Central Mackenzie Valley
Geological Fieldwork 2007

NEB ID 9237-D072-002E

Devon Canada Corporation
2000, 400- 3rd Avenue S.W.
Calgary, Alberta T2P 4H2

11th August 2008

I. Introduction

The main targets for exploration on Talisman/Devon ELs 436, 437, 438, and 439 are reservoir sands contained within the Mt Clark and Mt Cap Formations. Since these formations do not come up to the surface in the area of the exploration permits, outcrop studies were focused elsewhere. Field outcrops studied in 2007 were located in the Mackenzie and Franklin Mountains, and on the south-east side of Great Bear Lake, with exposed section along riverbanks, canyons, and exposed ridgelines.

The primary objectives of the 2007 fieldwork were to review previous field work locations (2005, 2006) in order to address outstanding issues with regard to surface and subsurface correlations and gain a better understanding of the depositional environments represented by the Cambrian Mount Clark and Mount Cap formations in the region. The results and interpretation of all three field seasons are presented in this report.

II. Outline of Geological Fieldwork Program

NEB ID 9237-D072-002E
August 24-31, 2007

Area of Study:

Central Mackenzie Valley (Sahtu Settlement Area and Tlicho Settlement Area)

Operation:

Helicopter-supported geological mapping based out of Norman Wells (4 days) and Deline (4 days), N.W.T.
Review of locations visited in previous years (2005, 2006) and reconnaissance of the Cambrian succession on the south-eastern side of Great Bear Lake.

Operating Companies:

Devon Canada Corporation (W.I. 50 %), and Talisman Energy (W.I. 50%)

Field Party Participants:

Chris Bergquist
Dennis Johnston
Paddy Chesterman
Christophe Serie
Ellie MacInnes

Prime Contractor:

Sahtu Helicopters

III Results and Interpretation.

TECTONO-STRATIGRAPHIC EVOLUTION AND EXPLORATION POTENTIAL OF THE CAMBRIAN MOUNT CLARK AND MOUNT CAP FORMATIONS, NORTHWEST TERRITORIES, CANADA

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8th August 2008

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Introduction

Detailed study of Proterozoic to Cambrian stratigraphy from field work conducted by Devon Canada Corporation and Talisman Energy in 2005 (NEB ID # 9237-D031-001E), 2006 (NEB ID# 9237-D072-001E) and 2007 (this report) have helped to gain a better understanding of the depositional environments represented by the Cambrian Mount Clark and Mount Cap formations. The study area extended from the east flank of the Mackenzie Mountains to the west side of the Great Bear Plain, site of Talisman/Devon ELs 436, 437, 438, and 439 (Figure 1).

Figure 1

17 measured sections located in the Mackenzie and Franklin Mountains form the primary result of the fieldwork (Attachment). Location co-ordinates are indicated in Table 1 along with those of significant deep wells which were used to tie to the subsurface in the following interpretation. Digital versions of these sections, field notes and associated photographs can be found in Appendix 1.

Location	Name	Lat	Long
1	Inlin Brook	64.2888497	-126.5444104
2	Little Bear River	64.4791568	-126.7894765
3	Carcajou Canyon	64.6713602	-127.1613386
4	Dodo Canyon	64.8966694	-127.2522608
5	Sheep River	64.8551624	-126.9551056
6	Mirror Lake	64.8050213	-126.9745565
7 (well)	C-17	65.10028	-126.04889
8 (well)	B-62	65.184069	-125.451349
9 (well)	L-04	64.39361	-125.02861
10	Clark Mountain	64.43467530	-124.2307016
11	Blackwater Lake	64.046585	-123.45511
12	Cap Mountain	63.408714	-123.23529
13 (well)	E-11	63.672219	-123.05833
14 (well)	G-52	64.022219	-122.92
15	Fan Creek	65.16602390	-128.3584991
16	Imperial River Canyon	65.1063221	-128.0315875
17	Loretta Canyon	65.0897419	-127.9392029
18	Jennifer Canyon	65.0502582	-127.7834975
19	Graffe River	64.9926143	-127.6452914
20	Katherine Creek	64.9297967	-127.5677209
21	Pete Creek	64.9420946	-127.5736459
22	Echo Falls	64.900297	-127.3123156

Table 1: Location of measured sections and deep wells

Stratigraphy and lithofacies

2.1 Stratigraphy

The stratigraphic framework of the Cambrian succession in the Northern Interior Plains is fairly well understood from both outcrop and subsurface data. Figure 2 shows the stratigraphic division and associated trilobite biostratigraphy for the Mount Clark, Mount Cap and Saline River formations, which are described in the following paragraphs.

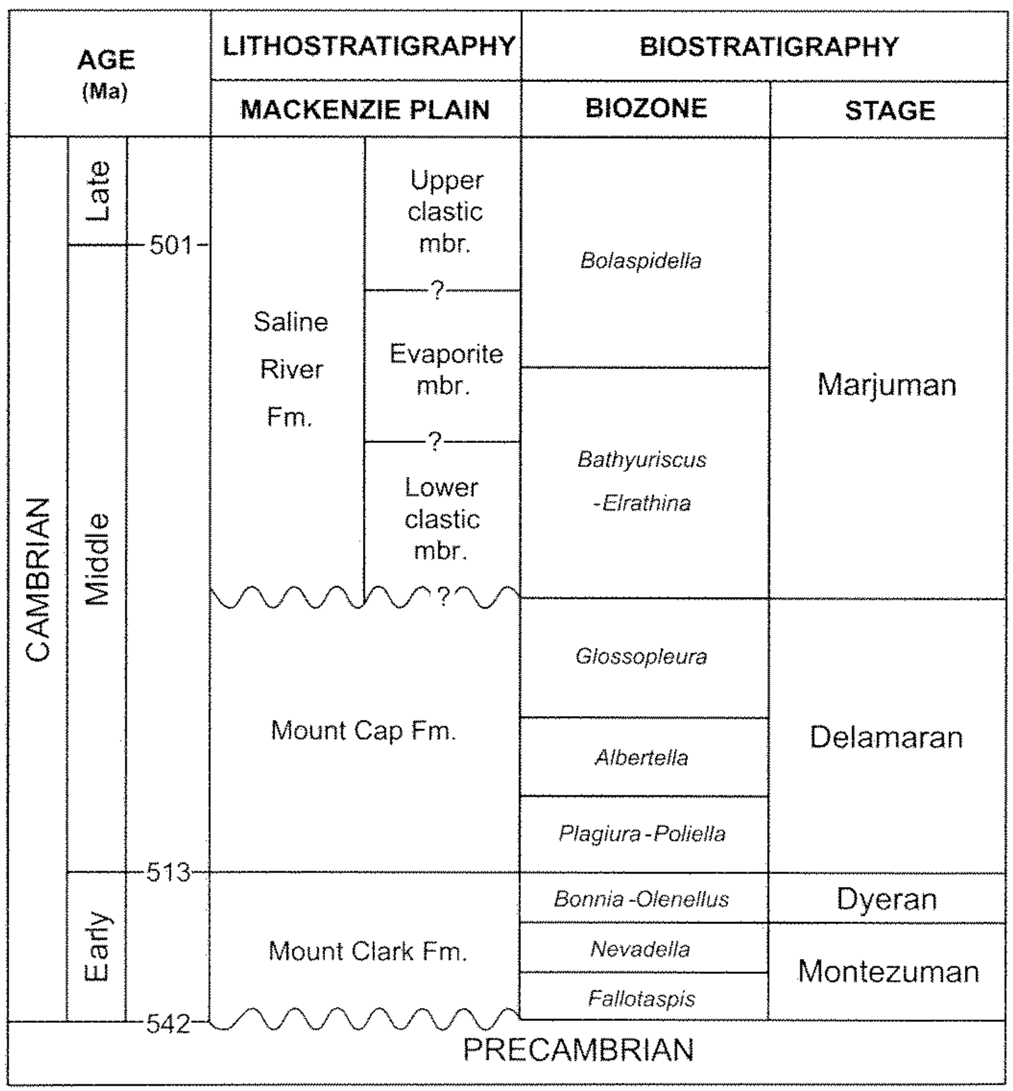

Figure 2. Table of Cambrian lithostratigraphic units and associated trilobite biostratigraphy. Time scale after Gradstein *et al.* (2004), formations after Dixon *et al.* (1998), and trilobite biostratigraphy based on the North American Cambrian stages after Ludvigsen *et al.* (1985), Palmer (1998), and Sundberg (2005).

2.1.1. Mount Clark Formation

The Mount Clark Formation, also known as the Old Fort Island Formation (Norris, 1965; Balkwill, 1971) was first defined by Williams (1922), from outcrop near Cap Mountain in the southern Franklin Mountains (Fig. 1). The defined type section consists of more than 200 m of massive, thick bedded, very fine to fine-grained quartzite, with granules and pebbles near its base, prominent cross-bedding that decreases upward, and abundant *Skolithos* burrows (Aitken *et al.*, 1973). In the subsurface, the Mount Clark Formation consists entirely of quartzose sandstone and local conglomerate with the exception of minor amounts of shale and siltstone, with a maximum known thickness of 64.3 m (Pugh, 1993). The Mount Clark Formation unconformably overlies Proterozoic and Archean rocks, and its upper contact is marked by a conformable lithological change to glauconitic sandstone, shale, and dolostone (Aitken *et al,*.1973, Pugh, 1993). The formation has been relatively dated as Early Cambrian, constrained by overlying trilobite-bearing shale and limestone units of late Early Cambrian *Bonnia-Olenellus* Zone (Aitken *et al.*,1973; Fritz, 1974). It has been suggested to be of fluvial origin (Macauley, 1987); thorough bioturbation and marine fossils, however, suggest it to be shallow marine (Hamblin,1990).

2.1.2. Mount Cap Formation

The Mount Cap Formation was defined by Williams (1922, 1923) from a succession located on the flanks of Clark Mountain in the southern Franklin Mountains (Fig. 1). The formation is made up of glauconitic sandstone, quartzose and glauconitic dolomite and limestone, and noncalcareous, sandy or silty, red, green, dark grey and black shale (Aitken *et al.*, 1973). It is up to 783 m thick in well B-62, located in the Mackenzie Plain Depocentre. The lower contact is conformable with the underlying Mount Clark Formation and unconformable with underlying Proterozoic rocks. The upper contact is characterized by an unconformable contact with the overlying Saline River Formation (Dixon, 1997; Dixon *et al.*, 1998); the scale of the unconformity, however, is poorly documented. Fossiliferous intervals containing trilobites indicate that the Mount Cap

Formation spans the lower-Middle Cambrian boundary and ranges into Middle Cambrian *Bonnia-Olenellus* to *Glossopleura* zones (Aitken *et al.*, 1973; Fritz, 1970, 1971). It is suggested to have been deposited in a low energy marine setting based on extensive bioturbation, carbonate lithologies, and shelly material (Dixon *et al.*,1998).

2.1.3. Saline River Formation

The Saline River Formation was first described by Williams (1923) with the occurrence of red and green shale with salt casts and gypsum beds. The formation was later divided into three members, the Lower Clastic member, Evaporite member and Upper Clastic member (Meijer Drees, 1975). The Evaporite member mainly consists of salt with interbedded shale, dolostone and anhydrite, whereas the two clastic members consist of interbedded shale, dolostone, and anhydrite. It is suggested to have been deposited in a restricted marine basin, with evaporates formed under subtidal conditions in relatively shallow water (Meijer Drees, 1986; Dixon *et al.*, 1998).

2.2 Description of Mount Clark and Mount Cap Lithofacies

Facies associations have been defined from detailed studies of 17 sections and 5 wells. Twelve facies associations were distinguished based on lithology, bed geometry and facies successions. Their main characteristics and interpreted depositional environments are summarised in Table 2 below.

Facies Association (FA)	Unit description	Grain size, bedding and structures	Interpretation
Clastic dominated			
FA 1 Cross-bedded sandstone and conglomerate	Pink, weathers purple, conglomeratic, down-cutting channels fills, grading into cross-bedded, fine to coarse grained sandstone; units 0.5-34.0 m thick	Fine to coarse sand, with some granules and pebbles, cross-bedded with high angle cross-beds and intersecting planar cross-beds, 5-40 cm thick beds, dune cross-bedded, accretion surfaces, ripples marks, indication of unidirectional flow, occasionally well cemented, non-bioturbated	Fluvial system

Facies Association (FA)	Unit description	Grain size, bedding and structures	Interpretation
FA 2 Sandstone	Light pink to white sandstone, weathers buff, with occasional coarse grains and granules at base, blocky to lens shape bedforms; units 1-10 m thick	Fine to medium sand, with coarse grains to granules at base, fining upwards, thin to thick bedded with beds up to 20-60 cm thick, with mud-clast layers, bi-directional low angle cross-bedding, bioturbated	Estuarine or tidal flat setting with distributary channels and sand flats
FA 3 Varicoloured shale and siltstone	Greenish grey to red, finely laminated, bioturbated shale and siltstone, occasionally dolomitic toward the top; units 2.0-10.0 m thick	Mud to fine silt, planar bedded with 5-25 cm bed-sets, finely laminated, extensively mud-cracked, salt casts, occasional gutter casts filled with fine sand, rippled thin-bedded siltstones, mottled shale, horizontal bioturbation	Intertidal flat setting
FA 4 Bright green shale and sandstone	Bright green, weathers green, glauconitic, cross bedded, medium to coarse grain sandstone, bioturbated; units 0.5-10.0 m thick	Medium to coarse grained sand, cross bedded, glauconitic, with occasional pyrite crystals, fossiliferous horizons, occasional hardground surfaces, bioturbated	Transgressive lag or condensed section
FA 5 *Skolithos* sandstone	Light grey to buff sandstone, massive, heavily bioturbated (*Skolithos)*, glauconitic; units 13.5-110.0 m thick.	Very fine to medium sand, massive, thin to thick bedded, occasionally irregular to planar bedded, with swaly cross-stratification glauconitic, heavily bioturbated, with horizontal burrows	Shoreface to lower shoreface and wave dominated delta
FA 6 Siltstone and dolomitic siltstone	Light grey to green siltstone, weathers orange to buff; occasionally interbedded with shale and very fine sandstone, progressively more dolomitic upwards; units 3.0-19.5m thick	Fine to coarse silt, thin bedded, with occasional interbedded mud and fine sand, finely laminated, occasionally flaggy, nodular, load casts with occasional ripple marks and stromatolitic laminations, moderately to heavily bioturbated	Shallow shelf to slope setting.

Facies Association (FA)	Unit description	Grain size, bedding and structures	Interpretation
FA 7 Graded sandstone	Grey, light green to white, weathers orange, with conglomeratic channel base, graded, glauconitic sandstone, fining upward, and occasionally interbedded with bioturbated, fine grained sandstone and siltstone; units 1.5 to 32.0 m thick	Very fine to coarse sand, with occasional coarse to cobble conglomerate, glauconitic, massive, thin to thick bedded varying from 5-40cm thick, generally fining upwards, trough cross-bedded, accretion surfaces, ripple marks, graded or inversely graded sand package	Upper turbidite fan complex or channel
FA 8 Heterolithic	Grey , weathers orange, fine sandstone, siltstone, and occasional shale, ; units 2-8m thick	Silt to fine sand, with occasional mud, and occasional pebbles, flat bedded, occasionally down-cutting, with 10 cm thick beds parallel lamination, bioturbated	Middle to lower turbidite fan complex or levee
FA 9 Shale	Recessive shale, black to dark grey, occasionally greenish, thin bedded with rare thin interbbeds of dolosiltstone, dolomite and dolomitic limestone; units 1-49 m thick	Mud to very fine silt, laminated, some beds contain abundant trilobites and brachiopods .	Open marine shale
Carbonate dominated			
FA 10 Stromatolitic dolostone	Dark grey, weathers buff greyish orange, dolostone with stromatolitic layering; units 2-3 m thick.	Finely crystalline, calcareous, argillaceous, very thin to thin bedded, with stromatolitic layering, and minor interbeds of shale and dolomitic siltstone.	Shallow subtidal carbonate shelf
FA 11 Interbedded limestone and sandstone	Greyish olive-green limestone, interbedded with sandstone, weathers rusty yellow orange, with minor interbeds of shale; unit 20 m thick	Micritic, dolomitic, argillaceous limestone, interbedded with fine to medium sand, thin bedded. Upper 4 m contains trilobite fragments and abundant glauconitic grains, associated with pyrite euhedra	Shallow carbonate shelf

Facies Association (FA)	Unit description	Grain size, bedding and structures	Interpretation
FA 12 Dolostone and dolomitic limestone	Dark grey, weathers rusty yellowish orange, light to medium grey, weathers rusty medium grey to yellowish brown, generally occurring with FA 9 (black shale); units 1-12m	Finely to medium crystalline, with occasional floating fine to coarse grained sand, generally thin bedded in 0.15-0.3 m thick sets with minor interbedded shale and fine grained silt	Open marine carbonate

Table 2. Description and interpretation of both clastic and carbonate dominated facies associations of the Mount Clark and Mount Cap formations, from detailed measured outcrops

Interpretation of Stratigraphy and Tectonic Evolution

3.1 Lithofacies correlation and sequence stratigraphy.

Surface to subsurface correlations of the Cambrian succession are illustrated in four cross sections (Fig. 3, 4, 5, 6). Correlations were derived from integrating facies associations, basin paleotopography, trilobite biostratigraphy (Fritz, 1970, 1973; and Ludvigsen, pers. comm. 2008) (Appendix 2), and the application of sequence stratigraphic concepts (Van Wagoner *et al.*, 1988, and Posamentier *et al.*, 1988).

The lower contact of the Cambrian succession is an unconformity. This surface is seismically interpreted as a regional angular unconformity, and from outcrop, the sequence boundary is locally associated with downcutting fluvial channel (FA 1) and subaerial exposure. The abrupt contact of the Mount Cap Formation and overlying Saline River Formation is also interpreted as a sequence boundary and described as a regional erosional surface (Dixon *et al.*, 1998), although in the present study this surface was obscured by scree cover.

The internal correlation of the Cambrian succession will be detailed through the description of the following four cross sections:

Cross section AA' (Fig. 3) illustrates a west-east regional transect across the Mackenzie Plain Depocentre. This transect shows a fault-bounded half-graben with clear thickening from the Mackenzie Arch toward the basin centre. Within the half-graben, the basin topography is characterized by a series of smaller grabens and half-grabens. These paleotopographic lows are filled with fluvial facies (FA 1), followed by an upward transition into shoreface to lower shoreface facies (FA 5). This deepening upward cycle is also associated with landward facies shift and the development of more distal shallow carbonate shelf with mixed siliciclastic facies (FA 11). This succession is characteristic of a transgressive system tract (TST) associated with the onset of a coastal transgression.
The lower part of a transgressive system tract is typically bounded by a transgressive surface (TS), or is associated with the lower sequence boundary (SB) in the absence of a lowstand system tract. The absence of the lowstand system tract is probably linked to the initial flooding of the basin after a long lived unconformity at the pre-Cambrian boundary, or alternatively, the lower fluvial facies (FA 1) may represent a lowstand system tract.
Continuous flooding of the basin and subsequent facies backstepping resulted in landward sediment accumulation and consequent low rates of sedimentation in a seaward position. Low rates of sedimentation are associated with marine condensed sections (FA 4) and may even produce a marine hiatus (Loutit *et al.*, 1998). This surface of maximum landward flooding with seaward condensed sections can be described as a maximum flooding surface (MFS). The presence of trilobites from the *Olenellus* Zone (Dyeran Stage), suggests a maximum flooding in the late Early Cambrian.
This maximum flooding surface is then overlain by turbidite fan complexes with upper fan (FA 7) and middle to lower fan facies (FA 8). This sharp change in sedimentation rate is likely to be related to an intermediate highstand system tract (HST), with prograding shoreface (FA 5) and estuarine facies (FA 2), enhancing sediment bypass to the slope and basin center, with the development of turbidite fan complexes downslope (FA 7, 8). Progradation of proximal facies (FA 2, 5) may be linked to a decrease in accommodation space, either associated with a period of relative low subsidence or a rate of sediment accumulation that exceeded the rate of relative sea level rise, or the combined affect of these two factors.

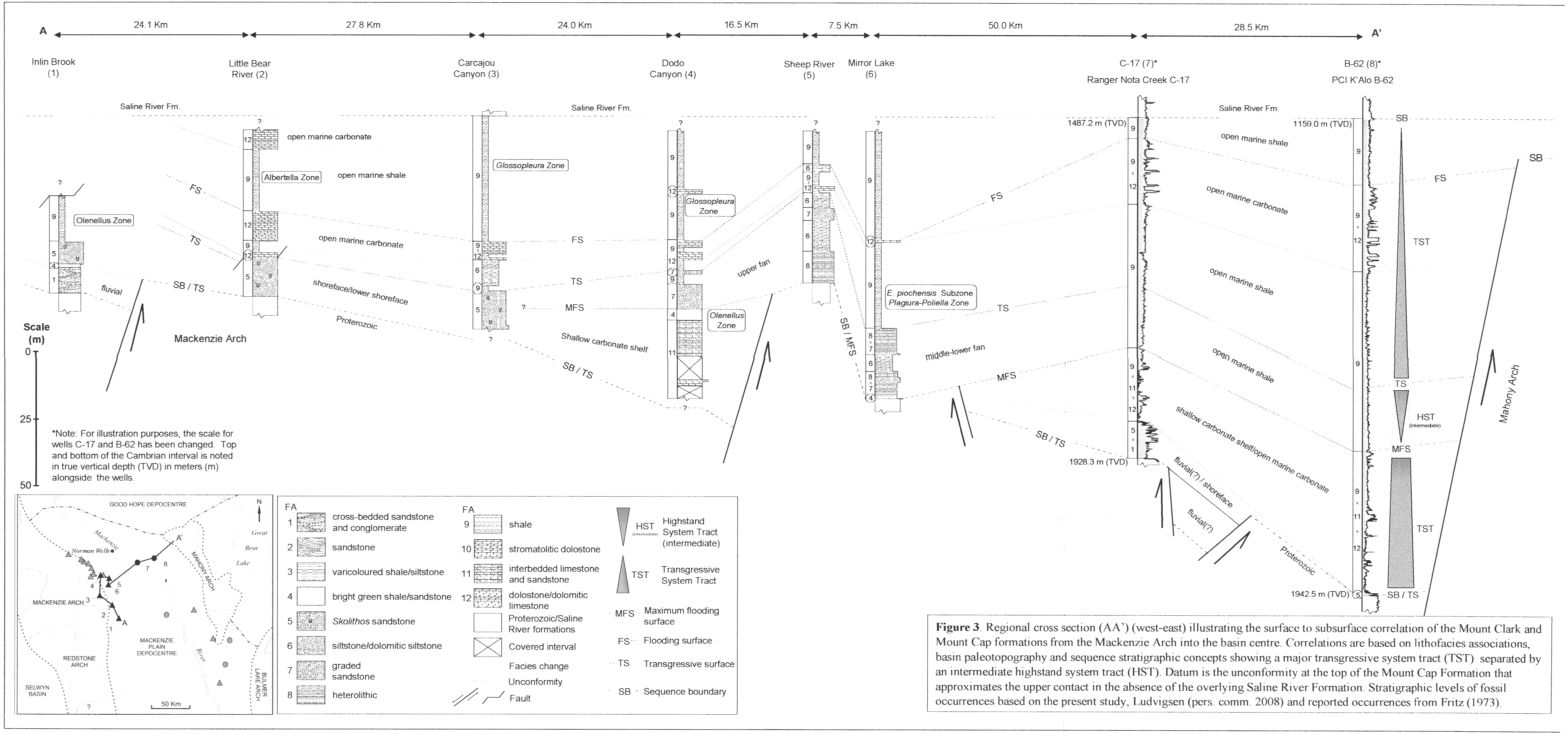

Figure 3. Regional cross section (AA') (west-east) illustrating the surface to subsurface correlation of the Mount Clark and Mount Cap formations from the Mackenzie Arch into the basin centre. Correlations are based on lithofacies associations, basin paleotopography and sequence stratigraphic concepts showing a major transgressive system tract (TST) separated by an intermediate highstand system tract (HST). Datum is the unconformity at the top of the Mount Cap Formation that approximates the upper contact in the absence of the overlying Saline River Formation. Stratigraphic levels of fossil occurrences based on the present study, Ludvigsen (pers. comm. 2008) and reported occurrences from Fritz (1973).

The upper marine shale (FA 9) and open marine carbonates facies (FA 12) suggest a deepening event in response to a renewed marine transgression. This renewed transgressive system tract is internally characterized by shale-to-carbonate cycles of varying thickness. Dixon *et al.* (1998) also noted those alternating cycles and interpreted them as shallowing-upward parasequences, representing periods of sedimentation starting with a transgression and deepening event, followed by progressive shoaling as sediment prograded and agraded, and abruptly terminated by another transgressive/deepening event, represented by a flooding surface (FS). This upper transgressive system tract is relatively dated as early Middle to Middle Cambrian, with the presence of trilobites ranging from the *E. piochensis* subzone of the *Plagiura-Poliella* Zone (Basal Delamaran Stage) to the *Glossopleura* Zone (Late Delamaran Stage).

Cross section BB' (Fig. 4) illustrates a regional transect from the basin centre east to the Blackwater graben which separates the Bulmer Lake Arch from the Mahony Arch. Along this transect, the Cambrian succession mainly consists of proximal wave-dominated delta front and shoreface facies (FA 5), with a seaward transition into more distal facies with interbedded thin sandtstone, siltstone and shale (FA 5, 6, 9), and an upward transition into shallow and open marine carbonates facies (FA 11, 12). In the upper carbonates, the presence of trilobites from the *Olenellus* Zone (Dyeran Stage), suggests that this transgressive succession is age correlative with the lower transgressive system tract observed in cross section AA'.

This lower transgressive system tract is directly overlain by the upper transgressive system tract containing distinctive alternating shale to carbonates cycles (FA 9, 12) of Middle Cambrian age, (*Glossopleura* Zone, Late Delamaran Stage). The apparent absence of the intermediate highstand system tract separating the lower and upper transgressive system tract may be related only to a lack of well and outcrop control, with a minimum correlation distance greater than 30.0 km, and some missing Cambrian succession, related either to erosion or penetration depth (i.e., Clark Mountain and L-04).

Cross section CC' (Fig. 5) represents a more detailed transect along the length of a small, northwest-southeast trending half-graben, characteristic of the early basin topography.

Similarly to cross section AA', the transgressive system tract is characterized by backstepping facies; however, this transect illustrates a more progressive transition from fluvial (FA 1), to tidal flat and estuarine (FA 2), into upper shallow subtidal carbonate facies (FA 10), and basinward transition into shallow carbonate shelf (FA 11).
The transition from fluvial (FA 1) to estuarine facies (FA 2) is sometimes associated with a transgressive lag (FA 4). This may suggest different stages of transgression and the presence of numerous parasequences, although a more refined stratigraphic interpretation is precluded by our current database. The turbidite fan complexes associated with the intermediate highstand system tract are thinning in a basinward direction.

Cross section DD' (Fig. 6) represents a lateral cross section of the above half graben, and shows thickening of turbidite fan complexes in the deeper part of the half-graben. Those turbidite fan complexes may have overfilled paleotopographic lows and spread over basin paleotopographic highs as suggested on this cross section. The upper transgressive system tract consists of more proximal facies, with shelf dolomitic siltstone (FA 6), but is time equivalent to the distal shale-to carbonate cycles based on trilobites from the *Albertella* Zone (Early Delamaran Stage).

3.2 Basin Evolution

A series of depositional models have been constructed in order to illustrate the evolution of the Mackenzie Plain Depocentre during the Early to Middle Cambrian; relative ages are based on trilobite biostratigraphy (Fritz, 1970, 1973; and Ludvigsen, pers. comm. 2008).

3.2.1 Early Cambrian

In the Early Cambrian (Fig. 7), the Mackenzie Plain Depocentre was dominated by fluvial systems, a wave-dominated delta (i.e., Mount Clark Formation), tidal flats, and a shallow carbonate shelf opening onto an open marine carbonate shelf to the southwest (i.e., Mount Cap Formation).

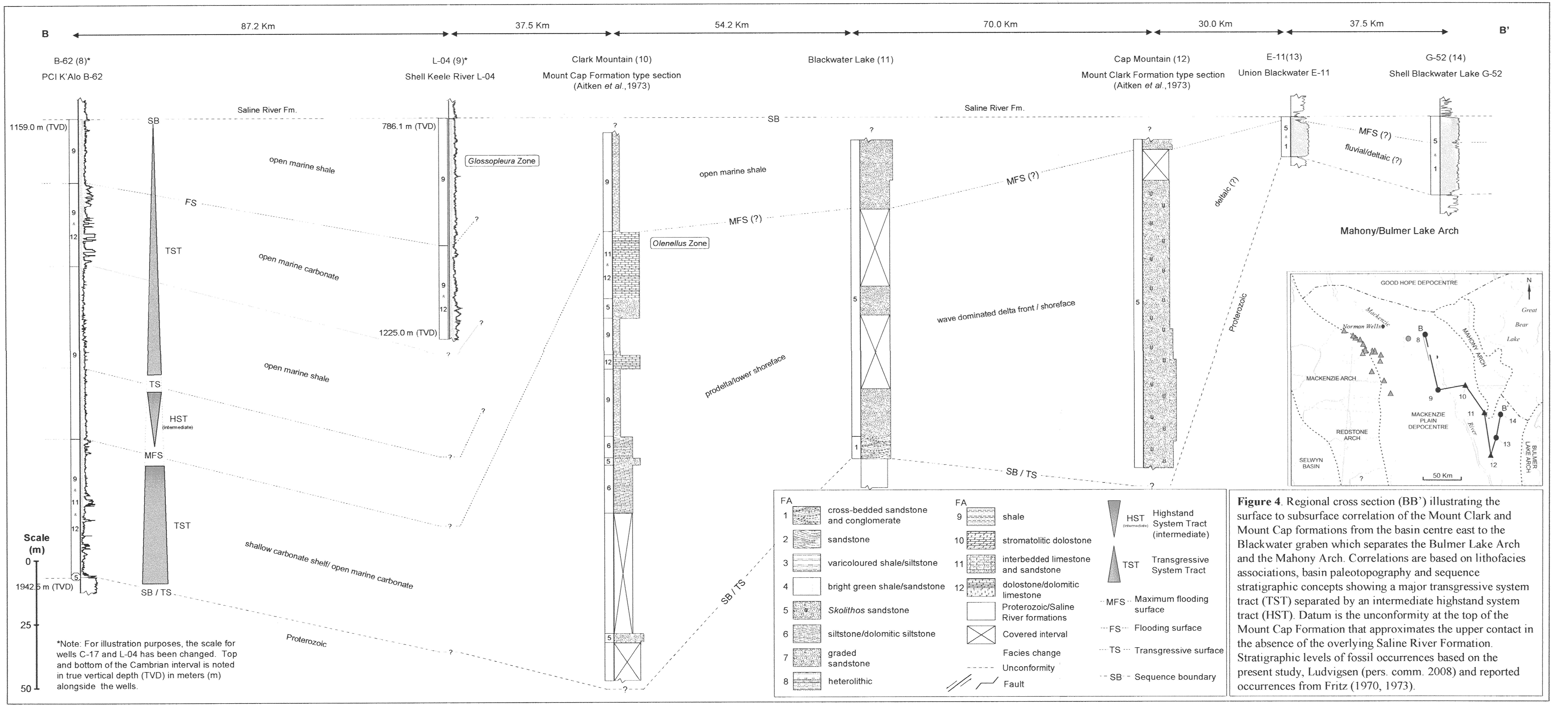

Figure 4. Regional cross section (BB') illustrating the surface to subsurface correlation of the Mount Clark and Mount Cap formations from the basin centre east to the Blackwater graben which separates the Bulmer Lake Arch and the Mahony Arch. Correlations are based on lithofacies associations, basin paleotopography and sequence stratigraphic concepts showing a major transgressive system tract (TST) separated by an intermediate highstand system tract (HST). Datum is the unconformity at the top of the Mount Cap Formation that approximates the upper contact in the absence of the overlying Saline River Formation. Stratigraphic levels of fossil occurrences based on the present study, Ludvigsen (pers. comm. 2008) and reported occurrences from Fritz (1970, 1973).

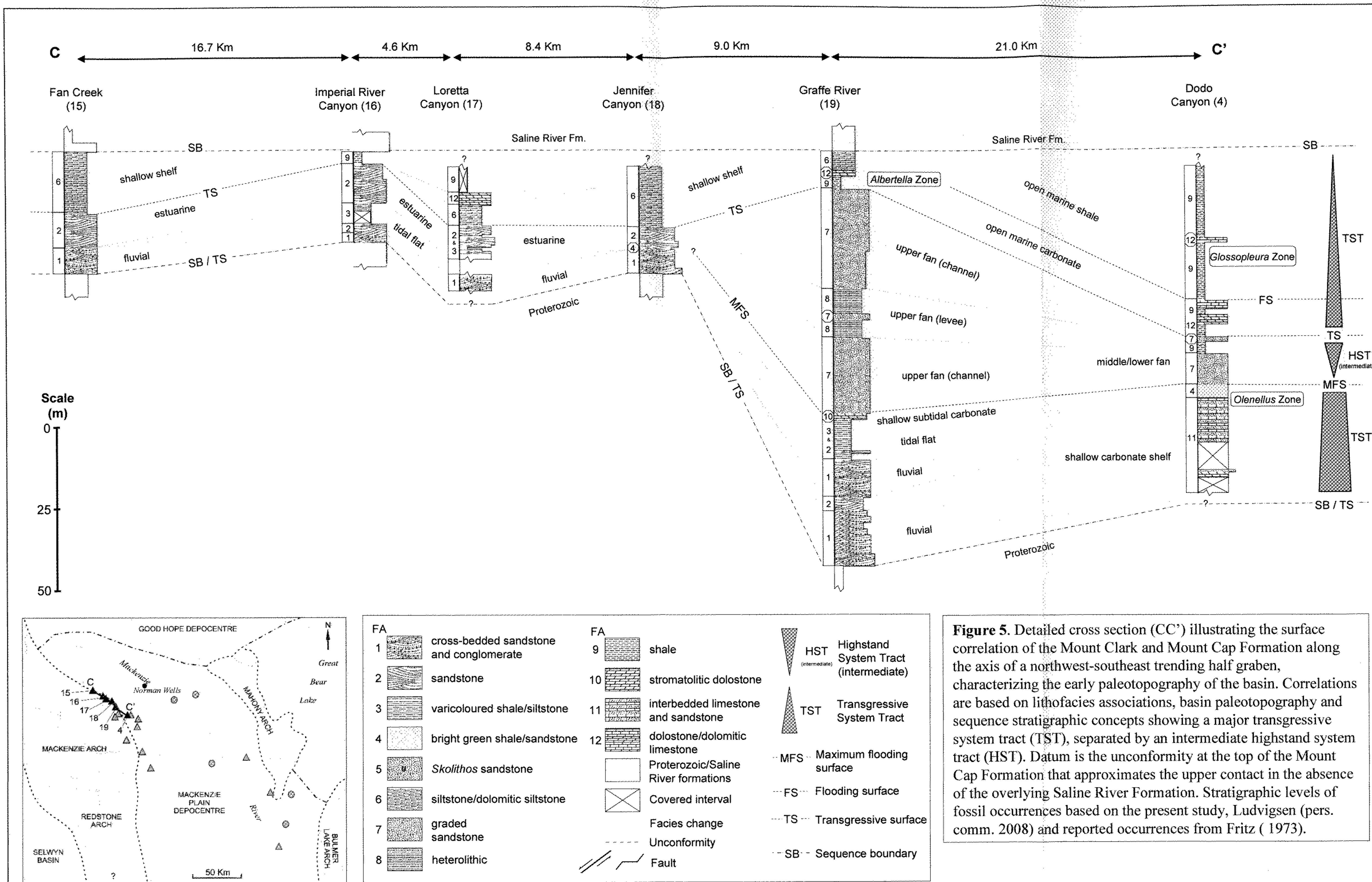

Figure 5. Detailed cross section (CC') illustrating the surface correlation of the Mount Clark and Mount Cap Formation along the axis of a northwest-southeast trending half graben, characterizing the early paleotopography of the basin. Correlations are based on lithofacies associations, basin paleotopography and sequence stratigraphic concepts showing a major transgressive system tract (TST), separated by an intermediate highstand system tract (HST). Datum is the unconformity at the top of the Mount Cap Formation that approximates the upper contact in the absence of the overlying Saline River Formation. Stratigraphic levels of fossil occurrences based on the present study, Ludvigsen (pers. comm. 2008) and reported occurrences from Fritz (1973).

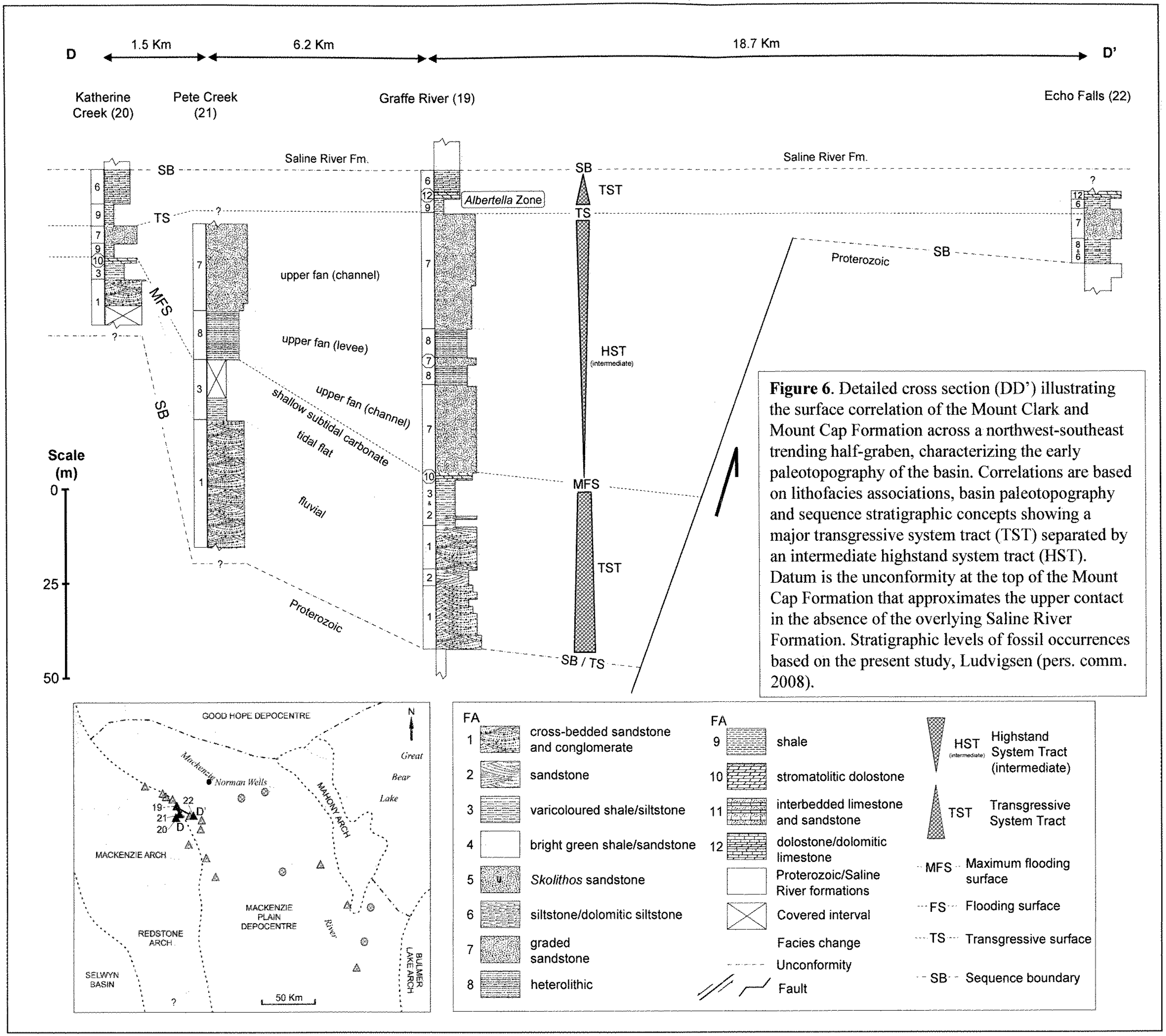

Figure 6. Detailed cross section (DD') illustrating the surface correlation of the Mount Clark and Mount Cap Formation across a northwest-southeast trending half-graben, characterizing the early paleotopography of the basin. Correlations are based on lithofacies associations, basin paleotopography and sequence stratigraphic concepts showing a major transgressive system tract (TST) separated by an intermediate highstand system tract (HST). Datum is the unconformity at the top of the Mount Cap Formation that approximates the upper contact in the absence of the overlying Saline River Formation. Stratigraphic levels of fossil occurrences based on the present study, Ludvigsen (pers. comm. 2008).

Sediments shed off nearby paleohighs were subsequently deposited in lows on the Precambrian unconformity surface, and along northwest-southeast trending graben and half-graben structures related to a possible early stage of basin extension and subsidence. These grabens and half grabens were the locus of fluvial systems feeding sediment to tidal flats and wave-dominated deltas, with most sediments deposited along the paleoshoreline. Siliciclastics may have been transported onto distal carbonate shelves during storm events.

The presence of thick, massive wave-dominated delta successions on the eastern side of the basin strongly suggests the presence of a large fluvial system draining from the Canadian Shield. This assumption is supported by the occurrence of fluvial strata within the Old Fort Island Formation in the La Martre Depocentre (Balkwill, 1971). The Blackwater graben, cutting through the Bulmer Lake Arch and the Mahony Arch (Aspler *et al.*, 2003; MacLean *et al.*, 2002), is likely to have acted as a sediment bypass from the La Martre Depocentre to the Mackenzie Plain Depocentre.

Continuous transgression associated with global sea level rise, as well as local extensional tectonics and basin subsidence resulted in major flooding of the basin. This major flooding was characterized by an important landward shift of sediment accumulation and subsequent basin starvation.

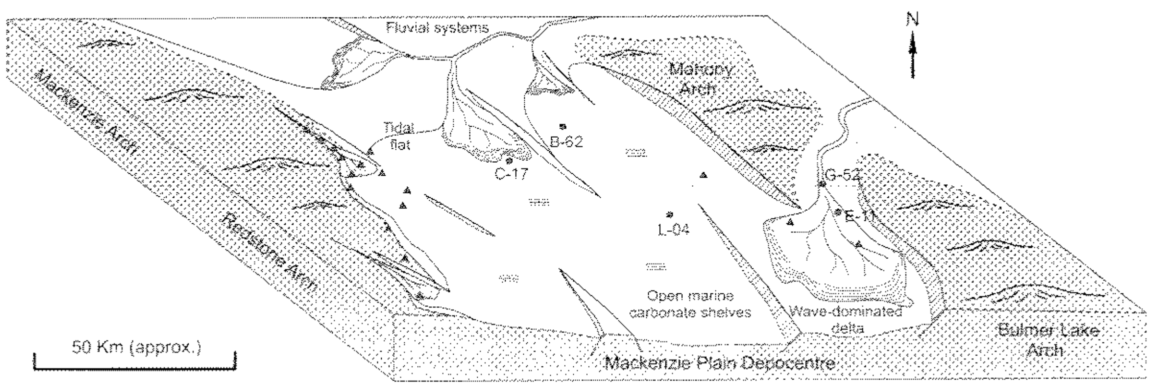

Figure 7. Early Cambrian paleogeographic reconstruction of the Mackenzie Plain Depocentre with surrounding paleohighs, nearby depocentres, and approximate locations of measured outcrops (▲) and wells (●); showing the structurally controlled distribution of fluvial systems, wave-dominated delta, and more distal open marine carbonate shelves developed during the onset of the Cambrian transgression.

3.2.2 Early-Middle Cambrian

Continuous flooding of the basin was interrupted by an intermediate regression, with delta, shoreface and estuarine facies prograding onto the shelf (i.e., Mount Clark Formation) (Fig. 8). Progradation may be linked to a decrease in accommodation space, and/or associated with a period of relative low subsidence or increasing rate of sediment supply exceeding the rate of relative sea level rise. Increasing sedimentation rates may have been enhanced by erosion of uplifted margins related to the early phase of local extensional tectonics and subsidence, and associated changes in slope gradient.

Progradation resulted in sediment bypass onto the shelf, with sediment funneling down early half graben structures and the subsequent development of turbidite complexes downslope (i.e., Mount Cap Formation)(Fig.8). These early features contain proximal stacked channels, characteristic of an upper fan complex which thins out into interbedded sand and siltstone of the mid to lower fan complex. Over time, these turbidite fan complexes may have spread over the surrounding basin paleohighs.

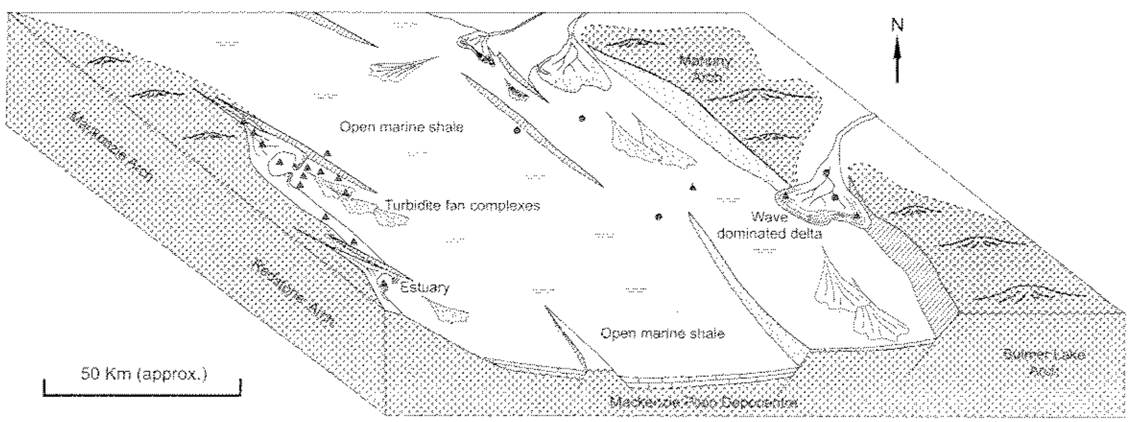

Figure 8. Early-Middle Cambrian paleogeographic reconstruction of the Mackenzie Plain Depocentre with surrounding paleohighs, nearby depocentres, and approximate locations of measured outcrops (▲) and wells (●); illustrating the continuous flooding of the basin, with the development on estuarine settings, although an increase in sediment supply or decrease in accommodation space resulted in sediment bypass to the shelf and subsequent downslope development of turbidite fan complexes.

3.2.3 Middle Cambrian

Renewed transgression, probably linked to low sediment supply and continuous eustatic sea level rise, resulted in the development of open marine conditions with alternating shale to carbonate cycles (i.e., Mount Cap Formation) (Fig. 9).

The absence of proximal facies and the relatively abundant fine sediment suggests flooding of previously eroded paleotopographic highs, such as the Mackenzie and the Redstone arches. This maximum flooding may suggest a possible connection with the Selwyn Basin to the west (Handfield, 1968), similar to the flooding of the Peel Arch which connected the Richardson Trough to the Good Hope Depocentre (Pugh, 1983).

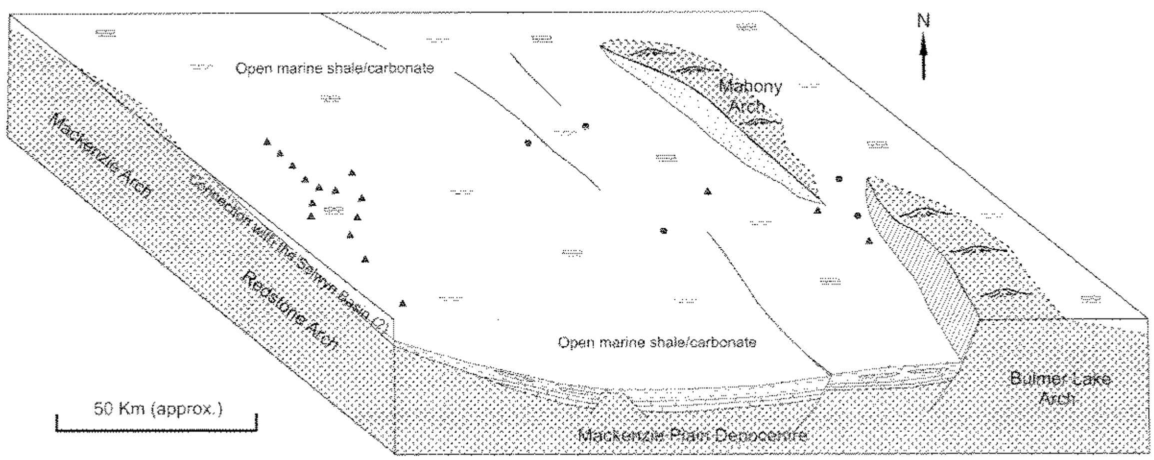

Figure 9. Middle Cambrian paleogeographic reconstruction of the Mackenzie Plain Depocentre with surrounding paleohighs, nearby depocentres, and approximate locations of measured outcrops (▲) and wells (●); illustrating renewed transgression associated with low sediment supply and continuous sea level rise which flooded most of the paleohighs and was characterized by alternating shale to carbonate cycles.

In the late Middle Cambrian, reactivation of submerged paleohighs probably caused erosion of previously deposited strata and subsequent reworking into the Lower Clastic member of the Saline River Formation. This erosion may explain the absence or thinning of Mount Clark and Mount Cap formations onto the arches, as well as the unconformable basal contact of the Saline River Formation (Dixon *et al.*, 1998). Pugh (1993) also suggests that the uplift may have provided a restricted setting, with consequent development of hypersaline marine conditions, characterized by the thick salt deposits of the Evaporite member.

The basin evolution of the Mackenzie Plain Depocentre during the Cambrian is summarized in Figure 10. The correlations illustrate the time equivalence of Mount Cap carbonates and Mount Clark fluvial and marine sandstones, suggesting that the Mount Cap Formation is Early to Middle Cambrian in age rather than just Middle Cambrian. These new correlations indicate the diachronous nature of the Mount Clark and Mount Cap formations.

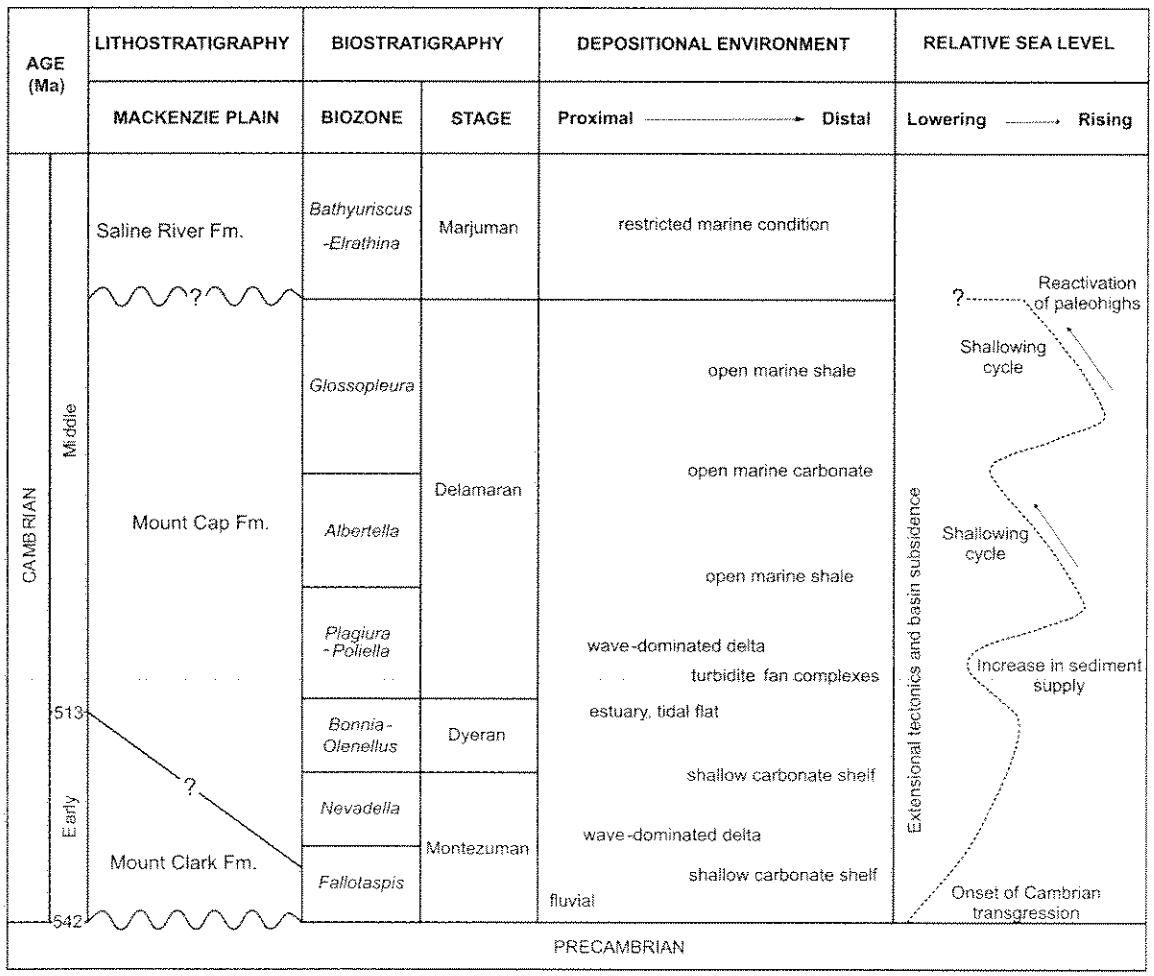

Figure 10. Cambrian basin evolution summary of the Mackenzie Plain Depocentre with associated depositional setting and a relative sea level curve based on the present study. Time scale after Gradstein *et al.* (2004) and trilobite biostratigraphy based on the North American Cambrian stages after Ludvigsen *et al.* (1985), Palmer (1998) and Sundberg, (2005).

4. Exploration Potential

An understanding of the tectono-stratigraphic evolution of this frontier basin has helped in identifying facies distribution, particularly of source and reservoir rocks, and as well brings new insight into hydrocarbon exploration in the Mackenzie Plain (Table 3).

The Cambrian strata of the Northern Interior Plains are known for their hydrocarbon potential in the Colville Hills with three discoveries in the 1980's (i.e., Tedji Lake, Tweed Lake, and Bele discoveries) with estimated reserves of 400 billion cubic feet of gas (Bcf) (median) (Northern Oil and Gas Directorate, 1995). In addition, the prospect of the Mackenzie Valley Pipeline has renewed exploration interest.

Discoveries in the Colville Hills consist of gas and condensate recovered from a thin laterally extensive basal Cambrian sandstone of the Mount Clark Formation (Hamblin, 1990). The pay zone consists of fine- to coarse-grained sandstone, with porosity varying from 4-20 percent (12 percent average), and permeability up to 500 millidarcy (mD) (25 mD average) (Hamblin, 1990). Potential source rocks have been reported from subsurface data, and defined as thin alignite-rich layers (i.e., organic-walled marine microfossils) from the lower Mount Cap Formation, with total organic carbon (TOC) ranging from 1.95 to 9.5 percent, and indicating immature to mature levels of thermal alteration (Dixon *et al.* 1998). Discoveries in the Colville Hills are found in structural traps, such as compressional anticlines with underlying precursor structures in Proterozoic rocks, related to the Laramide Orogeny in the Late Cretaceous to Early Tertiary (Hamblin, 1990, and MacLean *et al.*, 1992). Cambrian shales of the Mount Cap Formation act as an effective local top seal to the vertical migration of gas from underlying basal sandstones. The overlying thick salt deposits of the Saline River Formation provide a regional seal for the entire lower Cambrian petroleum system (Jones *et al.*, 1992).

The current study has confirmed the presence of potential reservoirs from outcrops, with the occurrence of fluvial, wave-dominated delta front, shoreface, and turbidite fan sandstones. Fluvial successions of 15.0 to 35.0 m thick consist of fine- to medium-grained sandstone, with occasional conglomerates. Wave-dominated delta front/shoreface facies are represented by clean, fine- to medium-grained sandstone, with thickness ranging from 10.0 to 130.0 m. As well turbidite fan complexes consist of siltstone and coarse grained sandstone, varying from 5.0 to 50.0 m thick, with the occurrence of sand packages up to 30.0 m.

The distribution of potential sand reservoirs is likely to have been controlled by the early basin paleotopography, but this is currently poorly understood due to the generally inadequate seismic data quality. If possible, reprocessing of old seismic data might improve imaging at the Cambrian and pre-Cambrian levels. In areas of limited seismic control, detailed magnetic and gravity survey could be of use in indentifying additional half-graben and graben structures similar to the Blackwater half-graben. These could have acted as sediment bypass, and could provide thick accumulations of potential reservoir rock.

In addition to potential siliciclastic reservoirs, thin dolostones and dolomitic limestones ranging from 5.0 to 20.0 m thick, could be considered as potential reservoir rocks, although in the Colville Hills similar strata are characterised by low porosity and permeability (Hamblin, 1990).

Outcrop samples of potential sandstone reservoir have indicated porosity varying from 1.3 to 22.4 percent and gas permeability up to 442 millidarcy (mD) (Kmax) (Appendix 3). These values are, however, based on outcrop data and might be overestimated due to leaching and erosion. In addition, preservation of reservoir properties in the subsurface may have been affected during deep burial, as suggested by the thick cover of Ordovician to Tertiary strata (Dixon *et al.*, 1998).

With regard to source potential, outcrop samples have confirmed the presence of source rock within the Mount Cap Formation (Appendix 3). RockEval pyrolysis on shale samples resulted in TOC values ranging from 0.09 to 5.56 percent. Further detailed petrographic examination of source rock samples may help in identifying the type of organic matter, and in turn suggest potential depositional setting, occurrence, and spatial distribution.

Although structural traps are currently the main focus of exploration in this frontier basin, stratigraphic traps are almost certainly present, with updip pinchouts as suggested by

Hamblin (1990), and turbidite fan complexes sealed by surrounding marine shale as suggested in this study.

Unlike in stratigraphic traps, the presence of hydrocarbons in structural traps is strongly dependant on the relative timing of hydrocarbon migration and trap development. As mentioned by Dixon *et al.* (1998) current burial history models are poorly constrained due to insufficient data.

Petroleum System Elements	STUDY AREA	COLVILLE HILLS
Source	- Marine shale (Mt. Cap Fm.) Total Organic Carbon: 0.09-5.56 %	- Alignite-rich shale (i.e., organic-walled marine microfossils) (Mt. Cap Fm.) Total Organic Carbon: 1.95-9.5 %
Reservoir	- Fluvial, wave-dominated delta, shoreface sandstone (Mt. Clark Fm.) Porosity: 1.3-22.4% Permeability: 442 mD (Kmax, gas) - Turbidite sandstone and carbonates (Mt. Cap Fm.) Note: these values are based on outcrop data, and might be overestimated due to leaching and erosion.	- Fluvial to shallow marine sandstone (Mt.Clark Fm.) Porosity: 4-20% Permeability: 500 mD (Kmax)
Seal	- Marine shale (Mt. Cap Fm.) providing local top seal - Salt deposits (Saline River Fm.) providing a regional seal	
Trap	- Structural traps with compressional anticline, inverted normal fault, related to the Laramide Orogeny, as observed on seismic - Stratigraphic traps with up-dip pinch out onto paleotopographic highs, and turbidite fan complexes sealed by marine shale, as suggested in this study	- Structural traps with compressional anticlines, related to the Laramide Orogeny, as proven by hydrocarbon discoveries
Timing	- Current burial history models are poorly restrained due to insufficient data	
Discoveries		400 billion cubic feet of gas (Bcf) (median)

Table 3. Exploration potential of the Cambrian succession in the study area, compared to the known petroleum system in the Colville Hills, with regard to the main petroleum system elements (i.e., source, reservoir, seal, trap, and timing).

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Appendices

Appendix 1. Detailed measured sections with pictures and field notes. (CD enclosed)

Appendix 2. Trilobite biostratigraphy report. (CD enclosed)

Appendix 3. Sample porosity and permeability and RockEval (CD enclosed)