Ancient Pacific Margin Part II: A Preliminary Comparison of Potential VMS-hosting Successions of the Yukon Tanana Terrane, from Finlayson Lake District to Northern British Columbia*

J.L. Nelson[1] and M.G. Mihalynuk[1], D.C. Murphy and M. Colpron[2], C.F. Roots[3] and J.K. Mortensen and R.M. Friedman[4]

INTRODUCTION

The Yukon-Tanana Terrane of Yukon, Alaska and northern British Columbia consists of poorly understood, lithologically diverse successions of metasedimentary and metavolcanic rocks and voluminous mid- and late Paleozoic granitic metaplutonic bodies (Mortensen and Jilson, 1985; Mortensen, 1992). Significant volcanogenic massive sulphide deposits occur in the terrane in the Delta and Bonnifield districts in Alaska and in the Finlayson Lake belt in southeastern Yukon, and the potential for further discoveries is considered to be high. However, exploration for new deposits has been hindered by the paucity of stratigraphic information from the terrane as a whole.

One of the goals of the Ancient Pacific Margin NATMAP project is to address the deficiencies in stratigraphic information from the Yukon-Tanana Terrane. The Central Component of the Ancient Pacific Margin Project, which spans both Yukon and British Columbia, includes bedrock geological mapping of the Finlayson Lake belt (Murphy and Piercey 1999, 2000; location 1 on Figure 1), the Glenlyon area in central Yukon (Colpron, 1999; Colpron and Reinecke, 2000; locations 2, 3 on Figure 1), the Wolf Lake/Jennings River map area straddling the Yukon/B.C. border (Roots *et al*., 2000; location 4 on Figure 1), the Big Salmon Complex in northern Jennings River map area (Mihalynuk *et al*. this volume; location 5 on Figure 1), and the southeastern Dorsey Terrane in south-central Jennings River map area (Nelson, this volume; location 6 on Figure 1). The Finlayson Lake belt is currently separated from the other areas by the Tintina Fault. Restoration of about 425 kilometres of displacement on the fault (Roddick, 1967; Murphy,Mortensen and Abbott, in prep.) aligns all of these areas in a continuous belt from the Finlayson Lake area to the southern Jennings River (Figure 1). The Yukon-Tanana Terrane along this belt represents a target for volcanogenic massive sulphide deposits that extends over 500 kilometres of strike length.

Sufficient geological mapping and uranium-lead dating have now been done to construct preliminary stratigraphic sections for areas scattered along the extent of the southeastern Yukon-Tanana Terrane (Figure 2). In the Finlayson project, Murphy and collaborators have covered the area of the Fyre Lake, Kudz Ze Kayah and Wolverine volcanogenic massive sulphide deposits. Their work provides a preliminary stratigraphic template that is useful for workers throughout the terrane where the potential for volcanogenic massive sulphide deposits is less well known. This template is used in this paper as a point of comparison for the stratigraphic columns farther south along the restored pericratonic belt. Figure 2 shows fundamental similarities between these areas and the Finlayson Lake district, as well as highlighting significant differences in the ages of volcanism along the belt.

STRATIGRAPHIC SUMMARIES

Finlayson Lake District (Figure 2, Column 1)

Stratified rocks in the Finlayson Lake massive sulphide belt have been subdivided into three first-order successions, each hosting volcanogenic massive sulphide deposits and prospects (Murphy and Piercey, 1999; Figure 2). The lower succession comprises pre-Late Devonian quartz-rich metaclastic rocks, marble and pelitic schist; Late Devonian to early Missisissippian mafic metavolcanic rocks with lesser amounts of carbonaceous metaclastic rocks, felsic metavolcanic and volcaniclastic rocks, and marble; early Mississippian felsic metavolcanic and volcaniclastic rocks and carbonaceous phyllite, and early Mississippian carbonaceous phyllite, quartzite, quartz-feldspar pebble meta-conglomerate and mafic metavolcanic rocks. These units were intruded by early

[1] *B.C. Geological Survey*

[2] *Yukon Geology Program*

[3] *GSC-Yukon*

[4] *UBC Geochronology Laboratory*

[4] *This article also published in Yukon Exploration and Geology, 1999, Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs, Canada*

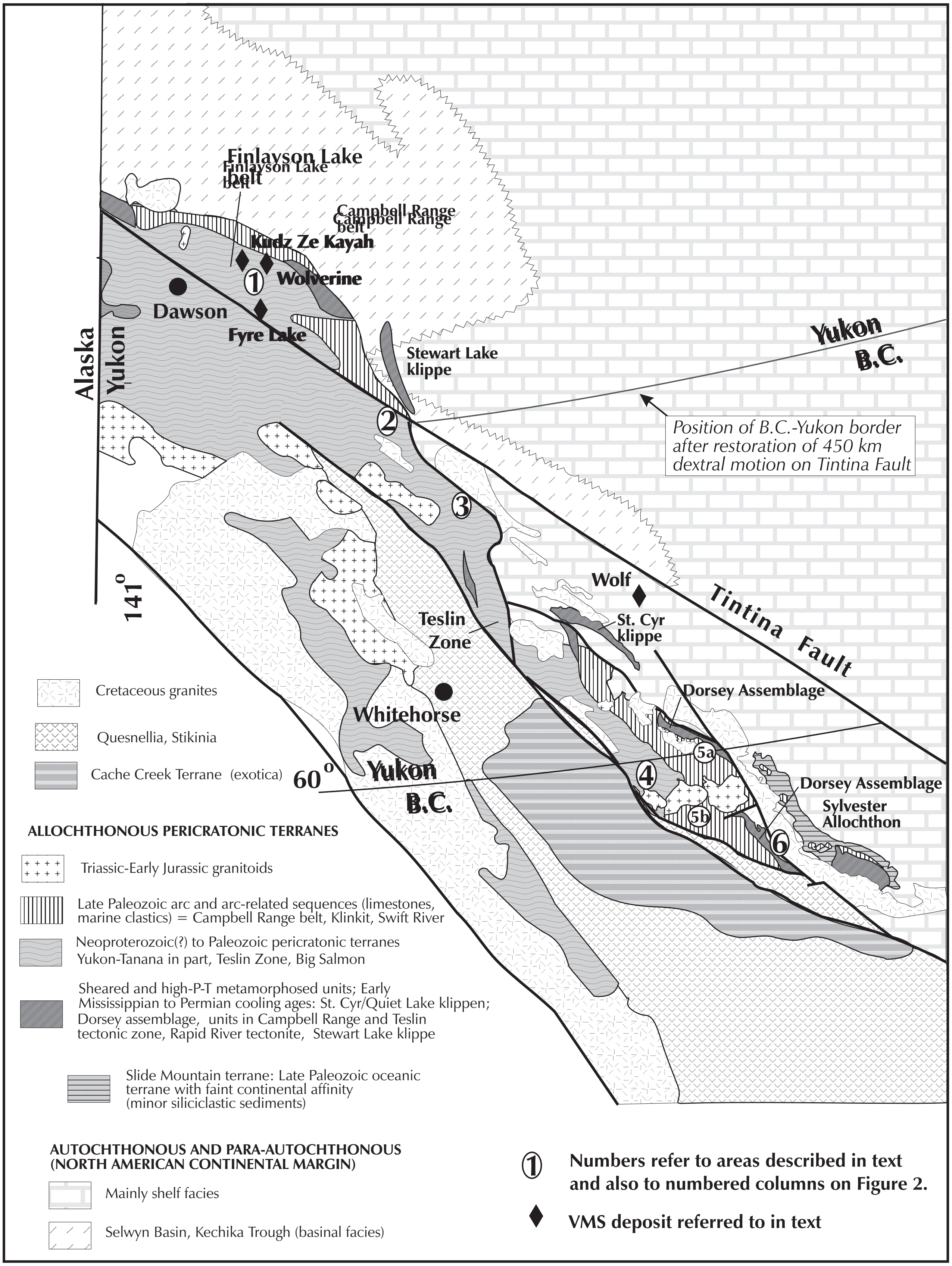

Figure 1. Location map of project area. The 450 km of dextrtal motion on the Tintina Fault has been removed.

Mississippian peraluminous granitic metaplutonic rocks, deformed, and re-intruded by slightly younger, late-kinematic, early Mississippian granitic metaplutonic rocks, before the unconformable deposition of the overlying middle stratigraphic succession. The lower succession hosts both the Fyre Lake Cu-Co-Au deposit and the Kudz Ze Kayah Cu-Pb-Zn-Au-Ag deposit, the former in the Late Devonian to early Mississippian mafic metavolcanic unit and the latter in overlying early Mississippian felsic metavolcanic rocks.

The middle succession, also of probable early Mississippian age, comprises carbonaceous metaclastic rocks, felsic schist and quartz-feldspar metaporphyry of volcanic, volcaniclastic and subvolcanic intrusive protolith. A distinctive, laterally persistent felsic tuff and exhalite unit caps the middle succession. The Wolverine Cu-Pb-Zn-Au-Ag deposit occurs near the top of the unit, just below the tuff/exhalite unit.

The upper succession corresponds to the Campbell Range belt of Mortensen and Jilson (1985). It consists of two intervals of basaltic volcanic and volcaniclastic rocks separated by a lithologically diverse and laterally variable unit of carbonaceous phyllite, greywacke, diamictite, variegated chert, chert-pebble conglomerate and limestone. Mid-Pennsylvanian to Early Permian radiolaria have been obtained from chert in the upper basalt (Harms, in Plint and Gordon, 1997) and Pennsylvanian conodonts were obtained from limestone (M.J. Orchard in Tempelman-Kluit, 1979). The Money occurrence is hosted by the upper Campbell Range basalt and the Ice Cu-Au volcanogenic massive sulphide deposit occurs in lithologically similar rocks about 70 kilometres northwest along strike from the Campbell Range succession.

Glenlyon Area (Figure 2, Columns 2, 3)

Detailed mapping in Glenlyon map area has identified two mid-Mississippian volcanic arc sequences of slightly different ages (Colpron, 1998; 1999a; 1999c; Colpron and Reinecke, 2000). In Little Kalzas Lake area, to the northwest, Early Visean calc-alkaline volcanic and volcaniclastic rocks conformably overlie a thick orthoquartzite unit (location 2 on Figure 1). This sequence was apparently deformed and metamorphosed prior to intrusion of the Tatlmain batholith in mid-Visean time. To the southeast, in Little Salmon Range, mid-Visean (and younger) volcanic and volcaniclastic rocks have mixed calc-alkaline and alkaline affinities (location 3 on Figure 1). The Little Salmon volcanic sequence rests unconformably on two different clastic units, exposed on the east and west limbs of a gentle synclinorium. On the east, it overlies arkosic grit intruded by a 353 Ma-old pluton (Oliver and Mortensen, 1998). On the west, it overlies a heterogeneous sequence of unknown age, which consists of quartzite, psammitic and pelitic schists, marble, greenstone and abundant discontinuous sills of meta-igneous rocks. The Little Salmon volcanic sequence contains Mn chert horizons and hosts a massive sulphide occurrence (Colpron, 1999b).

Northwestern Jennings River (Figure 2, Column 4)

Polydeformed pericratonic and overlying continental arc rocks of the Big Salmon Complex underlie the northwest and northeast corners of the Jennings River (104O/12,13,14W) and Atlin (104N/9E, 16) sheets respectively, and extend northwards into the Yukon (*cf.* Roots *et al*., 2000). A northwest-trending, amphibolite-grade core zone is flanked by greenschist grade rocks in which protolith textures are locally well preserved.

The inferred oldest unit in the Big Salmon Complex consists of quartz-rich clastic strata, locally with arkosic intervals, thin carbonate layers and, in its upper parts, felsic tuffaceous horizons. It is succeeded by voluminous subaqueous mafic volcanic strata, with structural thicknesses of up to 2 kilometres. Geochemical analyses show that these mafic volcanics formed in a continental arc. They were intruded by the 362 Ma Mt. Hazel body, and are thus dated as Latest Devonian in part. They are overlain by one of three lithologies:

- local felsic meta-volcanics a few metres to perhaps a hundred metres or more thick, commonly with pyritic quartz-sericite schist intervals;
- a regionally extensive chert with exhalative characteristics, known as “crinkle chert” because of its folded habit, is generally 5 to 10 metres thick, to 200 metres where structurally thickened; and
- a quartz-rich conglomeratic and turbiditic unit, known as the “dirty clastics”, that is at least 250 metres thick.

These three units all show evidence of having been deposited during waning of the late Devonian to Early Mississippian arc. Juxtaposition of radically different sedimentary facies calls for isolation of depocentres, probably on a rifted arc substrate. Sulphide lenses within the crinkle chert may be relicts of volcanogenic exhalative accumulations during syn-sedimentary faulting.

Regionally persistent, fossiliferous carbonate deposition above the crinkle chert and felsic volcanic units marks the recovery of reef-forming organisms following their demise in the Late Devonian. Clastic sedimentation appears to have persisted in adjacent basins.

Reefal carbonate deposition is punctuated by one or more conglomeratic horizons, which may represent uplift associated with a mid-Mississippian deformational event that affects the 354 Ma Logjam intrusion (Gleeson *et al.*, 2000). In places, the regional carbonate has been nearly stripped away during uplift. Deformation may have peaked with emplacement of 346 Ma eclogite and blueschist (*cf*. Erdmer *et al*., 1998) into the Yukon-Tanana Terrane arc complex. The deformation event is recorded in the Big Salmon Complex by folded strata that are cut by ~335 Ma dikes (unpublished data).

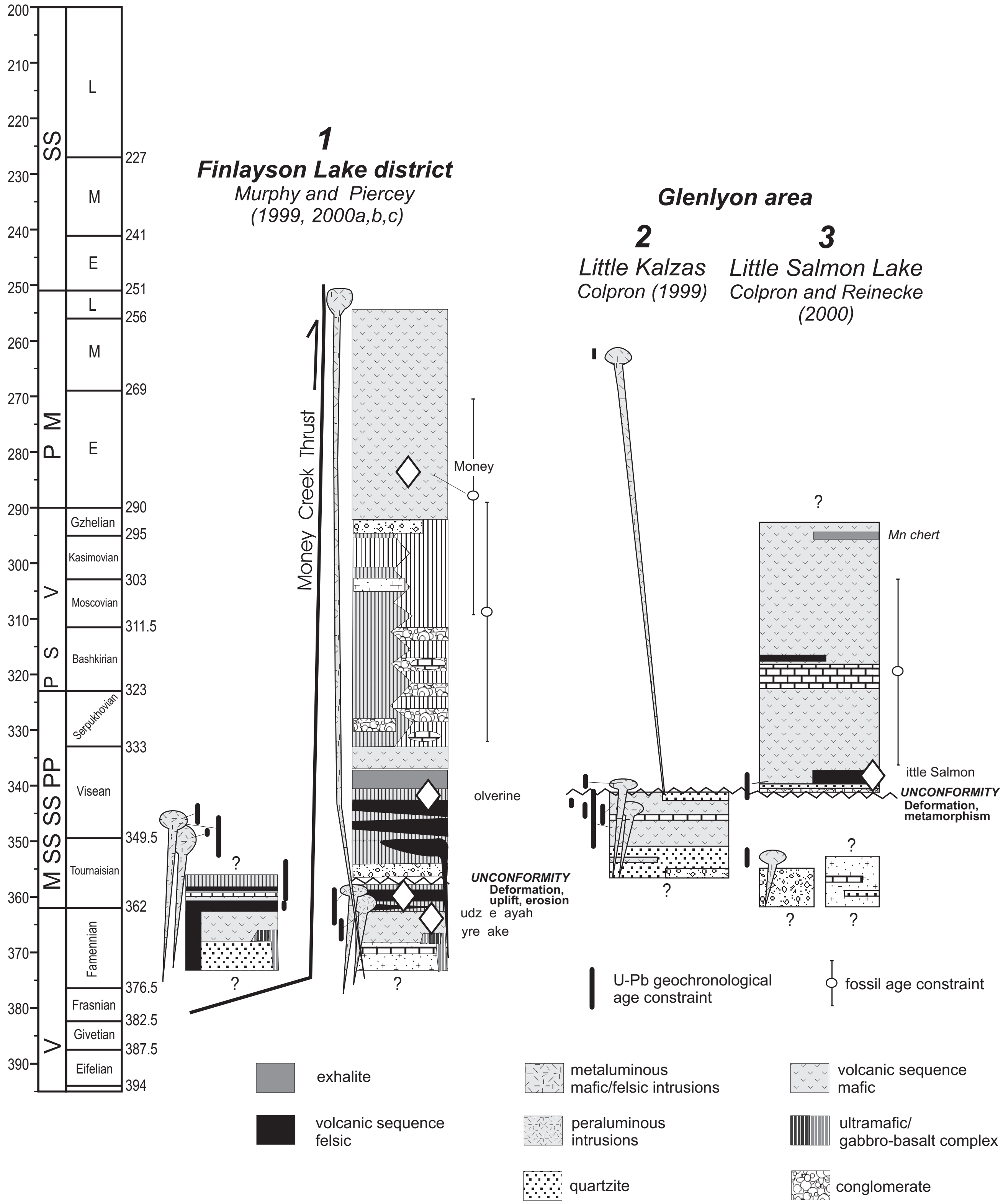

Figure 2. Selected stratigraphic columns from the Yukon-Tanana Terrane, Yukon and Northern British Columbia.

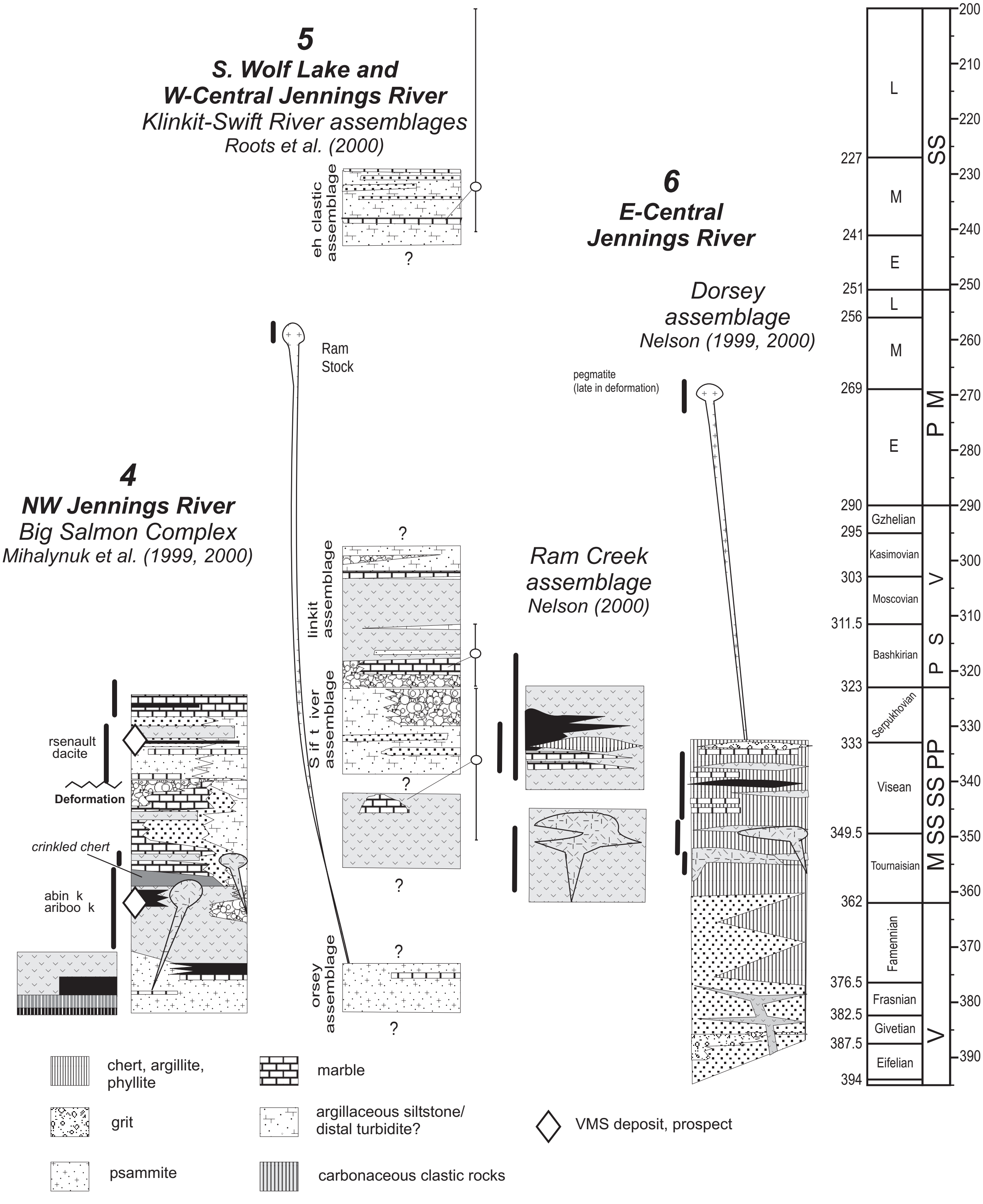

Figure 2. Selected stratigraphic columns from the Yukon-Tanana Terrane, Yukon and Northern British Columbia (continued).

Post-deformational sedimentation is highly varied. Both mafic and felsic distal tuffs and tuffites were deposited in both carbonate and clastic-dominated facies. Pulses of proximal felsic volcanism are recorded by coarse ignimbritic horizons such as those associated with base metal sulphide accumulations at the Arsenault property. A high degree of lithologic variability in the youngest Big Salmon Complex strata makes correlations difficult. However, the youngest dated Big Salmon Complex strata recognized in the Jennings River area are 326 Ma dacitic tuffs in carbonate of the heterolithic succession. No indications of a depositional hiatus exist at this point in the stratigraphy, so it is likely that younger Big Salmon Complex strata exist.

Southern Wolf Lake and West-central Jennings River Area (Figure 2, Column 5)

This section is derived from two areas, one straddling the Yukon/British Columbia border near Swift River (location 5a on Figure 1), and one in the west-central Jennings River map area (location 5b). It spans the Ram Creek, Dorsey, Swift River and Klinkit assemblages (Harms and Stevens, 1996). As suggested by Harms and Stevens, and corroborated in 1999 field mapping (Roots *et al*, 2000), each assemblage consists of related sedimentary and volcanic strata that are mappable and lithologically distinct from adjacent assemblages.

The oldest known rocks are included in the Dorsey assemblage (location 5a, Figure 1), which is exposed as a narrow, elongate strip near the northeastern side of the pericratonic belt. It is a siliceous succession including quartzite and quartzo-feldspathic metasedimentary protoliths, interspersed with quartz-augen felsic meta-tuff and marble layers, as well as foliated, sill-like leucocratic intrusions. It is characterized by a medium- to high-pressure metamorphic mineral assemblage. The Dorsey assemblage in Yukon was deformed prior to the emplacement of the mid-Permian Ram Stock (Stevens and Harms, 1995). Its oldest protoliths are probably pre-Devonian-Mississippian, the age of intrusions in southern Dorsey assemblage in British Columbia (see below).

The Swift River assemblage comprises several hundred metres, in structural thickness, of dark meta-siltstone and argillite with interbeds of quartzite; and thick-bedded, dark-coloured chert. There is no age control, except that a distinctive chert-pebble conglomerate facies at the top interfingers with, and is conformably overlain by Carboniferous (in part lower Pennsylvanian) Screw Creek limestone.

The Screw Creek limestone is white, thick-bedded, and contains abundant macrofossil debris. As mass flow deposits from a reef environment, this limestone is not a direct stratigraphic marker, but the Bashkirian conodonts (Abbott, 1981) provide an approximate age.

The Klinkit assemblage in central Jennings River area (location 5b, Figure 1) contains dark-coloured, thick-bedded chloritic meta-tuffs and breccias, volcanic-derived meta-siltstone and minor mafic flows, light-coloured limestone and siltstone-argillite layers. One or two prominently red quartzite (possible metamorphosed chert) layers lie several tens of metres above the base, which is locally a limestone that contains Carboniferous macrofauna, correlated with the Screw Creek limestone. The top of Klinkit assemblage, as used here, is a variable succession of meta-siltstone through quartzite with chloritic meta-tuff layers of unknown age.

The Triassic succession in west-central Jennings River area (The clastic assemblage; location 5b, Figure 1) consists of interbedded black argillite, meta-siltstone and quartzite, with minor chert, fetid limestone and conglomerate (T. Harms, personal communication, 1999). One limestone bed yielded a single Triassic conodont (M. Orchard, personal communication to T. Harms, 1997). This single age is considered preliminary. Moreover, although rocks that visually resemble this lithologic succession are found in several places in direct contact with Klinkit assemblage, field evidence for their stratigraphic relationship and even their stratigraphic order remains to be found.

East-central Jennings River (Figure 2, Column 6)

In east-central Jennings River area, rocks of the Big Salmon Complex disappear eastwards below less-metamorphosed younger strata of the Klinkit and Swift River assemblages. Possible equivalents, including Mississippian felsic volcanic units, reappear from beneath these to the east. They are assigned to the Dorsey and Ram Creek assemblages (Location 6 on Figure 1). The Dorsey assemblage, also described in the Wolf Lake map area (Location 5a), structurally overlies the Ram Creek assemblage across a post-mid Permian thrust fault (Nelson, this volume). For this reason, sections from these two assemblages are presented separately (Figure 2). The Dorsey assemblage is a metamorphic complex containing a variety of protoliths that range from siliciclastic to basinal sediments and tuffs, with isolated metabasic and ultramafic bodies. It is intruded by early Mississippian deformed granitoids. Early Mississippian intrusions also form part of the underlying Ram Creek assemblage. It is possible that during Mississippian time, the Dorsey assemblage was basement to the Ram Creek magmatic arc (Nelson, this volume). The Ram Creek assemblage contains tracts of mafic to rhyolitic meta-tuffs with local limestone and chert sequences. Two uranium-lead dates from the felsic tuffs are late Mississippian, coeval with tuffs in the Big Salmon Complex (Figure 2, column 4) and Little Salmon Lake sequence (Figure 2, column 3).

CONCLUSIONS

The columns described above demonstrate both the integrity and the variability of the southeastern Yukon-Tanana Terrane. Mafic to felsic arc activity in a pericratonic setting ranges in age from early Mississippian (*circa* 360-350 Ma) to late Mississippian-early Pennsylvanian (*circa* 335-320 Ma). The Finlayson Lake district contains significant volcanogenic massive sulphide deposits associated with the early Mississippian event (Murphy and Piercey, 2000). This syngenetic event is represented in the Big Salmon Complex near the British Columbia-Yukon border by the "crinkle chert", a siliceous meta-exhalite containing anomalous barium and manganese, and by small felsic accumulations with associated base-metal geochemical anomalies (Mihalynuk *et al*., this volume). Late Mississippian felsic tuffs occur in the Ram Creek assemblage, in the upper part of the Big Salmon Complex, and near Little Salmon Lake, where a small massive sulphide showing and cherty exhalite like the "crinkled chert" are also reported (Colpron, 1999b, Colpron and Reinecke, 2000). The late Mississippian volcanic suite, not apparently present in the Finlayson Lake district, represents a new, largely unexplored host for volcanogenic massive sulphide deposits in northern British Columbia and south-central Yukon.

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