Glenlyon project: Coherent stratigraphic succession of Yukon-Tanana Terrane in the Little Salmon Range, and its potential for volcanic-hosted massive sulphide deposits, central Yukon[1]

Maurice Colpron[2]
Yukon Geology Program

Melanie Reinecke
University of Victoria[3]

Colpron, M. and Reinecke, M., 2000. Glenlyon project: Coherent stratigraphic succession of Yukon-Tanana Terrane in the Little Salmon Range, and its potential for volcanic-hosted massive sulphide deposits, central Yukon. *In:* Yukon Exploration and Geology 1999, D.S. Emond and L.H. Weston (eds.), Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 87-100.

ABSTRACT

Geological mapping of Yukon-Tanana Terrane in Little Salmon Range has outlined a coherent stratigraphic succession in rocks that were previously described as strongly foliated and lineated mylonitic tectonites. The widespread occurrence of primary sedimentary and volcanic textures and the lateral continuity of the units are incompatible with the previous interpretation of the area. A laterally continuous volcanic arc sequence occupies the core of a broad synclinorium and rests unconformably on disparate clastic units to the east and west. The volcanic sequence is structurally overlain by an allochthonous sheet of distal turbidites. The occurrence of massive sulphide and exhalite within the volcanic sequence attests to the high mineral potential of this largely unexplored region.

RÉSUMÉ

La cartographie géologique du terrane de Yukon-Tanana, dans la chaîne de Little Salmon, a permis l'ébauche d'une succession stratigraphique cohésive, là où les roches étaient au préalable décritent comme des mylonites à forte schistosité et linéation. L'abondance de structures primaires d'origines sédimentaires et volcaniques, de même que la continuité des unités vont à l'encontre de l'interpretation antérieure pour cette région. Une séquence volcanique latéralement continue occupe le coeur d'un grand synclinorium. Elle repose en discordance sur deux unités sédimentaires clastiques différentes à l'est et à l'ouest. La séquence volcanique est surmontée structuralement par une écaille allochthone composée de turbidites distales. La présence de sulfures massifs et de roches exhalatives au seins de la séquence volcanique témoigne du haut potentiel minéral de cette région pratiquemment inexplorée.

[1]*Contribution to the Ancient Pacific Margin NATMAP project.*

[2]*maurice.colpron@gov.yk.ca*

[3]*School of Earth and Ocean Sciences, University of Victoria, Victoria, British Columbia, Canada V8W 3P6*

INTRODUCTION

Glenlyon area was first mapped between 1949 and 1954 at the scale of 1:253 440 by Campbell (1967). Campbell identified a 30-50 km-wide, northwest-trending belt of metasedimentary, metavolcanic and metaplutonic rocks which correlates with Yukon-Tanana Terrane (Wheeler et al., 1991).

The portion of Yukon-Tanana Terrane exposed along Little Salmon Lake, in southeastern Glenlyon area (Fig. 1), corresponds to the northern extension of the *Teslin suture zone* of Tempelman-Kluit (1979). Building on this model, and on the basis of micro-structural analysis, Oliver (1996) concluded that Yukon-Tanana rocks along Little Salmon Lake are the product of deformation in a subduction zone *(trench mélange)* and that the stratigraphic succession in the eastern part of the area (Oliver and Mortensen, 1998) represents a crustal fragment incorporated in the mélange. A key argument for this model was that regionally mappable units had not been identified in this portion of Yukon-Tanana Terrane. On the contrary, recent studies to the south, in the core of the Teslin suture zone, show that regionally mappable units can be outlined by careful, detailed mapping (e.g., Stevens et al., 1996; de Keijzer et al., 1999) and much of the structural features that had been attributed to deformation in a subduction zone are in fact later, post-accretionary tectonic features.

With these opposing interpretations of Yukon-Tanana Terrane geology in mind, a 1:50 000-scale regional mapping program of Little Salmon Range was undertaken by the Yukon Geology Program in 1999. This study was also fueled by the recent discovery of massive sulphide mineralization along the Robert Campbell Highway (Colpron, 1999a) and the potential for correlations with massive-sulphide-bearing strata of the Finlayson Lake district.

This report presents a brief overview of the stratigraphic and structural relationships in Little Salmon Range, north of the Robert Campbell Highway. It accompanies a preliminary geological map of the area (Colpron, 1999b) and includes a field guide to the roadside geology of Yukon-Tanana Terrane along the Robert Campbell Highway (see Appendix).

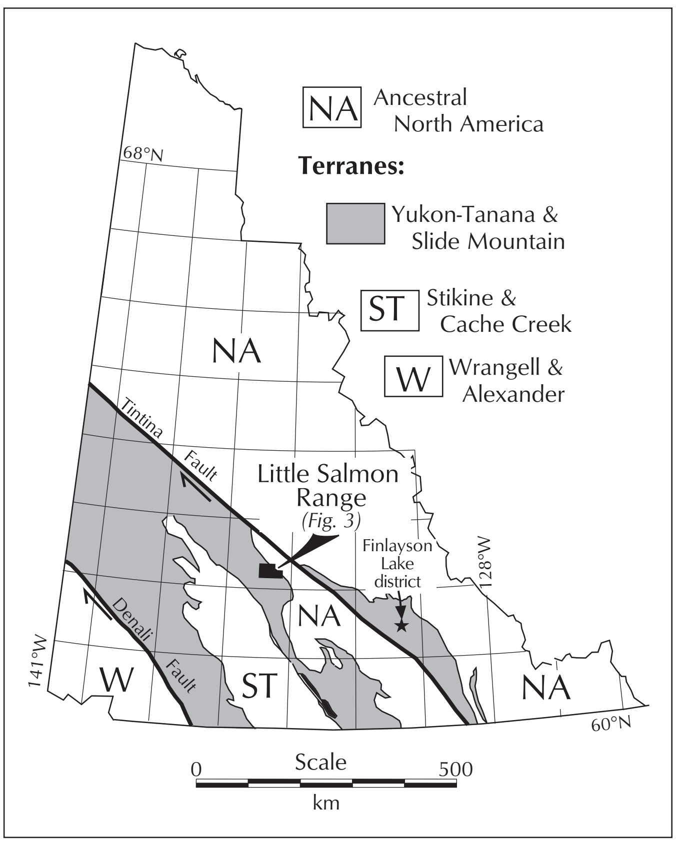

__Figure 1.__ Location of the Little Salmon Range area with respect to the Finlayson Lake district and to distribution of Yukon-Tanana Terrane in Yukon.

COHERENT STRATIGRAPHY

Detailed mapping in Little Salmon Range (Colpron, 1999b) shows that Yukon-Tanana Terrane consists of coherent stratigraphic units that can be followed for tens of kilometres and that primary textures are commonly well preserved (Figs. 2 and 3). Four distinct rock assemblages have been identified (Fig. 2): Unit 1: an arkosic grit sequence; Unit 2: a heterogeneous sequence of quartzite and psammitic schist, including several marble units and abundant orthogneiss sills; Unit 3: a volcanic sequence, which includes a fossiliferous

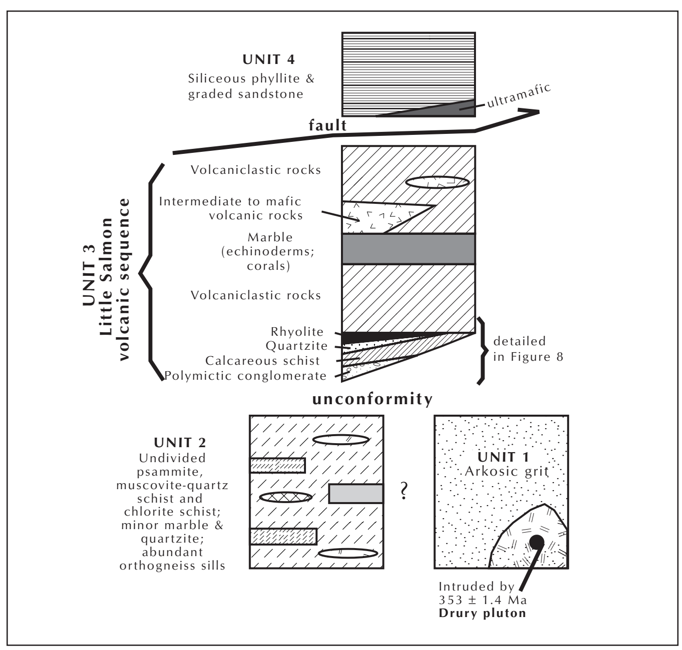

__Figure 2.__ Schematic stratigraphic columns for Yukon-Tanana Terrane in Little Salmon Range. Legend is shown on Figure 3.

marble unit and is inferred to unconformably overlie Units 1 and 2; and Unit 4: an allochthonous sheet of dark grey siliceous phyllite, graded sandstone, and minor serpentinite. At the eastern edge of the study area, near d'Abbadie Fault (Fig. 3), undeformed aphanitic basalt of presumed Tertiary age is inferred to be faulted against Yukon-Tanana rocks.

UNIT 1

The arkosic grit sequence (Unit 1) is restricted to the northeastern part of the map area (Fig. 3). It consists predominantly of coarse-grained arkosic grit with up to 20% angular feldspar granules (Fig. 4). Grey and light green quartzite are also common. The grit and quartzite are locally intercalated with dark grey, carbonaceous phyllite. The grit unit is the oldest unit in the area; it is intruded by a granodiorite gneiss dated at 353 ± 1.4 Ma (Oliver and Mortensen, 1998).

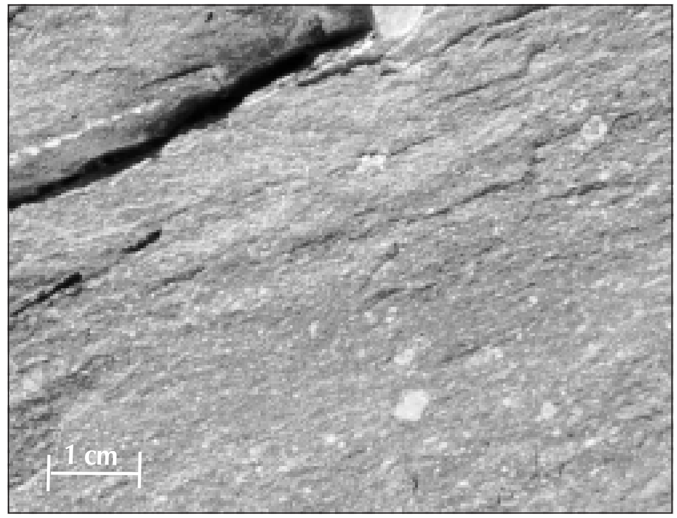

Figure 4. *Coarse-grained arkosic grit (Unit 1).*

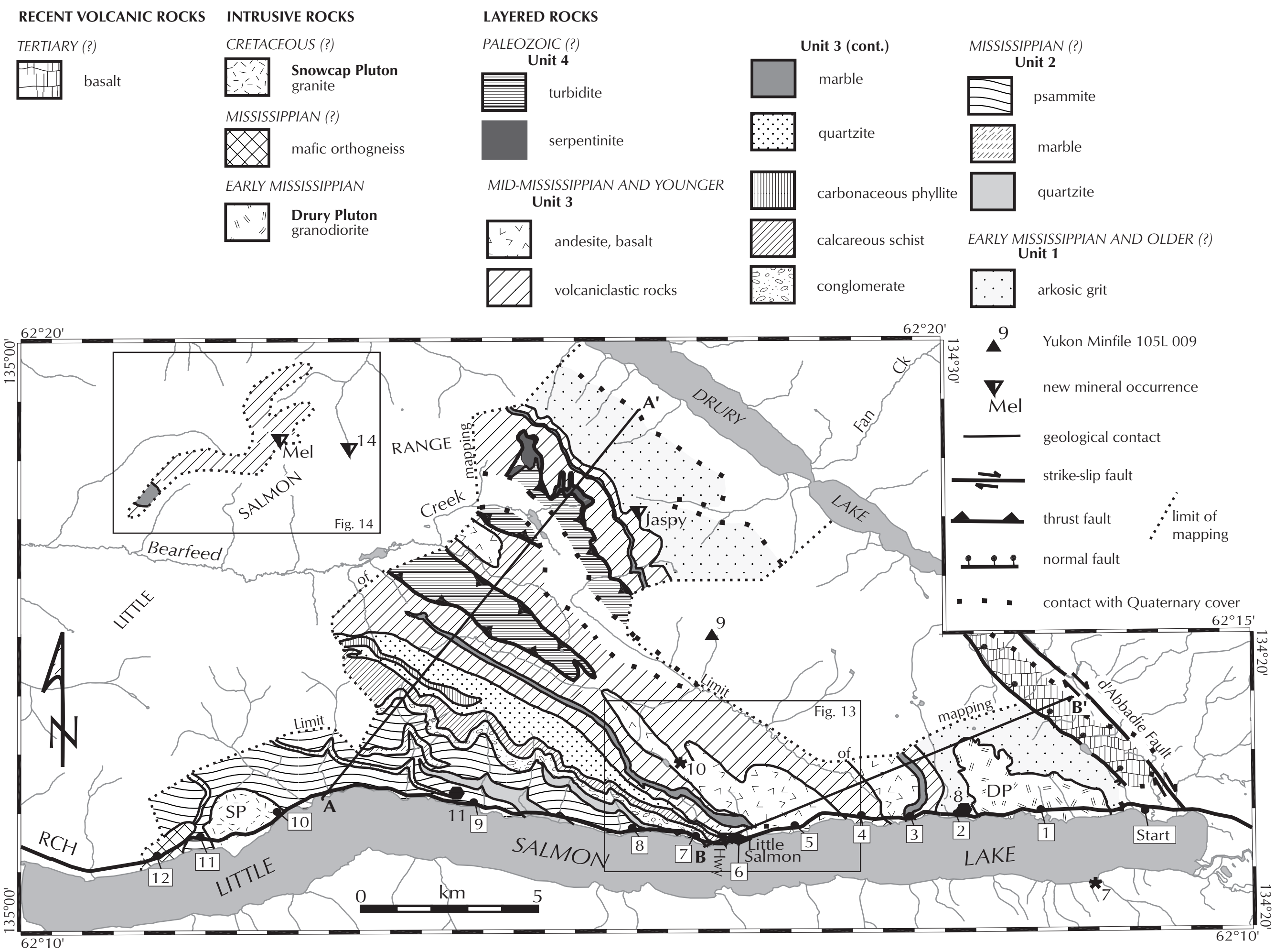

Figure 3. *Preliminary geological map of Little Salmon Range (portions of NTS 105L/1, 2 and 7; after Colpron, 1999b). Numbers in boxes correspond to field trip stops described in Appendix 1; bold numbers and symbols refer to Yukon Minfile, 1997, occurrences. New occurrences are named and described in the text. Sections A-A' and B-B' are shown in Figure 11. SP = Snowcap Pluton; DP = Drury Pluton; RCH = Robert Campbell Highway.*

UNIT 2

Unit 2, which is confined to the area southwest of the volcanic sequence (Unit 3; Fig. 3), comprises a mixture of light to medium grey quartzite and psammitic schist, medium to dark grey carbonaceous muscovite-quartz schist, light green chlorite-actinolite-carbonate schist, and light green quartzite. These rocks are commonly calcareous; marble layers are ubiquitous at scales ranging from centimetres to hundreds of metres in thickness. An important characteristic of this lithologic assemblage is the abundance of felsic to intermediate meta-igneous bodies. These commonly occur as foliation-parallel, 1- to 10-m-thick, discontinuous lenses throughout Unit 2.

UNIT 3 (LITTLE SALMON VOLCANIC SEQUENCE)

The Little Salmon volcanic sequence (Unit 3) occupies the core of a northwest-trending synclinorium in the centre of the map area (Fig. 3). It is inferred to unconformably overlie Units 1 and 2 (Fig. 2). This interpretation is primarily based on the apparent hiatus between the pre-353 Ma (early Mississippian) arkosic grits (Unit 1) and mid-Mississippian felsic volcanic rocks (preliminary U-Pb age; Mortensen, pers. comm., 1999) near the base of the volcanic sequence along the west flank of the synclinorium. In addition, the occurrence of a conglomerate at the base of the volcanic sequence, along the west flank of the synclinorium, also suggests an unconformity.

The bulk of the Little Salmon volcanic sequence (Unit 3) consists of volcaniclastic rocks. These include: light grey, light green and medium green epiclastic sandstone which are locally graded (Fig. 5); dark grey phyllite; brown-weathering calcareous schist and marble; olive-green phyllite; banded chlorite-epidote-plagioclase schist (intermediate to mafic tuff); plagioclase-muscovite-biotite schist (felsic tuff); and, in the northern part of the area, plagioclase-phyric crystal lithic tuff (Fig. 6) and polymictic volcanic conglomerate. The volcaniclastic rocks are intercalated with intermediate to mafic volcanic rocks which consist predominantly of medium green, massive chlorite-plagioclase-epidote ± biotite schist. The volcanic rocks locally display pillow structures, and at one locality, contain a mafic dyke swarm.

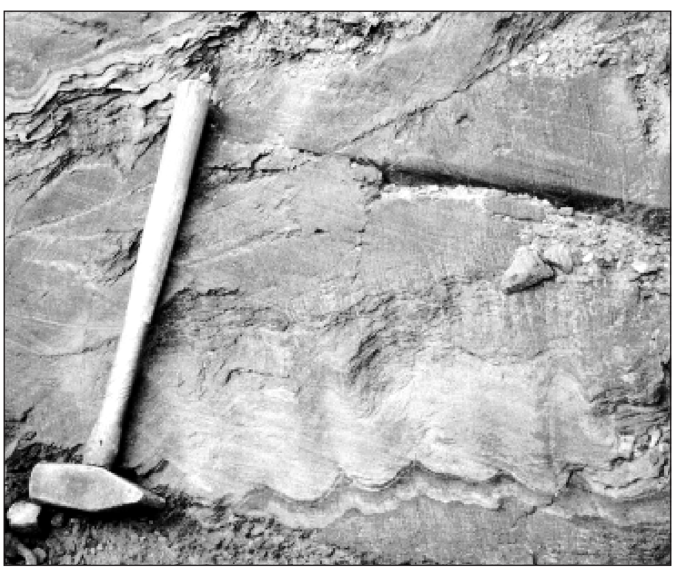

Figure 5. Graded bedding in epiclastic sandstone of the Little Salmon volcanic sequence (Unit 3). Exposure is located in borrow pit along the Robert Campbell Highway (Stop 4 in field trip guidebook, Appendix 1).

Felsic volcanic rocks, namely rhyolite and quartz-feldspar porphyry, are locally interspersed within the Little Salmon volcanic sequence. They occur at various stratigraphic levels within the sequence. These rocks host massive pyrite-magnetite-chalcopyrite horizons at the Little Salmon occurrence, where a quartz-feldspar porphyry yielded a preliminary mid-Mississippian U-Pb zircon age (J.K. Mortensen, pers. comm., 1999). Rhyolite is also found intercalated with pink manganiferous chert horizons north of Bearfeed Creek (Fig. 3). At this locality, one rhyolite horizon contains quartz lenses which may be flattened amygdules similar to those observed in rhyolite above the Kudz Ze Kayah deposit in the Finlayson district (Murphy, 1998).

An important marble marker horizon occurs within the Little Salmon volcanic sequence (Figs. 2 and 3). It consists of light to medium grey marble, light grey phyllitic marble, and lesser black calcareous phyllite and dark grey carbonaceous phyllite. The local occurrences of carbonate rhythmite, poorly sorted carbonate granule to pebble conglomerate, and coarsely crystalline marble (bioclastic calcarenite ?) strongly suggest that these carbonates were resedimented, perhaps as limestone turbidites. The marble marker locally contains echinoderm columnals and corals. Coral specimens collected along the west flank of the Little Salmon volcanic sequence (Fig. 7) indicate a

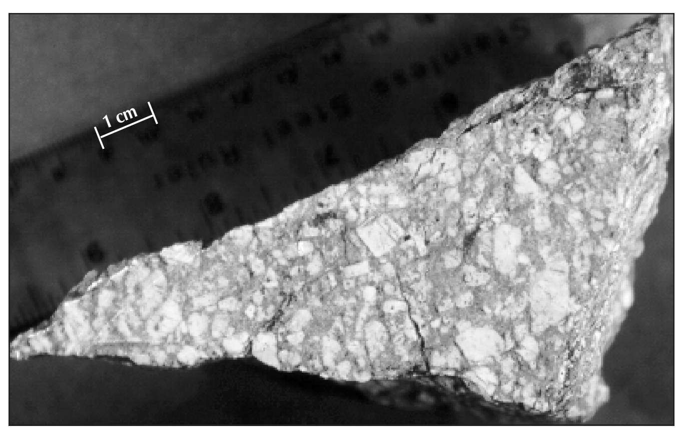

Figure 6. Plagioclase-phyric crystal lithic tuff, Little Salmon volcanic sequence (Unit 3). Hand sample collected north of Bearfeed Creek.

probable late Mississippian to mid-Pennsylvanian age (late Viséan to Moscovian) for this marble (E.W. Bamber, GSC Paleontological Report 3-EWB-1999). Although, these specimens are too poorly preserved for further identification and provide only a tentative age, it must be noted that this determination is consistent with the mid-Mississippian age of underlying felsic volcanic rocks.

A single conodont collection, from a correlative marble along the east flank of the volcanic sequence, yielded a probable Ordovician age (Poulton et al., 1999). Since the sequence is now firmly established as mid-Mississippian to Pennsylvanian in age, this conodont determination must reflect the age of the source rock from which the Little Salmon carbonates were derived.

Along the west flank of the synclinorium, the base of the Little Salmon volcanic sequence is marked by a distinct, mixed carbonate and siliceous clastic unit which commonly contains polymictic pebble to boulder conglomerate (Figs. 8 and 9). The

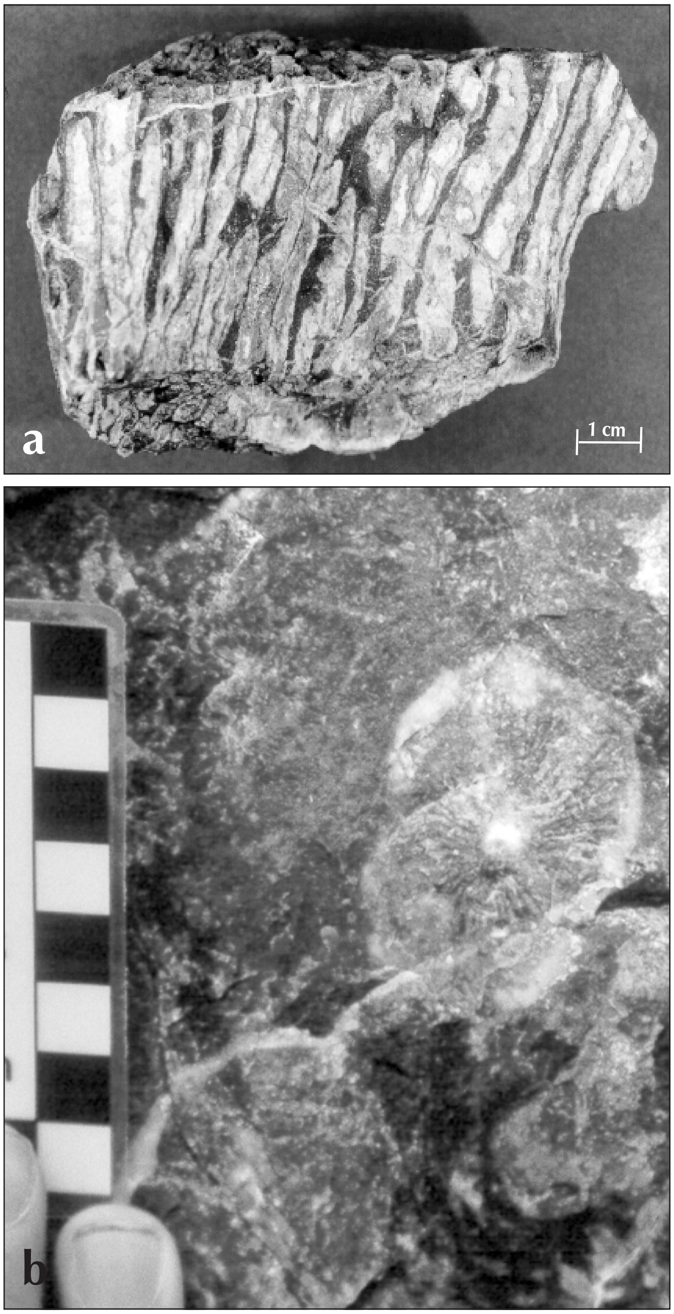

Figure 7. *Coral specimens from marble marker unit in Little Salmon volcanic sequence (Unit 3), from location near Robert Campbell Highway, above Little Salmon occurrence. a) colonial aulophyllid coral, possibly Cowenia sp. b) solitary dibunophyllid (?) coral (E.W. Bamber, GSC Paleontological Report 3-EWB-1999).*

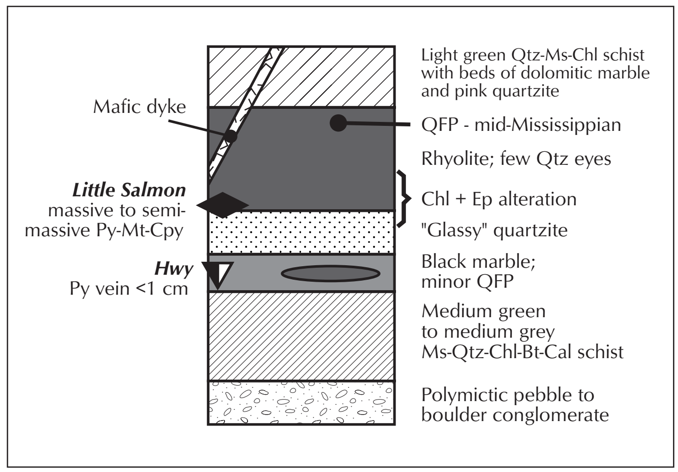

Figure 8. *Detailed stratigraphy of the base of Unit 3 near the Little Salmon occurrence, along the west flank of the Little Salmon volcanic sequence. Stratigraphic position of mineral occurrences are indicated. QFP = quartz-feldspar porphyry, Qtz = quartz, Ms = muscovite, Chl = chlorite, Ep = epidote, Bt = biotite, Cal = calcite, Py = pyrite, Mt = magnetite, Cpy = chalcopyrite.*

Figure 9. *Cobble conglomerate at the base of the Little Salmon volcanic sequence (Unit 3).*

conglomerate contains sub-angular to rounded clasts of quartz, K-feldspar, phyllite, dolomitic siltstone, dark grey marble, buff-weathering dolomitic marble, rhyolite, and granitoid; the matrix is calcareous, siliceous and/or carbonaceous. The conglomerate passes laterally into a mixture of buff-weathering dolomitic marble, light to dark grey quartzite and carbonaceous schist.

The conglomerate unit is overlain by light green quartz-chlorite-plagioclase-muscovite calcareous schist and light grey to light green quartzite (Fig. 2). The calcareous schist commonly contains 1-2 mm calcite porphyroblasts, and locally, 3-5-cm-thick beds of brown-weathering dolomitic marble. To the west, the quartzite is intercalated with dark grey to black carbonaceous phyllite. The quartzite is overlain by rhyolite and/or volcaniclastic rocks typical of the volcanic sequence (Figs. 2 and 8). The Little Salmon showing occurs at the contact between the quartzite and overlying rhyolite of Unit 3 (Fig. 8).

UNIT 4

The Little Salmon volcanic sequence is structurally overlain by an allochthonous sheet of distinct dark grey siliceous phyllite and light grey graded sandstone (Unit 4; Figs. 2 and 3). This unit likely represents a turbidite sequence of unknown age and origin. It locally contains dark grey marble and carbonate cobble conglomerate.

The occurrence of sheared serpentinite at the contact between Units 3 and 4 (Figs. 3 and 10) suggests that rocks of Unit 4 originated in an oceanic realm. The larger ultramafic bodies locally preserve relict cumulate textures.

INTRUSIVE ROCKS

Rocks of Yukon-Tanana Terrane are intruded by a wide range of granitoid rocks. Near the east end of Little Salmon Lake, arkosic grits of Unit 1 are intruded by the Drury Pluton (Fig. 3). It

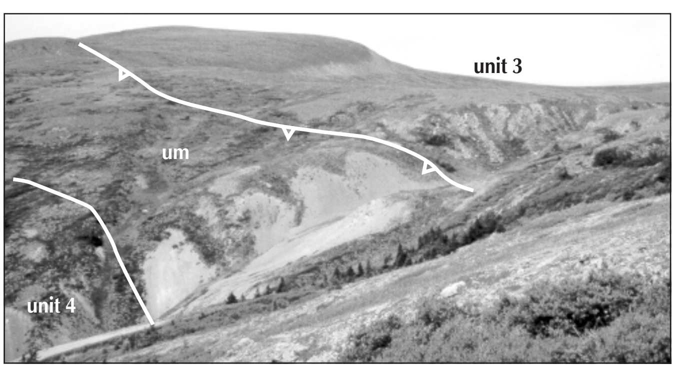

Figure 10. *Looking north at the eastern contact of the Unit 4 thrust sheet. Light grey scree slopes are serpentinite (um) that delineate the base of the thrust sheet. Volcanic rocks (Unit 3) in the footwall of the thrust are mylonitic. Dark grey phyllite of Unit 4 are in lower left corner.*

consists of variably foliated, fine- to medium-grained, equigranular biotite ± hornblende granodiorite. The Drury Pluton is typically uniform in composition. It is locally K-feldspar porphyritic and rarely more felsic (tonalitic) than average. At one locality, along the Robert Campbell Highway, it is a coarse-grained diorite with cumulate texture. The Drury Pluton was dated at 353 ± 1.4 Ma by U-Pb zircon (Oliver and Mortensen, 1998).

Unit 2 contains the widest variety of intrusive rocks. They occur as foliation-parallel, 1- to 10-m-thick, discontinuous lenses. Only locally do they form mappable bodies at the scale of 1:50 000 (50- to 100 m-thick). The igneous rocks vary from mafic (meta-gabbro) to intermediate (meta-diorite) in composition, and most likely belong to more than one magmatic suite. They are typically strongly foliated and commonly gneissic. These intrusions are currently interpreted to be of Mississippian age.

The base of Unit 3, along the west flank of the synclinorium, is locally intruded by a distinct, very coarse-grained (pegmatitic ?) hornblende diorite. It occurs as two ~50-m-wide bodies which are discordant with layering in the country rocks. The diorite is almost exclusively composed of plagioclase and hornblende, with hornblende commonly occurring as crystals up to several centimetres long. It is only weakly foliated and currently undated.

A medium-grained, equigranular hornblende leucogabbro intrudes the contact between the marble marker and volcaniclastic rocks (Unit 3) north of Bearfeed Creek. This rock is unfoliated and may therefore be somewhat younger than other igneous bodies in the area.

Finally, a post-tectonic, medium-grained, equigranular biotite granite (Snowcap Pluton; Fig. 3) intrudes rocks of Unit 2 near the west end of Little Salmon Lake. This pluton extends southward to the base of Snowcap Mountain south of Little Salmon Lake (Campbell, 1967). K-feldspar from the Snowcap Pluton yielded a $^{40}Ar/^{39}Ar$ integrated age of 85 Ma (Oliver, 1996). For this reason, we have assigned a Cretaceous age to this pluton. However, because K-feldspar typically has a very low closure temperature to argon diffusion (~150-200°C), this age assignment must be accepted with caution. The Snowcap Pluton may be much older.

STRUCTURE AND METAMORPHISM

Oliver (1996) described Yukon-Tanana Terrane rocks along Little Salmon Lake as strongly foliated and lineated tectonites of mylonitic character with little or no preservation of primary features with which to interpret protolith or relationships. Although all Yukon-Tanana Terrane rocks are penetratively deformed, we have found little evidence of the degree of deformation implied by Oliver (1996). Primary sedimentary and volcanic features such as fossils, graded beds, pillows, vesicles, etc., are common throughout the sequence and marker beds permit the definition and tracing of a stratigraphic succession.

The structure of the area is dominated by a broad synclinorium which is cored by volcanic rocks of Unit 3 and a thrust sheet of Unit 4 (Fig. 11). Axial planes of tight to isoclinal folds are defined by either a pressure-solution cleavage (in the east and in Unit 4), a penetrative schistosity (most widespread), or a strong transposition foliation and metamorphic segragation (in the west). The attitude of the dominant foliation varies across the area defining a structural fan with an axis that coincides with the core of the synclinorium (Fig. 11). Lineations are most commonly intersection and/or crenulation lineations. A mineral elongation lineation (quartz rodding, mica streaking) is locally developed, most typically at lower structural level in the western part of the area.

Mylonitic rocks are restricted to the footwall of the thrust fault at the base of the allochthonous rocks of Unit 4. At one locality, mylonitic volcanic rocks contain hornblende porphyroclasts with top-to-the-east asymmetry.

Evidence for an older phase of deformation is developed locally. Along the east side of the study area, isoclinal folds deformed by the dominant regional structures are locally outlined by pelitic horizons in grits of Unit 1. To the west, rocks of Unit 2 more typically contain an early schistosity folded by the dominant folds.

The dominant foliation is deformed by younger, gently plunging open folds with a northwest-striking axial planar crenulation cleavage. These structures appear to be related to the large antiform of the dominant foliation in the western part of the area, as previously suggested by Oliver (1996; his western antiform). However, Oliver's eastern synform (our synclinorium) doesn't appear to be of the same generation of structures; the dominant foliation fans across the synclorium rather than being folded by it (as implied by Oliver). We prefer to interpret the synclinorium as being linked to the dominant phase of deformation.

Another younger set of folds is restricted to the eastern part of the area (Unit 1 only). These have shallow, north-striking axial planar crenulation cleavage and typically deform the dominant foliation in tight east-verging folds. The relationship between these folds and open folds found to the west is unknown.

All rocks of Yukon-Tanana Terrane in Little Salmon Range are characterized by stable metamorphic mineral assemblages typical of greenschist facies. In the northeastern and northern parts of the area, the rocks are at chlorite grade. Elsewhere, the rocks contain biotite grade mineral assemblages. In the southwestern part of the area, rocks of Unit 2 have evidently experienced a more complex metamorphic history than the rest

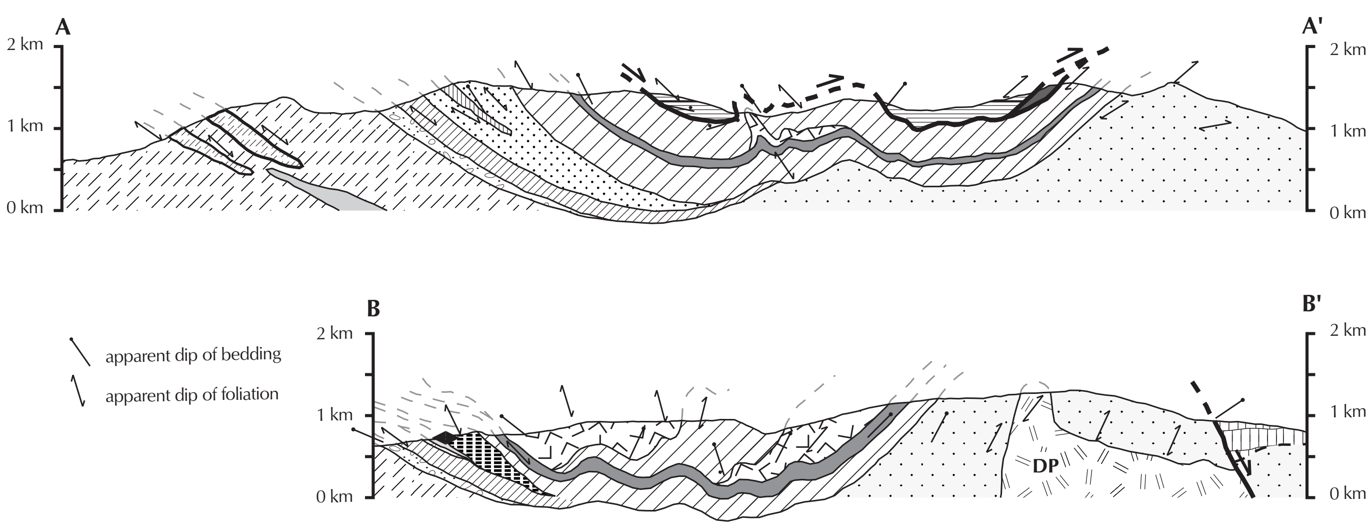

Figure 11. *Vertical cross-sections for Little Salmon Range. Line of sections and legend are located on Figure 2. Black diamond indicates location of Little Salmon massive sulphide occurrence.*

Figure 12. *Chlorite pseudomorphs after garnet in psammitic schist of Unit 2, along Robert Campbell Highway (field trip stop 8, Appendix 1).*

of Yukon-Tanana rocks in Little Salmon Range. The psammitic schist of Unit 2 commonly contains partially to completely retrograded syn- to post-tectonic garnet porphyroblasts (Fig. 12) and, locally, rectangular aggregates of muscovite which are probably pseudomorphs after an aluminosilicate phase. The significance of this earlier, higher grade metamorphism in rocks of Unit 2 has yet to be resolved.

$^{40}Ar/^{39}Ar$ dating of white micas along Little Salmon Lake yielded consistent integrated ages in the range of 180 to 193 Ma, with plateau ages tightly clustered at ca. 192 Ma (Oliver, 1996). This indicates that greenschist facies metamorphism most likely occurred in Early Jurassic time.

POTENTIAL FOR VOLCANIC-HOSTED MASSIVE SULPHIDE DEPOSITS

The discovery of a massive pyrite-magnetite-chalcopyrite occurrence along Robert Campbell Highway in 1998 (Colpron, 1999a) attests to the high mineral potential of the area. Lateral continuity of the volcanic host sequence (Unit 3) for over 20 km and the presence of manganiferous chert of possible exhalitive origin also underscores the prospectivity of this largely unexplored region.

Detailed mapping in the vicinity of the Little Salmon occurrence (Fig. 13) shows that the massive sulphide occurrence is located at the contact between a quartzite and felsic metavolcanic rocks (Fig. 8). Our mapping indicates that the felsic metavolcanic unit thins to the northwest, whereas the quartzite gets thicker. No new sulphide occurrences were located along this contact to the northwest, although this contact is covered for much of the area shown on Figure 3.

Small veins of pyrite, generally less than 1 cm wide, abound in an outcrop of black marble and felsic schist approximately 200 m to the west of the Little Salmon occurrence (Hwy. occurrence, Figs. 3 and 13). A pyrite vein returned anomalous concentrations of Cu, Pb, As and Au (Table 1). These veins may be related to sulphide concentrations at the main showing to the east.

An important new exploration vector within the Little Salmon volcanic sequence consists of the numerous manganiferous chert horizons that are present north of Bearfeed Creek (Fig. 14). These chert horizons occur as light to dark pink layers less than a metre thick within felsic volcanic rocks (rhyolite) of Unit 3. They contain up to 5% piedmontite (Mn epidote) and are probably of exhalative origin. The encasing rhyolite locally contains quartz lenses which may represent flattened amygdules; a possible near-vent facies. Grab samples from a discordant copper-bearing (bornite-malachite-tetrahedrite?) quartz vein within this sequence contain up to 5% Cu (Table 1). Similar veins may be present at the nearby Drury occurrence (Yukon Minfile, 1997, 105L 014; Fig. 3) where rumours of tetrahedrite have been reported. These veins may form part of a stockwork system. Further work is required to confirm this interpretation.

Another occurrence of a copper-bearing (malachite-bornite) quartz-carbonate vein is located at the contact between the volcanic sequence and arkosic grits of Unit 1 (Jaspy occurrence; Fig. 3). A grab sample from this occurrence contained anomalous concentrations in Cu, Pb, Zn, Ag and Ba (Table 1).

ADDITIONAL MINERAL OCCURRENCES

Other mineral occurrences include diopside-epidote-pyrite (± garnet) skarn in the aureole of Early Mississippian intrusions (Yukon Minfile, 1997, 105L 008 and 011; Fig. 3). The two occurrences that we visited only contained disseminated pyrite, with trace amounts of pyrrhotite at the Ulrike occurrence (Yukon Minfile, 1997, 105L 008). Samples from both occurrences were barren (Table 1).

Finally, an extensive zone of gossan with up to 2% disseminated pyrite occurs in arkosic grit (Unit 1) southwest of Drury Lake (southeast of the Jaspy occurrence). Although the one sample we have assayed was barren (Table 1), the extent of this zone warrants further work.

SUMMARY AND SPECULATIONS

Detailed mapping of Little Salmon Range has outlined a coherent stratigraphic succession from rocks which were previously described as strongly foliated and lineated (L-S) tectonites. The remarkable preservation of primary textures alone, in rocks of Units 1, 3 and 4, is inconsistent with the degree of deformation implied by previous studies (see Figs. 5, 6, 7 for examples).

The overall stratigraphic succession in the eastern part of the area is generally similar to that described by Oliver and

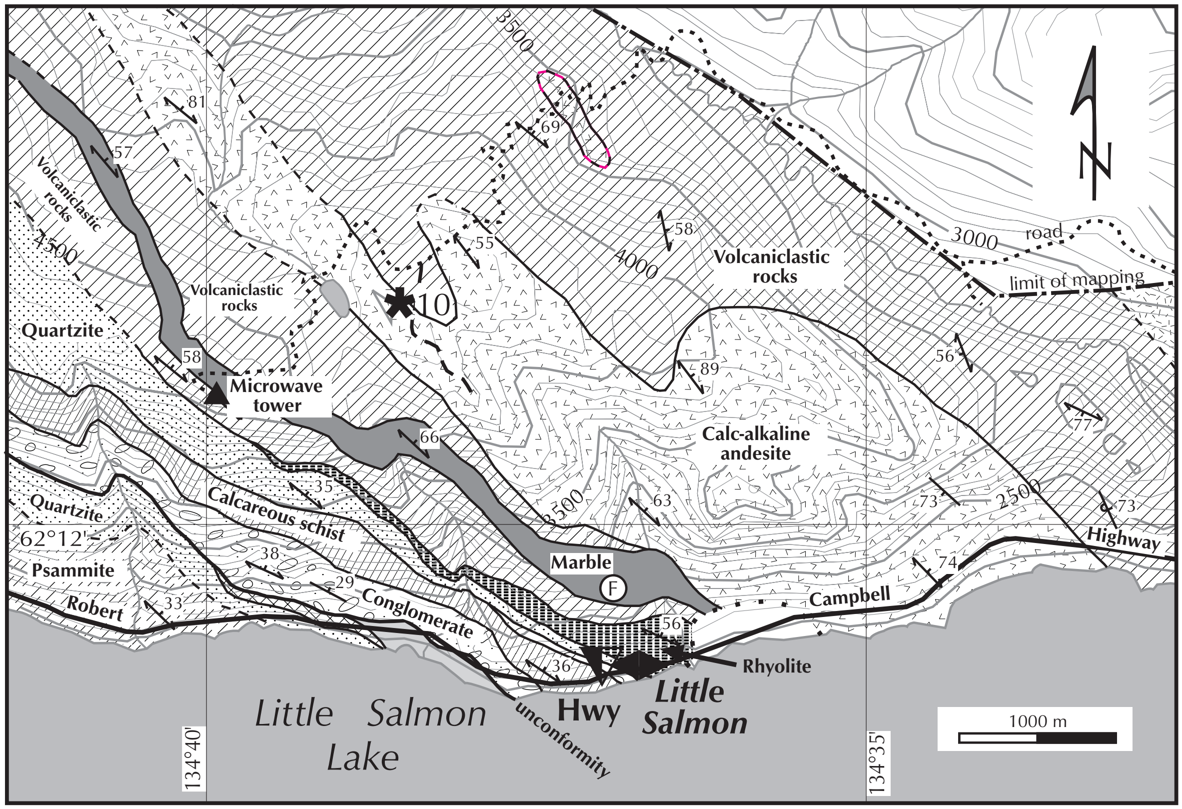

Figure 13. Detailed geological map of the area of the Little Salmon occurrence. Legend located on Figure 2. Location of coral specimens shown in Figure 7 is indicated by circled F.

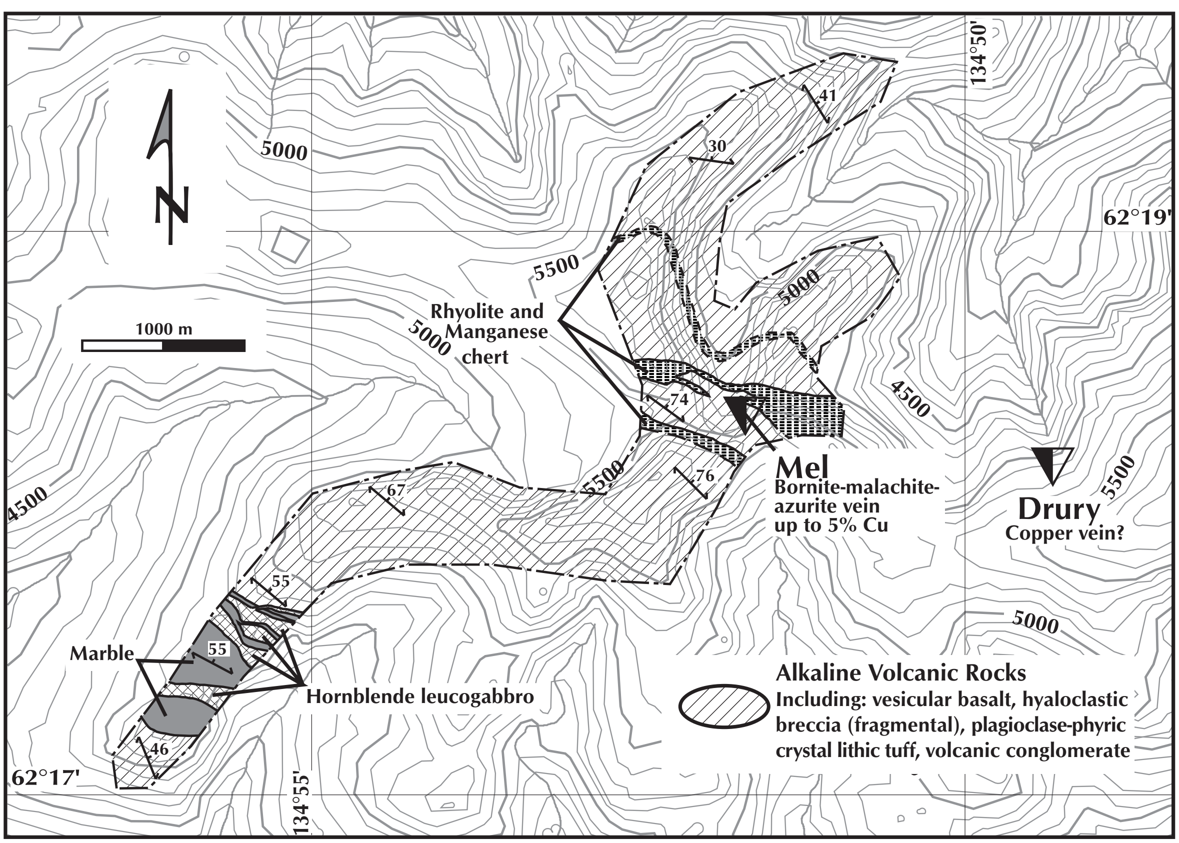

Figure 14. Detailed geological map of a transect north of Bearfeed Creek. Legend located on Figure 3.

Table 1. *Selected assay results from Little Salmon Range area.*

ELEMENT SAMPLES	Occurrence	Yukon Minfile	UTM-E Zone 8, NAD27	UTM-N Zone 8, NAD27	Mo ppm	Cu ppm	Pb ppm	Zn ppm	Ag ppm	Ni ppm	Co ppm	Mn ppm	Fe %	As ppm	Cd ppm	Bi ppm	Ba ppm	Hg ppm	Au ppb
99MC002	Hwy		520106	6895429	11	764	230	15	8.4	96	104	202	11.84	91	1	51	17	<1	96
99MC033	Ulrike	105L 008	526600	6896300	1	169	4	92	<.3	18	8	1240	2.31	5	1	<3	12	1	<2
99MC076	Fu in carbonate		516362	6897438	1	2	<3	18	<.3	355	47	2675	4.21	626	2.6	<3	21	<1	2
99MC143	Unit 1 gossan		519160	6904664	2	8	5	9	<.3	16	25	155	2.85	6	0.7	<3	27	<1	6
99MC151	Jaspy		517497	6905592	3	1874	180	134	76	9	1	348	0.49	166	16.6	<3	2137	23	8
99MC198-A	Stud	105L 011	512436	6896854	6	138	8	3	0.7	24	28	154	1.42	40	<.2	<3	67	<1	33
99MC198-B	Stud	105L 011	512436	6896854	6	260	5	4	0.4	18	22	256	1.29	27	<.2	<3	352	2	16
99MRT021-1	Mel		507277	6908273	<1	50,814	<3	143	4.3	164	40	285	4.7	2	2.1	<3	208	2	46
99MRT021-2	Mel		507277	6908273	4	232	<3	31	<.3	9	3	1657	0.81	7	<.2	<3	143	1	<2
99MRT021-3	Mel		507277	6908273	<1	17,463	<3	192	3.2	217	56	397	6.42	2	2.6	<3	1091	1	46

Notes: Analyses completed by Acme Analytical Laboratories Ltd., Vancouver, B.C. Au by fire assay/ICP; all other elements by ICP. Fu: fuchsite.

Mortensen (1998; our Units 1 and 3). This succession has been mapped for ~20 km to the northwest and may well extend for another 20 km to the north-northwest (Campbell, 1967). A key element of this stratigraphic succession is the Little Salmon volcanic sequence (Unit 3) which hosts a massive sulphide occurrence and probable exhalative horizons. If this sequence can indeed be mapped for more than 40 km, then it would greatly increase the area of prospective stratigraphy for hosting volcanogenic massive sulphide deposits.

As described by Oliver and Mortensen (1998), rocks in the western part of the area (our Unit 2) are more heterogeneous and marker beds are more difficult to define. These rocks have evidently experienced a metamorphic history which is distinct from other stratigraphic assemblages in the area. Further work is required in order to establish the origin and tectonic significance of this earlier amphibolite facies metamorphism.

We have suggested that both Units 1 and 2 are unconformably overlain by the Little Salmon volcanic sequence (Unit 3). If this is correct, then what is the relationship between Units 1 and 2? Unit 1 has apparently not experienced the higher grade metamorphic event recorded in Unit 2. One hypothesis would be that Units 1 and 2 were tectonically juxtaposed prior to deposition of the Little Salmon volcanic sequence (Unit 3). If that is the case, then perhaps the structure bounding Units 1 and 2 served as conduit for the emplacement of volcanic rocks of Unit 3.

Finally, the identification of an allochthonous sheet of distal turbidite (Unit 4) raises another problem of regional significance: what is the origin of this allochthon? The presence of serpentinized ultramafic rocks along the basal thrust suggests that an ocean basin separated the turbidite sequence from rocks of the Little Salmon sequence. Additional work is required in order to resolve the depositional and kinematic history of this enigmatic sequence.

ACKNOWLEDGEMENTS

This report has benefited from discussions and comments by Don Murphy (Yukon Geology Program), Steve Piercey (University of British Columbia), Jim Mortensen (UBC), and the participants of the 1999 Ancient Pacific Margin NATMAP field trip, from which the guidebook in Appendix 1 was derived. Additional field assistance was provided by Kaori Torigai and Annie Daigle. Field visits by Steve Piercey (UBC), Steve Johnston (University of Victoria) and Don Murphy (YGP) were greatly appreciated. Thanks to Al Carlos, of Whitehorse, for sharing his knowledge of the area and for pointing out areas where the bush was particularly bad; we should have listened to you Al! Helicopter services were provided by Brian Parsons (Carmacks) and Grant Shannon (Ross River) of TransNorth Helicopters. Editorial comments by Don Murphy, Leyla T.D. Weston and Diane Emond have greatly improved this manuscript. Camp safety was provided by Jasper W.P. Colpron.

REFERENCES

Campbell, R.B., 1967. Geology of Glenlyon map-area, Yukon Territory (105 L). Geological Survey of Canada, Memoir 352, 92 p.

Colpron, M., 1999a. A new mineral occurrence in Yukon-Tanana terrane near Little Salmon Lake, central Yukon (NTS 105L/2). *In:* Yukon Exploration and Geology 1998, C.F. Roots and D.S. Emond (eds.), Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 255-258.

Colpron, M., 1999b. Preliminary geological map of Little Salmon Range (parts of NTS 105L/1, 2 & 7), central Yukon. Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, Open File 1999-2, 1:50 000 scale.

de Keijzer, M., Williams, P.F. 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 Sciences, vol. 39, p. 479-494.

Murphy, D.C., 1998. Stratigraphic framework for syngenetic mineral occurrences, Yukon-Tanana Terrane south of Finlayson Lake: A progress report. *In:* Yukon Exploration and Geology 1997, Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 51-58.

Oliver, D.H., 1996. Structural, kinematic, and thermo-chronologic studies of the Teslin suture zone, south-central Yukon Territory. Unpublished Ph.D. thesis, Southern Methodist University, 231 p.

Oliver, D.H. and Mortensen, J.K., 1998. Stratigraphic succession and U-Pb geochronology from the Teslin suture zone, south central Yukon. *In:* Yukon Exploration and Geology 1997, Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, p. 69-75.

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 (comp.), Geological Survey of Canada, Open Files D3826; also Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, Open File 1999-1(D).

Stevens, R.A., Erdmer, P., Creaser, R.A. and Grant, S.L., 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, vol. 33, p. 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, 27 p.

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, 1:2 000 000 scale.

APPENDIX 1

A FIELD GUIDE TO THE GEOLOGY OF YUKON-TANANA TERRANE ALONG ROBERT CAMBELL HIGHWAY (LITTLE SALMON LAKE), CENTRAL YUKON

The field trip starts at the old service area and highway maintenance station near Drury Creek, at the east end of Little Salmon Lake. The transect is covered by NTS maps 105L/1 (Truitt Creek) and 105L/2 (Snowcap Mountain) and preliminary geological map Open File 1999-2 (Colpron, 1999b). Field trip stops are located on Figure 3.

0.0 km Drury Creek highway station.

0.8 km Outcrop of coarse-grained arkosic grit (Unit 1).

1.2 km Eastern contact between Drury Pluton and grit unit (Unit 1).

3.0 km STOP 1: Park at access road to gravel pit on north side of the road.

Drury Pluton: Exposure of biotite ± hornblende granodiorite dated at 353 ± 1.4 Ma (U-Pb, zircon; Oliver and Mortensen, 1998). This pluton is relatively uniform in composition. It is typically fine- to medium-grained and equigranular, although locally, it contains K-feldspar phenocrysts. Here, the granodiorite is only weakly foliated (foliation dips moderately to the southwest); it is typically more strongly foliated near its margins. The Drury Pluton intrudes the arkosic grit (Unit 1) exposed at the next stop.

4.8 km Western contact of Drury Pluton.

5.4 km STOP 2: Park in front of outcrop on north side of the road (km 474).

Light grey, fine- to medium-grained arkosic grit/ sandstone intercalated with medium to dark grey quartz-muscovite-biotite schist. This outcrop (and the next one – approximately 700 m to the west – STOP 2b) is typical of rocks that comprise Unit 1 which underlie the eastern part of Little Salmon Range. In addition, the structural relationships along the east side of the cleavage fan are well displayed here. Early isoclinal folds are prominantly displayed on the south side of the highway. There, two crenulation cleavages are superposed; the earliest one is believed to be equivalent to dominant regional fabric that we will observe farther west. The second cleavage (shallower) does not appear to have a regional equivalent in the western part of this transect.

Rocks at the western end of the outcrop are more calcareous, and for the most part, extensively replaced by garnet-diopside-epidote-calcite skarn. The skarn contains trace sulphides (pyrite). A 1.5-m-wide gossan, containing 5- to 10 cm-wide quartz veins with disseminated pyrite-pyrhotite ± chalcopyrite, is present at the east end of the outcrop. From here, walk along road to STOP 2b, approximately 700 m west.

5.9 km Parking area for STOP 2b is on the north side of the road.

6.1 km STOP 2b

Coarse-grained, thickly bedded (10-50 cm) and poorly sorted arkosic grit interbedded with rare, dark grey carbonaceous phyllite horizons (1-2 m). The grit consist of <10% feldspar granules; the majority of clasts are smokey, white and blue quartz granules; a few clasts of light grey siltstone are locally present. The grit passes westward into a >50 m section of carbonaceous phyllite with minor sandstone beds. Foliation here dips moderately to the west.

6.8 km STOP 3: Park at the start of outcrop (before curve).

This outcrop consists of dark grey carbonaceous phyllite which passes gradually westward into a sequence of interbedded (5-10 cm) light grey phyllitic marble and black calcareous phyllite. The marble beds consist of poorly sorted carbonate granule to pebble conglomerate – a strong indication of the detrital origin of the carbonate. This appears to be the case for all carbonate units in the area. Although there is lack of sedimentary structures supporting this interpretation, the rhythmic nature of this sequence suggests deposition as limestone turbidites. A 1-2-m-thick horizon of light green siltstone is intercalated with the carbonate rhythmites.

The carbonate rhythmite sequence is overlain by thickly bedded (50 cm to 2 m), medium grey, coarsely crystalline marble. The large (~0.5 to 1 cm) calcite spar which characterizes this marble are most likely recrystallized echinoderm fragments; such fragments are locally well preserved in this outcrop. A sample from this outcrop yielded Ordovician (?) conodonts (Poulton et al., 1999). However, this age determination is inconsistent with other age constraints discussed above. The massive marble is overlain to the west by a finer grained, dark grey to black cherty marble. This, in turn, is overlain by another coarsely crystalline, poorly bedded (>2 m) marble.

These massive marble beds are strongly boudinaged at the scale of the outcrop, between less competent, more phyllitic horizons. At a first glance, this apparent strain partitioning may suggest that the more massive marbles are fault bounded. However, a closer examination reveals that this is most likely a coherent section of lithologies with varying competencies. The west end of the outcrop displays a large northeastverging fold; this fold is associated with the dominant regional phase of deformation.

7.5 km Outcrop of greenstone (Unit 3).

8.2 km STOP 4: Park near small borrow pit.

Volcaniclastic rocks (Unit 3): This outcrop, and the next one down the road, consist of rhythmically interbedded light grey to light green sandstone, carbonaceous phyllite, and brown-weathering calcareous schist. Exposures on the floor of the borrow pit exhibit convincing graded beds that indicate stratigraphic top to the west (see Fig. 5).

In the main roadcut to the west, the sandstone beds are generally thicker (~1.5 m) and coarser grained, and interbedded with dark grey and olive-green phyllite. The sandstone becomes more thinly bedded (~3-10 cm) upsection; dark grey phyllite is less abundant and the sandstone is typically more green in colour. One exposure of this unit, approximately 1.3 km to the northwest, contains well-preserved pumice fragments in a light green sandstone matrix. This is a good indication of the volcanic origin of the clastic rocks.

Here, the foliation dips moderately to steeply to the east, indicating that we have now crossed the axis of the cleavage fan.

10.2 km STOP 5: Park just before outcrop.

Intermediate volcanic rocks (Unit 3): This outcrop consists of intermediate to mafic metavolcanic rocks (medium green, massive chlorite-plagioclase-epdiote-biotite schist) which are locally intercalated with minor light green, banded calcareous schist, dark grey carbonaceous schist and marble. The abundance of plagioclase in this unit suggests an intermediate composition (andesitic). Outcrops of this greenstone up the hill display well-preserved (although strained) pillow structures and a mafic dyke swarm. At this locality, the greenstone commonly contains magnetite and is more chlorite-rich than exposures along the road, suggesting that it is in part of a more mafic composition.

On our way to the next stop, we will be passing a covered interval which conceals an important stratigraphic marker – a distinctive marble unit which occurs between a light green quartzite and phyllite unit to the east and a light to medium green calcareous schist unit to the west. One outcrop of this marble contains solitary and colonial corals which suggest a probable late Mississippian to mid-Pennsylvanian age of this unit. The colonial corals occur in discrete beds 10-20 cm thick, suggesting a detrital origin. Similarly, the solitary corals are randomly oriented, also suggesting transport. This marble unit constitutes the most important stratigraphic marker in this part of Yukon-Tanana Terrane. It is considered equivalent to the carbonate rhythmite sequence that occurs at STOP 3.

11.7 km Park here for STOP 6 – located 300 m down the road.

12.0 km STOP 6: Little Salmon showing (Cu).

This outcrop consists of meta-rhyolite and contains the massive sulphide occurrence discovered by Don Murphy in 1998 and for which a preliminary description is given by Colpron (1999a).

The east end of the outcrop consists of quartz-feldspar meta-porphyry which grades to the west into more massive meta-rhyolite with fewer quartz-eyes. As the sulphide-rich zone is approached, the meta-rhyolite is altered to chlorite + epidote and locally contains magnetite veins. The sulphide zone itself, which is approximately 3 m wide, consists of semi-massive pyrite-magnetite-chalcopyrite horizons in a chlorite + quartz matrix. Another zone of non-magnetic massive sulphides, less than 1 m wide, occurs in a small isolated outcrop just to the west of the main roadcut. Assays from this occurrence returned Cu values of ~600 ppm and background values for other metals (Colpron, 1999a). The extensive chloritic alteration and anomalous Cu concentrations of the mineralized zone suggest that it may have formed in a sub-seafloor hydrothermal system.

The meta-rhyolite thins to the northwest, where it has been traced for approximately 3 km. It occurs at the contact between (1) a calcareous schist unit consisting of light to medium green quartz-muscovite-chlorite schist intercalated with ~10-cm-thick, buff-weathering dolomitic marble and minor pink calcareous quartzite (structurally above the meta-rhyolite); and (2) a light grey to light green quartzite (structurally below the meta-rhyolite; see Fig. 8). Near the road, the quartzite is generally coarse-grained and glassy. It is underlain (structurally) by a sequence of black marble and felsic schist which gradually passes into schistose marble and pebble to cobble conglomerate with a psammitic matrix.

Preliminary U-Pb zircon date indicates a mid-Mississippian age for the meta-porphyry (Mortensen, pers. comm., 1999).

13.3 km STOP 7

The first outcrop consists of a pebble conglomerate where clasts of quartz, K-feldspar, phyllite, dolomitic siltstone, dark grey marble and felsic metavolcanic rocks (?) are hosted in a fine-grained quartzite matrix. To the west, the rock becomes more schistose and darker in colour with only rare clasts. It is for the most part a carbonaceous schist with few horizons (<10 cm) of dark grey quartzite and buff-weathering dolomitic marble. A few metres above the road, outcrops in the bush reveal excellent exposures of a cobble to boulder, matrix-supported polymictic conglomerate (see Fig. 9). The clasts are sub-angular to rounded; the matrix consists of carbonaceous and calcareous schist.

14.9 km STOP 8: Park immediately after outcrop

This outcrop, and the next one to the west, are characteristic of the heterogeneous sequence of rocks which is exposed along the western half of the transect. It consists of light to medium grey quartzite and psammitic schist, medium and dark grey carbonaceous muscovite-quartz schist, and light green chloritic schist and quartzite. These rocks are commonly calcareous; thin horizons of marble are locally present (but not in these roadcuts). Another important feature of this lithologic package is the abundance of orthogneiss bodies within it. These are commonly only a few metres thick (i.e. not mappable) and usually discontinuous. Examples of orthogneiss lithologies will be seen at STOP 9 and 12.

The foliation in the first outcrop is locally of mylonitic character. Exposures above the road show lenticular distribution of these lithologies – could this be a fault zone? The next outcrop to the west displays 3 tectonic fabrics: an early schistosity is defined by alignment of micas in microlithons of the dominant, penetrative schistosity. The dominant fabric is in turn deformed by a northwest-striking crenulation cleavage. Small isoclinal folds of calcareous horizons are present in this outcrop – these have the dominant foliation in their axial plane. Both senses of asymmetry are recorded by these minor folds.

The rocks in these outcrops (like most of the rocks along the western part of the transect) have a different metamorphic history than those to the east. These roadcuts show evidence for an amphibolite grade metamorphic event now retrograded to greenschist facies. This is best shown by the occurrence of partially to totally retrograded garnet porphyroblasts. These porphyroblasts are syn- to post-tectonic. Calcareous rocks commonly have randomly oriented actinolite clusters. More evidence for this higher grade metamorphic event will be observed at STOP 11, farther west.

19.9 km STOP 9

This outcrop consists of light to medium green quartz-biotite-chlorite psammitic schist, medium green quartz-plagioclase-chlorite-biotite ± epidote ± muscovite calcareous schist, light grey quartz grit and white marble. At the west end of the outcrop, the marble is silicified and partially replaced by epidote ± diopside. This calc-silicate alteration is similar to that observed at the Stud occurrence (Yukon Minfile, 1997, 105L 011), a few hundred metres to the northwest, where disseminated pyrite occurs with the calc-silicate minerals. This calc-silicate alteration is interpreted as skarn in the aureole of a probable Mississippian intrusion (similar to that observed at Stop 2). The next two outcrops to the west (~300 m) consist of foliated quartz-plagioclase-chlorite-muscovite ± epidote orthogneiss (quartz diorite).

25.7 km STOP 10

Snowcap Pluton: This outcrop consists of medium-grained, equigranular biotite granite typical of the Snowcap Pluton. A Cretaceous age is assigned to this granite based on a K-feldspar $^{40}Ar/^{39}Ar$ integrated age of 85 Ma (Oliver, 1996).

28.2 km STOP 11

This stop presents further indications for an earlier amphibolite facies metamorphic event in rocks of Unit 2. The outcrop consists of a fine-grained, quartz-plagioclase-muscovite-biotite ± chlorite schist which contains randomly oriented, rectangular clusters of silvery muscovite. These rectangular clusters are interpreted to be muscovite pseudomorphs after an aluminosilicate phase. The eastern portion of the outcrop contains abundant chlorite pseudomorphs of garnet, similar to those observed at Stop 9 and shown in Figure 12.

29.6 km STOP 12

This outcrop consists of fine- to medium-grained, dark green, chlorite-epidote-plagioclase ± muscovite ± hornblende ± biotite mafic orthogneiss, intercalated with thin (5-10 cm) quartzite layers. The orthogneiss locally contains pyrrhotite ± magnetite. It becomes more mica-rich (muscovite ± biotite) to the east, where quartzite is more abundant. This outcrop is part of a larger body of mafic orthogneiss; the quartzite probably represents xenoliths of country rock with mica enrichment indicating partial assimilation of the sedimentary rocks.