Ancient Pacific Margin Part III: Regional Geology and Mineralization of the Big Salmon Complex (NTS 104N/9E,16 & 104O/12,13,14W)

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KEYWORDS: *Regional geology, Big Salmon Complex, Nisutlin Assemblage, Klinkit Assemblage, Swift River Assemblage, Yukon-Tanana Terrane, Kootenay Terrane, Dorsey Terrane, Slide Mountain Terrane, Teslin Fault, volcanogenic massive sulphide, mineralization, Atlin, Teslin, Jennings River.*

INTRODUCTION

Regional geological mapping of the Big Salmon Complex in northwestern British Columbia (104N/09 & 16 and 104O/12, 13 & 14W, Figure 1) was conducted in 1999 under the aegis of the Ancient Pacific Margin National Mapping Program (NATMAP, *cf*. Nelson, *et al.*, 2000, this volume; Roots, *et al.*, 2000). This mapping builds on 1997 reconnaissance mapping (Mihalynuk *et al.*, 1998) that confirmed long-standing correlations between the Big Salmon Complex in British Columbia and the Yukon (*e.g.* Mulligan, 1963; Gabrielse, 1969; Figure 2).

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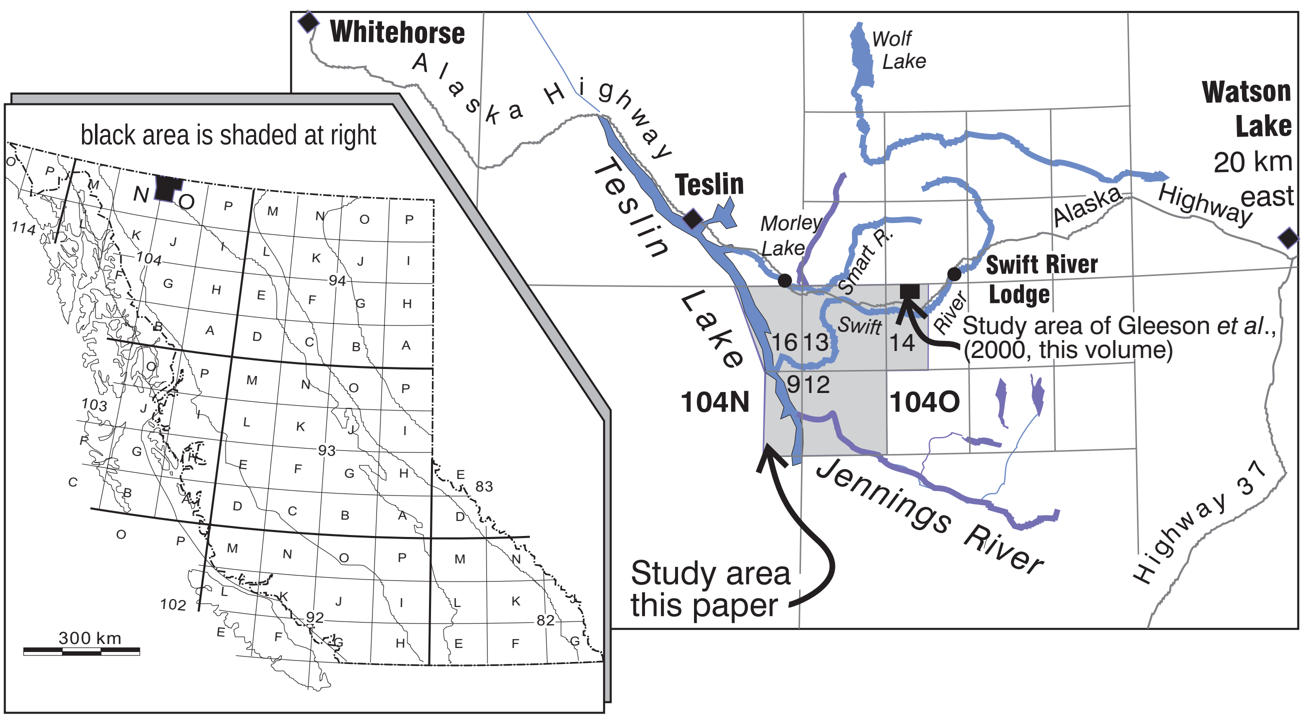


Figure 1. Location map showing the location of the Big Salmon Complex study area in northern British Columbia and southern Yukon (after Roots *et al.*, 2000). The area of Figure 3 is shown by the shading.

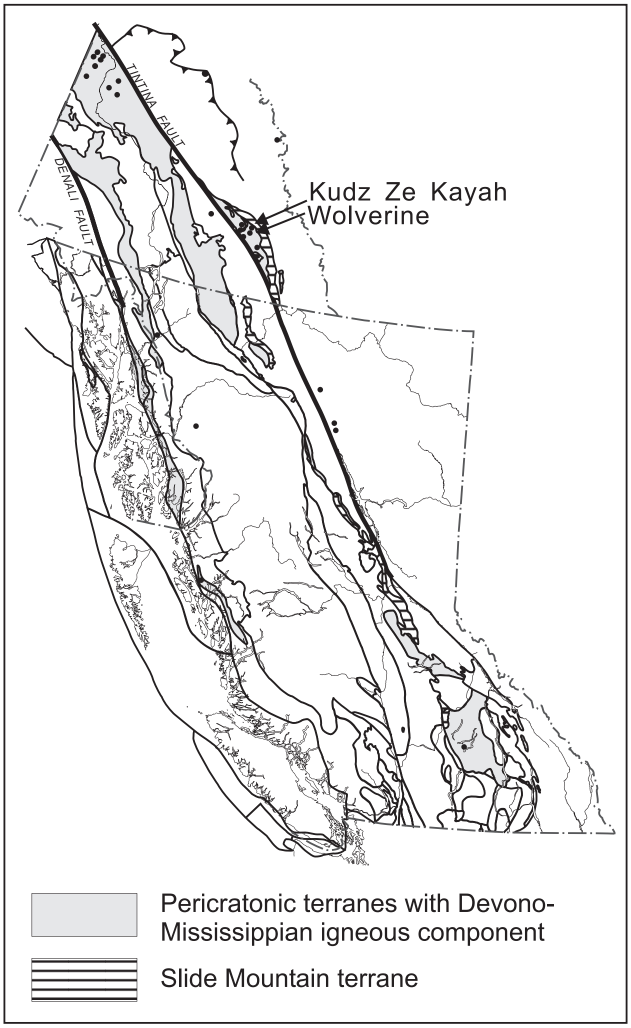


Figure 2. Tectonic assemblage map showing the approximate distribution of Yukon-Tanana and Slide Mountain terranes. Modified after Wheeler *et al*. (1991).

In southern Yukon, Big Salmon Complex rocks have subsequently been included with the Kootenay Terrane (Gordey, 1995) which include the Lower and Middle Units of the Yukon-Tanana Terrane as used by Mortensen (1992). This correlation is important because Yukon-Tanana Terrane rocks, historically ignored by mineral exploration geologists, have been the focus of mineral exploration programs since 1993 with the discovery of mineralized float at what came to be the Kudz Ze Kayah deposit. Other exploration successes include the Wolverine and Fyre Lake volcanogenic massive sulphide deposits.

Highlights of the 1999 field program are reported here together with descriptions of map units and geological relationships, and new insights. Mihalynuk *et al.* (1998) describe units encountered in the 1997 field season and present a structural synthesis, the details of which are not repeated here.

LOCATION AND PHYSIOGRAPHY

During the six week field program (early July to mid-August), mapping concentrated on low-lying, tree or swamp-covered areas (Photo 1) that occupy more than 90% of the area bounded by the British Columbia-Yukon border on the north, Teslin Lake on the west, Mount Charlie Cole to the south and Simpson Peak to the east (Figure 3). Most of the area is covered by fluvial and glacial deposits that attain thicknesses of 40 metres or more (Dixon-Warren and Hickin, 2000, this volume); although, air photo analysis and fixed wing aerial reconnaissance revealed that outcrop is more abundant than indicated on previous maps (Gabrielse, 1969). Reaching the outcrops can, however, be a challenge, usually requiring foot travel between swamps that provide the only helicopter landing spots.

The map area is accessed from the Alaska Highway, which crosses it near the Yukon border, between Watson Lake and Whitehorse (Figure 1). Only three rough secondary roads reach more than a kilometre from the highway. These mineral exploration roads; each extend about 10 kilometres in British Columbia. Two lead into the Yukon, up the west side of Logjam Creek and east side of Smart River valleys. However, washouts on the Smart River Road render it impassable after a few kilometres. Another road, constructed to provide access to the Arsenault property, can only be traveled as far as the Swift River where the bridge has long since washed away. Fuel and rudimentary supplies are available at Swift River and Morley River Lodge, just outside the eastern and western limits of the map area, respectively.

Charter fixed wing aircraft are available year round at Teslin from Teslin Lake or at a converted military gravel strip, both, about 45 kilometres west of the map area. Charter helicopters are available year round from Atlin, about 80 air kilometres west of the map area.

GEOLOGIC FRAMEWORK

Most of the field area is underlain by the Big Salmon Complex (Figure 3). Dominant protoliths are mafic vol-

Photo 1. An aerial view of the low-lying, swamp and tree-covered Nisutlin Plateau near the south end of Teslin Lake.

canic rocks, quartz-rich clastic sediments, and intrusive rocks of diorite, tonalite and leucogranite composition. Felsic tuff, crystalline limestone and chert-exhalite units are volumetrically minor, but conspicuous and mappable units. A lower amphibolite grade "core zone" in which protolith textures are mostly destroyed, is broadly parallel to the northwest trend of the Big Salmon Complex, and is flanked by greenschist grade rocks to both the southwest and northeast in which relict protolith textures may be relatively well preserved. Metamorphosed tonalite, lesser diorite and minor leucogranite, herein called the Hazel orthogneiss, dominate the north-central part of the "core zone" (Figure 3).

Big Salmon Complex rocks are bounded to the southwest by Teslin Lake (Teslin fault, *see* de Keijzer *et al.*, 2000) and Cache Creek Terrane in the Atlin area (Aitken, 1959; Figure 3). They clearly extend northwest into the Yukon (Roots *et al.*, 2000) and are probably equivalent to Mississippian volcanics in the Teslin area (unit Mv of Gordey and Stevens, 1994; Gordey, 2000). Relationships with rocks to the southeast and northeast are less certain (*see* Discussion).

Both Aitken (1959) and Gabrielse (1969) considered the Big Salmon Complex to be at least partly correlative with the Sylvester Group (Slide Mountain Terrane) based upon the abundance of mafic volcanic protoliths, but this assignment is not supported by more recent data. For example, Mihalynuk *et al.* (1998) showed that the Big Salmon Complex greenstones are geochemically like continental arc volcanics, not mid ocean ridge basalts typical of the Slide Mountain Terrane. Along strike in the Teslin zone, Creaser *et al.* (1997) showed that the geochemistry of both sedimentary and volcanic rocks lithologically correlative with the Big Salmon Complex is not permissive of genesis in the Slide Mountain ocean basin because εNd values are strongly negative (+0.5 to –26.2), indicating a significant continental component.

Tempelman-Kluit (1979) interpreted rocks in the Yukon that are equivalent to, and along strike with the Big Salmon Complex as part of a subduction/collisional complex (Teslin suture zone), a contention supported by discovery of relict high pressure metamorphic assemblages including eclogite (Erdmer and Helmstaedt, 1983; Erdmer, 1985; Erdmer and Armstrong, 1989). Working along the western part of the Big Salmon Complex, Hansen (1989, 1992a, 1992b) and Hansen *et al.* (1989, 1991) claimed to outline a fossil Permo-Triassic subduction zone with off-scraped sediments affected by tectonic backflow. More recent work by Stevens (1992, 1994), Stevens and Erdmer (1993), Stevens and Harms (1995), Stevens *et al.* (1996) and Colpron (1999) shows that the Teslin "suture zone" is comprised not of mélange of off-scraped oceanic sediments and subduction zone tectonites, but of continental margin strata (Creaser *et al.*, 1997) with relatively coherent stratigraphic relationships. This coherent stratigraphy has enabled the definition of a polydeformed nappe (deKeijzer and Williams, 1999) within the former Teslin suture zone. Likewise, a persistent stratigraphy can be traced throughout the study area, and none are composed of scaly subduction mélange.

STRATIGRAPHIC FRAMEWORK

A persistent stratigraphy provides the foundation for correlating from one area to another in the Big Salmon Complex. In British Columbia, three distinctive and contrasting units are recognized as forming a marker succession (Mihalynuk *et al.*, 1998; Figure 4). Based on new isotopic and geologic constraints, their stratigraphic order, from oldest to youngest is now known to be:

- 1200 m of tuffite-dominated greenstone;
- 30-150 m of buff to grey weathering limestone with metre-thick tuffaceous and thin centimetre to decimetre quartzite layers;
- 20-50 m of thinly bedded, finely laminated manganiferous crinkle chert/quartzite with muscovite partings;

This marker succession persists in southeast and northwest 104O/13 and south-central 104O/12. In northern 104N/16 a hybrid unit having some characteristics of felsic tuff mixed with crinkle chert occurs in place of the crinkle chert unit.

Two other more broadly defined rock packages are recognized:

- >150 m of dirty clastics: brown to tan wacke, stretched quartzite-pebble and granule conglomerate and slate;
- >1000 m of heterolithic, quartz-rich clastics interbedded with thin limestone and mafic and felsic tuffs.

Lacking age control, Mihalynuk *et al.* (1998) concluded that the "dirty clastics" were considerably younger than the unconformably underlying greenstone unit, because they contained clasts that appeared to be derived from the older polydeformed and polymetamorphic units. And because the "dirty clastics" unit was observed to sit only on the greenstone unit, greenstone was considered the next youngest unit, prompting the conclusion: "A thick greenstone 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."

Subsequent petrographic analysis showed that polydeformed phyllite clasts within the "dirty clastics" succession were deformed *in situ*, and were not derived from a previously deformed terrain. Two fabrics shown by the phyllite clasts are seen in thin section to be weakly developed in adjacent, phyllosilicates-poor quartzite clasts (Photo 2). Furthermore, new isotopic age data from samples of the former lower (Mt. Francis dacite at 325 Ma) and upper (Hazel orthogneiss at 362 Ma) parts of the stratigraphy require that the stratigraphy of Mihalynuk *et al.* (1998) is inverted, with important consequences for regional correlations (*see* Geochronology and Discussion). A revised stratigraphy is shown in Figure 4.

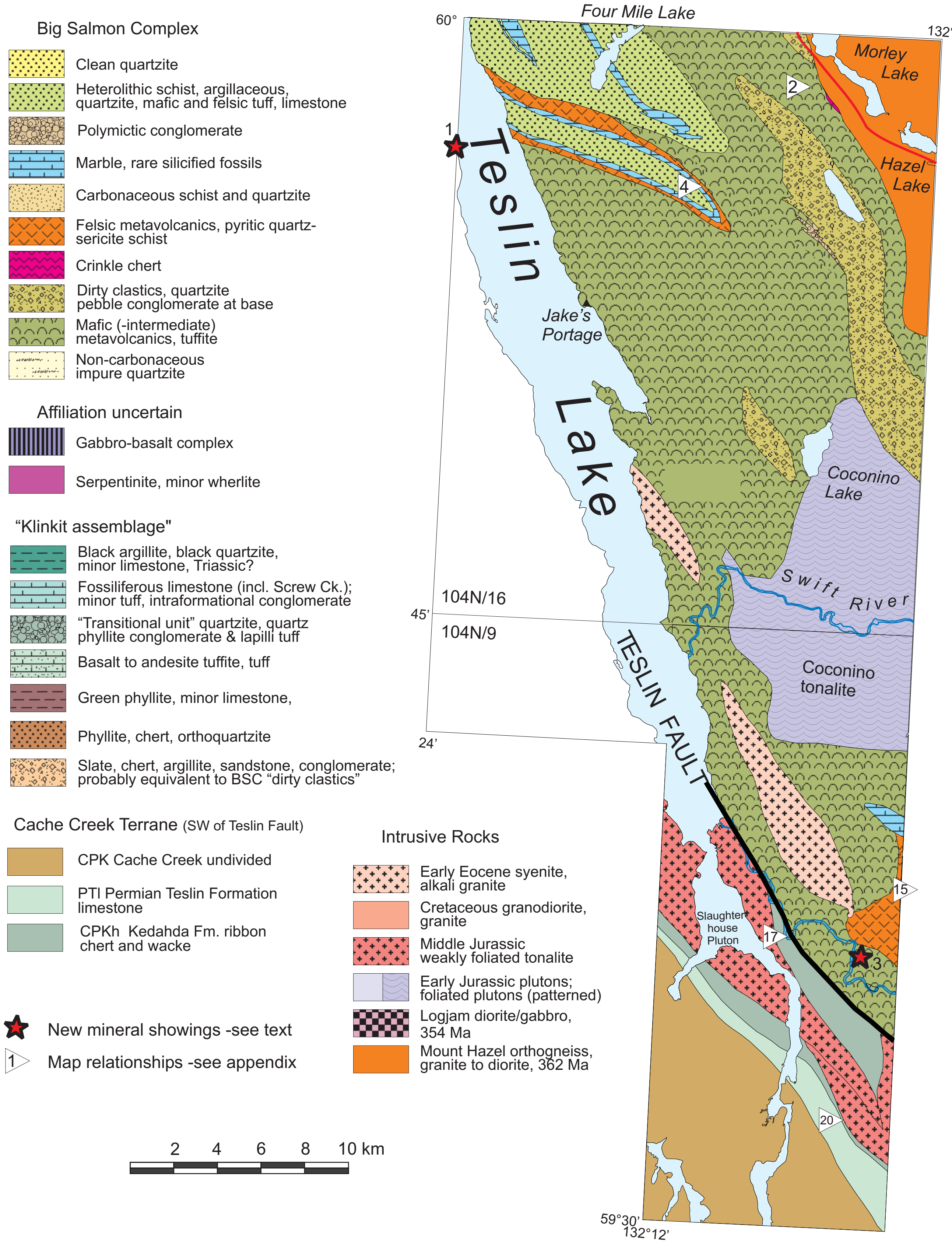
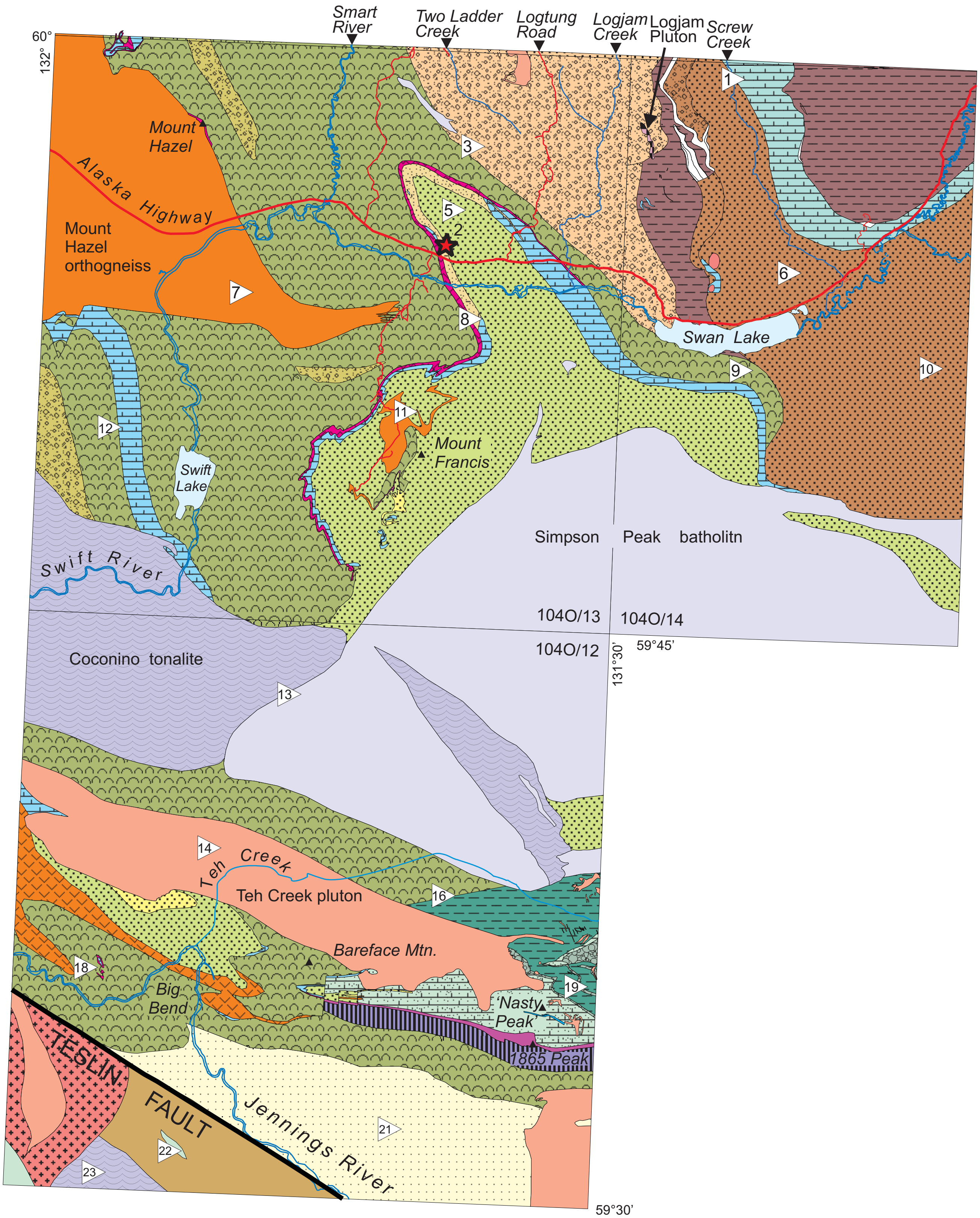


Figure 3. Generalized geology of the map area showing place names, access roads and sample sites referred to in the text.


Smart River
Two Ladder Creek
Logtung Road
Logjam Creek
Logjam Pluton
Screw Creek
60°
132°
Mount Hazel
Alaska Highway
Mount Hazel orthogneiss
Swift Lake
Swift River
Mount Francis
Swan Lake
Simpson Peak batholitn
104O/13
104O/14
104O/12
59°45'
131°30'
Coconino tonalite
Teh Creek
Teh Creek pluton
Bareface Mtn.
Big Bend
'Nasty Peak'
1865 Peak
TESLIN FAULT
Jennings River
59°30'
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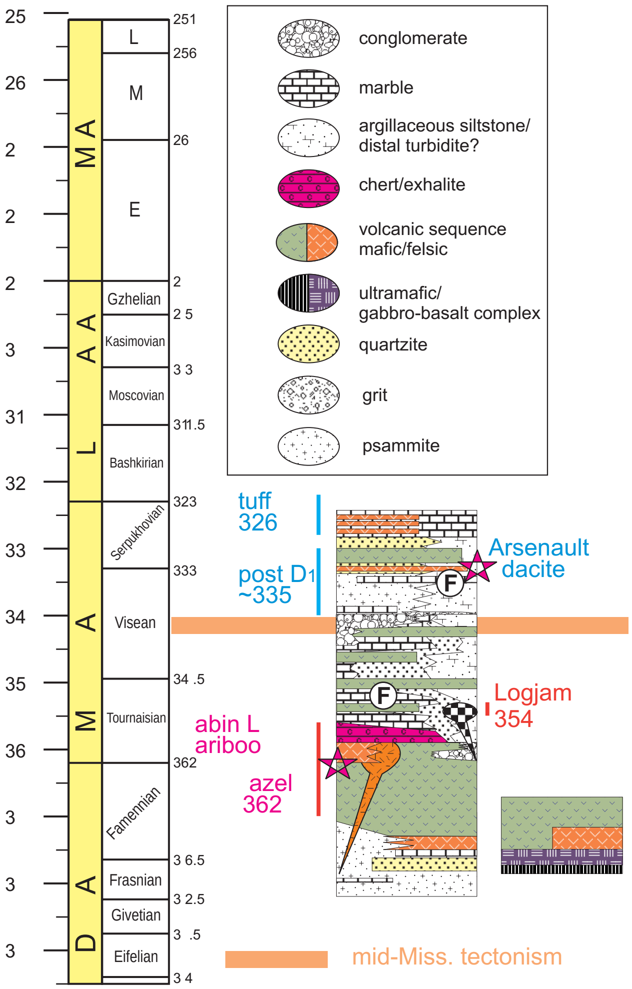

Figure 4. Generalized stratigraphy of the Big Salmon Complex in British Columbia.

Facing indicators are among the textures commonly preserved on the relatively weakly metamorphosed flanks of the Big Salmon Complex. However, unless they can be observed at the interface of the units being compared, they must be considered suspect because isoclinal folds are pervasive. In particular, the “dirty clastics” unit, which displays good graded bedding, is strongly deformed near its contact with the greenstone due to high rheological contrast (Photo 3).

A heterolithic 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, are now considered to sit near the top of the Big Salmon Complex stratigraphy as they include the 325 Ma dacite layers. A lower quartz and feldspar-rich metaclastic unit that is lithologically similar, but not identical to some metaclastics of the upper unit, apparently underlies the greenstone unit upstream of the Big Bend (104O/12 south). Immediately to the north, a basalt-gabbro-ultramafite succession occurs within the greenstone near Teh Creek, where rock units belonging to the “Klinkit assemblage” are well exposed. Layered and intrusive units not previously described by Mihalynuk *et al.* (1998) are described here, beginning with the oldest layered rocks.

Lower Quartz and Feldspar-Rich Metaclastic Unit

In southern 104O/12, a > 350 m thick (structural) succession dominated by quartz-rich and lesser quartz-feldspar-rich metaclastic rocks lies structurally below the greenstone unit. In order of abundance, the rock types are: muscovite-quartz schist; biotite-muscovite±garnet quartz schist; muscovite-quartz±chlorite±feldspar schist, and biotite-chlorite-feldspar-quartz-schist. Feldspathic schists may be strongly deformed granitoid bodies, but the gradual appearance of feldspar down section from the greenstone argues for a sedimentary source. Sinistral shear bands are well developed in the feldspathic schist; about 2.5 kilometres north of the presumed trace of the Teslin fault (Figure 3).

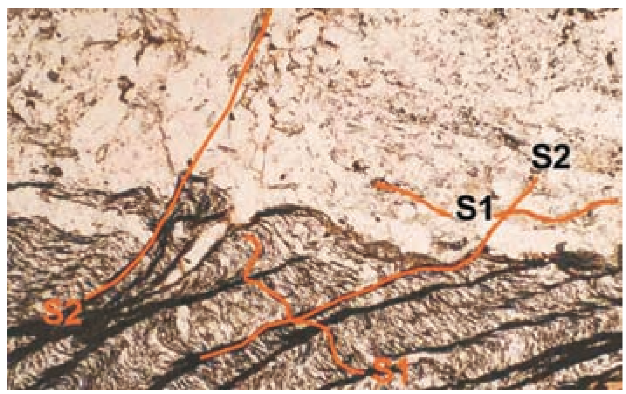

Photo 2. Photomicrograph of stretched quartzite pebble conglomerate of the dirty clastic succession shows that the phyllitic fabric displayed by argillaceous clasts (S1) continues into the adjacent quartzite clasts. A second fabric (crenulation cleavage, S2) is also printed on both phyllite clasts and quartz clasts. Such fabric development demonstrates that the conglomerate was deposited prior to at least two phases of deformation, and that the phyllite clasts need not have been derived from a previously deformed and metamorphosed terrain. Width of the photomicrograph represents 4 mm.

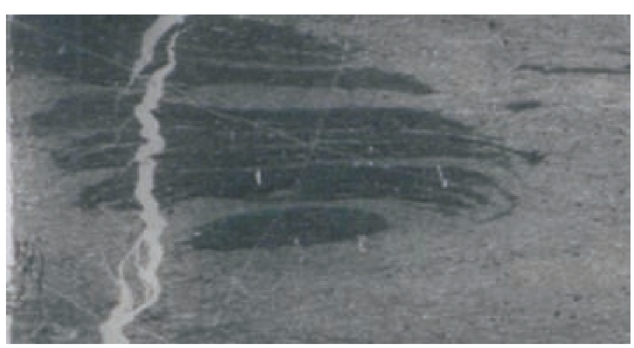

Photo 3. Sheath fold in turbiditic siltstones of the “dirty clastics” unit from within 5 metres of the greenstone contact (8x magnification).

Ultramafite-Gabbro-Basalt-Porphyry

A north to south succession of ultramafite (70-600m), gabbro (150-700m) and basalt (>20-2000m) can be traced for about 13 kilometres (Figures 3 and 4, all thicknesses are structural). It extends from the eastern limit of the map area, the Butsih Creek valley, and extends west almost to Bareface Mountain (informal, on Figure 3) where serpentinite was previously recognized by Gabrielse (1969). Farther west, the serpentinite disappears and the gabbro-basalt complex merges with the Big Salmon Complex greenstone unit. Greenstone with gabbro intervals is well exposed on both the long south ridge and the southwest flank of Bareface Mountain. At the eastern end of the belt, exposures are lost beneath glacial cover of the Butsih Creek valley. The easternmost 2 kilometres of serpentinite outcrops are bordered to the north by distinctive, coarsely porphyritic andesitic volcanic and hypabyssal rocks. All contacts of the ultramafite are faulted; they are either intrusive contacts that have been structurally modified, or original tectonic contacts.

Ultramafite exposures are typically orange, waxy yellow or dark green-black on both weathered and fresh surfaces. They are dominantly strongly foliated serpentinite, but lozenges of less foliated lherzolite are common on "1865m peak" (Figure 3) where the unit is thickest and best exposed. Where first encountered, the lherzolite was described as a wherlite, but geochemical anlaysis shows the rock to be too Mg-rich to support an abundance of clinopyroxene, so the pyroxenes are probably deformed hypersthene. At a locality 1.8 km west of the peak, coarsely crystalline lherzolite cumulate is preserved as a septa bounded to the north and south by gabbro. Exposures are not sufficient to determine whether this relationship is due to structural interleaving or is a relict of an originally intrusive contact. A series of outcrops on the north side of Teh Creek valley displays trains of serpentinized pyroxenes that may be a relict mantle tectonite fabric, but a pervasive late foliation renders this interpretation tenuous. (Harzburgite tectonite erratics are common along the belt. When first encountered, the erratics were suspected to be of local derivation. However, they occur throughout the map area and beyond, and are evidence of a once extensive, preglacial ophiolite terrain.)

The gabbro and basalt comprise an intrusive complex. Gabbro is cut by basalt and basalt is cut by gabbro. At the northern margin of the complex, gabbro predominates and at the southern margin, basalt predominates. Gabbro is white to green on fresh or weathered surfaces, although it can also be ruddy weathering. It is medium to very coarse-grained; locally it is pegmatitic. Plagioclase, pyroxene, and hornblende are epidote- and chlorite-altered and comprise more than 90% of the rock. Pyroxene is probably largely altered to hornblende, but this is not yet confirmed by petrographic analysis. Contacts with the ultramafite are best exposed within 0.5km of "1865 Peak" where they are clearly tectonic. Gabbro grain size is cataclastically reduced from greater than 1 cm to less than 0.01 cm over a width of 4 metres at the ultramafite contact. Shallowly-plunging mineral lineations suggest transcurrent motion, in support of map-scale sinistral shear bands; however, these lineations are folded and macroscopic kinematic indicators are inconsistent or equivocal.

The basalt is dark green weathering, aphanitic or microporphyritic. Flat chlorite disks up to 1 cm across are probably relict amygdales. They may comprise as much as 3% of the rock and are best displayed at one outcrop on the southern flank of "1865 Peak", where they are concentrated in concentric zones in what appear to be stretched pillows (Photo 4).

Basalt outcrops are lost beneath thick colluvial and glacial deposits in the valley south of "1865 Peak". Green-weathering basalt and andesite lapilli tuff dominate the next ridge to the south. They are extensively epidote-chlorite altered, foliated, and plagioclase-phyritic, with locally preserved pyroxene and hornblende phenocrysts. Less abundant, strongly planar beds of dust tuff or tuffite are conspicuous because of alternating, centimetre-thick, lime yellow and dark green bands. Pillowed and subaqueous sheet flows are also locally preserved. Similar units occur within the Big Salmon Complex greenstone unit along strike to the west (Figure 3), where they show higher degrees of strain.

Photo 4. Stretched pillows(?) within the basalt-gabbro-ultramafite complex. If these are pillows, then part of the complex was deposited in a submarine environment.

Coarsely Porphyritic Andesite

A package of distinctive, coarsely porphyritic, green-weathering, volcanic and hypabyssal andesitic rocks underlie most of the northern spur of “1865 Peak” where they are structurally admixed with serpentinite along their southern contact. They are separated from tuffite-dominated succession of “lower Klinkit assemblage” north of the spur by a colluviated valley. A stream occupies the valley bottom 1.6 km to the east where outcrops of dark green, fine-grained tuff are washed clean. In places, the tuff appears autoclastic. Broad zones, tens of metres across, are plagioclase-porphyritic, and in one 20 cm wide zone, flattened pyroxene crystals up to 4 mm across (average 2-3 mm) are preserved. Near the serpentinite, the unit is megaporphyritic. Plagioclases up to 4 cm long are strongly zoned, possibly to K-feldspar. Blocky black hornblendes range up to 2.5 cm long. Both feldspar and hornblende megacrysts are aligned down dip in a green, fine-grained foliated matrix (305°→65° to vertical). Some broken phenocrysts display an asymmetry that suggests north-side-up reverse motion, but most show ambiguous shear sense.

These tuffs could have provided the source for epiclastic deposits in the “lower Klinkit assemblage”, although such a contention cannot be proven at this time. Granodioritic intrusives hornfels both porphyritic tuffs and epiclastics and chalcopyrite (<0.25%) is widely disseminated in the porphyritic tuffs.

Klinkit Assemblage

Rocks of the “Klinkit Assemblage” (Stevens and Harms, 1996) crop out in the eastern portions of the map area (104O/12E, 13NE, 14W; Figure 3). Harms mapped much of the “Klinkit assemblage” near Teh Creek (104O/12E, Figure 3; Harms, written communication, 1999) and established a useful subdivision which aided our 1999 mapping in the area. In 104O/13NE and 14W the “Klinkit assemblage” includes a lower unit equivalent to the “dirty clastics” and higher (?) units described by Gleeson *et al.* (2000, this volume; not described here). The fossiliferous Screw Creek limestone apparently sits near the top of the “Klinkit assemblage”, although existing age data suggest protracted limestone deposition. Observations from the Teh Creek succession and Screw Creek limestone are presented here, from oldest to youngest.

Tuffite (240 m)

Well-preserved graded planar beds 10 to 100 cm thick of fine-grained tuffiteare characteristic of this unit. Approximately 200 metres of rhythmic deposits consist mainly of sets that average 3 metres thick and grade upwards from massive hornblende-feldspar-phyric lapilli that form 2/3 of their thickness, through fine-grained, planar-bedded ash and into laminated dust tuff. Sets may be capped by cross-stratified volcanic siltstone. Fine-grained detrital hornblende and plagioclase are abundant enough in some layers to produce a felted texture. In some cases, fine mafic grains are equant and may originally have been pyroxene, now replaced by actinolite. Fresh, coarse augite porphyry was observed in talus. Some intervals are very fine grained and cherty, resembling pelagic deposits. They are interpreted as dust tuff layers and may preserve ball and pillow structures. Sparse decimetre-scale calcareous layers are accentuated in thermal aureoles of thick sills and stocks by the development of light-coloured calc-silicates (grossular, diopside, epidote and quartz). One gossanous laminated white calcsilicate is, at a minimum, 6 metres thick.

Exceptionally well-preserved bedding and fine depositional features including cross-stratification, graded bedding, various water escape features, and scours permit assessment of facing directions. The succession is right way up and deformed by upright open to close folds in which foliation is only weakly developed, except for the fold core regions in which protolith textures are in part obliterated. Rhythmic deposits resemble thick turbidites, possibly ABC Bouma sequences; however, the predominance of reverse grading in planar-bedded ash layers suggests water lain tuffs that have not been reworked.

This unit has yielded neither fossil nor isotopic ages from within the map area. Similar tuffite in the Teslin sheet (Gordey, 2000) contain minor interbedded limestones with Middle Mississippian (Viséan) conodonts (M.J. Orchard *in* Poulton *et al*., 1999; *see* Figure 2 in Nelson *et al.*, 2000, this volume). However, the reliability of this distant extrapolation is questionable.

Near both the eastern and western limits of the tuffite displays apparent stratigraphic contacts with overlying conglomerate of the transitional unit.

Transitional Unit(s)

The transitional unit is so named because it marks a distinct change from volcanic to carbonaceous and quartz-rich clastic sedimentation. Two units define this transition: a light grey tuff/tuffite, and a conglomerate with quartz-rich clasts.

A complete section of grey, fine lapilli and coarse ash tuff and tuffite has not been observed. It is probably about 40 metres thick and is partly interbedded with the conglomerate unit. Some tuffaceous layers appear felsic, due to their siliceous nature, however, no quartz phenocrysts have been observed. Tuff is probably subordinate to grey or purple-brown phyllitic siltstone, which in places resembles microdiorite due to thermal alteration and growth of fine biotite. Siltstone is generally very well bedded on millimetre to centimetre scales, and may display cross laminae, but clear way-up indicators are rare, and these show that the unit is isoclinally folded. High strain zones are common and their orientation with respect to strongly transposed bedding indicates that they are axial-parallel and focused at fold hinges. In contrast, later, near-vertical mylonitic zones cut across folded limbs.

Granules to cobbles of quartzite, quartz-rich phyllite and possibly recrystallized chert are the principal components of the conspicuous conglomerate unit (Photo 5) that marks the transitional unit north of "Nasty Peak" (informal, Figure 3). Conglomerate matrix material varies from light grey-green phyllite to grit. Clasts are typically slightly stretched. Structural complexity makes thickness estimates difficult, but it is at least 5 m thick, and probably attains thicknesses of 30 m.

Highly strained, probable equivalents occur 4 km east of Bareface Mountain and on the southern ridge of the mountain. Quartz cobbles are flattened to sub-millimetre thicknesses (Photo 6), but low strain zones show good preservation of grey ash tuff interbeds.

Black Argillite-Quartzite

Rusty, pyritic and locally graphitic black argillite and thinly interbedded siltstone is the most abundant lithology within the black argillite-quartzite unit. Centimetre to decimetre thick beds of vitreous black sandstone are, however, characteristic, and at least one conspicuous, 4-8 m thick layer of tan, carbonate matrix-supported quartz grit occurs near the top(?) of the unit. Total thickness of the unit is difficult to assess due to the affects of at least one phase of isoclinal folding overprinted by upright folds. It is probably in excess of 200 m thick with structural thicknesses of more than a kilometre.

Screw Creek Limestone

One of the most complete sections through the fossiliferous Screw Creek limestone in British Columbia is east of Screw Creek, near the border with Yukon (104O/14W; Figure 3). Along this transect the structurally lowest outcrops are decimetre thick limestone beds with planar, centimetre-thick cherty maroon and green layers, probably silicified tuffs. Facing indicators in these brightly coloured layers are not well preserved, but truncated layering gives the impression that the units are right way up. The next highest unit is calcareous sharpstone conglomerate which are clearly upside-down based on well-developed channel scours and lags (Photo 7a). Intraclasts predominate; they appear to have been derived from the cherty tuff layers. Overlying coralline boundstone is also upside-down as indicated by corals in growth position (Photo 7b). At yet higher elevations a west-closing recumbent fold hinge is traversed and the sharpstone conglomerate is repeated. A third repetition of the sharpstone conglomerate is succeeded by highly fossiliferous limestone indicating a return to inverted stratigraphy. Highest limestone exposures enclose a 2-5 metre thick tuffaceous interval containing 2 – 10 cm thick planar bedded white tuff layers interlayered near the top of the succession with decimetre thick carbonate. These lithologies are joined by black siltstone beds several centimetres thick. The highest carbonate layers contain black phyllitic clasts. Carbonate content diminishes abruptly over several metres until well-bedded black and brown siltstone and feldspathic sandstone predominate.

Photo 5. Conglomerate of the "transitional unit" of the "Klinkit assemblage".

Photo 6. Strongly flattened quartz clast conglomerate, probably the "transitional unit".

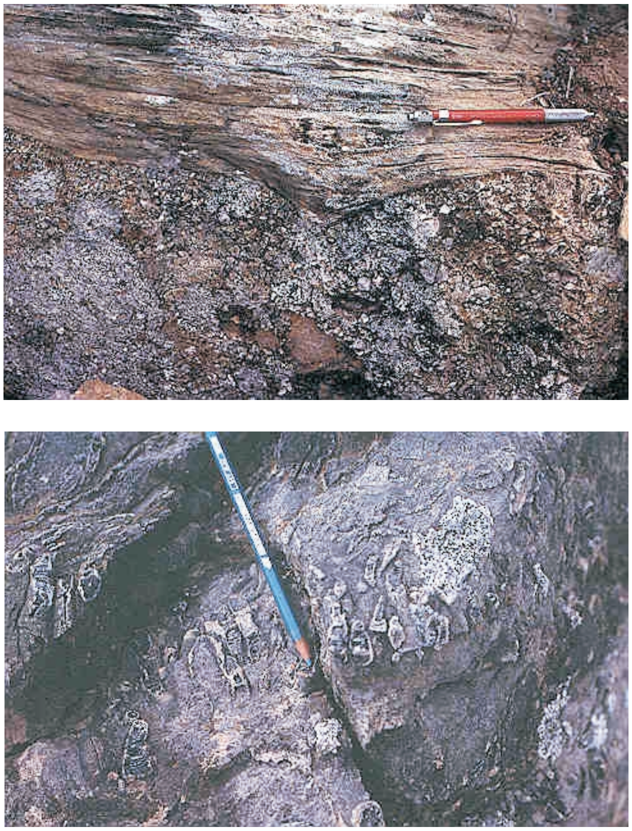

Photo 7. Screw Creek limestone: (a) cross stratified overturned sharpstone conglomerate with clasts cannibalized from lower beds, and (b) rugosan boundstone with fossils preserved in overtuned growth position. Both photos are taken on the overturned limb of a regional recumbent fold.

This latter lithology apparently belongs to the "Swift River assemblage" (*see* Nelson *et al.*, 2000). If this is true, then the contact between the lowest Screw Creek limestone ("Klinkit assemblage") and "Swift River assemblage", is gradational.

GEOCHRONOLOGY

Critical age data from two units are presented here. A sample of Hazel orthogneiss was collected near a repeater tower on the south flank of Mount Hazel (located on Figure 3). Hazel orthogneiss occurs within the greenstone unit, which it apparently cuts, thereby providing a minimum age on the greenstone which underlies more than half of the map area.

A second data set is reported for a sample of intermediate to dacitic tuff that is interbedded with limestone on the north flank of Mount Francis (*see* Figure 3). It is believed to occupy one of the highest stratigraphic positions within the Big Salmon Complex (Figure 4).

Mount Hazel Orthogneiss

A sample of a massive to weakly deformed, granite from the Mt. Hazel orthogneiss yielded a modest quantity of cloudy, metamict, to less commonly clear, pale pink prismatic zircon. Eight fractions of the clearest and coarsest grains available all gave discordant results (2-10% discordant), with ellipses aligned in a linear fashion (Figure 5, Table 1). An upper intercept of $362.3^{+7.9}/_{-6.8}$ Ma (eight-point Davis regression) is interpreted as the best estimate for the igneous age of the Mt. Hazel pluton. A well-defined lower intercept of $189^{+16}/_{-17}$ Ma may correspond with the time of Pb loss. Lead loss may be due to a late deformational event which produces a strong fabric in the *circa* 196 Ma Coconino tonalite (Mihalynuk, *et al.*, 1998), whereas the *circa* 185 Ma Simpson Peak batholith (recalculated from Wanless *et al.*, 1970) is mostly undeformed.

Mount Francis Dacitic Tuff

This foliated metadacite yielded a moderate amount of cloudy to rarely clear, pale pink prismatic zircon. Seven strongly abraded fractions of the clearest grains available were analysed (Figure 6, Table 1). All of these likely show the effects of Pb loss, despite the strong abrasion. Four fractions (A, F, G and H) are discordant, and are inferred to contain significant inheritance; they give 207Pb/206Pb ages of ca. 546-1235 Ma. Fractions B and C give $^{207}Pb/^{206}Pb$ ages of about 325 Ma. The weighted average $^{207}Pb/^{206}Pb$ age for these two fractions, 325.1±3.0 Ma, provides the best estimate for the age of the rock. Slightly discordant fraction D is interpreted to contain minor inheritance. Another tuff bed from the same outcrop yields concordant fractions giving the same *circa* 325 Ma age.

PLUTONIC ROCKS

The Coconino tonalite, Simpson Peak batholith, Slaughterhouse quartz diorite, Two Ladder tonalite and Midshore granite bodies (Figure 3) were described previously by Mihalynuk *et al.* (1998). New observations in the Simpson Peak batholith show it to be compositionally and

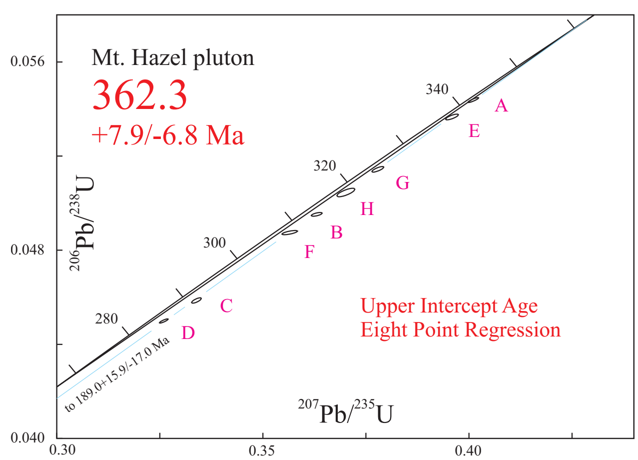

Figure 5. Concordia plot showing isotopic ratios with error estimates for four zircon (A to D) and two titanite (T1, T2) mineral fractions from the Mount Hazel orthogneiss.

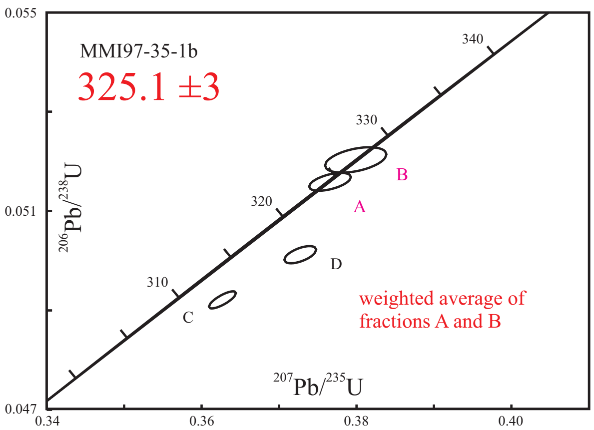

Figure 6. Concordia plot showing isotopic ratios with error estimates for zircon mineral fractions from tuff layers in limestone on the north flank of Mount Francis.

textürally variable, and the Midshore granite is now believed to be part of a syenitic intrusive suite. These observations, together with descriptions of plutons encountered during mapping in 1999, are reported here from presumed oldest to youngest:

Charlie Cole Pluton (EJCg)

A large body of strongly foliated light grey to white-weathering granite underlies Mount Charlie Cole (Gabrielse, 1969), and a few outcrops on its northern flank extend onto southwestern 104O/12 in the present map area. It consists of medium-grained quartz (30%) and plagioclase (30%), with K-Feldspar as phenocrysts (20%) and matrix (10%), and 15% smeared, chloritized mafics (biotite?). S-C fabrics are well developed for nearly a kilometre across strike. They indicate sinistral motion on C-planes (Photo 8), but the fabric appears folded in at least one locality where shear sense switches rapidly. Charlie Cole pluton is 4 kilometres south of the inferred trace of the Teslin Fault, which trends 300°. Ori-

TABLE 1
ISOTOPIC DATA FOR TWO SAMPLES OF THE BIG SALMON COMPLEX

Fraction[1]	Wt (mg)	U[2] (ppm)	Pb*[3] (ppm)	$^{206}Pb/^{204}Pb$[4]	Pb[5] (pg)	^{208}Pb[6] (%)	Isotopic ratios (1σ,%)[7] $^{206}Pb/^{238}U$	$^{207}Pb/^{235}U$	$^{207}Pb/^{206}Pb$	Apparent ages (2σ,Ma)[7] $^{206}Pb/^{238}U$	$^{207}Pb/^{206}Pb$
Mt. Francis Dacite, MMI97-35-1a: 325.1±3.0 Ma											
A c,N2,p,b	0.067	450	29	11032	10	13.2	0.06041 (0.09)	0.5265 (0.15)	0.06321 (0.08)	378.1 (0.7)	715.2 (3.5)
B m,N2,p,b	0.036	361	16	3496	10	13.6	0.04333 (0.10)	0.3163 (0.18)	0.05294 (0.10)	273.5 (0.5)	326.0 (4.5)
C f,N2,p	0.038	493	26	9843	6	14.5	0.05042 (0.14)	0.3677 (0.19)	0.05290 (0.09)	317.1 (0.8)	324.3 (4.1)
D ff,N2,p	0.010	592	33	5489	4	15.9	0.05248 (0.10)	0.3849 (0.17)	0.05320 (0.11)	329.7 (0.6)	337.4 (4.9)
F m,N2,p	0.007	493	30	2902	4	14.0	0.05577 (0.11)	0.0627 (0.18)	0.08156 (0.11)	349.8 (0.8)	1234.9 (4.4)
G f,N2,p	0.007	470	18	2041	4	10.7	0.03776 (0.14)	0.3042 (0.23)	0.05843 (0.17)	269.7 (1.1)	546.0 (7.3)
H f,N2,p	0.009	490	25	3579	4	13.2	0.04869 (0.15)	0.4661 (0.22)	0.06943 (0.13)	306.5 (0.9)	911.5 (5.4)
Mt. Hazel Pluton, MMI97-29-1: 362.3+7.9/-6.8 Ma											
A m,N2,p	0.037	349	20	7988	6	13.3	0.05438 (0.10)	0.4010 (0.16)	0.05349 (0.09)	349.5 (3.9)	349.5 (3.9)
B m,N2,p	0.025	413	21	1039	32	13.5	0.04952 (0.08)	0.3631 (0.18)	0.05317 (0.14)	336.0 (6.5)	336.0 (6.5)
C f,N2,p	0.016	534	25	6861	4	11.2	0.04586 (0.12)	0.3339 (0.18)	0.05280 (0.12)	320.1 (5.2)	320.1 (5.2)
D m,N2,p,b	0.032	719	33	8566	8	12.4	0.04499 (0.10)	0.3260 (0.16)	0.05254 (0.09)	309.1 (4.0)	309.1 (4.0)
E m,N5,p,s	0.013	599	35	4269	6	16.4	0.05366 (0.11)	0.3959 (0.20)	0.05350 (0.13)	350.2 (5.9)	350.2 (5.9)
F m,N5,p,e	0.014	240	12	1870	6	13.0	0.04875 (0.09)	0.3565 (0.26)	0.05304 (0.21)	330.5 (9.6)	330.5 (9.6)
G m,N5,p,e	0.010	489	27	4429	4	15.1	0.05144 (0.12)	0.3779 (0.19)	0.05328 (0.12)	340.8 (5.5)	340.8 (5.5)
H f,N5,p,b	0.010	560	31	2391	7	16.5	0.05045 (0.18)	0.3701 (0.29)	0.05321 (0.20)	317.3 (1.1)	337.7 (8.9)

[1] Upper case letter = zircon fraction identifier. All zircon fractions air abraded; Grain size, intermediate dimension: c=>134μm, m=<134μm and >104μm, f=<104μm and >74μm, ff <74μm;
Magnetic codes:All zircons are nonmagnetic on Franz magnetic separator at field strength of 1.8-2.0A and a sideslope of 5°. Front slope for all fractions=20°; Grain character codes: e=elongate, p=prismatic, s=stubby.

[2] U blank correction of 1pg ± 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 0.0035/amu ± 20% (Daly collector) and 0.0012/amu ± 7% and laboratory blank Pb of 1-3pg ± 20%. Laboratory blank Pb concentrations and isotopic compositions based on total procedural blanks analy

[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 $^{207}Pb/^{206}Pb$ age of the fraction.

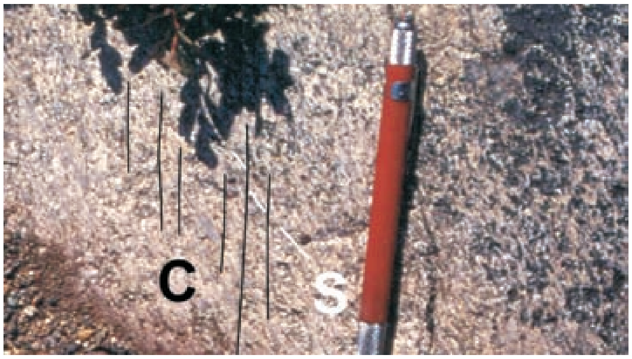

Photo 8. S-C fabrics are well displayed in outcrops on the north flank of Mount Charlie Cole about 4 kilometres south of the Teslin Fault.

entation of most of the C-planes is 185° to 020° such that their development cannot be attributed to simple kinematic linkage with the Teslin Fault. Because of apparent late folding of the S-C fabrics, their use in constraining any regional structural interpretation would be suspect. However, a sample collected for isotopic age dating should provide a maximum age for this fabric.

Simpson Peak Batholith (EJSg1, 2, 3, EJSgd)

Four lithologies comprise the Simpson Peak batholith. These are described from oldest to youngest based on field relationships:

Hornblende>biotite granite (EJSg1) with flattened pink K-feldspar megacrysts is well foliated, but poorly lineated. This unit was sampled at two localities and vantage point mapping suggests that rocks with similar weathering characteristics crop out in a gently northwest tapering wedge of pluton in northeastern 104O/12.

Medium-grained grey to tan granite (EJSg2) contains white to pink intergrowths of plagioclase and K-feldspar (60%), fresh biotite (10%, or up to 5% chloritized) and coarse smoky quartz (30%). It is blocky weathering with distinctive low angle jointing, and weathers to abundant grus. Joint surfaces may be chlorite coated. Foliation is weak to absent. It is the most abundant unit in the batholith.

Biotite porphyry dominates a gently northwest-dipping tabular complex about 240 metres thick (EJSg3). It is medium-grained,with subequant feldspar and grey quartz phenocrysts and medium to fine-grained rusty biotite, in a tan to flesh coloured, non-foliated, sucrosic siliceous matrix. Numerous 0.5 to 3 metre thick quartz dioritic sills cut the complex, giving it a strongly jointed appearance from a distance. The complex clearly cuts foliated K-feldspar megacrystic granite as do irregular fleshy pink aplitic dikelets interpreted as coeval.

Weakly to non-foliated quartz-diorite to granodiorite (EJSgd) forms medium-grained tabular zones within the batholith, and occurs as fine to medium-grained dikes that cut the sill complex porphyry.

Teh Creek Pluton (KGg)

White hornblende < biotite granodiorite, granite and lesser grey quartz diorite comprise this elongate, west northwest-trending body that stretches across mapsheet 104O/12. Mafics, including about 1% yellow-brown sphene, comprise about 16% of the rock. Slightly porphyritic K-feldspar comprises 10% (to 30% including matrix), plagioclase ~25% and xenomorphic quartz about 30% of the rock.

Originally mapped as belonging to three separate suites, including parts of the Klinkit and Simpson Peak batholiths (Gabrielse, 1969), the Teh Creek pluton is most likely an extension of the Klinkit batholith, a satellite of which is mapped east of upper Butsih Creek (just east of 104O/12). Although, the Klinkit batholith is described as foliated (Gabrielse, 1969), no planar fabric is developed within the map area. Thus, the Teh Creek pluton is treated separately. It appears to have intruded by stoping of blocks controlled by two sets of joints; north and west-northwest sets, resulting in pluton margins that are demarked by sets of orthogonal dikes (*see* headwaters of Teh Creek, Figure 3).

Early Eocene Syenite (EEsy)

Pink, varitextured, unfoliated syenite occurs as two elongate, high-level plutons east of Teslin Lake. The southern body gives way on its southern margin to a sill complex. Xenoliths of complexly folded Big Salmon Complex are common. Textures range from fine-grained, felted intergrowth of feldspar and amphibole in which feldspar phenocrysts may range from a sparse to dominant component. Feldspars are up to 3 centimetres across and are typically zoned; they have white calcic? cores and pink potassic rims. The northern pluton was called the Midshore granite by Mihalynuk *et al.* (1998). A compositionally distinctive zone at its northern end is composed of 75% coarse, zoned feldspar and is pink with tan weathering. Amphiboles are typically acicular. The southern syenite body is reported to contain the sodic pyroxene aegerine (Aitken, 1959). U-Pb isotopic analysis of zircons extracted from the Midshore granite indicate an Early Eocene age (unpublished). A sample collected from the southern body should confirm correlation with the dated pluton to the north.

New Occurrences and Mineral Potential

Several new mineralized zones were discovered during the course of mapping in 1999. They are either intrusion-related gold veins or stratabound copper-rich lenses in crinkle chert. The most prospective examples are reported below together with analytical results where available (analyzed by Instrumental Neutron Activation and Inductively Coupled Plasma Emission Spectroscopy (note that ICP digestion is by aqua regia which is incomplete for most elements); *see* also Table 2). One pyritic sericite schist is geochemically unremarkable, but it is extensive and is included below.

Assay Data from Three Mineralized Zones

West Teslin Lake border area. Along west shore of northern Teslin Lake, 6 km south of the Yukon border (just west of the map area, "1" on Figure 3), a set of moderately to steeply west to northwest dipping brittle shears, spaced about 5-10 metres apart within an Eocene granitoid body, show evidence of west-side-up movement. They are invaded by quartz veins and rusty, pyritic mineralization with rare malachite staining and variably developed alteration envelopes. One 2-3 cm thick vein with a somewhat wider than average 20 centimetre alteration envelope was chip sampled for 2.5 metres along the vein. It returned values of 1320 ppb Au, 0.4% As, and 194 ppm Sb (MMI99-22-3; Table 2; location 1 on Figure 3).

Copper in the Crinkle Chert. Numerous occurrences of minor sulphide mineralization and copper staining were encountered in the crinkle chert unit, further indication of the high mineral content of this unit as previously established by mapping in 1997. Most significantly, a chlorite-porphyroblastic, 6 metre by 0.5 metre lens with disseminated chalcopyrite returned 0.9% Cu; 0.3g Au, 2.9g Ag, 6.8% Fe, and 0.17% Ba from a chip sample across its width (MMI99-27-19, Table 2; location 2, Figure 3).

Jennings River "knee". Pyrite-rich sericite schist crops out at many localities within the map area. Most extensive are those at locality "3" on Figure 3, near the Jennings River "knee". Here it is well developed within a regional quartz-phyric horizon of probable dacite composition. Old claim posts indicate that the mineralization was known previously, but the claims were apparently never registered. The one sample analyzed did not return anomalous metal values (99JN-27-1C, Table 2). Despite scant exposures, the felsic host unit is intermittently exposed for at least 16 km (Location 3 on Figure 3). If it is indeed continuous, it could represent a significant mineralizing system that warrants further work.

DISCUSSION

In southern Yukon and British Columbia, the Big Salmon Complex can be reliably mapped on the basis of the stratigraphy presented herein. In British Columbia, it is possible to walk Big Salmon Complex greenstone from transitional greenschist-amphibolite facies near the core of the Big Salmon Complex, either southeast or northwest into greenschist-grade rocks that display good protolith textures. Stevens and Harms (1996) include the former, relatively high grade rocks with the "Hazel Assemblage", and the latter, lower grade rocks with the "Klinkit assemblage". This raises two questions: what is the usefulness of the term Big Salmon "complex" given that a coherent stratigraphy is present?, and what is the utility of this assemblage given that it is possible to trace units (like the greenstone) from higher grade "Hazel assemblage" to lower grade "Klinkit Assemblage".

Is Big Salmon Complex a Complex?

Use of the term "complex" is recommended in the North American Stratigraphic Code "…where the mapping of each separate lithic component is impractical at ordinary mapping scales. "Complex" is unranked but commonly comparable to suite or supersuite, therefore, the term may be retained if subsequent, detailed mapping distinguishes some or all of the component lithodemes or lithostratigraphic units." (NACSN, 1983, page 861). Clearly, resolution of regionally mappable units within the Big Salmon Complex does not in itself justify abandonment of the name. Future work may demonstrate justification, but in the interim, we have elected to retain the original name of "Big Salmon Complex" rather than adopt the nomenclature of Stevens and Harms (1996). Dual nomenclature is confusing and prone to misleading interpretation especially when the assemblages are implicitly fault-bounded with distinct stratigraphies and structural and metamorphic characteristics (*see* definitions of Stevens and Harms, 1996). Rigorous unit definitions together with reference sections or type localities need to be established in order to address this problem.

Big Salmon Complex-"Klinkit Assemblage" Relationships

Gabrielse (1969) showed the Big Salmon Complex as bounded to the northeast by a belt of Mississippian "Sylvester Group", including massive greenstone, chert, agglomerate and metadiorite which he designated as "unit 7"; and he showed Big Salmon Complex bounded to the southeast by the Simpson Peak batholith and other plutons in the Jennings River area. However, it is now clear that to the northeast, some "unit 7" rocks north of the Alaska Highway belong to the Big Salmon Complex. To the southeast, marker units can be traced to the "Big Bend" of the Jennings River (Figure 3, location 18), and the enclosing strata probably extend an additional 20 kilometres farther east southeast where they apparently merge with the "Klinkit assemblage" of Stevens and Harms (1996). These authors included both "unit 7" as well as the presumably younger "unit 12" chert, argillite, limestone and conglomerate of Gabrielse (1969) and units Mv and Ml of Gordey and Stevens (1994) in their informal "Klinkit assemblage". The age of the "Klinkit assemblage" is constrained by Middle Mississippian (Viséan) conodonts from limestone layers in the volcanic division (unit "Mv" of Gordey, 2000; fossil age compiled by M.J. Orchard in Poulton *et al*., 1999), by Triassic conodonts in the dark clastic division (M. Orchard *in* Harms and Stevens, 1996), and especially by the fossiliferous Screw Creek formation limestone (informal; Poole, 1956) which contains Early to Middle Carboniferous macrofossils (Abbott, 1981), early Pennsylvanian fusulinids (Gabrielse, 1969), and is structurally underlain by thin limestone layers with conodonts of Middle Penn-

TABLE 2
ANALYTICAL RESULTS FROM MINERALIZED ZONES

			Element	Au	Mo	Cu	Pb	Zn	Ag	Co	Fe	Fe	As	As
			Units	ppb	ppm	ppm	ppm	ppm	ppm	ppm	%	%	ppm	ppm
			Method[1]	INA	AICP	AICP	AICP	AICP	AICP	AICP	AICP	INA	AICP	INA
			Lab.[2]	ACT	ACM	ACM	ACM	ACM	ACM	ACM	ACM	ACT	ACM	ACT
			Dect'n Limit	2	1	1	3	1	0.3	1	0.01	0.02	2	0.5
Field No.	Mapsheet	Northing	Easting											
99JN-27-1C	104N/9E	6613006	667397	18	7	32	157	4	0.3	1	1.6	1.7	3	3.5
MMI99-22-3	104N/16	6648136	645330	1320	4	42	< 3	17	0.7	3	1.88	2.01	4420	4290
MMI99-27-19	104O/13E	6646808	349969	311	1	8786	14	155	2.9	24	6.83	8.42	< 2	4.5

			Element	Sb	Sb	Bi	V	P	Mn*	Al	Na	K	Ba	Ba
			Units	ppm	ppm	ppm	ppm	%	ppm	%	%	%	ppm	ppm
			Method[1]	AICP	INA	AICP	AICP	AICP	AICP	AICP	AICP	AICP	INA	AICP
			Lab.[2]	ACM	ACT	ACM	ACM	ACM	ACM	ACM	ACM	ACM	ACT	ACM
			Dect'n Limit	2	0.1	2	1	0	2	0.01	0.01	0.01	50	1
Field No.	Mapsheet	Northing	Easting											
99JN-27-1C	104N/9E	6613006	667397	< 3	0.2	< 3	27	0.023	183	0.57	0.11	0.33	580	88
MMI99-22-3	104N/16	6648136	645330	145	194	8	12	0.038	351	0.95	0.07	0.28	820	94
MMI99-27-19	104O/13E	6646808	349969	< 3	1.6	10	104	0.066	2044	3.99	0.07	0.27	3400	1731

1 Methods: AICP = Inductively coupled plasma, Aqua regia digestion; INA = Instrumental neutron activation

2 Lab.: ACM = Acme Analytical Laboratories Ltd., Vancouver; ACT = Activation Laboratories Ltd., Ancaster, Ontario

sylvanian age (Abbott, 1981). Stevens and Harms (1996) suggest that carbonate units within the "Klinkit assemblage" contain conodonts as young as Early Permian. However, at least part of "unit 12" of Gabrielse (1969) that Stevens and Harms (1996) included in the "Klinkit assemblage" must be older than the Screw Creek limestone based on the findings of Gleeson *et al.* (2000, this volume) who mapped four ridges underlying the northeastern limits of "unit 12". They report U-Pb isotopic age results that constrain the age of the clastics to between Earliest Mississippian and Silurian, much older than previously expected, and much older than any lithologically comparable units in the "Klinkit Assemblage". Such fundamental departures from recent stratigraphic interpretation show that our understanding of the Big Salmon Complex is not yet mature and that detailed tectonic syntheses involving the eastern Big Salmon Complex must be considered speculative.

Effects of Structural Complexity

Direct age comparisons are made difficult by isoclinal, mountain scale, south and southwest-verging folds and parasitic folds that exert a fundamental control on the distribution of different units. For example, the new isotopic ages reported here together with structural observations show that substantial parts of the stratigraphy are inverted by large-scale nappes, but even so, some age conflicts cannot be reconciled. Distribution of units is further complicated by both older and younger folding.

Recognition of intense, regional strain partitioning (in part related to nappes) shows that correlations cannot be reliably based on degree of strain, although local differences in metamorphic history may warrant division of units into separate assemblages. An early, nearly layer-parallel fabric is folded by the large scale folds and is commonly overprinted by a second or third schistosity imparted during subsequent deformational events.

A mid-Mississippian deformational event is well documented to the north in the Glenlyon area (M. Colpron *in* Nelson *et al.*, 2000) and in the Finlayson area (Murphy and Piercey, 1999; although it could be slightly older). This same event might have affected the Jennings River area, but the age is less tightly constrained. It is represented by deformational discordance above and below a conglomerate within the regional carbonate unit. A dike cuts folded strata that predate the conglomerate, thus providing an upper constraint on the age of deformation ~335 Ma (unpublished). The conglomerate is interpreted as a post-deformational basal facies. A maximum age limit for early deformation in the area is provided by the 354 Ma Logjam pluton (Gleeson *et al.*, 2000, this volume). This deformation may correspond to a regional collisional event during which blueschist and eclogite facies rocks were emplaced within the Yukon-Tanana Terrane *circa* 346 Ma (Erdmer *et al.*, 1998). As suggested by Murphy and Piercey (1999), this deformational pulse may prove to be a useful feature for regional correlations.

Broader map coverage and new kinematic data show that the deformational history culminated in an important north-south compressional event that affects the southern margin of the Simpson Peak batholith, although this event is not everywhere in evidence. New discovery of superb exposures of the Teslin fault along Jennings River reveal a broad zone of mylonite with sinistral kinematics, overprinted by quasi-ductile dextral fabrics (de Keijzer *et al.*, 2000), but the age and duration of these kinematic events and how they relate to deformational events in the adjacent rocks are unknown.

Stratigraphy Inverted, or Not?

The revised stratigraphy here relies heavily on the intrusive relationship of Hazel orthogneiss into greenstone, providing a minimum age of 362 Ma for the greenstone and underlying rocks. However, the contact relationship between the main body of the Hazel orthogneiss and greenstone has not been unequivocally established. Outcrop patterns support such an interpretation as do thin apophyses of orthogneiss within greenstone, but such apophyses have not been traced back to the main body of Hazel orthogneiss. No such apophysies have been recognized in presumably younger units. Neither are presumably younger units cut by the main body, even though the outcrop pattern on Figure 3 would seem to show this for both the crinkle chert and carbonate units. At three localities, the margin of the Hazel body follows and does not cross-cut crinkle chert (at Mount Hazel, and near localities 2 and 7 on Figure 3), or carbonate (north of locality 12). Where outcrop control is best, from Mount Hazel to the BC-Yukon border, the crinkle chert apparently occurs within a synformal keel immediately northeast of the Hazel orthogneiss. At Mount Hazel a septa of strongly foliated felsic, muscovite- and magnetite porphyroblast-rich tuff (?) or intrusive border phase (not shown on Figure 3) separates the chert from less deformed Hazel pluton.

Syndepositional Faulting?

The "dirty clastics" unit and crinkle chert unit are both observed to record the same deformational events and both rest depositionally atop greenstone. They rest on no other units. Crinkle chert is clearly overlain by limestone and a succession of other lithologies. In contrast, the "dirty clastics" unit is not overlain by other units west of Two Ladder Creek. If the "slate, chert, argillite, conglomerate" unit of the "Klinkit assemblage" that extends eastward from Two Ladder Creek (where it was originally included with the "dirty clastics" unit by Mihalynuk *et al.*, 1998 because of close lithologic similarity) is correlative with the "dirty clastics", then it is overlain by a "phyllite and minor limestone" unit and both are intruded by the 354 Ma Logjam intrusion (Gleeson *et al.*, 2000, this volume). Thus, the crinkle chert may have been deposited at the same time as the conglomeratic "dirty clastics", suggesting that the extents of these contrasting facies were controlled by syndepositional faults. Crinkle chert may have accumulated as mixed hydrothermal and biogenic sediment in a rift graben, protected from the influx of voluminous "dirty clastics". Similar synsedimentary faults are suggested to control mineralization controls at the Fyre Lake and Kudz Ze Kayah deposits (Murphy, personal communication, 1999). This rift event apparently marks a fundamental change in the continental arc in which the greenstone was deposited, because younger volcanic rocks in the Big Salmon Complex are much less voluminous.

An enigmatic basalt-gabbro-ultramafite succession between Teh and Butsih Creeks (southeastern 104O/12) is 2 kilometres thick and 13 kilometres long and enveloped by Big Salmon Complex greenstone. If it is an oceanic crustal fragment, the structure that emplaced it does not appear to extend west of Bareface Mountain, because greenstone crops out over extensive areas both north and south of where such a hypothetical structure should exist. Alternatively, it could have been emplaced during arc rifting and cessation of *circa* 362 Ma volcanism in the continental arc, which led to exhalative contributions and crinkle chert deposition. It does appear to sit near the top (termination?) of the greenstone succession. Alternatively, it may be a differentiated sill that pinches out to the west, in similar fashion to those believed to have been emplaced along syndepositional faults in the Finlayson area (Murphy and Piercy, 1999). In either case, such faults are important conduits for mineralizing fluids and the coincidence of 95th percentile regional geochemical results in this area (Cook and Pass, 2000, this volume) may reflect such a mineralizing system. Geochemical results aimed at this problem are pending.

SUMMARY

U-Pb isotope geochronological data is key to unraveling the stratigraphy and geological history of the Big Salmon Complex and adjacent terrains. Two new age dates are reported here. A 362 Ma age from the Hazel orthogneiss provides a minimum age for the greenstone, which it appears to intrude, and underlying rocks. The other isotopic age is 325 Ma from some of the structurally highest felsic tuffaceous units. These ages require that most of the stratigraphy outlined by Mihalynuk *et al.* (1998) is inverted. Regardless of the stratigraphic younging direction, the greenstone-chrinkle chert-limestone marker succession can be confidently traced throughout the Big Salmon Complex in British Columbia and southernmost Yukon (*cf.* Roots *et al.*, 2000), and a crude metallogenic history can be pieced together.

Vigorous continental arc volcanism in the late Devonian to Early Mississippian (*circa* 370-360 Ma) resulted in the accumulation of voluminous, submarine, dominantly mafic tuff and tuffite on a substrate of pericratonic strata. A pulse of felsic volcanism and arc rifting and probably marks the end of the magmatic cycle and the formation and preservation of a regionally developed exhalative chert horizon known as the "crinkle chert" as well as coeval clastic facies preserved in fault-bounded basins. Felsic volcanic intervals immediately beneath the crinkle chert commonly contain pyritic quartz-sericite schist intervals. These may serve as potential pathways to volcanogenic massive sulphide deposits. Within the crinkle chert, a Cu-Zn-Fe-Mn-Ba-rich lens several metres long points to the potential for volcanogenic exhalative deposits.

Carbonate deposition atop crinkle chert probably marks a rise in carbonate productivity in the Early Mississippian, following the Late Devonian crisis and extinction reef organisms. Thick carbonate banks probably co-existed with basins in which terrigenous clastics were deposited. Complex facies may have been linked by pulses of volcanism and widespread tuff deposition. A mid-Mississippian deformational event (between 354 and 335 Ma) may have peaked with emplacement of 346 Ma eclogite and blueschist (*cf*. Erdmer *et al.*, 1998). It caused uplift and erosion of units and deposition of widespread conglomeratic facies. The ensuing strata display at least as much lithologic variability as do pre-deformation sediments, but felsic volcanism is again proximal as it was at the close of greenstone deposition. Base metal sulphides are associated with these felsic volcanics such as at the Arsenault property.

The youngest Big Salmon Complex strata recognized in the Jennings River area are 325 Ma dacitic tuffs in carbonate. They do not correspond in any way to a clear break in deposition, and much younger Big Salmon Complex strata could exist in other areas. Peak metamorphism predates the 196 Ma Coconino tonalite and may have occurred around 270 Ma when blueschist and eclogites were incorporated into the Yukon Tanana Terrane (Erdmer *et al.*, ibid.). The youngest regional deformational event produced a strong fabric in the ~196 Ma Coconino tonalite, but affected only the southern margin of the *circa* 185 Ma Simpson Peak batholith. Youngest magmatism is Eocene, and one Eocene pluton west of north Teslin Lake hosts a set of veins with elevated gold values. Clearly, the area has a long and complex history and significant mineral potential.

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REFERENCES

Abbott, J.G. (1981): Geology of the Seagull Tin District; in Yukon Exploration and Geology 1979-1980, *Indian and Northern Affairs Canada,* pages 32-44.

Aitken, J.D. (1959): Atlin Map-area, British Columbia; *Geological Survey of Canada*, Memoir 307, 89 pages.

Creaser, R.A., Erdmer, P., Stevens, R.A. and Grant, S.L. (1997): Tectonic affinity of Nisutlin and Anvil assemblage strata from the Teslin Tectonic Zone, Northern Canadian Cordillera: Constraints from neodymium isotope and geochemical evidence; *Tectonics,* Volume 16, pages 107-121.

Colpron, M. (1999): Glenlyon project: Preliminary stratigraphy and structure of Yukon-Tanana Terrane, Little Kalzas Lake area, central Yukon (105L/13); *in* Roots, C.F. and Emond, D.S. (editors), Yukon Exploration and Geology 1998, Exploration and Geological Services Division, Yukon, *Indian and Northern Affairs Canada*, pages 63-71.

Cook, S. and Pass, H. (2000): Ancient Pacific Margin Part V: Preliminary results of geochemical studies for VMS deposits in the Big Salmon Complex, Northern British Columbia, in Geological Fieldwork 1999, *B.C.Ministry of Energy and Mines*, Paper 2000-1, this volume.

deKeijzer, M., Williams, P. and Brown, R.L. (1999): Kilometre-scale folding in the Teslin zone, northern Canadian Cordillera, and its tectonic implications for the accretion of the Yukon-Tanana Terrane to North America; *Canadian Journal of Earth Science*, Volume 36, pages 479-494.

de Keijzer, M., Mihalynuk, M.G. and Johnston, S.T. (2000): Structural investigation of an exposure of the Teslin Fault; in Current Research, *Geological Survey of Canada*, Paper 2000-A, (in press).

Dixon-Warren, A. and Hickin, A. (2000): Ancient Pacific Margin NATMAP Part IV: Surficial mapping and till geochemistry in the Swift River Area, north western British Columbia; in Geological Fieldwork 1999, *B.C. Ministry of Energy and Mines*, Paper 2000-1, (in press).

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.

Erdmer, P. and Armstrong, R.L. (1989): Permo-Triassic isotopic dates for blueschist, Ross River area, Yukon; *in* Yukon Exploration and Geology, Volume 2: Exploration and Geological Services Division, Yukon, I*ndian and Northern Affairs Canada*, pages 33-36.

Erdmer, P., Ghent, E.D., Archibald, D.A. and Stout, M.Z. (1998): Paleozoic and Mesozoic high pressure metamorphism at the margin of ancestral North America in central Yukon; Geological Society of America Bulletin, Volume 110, pages 615-629.

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

Gleeson, T.P., Friedman, R.M. and Wahl, K. (2000): Stratigraphy, structure, geochronology and provenance of the Logjam Creek area, northwestern British Columbia (NTS

104O/14W); in Geological Fieldwork 1999, *B.C. Ministry of Energy and Mines*, Paper 2000-1, (in press).

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. (2000): Geology, Teslin, Yukon Territory (105C); *Geological Survey of Canada,* Open File 2886, scale 1:250 000.

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, scale 1:250 000.

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 40Ar/39Ar data; *Tectonics*, Volume 10, pages 51-76.

Harms, T.A. and Stevens, R.A. (1996): A working hypothesis for the tectonostratigraphic affinity of the Stikine Ranges and a portion of the Dorsey Terrane; in Cook, F. and Erdmer, P. (compilers), Slave-Northern Cordillera Lithospheric Evolution Transect and Cordilleran Tectonics Workshop Meeting, *University of Calgary*, Lithoprobe Report No. 50, pages 93-95.

Mihalynuk, M.G., Nelson, J. and Friedman, R.M. (1998): Regional geology and mineralization of the Big Salmon Complex (104N NE and 104O NW) in Geological Fieldwork 1997, *B.C. Ministry of Employment and Investment*, Paper 1998-1, pages 157-170.

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.

Murphy, D.C. and Piercey, S.J. (1999): Finlayson project: Geological evolution of Yukon-Tanana Terrane and its relationship to Campbell Range belt, northern Wolverine Lake map area, southeastern Yukon; in Roots, C.F. and Emond, D.S. (editors.), Yukon Exploration and Geology 1998, Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, pages 47-62.

Nelson, J.L., Mihalynuk, M. G., Murphy, D.C., Colpron, M., Roots, C.F., Mortensen, J.K. and Friedman, R.M. (2000): Ancient Pacific Margin Part II: A preliminary comparison of potential VMS-hosting successions of Yukon-Tanana Terrane, from Finlayson district to northern British Columbia; *in* Geological Fieldwork 1999, *B.C. Ministry of Energy and Mines*, Paper 2000-1, (this volume).

North American Commission on Stratigraphic Nomenclature (1983): North American stratigraphic code; The American Association of Petroleum Geologists Bulletin, Volume 67, pages 841-875.

Poole, W.H. (1956): Geology of the Cassiar Mountains in the vicinity of the Yukon-British Columbia boundary; unpublished Ph.D. thesis, Princeton University, 247 pages.

Poulton, T., Orchard, M.J., Gordey, S.P. and Davenport, P. (1999): Selected Yukon fossil determinations; *in* Yukon digital geology, S.P. Gordey and A.J. Makepeace (compilers), *Geological Survey of Canada*, Open File D3826, *and* Exploration and Geological Services Division, Yukon, *Indian and Northern Affairs Canada*, Open File 1999-1(D).

Roots, C.F., de Keijzer, M., Nelson, J.L. and Mihalynuk, M.G. (2000): Revision mapping of the Yukon-Tanana and equivalent terranes in northern B.C. and southern Yukon between 131° and 132°W; in Current Research, Geological Survey of Canada, Paper 2000-1A, pages (in press).

Stevens, R.A. (1992): Regional geology, fabric and structure of the Teslin suture zone in Teslin map area, Yukon Territory; in Current Research, Geological Survey of Canada, Paper 92-1A, pages 287-296.

Stevens, R.A. (1994): Geology of the Teslin suture zone in parts of Laberge (105E/1), Quiet Lake (105F/4) and Teslin (105C/11, 13, 14) map areas, Yukon Territory; Geological Survey of Canada, Open File 2768.

Stevens, R.A. and Erdmer, P. (1993): Geology and Structure of the Teslin suture zone and related rocks in parts of Laberge, Quiet Lake and Teslin map areas, Yukon; in Current Research, Geological Survey of Canada, Paper 93-1A, pages 22-20.

Stevens, R.A. and Harms, T.A. (1995): Investigations in the Dorsey Terrane, Part 1: Stratigraphy, Structure and Metamorphism in the Dorsey Terrane, Southern Yukon Territory and Northern British Columbia; in Current Research, Geological Survey of Canada, Paper 95-1A, pages 117-128.

Stevens, R.A. and Harms, T.A. (1996): Geology in the vicinity of the Dorsey Range, southern Yukon Territory and northern British Columbia; scale 1:50 000; in Cook, F. and Erdmer, P. (compilers), Slave-Northern Cordillera Lithospheric Evolution Transect and Cordilleran Tectonics Workshop Meeting, University of Calgary, Lithoprobe Report No. 50, pages 222-225.

Stevens, R.A., Erdmer, P., Creaser, R.A. and Grant, L.S. (1996): Mississippian assembly of the Nisutlin assemblage: Evidence from primary contact relationships and Mississippian magmatism in the Teslin tectonic zone, part of the Yukon-Tanana Terrane of south-central Yukon; Canadian Journal of Earth Sciences, Volume 33, pages 103-116.

Tempelman-Kluit, D.J. (1979): Transported cataclasite, ophiolite and granodiorite in Yukon: evidence of arc-continent collision; Geological Survey of Canada, Paper 79-14.

Wheeler, J.O., Brookfield, A.J., Gabrielse, H. Monger, J.W.H., Tipper, H.W. and Woodsworth, G.J. (1991): Terrane map of the Canadian Cordillera; Geological Survey of Canada, Map 1713A.

Appendix I: Notes on Figure 3

Thick Quaternary deposits completely blanket some parts of the map area for tens of square kilometres. These are problem areas in which tenuous extrapolations are required to produce the map of Figure 3. Many extrapolations, if correct, carry important implications. Other extrapolations, drawn to mimic local structural style, imply detailed knowledge of unit distributions that does not exist. Most limitations of Figure 3 will become apparent with future publication of 1:50 000 scale Open File maps which will show inferred contacts and limits of outcrop; however, many of the following remarks are germane to those maps as well. The numbered points below correspond to the numbers, ordered from north to south, enclosed by triangles on Figure 3.

1. Western contacts of the Screw Creek limestone have not been found in the Screw Creek valley bottom. Lowest exposures of limestone are apparently right way up based on poorly preserved grading in siliceous tuffaceous layers. Structurally higher parts of the limestone are clearly upside down (described above).
2. Crinkle chert occurs in the old Alaska Highway road cut, but the area to the west is swamp; no greenstone is mapped.
3. This contact is well constrained between the elongate pluton of presumed Jurassic age and the Alaska Highway, but has not been observed north or south of those points.
4. The syncline is constrained along the shoreline and near "4". However, closure could not be confirmed by mapping. Felsic volcanics on the southern limb are locally very siliceous and might be a volcanic-crinkle chert hybrid.
5. Closure of the fold has not been demonstrated unequivocally. However, all indications point to fold closure: only greenstone is mapped along the Smart River road, both limbs have been mapped to within a couple kilometres of the hinge and layer-cleavage relationships on the limbs are consistent with closure.
6. Mapping of 104O/14W is incomplete. Low outcrops in the downstream stretches of the Screw Creek valley include small areas of limestone, perhaps hinges of folds developed on the lower limb of the Screw Creek limestone.
7. Crinkle chert occurs as a large area of angular boulders atop Hazel orthogneiss where it is assumed to be locally derived. Crinkle chert is known to occur along the contact of the Hazel orthogneiss at location 2 and near the Peak of Mount Hazel.
8. Only small lenses of carbonate are found in the axial zone of the fold. Carbonate on the fold limbs apparently grades laterally into graphitic wacke near the fold core.
9. Only three areas of outcrop constrain the eastern limestone belt south of the Alaska Highway. One is near the north margin of the Simpson Peak batholith another is south of central Swan Lake on Hook Creek (creek not shown on Figure 3), and third is an area of sparse outcrops in the forest west of Swan Lake. At none of these localities is the crinkle chert unit exposed.
10. Geology near "10" and an equal distance due north of the highway has been compiled mainly from vantage point mapping. It requires confirmation by direct observations.
11. Orthogneiss near Mt. Francis is lithologically similar to the Hazel orthogneiss in many respects; however, it apparently cuts younger stratigraphy. It is presumably between 362 and 335Ma, because it is younger than the greenstone, but is overlain by conglomerate believed derived subsequent to a deformational event around 345 Ma. (*see* Discussion).
12. Only scattered outcrops of limestone and greenstone cut by tonalite are present at the southern end of the carbonate belt. More persistent outcrop near the northern end of the belt leads to a map pattern that implies that the Hazel orthogneiss also cuts the limestone, but this is probably not the case. It appears more likely that the limestone belt outlines a tight synformal keel that is bent to the west and extends over the Hazel orthogneiss (*see* location 7). The crinkle chert unit was apparently not deposited at this locality below the limestone.
13. All contacts between Coconino tonalite and Simpson Peak batholith are covered. Since Coconino tonalite is older and more deformed than the Simpson Peak batholith, the interpreted contact configuration is meant to show the former cut by the latter.
14. Teh Creek pluton is shown as an elongate body trending 290°. In fact, most of the central portion traversed by Teh Creek is covered and two separate bodies could be present. However, the plutonic rocks exposed at either end of the body lithologically indistinguishable, and the body is known to continue in similar fashion to the east beneath a carapace of Klinkit assemblage rocks to where it is exposed in the Butsih Creek valley. Several correlated geochemical anomalies coincide with carapace rocks in easternmost 104O/12 (near 19; *see* also Cook and Pass, 2000, this volume).
15. Felsic volcanics are not mapped north of "15", but are shown extending through a covered area to the limestone belt because of their common association with limestone elsewhere.
16. As is the case for locality "14", no outcrop exists to support the interpretation of a continuous septa of greenstone. However, clear relationships occur at both the western and eastern ends of the septa. The contact shown between greenstone and Klinkit argillite is purely conjectural.
17. Teslin fault is beautifully exposed here (*see* deKeijzer *et al.*, 2000).
18. A tight synformal keel of crinkle chert and limestone is enveloped by greenstone. In particular, limestone layers are strongly folded and rodded, producing a "false stretched monomict conglomerate" in which the apparent stretched limestone "cobbles" are actually decapitated, isoclinal interference folds. Protolith textures are destroyed due to the coincidence of interference fold cores; however, good protolith textures are displayed in greenstone where it occurs out along the relatively planar fold limbs.
19. Teh Creek pluton in subsurface produces hornfels and multielement geochemical anomalies in local stream sediments (*see* "14" above and Cook and Pass, this vol-

ume). Roof rocks are cut by abundant thick dikes and the pluton is again exposed in Butsih valley to the east.

20. Cherty argillite believed to be part of the Cache Creek Kedahda Formation is strongly hornfelsed near the intrusive contact.

21. Most of the unit is covered within 5 kilometres of the River. Observations are restricted to within 2 kilometres of the northern contact.

22. A few scattered outcrops of strongly foliated, blue grey limestone occur in the middle of a broad glacial outwash plain east of Kachook Creek. They are included with the Permian Teslin Formation based only upon lithological similarity. Thus, the trace of the Teslin Fault must run to the north, down the Jennings River.

23. Both northwest and northeast contacts of the Charlie Cole pluton are covered.