less common volcanogenic sandstone and massive volcanic flows, rare volcanic-clast pebble conglomerate, very rare fossiliferous limestone wackestone beds; volcanic rocks commonly augite phyric	Extensive volcanic arc dominated by debris flows, breccia slopes and lahars. Less common volcanic flows. Generally appears nonmarine but rare coral-bearing carbonate marine facies	>2000
base not exposed					

Eocene Tatla Lake metamorphic core complex underlies the northeastern part of the study area; it is separated from the other domains by the transcurrent Yalakom fault. All rocks east of and including the imbricate zone are here included in the Intermontane Belt.

VOLCANIC AND SEDIMENTARY LITHOSTRATIGRAPHIC UNITS

The study area contains a diverse assemblage of Upper Triassic to Upper Cretaceous volcanic and sedimentary successions. Most contacts are faults, although a few lithologic contacts between units are preserved. The main lithostratigraphic units are shown on Figure 4 and summarized in Table 1. For summary, the map area is subdivided into four fault-bounded, west to northwest-trending tectonostratigraphic domains, described below, starting in the south.

UPPER TRIASSIC

Upper Triassic sedimentary and volcanic rocks make up the bulk of complexly interleaved thrust panels in the southwest quarter of the Tatla Lake map area, continuing to the southeast into the Razorback map area and for a short distance to the west into the Bussel Creek and Siva Glacier (92N/11) map areas (Figure 2,). Mapping in the Razorback and Queen Bess map areas prompted Rusmore and Woodsworth (1991b) to recognize two informal formations; the Carnian to lower Norian volcanic-dominated Mt. Moore formation and an overlying Norian sedimentary package they termed the Mosley formation. Our detailed mapping, supplemented by two stratigraphic sections measured in well exposed areas and new fossil collections, generally supports the Rusmore and Woodsworth divisions (although the age range of the Mt. Moore formation is expanded to Anisian to lower Norian) and we retain their proposed, although informal names.

MT. MOORE FORMATION

Volcanic and rare interbedded sedimentary rocks of the Mt. Moore formation occur in two areas (Figure 2): as thrust slices within the main imbricated thrust zone in the southwest Tatla Lake and southeast Bussel Creek map areas; and in two outcrop belts offset by the Tchaikazan Fault on the west and east sides of Bluff Lake. The Mt. Moore formation is at least 2000 metres thick east of Bluff Lake, but is everywhere in fault or intrusive contact with other units and thus the true thickness and contact relationships are unknown.

The formation is dominated by mafic to intermediate volcanic breccia, conglomerate, flows and sills. The breccia and conglomerate comprise angular green to, less common, maroon-volcanic clasts in a green or maroon volcaniclastic matrix. Clasts are identical in composition to flows of this unit, with ubiquitous plagioclase and, in some places, distinctive pyroxene phenocrysts in a fine groundmass. This unit resembles the younger Ottarasko formation, but differs in the presence of pyroxene (augite?) phenocrysts up to 3 centimetres long. Rare interbeds of siliceous mudstone and thin-bedded tuffaceous sandstone occur in thrust slices west of Bluff Lake.

Age control was previously limited to late Carnian to early Norian based on conodonts recovered from an interbedded limestone lens near Mount Moore (M. J. Orchard *in* Rusmore and Woodsworth, 1991b). The intrusive relationship of the *ca.* 212 Ma Niut pluton southeast of Bluff Lake (Figures 2 and 5) also suggests an early Norian or older age for the Mt. Moore formation in this region, compatible with the age suggested from the Mt. Moore area. Rare chert in the central to lower part of the large volcanic unit east of Bluff Lake contains middle Triassic radiolarians (Cordey, 1994), which supports our correlation of this unit with the Mt. Moore formation and suggests the lower Mt. Moore formation in this area is at least as old as Anisian to Ladinian.

The Mt. Moore formation rock types and field relationships suggest an island arc setting, an interpretation also suggested by Rusmore and Woodsworth (1991b) for the formation in the map areas to the south, with additional supporting evidence from basalt and pyroxene chemistry. The presence of rare coral-bearing limestone beds suggests that at least part of the formation was deposited in a shallow marine setting. The bulk of the formation consists of volcanic breccia and massive volcanics, probably reflecting extensive flows and reworking of eroded volcanic flows as debris flows or lahars.

MOSLEY FORMATION

Most of the Triassic succession in the map area is distinctive dark red to cream-pink siliciclastic and tuffaceous sandstone. Less abundant grey limestone clastics occur as a mappable, but laterally discontinuous facies within the red unit. In the best-exposed area of the Mosley formation, a lower facies of massive to faintly laminated grey-brown limestone/mudstone to fine-grained wackestone is also present. The Mosley formation occurs in several thrust slices and no formation contacts are preserved, inhibiting formal formation definition (Figure 2). A measured stratigraphic section in one well exposed thrust slice documents a minimum thickness of 650 metres for this formation with a thickness exceeding 1 kilometre indicated by the map pattern in other places.

Previous fossil collections from the Mosley formation (Tipper, 1969; Rusmore and Woodsworth, 1991b, 1993) indicated an early to late Norian age. New collections include *Halobia* in the lower part of this unit, which suggests a Carnian to early Norian age for the lower Mosley formation. The upper age of the Mosley formation is not constrained. The late Norian bivalve *Monotis subcircularis* has been collected in several places, but these occurrences are overlain by at least several hundred metres of unfossiliferous sandstone and mudstone. Thus the upper part of the formation could be considerably younger, possibly extending into the Lower Jurassic.

Features of the noncalcareous clastics indicate deposition in a generally nonmarine setting, probably a lower alluvial fan to coarse fan delta or debris apron with a nearby volcanic source area providing the abundant volcaniclastic material. However, the fossiliferous carbonate sandstone-mudstone facies suggests lateral transition to shell banks and rare patch reefs of a marine platform.

LOWER CRETACEOUS

Lower Cretaceous strata consist of two regional units informally designated the Cloud Drifter and Ottarasko formations, respectively, by Rusmore and Woodsworth (1989, 1993) in map areas to the south, a practice we continue.

OTTARASKO FORMATION

The volcanic to volcaniclastic Ottarasko formation is preserved beneath the Cloud Drifter formation in the central map area and in one thrust-bound panel in the main imbricate thrust zone in the southwest (Figure 2). No basal formation contact is known from our map area or from areas to the south, thus the true thickness is unknown, although a thickness exceeding 500 metres is suggested by the map patterns and extent. A gradational contact over 50 metres where the Ottarasko formation changes into the overlying Cloud Drifter formation is preserved on a ridge northwest of Perkins Peak, the first documented contact of these formations.

No diagnostic fossils have been recovered from the Ottarasko formation, and no radiometric dates have been successfully measured from the volcanic flows. The age is constrained only by the gradational contact with the overlying Cloud Drifter formation, which contains abundant fossils indicating a Hauterivian age. Thus the Ottarasko formation is early Hauterivian or older, and we speculate it is not older than Early Cretaceous.

The formation generally consists of greyish yellow-green to grey-green volcanic breccia and conglomerate with less common intermediate to mafic volcanic flows (rarely pillowed). The volcanic conglomerate and breccia are matrix supported, poorly stratified to unstratified and massive, with rare pyroclastic bombs.

The volcanic nature of the formation indicates a renewed period of volcanism, probably in the Early Cretaceous. Much of the volcanic material appears to be slightly reworked pyroclastic detritus, probably redeposited as debris flows from the margins of the main volcanic centres. Primary flows and some primary pyroclastic deposits are present however, suggesting a very local volcanic source. The gradational change upward to marine sandstone and mudstone of the Cloud Drifter formation probably reflects a slow transgressive interval in the region, with late stages of Ottarasko volcanism, possibly subaerial, coinciding with early Cloud Drifter formation deposition in an adjacent marine shelf environment.

CLOUD DRIFTER FORMATION

The Cloud Drifter formation is a thick package of lower Cretaceous sandstone, siltstone, minor mudstone and conglomerate preserved in the central map area thrust sheets (Figure 2). Characterized by fine to medium-grained lithic arenite or wacke in medium to thick beds, the lower contact is gradational over a few hundred metres with the underlying Ottarasko formation. The upper contact of the formation is not preserved and thus the true thickness is unknown. A minimum thickness of about 1500 metres is suggested in parts of the map area where cross-sections can be drawn with some confidence.

Fossils collected by Tipper (1969) and new collections from this project include common inoceramid bivalves and rare ammonites and belemnites. Poorly preserved carbonaceous plant fragments also occur in some siltstone. Although the ranges of several of the identified fossils are broad, the suite of fossils together indicates a Hauterivian age for Cloud Drifter deposition (Jeletzky, 1968; Tipper, 1969; Haggart, 1994, 1995).

Deposition of the Cloud Drifter formation in this area is interpreted in terms of a sand-dominated, open clastic shelf environment. A general lack of high-energy or wave structures suggests deposition in relatively deep shelf conditions, although rare hummocky cross-stratification and *Skolithos* ichnofacies indicate at least some deposition above storm wave base. Rare conglomerate beds represent coarse-sediment gravity flow deep onto the shelf. The volcanic-rich lithic composition of the sandstone, and volcanic-clast dominated conglomerate, are compatible with derivation from Ottarasko formation or exhumed volcanic arc sources, with source areas probably to the southwest or south.

LOWER TO "MID" CRETACEOUS

TAYLOR CREEK GROUP

A thrust slice preserved a few kilometres west of Bluff Lake (Figure 2) consists of about 50 to 60% thickly bedded feldspathic to lithic arenite including sedimentary chert clasts and interbedded with dark grey siltstone and mudstone, the latter commonly slightly carbonaceous and containing plant debris. We correlate this unit with the Taylor Creek Group, in agreement with the interpretation of Tipper (1969). The slice is contained by thrust faults and moderately deformed, but appears to encompass at least 500 metres of stratigraphic thickness.

In addition, in the range east of Perkins Peak, poorly stratified, dominantly felsic volcaniclastic rocks are preserved in thrust slices. We also include this felsic volcani-

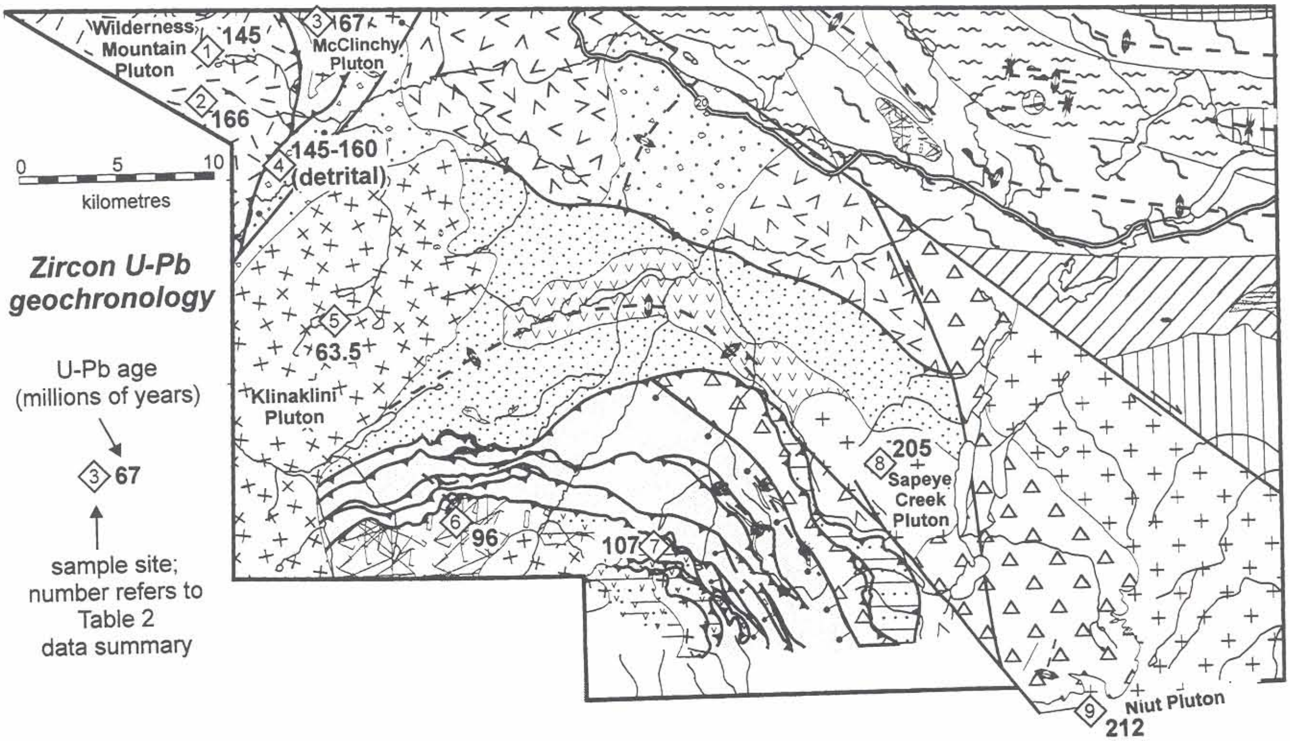

Figure 5. Location and age (rounded to nearest million years) of U-Pb on zircon analyses from plutons, volcanic and metamorphic rocks, and detrital zircons from sandstone. Numbers within location diamond are keyed to location and analysis information provided in Table 2. See legend for Figure 2 for explanation of geology map unit symbols.

TABLE 2
SUMMARY OF U-Pb ZIRCON GEOCHRONOLOGY AGES RESULTING FROM THIS STUDY

Sample Site	Map Unit	Rock Type	Interpreted U/Pb Date (Ma)	Interpreted Geological Significance
1	Wilderness Mountain Pluton	biotite-hornblende tonalite	145.4 +/- 1.0	emplacement age, part of complex composite igneous event
2	Wilderness Mountain Pluton	mylonitized tonalite	166 +7.7/-1.1	emplacement age, part of complex composite igneous event
3	McClinchey Pluton	tonalite	67.0 +/-0.5	emplacement age
4	Silverquick formation	arkosic sandstone	145-160 (8 grains)	detrital, derived from Coast Belt, immediately west
5	Klinaklini Pluton	biotite granodiorite	63.5 +/- 0.2	emplacement age
6	unnamed pluton	biotite hornblende tonalite	96.1 +/- 0.8	emplacement age
7	Taylor Creek Group	felsic volcanic	106.8 +7.0/-0.4	age of volcanic flow deposition
8	Sapeye Creek Pluton	hornblende tonalite	204.6 +10.0/0.8	emplacement age
9	Niut Pluton	quartz diorite	212 +/- 0.6	emplacement age

clastic unit within the Lower Cretaceous Taylor Creek Group, based on a U-Pb age from zircons in this unit of *circa* 107 Ma (Figure 5 and Table 2).

Several new fossil collections from the fault-bounded slice of sedimentary rock preserved west of Bluff Lake include bivalves identified as several types of pholadomyids, known from other areas to span an age range of upper Valanginian to Albian (Haggart, 1995). As discussed by Haggart, the unit is most likely post-Hauterivian age and this supports correlation of this fault slice with the Albian Taylor Creek Group.

UPPER CRETACEOUS

SILVERQUICK FORMATION

A thick unit of nonmarine, very coarse to medium-grained arkosic arenite interbedded with pebble-cobble conglomerate and rare mudstone, is preserved in the west Klinaklini River valley and well exposed on west-facing cliffs of a prominent ridge locally known as Finger Peak (Figure 3). We correlate this unit with the Silverquick formation known from areas to the southeast.

The lower contact is not exposed; the upper contact is gradational over several tens of metres into an overlying volcaniclastic and volcanic unit we correlate with the Powell Creek formation. Map relationships suggest the sedimentary unit is at least 750 metres thick and possibly more than 1000 metres thick.

Leaves in the upper part of the gradational contact strata between the top of the Silverquick formation and the base of the Powell Creek formation were tentatively identified as Cenomanian (W.A. Bell *in* Tipper, 1969, p. 95). New collections of leaves from within the gradational contact strata were identified as Albian to Cenomanian, although some types are thought by some workers to be restricted to the late Albian to Cenomanian (McIver, 1994a). Thus a broad late Albian to Cenomanian age seems most likely for Silverquick formation and the overlying Powell Creek formation.

Sandstones are immature with abundant subangular plagioclase and potassic feldspar grains and quartz making up the bulk of most, although volcanic lithic grains are more abundant in the upper part of the formation. Some sandstones have compositions of typical granitoids and appear to be slightly transported grus or other first cycle derivatives of a plutonic source.

Paleocurrents from imbricated pebbles and sandstone crossbeds define a radial pattern of transport varying from northeast to southeast. This, together with the sedimentary features described above, suggest deposition in a lower alluvial fan to braidplain environment with a western source. Uranium-lead dating of these zircons resulted in ages ranging from about 145 to 160 Ma. Zircons of these ages are known from the Wilderness Mountain Plutonic Complex, which is in fault contact with the Silverquick formation immediately to the west (Figure 5 and Table 2). It seems likely that this complex was the source for much of the Silverquick detritus. We suggest that the thrust fault which marks the contact between the Silverquick formation and the Wilderness Mountain pluton was a synsedimentary thrust, with the Silverquick formation detritus shed as a clastic wedge in front of the thrust slice carrying the complex.

POWELL CREEK VOLCANICS

A gradational change over tens of metres marks the contact between the Silverquick conglomerate and an overlying volcaniclastic and volcanic unit we correlate with the Powell Creek volcanics of areas to the southeast. This unit is best exposed in the northeast Bussel Creek and northwest Tatla Lake map area (Figure 2). The upper contact is not exposed and probably is cut off by the Yalakom fault to the northeast. A minimum thickness of several hundred metres (probably greater than 500 m) is suggested from the outcrop extent.

The unit is dominated by matrix-supported volcaniclastic breccia and conglomerate. Bedding is rarely definable, with tens to hundreds of metres of apparent thickness of massive, green-grey medium to fine-grained volcaniclastic wacke containing 5 to 30% subangular to angular volcanic pebbles to boulders randomly distributed throughout.

Age constraints for this unit come from the plant remains preserved in the basal gradational contact strata with the underlying Silverquick formation. As discussed for that formation, the age of these plants is most likely late Albian to Cenomanian. Thus the Powell Creek formation is this age and possibly slightly younger; there is no constraint on the upper age of the unit.

The depositional environment of this volcaniclastic-volcanic unit is interpreted as a nonmarine, debris flow dominated, alluvial fan system; part of an area of active volcanism. The tentative Cenomanian age supports correlation with Powell Creek volcanics described in areas to the southeast (Garver, 1989; Glover *et al.*, 1988).

PLUTONIC ROCKS

TRIASSIC - EARLY JURASSIC PLUTONIC ROCKS

Two plutons in the eastern part of the Bussel Creek map area (Sapeye Creek and Niut plutons on Figure 5) were previously undated and assumed to be Late Cretaceous or early Tertiary in previous studies (Tipper, 1969; Rusmore and Woodsworth, 1993). Both are massive, fine to medium-grained hornblende tonalites to quartz diorites. Both are cut by the Tchaikazan fault on one margin and have exposed intrusive contacts with volcanic and sedimentary rock units we correlate with the Middle to Upper Triassic

Mt. Moore formation. The Sapeye Creek pluton is bounded on its northern and west margin by Cretaceous sedimentary or volcanic rocks, however, the contacts with these units are not exposed and are interpreted as either faults or unconformities (Figure 2, and Mustard *et al.* 1994b).

Zircons from both plutons yielded U-Pb ages interpreted as the age of intrusion (R.M. Friedman, unpublished UBC geochronology report, 1994). The intrusive age for the Sapeye Creek pluton is reported as 204.6 + 0.6/-0.8 Ma, an earliest Jurassic age. The Niut pluton yielded a latest Triassic U-Pb age of 212.2±0.6 Ma. Both results support the correlation of the volcanic and sedimentary succession intruded by these plutons with the Middle to Upper Triassic Mt. Moore formation and negate earlier suggestions that these units could be Cretaceous in age (Tipper, 1969; Rusmore and Woodsworth, 1993).

COAST BELT PLUTONIC ROCKS

The eastern boundary of the Coast Belt in the study area is interpreted as a south-southwest-dipping thrust fault which marks the upper boundary of a major imbricate thrust zone (Figure 2). We correlate the imbricate zone with a similar zone at the base of the Coast Belt in the Razorback (92N/10) and Mount Queen Bess (92N/7) map areas (Rusmore and Woodsworth, 1988, 1989, 1993); as in those areas, the Coast Belt rocks in the study area occupy the highest thrust sheet in the East Waddington thrust belt. South of Perkins Peak this thrust sheet is dominated by biotite hornblende tonalite with a locally well developed, south-southwest-dipping mylonitic foliation. Zircons from an unfoliated part of the tonalite yielded a 96 +4.2/-0.8 Ma date, interpreted as the emplacement age of the pluton (Figure 5 and Table 2). Mylonites are particularly well developed adjacent to the thrust contact with underlying metavolcanic schists and phyllites at the top of the imbricate zone. Tonalite dikes in volcanic breccia near the shear zone are clearly derived from the adjacent pluton, and the shear zone is interpreted as a strongly disrupted intrusive contact. Rare southwest-dipping lineations and slickensides suggest top-to-the-northeast sense of shear.

In the range east of Perkins Peak, rocks closely resembling and here correlated with the 96 Ma tonalite are present only as small, locally sheared, but demonstrably intrusive domains within poorly stratified, dominantly felsic volcaniclastic rocks correlated with the Taylor Creek Group. The southern extent of these plutonic domains is unknown, and their connection with the 96 Ma tonalite south of Perkins Peak is obscured by a younger granodiorite intrusion. The 96 Ma tonalite and the felsic volcanic rocks which it is inferred to intrude apparently represent different parts of the same thrust sheet; they are here both included in the Coast Belt.

The northwest corner of the study area is underlain by tonalite of the Wilderness Mountain pluton, a large Middle to Late Jurassic intrusive complex (van der Heyden, 1991; van der Heyden *et al.*, 1993), which we include in the upper Coast Belt thrust sheet. It is characterized by a strongly developed, northwest-dipping mylonitic fabric. A relatively undeformed tonalite sample from the northwestern limit of the present map area has yielded a concordant 145.4±1.0 Ma zircon U-Pb age (Figure 5 and Table 2). Zircon U-Pb dating of a strongly mylonitic tonalite sample yielded a U-Pb age of 166 +7.7/-1.1 Ma, suggesting Wilderness Mountain pluton is probably a composite of several intrusions. (Figure 5 and Table 2). The contact with adjacent supracrustal rocks is not exposed, but rocks on both sides of the contact are cut by well developed, west to northwest-dipping brittle shear zones; we tentatively infer the contact to be a major thrust fault.

The upper thrust sheet, the adjacent imbricate zone, and the structurally underlying rocks of the Tyaughton trough are intruded by the Klinaklini pluton west and north of Perkins Peak, and by the McClinchy pluton north of Klinaklini River. The Klinaklini pluton is dominated by coarse-grained tonalite and lesser granodiorite with conspicuous accessory titanite. Zircons from a granodiorite sample yielded concordant 63.5±0.2 Ma U-Pb dates, interpreted as the emplacement age of the Klinaklini pluton (Figure 5 and Table 2). Granodiorite and quartz monzonite, with locally conspicuous potassium feldspar megacrysts, at the southwestern limit of the study area are probably compositionally distinct phases of the Klinaklini pluton. A satellitic granodiorite stock southeast of Perkins Peak has a strongly silicified and pyritized contact aureole; pyrite-galena-quartz boulders found in float near the contact are probably derived from veins related to this intrusion. The McClinchy pluton is dominated by medium-grained, locally porphyritic tonalite and granodiorite. Zircons from this pluton have yielded concordant U-Pb ages of 67.0± 0.5 Ma, comparable to the age of the Klinaklini pluton (Figure 5 and Table 2).

STRUCTURAL GEOLOGY SOUTHWEST OF YALAKOM FAULT

Several phases of deformation have effected the map area. Most prominent are the effects of northeasterly directed thrusting in the Late Cretaceous, which have deformed the area southwest of the Yalakom fault into a series of generally southwest to south-dipping thrust sheets, each internally deformed into folds (generally northeast vergent) and in places cut by minor high-angle faults apparently restricted to individual thrust sheets (Figures 2 and 3). The other major deformation event is a phase of latest Cretaceous to early Tertiary dextral strike-slip faulting, most evident as the Yalakom and Tchaikazan faults, two major linear dextral strike-slip fault zones which cut across older structures in the map area (Figure 2). Possibly related to the dextral strike-slip faulting is the existence of a broad, upright northeast-trending open fold which is evident in the upper central part of the map area, folding Silverquick formation and Powell Creek volcanic units (Figures 2 and 3).

More than 2000 structural measurements were taken in the course of mapping of the area. Major structural domains became evident during detailed mapping, and were defined more precisely by plotting field data onto stereonets in several different combinations of possible domains. The main data set is presented directly on the published geologic map (Mustard *et al.*, 1994b). A summary of the main features is given below.

IMBRICATE ZONE STRUCTURAL DOMAIN

The Coast Belt is separated from Cretaceous strata of Tyaughton trough by a major imbricate thrust zone, consisting of multiple thrust-bounded panels of Upper Triassic volcanic and sedimentary rocks (Figures 3 and 4). The imbricate zone is about 8 kilometres wide in the Tatla Lake map area, narrows abruptly to about 3 kilometres in the Bussel Creek area near Perkins Peak, and appears to be represented only by a single fault sliver of Upper Triassic volcanic rocks north of Klinaklini River. The imbricate zone of this study continues to the southeast into the Razorback map area (92N/10) where it was defined by Rusmore and Woodsworth (1991b, 1993, 1994) as part of a major thrust belt they termed the Eastern Waddington thrust belt. Data from the Razorback and Queen Bess map areas to the south provide indirect evidence that it was active at 84 Ma, and probably at 87 Ma (Rusmore and Woodsworth, 1994). Our data suggest it may have also been active during emplacement of the *circa* 96 Ma pluton south of Perkins Peak (van der Heyden *et al.*, 1994).

LOWER CRETACEOUS STRUCTURAL DOMAIN

Lower Cretaceous strata of the Ottarasko and Cloud Drifter formations are restricted to one thick thrust sheet which intersects the surface immediately north of the imbricate zone (Figures 2 and 3). Within it, strata are deformed in both tight, inclined folds which generally display a north or northeast sense of vergence, or in the Miners Lake area a larger, broader anticline cored by the Ottarasko formation (Figure 3, cross-section B-B').

UPPER CRETACEOUS STRUCTURAL DOMAIN

The Upper Cretaceous Silverquick formation and Powell Creek volcanics are, with one exception, confined to a region north of the thrust fault carrying the Lower Cretaceous strata discussed above. This domain is bounded on the west by the margins of the younger Klinaklini and McClinchy plutons, by a thrust contact with the older Wilderness Mountain pluton, and by an unconformity contact with a small remnant of Upper Triassic Mosley formation (Figure 2).

The Upper Cretaceous structural domain may be part of a northerly sheet of the East Waddington thrust belt, but if so, the northern thrust contact has been cut out by the younger Yalakom fault. The main influence on the structure of the Upper Cretaceous domain is a broad, open anticline which trends to the northeast and is displayed in the map pattern by a core of Silverquick formation with Powell Creek volcanics exposed on both east and west.

TCHAIKAZAN FAULT STRUCTURAL DOMAIN

A major right-lateral strike-slip fault is present in the valley containing Bluff, Horn and Sapeye lakes on the eastern side of the map area (Figure 3), and is thought to be a continuation of the Tchaikazan fault originally recognized by Tipper (1969). Tipper mapped this fault as continuing to the west of the Sapeye Creek pluton, and not in the major valley as we show it on Figure 3. Our new mapping suggests the western faults Tipper considered the main Tchaikazan fault are splays of the main fault and can only be traced to the central part of the map area. We believe the main Tchaikazan fault cuts the Mt. Moore formation east of Bluff and Sapeye lakes and appears to merge into the main Yalakom fault system about 10 to15 kilometres west of the village of Tatla Lake (Figure 3). This conclusion is strongly supported by the regional aeromagnetic data for the area, which shows a prominent linear feature continuing along the east side of Bluff and Sapeye lakes and apparently merging with the Yalakom fault (Geological Survey of Canada, 1994; Teskey *et al.*, 1997, this volume).

A unique facies, containing rare limestone beds with silicified corals, is present in the Mt. Moore formation on both sides of the main fault in the ridges near Bluff Lake, and offset of this marker unit indicates 7 to 8 kilometres of right-lateral movement on the Tchaikazan fault.

TATLA LAKE COMPLEX

The northwestern part of the Tatla Lake map area is underlain by crystalline rocks of the Tatla Lake Metamorphic Complex. It was not examined in detail during the present study, and no significant new observations were made, in deference to the detailed mapping and research reported in Friedman (1988, 1992) and Friedman and Armstrong (1988).

ECONOMIC GEOLOGY

Exploration activity in the map area has been relatively minor, and only a few gold, copper and iron prospects are known. Only the Perkins Peak gold prospect (described below) is the site of active (though minor) continuing exploration as of 1995. The following descriptions of properties in the area are summarized from the B.C. Geolocial Survey Branch MINFILE database, supplemented by new information from this study.

NEWMAC CLAIM GROUP (PORPHYRY Cu, Au)

The Newmac claims (MINFILE 92N-55) are currently owned by Canevex Resources Ltd and Noranda Exploration Company Limited. The area is underlain by thick packages of andesitic volcanic breccias and flows with lesser tuffaceous layers and felsic flows and tuffs; minor conglomerates, arkosic sandstone, and a few interbeds of coral-bearing limestone. Quartz diorite intrudes the volcanics to the north, south and east of the claims, smaller dioritic and felsic dikes and stocks intrude the volcanic rocks on the property. All rocks are cut by strongly developed northwest and northeast-trending fracture sets and some minor faults.

The property was originally staked due to the presence of minor placer gold (including one nugget) in the main drainage, copper-gold soil anomalies, high induced polarization responses, and supposed similar host (thought to be Early Cretaceous) and intrusive ages (thought to be Late Cretaceous to Tertiary) to the porphyry copper-gold deposit at Fish Lake. Nine core holes were drilled during 1988 to 1991. Elevated copper assays and, rarely, minor gold values were returned from some drill core sections. Results were not sufficiently encouraging for continued drilling after the 1991 program.

Uranium-lead dating of zircons from the Niut pluton, which intrudes the host volcanic-volcaniclastic succession at the south end of the property (and possibly is part of a continuous plutonic complex on the east and north side of the property) provide a Late Triassic age (*ca.* 212 Ma) for the pluton. A single chert sample from the property yielded radiolarians interpreted as Middle Triassic age (Cordey, 1994). Thus the volcanic-volcaniclastic unit is not Early Cretaceous and is here correlated with the Mt. Moore formation.

PERKINS PEAK (VEIN Au)

The Perkins Peak claim group (also known as Mountain Boss, Commodore, Mountain King claims; MINFILE 92N-010) are owned by Kleena Kleene Gold Mines Ltd. Gold and minor silver-bearing arsenopyrite-quartz veins and silicified argillite zones have been drilled and explored by adits and exploration trenches since the 1930s. Currently several hundred metres of tunnelling from two adits is in place and active underground drilling and minor gold recovery from the vein systems is continuing.

Quartz veins and silicified argillite occur in both Early Cretaceous sedimentary rocks of the Cloud Drifter formation and in quartz diorite stocks and dikes of probable Late Cretaceous to early Tertiary age, which cut the sedimentary package. The sedimentary succession and mineralized zones occur within a generally southwest-dipping thrust plate, part of the northeast-vergent, Late Cretaceous East Waddington thrust system. The sedimentary rocks are folded into northeast-vergent, inclined anticline-syncline pairs. Well developed fractures and minor faults occur in distinctive east, northwest, and northeast trending sets, and mineralized zones are slightly offset by some of the faults. The auriferous quartz veins may be extension fractures that formed perpendicular or obliquely at high angles to thrust faults in late stages of the thrusting event.

OTHER MINERAL PROSPECTS

South of Perkins Peak the imbricate zone is extremely gossanous and pyritic schist is common; much of the valley south of Perkins Peak is covered with strongly oxidized ferricrete breccias. The iron alteration in this area is locally associated with stratiform hematite replacement and quartz-specularite veining in the Upper Triassic volcaniclastic rocks (Briton iron prospect, MINFILE 092N-011). Sheared quartz-calcite-magnetite-malachite-azurite and chlorite-epidote-magnetite veins are locally present in thrust-related shear zones. Bornite-chalcopyrite-chalcocite-malachite float and disseminated chalcopyrite and malachite in altered Upper Triassic volcanic rocks southeast of Perkins Peak (Pin copper showing, MINFILE 92N-053), is also associated with shear zones of the imbricate zone. Several auriferous quartz veins in the study area (Orwill Au-Ag-Cu-Zn-Pb-Sb-Bi prospect, MINFILE 92N-053; Golden Rose Au-As showing, MINFILE 92N-046) also appear to be spatially associated with thrust faults of the imbricate zone.

A satellitic granodiorite stock of the 63.5 Ma Klinaklini pluton, southeast of Perkins Peak, has a strongly silicified and pyritized contact aureole; pyrite-galena-quartz boulders found in float near the contact during mapping for this study are probably derived from veins related to this intrusion.

REGIONAL SIGNIFICANCE

This study has resulted in several significant advancements in the understanding of the geology of the Coast Belt - western Intermontane Belt in west-central British Columbia. We have extended the length of the Late Cretaceous Eastern Waddington thrust belt several tens of kilometres northwest of its previous known extent. The thrust belt continues at least to the Perkins Peak area, where it is intruded by the *ca.* 63 Ma Klinaklini pluton. There are two possibilities for the continuation of the belt beyond the pluton, to the west or to the north. West of the Klinaklini pluton, Roddick and Tipper (1985) show a steeply dipping structure separating Central Gneiss Complex to the south (their unit nsc) from an Early Cretaceous pluton (their unit lKqd, correlative with the Late Jurassic Wilderness Mountain pluton of this study) to the north. However, we do not believe this contact represents a continuation of the Eastern Waddington thrust belt. In the thrust belt, rocks of the Coast complex, which locally include Late Jurassic orthogneiss (Rusmore and Woodsworth, 1993), are typically thrust over relatively unmetamorphosed supracrustal rocks. We include the locally strongly mylonitic Wilderness Mountain pluton in the Coast Belt, and suggest that the northeast-trending thrust fault which separates it from underlying supracrustal rocks north of Klinaklini River represents the northern continuation of the thrust belt (Figure 2, Mustard *et al.*, 1994b). This fault is intruded by the *circa* 67 Ma McClinchey pluton. The imbricate zone of the thrust belt is relatively wide in the south study area and in the Razorback map area to the southeast. It narrows near Perkins Peak and is largely missing north of the Klinaklini River, suggesting that the numerous thrusts of the belt merge into only one or two strands at the base of the Wilderness Mountain pluton, and that the belt dies out to the north.

Our study also extends the known Cretaceous strata of the Tyaughton trough to the northwest. Cretaceous marine strata of Tyaughton trough (Cloud Drifter formation and Taylor Creek Group) are almost absent northwest of Klinaklini River (a small isolated exception is shown on the map of Roddick, 1994, and discussed in Rusmore *et al.*, in press). Jurassic marine strata of the trough (Relay Mountain Group and Last Creek formation) are absent north of the Potato Range (*ca.* 35 km southeast of the study area). It seems likely that the Tyaughton trough may have had a northwestern margin in or near the present map area.

Our study provides the first direct evidence of a gradational contact between the Lower Cretaceous Ottarasko and overlying Cloud Drifter formations. We suggest the Ottarasko formation represents the deposits of a western volcanic arc, in turn the source of the clastic facies of the Cloud Drifter formation to the east of the arc complex. This interpretation is also suggested by Umhoeffer *et al.* (1994).

The known extent of Upper Triassic rocks in northern Mount Waddington map area has been greatly expanded due to recognition of more extensive preservation of the Mt. Moore formation than previously mapped and the dating of the Sapeye Creek and Niut plutons as earliest Jurassic and Late Triassic, respectively. Recent mapping to the east of the study area (NTS 92N/09) has identified Triassic sedimentary and volcanic successions from the northeast of Chilko Lake to the Yalakom fault which are intruded by several plutons, at least one of which is probably Late Triassic in age based on preliminary U-Pb geochronology (Schiarizza *et al.*, 1995, Schiarizza and Riddell, 1996).

Rusmore and Woodsworth (1993) and Umhoeffer *et al.* (1994) correlated Upper Triassic rocks of the northern Mount Waddington area with Stikinia. Our new information supports this correlation, most significantly in the recognition of Early Jurassic and Late Triassic plutons in this area, intrusive ages and types common and distinctive of Stikinia in northern British Columbia (Anderson and Bevier, 1992; Anderson, 1993). The presence of Upper Triassic rocks between the Yalakom and Tchaikazan faults, together with Lower Cretaceous strata of Tyaughton trough, suggests that the northern margin of the basin was underlain by Stikinia. A similar suggestion was made by Umhoeffer (1990) and more recently by Umhoeffer *et al.* (1994). Schiarizza *et al.* (1995) suggested Triassic successions in their study area, immediately east and southeast of the Bussel Creek area, are similar to Cadwallader Terrane successions to the southeast, although Late Triassic plutons have not been recognized in classical Cadwallader Terrane. A reasonable interpretation of these similarities to the Triassic successions of both Stikine and Cadwallader terranes is that they were part of the same volcanic-arc system and have been juxtaposed by later, relatively minor translation (Umhoeffer, 1990; Rusmore and Woodsworth, *1991*b; Umhoeffer *et al., 1994*; Schiarizza *et al., 1995)*

SUMMARY

The Tatla Lake and Bussel Creek map areas southwest of the Yalakom fault contain the northern terminations of the East Waddington thrust belt and Tyaughton trough. Foliated plutons and volcanics of the Jura-Cretaceous Coast Belt arc are thrust northeast over an Upper Triassic arc succession correlated with Stikine Terrane, although with some similarities to the Cadwallader Terrane to the southeast. Triassic strata include the Anisian to lower Norian, volcanogenic Mt. Moore formation, and the Norian Mosley formation, a mixed siliciclastic-carbonate nonmarine and shallow-marine succession which changes laterally to the west to a subaerial volcaniclastic breccia complex. The Triassic arc rocks, in turn, are thrust over a central series of thrust sheets containing two Early Cretaceous units: the volcanogenic Ottarasko formation and gradationally overlying Cloud Drifter formation, a succession of shelf clastics containing Hauterivian fossils. These Early Cretaceous units are interpreted as the northwestern deposits of the Cretaceous Tyaughton trough, in part derived from a westerly, mixed volcanic-plutonic source. At the northern limit of the map area, Coast Belt plutons and Triassic rocks are thrust directly on Late Cretaceous nonmarine Silverquick formation; marine strata of Tyaughton trough are absent, and the thrust belt is intruded by the *circa* 63-67 Ma Klinaklini and McClinchy plutons. The northeasterly structural panels contain the youngest units: a single slice of Albian to Cenomanian marine turbidites correlated with the Taylor Creek Group; a nonmarine immature sandstone and conglomerate unit correlated with the Silverquick formation; and a volcanic breccia/conglomerate unit correlated with the Powell Creek volcanics, the latter two units of probable late Albian to Cenomanian age.

A much more extensive Triassic succession than previously recognized includes the newly dated *circa* 205 Ma Sapeye Creek pluton, and the *circa* 212 Ma Niut pluton exposed in the southeast part of the map area. Possibly a

southern extension of Stikine Terrane, this succession may underlie the Tyaughton trough between the Yalakom and Tchaikazan faults. The area northeast of the Yalakom fault is underlain by the Eocene Tatla Lake metamorphic core complex.

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