Stratigraphy summary for southeast Yukon (NTS 95D/8 and 95C/5)

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ABSTRACT

Sedimentary strata located within NTS map sheets 95C/5 and 95D/8, southeast Yukon, have a combined thickness ranging between 5000 and 15 000 m and depositional ages ranging from Proterozoic to Paleocene. They can be grouped into eight successions with formations within each succession indicating either similar depositional environments or a horizontal or vertical lithological facies zonation. Early to middle Paleozoic successions are best exposed; Proterozoic, Late Paleozoic, Mesozoic and Cenozoic successions are only locally exposed. Many of the successions are bounded by unconformities; some also contain internal depositional hiatuses. The deposition and preservation of the successions reflect the regional tectonic framework of the Canadian Cordillera from Neoproterozoic to present.

RÉSUMÉ

Les strates de roches sédimentaires dans les régions des cartes 95C/5 et 95D/8 du SNRC, au sud-est du Yukon, ont une épaisseur combinée variant de 5000 à 15 000 m, et ont été déposées du Protérozoïque au Paléocène. Elles peuvent être groupées en sept successions stratigraphiques, qui contiennent chacune des formations indiquant soit des milieux de sédimentation similaires ou une zonation horizontale ou verticale du lithofaciès. Les successions datant du Paléozoïque précoce à moyen sont les mieux exposées; les successions datant du Protérozoïque, du Paléozoïque tardif, du Mésozoïque et du Cénozoïque ne sont apparentes que par endroits. Plusieurs des successions sont limitées par des discordances; certaines comportent également des lacunes de sédimentation internes. La stratification lithologique et les discordances qui séparent les strates peuvent être sommairement interprétées comme des cycles de transgression-régression. La sédimentation et la préservation des successions reflètent le cadre mégatectonique de la Cordillère canadienne depuis le Néoprotérozoïque jusqu'au présent.

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INTRODUCTION

The Central Foreland Ancient Pacific Margin National Mapping (NATMAP) project was a multi-disciplinary collaborative geological mapping project initiated to better define the stratigraphy, structure, and mineral and hydrocarbon potential of the Foothills of the Rocky Mountains in northeastern British Columbia, and the Liard Basin region of the southern Northwest Territories and southeast Yukon Territory. The Yukon Geology Program (YGP) joined the Central Foreland NATMAP Project during the 2000 field season and continued to participate during the 2001 and 2002 field seasons. NTS map sheet 95C/5 (Pool Creek) was the primary field area (Fig. 1) for YGP during the 2000 and 2001 field seasons. Bedrock mapping in the western half of NTS map sheet 95C constituted the final field season for YGP in the NATMAP project in 2002.

Yukon Geological Survey (YGS) continued field work (Fig. 1) in NTS map sheet 95D/8 during the 2003-2005 field seasons. The 95D/8 geology mapping was a small-scale program designed to further explore stratigraphy and structure delineated as part of the earlier geological mapping.

This paper summarizes the stratigraphy and facies relations documented as a result of the geology mapping completed by the Yukon Geological Survey during 2000-2005. A more detailed report of the geology of the map areas is in preparation and will be published as a YGS bulletin.

LOCATION AND PHYSIOGRAPHY

NTS map sheets 95C/5 (Pool Creek) and 95D/8 (Fig. 1) are located 150 km west-northwest of Fort Liard, Northwest Territories and 155 km east-northeast of

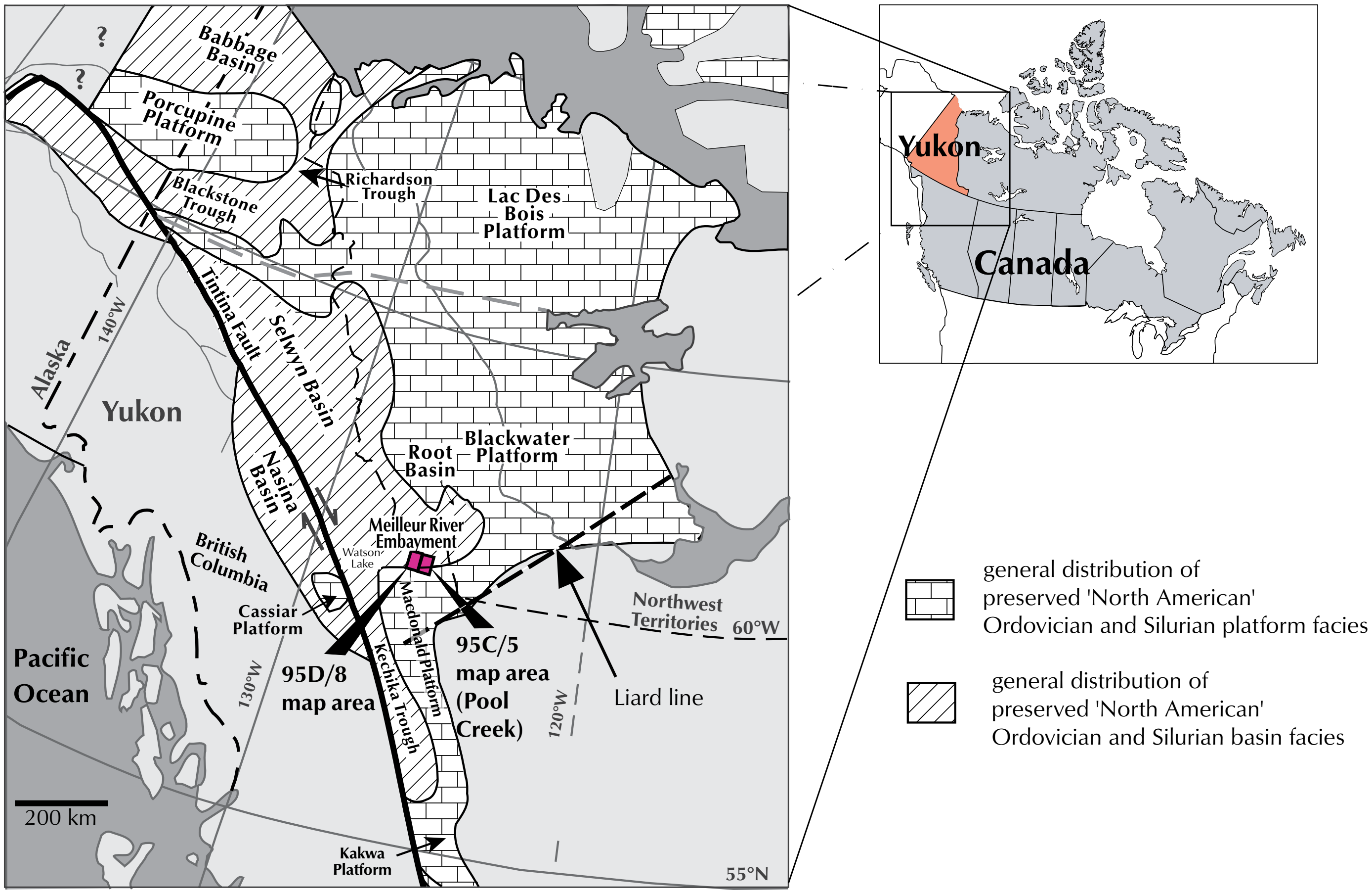

Figure 1. *Location of NTS map sheets 95D/8 and 95C/5 in southeast Yukon. General distribution of Ordovician-Silurian platform carbonate and basinal shale facies for Canadian Cordillera and Alaska are indicated. Modified from Cecile et al. (1997).*

Watson Lake, Yukon Territory. Topography in both map sheets consists of low rounded hills with incised stream drainages. Elevations range from 1500 feet (460 m) to 4600 feet (1400 m) asl (above sea level). The area is heavily forested with a single, north-tending ridge in the Pool Creek map area extending above tree line for 8 km. Beaver River flows from northwest to southeast through the area into the Liard River and then into the Mackenzie River which drains northward to the Beaufort Sea. Bedrock exposure is 10% or less, with most outcrops occurring as exposures along streams and rivers. Map sheet 95D/8 area contains scattered large lakes which drain southward into the Smith River and then the Liard River, or northward into the Beaver River.

Access was by helicopter from Fort Liard (95C/5) and Watson Lake (95D/8). A fixed-wing aircraft on floats from Watson Lake was used to mobilize and demobilize camps established adjacent to the larger lakes in map sheet 95D/8. Fieldwork was completed primarily by foot and boat traverses from base camps. Spot checks and short foot traverses were completed in other areas where helicopter landing was feasible.

PREVIOUS WORK

The Geological Survey of Canada completed 1:253 440-scale geological bedrock mapping in La Biche River map area (95C) in 1957 as part of Operation Mackenzie (Douglas and Norris, 1959). The geology of the area was further updated based on subsequent fieldwork and compilations completed in adjacent map areas (Douglas, 1976). Framework geological bedrock mapping in Coal River map area (95D) was completed at 1:253 440 scale by the Geological Survey of Canada, largely during 1967 (Gabrielse and Blusson, 1969).

Mineral exploration in 95C/5 between 1973 and 1986 identified U-Th-REE prospects in the contact metamorphic aureole of the Pool Creek syenite, sedimentary-exhalative (SEDEX) targets in lower Paleozoic shales and carbonates, and barite veins in Devonian carbonates (Deklerk and Traynor, 2005). Mineral exploration has been limited since 1986. No mineral claims have been staked in 95D/8; the single MINFILE occurrence in 95D/8 (Deklerk and Traynor, 2005) resulted from the regional mapping completed by Gabrielse and Blusson (1969). Oil and gas exploration activities within Yukon have been largely east and north of the map area.

Preliminary research studies on geology of the map area as part of the Central Foreland NATMAP have been published in various Yukon Geological Survey Open Files and reports (Allen and Pigage, 2000; Allen *et al.*, 2001; Pigage and Allen, 2001; Pigage, 2004; Pigage and MacNaughton, 2004) and one NATMAP volume (Pigage and Mortensen, 2004). Updated geology maps for adjacent areas in the La Biche River map sheet (NTS 95C) have recently been completed (MacNaughton and Pigage, 2003; Fallas *et al.*, 2004, 2005).

REGIONAL GEOLOGY

NTS map areas 95C/5 and 95D/8 (Fig. 1) are located in southeast Yukon in the Cordilleran miogeocline, a depositional prism of sedimentary rocks of Precambrian to Middle Jurassic age along the relatively stable western continental margin of ancestral North America (Abbott *et al.*, 1986). The map area contains eight successions of sedimentary rocks, ranging from Proterozoic to Paleocene in age. Regional unconformities have been identified between several of these successions, and some of the successions also contain internal unconformities. Early to Middle Paleozoic stratigraphic successions are best preserved in the map area, with younger strata being only locally preserved. Sparse outcrop precluded seeing detailed contact relations between formations in many places. Lateral facies relations are commonly inferred from distribution of the lithologies and time equivalence of the different formations. It is assumed that lithologic facies older than Jurassic are part of a regional west- to southwest-facing marine passive margin of ancestral North America. Sedimentary successions younger than Jurassic are depositionally linked to Cordilleran deformation caused by accretion of exotic terranes to the western margin of North America (Coney *et al.*, 1980).

Figure 2 is a schematic cross-section illustrating the sedimentary formations and successions for the area of interest. The formations and successions are illustrated in time-stratigraphic columns in Figures 3 and 4. These latter figures also indicate the fossil control available for the different formations in the map area.

Intrusive igneous activity in Neoproterozoic and Eocene occurred in close proximity in the map area (Pigage and Mortensen, 2004). Extrusive volcanic rocks are dated stratigraphically or with isotopic age dating as Proterozoic, Cambrian to Ordovician, and Paleocene. Fossil constraints on extrusive activity are locally very poor.

STRATIGRAPHY

SUCCESSION 1 (PROTEROZOIC STRATA)

Succession 1 (Figs. 2,3,4) is exposed in the immediate hanging wall of the Beaver River Thrust in the western part of map sheet 95C/5 (Pigage and Allen, 2001) and consists of two units, a lower siliciclastic unit (Ps) and an upper volcaniclastic unit (Pls). An interpreted fault separates the two units, and stratigraphic relations between them are therefore unknown. Succession 1 strata are unconformably overlain by Crow map unit (unit COC of Pigage and Allen, 2001) belonging to succession 2. Both units Ps and Pls share a common folding deformation, which is not present in any of the younger strata.

Unit Ps

Unit Ps (Allen *et al.*, 2001; their units 1 and 2) consists of interbedded light to dark grey quartzose sandstone and siltstone capped by calc-silicate rock. A minimum exposed stratigraphic thickness for this unit is approximately 500 m; the stratigraphic base is not exposed, and the upper contact is eroded. Sandstones and siltstones are typically finely planar-laminated with laminae being 1-2 mm thick spaced about every 1 cm. Minor intervals up to 1 m thick contain soft-sediment deformation folds.

Planar bedding denotes deposition in quiet water below wave-base. Soft-sediment deformation folds indicate local transport on a slight slope. A proximal offshore depositional environment is indicated because of the thick accumulation of sand-sized material.

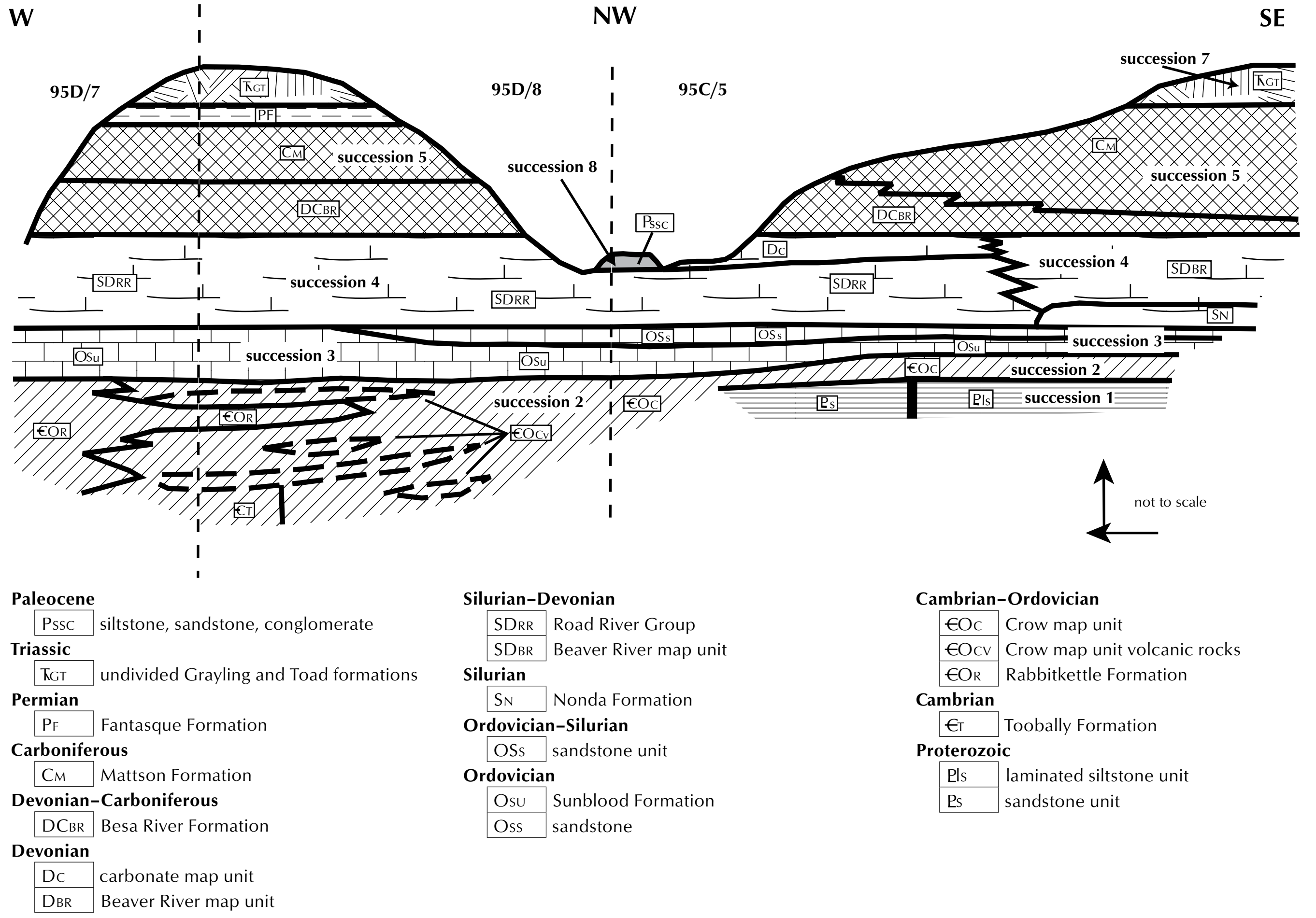

Figure 2. *Schematic cross-section for geology contained in 95C/5 and 95D/8. Not to scale. Western part of section oriented east-west; eastern part oriented northwest-southeast. Modified from Fallas et al., (2004).*

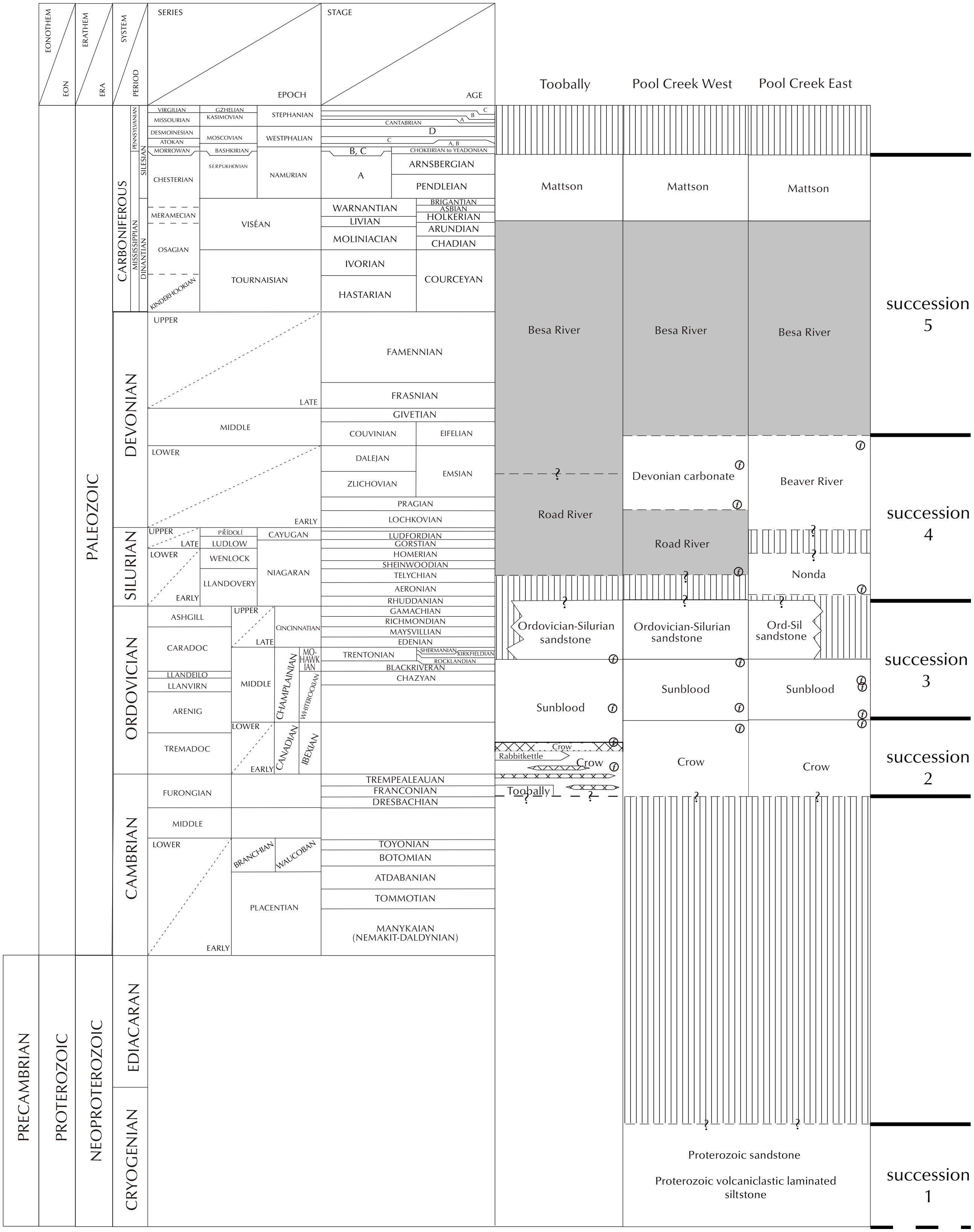

Figure 3. *Stratigraphy-time column for Proterozoic, Lower and Middle Paleozoic formations in Figure 2. Fossil control (small 'f' in circle) from McCracken (2003a, 2003b), A.D. McCracken (pers. comm., 2003), Norford (2001, 2002), Nowlan (2004), L.J. Pyle (unpublished data, 2001, 2004). Time scale from Okulitch (2001).*

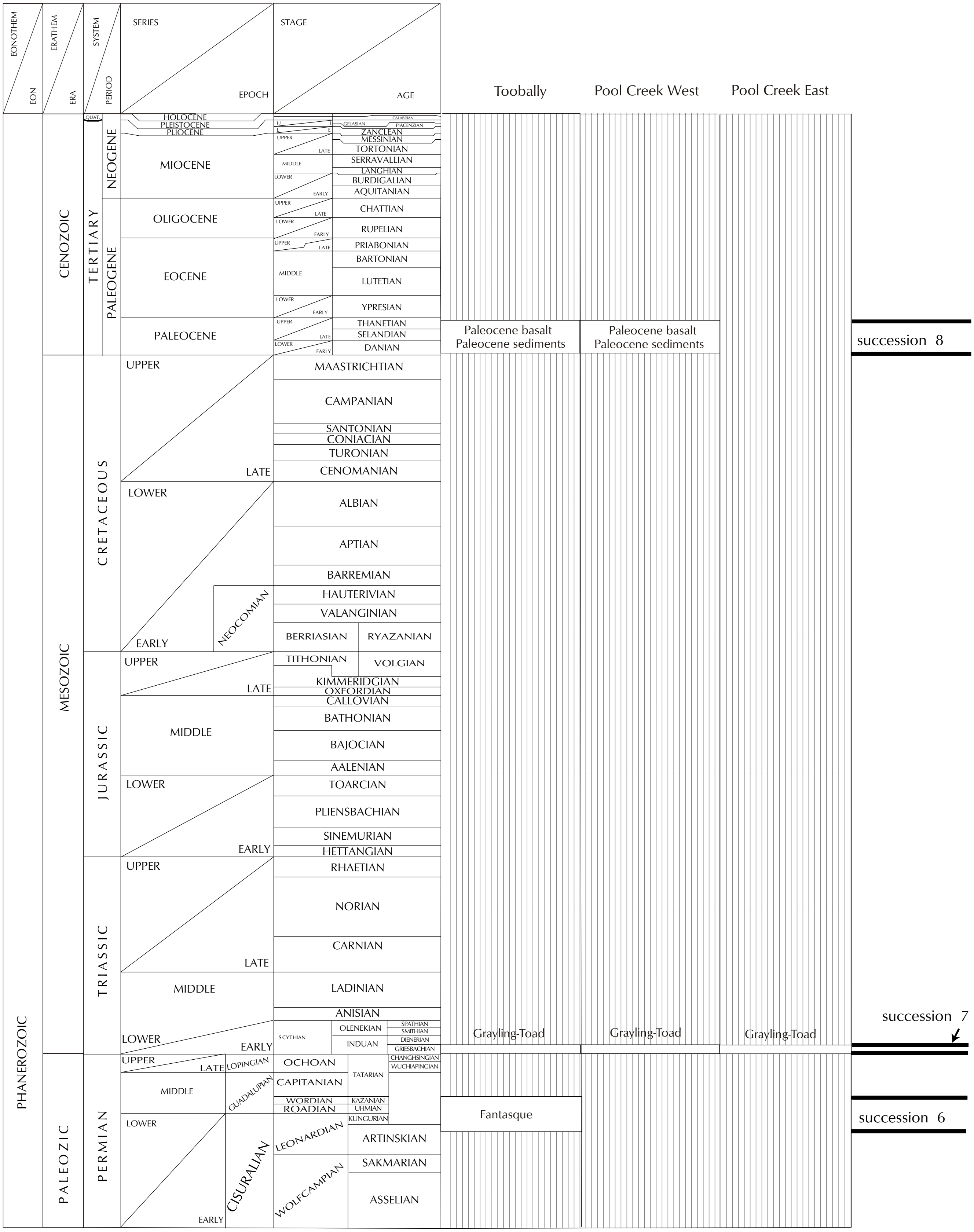

Figure 4. *Stratigraphy-time column for Upper Paleozoic, Mesozoic, and Cenozoic formations in Figure 2. Time scale from Okulitch (2001).*

Figure 5. *Polymictic diamictite, Toobally Formation.*

Unit Ps is nonfossiliferous. It is intruded and hornfelsed by the Pool Creek syenite and correlative dykes, which have been isotopically dated at 650 Ma (Pigage and Mortensen, 2004). Isotopic dating of detrital zircons from one sample of Unit Ps provides a maximum depositional age of 1832 ± 23 Ma (G. Gehrels, pers. comm., 2005).

Unit Pls

Unit Pls consists predominantly of pale green argillaceous siltstone with thin, cream, locally calcareous, very fine-grained sandstone interbeds (Allen *et al.*, 2001; their unit 3). The sandstone interbeds are 1-5 cm thick and generally make up 5-50% of the siltstone. Lesser lithologies in unit Pls include green, poorly sorted, matrix- to clast-supported basalt breccias and a brown to green, crudely bedded, poorly to moderately sorted basalt conglomerate (unit 3a in Allen *et al.*, 2001).

As with unit Ps, a minimum exposed stratigraphic thickness for unit Pls is approximately 500 m, with the stratigraphic base not being exposed, and the upper contact being eroded. Unit Pls locally contains isoclinal slump folds oriented at a low angle to bedding (Allen *et al.*, 2001).

No fossils have been noted in unit Pls. It is thought to be older than 650 Ma because of the occurrence of metamorphic epidote and actinolite, which is considered to be due to hornfelsing caused by intrusion of the Pool Creek syenite. Deposition was in quiet water, as indicated by the fine grain size and planar bedding. The occurrence of slumping and massive breccia beds suggests deposition on a slope. These features are consistent with deposition in a slope-shelf or uppermost slope setting (Allen *et al.*, 2001).

SUCCESSION 2

Toobally Formation, Crow map unit, and Rabbitkettle Formation constitute succession 2 (Figs. 2,3,4). In 95C/5, succession 2 consists entirely of Crow map unit, and it unconformably overlies unit Pls and Pool Creek syenite. In west 95D/8, the lower contact of succession 2 is structural and consists of the Toobally fault (Pigage, 2004).

Toobally Formation occurs immediately west of north Toobally Lake in 95D/8. Crow map unit occurs in both 95C/5 and 95D/8. In westernmost 95D/8, a tongue of Rabbitkettle Formation was mapped within the uppermost Crow map unit (unit Os in Pigage, 2004). The upper contact of succession 2 is diachronous, as Crow map unit is overlain by Sunblood Formation of different ages in 95D/8 and 95C/5 (Fig. 3).

Toobally Formation

Toobally Formation (Pigage and MacNaughton, 2004) consists of massive, orange-weathering, polymictic, matrix-supported conglomerates to pebbly mudstones (Fig. 5) with a minimum inferred thickness of 1800 m. Bedding cannot generally be recognized within this unit. Clasts consist of a variety of rock types, including sandstones, siltstones, dolostones, limestones, and rare volcanic rocks. In one locality a large, finely laminated dolostone olistolith, at least 20 m thick, was mapped overlying outcrop exposures of diamictite.

Pigage and MacNaughton (2004) interpreted the Toobally Formation as being produced by relatively viscous, sediment-gravity flows, probably debris flows. They also noted its similarity to Neoproterozoic glacial diamictites in the Canadian Cordillera and tentatively considered it to be correlative with the Ice Brook and Vreeland formations. Further mapping in 2005 determined that Crow map unit sandstones occur along strike immediately north of Toobally Formation exposures in the central part of 95D/8. Crow map unit, therefore, both overlies the Toobally Formation and occurs along strike with it. This map pattern has important consequences for the ages of both the Toobally Formation and the lower Crow map unit; the ages of these units will be discussed further in the section on the Crow map unit (see below).

Figure 6. *Subarkosic quartz sandstone, Crow map unit. Bedding dips gently to the right in the photo.*

Figure 7. *Clast-supported conglomerate, Crow map unit. Predominant clasts are white, pink and grey quartz sandstones. 95C/5 map sheet. Swiss Army knife for scale (circled).*

Crow map unit

The Crow map unit consists predominantly of poorly sorted, thick-bedded to massive, coarse- to fine-grained, pebbly, variably subarkosic sandstones with subangular to subround monocrystalline quartz clasts (Fig. 6). The sandstones are typically indistinctly bedded with bed thicknesses ranging from 20-70 cm. Locally scattered through the sandstone are well rounded quartz pebbles, up to 2 cm across (1-3%), consisting largely of monocrystalline quartz.

Interbedded with the pebbly sandstone on map sheet 95C/5 are lesser intervals of white to light grey, noncalcareous, clast-supported, cobble conglomerate (Fig. 7). Cobbles are well rounded and consist dominantly of quartz sandstone in shades of grey and pink. The matrix for the cobbles is medium- to coarse-grained quartz sand. In one location, the conglomerate has a minimum thickness of 9 m. Imbrication of the cobbles is not visible.

Minor dark maroon, silty argillite is interbedded with the above coarse siliciclastic rock. Dolostone and limestone interbeds are scattered throughout the upper part of the formation in map sheet 95D/8. One prominent, 200-m-thick fossiliferous carbonate horizon occurs about 530 m below the top of the formation in the west part of 95D/8. Carbonate horizons do not occur within Crow map unit in the 95C/5; some intervals of sandstone and siltstone in that map sheet, however, are calcareous.

West of north Toobally Lake, in map sheet 95D/8, the Crow map unit contains dark purplish green, amygdaloidal to vesicular, massive to pillowed alkali basalts and interbedded, thick-bedded to massive, lapilli tuffs occurring at four stratigraphic levels. No volcanic rocks were recognized in the formation in 95C/5. The most prominent of these horizons (horizon 2) is about 890 m thick and has been mapped laterally along strike for a distance of slightly greater than 15 km. Previously, these volcanic horizons (Goodfellow *et al.*, 1995) have informally been referred to as the Toobally (horizon 2) and Gusty volcanics (horizon 4). Geochemistry of the basalts is consistent with the volcanic horizons being within-plate alkali basalts (Pigage and MacNaughton, 2004).

The upper and lower contacts of the Crow map unit are not directly exposed. In 95C/5, the lower contact is unconformable as the Crow map unit overlies both succession 1 strata and the Pool Creek syenite. In 95C/5, thickness of the Crow map unit is approximately 300 m;

Figure 8. *Desiccation cracks and ripples in subarkosic sandstone, Crow map unit.*

in the west part of 95D/8, it has an interpreted thickness in excess of 5700 m if the unit is structurally intact.

The occurrence of poorly sorted, fine- to coarse-grained, locally cross-bedded sandstones interbedded with pebbly sandstones, cobble conglomerates, maroon siltstones and argillites, and fossiliferous carbonates indicates a shallow water marine to subaerial fluvial depositional environment. The common presence of desiccation cracks, herringbone cross-bedding and ripples (Fig. 8) also indicates a shallow to intertidal to subaerial depositional environment. Subangular shapes for grains and subarkosic composition suggest an immature clastic succession.

Conodont fossil collections from the upper part of the Crow map unit and the overlying Sunblood Formation indicate the upper contact is diachronous, ranging from earliest Whiterockian to Tremadocian (Fig. 3). A maximum age for the lower part of the Crow map unit has not been defined through fossils. Given a total thickness of 4000 to 5700 m for the Crow map unit in 95D/8, it is reasonable to assume that the lower part of the map unit is Cambrian. A Cambrian age, however, is at variance with the interpreted age of Neoproterozoic for the Toobally Formation, which is directly along strike with it (Pigage, 2004).

Figure 9 illustrates three possible stratigraphic and structural scenarios for interpreting the map pattern for the Toobally Formation and Crow map unit. Scenarios 9a and 9b retain the Neoproterozoic age for the Toobally Formation. A major unconformity is required at the base of the volcanic horizon immediately above the Toobally Formation to account for the volcanic horizon being uninterrupted along strike. In scenario 9a, the lateral contact between Toobally Formation and Crow map unit is an early, pre-unconformity fault. The unconformity at the top of the Toobally Formation is internal to the Crow map unit in the northern part of 95D/8. With scenario 9b, the unconformity at the top of the Toobally Formation has erosional relief, cutting down through the Toobally Formation in a northward direction. In this interpretation,

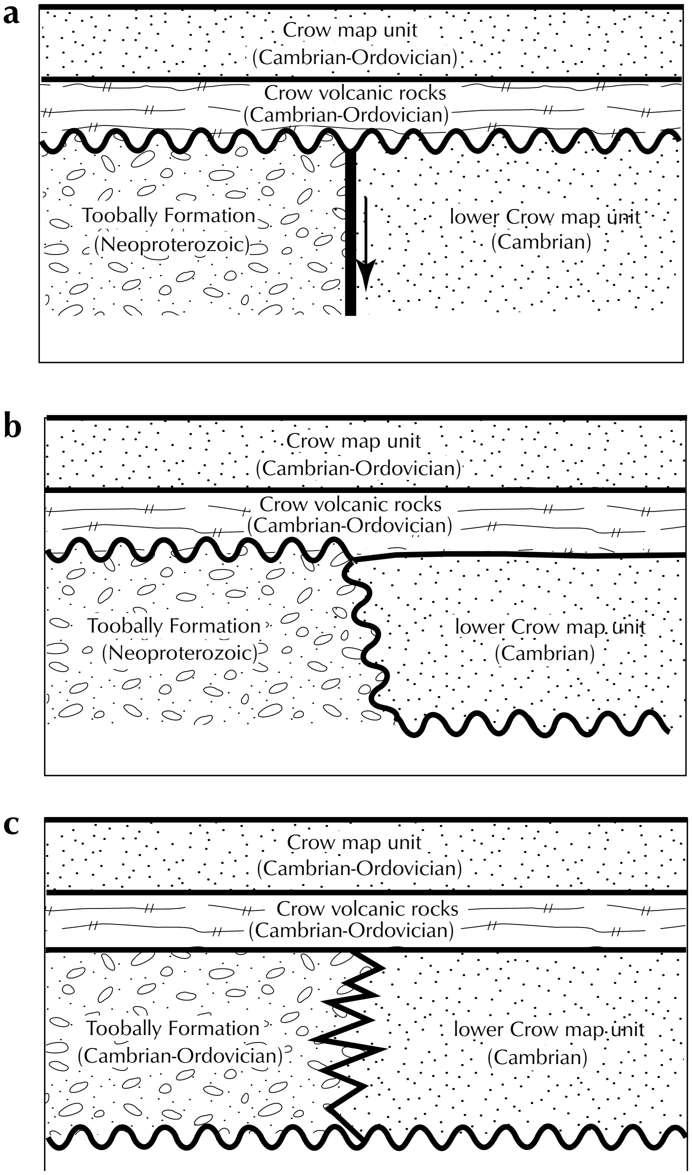

Figure 9. *Interpreted stratigraphic and structural relations between Toobally Formation and Crow map unit. In **(a)** and **(b)**, Toobally Formation is Neoproterozoic and lower Crow map unit is Cambrian. In **(c)**, Toobally Formation and Crow map unit are Cambrian-Ordovician.*

the unconformity remains at the base of the Crow map unit throughout the map area. Scenario 9c introduces the possibility that the correlation of Toobally Formation with Neoproterozoic glacial diamictites is in error, and the along-strike contact between Toobally Formation and Crow map unit is a lateral facies change. The major unconformity at the base of the Crow map unit in 95C/5 is inferred to occur at the base of the Toobally Formation in 95D/8.

All three interpretations have geological challenges. With 9a, the Crow map unit contains an internal unconformity representing a time interval of over 30 million years with identical lithologies above and below the unconformity surface. With 9b, the unconformity at the base of the Crow map unit has an erosional relief of some 1400 m within a 1-km lateral distance. With interpretation 9c, the expected interbedding of Toobally diamictite and Crow map unit sandstone close to the lateral transition between the two units has not been seen in the field. In support of interpretation 9c, the Toobally Formation lacks readily visible bedding and dropstones (primary sedimentary features which are present in both Ice Brook and Vreeland formations), making a lithologic correlation of the Toobally with these units less compelling. I have inferred interpretation 9c in Figure 3; further work is needed to properly constrain the ages of the Toobally Formation and lower Crow map unit.

Rabbitkettle Formation

In the western part of 95D/8, the upper part of the Crow map unit contains an interval of thin-bedded, brownish grey, slightly dolomitic siltstone approximately 750 m thick. The uppermost part of the siltstone contains distinctive interbeds of nodular, medium-grey limestone (Fig. 10). Neither upper and lower contacts are exposed. I have interpreted this interval as a tongue of Rabbitkettle Formation (Gabrielse *et al.*, 1973) based on age and lithologic characteristics. The Rabbitkettle Formation thins rapidly and disappears to the south, as it was not observed in the southern part of 95D/8 (Pigage, 2004). It also was not observed in the east-half of 95D/8, nor in 95C/5. Mapping by Gabrielse and Blusson (1969) confirmed that Rabbitkettle Formation increases significantly in thickness to the west and north, and Crow map unit is absent in the same directions. The schematic cross-section in Figure 2 therefore interprets a lateral facies change from shallow-water, coarse clastics of Crow map unit to deeper water, fine clastics of Rabbitkettle Formation towards the west and north.

Figure 10. *Nodular limestone beds in dolomitic siltstone, Rabbitkettle Formation.*

Fossils collected regionally from the Rabbitkettle Formation encompass Late Cambrian (Franconian) through Early Ordovician (Gabrielse *et al.*, 1973; Tipnis *et al.*, 1978; Cecile, 1982). The formation in the type area is bounded by unconformities at both its lower and upper contacts. The lower unconformity is angular and marks a major stratigraphic break, as regionally, the Rabbitkettle Formation overlies strata as old as the Precambrian-Lower Cambrian Hyland Group (Gabrielse *et al.*, 1973). This major unconformity is presumed to be at the base of the Crow map unit in Figures 2, 3 and 9c. In the map area, fossil control constrains the Rabbitkettle tongue in 95D/8 as being Tremadocian (Fig. 3).

SUCCESSION 3

Succession 3 is comprised of the Sunblood Formation, conformably overlain by interbedded sandstones, shales, and bioturbated siltstones of unit OSs. West of the map area unit OSs is absent (Gabrielse and Blusson, 1969).

Sunblood Formation

In the map area, the Sunblood Formation (Kingston, 1951) consists of medium to dark grey, tan to tan-grey weathering, fine-grained, interbedded dolostones and limestones (Fig. 11). It is a resistant unit and locally forms cliffs over 30 m high. Beds typically range between 5 cm and 1 m in thickness. Dolostone is the predominant lithology; limestone intervals within the dolostone range up to 60 m thick. Both limestone and dolostone are essentially monomineralic, with only very minor amounts of opaque minerals and quartz.

Figure 11. *Mottled bedding plane surface, Sunblood Formation. Mottling caused by burrowing.*

Figure 12. *Interbedded sandstone and dolomitic siltstone, unit OSs. Bedding dips back into the photo. Intervals with rough, recessive outcrop are dolomitic siltstone. Previously published as Figure 14 in Allen et al. (2001).*

Interpreted thickness of the Sunblood Formation in 95C/5 ranges from 150 to 550 m (Pigage and Allen, 2001). The formation is thinnest in the south-central part of 95C/5. It increases in thickness to the west, with an interpreted thickness of greater than 2000 m in the western part of 95D/8 (Pigage, 2004).

The lower contact of the Sunblood Formation is diachronous, ranging in age from earliest Middle Ordovician (Whiterockian) in 95C/5 to early Early Ordovician (middle Tremadocian) in 95D/8 (Fig. 3). Conodonts from the uppermost part of the Sunblood Formation give an early Late Ordovician (early to middle Caradocian) age.

Sunblood Formation is exposed in Northwest Territories and Yukon over a widespread area north and west of the map area. Sunblood carbonates were deposited in a shallow, dominantly sublittoral (0-100 m depth) environment on a carbonate platform up to 100 km wide (Ludvigson, 1975). The formation is bounded on the southwest by deeper water, dark grey to black shale facies of Selwyn Basin (Cecile *et al*., 1997); this facies transition is located west of the map area.

Unit OSs

Unit OSs occurs as scattered outcrops of sandstone and pebbly sandstone, with lesser interbeds of pebble to cobble conglomerate, bioturbated dolomitic siltstone, and dark grey, silty shale (Fig. 12). It has an interpreted thickness of 160 to 200 m. The lower contact with Sunblood Formation is conformable and is marked by an abrupt, but gradational change from dolostone through calcareous sandstone to sandstone. The upper contact is not exposed, but is marked by a rapid change to black, silty, graptolitic shales and limestones of the Road River Group. This upper contact is considered to be an unconformity because of the time gap inferred from fossil control (Fig. 3).

Unit OSs is described in more detail as unit 6 in Allen *et al*. (2001). Dolomitic siltstone and dark grey to black shale lithotypes decrease in abundance to the southeast in 95C/5. Outcrops along the Beaver River in the central part of 95C/5 consist entirely of quartz sandstone, and approximately 50% of the unit in the northwest corner of 95C/5 consists of dolomitic siltstone and interbedded grey shale.

Unit OSs does not contain diagnostic fossils for determining an age of deposition. It is considered to be Ordovician to possibly earliest Silurian because it conformably overlies the Ordovician Sunblood Formation and underlies the Silurian Road River Group (see below).

Extensive *Teichichnus, Phycodes* and *Planolites* ichnogenera and bioturbation indicate the depositional environment contained abundant nutrients and was most likely in the offshore transitional zone between fair-weather and storm wave bases (MacNaughton, 2002a). The common occurrence of sand and locally coarser clastic sediments suggests a proximal rather than distal depositional environment.

SUCCESSION 4

Succession 4 contains the lateral facies transition from carbonate platform sediments of Macdonald Platform to fine clastic, basinal sediments of Selwyn Basin (Cecile *et al.*, 1997; Fig. 1). The facies transition occurs in 95C/5 with shales of the Road River Group being restricted to the northwest corner of the map sheet, and time-equivalent thick carbonate rocks of the Nonda Formation, Beaver River map unit and the Devonian carbonate map unit occurring south and east of the Road River shale outcrops. The transition is rapid, but is also foreshortened by thrust faults in the area of the transition.

The carbonate Macdonald Platform is represented by, from oldest to youngest, the Nonda Formation, Beaver River map unit and the Devonian carbonate map unit. This succession of carbonates is 1300 m to 1400 m thick.

Nonda Formation

The lowermost Nonda Formation (Norford *et al.*, 1966) is a dark, fetid dolostone, locally with cherts. Its lower contact is sharp and is marked by an abrupt change from thick- bedded dolostones of the underlying Sunblood Formation to thin-bedded dolostones. Interpreted thickness of the Nonda Formation ranges from 90 m to 200 m. Fossil control for the age of the Nonda Formation is not available from the map area. Regionally, both upper and lower contacts are unconformable; in the type area, the formation is late Llandovery (Early Silurian) in age (Norford *et al.*, 1966).

Figure 13. *Thick-bedded dolostone cliffs of Silurian-Devonian carbonates, Beaver River Formation. Bedding dips moderately to right in photo. Outcrop occurs in canyon along the Beaver River. Height from Beaver River to top of ridge is about 335 m.*

Beaver River map unit

Dolostones of the Nonda Formation are overlain by a 1200-m-thick, monotonous succession of thick-bedded, generally nonfossiliferous, medium-grey, tan-weathering dolostones (Fig. 13) of the Beaver River map unit (Pigage, unpublished data). Its occurrence is restricted to east and south parts of 95C/5. Beds range from 10 cm to greater than 7 m thick, generally being 1-2 m thick. The uppermost 120 m of Beaver River map unit is fossiliferous, with visible two-hole crinoids. Based on fossil control, this uppermost part of the carbonate succession is middle Devonian (Fig. 3). The Beaver River map unit is correlated with Muncho-McConnell, Stone and Dunedin formations in northeastern British Columbia (Taylor and Mackenzie, 1970). The early Devonian Muncho-McConnell Formation unconformably overlies the Nonda Formation in northeastern British Columbia; by correlation, the maximum age of the Beaver River map unit is considered to be early Devonian, and its lower contact is also possibly unconformable (Fig. 3).

Devonian carbonate map unit

The Devonian carbonate map unit overlies the Road River Group and occurs northwest of the Beaver River map unit (Pigage and Allen, 2001). It is laterally equivalent to the uppermost fossiliferous part of the Beaver River map unit and the Dunedin Formation. Both limestone and dolostone occur within this unit. Limestone intervals consist of interbedded argillaceous limestones and fossiliferous grainstones. Dolostones commonly contain irregular black chert lenses. The maximum extent of the Devonian carbonate unit to the northwest occurs in nearby map sheets 95C/12, 95C/11, and 95C/14 (Fallas *et al.*, 2005). Fossils indicate a Middle Devonian age for this unit (Fig. 3).

Road River Group

Road River Group (Jackson and Lentz, 1962; Gordey and Anderson, 1993) is restricted to the northwestern corner of 95C/5 and eastern exposures in 95D/8. It is a heterolithic unit with the dominant lithology being a dark grey, noncalcareous to calcareous, graptolitic, silty shale. Interbeds within the shale include dark grey to black limestone and tan-weathering sandstone and siltstone. Overwhelmingly, the distinctive characteristics of the Road River Group are the presence of dark grey to black, organic material and the common occurrence of graptolites (Fig. 14). In the northwest corner of 95C/5,

Figure 14. *Graptolites on bedding plane surface of dark grey limestone, Road River Group.*

Figure 15. *Dark grey to black, siliceous shale of Besa River Formation.*

however, the upper part of Road River is a dark grey to black siliceous shale without graptolites.

Graptolites and conodonts collected from Road River Group indicate an age range of late Llandoverian (late Early Silurian) to Lochkovian (Early Devonian). The lower contact is unconformable because of the time gap inferred from the fossil control (Fig. 3). The upper contact is abrupt; fossil collections have not been systematic enough to determine if it is conformable. Interpreted thickness of the Road River Group in the map area is 950 m.

SUCCESSION 5

Succession 5 consists of the dark grey to black, siliceous shales and bedded cherts of the Besa River Formation, overlain by the sandstones with lesser shales and limestones of the Mattson Formation.

Besa River Formation

Besa River Formation (Kidd, 1963) is generally recessive. It consists of dark grey to black bedded cherts and interbedded light grey-weathering, siliceous, carbonaceous shales (Fig. 15). Locally, the shales contain large limestone concretions. It has an interpreted thickness of 250 m to 750 m. The lower contact is not exposed. The upper contact is gradational with the Mattson Formation sandstones. Sandstone near the contact contains interbeds of dark grey shale typical of Besa River Formation.

The Besa River Formation is Middle Devonian to late Visean (Lower Carboniferous) in age (Richards, 1989). Both upper and lower contacts are diachronous, with the age of the lower contact increasing, and the age of the upper contact decreasing from east to west. Macrofossils were not found in the Besa River Formation in the Pool Creek area. Condont collections from limestone interbeds within the formation indicate Middle Devonian ages.

Deposition of Besa River shales was in a dysaerobic marine basin at moderate water depths (Richards, 1989). Richards (1989) suggested that shale and chert resulted from a combination of hemipelagic sedimentation and deposition from weak, gravity-assisted suspension currents.

Mattson Formation

Mattson Formation (Patton, 1958) in 95D/8 consists of fine-grained, thick-bedded, grey quartz sandstone. It has an interpreted thickness of 1450 m. In 95C/5, Mattson Formation becomes much thicker, ranging from 1850 m to 2850 m in interpreted thickness. It can be divided into two members in 95C/5, a lower member consisting of quartz sandstone with interbedded black shales (Fig. 16), and an upper member consisting predominantly of thick-bedded quartz sandstones with minor interbedded limestones. The upper contact is unconformable with a significant time gap before deposition of the overlying Fantasque Formation or undivided Grayling and Toad formations (Figs. 3 and 4).

Figure 16. *Interbedded grey sandstone and dark grey siliceous shale, lower Mattson Formation.*

East of the present map area, the interpreted depositional environment for the Mattson Formation is a south- to southwest-prograding delta complex with interbedded eolian sands, coals, fluvial deposits, channel-fill deposits, submarine channels, and delta shoreline deposits (Richards *et al.*, 1993). Exposures in the map area are clean quartz arenites, and therefore are not typical prodelta deposits; more sedimentological research is required to delineate the depositional environment. Age definitive fossils were not found in the area of interest. Fossils from thicker intervals to the east indicate the formation is upper Visean to Serpukhovian (Richards *et al.*, 1993).

Figure 17. *Siliceous, dark grey shales, Fantasque Formation. Beds dip moderately left in photo. Interval of change between bedded and thin bedded in centre of photo contains numerous carbonate concretions.*

SUCCESSION 6

Succession 6 consists of siliceous shales and limestones of the Permian Fantasque Formation. It is preserved in the map area only in one structural panel forming the immediate footwall to the Toobally fault (Pigage, 2004) in 95D/8.

Fantasque Formation

Fantasque Formation (Harker, 1961) consists of siliceous shale with one interbed of thin-bedded, dark grey limestone. The shales are internally bedded on a scale of 5 to 20 cm (Fig. 17); nodular limestone beds occur scattered through the shale succession. Interpreted thickness of the unit is approximately 1700 m. In this structural panel, the Fantasque Formation disconformably overlies the Mattson Formation (Fig. 4) and is disconformably overlain by Triassic Grayling and Toad formations (Figs. 3 and 4).

Lateral areal exposure of the Fantasque Formation is much less extensive than that of the earlier successions, most likely indicating more extensive erosion after deposition. Regionally, the Fantasque Formation is late Artinskian (Early Permian) through Wordian (Late Permian; Henderson *et al.*, 1993) in age. One conodont collection from the area of interest had a broadly Permian age (L.J. Pyle, unpublished data, 2004). Depositional environment is presumed to be similar to that of the Besa River Formation, consisting of a dysaerobic marine basin at moderate water depths.

Figure 18. *Soft, grey shales of the undivided Triassic Grayling and Toad formations.*

SUCCESSION 7

Grayling and Toad formations

Dark grey, soft recessive shales with lesser interbedded thin, tan-weathering sandstones (Fig. 18) constitute Triassic sedimentary rocks in the map area. Since outcrop control is sparse, Triassic siliciclastic sedimentary rocks have generally been mapped as consisting of undivided Grayling and Toad formations (Kindle, 1944; Fallas and Lane, 2001). Shales are preserved mainly in synclinal fold keels, and in the immediate footwall of thrust faults in southern 95C/5 and central 95D/8. Interpreted thicknesses in the map area are very subjective, depending on assumed orientations of the overlying thrust faults and cross-sectional interpretation of the synclinal fold pattern. Interpreted sections within the map area have an inferred thickness ranging from a minimum of 150 m to a maximum of 850 m (Pigage, 2004). Regionally, within southwest 95C, interpreted thicknesses range from 1000 m to 1500 m (Fallas *et al*, 2004).

Pollen samples for the undivided Grayling and Toad formations in southeast Yukon were identified as Griesbachian (Early Triassic; Utting *et al*., 2005). Fossils from underlying and overlying sediments indicate both upper and lower contacts for Triassic siliciclastic rocks are disconformities. Detailed stratigraphic studies of the Early Triassic section in Mount Martin (95C/1) and Mount Merrill (95C/2) areas indicate that deposition of the Triassic sediments was in a nearshore shallow marine environment (MacNaughton, 2002b; Utting *et al*., 2005).

SUCCESSION 8

Unit Pssc

Succession 8 consists of a slightly greater than 160-m-thick succession of horizontal, tan, noncalcareous, poorly consolidated, siltstones, sandstones, and conglomerates. They underlie an east-trending, ridge-length of approximately 5 km in the northwest corner of 95C/5, and possibly extend slightly into 95D/8. In one small area, the sedimentary rocks are conformably overlain by a 15- to 20-m-thick, dark brown, columnar-jointed, massive to slightly vesicular basalt flow. The conglomerate immediately beneath the basalt flow is baked and therefore more resistant to erosion, resulting in an inverted topography, as poorly consolidated sediments have been removed by erosion from other areas. The sediments unconformably overlie folded Silurian-Devonian Road River Group strata.

The sandstones contain thinner interbeds of clay siltstone to mudstone and highly variable ‘red beds’. Siltstone intervals consist of well sorted clayey siltstone to mudstone. Lithologies are discontinuous across the section, occurring as thin lenses up to 20 m long. Locally abundant organic material, much of which is coalified, occurs as small lenses. Red-bed intervals consist dominantly of a dark-red-stained, matrix-supported conglomerate with a strongly to moderately cemented sand-silt matrix. Lesser discontinuous interbeds within the conglomerate include well sorted siltstone, sandstone, and fine conglomerate. Marginal contacts are gradational or sharp and are typically irregular.

The presence of columnar jointing in the basalt, the occurrence of red beds and coal in the sediments, and the widespread presence of gravels and sands with interbedded discontinuous silts and sands, all indicate a fluvial depositional environment, probably a clastic braided river environment (I.R. Smith, pers. comm., 2001). Imbrication and bar forms, and columnar leaning in the basalt all indicate a paleoflow direction of east to east-southeast.

A sample of the basalt flow was dated with $^{39}Ar/^{40}Ar$ methods by Dr. M. Villeneuve of the Geological Survey of Canada Geochronology Laboratory as 56.2 ± 0.8 Ma (2σ) (M. Villeneuve, pers. comm., 2003). The basalt flow is therefore Late Paleocene, and underlying sediments are also assumed to be Paleocene.

DISCUSSION AND SUMMARY

The various sedimentary formations of 95C/5 and 95D/8 areas have been presented above as eight major stratigraphic successions, ranging from Proterozoic to Paleocene, with a combined thickness on the order of 5000 m to 15 000 m. Early to Middle Paleozoic stratigraphic successions are best preserved in the map area with later strata being only locally preserved. Each succession contains one or more formations with related lithologic facies and depositional environments. In many cases, these successions are separated by unconformities, mostly marking significant hiatuses. Internally, the successions also locally contain unconformities.

The sedimentary successions record vertical and lateral changes in the depositional environment through time. In a broad sense, discussion of the stratigraphy in this format is similar to, but not as detailed as, a sequence stratigraphy approach (Cantuneanu, 2003). The variations in the sedimentary depositional environment are caused by an interplay of tectonics, eustasy and climate (Cantuneanu, 2003).

Succession 1 is older than 650 Ma and younger than about 1830 Ma. Exposed Proterozoic sedimentary rocks in the Canadian Cordillera have been divided into three successions A, B, C (Young *et al.*, 1979). Given the above age constraints, succession 1 is a possible correlative with any of Sequences A, B or C. Additional detrital zircon research may further restrict the age of deposition of succession 1 strata and better constrain possible regional correlations.

Without tighter age constraints, it is difficult to determine if this succession is associated in any way with the early rifting of Laurentia (Bond and Kominz, 1984; Ross, 1991; Colpron *et al.*, 2002). The absence of coarse clastic rocks in unit Ps suggests this succession may predate Proterozoic to Cambrian rifting. Alternatively, volcanic rocks and coarse breccias and conglomerates in unit Pls may record volcanism and rifting during initial breakup of Laurentia.

Successions 2 through 5 record miogeoclinal sedimentation on the western margin of ancestral North America. Both successions 2 and 4 contain a horizontal facies zonation westward from a shallow marine depositional setting to a deeper water marine depositional environment. In succession 2, proximal sedimentation is dominated by quartzose siliciclastic rocks, and in succession 4, the transition is marked by a rapid lateral facies change from shallow marine carbonates to deeper water marine shales.

Succession 3 in the map area consists predominantly of shallow-water platform carbonates of the Sunblood Formation. The facies transition to marine basinal shales occurs farther west than the area of interest (Cecile *et al.*, 1997).

Succession 2 in southeast Yukon reflects a large measure of local and/or regional tectonic control. The upper part of the Crow map unit is time-correlative with the early to middle Ordovician Mackenzie carbonate platform, to basinal shale transition in central Yukon (Abbott *et al.*, 1986), and a similar transition between Macdonald Platform carbonates and Kechika Trough basinal shales in northeastern British Columbia (Pyle and Barnes, 2000). The Early Ordovician, coarse siliciclastic sedimentary rocks of the Crow map unit are unique to southeast Yukon and do not occur along strike to the north or south. Dramatic thickening of the Crow map unit between map sheets 95C/5 (300 m) and 95D/8 (5700 m) suggests a local paleohigh in 95C/5, possibly related to faulting. It is interesting to note that Cecile *et al.* (1997) identified the Liard Line (Fig. 1), slightly south of the map area of interest, as a major northeast-trending ancestral transfer fault, with substantial uplift occurring south of it during early Paleozoic.

Succession 5 records a shallowing-upward trend, with coarse clastic rocks of the Mattson Formation conformably overlying carbonaceous shales of the Besa River Formation. The lateral facies transition from basinal shales of the Besa River Formation to carbonates of the Flett and upper Banff formations (Richards, 1989) occurs east of the map area in the east side of 95C.

Permian (succession 6), Triassic (succession 7) and Paleocene (succession 8) sedimentary rocks are only locally preserved in the map area. The absence of Permian to Paleocene sedimentary rocks indicates that substantial erosion occurred in the map area as a result of contractional deformation and consequent structural thickening that caused mountain building and associated development of foredeeps (Stott *et al.*, 1993). This east-verging deformation was caused by collision and accretion of exotic terranes to the western margin of North America starting in Jurassic time (Coney *et al.*, 1980).

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REFERENCES

Abbott, J.G., Gordey, S.P. and Tempelman-Kluit, D.J., 1986. Setting of stratiform, sediment-hosted lead-zinc deposits in Yukon and northeastern British Columbia. *In:* Mineral Deposits of Northern Cordillera, J.A. Morin (ed.), Canadian Institute of Mining and Metallurgy, Special Volume 37, p. 1-18.

Allen, T.L. and Pigage, L.C., 2000. Geological map of Pool Creek (NTS 95C/5), southeastern Yukon (1:50 000 scale). Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, Open File 2000-11.

Allen, T.L., Pigage, L.C. and MacNaughton, R.B., 2001. Preliminary geology of the Pool Creek map area (95C/5), southeastern Yukon. *In:* Yukon Exploration and Geology 2000, D.S. Emond and L.H. Weston (eds.), Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, p. 53-72.

Bond, G.C. and Kominz, M.A., 1984. Construction of tectonic subsidence curves for the early Paleozoic miogeocline, southern Canadian Rocky Mountains: Implications for subsidence mechanisms, age of breakup, and crustal thinning. Geological Society of America Bulletin, vol. 95, p. 155-173.

Cantuneanu, O., 2003. Sequence stratigraphy of clastic systems. Geological Association of Canada, Short Course Notes, vol. 16, 248 p.

Cecile, M.P., 1982. The Lower Paleozoic Misty Creek embayment, Selwyn Basin, Yukon and Northwest Territories. Geological Survey of Canada, Bulletin 335, 78 p.

Cecile, M.P., Morrow, D.W. and Williams, G.K., 1997. Early Paleozoic (Cambrian to Early Devonian) tectonic framework, Canadian Cordillera. Bulletin of Canadian Petroleum Geology, vol. 45, p 54-74.

Colpron, M., Logan, J.M. and Mortensen, J.K., 2002. U-Pb zircon age constraint for late Neoproterozoic rifting and initiation of the lower Paleozoic passive margin of western Laurentia. Canadian Journal of Earth Sciences, vol. 39, p. 133-143.

Coney, P.J., Jones, D.L. and Monger, J.W.H., 1980. Cordilleran suspect terranes. Nature, vol. 288, p. 329-333.

Deklerk, R. and Traynor, S., 2005. Yukon MINFILE – A database of mineral occurrences. Yukon Geological Survey, CD-ROM.

Douglas, R.J.W., 1976. Geology of La Biche River map area (95C), District of Mackenzie. Geological Survey of Canada, "A" Series Map 1380A, 1:250 000 scale.

Douglas, R.J.W. and Norris, D.K., 1959. Fort Liard and La Biche map-areas, Northwest Territories and Yukon 95B and 95C. Geological Survey of Canada, Paper 59-6, 23 p.

Fallas, K.M. and Lane, L.S., 2001. Geology of the Mount Martin, Fisherman Lake, and Mount Flett map areas, Yukon Territory and Northwest Territories. Geological Survey of Canada, Current Research 2001-A5, 11 p.

Fallas, K.M., Pigage, L.C. and MacNaughton, R.B. (compilers), 2004. Geology, southwest La Biche River (95C/SW), Yukon Territory and British Columbia. Geological Survey of Canada, Open File 4664, 1:100 000-scale map and cross-sections.

Fallas, K.M., Pigage, L.C. and Lane, L.S. (compilers), 2005. Geology, La Biche River northwest (95C/NW), Yukon and Northwest Territories. Geologicial Survey of Canada, Open File 5018, 1:100 000 scale.

Gabrielse, H. and Blusson, S.L., 1969. Geology of Coal River map-area, Yukon Territory and District of Mackenzie (95D). Geological Survey of Canada, Paper 68-38, 22 p.

Gabrielse, H., Blusson, S.L. and Roddick, J.A., 1973. Geology of Flat River, Glacier Lake, and Wrigley Lake map-areas, District of Mackenzie and Yukon Territory. Geological Survey of Canada, Memoir 366 (Parts I and II), 421 p.

Goodfellow, W.D., Cecile, M.P. and Leybourne, M.I., 1995. Geochemistry, petrogenesis and tectonic setting of lower Paleozoic alkalic and potassic volcanic rocks, Northern Canadian Cordilleran miogeocline. Canadian Journal of Earth Sciences, vol. 32, p. 1236-1254.

Gordey, S.P. and Anderson, R.G., 1993. Evolution of the Northern Cordilleran miogeocline, Nahanni map area (105I), Yukon and Northwest Territories. Geological Survey of Canada, Memoir 428, 214 p.

Harker, P., 1961. Summary account of Carboniferous and Permian formations, southwestern District of Mackenzie. Geological Survey of Canada, Paper 61-1, 25 p.

Henderson, C.M., Bamber, E.W., Richards, B.C., Higgins, A.C. and McGugan, A., 1993. Permian; Subchapter 4F. *In:* Sedimentary Cover of the Craton in Canada, D.F. Stott and J.D. Aitken (eds.), Geological Survey of Canada, Geology of Canada, no. 5, p. 272-293.

Jackson, D.E. and Lenz, A.C., 1962. Zonation of Ordovician and Silurian graptolites in northern Yukon, Canada. American Association of Petroleum Geologists Bulletin, vol. 46, p. 30-45.

Kidd, F.A., 1963. The Besa River Formation. Bulletin of Canadian Petroleum Geology, vol. 11, p. 369-372.

Kindle, E.D., 1944. Geological reconnaissance along Fort Nelson, Liard, and Beaver Rivers, northeastern British Columbia and southeastern Yukon. Geological Survey of Canada, Paper 44-16, 19 p.

Kingston, D.R., 1951. Stratigraphic reconnaissance along the upper South Nahanni River, NWT. American Association of Petroleum Geologists Bulletin, vol. 35, no. 11, p. 2409-2426.

MacNaughton, R.B., 2002a. Report on one sample from Ordovician strata, Pool Creek map area, Yukon Territory, collected by Lee Pigage (Yukon Geology Program) and submitted for trace-fossil identification: NTS 95C/5. Geological Survey of Canada, Report 001-RBM-2002, 3 p.

MacNaughton, R.B., 2002b. Sedimentology of Triassic siliciclastic strata, Mount Martin and Mount Merrill map areas, Yukon Territory. Geological Survey of Canada, Current Research 2002-A4, 10 p.

MacNaughton, R.B. and Pigage, L.C., 2003. Geology, Larsen Lake (95C/4), Yukon Territory and British Columbia. Geological Survey of Canada, Open File 1797, 1:50 000 scale.

McCracken, A.D., 2003a. Report on 12 conodont samples (Con. No. 1762) from Middle Ordovician and Devonian strata from British Columbia collected by A. Khudoley and L. Pigage and submitted by L. Lane (GSC-C). NTS 94G/12, 95C/04, 95C/05, 95C/11, 95C/12, 95C/13. Geological Survey of Canada, Report 6-ADM-2003, 8 p.

McCracken, A.D., 2003b. Report on one conodont sample (Con. No. 1674) from Middle Ordovician strata from southeastern Yukon Territory collected by R.B. MacNaughton (GSC-C) NTS 95C/05. Geological Survey of Canada, Report 7-ADM-2003, 4 p.

Norford, B.S., 2001. Report on six collections from the Trutch and La Biche River map areas, northern British Columbia and adjacent Yukon Territory submitted by Dr. L.S. Lane in 2001 (NTS 94G/04, 95C/05). Geological Survey of Canada, Report S-3 BSN 2001, 2 p.

Norford, B.S., 2002. Report on two lots of fossils from the La Biche River map-area, southern Yukon Territory, collected by Mr. Lee Pigage and Ms. Tammy Allen in 2001 and submitted by Dr. L.S. Lane, 2001 (95C/5). Geological Survey of Canada, Report S-1-BSN-2002, 2 p.

Norford, B.S., Gabrielse, H. and Taylor, G.C., 1966. Stratigraphy of Silurian carbonate rocks of the Rocky Mountains, northern British Columbia. Bulletin of Canadian Petroleum Geology, vol. 14, p. 504-519.

Nowlan, G.S., 2004. Report on eighteen samples from Cambrian, Ordovician, Silurian and possibly Devonian strata in the southeastern part of Yukon Territory submitted for conodonts analysis by Larry Lane, Rob MacNaughton and Karen Fallas (Geological Survey of Canada, Calgary) and Lee Pigage and Tammy Allen (Yukon Geological Survey); NTS 0095C/05; CON #1657. Geological Survey of Canada, Report 002-GSN-2004, 10 p.

Okulitch, A.V., 2001. Geological time scale, 2001. Geological Survey of Canada, Open File 3040 (National Earth Science Series, Geological Atlas) – REVISION.

Patton, W.J.H., 1958. Mississippian succession in South Nahanni River area, Northwest Territories. *In:* Jurassic and Carboniferous of Western Canada, A.J. Goodman (ed.), American Association of Petroleum Geologists, John Andrew Allan Memorial Volume, p. 309-326.

Pigage, L.C., 2004. Preliminary geology of NTS 95D/8 (north Toobally Lakes area), southeast Yukon (1:50 000 scale). Yukon Geological Survey, Open File 2004-19.

Pigage, L.C. and Allen, T.L., 2001. Geological map of Pool Creek (NTS 95C/5), southeastern Yukon (1:50 000 scale). Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs Canada, Open File 2001-32.

Pigage, L.C. and MacNaughton, R.B., 2004. Reconnaissance geology of northern Toobally Lake (95D/8), southeast Yukon. *In:* Yukon Exploration and Geology 2003, D.S. Emond. and L.L. Lewis (eds.), Yukon Geological Survey, p. 199-219.

Pigage, L.C. and Mortensen, J.K., 2004. Superimposed Neoproterozoic and early Tertiary alkaline magmatism in the La Biche River area, southeast Yukon Territory. Bulletin of Canadian Petroleum Geology, vol. 52, p. 325-342.

Pyle, L.J. and Barnes, C.R., 2000. Upper Cambrian to Lower Silurian stratigraphic framework of platform-to-basin facies, northeastern British Columbia. Bulletin of Canadian Petroleum Geology, vol. 48, p. 123-149.

Richards, B.C., 1989. Uppermost Devonian and lower Carboniferous stratigraphy, sedimentation, and diagenesis, southwestern District of Mackenzie and southeastern Yukon Territory. Geological Survey of Canada, Bulletin 390.

Richards, B.C., Bamber, E.W., Higgins, A.C. and Utting, J., 1993. Carboniferous; Subchapter 4E. *In:* Sedimentary Cover of the Craton in Canada, D.F. Stott and J.D. Aitken (eds.), Geological Survey of Canada, Geology of Canada, no. 5, p. 202-271.

Ross, G.M., 1991. Tectonic setting of the Windermere Supergroup revisited. Geology, vol. 19, p. 1125-1128.

Stott, D.F., Caldwell, W.G.E., Cant, D.J., Christopher, J.E., Dixon, J., Koster, E.H., McNeil, D.H. and Simpson, F., 1993. Cretaceous, Subchapter 4I. *In:* Sedimentary Cover of the Craton in Canada, D.F. Stott and J.D. Aitken (eds.), Geological Survey of Canada, Geology of Canada, no. 5, p. 358-438.

Tipnis, R.S., Chatterton, B.D.E. and Ludvigsen, R., 1978. Ordovician conodont biostratigraphy of the southern District of Mackenzie, Canada. *In:* Western and Arctic Canadian biostratigraphy, C.R. Stelck and B.D.E. Chatterton (eds.). Geological Association of Canada, Special Paper 18, p. 39-91.

Utting, J., Zonneveld, J.P., MacNaughton, R.B. and Fallas, K.M., 2005. Palynostratigraphy, lithostratigraphy and thermal maturity of the Lower Triassic Toad and Grayling, and Montney formations of western Canada, and comparisons with coeval rocks of the Sverdrup Basin, Nunavut. Bulletin of Canadian Petroleum Geology, vol. 53, p. 5-24.

Young, G.M., Jefferson, C.W., Delaney, G.D. and Yeo, G.M., 1979. Middle and Late Proterozoic evolution of the northern Canadian cordillera and shield. Geology, vol. 7, p. 125-128.