# Ancient Pacific Margin Part VI
# Still Heading South: Potential VMS Hosts in the Eastern Dorsey Terrane, Jennings River (104O/1; 7, 8, 9, 10)

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**KEYWORDS:** *Mississippian, Dorsey Terrane, Yukon Tanana Terrane, northern British Columbia, volcanogenic massive sulphides.*

## INTRODUCTION

The goal of this project is to trace out, within central northern B.C., stratigraphy favorable to the formation of Early Mississippian volcanogenic massive sulphide deposits similar to Kudz Ze Kayah, Wolverine, and Fyre Lake, which are hosted by the Yukon-Tanana Terrane in the Finlayson Lake belt of central Yukon. Begun in 1997, the project has focussed on two areas, the eastern Dorsey Terrane near the headwaters of the Cottonwood River in central Jennings River map area (Figure 1; Nelson *et al*., 1998a, Nelson, 1999), and the Big Salmon Complex (Mihalynuk *et al*., 1998 and this volume). Fieldwork in the eastern Dorsey Terrane in 1999 extended the area of coverage south into 104O/1, and taking advantage of the expertise and logistical support provided by the new An-

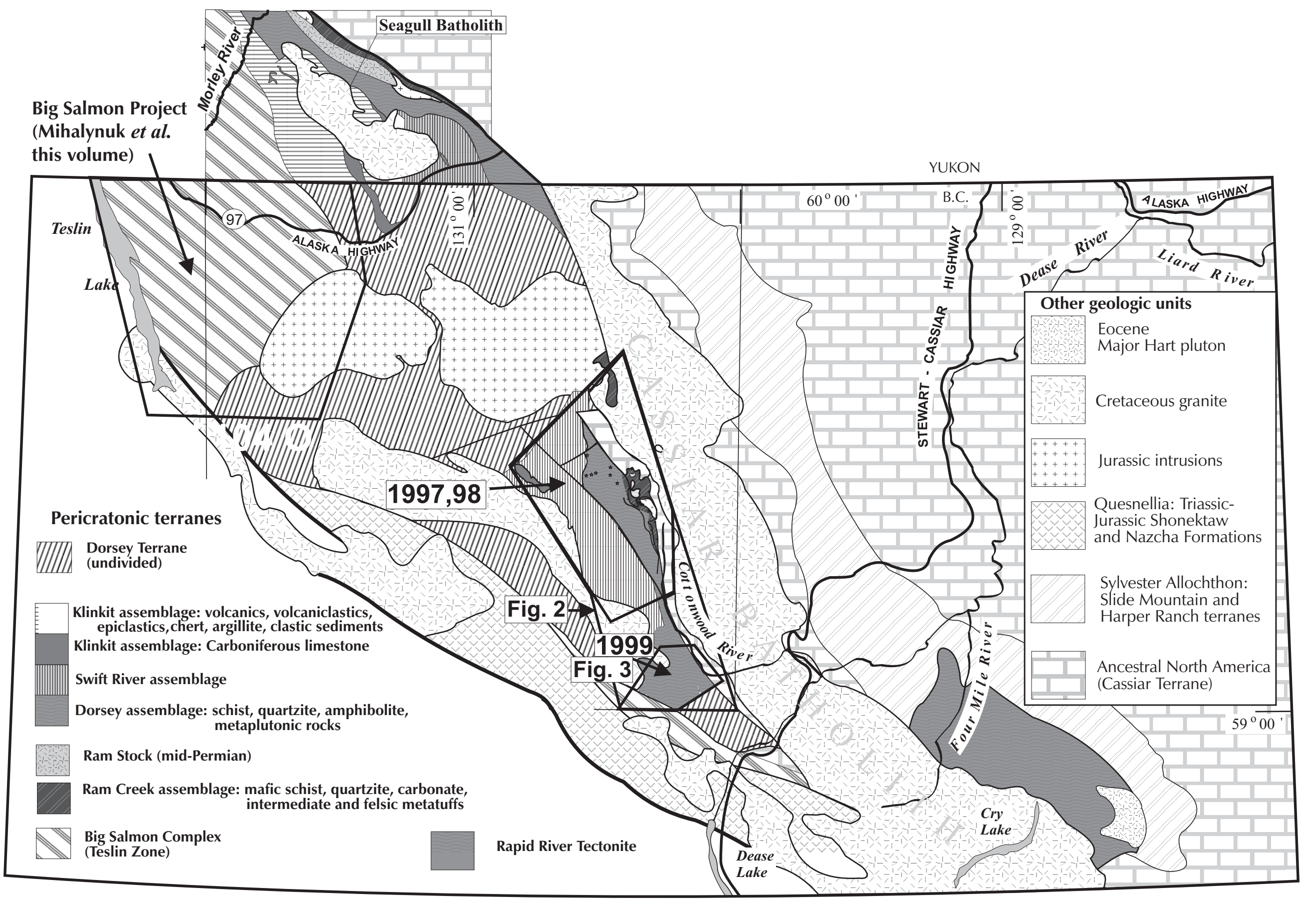


Figure 1. Location and tectonic setting of the southeastern Dorsey Terrane project. Regional geology from Gabrielse (1963, 1969, 1994) and Stevens and Harms (1995).

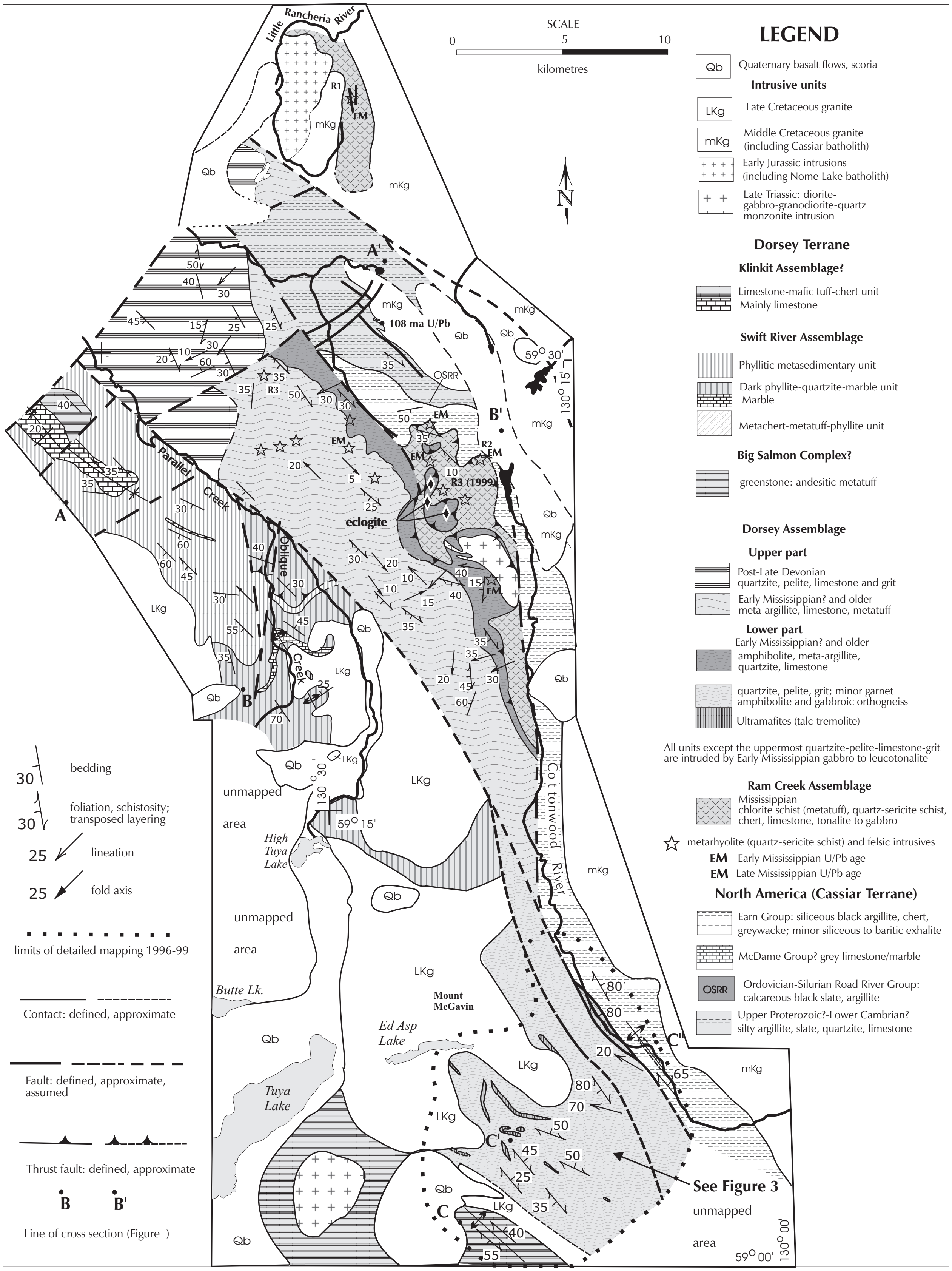


Figure 2. Geology of the area near the headwaters of the Cottonwood River and Parallel Creek (104O/7, 8, 9, 10). Based on 1999 mapping by J. Nelson, M. Mihalynuk, M. DeKeijzer, C. Roots, and P. Erdmer; 1998 mapping by J. Nelson, W. Zantvoort, T. Gleeson and K. Wahl; 1997 mapping by T. Harms, J. Nelson, and M. Mihalynuk; 1996 mapping by J. Nelson; and Gabrielse (1963).

cient Pacific Margin Natmap Project, completed the area covered in 1997-98 with specialized, problem-oriented traverses. A map covering parts of 104O/7, 8, 9 and 10 is now published as an open file (Nelson *et al*., 2000). This report first summarizes the results of a month's new field mapping in 104O/1, and then presents new field and geochronological data that modify and refine geological interpretations from the the 1997-98 map area.

In the central Jennings River map area, the well-exposed basal contact of the Dorsey Terrane rests structurally on metamorphosed basinal strata of the Cassiar Terrane, the western edge of the North American passive continental margin (Nelson *et al*., 1998). Following the usage of Harms and Stevens (1996) the eastern and central Dorsey Terrane has been divided into four assemblages (Figure 2). From most easterly and structurally lowest they are: the Ram Creek, Dorsey, Swift River and Klinkit assemblages. It should be pointed out that the Dorsey Assemblage is a sub-unit of the Dorsey Terrane.

The Ram Creek Assemblage, previously designated the "greenstone-intrusive unit", is confirmed to be of Mississippian age on the basis of three new U/Pb ages on quartz-sericite schist and tonalite. It is interpreted as a Mississippian arc edifice, with a varied volcanic to epiclastic suite ranging from andesite to dacite and rhyolite, accompanied by limestone patch reefs and basinal chert/tuff sequences, all intruded by coeval intermediate plutons. It is comparable to the suite of rocks that hosts VMS deposits in the Yukon-Tanana Terrane near Finlayson Lake, Yukon (Mortensen and Jilson, 1985; Hunt, 1997; Murphy and Piercey, 1999, 2000).

The Dorsey Assemblage, the "metasediment-amphibolite unit", like the Ram Creek Assemblage, is intruded by early Missisippian intermediate to felsic plutons. Unlike the Ram Creek, protoliths and the record of metamorphic/tectonic events in it also predate the early Mississippian. Penetrative ductile fabrics in quartzite and metatuff are cut by the intermediate to felsic intrusions, and eclogite facies metamorphic assemblages are overprinted by those formed at amphibolite grade. The Dorsey Assemblage is overlain structurally by the "metachert-metatuff-phyllite unit", which is assigned to the Swift River Assemblage. This assemblage, which also includes the "dark phyllite-quartzite-marble unit" and the "phyllitic metasedimentary unit" southwest of Parallel Creek (Figure 2), shows lower metamorphic grades and somewhat less intense penetrative deformation than the upper Dorsey assemblage. A large body of limestone and associated mafic metatuff and chert overlies metachert and phyllite of the Swift River Assemblage in the northwestern corner of the map area (Figure 2). This "limestone-tuff-chert unit", considered part of the Klinkit Assemblage, lies on strike with Klinkit limestones north of Klinkit Lake (unit 11g, Gabrielse, 1969).

Mapping in 1999 extended into the southwestern Dorsey Terrane. Greenstones in the mountains southeast of Tuya Lake, tentatively assigned to the Triassic Shonektaw Formation by Gabrielse (1969), strongly resemble metabasalts of the Big Salmon Complex east of Teslin Lake (Mihalynuk *et al.*, this volume). The greenstones near Tuya Lake are separated by a Late Cretaceous granite from lower Dorsey Assemblage metamorphic rocks (Figure 2, 3).

## MAPPING IN SOUTHEASTERN JENNINGS RIVER (104O/1)

Mapping of a part of 104O/1 (between the Cottonwood River and Tuya Lake; Figure 3) in 1999 tested strike continuity of units identified in 1997-1998 mapping farther north (Figure 2), and established a partial east-west cross section of the southern Dorsey Terrane. From east to west the following units are exposed: Earn and McDame group equivalents of the westernmost Cassiar Terrane; highly deformed metadiorite; a metamorphic complex of quartzite, grit and pelite with minor ultramafites and metabasites that resembles the lower part of the Dorsey Assemblage; and metabasalts similar to those of the Big Salmon Complex. All of these units are juxtaposed across high-angle faults. In the valley of the Cottonwood River, major northwest-trending faults are accompanied by gently plunging lineations in nearby outcrops. They are probably splays of the Cassiar fault.

### North American Marginal Strata (Earn and McDame Groups)

Outcrops along and east of the Cottonwood River are dominated by dark grey to black phyllite and argillite, with lesser dark grey grit and limestone. These rocks are assigned to the Earn Group based on lithologic similarity to its exposures along strike to the north, except for one band of pure grey limestone that may represent the McDame Group. It occurs as a relatively wide, northwest-trending antiformal hinge zone that is best exposed along the banks of the Cottonwood River just below its confluence with Ed Asp Creek (Figure 3). Earn Group exposures typically weather very rusty, due to finely disseminated pyrite. Small grains of andalusite indicate that these rocks have been metamorphosed at low to moderate pressures, like the Earn Group and underlying strata near the headwaters of the Cottonwood River (Nelson *et al*., 1998).

One small subcrop of yellow-white, pyritic chert-barite exhalite was discovered on the northeastern shore of Scaup Lake, a small lake 2 kilometres east of the Cottonwood River (Figure 3). A representative grab sample contains 23,000 ppm (2.3%) barium, along with somewhat anomalous copper (80 ppm) and zinc (154 ppm, INAA; Table 1). The presence of such exhalites allies these rocks with those on the COT claims 5 kilometres south of the Cottonwood River headwaters, where baritic exhalites and anomalous base metals are a recurrent feature within the Earn Group (Nelson, 1997).

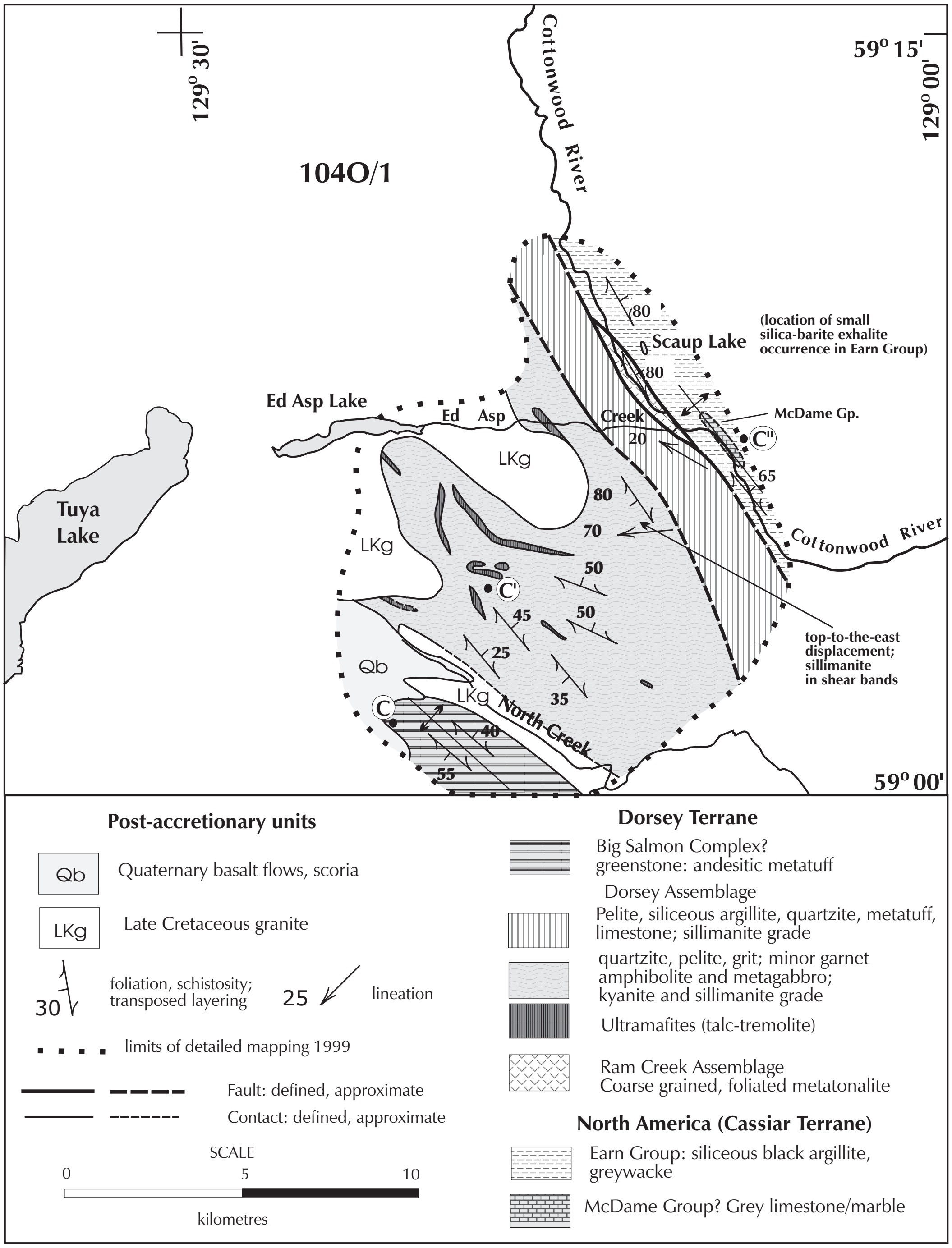


Figure 3. Geology of part of 104O/1. Based on 1999 mapping by J. Nelson and K. Wahl.

## Deformed Metadiorite: Ram Creek Assemblage?

Along the Cottonwood River canyon near Ed Asp Creek, Earn Group phyllites and argillites lie in fault contact with a lensoid body of dark green, coarse grained, highly foliated and lineated metadiorite (Figure 3). Its appearance in outcrop is distinctive, with dark green actinolite and biotite streaks standing out in a paler green matrix. This lensoid body can be traced over 5 kilometres in strike length, but is only 500 metres across. Its western contact is a fault against metamorphic rocks of the Dorsey Assemblage. The metadiorite is somewhat variable in texture and composition, ranging from very dark green metagabbro to lighter, more felsic diorite. Mafic minerals have been replaced by elongate smears of actinolite, perhaps due to strike-slip motion on its bounding faults. It resembles metadiorites and metatonalites of the Ram Creek Assemblage near the headwaters of the Cottonwood River.

**TABLE 1**
**ANALYSIS OF ROCK SAMPLE OF SILICA-BARITE EXHALITE, SCAUP LAKE**

| Element | Au | Ag | Cu | Pb | Zn | Zn | As | Ba | Ca | Co | Cr | Fe | Rb | Sb | Sc | La | Ce |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Units | PPB | ppm | ppm | ppm | ppm | PPM | PPM | PPM | % | PPM | PPM | % | PPM | PPM | PPM | PPM | PPM |
| Method | INA | AICP | AICP | AICP | AICP | INA | INA | INA | INA | INA | INA | INA | INA | INA | INA | INA | INA |
| Lab. | ACT | ACM | ACM | ACM | ACM | ACT | ACT | ACT | ACT | ACT | ACT | ACT | ACT | ACT | ACT | ACT | ACT |
| Dect'n Limit | 2 | 0.3 | 1 | 3 | 1 | 50 | 0.5 | 50 | 1 | 1 | 5 | 0.02 | 15 | 0.1 | 0.1 | 0.1 | 3 |
| **99JN1-4** | **-2** | **1.6** | **80** | **5** | **111** | **154** | **4.2** | **23000** | **5** | **19** | **251** | **3.69** | **98** | **1** | **30.4** | **21.2** | **34** |

**Notes**

Analysis of steel milled @ GSB. Sample. Fe (200-300 ppm) and Cr contamination possible

INA - Thermal neutron activation analysis

ACT - ActLabs, Ancaster, Ontario.

AICP = Aqua regia digestion-ICPES

ACM = ACME Analytical

BAL - Balance

## Dorsey Assemblage

Metamorphic rocks occupy most of the mapped area between the Cottonwood River and North Creek (Figure 3). This unit is a fairly monotonous sequence of quartzite, pelite, and grit, including about 2% ultramafite and garnet amphibolite as small lenses and thin tabular bodies (Figure 2, 3). The sequence has undergone Barrovian metamorphism, with biotite-muscovite- plagioclase+ kyanite+sillimanite developed in pelites and quartzites, and coarse tremolite-talc in ultramafites. These thoroughly metamorphosed rocks retain little of their protolith textures, and distinctions between, for instance, granite and grit, are not trivial. All but a possible few of the quartz-plagioclase-mica layers are interpreted as grits, based on the paucity of plagioclase (typically 5-15%), and by their repetitive interlayering with muscovitic quartzite. Photo 1 shows a particularily convincing example of a quartz-pebble conglomerate from the siliciclastic sequence.

Ultramafites and garnet amphibolites form a minor but persistent and characteristic part of the package, occurring as tabular bodies and lenses parallel to layering in the metasediments. The ultramafic bodies are thin but laterally continuous: the longest has a strike length of 3 kilometres. In one ridge-top exposure, ultramafite contains a texturally intact gabbro pegmatite body with comb-textured hornblendes up to 10 cm long. The ultramafites and amphibolites have undergone the same metamorphic and deformational history as the surrounding metasediments; thus their emplacement or juxtaposition must have been a relatively early stage event.

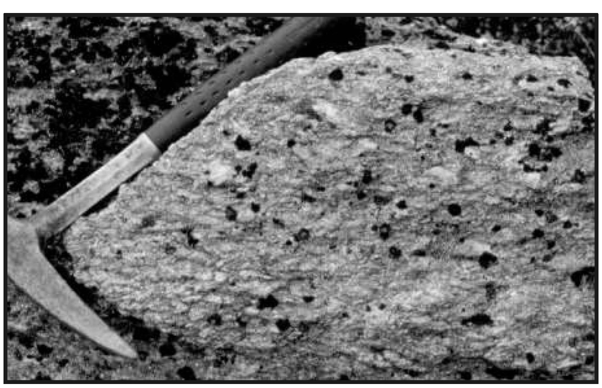

Photo 1. Quartz-pebble conglomerate from a quartzite-grit succession in the Dorsey Assemblage near Ed Asp Lake.

### *Metamorphism*

Garnets are ubiquitous, accompanied by calcic plagioclase (An 30-50), biotite and muscovite in the metamorphosed siliciclastic rocks, and by dark green hornblende±biotite in the garnet amphibolites. Ultramafites are coarse grained assemblages of radiating tremolite and interstitial talc. Bright green actinolite in talc, and massive biotite form discontinuous "blackwall" at their margins.

Kyanite is rare in the metasediments. It forms prisms and, in one sample, strained, recrystallized aggregates with irregular extinction. All kyanite is pre-kinematic, deeply corroded and heavily mantled with muscovite (Photo 2). By contrast, fibrolitic sillimanite grows within syn-kinematic muscovite as well-oriented sheafs and bundles. It also forms sprays of radiating fibres that cut across the foliation. In one key sample, 99JN9-3A, fibrolite is deformed by, and also grows within, top-to-the-east shear bands (Photo 3; location on Figure 3). The succession of kyanite to sillimanite indicates pressure-temperature conditions above the aluminosilicate triple point.

Garnet amphibolites contain pre-kinematic garnet, synkinematic hornblende and in some samples, biotite, plagioclase, and blobby sphenes with tiny relict rutile and ilmenite grains in their cores. In once instance, clinopyroxene is present. These strongly resemble the garnet amphibolites elsewhere in the lower Dorsey Assemblage (Nelson 1999), which are now considered to represent retrograde metamorphism of original eclogite facies assemblages. As is the case farther north, amphibolite-grade metamorphism was complete prior to the juxtaposition of these rocks with the greenschist-grade

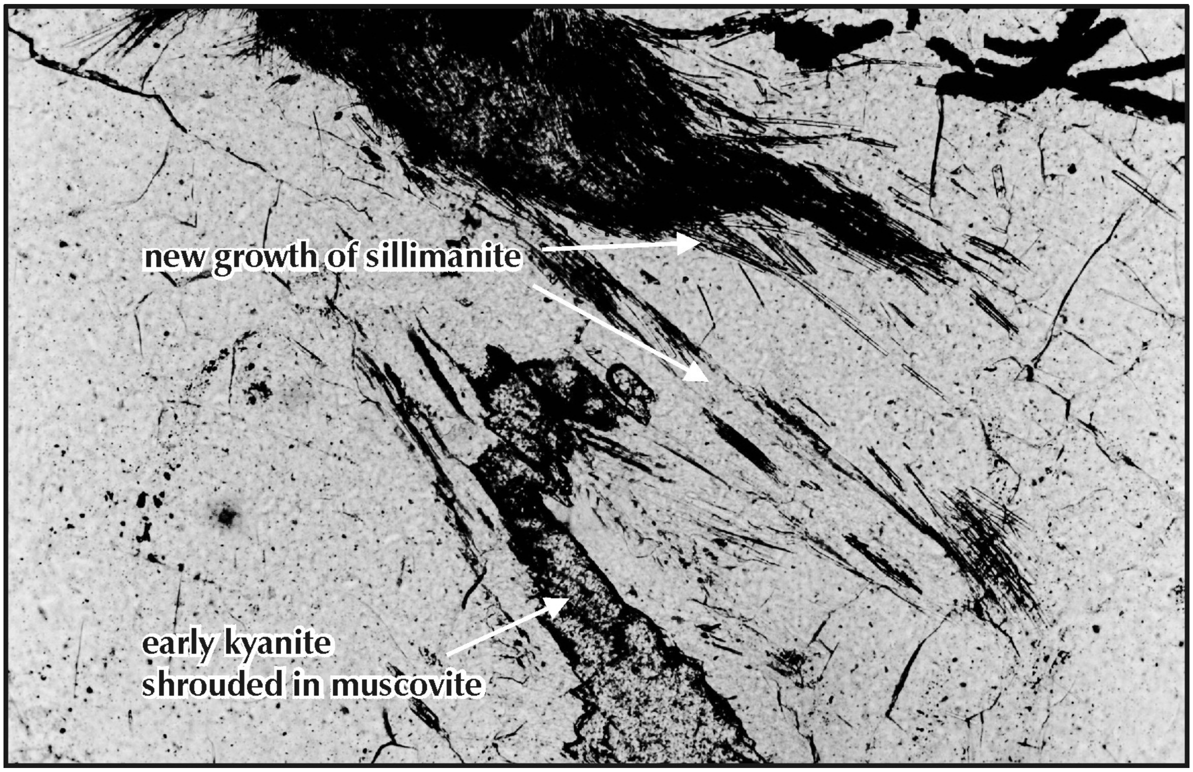


Photo 2. Early kyanite and later sillimanite in metamorphosed impure grit, Dorsey Assemblage near Ed Asp Lake (Field of view 2 X 4 mm).

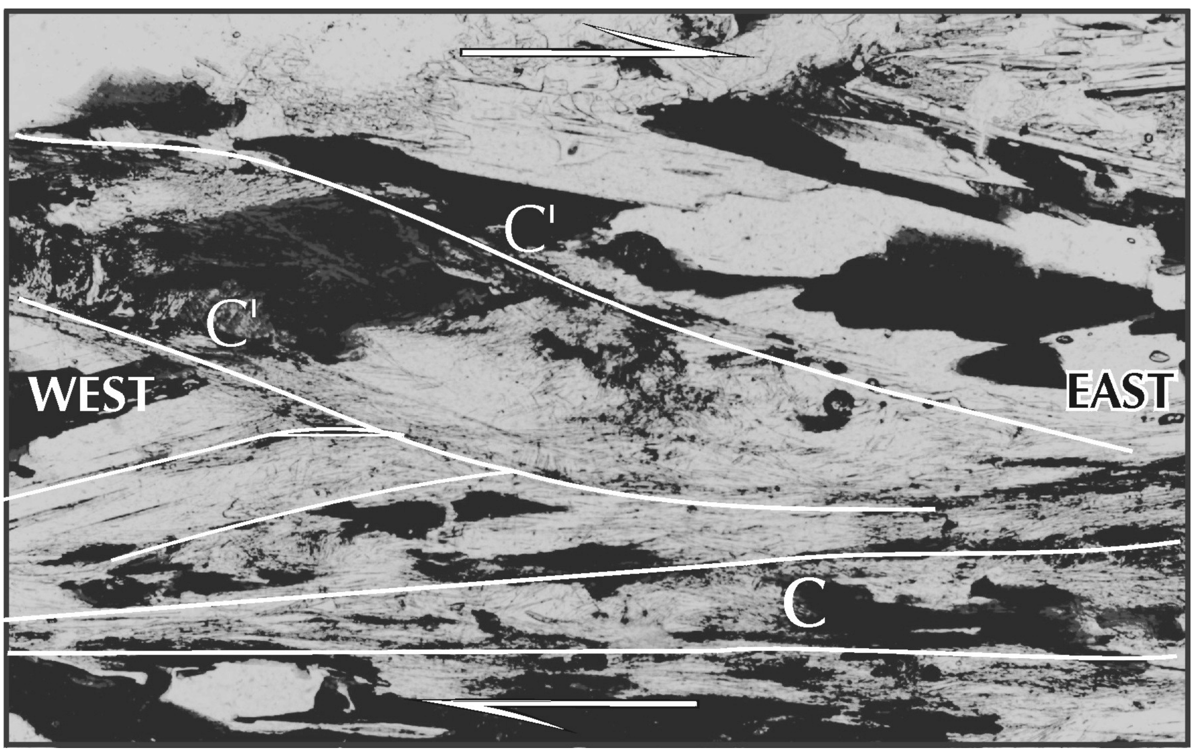


Photo 3. Top-to-the-east shear bands involving metamorphic sillimanite from locality southeast of Ed Asp Lake (Field of view 2 X 4 mm).

metatonalite and the Earn Group, which contains metamorphic andalusite.

### *Interpretation*

The metamorphic sequence in 104O/1 between the Cottonwood River and North Creek is assigned to the lower Dorsey Assemblage, based on its metamorphic grade and the presence of garnet amphibolite and ultramafite. Although minor exposures of pelite and quartzite with garnet amphibolite occur near the base of the Dorsey Assemblage between 3 and 12 kilometres south of the Cottonwood River headwaters, this broad region of dominantly coarse, silicicliclastic sediments is unusual in the Dorsey Assemblage and indeed in the Dorsey Terrane as a whole. The area is also anomalous in the widespread preservation of original metamorphic assemblages. The chlorite overprint that is pervasive farther north is not developed here, and thus these rocks provide a window into the early high-grade metamorphic history of the Dorsey Assemblage.

The association of coarse siliciclastic metasediments with minor, thin, layer-parallel ultramafic to mafic bodies poses a conceptual problem. Are the ultramafites and metabasites mantle materials that mark thrust faults? In this case, why does the rock sequence not change across them? What tectonic environment is being telescoped: one of pure quartzite and grit deposited across an ophiolitic basement? Alternatively, could the ultramafites and garnet amphibolites have been sills and dikes within a continental sequence, as described within the Late Proterozoic Horsethief Creek Group by Sevigny (1988)? Petrochemical studies in progress will give clues to the origin of these rocks.

## Big Salmon Complex?

Dark green metatuffs on the southwestern side of North Creek are separated from the Dorsey Assemblage by an elongate, northwesterly striking granite body. Although this unit was tentatively assigned to unit 17, the Shonektaw Formation, by Gabrielse (1969), it bears little resemblance either in original volcanic textures and mineralogy, or in metamorphic and structural history to typical Shonektaw exposures. Protoliths for these rocks were a monotonous sequence of laminated tuffs, some with very small plagioclase crystals. Conspicuously absent are the augite phenocrysts so typical of Triassic volcanics of Quesnellia. Layering in the tuffs has been transposed, and the transposition fabric outlined by actinolite, albite, epidote and chlorite is itself refolded. Yellow-green stripes of epidote subparallel to compositional laminations are common.

The metatuffs are intruded by small bodies of gabbro-diorite with highly variable composition and texture. They range from pegmatitic to diabasic, from seriate porphyritic to coarse-grained equigranular, and from hornblende-dominated to equal abundance of hornblende and plagioclase. These variations occur over as little as a few metres. The intrusive rocks are foliated, but they cross-cut the intense transposition fabric of the metatuffs. They in turn are cut by unfoliated, fine grained, acicular hornblende-phyric andesite dikes. The gabbro-diorite and acicular hornblende porphyries are texturally like Triassic and Jurassic intrusive rocks seen elsewhere in the Dorsey Terrane, as well as in Quesnellia. They also resemble gabbros near Logjam Creek in northern Jennings River area, which are now known to be early Mississippian (Gleeson *et al*., this volume). If either correlation is correct, then the metatuffs are most likely Paleozoic, since they were deformed and metamorphosed prior to emplacement of the intrusions.

The laminated and epidote-striped textures of the metatuffs are like those of the greenstone unit of the Big Salmon Complex near Logjam and Two Ladder Creeks (Mihalynuk *et al*., 1998). Mapping in 1999 (Mihalynuk *et al*., 2000) has shown that this unit extends at least as far south as the Jennings River and east to Butsih Creek (latitude 59$^{o}$30'), roughly on strike with the North Creek metatuffs. It is possible that the greenstone unit lies along the southwestern margin of the Dorsey Terrane throughout the Jennings River map area. In northern Jennings River and Wolf Lake map areas this unit is highly prospective for volcanogenic massive sulphide deposits (Roots *et al*., 2000; Mihalynuk *et al*., this volume). It hosts occurrences of quartz-sericite schist, some accompanied by multi-element soil geochemical anomalies (Ed Balon and Wojtek Jakubowski, personal communication 1998, 1999), and it is directly overlain by manganese-barium-bearing, metamorphosed siliceous exhalite, the crinkled chert unit of Mihalynuk *et al*. (1998).

Although it is now invaded by a Late Cretaceous granite, the precursor contact between the greenschist-facies metatuff unit and the amphibolite grade siliciclastic Dorsey Assemblage is interpreted to have been a steep west-side-down fault.

### *Late Cretaceous granite*

Both the Dorsey Assemblage and metatuff unit are intruded by granitic plutons, apophyses of the Parallel Creek batholith (Gabrielse 1969). This body has yielded a biotite K-Ar age of 78+4 Ma (GSC 67-14). The granite is medium grained, mostly equigranular, with biotite and muscovite. It is unfoliated to very weakly foliated; its apophyses interfinger extensively with the metamorphic country rocks. The granite body at the head of North Creek has a gently convex upper contact that has domed the layered rocks above it (Figure 3 and cross section 4c). Structural attitudes in the Dorsey Asemblage are deflected to northeasterly to the south of this dome, indicating forceful diapiric emplacement of the intrusion.

## Structure

The gross structure of 104O/1 differs from that farther north (*see* Nelson, 1999, and discussion in following section of this paper). Near the headwaters of the Cottonwood River, layered rocks overall dip gently to moderately southwest and major thrust contacts are less steep than layering within units (Figure 4 A-A' and B-B'). The Ram Creek and Dorsey/Swift River/Klinkit assemblages form a gently southwest-dipping stack, a geometry that reflects their emplacement as allochthons onto the margin of the Cassiar Terrane. By contrast, layered sequences of Cassiar Terrane and Dorsey Assemblage in 104O/1 form a set of homoclinal, steep northeasterly dipping panels (Figure 4, C-C'-C''). Intact, top-to-the-east shear sense indicators near the base of the Dorsey Assemblage in 104O/1 (Figure 3, photo 3) suggest that this configuration represents the overturning of a once gently-dipping east-verging thrust sequence like that shown in Figure 4, sections A-A' and B-B'.

Minor structures were formed during two phases of deformation. Geometrically these show identical expressions in the North American rocks, the metadiorite, and the Dorsey and Big Salmon(?) assemblages. $D_1$ created transposition fabrics in all of the units, isoclinal intrafolial folds, and mineral lineations. Although no major $D_1$ folds are recognized, the great apparent thickness of Dorsey Assemblage metasediments, and converging trends of some of the ultramafic bodies suggest that they are present (Figure 3). Minor linear elements show a contour density peak at 331°/15° and a subsidiary peak of steep westerly plunges at 270°/75 °(Figure 5). Streaky biotite lineations in the sample in which fibrolite displays top-to-the-east shear (Photo 3) belong to the steeply plunging population, with an orientation of 266°/66°.

Actinolite and biotite streaks in the metadiorite exposed along the Cottonwood River (Figures 3 and 5) plunge gently to the northwest. They are geometrically and mineralogically like $D_1$ linear structures; however their intense development in proximity to cataclastic zones interpreted as major steep faults suggests that they may have developed during late transcurrent motion. No kinematic indicators were observed associated with them.

The second deformational event, $D_2$, folds the transposition fabrics. Outcrop-scale open to close folds are common in quartzites of the Dorsey Assemblage. A mountain-scale open synform affects the Big Salmon(?) greenstone southwest of North Creek. McDame Group(?) limestone is exposed in an open antiformal culmination cut by the Cottonwood River. Minor folds show a well-developed contour density peak at 322°/06°. Southwesterly

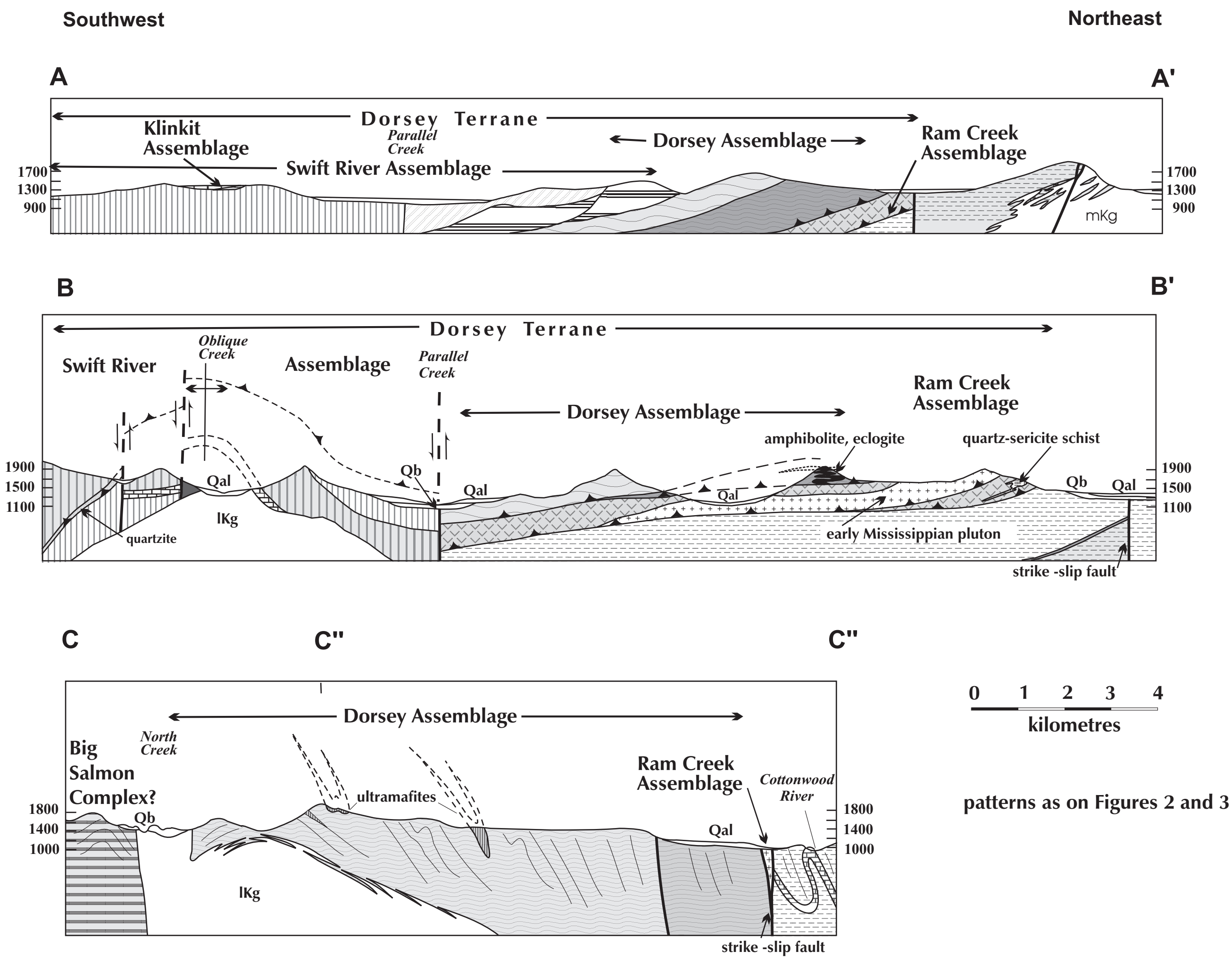


Figure 4. Cross sections of the eastern Dorsey Terrane and western edge of the Cassiar Terrane; locations on Figures 2 and 3.

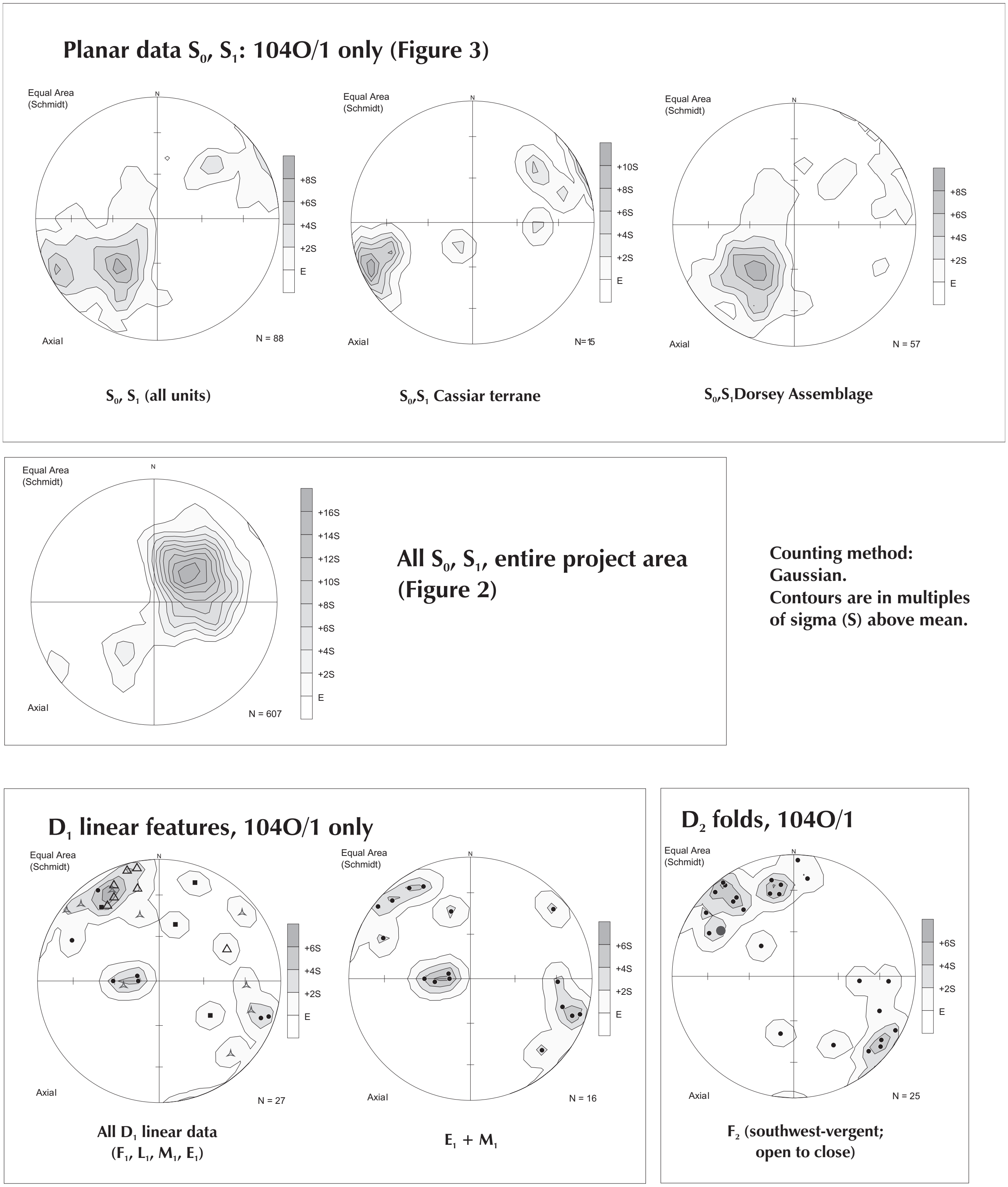


Figure 5. Structural data from 104O/1.


Photo 4. Southwest-verging outcrop-scale fold in Dorsey Assemblage quartzites ($D_2$).

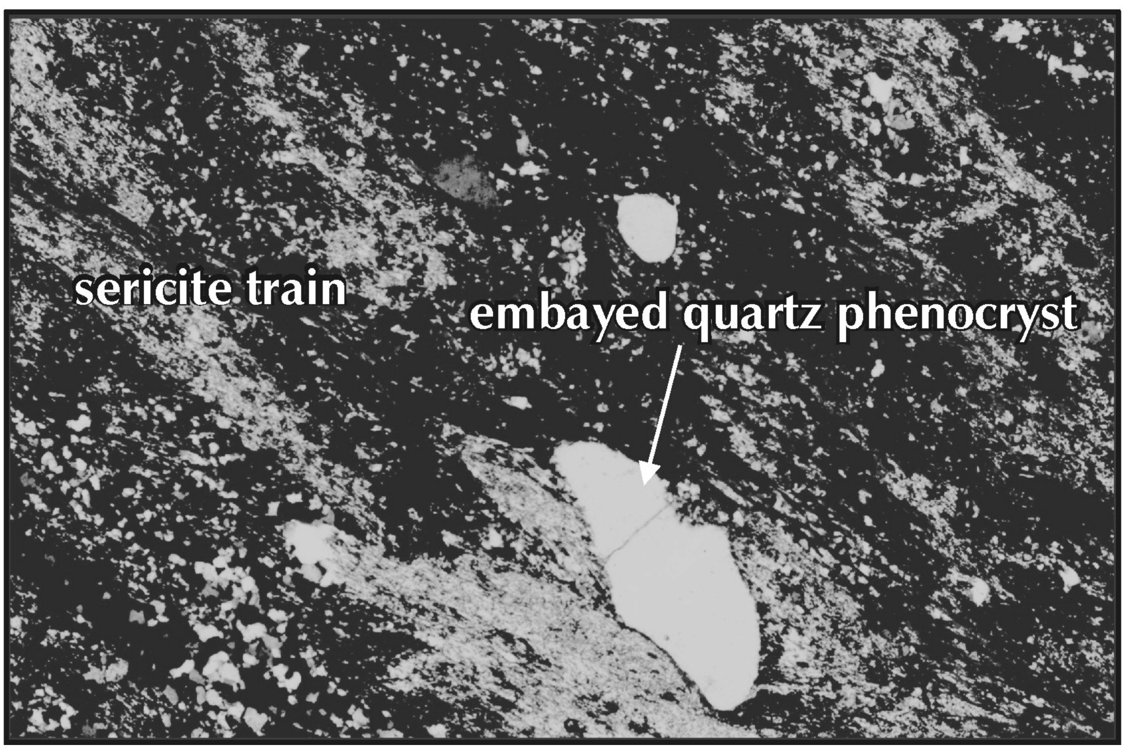


Photo 5. Photomicrograph of quartz-phyric quartz-sericite schist in the upper Ram Creek Assemblage (Field of view 2 X 4 mm).

vergences dominate in the Dorsey Assemblage (Photo 4). Thin, weakly foliated granite sills are affected by the $D_2$ deformational event. One of them was collected for uranium-lead dating.

$D_2$ is not recognized along strike farther north along the Cottonwood River. The southwesterly vergences associated with it may relate to the inferred post-accretion southwesterly overturning of the sequence that makes the cross section in this area so different from those farther north (Figure 4). The cause for this difference is unclear. It could have arisen from local transpression related to the regional Cassiar Fault.

## NEW DATA AND INTERPRETATIONS RELEVANT TO 1998 MAP AREA (104O/ 7, 8, 9, 10)

The joint field program afforded by the Ancient Pacific Margin Natmap in August 1999 brought a strong scientific team to bear on some of the outstanding geological problems in the 1998 map area. New radiometric data obtained in 1999 have strengthened our interpretations of some of the map units, in particular the potentially economically significant Ram Creek Assemblage. These new results and conceptual advances are summarized here, as an update to Nelson (1999) and accompaniment to the open file map (Nelson *et al*., 2000).

### Ram Creek Assemblage

The Ram Creek Assemblage has two main outcrop areas, one south of the bend in the Little Rancheria River at the northern end of the map area, and one immediately west of the lake at the headwaters of the Cottonwood River (Figure 2). Pyritic quartz-sericite schist, with relict quartz and plagioclase phenocrysts, forms a significant part of both of these exposures. Samples were collected by J. Mortensen for uranium-lead dating in 1998. The northern quartz-sericite schist is 320-325 Ma with a maximum probable age of 336±4 Ma; the southern one is 334±6 Ma (Richard Friedman, personal communication 1999). These two dates are essentially coeval, and represent a previously unrecognized late Mississippian felsic volcanic event in the area. This event has several regional parallels, including tuffs near Mt. Francis in the upper part of the Big Salmon Complex (Mihalynuk *et al*., 1998 and this volume), rhyolite bodies that hosts the Tulsequah Chief deposit (Childe, 1995), and felsic volcanic rocks near Little Salmon Lake (Colpron, 2000).

A strongly deformed, well-foliated metatonalite in the Ram Creek Assemblage west of the Cottonwood River headwaters has an early Mississippian U-Pb age of 356.3±6 Ma (R. Friedman, personal communication, 1999). It lies structurally higher than the dated late Mississippian felsic volcanic sequences, but structurally lower than extensive quartz-eye porphyry tuffs and flows/intrusions identified within the upper Ram Creek Assemblage two kilometres west of the Cottonwood headwaters (Photo 5; locality R3 on Figure 2). This indicates that the Ram Creek Assemblage itself is internally imbricated.

The Ram Creek Assemblage contains a record of both early and late Mississippian arc-related igneous activity. This range of igneous ages is like that of the Yukon-Tanana Terrane in the Finlayson belt and central Yukon (Murphy and Piercey, 1999, 2000, Colpron, 2000).

### Dorsey Assemblage

The Dorsey Assemblage is a complex of metamorphic and intrusive rocks, including highly deformed Mississippian plutons (349.9±4.2 Ma; Nelson *et al*., 1998a; 355.3±.9; 340.4±5.5 Ma; R. Friedman, personal communication 1999). In its lower part, amphibolite-grade metamorphic assemblages are common. The upper Dorsey Assemblage has been thoroughly metamorphosed at chlorite grade, although relict garnets hint at earlier high-grade metamorphism. The contact between upper and lower parts is transitional, involving the upwards disappearance of metabasites. Metamorphosed granitoids also become rare in the upper Dorsey Assemblage.

The Dorsey Assemblage overlies the Ram Creek Assemblage above a major thrust fault (Figure 4). The interpretation of the Dorsey-Ram Creek contact as a thrust fault is partly based on older-over-younger relationships: the youngest rocks in the underlying Ram Creek Assemblage are late Mississippian; the oldest rocks in the Dorsey Assemblage are pre-Mississippian. Other evidence includes strong shearing near the contact, and emplacement of amphibolite-grade over greenschist-grade rocks. North of the Yukon border, this fault is constrained to be post-mid-Permian because it truncates the Ram Stock (Stevens and Harms 1995), but pre-Jurassic because it is sealed by a (locally undated) pluton of the Early Jurassic suite (Stevens, unpublished mapping; and author's field observations, 1999). Mississippian plutons are a common element that link the Dorsey and Ram Creek assemblages. Therefore the fault that separates the Dorsey from the Ram Creek Assemblage is considered to be a major intra-arc feature, not a terrane boundary.

#### *High P/T Metamorphism in the Dorsey Assemblage*

The lower part of the Dorsey Assemblage contains large bodies of garnet amphibolite. Prior to 1999, remnants of eclogite facies metamorphism had been recognized in a single thin section (Philippe Erdmer, personal communication, 1998). Fieldwork by Erdmer in August 1999 resulted in the discovery of two new eclogite outcrops within garnet amphibolite, showing a wider distribution of eclogite than previously recognized. Garnet amphibolites throughout the Dorsey Assemblage contain abundant large titanites with tiny grains of rutile and/or ilmenite in their cores, which may represent the last vestiges of eclogite-grade metamorphism. In general the mineralogy and texture of the amphibolites are identical to those described as retrograde products of eclogites elsewhere on the fringes of the Yukon-Tanana Terrane

(Erdmer 1992) The amphibolites show sharp, unsheared contacts with surrounding schists and quartzites, and are isoclinally interfolded with them. There is no evidence that the eclogites were discrete slivers incorporated into their matrix at a late stage. Rather, it is most reasonable that first eclogite and then garnet amphibolite facies metamorphism affected at least the lower part of the Dorsey Assemblage. This probably requires that the Dorsey Assemblage was partly subducted prior to its residence in a mid- to lower crustal setting.

The garnet amphibolite-facies metamorphism predated the thrusting of the Dorsey Assemblage on top of the greenschist-grade Ram Creek Assemblage, and of the juxtaposition of these with the underlying Cassiar Terrane, which contains andalusite and cordierite as a peak metamorphic assemblage (Nelson, 1998).

The overall thickness of the Dorsey Assemblage, measured from its base to its upper contact with the Swift River Assemblage, is only 1600 metres (Figure 4. Section A-A'). This poses a problem with respect to the high grade metamorphic assemblages in its lower part. What constituted the tectonic load necessary to create high pressures within it? Where are the rocks now, and how were they removed? By erosion? By detachment faulting? When did this occur?

### *Relationship of the Dorsey and Swift River Assemblages*

Unlike its basal thrust fault contact, the nature of the upper contact of the Dorsey Assemblage, and therefore the relationship of the Dorsey to the overlying Swift River assemblage, have not been well described or understood. This problem formed a focus of interest for 1999 field work both here and in the Yukon (Roots *et al*., 2000). During the re-examination the 1997-98 map area, two previously unknown exposures of the Dorsey-Swift River contact were studied.

Regionally, the Dorsey Assemblage contains pre-Mississippian rocks but also a post-Late Devonian grit within the uppermost "quartzite-pelite" unit (Nelson 1999). The overlying Swift River Assemblage has no internal age control. It is probably post-early Mississippian because it is not intruded by this prominent plutonic suite. It is depositionally overlain by late Mississippian to early Pennsylvanian limestone (Nelson, 1997, and 1999 field observations).

The Swift River Assemblage overlies the Dorsey Assemblage on a gently southwest-dipping, foliation-parallel contact. This contact is exposed on a low hill south of the Little Rancheria River in the northernmost part of the map area (Photo 6), and on two ridges northeast of Parallel Creek, where the "metachert-metatuff-phyllite unit" overlies the "quartzite-pelite" and the upper metasedimentary unit of the Dorsey Assemblage (Figure 2). Although regionally there are distinct differences between these units, locally the rock types above and below the contact are not greatly dissimilar. Quartzites, green chloritic metatuffs and metacherts occur in both assemblages. On the more northerly of the two ridges near Parallel Creek, a transitional contact is drawn below the structural level where well-bedded chert and phyllitic argillite become a dominant part of the section. This approximately corresponds to the upper limit of metamorphic garnet, although pre-kinematic garnets are present at scattered localities in the lower Swift River Assemblage.

On the hill near the Little Rancheria River and on the more southerly of the two ridges near Parallel Creek, the Dorsey/Swift River contact is more abrupt. Near Parallel Creek, a steep fault juxtaposes upper Dorsey chlorite-muscovite-garnet phyllite with Swift River dark grey argillite, siltstone and chert. Near the Little Rancheria River, white bedded chert overlies chlorite-muscovite-garnet phyllite and orthoquartzite; rocks near the contact are broken into a series of lensoid packages with strong internal deformation. A series of low angle (normal?) faults is inferred (Photo 6).

The Dorsey/Swift River contact, where not obscured by faults, appears to be a lithologic gradation. Although mappably distinct, the Swift River and upper Dorsey assemblages represent similar depositional environments of basinal sedimentation with periodic influx of distal tuffs and quartz (-plagioclase) sandstones. Unusually

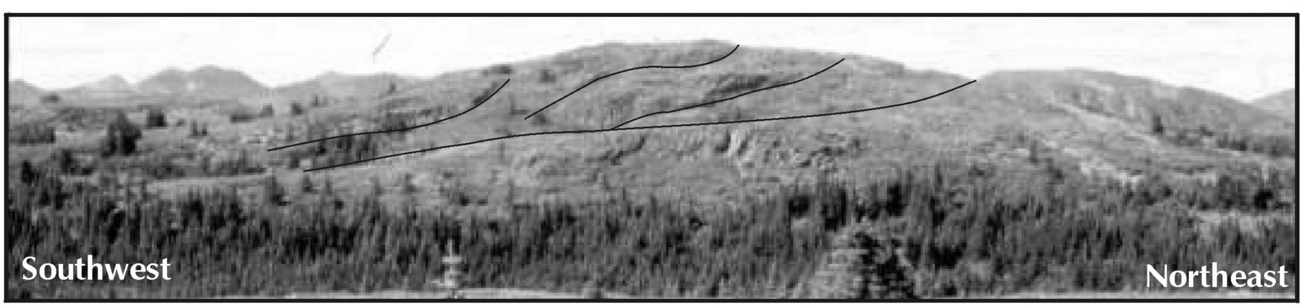


Photo 6. Base of the Swift River Assemblage south of the Little Rancheria River. Strongly deformed quartzite (metachert) is broken into a series of gently southwest-dipping panels. Structures within the panels are steep and discordant with each other. Gently dipping normal faults are inferred between the panels.

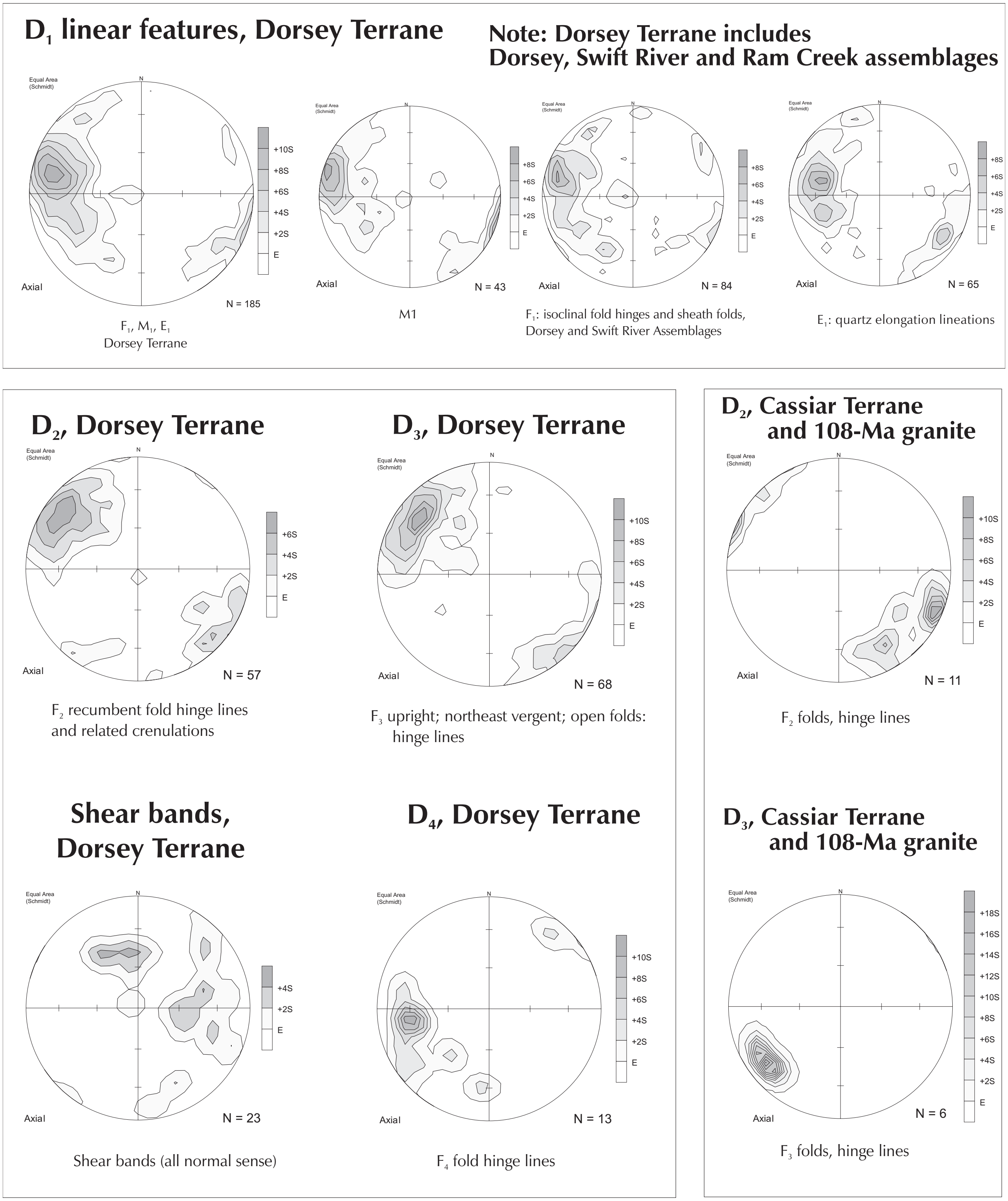


Figure 6. Structural data from 104O/7, 8, 9, 10.

abundant tourmaline is seen in thin sections of metasediments and metatuffs from both assemblages. Their structural histories are similar (*see* below).

Unlike the Dorsey/Ram Creek contact, which is an obvious thrust fault, the contact between the Dorsey and Swift River assemblages is a shear-modified lithologic and metamorphic gradient. It may have been the locus of significant motion, but it does not show the character of a terrane boundary.

### *Structural History of the Dorsey and Swift River Assemblages*

Detailed work by Martin deKeijzer, Mitch Mihalynuk and Charley Roots has improved understanding of the structural history of the Dorsey Assemblage and its relationship to the Swift River Assemblage. The Dorsey Assemblage has undergone a protracted deformation history, from pre-Mississippian to post-Late Triassic (Nelson, 1999). The intensity of the deformation is shown by isoclinal folds at scales ranging from microscopic to mountain-size, refolded isoclines and sheath folds, and mineral and quartz-elongation lineations. Although less metamorphosed, the Swift River Assemblage exhibits a similar structural style. In particular, early southwest-plunging, "downdip" quartz lineations, refolded isoclines and sheath folds have now been observed at several localities in the lower Swift River Assemblage, suggesting that it was affected by the same deformational events as the Dorsey Assemblage.

Figure 6 shows structural data from the combined Dorsey and Swift River assemblages in the central Jennings River map area. The outlined sequence of four structural events is simplified from that in Nelson (1999).

Widespread planar fabrics are assigned to $D_1$, although scattered remnants hint at an earlier and probably intense deformation history. Very early planar fabrics include those in relict eclogites, foliations preserved within garnets, and foliations cross-cut at a very low angle by sill-like, highly deformed (Mississippian?) granitoids. This early deformation involved layer transposition and thorough development of metamorphic textures not seen in the granitoids.

$D_1$ includes transposition fabrics, intrafolial isoclines, isoclines that are refolded by other isoclines, sheath folds, and the development of linear fabrics involving amphibole, muscovite, biotite, and quartz. Major isoclinal hinge lines, such as those of folded garnet amphibolite bodies, trend west-northwest. Linear fabrics (fold hinge lines, mineral and quartz lineations) form a girdle from a maximum contoured density of $283^o/06^o$ to a subordinate cluster near $230^o/40^o$ (Figure 6). Quartz lineations in early Mississippian (349.9±4.2 Ma) metatonalite plot in both clusters. Minor granitoid sills form sheath folds.

$D_2$ features include recumbent isoclinal folds, isoclines that refold other isoclines, crenulations on $S_1$, and mineral lineations that involve retrograde minerals such as chlorite or actinolite. Geometrically $D_2$ linear features are like those of $D_1$, except that they cluster well with a WNW trend and never show steep southwesterly plunges (Figure 6). $D_1$ and $D_2$ were probably part of a single episode of progressive shear deformation.

$D_3$ features include open, upright and chevron-style folds, and cleavages that are not parallel to the $D_1$ and $D_2$ transposition layering. $F_3$ is coaxial with $F_2$ (Figure 6), and may represent the waning stages of deformation. Folds with styles like these affect stratified units in the Cassiar Terrane and also apophyses of mid-Cretaceous granite. They are designated $F_2$, as they only demonstrably fold a single older transposition fabric. They are coaxial with $F_3$ folds in the Dorsey Terrane (Figure 6), and it is possible that they developed together.

$D_4$ comprises sporadic west-southwesterly to southwesterly kinks. The hinge lines of $F_3$ kinks in Cassiar Terrane rocks form a contoured maximum that plots slightly to the southwest (Figure 6).

In the field and microscopically, three shear-sense populations can be distinguished. The first occurs near the base of the Dorsey Assemblage and is associated with down-dip, west to southwesterly-plunging quartz lineations. Top-to-the-northeast and east shear indicators such as muscovite fish, asymmetric pressure shadows, C-S fabrics and C' shear bands are developed in assemblages that range from peak metamorphic through retrograde conditions. At a locality southeast of Ed Asp Lake (Figure 3), synkinematic sillimanite is deformed by, and also recrystallized into, top-to-the-east shear bands (Photo 3). At the locality described in Nelson (1999), this shear deformation affects an undated, but probably Mississippian, granitic orthogneiss. Mineral assemblages syn-kinematic to the shearing range from muscovite-biotite-clinozoisite-(garnet?) to late sericite-chlorite. One sample from the top of the Ram Creek Assemblage shows the effects of top-to-the-northeast motion. This episode matches $D_1$ in orientation and style. $D_1$ sheath folding is probably related to northeasterly transport.

The second shear-sense group, which only involves retrograde assemblages, is more common in the upper part of the Dorsey Assemblage. In samples with well-developed west-northwesterly chlorite and muscovite lineations, top-to-the-west-northwest shear bands and assymmetric pressure shadows around garnet porphyroblasts are seen microscopically (Photo 7). These lineations correspond to the $D_2$ episode. Perhaps the shear sense is the expression of an orogen-parallel component of motion.

Two sets of steep macroscopic shear bands were seen in mapping in 1999 (Photo 8; Figure 6). They concentrate in the upper Dorsey Assemblage, but are also present in the Swift River, lower Dorsey and even in the Ram Creek Assemblage. They indicate top-down-to-the-southwest and top-to-the-west shear. Development of retrograde chlorite-muscovite in the shear bands suggests that they formed late in the kinematic history. Top-down-to-southwest and west sense of shear would result in the structurally higher, lower grade, and probably younger Swift River Assemblage moving downwards with respect to the

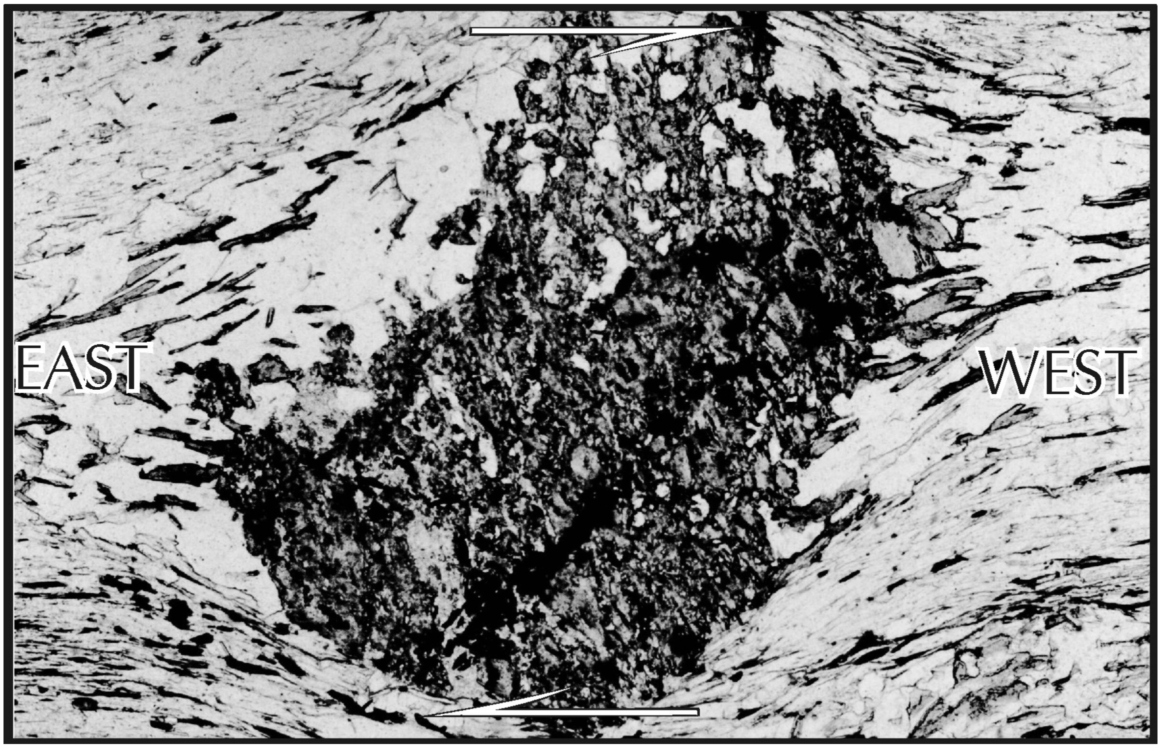


Photo 7. Top-to-the-west shearing shown by assymmetric pressure shadows around retrograded garnet porphyroblast. Retrograde chlorite and sericite participate in this fabric (Field of view 2 X 4 mm).


Photo 8. Macroscopic shear bands show late-stage down-to-the-west-southwest motion in serpentinitized talc schist, base of Dorsey Assemblage.

Dorsey Assemblage; in other words, tectonic denudation. Normal faults at the Dorsey/Swift River contact may have formed during this process. It would explain the otherwise perplexingly condensed metamorphic facies, and the presence of eclogite reverting to garnet amphibolite less than 2 kilometres below purely chlorite-grade rocks. The timing of the denudation event is not well known. It must post-date $D_1$, which is cross-cut by mid-Permian granites. It could be as old as late Permian or as young as Cretaceous. Future Ar-Ar work by M. Villeneuve is aimed at resolving this important question.

## DISCUSSION AND CONCLUSIONS

The eventful geological history of the Dorsey Terrane continues to come to light through the findings of this project and others (Mihalynuk *et al*., 2000, Roots *et al*., 2000), following on the pioneering work of Gabrielse (1969) and Harms and Stevens (1996). The terrane presents a regionally consistent internal anatomy. Its oldest unit is the Dorsey Assemblage, in which eclogite facies was overprinted by amphibolite facies metamorphism, all prior to the emplacement of early Mississippian plutons. Plutons of this age also occur within the Ram Creek Assemblage, an arc edifice that is now known to include late Mississippian felsic to intermediate volcanic rocks.

The overall volcanic-dominated character, early Mississippian plutons and late Mississippian felsic volcanic rocks of the Ram Creek Assemblage suggest that

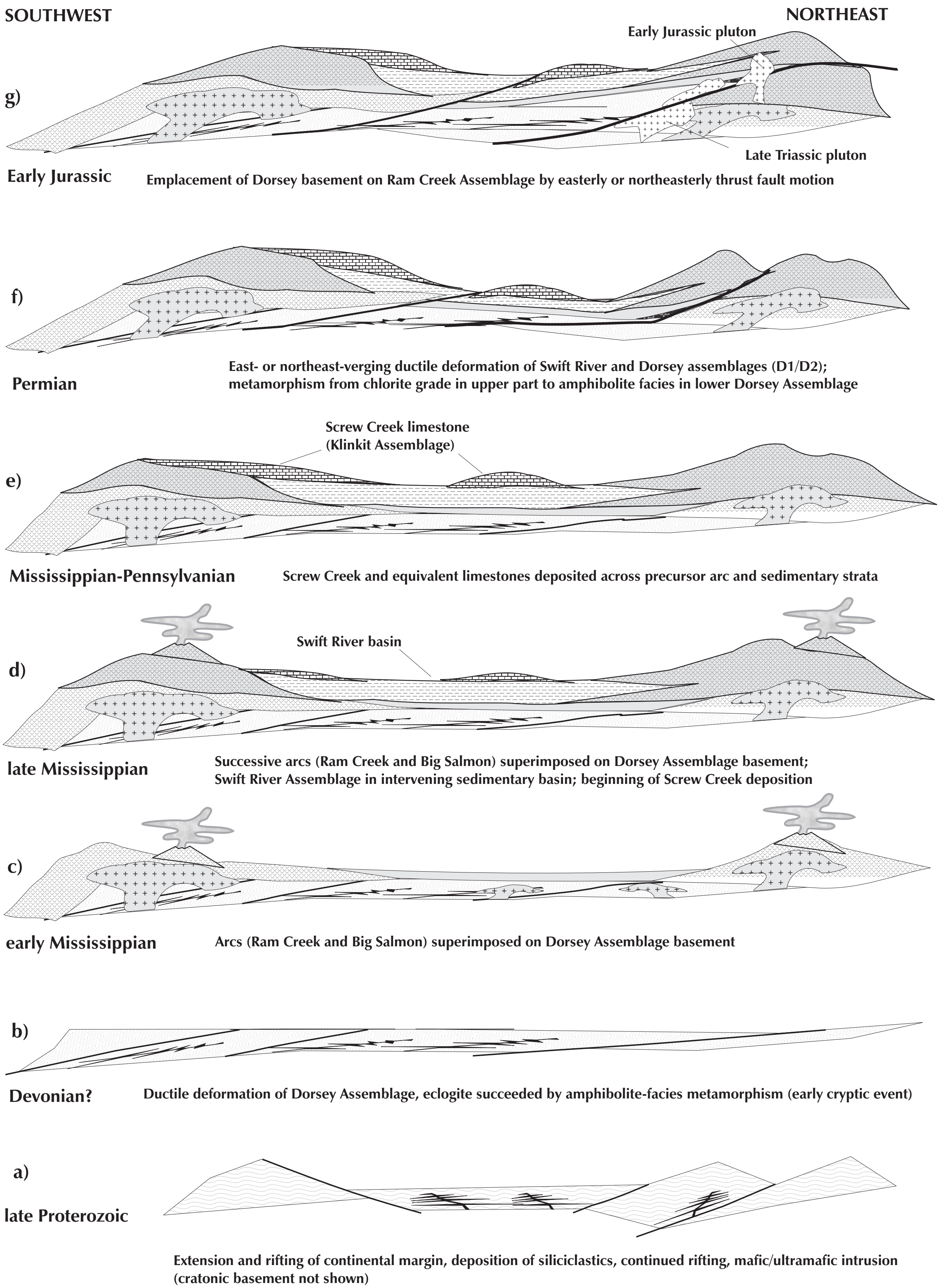


Figure 7. Cartoon evolution of the Dorsey Terrane, from late Proterozoic to Early Jurassic.

they correlate with the Big Salmon Complex on the western side of the Dorsey Terrane. However, intervening major rock sequences complicate this correlation. The Dorsey Assemblage is a likely candidate for basement to the Ram Creek, emplaced on top of it by a thrust fault of post-mid-Permian but pre-Jurassic age (Figure 4). However the Dorsey Assemblage is not overlain by a repeated Ram Creek Assemblage, but instead by basinal sediments, siliciclastic sediments and minor tuffs of the Swift River Assemblage. Very minor quartz-sericite and chlorite-quartz-sericite schist in the upper Dorsey Assemblage could be a distal equivalent to the voluminous Ram Creek igneous suite. In this scenario, a late Mississippian Ram Creek arc to the east would be in part coeval with Swift River sedimentation to the west (Figure 7d).

The external relationships of Big Salmon Complex constitute a major remaining problem in the reconstruction of the Dorsey Terrane. Near Logjam Creek just south of the B.C.-Yukon border, northeasterly-dipping clastic rocks lie structurally above the Big Salmon Complex, but the nature of the contact remains poorly understood (Gleeson *et al*., this volume; Mihalynuk *et al*., this volume). One of the units that overlies the Big Salmon Complex, Unit 3 of Gleeson *et al.,* strongly resembles the "phyllitic metasedimentary unit" southwest of Parallel Creek, which is assigned to the Swift River Assemblage (Figure 2). The base of unit 3 near Logjam Creek is cut by an early Mississippian pluton, which also cuts previously deformed schists that lie structurally below it. Perhaps this contact is analogous to the upper contact of the Dorsey Assemblage with the Swift River Assemblage.

## Geologic History in the Regional Context of Southern Yukon and Far Northern B.C.

### *Pre-Mississippian*

New mapping of 104O/1 in the southeastern corner of the Jennings River map area emphasises the variability of the lower Dorsey Assemblage. Pre-Mississippian protoliths are now seen to range from basinal sediments and tuffs in the north, to a thick section of siliciclastic sediments in the south with sparse amphibolite and ultramafite, which strongly resembles relatively coarse sections of the autochthonous Windermere Group. All of these rocks are undoubtedly allochthonous to North America, separated from the Cassiar Terrane by Mississippian arc-related igneous suites. They may be rifted blocks from the North American continental margin, which partly underpin the pericratonic terranes (Figure 7a).

Remnant eclogite in the lower Dorsey Assemblage is believed to record pre-early Mississippian subduction of unknown polarity. Thorough overprinting by Barrovian metamorphism and continued fabric development also predated some of the early Mississippian plutons. A similar geological history, without (so far) documented eclogite metamorphism, characterizes the Rapid River Tectonite in the Sylvester Allochthon (Gabrielse and Harms, 1989), where early Mississippian plutons cross-cut early ductile fabrics in garnet-amphibolite facies rocks, but are themselves in part mylonitized (Nelson *et al*., 1998b and unpublished data; Gabrielse *et al.*, 1993). Eclogites with early Mississippian cooling ages also occur in a klippe near Stewart Lake in the southern Yukon (Erdmer *et al*., 1998).

Other possible correlatives of the Dorsey Assemblage include the Anvil Assemblage in the Teslin Zone near Quiet Lake (deKeijzer *et al*., 1999), and the St. Cyr klippe (Fallas, 1997). However, the Last Peak eclogite in the Teslin Zone has yielded a mid-Permian zircon age (Erdmer *et al*., 1998), and St. Cyr eclogites are show to be mid-Permian by Ar-Ar and possibly U-Pb methods (Fallas, 1997 and personal communication to Erdmer 1998). These are significantly younger than the geologically suggested pre-Mississippian age of eclogite metamorphism in the Dorsey Assemblage. They belong to the Permian tectonic history described below.

### *Mississippian*

Intermediate to felsic plutons of early Mississippian age, and late Mississippian intermediate to felsic volcanics, are now well-documented within the Ram Creek Assemblage. Coeval, cogenetic plutons occur in the Dorsey Assemblage. This age range of arc-related igneous-activity is one of the diagnostic attributes of the Yukon-Tanana Terrane, and also provides the framework for its volcanogenic metallogeny. The Ram Creek Assemblage is a newly-defined piece of the puzzle.

### *Late Mississippian to Early Permian*

Volcanism in the Ram Creek Assemblage is as young as late Mississippian. The Swift River Assemblage structurally overlies the Dorsey Assemblage, and is apparently not cut by Mississippian plutons. Regionally it is depositionally overlain by late Mississippian and early Pennsylvanian limestone. These relationships suggest that the Swift River Assemblage was Mississippian and coeval with Ram Creek volcanism, yet it is dominantly a chert-argillite-quartzite sequence with minor tuffaceous components. A dramatic facies contrast is implied. The facies boundary may have been linked to a through-going crustal break, perhaps the one that later became the thrust fault at the base of the Dorsey Assemblage (Figure 7f,g). Late Mississippian volcanic activity is recorded in the Big Salmon Complex yet farther west. The relationship between these two coeval arc assemblages, separated across the mainly sedimentary Swift River Assemblage, is not known.

### *Permian*

It has been argued in this paper that strong shear deformation affected the Dorsey Assemblage and the overlying Swift River Assemblage together. A minimum age for the deformational event ($D_1$-$D_2$) is provided by cross-cutting mid-Permian granite dikes in the lower Dorsey Assemblage ( 269 Ma; R. Friedman personal communication 1998). Post-kinematic plutons ranging from 262 to 270 Ma occur in the Rapid River Tectonite (Gabrielse *et al.*, 1993), and an undeformed 269 Ma tonalite seals a thrust fault between Mississippian and Pennsylvanian limestone in the panel immediately underlying the tectonite (Harms, 1985; Gabrielse *et al.*, 1993). Perhaps Permian ductile deformation in the Dorsey Assemblage and Rapid River Tectonite culminated in their eastward emplacement onto higher level rocks and generated imbrication of underlying late Paleozoic arc sequences such as the Ram Creek assemblage and Package II of Harms (1985) in the Sylvester Allochthon.

A second episode of eclogite emplacement (exhumation?) accompanied this tectonic event. All of the eclogites of Permian age, except for Last Peak, are exposed on the eastern margin of the Yukon-Tanana Terrane (Erdmer *et al*., 1998). DeKiejzer *et al.* (1999) have reinterpreted Last Peak as lying at the base of a klippe in close proximity to rocks of Ancestral North America. Thus it could occupy a structural position analogous to the others, separating North America and the Slide Mountain Terrane from a combined pericratonic terrane which includes Yukon Tanana, Dorsey, Rapid River Tectonite, Ram Creek Assemblage and upper Paleozoic arc-related strata of Division III of the Sylvester Allochthon (Nelson, 1993).

The movement of structurally higher rocks down to the west and southwest could either have taken place during a late stage of this event, or later during the early Mesozoic.

## *Mesozoic*

In the lower Dorsey Assemblage, a Late Triassic pluton transects the structural fabric and has mildly folded apophyses (Nelson, 1999). Regionally, the Early Jurassic Nome Lake and Simpson Peak batholiths cut all units and post-date most structures in the Dorsey Terrane, although the southern margin of the Simpson Peak batholith is strong foliated with 290$^{o}$-striking planar fabrics (Mihalynuk *et al*., this volume). Small bodies of granodiorite south of the Little Rancheria River are presumed to be apophyses of the Nome Lake batholith. They are unfoliated and generally cut across structures in the upper Dorsey and lower Swift River assemblages, although a few sills are involved in low-angle shears near the contact.

The plethora of Early Jurassic intrusions in the Dorsey Terrane, compared with their absence in the structurally underlying Cassiar Terrane, is taken as evidence that the allochthonous rocks were not emplaced on the continental margin until after that time. Emplacement-related fabrics appear to be shears restricted to the immediate area of the basal thrust fault that separates the Ram Creek Assemblage from Earn Group equivalents.

Near the headwaters of the Cottonwood River, a strongly foliated pluton, which shows involvement in easterly-verging minor folding and subsequent dextral transport (Nelson *et al*., 1998), has a U-Pb zircon age of 108+3 Ma ( R. Friedman, personal communication 1999). This is the inferred age of motion on the dextral Cassiar fault (Gabrielse, 1985). The main strands of the Cassiar fault are mylonite zones within and at the western margin of the batholith. Steep faults in the valleys of the Cottonwood River and Parallel Creek (Figure 2) are probably splays from this system.

## *Mineral Potential of the Eastern Dorsey Terrane*

The preceding discussion of regional tectonics places the local assemblages of the Dorsey Terrane firmly within the broader context of an evolving Yukon-Tanana Terrane. They should not be viewed in isolation, but rather as part of that vast pericratonic terrane with its persistent volcanogenic metallogeny, from the Alaska Range to the Ecstall belt, from the Finlayson Lake district to northern British Columbia. In turn, the Devonian-Mississippian evolution of the Yukon-Tanana Terrane may well have been linked to backarc extension and sedex mineralization in the Earn Group along the western margin of North America. From an economic perspective, the most important achievement of this project has been to document, within a remote area seldom visited by mineral explorationists, arc suites and also autochthonous units that are potential hosts for syngenetic mineralization.

The Ram Creek Assemblage hosts late Mississippian felsic tuffs. This arc assemblage is a likely correlative of the Big Salmon Complex on the western side of the Dorsey Terrane, which similarly hosts quartz-sericite schists and also a regional exhalative unit (Mihalynuk *et al.*, this volume; Roots *et al*., 2000). Some of the Ram Creek felsic tuffs are highly pyritic, and traces of chalcopyrite were discovered within one of them in 1998 (Nelson *et al.*, 1999).

The Earn Group is an interesting metallotect locally as well as regionally, with a new exhalite occurrence at Scaup Lake. This occurrence resembles showings on the COT claims, where previous work has outlined geochemical anomalies in Pb, Zn, and Ba, and disseminated sulphides in black argillite (Gal and Nicholson, 1992; Cathro, 1985). This summer several iron-aluminum oxide seeps were seen in cliff-face exposures of the Earn Group west of the lake that heads the Cottonwood River. Streams draining this area are anomalous in zinc, lead, copper and silver (Regional Geochemical Survey; Geological Survey of Canada, 1978).

In the Yukon-Tanana Terrane in the Finlayson Lake area, southern Yukon, Mississippian meta-rhyolites, marine metasedimentary rocks and intermediate to mafic metatuffs host volcanogenic massive sulphide deposits such as Kudz Ze Kayah, Wolverine and Fyre Lake (Murphy and Piercey, 1999). This assemblage can be traced southwards across a restored Tintina Fault into the Teslin Zone, where Colpron (2000) and Mihalynuk *et al.* (1998, 2000) have identified exhalative occurrences associated with Mississippian volcanic sequences (Nelson *et al*., this volume). These rocks, locally termed the Big Salmon Complex, may extend into far southern Jennings River map area. The Ram Creek and Dorsey Assemblages can be considered a separate eastern extension of this trend. As mapping this year has shown, we have not yet reached the limit of exposure for Yukon Tanana equivalents in northern British Columbia: they are still heading south.

## ACKNOWLEDGMENTS

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