REGIONAL GEOLOGY AND MINERALIZATION OF THE BIG SALMON COMPLEX (104N NE AND 104O NW)

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KEYWORDS: Big Salmon Complex, volcanogenic massive sulphide, regional geology, mineralization, Nisutlin Assemblage, Yukon-Tanana Terrane, Kootenay Terrane, Atlin, Jennings River

INTRODUCTION

Reconnaissance mapping in the Big Salmon Complex in northwestern British Columbia (104N NE and 104O NW, Figure 1a) was initiated in 1997 to test long-standing correlations (e.g. Mulligan, 1963) with rocks of the Yukon-Tanana Terrane (formerly Yukon Group) in southern Yukon (Figure 1b). Such correlations are especially important from an economic standpoint (e.g. Nelson, 1997) because of the recently recognized potential for volcanogenic massive sulphide deposits in these rocks following discovery of the Kudz Ze Kayah, Wolverine and Fyre Lake deposits in the Yukon. A single traverse of the Big Salmon Complex by Nelson (1997) served to highlight similarities between stratigraphic elements in northern British Columbia and those at the Wolverine deposit. This report provides details on the stratigraphic and structural setting of the Big Salmon Complex, as well as mineral potential in light of strengthened correlations with Yukon-Tanana Terrane (YTT) in the Yukon.

Mapping was conducted over a six week period in July and early August. More than 90% of the region is below treeline in broad fluvially-modified glacial valleys occupied by the lower Swift River and its tributaries (Plate 1). Although fluvial and glacial deposits are tens to (?)hundreds of metres thick in the main Swift River valley, above an elevation of about 900 m, there is only a thin veneer of alluvium, colluvium or organic debris and bedrock exposures are common. Outcrop is much more abundant than indicated on previous maps. Most road construction, unless following valley bottoms or perched glacial terraces, exposes semi-continuous outcrop at elevations above 900m. Thus the deep roadwork along the new Alaska Highway Route and burrow pits (circa 1988) and access roads to mineral properties both north and south of the highway, provide good sections through stratigraphy. Logtung and Pure Silver access roads are washed out at 6.5 km and 5 km respectively and the Arsenault road is washed out at the Swift River, but all are passable by foot.

TECTONIC FRAMEWORK

In British Columbia, ptotoliths of the Big Salmon Complex are composed primarily of quartz-rich sediments, mafic to felsic volcanic rocks and diorite, tonalite and leucogranite intrusions; all are polydeformed and metamorphosed to grades ranging from greenschist to lower amphibolite facies. Previous work in the Big Salmon Complex of British Columbia show them to underlie a roughly triangular area bounded to the west by Teslin Lake (Teslin fault) in the Atlin area (Aitken, 1959) and to the southeast by the Simpson Peak batholith and other plutons in the Jennings River area (Gabrielse, 1969). Both Aitken (1959) and Gabrielse (1969) separated thick sections of crystalline limestone from the remainder of the Big Salmon Complex, and both considered the Big Salmon Complex to be at least partly correlative with the Sylvester Group. Prior to our 1997 mapping program, further regional subdivision and correlations had not been attempted in British Columbia.

Tempelman Kluit (1979) interpreted the Yukon rocks as a subduction/collisional complex (Teslin suture zone) comprised of dismembered ophiolite of the Anvil allochthon and siliceous cataclasite of the Nisutlin allochthon. Discovery of high pressure eclogite (Erdmer and Helmstaedt, 1983; Erdmer, 1985) supported the collisional concept and work along the western part of the Big Salmon Complex (Hansen, 1989, 1992a, 1992b; Hansen et al. 1989, 1991) appeared to outline a fossil Permo-Triassic subduction zone with offscraped sediments affected by tectonic backflow. Most recently, work by Stevens (1992, 1994), Stevens and Erdmer (1993), Stevens and Harms (1995) and Stevens et al. (1996) shows that the Teslin "suture zone" is comprised not of disparate offscraped oceanic sediments, but of continental margin strata (Creaser et al., 1995) with relatively coherent stratigraphic relationships that correlate with Lower to Middle Units (*sensu* Mortensen, 1992) of the Yukon-Tanana Terrane farther north. These workers have accordingly renamed the Teslin **Suture** zone as the Teslin **Tectonic** zone. In an even more extreme departure from the subduction zone interpretation, DeKeijzer and Williams (1997) subsequently remapped part of the Teslin Tectonic zone as a polydeformed nappe.

Strata of the YTT Lower and Middle Units do appear to extend south into British Columbia where they underlie most of what was formerly mapped as the Big Salmon Complex. Despite polyphase deformation and metamorphism, a good, persistent stratigraphy is preserved across the area and direct correlations can be made with the Lower and Middle units farther north (Figures 2, 3 and 4). Thus, rocks of the Big Salmon Complex in British Columbia are at least partly equivalent to those in the Finlayson Lake area which host the newly discovered deposits mentioned above. Our mapping does not support assignment of the Big Salmon Complex in British Columbia to the Slide Mountain Terrane as suggested by Wheeler and McFeely (1987), but would be more consistent with inclusion in their Kootenay Terrane
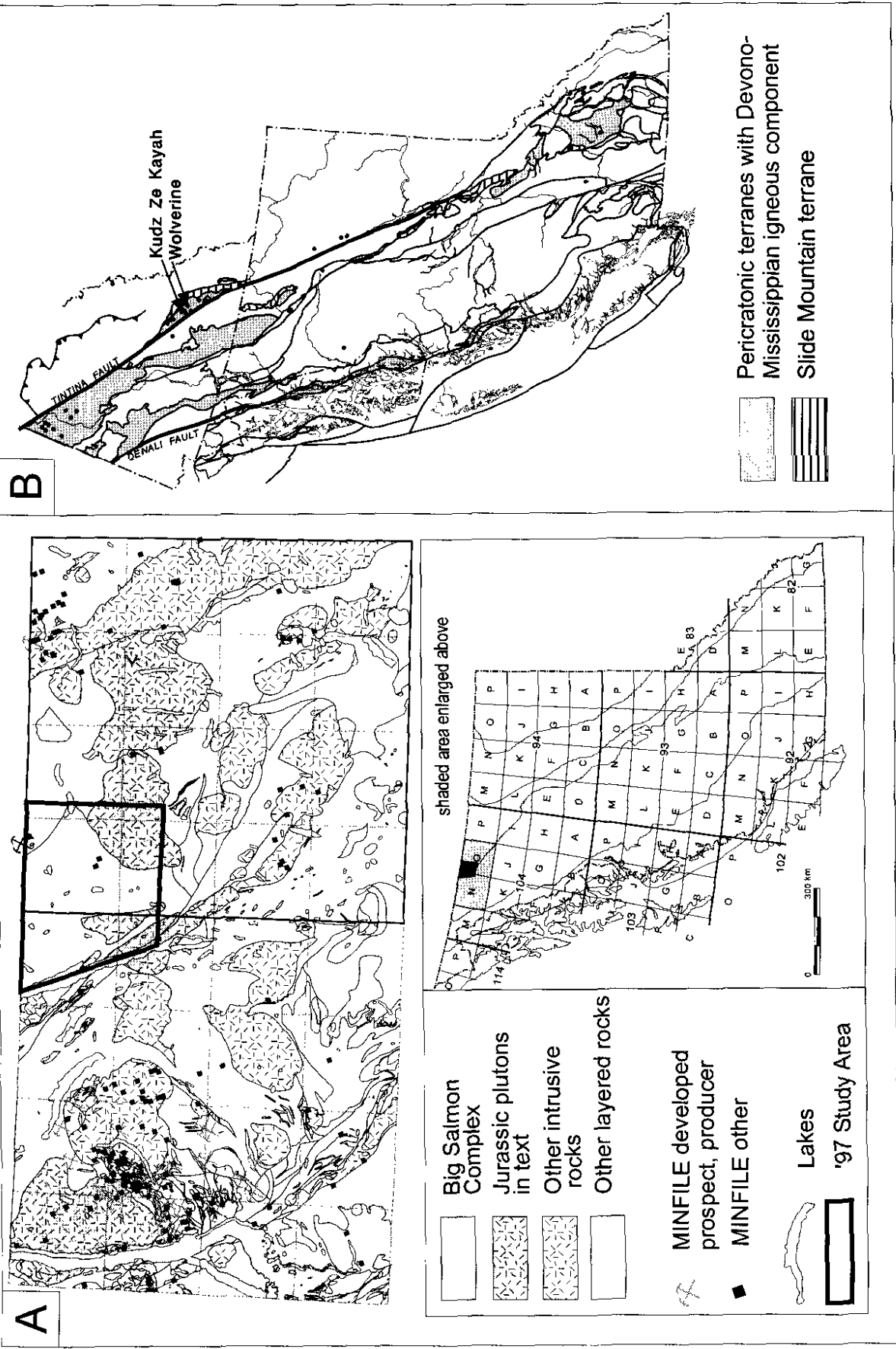
Figure 1A. Location map showing the regional geological setting of the Big Salmon Complex in British Columbia (after Mihalynuk et al., 1996). The area of Figure 2 is shown by the heavy outline. (B) map area in relation to Yukon-Tanana Terrane. Massive sulphide occurrences are shown by the black dots. Mineral deposits referred to in the text are labelled for reference.
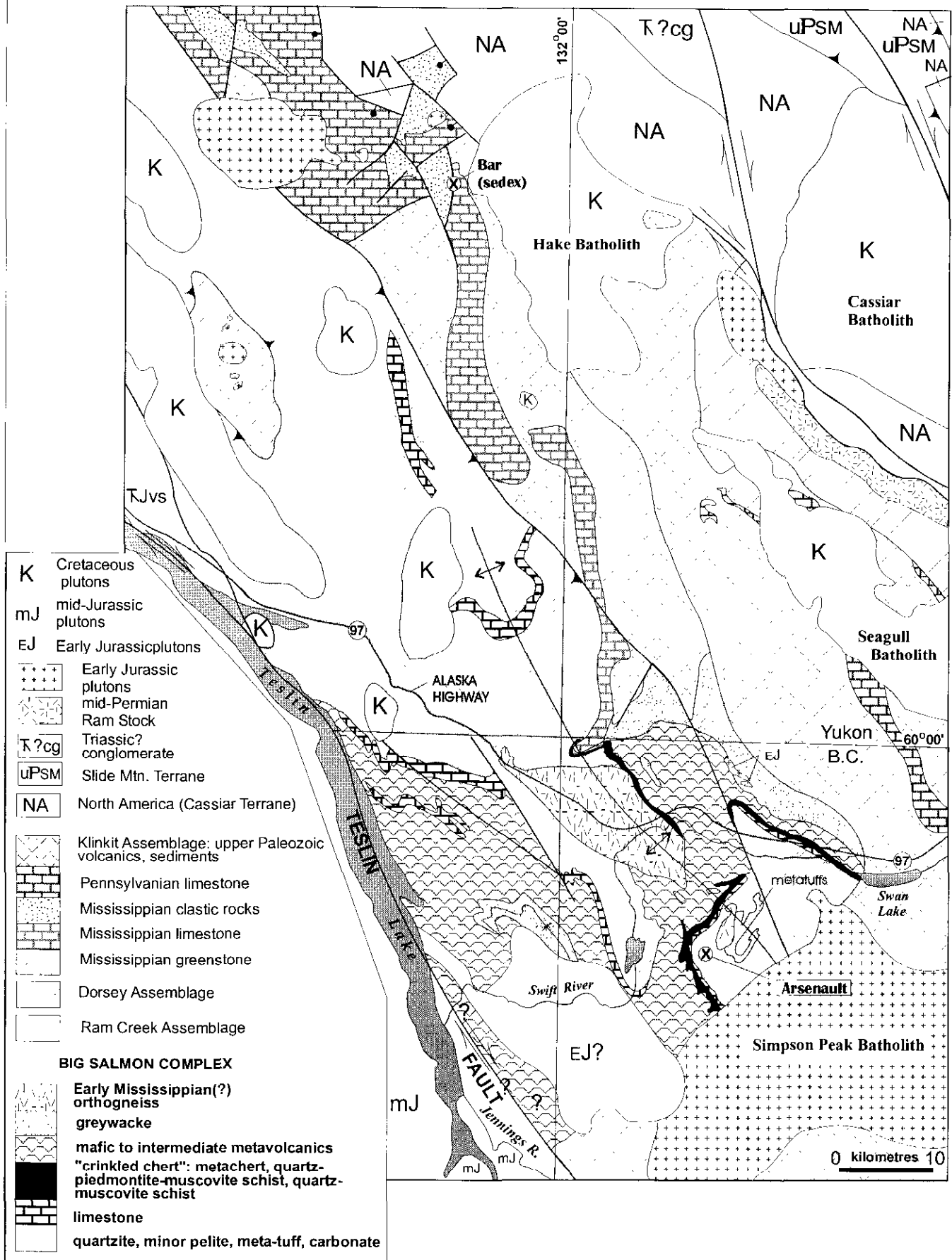
Legend (Map A):
- Big Salmon Complex
- Jurassic plutons in text
- Other intrusive rocks
- Other layered rocks
- MINFILE developed prospect, producer
- MINFILE other
- Lakes
- '97 Study Area

Legend (Map B):
- Pericratonic terranes with Devono-Mississippian igneous component
- Slide Mountain terrane

shaded area enlarged above

Map B labels: Kudz Ze Kayah, Wolverine, TINTINA FAULT, DENALI FAULT

K Cretaceous plutons

mJ mid-Jurassic plutons

EJ Early Jurassicplutons

Early Jurassic plutons

mid-Permian Ram Stock

T̄?cg Triassic? conglomerate

uPSM Slide Mtn. Terrane

NA North America (Cassiar Terrane)

Klinkit Assemblage: upper Paleozoic volcanics, sediments

Pennsylvanian limestone

Mississippian clastic rocks

Mississippian limestone

Mississippian greenstone

Dorsey Assemblage

Ram Creek Assemblage

BIG SALMON COMPLEX

Early Mississippian(?) orthogneiss

greywacke

mafic to intermediate metavolcanics

"crinkled chert": metachert, quartz-piedmontite-muscovite schist, quartz-muscovite schist

limestone

quartzite, minor pelite, meta-tuff, carbonate

Map labels: NA, K, Bar (sedex), Hake Batholith, Cassiar Batholith, T̄?cg, uPSM, uPSM, T̄Jvs, Teslin L̄ake, TESLIN FAULT, Jennings R., Swift River, ALASKA HIGHWAY, 97, mJ, EJ?, EJ, Seagull Batholith, Yukon B.C., 60°00', metatuffs, Swan Lake, Arsenault, Simpson Peak Batholith, 132°00', Ram Stock

0 kilometres 10

Figure 2. Generalized geology of the map area and interpretation of correlations with strata north of the Yukon border. Note location of the Arsenault and Bar occurrences. A presumed thrust contact between Kootenay Terrane (Yukon-Tanana) and North American strata in the Yukon (Gordey and Stevens, 1994) has no obvious equivalent in northern British Columbia.

(terminology also used by Gordey, 1995) which would include the Lower and Middle Units of the Yukon-Tanana as used by Mortensen (1992). A thick greenstone unit and overlying clastic strata within the Big Salmon Complex of British Columbia have no obvious correlatives within the Yukon-Tanana Terrane and may be considerably younger.

GENERAL GEOLOGY

First order geological features in the Big Salmon Complex are a northwest-trending lower amphibolite grade "core zone" where protolith textures are mostly destroyed, flanked by greenschist grade rocks to both the southwest and northeast where relict protolith textures are relatively well preserved (Figure 2b). Mountain scale, southwest-verging folds and parasitic folds exert a fundamental control on the distribution of different units, but this distribution is complicated by both older and younger folding (see below). An early, nearly layer-parallel fabric is folded by the large scale folds and is commonly overprinted by a second schistosity imparted during the folding. Metamorphosed tonalite, lesser diorite and minor leucogranite, herein called the Hazel orthogneiss, dominate the north-central part of the core zone.

In general, lower, deeper parts of the stratigraphy have been more strongly deformed than presumably younger strata. No age data exists for layered rocks in the map area, but the youngest, weakly foliated and moderately lineated strata include conglomerates with phyllitic clasts that are probably derived from the underlying, previously metamorphosed units, implying at least some unconformable relationships.

STRATIGRAPHIC FRAMEWORK

Stratigraphic associations that are well preserved and exposed on the less deformed flanks of the Big Salmon Complex can be traced into the higher grade interior. A sequence of four distinctive and contrasting units, locally displaying gradational contacts, provide the foundation for correlating from one area to another. From oldest to youngest they are: 30-150 m of buff to grey weathering limestone with metre-thick tuffaceous and thin quartzite layers; 20-50 m of thinly bedded, finely laminated manganiferous chert/quartzite with muscovite partings; 1200 m of tuffite-dominated greenstone; and a more than 150m thickness of sub-greenschist grade, brown to tan wacke, stretched quartzite-pebble and granule conglomerate and slate (Figure 4). Excellent preservation of protolith textures on the flanks of the Big Salmon Complex, including way-up indicators, permits moderately confident relative age assignment. Underlying this four-fold sequence is a lithologically variable succession, dominated by quartz-rich clastics with minor grey-weathering carbonate layers 1-10m thick and quartz-phyric volcanic tuff layers up to 40m thick, in which units in this variable package can be correlated only locally. More detailed lithologic descriptions, from oldest to youngest, are given below.

Plate 1. A view to the south from Mount Hazel towards the Swift River valley and low, tree-covered mountains beyond.

Graphitic quartz granule conglomerate - phyllite (>135m stratigraphic, 900m structural)

Bimodal black to silver grey, quartz-rich clastics dominate the lower part of the unit and persist in subequal amounts with combined chlorite phyllite (tuff?), carbonate and lineated quartzite in its upper parts. Protolith textures are best displayed in a borrow pit near the junction of Highway 97 and the Logtung property access road, but relict textures do occur intermittently throughout the map area. Coarse grit to granule conglomerates characterize the unit. These contain very clear to lesser milky blue quartz grains up to 4 mm in diameter which commonly comprise 4% of the rock, but are up to 40% of some layers that range from 0.5 to a few metres thick. Rounded to subangular quartz grains (50-80%) are supported by a phyllitic and schistose matrix of graphitic muscovite + feldspar. Argillite "granules" are preserved as pea-sized phyllitic smears. Dark grey graphitic phyllite forms decimetre thick interbeds which apparently increase in abundance down(?)section. Commonly the phyllite contains up to 5% pyrrhotite porphyroblasts that are consistently elongated at a small angle to the phyllitic fabric. Where these rocks are oxidized they become bleached silvery grey and commonly display the yellow coloration typical of jarosite. Where calcareous, the graphitic argillite lacks a good phyllitic fabric. A bright green mineral (chrome mica?) comprises up to several percent of one calcareous argillite(?) layer in the borrow pit. Carbonate layers are not abundant, but do occur near the base of the unit where they comprise abundantly calcite veined, dark grey recrystallized fetid limestone up to several metres thick. Carbonate also occurs near the top of the unit as hackly-weathering decimetre-thick layers associated with tuffaceous chloritic phyllite. Also near the top of the unit, a 10m thick dolomitic limestone layer, together with a 2-3m thick tuffaceous layer, sandwiched within lineated quartzite and a more than 2m thick silicified limestone/quartzite layer that contains 5% pyrite in anastamosing bands up to 2 cm thick (exposed along
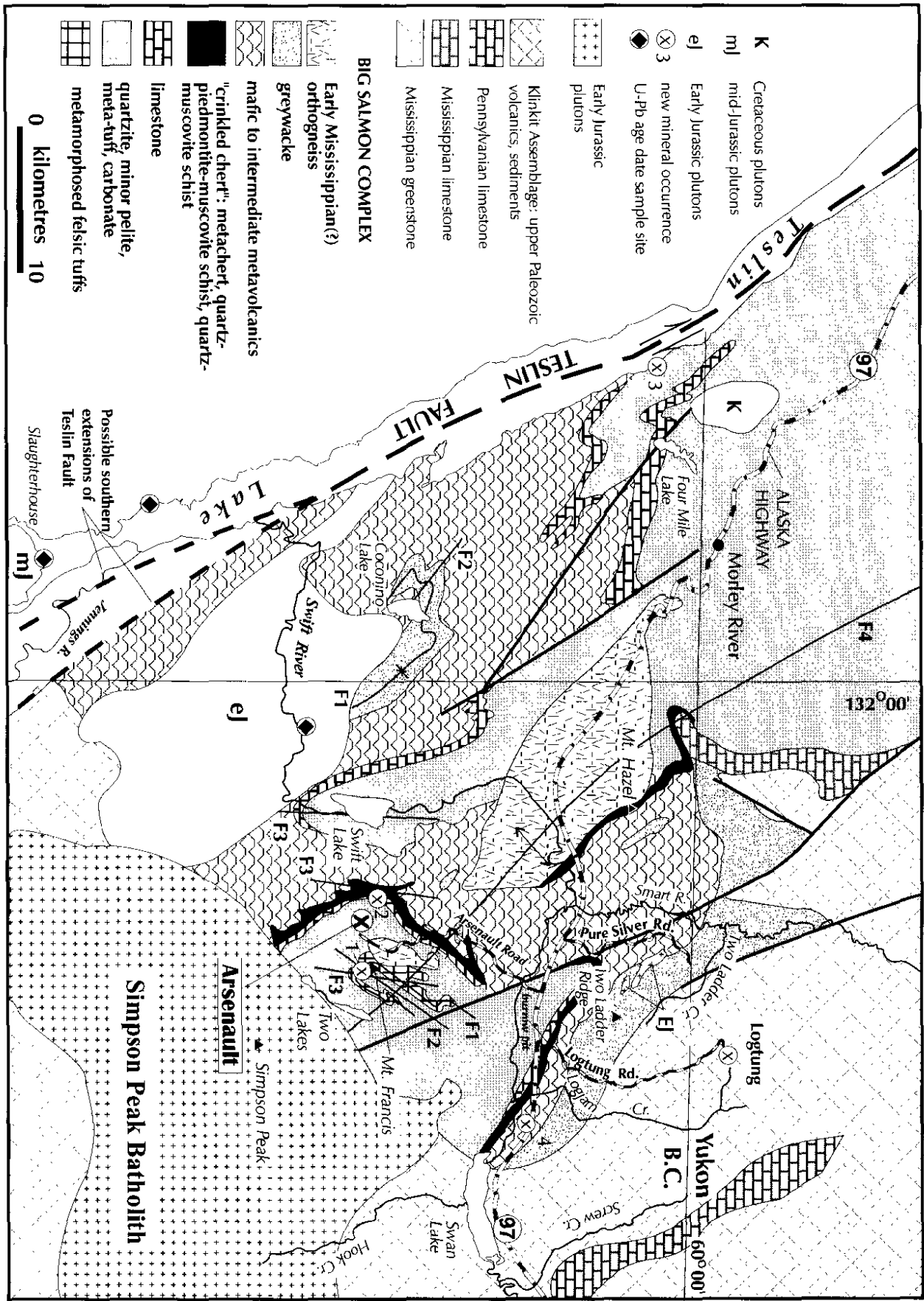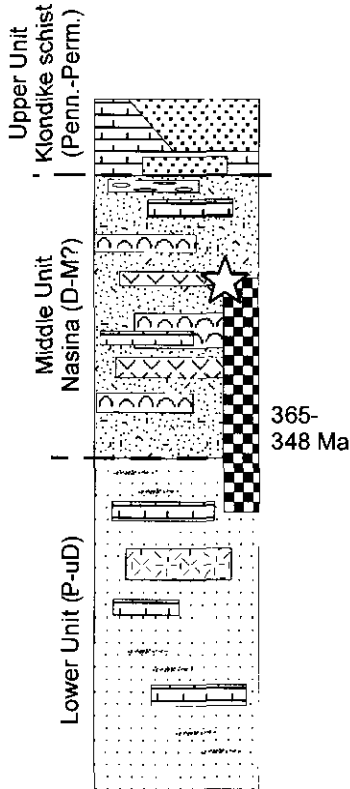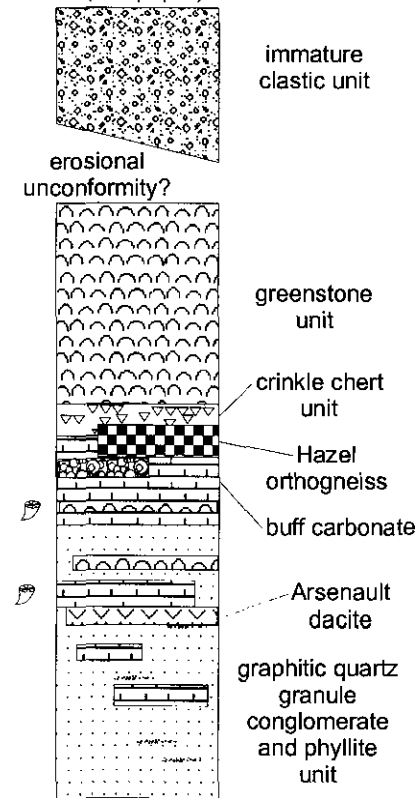
Figure 3. Generalized geology of the map area showing place names, access roads and sample sites referred to in the text. Axial surface traces of major fold generations are diagrammatically depicted.

LEGEND (rotated)

K   Cretaceous plutons

mJ   mid-Jurassic plutons

eJ   Early Jurassic plutons

⊗ 3   new mineral occurrence

◆   U-Pb age date sample site

Early Jurassic plutons

BIG SALMON COMPLEX

Klinkit Assemblage: upper Paleozoic volcanics, sediments

Pennsylvanian limestone

Mississippian limestone

Mississippian greenstone

Early Mississippian(?) orthogneiss

greywacke

mafic to intermediate metavolcanics

"crinkled chert": metachert, quartz-piedmontite-muscovite schist, quartz-muscovite schist

limestone

quartzite, minor pelite, meta-tuff, carbonate

metamorphosed felsic tuffs

0   kilometres   10

Yukon-Tanana Terrane
Southern Yukon
(modified from Mortensen, 1992)

Upper Unit
Klondike schist
(Penn.-Perm.)

Middle Unit
Nasina (D-M?)

Lower Unit (P-uD)

365-
348 Ma

Big Salmon Complex
in British Columbia
(this paper)

immature
clastic unit

erosional
unconformity?

greenstone
unit

crinkle chert
unit

Hazel
orthogneiss

buff carbonate

Arsenault
dacite

graphitic quartz
granule
conglomerate
and phyllite
unit

Slide MountainTerrane
north-central
British Columbia
(modified from Ferri, 1997)

early - middle
Penn. (Bashkirian-
Moscovian)

1000

metres

0

CASSIAR
TERRANE

Non-carbonaceous
impure quartzite

Carbonaceous schist
and quartzite

Clean quartzite

Stretched pebble
conglomerate

Marble

Felsic metavolcanics

Mafic (-intermediate)
metavolcanics

peraluminous pluton

hornblende-bearing
plutonic rocks

Dirty clastics,
stretched pebble congl.

Polymictic
conglomerate

Coral-bryozoan collection

Volcanogenic massive
sulphide occurrence

Massive basalt,
minor gabbro

Pillow basalt

Volcanic breccia

Gabbro

Argillite, minor chert

Bedded to massive chert

Tuffaceous siltstone

Quartz sandstone
horizons

Ultramafic intrusion
(wehrlite)

Conodont collection

Figure 4. Comparative stratigraphy of southern Yukon-Tanana terrane (generalization of 2 columns from Figure 2 in Mortensen, 1992) with type sections of Slide Mountain Terrane (adapted from Figure 6 in Ferri, 1995) and Big Salmon Complex in British Columbia (this study).

the new Highway 97 roadcut). Similar, although not commonly dolomitic, limestone occurs at several localities near Mount Francis where it is interlayered (bedded?) with dacitic tuff and/or epiclastics similar to the Arsenault dacite (Plate 2).

Plate 2. Grey limestone with interbedded 0.2 m thick tuff bands.

Orange felsic lapilli ash tuff (25m, 5m, 2m)

Several layers of bright orange-weathering, sparsely-quartz phyric tuff occur within the structurally lowest parts of the quartz granule conglomerate unit. Flattened, white sericitic fragments ranging in size from coarse ash to fine lapilli (up to 2 cm), float in a fine, foliated ash and dust matrix. Quartz phenocrysts are fine-grained and rare. Fine pyrite is widely disseminated (1%).

Widespread, strongly pyritic, feldspathic quartzite on the ridges northwest of Two Lakes may be a more highly metamorphosed equivalent of this tuff.

Arsenault dacite tuff (to 60M or more)

Conspicuous, coarse, blue quartz-eye dacite is best exposed at the Arsenault showing (2.5 km west southwest of Mount Francis) where it is coarsest and attains maximum thickness of about 60m. It forms a white to green-grey-weathering marker horizon that can be traced for several kilometres, helping to outline major folds. Medium grey ash with fine-grained feldspar fragments fill
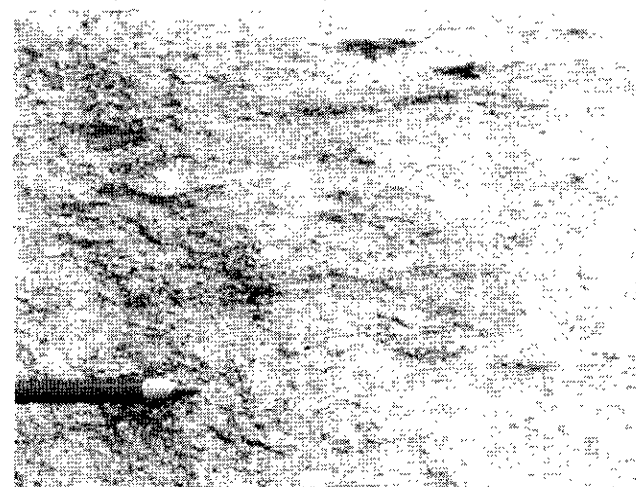
Plate 3 Arsenault dacite displaying flattened clasts and coarse quartz-eyes.

interstices between flattened, grey to cream-coloured, coarse lapilli and breccia clasts (up to 10 cm diameter and 2 cm thick, Plate 3). Quartz eyes, which comprise about 6% of the rock, are generally 3 to 5 mm diameter but range up to 2 cm in both matrix and clasts. Locally the unit contains up to 5% rounded magnetite porphyroblasts, typically 2-5 mm in diameter. Sparse accidental quartzite clasts occur near the base (?) of the unit. Structurally underlying the unit at one locality is a distinctive pure quartzite conglomerate comprised exclusively of pale pink or cream-coloured, rounded quartzite pebbles.

Buff carbonate (70-300m with interbeds of tuff and conglomerate)

Buff coloured carbonate is grey to white on fresh surfaces. Along Highway 97 it has a continuously exposed structural thickness of 70m and another 70m that is discontinuously exposed. Along the Logtung road it has a discontinuously exposed structural thickness of 160m, and on the Arsenault property its structural thickness is 180 to 270m, but there it has been thickened, perhaps more than doubled, by folding.

Along Highway 97, the upper 70m of the carbonate is massive, except for two bedding surfaces outlined by poorly preserved, silicified bryozoans, coralites and possible bivalve fossils (Plate 4). These are the only macrofossils recovered from this unit. The lower 70+m section contains at least four 0.5 to 2m thick, bright green chloritic/tuffaceous beds that grade upwards into carbonate. Recrystallization is locally extreme with some irregular calcite crystals reaching decimeters across. Disseminated fine-grained pyrite glomerocrysts are relatively equant with no evidence of stretching. Similar massive and tuffaceous units occur along the Logtung Road, nearly 2 km along strike to the northwest.

Plate 4. Silicified coral and bryozoan fossil debris outlining bedding in otherwise massive buff limestone.

Polymictic boulder conglomerate (5-10M)

One 3 by 6m outcrop of flattened intrusive and volcanic cobble and small boulder conglomerate, located 1.8 km up the Logtung Road, is between layers of buff carbonate, each greater than 20m thick. Clast types include

(in approximate order of abundance): greasy grey dacite tuff with purple-blue quartz eyes up to 1.5 cm diameter; green to grey, aphanitic to sparsely feldspar porphyritic basalt; porphyritic granite with purple-blue or rose-coloured quartz eyes; yellow-orange quartzite; grey phyllite; and green phyllite. Clast flattening ratios are about 3:1 to 8:1 with slight elongation.

Basalt, pink quartzite, bleached quartz diorite and carbonate are the dominate clasts in a debris flow unit near the stratigraphic top of a strongly recrystallized carbonate 3.5 km northwest of Mount Francis. Blocks of medium to coarse plagioclase porphyritic basalt up to 0.5m diameter and mainly cobble-sized diorite clasts are subangular to subrounded, whereas quartzite clasts are typically about 5 cm diameter and angular. The blocks are cemented by a dirty carbonate matrix. All lithologies in the unit have been partly replaced by moderate to strong propyllitic alteration.

Crinkled chert (25-60m)

White to pink-weathering, thinly bedded to laminated and contorted recrystallized chert forms a distinctive, photogenic marker horizon throughout the map area (Plate 5). Where least recrystallized, beds are generally less than 2 cm thick, but range up to 10 cm thick, and display a grey to greenish-coloured fresh surface. Locally the weakly metamorphosed unit displays pinkish streaks or a pale pinkish cast. The beds are comprised of silica, lesser argillite and minor, very fine tuff(?).

Where it is strongly recrystallized, the unit displays centimetre to decimetre thick layering of micaceous quartzite with millimetre to centimetre thick interlayers of white mica. Idiomorphic garnet, specular hematite and staurolite can be observed optically. Locally it is strongly coloured pink to red due to the prograde development of piedmontite (Mn-epidote). Piedmontite is sporadically developed along an intermittently exposed 12 km strike length between Mt. Francis and Swift Lake. Some of the best piedmontite occurrences are approximately 1 km northwest of the summit of Mount Hazel (Plates 6a, b).

Two samples of crinkle chert were analyzed by inductively coupled plasma emission spectroscopy for total barium content. They are highly anomalous (average 2254

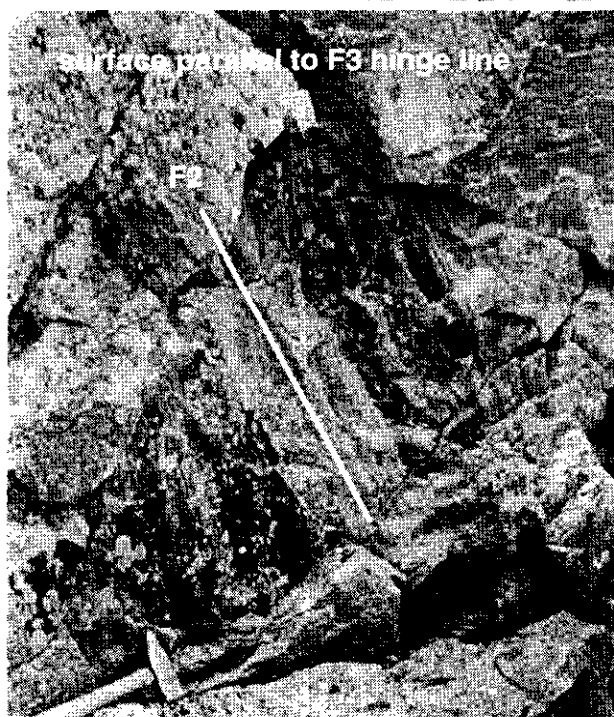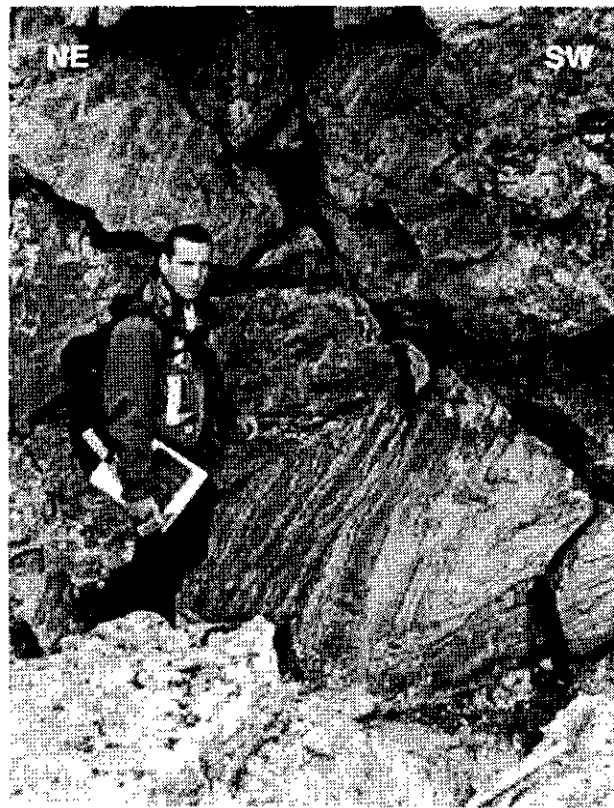Plate 5. Typical weathering of finely laminated crinkle chert.

Plate 6 (a) A view to the southeast of F3 parasitic southwest-verging folds within Mount Hazel orthogneiss. (b) flattened F2 fold hinges are outlined on an F3 limb by the preservation of a strong, folded mineral lineation (mainly piedmontite and garnet formed at peak PT) parallel with the F2 axial trace.

ppm) with respect to the other 28 samples analyzed (average 59 ppm; Figure 5). Samples analyzed do not represent the full range of lithologies present in the map area, but the values obtained are consistent with published

values for average barium content in sandstone (10-100 ppm; Levinson, 1980). Thus, contained Ba may be a useful criteria for distinguishing highly recrystallized crinkle chert from other quartzites, especially where piedmontite is absent.

At most localities the crinkle quartzite is underlain by carbonate and overlain by greenstone. At 2.6 km up the Logtung Road well preserved protolith textures show the crinkle chert grading into overlying finely laminated tuff of the greenstone unit.
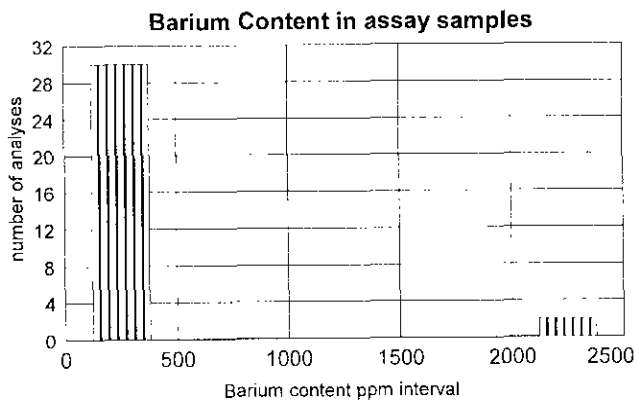
Barium Content in assay samples

Figure 5. Histogram showing total barium content for all samples analyzed. Ba content of each crinkle chert samples is more than an order of magnitude greater than the average of all other samples (average 2254 vs. 59).

Greenstone (600-1800m)

Resistant, dark green to black weathering basalt and intermediate to mafic tuff comprise the most voluminous unit west of Mount Francis and Logjam Creek. Well preserved protolith textures are common near Logjam Creek and east of southern Teslin Lake. Volcanic ash and dust tuff (tuffite?) display exquisitely preserved laminae, clastic textures including abundant facing indicators and mesoscopic scale shears and folds which show the unit is significantly thickened. Well-bedded, bright green, aphanitic lapilli tuff is perhaps the most common lithology. Massive flows can be unequivocally identified in only a few instances; most massive mafic units could be sills. One such flow and flow breccia succession is comprised of medium to coarse-grained pyroxene porphyry. Near Mount Francis, metamorphic grade increases to lower amphibolite facies and two generations of schistosity affect the greenstone; protolith textures are obliterated.

Upper immature clastic succession

Light grey, tan and brown, immature, quartz-rich clastics mark the top of more-or-less continuous stratigraphy within the map area. Stratigraphically lowest units of the succession are quartzite granule and pebble conglomerate and arkosic conglomerate interbedded with brown wacke containing aggregates of metamorphic biotite. Overlying units are black slate with a locally developed weak phyllitic fabric and interbedded
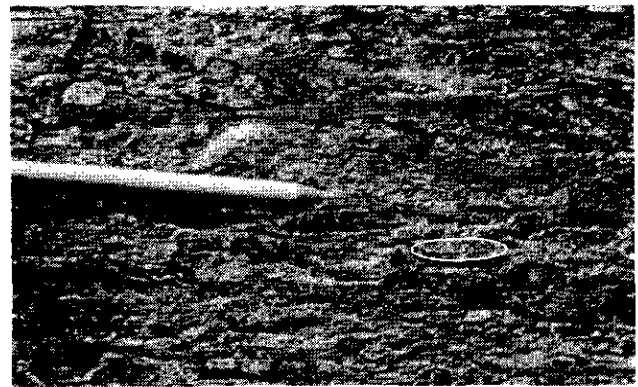

Plate 7. Stretched quartzite pebble conglomerate of the upper dirty clastic succession.

intraformational conglomerate containing angular argillite rip up clasts, carbonate, aphanitic green tuff(?) and sparse crenulated phyllite. The top of this succession was not mapped.

Slatey cleavage differs from bedding orientation by only a few degrees, suggestive of large, high amplitude and very tight folding. In wackes with a high tuffaceous content the metamorphic mineral assemblage includes actinolite, epidote and biotite, but more typically a subgreenschist assemblage is developed. Granules and pebbles are elongated with typical strain ratios of 4 to 8 (Plate 7); although strain ratios up to 20 occur rarely in the lower, quartz-pebble-rich conglomerate.

No unequivocal depositional contact with the underlying greenstone has been observed, and one may not exist. On Two Ladder ridge (informal) the contact is covered, but field traverses crossed it at least four times along strike and the character of rocks on either side of the contact are consistent from one place to another. Phyllite clasts in pebble conglomerate of the lower clastic package suggest an erosional unconformity. Maximum pebble elongation strain of 8 to 10 (length/width) near the contact is bedding parallel, suggestive of low angle fault motion. The contact is almost exposed 2 km west of Coconino Lake where extensive outcrops of both isoclinally folded tuff of the greenstone unit and wacke of the immature clastic unit are separated by a covered interval of only a few metres. Although excellent and independent facing indicators in the tuffs show that it has been isoclinally folded (as is common elsewhere), and layering in the wacke is concordant, no clear examples of interfolding of the two have been observed. However, in isolated road cut exposures near an elevation of 1100 metres on the Arsenault Road, the distribution of lithologies might indicate that such infolding occurs.

Hazel Orthogneiss

Strongly foliated white to green or light pink-weathering orthogneiss underlies at least 250 km^2 along the northern margin of the map area, from the peak of Mount Hazel to 8 km south of Highway 97. Compositions range from diorite to alaskite, but tonalite dominates. Schistosity is outlined by fine-grained biotite (15%), which

is 90% chloritized. Medium-grained quartz and albite are intergrown to weakly porphyritic, and 1-2% fine-grained epidote is generally present. Volumetrically, minor quartz porphyry occurs as layers a few metres to, rarely, tens of metres thick. These are light to dark green muscovite-chlorite-quartz-feldspar schist containing 1 to 20% conspicuous milky blue quartz eyes (to 3 mm). Porphyritic zones appear to be concentrated near the margins of the body; for example, at Mount Hazel where orthogneiss is in contact with piedmontite schist of the crinkle chert unit, and are infolded with the greenstone unit

Pink Granite orthogneiss

About 1 km east of Teslin Lake, near the Yukon border, a northwest trending body of chloritized granitoid is at least 20m thick and can be traced for more than half a kilometre. It is medium-grained to slightly porphyritic, pink to light green-weathering and moderately to strongly foliated. Although compositionally variable, quartz and feldspar comprise approximately 25 and 50% of the rock respectively. Presumably the original mafic minerals are chloritized and smeared out into the foliated matrix. Host rocks are quartzite and tuffaceous chlorite schist. The granitoid may represent a volcanic feeder, but the nearest potential coarse proximal units are pyritic quartz sericite schists on the shore of Teslin Lake.

Tonalite sill

A foliated tonalitic sill that is at least 5m thick intrudes greenstone about six kilometres southeast of southern Four Mile Lake. It is light green weathering and strongly foliated. Contacts have been affected by two phases of deformation (Plate 8); no crosscutting relationships are preserved. Porphyritic margins on the tonalitic body and indurated greenstone at the contact support an originally intrusive relationship.
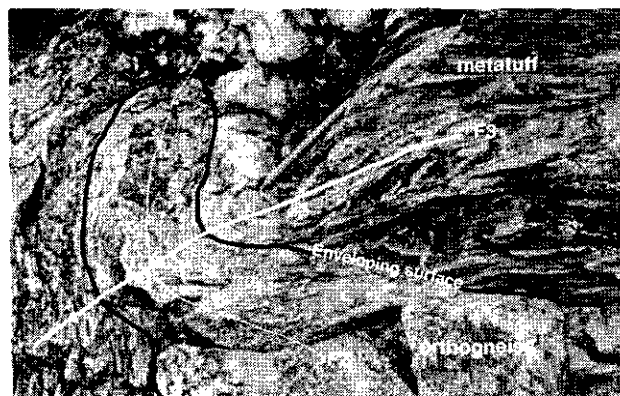

Plate 8. Foliated tonalite in the core of a flattened F2 fold refolded about F3 (view to the south).

PLUTONIC ROCKS

Slaughterhouse quartz diorite

Dark grey to red-weathering quartz diorite underlies Southern Teslin Lake. It is weakly to moderately foliated with rare strongly foliated zones. It is comprised of green hornblende (25%), biotite (10%), sphene (up to 1%), plagioclase (60%) and quartz (10%). Hornblende commonly displays cores of pyroxene, and biotite may occur as single grains or many clustered subgrains. Medium-grained sphene occurs as idiomorphic grains comprising up to 1% of some samples. Plagioclase is turbid due to alteration to white mica, prehnite and epidote. Plagioclase crystals occur as interlocking elongated lozenges that are moderately well aligned in foliated samples.

Alignment of plagioclase may indicate either subsolidus flow foliation or syntectonic intrusion. However, polygonized, quartz grains broken into domains with undulatory extinction and mortar-textured quartz at feldspar borders represent textures formed at subsolidus temperatures. Such deformation textures are supportive of late syntectonic emplacement.

Age and Implications

Sample crushing, mineral separation, and isotopic analysis of weakly foliated Slaughterhouse diorite collected from west of southern Teslin Lake(MMI96-2-11, Table 1) were performed at the Geochronological Laboratory at the University of British Columbia. High quality clear, pale pink, prismatic (stubby to elongate and multifaceted) and tabular zircon, and also clear pale yellow, broken fragments of euhedral titanite grains were recovered. Six analysed fractions (four zircons and two titanites. Table 1, Figure 6) plot on or near concordia at about 170 Ma. Three of the zircon fractions are slightly discordant, suggesting the presence of inherited zircon components, and superimposed Pb loss for fraction C. Fine elongate zircon fraction D is concordant at about 170 Ma. Both titanite analyses are concordant: fraction T1 is relatively imprecise but is in agreement with zircon fraction D, while T2 is slightly older at about 171 Ma. The 170.2 ± 1.2 Ma age suggested for this sample is a good conservative estimate based on the average $^{206}Pb/^{238}U$ age of concordant fractions D and T2, with associated precision derived from the total range of overlap of these analyses with the concordia curve. Note the possibility of minor Pb loss for fractions D and T1, which would render the older portion of the error envelope, based on T2, as the most likely age for this rock.

Pyroxene cored hornblende is characteristic of both the Slaughterhouse pluton and various phases of the circa 172 Ma (Mihalynuk et al., 1992) Fourth of July batholith near Atlin (part of the more regional Three Sisters plutonic suite of Woodsworth and Anderson, 1991). The new U-Pb isotopic age determination from a sample of weakly foliated Slaughterhouse diorite performed at, is 170.2 ± 1.2 Ma, confirming the Fourth of July suite association. Preliminary U-Pb age determinations from a sample collected at the south end of Teslin Lake suggest an age of 168 to 175 Ma.

TABLE 1. U-Pb ANALYTICAL DATA

Fraction[1]	Wt mg	U[2] ppm	Pb*[3] ppm	206Pb[4]/204Pb	Pb[5] pg	208Pb[6] %	Isotopic ratios (1σ,%)[7] 206Pb/238U	207Pb/235U	207Pb/206Pb	Apparent ages (2σ,Ma)[7] 206Pb/238U	207Pb/206Pb
MMI96-2-11 TTZ Granitoid											
A cc,N2,p,s	0.228	292	8.0	5599	20	12.1	0.02668 (0.10)	0.1825 (0.17)	0.04961 (0.09)	169.8 (0.3)	176.8 (4.4)
B c,N2,p,e	0.148	259	7.1	1162	56	12.4	0.02678 (0.12)	0.1835 (0.26)	0.04968 (0.18)	170.4 (0.4)	180.3 (8.4)
C m,N2,p,e	0.196	300	8.2	4727	21	12.4	0.02645 (0.11)	0.1811 (0.18)	0.04966 (0.10)	168.3 (0.4)	179.3 (4.8)
D f,N2,p,e	0.115	266	7.3	3732	14	12.4	0.02662 (0.11)	0.1815 (0.18)	0.04946 (0.11)	169.4 (0.4)	169.9 (4.9)
T1 cc,N2,b	0.465	403	10	383	851	3.3	0.02656 (0.41)	0.1819 (1.07)	0.04967 (0.81)	169.0 (1.4)	179 (38)
T1 cc,N2,b	0.470	422	11	416	834	3.0	0.02687 (0.15)	0.1833 (0.50)	0.04950 (0.41)	170.9 (0.5)	171 (19)

Notes: Analytical techniques are listed in Mortensen et al. (1995).

[1] Upper case letter = fraction identifier; All zircon fractions air abraded; Grain size, intermediate dimension: cc= <180 μm and >134μm, c=<134μm and >104μm, m=<104μm and >74μm, f=74μm. Magnetic codes:Franz magnetic separator sideslope at which grains are nonmagnetic (N) or Magnetic (M); e.g., N1=nonmagnetic at 1°; Field strength for all fractions =1.8A; Front slope for all fractions=20°; Grain character codes: b= broken fragments, e=elongate, eq=equant, p=prismatic, s=stubby, t=tabular, ti=tips.

[2] U blank correction of 1-3pg ± 20%; U fractionation corrections were measured for each run with a double ^{233}U-^{235}U spike (about 0.005/amu).

[3] Radiogenic Pb

[4] Measured ratio corrected for spike and Pb fractionation of 0.0043/amu ± 20% (Daly collector) and 0.0012/amu ± 7% and laboratory blank Pb of 10 pg ± 20%. Laboratory blank Pb concentrations and isotopic compositions based on total procedural blanks analysed throughout the duration of this study.

[5] Total common Pb in analysis based on blank isotopic composition

[6] Radiogenic Pb

[7] Corrected for blank Pb, U and common Pb. Common Pb corrections based on Stacey Kramers model (Stacey and Kramers, 1975) at the age of the rock or the 207Pb/206Pb age of the fraction.

Simpson Peak batholith

Simpson Peak batholith marks the southeastern limit of the Big Salmon Complex. Potassium feldspar porphyritic granite is typical, although marginal phases are compositionally heterogeneous, ranging from dark, hornblende-rich diorite to granodiorite. Near Simpson Peak the body is weakly foliated and strongly jointed. It is white to grey-weathering with a greenish or pinkish cast. Idiomorphic pink potassium feldspar crystals are conspicuous as they are up to 3 centimetres in diameter. These crystals are microperthitic and, together with medium to fine-grained potassium feldspar, comprise about 30% of the rock. Plagioclase (30%), polygonized quartz (25%) and chloritized patches of biotite (10%) are other major constituents. Subidiomorphic sphene comprises about 1%. Epidote (2%) is the dominant alteration mineral.

Although the Simpson Peak batholith is generally weakly deformed, and well foliated at its northern margin, it clearly postdates deformation of the Big Salmon Complex, cutting across fold axes, skarning deformed limestone, and hornfelsing other Big Salmon Complex lithologies. Published K-Ar age determinations for the Simpson Peak Batholith (Wanless et al., 1970) are recalculated using modern decay constants as 185 ±14 (hornblende) and 169 ±8 (biotite, reset). Recalculated ages from the adjacent Nome Lake batholith are essentially concordant at 187 ±9 (both hornblende and biotite; *ibid.*)

Midshore granite

Coarse tan to pink granite crops out along 2.5 km of the eastern shore of Teslin Lake, midway between its southern end and the Yukon border. It is comprised of 30% coarse perthitic potassium feldspar, 25% smoky grey quartz with undulatory extinction, 35% strongly zoned plagioclase, 10% biotite and accessory tourmaline and zircon (100 microns in diameter). Alteration minerals
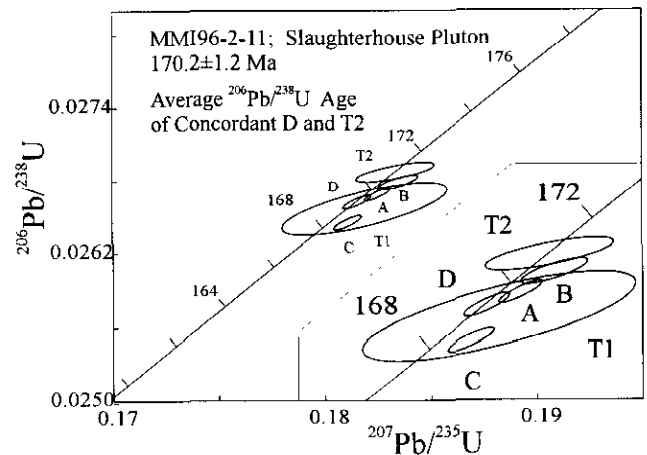

Figure 6. Concordia plot showing isotopic ratios with error estimates for four zircon (A to D) and two titanite (T1, T2) mineral fractions from the Slaughterhouse pluton.

include chlorite after biotite and white mica, prehnite and calcite after feldspars.

Two Ladder Tonalite

Fine to medium-grained dark grey weathering hornblende tonalite forms a series of northwest-elongate, kilometre-long bodies on the ridges above Two Ladder Creek. Locally the bodies are sparsely hornblende porphyritic (up to 5 mm diameter), but are more typically equigranular. Near their margins they may display a weak foliation; although they are discordant with respect to the enclosing strata, which are hornfelsed. Away from their contacts, the bodies are not foliated.

Coconino Tonalite

Foliated hornblende-biotite tonalite, lithologically and petrographically indistinguishable from parts of the Slaughterhouse pluton, underlies the low ridges east and south of Coconino Lake, extending 15km south of the Swift River. It forms a roughly equidimenssional body with a northwestern apophysis that may have been drawn into the Teslin Fault with dextral shear. A sample collected from within a few hundred metres of its northern contact displays chill textures with idiomorphic feldspars (up to 2cm, 50%), sphene (up to 0.1cm, 2%) and minor idiomorphic apatite rimmed with interstitial quartz (20%). Weakly-oriented, fine-grained biotite forms elongated clots (20%) up to 1cm long after original biotite. Some of the biotite clots are cored with epidote, probably replacing hornblende. Most plagioclase is strongly replaced by epidote and muscovite.

A new, unpublished U-Pb age date indicates that the Coconino tonalite is about 25m.y. older than the Slaughterhouse pluton; perhaps age equivalent to the Simpson Peak and related plutons (185 ±14 to 187 ±9 Ma: K-Ar hornblende ages recalculated from Wanless et al., 1970), but only at the oldest limit of the K-Ar error.

STRUCTURE AND METAMORPHISM

In general, the Big Salmon Complex consists of a northwest-trending "amphibolite" grade core zone, in which protolith textures are destroyed, flanked by greenschist grade rocks in which protolith textures are moderately to well preserved. Upper greenschist to transitional greenschist-amphibolite facies conditions are recorded in the dominant stable regional metamorphic mineral assemblages throughout the area. However, in the core zone, relicts of staurolite, andalusite, and possibly kyanite, point to an amphibolite grade, early peak metamorphic event (F2. Plates 9 and 10). Amphibolite grade peak metamorphic mineral assemblages are typically retrograded to epidote, chlorite, muscovite, and calcite.

A strong, nearly layer parallel schistose or phyllitic fabric dominates the Big Salmon Complex. Evidence of at least two phases of deformation is everywhere present, and in the higher grade core zone an additional distinct, noncoaxial fold set is developed. Third phase folds are
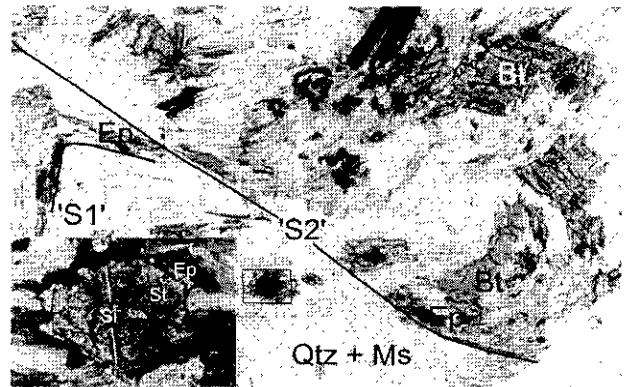

Plate 9. Earliest schistosity is recorded by inclusion trails in idiomorphic staurolite porphyroblasts (Si in inset) that are mantled by epidote. S1 is folded by S2 crenulation cleavage. Greenschist grade minerals: epidote and chlorite grow along the S2 planes. Mineral abbreviations are those recommended by Kretz (1983). Long dimension of photomicrograph is 4mm.
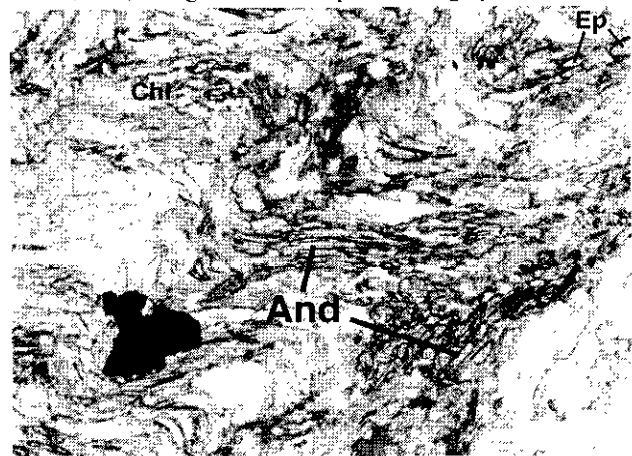

Plate 10. Viridine? (Mn andalusite (And)) in S1, is folded about S2 crenulation. This mineral is strongly sericitized along cleavage planes (photomicrograph long dimension represents 4mm).

further modified by local kinking and warping, especially in the high grade core region. At least one other deformational event can be recognized petrographically. It is cryptic, expressed mainly as deformed pre-regional S1 inclusion trails within quartz, feldspar, garnet and staurolite crystals (Plates 9, 11). So far, the extent and overall effects of this earliest event are largely unknown.

A rigorous domain by domain structural analysis of the Big Salmon Complex is beyond the scope of this paper. Nevertheless, a generalized deformational history is offered here (Figure 7). It is important to note that this interpretation is biased by the areas of best exposure, and may be inaccurate at the domain level.

Earliest deformation, here designated as D0, is only sporadically recorded in the highest grade core zone rocks as deformed inclusion trails of metamorphic minerals within porpyroblasts (Plates 9, 10). It has not been recognized in rocks younger than the Crinkle Chert unit. Preservation of D0 may be controlled by a number of factors: sufficiently argillaceous protoliths to produce schistosity, bulk rock composition suitable for porphyroblast growth, conditions permitting physical
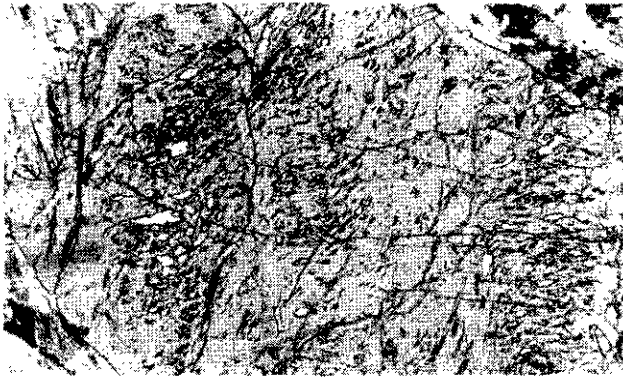
Plate 11. Crenulated shistosity preserved as inclusion trails in subidioblastic garnet (Grt).

Plate 12. An intrafolial isocline in slate of the upper dirty clastic succession (photomicrograph long dimension represents 4mm).
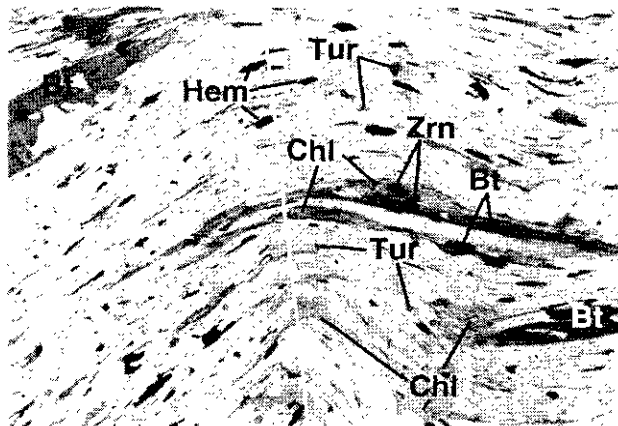

Plate 13. Crinkle chert displaying well developed S1 outlined by biotite (Bt), hematite (Hm) and and muscovite. Along incipient S2 surfaces biotite is replaced by chlorite (Chl). Note that tourmaline (Tur, metamorphic?) and zircon (Zrn, detritial?) are common but volumetrically minor (photomicrograph long dimension represents 4mm).

preservation of porphyroblasts, and others. It is possible that coeval structures are present in Big Salmon Complex superstructure, but are not recognized due to lower PT conditions and consequent lack of porphyroblast development at such high structural levels. However, the predominance of quartzite pebbles and sparse crenulated phyilite clasts in the upper dirty clastic succession is most simply explained by derivation from the lower Big Salmon Complex following a deformational event that predates deposition of the upper succession. The fabric associated with D0 is here termed Si (internal schistosity).

D1 deformation produced the first regionally recognizable set of folds and related schistosity and it is the first event that appears to have affected all units of the Big Salmon Complex. including Hazel orthogneiss and the dirty clastic succession. Thus, the folds and schistosity are designated F1 and S1 respectively. In most places D1 is manifested as a schistosity or phyllitic fabric that is within 10 degrees and commonly within 2 degrees of the bedding orientations. Such widespread near bedding parallel foliation is either due to original high amplitude and isoclinal folding (in which enveloping surfaces are not generally involved) or widespread subsequent transposition, or both. At the highest structural and stratigraphic levels. the dirty clastic succession also displays persistent very low angle bedding-cleavage relationships that support the existence of high amplitude folds. and on a microscopic scale. intrafolial isoclines within the same succession (Plate 12) indicate strong transposition. F1 fold hinges are most commonly preserved in the superstructure domains flanking the Big Salmon Complex core zone. They are open to close, upright to recumbent, subhorizontal to steeply plunging (Figure 8). Elongation lineation orientations, mainly stretched pebbles and lapilli, generally fall into one of two populations (Figure 7); both are at high angles to the S0-S1 intersection lineation. Thus, they are probably the product of flexural slip folding and formed subparallel to the D1 tectonic transport direction. Non-coaxial transposition of upper and lower limb lineations could have produced the bimodal pattern observed (Figure 7). Within most of the Big Salmon Complex. D1 produced S1, the dominant schistose fabric.

F2 folds are ubiquitous and are synchronous with peak D2 metamorphism (Plate 6a). They are outlined by deformation of the S1 fabric into parabolic to nearly chevron shapes that are open to tight, gently inclined to upright, subhorizontal to, less commonly, steeply plunging (Figure 8). However, where transposed, they are nearly recumbent and tight to isoclinal. F2 folds are most commonly observed with wavelengths and amplitudes in the range of 1 to 10 metres. Although larger F2 folds undoubtedly exist, as suggested by regional outcrop patterns, none have been traced out on the ground. Despite the peak metamorphic grades that are attained during D2, a regional coeval schistosity is NOT developed. However, axial parallel schistosity is locally formed in the core zones of these folds (designated here as S2). Well-developed shallow southeast-plunging mineral elongation lineations (Figure 7) are parallel to F2 hinge lines. Contoured poles to S1 show a bimodal distribution of relatively-lying flat limbs (Figure 8), reflecting the variable southwest and northeast vergence displayed by these folds, their tendency towards straight limbs and transposition by F3 folds (e.g. Plates 6b and 7).

F3 folds are close to isoclinal, subhorizontal, inclined to overturned and west southwest-verging (Figure 8). They
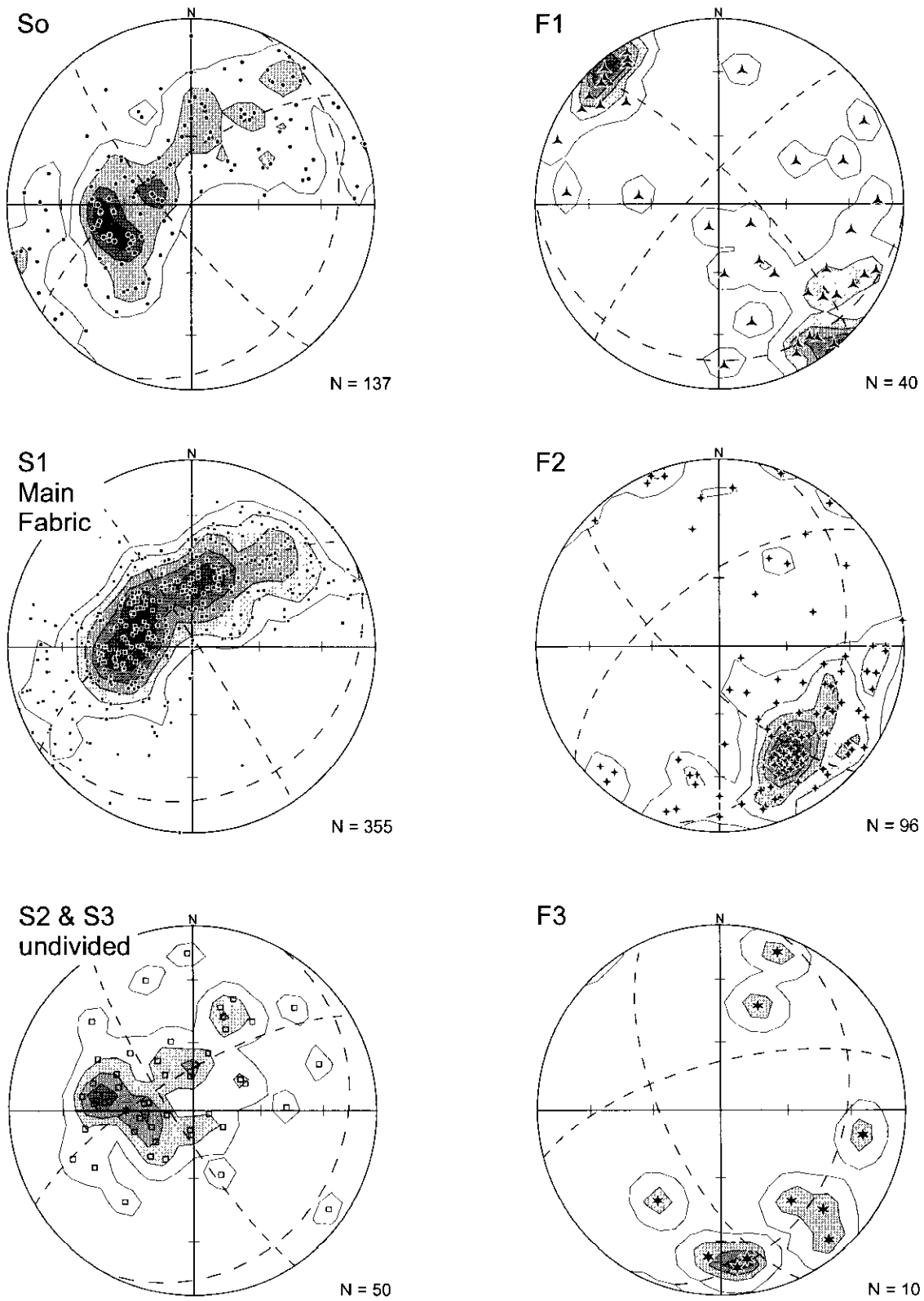
Figure 8. Stereonet plots of poles to bedding (So), first regional schistosity (S1), second schistosity (S2), first phase folds (F1), second phase folds (F2) and third phase folds (F3). Data are contoured by Gaussian counting using a weighting function equivalent to a fractional counting area of 0.01. Contour intervals are 2, 4, 6, 8, 10, 12 and 14 sigma.
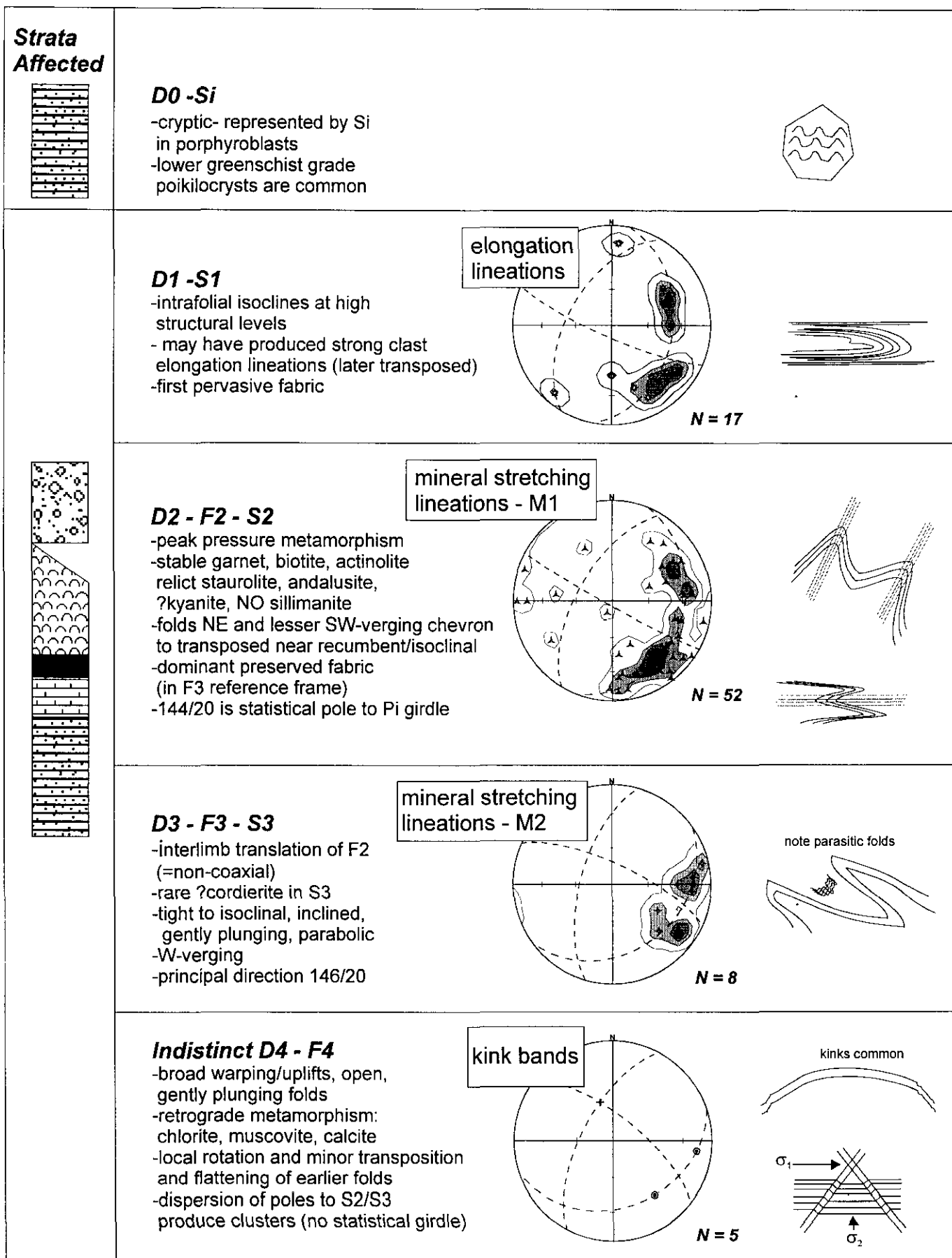
Strata Affected		

D0 -Si
-cryptic- represented by Si
 in porphyroblasts
-lower greenschist grade
 poikilocrysts are common

D1 -S1
-intrafolial isoclines at high
 structural levels
- may have produced strong clast
 elongation lineations (later transposed)
-first pervasive fabric

elongation lineations

N = 17

D2 - F2 - S2
-peak pressure metamorphism
-stable garnet, biotite, actinolite
 relict staurolite, andalusite,
 ?kyanite, NO sillimanite
-folds NE and lesser SW-verging chevron
 to transposed near recumbent/isoclinal
-dominant preserved fabric
 (in F3 reference frame)
-144/20 is statistical pole to Pi girdle

mineral stretching lineations - M1

N = 52

D3 - F3 - S3
-interlimb translation of F2
 (=non-coaxial)
-rare ?cordierite in S3
-tight to isoclinal, inclined,
 gently plunging, parabolic
-W-verging
-principal direction 146/20

mineral stretching lineations - M2

note parasitic folds

N = 8

Indistinct D4 - F4
-broad warping/uplifts, open,
 gently plunging folds
-retrograde metamorphism:
 chlorite, muscovite, calcite
-local rotation and minor transposition
 and flattening of earlier folds
-dispersion of poles to S2/S3
 produce clusters (no statistical girdle)

kink bands

kinks common

σ_1

σ_2

N = 5

Figure 7. Deformational history. Note that lithologic patterns are consistent with those in Figure 4. Contoured stereonet plots of elongation lineations (E1) and mineral lineations (M1, M2) follow the methodology used for structural plots in Figure 8 (see also text for discussion). Mineral abbreviations are those recommended by Kretz (1983).

are semi-elliptical to parabolic in shape with high amplitudes and relatively straight limbs. Parasitic folds and an axial planar fabric are commonly developed and can be recognized in mountain scale F3 folds. However, unless fold-fabric relationships can be established at the outcrop, it is not always possible to distinguish F2 and F3 schistosities, even though they are here designated as S2, and S3 respectively. S3 **can** be recognized petrographically because it formed during retrograde D3 and is commonly outlined by the growth of chlorite (Plate 13), muscovite, calcite + epidote (Plate 9). In some cases chlorite-lined S3 surfaces can be distinguished in outcrop. The dispersion of poles to S2 shown in Figure 8 is the result of inclusion of S2 with S3 data, and a concentration of measurements from domains most strongly affected by F4 warping.

F4 folds are broad warps with little preferred orientation. They appear unrelated to a distinct deformational event, but probably reflect the combined effects of tectonic exhumation and stress transmitted from large bounding strike slip faults, like motion on the Teslin lineament. One large, northwest-trending warp may be responsible for uplift of the Big Salmon Complex core zone as indicated from outcrop distribution in Figures 3 and 4. Local strong development of kink bands in chlorite and muscovite schist (retrograde S3) formed during this late warping. While kink bands are relatively common, conjugate kink band sets are not widely developed within the map area. In this study, only one set was measured near Four Mile Lake. In controlled experiments, conjugate kink bands are oriented such that the obtuse and acute angles between the two kink band arrays face the shortening and stretching directions, which are approximately parallel to the major and minor principal stress directions respectively **at that site**. Figure 7 shows the maximum and minimum principal stresses orientations that might have existed at the time of the kink band formation. Interestingly, the maximum and minimum principal stresses are orogen parallel and orogen normal respectively.

Age of deformation

Like the protoliths within the Big Salmon Complex of British Columbia, there are currently no concrete constraints on the age of deformational events within the Big Salmon Complex. K-Ar (muscovite) cooling ages have been reported from similar rocks immediately north of the Yukon border: 222 (Mulligan, 1963; no uncertainty quoted; from Mile 778 (about 1.5 km west of Morley River), 214 ±25 (R.K. Wanless in Mulligan, 1963; no location reported) and from British Columbia in the northwestern corner of 104O: 194 ±15Ma (Leech et al., 1963; GSC Paper 44-25). The reliability of all these ages must be considered suspect since [36]Ar was not determined.

Regional fabrics are cut by the Early Jurassic Simpson Peak batholith (K-Ar hornblende is 185 ±14 Ma, recalculated from Wanless et al., 1970). It intrudes, skarns and hornfelses previously deformed and metamorphosed rocks of the Big Salmon Complex and thus provides a minimum age constraint on the ductile fabrics. However, the batholith locally displays a weak tectonic foliation indicating that the latest deformation outlasted its intrusion. Weak to rarely moderately strong foliation is also developed in the Middle Jurassic (170 Ma, Figure 6) Slaughterhouse pluton at the south end of Teslin Lake. However, the body where it has been dated cannot be shown to cut the Big Salmon Complex.

MINERALIZATION

Within the entire Big Salmon Complex in British Columbia, the only base metal mineral occurrences recorded in MINFILE are those on the Arsenault and adjacent claims about 14 km south of the Smart and Swift River confluence. Copper mineralization was discovered on the Arsenault property by Wilf McKinnon of Hudson's Bay Mining and Smelting in the 1940's (Sawyer, 1979). Geological and geochemical work performed in 1967 included the excavation of 16 trenches; 0.10 oz/t Au over 3 metres was reported from one trench (Sawyer, 1967). Between 1970 and 1972 a major exploration program was conducted by Bolivar Mining Corporation (subsidiary of Cyprus Mines Corp. Ltd.) that included construction of an access road, airborne EM, magnetometer, induced polarization and geochemical surveys, geological mapping and 1080 metres diamond drilling on the four best anomalies. A further 440m of diamond drilling was conducted in 1979 and 235.5m in 1981 by Rebel Developments Ltd. (Sawyer, 1979; Phendler, 1982).

Mineralization exposed at surface is dominated by chalcopyrite and pyrite with associated epidote, garnet, actinolite, magnetite (Plate 14) and wollastonite (Plate 15) in quartz-rich strata at their contact with carbonate. Mineral textures preserved suggest static crystallization. Traces of bornite, molybdenite, piedmontite (Mn-epidote) and spessartine (Mn-garnet) have also been reported (Sawyer, 1979). Tourmaline is common in both the quartzite and tuff.

Although the quartz-carbonate association and calc-silicate mineralogy and textures are suggestive of skarn, no causative intrusion has been found. Pink quartz-feldspar porphyry dikes, one within 200m of two mineralized trenches, others up to a kilometre away, cut the succession but they clearly post-date deformation that has affected the calc-silicate mineralogy. Furthermore, there is no correlation between soil geochemical Cu anomalies and the location of the closest dike (Sawyer, 1979). If Arsenault is a skarn, then the best candidate for an associated pluton is the dioritic complex that crops out over 2 km away, in the north face of Mount Francis, but the diorite is strongly foliated and folded, whereas calc-silicate mineralization at the Arsenault appears to have developed under mainly static conditions. Alternatively, if calc-silicate development is a product of regional metamorphism, the source of copper remains in question. Clearly, metamorphic grade and reactive lithologies alone do not form copper-rich calc-silicate zones.

The only quartzite-carbonate contacts within the area with associated chalcopyrite are those adjacent to the Arsenault dacite. Such occurrences extend from the western Arsenault showings to the east flank of Mount
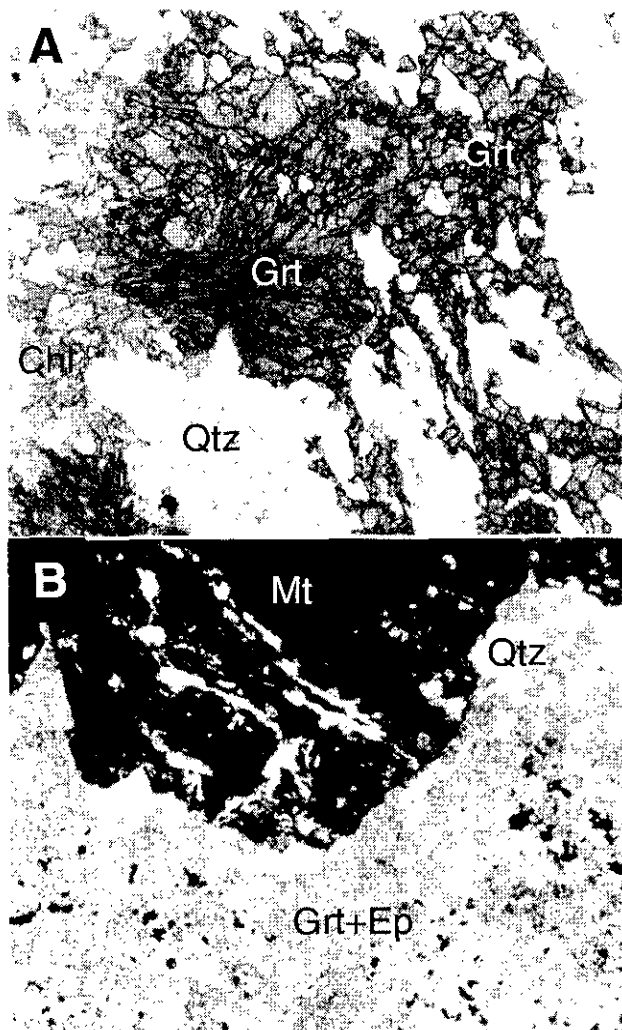
Plate 14. (a) apparent static growth of garnet (Grt) and quartz and (b) static growth of mixed garnet (Grt), epidote (Ep) and idiomorphic magnetite (Mt) looks like a skarn texture (long dimension of photomicrographs represents 4mm).
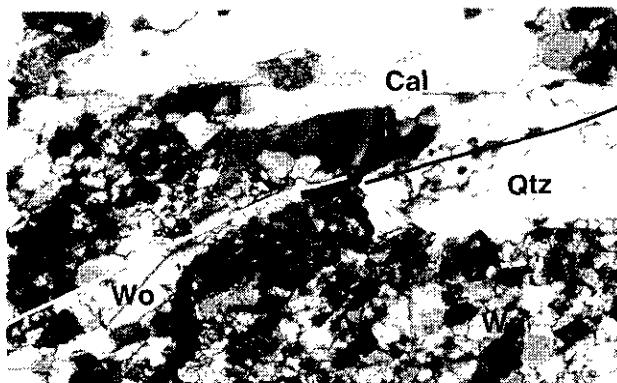

Plate 15. Stubby wollastonite crystals are aligned parallel to zones of cataclasis in adjacent quartz layers indicating a late synkinematic origin (photomicrograph long dimension represents 4mm).

Francis, a distance of 2.5 km. Chalcopyrite also occurs as disseminations and veinlets within the Arsenault dacite, both in the eastern trenches and where it crops out about 0.5 km farther to the south-southeast. This rather widespread and consistent lithological association suggests

a syngenetic origin for the copper mineralization, as originally proposed by Sawyer (1979). In support of this interpretation is the association of Mn-bearing minerals, as well as tourmaline, with the mineralized horizon. Once a clearer understanding of protolith ages within the Big Salmon Complex emerges, it should be possible to determine whether the Arsenault mineralization Pb signature (in progress) is syngenetic or a product of a cryptic, younger magmatic-related event.

New occurrences

Four previously unrecorded mineral occurrences were encountered during the course of mapping. The first two of these are interpreted to occur in roughly the same 100m stratigraphic interval as the Arsenault, and each display some evidence of having been previously sampled. Samples collected from the new occurrences were analyzed by aqua regia digestion and inductively coupled plasma emission spectroscopy. Note that the digestion method is incomplete for most elements, particularly those marked with an asterisk. Some of the outstanding results are listed below, and the complete data set may be viewed or downloaded from our web site at http://www.ei.gov.bc.ca/geosmin/fieldpgm/97-98/6br-dm.htm.

Arsenault east

On the east flank of Mount Francis, near the eastern limit of the now lapsed Arsenault I claim, is a moderately steeply east-dipping, strongly deformed section of decimetre thick interbeds(?) of limestone and tuff. These are infolded with clean quartzite. Within the carbonate, near the quartzite contact, is a well developed vein replacement zone of garnet-epidote-quartz-calcite-magnetite-actinolite-chalcopyrite. The zone is 2.5 m wide and is exposed for 10 m along strike. Chalcopyrite is concentrated in the northern third of the zone in pods and irregular veins up to 4 cm wide and as much as 30 cm long. Mineralized chips collected across the 2.5m wide zone yielded 4.6% Cu, 0.3% Zn*, 9.5 ppm Ag, 322 ppm Co*, 26 ppm Cd and 115 ppm Bi.

Teslin Lake border area

Along east shore of northern Teslin Lake, 2 km south of the Yukon border, a series of mafic to felsic tuffaceous rocks, quartz-sericite schists and siltstones are exposed along a kilometre-long section of lakeshore. All are phyllitic to schistose and relict textures are rare. Several zones display widespread pyrite and traces of chalcopyrite. For example, at the south end of the outcrop belt a 20 m thickness of locally strongly pyritic felsic metatuff is sandwiched between mafic metatuff. The gossanous layers are up to 30 cm thick and typically contain 10% or more pyrite. Chalcopyrite occurs as sparse cm-sized clots and irregular stringers. It is evident at several localities that the zone has been previously sampled. Analysis of a single grab sample yielded 2.2% Cu and 28 ppm Ag.

Copper in the Crinkle Quartzite

Two occurrences of minor sulphide mineralization and copper staining include consist of chalcocite and specularite at the peak of Mount Hazel, and chalcopyrite on the west end of the low ridge containing the Arsenault showing. At the first locality, deformed chalcocite and specularite occur as fist-sized patches in a 0.9 m thick bull quartz vein on the southeast side of Mount Hazel near the contact between crinkle quartzite and tuffaceous rocks of the greenstone unit. A similarly mineralized vein occurs on the northwest side of the peak, although it could be an along-strike continuation of the southeast vein. The second locality is below tree line about 2 km west of the old exploration camp where a few chalcopyrite veins up to a centimetre thick occur within the upper third of a 10 m cliff exposure of crinkle quartzite. No signs of prior sampling are evident.

Highway 97

Extensive upgrading and straightening of Highway. 97 in 1988 resulted in a number of new roadcut exposures and some extensive outcrop in burrow pits. In one new exposure, about 3.5 km west of Swan Lake, a 3 m wide gossanous zone occurs within the greenstone unit. Several north-northwest trending quartz-chlorite-magnetite-pyrite-chalcopyrite veins cut the zone. The veins attain a maximum thickness of 30 cm. There is no sign of this zone having been previously sampled. Mineralized chips collected across a 1.5m true thickness that is 80% vein material returned 0.2% Cu, 165 ppm Co*, 210 ppm As and 45 ppm W*.

SUMMARY

Mapping along the British Columbia-Yukon border leaves little doubt that the Big Salmon Complex extends into the Yukon as suggested by earlier workers (Mulligan, 1963), and must extend into rocks recently mapping by Gordey (1995) who includes them in the Kootenay Terrane. Rocks assigned to the Kootenay Terrane in Yukon are considered to be part of the Yukon-Tanana Terrane, but the Kootenay Terrane in southeastern British Columbia is a separate tectonic entity that has demonstrable stratigraphic ties to North America (e.g. Colpron and Price, 1995). It is clear that the Big Salmon Complex bears little resemblance to classical Slide Mountain terrane (e.g. Ferri, 1995), and the assignment of Big Salmon Complex to Slide Mountain Terrane (Wheeler et al., 1991) is here considered incorrect. However, on the basis of lithological comparison alone it is not possible to unequivocally assign the Big Salmon Complex to the Yukon Tanana Terrane. Certainly the lower quartz-rich succession, Mount Hazel orthogneiss and felsic volcanic strata are lithologically similar to parts of the Yukon Tanana Terrane, but until some age control on these units is available, such correlations are speculative.

New age data from the Slaughterhouse diorite show that it is temporally equivalent to the Three Sisters plutonic suite.

Two stratigraphic intervals appear most prospective for base metal sulphide exploration: (1) porphyritic blue quartz-eye dacite tuff with interlayered limestone/quartzite that are stratigraphically equivalent to rocks that host the Arsenault occurrence and (2) barium-manganese-rich rocks of the crinkle chert unit. An exhalative origin for piedmontite schist of the crinkle chert unit was suggested by Nelson (1997). The elevated barium contents in samples from this unit supports its exhalative origin, but it also contains fine dark zircons of probable detrital origin. Scattered copper mineralization within the unit is a further indication of the importance of this unit as a potential pathway to base metal sulphide deposits.

Despite strong development of calc-silicate minerals and skarn textures with copper mineralization at the Arsenault occurrence, its classification is equivocal. Copper mineralization occurs locally over an area of about 10 km^2 and, if correlation with strata along Teslin Lake is correct, the copper-rich nature of this horizon is regional in extent. This suggests a syngenetic control and potential for volcanogenic massive sulphide mineralization. Blue quartz eyes are conspicuous not only in the Arsenault dacite, but interestingly also occur in graphitic quartz-granule conglomerate as well as porphyritic phases of the Hazel orthogneiss. It is possible that the Arsenault dacite and Mount Hazel orthogneiss are comagmatic and provide a detrital or pyroclastic source of blue quartz eyes for the quartz granule conglomerate. However, the simplest structural interpretation (the one preferred here) places the blue quartz-eye clastic rocks stratigraphically below the Arsenault dacite.

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REFERENCES CITED

Aitken, J.D. (1959): Atlin Map-area, British Columbia; *Geological Survey of Canada*, Memoir 307.

Creaser, R.A., Erdmer, P., Grant, S.L. and Stevens, R.A. (1995): Tectonic Identity of Metasedimentary Strata from the Teslin Tectonic Zone, SE Yukon: Geochemical and Nd Isotopic Constraints; *in* Lithoprobe, Slave-Northern Cordillera Lithospheric Evolution (SNORCLE), Report of 1995 Transect Meeting, April 8-9, 1995, Lithoprobe Report No. 44, pages 51-55.

Colpron, M. and Price, R.A. (1995): Tectonic Significance of the Kootenay Terrane, Southeastern Canadian Cordillera: an Alternative Model; *Geology*, Volume 23, pages 25-28.

Erdmer, P. (1985): An Examination of Cataclastic Fabrics and Structures of Parts of Nisutlin, Anvil and Simpson Allochthons, Central Yukon: Test of the Arc-Continent Collision Model; *Journal of Structural Geology*, Volume 7, pages 57-72.

Erdmer, P. and Helmstaedt, H. (1983): Eclogite from Central Yukon: a Record of Subduction at the Western Margin of Ancient North America; *Canadian Journal of Earth Sciences*, Volume 20, pages 1389-1408.

Ferri, F. (1997): Nina Creek Group and Lay Range Assemblage, North-Central British Columbia: Remnants of Late Paleozoic Oceanic and Arc Terranes; *Canadian Journal of Earth Sciences*, Volume 34, pages 853-874.

Gabrielse, H. (1969): Geology of the Jennings River Map-Area, British Columbia (104-O); *Geological Survey of Canada*, Paper 68-55.

Gordey, S.P. (1995): Structure and Terrane Relationships of Cassiar and Kootenay (Yukon-Tanana) Terranes, Teslin Map Area, Southern Yukon Territory; *in* Current Research 1995-A; *Geological Survey of Canada*, pages 135-140.

Gordey, S.P. and Stevens, R.A. (1994): Preliminary Interpretation of Bedrock Geology of the Teslin Area (105C), Southern Yukon; *Geological Survey of Canada*, Open File 2886.

Hansen, V.L. (1989): Structural and Kinematic Evolution of the Teslin Suture Zone, Yukon: Record of an Ancient Transpressional Margin; *Journal of Structural Geology*, Volume 11, pages 717-733.

Hansen, V.L., (1992a): P-T Evolution of the Teslin Suture Zone and Cassiar Tectonites, Yukon, Canada: Evidence for A- and B-type Subduction; *Journal of Metamorphic Geology*, Volume 10, pages 239-263.

Hansen, V.L. (1992b): Backflow and Margin-parallel Shear Within an Ancient Subduction Complex; *Geology*, Volume 20, pages 71-74.

Hansen, V.L., J.K. Mortensen, and Armstrong, R.L. (1989): U-Pb, Rb-Sr, and K-Ar isotopic constraints for ductile deformation and related metamorphism in the Teslin suture zone, Yukon-Tanana terrane, south-central Yukon; *Canadian Journal of Earth Sciences*, Volume 26, pages 2224-2235.

Hansen, V.L., M.T. Heilzer, and Harrison, T.M. (1991): Mesozoic Thermal Evolution of the Yukon-Tanana Composite Terrane: New Evidence from $^{40}Ar/^{39}Ar$ Data; *Tectonics*, Volume 10, pages 51-76.

De Keijzer, M. and Williams, P.F. (1997): A New View of the Structural Framework of the Teslin Zone, South-central Yukon; *in* Lithoprobe, Slave-Northern Cordillera Lithospheric Evolution (SNORCLE), Report of 1997 Combined Meeting, March 7-9, 1997, Lithoprobe Report No. 56, pages 96-102.

Kretz, R. (1983): Symbols for Rock-forming Minerals; *American Mineralogist*, Volume 68, pages 277-279.

Leech et al. 1963. Age Determinations and Geological Studies; *Geological Survey of Canada*, Paper 63-17.

Levinson, A.A. (1980): Introduction to Exploration Geochemistry; *Applied Publishing Ltd.*, Wilmette, Illinois, 924 pages.

Mihalynuk, M.G., M.T. Smith, J.E. Gabites, D. Runkle, and Lefebure, D. (1992): Age of Emplacement and Basement Character of the Cache Creek Terrane Constrained by New Geochemical Data; *Canadian Journal of Earth Sciences*, Volume 29, pages 2463-2477.

Mihalynuk, M.G., Bellefontaine, K.A., Brown, D.A., Logan, J.M., Nelson, J.L., Legun, A.S. and Diakow, L.J. (1996): Geological Compilation, Northwest British Columbia (NTS 94E, L, M; 104F, G, H, I, J, K, L, M, N, O, P; 114J, O, P); *B.C. Ministry of Energy, Mines and Petroleum Resources*, Open File 1996-11.

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): Cordilleran terranes; *in* Geology of the Cordilleran Orogen in Canada, Geology of Canada, Volume 4, edited by H. Gabrielse and C.J. Yorath, Chapter 8, pages 281-327, *Geological Survey of Canada*, Ottawa, Ont..

Mortensen, J.K. (1992): Pre-mid-Mesozoic Tectonic Evolution of the Yukon-Tanana terrane, Yukon and Alaska; *Tectonics*, 11, pages 836-853.

Mortensen, J. K., Ghosh, D.K. and Ferri, F. (1995): U-Pb Geochronology of Intrusive Rocks Associated with Copper-Gold Porphyry Deposits in the Canadian Cordillera; *in* Porphyry Deposits of the Northwestern Cordillera of North America, Schroeter, T.G., Editor, *Canadian Institute of Mining, Metallurgy and Petroleum*; Special Volume 46, pages 142-158.

Mulligan, R. (1963): Geology of the Teslin Map-Area, Yukon Territory; *Geological Survey of Canada*, Memoir 326, 96 pages.

Nelson, J. (1997): Last Seen Heading South: Extensions of the Yukon-Tanana Terrane into Northern British Columbia; *in* Geological Fieldwork 1996, *B.C. Ministry of Employment and Investment*, Paper 1997-1, pages 145-156.

Phendler, R.W. (1982): Report on Assessment Work (Diamond Drilling) on the Arsenault #1, #2 and #3 Claims, Jennings River Area, Atlin Mining Division,