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Devonian of the Northern Canadian Mainland Sedimentary Basin (a contribution to the Geological Atlas of the northern Canadian Mainland Sedimentary Basin)

D.W. Morrow

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doi:10.4095/290970

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Recommended citation:
Morrow, D.W., 2012. Devonian of the Northern Canadian Mainland Sedimentary Basin (a contribution to the Geological Atlas of the northern Canadian Mainland Sedimentary Basin); Geological Survey of Canada, Open File 6997, 88 p. doi:10.4095/290970

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INTRODUCTION

Devonian-aged strata are present across most of the northern Canadian mainland sedimentary basin. They extend westward from near the edge of the Canadian Shield across the Northern Interior Plains, and across the mountain belts of the northern Cordillera towards Alaska (Fig. 1, 2). Devonian strata are exposed as part of a gently west-dipping lower Paleozoic succession in an outcrop belt bordering the western edge of the Shield along the eastern edge of the Northern Interior Plains.

These strata extend westward in the subsurface and in outcrop across approximately 600,000 km^2 of the northern mainland and are present in the subsurface across large areas of the Northern Interior Plains, in the northern Yukon and across Liard Plateau west of Fort Liard (Fig. 1). Farther west, Devonian strata outcrop within north and northwest-trending arcuate bundles of folds and faults across the Mackenzie, Selwyn, Wernecke, Richardson and Ogilvie mountains of the Northern Cordillera.

Devonian strata also occur in the subsurface adjacent to outcrop belts associated with these regional folds and faults. The most significant of these is the area of subsurface Devonian that may lie in the footwall beneath the Plateau Thrust Fault in the central Mackenzie Mountains (Fig. 1, 2), originally thought to be fairly large but is now known to be of small extent (Gordey et al. 2011). West of the Pelly and Yukon rivers in the southwestern part of the Yukon lie the Allochthonous Terranes, which have been tectonically transported hundreds to thousands of kilometres northwest to their present position along the western flank of North America (Fig. 1, 3; Wheeler, 1997). The ages of strata in these tectonically-transported terranes are poorly constrained. Only units within terranes that may include Devonian strata are illustrated (Fig. 1; Wheeler et al. 1997). Devonian strata within these terranes west of Tintina Trench, or Tintina Fault (Fig. 2, 3) are not further described here and the interested reader is referred to Wheeler (1996), Morrow and Geldsetzer (1992) and Geldsetzer and Morrow (1992) for the relatively small amount of information available concerning Devonian strata, or strata that may possibly be Devonian in age within the Allochthonous Terranes.

The Devonian succession of the Northern Mainland includes the uppermost “Tippecanoe Sequence” and the lower part of the “Kaskaskia Sequence”, which were originally defined by Sloss (1963) as two of the six unconformity bounded, transgressive-regressive successions of strata, or sequences that form the entire Phanerozoic succession across the North American craton (Sloss, 1988).

The principal stratigraphic subdivisions of the Devonian succession across the northern mainland include five stratigraphic assemblages of formations, which, in ascending stratigraphic order, have been named here the “Delorme” Assemblage, the “Bear Rock” Assemblage, the “Hume-Lonely Bay” Assemblage, the “Slave-Kakisa” Assemblage, and the “Kotcho-Tetcho” Assemblage (Fig. 4). These correspond closely with the “Delorme” Assemblage, the “Bear Rock-Stone” Assemblage, the “Hume-Dunedin” Assemblage, the “Fairholme” Assemblage, the “Ronde-Kakisa” Assemblage, and the “Palliser” Assemblage previously defined for western Canada by Morrow and Geldsetzer (1992), and by Geldsetzer and Morrow (1992). Their combined “Fairholme” and “Ronde-Kakisa” assemblages are correlative with the single “Slave-Kakisa” Assemblage in the northern mainland region of this report. These assemblages correspond in part also to the Devonian “Sequences” outlined by Moore (1993).

The term “assemblage” is used here because the boundaries between these stratigraphic packages are not all unconformities and may not be correlative with depositionally updip unconformities of the same magnitude as the sequences of Moore (1993). The relevant, depositionally -updip, strata are not preserved east of the erosional limit of Paleozoic strata along the western edge of the Canadian Shield.

Stratigraphic sequences were initially defined as continent-wide successions of strata bounded by unconformities (see Sloss, 1963). More recent usage (Mitchum et al., 1977) has amended the definition of a stratigraphic sequence, or depositional sequence, to include “a relatively conformable succession of strata bounded at their tops and bottom by unconformities or correlative conformities” and that depositional sequences occur across a wide range of scales with smaller scale sequences occurring within larger scale sequences. In common to all these sequence definitions, and to almost all other modern definitions of sequences is the perception that sequences are comprised of approximately synchronous depositional successions deposited during cycles of marine transgressions and regressions that follow repetitive and oscillatory changes in sea level (Handford and Loucks, 1993). The term “sequence” is itself now generally reserved to describe successions or groupings of strata or stratigraphic units that have been interpreted to have originated during deposition of individual cycles of marine transgression and regression. It is understood that smaller sequences are nested within and collectively form larger scale sequences. The less formal term "assemblage" is used here also, as not all of the formational groupings described here correspond to unconformity-bounded successions of strata deposited during complete cycles of marine transgression and regression.

The stratigraphic assemblages described here include strata that were deposited during times of continuous deposition. Some of these, the Hume-Lonely Bay and the Slave-Kakisa assemblages are clearly bounded by unconformities at the base of the Headless Formation or Ebbutt Member, at the base of the Watt Mountain Formation and at the base of the Trout River Formation (Figs. 4, 5) and thus can be regarded as complete depositional sequences. The Slave-Kakisa Assemblage correlates southward with the "second order" Devonian depositional sequence including strata between the base of the Gilwood Formation to the base of the Graminia Formation in Alberta (Potma et al., 2001). This second order sequence is comprised of three "third order" depositional sequences that coincide approximately, although not exactly, with the Beaverhill Lake, Woodbend and Winterburn groups, which form most of the Devonian succession preserved across Alberta (Oldale and Munday, 1994; Switzer et al., 1994; Potma et al., 2001). Similarly, the Wabamun Group (Halbertsma, 1994) across Alberta coincides approximately, but not exactly, with the Kotcho-Tetcho Assemblage (Fig. 4, 5). The Beaverhill Lake, Woodbend, Winterburn and Palliser-Wabamun "megacycles" of Savoy and Mountjoy (1995) are also similar to the depositional sequence-based assemblages described here in that the transgressive phases represented by the Watt Mountain Formation and the stratigraphically higher Sassenach Formation (i.e., Trout River Formation equivalent) are included in the lowermost parts of their Beaverhill Lake and Palliser-Wabamun megacycles respectively.

The Delorme, Bear Rock, and Kotcho-Tetcho assemblages lack bounding unconformities either along their bases or tops. These latter assemblages are instead stratigraphic subdivisions that are separated by conformable formational contacts. These contacts are approximate synchronous lithologic transitions at the regional stratigraphic and chronologic scales of these assemblages and correspond to changes in overall depositional trend at the scale of the "second order" depositional sequences or T-R cycles that are described here (e.g., T-R Cycle A in Fig. 4, 5).

The Delorme Assemblage is separated from the overlying Bear Rock Assemblage by an abrupt upward transition from sandy carbonates of the Tsetso and Mirage Point formations and their equivalents to the overlying clean carbonates and evaporites of the Arnica and Fort Norman Formations in most areas of the northern mainland except across regions occupied by early Devonian landmasses, such as Tathlina Uplift (Fig. 4, 5). Taken together, these two assemblages constitute a single depositional transgressive-regressive sequence bounded by unconformities, with the Delorme Assemblage overlying the unconformable base of the Kaskaskia Sequence (Sloss, 1963; Moore, 1993), or the informally-named 'sub-Devonian unconformity', across the Interior Plains of the northern mainland.

The transgressive-regressive depositional sequence represented by the combined Delorme and Bear Rock assemblages is termed here "T-R Cycle A" with the Delorme Assemblage as the dominantly transgressive phase overlain by the Bear Rock Assemblage as the regressive phase (Fig. 4B). The Hume-Lonely Bay Assemblage constitutes the entirety of T-R Cycle B, the Slave-Kakisa Assemblage forms T-R Cycle C and the Kotcho-Tetcho Assemblage forms the lower transgressive part of T-R Cycle D, which continues stratigraphically higher into Carboniferous strata of the Banff and Pekisko formations in the western part of Great Slave Plain (Fig. 4B). The black shale of the Exshaw Formation, which caps the entire Devonian System, was deposited during the time of maximum marine transgression during deposition of T-R cycle Cycle D and includes within it the material surface, or stratigraphic horizon that marks the time of maximum transgression. This may be regarded as the upper boundary of the Kotcho-Tetcho Assemblage, although from a regional perspective, the base of the Exshaw Formation is the mappable top of the Kotcho-Tetcho Assemblage. Each T-R cycle is bounded by regional unconformities and therefore may be regarded as an individual, large large-scale second order depositional, or stratigraphic, sequences (Fig. 4B).

The discussion of the Devonian system across the northern mainland is focused primarily on the Interior Plains and Mackenzie Mountains with less emphasis on the Devonian across the northern Yukon Territory (Fig. 1, 5B). It is noteworthy that the assemblages extending across the Interior Plains cannot be recognized within the shallow water carbonate and shale platform successions across northern Yukon Territory. Only the base of Kaskaskia unconformity can be recognized in northern Yukon and there are no recognized Devonian unconformities preserved at higher stratigraphic levels (Fig. 5B) that could be correlative with the base of the Watt Mountain or the base of the Trout River unconformities of Great Slave Plain in the Northwest Territories (Fig. 4B). Also, T-R cycles C and D cannot be recognized across most of the northern Great Bear Plain and farther north because of the absence of the carbonate platform successions that typify these depositional cycles across Great Slave Plain (Fig. 4).

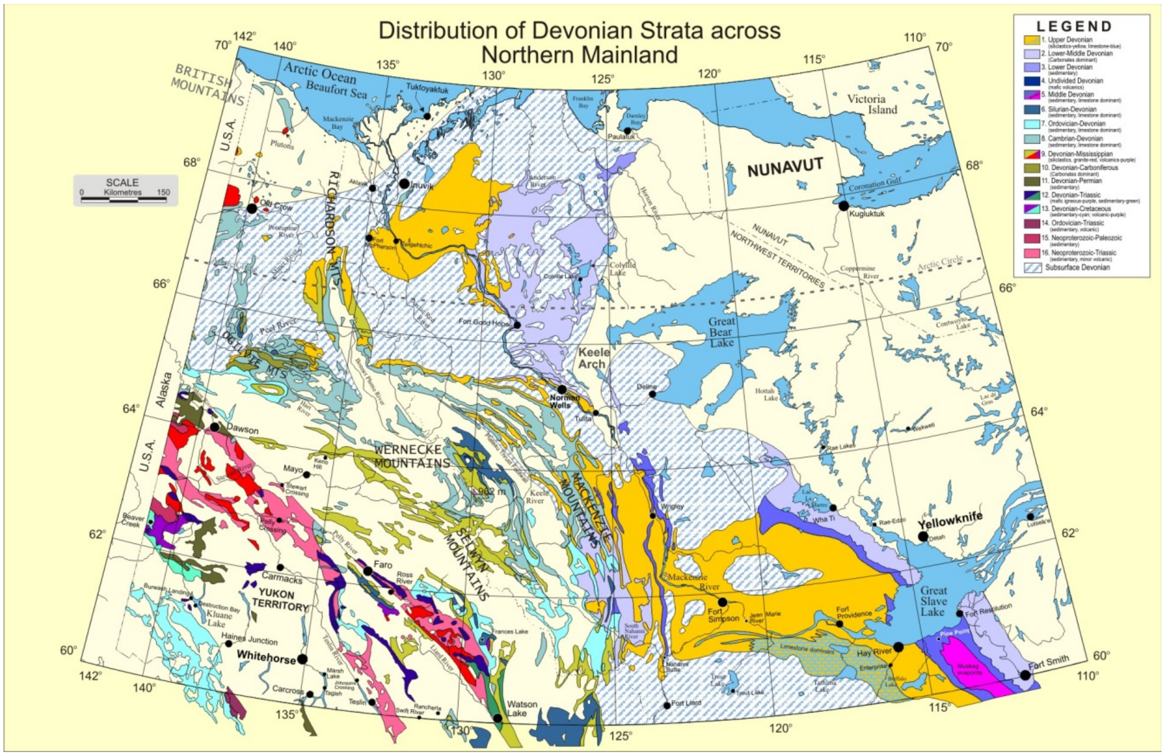

Figure 1. Map showing distribution of Devonian strata across the northern Canadian mainland. Devonian strata occupy large areas of the subsurface across the Interior Plains and the northern Yukon. Devonian strata are also exposed across parts of the southern and northern Northwest Territories as well as in large belts of structurally-controlled outcrop belts in mountain ranges west of the Mackenzie River. Outcrop belts may include strata other than Devonian, particularly southwest of the towns of Dawson and Faro. (Hi-Res)

PREVIOUS WORK

Comprehensive Syntheses

The most recent summaries of the Devonian System across the northern mainland of Canada have been published in the Decade of North American Geology (DNAG) series of volumes published by the Geological Society of America to mark their Centennial and by the Geological Survey of Canada. These publications include important summaries of the Devonian System (Moore, 1993; Morrow and Geldsetzer, 1992; Geldsetzer and Morrow, 1992). Previous to DNAG, the Proceedings of the “Second International Symposium on the Devonian System” of the Canadian Society of Petroleum Geologists also contain summaries of the entire Devonian System across the northern Canadian mainland (Moore, 1988; Morrow and Geldsetzer, 1988).

Earlier comprehensive summaries of northern mainland Devonian strata were published by the Alberta Society of Petroleum Geologists and by the University of Toronto as part of the first “International Symposium on the Devonian System” and as part of a summary of “Geology of the Arctic” (Basset and Stout, 1967; Bassett, 1961).

Morrow et al. (2006) is a recent overview of significant petroleum and mineral resources of the northern Canadian mainland (e.g., Fig. 3).

Figure 2. Map showing topography and physiographic regions of the Northern Canadian Mainland Sedimentary Basin (Bostock, 1970). Great Slave, Great Bear, Peel, Horton and Anderson Plains and the Colville Hills are all part of the Interior Plains of Western Canada. (Hi-Res)

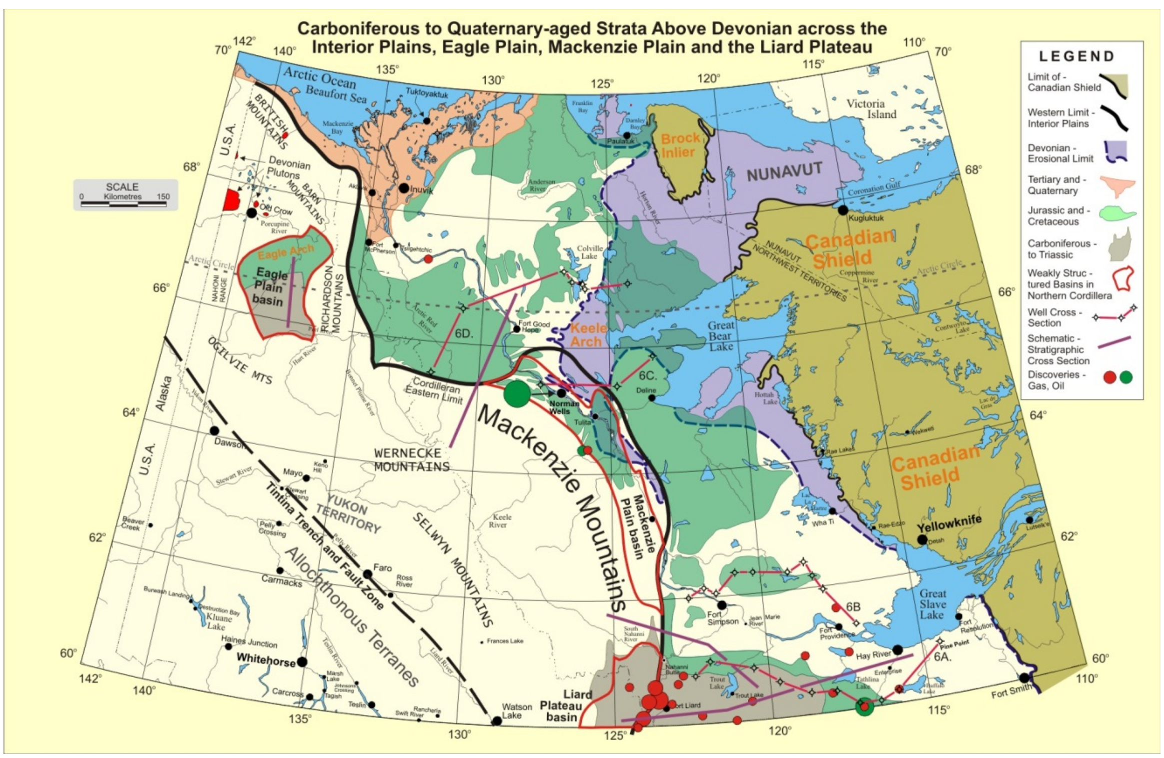

Figure 3. Map showing extents of Cretaceous and Carboniferous to Triassic-aged strata that overlie subsurface Devonian strata. The Tintina Trench and fault zone marks the northeastern limit of the "Allochthonous Terranes" in southwestern Yukon Territory. Also shown are the lines of section for the well cross-sections illustrated in Fig. 6 (6A,B,C,D) and the schematic sections shown in Fig. 7 and 9. (Hi-Res)

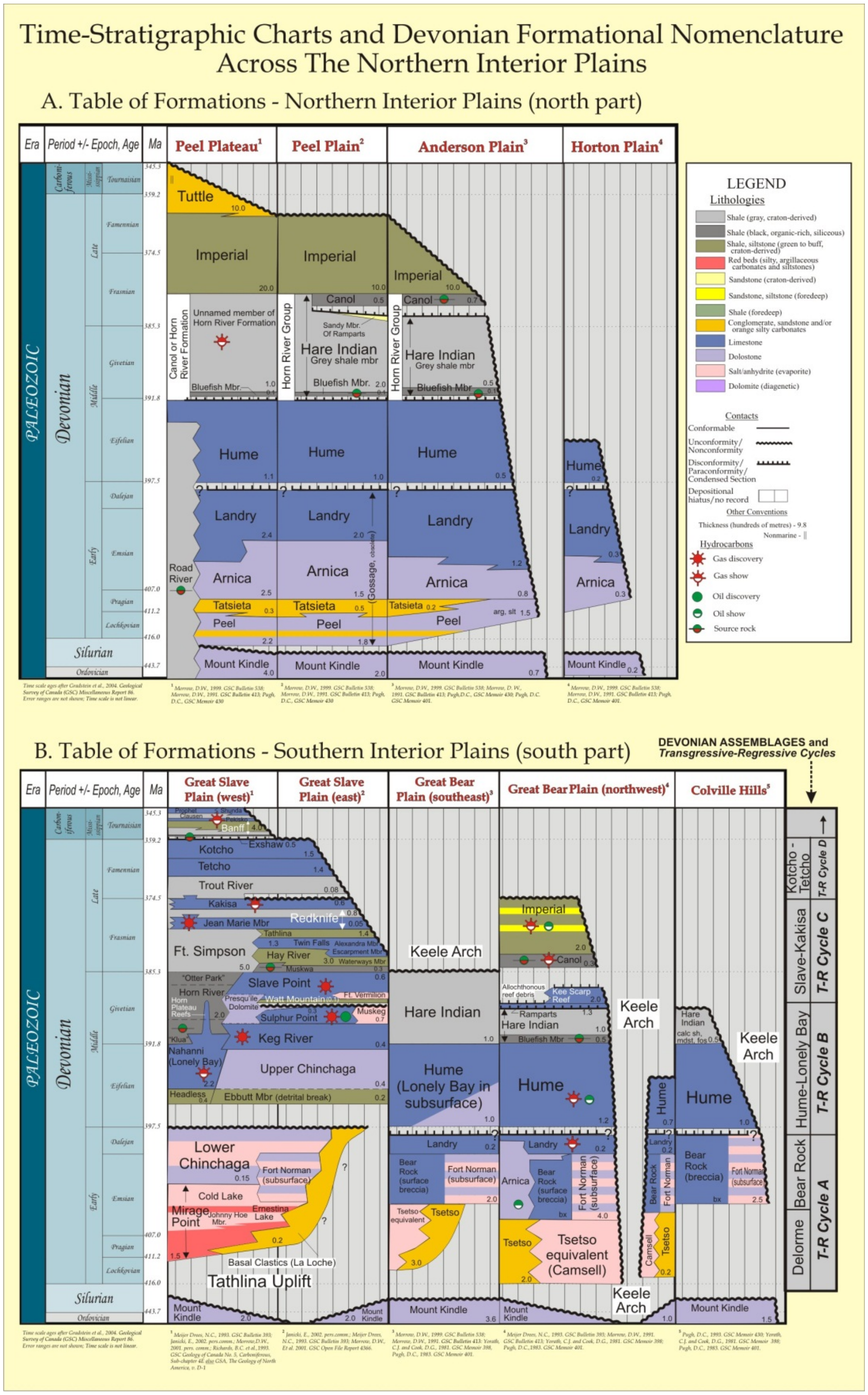

Figure 4. Stratigraphic charts illustrating lithostratigraphic and chronostratigraphic relationships of Devonian strata across the northern and southern parts of the northern Interior Plains. By convention, individual charts (e.g., Great Bear Plain (southwest)) illustrate westward stratigraphic variations from right to left. Note that generalized thicknesses for most stratigraphic units are indicated in the lower right hand corners of each unit. The numbers shown denote hundreds of metres of strata (e.g., 1.2 indicates 120 metres). Devonian strata were deposited during three distinct cycles of marine transgression and regression (T-R cycles A, and, C) and during the trangressive phase of T-R Cycle D. These strata have been grouped into five assemblages of formations. Boundaries of assemblages coincide with T-R cycle boundaries or occur within cycles. (Hi-Res)

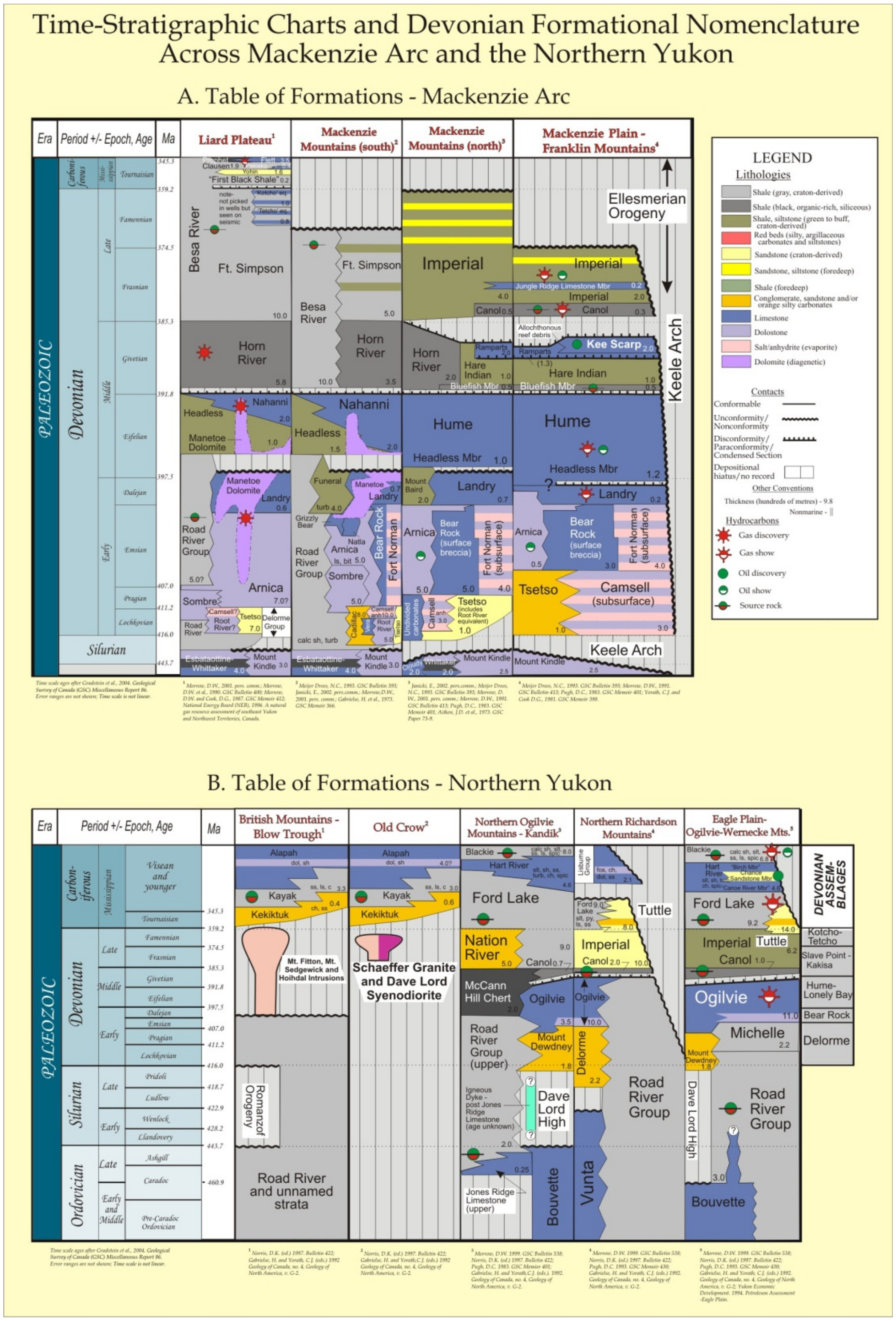

Figure 5. Stratigraphic charts illustrating lithostratigraphic and chronostratigraphic relationships of Devonian strata across the Mackenzie Arc and the northern part of the Yukon Territory. By convention, individual charts (e.g., Mackenzie Plain – Franklin Mountains) illustrate westward stratigraphic variations from right to left. Note that generalized thicknesses for most stratigraphic units are indicated in the lower right hand corners of each unit. The numbers shown denote hundreds of metres of strata (e.g., 1.2 indicates 120 metres). The age boundaries of formational assemblages of the Interior Plains (Fig. 4B) are indicated here for northern Yukon. Bounding surfaces for some assemblages of the Interior Plains, such as the base of Watt Mountain unconformity, have no counterpart across northern Yukon. (Hi-Res)

Regional Studies

Regional studies, primarily as papers, bulletins and memoirs of the Geological Survey of Canada, provide more detail concerning Devonian geology of specific areas than do the comprehensive synthesis publications mentioned above. Subsurface Devonian stratigraphy of the Great Slave Plain is described in detail by Meijer-Drees (1993) and by Williams (1977). Farther north, the publications of Tassonyi (1969) and of Pugh (1983; 1993) describe subsurface Devonian stratigraphy across most of the northern mainland north of 63˚ north latitude. Morrow (1999) and Norris (1965; 1985; 1997) describe surface and subsurface Devonian stratigraphy across the northern Yukon and adjoining parts of the Northwest Territories. Pyle and Jones (2009) is a more recent, regional study of Paleozoic and Mesozoic strata across the Peel Plain and Plateau physiographic regions.

Several regional studies provide information on the Devonian geology of outcrop belts in the Mackenzie Mountains including Lenz (1972), Gabrielse et al. (1973), Aitken et al. (1973), Cecile (1982), Morrow and Cook (1987), and Morrow (1991). Gordey et al. (1993) discuss the Devonian outcrop belts exposed farther west across the central Selwyn Mountains. A number of less formal Geological Survey of Canada open file publications by Williams (1981; 1986a; 1989a; 1989b; 1990 and 1996) provide additional regional information concerning Devonian stratigraphy, paleogeography and tectonic development along the “Mackenzie Corridor” of the Interior Plains and the eastern Mackenzie Mountains. Cecile et al. (1997) and Lane (2007) provide interpretative summaries of the regional early and late Devonian tectonic development respectively across the northern mainland. Gabrielse (1967) was an early publication that summarized the entire Phanerozoic tectonic development of the western part of the northern Canadian mainland.

Area- and Stratigraphic-specific Studies

There are a great many studies of the Devonian in relatively small areas or of individual stratigraphic units or groupings of units. Some of these are related to units of economic interest, such as the Kee Scarp Member of the Ramparts Formation (Williams, 1986a; Kaldi, 1989; Muir et al., 1985) that forms the reservoir for the giant oil field at Norman Wells (Fig. 3, 5A, Yose et al., 2001). The “Manetoe Dolomite”, developed throughout the Liard Plateau and the southern Mackenzie Mountains (Fig. 3, 5A) is another stratigraphic unit of economic importance that is the host reservoir for some of Canada’s largest gas fields (Morrow et al., 1990; Morrow and Aulstead, 1995).

Other studies are related to the depositional origin of specific stratigraphic units. Some of these include; Noble and Ferguson (1970) concerning the Nahanni and Headless formations; Muir et al. (1985) on the Hare Indian and Ramparts formations; Dubord et al. (1986) concerning the shelf-to-basin transition of the Ogilvie Formation; and a detailed sedimentological analysis of the Alexandra Member of the Twin Falls Formation by MacNeil and Jones (2006).

Numerous biostratigraphic and paleontologic studies of Devonian flora and fauna have been published. The most stratigraphically significant of these are referenced in the publications cited here. A few, biostratigraphically important publications include Norford et al. (1970; 1971; 1972), Pedder (1971), Barnes et al. (1974), Brideaux et al. (1976), Chatterton (1978) and Uyeno (1979).

GEOLOGICAL FRAMEWORK

Devonian System across northern mainland

Devonian strata across the wide expanse of the Interior Plain (Fig. 2) east of the eastern limit of Cordilleran deformation, as well as across most of the weakly structured geological basins that lie within mountainous regions west of the Interior Plains (Fig. 2), the Eagle Plain and Mackenzie Plain basins and the Liard Plateau basin, are largely covered by Carboniferous to Cretaceous-aged strata (Fig. 3). The term ‘basin’ is used here in the very general sense of a relatively flat, low relief area, which is underlain by a thick sedimentary succession and commonly bordered in part at least by ranges of hills or mountains typically formed of moderately to highly deformed rocks. The Liard Plateau basin also coincides, very approximately, with the outline of a Carboniferous- to Permian-aged depocentre termed the Liard Basin (Gabrielse, 1967). However, it should be kept in mind that none of the present-day intermontane basins discussed here coincide with Devonian depocentres. Instead they are what are best termed ‘preservational basins' of relatively undisturbed subsurface strata that include thick Devonian-aged sedimentary successions.

The entire preserved Phanerozoic succession, including the Devonian System, across the Interior Plain towards the Makenzie Plain and Mackenzie Mountains slopes gently southwestward with a five degree dip (Fig. 6A, B). The direction and magnitude of dip of the Devonian coincides almost exactly with that of the underlying base of the Phanerozoic unconformity, or, in other words, with the upper surface of the pre-Phanerozoic Precambrian. Some large variations in dip direction and magnitude occur locally due to structural deformation, primarily faulting, of the Precambrian 'basement' (e.g., Fig. 6C, D). Locally, there are some changes in dip of the Devonian due to post-Devonian deformation, such as between Hoosier Ridge, the Norman Range and Kelly Lake where deformation within the more ductile halite-dominated upper part of the Saline River Formation has caused uplift that formed the Norman Range as part of the Franklin Mountains (Fig. 6C; Gabrielse, 1992; MacLean and Cook, 1992).

North of Great Slave Lake, the eastern limit of preserved Devonian lies west of the Canadian Shield and the Brock Inlier (Fig. 3). Across most of this region west of the Canadian Shield, sub-Devonian strata are either exposed or overlain by thin Quaternary sediments or are unconformably overlain by Cretaceous-aged strata (Fig. 3), such as at the Mahony Lake G-22 well near Mahony Lake (Fig. 6C). Extrapolation of the unconformity at the base of the Cretaceous laterally along the lines of section shown in Figure 6 indicates that probably all, or almost all, preserved sub-Devonian Phanerozoic strata between the Canadian Shield and the eastern limit of preserved Devonian were overlain unconformably by Cretaceous strata, which subsequently have been removed by post-Cretaceous erosion.

Cretaceous strata rest unconformably on Devonian strata across most of the Interior and Mackenzie plains (Fig. 3; Fig. 6A). Across the Eagle Arch in the northern part of the Eagle Plain basin subsurface, Devonian strata also unconformably underlie Cretaceous strata (Fig. 3; Fig. 7). Carboniferous to Triassic-aged strata, conformably to unconformably overly the Devonian succession across Liard Plateau basin and the adjoining Trout Lake region (Fig. 6A, B) and across the south-central parts of Eagle Plain basin (Fig. 7) where, northward, successively older Devonian units subcrop beneath Cretaceous strata. The axis of Eagle Arch extends approximately east-west a few kilometres north of the line of section in Figure 7 (Fig. 3; Dixon, 1992), which illustrates the southward-dipping south flank of this subsurface arch.

The base of the Devonian System displays a pronounced change in overall slope direction passing northward from the Great Slave Plain to the Great Bear, Peel, Anderson and Horton Plains. Contours trend north-northwest south of Great Bear Lake but they change orientation to a north-northeast orientation in Anderson and Horton Plains north of Great Bear Lake (Fig. 8).

Keele Arch is a large southwesterly to southeasterly-directed early Cretaceous-aged tectonic feature across which Devonian strata have been stripped by pre-mid Cretaceous erosion (Cook, 1975). This arch lies directly across the region where the base of Devonian surface changes its regional orientation (Fig. 8). The Late Jurassic to Early Cretaceous time interval coincided with the opening of Canada Basin in the Arctic Ocean north of Mackenzie Delta (Embry and Dixon, 1990; Houseknecht and Bird, 2009). It is possible that the rifting of the northern mainland southeast of Mackenzie Delta, which occurred during the southeastward-directed opening of Canada Basin during Late Jurassic to Early Cretaceous sea floor spreading, may have contributed to these changes in orientation of the base of Devonian surface and possibly contributed to uplift and erosion of pre-Mesozoic strata across Keele Arch itself. The more northerly directed slope of the base of the Devonian north of Great Bear Lake may then be due to subsidence of a northward-directed continental margin associated with the rifting and opening of the Canadian, or Amerasian, Basin following pre-mid Cretaceous erosion (Embry and Dixon, 1990).

Another prominent post-Paleozoic, but largely pre-mid Cretaceous arch, occurs along an axis extending southwest from the town of Fort Simpson in the western Great Slave Plain towards the community of Nahanni Butte. This pre-mid Cretaceous arch has been termed the "Liard High" (Meijer-Drees, 1993; Fig. 8). The map pattern (Okulitch, in prep.) indicates periods of both pre-mid Cretaceous and of post-Cretaceous uplift along the axis of Liard High, similar in timing to movements along Keele Arch. However, the Devonian system was only partly removed by pre-Cretaceous erosion across Liard High, unlike Keele Arch where Devonian strata were removed entirely (Cook, 1973; Fig. 8).

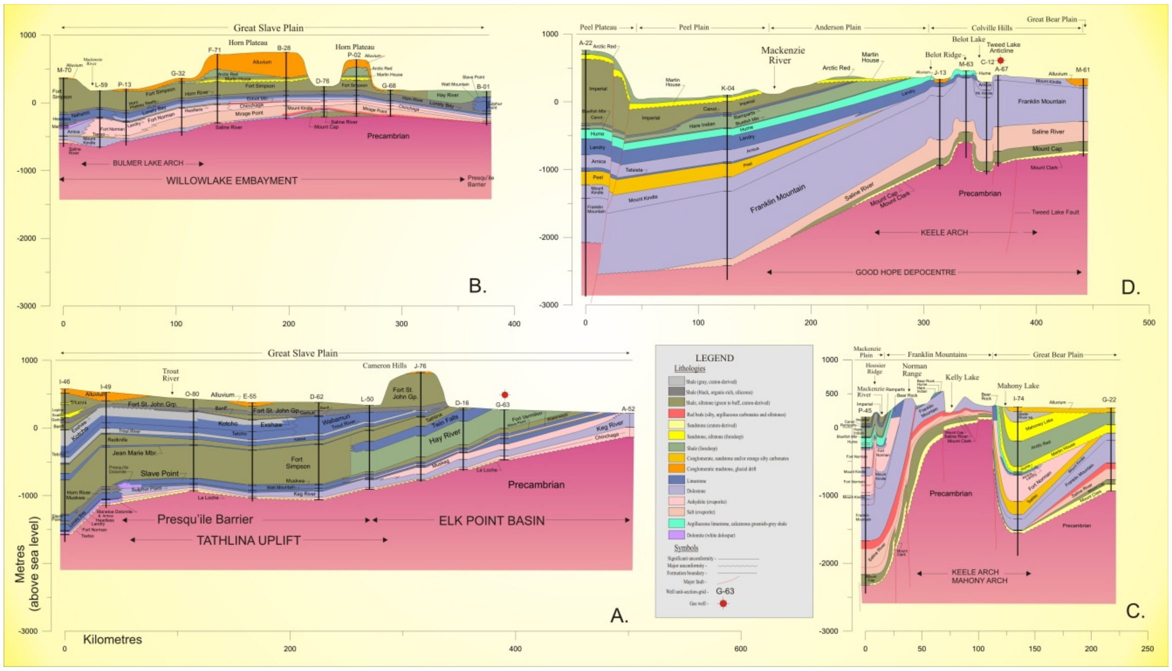

Figure 6. Regional structural well cross sections (Fig. 3) illustrate stratigraphic and structural variations of the entire Phanerozoic succession across the northern Interior Plains of the northern Mainland. Devonian strata form the dominant portion of this subsurface Phanerozoic succession. Two cross-sections (A, B) extend westward across the Great Slave Plain; one extends westward from Great Bear Plain across the Franklin Mountains and into Mackenzie Plain near Norman Wells (C); and one extends westward from the Colville Hills across Anderson and Peel plains and into the Cordilleran deformational frontal structures of Peel Plateau (D). (Hi-Res)

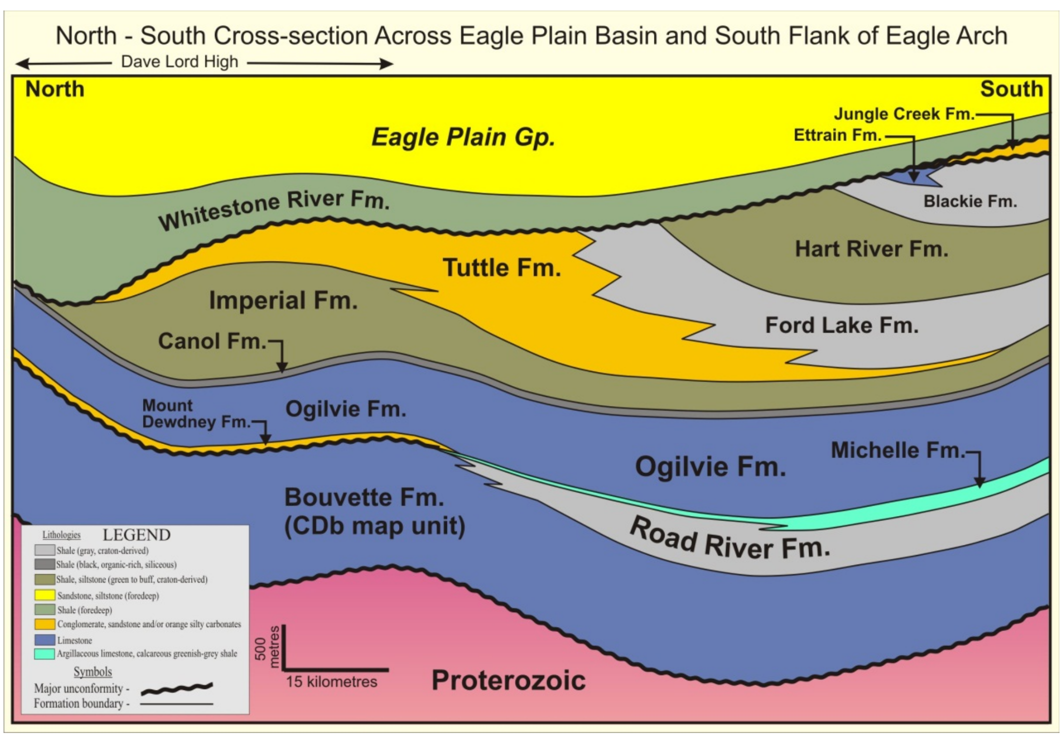

Figure 7. A schematic structural cross section displaying Phanerozoic strata along a north-south line of section across Eagle Plain basin in northern Yukon Territory (Fig. 3). The Devonian and Carboniferous subsurface succession is truncated beneath the unconformity along the base of the Cretaceous succession across the southern flank of the subsurface Eagle Arch (Dixon, 1992). Lithostratigraphic data for this cross-section were interpolated from nearby well boreholes and surface sections (Dixon, 1992; Morrow, 1999).

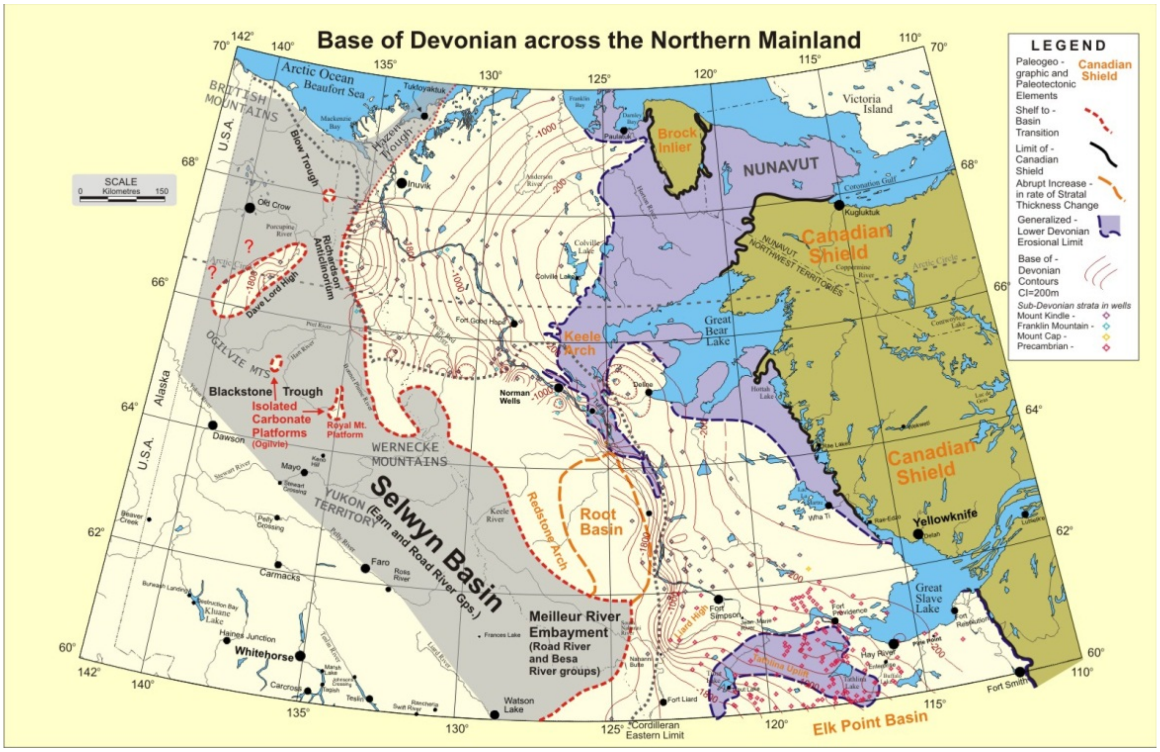

Figure 8. Structure map showing contours on the base of the Devonian System in the subsurface of the northern mainland. There is a change in the overall trend of these contours from a southeast-northwest orientation south of 66° north latitude to a southwest-northeast orientation north of this latitude north of the town of Fort Good Hope west and northwest of Keele Arch. West of the contoured area (Selwyn Basin and in the Mackenzie Mountains) the base of the Devonian is affected by local structures developed during the Jurassic-Cretaceous Columbian Orogeny and later during the Tertiary Laramide Orogeny and does not display regional trends. (Hi-Res)

Overview of Devonian System Stratigraphy

Northern Interior Plains, Liard Plateau basin, Mackenzie, Wernecke and Selwyn mountains

Within the Devonian System, shallow marine platform carbonates (e.g., Arnica, Sombre, Landry, Nahanni, Hume, Keg River, Slave Point, Ramparts, Twin Falls, Kakisa, Tetcho and Kotcho formations and the Jean Marie Member) with intercalated shelf-deposited calcareous shales (e.g., Funeral, Headless, Waterways, Hay River, Hare Indian, Tathlina and Redknife formations) extend westward across the northern Interior Plains (e.g., Great Slave and Great Bear plains, the Anderson and Horton plains and the Peel Plain in Fig. 2, 9). All of these shelf-deposited strata pass farther westward and southwestward to more open marine, much deeper water basinal shale successions of the Lower Devonian Road River Group, the Middle Devonian Horn River Group and the Middle Devonian to Carboniferous-aged Besa River Formation across Selwyn Basin in the central Mackenzie, Selwyn and Wernecke mountains, and in the Meilleur River Embayment across the southern part of the Mackenzie Mountains and the western part of Liard Plateau (Fig. 2, 4, 5, 8, 9).

Farther north these shelf platform strata pass abruptly westward from Peel Plateau, or Peel Shelf, into the Richardson Trough (Fig. 10), a northerly trending region of deep water shale and basinal limestone deposition that persisted throughout early Paleozoic time (Cecile et al., 1997). Richardson Trough was bordered throughout Devonian time by shelf deposits across Peel Plateau to the east and by carbonate-dominated shelf platform deposits across the Yukon Stable Block (Fig. 10) and the Eagle Plain basin (Fig. 2). Post-Paleozoic orogenesis has led to structural elevation of basinal Richardson Trough shales to form the present day Richardson Mountains (Fig. 2, 3), the topographic expression of the Richardson Anticlinorium (Norris, 1997).

The Devonian succession of Great Slave Plain is capped by the thin black radioactive shale of the Exshaw Formation (Fig. 9B, C) which straddles the Devono-Carboniferous boundary (Fig. 4B). In the Liard Plateau basin, an Exshaw-equivalent dark radioactive shale falls within The the Besa River

Formation as an informal marker called "the first black shale" (Fig. 5A). Farther north, the top of the Devonian falls within the sandstone and conglomerate succession of the Tuttle Formation in the Peel Plateau area (Fig. 4A; Fig. 9A). Across most of the Interior Plains, variable thicknesses of the upper portion of the Devonian System have been removed by pre-mid Cretaceous, or by post-Cretaceous, erosion (Fig. 3, 4).

In the outcrop belts of the Selwyn Mountains west of Mackenzie Mountains and south of Wernecke Mountains, Devonian strata are represented almost entirely by very dark cherty shales of the Portrait Lake Formation (Fig. 8- lower part of Earn Group, see Gordey and Anderson, 1993). Hard black, organic rich shales of the Canol Formation and Horn River Formation (Group) may be regarded as eastward-extending tongues across the northern Interior Plains and Mackenzie Mountains of the upper part of the Portrait Lake Formation in Selwyn Basin. Very likely, the variably sandy and silty brown shales of the Imperial and Fort Simpson formations, which pass westward to the Besa River Formation (Fig. 5), probably are also lateral facies correlatives of the uppermost Portrait Lake dark shales of Selwyn Basin.

The top of the Road River Group basinal shales and limestones was deposited approximately at the start of the Devonian Period in Selwyn Basin (Gordey and Anderson, 1993) but farther east, along the western ranges of the Mackenzie Mountains and in the Meilleur River Embayment, the top of the Road River is somewhat younger and is dated as being approximately at the end of Early Devonian time (Fig. 4A, B). These uppermost Road River strata are correlative eastward with strata of the Delorme, Bear Rock, and Hume-Lonely Bay assemblages (Tsetso, Camsell, Cadillac, Root River, Vera, Sombre, Arnica, Fort Norman, Landry, Headless, Nahanni and Hume formations in Fig. 9).

Uppermost Devonian (Famennian) in the Selwyn Mountains is represented by the cherty conglomerates and sandstones of the Prevost Formation, which, commonly unconformably, overly the dark Portrait Lake shales (Gordey and Anderson, 1993). These coarse clastics may be correlative with the Famennian-aged coarse clastics of the Tuttle Formation across northern Yukon Territory and in the extreme northwest part of the Northwest Territories (Fig. 4A, 5B; Fig. 9A).

Northern Yukon

In Devonian time, Northern Yukon was largely an area of shallow water shelf carbonate and shale deposition bordered along its east side by Richardson Trough and along its southern boundary by the Selwyn Basin. Blow and Hazen troughs bordered the northern edge of this relatively shallow water region termed the Yukon Stable Block (Fig. 10; Cecile et al., 1997). The subsurface Devonian preserved in Eagle Plain basin (Fig. 3) occupies the central part of this region. The outer edges of this shelf platform region are exposed along mountain belts, such as the Nahoni and Ogilvie mountains and the Keele Range (Fig. 2) that border Eagle Plain basin (Morrow, 1999; Fig. 3).

Devonian stratigraphy across the Yukon Stable Block exhibits little similarity to that east of the Yukon Territory. There are no counterparts in the Yukon to the base of Watt Mountain and base of Trout River unconformities, which punctuate the Devonian shelf succession of the Northwest Territories. Across the Yukon Stable Block, only the base of Devonian unconformity can be recognized in the region of the Dave Lord High in the western part of the northern Yukon (Fig. 5B, 8).

Lowermost Devonian strata are represented by orange-coloured silty dolostones of the Mount Dewdney Formation resting unconformably on Ordovician to Silurian-aged Bouvette Formation shallow marine limestones which were exposed across Dave Lord High during latest Silurian to earliest Devonian time (Fig. 5B, 7, 8). Southeast of Dave Lord High, the Bouvette is overlain by a few hundred metres of Ordovician to earliest Devonian-aged Road River Formation slope and basin-deposited grey calcareous shale which passes upward to the Michelle Formation, a relatively thin unit of marine, upper slope-deposited greenish-grey argillaceous limestone, which is probably the lateral facies correlative of the Mount Dewdney Formation farther north on Dave Lord High (Fig. 5B, 7; Morrow, 1999). Both the Mount Dewdney and the Michelle are overlain by the regionally widespread dolomitic limestones of the Ogilvie Formation that extend across almost the entire Yukon Stable Block (Fig. 7).

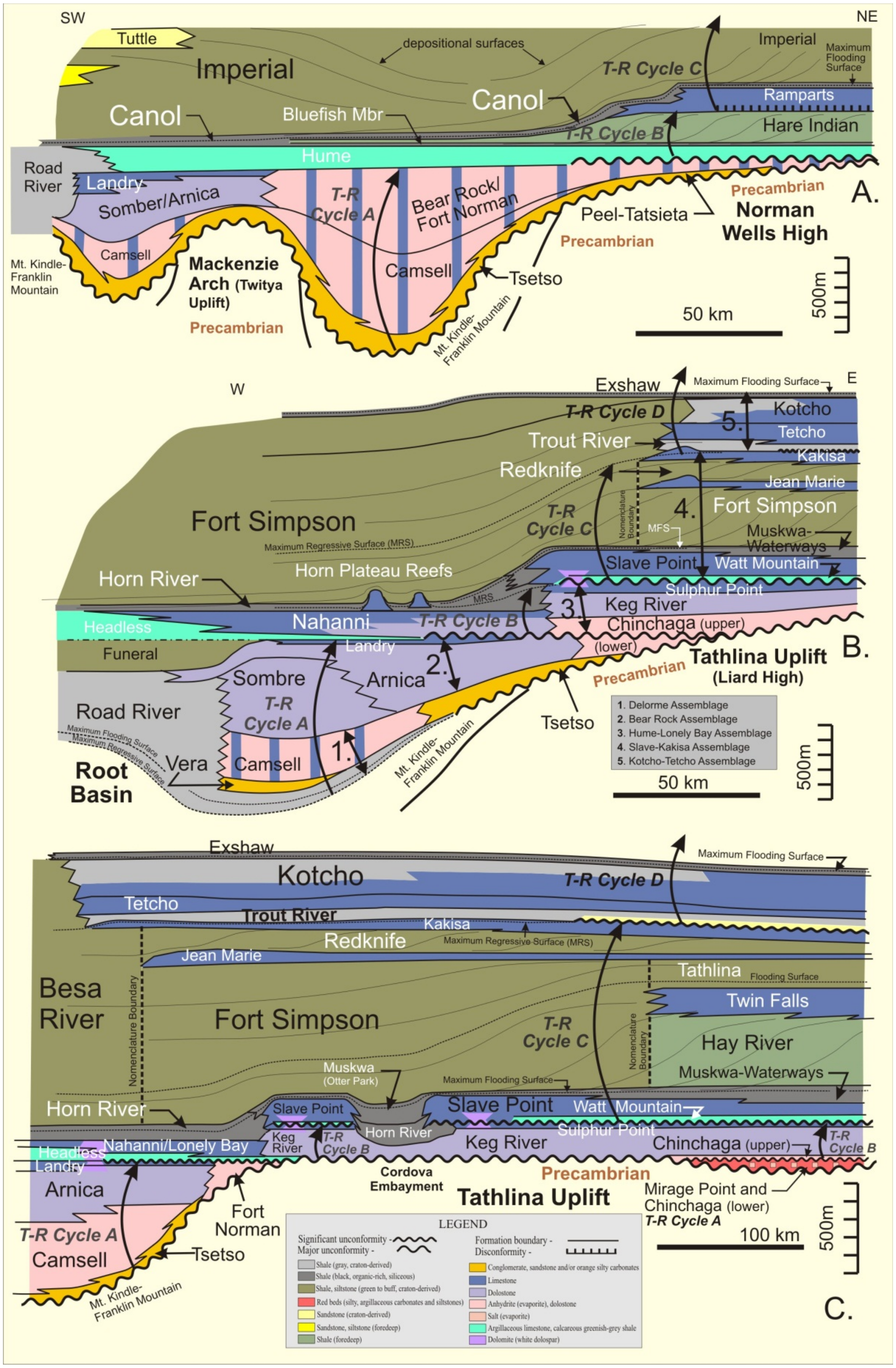

Figure 9. Schematic stratigraphic cross-sections of Devonian strata showing formational nomenclature and lithostratigraphic relationships in three cross-sections that are oriented approximately parallel to original depositional dips (Fig. 3). These sections extend westward or southwestward across the Interior Plains and into the mountains of the Cordilleran Disturbed Belt. Major formational assemblages (e.g. Delorme Assemblage) and transgressive-regressive depositional sequences (e.g. T-R Cycle A) are shown.

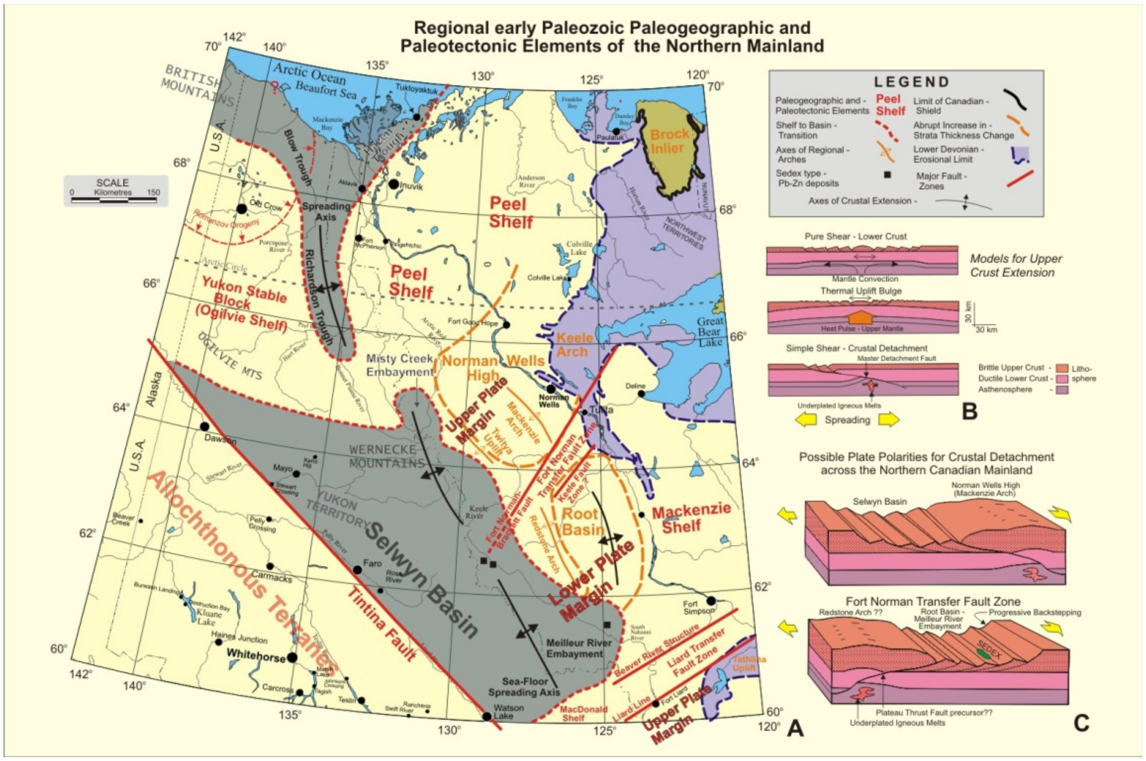

Figure 10. Map illustration of Early Devonian paleogeographic and paleotectonic elements of the Northern Mainland during deposition of the Delorme Assemblage. Keele Arch and Tathlina Uplift were large land areas within the Mackenzie and Peel shelf platforms. Root Basin was a large intrashelf basin. Selwyn Basin, a region of uninterrupted basinal shale and deep water carbonate deposition, lay to the west of these shelf platforms. The Liard and Fort Norman Transfer Fault Zones are inferred to separate lithospheric upper plate from lower plate margins which are characterized by simple shear shallow-dipping crustal fault detachments of opposite directions of dip slip, or polarity. Richardson Trough may have been a failed aulacogen that developed along an axis of crustal pure shear spreading separating Yukon Stable Block from the Peel Shelf Platform. In this and subsequent figures, names of larger paleotectonic and paleogeographic elements are shown in red lettering whereas smaller elements are in orange lettering.

This region of Early Devonian slope and basin, shale-dominated deposition south of Dave Lord High is termed the Blackstone Trough (Pugh, 1983; A.W. Norris, 1997) bordering Selwyn Basin (Fig. 8). Several large shallow water carbonate pedestals, such as Royal Mountain Platform, extend upward stratigraphically into the Road River and Michelle strata in Blackstone Trough in the Ogilvie and Wernecke mountains (Fig. 8) south of Eagle Plain basin (Fig. 3). The entire Ordovician to Middle Devonian carbonate and shale succession of the Yukon Stable Block passes abruptly eastward to the deep water dark shale and basinal limestone succession of the Road River Group in Richardson Trough, which bordered the east side of the Yukon Stable Block (Fig. 5B, 10) throughout Ordovician to Early Devonian time. Westward towards Alaska, the platform carbonates and siliciclastics of the Bouvette, Jones Ridge Limestone, and Mount Dewdney formations pass to basinal Road River Group shales and the McCann Hill Chert, which is also laterally equivalent to parts of the Ogilvie Formation (Fig. 5B; Morrow, 1999).

The black hard siliceous shale of the Canol Formation uniformly overlies the entire Lower and Middle Devonian shelf succession of the Yukon Stable Block (Fig. 5B). The Canol extends eastward into Richardson Trough and across Peel Plateau where it is mapped as Horn River Group, or as Canol (Fig 9A; see Williams, 1983; Pugh 1983). An anomalously thick Canol shale succession of about 200 metres filled most of the remaining bathymetric relief across Richardson Trough in early Late Devonian, or Frasnian, time (Morrow, 1999).

Canol deposition was followed in Late Devonian time by deposition of brown-weathering silty shales and sandstones of the Imperial Formation across the Yukon Stable Block except where removed by pre-mid Cretaceous erosion, commonly beneath the Whitestone River Formation, or by post-Cretaceous erosion (Dixon, 1992; Fig. 3, 5B, 7). These Imperial siliciclastics, up to about 1000 metres thick, are in lithostratigraphic continuity with the Imperial Formation east of Richardson Trough (Fig. 4A). The coarse sandstones and conglomerates of the Tuttle Formation, also up to about 1000 metres thick, overlie the Imperial in both the Yukon Territory and to the east in the Peel Plateau area (Fig. 4A, 5B). Across the southwest part of the Yukon Stable Block and the Eagle Plain basin, the Ford Lake shale, a facies equivalent of the Tuttle, overlies the Imperial (Fig. 5B, 7; Pugh, 1983). Both the Tuttle and the Ford Lake formations were deposited from Late Devonian (Famennian) to Early Carboniferous (Tournasian) time. The Carboniferous-aged marine slope-deposited calcareous siliciclastics of the Hart River Formation overlie the Ford Lake shales across southern Eagle Plain basin and in outcrop south of Eagle Plain (Fig. 5B, 7).

The Romanzof Orogeny (Lane, 2007) caused early to mid-Devonian erosion so that Proterozoic to Early Devonian-aged rocks are unconformably overlain by Carboniferous-aged (Tournaisian) sandstones and conglomerates of the Kekiktuk Formation across the extreme northwest parts of northern Yukon in the British Mountains and around the community of Old Crow (Fig. 5B). Post-orogenic granitic plutons, such as those at Mount Fitton and Mount Sedgewick, were emplaced across this region in Middle to Late Devonian time (Fig. 5B; A.W. Norris, A.W., 1997; Lane, 2007) during the waning stages of the Romanzof Orogeny (Fig. 10; Lane, 2007).

STRATIGRAPHIC NOMENCLATURE - HISTORY AND DEVELOPMENT

A key aspect in the evolution of Devonian stratigraphic nomenclature has been paleontologic information. This type of information and its application to stratigraphy provides essential information concerning estimation of the relative degree of time equivalence between formations and between diverse lithologic facies, or members, developed within formations. Biostratigraphic information has been particularly important for the identification of time equivalent successions in outcrop belts where laterally extensive and easily correlated carbonate-dominated shelf platform successions pass basinward to silt and shale-dominated submarine slope and basin successions, such as in the western parts of the Great Slave Plain (Fig. 4B) and of the Liard Plateau and Mackenzie Plain (Fig. 5A).

Correlations between successions have also benefitted from the identification of laterally continuous, thin ‘marker beds’, or ‘marker horizons’ (Fig. 9), particularly in the subsurface, where such beds show clearly on geophysical well logs.

Figures 4 and 5 outline the presently accepted stratigraphic nomenclature of, and the fundamental stratigraphic relationships within, the Devonian System across most of the autochthonous, or tectonically in-place, part of the northern Canadian mainland east of the Tintina Fault system in the Yukon (Fig. 10). Stratigraphic nomenclature of the northern Canadian mainland Devonian System has undergone a process of continual refinement and change since the early investigations of Hume and Link (1945) which were spurred by the strategic need for oil and gas to fuel the war effort of the allied forces during the Second World War and which led to the development of the giant Norman Wells oil field and construction of the Canol Pipeline, which, in turn, led to the establishment of the community of Norman Wells (Fig. 2) on Mackenzie River. Hume and Link (1945) includes a complete summary of all previous reports and of the lower Paleozoic nomenclature that was current to that time for the Interior Plains part of the northern Canadian mainland. This report may be regarded as ushering in a more modern, post-World War II era of geological investigations for this region of northern Canada. The Norman Wells oil field itself was discovered in 1920 by the Imperial Oil Company in the reefal limestones of the Kee Scarp Member of the Middle Devonian Ramparts Formation (Fig. 5A) about 150 metres below the present day land surface at Norman Wells.

Much of the evolution of stratigraphic nomenclature has been concerned with subdivision of thick units previously recognized as Devonian formations in earlier geological publications. Some of these units have become obsolete, such as the former ‘Gossage Formation’ (Tassonyi, 1969; Pugh, 1983), which was previously mapped throughout the subsurface of Peel (Fig. 5A), Anderson and Great Bear Plains plains. The former members of the ‘Gossage Formation’ have since been raised to formation status (e.g., Arnica and Landry formations). In some cases, however, pre-existing earlier formational names have been totally superseded. Hume and Link (1945) themselves suggested discarding the name “Beavertail formation” (sic) which was current at that time, and instead included all strata formerly contained within the “Beavertail formation” as the uppermost part of a stratigraphically expanded Ramparts Formation, which, previous to Hume and Link (1945), underlay the “Beavertail”. This recommendation has been subsequently validated and the names “Beavertail formation”, or “Beavertail limestone”, are no longer used.

The names of some formerly mapped thick formations, such as that of the Delorme Formation, have been retained as names for groups of formations. The Delorme Group is now considered to contain several formations, such as the Tsetso, Camsell, Root River, Vera and Cadillac formations (Morrow and Cook, 1983; Morrow, 1991). Another important unit, the former Horn River Formation, is now considered to be a group of formations that includes the Hare Indian, Canol and Ramparts formations in the Peel Plateau, Peel Plain, Mackenzie Plain and Great Bear Plain (Fig. 4A, 4B, 5A). Farther south in Great Slave Plain units such as the Bituminous shale and the Buffalo River Formation at Pine Point are part of the Horn River Group (Williams, 1983).

Stratigraphic nomenclature of strata of all ages, none more so than Devonian strata, is subject to continual revision and refinement. Refinement of nomenclature often consists of simple recognition of the lateral mappability of thinner subdivisions of thicker units, such as the formations now recognized within the Delorme or Horn River groups that were previously not recognized or were identified merely as ‘members’.

However, some formerly mapped formations, such as the Manetoe and Presqu’ile formations, are now recognized to be largely diagenetic in origin and superimposed on pre-existing stratigraphic units of primary depositional origin that have retained their identities to a greater or lesser extent (Morrow et al., 1990; Williams, 1977). Consequently, the Manetoe and Presqu’ile dolomites are now formally defined as diagenetic facies that has have altered strata of the Landry, Nahanni, Sulphur Point and Slave Point formations post-depositionally (Fig. 4B, 5A). Previously, both the Manetoe and Presqu’ile “formations” were thought to coincide with the development of reefal facies along specific stratigraphic horizons (Morrow et al., 1990; Williams, 1977).

Ambiguities and inconsistencies are invariably present in stratigraphic nomenclature as more information is gained concerning the lithologic variations within stratigraphic units of all ranks. Changes in stratigraphic nomenclature are commonly the result of efforts to resolve these inconsistencies. A recent example is the recognition that the limestone breccias mapped as the Bear Rock Formation on published geological bedrock maps are the direct lateral time equivalents of successions of interbedded anhydrite and dolostone in the subsurface, which led to their recognition as a new formation, the Fort Norman Formation (Fig. 4B, 5A; Meijer-Drees, 1993). Future work may focus on recognition of the Bear Rock Formation as a post-depositional diagenetic alteration by solution-collapse brecciation of Fort Norman evaporites exposed to surface weathering (Morrow, 1991).

Advances in understanding of sedimentology and the origin of depositional systems tracts have also begun to play exert a more subtle influence on refinements of stratigraphic nomenclature. These developments though tend to affect the interpretation of relatively thin stratigraphic units in those areas where well control or surface exposures are laterally continuous enough to provide the density of information necessary for their interpretation. The recent study report by MacNeil and Jones (2006) on depositional systems tracts within the Alexandra Member of the Twin Falls Formation is an example of this type of study. The future will undoubtedly see the development of stratigraphic nomenclature to more formally identify the high resolution stratigraphic units examined in studies such as MacNeil and Jones (2006). However, widespread application of such high resolution stratigraphy in the subsurface in the northern Canadian mainland awaits a considerable increase in the density of wells drilled for petroleum.

REGIONAL CROSS-SECTIONS, UNIT THICKNESSES AND DISTRIBUTIONS

Introduction

Devonian stratigraphy across the northern Canadian mainland is illustrated here by a series of stratigraphic cross-sections, mainly of Devonian strata beneath the Interior Plains and the Liard Plateau, but also including strata exposed in the Mackenzie Mountains. Across the Interior Plains, subsurface lines of section at various latitudes and oriented generally east to west incorporate the available petroleum well data. The approximate east-west orientation of these sections corresponds to the dominant depositional dip direction that prevailed during early to middle Devonian deposition (Morrow and Geldsetzer, 1988, 1992; Moore, 1988, 1993).

There are, however, factors that dictate deviations from ideal orientations perpendicular to structural dips for many of these lines of section. Firstly, there is a relatively low density of petroleum wells and of outcrop stratigraphic sections that contain complete Lower and Middle Devonian thicknesses (Fig. 11), or complete Upper Devonian thicknesses (Fig. 12), or for total Devonian thicknesses (Fig. 13). The density of well control abruptly decreases north of 60° north latitude by nearly an order of magnitude (Mossop and Shetsen, 1994). Secondly, there is considerable geographic non-homogeneity of the data base with the bulk of the well data confined to the Interior Plains south of 63° north latitude (Fig. 11, 12, 13). Finally, there is a pronounced constriction in the geographic distribution of Devonian control points in the vicinity of Keele Arch west of Great Bear Lake (Fig. 13).

The description of stratigraphic cross-sections that follows here proceeds from south to north. Within regions, the order of discussion of stratigraphic sections begins with cross-sections that display older Devonian strata.

Southern Great Slave Plain, Liard Plateau and southernmost Mackenzie Mountains

This region lying between 60° and 61° north latitude has a relatively high well density over a broader extent compared with more northerly areas (Fig. 13), which is reflected in a proportionately greater number of stratigraphic cross sections for the illustration of Devonian stratigraphic relationships in this region. Figures 14 and 15 show lines of section for three stratigraphic cross sections (Fig. 16, 17, 18) which display mainly Lower and Middle Devonian stratigraphy in the western portion of this region.

One of these cross sections extends westward from the edge of the Presqu'ile Barrier to the outcrop belt deep within Liard Plateau (Fig. 16). The other cross section (Fig. 17) extends across the Cordova Embayment in the northwest part of the Lower and Middle Devonian Presqu'ile Barrier reef complex westward to near the northwest limit of the Arrowhead Salient of the Presqu'ile Barrier (Fig. 14). These cross-sections display complete stratigraphic successions for the two lowermost and part of a third second order transgressive-regressive Devonian sequences (T-R cycles A, B and C in Fig. 16, 17 and 18). The lowermost sequence (T-R cycle A in Fig. 16, 17), as discussed previously, contains both the Delorme and Bear Rock assemblages. Dolomitic quartz sandstones and pea gravel conglomerates of the typically buff to orange-coloured Tsetso Formation and siltstones and anhydritic evaporates evaporites of the unnamed red beds and the Ernestina Lake Formation (correlative with the Mirage Point Formation farther east) have onlapped an eroded metasedimentary and granitic Precambrian unconformity surface across the Tathlina Uplift during eastward marine transgression in earliest Devonian time (Fig. 16, 17).

Continued transgression led to deposition of shallow lagoonal, and possibly sabkha-like, interbedded anhydrite and cream-coloured dolomudstones of the lower Chinchaga Formation across Tathlina Uplift and the more open marine finely to medium crystalline dominantly subtidal dolostones of the Arnica Formation and the pelletal lime packstones and grainstones of the Landry Formation west of Tathlina Uplift (Fig. 17). The grainstone/packstone deposits of the Landry Formation may represent deposition as shallow water carbonate sand belts bordering restricted marine evaporitic lagoon deposition of lower Chinchaga evaporates. This cross section illustrates clearly the beginning of the pronounced increase in the rate of thickness increase of the Delorme and Bear Rock assemblages westward from Tathlina Uplift towards the Liard Plateau. Available faunal data (Meijer-Drees, 1993; Morrow and Cook, 1987) indicate that strata of the Delorme Assemblage (Tsetso) and the Bear Rock Assemblage (Arnica and lower Chinchaga) do not intertongue at the scale of these cross sections.

Marine regression at the close of Landry and lower Chinchaga deposition led to widespread subaerial exposure and erosion that formed a regional unconformity, which also extends across western Canada south of the northern Canadian Mainland (Morrow and Geldsetzer, 1988). Deposition of shoreface lime mudchip and greenish-grey calcareous and argillaceous siltstones of the Headless Formation and of the Ebbutt Member (mid-Chinchaga) marked the initial marine transgression of T-R cycle B formed of the Hume-Lonely Bay Assemblage (Fig. 19). Continued marine transgression led to deposition of the open marine shelf fossiliferous lime wackestones of the Lonely Bay and Nahanni formations west of the former Tathlina Uplift. More restricted marine deposition of upper Chinchaga evaporites and dolomudstones occurred across the area formerly occupied by Tathlina Uplift.

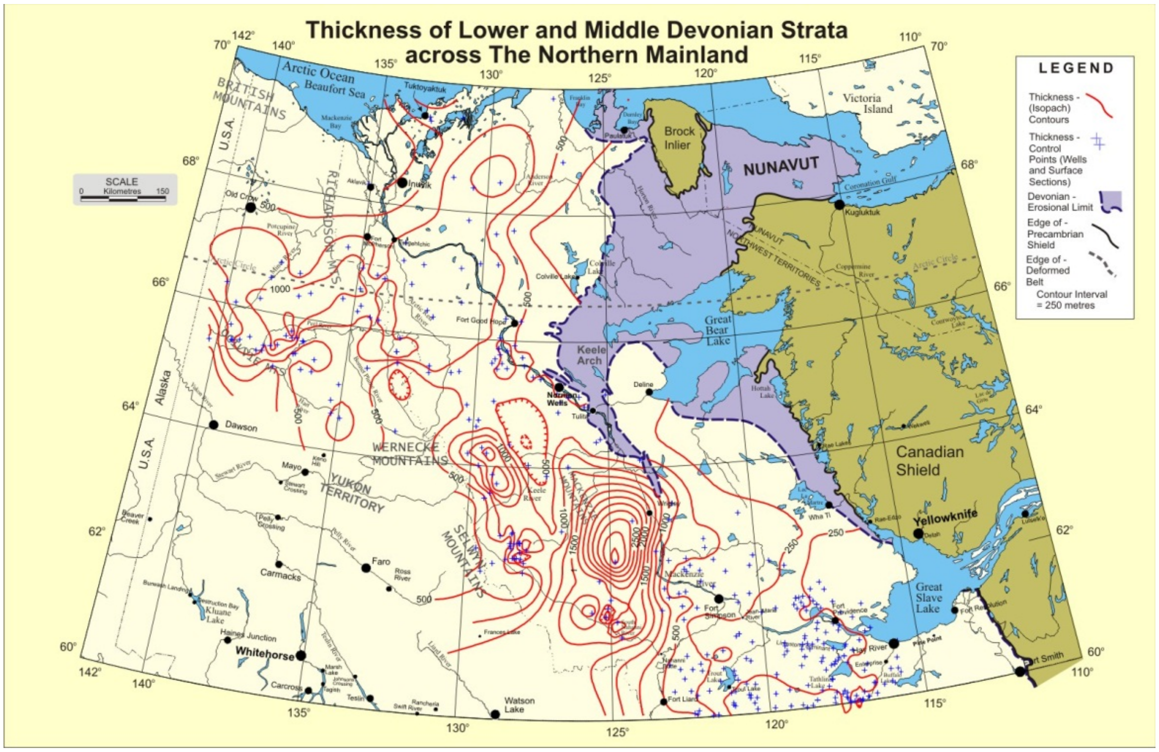

Figure 11. Map of the total thickness in metres of all Lower and Middle Devonian Strata preserved across the northern mainland. This succession has an almost constant thickness of about 250 metres across the Great Slave Plain. Root Basin is well defined as an up to 3000 metre thick succession preserved southwest of the town of Wrigley. The thickness of this succession is partly preservational beneath Cretaceous strata across the Interior Plains north of 66° north latitude. Closed isopach depressions are indicated by inward-facing hachures. (Hi-Res)

South of 61° north latitude the Headless Formation is uniformly thin and may not extend the entire distance westward to the shelf edge succession exposed at Pool Creek near the Meilleur River Embayment (Fig. 14, 16). The Nahanni Formation of this area closely resembles the Dunedin Formation of northeast British Columbia, which contains a thin silty basal member correlative with the Headless Formation (Fig 16; Morrow, 1978). This basal unit is inferred to be the initial transgressive deposit above the sub-Dunedin regional unconformity and is probably continuous with the sub-Headless unconformity (Morrow and Geldsetzer, 1988).

North of 61° north latitude, the relationship between the Headless and Nahanni is somewhat different. Here, the argillaceous limestones of the Headless Formation thicken dramatically westward towards the Mackenzie Shelf edge and the Meilleur River Embayment at the expense of the overlying clean limestones of the Nahanni Formation (Fig. 5A; see inset in Fig. 16). Here, the combined Nahanni-Headless formations have been interpreted to be the product of a progradational, or regressive, mode of deposition following a rapid rise in relative sea-level. This interpretation is consistent with the relatively isochronous character, and with the absence of any observable intertonguing with overlying Horn River shale of the top of the Nahanni north of 61° north latitude (Fig 4A; see inset in Fig. 16; Chatterton, 1978) versus the observed intertonguing of the top of the Dunedin Formation, and the probable intertonguing of the Nahanni with overlying Besa River shale south of 61° north latitude (Fig 16; Morrow, 1978).

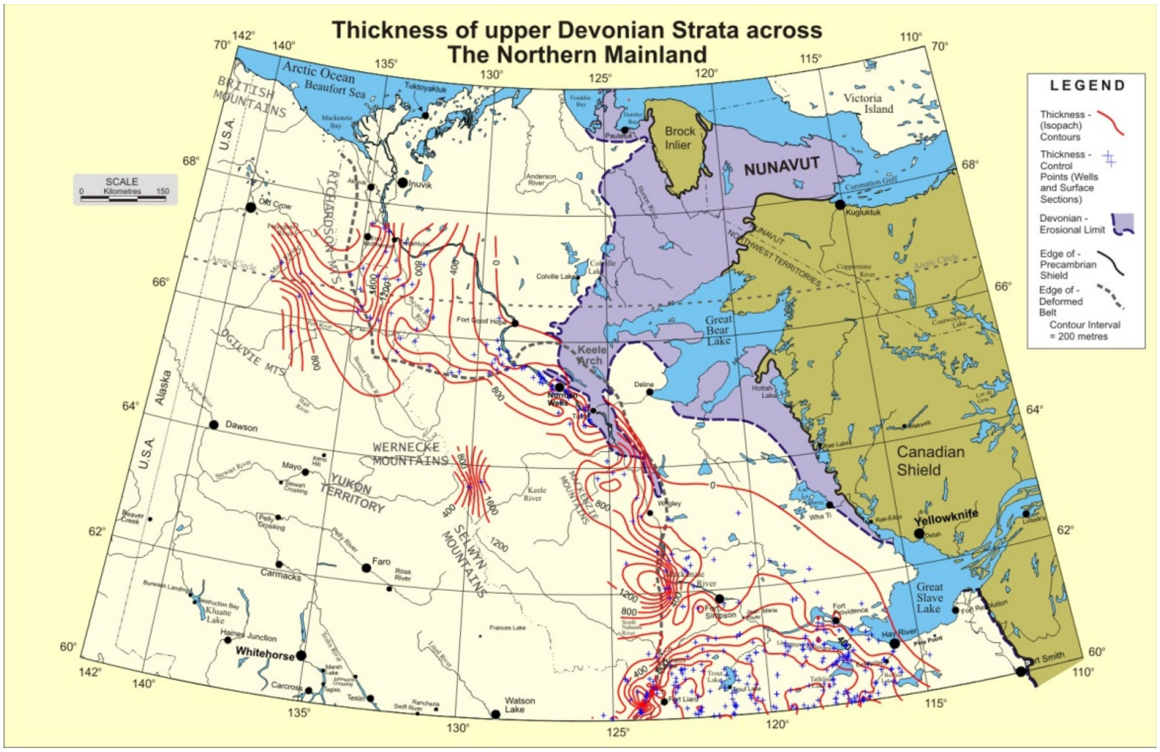

Figure 12. Map of the total thickness in metres of all Upper Devonian Strata that are preserved across the northern mainland. These strata thicken southwestward from a sub-Cretaceous erosional edge that is a few tens to hundreds of kilometers west of the Precambrian Shield. (Hi-Res)

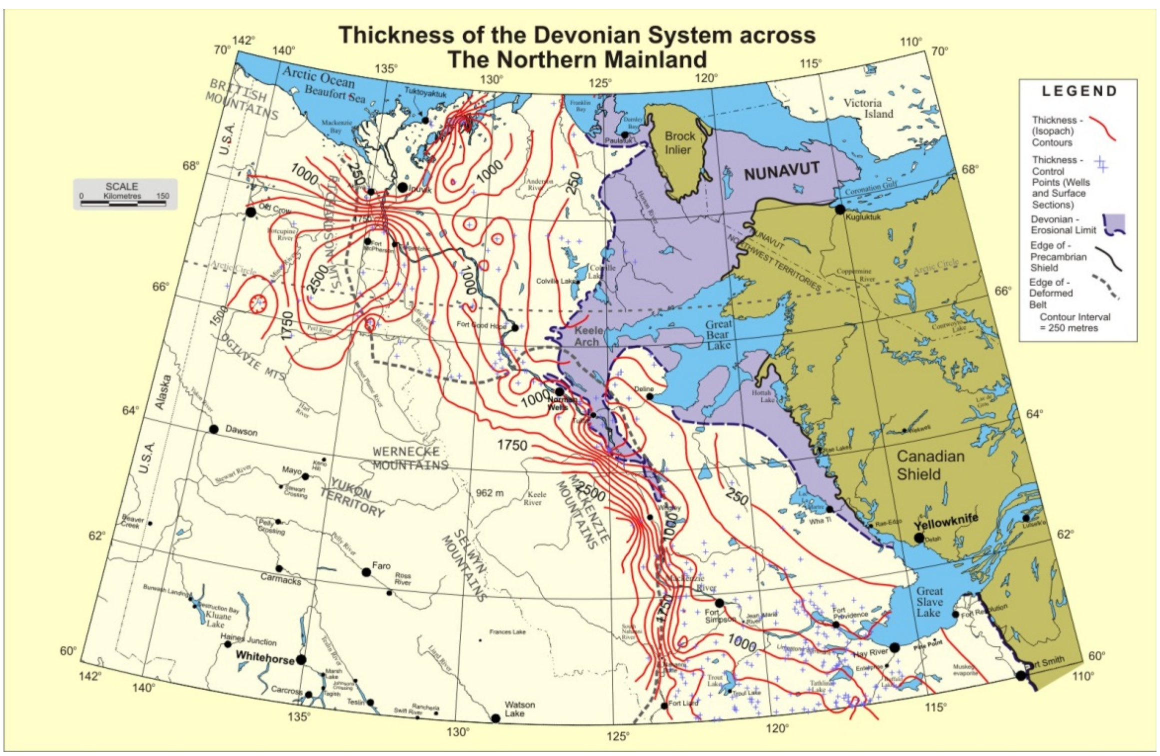

Figure 13. Map of the total preserved thickness in metres of the Devonian System across the northern mainland. South of 66° north latitude the entire Devonian succession thickens southwestward to over 3000 metres in the Mackenzie Mountains west of Wrigley. North of 66° north latitude the Devonian succession thickens westward towards a northeast-trending axis of maximum thickness, which extends through the town of Fort McPherson. Closed isopach depressions are indicated by inward-facing hachures. (Hi-Res)

The entire Sombre to Nahanni formational succession is exposed along the sides of the spectacular canyons of the South Nahanni River (Fig. 14). At First Canyon (Fig 20), the total exposed thickness of this succession is over greater than 1000 metres (Morrow and Cook, 1987). This includes a complete Arnica Formation of 625.5 metres thick, a Landry Formation of about 55 metres thick and a Headless Formation 30 metres thick (Morrow and Cook, 1987). At First Canyon, almost half of the total volume of the Landry Formation limestone has been replaced by the white, coarsely crystalline Manetoe Dolomite (Fig. 20) as a post-lithification, diagenetic replacement facies. Near First Canyon, complete outcrop sections of the Nahanni Formation limestone are between 200 and 250 metres thick (Morrow and Cook, 1987). The base of the Headless Formation may be unconformable, or disconformable, here as there are numerous ochre-stained bed-partings (Morrow and Cook, 1987). Fifty kilometres northwest of First Canyon, at Ram Plateau, the Headless Formation is over 200 metres thick as part of a general northwestward and westward thickening of the Headless towards the Meilleur River Embayment (Fig. 14).

Chinchaga deposition was followed by deposition of the Keg River Formation across the region of the former Tathlina Uplift (Fig. 17). The Keg River Formation is notably thicker along the western edge of the former Tathlina Uplift than farther east (Fig. 17). Keg River deposition marks the beginning of the development, in Middle Devonian time, of the Presqu'ile Barrier Reef across the former Tathlina Uplift. Thick Keg River dolomitized reefal coralline and stromatoporoidal lime framestone and rudstone developed along the margin of this reef complex. The Keg River Formation farther east behind the outer edge of the barrier is thinner and more bituminous and crinoidal, rather than coralline, and with a darker, more lagoonal appearance. The deposition of shallow water peritidal lime wackestone and packstone and dolostone of the Sulphur Point Formation across the Presqu'ile Barrier marked the upward transition from marine transgression to regression in the depositional T-R sequence of cycle B. Dark, organic-rich and siliceous slope and basinal shale of the Horn River Group accumulated west of the Barrier during deposition of the upper Keg River to Watt Mountain succession (Fig. 17).

The thickness of the Hume-Lonely Bay Assemblage (the combined thickness of the Nahanni and Headless formations) across southern Great Slave Plain is about 100 to 200 metres increasing abruptly to 300 metres or more west of the eastern limit of Cordilleran deformation in the Liard Plateau and southern Mackenzie Mountains (Fig. 19).

Emergence and erosion at the end of deposition of T-R Cycle B (Hume-Lonely Bay Assemblage) led to development of the regional unconformity beneath the Watt Mountain Formation (Fig. 16, 17, 18). This unconformity, along with the very thin Watt Mountain Formation above the unconformity, marked the end of deposition of the Elk Point Group in western Canada (Meijer-Drees, 1994; Oldale and Munday, 1994). This sub-Watt Mountain unconformity may be traced across most of continental North America (Johnson et al., 1985). It can be traced eastward across the entire Presqu'ile Barrier in the eastern part of the southern Great Slave Plain (e.g. Fig. 18) but is not recognizable near the outer reefal margin of the Presqu'ile Barrier reef complex where the Watt Mountain green shale marker disappears and the Sulphur Point and Slave Point formations are not readily distinguished and are mapped as an undivided Slave Point-Sulphur Point subsurface map unit (Fig. 17; Meijer-Dress, 1993).

Deposition of T-R cycle C, or the Slave-Kakisa Assemblage, commenced with marine transgression and accumulation of the greenish-grey argillaceous and calcareous siltstones of the Watt Mountain Formation and the Ebbutt Member across the almost the entire Presqu'ile Barrier (Fig. 17, 18). Continued transgression led to deeper submergence of the Presqu'ile Barrier and deposition of the shallow marine shelf fossiliferous lime wackestones of the Slave Point Formation (Fig. 16, 17, 18). Hemispheroidal stromatoporoids and corals are abundant near the Presqu'ile Barrier shelf margin and provide good primary reservoir porosity for gas pools, such as at the Netla C-07, which was discovered in a reefal buildup along the barrier shelf margin of the Arrowhead Salient (Fig. 14, 16, 17). Offshore, north and east of the Barrier, slope and basin deposition of organic rich grey shale of the Horn River Group occurred during Slave Point deposition across the barrier. Horn River shale is about 40 metres thick north of the Presqu'ile Barrier around Fort Simpson but thickens rapidly westward up to more than 200 metres near Meilleur River Embayment (Fig. 21). It is also very thick in the Deep Bay area around Fort Providence near Great Slave Lake (Fig. 21; Meijer-Drees, 1993). Shale of the Horn River Group encases the Horn Plateau Reefs that overly the Nahanni Formation north of the Presqu'ile Barrier (Fig. 21).

Accelerated marine transgression led to drowning of the Presqu'ile Barrier and initiation of basinal shale deposition of the Muskwa Formation during the time of maximum transgression of T-R cycle C (Fig. 15, 16, 17). Westward inclined log marker horizons in the overlying calcareous greenish-grey shale of the Hay River Formation, which can be traced westward into the underlying Muskwa Formation, indicate that the Hay River Formation was a westward prograding subtidal and slope-deposited mudbank and that the Muskwa was deposited contemporaneously as a toe-of-slope basinal deposit below the photic zone and below storm wave base in front of an advancing Hay River mudbank (Fig. 8, 18; Williams, 1977). Muskwa shale is confined largely to the small area of the Presqu'ile Barrier itself and thins generally westward across the Barrier from about 150 metres thick near Buffalo Lake to less than 20 metres thick across the western portion of the barrier (Fig. 22). Muskwa shale merges with upper Horn River shale northwestward, or basinward, of the Presqu'ile Barrier.

At the end of Hay River deposition shallow water deposition of clean stromatoporoidal limestones of the Twin Falls Formation (equivalent to the Grosmont Formation in northern Alberta (Williams, 1977)) and Alexandra Member commenced. The end of Twin Falls deposition coincided with a small increase in water depth and the accumulation of the argillaceous and fossiliferous shelf ramp-deposited lime wackestones of the Tathlina Formation (Fig. 9, 18). Markers within the Tathlina Formation display very slight westward dip, an indication that deposition at this time occurred across a westward inclined submarine ramp at a low angle. The base of the overlying Redknife Formation is marked by a thin, but prominent, clean limestone, the Jean Marie Member (Fig. 9, 18). Brown silty shales of the Redknife Formation overlying the Jean Marie Member do not display westward inclined internal log markers but the general westward thickening of the Redknife shale wedge may indicate accumulation on a westward-inclined submarine ramp that underwent differential subsidence during deposition. Deposition of T-R cycle C and the Slave-Kakisa Assemblage across the southern Great Slave Plain ended with marine regression and deposition of the clean coralline and stromatoporoidal lime wackestone of the Kakisa Formation followed by emergence and subaerial erosion to form the sub-Trout River unconformity (Fig. 9, 18).

It seems likely that the relatively greater argillaceous and shaley siliciclastic contents of limestone units, such as the Tathlina, Tetcho and Kotcho formations, above the Hay River Formation may have been controlled less by water depths and more by the rate of influx of siliciclastic material supplied by the Arctic Ellesmerian Orogeny which was active during Middle to Late Devonian time (Lane, 2007; D.K. Norris, 1997). The absence of prominent westward inclined log markers within strata above the Hay River Formation is consistent with this interpretation.

Deposition of the Kotcho-Tetcho Assemblage, or the lower part of T-R cycle D, commenced with marine transgression and accumulation of silty and sandy limestones and sandstones of the Trout River Formation. Continued transgression led to deposition of shallow water light grey open marine shelf lime wackestone of the Wabamun Formation. The Wabamun passes westward by facies transition to the Tetcho and Kotcho Formations. Limestone of the Tetcho Formation is similar to that of the Wabamun farther east but with some shaley zones. The Kotcho Formation is a medium grey lime mudstone, which becomes darker and shaley farther west with a more basinal appearance (Fig. 9, 18). Widespread submergence to basinal depths at the end of Kotcho deposition was accompanied by accumulation of the black organic-rich, siliceous shale of the Exshaw Formation (Fig. 9, 18), which marked the close of deposition of the Devonian System in the southern Great Slave Plain. T-R cycle D itself may be regarded as having continued into Carboniferous time with deposition of the overlying Banff Formation and other overlying Carboniferous Formations (e.g., Pekisko Formation).

The rather narrow Cordova Embayment (Fig. 14) extends about 150 kilometres southward into the western part of the Presqu'ile Barrier (Fig. 17). There is evidence that this embayment was formed during deposition of the Sulphur Point and Slave Point formations, inasmuch as the Muskwa Formation (Fig. 17) and overlying Devonian formations extend across the embayment with minor or no vertical displacement where they cross the embayment flanks (Morrow et al., 2002). The top of the Keg River Formation is significantly lower within the embayment by almost a hundred metres (Fig. 17). The Horn River Group shales (Klua and Otter Park) and basinal limestones (Slave Point and Sulphur Point basinal equivalents) appear to have largely filled the embayment topography by the end of Slave Point time (Fig. 17). The stratigraphic nomenclature of Horn River strata that occupy Cordova Embayment is in need of more rigorous definition, but here follows the provisional nomenclature of Morrow et al. (2002), which is similar to that of northeast British Columbia (see Williams, 1983). The Otter Park Member and the informal “Slave Point-Sulphur Point basinal” unit together could constitute an, as yet unnamed, formation. Together with the Klua Formation, this unnamed formation would then comprise the Horn River Group in Cordova Embayment (Fig. 17).

The Klua shales are largely dark grey, organic-rich and radioactive with good petroleum source rock potential. Klua strata are overlain abruptly by resedimented fossiliferous shelf lime wackestones of the Slave Point-Sulphur Point basinal unit, which have beenwere shed into the embayment from the flanking shelf platform carbonates of the Sulphur Point and Slave Point formations (Fig. 17). Both the Klua shale and the Slave Point-Sulphur Point basinal unit extend eastward several kilometres beneath Sulphur Point and Slave Point strata within the platform succession on the east side of the embayment (Fig. 17).

Seismic lines across the flanks of the embayment display normal down-to-embayment fault displacements that have clearly offset the top of Precambrian-base of Devonian unconformity along the flanks of the embayment (Morrow et al., 2002). Cordova Embayment appears to have developed as a fault-bounded graben as a product of east-west extensional tectonics in Middle Devonian (Givetian) time. It separates the Arrowhead Salient of the Presqu’ile Barrier from the main part of the Barrier east of the embayment.

Economically important hydrothermal white dolomite has replaced parts of the carbonate platform successions of the Bear Rock, Hume-Lonely Bay and Slave-Kakisa assemblages across the southern Great Slave Plain and Liard Plateau. White coarsely crystalline dolomite that has replaced Arnica, Landry, Lonely Bay and Nahanni strata is termed “Manetoe Dolomite” (Morrow et. al., 1990; Fig. 16, 20). This dolomite forms the petroleum reservoir for the large producing natural gas fields, such as at Pointed Mountain and at Kotaneelee located in Liard Plateau (Fig. 3; Morrow et al., 2006). Farther east, white coarsely crystalline hydrothermal dolomite has replaced parts of the carbonate succession within the Presqu’ile Barrier reef complex (Meijer-Drees, 1993). Units in the barrier complex, such as the Keg River, Sulphur Point and Slave Point formations, have been variably replaced by white coarsely crystalline dolomite that has been termed the Presqu’ile Dolomite (Meijer-Drees, 1993: Fig. 16, 17). The Presqu’ile Dolomite is well known from early exploration and mapping along the southwestern shores of Great Slave Lake and was subsequently found to be the host for one of the largest Mississippi-Valley-type of lead-zinc deposits of the world (Rhodes et al., 1984). The Presqu’ile Dolomite also forms the reservoir for several gas pools discovered within the Presqu’ile Barrier (Fig. 3, 17; Hannigan et al., 2006, Morrow et al., 2006).

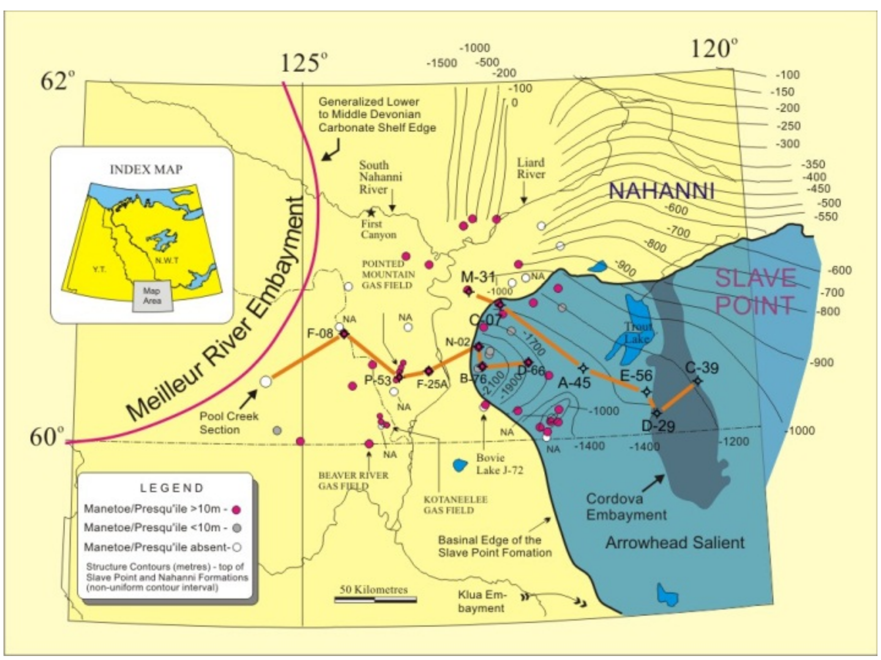

Figure 14. Map illustrating distribution of Manetoe and Presqu’ile Dolomite south of 61.2° north latitude (i.e., south of First Canyon on South Nahanni River) around the Arrowhead Salient of the Presqu’ile Barrier. Lines of section for stratigraphic cross-sections in figures 16 and 17 are also shown.

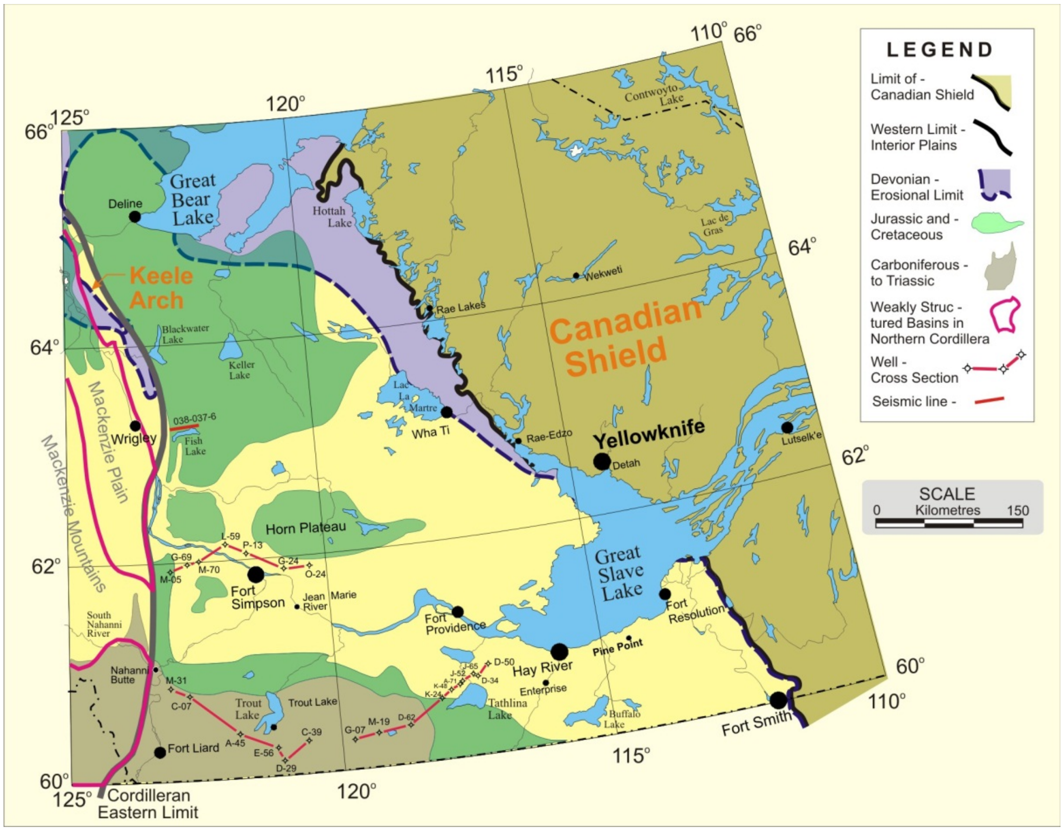

Figure 15. Map view showing extent of Cretaceous and Carboniferous to Permian strata overlying Devonian strata west of Great Slave Lake and south of Great Bear Lake. Lines of section for stratigraphic cross-sections in figures 16, 18, and 23 are also shown.

Northern Great Slave Plain, southern Great Bear Plain, southern Mackenzie Plain and the Mackenzie Mountains

In the Horn Plateau area of the northern Great Slave Plain, Lower and Middle Devonian strata form a generally westward-thickening prism of carbonate-dominated strata, comprised almost entirely of the Delorme and Bear Rock assemblages (T-R cycle A) and the Hume-Lonely Bay Assemblage (T-R cycle B). These dominantly carbonate and evaporate strata are covered by a thin, partially preserved cover of dominantly siliciclastic Middle to Upper Devonian strata of the Fort Simpson Formation in the Slave-Kakisa Assemblage (T-R cycle C in Fig. 23). Across most of the south central part of the Great Slave Plain strata of the Fort Simpson Formation are either exposed, or are overlain unconformably by Cretaceous strata (Fig. 3, 6), such as across Horn Plateau (Fig. 15).

Very little of the Delorme Assemblage is preserved in this area, with only a thin Tsetso and Mirage Point formation present in some wells (Fig. 23). Where Delorme Assemblage strata are absent, as across the western portion of the cross-section shown in Figure 23, located at about 62° north latitude, a basement high, the Liard High (Fig. 8), is inferred to have been a broad structural arch that was a subaerially exposed upland during earliest Devonian time across this part of the northern Great Slave Plain (Meijer-Drees, 1993).

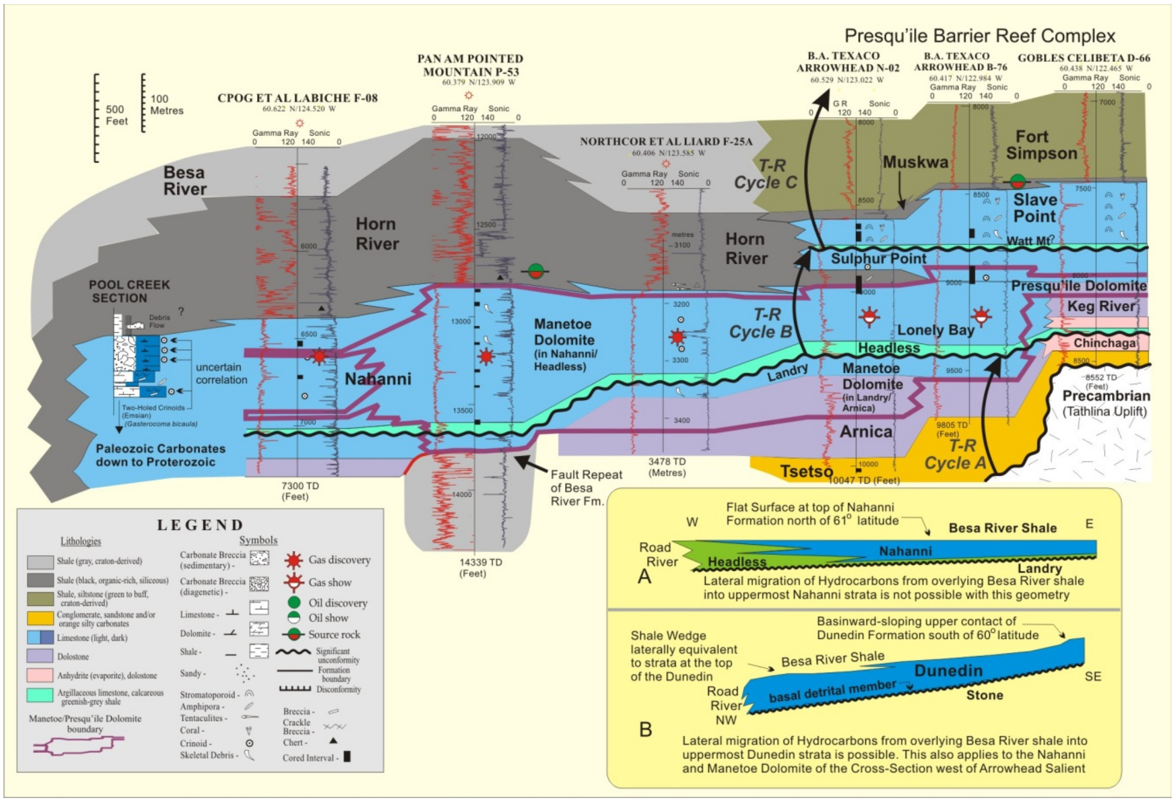

Figure 16. Stratigraphic cross-section of Devonian strata extending westward from the Presqu'ile Barrier to the edge of Meilleur River Embayment (Fig. 14). This includes T-R cycles A and B and part of T-R Cycle C. The stratigraphic extent of the Manetoe and Presqu'ile hydrothermal dolomites is also shown. Inset panel compares shelf-to-basin transition of Hahanni and Dunedin north of 61º north latitude and south of 60º north latitude respectively.

Farther east, Mirage Point and Mirage Point-equivalent evaporites in the Fort Norman Formation (anhydrite and halite) of the Delorme Assemblage accumulated in the shallow water Willowlake Embayment (Meijer-Drees, 1993; Fig. 23). The overlying Bear Rock Assemblage (Fort Norman, Arnica and Landry formations) thickens westward from less than 300 feet thick at the Green Island O-24 well east of Fort Simpson to more than 1000 feet at the Cli Lake M-05 well at the eastern limit of the disturbed belt in front of the Nahanni Range (Fig. 15, 23). The Fort Norman succession of intercalated evaporites and dolomudstone passes westward by facies transition to finely and medium crystalline brown Arnica dolostones and pelletal lime packstone and wackestone of the Landry Formation with a facies transition along the east flank of Liard High (Fig. 23, 24). The Landry Formation and a portion of the upper part of the Arnica Formation west of the Strong Point G24 well, have been partly, or completely, replaced by the coarsely crystalline white dolospar of the Manetoe Dolomite (Fig. 23). The top of the Bear Rock Assemblage of T-R Cycle A is marked by the widespread unconformity developed beneath the greenish-grey calcareous shale and fossiliferous, argillaceous lime mudstone of the Headless Formation, which contain the basal transgressive shoreline deposits of T-R Cycle B of the overlying Hume-Lonely Bay Assemblage (Fig. 23). The overlying Nahanni and laterally equivalent Lonely Bay formations were deposited largely during a succeeding regression. The Headless Formation thickens westward and its upper part probably formed on a westward-facing submarine slope in front of a prograding carbonate shelf of coralline lime wackestone of the Nahanni Formation (Fig. 23; Noble and Ferguson, 1970).

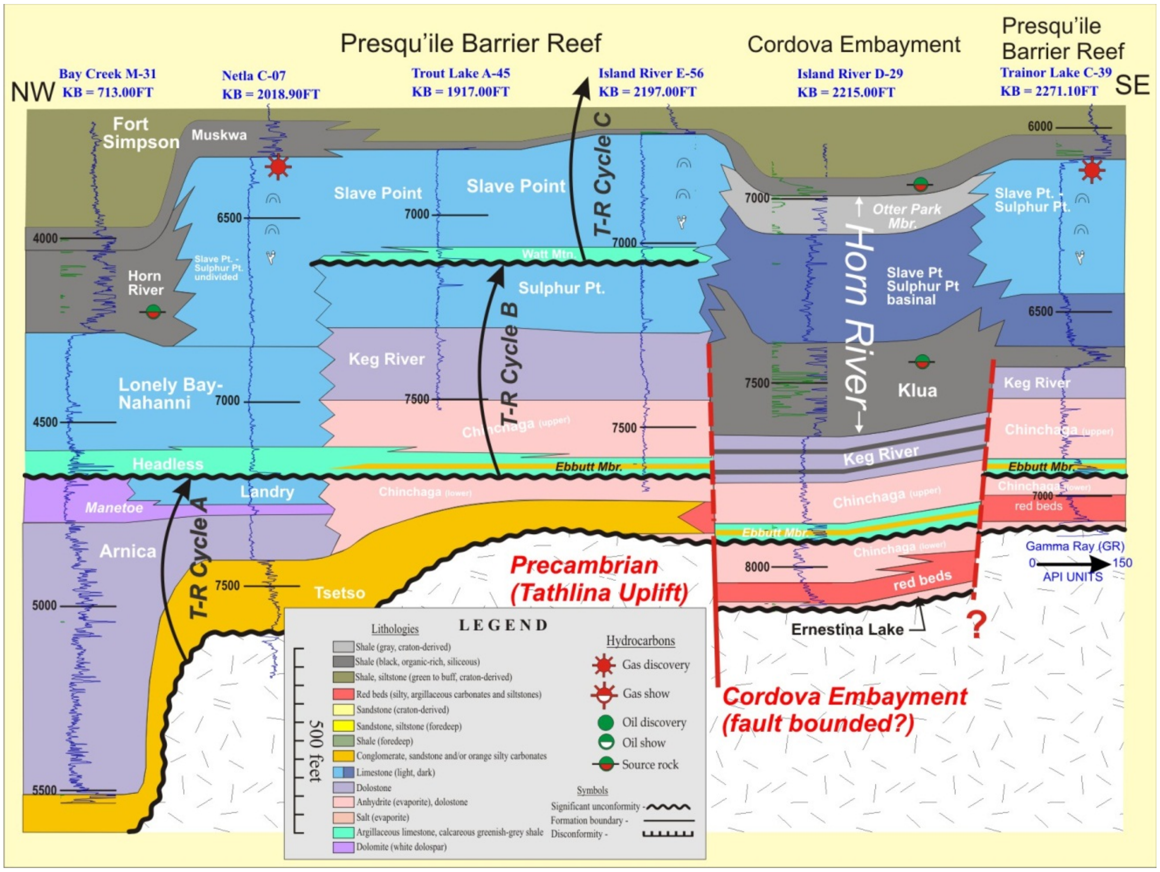

Figure 17. Stratigraphic cross-section of Devonian strata extending across the Cordova Embayment within the Arrowhead Salient of the Presqu'ile Barrier (Fig. 14, 15). This includes T-R cycles A and B and part of T-R Cycle C. Cordova Embayment is probably a fault-bounded graben and contains a deeper water shale-dominated succession, the Horn River Group.

In the northern Mackenzie Mountains several hundred kilometres northwest of Horn Plateau (Fig. 15) an east-west line of section illustrates the stratigraphic expression of Twitya Uplift (Fig. 25) between Keele and Mountain Rivers at about 64° north latitude (Fig. 26). This cross-section shows the sub-Devonian unconformity developed beneath the Tsetso dolomitic sandstones and siltstones across the axis of the underlying Twitya Uplift and the truncation of the underlying Proterozoic to Silurian-aged succession (Fig. 25, 24). The truncation of Proterozoic strata beneath the Cambrian-aged unconformity beneath the Franklin Mountain Formation (Fig. 25) represents erosional truncation across the older Mackenzie Arch (Fig. 24; Aitken et al., 1973). The sub-Cambrian unconformity is itself truncated beneath the sub-Devonian unconformity and has been removed across the central axis region of Twitya Uplift between sections 4.and 11of cross-section A-B (Fig. 25, 27).

The combined thickness of the Delorme and Bear Rock assemblages (T-R cycle A) is commonly less than 200 metres across and east of Twitya Uplift (Fig. 25). This was part of a broad area termed the "Norman Wells High" (Fig. 24; Williams, 1990; Morrow, 1991) across which the combined thickness of these assemblages (Tsetso and Fort Norman formations including the Bear Rock breccia) is 200 metres or less. The combined thickness of the Delorme and Bear Rock assemblages increases abruptly to over 1000 metres west of Twitya Uplift (Section 20 in Fig. 25). The Camsell Formation breccias of Section 11 of cross-section A-B (Fig. 25) were formed by solution collapse of soluble anhydrite that previously was interbedded with dolomudstones (Morrow, 1991). This abrupt thickness increase of T-R cycle A west of Twitya Uplift is the main contributor to the thick Lower and Middle Devonian depocentre developed between Keele River and the Wernecke Mountains (Fig. 11; Morrow, 1991).

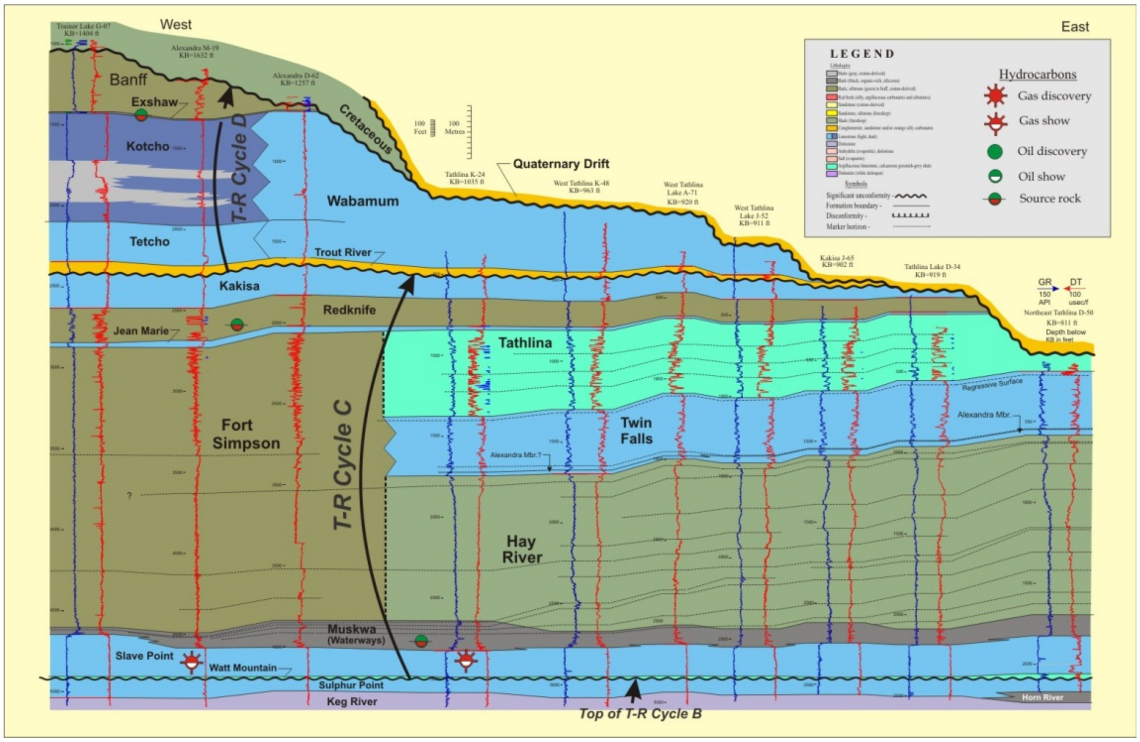

Figure 18. Stratigraphic cross-section of Devonian strata extending southwest across Great Slave Plain near Tathlina Lake (easternmost cross-section in Fig. 15). This includes T-R cycles C and parts of T-R cycles B and D. Platform carbonates that extend variable distances westward are intercalated between shale-dominated units. Abundant marker horizons define west-facing depositional dip-slopes, or clinoforms, within these strata. (Hi-Res)

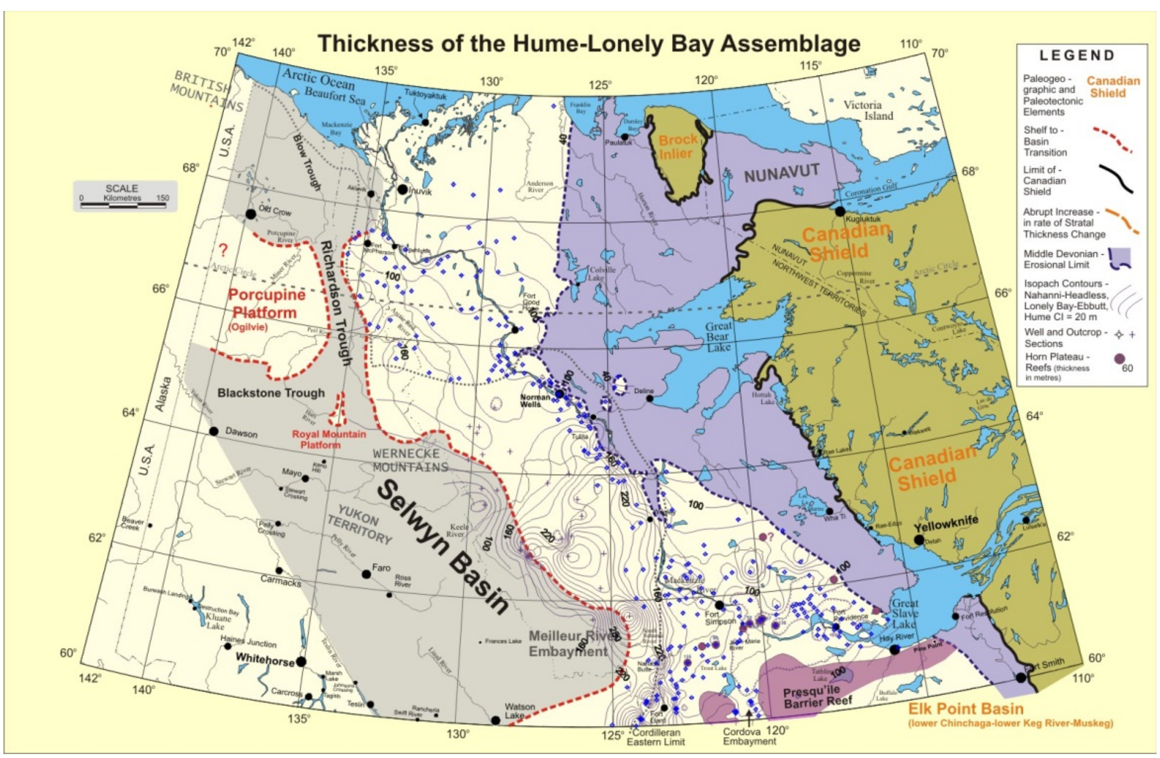

Figure 19. Isopach map of the Hume-Lonely Bay Assemblage across the northern mainland. This interval exhibits an overall westward increase in thickness from 100 metres near the Canadian Shield to over 360 metres thick in the Cordilleran Mountains west of Fort Simpson. Northwest of Norman Wells this interval is fairly constant in thickness and less than 200 metres thick. Locations of Horn Plateau reefs that developed

above the Lonely Bay and Nahanni formations are also shown. Age-equivalent Hume-Lonely Bay Assemblage strata in northern Yukon are not contoured here because of the absence of a recognizable base of Headless-equivalent unconformity across the Porcupine Platform. (Hi-Res)

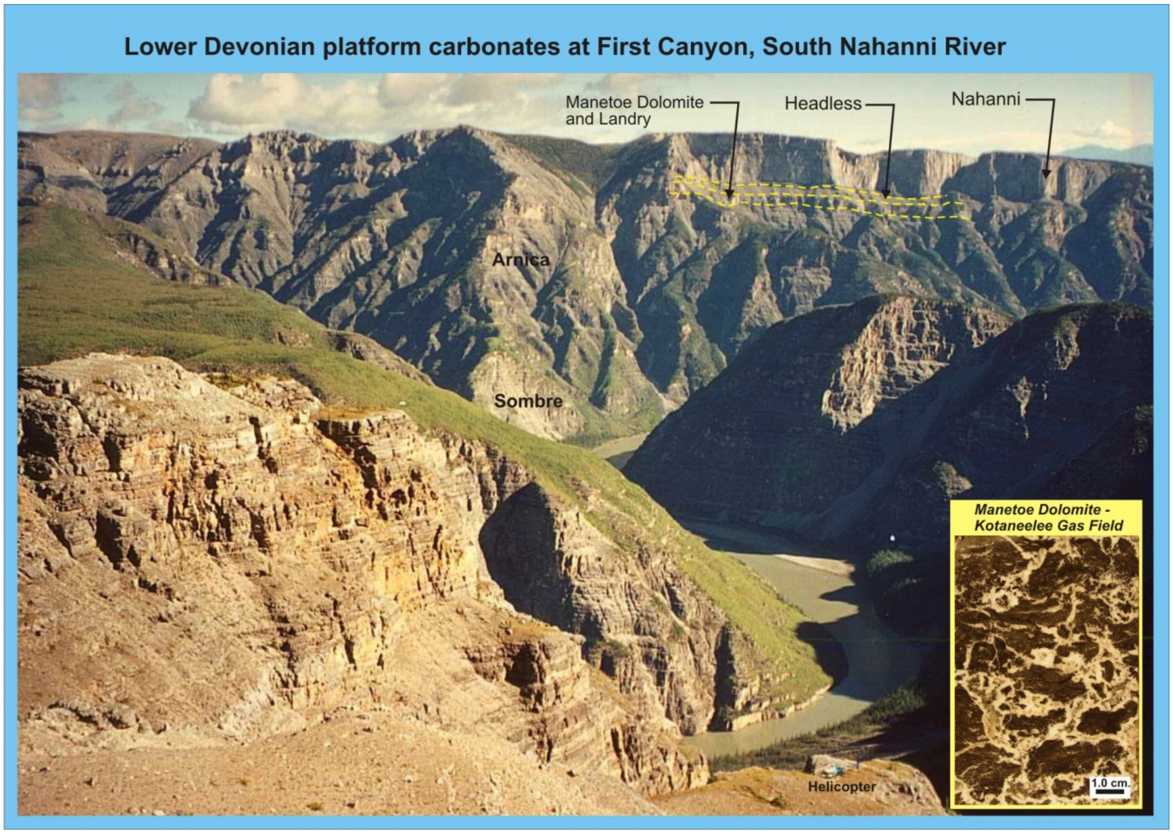

Figure 20. Panoramic view of the Lower and Middle Devonian succession exposed at First Canyon along South Nahanni River. Nahanni, Headless and Landry formational contacts are shown in yellow dashes. About 2000 metres of strata are exposed (note helicopter for scale). Inset photo of a core sample from the Kotaneelee Gas Field illustrates dolomite-cemented solution-collapse breccias typical of the Manetoe Dolomite.

South of Keele River and the Norman Wells High (Fig. 24; 28, 29) is a large northerly oriented, oval shaped Lower and Middle Devonian depocentre that extends northward from the South Nahanni River to near the Keele River (Fig. 11). This large intrashelf depocentre is termed the “Root Basin” (Fig. 24, 27, 28; Williams, 1989a; 1990; 1996; Morrow; 1987; Gabrielse, 1967; 1973) and lies within Mackenzie Shelf (Fig. 24, 29). The Redstone Arch (Gabrielse, 1967, 1973; Williams, 1989a, 1990, 1996; Morrow, 1991) has been inferred to have been a southeast-trending uplift that caused depositional thinning of both the Delorme Assemblage (Fig. 24, 26) and of the Bear Rock Assemblage (Fig. 28, 29) across its central axial region. Root Basin was flanked on its west side by the Redstone Arch on its north side by the Norman Wells High (Fig. 28, 29). Root Basin opened southward into the Meilleur River Embayment of Selwyn Basin (Fig. 24, 29) throughout Early Devonian time. The southward outlet of Root Basin became a shallow water south-facing embayment termed the Prairie Creek Embayment (Fig. 29) during Bear Rock Assemblage deposition.

This depocentre began as a depositional basin in Ordovician and Silurian time (Gabrielse, 1967) and was an area of basinal grey shale and basin and slope-deposited lime mudstone of the Road River Group at the close of Silurian time (Morrow and Cook, 1987). Near the centre of Root Basin at Pastel Creek south of Root River (Fig. 26, 28, 30), the Delorme and Bear Rock assemblages are exposed in a structurally undisturbed succession. Here, Road River strata are overlain by over 500 metres of thick bedded, cliff-forming resistant biostromal dolostones of the Root River Formation and by about 170 metres of very thin bedded brownish-grey basinal slope-deposited skeletal lime wackestones rhythmically intercalated with thin bedded yellow-weathering argillaceous lime mudstones of the Vera

Formation (Fig. 4A; Morrow and Cook, 1987) forming the lower part of the Delorme Assemblage (Group). Deposition of the Vera Formation and the correlative, slope-deposited orange siltstones of the Cadillac Formation during earliest Devonian time (Lochkhovian) coincided with the partial infilling of Root Basin and the progressive partial closure of its southern outlet towards Selwyn Basin near South Nahanni River (Fig. 24; Morrow and Cook, 1987). Spectacular orange and pink weathering limestone breccia of the Camsell Formation up to 570 metres thick overlies the Vera Formation to form the upper part of the Delorme Assemblage at Pastel Creek (Fig. 30). In subsurface well sections in Root Basin, Camsell strata are composed of slightly argillaceous, intercalated thin bedded dolomudstones and anhydrite (Morrow, 1991; Meijer-Drees, 1993).

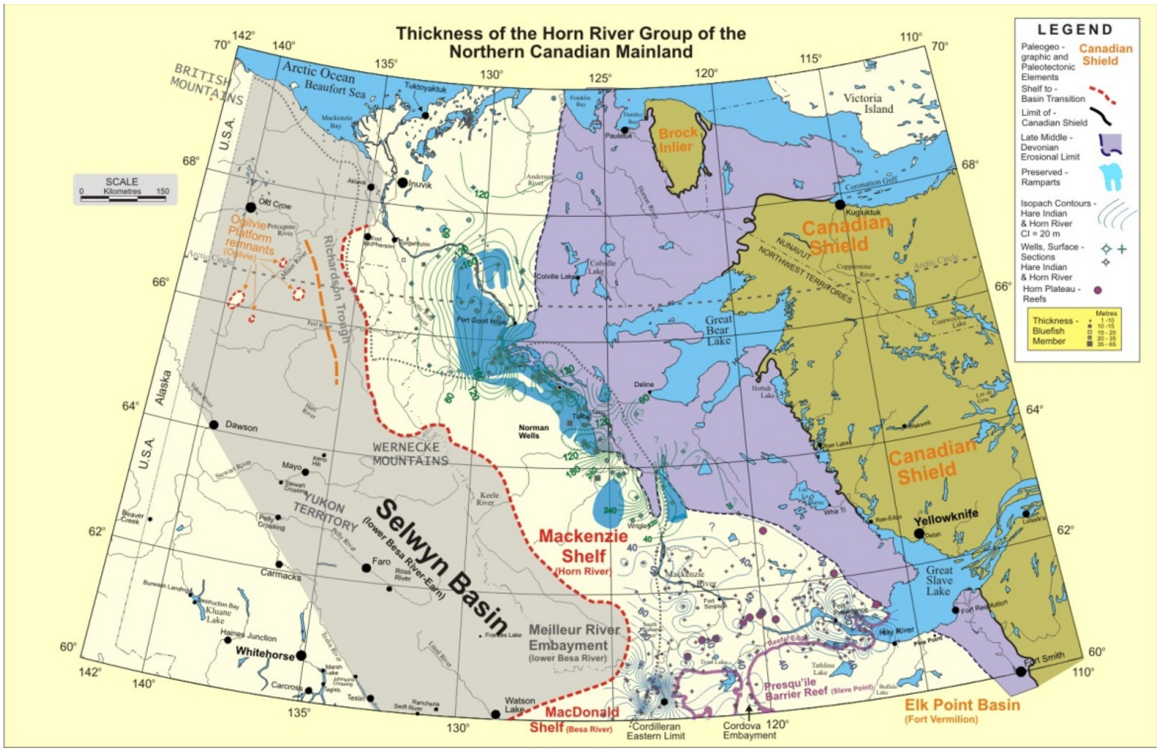

Figure 21. Isopach map of the preserved Horn River Group across the northern mainland. In the south, grey shales and argillaceous limestones of the Horn River Group (formation) form a northward and westward extending, irregular sediment wedge, 40 to over 200 metres thick, and which encases Horn Plateau reefs in front of the Presqu'ile Barrier. Farther north, age-equivalent shales and argillaceous slope-deposited limestones of the Hare Indian Formation form a westward-thinning wedge beneath the Ramparts Formation reefal limestones. Hare Indian thicknesses range from less than 60 metres to over 200 metres near Fort Good Hope and Tulita. (Hi-Res)

At Pastel Creek the Bear Rock Assemblage is represented by a combined thickness of shallow marine subtidally and peritidally-deposited medium to thick bedded light grey to medium brownish-grey, dolostones of the Sombre and Arnica formations of about 850 metres (Morrow and Cook, 1987; Fig. 30). Typically light grey medium dololaminite beds alternate with thick darker greyish-brown biostromal beds imparting a characteristic colour-banded appearance with lighter coloured Sombre strata passing upwards to darker more subtidally-dominated strata in the upper part of the Sombre and in the Arnica Formation (Fig. 26). Sombre strata are restricted to the western part of the Mackenzie Mountains and pass eastward by facies transition to Arnica strata (Fig. 25). Commonly, the facies transition between these two units is not vertical but is inclined so that Sombre strata become progressively thicker and overlying Arnica strata become progressively thinner westward such that Arnica strata are absent along the outer edge of Mackenzie Shelf facing Selwyn Basin (Fig. 9B, 29).

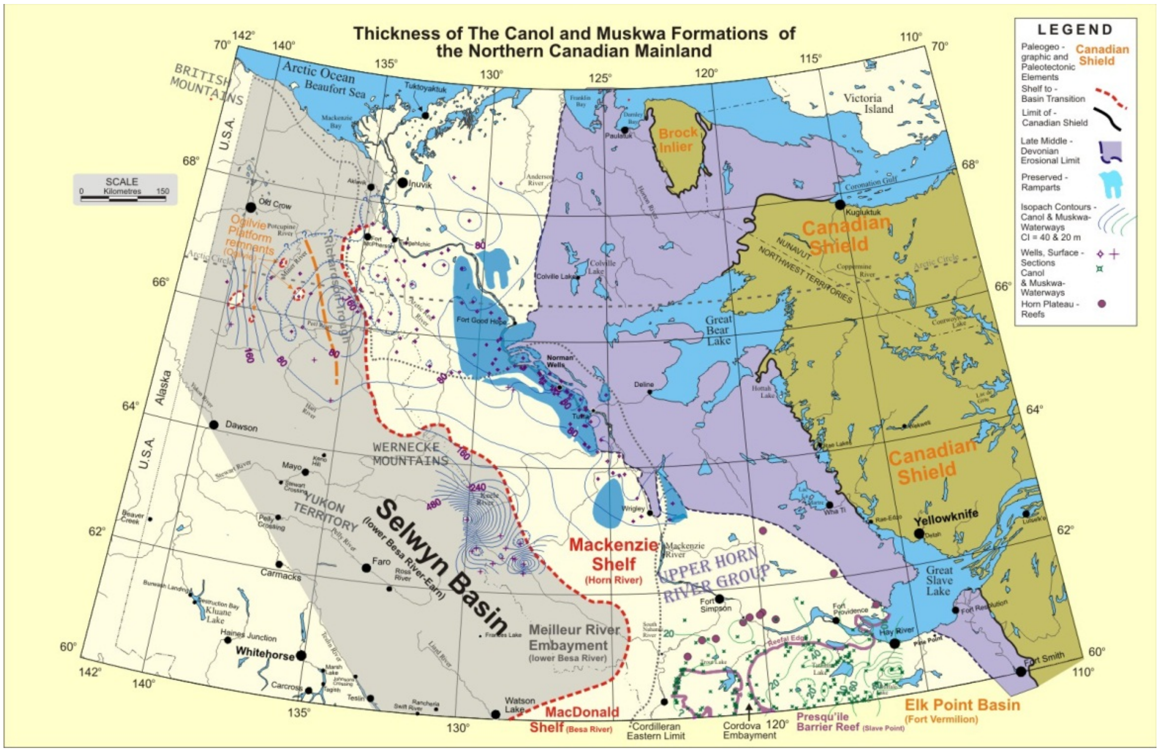

Figure 22. Isopach map of the preserved Canol and Muskwa formations across the northern mainland. This interval contains the maximum flooding surface for T-R Cycle C within the Slave-Kakisa Assemblage (Fig. 9). A northwestward-thinning wedge of dark toe-of-slope shales of the Muskwa Formation developed above the Slave Point Formation across the Presqu'ile Barrier. Farther north, dark organic-rich shale of the Canol Formation has a constant thickness of about 80 metres across the Peel and Anderson plains. Canol shales thicken dramatically in Selwyn Basin and in the Richardson Trough. (Hi-Res)

Dolostones of the Arnica and Sombre formations pass northeast to interbedded anhydrite and dolostone of the Fort Norman Formation (Meijer-Drees, 1993) in the subsurface of the northern part of Root Basin and to Bear Rock solution collapse breccias (Bear Rock Formation) in outcrop across both northern Root Basin and the Norman Wells High (Fig. 5A, 28). Outcrop of the Bear Rock breccias tends to be massive, non-bedded and very rough weathering, commonly as pinnacle and knobs and is generally a limestone particulate rubble packbreccia (Morrow, 1991; Fig 31).

The uppermost part of the Bear Rock Assemblage in Root Basin is represented by strata of the Landry and Funeral formations (Fig. 5A, 9). Landry strata, composed of poorly fossiliferous, medium medium-bedded, shallow shallow-marine, pelletal lime packestone and wackestone, commonly range from 100 to about 200 metres in thickness across the northeastern part of Root Basin and the Mackenzie Mountains (Morrow and Cook, 1987; Morrow, 1991; Fig. 9, 25). Buff-weathering shale and platy argillaceous non-fossiliferous lime mudstones of the Funeral Formation represent the final phase of deposition that filled Root Basin southwest of the Landry shelf edge across the northeastern part of the basin. Funeral Formation strata range up to 470 metres thick but commonly are about 150 metres thick within Root Basin (Fig. 29; Morrow and Cook, 1987; Williams, 1989a; Morrow et al., 1990).

South of 64° north latitude, greenish-grey, argillaceous limestones of the Headless Formation and bluish-grey limestones of the Nahanni Formation (Hume-Lonely Bay Assemblage) disconformably overlie strata of the Bear Rock Assemblage in the Mackenzie Mountains and the region occupied by Redstone Arch and Root Basin (Fig. 32). North of 64° the combined Headless and Nahanni Formations are mapped as the Hume Formation across the Norman Wells High and Twitya Uplift (Fig. 25). Strata of the entire Hume-Lonely Bay Assemblage west of Mackenzie River and southwest of Norman Wells increase in thickness uniformly southward from 100 metres west of Norman Wells, such as at Dodo Canyon (Fig. 31) to over 300 metres near Root River (Fig. 32). Hard siliceous dark shale of the Canol Formation and incomplete thicknesses of Imperial Formation brown siltstones overlie Hume and Nahanni carbonates in the mountain outcrop belts of this area. The influence of Redstone Arch on the Hume-Lonely Bay Assemblage is slight, but nonetheless discernible as thinning across the arch axis (Fig.32).

North of Horn Plateau and a few kilometres east of the town of Wrigley, Devonian strata are covered unconformably by Cretaceous strata (Fig. 15, 33). Near the western limit of the Interior Plains close to the edge of the Cordillera there are approximately 1000 metres of Devonian strata beneath the Cretaceous cover (Fig. 33). A considerable amount of pre-mid Cretaceous, as well as post-Cretaceous deformation, has occurred in this area in the subsurface of the plains close to the mountain front. Large contractional faults and anticlinal fault-related folds that trend parallel to the mountain front have developed in Devonian strata beneath the less deformed Cretaceous cover (Fig. 33).

The small degree of deformation of the Cretaceous strata in this area (Fig. 33) may be attributed to the Early Tertiary (or Paleogene) Cordilleran Laramide Orogeny. The relatively greater amount of pre-mid Cretaceous deformation of Paleozoic strata beneath the Cretaceous (Fig. 33) may have occurred either during the Late Devonian to Carboniferous Ellesmerian Orogeny that affected large parts of northern Canada (Lane, 2007), or, possibly, during the latest Jurassic to Early Cretaceous Columbian Orogeny that affected most of western and northern mainland Canada (Gabrielse, 1992; Dixon, 1992, 1999).

Recently, commercial quantities of both oil and gas have been found in Landry and Arnica strata along a similar, but structurally more elevated, anticlinal structure near Summit Creek at the eastern edge of the Mackenzie Mountains a few kilometres north of Keele River and about 75 kilometres south-southwest of Tulita (Fig. 3; Morrow et al., 2006) about 200 kilometres northwest of the buried deformed Devonian visible in seismic east of Wrigley (Fig. 15, 33).

Northern Great Bear Plain, Peel Plain and Plateau, Anderson, Colville and Horton plains and Northern Yukon

Devonian strata are present across almost the entire expanse of the northern part of Great Bear Plain, Peel Plain and Plateau, the northern Yukon, as well across Anderson, Colville and Horton Plains west of the erosional limit of Devonian strata west of the Canadian Shield (Fig. 11, 12, 13). Devonian strata were also eroded across a well-defined tectonic feature, the Keele Arch, in Cretaceous time east of Norman Wells (Cook, 1975). This arch extends southward into the southern part of Great Bear Plain as a prominent southward-directed re-entrant of the western erosional limit of Devonian strata on the east side of Great Bear Plain (Fig. 11, 12, 13). Devonian strata increase in thickness westward from Colville and Horton plains and reach a total thickness of more than 2500 metres south of Fort McPherson (Fig. 13).

Jurassic to Cretaceous-aged strata unconformably overlie Devonian strata across almost this entire region, except where Cretaceous strata have been removed by post-Cretaceous erosion (Fig. 3, 6). The Upper Devonian is preserved over a smaller area than Lower and Middle Devonian strata largely because of the progressive eastward truncation of the westward dipping Devonian beneath the sub-horizontal unconformity at the base of the Cretaceous succession (Fig. 6D). West of the eastern limit of the Cordilleran Mountains Devonian strata are involved in folding and faulting of the Laramide Orogeny, such as in the Franklin Mountains near Norman Wells (Fig. 6C). Farther west, in the northern Yukon, Devonian and Carboniferous strata are truncated northward in Eagle Plain basin across the northern flank of the Eagle Arch (Fig. 3, 7). Carboniferous strata conformably overlie the Devonian in the southern part of the basin (Fig. 7).

Strata of the Delorme Assemblage, or Delorme Group, are absent across most of Norman Wells High or are represented by only a few unnamed sandy beds at the base of the Fort Norman Formation where it rests unconformably on Mount Kindle dolostone immediately northwest of Norman Wells (Fig. 34; 35). Strata of the Fort Norman, Arnica and Landry formations of the Bear Rock Assemblage extend across Norman Wells High with a combined thickness of about 300 to 400 metres and display some thinning across the arch (Fig. 34).

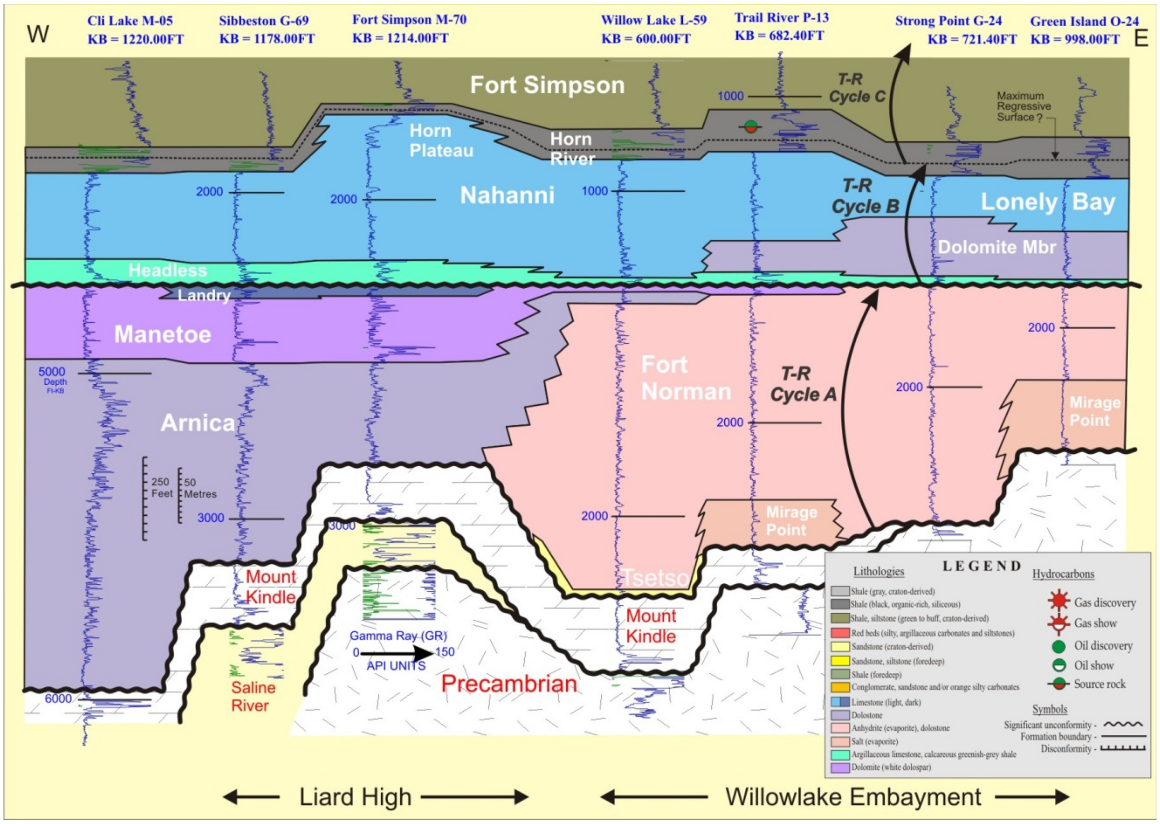

Figure 23. Stratigraphic cross-section of Devonian strata extending westward across the Great Slave Plain near Fort Simpson up to the eastern limit of the Cordilleran disturbed belt (Fig. 15). This includes T-R cycles A and B and part of T-R Cycle C. The influence of the Liard High as an Early Devonian tectonic feature is evident where strata (Arnica and Fort Norman formations) of T-R Cycle A thin west of Fort Simpson.

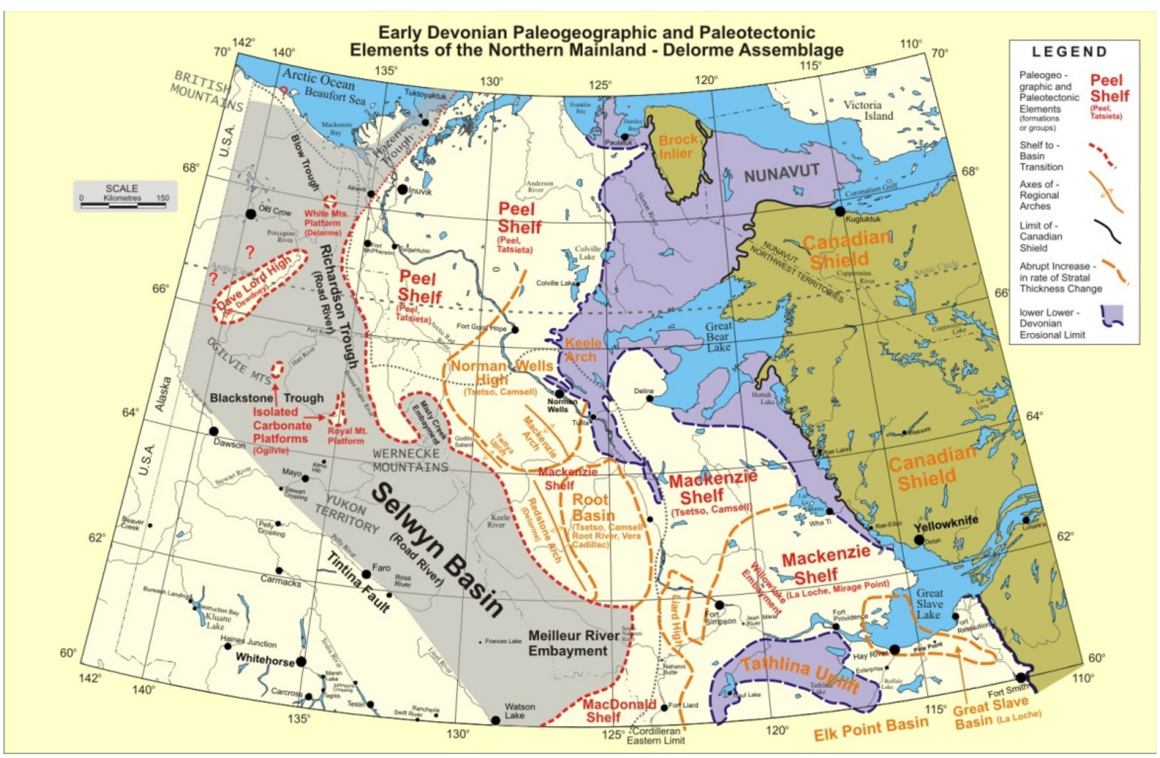

Figure 24. Map of paleogeographic and paleotectonic elements that influenced Early Devonian sedimentation across the northern mainland during deposition of the Delorme Assemblage. Mackenzie and Peel shelf

platforms pass westward to Root and Selwyn basins. The Norman Wells High was a broad area of uplift that separated the Peel and Mackenzie shelves. (Hi-Res)

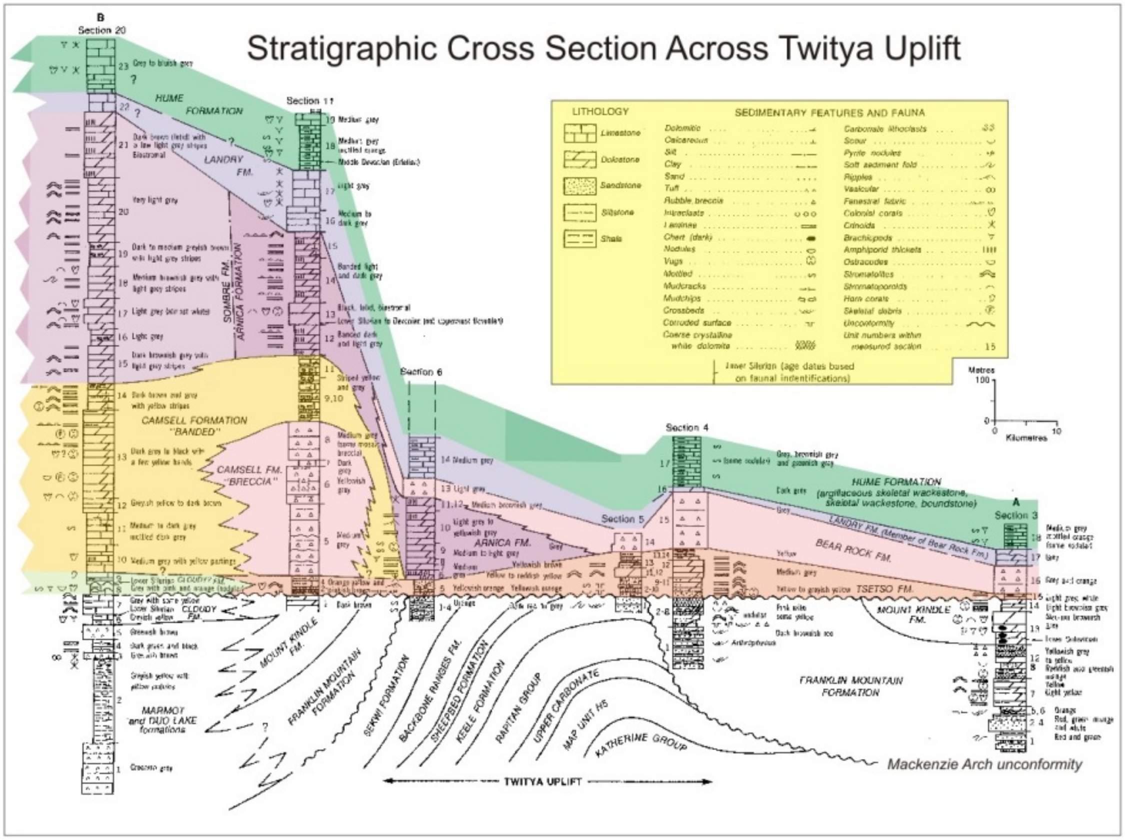

Figure 25. Stratigraphic cross-section of Lower and Middle Devonian strata exposed across Twitya Uplift in the central part of the Mackenzie Mountains (Fig. 26; Morrow, 1991). This succession is thin across the west flank of Norman Wells High. Evaporites of the Camsell Formation, represented by limestone breccia in Section 11, accumulated in a small basin west of Norman Wells High. This cross-section extends southwestward to the edge of Mackenzie Shelf where the entire Lower and Middle Devonian succession passes basinward to the basinal shales, argillaceous limestones and dolostones of the Road River Group. Green represents argillaceous limestone, violet represents bluish-grey limestone and and finely crystalline dolostone, pink represents limestone breccia, yellow silty clour-banded dolostones and orange silty and sandy dolostones.

Farther northwest across Peel Plain and Plateau, the Delorme Assemblage is composed of the greenish to orange-coloured argillaceous dolostone and limestones of the Peel and Tatsieta formations that thicken westward from a zero edge along the west side of Norman Wells High to a maximum of over 400 metres near Richardson Trough (Pyle and Jones, 2009). Similarly the combined thickness of the Arnica and Landry formations of the Bear Rock Assemblage increases westward to more than 600 metres near the Richardson Trough (Pyle and Jones, 2009). The Fort Norman evaporite succession passes laterally and completely to the Arnica succession a short distance northwest of Norman Wells (Fig. 34; Norris, 1993).

The Peel and Tatsieta formations increase in combined thickness from a zero edge at about 126° west longitude westward across Horton and Anderson plains to over 200 metres west of Fort Good Hope (Norris, 1993). Similarly, the combined thickness of the Arnica and Landry increases westward across Horton and Anderson plains to more than 400m metres northwest of Fort Good Hope (Norris, 1993).

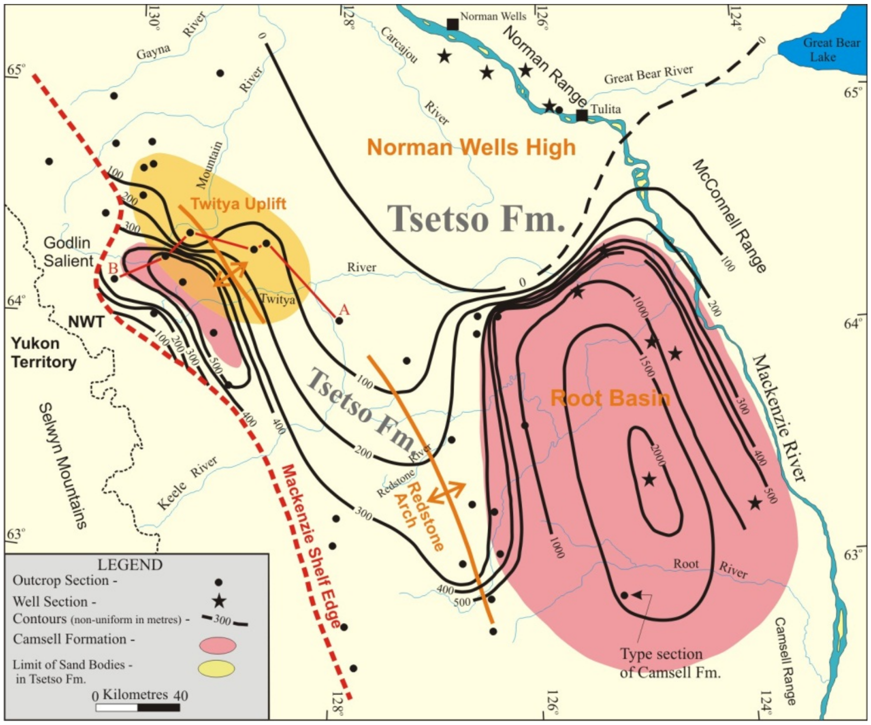

Figure 26. Isopach map of the Delorme Assemblage west of Mackenzie River. Redstone Arch, active in Early Devonian time, separated the evaporites of the Camsell Formation deposited in the large Root Basin east of the arch from a smaller basin west of the arch in the Godlin Salient.

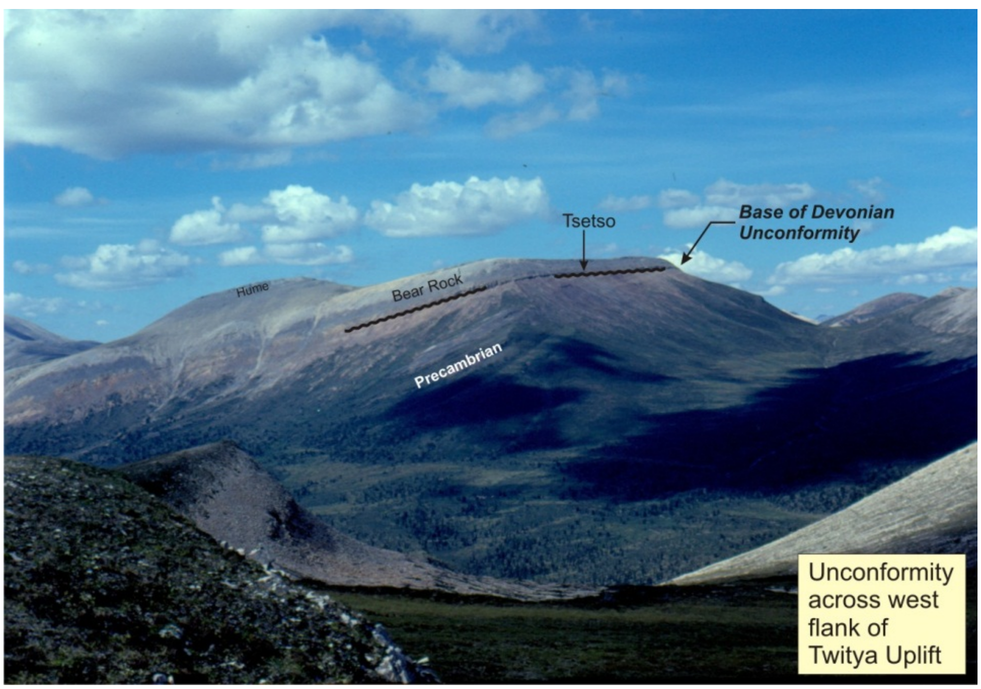

Figure 27. Panoramic view northward of the Delorme Assemblage resting with angular conformity on Precambrian strata of the Keele Formation. Tsetso Formation quartzarenite, a transgressive shoreface sandstone, rests directly on the unconformable surface and represents the onset of the transgression that began deposition of T-R Cycle A.

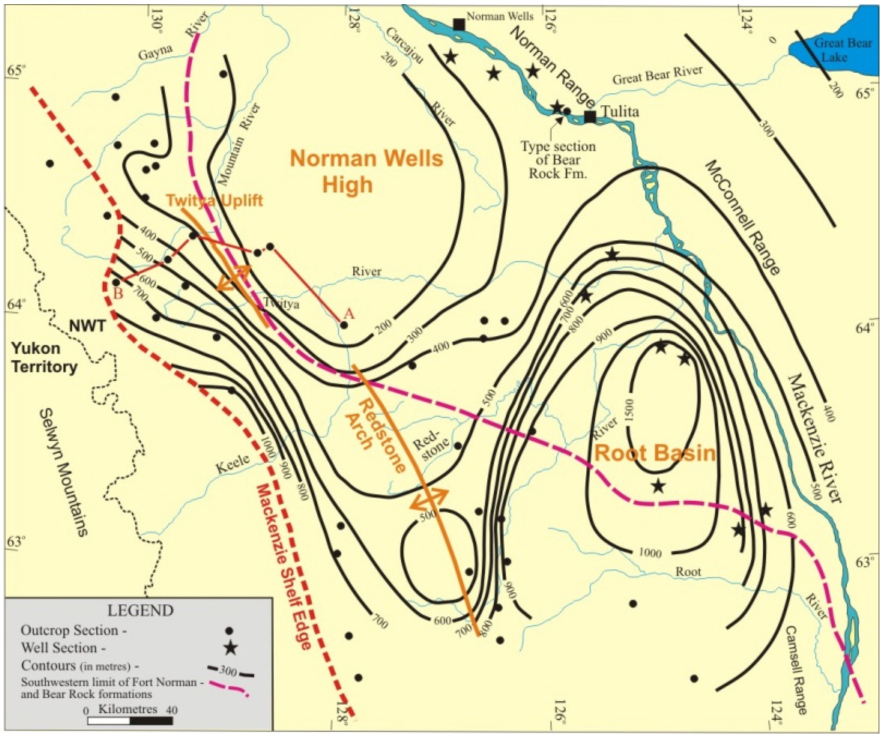

Figure 28. Isopach map of the Bear Rock Assemblage west of Mackenzie River. Norman Wells High, Root Basin and the Redstone Arch continued to influence deposition of this assemblage following deposition of the Delorme Assemblage. The southern limit of the Fort Norman Formation and the Bear Rock breccias extends southeastward across this area.

Figure 29. Paleogeographic and paleotectonic elements that influenced Early Devonian sedimentation during deposition of the Bear Rock Assemblage. Mackenzie and Peel shelf platforms pass westward to Root and Selwyn basins. The Norman Wells High was a broad area of uplift between the Peel and Mackenzie shelves. Porcupine Platform was an isolated carbonate platform in northern Yukon. (Hi-Res)

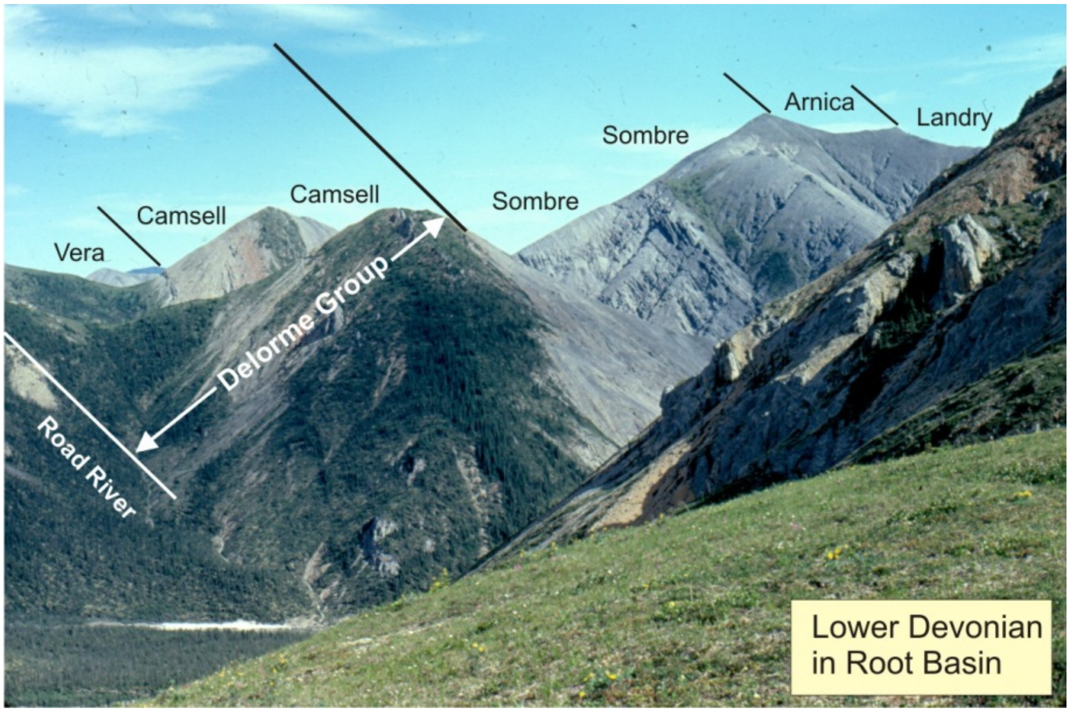

Figure 30. Panoramic view northward of the Lower Devonian succession exposed in Root Basin at Pastel Creek. This stratigraphic section includes the brightly-coloured breccias of the type section of the Camsell Formation (Fig. 26).

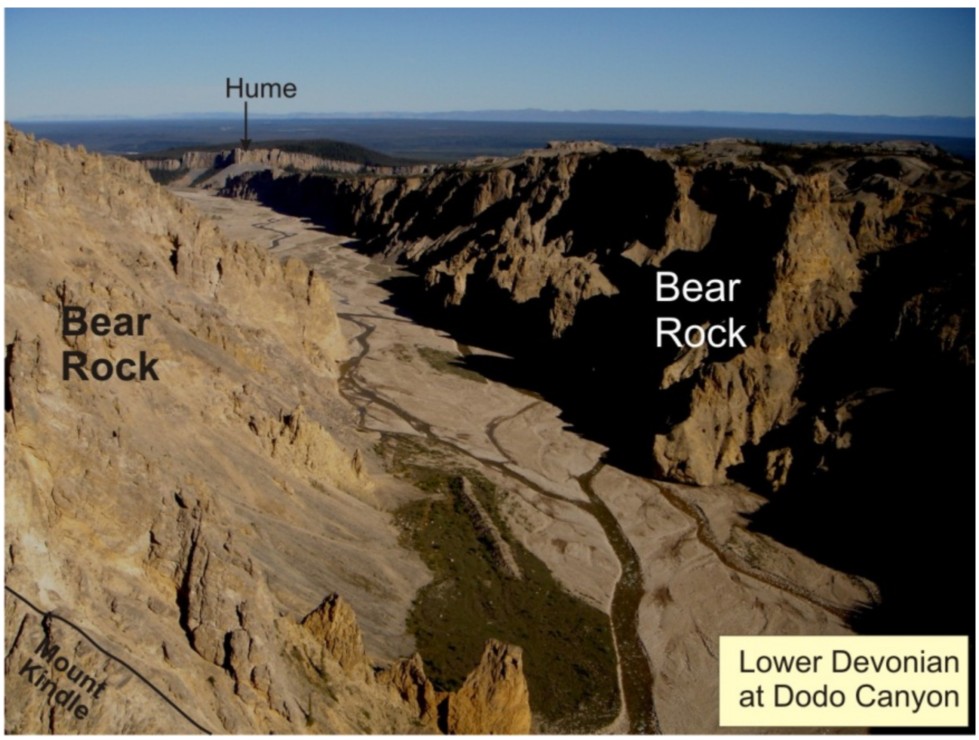

Figure 31. View eastward of the Bear Rock and Hume formations at the entrance to Dodo Canyon (Fig. 32) in the Carcajou Canyon map area. Massive bedded orange and grey-weathering Bear Rock breccia in the foreground is overlain by bluish-grey cliff-forming medium bedded Hume limestone in the distance.

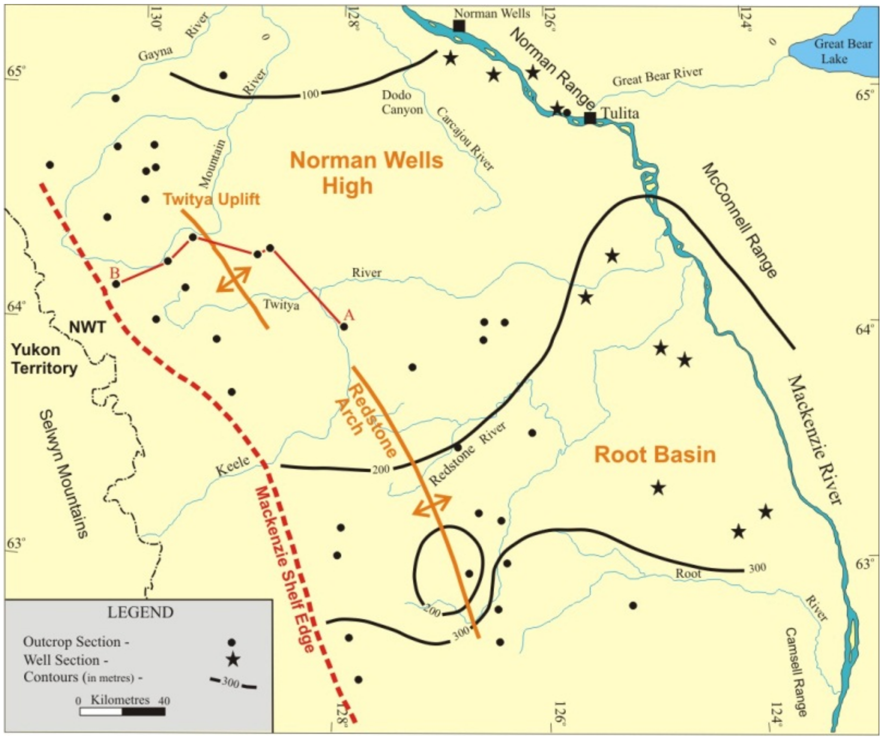

Figure 32. Isopach map of the Hume, Nahanni and Headless formations of the Hume-Lonely Bay Assemblage west of Mackenzie River. Redstone Arch, active in Early Devonian time has a faint, but discernible, influence on Hume thicknesses.

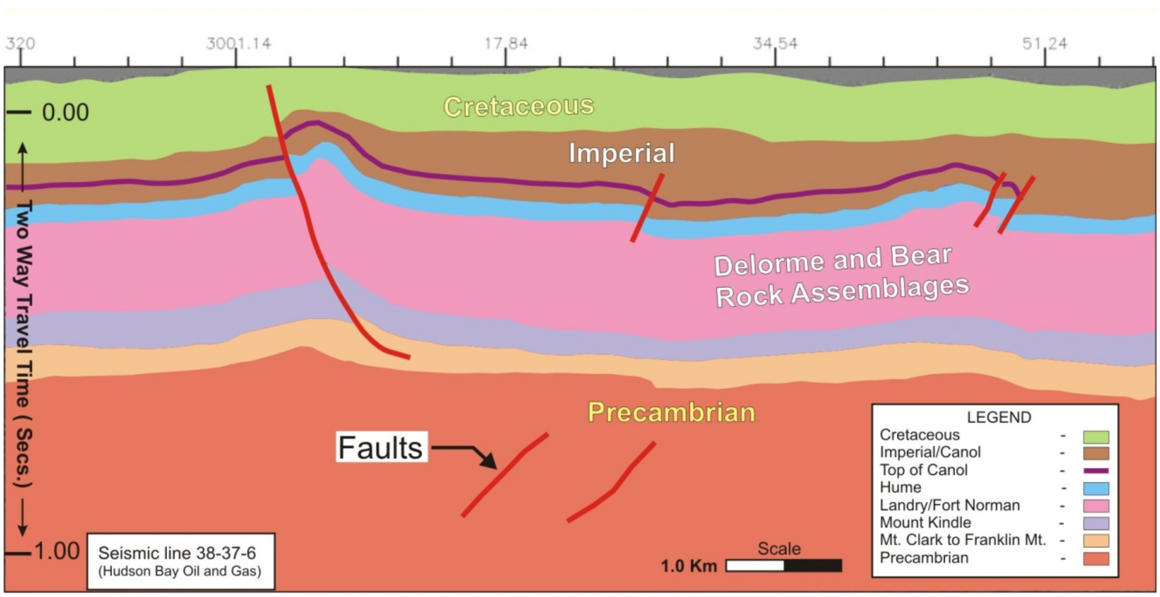

Figure 33. Seismic line extending east-to-west showing buried structures developed within Devonian strata unconformably overlain by relatively undeformed Cretaceous strata. The prominent westward-verging contractile fault developed within Devonian strata on the west side of the seismic section clearly developed largely in the post-Devonian to early Cretaceous time interval although a small amount of additional movement is syn- to post-Cretaceous and probably Laramide. Line location is shown on Figure 15 near Fish Lake. Interpretation by B.C. MacLean (Geological Survey of Canada).

The Hume Formation (Hume-Lonely Bay Assemblage) maintains a remarkably constant thickness of between 100 and 170 metres across Peel Plateau and Plain and northern Great Bear Plain and thins gradually northward across Anderson, Horton and Colville plains to less than 40 metres thick east of

Inuvik (Fig. 19; Norris, 1993; Pyle and Jones, 2009). The Lonely Bay-Hume Assemblage is markedly thinner north of Norman Wells than it is south of this community and exhibits a slight but recognizable degree of thinning across the Norman Wells High (Fig. 34).

The entire Lower to Middle Devonian succession including the combined Delorme, Bear Rock and Hume-Lonely Bay assemblages pass westward to the basinal shales and argillaceous limestones of the Road River Group in Richardson Trough (Fig. 4A, 34; Morrow, 1999; Pugh, 1983; Pyle and Jones, 2009).

As in areas south of this region, the base of the Delorme Assemblage here represents the initial deposits of the marine transgression associated with T-R Cycle A and the Hume Formation represents deposition associated with transgression during T-R Cycle B (Fig. 34). In detail, the Hume Formation is composed of several internal, upward shoaling cycles of argillaceous nodular limestones passing upward to fossiliferous, coralline non-argillaceous limestone with more argillaceous strata dominant in the lower part of the formation (Pugh, 1983, 1993; Pyle and Jones, 2009). These multiple depositional cycles are visible on gamma ray well logs as generally upward shoaling aspect of the Hume (e.g., Fig. 34; Pugh, 1993).

West of Richardson Trough, the Yukon Stable Block (Fig. 10) was dominated by shallow water carbonate deposition of the Ogilvie Formation (Fig. 5B, 7) across Porcupine Platform and the uppermost part of the Bouvette Formation across the smaller Royal Mountain Platform (Fig. 19). Blackstone Trough along the south side of Porcupine Platform was filled with Road River dark limestone and shale (Morrow, 1999). Dave Lord High (Fig. 24), in northwest Yukon, was subaerially exposed at the end of Silurian time and bright orange silty dolostone of the Mount Dewdney Formation (Fig. 5B, 7) were was deposited across this high in earliest Devonian time accompanying marine transgression contemporaneous with that of T-R Cycle A east of Richardson Trough and deposition of the Delorme Assemblage. Deposition of shallow water limestone and dolostone of the Ogilvie Formation may have begun across Dave Lord High and spread laterally southward toward Blackstone Trough over argillaceous slope limestone of the Michelle Formation and Road River Formation (Fig. 7) and eastward and northward to form Porcupine Platform.

The Lower and Middle Devonian stratigraphic assemblages, so readily recognizable east of Richardson Trough, are not evident across the northern Yukon and the unconformity at the base of the Lonely Bay-Hume Assemblage in the Interior Plains cannot be recognized in northern Yukon (Morrow, 1999). However the upper portion of the Ogilvie Formation in northern Yukon (Fig. 5B) is correlative with the Hume (Fig. 4A) east of Richardson Trough (Fig. 19).

Dark, organic rich shale overlies the Lower to Middle Devonian carbonate successions on both sides of Richardson Trough (Fig. 4A, 5B). East of the trough, a prominent oil prone dark shale source rock, the sooty Bluefish Member of the Hare Indian Formation sharply overlies the Hume shelf platform limestone (Fig. 34, 4). Similarly, west of the trough, correlative dark shale of the lower portion of the Canol Formation abruptly overlies Ogilvie limestone (Fig. 5B, 7). A relatively thick interval of siliceous dark Canol Formation shale also is mapped across Richardson Trough as part of a regionally continuous blanket of Givetian to Frasnian-aged shale (Fig. 22).

A reefal limestone containing abundant stromatoporoids, the Ramparts Formation, conformably to disconformably overlies the Hare Indian Formation grey calcareous shale (Fig. 34) across a broad northwest-trending area around Norman Wells and Fort Good Hope (Fig. 35, 36). The uppermost fossiliferous and reefal part (Kee Scarp Member) of the Ramparts occupies a smaller area lying entirely within the broader region of the preserved underlying Ramparts (Fig. 35). The historic Norman Wells oil field is developed within the Kee Scarp Member of the Ramparts Formation at Norman Wells (Fig. 34, 35; Williams, 1986b). The Canol Formation conformably to disconformably overlies the Ramparts at Norman Wells and is the source rock for oil in the historic Norman Wells oil field (Williams, 1986b; Yose et al., 2001; Fig. 5A). The combined Hare Indian and Canol formations comprise the Horn River Group in the Norman Wells area (Fig. 4A).

The Hare Indian Formation, including the Bluefish Member oil source shale, which forms the upper part of the Lonely Bay – Hume Assemblage (T-R Cycle B), extends farther west than the than the Ramparts Formation and thin westward from a combined thickness of more than 200 metres near Norman Wells (Fig. 34) to less than 100 metres in the Peel Plateau area where they pass westward to the darker grey shale of the Horn River Formation, within which the more radioactive shale of the Bluefish

Member can still be discerned (Fig. 5A; Pugh, 1993). Alternatively, this entire shale interval west of the western limit of recognizable Hare Indian shale has been assigned to the Canol Formation (e.g., Pyle and Jones, 2009). West of Peel Plateau in northern Yukon, the undivided Horn River Group is mapped as "Canol Formation" both on surface geological bedrock maps and in the subsurface (Fig. 5B, 9A; Pugh, 1983; Norris, 1997).

Williams (1983) provides a summary of the stratigraphic nomenclature of the interval between the top of the Hume Formation (i.e., top of the Lonely Bay – Hume Assemblage) and the top of the Canol Formation and an interpretation of the Horn River Group, including the Hare Indian and Ramparts formations (Pugh, 1993), as a depositional wedge that prograded basinward, or westward, beyond the western limit of Ramparts shallow water shelf limestone deposition across an open marine shelf (Fig. 4, 5, 9A, 35). He also noted that a similar relationship existed between the Horn River Group shales deposited as a depositional apron basinward of the Eifelian to Givetian Presqu'ile Barrier in the Great Slave Plain area. Deposition of the Ramparts marks the start of marine transgression of the lower part of the Slave – Kakisa Assemblage (T-R Cycle C) north of 64° north latitude and the overlying Canol Formation contains the maximum flooding surface of T-R Cycle C. Williams (1983) interpreted the western limit of the Ramparts Formation as a depositional edge, rather than as an erosionally truncated limit beneath an angular unconformity at the base of the overlying Canol Formation (see also Pyle and Jones, 2009).

The brownish-grey weathering silty shales and fine sandstones of the Imperial Formation conformably overlie the dark bituminous Canol shales across the region (Fig. 4A, 34, 37, 38). Imperial siliciclastics thicken westward in the subsurface from an eastern erosional edge near the Canadian Shield to a maximum of over 1700 metres in the Peel Plateau near the Yukon border (Fig. 39). Across much of this area the Imperial is unconformably overlain by Cretaceous strata (Fig. 3, 37) or outcrops across broad areas (Fig. 6D).

Along a line of section west of Mackenzie River and extending northwest from about 63.5° north latitude to a point west of the community of Tulita (Fig. 38) the Imperial displays a number of northwestward-dipping log markers that define a series of west-facing clinoforms, or depositional mudbank slopes (Fig. 37). Sandstone bodies occur in both the upper and lower parts of the Imperial, including one formally-named unit, the oil-bearing Canyon Creek sandstone lentil (Pugh, 1993), close to the base of the Imperial at the Bluefish A-49 well near Tulita (Fig. 37). A prominent fossiliferous limestone, the Jungle Ridge limestone Member (Tassonyi, 1969; Pugh, 1993), approximately 50 metres thick, extends along this line of section towards a northwestward limit between the communities of Tulita and Norman Wells (Fig. 37, 38). This unit probably is correlative with the Frasnian-aged Jean Marie Member of the Redknife Formation in the Great Slave Plain south of 62° north latitude (Fig. 4B, 5A; MacLean and Klapper, 1998).

Southwest-dipping clinoforms, indicative of slope deposition within the Imperial Formation, are clearly visible in reflection seismic lines northwest of Norman Wells (Fig. 40). The interbedded lobate sheet sandstones and channel sands interbedded with siltstones and shales exposed at Imperial outcrops along the southern margins of the Peel Plain and Plateau and in nearby petroleum exploration wells (Fig. 41A) have been interpreted as deposited as a westward-prograding delta and submarine prodelta slope complex with a depositional slope of about 1.5 degrees (Fig. 40, 41B, C; Hadlari et al., 2009). Most of the fine grained sandstones are interpreted to be slope-deposited turbidites (Fig. 42) including a well-developed thick amalgamated basal sandstone interval at the base of many sections interpreted as a base of slope submarine turbidite fan deposits (Fig. 41; Hadlari et al., 2009; Tyloski et al., 2009).

Farther northwest towards Peel Plateau (Fig. 2), The the Imperial Formation is conformably overlain by up to 1250 metres of uppermost Devonian to Carboniferous strata of the Tuttle Formation (Fig. 4A, 41; Pugh, 1983; Hadlari et al., 2009). The base of the Tuttle is marked by the appearance of more abundant, medium to thick bedded, medium to coarse, kaolinite-cemented quartz sandstones and quartz and chert pebble conglomerates intercalated with shales and shaly siltstones (Pugh, 1983; Allen et al., 2009; Fig. 4A, 41, 43). The Tuttle extends westward from Peel Plateau across the Richardson Mountains and in the subsurface of Eagle Plain (Fig. 38) where up to 1400 metres of Tuttle strata are preserved (e.g., Schaeffer Creek YT O-22 well in Fig. 43). Coal beds, plant fragments and palynomorphs are common (Pugh, 1983).

Marker beds clearly demonstrate that uppermost Imperial strata correlate with lowermost Tuttle beds (Fig. 41, 43) supporting an interpretation that the Tuttle was deposited as part of a Late Devonian to earliest Carboniferous delta system (Pugh, 1983). Exposures of the lowermost Tuttle sandstones and conglomerates at Trail Creek in the Richardson Mountains have been interpreted to be proximal turbidites (Allen et al., 2009) that might have been shed from a southwestward or southeastward prograding delta complex. Most of the Tuttle Formation sandstones have previously been interpreted to have been deposited within a fluvio-deltaic complex (Lutchman, 1977).

Cretaceous strata unconformably overlie Tuttle strata over most of their extent (Fig. 41, 43) except where Tuttle strata are exposed, as along the flanks of the Richardson Mountain anticlinorium. The upper part of the Tuttle Formation passes laterally southwestward to the dark grey siliceous shale of the Ford Lake Formation in the Richardson Mountains and in the subsurface of Eagle Plain (Fig. 5B, 43).

In the northern Yukon, south and west of Eagle Plain and the Ogilvie Mountains towards the Kandik Basin (Fig. 2), the Canol passes to the McCann Hill Chert, a dark grey rusty weathering siliceous and cherty black shale and overlying Imperial strata pass westward to Ford Lake shale and further west to sandstones and conglomerates of the Nation River Formation near the Alaska border (Fig. 5B; Norris, D.K., 1997). Farther south, across the Yukon Plateau and Selwyn Mountains (Fig. 2), the dark siliceous shales of the Prevost Formation and the cherty dark barite-bearing shales and chert pebble conglomerates of the Portrait Lake Formation, which together comprise the Earn Group of the Selwyn Basin (Fig. 8), are the southwestern correlatives of the Canol-Imperial succession (Gordey, 1992; Gordey and Anderson, 1993).

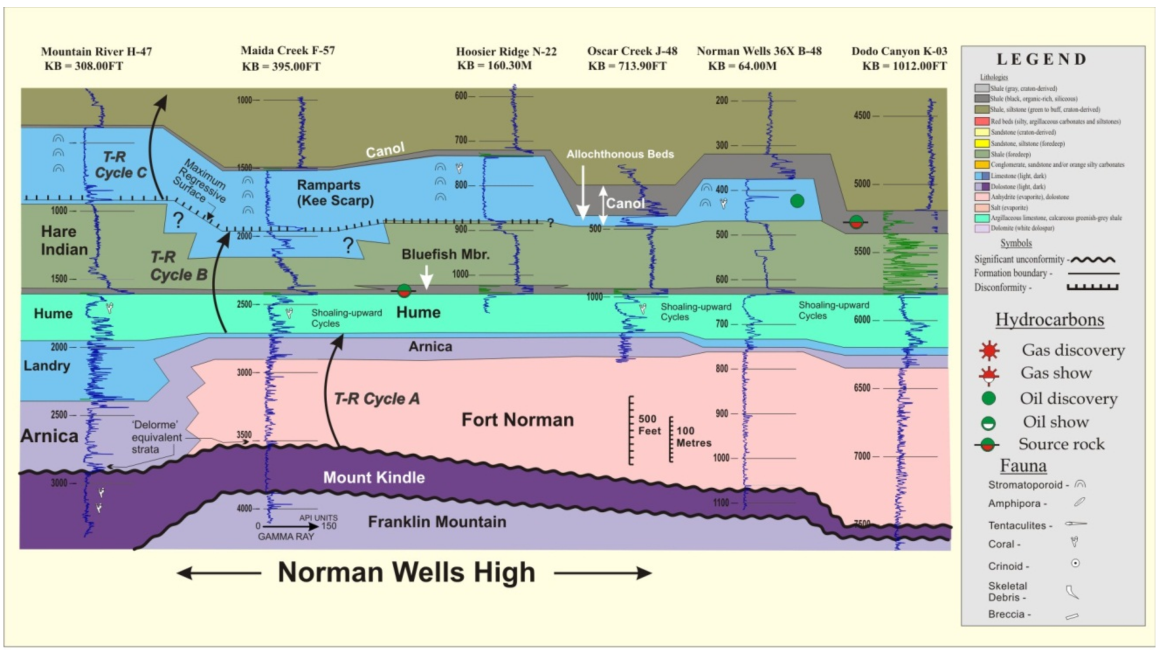

Figure 34. Stratigraphic cross-section across the Norman Wells High near Norman Wells (Fig. 35). This includes strata deposited during T-R cycles A, B and C. The Delorme and Bear Rock assemblages are thin across the Norman Wells High, as is the Hume Formation. The organic-rich shale of the Bluefish Member of the Hare Indian Formation is a regional oil source rock and contains the maximum flooding surface of T-R Cycle B. Deposition of the Ramparts Formation biostromal limestones above the Hare Indian shale began during the initial marine transgression associated with T-R Cycle C. The organic-rich siliceous dark shale of the Canol Formation is an important oil source rock for the historic Norman Wells oilfield.

TECTONIC AND STRATIGRAPHIC HISTORY

Introduction

The Devonian shelf platforms of the northern mainland were not typical passive margin shelves characterized by broadly conformable successions that commonly display uniform thickness and facies variations. Instead the northern mainland shelf successions exhibit large geographic thickness, and facies variations, and many intrashelf basins and arches, unlike the more uniform lower Paleozoic shelf succession of the Western Canadian Sedimentary Basin southeast of the northern mainland (see Mossop and Shetsen, 1994).

The major regional paleogeographic and paleotectonic elements that influenced Early and Middle Devonian sedimentation across the northern mainland and that existed during parts of early Paleozoic time and include Mackenzie Shelf (or Mackenzie Platform), Peel Shelf (or Peel Platform), and the Yukon Stable Block (or Ogilvie Shelf), Mackenzie, Peel, Keele and Redstone arches, Tathlina Uplift, Selwyn and Root Basins, Richardson Trough, and the Meilleur River and Misty Creek embayments, and the Dave Lord High (Gabrielse, 1967; Williams, 1989a, b; Cecile et al., 1997; Fig. 10). Richardson Trough, Selwyn Basin, and possibly Root Basin, developed as a response to extensional tectonism along northwest-trending axes of sea floor spreading (Fig. 9; Gordey, 1992; Williams, 1989a, b; Cecile et al., 1997). The narrow Richardson Trough was probably a juvenile extensional aulacogen initiated in Cambrian time (Morrow, 1999) that failed to develop into a broad seaway, but which widened northward to the Hazen and Blow troughs and merged with Selwyn Basin southward (Cecile et al., 1997; Fig. 10A, 29). Misty Creek Embayment was another northwest oriented extensional basinal area that developed in early Paleozoic time (Fig. 10, 24). Vulcanism occurred in the centre of this shelf edge embayment in Silurian time followed by sediment infilling during Devonian time (Cecile, 1982; Morrow, 1999). The influence of all these intrashelf tectonic arches and basins and troughs on sedimentation waned throughout Early to Middle Devonian time.

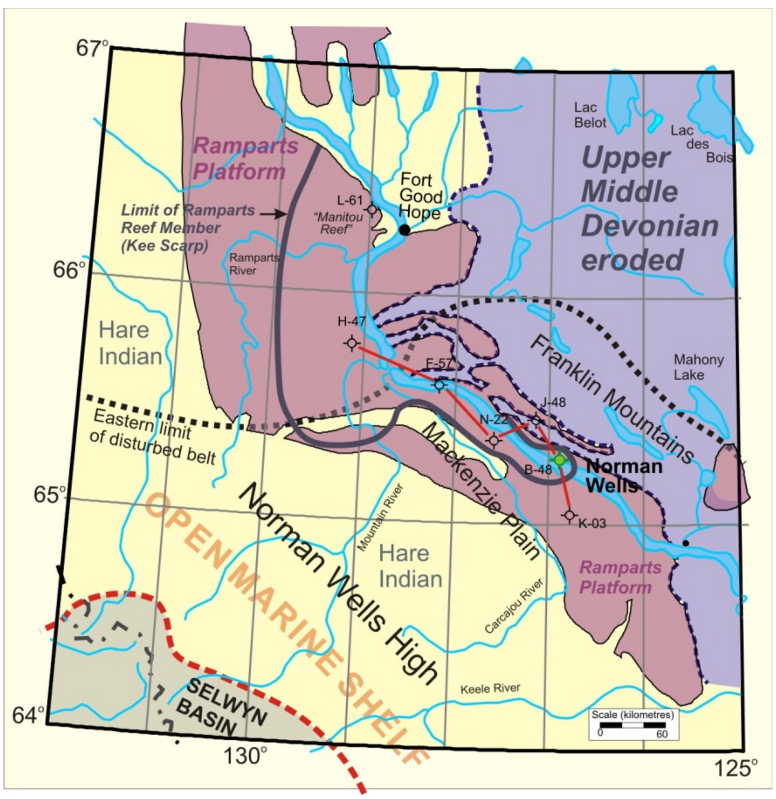

Figure 35. Map view showing the extent of the Ramparts Platform and the western limit of the uppermost reefal member of the Ramparts, the Kee Scarp Member. Hare Indian shale extends west of the Ramparts Formation.

The predominant mode of crustal extension across the northern mainland during this time may have conformed to a simple shear model for detachment-style crustal extension across crustal scale shallow-dipping normal extensional master faults that extended downwards through the entire lithosphere to the underlying asthenosphere, as opposed to a pure shear style of crustal thinning and extension (Fig. 10B; Cecile et al., 1997). A simple shear mode of extension is consistent with the development of Root Basin and the Meilleur River Embayment as parts of a lower plate margin extensional basin developed above the backstepping footwall of a west-dipping master crustal detachment fault (Fig. 10C). In this scenario, Redstone Arch, which demarcates the west flank of Root Basin, may have been an upper plate margin arch (Fig. 10C), or simply a large footwall detachment block rafted above the master detachment fault (Cecile et al., 1997). There is a possibility that the present day eastward-vergent Plateau Thrust Fault (Fig. 1; Fig. 18.68 in Gabrielse, 1992) that extends along the east side of the Redstone Plateau immediately west of Root Basin may simply be, in its present day configuration, an ancient Devonian master detachment crustal extensional fault that has been reactivated by eastward-directed contractional Tertiary-aged Laramide orogenesis.

Upper plate margins facing Selwyn Basin may have developed in early Paleozoic time north and south of Root Basin (Fig. 10A) along the hanging walls of east-dipping master crustal detachment faults, which developed north and south of the Root Basin lower plate margin (Cecile et al., 1997). The Fort Norman and Liard strike slip transfer fault zones separate these upper plate margins from the Root Basin lower plate margin (Fig. 10A, C; Cecile et al., 1997). The dip directions of master crustal extensional faults reverse across transfer fault zones where they pass from upper to lower plate margins.

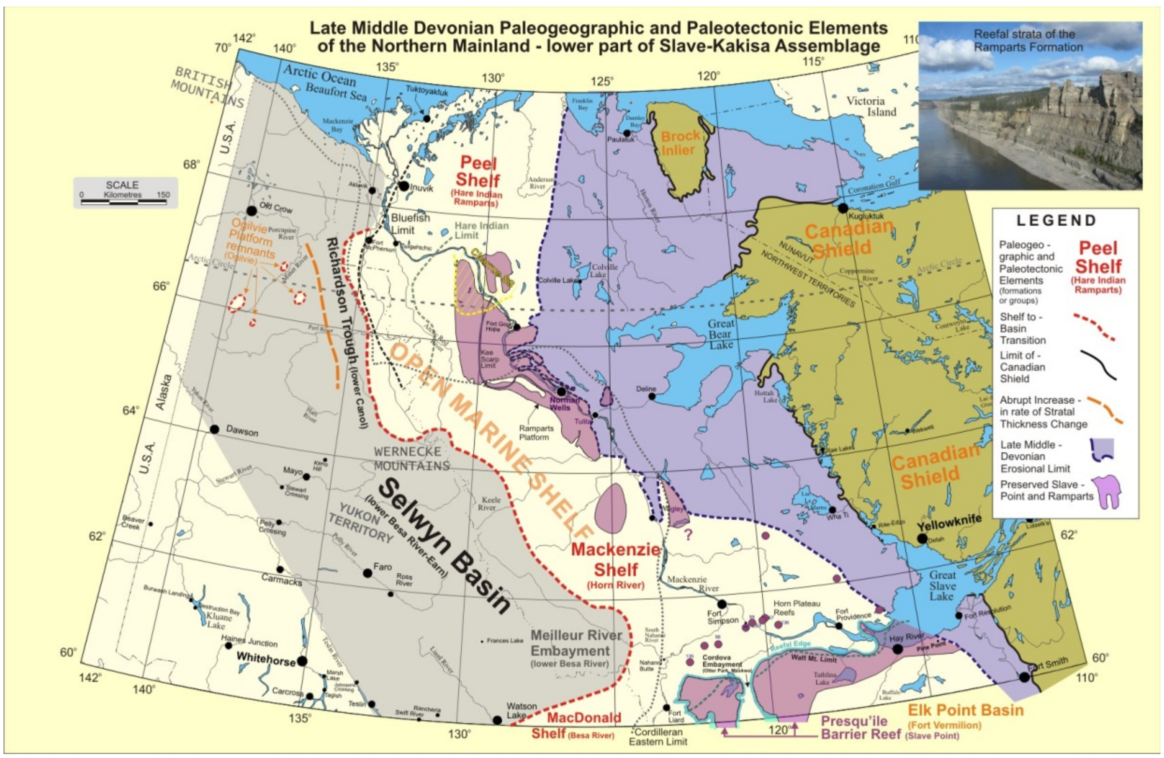

Figure 36. Map of paleogeographic and paleotectonic elements that influenced Late Devonian sedimentation across the northern mainland including the lower part of the Slave-Kakisa Assemblage deposited during the transgressive phase of T-R Cycle C. This succession includes the Watt Mountain, Slave Point formations and the lower part of the Muskwa Formation across the Presqu'ile Barrier and the Ramparts Formation and the lower part of the Canol Formation across Ramparts Platform on Peel Shelf. The lower part of the Horn River shale was deposited across Mackenzie and Peel shelves during this time. (Hi-Res)

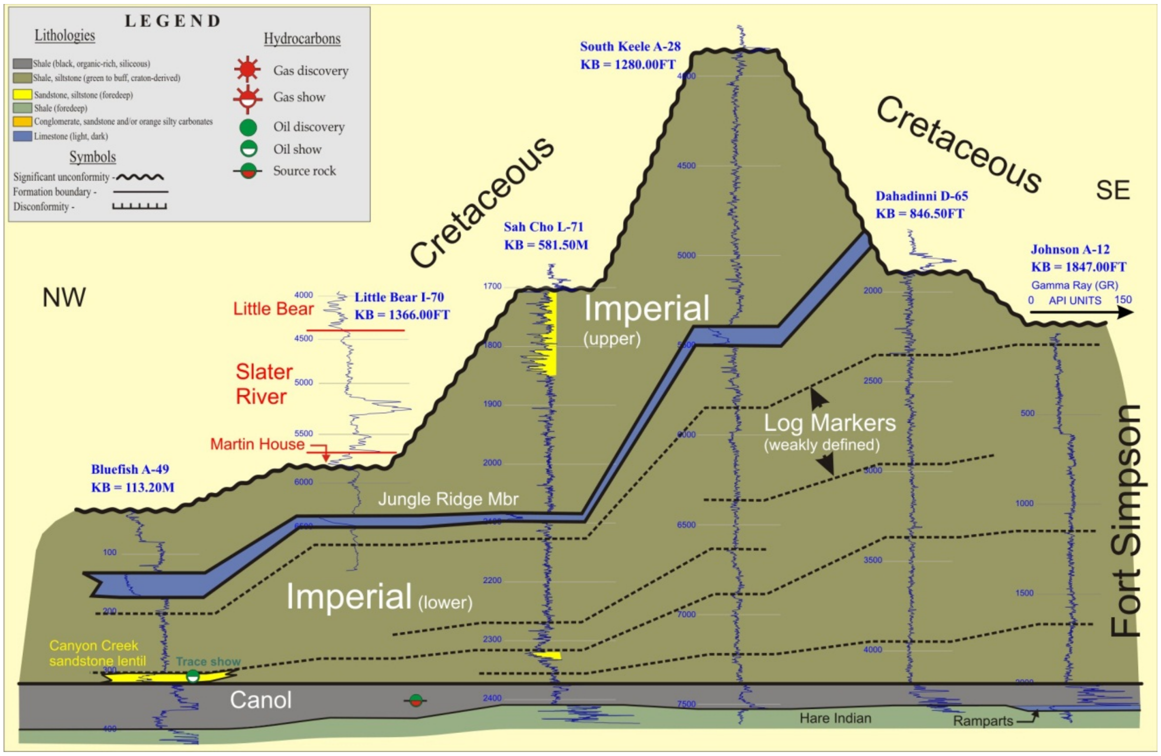

Figure 37. A stratigraphic cross-section of Upper Devonian strata southwest of Tulita west of Mackenzie River (Fig. 38). Log markers within Imperial Formation indicate deposition on northwest prograding shelf mudbank slopes. An oil show occurs in the Canyon Creek sandstone at the base of the Imperial. The Jungle Ridge Member limestone of the Imperial is age-equivalent to the Jean Marie Member limestone of the Redknife shale farther southeast.

Norman Wells High was a broad elevated region that developed in Early Devonian time, occupying the same region as but postdating the Cambro-Ordovician aged Mackenzie Arch but postdating its development (Fig. 10A). Both of these features are consistent with the development of tectonic arches above underplated igneous melts beneath master detachment faults (Fig. 10B, C). The much narrower Twitya Uplift may have developed in earliest Devonian time above a sub-crustal transient thermal pulse near the outer edge of the northern upper plate margin (Fig. 10A, B; Morrow, 1991). Peel Arch has been regarded as the northern continuation of Mackenzie Arch and similarly developed mainly in pre-Devonian time but exerted comparatively little influence on Devonian deposition, (Cecile et al. 1997; Pyle and Jones, 2009).

Keele Arch developed mainly in post-Paleozoic, but pre-Cretaceous time, when the Paleozoic sedimentary cover was largely removed by erosion, but the arch also had a period of mild pre-Devonian uplift that caused strata of the Mount Kindle Formation beneath the Devonian succession to be eroded down to the older Franklin Mountain Formation (Cook, 1975; Fig. 6C). The direct influence of Keele Arch on Devonian deposition was probably slight, and during this time Keele Arch was merely part of the southwest flank of the broad Norman Wells High (Meijer-Drees, 1993; Pugh, 1993).

The Yukon Stable Block in the northern Yukon west of the Richardson Trough is not characterized by extensional tectonics. The Dave Lord High was emergent at the end of Silurian time but exerted no discernible influence on the thickness of the Devonian across the Yukon Stable Block. The Romanzof Orogeny, an episode of contractional deformation, affected the northeastern part of the Yukon Stable Block from latest Early Devonian to earliest Middle Devonian time and is associated with an unnamed turbiditic Lower Devonian sand and shale succession in the British Mountains (Lane, 2007; Fig. 10A). The numerous postorogenic Late Devonian granite plutons in northwestern Yukon (Fig. 5B) may have coincided with the end of the Romanzof Orogeny (Lane, 2007).

The Ellesmerian Orogeny, centered in the Arctic Islands north of the Canadian mainland, was a major contractional orogeny that began in latest Devonian (Famennian) time and continued into Early Carboniferous time (Lane, 2007). Deformation associated with this orogeny encroached southward in

Early Carboniferous time onto the northern mainland and probably overprinted the earlier, more cryptic, Romanzof Orogeny in the extreme northwest corner of Yukon Territory (Fig 10A; Lane, 2007). The unconformity at the base of the Lower Carboniferous Kekiktuk Formation conglomeratic sandstones (Fig. 5B) in this part of the Yukon is associated with the development of the Ellesmerian Orogeny (Lane, 2007). This orogeny marked a major transition from the carbonate-dominated passive margin style of sedimentation of the Early and Middle Devonian to the clastic wedge-dominated style of sedimentation that dominated the Late Devonian across the northern mainland.

Lower and Middle Devonian

Delorme Assemblage – T-R Cycle A (lower part)

The Delorme Assemblage, or the lower part of T-R Cycle A, spans the time interval between the end of the Silurian Period (Pridoli Age) and the middle of the Emsian Age of the Early Devonian Epoch (Fig. 4B). Deposition of this assemblage across the northern Canadian Mainland coincided with the initial stage of the major marine transgression that marked the onset of deposition of the continent-wide Kaskaskia Sequence (Sloss, 1963), which spanned the entire Devonian and part of Carboniferous time (Morrow and Geldsetzer, 1992). The age of the initial transgressive deposits at the base of the Kaskaskia Sequence, where originally defined across the interior of the continental United States, is Middle Devonian (Sloss, 1963). However, it is evident that across the northern Canadian mainland, the initial Kaskaskia transgressive deposits of the Peel and Tsetso formations are earliest Devonian, Lockhovian and Pragian age (Morrow and Cook, 1987; Morrow, 1991; Morrow, 1999; Williams, 1996), and overlie the widespread 'sub-Devonian' unconformity above Silurian-aged units (e.g., Mount Kindle; Fig. 4, 5) of the underlying Tippecanoe Sequence (Morrow and Geldsetzer, 1992).

At the end of Silurian time, most of the northern Interior Plains were subaerially exposed up to a western limit that coincides with the shelf to basin transition of the northern shelves with the Selwyn Basin, and around the Root Basin depocentre (Fig. 24; Williams, 1989a). Isolated areas in the northern Yukon, such as the Dave Lord High and the White Mountains Platform, were also emergent.

Transgression began with peritidal deposition of orange and yellow sandy and argillaceous carbonates of the Tsetso, Peel and Tatsieta formations across the exposed Mackenzie and Peel shelves and the Norman Wells High (Fig. 4, 5; Morrow and Geldsetzer, 1992; Williams, 1990). Clean quartz sandstones of the La Loche Formation accumulated in Great Slave Basin (Meijer-Drees, 1993; Fig. 24). Tathlina Uplift, a large arcuate highland extending between Trout and Tathlina lakes, remained exposed during this initial marine transgression (Fig. 24). Halite (Johnny Hoe and Cold Lake Salt members) and anhydrite of the Mirage Point and Ernestina Lake formations (Fig. 4B) accumulated in the restricted marine intrashelf basin of the Willowlake Embayment and Great Slave Basin (Fig. 24; Meijer-Drees, 1993) contemporaneously with deposition of Tsetso and La Loche siliciclastics onto surrounding highs, such as Tathlina Uplift (Fig. 24).

The unconformity at the base of the Devonian is almost bed parallel over most of its extent and is therefore a disconformity, or even a paraconformity in areas adjacent to Selwyn and Root basins. Across intrashelf arches and uplifts, Devonian strata rest with slight to great angularity on underlying strata, such as across Twitya Uplift and to a lesser extent, across Redstone Arch and the Liard High (Fig. 24, 25, 27) and across Keele Arch where Ordovician to Silurian-aged strata of the Mount Kindle has have been eroded across the arch axis and Devonian strata (Bear Rock) rest unconformably on Ordovician Franklin Mountain dolostone (Fig. 6D). Across the axis of Twitya Uplift both the Mount Kindle and the Franklin Mountain formations have been removed by latest Silurian to Early Devonian erosion and basal Devonian strata rest on Proterozoic strata (Fig. 25). Here, the regionally widespread older Early Cambrian-aged unconformity beneath the Franklin Mountain Formation of the Mackenzie Mountains, which developed during uplift across the much broader Early Cambrian Mackenzie Arch, has been exumed beneath the 'sub-Devonian' unconformity along Twitya Uplift across the western flank of the older Mackenzie Arch (Fig. 25; Aitken et al., 1973; Aitken, 1993).

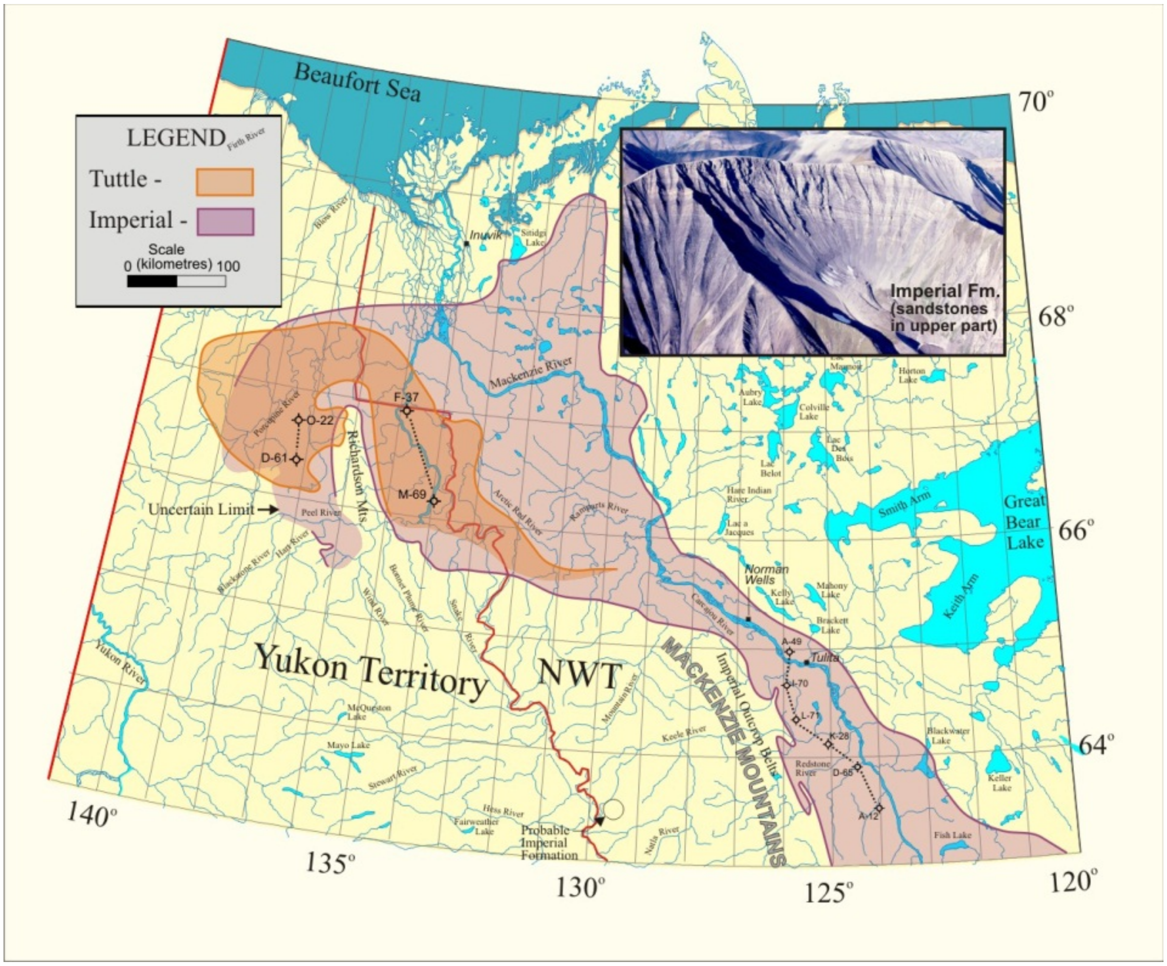

Figure 38. Map showing regional extent of the Imperial and Tuttle formations in the subsurface across the northern mainland. Inset photograph shows outcrop view of Imperial equivalent shale and sandstone by Keele River indicated on map as probable Imperial near the Yukon border. Imperial Formation also outcrops extensively in the Mackenzie Mountains.

In the northern Yukon Territory, the base of Devonian unconformity is also present across the Dave Lord High, where orange weathering tan silty peritidal dolomudstone of the Mount Dewdney Formation (Morrow, 1999) unconformably overlies Ordovician limestone of the Bouvette Formation (Fig. 5B; Morrow, 1999). Another distinctive outcrop belt of silty dark grey shale and turbiditic fine to medium sandstone of Early Devonian age extends 75 kilometres along the northeastern slopes of the British Mountains. This Early Devonian fossil plant-bearing succession unconformably overlies Ordovician Road River chert and slate (Lane, 2007). These strata may have been deposits related to the development of the earliest Devonian Romanzof Orogeny, which only affected the extreme northeastern corner of the Yukon (Fig. 5B, 10; Lane, 2007).

The base of Devonian unconformity does not extend into the Selwyn Basin, Richardson Trough and Blackstone Trough, where basinal marine deposition of dark siltstones, limestones and shales of the Road River Group continued without interruption (Fig. 4, 5, 24). The basal unconformity is also absent in Root Basin and in the Meilleur River Embayment and is represented by orange and yellow-weathering fine grained turbiditic sandstone of the Cadillac Formation and by yellow-weathering calcareous silty shale of the Road River Formation respectively (Fig. 5A). These units are formed of clastics inferred to have been eroded from the exposed Mackenzie Shelf farther east in latest Silurian to earliest Devonian time and shed into Root Basin and the Meilleur River Embayment (Morrow and Cook, 1987). The yellow-weathering Upper Silurian and lowermost Devonian calcareous siltstone and shale units of the Road River Group in Richardson Trough may also be formed of clastics eroded from Peel Shelf during latest Silurian to earliest Devonian exposure of the eastern shelves (Morrow, 1999).

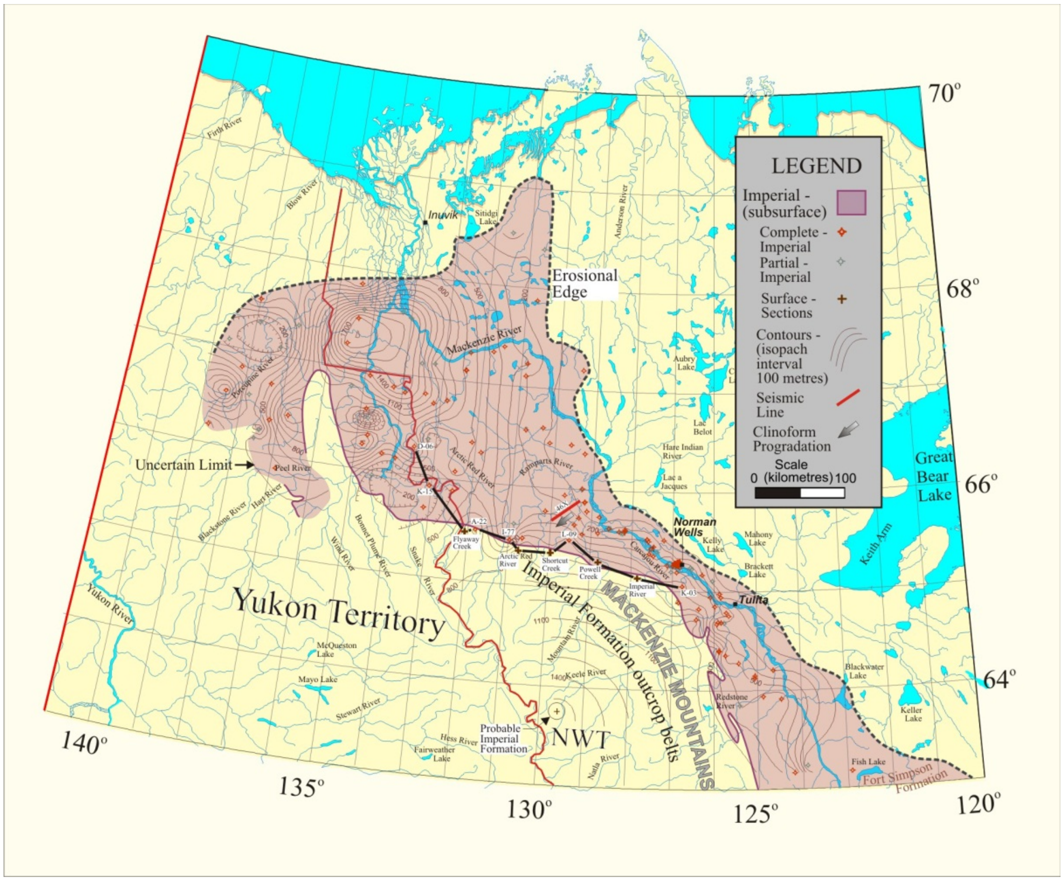

Figure 39. Map showing regional extent and thickness of the Imperial Formations in the subsurface across the northern mainland. Imperial siliciclastics thicken westward from an eastern erosional feather edge up to over 1700 metres thick southwest of Inuvik.

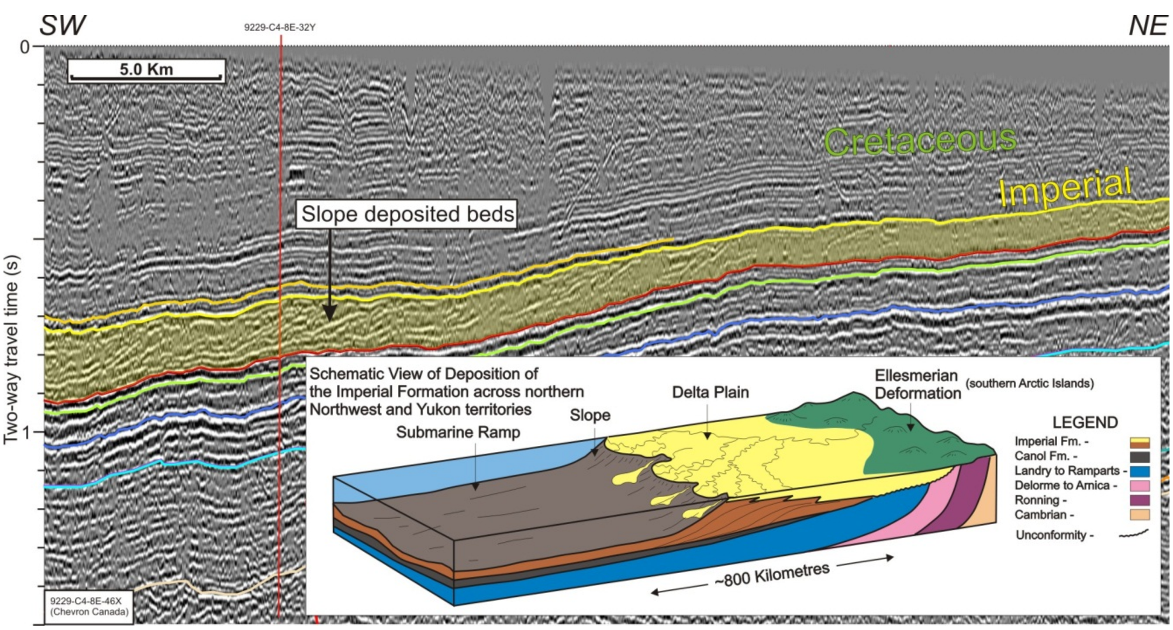

Figure 40. A segment of a southwest oriented seismic line near Mackenzie River north of Norman Wells as shown on Figure 39. Westward directed clinoforms are clearly visible within the Imperial interval. The inset schematic diagram portrays deposition of the Imperial Formation as an open deeper water shelf delta complex fed by siliciclastics shed from uplifts of the Ellesmerian Orogeny of the Arctic Islands. Published with permission by Chevron Resources Canada, Northwest Territories Geoscience Office and the Yukon Geological Survey (adapted from Figure 7.1.5 in Hadlari et al., 2009).

Up to 2100 metres of interbedded anhydrite and dolomudstones of the Camsell Formation (or Camsell orange-weathering solution-collapse limestone breccias in surface exposures) accumulated in the Root Basin depocentre and several hundred metres also accumulated in Godlin Salient, a small subbasin west of Twitya Uplift contemporaneous with deposition of much thinner successions of Tsetso clastics on the flanks of these basins (Fig. 5A, 24, 25, 26). Tsetso clastics thin to a feather edge where they onlap the Norman Wells High (Fig. 26) and pass laterally to silty and sandy beds a few metres above the base of the Fort Norman Formation (or the Bear Rock Formation breccia succession in surface exposures) across the central part of Norman Wells High. Deposition of the Tsetso sandy carbonates was very diachronous where this unit onlapped exposed highlands, such as Tathlina Uplift and Liard High (Fig. 4B; 24; Meijer-Drees, 1993).

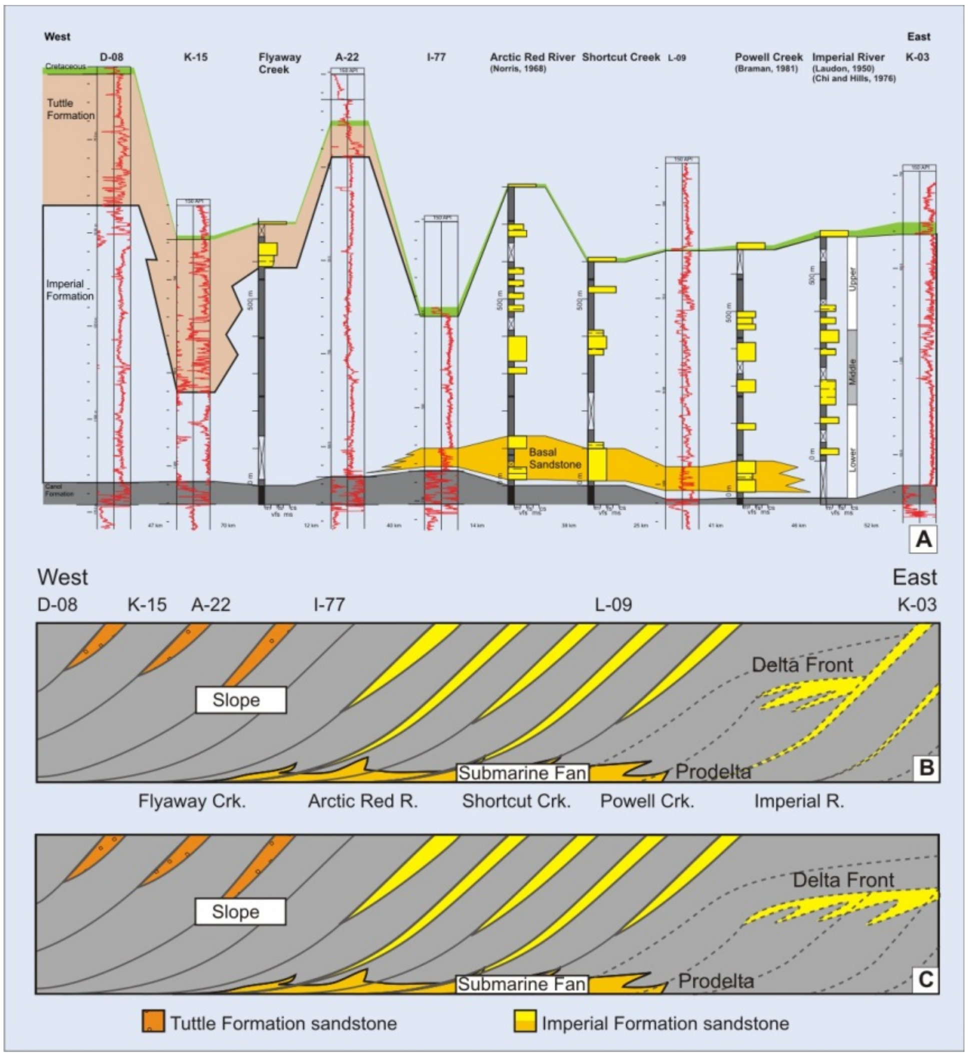

Figure 41. A stratigraphic cross-section of Upper Devonian to Carboniferous strata (A) along a line of section extending northwestward from Tulita to the Yukon-NWT border, as shown on Figure 39. The Imperial Formation is interpreted to have been deposited as a westward-prograding delta and submarine prodelta slope complex. Alternate interpretations for the Imperial exposed at the Imperial River section are shown in B and C. Published with permission by Geoscience Office of the Northwest Territories and the Yukon Geological Survey (adapted with minor modification from Figure 7.1.4 in Hadlari et al., 2009).

Bear Rock Assemblage – T-R Cycle A (upper part)

The Bear Rock Assemblage, or upper part of T-R Cycle A, spans the time interval between the middle of the Emsian Age to the end of the Dalejan Age of the Early Devonian Epoch (Fig. 4B). The Bear Rock and Delorme assemblages together span the entire Early Devonian Epoch.

The marine transgression of T-R cycle A continued in Emsian time to inundate the Mackenzie and Peel shelves. and uUp to 1000 metres of clean peritidal to shallow subtidal carbonates, dominantly sucrosic, slightly fossiliferous dolostone, of the Arnica and Sombre formations accumulated in a broad belt along the basinward, or western part of the Mackenzie and Peel shelves bordering Selwyn Basin (Fig. 4, 5, 9, 25, 29). Sombre dolostone, which occupies the most distal, shelf edge position are is lighter grey, less organic-rich and contains a much greater proportion of intertidal dololaminite and dolomudstone intervals than does the Arnica (Fig. 5A, 25; Morrow and Cook, 1987). Sombre dolostone passes upward and laterally eastward to darker, more subtidal, amphiporid-bearing, sucrosic slightly bituminous dolostone (Fig. 9B). This peritidal dolostone may represent deposition by a belt of nearly emergent carbonate mud mounds, similar perhaps to those of the present day Florida Keys, or of the Bahamas (e.g., Shinn et al., 1969). The darker, more fossiliferous Arnica dolostone may have accumulated in lagoonal settings landward of the Sombre shelf edge belt of intertidally-dominated carbonate mud mounds along the outer margin of the Mackenzie Shelf (Morrow and Cook, 1987). Resedimented beachrock carbonate lithoclasts forming abundant grainflow and carbonate turbidite beds were shed subaqueously into Selwyn Basin, such as in the Prairie Creek Embayment (Morrow and Cook, 1987), from Sombre shoals bordering the Mackenzie Shelf margin. Sombre carbonates reach a maximum thickness of about 1000 metres. Arnica dolostone attains a maximum thickness of about 700 metres and thins progressively eastward to less than 50 metres, mainly because of the facies transition eastward to evaporites of the Fort Norman Formation (Fig. 23; Meijer-Drees, 1993).

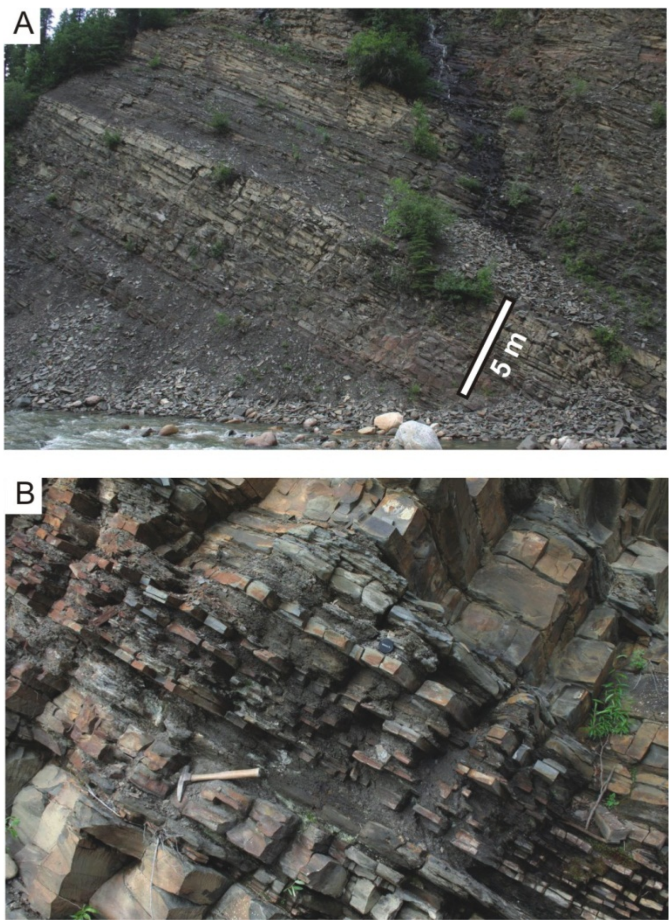

Figure 42. Outcrop views of thin to medium bedded turbiditic sandstones and siltstones in the Basal Sandstone of the Imperial Formation exposed at Shortcut Creek in the northern Mackenzie Mountains west of Norman Wells (Hadlari et al., 2009; Fig. 41). Photo B is a closer view of beds exposed in Photo A. Published with permission by Geoscience Office of the Northwest Territories and the Yukon Geological Survey (from Figure 7.1.8A and B in Hadlari et al., 2009).

Arnica dolostone passes eastward to the Fort Norman interbedded succession of dolostone and anhydrite that thins eastward from up to 1500 metres thick at the facies change within Root Basin (Fig. 28) to less than 100 metres thick near its present day erosional edge bordering the Canadian Shield (Fig. 21 in Meijer Drees, 1993). In the restricted, more evaporitic setting of the Willowlake Embayment, the Fort Norman Formation passes laterally to the upper part of the argillaceous red bed dolomudstones and halite of the Mirage Point Formation and to the lower part of the Chinchaga Formation beneath the unconformable base of the Ebbut Member, or the mid-Chinchaga detrital break (Fig. 4B, 23; Meijer-Drees, 1993). Northwest of the Norman Wells High, the Bear Rock Assemblage is comprisedcomprises only of the Arnica and Landry formations (Fig. 29). Where the Fort Norman Formation is exposed west and south of the eastern limit of Cordilleran deformation, Fort Norman evaporites have undergone solution-collapse and dedolomitization to form the Bear Rock breccia, a diagenetic facies of the Fort Norman Formation (Pyle and Jones, 2009). Across most of Peel Shelf, the Arnica is between 100 and 300 metres thick (Pugh, 1993; Fig. 4A) and thins progressively eastward.

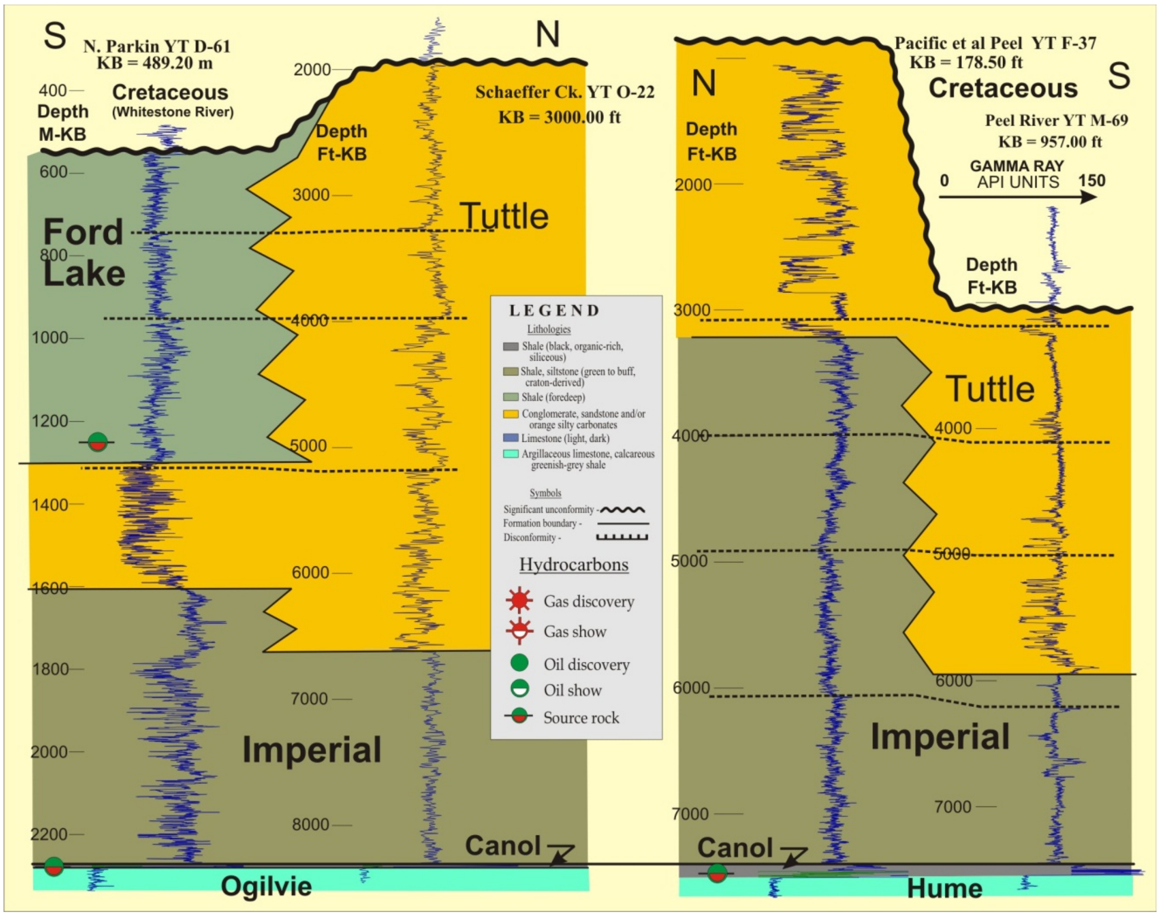

Figure 43. Two north-south oriented stratigraphic cross-sections of the Canol, Ford Lake, Imperial and Tuttle formations near the Richardson Mountains of northern Yukon. Coarse sandstones and conglomerates are abundant in the Tuttle Formation. Log marker horizons indicate facies equivalences between these formations.

Marine transgression continued from Emsian to Dalejan time and land masses, such as Tathlina Uplift and Liard High, were largely submerged. Deposition of less restricted shallow marine subtidal pelletal lime mudstone, wackestone and packstone of the Landry Formation spread across the Peel and Mackenzie shelves above the Arnica and Fort Norman formations (Fig. 4, 5, 23, 34; Meijer-Drees, 1993; Pugh, 1993; Morrow, 1991, 1999). Landry strata range from more than 100 metres thick at the basinward shelf edges to less than 50 metres thick either at its the formation’s eastward erosional edge near the Canadian Shield, or where these strata pass laterally to the uppermost beds of the Fort Norman Formation in the subsurface (e.g., Fig. 23; Meijer-Drees, 1993) or to the uppermost interval of the Bear Rock Breccia as in the Colville Hills (Fig. 4B; Fig. 25) in surface exposures.

During Dalejan to Eifelian time, up to 400 metres of basinal or basin-slope-deposited non-fossiliferous, buff-coloured platy calcareous and dolomitic shale of the Funeral Formation filled the remainder of Root Basin (Fig. 5A, 29; Morrow and Cook, 1987). Funeral basin slope shale deposition was coeval with shallow water shelf deposition of a crinoidal Landry and upper Arnica, limestone that formed a high energy shelf rim that partly enclosed an embayment within former Root Basin (Fig. 29; Morrow and Cook, 1987). This embayment filled with Funeral shale may have been the result of enlargement of the smaller, slightly older Prairie Creek Embayment that existed during deposition of the Arnica and Sombre formations. Farther north in the Mackenzie Mountains bordering Peel Plateau, up to 330 metres of the non-fossiliferous, buff-coloured platy calcareous and dolomitic shale of the Mount Baird Formation, age-equivalent to the Landry Formation, underlie the Hume Formation and are underlain by a thin Road River shale tongue and dark silicified limestone of the Arnica Formation (Fig. 5A; Morrow, 1999, Pyle and Jones, 2009). The Mount Baird Formation may have been deposited on a local embayment that formed along the Mackenzie Shelf margin in Dalejan time (Fig. 5A) and that faced westward towards Richardson Trough west of Snake River. The Mount Baird formed at the same time and possibly in a depositional setting similar to that of the Funeral Formation of the southern Mackenzie Mountains (Fig. 5A).

Across northern Yukon, the marine transgression associated with the upper part of T-R Cyle A caused the exposed Dave Lord High to be inundated and shallow marine shelf platform deposition of the crinoidal and coralline lime wackstonewackestone of the Ogilvie Formation formed the broad Porcupine Platform west of the Richardson Trough (Fig. 29; Norris, 1997; Morrow, 1999). The Ogilvie shelf limestone overlies the peritidal Mount Dewdney Formation across Dave Lord High and prograded basinwards overstepping basin slope argillaceous slope limestone of the Michelle Formation and basinal shale of the Road River Formation in Blackstone Trough south of Porcupine Platform (Fig. 7). Isolated small carbonate platforms, such as the Royal Mountain and White Mountains platforms, formed of Bouvette and Ogilvie Formation limestone, are found in Blackstone and Blow Troughs south and north of Porcupine Platform (Fig. 29).

Most pre-existing topographic basins, such as Root Basin, were filled to near sea level near the end of Bear Rock Assemblage deposition during deposition of the laterally extensive shallow subtidal Landry Formation and after deposition of the Funeral Formation, or in other words at the end of the T-R Cycle A of Lockhovian to Dalejan marine transgression and regression. The upper contact of the Landry is irregular (Meijer-Drees, 1993) and unconformable with the overlying Headless Formation across the Mackenzie Shelf (Fig. 4B, 5A, 23) and disconformable with the overlying Hume Formation across the eastern part of Peel Shelf (Fig. 4A). Across the eastern part of the Mackenzie Shelf of eastern Great Slave Plain where the Nahanni and Lonely Bay formations pass to the upper part of the Chinchaga Formation, the lower part of the Headless Formation passes to the Ebbutt Member of the Chinchaga which unconformably overlies lower Chinchaga strata near Tathlina Uplift (Fig. 4B; Meijer-Drees, 1993). In a basinward direction farther west, such as in the southern Mackenzie Mountains and in Liard Plateau (Fig. 2), the base of Headless unconformity is less evident (Fig. 5A).

This sub-Headless and Ebbutt unconformity, which correlates with the regionally developed unconformity at the base of the mid-Chinchaga detrital break of the Western Canadian Sedimentary Basin, marks a continent-wide episode of marine regression and subaerial exposure (Morrow and Geldsetzer, `1988, 1992; Moore, 1988, 1993) at the end of T-R Cycle A. This unconformity has not been recognized across Porcupine Platform west of Richardson Trough where deposition of the Ogilvie Formation was continuous (Fig. 5B).

Hume-Lonely Bay Assemblage – T-R Cycle B

The Hume-Lonely Bay Assemblage, or T-R Cycle B, spans the time interval between latest Dalejan Age and the end of the Eifelian Age of the Middle Devonian Epoch (Fig. 4B). This assemblage is bounded by unconformities at the base of the Headless Formation and Ebbutt Member and at the base of the Watt Mountain Formation (Fig. 4B).

Marine regression at the end of T-R Cycle A was followed by transgression marking the beginning of deposition of the Hume-Lonely Bay Assemblage and T-R Cycle B at the beginning of Eifelian time (Fig.

4, 5). Basal limeclast conglomerate, silty calcareous shale and fine sandstone of the Headless Formation, the Headless Member of the Hume Formation, and of the Ebbutt Member within the Chinchaga Formation, were the initial shoreline deposits of this transgression above the unconformity beneath the Headless Formation and Ebbutt Member (Fig. 4B, 5A, 9; Meijer-Drees, 1993). Land areas, such as Tathlina Uplift, which had remained subaerially exposed at the end of deposition of the Bear Rock Assemblage (Fig. 29), were completely submerged during this transgression (Fig. 44).

Across eastern Great Slave Plain (Fig. 2), or the inner part of Mackenzie Shelf (Fig. 44), the Hume-Lonely Bay Assemblage is comprised ofcomprises the Ebbutt Member and the upper part of the Chinchaga Formation (Fig. 4B). The upper Chinchaga consists of Iintercalated tan dolomudstone and white anhydrite comprise the upper Chinchaga. More open marine deposition of fossiliferous lime wackestone and dolomudstone of the Lonely Bay Formation and coralline lime wackestone of the Nahanni Formation occurred at this time farther west and north across the southern part of Mackenzie Shelf (Fig. 4B, 9; Meijer-Drees, 1993; Morrow and Cook, 1987). Near the western edge of Mackenzie Shelf, the Headless and Nahanni formations together form a progradational, or regressive, package of strata in which coralline- and stromatoporoidal-bearing Nahanni shallow water shelf platform limestone built outward and westward over coeval argillaceous and fossiliferous slope-deposited limestone of the Headless Formation. The Headless is characterized by a well preserved, diverse, open marine, brachiopod and crinoids-dominated fauna (Fig. 5A, 9B; Morrow and Cook, 1987; Noble and Ferguson, 1971). Farther west towards Selwyn Basin and the Meilleur River Embayment, strata of these units pass laterally to basinal dark shale of the uppermost Road River Group (Fig.4B, 44). The Lonely Bay Formation lies southeast of the Nahanni Formation where limestone of the lower Nahanni pass southeastward to the Dolomite Member of the Lonely Bay Formation, which in turn passes south eastward to the upper part of the Chinchaga Formation near Great Slave Lake (Meijer-Drees, 1993; Fig. 4B).

North of Great Slave Plain, across the northern part of the Mackenzie Shelf and across Peel Shelf, The Hume-Lonely Bay Assemblage is represented by the Hume Formation. The lower part of the Hume is distinctly more argillaceous than the upper part and has been assigned, by some authors, to a Headless Member (Fig. 4, 5; Pugh, 1993) of the Hume across Great Bear and Peel plains (Fig. 2). The lower part of the Hume is composed of several transgressive-regressive shoaling-upward cycles of slope-deposited open marine fossiliferous, argillaceous lime wackestone grading up to clean coralline thick-bedded limestone within the overall larger scale shoaling upward, or “cleaning upward” depositional cycle for the entire Hume interval (e.g., Fig. 34; Pyle and Jones, 2009). The upper non-argillaceous and coralline limestone of the Hume are similar to the laterally equivalent Nahanni Formation farther south and similarly are highstand deposits that prograded westward over lower Hume strata containing open marine brachiopod-dominated fauna. Like the Nahanni and Headless formations, the Hume Formation passes westward to sparsely fossiliferous grey platy argillaceous lime mudstone and shale of the uppermost Road River Group in the Northern Selwyn Basin and Richardson Trough (Fig. 44). Misty Creek Embayment along the northern Mackenzie Shelf margin was probably filled to near sea level by Hume strata and ceased to influence sedimentation at the end of Eifelian time (Fig. 44). The thickness of the Hume-Lonely Bay Assemblage is about 80 to 140 metres thick across most of the Mackenzie and Peel shelves, but is markedly thicker, locally more than 300 metres thick, in the Root Basin depocentre (Fig. 19), which was filled to near sea level by the end of Eifelian time at the close of Hume deposition (Fig. 44). There is also a slight depositional thinning of these strata over Redstone Arch on the west flank of Root Basin (Fig. 32). Redstone Arch and Root Basin were both tectonically active during deposition of the Hume-Lonely Bay Assemblage, but probably ceased to influence sedimentation by the beginning of Givetian time.

West of Richardson Trough, the Hume-Lonely Bay Assemblage is represented by coralline and stromatoporoidal limestone of the Ogilvie Formation (Fig. 5B; Morrow, 1999). Shallow water carbonates of the Ogilvie Formation prograded radially outward from the pre-existing Dave Lord High land area (Fig. 24) to form the large Porcupine Platform carbonate shelf that extends across most of northern Yukon (Fig. 29, 44) during T-R Cycle B marine transgression. Unlike the Hume-Lonely Bay Assemblage, which extended across the entire Mackenzie and Peel shelves, the Ogilvie Formation does not contain an unconformity, nor does it exhibit lithologic contrasts that could be comparable to the sub-Headless, sub-Ebbutt, or sub-Hume unconformity that marks the base of the Hume-Lonely Bay Assemblage across the eastern shelves (Fig. 4, 5).

Continued marine transgression led to drowning of the vast carbonate platforms of the Nahanni, Hume and Ogilvie formations and the widespread deposition of dark siliceous organic-rich shale of the Horn River Group across most of Mackenzie Shelf and of the lower part of the dark siliceous organic-rich Canol Formation shale across western Peel shelf and across Ogilvie Platform (Fig. 4, 5, 9; Meijer-Drees, 1993; Pugh, 1983, 1993; Williams, 1983). Across the eastern part of Peel Shelf, the Horn River Group is represented by the Hare Indian Formation (Fig. 4B; Williams, 1983), comprised which consists of, in ascending order, a the basalBluefish Member, a very organic-rich, spore-bearing, bituminous and sooty black shale containing pelagic fauna (tentaculites tentaculitids and fish scales) in very thin limestone beds, theand which is overlain gradationally by Bluefish Member, grading upwards the Grey Shale Member, to a unit of medium and light grey calcareous shale and argillaceous limestone, the Grey Shale Member (Pugh, 1993; Pyle and Jones, 2009). These strata formed a westward prograding clastic wedge. The with the bituminous Bluefish Member was a deeper water basinal deposit that accumulated offshore from a westward dipping mudbank (formed by sediments of the Grey Shale Member), of the Hare Indian Formation and which prograded westward over the Bluefish Member (Fig. 4, 9A). Farther southwest and northwest these units pass laterally to the lower part of the Canol Formation in the Peel and Anderson plains and in Peel Plateau (Fig. 4B; Williams, 1983). Both the Canol Formation and Bluefish Member are significant petroleum source rocks (Fig. 4, 5)

Across the southern part of Mackenzie Shelf, the Presqu'ile Barrier Reef complex (Fig. 9, 44; Williams, 1981, 1986a; Meijer-Drees, 1993) began to develop above and around the areas of Tathlina Uplift that were exposed at the end of deposition of the Bear Rock Assemblage in latest Eifelian time (Fig. 29). This ancient Middle Devonian barrier reef played an important role in the development of one of Canada's greatest industries, the potash industry of Saskatchewan, as well as being the host for several oil and gas fields (Morrow et al., 2006; Meijer-Drees, 1993). The Presqu'ile Barrier Reef acted as a partial barrier to the flow of normal marine water from the open marine Mackenzie Shelf southeastward into the very restricted marine evaporitic setting of the Middle Devonian Elk Point Basin, an intracratonic basin that stretched across western Canada (Fig. 44; Meijer-Drees, 1994). Multiple episodes of extreme evaporation of marine waters in Elk Point Basin led to accumulation of the world's largest deposits of industrial grade potash salts (e.g., Sylvite (KCl)) as a consequence of the restriction of marine influx into Elk Point Basin from open marine areas northwest of the Presqu'ile Barrier Reef (Meijer-Drees, 1993; 1994).

Stromatoporoidal and coralline masses in the upper part of the Keg River Formation finely crystalline dolostone and dolomitic limestone formed the initial framework of the Presqu'ile Barrier Reef and were coeval with slope and basin-deposited Horn River shale that accumulated northwest of the Barrier (Fig. 4B, 9, 16, 17). Above the Keg River, biostromal dolomitic limestone and peritidal dolostone of the Sulphur Point Formation extends across the Barrier (Fig. 4B, 9, 16, 17). Faunas include abundant hemispheroidal and digitate stromatoporoids (e.g., *Stachyodes*) and corals (e.g., *Thamnopora*) as well as calcispheres, ostracodes and gastropods in a variably dolomitic peloidal lime packstone matrix (Meijer-Drees, 1993).

In places along the barrier, Sulphur Point strata have prograded basinward over underlying Lonely Bay and Keg River strata, and even farther over Horn River shale basinward of Keg River Formation along the outer edge of the barrier (Fig. 17, 29). Southward, behind the Presqu'ile Barrier Reef complex, interbedded and interlaminated tan peloidal dolomudstone and white anhydrite of the Muskeg Formation accumulated in Elk Point Basin during deposition of the Sulphur Point Formation in mid-Givetian time (Fig. 4B, 44). The Muskeg Formation evaporites pass southeastward to the more evaporitic halite and potash beds of the Prairie Evaporite in the centre of the Elk Point Basin (Meijer-Drees, 1994).

Many isolated, pinnacle-style, reefs developed north of Presqu'ile Barrier during growth of the barrier. These reefs, known as the Horn Plateau reefs, grew upward from the top of the Lonely Bay and Nahanni formations across south-central Great Slave Plain (Fig. 4B, 19) during T-R Cycle B transgression. These reefs are encased in organic-rich shale of the Horn River Formation, a regional petroleum source rock (Fig. 4B, 21). Several Horn Plateau reefs contain significant gas discoveries (Hannigan et al., 2006). Farther north near Fort Good Hope at least one reef mass, the Manitou L-61 reef, grew upwards from the top of the Hume Formation during this marine transgression, and is encased in Hare Indian shale (Fig. 35).

Cordova Embayment was a large north-facing basinal re-entrant that developed along the northwest part of the Presqu'ile Barrier during deposition of the Keg River Formation (Fig. 14, 17, 19; Williams. 1981, 1986A; Morrow et al., 2002). This embayment had a narrow northern entrance through the basinward margin of the barrier but broadened southward within the barrier to a maximum width of about 45 kilometres at 60° north latitude (Fig. 17). Dark grey organic-rich shale and basinal resedimented limestone of the Horn River Group (Klua Formation shale, Slave Point and Sulphur Point basinal limestone and Otter Park Member shale) filled the embayment (Fig. 17). The nomenclature of basinal and basin slope units that occupy Cordova Embayment is not yet completely formalized according to accepted guidelines for stratigraphic nomenclature, but all these units may all be regarded as part of the Horn River Group of Givetian-aged basinal shale and dark limestone (Williams, 1983; American Association of Petroleum Geologists, 1983)

The uppermost strata of T-R Cycle B across Peel and Mackenzie shelves display features that indicate deposition during widespread marine regression. This is particularly true for the Presqu'ile Barrier Reef complex where the top of the Sulphur Point Formation is marked by a prominent regional unconformity at the base of the overlying green argillaceous siltstone and fine sandstones of the Watt Mountain Formation (Fig. 9, 16, 17; Meijer-Drees, 1993).Biostromal and fossiliferous subtidally-deposited strata of the lower part of the Sulphur Point grade upward to interbedded peritidal "fine textured" light grey limestone containing fenestral fabric and green silty shale (Meijer-Drees, 1993) reflecting marine regression in the upper part of T-R cycle B. In well cores the upper contact with the Watt Mountain is sharp and the uppermost Sulphur Point limestone beneath the Watt Mountain contains abundant centimetre-sized dissolution cavities (Meijer-Drees, 1993).

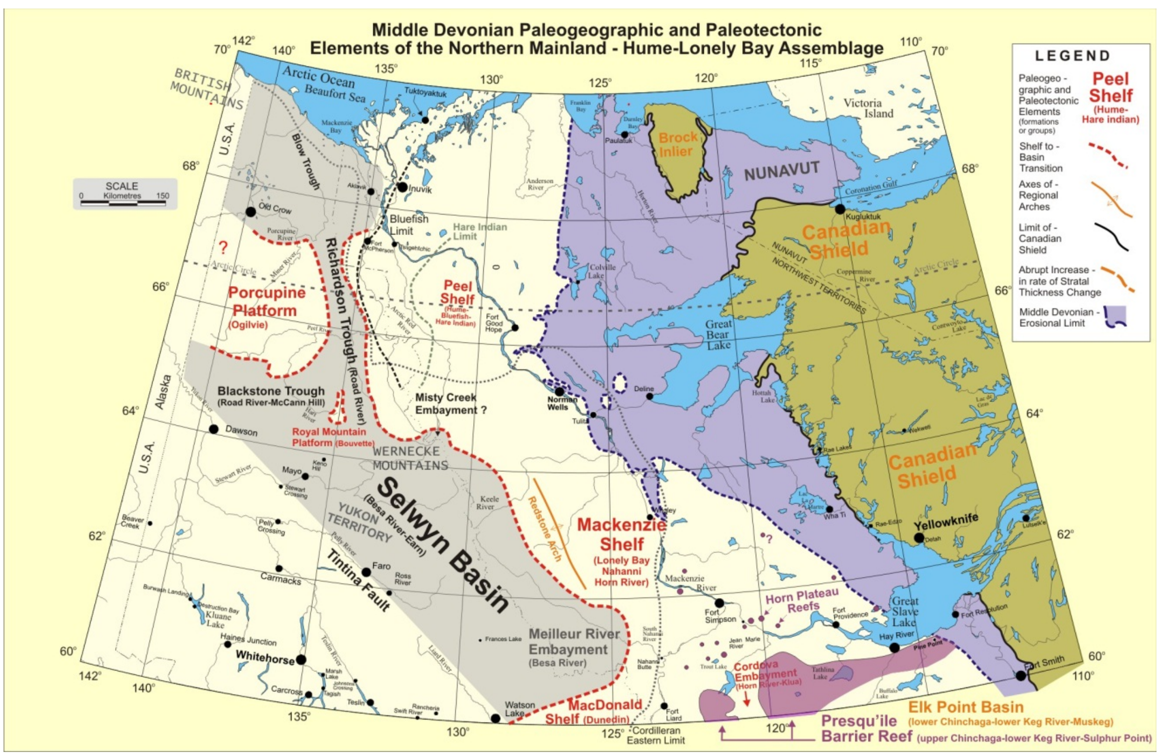

Figure 44. Map of paleogeographic and paleotectonic elements that influenced Middle Devonian sedimentation across the northern mainland during deposition of the Hume-Lonely Bay Assemblage. Mackenzie and Peel shelf platforms passed westward to Selwyn Basin and Richardson Trough. The Presqu'ile Barrier Reef complex began to form approximately above the site of the former Tathlina Uplift southwest of Great Slave Lake. Porcupine Platform deposition persisted in the northern Yukon. (Hi-Res)

Evidence for the terminal end of cycle regression is less obvious farther north across Great Bear, Peel, and Anderson plains where the southwestward-facing Hare Indian clastic wedge is overlain by the Ramparts Formation limestone (Fig. 4, 9A, 34). There is no overt unconformity to mark the regression at the top of T-R Cycle B (Pyle and Jones, 2009), but a well sorted thin sandstone marker bed, informally known as the Charrue sandstone, which is interpreted to be a shoal deposit (Williams, 1986b; Fig. 36), occurs within the uppermost beds of the Hare Indian and beneath Canol Formation shale. This may indicate that regression occurred at the end of Hare Indian deposition and coinciding with deposition of the lower thamnoporid-bearing platform-reef member overlying the eastern portion of the Hare Indian mudbank clastic wedge (Williams, 1986b; Fig. 4, 34, 36).

There is no recorded evidence for regression at the end of T-R Cycle B west of Richardson Trough where deposition of the Ogilvie Formation shelf platform limestone continued unabated throughout Middle Devonian time (Fig. 5B). This may be an indication that the sub-Watt Mountain regression at the end of T-R Cycle B is primarily tectonic, rather than eustatic in origin and that accommodation space for deposition west of Richardson Trough developed independently from that of the Mackenzie and Peel shelf areas.

Slave-Kakisa Assemblage – T-R Cycle C

The Slave-Kakisa Assemblage, or T-R cycle C, spans the time interval between the middle of the Givetian and the end of the Frasnian ages (Fig. 4B). These strata are bracketed by the unconformities at the base of the mid-Givetian-aged Watt Mountain Formation and at the base of the Famennian-aged Trout River Formation (Fig. 4B). There was a marked change in paleogeography during deposition of this assemblage. Initially, shallow water deposition was confined to paleogeographic elements that were in place at the end of Hume-Lonely Bay Assemblage deposition, such as the Presqu'ile Barrier Reef and the Ramparts Platform (Fig. 36) and across which fossiliferous shallow water limestones of the Sulphur Point Formation and the lower ramp and upper platform-reef members of the Ramparts Formation accumulated before the start of Slave-Kakisa Assemblage deposition (Fig. 4B, 9; Meijer-Drees, 1993; Pyle and Jones, 2009). These paleogeographic elements disappeared after deposition of the Slave Point Formation and the reefal Kee Scarp Member of the Ramparts Formation during the early stages of T-R Cycle C and were replaced by deposition on carbonate shelf platforms, such as the Twin Falls and Kakisa formations and the Jean Marie Member, across southern Mackenzie Shelf and by siliciclastic-dominated deltaic slope and basin deposition of the Imperial and Tuttle formations farther north across northern Mackenzie Shelf and Peel Shelf (Fig. 45).

Across southern Mackenzie Shelf (i.e., Great Slave Plain region-Fig. 2) this assemblage is comprised of a repetitive series of progradational shelf platform carbonates, including the Slave Point, Twin Falls, and Kakisa formations and the Jean Marie Member, which, except for the Slave Point Formation, accumulated in shallow water above westward-prograding mudbanks of slope and basin shale and siltstone. These intervening siliclastic calcareous shale and siltstone dominated slope-deposited sediment wedges include the Muskwa, Waterways, Hay River and Tathlina formations and the Redknife Formation above the Jean Marie Member (Fig. 4B, 18, 36, 39; Williams, 1977). Open marine benthic brachiopod, gastropod and ostracode-dominated paleofaunas are dominant in these units (e.g., Williams, 1977).

Deposition during the initial marine transgression of T-R Cycle C across the southern Mackenzie Shelf began with the accumulation of shoreface deposits of the Watt Mountain argillaceous and silty limestones and siltstones above the subaerially-exposed unconformity surface along the upper contact of the Sulphur Point Formation (Fig. 4, 9, 18) across the southern part of Great Slave Plain (Fig. 2). Watt Mountain deposition was confined to the Presqu'ile Barrier Reef complex (Fig. 9, 16, 17) and southeastward across the Elk Point Basin (Fig. 36; Meijer-Drees, 2004). Horn Plateau reefs continued to grow across the open marine southern Mackenzie Shelf north of the barrier during Watt Mountain deposition (Fig. 36; Johnson et al., 1985).

Continued marine transgression may have drowned the gas-bearing Horn Plateau reefs and ended their growth during the earliest phase of Slave Point Formation deposition (Fig. 4B, 9; Meijer-Drees, 1993). Fossiliferous limestone of the Slave Point Formation blanketed the Presqu'ile Barrier Reef complex and spread southward across the former Elk Point Basin in late Middle Devonian time (Oldale and Munday, 2004) contemporaneous with the development of a particularly reefal and porous outer barrier rim (Fig. 36) which forms the reservoir facies for several gas pools (Fig. 17). Cordova Embayment continued as a narrow north-facing basinal re-entrant along the northern margin of the Barrier during Slave Point deposition (Fig. 17, 36). Silty anhydrite beds of the Fort Vermilion Member of the Slave Point Formation accumulated in a restricted evaporitic marine setting in Elk Point Basin south of the barrier complex during the initial stages of Slave Point deposition (Fig. 4B, 36).

Farther north across the Mackenzie, Peel and Great Bear plains and in the Franklin Mountain (Fig. 2), the upper part of the reefal platform facies, and the reef mound facies, the Kee Scarp Member, of the Ramparts Formation grew above the "Ramparts Platform" (Fig. 4B, 5A, 36; Williams, 198b; Pyle and Jones, 2009). A Kee Scarp Member reef mound near Norman Wells is the reservoir for the historic Norman Wells oil field (Fig. 2; Hume and Link, 1945; Yose et al., 2001; Morrow et al., 2006). This early transgressive phase of the Slave-Kakisa Assemblage coincides with deposition of the Beaverhill Lake Megacycle of Alberta (Savoy and Mountjoy, 1995).

In earliest Late Devonian time, or early Frasnian age, continued marine transgression caused progressive drowning of both the Ramparts and Slave Point carbonate platforms and initiated deposition of basinal, organic-rich black shale of the Canol and Muskwa formations above the Ramparts and Slave Point respectively (Fig. 4B,5A, 22; Pugh, 1993; Meijer-Drees, 1993). Muskwa shale, ranging from about 10 metres to more than 140 metres thick, represents the basinal toe of slope of a large westward-progradationaling clastic wedge of calcareous shale and siltstone represented by the overlying Hay River Formation (Fig. 4B, 18; Williams, 1977). The maximum flooding surface (MFS) for T-R Cycle C lies within the Muskwa and Canol formations (Fig. 9). Both of these units are significant regional petroleum source rocks (Fig. 4B, 5A; Hannigan et al., 2006, Morrow et al., 2006).

Westward from the Presqu'ile Barrier Reef complex, the lower transgressive part of the Slave-Kakisa Assemblage, including the Watt Mountain and Slave Point formations, passes to slope and basin-deposited dark shale of the Horn River Group (Fig. 4B, 5A, 9, 36). In the Cordova Embayment, the upper Slave Point passes to Otter Park shale within the Horn River Group and farther west to undivided Horn River shale (Fig. 9). Farther north across Peel Shelf, the Ramparts Formation passes southwestward to basinal dark shale of the lower part of the Canol Formation as part of the Horn River Group (Fig. 4B, 5A, 9, 36)

Across the southern part of Mackenzie Shelf, the change from transgression to regression within T-R Cycle C, or the Slave-Kakisa Assemblage, is recorded by deposition of a series of carbonate platforms including the Twin Falls Formation, Jean Marie Member and the Kakisa Formation, all of which are fossiliferous limestones and contain scattered coral and stromatoporoid bioherms, and which built out successively farther west (Fig. 45) above intercalated siliciclastic-dominated units (Tathlina Formation and the upper shale-dominated unnamed member of the Redknife Formation) during the remainder of Late Devonian Frasnian time (Fig. 4B, 9, 18).The Kakisa Formation represents the time of maximum regression of T-R cycle C and its upper contact with the overlying Trout River Formation siltstone is disconformable (Fig. 4B, 18; Moore, 1993; Geldsetzer and Morrow, 1992). The Trout River Formation correlates with the sandstone-bearing Sassenach Formation in the Rocky Mountains of west-central Alberta which has a definite unconformable lower contact with the underlying uppermost Frasnian platform carbonates of the Blue Ridge, Ronde and Simla formations and which is considered to coincide with a time of maximum regression across the western Canada (Moore, 1988, 1993; Geldsetzer and Morrow, 1992; Savoy and Mountjoy, 1995).

West-sloping marker beds within siliciclastic-dominated units, such as within the Hay River Formation, indicated that successive episodes of westward progradation and basin infilling occurred were punctuated by more aggradational deposition across shallow water carbonate platforms (Fig. 9, 18). These marker horizons extend westward from the Hay River Formation into the uppermost strata of the dark organic-rich basinal Muskwa shale (Fig. 9, 18) indicating that uppermost Muskwa strata are time equivalent to lower to middle Hay River strata (Fig. 9, 18; Williams, 1977).

The upper part of the Slave-Kakisa Assemblage is equivalent to strata that comprise make up the combined Woodbend and Winterburn megacycles across Alberta (Savoy and Mountjoy, 1995). The regressive surface developed near the top of the Twin Falls Formation within the Slave-Kakisa Assemblage of T-R Cycle C (Fig. 9, 18) may mark the boundary between Woodbend and Winterburn megacycles across Great Slave Plain. Consequently, the Woodbend third third-order depositional sequence (or megacycle) includes uppermost Muskwa-Waterways, Hay River and Twin Falls strata (Grosmont equivalent) and the Winterburn third order sequence includes uppermost strata of the Twin Falls, the Tathlina Formation, the Redknife Formation and Jean Marie Member and the Kakisa Formation across Great Slave Plain (Fig. 39; McLean and Klapper, 1998; Potma et al., 2001). These strata pass westward to grey and brownish-grey basinal calcareous siltstone and shale of the Fort Simpson

Formation and to silty dark basinal Besa River shale (Fig. 4B, 5A, 9, 18). The disconformable upper contact of the Kakisa marks the final regression at the end of T-R Cycle C (Fig. 9, 18).

North of Liard High, the upper regressive part of the Slave-Kakisa Assemblage is represented almost exclusively by slope-deposited greyish-brown fine sandstone, siltstone and shale of the Imperial Formation (Fig. 9, 38, 39, 40, 41, 45). Marker beds defined by log and seismic markers indicate northwest-directed depositional slopes south of Norman Wells (Fig. 37) and southwest-directed depositional slopes north and west of Norman Wells across Mackenzie and Peel plains and Peel Plateau (Fig. 40, 41; Hadlari et al., 2009). The Imperial Formation was deposited within a dominantly westward prograding shelf delta front, slope and basin turbidite depositional system characterized by many intervals of amalgamated thin to medium bedded turbidite submarine channel sheet sandstone bodies (Fig. 40; Hadlari et al., 2009; Tyloski et al., 2009). A nearly 100 metre thick submarine fan-deposited sandstone body at the base of the Imperial is developed across 150 kilometres along the southern margin of Peel Plateau (Fig. 41; Hadlari et al., 2009).

South of Norman Wells, a prominent but thin limestone marker bed, the Jungle Ridge Limestone Member is probably correlative with the Jean Marie Member of the Redknife Formation developed across Great Slave Plain (Fig. 5A, 37; Pugh, 1993; McLean and Klapper, 1998). Across most of the northern Mainland south of the Mackenzie Delta area the Imperial is overlain unconformably by Cretaceous strata (Fig. 37, 41). The Canyon Creek sandstone lentil at the base of the Imperial Formation identified in wells west of Tulita (Fig. 37: Pugh, 1993) may be a submarine fan deposit similar to the thicker basal sandstone developed farther northwest along the southern edge of Peel Plateau (Fig. 41), but is thinner and developed across a much smaller area (Pugh, 1993). Thick sandstone-dominated intervals also occur locally within the upper part of the Imperial above the Jungle Ridge Limestone (Fig. 37).

Figure 45. Map of paleogeographic and paleotectonic elements that influenced Late Devonian sedimentation across the northern mainland including the upper part of the Slave-Kakisa Assemblage (Hay River to Kakisa formations) and the Kotcho-Tetcho Assemblage. Mackenzie and Peel shelves continued as sites of offshore deeper water shelf deposition which passed westward to still deeper water deposition in Selwyn Basin. Platform carbonates (e.g., Twin Falls) intercalated with slope-deposited shales (e.g., Hay River) across Mackenzie Shelf pass northward to siliciclastic deltaic deposition of the Imperial and Tuttle formations across Peel Shelf. (Hi-Res)

The Imperial Formation is part of the orogenic clastic wedge that accumulated in front of the Late Devonian Ellesmerian mountain-building orogen of the Arctic Islands (Fig. 40; Hadlari et al., 2009; Moore, 2003). Deformation associated with this orogen encroached southward onto the northern mainland in the area of Mackenzie Delta (Fig. 10; Lane, 2007). Preserved Imperial strata increase in thickness westward from an erosional zero edge near the Canadian Shield to nearly 2000 metres in the Peel Plain and Peel Plateau area (Fig. 39). Siliciclastic successions more than 1500 metres thick, mapped as unnamed Devono-Missippian, or Devono-Carboniferous strata that are probably equivalent to Imperial Formation, are locally preserved in scattered outcrop belts within the Mackenzie Mountain westward up to the Yukon border (Fig. 38, 39). West of the Mackenzie Mountains and Liard Plateau and Mackenzie Shelf (Fig. 2; 45), Imperial equivalent strata pass to black shale and siltstone and locally-developed thick syntectonic chert pebble conglomerate in the Earn Group (Portrait Lake Formation) across Selwyn Basin (Fig. 45; Gordey, 1992: Gordey and Anderson, 1993). During Frasnian to Famennian time, Selwyn Basin in south central Yukon Territory may have undergone extensional, or transtensional, tectonic rifting, accompanied by accumulation of eroded Proterozoic clastics as Earn Group strata in local grabens (Gordey, 1992).

The Canol and Imperial formations extend westward across the Richardson Anticlinorium (Norris, D.K., 1997) and into northern Yukon and Eagle Plain (Fig. 5B; 7, 39; Geldsetzer and Morrow, 1992). Farther west Imperial strata pass laterally to dark finer-grained siltstone and pyritic shale of the Ford Lake Formation in the northern Ogilvie Mountains and Kandik Basin (Fig. 2) and finally to sandstones and conglomerates of the Nation River Formation near the Alaska border (Fig. 5B; Pugh, 1983; Norris, A.W., 1997). No Slave-Kakisa Assemblage age strata are preserved across the British Mountains, Blow Trough or Old Crow (Fig. 2) areas of northwestern Yukon, but several large post-tectonic granite plutons of Frasnian to Famennian age are emplaced here (Fig. 5B; Norris, A.W., 1997; Lane, 2007). It seems possible that uplift and erosion of these areas may have occurred concomitantly with emplacement of plutons during the Late Devonian when the Ellesmerian Orogeny was in progress to the northeast in the Arctic (Fig. 10; Lane, 2007).

Kotcho-Tetcho Assemblage – T-R Cycle D (lower part)

The paleogeographic elements of the Mackenzie and Peel shelves continued largely unchanged from the end of Slave-Kakisa Assemblage time, or latest T-R Cycle C time, to the time of deposition of the Kotcho-Tetcho Assemblage, or the lower part of T-R Cycle D (Fig. 45). Dominantly shallow water carbonate platform (i.e., Kotcho and Tetcho formations) deposition continued across the southern Great Slave Plain, and dominantly fine-grained siliciclastic deposition (i.e., Imperial and Tuttle formations), or southern Mackenzie Shelf continued across the northern part of Mackenzie Shelf and across Peel Shelf (Fig. 9, 45) after Slave-Kakisa Assemblage deposition.

Across the southern Mackenzie Shelf, the Kotcho-Tetcho Assemblage, or the lower transgressive part of T-R Cycle D, accumulated in latest Devonian to earliest Carboniferous time, and includes uppermost Frasnian, Famennian and lower Tournaisian strata (Fig. 4B, 5A). This assemblage is comprised composed of strata occupying the stratigraphic interval between the uppermost Frasnian-aged Kakisa Formation and the Tournasian Banff Formation across Great Slave Plain (Fig. 5B4B; , 45). These strata include the Trout River, Tetcho, Kotcho and Exshaw formations (Fig 5B, 9), which extend northward from from their type areas in northeastern British Columbia (Fig. 45; Griffin, 1967). The limestone-dominated Kotcho and Tetcho formations together form the Wabamun Group in the Northwest Territories and in northeastern British Columbia (Fig. 18; Halbertsma, 1994). In the extreme southeastern corner of Great Slave Plain, undivided Kotcho and Tetcho strata are mapped as Wabamun Formation (Fig. 45). Most of this assemblage is correlative with the Wabamun-Palliser Megacycle of Savoy and Mountjoy (1997) which recorded the transgressive phase of sedimentation beginning with deposition of siltstones and sandstones of the Sassenach Formation above the major unconformity formed at the end of their Winterburn Megacycle. The Trout River Formation, is correlative with the Sassenach correlative, (Geldsetzer and Morrow, 1992). and is the basal unit of the Kotcho-Tetcho Assemblage.

A notable feature of the Kotcho and Tetcho lime mudstone and shaly limestone is the absence of the reef-forming corals and stromatoporoids that were prolific in Frasnian strata of the underlying Slave-Kakisa Assemblage. The transition from Frasnian to Famennian time, and the Late Devonian in general, was characterized by several closely-spaced mass extinctions of marine biota, including almost all reefbuilding rugose corals and stromatoporoids (McGhee, 1996). The profound Late Devonian extinction events have been attributed to number of proximate causes including extraterrestrial bolide impact, eutrophication of shallow marine shelves by abrupt influx of terrestrial organic plant material, increased turbidity of shallow marine seaways and profound cooling of shallow marine seas (e.g., McGhee, 1996). The shallow marine lime mudstone of the Kotcho and Tetcho formations are typical of Famennian strata worldwide in that they contain none of the coral and stromatoporoid reef mounds that characterize all older Givetian and Frasnian platform carbonates worldwide, such as those of the Slave-Kakisa Assemblage underlying the Kotcho-Tetcho Assemblage.

The uppermost stratigraphic unit of the Kotcho-Tetcho Assemblage is the Exshaw Formation, , thean organic-rich black sooty shale of the Exshaw Formationthat overlies the Kotcho Formation paraconformably, or with a very condensed conformable stratigraphic succession that approximates a paraconformity, overlies the Kotcho Formation. The Exshaw contains the boundary between the Devonian and Carboniferous systems (Fig. 4B, 9; Geldsetzer and Morrow, 1992; Moore, 1993). Exshaw-equivalent dark shale is recognized within siltstone and shale of the Besa River Fomation across Liard Plateau as the “First Black Shale”, an informally recognized drilling marker horizon (Fig. 5A). The Exshaw Shale is correlative with other extensive uppermost Devonian black shales , such as the oil-producing Bakken Formation, across western North America , such as the oil-producing Bakken Formation (Moore, 1993). The maximum flooding surface of T-Cycle D falls within the thin Exshaw Formation, which is less than 10 metres thick across eastern Great Slave Plain (Fig. 9, 18). The Kotcho-Tetcho Assemblage itself is defined here to include strata that fall between the unconformity at the base of the Trout River Formation and an, as yet to be precisely determined, maximum flooding surface within the Exshaw Formation (Fig. 9, 18).The top of T-R Cycle D falls within Carboniferous strata above the regressive Banff Formation (Fig. 4B).

Following the initial marine transgression of T-R Cycle D, which deposited the Trout River siliciclastics, marine flooding of southern Mackenzie Shelf was accompanied by deposition of the shallow marine light grey “clean” peloidal and intraclastic lime wackstonewackestone and packstone of the Tetcho Formation, which resembles Wabamun strata of northern Alberta (Halberstma, 1994). Continued transgression was accompanied by deposition of the darker, more organic-rich, deeper water open marine shelf lime mudstone and calcareous shale of the Kotcho Formation and finally by deposition of the Exshaw black shale during the time of maximum marine transgression of T-R cycle D (Fig. 9, 18). The carbonate platform edge of the Tetcho Formation lies about 50 kilometres farther west from the dominant carbonate platform edge of the overlying Kotcho (Fig. 6A, 45) as a consequence of increasing depositional accommodation space during continuous marine transgression. Both of these units pass westward to siltstone and shale of the Besa River Formation (Fig. 5A).

Farther north across the northern part of Mackenzie Shelf, across Peel Shelf, and across the Richardson and Blackstone troughs and the Porcupine Platform of the Northwest and Yukon territories (Fig. 44), platform carbonates are absent in the Kotcho-Tetcho Assemblage. In these areas, which include the northern part of Great Slave Plain, the Great Bear, Mackenzie, Peel, Anderson and Eagle plains, and the Mackenzie, Franklin, Ogilvie-Wernecke, and Richardson mountains (Fig. 2), the Kotcho-Tetcho Assemblage is comprised of siliclastics including the upper, or Famennian, part of the Imperial Formation and the uppermost Famennian and Tournaisian part of the overlying Tuttle Formation (Fig. 4, 5, 38). Deposition of the Imperial siliciclastics continued in a westward-directed shelf-slope turbidite setting in front of an advancing open shelf deltaic depositional system (Fig.40) that continued uninterrupted from T-R Cycle C to T-R Cycle D time. Tuttle strata are preserved in Peel Plateau and the Peel and Eagle plains across a much smaller area than the underlying Imperial (Fig. 38). The abundant coarse sandstone and chert pebble conglomerate bodies that punctuate the fine sandstone and siltstone of the plant fragment-bearing Tuttle Formation (Fig. 41, 43) are interpreted to be turbiditic sandstone and conglomerate mass flow deposits along a delta front and slope although some may represent delta plain fluvial channel deposits (Lutchman, 1977; Pugh; 1983; Allen et al., 2009). It seems probable that the Tuttle originally extended far to the east and north above the preserved Imperial, across the Interior Plains and Peel Shelf, and may, in part, represent the delta system that supplied finer siliclastics for Imperial turbidite deposition in a distal slope setting southwest of a progradational Tuttle delta system (Fig. 41). The age equivalence of parts of the uppermost Imperial with lowermost Tuttle (Fig.5B, 41, 43; Pugh, 1983; Allen et al., 2009) is consistent with this interpretation. Both the Imperial and Tuttle formations are part of the clastic wedge that formed southward in front of the advancing Ellesmerian orogenic mountain belt in Late Devonian and Carboniferous time (Fig. 10; Lane, 2007; Gordey, 1992; Geldsetzer and Morrow, 1992; Moore, 1993).

Farther southwest towards Selwyn Basin these strata pass to dark shale and siltstone of the Besa River Formation and turbidite-deposited siltstone and shale of the Provost Formation of the Earn Group (Fig. 45; Gordey, 1992; Gordey and Anderson, 1993). In the northern Yukon in Eagle Plain, strata of the Imperial and the lower portion of the Tuttle pass southwestward to the Ford Lake shale by facies transition and farther west near the Alaska border to the sandstone and chert pebble conglomerate of the plant fragment-bearing Nation River Formation (Fig. 5B; 7, 43; Pugh, 1983; Gordey, 1992). The Nation River formed part of the Ellesmerian orogenic clastic wedge immediately south of documented Ellesmerian deformation near the Alaska border (Fig. 10; Lane, 2007).

Over most of the Interior Plains and northern Yukon, both the Imperial and the Tuttle are overlain by Cretaceous strata with a profound regionally angular unconformity (Fig. 3, 6D; 7). Post-Devonian Laramide-aged uplift and structural inversion of Richardson Trough to form Richardson Anticlinorium during the Cenozoic Eon was accompanied by erosion of all Devonian strata, including both the Imperial and Tuttle formations, across the axis of the anticlinorium (Fig. 38, 39; Norris, D.K., 1997). Devonian strata are overlain, largely conformably, by Carboniferous strata in two widely separated regions (Fig. 3). In the southern region, including the western Great Slave Plain and Liard Plateau, the Devonian Exshaw Formation is overlain conformably by Carboniferous calcareous shale and siltstone of the Banff Formation (Fig. 4B). Far to the north in the Richardson Mountains and Eagle Plain, the Ford Lake and Tuttle formations are overlain by turbiditic calcareous siltstone and shale of the Carboniferous Hart River Formation (Fig. 5B, 7).

ACKNOWLEDGMENTS

B. (Bernie) C. MacLean provided seismic interpretations. Thanks are due also to N.C. Meijer-Drees, D.C. Pugh and G.K. Williams, formerly of the Geological Survey of Canada for assistance with aspects of Devonian stratigraphy and to M.P. Cecile and L.S. Lane, both of the Geological Survey of Canada, for assistance with Devonian stratigraphic and tectonic interpretation. D.G. Cook, of the Geological Survey of Canada, provided many invaluable insights into Devonian mapping and structural interpretations across the northern Canadian mainland. T. Hadlari, of the Geological Survey of Canada, provided valuable updates concerning stratigraphy of the Upper Devonian. Thanks are also extended to A.W. Norris, formerly of the Geological Survey of Canada, for his help with both Devonian stratigraphy and paleontology.

The staff and personnel of the both the Northwest Territories Geoscience Office and the Yukon Geological Survey provided continuing support for geological studies that materially aided in the production of this report. In particular, thanks are due to Ms. Adrienne Jones, formerly of the Northwest Territories Geoscience Office. Mr. Brent Hogue of the National Energy Board contributed many corrections to subsurface formation picks from well logs.

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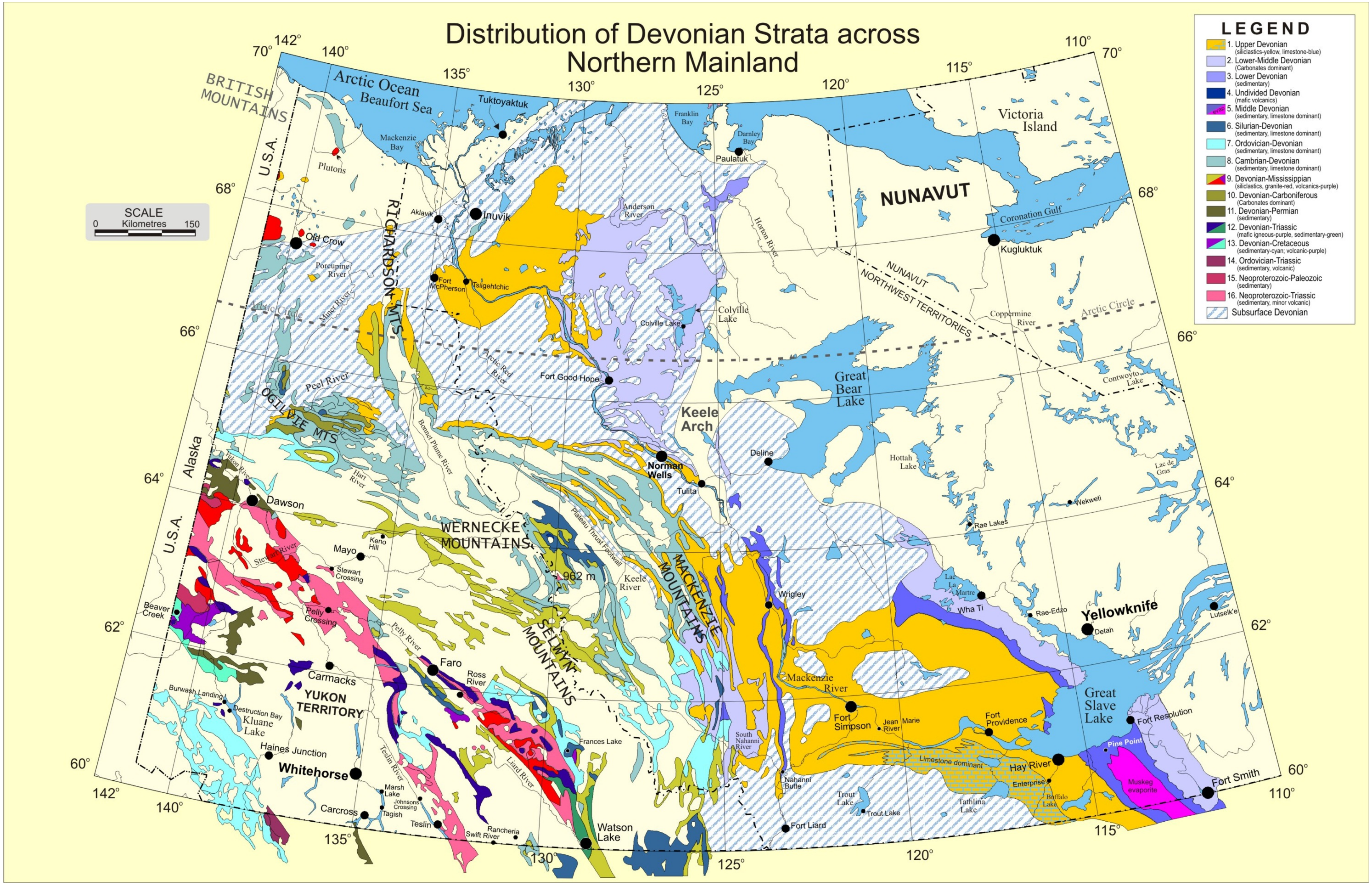

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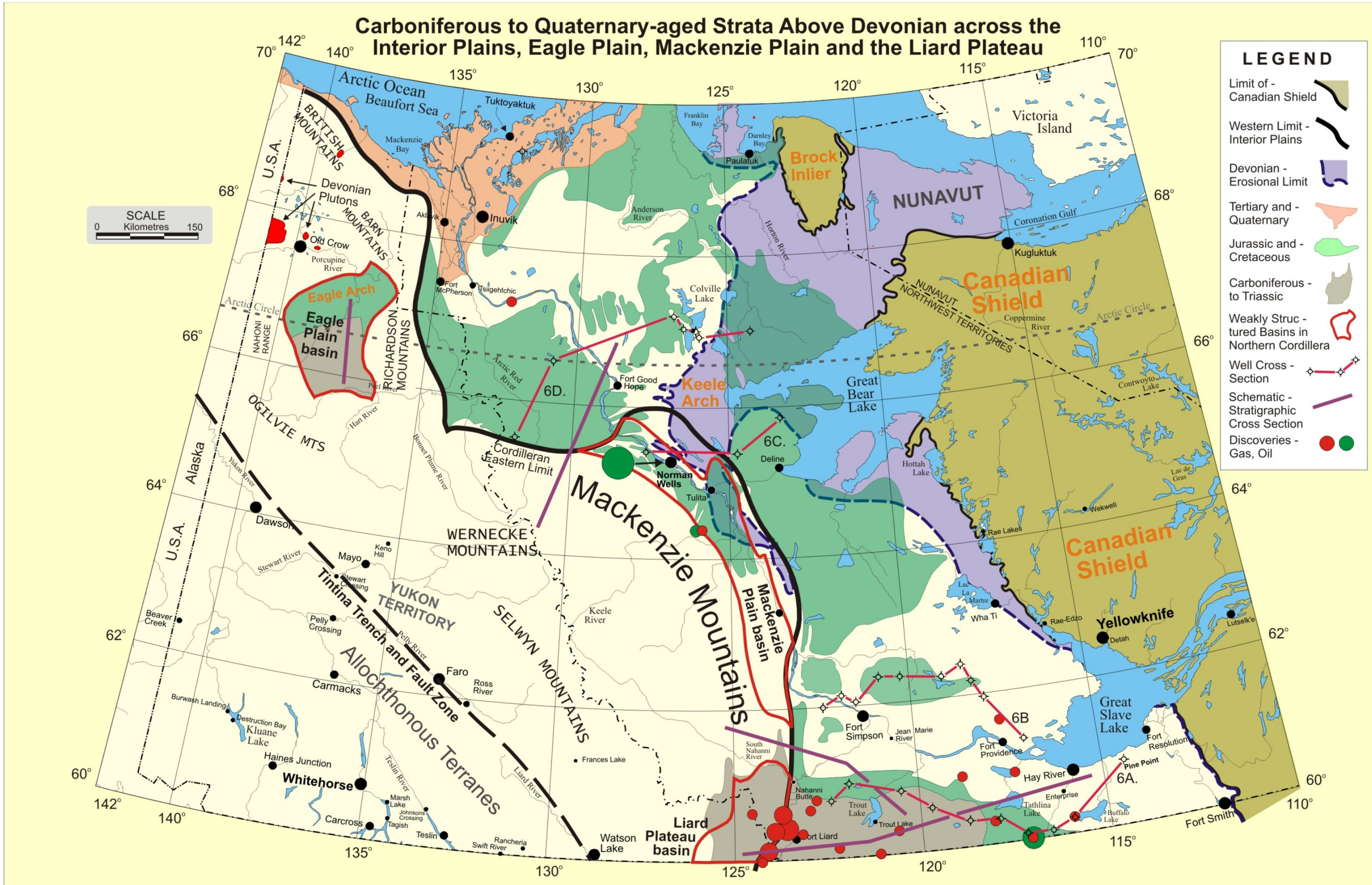

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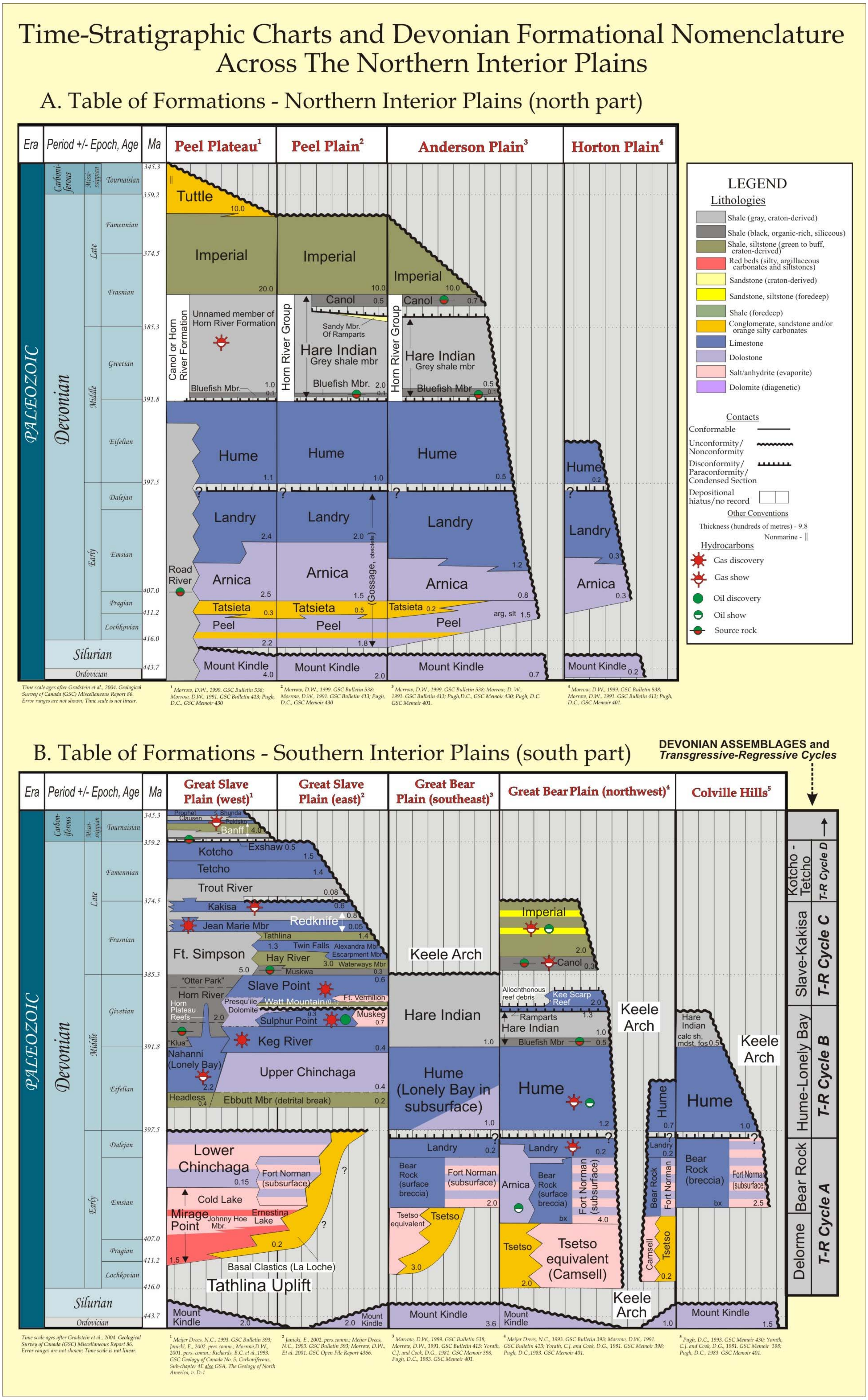

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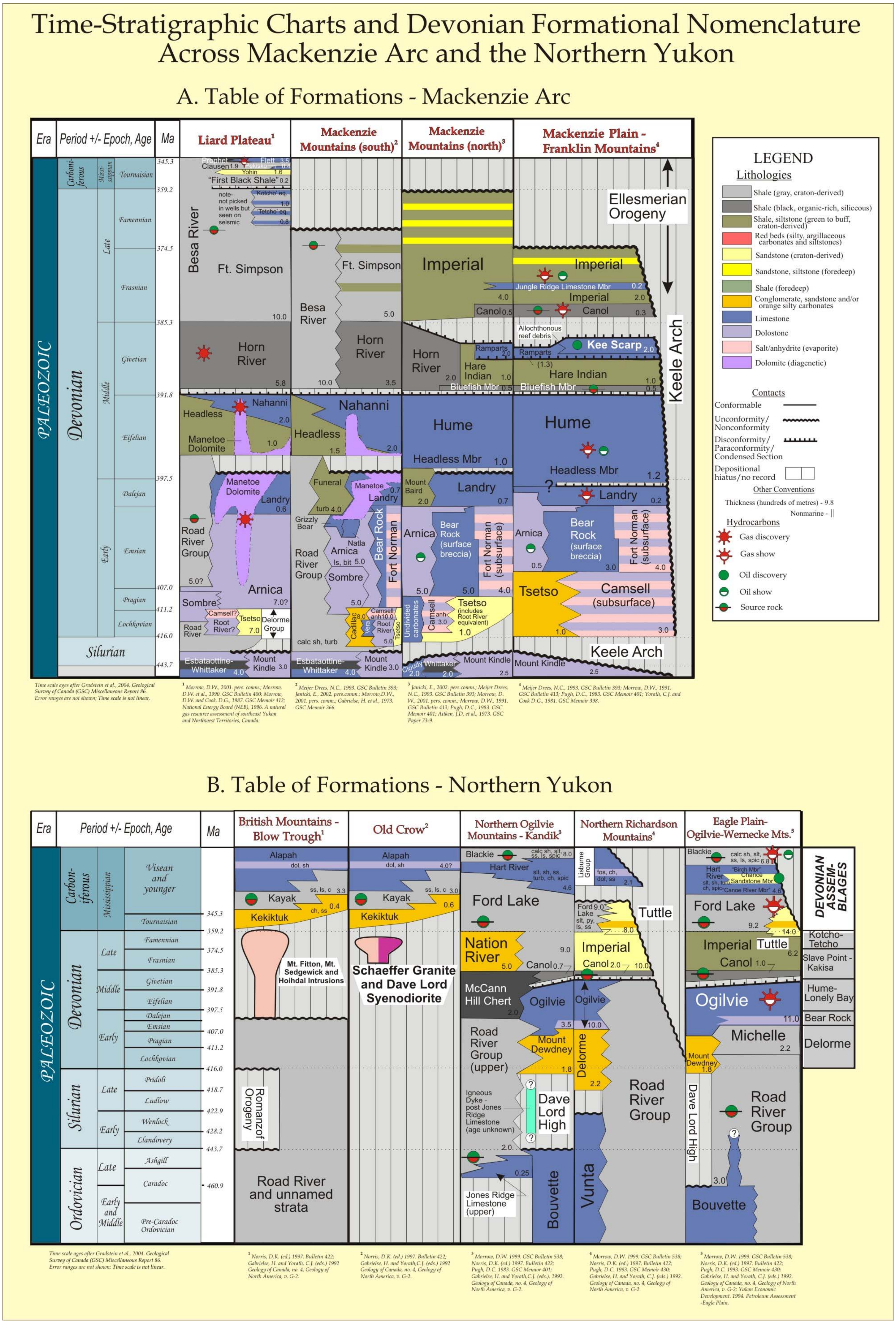
Time-Stratigraphic Charts and Devonian Formational Nomenclature Across Mackenzie Arc and the Northern Yukon



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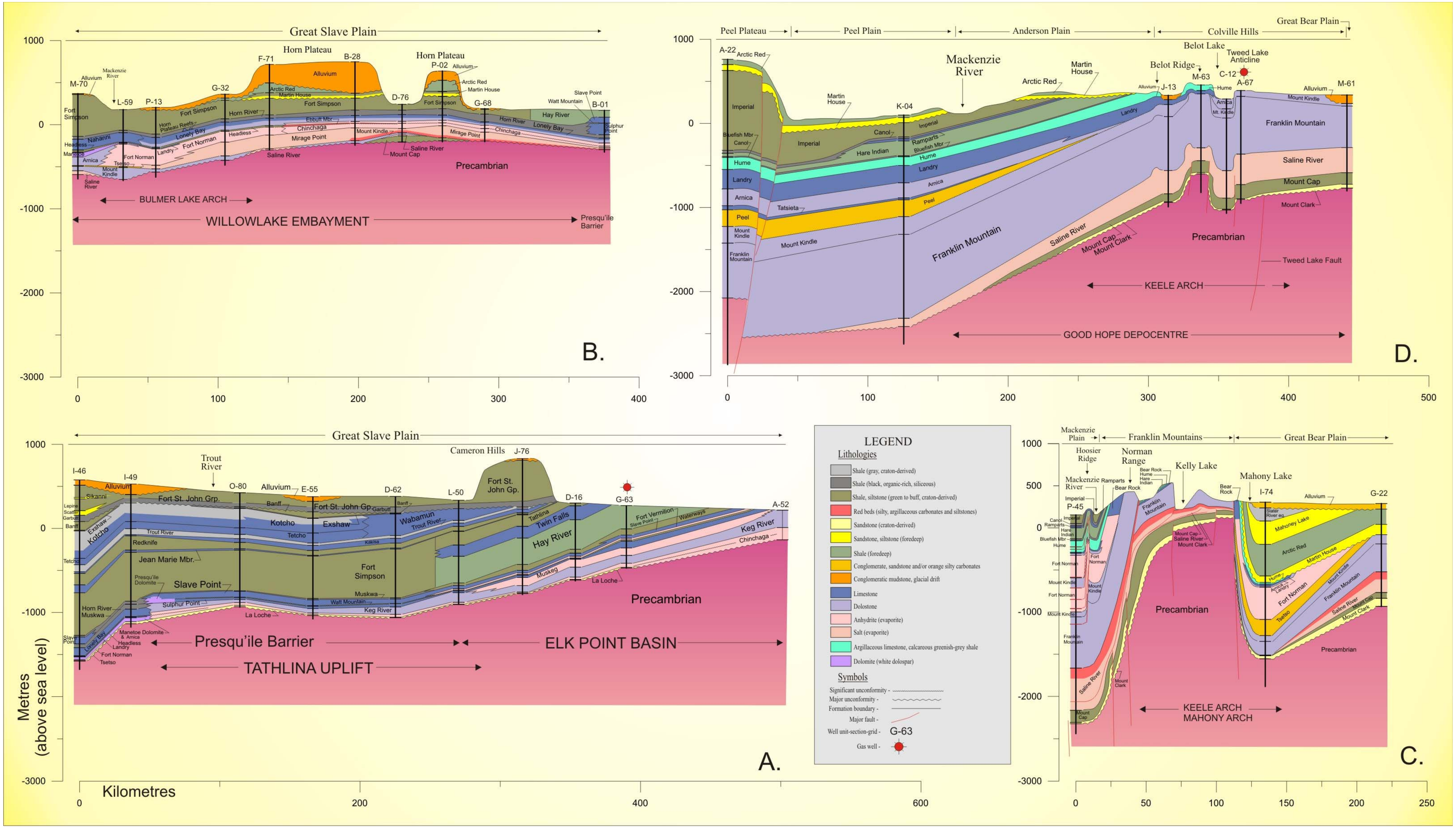

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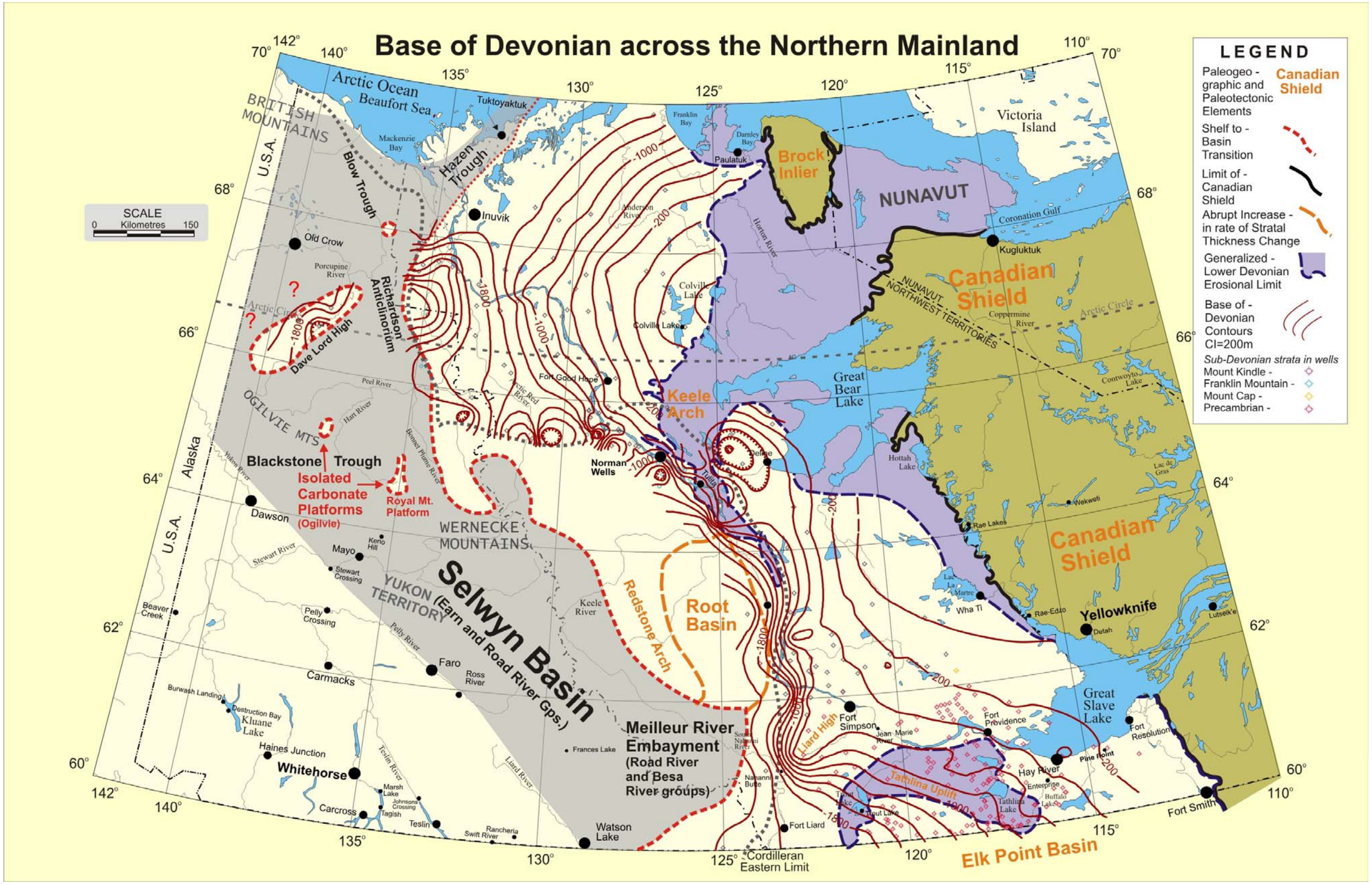

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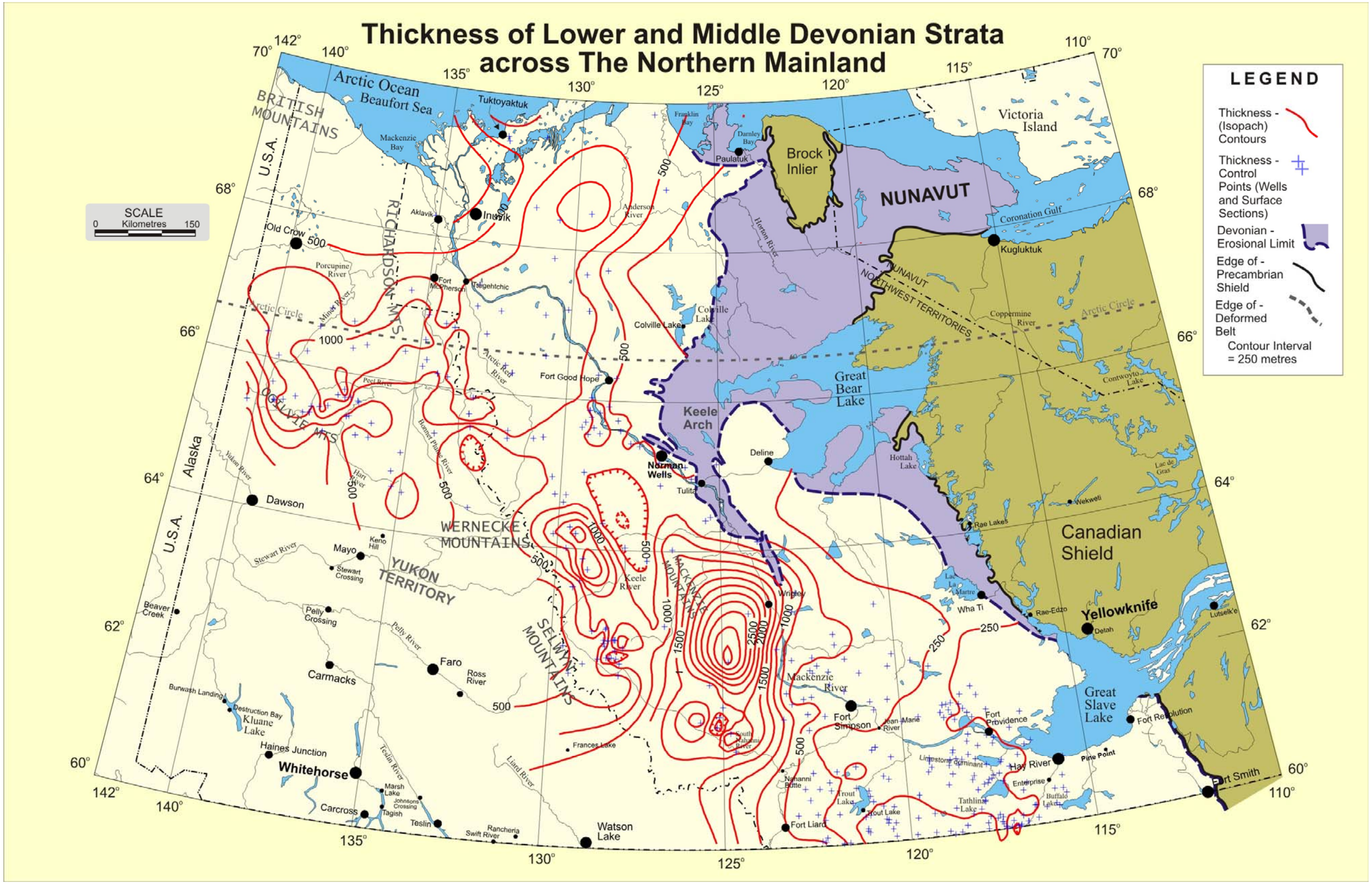

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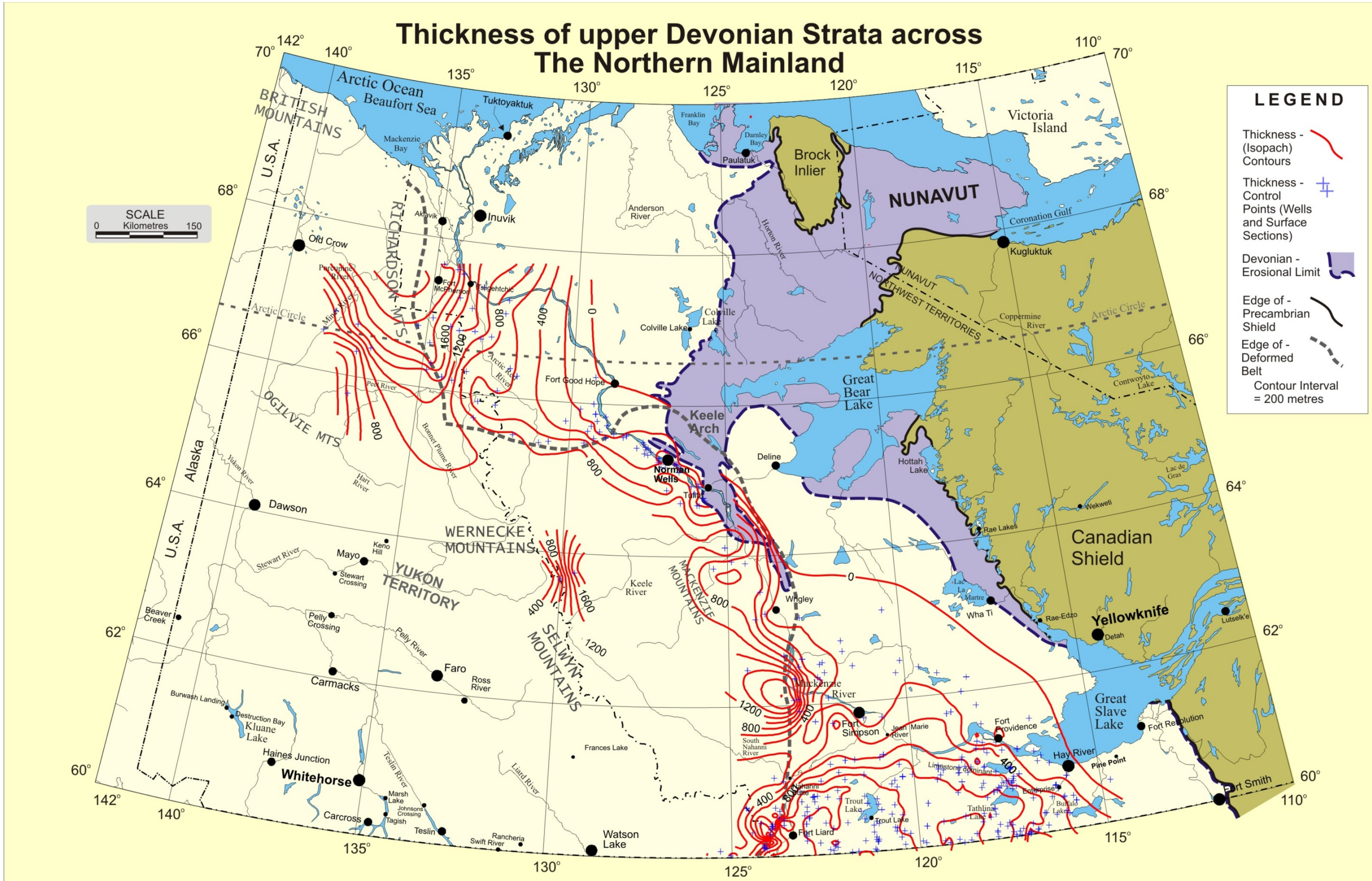

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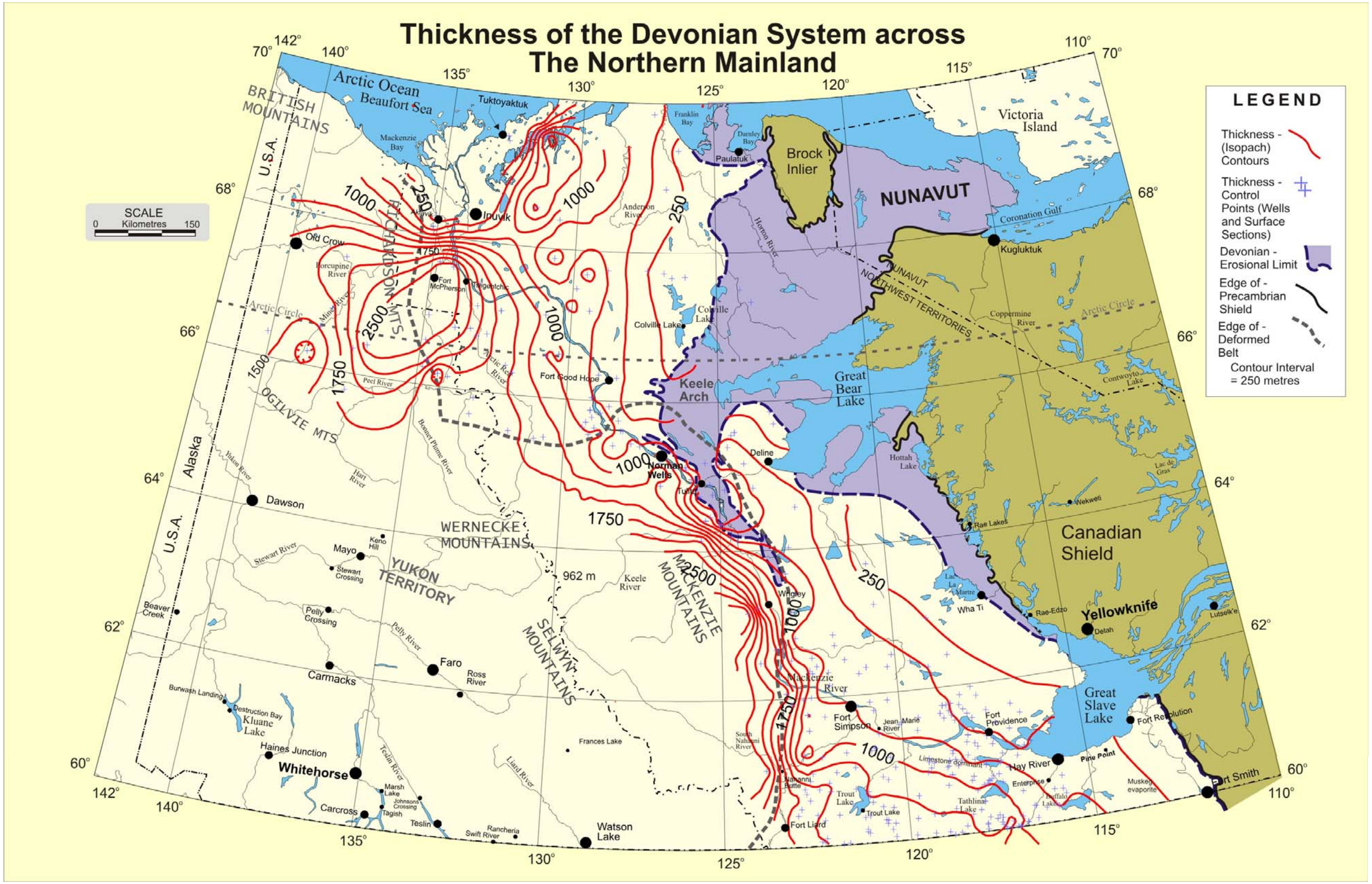

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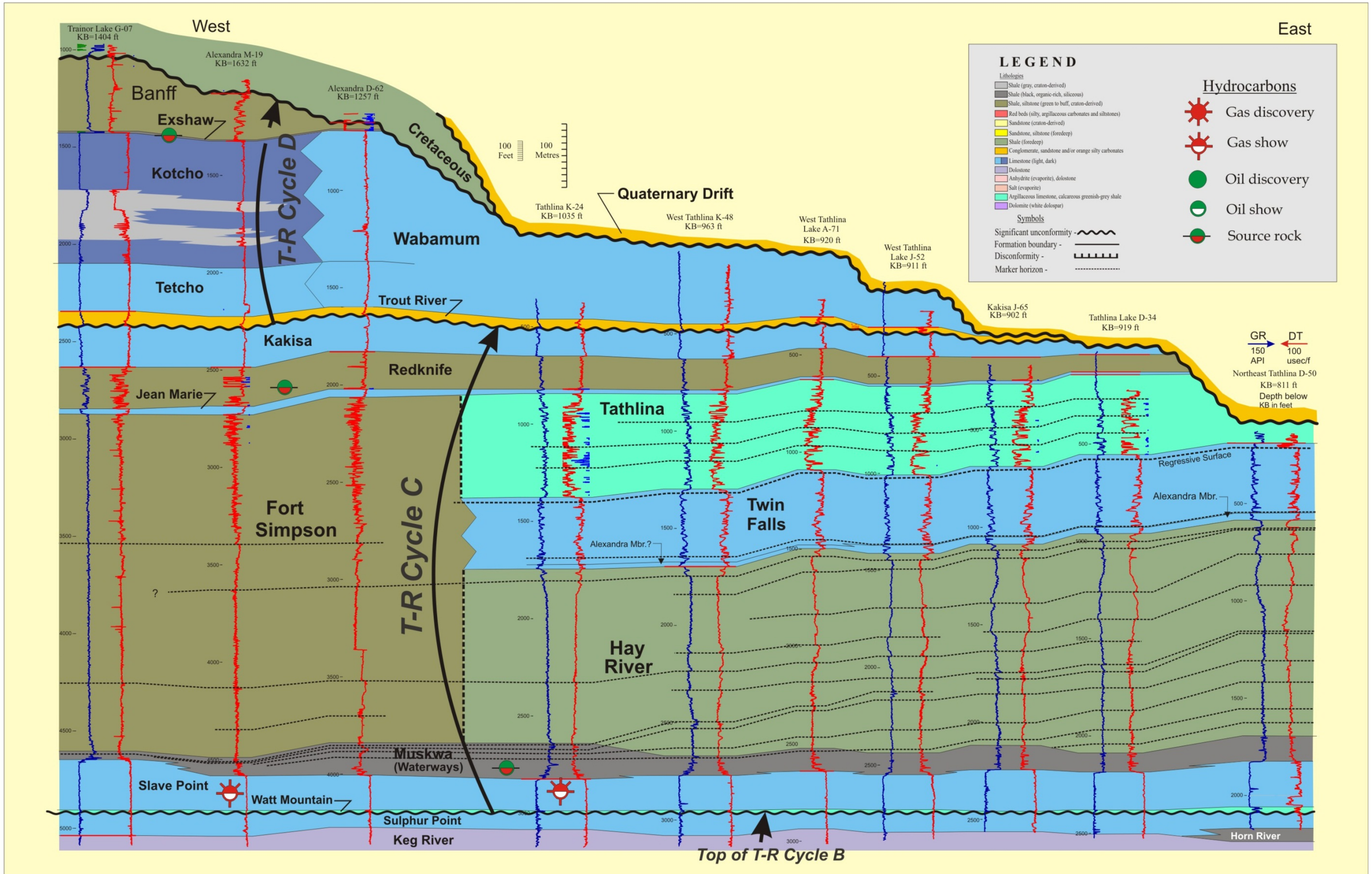

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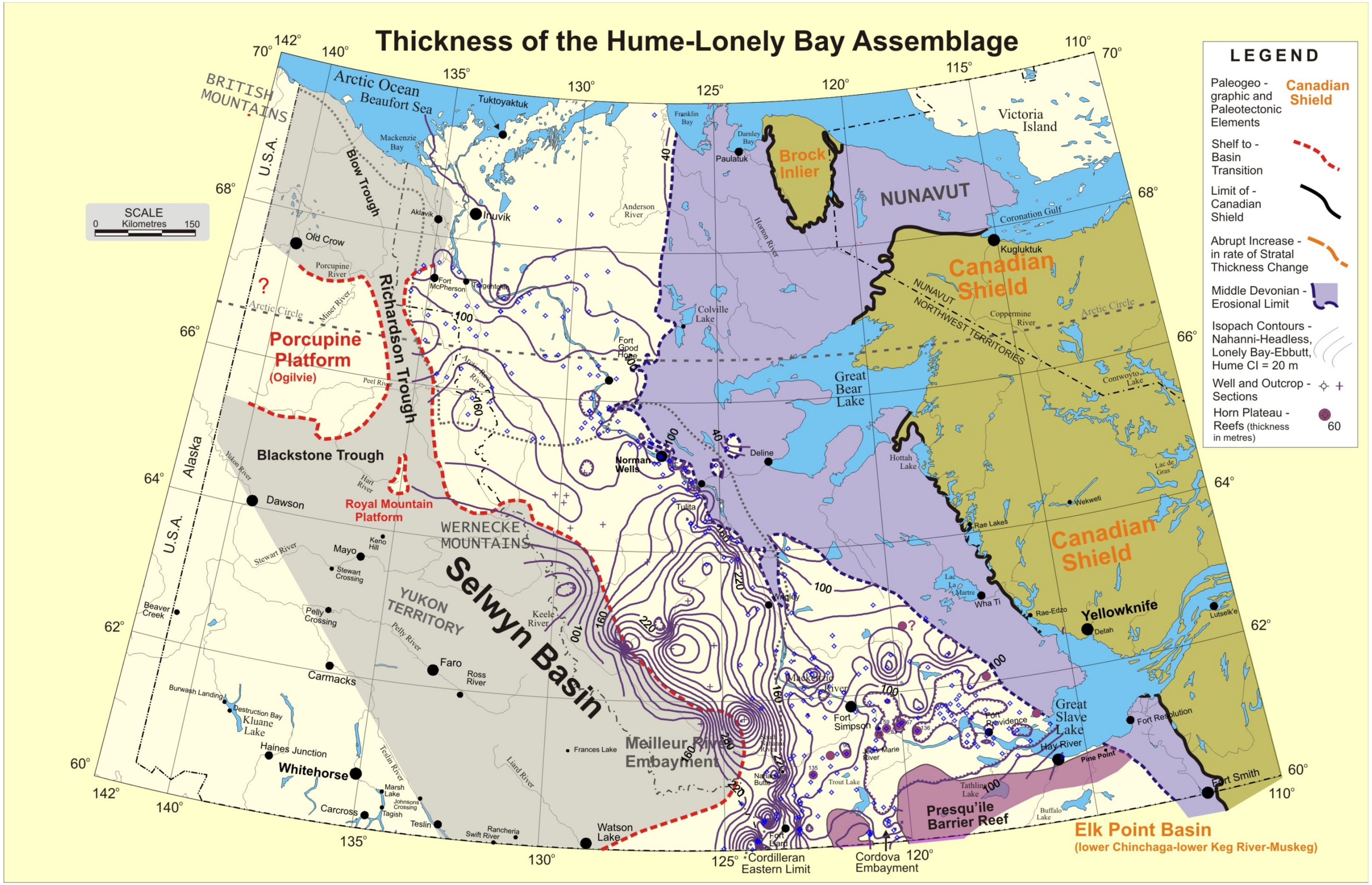

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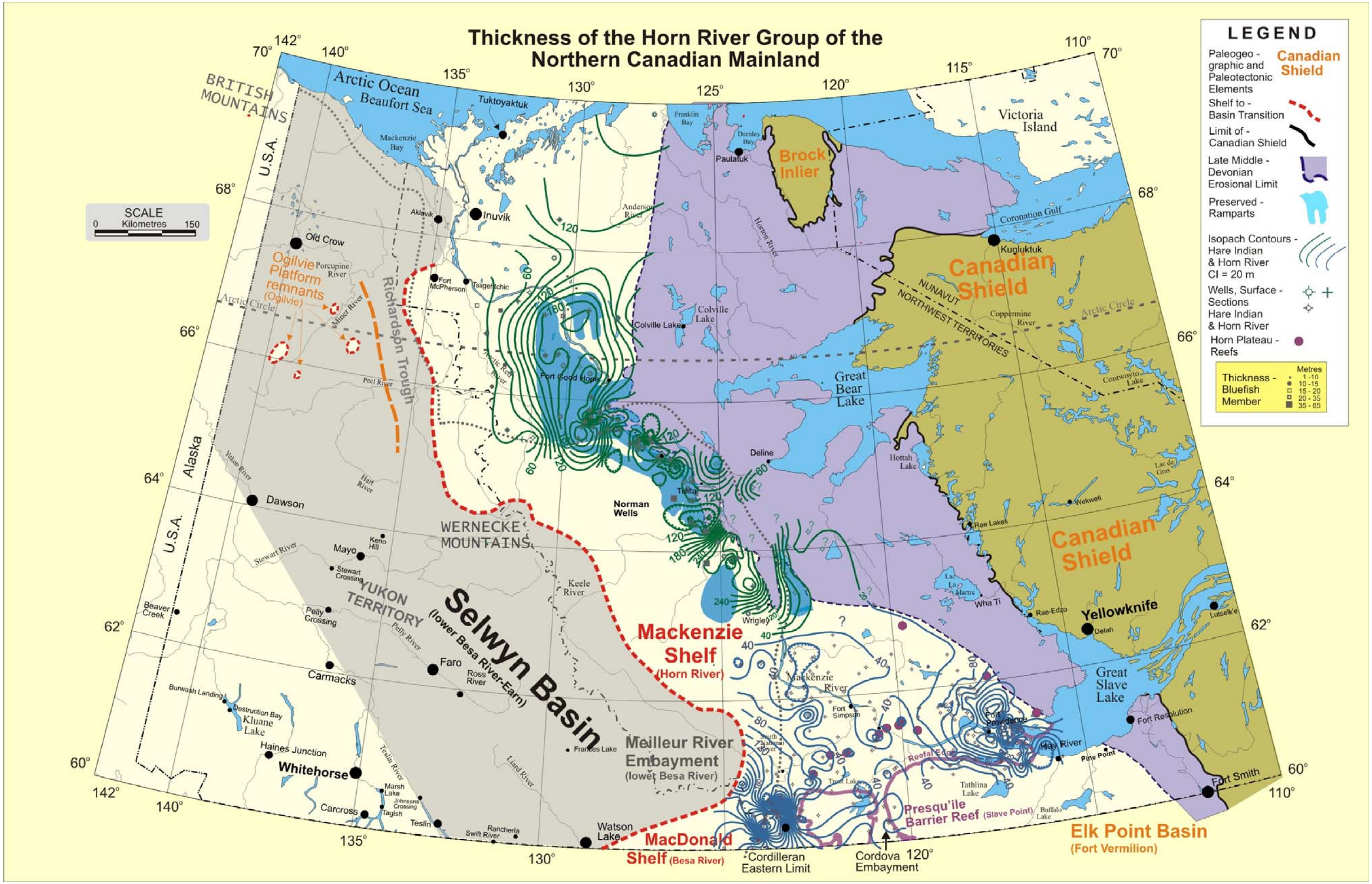

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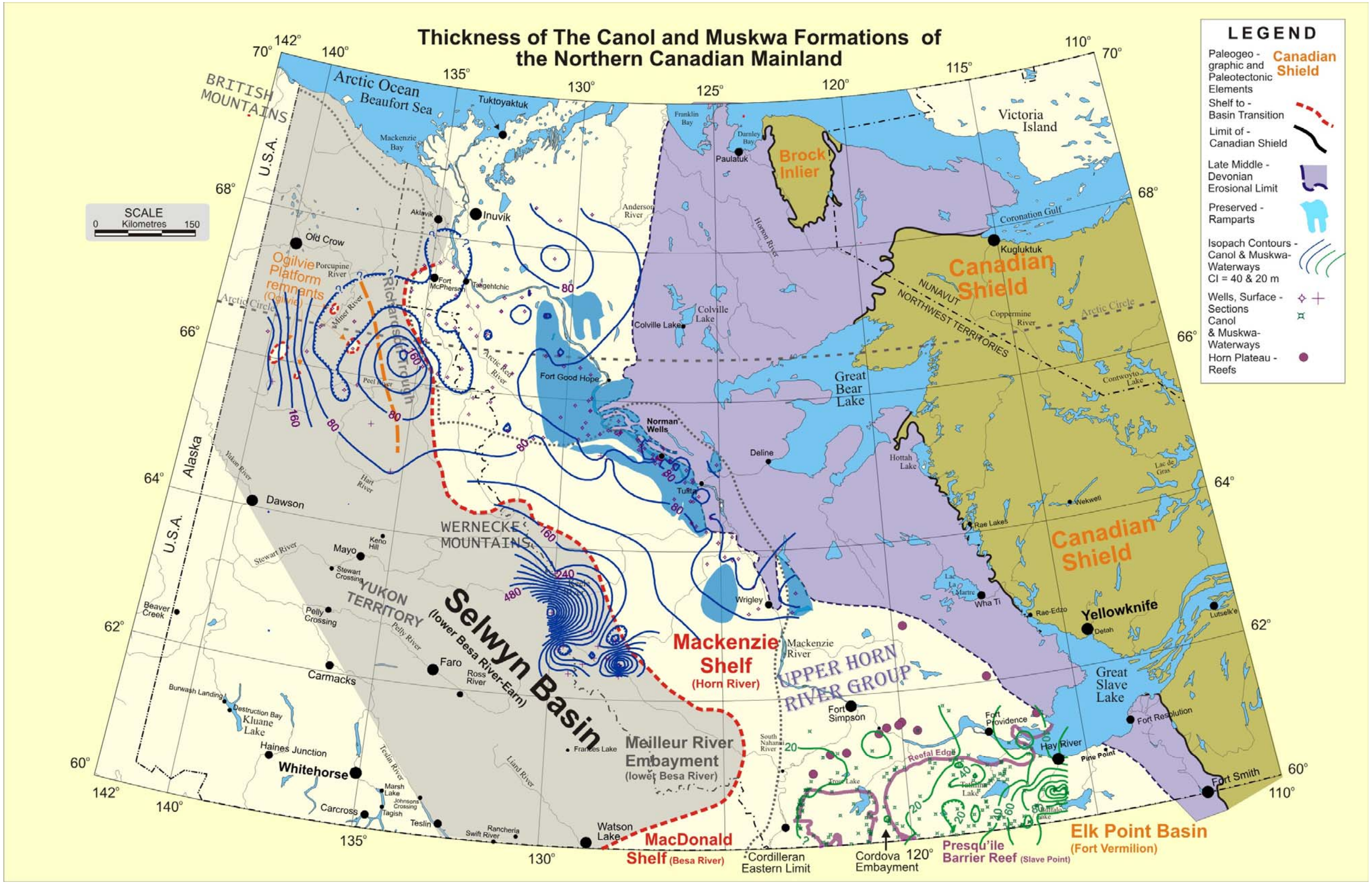

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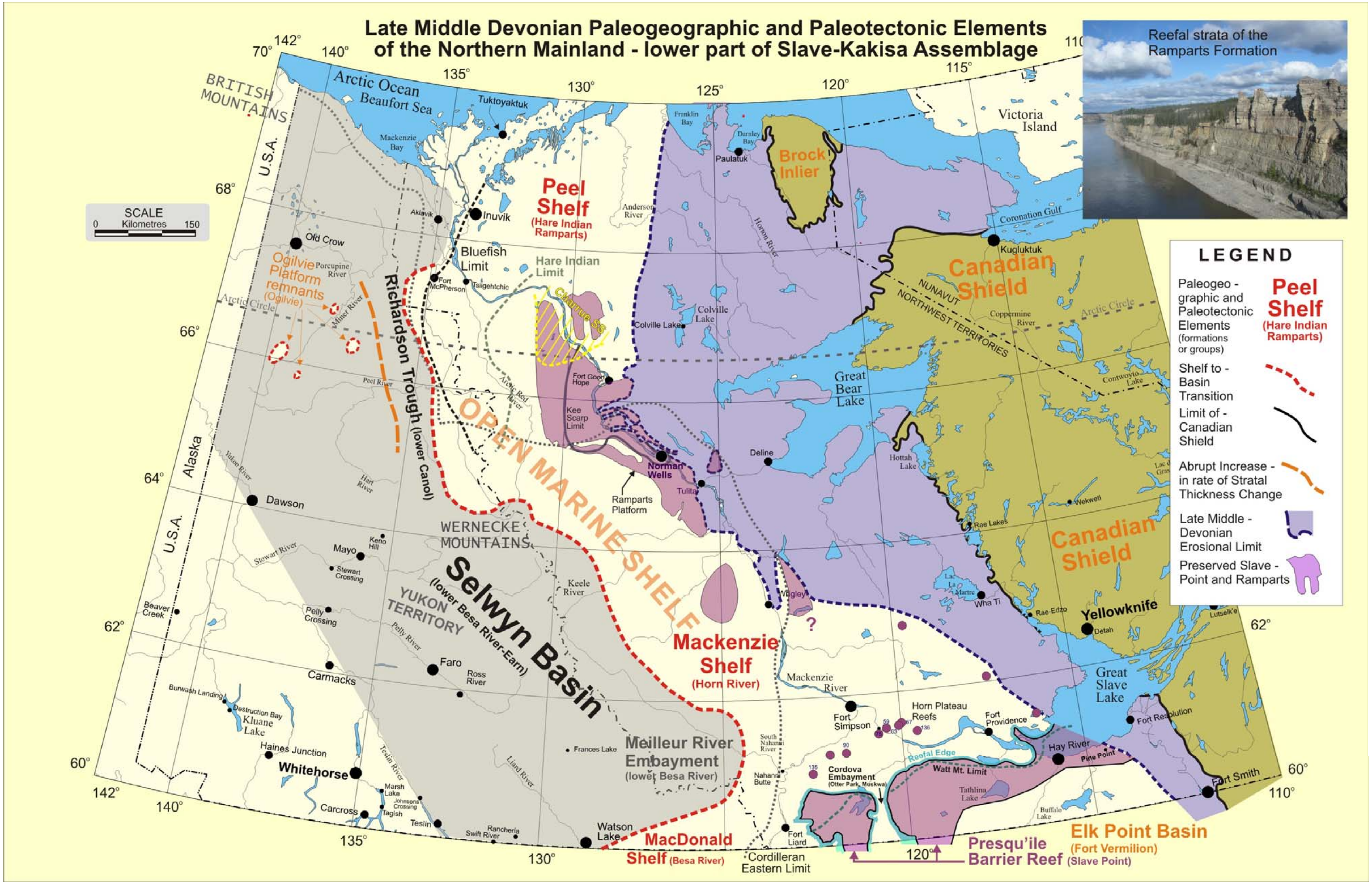

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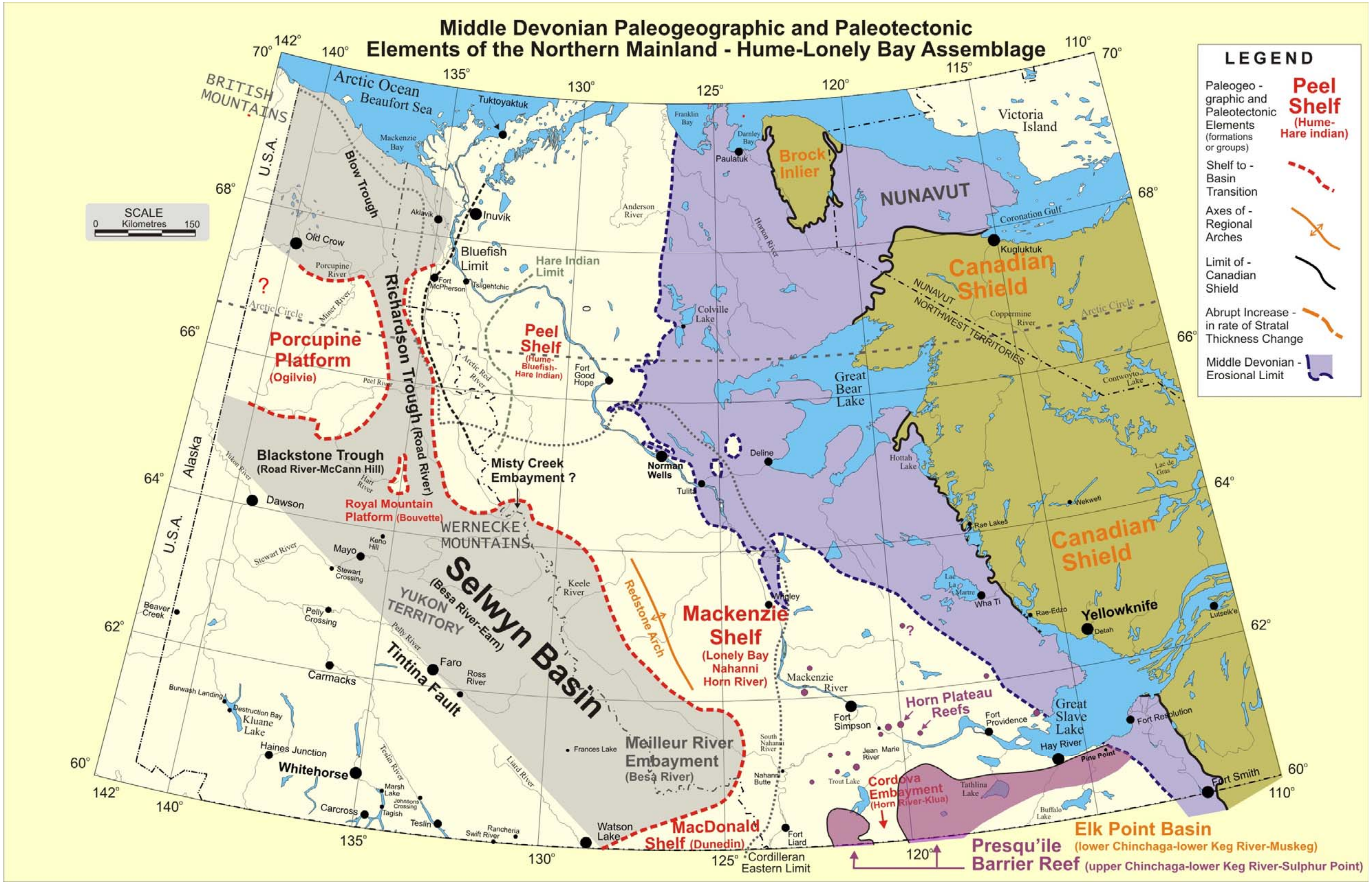

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