

STRUCTURAL RELATIONSHIP BETWEEN THE LABERGE GROUP AND SINWA FORMATION ON COPPER ISLAND, SOUTHERN ATLIN LAKE, NORTHWEST BRITISH COLUMBIA

by Kara L. Wight, Joseph M. English and Stephen T. Johnston

University of Victoria

KEYWORDS: *King Salmon Thrust, Whitehorse Trough, Llewellyn Fault, Atlin Lake, Copper Island Fault*

INTRODUCTION

The Whitehorse Trough is an elongate Mesozoic arc-marginal volcano-sedimentary basin that extends from central Yukon to Dease Lake in northwest British Columbia (Figure 1). The Whitehorse Trough contains volcanoclastic and carbonate strata of the Upper Triassic Stuhini Group and siliciclastic strata of the Lower to Middle Jurassic Laberge Group (Figure 2). Major structures within the southern Whitehorse Trough include the Llewellyn and Nahlin Faults and the southwest-vergent King Salmon Thrust.

The King Salmon Thrust carries the Upper Triassic Sinwa Formation (Stuhini Group) and Lower Jurassic Inklin Formation (Laberge Group) in its hanging wall over top of more proximal facies of the Laberge Group to the southwest (Souther, 1971; Figure 1). Regional mapping suggests that the King Salmon Thrust extends northwards into the southern Atlin Lake region (*e.g.* Wheeler and McFeely, 1991). The major structure in the Atlin Lake region is, however, the Llewellyn Fault (Wheeler and McFeely, 1991), a steep north-northwest-trending strike-slip fault of largely Triassic to Cretaceous age (Mihalynuk, 1999). The fault that marks the southwest limit of the Laberge Group in the southern Atlin Lake region (herein called the Copper Island Fault) has previously been interpreted to be the northern extension of the King Salmon Thrust. Both the King Salmon Thrust and the Copper Island Fault trend northwest. The main goal of this paper is to determine if the Copper Island Fault in the southern Atlin Lake region is an extension of the King Salmon Thrust, or if it is a separate and possibly younger structure. To address this question, a detailed geological mapping program was undertaken on Copper Island in southern Atlin Lake. Mapping focussed on determining the nature of the Copper Island Fault, the relationship to other regional structures, and on documenting the structure and stratigraphy of adjacent strata of the Laberge.

The goals of this paper are to: (1) describe the stratigraphy and structure of Copper Island, (2) construct and discuss the structural cross sections for Copper Island

and (3) establish if the Copper Island Fault is a northern continuation of the King Salmon Thrust as previously assumed or a separate entity.

GEOLOGICAL BACKGROUND

Early Mesozoic arc marginal volcano-sedimentary rocks of the Whitehorse Trough include conglomerate, siltstone, sandstone and greywacke that were deposited in a deep marine setting of submarine fans and conglomeratic fan deltas (*e.g.* Dickie and Hein, 1995, Johannson *et al.*, 1997). Laberge Group sediments were derived from the unroofing of the Stikine magmatic arc and Yukon-Tanana terrane to the west and southwest (Dickie and Hein, 1995; Johnston *et al.*, 1996; Johannson *et al.*, 1997) and are divisible into a distal sandstone facies in the northeast (Inklin Formation) and a proximal conglomeratic facies in the southwest (Souther, 1971; Monger *et al.*, 1991).

The marine Inklin Formation consists of a ~ 3 km thick succession of interbedded greywacke, shale and siltstone with minor conglomerate (Johannson *et al.*, 1994), interpreted as the distal facies of coalescing submarine fans and conglomeratic fan deltas (Dickie and Hein, 1995). In the southern Atlin Lake area, the Inklin Formation ranges in age from Early Sinemurian to Late Pliensbachian (Johannson *et al.*, 1997). In the southern Whitehorse Trough, the conglomeratic facies of the Laberge Group onlaps the Upper Triassic volcanic and carbonate rocks of the Stuhini Group (Souther, 1971). In the southern Atlin area, the distal Laberge Group facies are faulted against the Stuhini Group strata by the Copper Island Fault and the proximal conglomeratic facies of the Laberge Group are missing.

The Whitehorse Trough was tectonically shortened during the Middle Jurassic as a result of a collisional event that involved the west directed emplacement of the Cache Creek terrane over the Whitehorse Trough and Stikine terrane (Mihalynuk, 1999). Structures of the central Whitehorse Trough are dominated by southwest-vergent folds and thrusts (English *et al.*, 2003). The age of the fold and thrust belt development is constrained as mainly Middle Jurassic on the basis of biostratigraphy (Tipper, 1978) and between 174 and 172 Ma based on

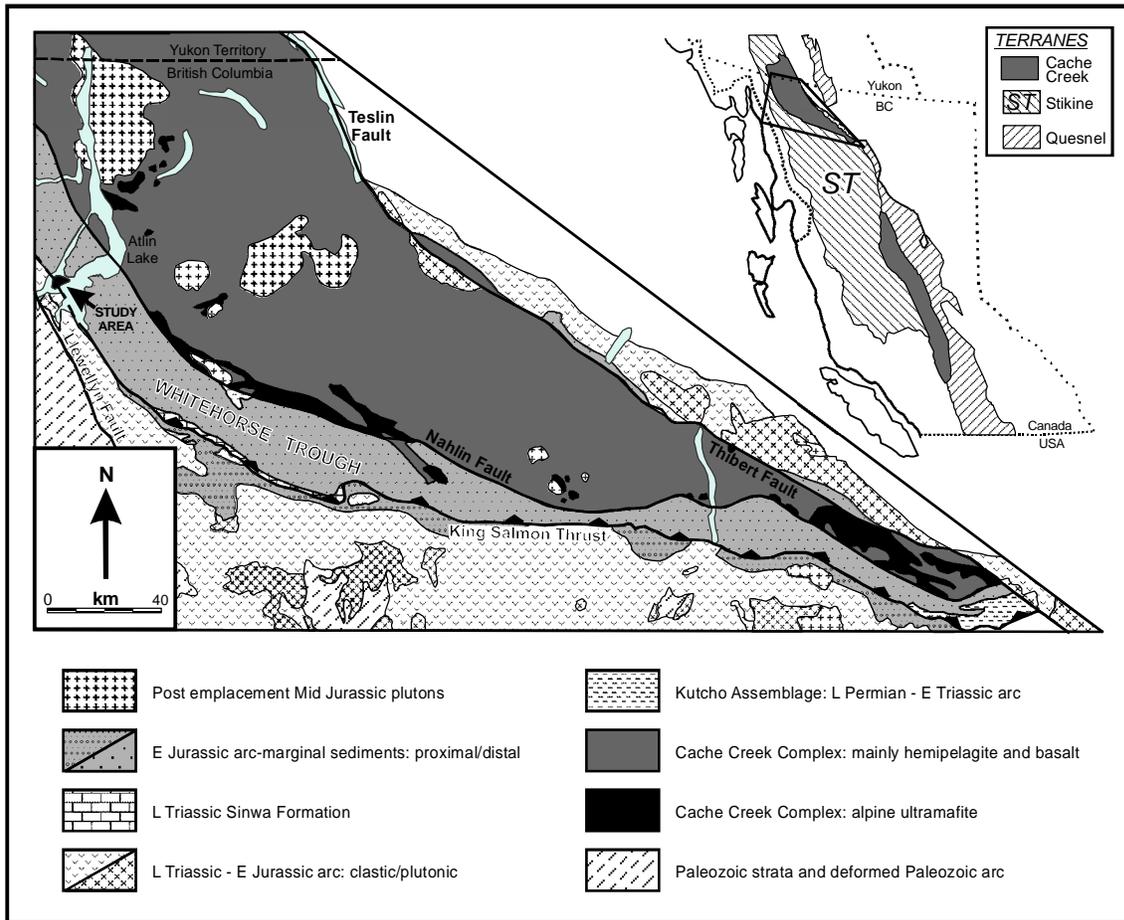


Figure 1. Location of Copper Island Study Area in southern Atlin Lake.

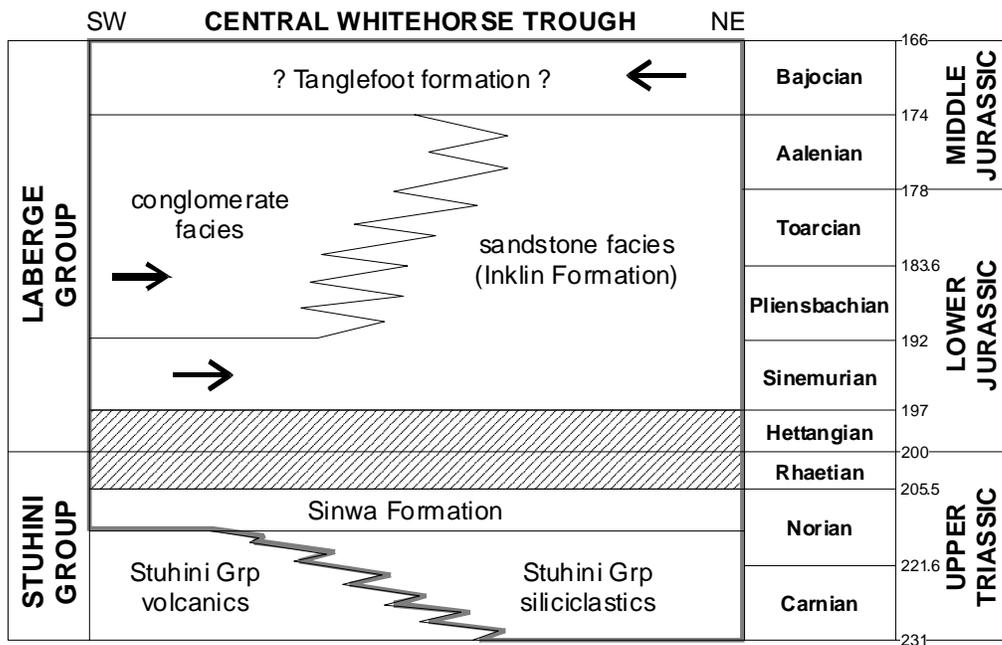


Figure 2. Stratigraphy of Laberge Group within the Whitehorse Trough. Arrows indicate paleoflow direction. Tanglefoot formation is a chert and pebble conglomerate from the Cache Creek terrane in Yukon (source: English *et al.*, in review).

isotopic cooling age determinations (Mihalynuk *et al.*, in press).

Two major thrust faults that developed during collision were the King Salmon Thrust and the Nahlin Fault. The Nahlin Fault bounds the northeast limit of the Whitehorse Trough at the surface (Aitken, 1959) and carries Cache Creek terrane in its hanging wall. In the southern Whitehorse Trough, the King Salmon Thrust carries the Upper Triassic Sinwa Formation and Lower Jurassic Inklin Formation in its hanging wall over more conglomeratic facies of the Laberge Group in its footwall. The King Salmon Thrust occurs near the base of the Sinwa Formation and subsidiary thrust faults splay from and mimic the trend and vergence of this major structure (English *et al.*, 2003).

The northern extent of the King Salmon Thrust is, however, uncertain. In the area southeast of Atlin Lake, Early Eocene Sloko Group volcanic rocks conceal the northern continuation of the King Salmon Thrust (Aitken, 1959; Mihalynuk, 1999). A similarly positioned fault, the Copper Island Fault, occurs on the northwest side of the exposed Sloko Group through Atlin Lake and was previously interpreted as the King Salmon Thrust. The Copper Island Fault can be distinguished from the King Salmon Thrust based on its geometry and relationship of adjacent rocks. This fault may instead represent a splay of the Llewellyn Fault and the possibility that the Copper Island Fault is a strike slip splay was investigated.

STUDY AREA

The structure and stratigraphy of the Laberge Group on Copper Island in southern Atlin Lake were used to evaluate the Copper Island Fault. The study area covers a 30 km² region straddling the Copper Island Fault. This fault that separates the Sinwa Formation and Inklin Formation was mapped from the southwest shore of Atlin Lake, across Second Narrows and Copper Island, to the western shore of Torres Channel (Figure 3). At its western extent, the Copper Island Fault is plugged by a Late Cretaceous intrusion in the vicinity of Cathedral Mountain (Mihalynuk, 1999).

STRATIGRAPHY

The study area is underlain by volcanic, volcanoclastic and carbonate strata of the Upper Triassic Stuhini Group and Lower Jurassic Inklin Formation (Figures 2 and 3). Volcanic rocks of the Stuhini Group are a minor component of the area and outcrop on the southwestern corner of Copper Island.

The Norian Sinwa Formation of the Stuhini Group consists of light to dark grey massive to bedded

limestone. Fossiliferous undulating light grey beds are 0.2 - 5 cm thick and interbedded with 0.25 - 2 cm beds of dark grey limestone. Some of these shallow marine carbonates have an extensive lattice of calcite veining and a marbled appearance near the contact zone with the Laberge Group. Some samples were fetid. In the Second Narrows region, limestone is intercalated with Late Triassic volcanoclastic strata and pyroclastic rocks of the Stuhini Group (Mihalynuk, 1999). The fault zone extending across Second Narrows marks the unexposed contact between the Sinwa Formation limestone and the Laberge Group.

Early to Late Pliensbachian greywacke, siltstone, argillite, sandstone and minor conglomerate are characteristic of the Inklin Formation within the Laberge Group. The most common sediments on Copper Island consisted of medium grey to dark grey-green massive to graded wacke beds (more than 15% matrix) that range from 1.5 - 100 m thick, with the thickest beds exposed on the northwest shore of Copper Island. Two to three meter thick beds of these lithic wackes are commonly interbedded with argillite, siltstone and sandstones. Flame structures, and convoluted and planar contacts mark the boundaries between beds. The greywacke consists of angular, poorly sorted, medium to coarse sand in a 15-70 % mud matrix. Clasts include lithic clasts (predominantly volcanic rock), feldspar, quartz, biotite and <15% mafic minerals. Most beds were right way up, however, bedding of greywacke and siltstone is overturned in the central portion of Copper Island. Veins of calcite are found in the vicinity of fault zones and orange weathering is common.

Within the Inklin Formation, there is a siliciclastic unit of medium to coarse grained quartz rich wacke and sandstone that occurs as 100+ m thick beds, coarsens upwards and displays dark orange weathering. Rip up clasts (~20 x 40 cm) and lenses of siltstone are commonly contained within the sandstone.

Siltstone occurs as 1 - 10+ m thick, black to medium rusty brown 0.5 - 3 cm laminated beds. The bedding varies from undulating and convoluted to planar. The siltstone is subordinate within wacke dominant sequences, and is commonly interbedded with coarser orange brown fine grained sandstone. Bioturbation, orange weathering and lenses of sandstone are common.

Pebble to cobble conglomerate occurs as one minor 20 m thick bed on southeast Copper Island. The clasts are dominantly rounded to subrounded volcanics, greywacke and shale. This unit was not found to outcrop in any other portion of the island. The absence of the conglomeratic facies of the Laberge Group in the southern Atlin area is different than the stratigraphy found in the footwall of the King Salmon Thrust in the Taku River area where coarse conglomeratic facies of the Laberge Group are dominant (Souther, 1971).

Copper Island, Southern Atlin Lake

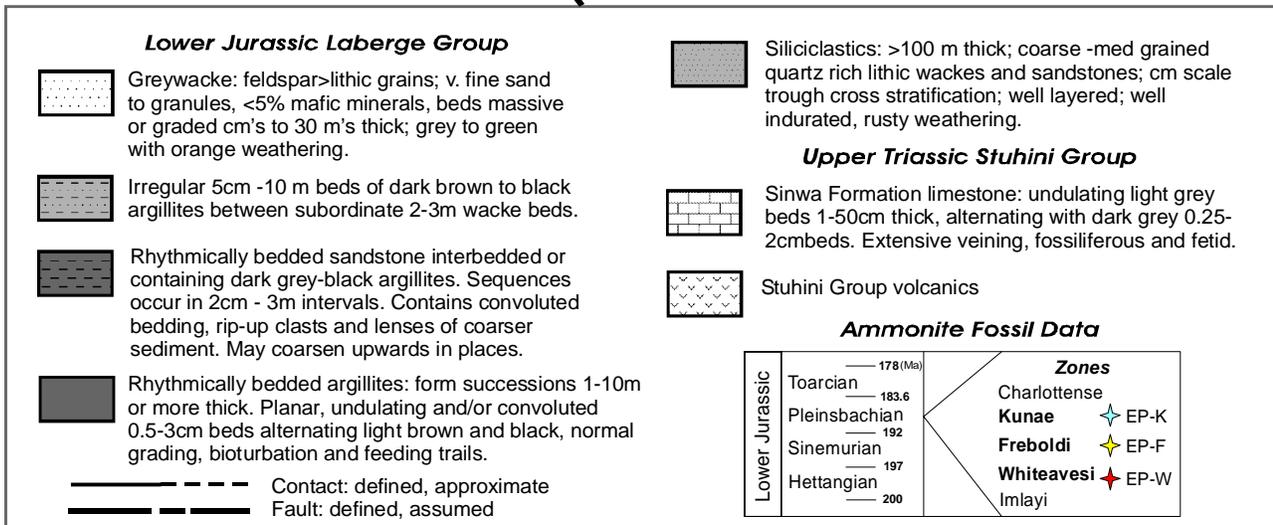
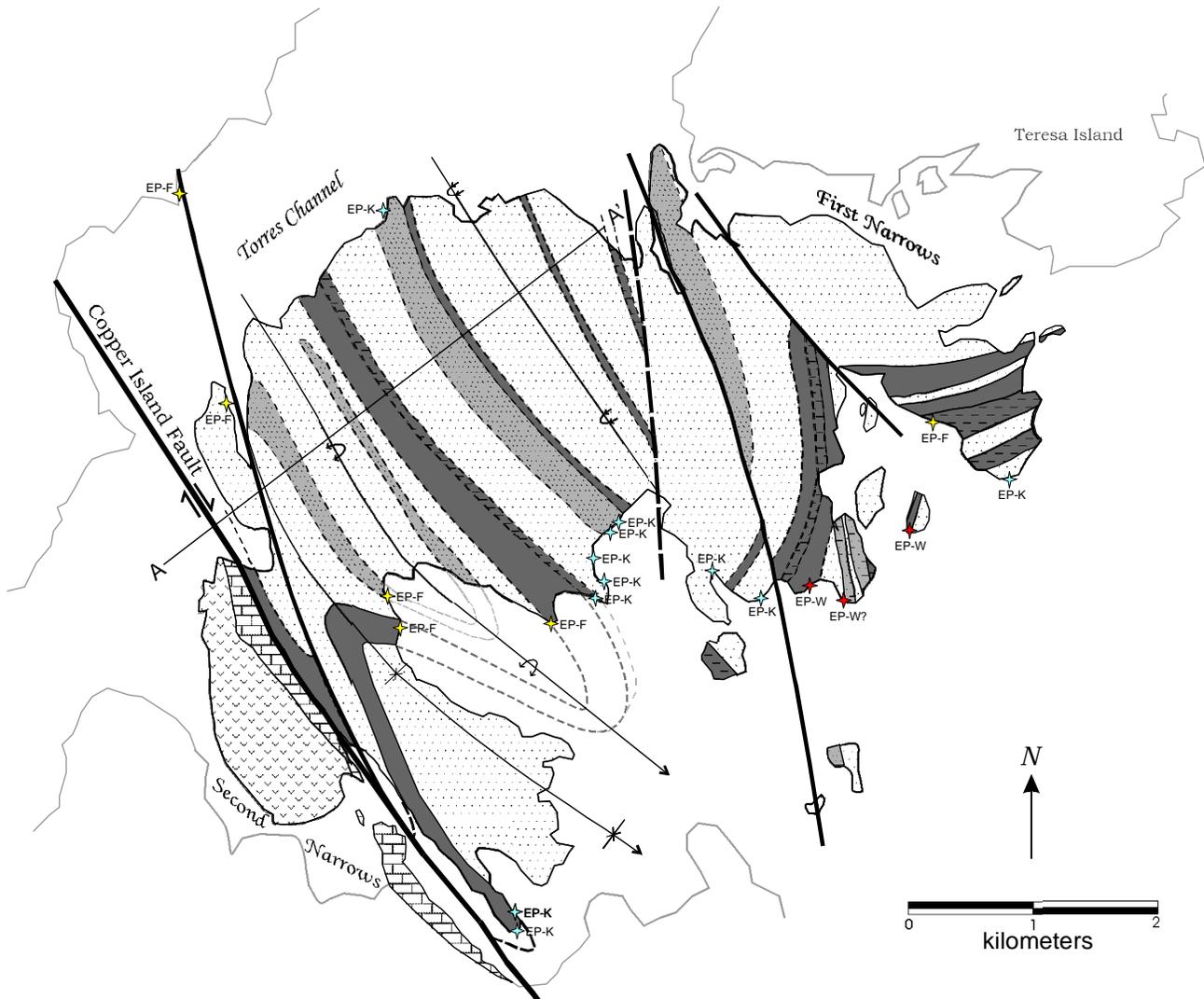


Figure 3. Bedrock geology map of Copper Island.

STRUCTURE

Copper Island is characterised by northwest/southeast trending folds and faults. One shallowly southeast plunging syncline occurs on southwest Copper Island adjacent to the Copper Island Fault. An overturned anticline in central Copper Island shallowly plunges to the southeast (Figure 4 and 5). Minor folds perpendicular to the Copper Island Fault occur along the ridge top northeast of Second Narrows. A tight minor antiform on a centrally located island off the southeast shore of Copper Island could not be followed onto Copper Island.

The Copper Island Fault separates the Sinwa Formation to the southwest from the younger Inklin Formation to the northeast. Laberge Group siltstone adjacent to the fault contains Late Pliensbachian (Kunae Zone) ammonites (Johansson *et al.*, 1997) and previous dating of the Sinwa Formation concludes the age to be Norian (Upper Triassic) (Souther, 1971).

Bedding attitude is variable adjacent to the Copper Island Fault; the Sinwa Formation limestone dips from subvertical to shallow in multiple orientations (*e.g.* 138/79; 260/60; 356/011). The Inklin strata are moderately shallow and dip inconsistently (*e.g.* 018/23; 226/40; 233/52; 336/54). Variability in bedding may be due to local deformation along the Copper Island Fault. The Copper Island Fault is a subvertical structure trending northwest through Second Narrows and Copper Island (Figure 3 and 5). The linear fault zone is 175-200 meters wide and crosscuts different aged bedding of adjacent strata. Extensively fractured rocks and slickenfibres lineations that shallowly plunge to the southeast ($17^\circ \Rightarrow 148^\circ$) and ($18^\circ \Rightarrow 126^\circ$) are observed in the Copper Island Fault zone. The shallow orientation of the slickenfibres may indicate a largely translational motion on the Copper Island Fault.

Additional post Mid-Jurassic linear faults divide the northeast portion of Copper Island and crosscut Laberge Group bedding and the northwest-trending folds. The rocks in these faulted areas are shattered or gouged, and the faults form linear features on air photos and commonly have intrusions along the margins of the fault zone. Intrusions often were in or directly next to linear narrow bays that formed along the fault zones. The younger faults variably cut across the folds formed in the Mid-Jurassic (Tipper, 1978; Mihalynuk, in press). Several other faults cut across Copper Island on the eastern shore variably trending 270-330°. Variable orientations and the number of faults added much complexity to structural interpretation of the east portion of Copper Island. In detail, thick beds may disappear over short distances and are thought to be interrupted by a fault rather than pinched out stratigraphically.

Subvertical strike slip faults are common in the southern Atlin Lake area and are exposed along Atlin Lake, Bastion and Griffith Islands (English *et al.*, in review). Additionally, the subvertical Llewellyn Fault

trends northwest across Llewellyn Inlet. Mihalynuk (1999) documented abundant vertical to subvertical northeast trending faults of sinistral and dextral motion with <10 meter offset in the Tagish Lake Area. Regionally, the subvertical Copper Island Fault continues to separate the Upper Triassic Stuhini Group and the Lower Jurassic Laberge Group to the northwest and merges with the Llewellyn Fault near Tagish Lake (based on bedrock geology map of Mihalynuk, 1999). Therefore, the Copper Island Fault represents a splay on the Llewellyn strike slip system rather than a continuation of the King Salmon Thrust.

DISCUSSION

The Copper Island Fault is commonly interpreted as an extension of the King Salmon Thrust (Wheeler and McFeely, 1991); however, these two faults may be independent structures.

In the central portion of the Whitehorse Trough near the Taku River, the Sinwa and Inklin Formations occur northeast of and in the hanging wall of the King Salmon Thrust, and are carried over younger Lower Jurassic conglomeratic facies of the Laberge Group to the west (Souther, 1971). The Copper Island Fault, however, juxtaposes older, Upper Triassic Sinwa Formation limestones, to the southwest, against younger, Late Pliensbachian Laberge Group strata to the northeast; Sinemurian and Early Pliensbachian strata are absent across the fault. The cutting out and structural thinning of the stratigraphic section, and the juxtaposition of younger rocks to the northeast against older rocks to the southwest is the opposite of what would be expected if the Copper Island Fault were a west verging thrust fault.

Arguably, the history of the King Salmon Thrust is similar to the history of the Nahlin Fault. The Nahlin Fault bounds the northeast margin of the Whitehorse Trough (Figure 1) and originated as a thrust fault during emplacement of the Cache Creek terrane (Mihalynuk, 1999). As the Nahlin Fault extends into Atlin Lake area, the structure becomes vertical and displays dextral wrench displacement perhaps due to reactivation between ~55 and ~46 Ma (Mihalynuk *et al.*, 2003). Thus, the Copper Island Fault could represent younger strike slip motion on a northern continuation of the King Salmon Thrust. However, this remains problematic because the age relation of stratigraphy across Copper Island Fault differs to that of the King Salmon Thrust.

The steep nature of the Copper Island Fault, variable bedding adjacent to the structure, shallowly plunging slickenfibres, and the crosscutting of beds suggest a translational strike slip motion for the Copper Island Fault. In addition, the well developed fold and thrust belt characteristic of the southern Whitehorse Trough is not seen in southern Atlin Lake (English *et al.*, in review) and local and regional faults in the area are dominantly strike slip in nature (*e.g.* Llewellyn Fault, Figure 1). Given that

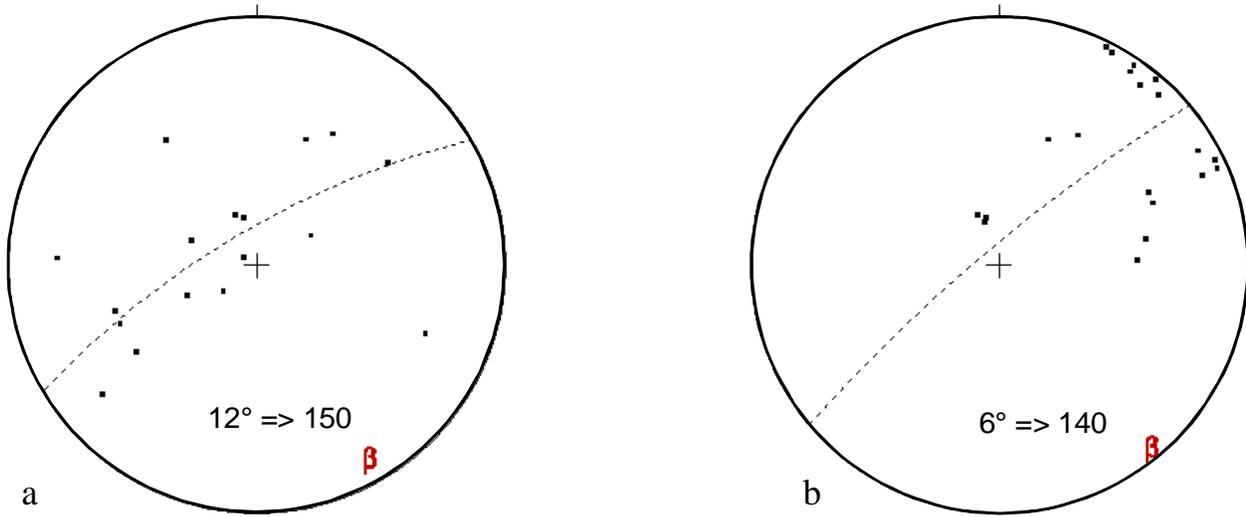


Figure 4. Syncline (a) and overturned anticline (b) plunging shallowly towards the southeast located northeast of Copper Island Fault. Compare to air photo (c) which shows the plunging nature of syncline (a) (source: BC5624 059).

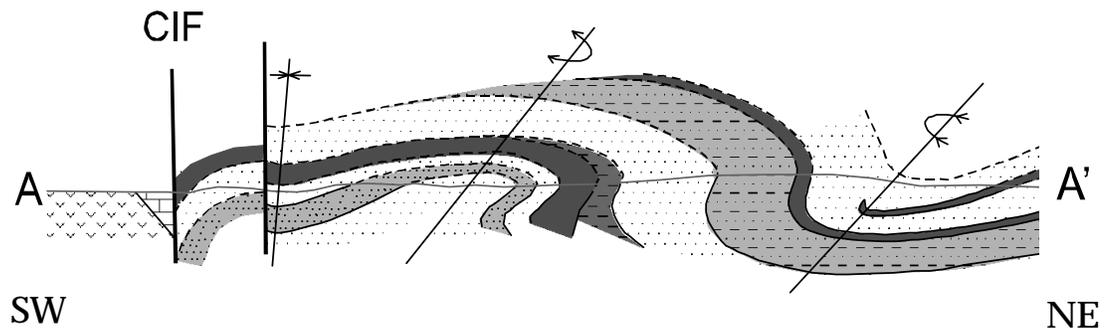


Figure 5. Cross section of western Copper Island. Central folds are overturned and have undergone further deformation perpendicular to fold axis. Note the vertical-subvertical Copper Island Fault in the SW and fault splay slightly NE of the CIF. See Figure 3 for section line and legend.

the subvertical Copper Island Fault can be traced to the northwest, continuing to separate the Stuhini Group and the Laberge Group, until it merges with the Llewellyn Fault near Tagish Lake, the Copper Island Fault represents a splay of the Triassic to Cretaceous Llewellyn strike slip system rather than a northern continuation of the King Salmon Thrust.

IMPLICATIONS OF HYDROCARBONS

In the Taku River area, the Sinwa Formation carbonates extend to depth beneath the Laberge Group in the hanging wall of the shallow angle King Salmon Thrust and may be a potential source rock for hydrocarbon accumulations. However, this relationship is not as clear in the southern Atlin Lake and Copper Island areas. The steep angle fault separating the Sinwa Formation from the Laberge Group may have developed during strike-slip motion and the extent of the Sinwa Formation, and concomitant source rock potential, in the subsurface beneath the Laberge Group in the Atlin Lake area remains unconstrained (Figure 5).

CONCLUSIONS

In the southern Atlin Lake region, the subvertical Copper Island Fault separates the Upper Triassic Sinwa Formation from Late Pliensbachian sediments of the Inklin Formation. The Copper Island Fault has previously been interpreted to represent the northwestern continuation of the King Salmon Thrust. The geometry and stratigraphic relationship across the fault suggest that the Copper Island Fault is a separate and younger feature from the King Salmon Thrust, and is probably characterised by strike slip displacement. The King Salmon Thrust carries the Sinwa and Inklin Formations in its hanging wall, and places them above the proximal conglomerate facies of the Laberge Group. These conglomerates are not exposed in the Atlin Lake area and the subvertical Copper Island Fault does not display an

older-over-younger relationship. Moreover, the basal Sinemurian strata of the Inklin Formation are missing across the fault. The Copper Island Fault can be traced to the northwest until it merges with the Llewellyn Fault, and, therefore, the Copper Island Fault represents a splay of the Llewellyn strike slip system rather than a northern continuation of the King Salmon Thrust.

REFERENCES

- Aitken, J. D. (1959): Atlin map-area, British Columbia; *Geological Survey of Canada*, Memoir 307, 89 pages.
- Dickie, J. R. and Hein, F. J. (1995): Conglomeratic fan deltas and submarine fans of the Jurassic Laberge Group, Whitehorse Trough, Yukon Territory, Canada: fore-arc sedimentation and unroofing of a volcanic island arc complex; *Sedimentary Geology*, Volume 98, pages 263-292.
- English, J. M., Johannson, G. G., Johnston, S. T., Mihalynuk, M. G., Fowler, M. and Wight, K. L. (in review): Structure, stratigraphy and hydrocarbon potential of the central Whitehorse Trough, northern Canadian Cordillera; *Bulletin of Canadian Petroleum Geology*.
- English, J. M., Mihalynuk, M. G., Johnston, S. T., Orchard, M. J., Fowler, M. and Leonard, L. J. (2003): Atlin TGI, Part VI: Early to Middle Jurassic sedimentation, deformation and a preliminary assessment of hydrocarbon potential, central Whitehorse Trough and northern Cache Creek terrane; in *Geological Fieldwork 2002; B.C. Ministry of Energy and Mines*, Paper 2003-1, pages 187-201.
- Johannson, G. G. (1994): Provenance constraints on Early Jurassic evolution of the northern Stikinian arc: Laberge Group, Whitehorse Trough, northwestern British Columbia; M.Sc. thesis; *University of British Columbia*, 297 pages.
- Johannson, G. G., Smith, P. L. and Gordey, S. P. (1997): Early Jurassic evolution of the northern Stikinian arc: evidence from the Laberge Group, northwestern British Columbia; *Canadian Journal of Earth Sciences*, Volume 34, pages 1030-1057.
- Mihalynuk, M. G. (1999): Geology and mineral resources of the Tagish Lake area (NTS 104M/8, 9, 10E, 15 and 104N/12W) northwestern British Columbia; *B.C.*

Ministry of Energy, Mines and Petroleum Resources, Bulletin 105, 217 pages.

- Mihalynuk, M. G., Erdmer, P., Ghent, E. D., Cordey, F., Archibald, D., Friedman, R. M. and Johannson, G. G. (in press): Subduction to obduction of coherent French Range blueschist - In less than 2.5 Myrs?; *Geological Society of America Bulletin*.
- Mihalynuk, M. G., Johnston, S. T., English, J. M., Cordey, F., Villeneuve, M. E., Rui, L. and Orchard, M. J. (2003): Atlin TGI, Part II: Regional geology and mineralization of the Nakina area (NTS 104N/2W and 3); in *Geological Fieldwork 2002, B.C. Ministry of Energy and Mines, Paper 2003-1, pages 9-37.*
- Monger, J. W. H., Wheeler, J. O., Tipper, H. W., Gabrielse, H., Harms, T., Struik, L. C., Campbell, R. B., Dodds, C. J., Gehrels, G. E. and O'Brien, J. (1991): Upper Devonian to Middle Jurassic assemblages - Part B. Cordilleran terranes; in *Geology of the Cordilleran Orogen in Canada, The Geology of North America, Gabrielse, H. and Yorath, C. J., Denver, Colorado, Geological Society of America, pages 281-327.*
- Souther, J. G. (1971): Geology and mineral deposits of Tulsequah map-area, British Columbia; *Geological Survey of Canada, Memoir 362, 84 pages.*
- Tipper, H. W. and Richards, T. A. (1976): Jurassic stratigraphy and history of north-central British Columbia; in *Current Research Part A, Geological Survey of Canada, Paper 78-1a, pages 25-27.*
- Wheeler, J. O. and McFeely, P. (1991): Tectonic assemblage map of the Canadian Cordillera and adjacent portions of the United States of America; *Geological Survey of Canada, Open File 1712A.*