



Horseshoe Canyon-Bearpaw Transition and Correlation of Associated Coal Zones Across the Alberta Plains

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Abstract

The Horseshoe Canyon Formation contains about 40% of the total coalbed methane gas resources of the Upper Cretaceous-Tertiary succession, of which about 58% are hosted by the Drumheller and the Basal coal zones. This study correlates the Horseshoe Canyon–Bearpaw transition and associated coal zones across central and southern Alberta Plains and examines outcrops and associated subsurface strata of the Horseshoe Canyon Formation in the Edmonton area.

Three Bearpaw marine tongues are interfingered with the Lower and Middle Horseshoe Canyon Formation. The Lower and Middle Bearpaw marine tongues consist of two distinctive marine regressive (coarsening-up) sequences, whereas the Upper Bearpaw Marine Tongue consists of only one. At least five major flooding surfaces are present in the Horseshoe Canyon–Bearpaw transitional zone, each of which marks a marine transgression followed by a marine regression. Amongst the flooding surfaces, the First Flooding Surface can be traced to west-central Alberta.

The gradual regional shifting of facies between the Bearpaw marine tongues and Horseshoe Canyon nonmarine deposits were controlled by relative fluctuations of sea level, which were controlled by global eustasy and regional tectonics. In contrast, frequent facies changes at particular locations may have been controlled by basement discontinuities.

Ten coal seams are developed in the Edmonton area. Seams #1, #2 and #3 are correlated with the Basal Coal Zone in the Drumheller area. Seams #4, #5 and #6 are correlated with the Lower Drumheller Coal Zone in the Drumheller area. Seams #7 and #8 are most likely equivalent to those in the Upper Drumheller Coal Zone in the Drumheller area. Seams #9 and #10 appear to be correlative to the Daly/Weaver Coal Zone.

In the Edmonton area, coal seams are mainly of sub-bituminous rank and highly fractured. Strike of the face cleats is N40–45°E (perpendicular to the Rocky Mountain Thrust Belt) and strike of the butt cleats is N50°–45°W, roughly perpendicular to the face cleats.

1 Introduction

Interest in coalbed methane (CBM) in the Western Canada Sedimentary Basin (WCSB) was renewed at the start of the 21st century. Following the regional CBM potential studies in Alberta (Langenberg et al., 2002; Beaton et al., 2002), the Alberta Geological Survey focused on the Lower and Middle Horseshoe Canyon coal zones in the Alberta Plains (Chen et al. 2002; Pana and Beaton, 2002). Since then, approximate 3500 CBM wells have been drilled, and production has been established in the Formation. For example, EnCana's 2004 CBM production from the Horseshoe Canyon in southern Alberta averaged 17 million cubic feet (mmcf, 0.48 million m³) per day with fourth quarter production averaging 27 mmcf (0.76 million m³) per day (Nickle's Daily Oil Bulletin, February 24, 2005).

The Upper Cretaceous Horseshoe Canyon Formation of Alberta Plains contains 66 trillion cubic feet (Tcf, 1.87 trillion m³) gas-in-place (Beaton et al., 2002), which represents about 40% of the total CBM gas resources hosted by the coal-bearing Upper Cretaceous-Tertiary succession in the Alberta Plains. The Horseshoe Canyon Formation includes four coal zones. They are, in ascending order, the Basal, Drumheller (McCabe et al., 1989), Daly/Weaver and Carbon-Thompson coal zones. About 58% (43 Tcf, 1.22 trillion m³) of the Horseshoe Canyon CBM gas resources occur in the Drumheller and the Basal coal zones. The other 42% (31 Tcf, 0.88 trillion m³) are contained in the Carbon-Thompson and the Daly/Weaver coal zones.

The Drumheller coal zone covers an area of about 1.28×10^5 km². The average net coal thickness is 8 metres. Thick (up to 18 m) net coal occurs in a north-trending belt in the southern and south-central plains. Low rank (sub-bituminous B) coals are present at shallow depths. The coal rank of the Drumheller coals generally increases toward the west and north, where rank of high volatile bituminous B is attained. Gas-in-place contents (dry-ash free basis) range from 1.7 to 3.5 cc/g in the deep basin and from 0.5 to 1 cc/g in shallow coals. Gas-in-place is less than 1 billion cubic feet (bcf, 28.32 million m³)/section in most of the region and averages 2 to 3 bcf (56.63-84.95 million m³)/section in the north-trending central belt with local areas exceeding 4 bcf (113.27 million m³)/section (Beaton et al., 2002).

The development of abundant coal and CBM resources in the Horseshoe Canyon Formation is related to the Bearpaw marine transgressions and regressions. The knowledge of the Bearpaw and Horseshoe Canyon formations in southern Alberta Plains has been well established through studies on outcrops and subsurface geophysical logs in the Drumheller and Red Deer areas (Allan and Sanderson, 1945; Lines, 1963; Rahmani, 1981; Ainsworth, 1994; Eberth and Straight, 1998; Pana and Beaton, 2002; Hamblin, 2004).

The Horseshoe Canyon coals in the Edmonton area were studied by Beach (1934) and Taylor (1971) along the North Saskatchewan River. Except for a schematic chart (Beach, 1934), both studies did not provide a subsurface correlation of the coals and associated formations in the area. A collection of maps and cross-sections on the Morinville area north of Edmonton was compiled by Hughes (unpublished); however, the project area was limited, and the local identifications were not correlated across the central Alberta Plains. Using stratigraphic criteria, Catuneanu (2002) and Chen et al. (2002) correlated the Bearpaw and Lower Horseshoe Canyon formations west of Edmonton in the central plains.

This geo-note intends to

- correlate the Horseshoe Canyon–Bearpaw transition and associated coal zones across the central and southern Plains;
- provide information about Horseshoe Canyon coal outcrops in the Edmonton area;

- calibrate the subsurface strata with outcrop information; and
- characterize the Horseshoe Canyon–Bearpaw transitional zone across the Alberta Plains.

Figure 1 shows the locations of the

- study area in central and southern Alberta;
- reference log for the southern Plains;
- classic Horseshoe Canyon–Bearpaw outcrop at Willow Creek close to Drumheller;
- outcrops examined by this study;
- cross-sections correlated;
- cross-sections selected for this geo-note; and
- mapping area by Chen et al. (2002).



Figure 1. Study area in central and southern Alberta. Four cross-sections A-A', B-B', C-C' and D-D' are discussed in this geo-note. The red dot east of Calgary represents the location of the reference log 4-12-25-25W4 for the southern Plains. The red dots in the Edmonton area are the locations of the outcrops examined by this study. The area bounded by dashed black lines west of Edmonton is the mapping area by Chen et al. (2002). The solid black lines are additional cross-sections that have been correlated but not selected for this geo-note. The green dot, northeast of Calgary, indicates the location of the classic Horseshoe Canyon–Bearpaw outcrop at Willow Creek near Drumheller.

2 Horseshoe Canyon–Bearpaw Transition

2.1 Reference Logs and Brief Formational Features

To better characterize the Bearpaw and Horseshoe Canyon formations, well 4-12-25-25W4, east of Calgary, was chosen (Figure 2) as the reference well for this study. This well is close to the historical well 7-12-25-25W4, which was studied by Havard (1970) and Hamblin (1998) upon which much of the understanding of the Horseshoe Canyon and Bearpaw strata was developed. Well 4-12-25-25W4 was drilled in 2000, and its better quality logs demonstrate the geophysical characteristics of the formations of interest and associated coal zones. The disadvantage of this site is that the Upper (third) Bearpaw Marine Tongue is not developed at this location due to the retreat of the Bearpaw Sea to the east. In Figure 2, the left log trace shows the gamma ray, and the right log trace shows resistivity. In addition to this pair of logs, coal seams were picked with assistance from density or sonic logs and displayed as black bars in the middle column.

Underlying the Bearpaw Formation, the Belly River Group is composed of fluvial-dominated deposits and can be divided, in ascending order, into three formations: the Foremost, Oldman and Dinosaur Park, each of which has a distinct package of log signatures (Figure 2).

Abruptly, but conformably, overlying the Dinosaur Park Formation, the Bearpaw Formation consists of laminated shale and siltstone, with some sandstone beds and kaolinitic claystone lenses, deposited in nearshore or marginal marine environments. Three Bearpaw marine tongues and the higher Drumheller marine tongue are developed in the southern Alberta Plains (Hamblin, 2004) and are interfingered with the Lower and Middle Horseshoe Canyon Formation (McCabe et al., 1989). The Horseshoe Canyon Formation consists of nonmarine sandstone, siltstone, shale/mudstone, coal, ironstone concretions and isolated bentonite beds, and contains four coal zones. Up to ten potentially economic coal seams have been identified.

There are at least five flooding surfaces in the Horseshoe Canyon–Bearpaw transitional zone, which are marked by red arrows in Figure 2. Each of the flooding surfaces indicates a transgression of the Bearpaw Sea and marks the base of a coarsening-up shallow-marine sequence. The first flooding surface (1st FS) is traceable in southern and central Alberta Plains and separates the Bearpaw Formation from the Belly River Group. It is distinguishable by the overall bell-shaped log signature packages (responses of fining-up sequences) below the 1st FS, and the funnel-shaped packages (responses of coarsening-up sequences) above the 1st FS. The second flooding surface (2nd FS) is within the Lower Bearpaw Marine Tongue. The third flooding surface (3rd FS) marks the base of the Middle Bearpaw Marine Tongue, and the fourth flooding surface (4th FS) is within the Middle Bearpaw Marine Tongue. The fifth flooding surface (5th FS) is present at the base of the Upper Bearpaw Marine Tongue, which is restricted to the east of this reference well. The unit between the 5th FS and the Upper Drumheller Coal Zone in Figure 2 is the equivalent of the Upper Bearpaw Marine Tongue.

The Lower and Middle Bearpaw marine tongues consist of two distinctive marine regressive sequences of coal-barren strata, but the Upper Bearpaw Marine Tongue consists of one (Figure 2). The lower regressive sequence of the Middle Bearpaw Marine Tongue was named the first coarsening-up unit (CU1) by Langenberg et al. (2000). The sandstone in CU1 correlates with the Dorothy Sandstone, a brownish-grey, medium to coarse-grained, glauconitic, bentonitic, massive, ledge-forming sandstone exposed near the town of Dorothy, representing a bar-type deposit (Given and Wall, 1971).

Two coal zones are developed in the Lower and Middle Horseshoe Canyon Formation (Figure 2).

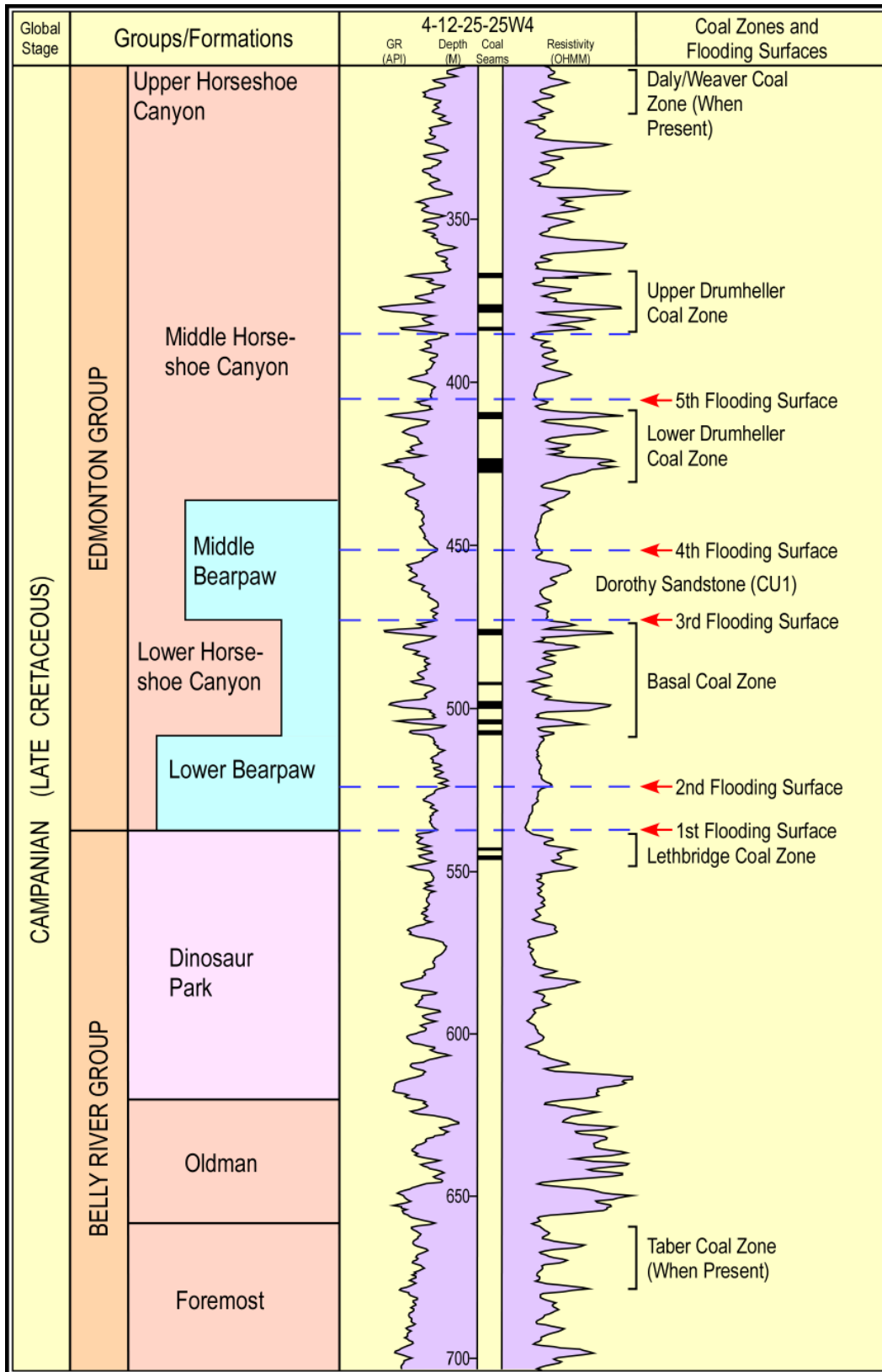


Figure 2. Reference log for southern Alberta Plains. The well is located east of Calgary. Black bars in the column between log traces indicate coal seams.

The Basal Coal Zone (McCabe et al., 1989) is between the Lower and Middle Bearpaw tongues. The Drumheller Coal Zone is above the Middle Bearpaw Tongue and divided by the Upper Bearpaw Tongue/ equivalent into the Lower and Upper Drumheller coal zones. The coal zones are laterally continuous intervals of interbedded coal and inorganic partings. The individual coal zones commonly contain more than 50% coal (by volume). The coal seams at Willow Creek and east Coulee, near the town of Drumheller, define the Lower Drumheller Coal Zone (Allan and Sanderson, 1945; Hamblin, 2004).

2.2 Correlation of Horseshoe Canyon Coal Zones

The Horseshoe Canyon–Bearpaw transition and associated coal zones, defined in Figure 2, are correlated from the southern (cross-section A-A', Figure 3) through central (cross-section B-B', Figure 4) to the west-central Alberta Plains (cross-section C-C', Figure 5). (See Figure 1 for the location of the cross-sections.) Cross-sections A-A' and B-B' are tied at well 14-13-38-28W4. Cross-sections B-B' and C-C' are tied at well 15-27-47-7W5. All cross-sections trend northwest-southeast and hang on the 1st FS at the base of the Bearpaw Formation (datum).

The sequences of the interfingered Horseshoe Canyon and Bearpaw strata are best shown in cross-section A-A' (Figure 3). Bearpaw marine tongues are well developed in this area. Each of the marine tongues is floored by a flooding surface and overlain by a coal-bearing succession on the landward side of a shoreline. Most of the Bearpaw tongues are restricted to an area east of the paleo-shoreline, located between Calgary and Edmonton, except the lower part of the Lower Bearpaw Tongue, which can be traced to west-central Alberta (Figure 5). The 'fairway' of the Drumheller coals is developed along the paralic belt parallel to the Bearpaw Sea.

The relationship between the retreating Bearpaw Sea and the progradation of coal-bearing strata is well illustrated by the Middle Bearpaw Marine Tongue and the Lower Drumheller Coal Zone (Figure 3). In Figure 3, the 3rd FS marks one of the major transgressions of the Bearpaw Sea. On the top of the 3rd FS, the coarsening-up sequence (CU1) was developed mainly southeast of well 16-10-34-26W4 with the regression of the Bearpaw Sea. In the vicinity of well 16-10-34-26W4, Lower Drumheller peat was deposited. Subsequently, a marine transgression (4th FS) occurred, followed by a regression, which built up the coarsening-up sequence above the 4th FS. During this time, the Bearpaw Sea was more restricted and Drumheller peat was deposited in the vicinity of well 5-3-31-23W4. Finally, the marine regression resulted in deposition of peat to the west (well 12-7-28-20W4) and associated shoreline sandstone to the east (well 15-32-25-17W4).

The gradual shifting of facies between the Bearpaw marine tongues and Horseshoe Canyon nonmarine deposits were controlled by relative fluctuations of the sea level, which resulted from global eustatic changes and regional tectonic events during deposition. In contrast, frequent facies changes near Drumheller (between wells 12-7-28-20W4 and 15-32-25-17W4 in Figure 3), west of Red Deer (between wells 1-2-40-2W5 and 14-13-38-28W4 in Figure 4; i.e., Boundary of Rimbey and Lacombe Precambrian domains), and across the North Saskatchewan and Pembina rivers (between wells 10-12-50-10W5 and 15-27-47-7W5, Figure 5) may be due to the influence of basement discontinuities and tectonic activities.

3 Outcrops of Horseshoe Canyon–Bearpaw Transition in the Edmonton Area

3.1 Formation Contacts and Coal Seams in the Edmonton Area

Figure 6 shows the locations of the five outcrops visited and the location of the cross-section that

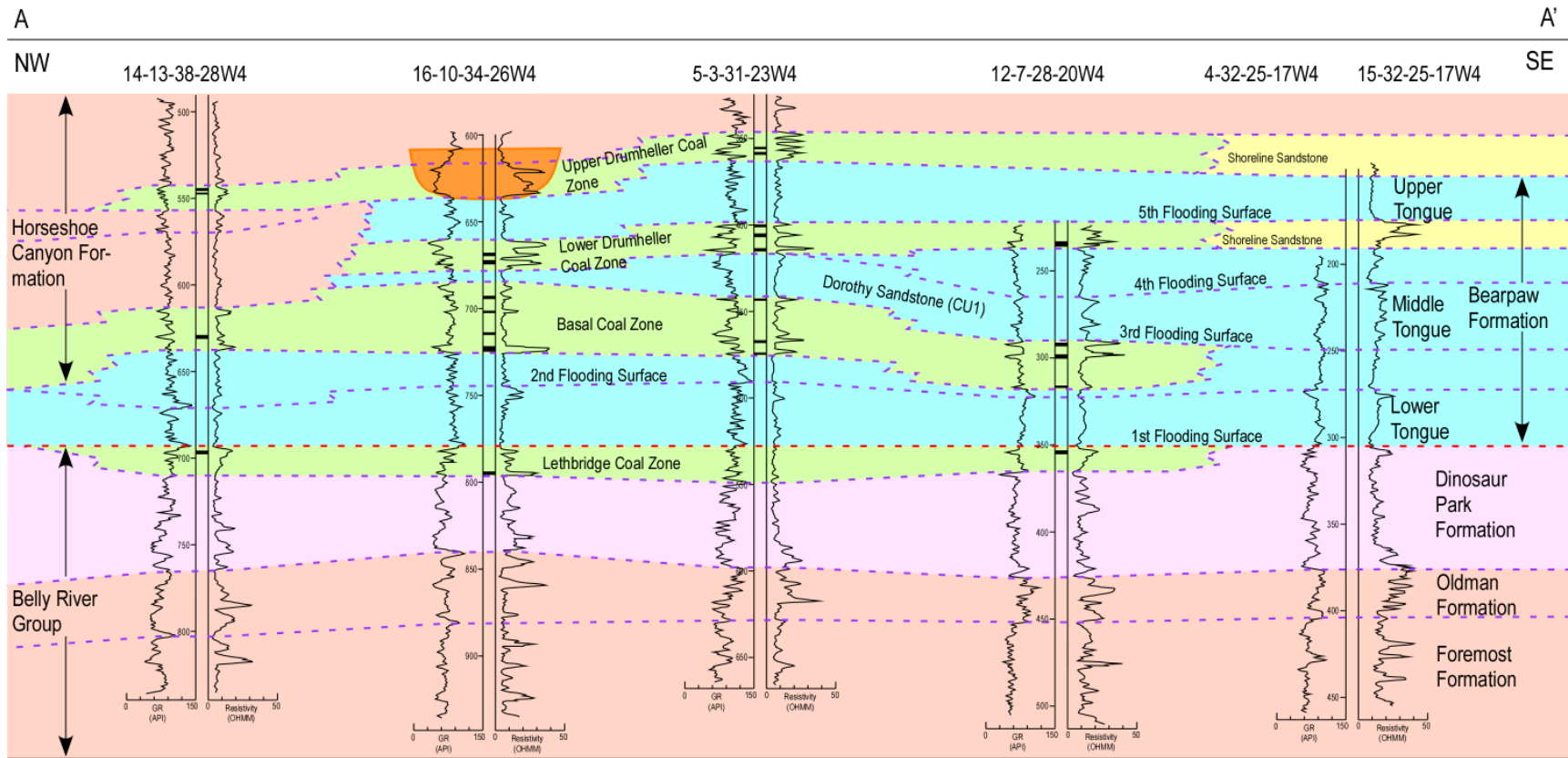


Figure 3. Cross-section A-A' in southern Alberta Plains, showing the Horseshoe Canyon-Bearpaw transition and associated coal zones. Correlation datum, dashed red line, the First Flooding Surface at the base of the Bearpaw Formation. Blue colour, Bearpaw main tongue. Green colour, coal zone. Black bar in the column between log traces, coal seam. Orange colour, incised channel. Pink and light brown colour, fluvial dominated deposits.

B

B'

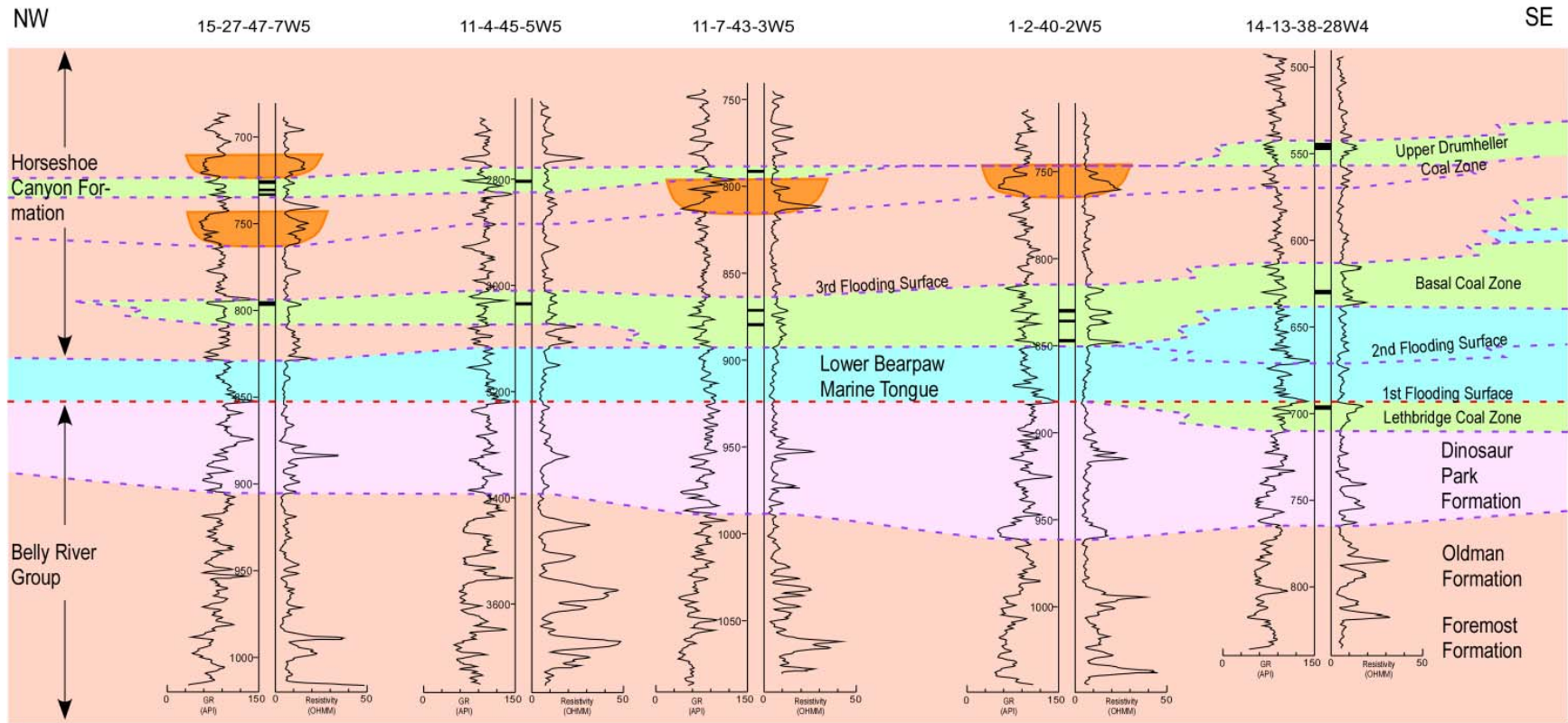


Figure 4. Cross-section B-B' in central Alberta Plains, showing the Horseshoe Canyon-Bearpaw transition and associated coal zones. Correlation datum, dashed red line, the First Flooding Surface at the base of the Bearpaw Formation. Blue colour, Bearpaw marine tongue. Green colour, coal zone. Black bar in the column between log traces, coal seam. Orange colour, incised channel. Pink and light brown colour, fluvial dominated deposits.

C

C'

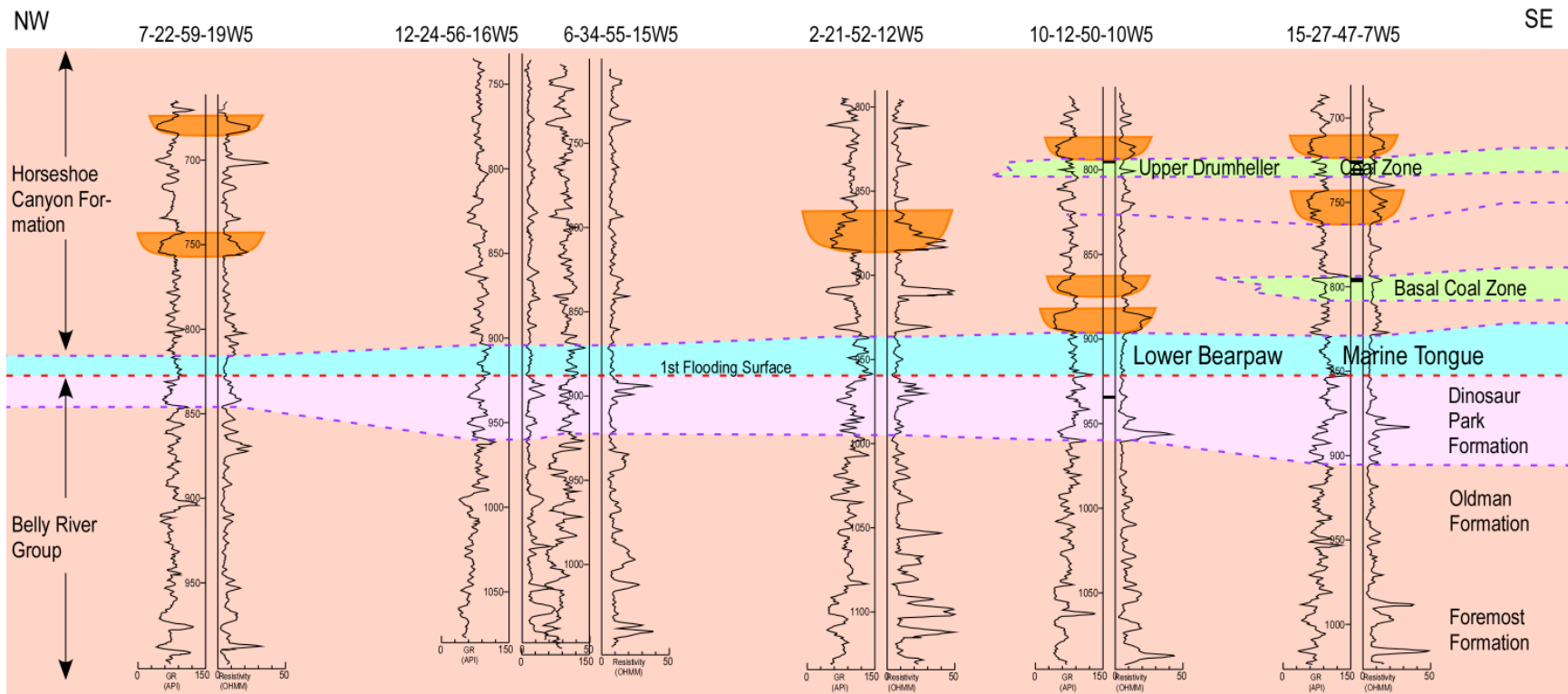


Figure 5. Cross-section C-C' in west-central Alberta Plains showing the Horseshoe Canyon-Bearpaw transition and associated coal zones. Correlation datum, dashed red line, the First Flooding Surface at the base of the Bearpaw Formation. Blue colour, Bearpaw marine tongue. Green colour, coal zone. Black bar in the column between log traces, coal seam. Orange colour, incised channel. Pink and light brown colour, fluvial dominated deposits.

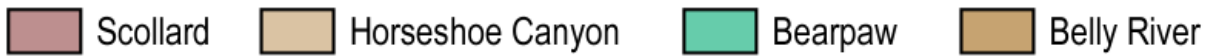
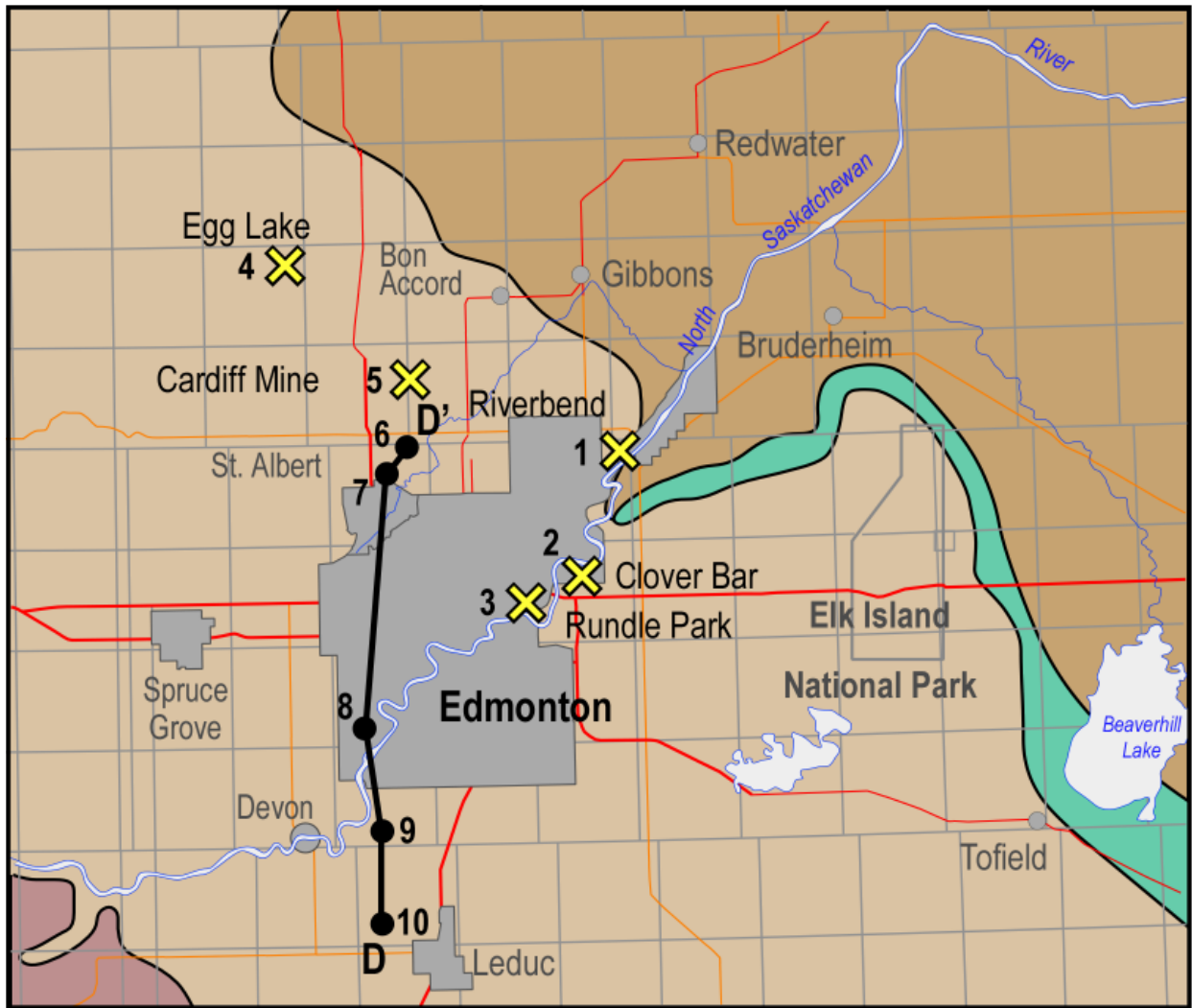


Figure 6. Location of outcrops and cross-section D-D' in Edmonton area.

1. Riverbend site 4-23-54-23W4, seams #1 and #2 of Basal Coal Zone (Figs. 7 and 9).
2. Clover Bar site 3-27-53-23W4, seam #3 of Basal Coal Zone (Figs. 12A and 12B).
3. Rundle Park site 1-12-53-24W4, seams #4 and #5 of Lower Drumheller Coal Zone (Fig. 10).
4. Egg Lake mine site 7-36-56-26W4, Drumheller coal (Fig. 11).
5. Cardiff mine site 6-24-55-25W4, Drumheller coal (Figs. 12C and 12D).
6. Well TH. 76-6, 35-54-25W4
7. Well TH. 7-75, 28-54-25W4
8. Well 3-5-52-25W4
9. Well 4-5-51-25W4
10. Well 12-6-50-25W4

See Figure 14 for cross-section D-D' details.

enables correlation of the outcrops to the subsurface. The overall dip of the formations is southwest, and increased erosion of the formations occurred to the northeast. The subcrop of the bedrock is the Belly River Group in the region northeast of Edmonton. The Bearpaw Formation (green area in Figure 6) is exposed on the North Saskatchewan River. Coal seams are exposed along the North Saskatchewan River in ascending order to the southwest.

Figure 7 shows the Riverbend outcrop on the North Saskatchewan River northwest of Edmonton. The indicated boundaries are the contacts between the Belly River and Bearpaw formations (lower contact), and between the Bearpaw and Horseshoe Canyon formations (upper contact). The Bearpaw Formation consists of chocolate brown shale with ironstone layers and is 6 m thick at the site. It is less resistant than the Belly River Group below and the Horseshoe Canyon Formation above. The overlying Horseshoe Canyon Formation, which is dominated by sandstones with shales and coal seams, forms a cliff at the Riverbend outcrop.

Based on the outcrop examination and subsurface correlation, Figure 8 provides a chart of coal seams modified from Beach (1934, unpublished). The right-hand side of the diagram shows the coal seams in the Edmonton area, and the left-hand side of the diagram shows correlative seams of the southern Alberta Plains (Drumheller area). Ten coal seams are developed in the Edmonton area (from Beach 1934):

- Seam #1, Deep Seam, was originally known from a cored well at Jasper Avenue and 98 Street in Edmonton where it is about 2.4 m thick. It is exposed at the Riverbend outcrop northeast of Edmonton.
- Seam #2, Jasper Avenue Seam, was originally known from the same cored well as #1 where it is about 2.4 m thick. It probably outcrops at the Riverbend site northeast of Edmonton.
- Seam #3, Lower Seam, outcrops at the North Saskatchewan River level in section 28-53-23W4 (Clover Bar) where it is 0.6 m thick.
- Seam #4, Clover Bar Seam, is 1.5 to 2 m at Clover Bar. It also outcrops in Rundle Park in Edmonton.
- Seam #5, Low Level Bridge Seam, is a thin (less than 0.9 m) but persistent seam, exposed in Rundle Park.
- Seam #6 was originally named as Weaver (Daly) Seam, but the use of that name is not recommended because the Daly/Weaver Seam appears to be correlated with seams # 9 and 10. Seam #6 is thin and non-persistent (<0.6 m). It occurs at water level at the Dawson Mine and is traceable downstream to the Imperial Oil refinery.
- Seam #7, again, was originally named as Weaver (Daly) Seam (use of name not recommended). It varies from 0.1 to 1.8 m in thickness.
- Seam #8, Whitemud Seam, is non-persistent and outcrops only opposite Whitemud Creek, where it is about 0.9 m thick.
- Seam #9, Big Island Seam, was mined at Big Island and at the south end of the Whitemud Creek. It is about 0.6 m thick at the High Level Bridge.
- Seam #10 occurs close to the tops of the riverbanks near Big Island.

Seams #1, #2 and #3 are correlated with the Basal Coal Zone in the Drumheller area. Seams #4, #5 and #6 are correlated with the Lower Drumheller Coal Zone in the Drumheller area. Seams #7 and #8 are equal to those in the Upper Drumheller Coal Zone in the Drumheller area. The coal seams #9 and #10 appear to be correlative to the Daly/Weaver Coal Zone according to their relative stratigraphic position.

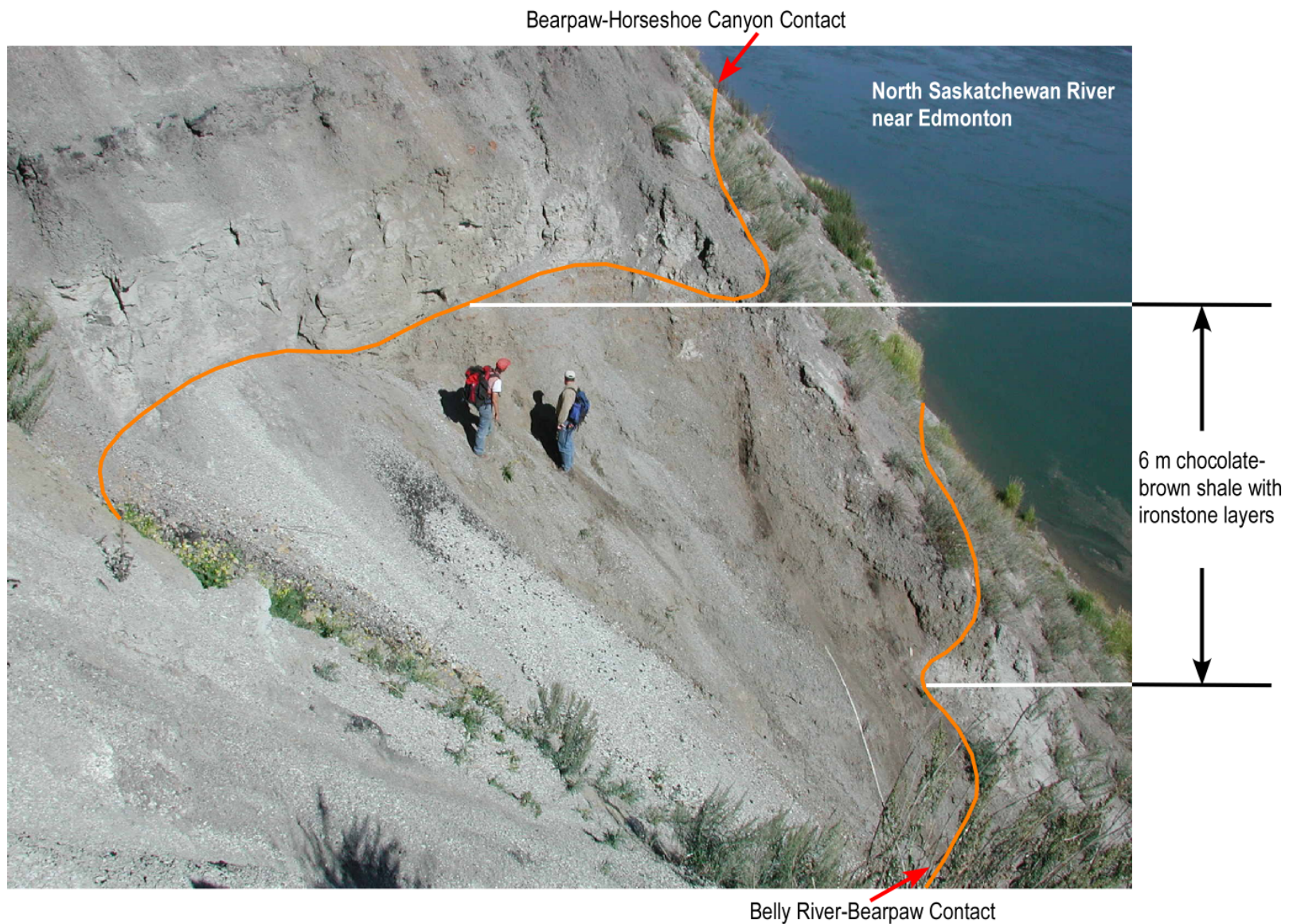


Figure 7. Riverbend outcrop on the North Saskatchewan River near Edmonton (see Figure 6 for location) showing the Bearpaw Formation, the Belly River-Bearpaw contact and the Bearpaw-Horseshoe Canyon contact.

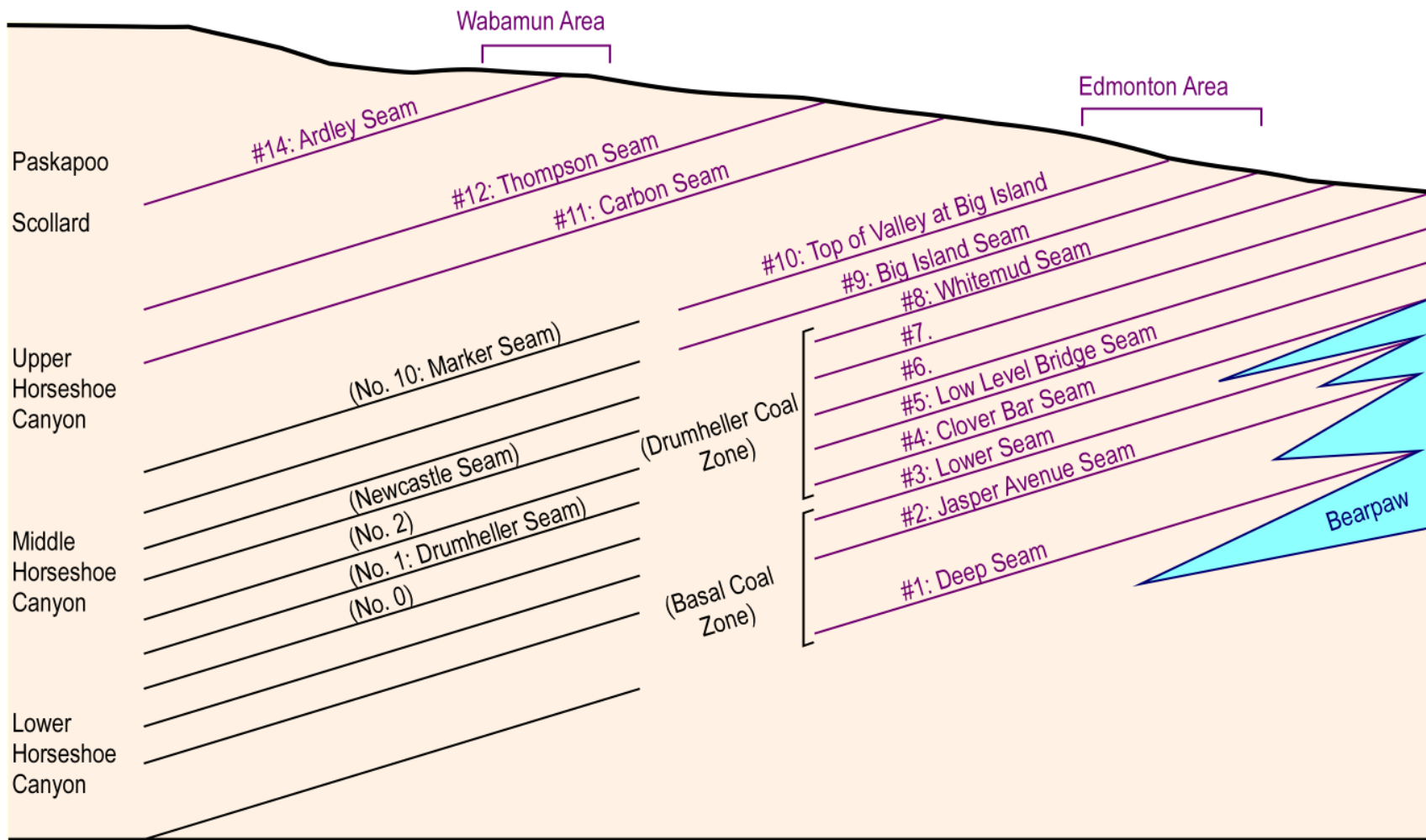


Figure 8. Coal seams in the Edmonton area (in purple, modified from Beach, 1934) and correlation of the seams to those in the Drumheller area (in black). Seams #1, #2, and #3 are correlated to the Basal Coal Zone. Seams #4, #5, and #6 are correlated to the Lower Drumheller Coal Zone. Seams #7 and #8 are suggested to be in the Upper Drumheller Coal Zone. Coal seam #10 and possibly #9 at Big Island may be correlative to the Daly/Weaver Coal Zone.

3.2 Outcrops of Horseshoe Canyon Formation and Associated Coal Seams near Edmonton

The Lower Horseshoe Canyon Formation, with coal seams #1 and #2, is well exposed at the Riverbend outcrop on the North Saskatchewan River, northeast of Edmonton (Figures 6 and 9). At the Riverbend outcrop, the Lower Horseshoe Canyon consists of, in ascending order, grey sandstone (2.2 m), grey to dark grey silty shale (1-1.2 m), coal seam (0.3 m), grey shale and grey-brown ironstone (1.3 m), bentonite (0.1 m), grey shale and silty shale (2 m), grey silty sandstone (4 m), bentonite (0.1 m) and coal seam (1 m). The rank of both coal seams #1 and #2 is sub-bituminous. The preserved Lower Horseshoe Canyon Formation at the Riverbend site is about 12 m thick and the Horseshoe Canyon sediments above Coal Seam #2 are overlain by glacial deposits.

Figure 10 shows the Rundle Park outcrop on the North Saskatchewan River in Edmonton. The strata at the site are correlated to the lower Middle Horseshoe Canyon in southern Alberta. Coal seams #4 and #5 are equivalent to coal seams in the Lower Drumheller Coal Zone. Coal Seam #4 (Clover Bar Seam) is sub-bituminous to high volatile bituminous in rank, highly fractured and >0.4 m exposed. Face cleat strikes N40°E with a spacing of 3 to 10 cm, perpendicular to the Rocky Mountain Thrust Belt. Butt cleats are irregular, strike N50°W, parallel to the Rocky Mountain Thrust Belt.

Figure 11 illustrates the Drumheller coal seam at the reclaimed Egg Lake mine northwest of Edmonton. About half a metre of low rank coal and shaly coal is exposed at the mined-out pit. The coal seam is highly fractured. The strike of the face cleats is N45°E and the strike of the butt cleats is N45°W.

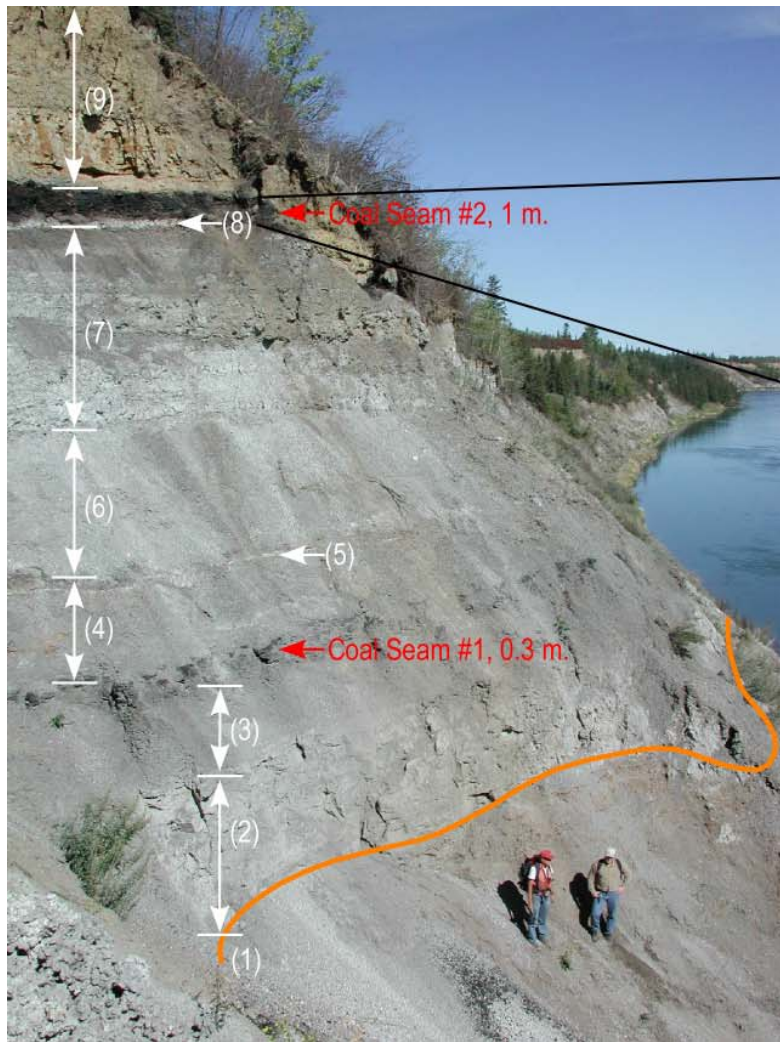
Figures 12A and 12B show coal seam #3 on the Saskatchewan River at Clover Bar east of Edmonton. The seam is composed of shaly coal and coaly shale. Figure 12C shows a portion of the reclaimed Cardiff mine in Morinville where coals have been mined out. A coal sample collected from this site is displayed in Figure 12D, showing the highly fractured nature of the sub-bituminous coal of the Drumheller Coal Zone.

3.3 Correlation between Outcrop and Subsurface near Edmonton

Figure 13 shows the correlation of formations between outcrop and subsurface in the Edmonton area. The Riverbend outcrop (refer to Figure 9) is shown on the right of Figure 13. Coal well TH. 76-6, 35-54-25W4 (refer to Figure 14) is shown on the left of Figure 13. The Lower Horseshoe Canyon Formation of well TH. 76-6, 35-54-25W4 is expanded (middle of Figure 12) and correlated to the Riverbend outcrop. The distance between the Riverbend outcrop (4-23-54-23W4) and well TH. 76-6, 35-54-25W4 is about 20 km. The thickness between coal seams #1 and #2 is about 7.3 m at the Riverbend outcrop and 37.3 m in well TH. 76-6, 35-54-25W4.

The Horseshoe Canyon and Bearpaw formations and associated coal zones are correlated in cross-section D-D' (Figure 14). The correlation datum is the 1st FS at the base of the Bearpaw Formation. The Basal Coal Zone is present, but not well developed between the Lower and the Middle Bearpaw equivalent units. The Drumheller Coal Zone above the Middle Bearpaw equivalent unit is well developed in the Edmonton area.

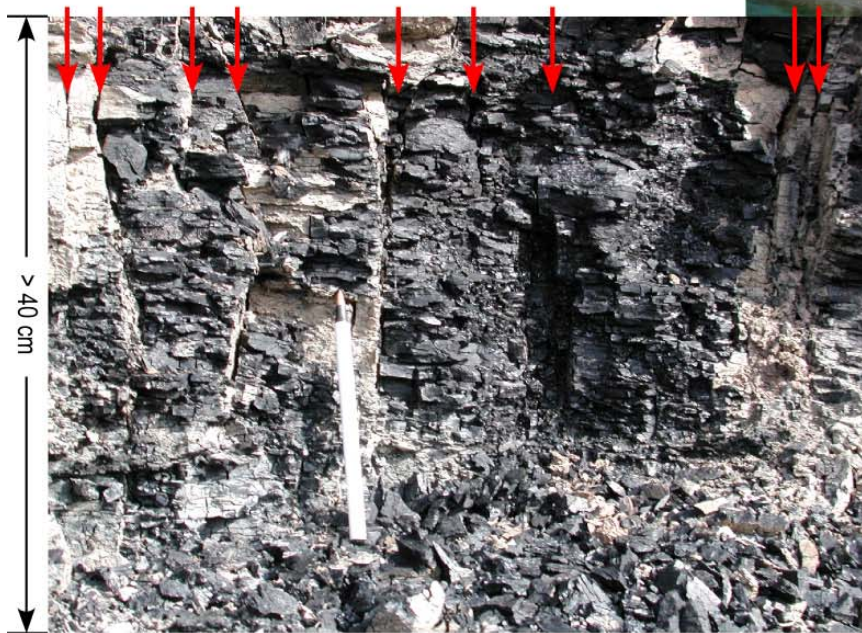
Coal seams, interfingering with clastics and marine strata, trend north-south, parallel to the paleo-shoreline of the Bearpaw Sea. Individual seams average 0.5 to 1.0 m thick and may be up to 3 m or more thick; particularly thick coal seams (commonly 2 to 4 m; 6 to 10 m in a few wells) have been identified in the areas of Wetaskiwin, Alix, Delburne, Bashaw, Strathmore and Milo (McCabe et al., 1989).



- (1) Bearpaw-Horseshoe Canyon contact
- (2) Sandstone, 2.2 m
- (3) Silty shale, >1 m
- (4) Grey shale and ironstone, 1.3 m
- (5) Bentonite, 0.1 m
- (6) Grey shale and silty shale, 2 m
- (7) Grey silty sandstone, 4 m
- (8) Bentonite, 0.1 m
- (9) Sandstone and till

Figure 9. Riverbend outcrop on the North Saskatchewan River near Edmonton (see Figure 6 for location), showing the Horseshoe Canyon Formation and coal seams #1 and #2.

**Lower Drumheller Coal
Seams at Rundle Park
in Edmonton**



Seam #4 - Clover Bar Coal Seam

Figure 10. Rundle Park outcrop in Edmonton (see Figure 6 for location) showing Lower Drumheller coal seams #4 and #5. Above: Coal seams #4 and #5 at Rundle Park by the North Saskatchewan River. Left: Details of seam #4 (Clover Bar seam). Red arrows indicate face cleat, spacing 3 to 10 cm, strike N40°E. Butt cleats: irregular, strike N50°W.

**Drumheller Coal Seam at Egg
Lake Mine**



Figure 11. Egg Lake mine site outcrop near Morinville (see Figure 6 for location) showing Drumheller coal seam. Above: Egg Lake mine. Right: Red arrows indicate face cleats, strike N45°E. Butt cleats strike N45°W.

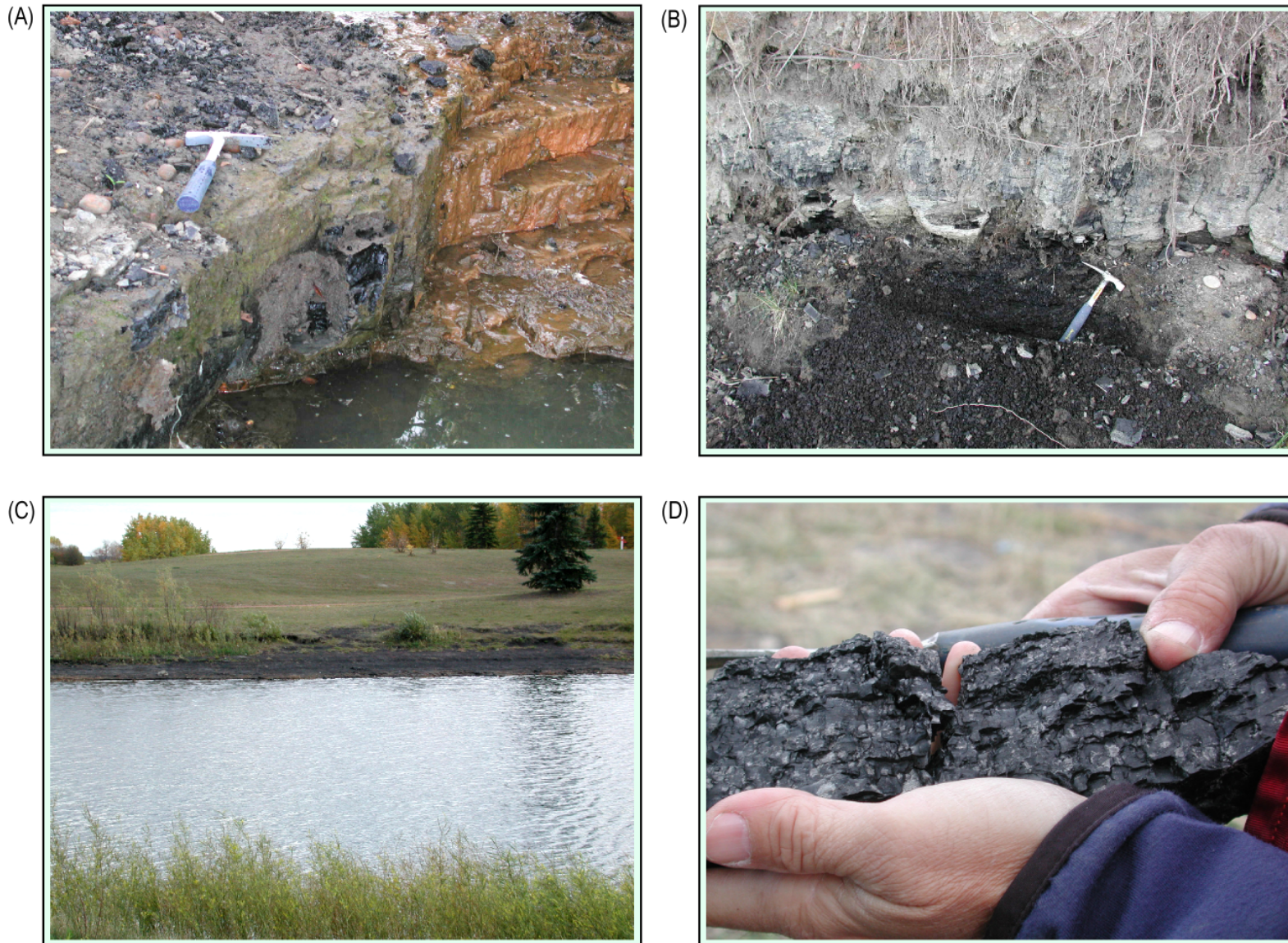


Figure 12. Coal seam #3 at Clover Bar near Edmonton and coal from the Cardiff mine near Morinville (see Figure 6 for locations). (A) and (B): Coal seam #3 at Clover Bar by the North Saskatchewan River near Edmonton. (C): Cardiff mine (reclaimed) near Morinville. (D): Coal sample from the Cardiff mine, sub-bituminous rank, highly fractured/cleated.

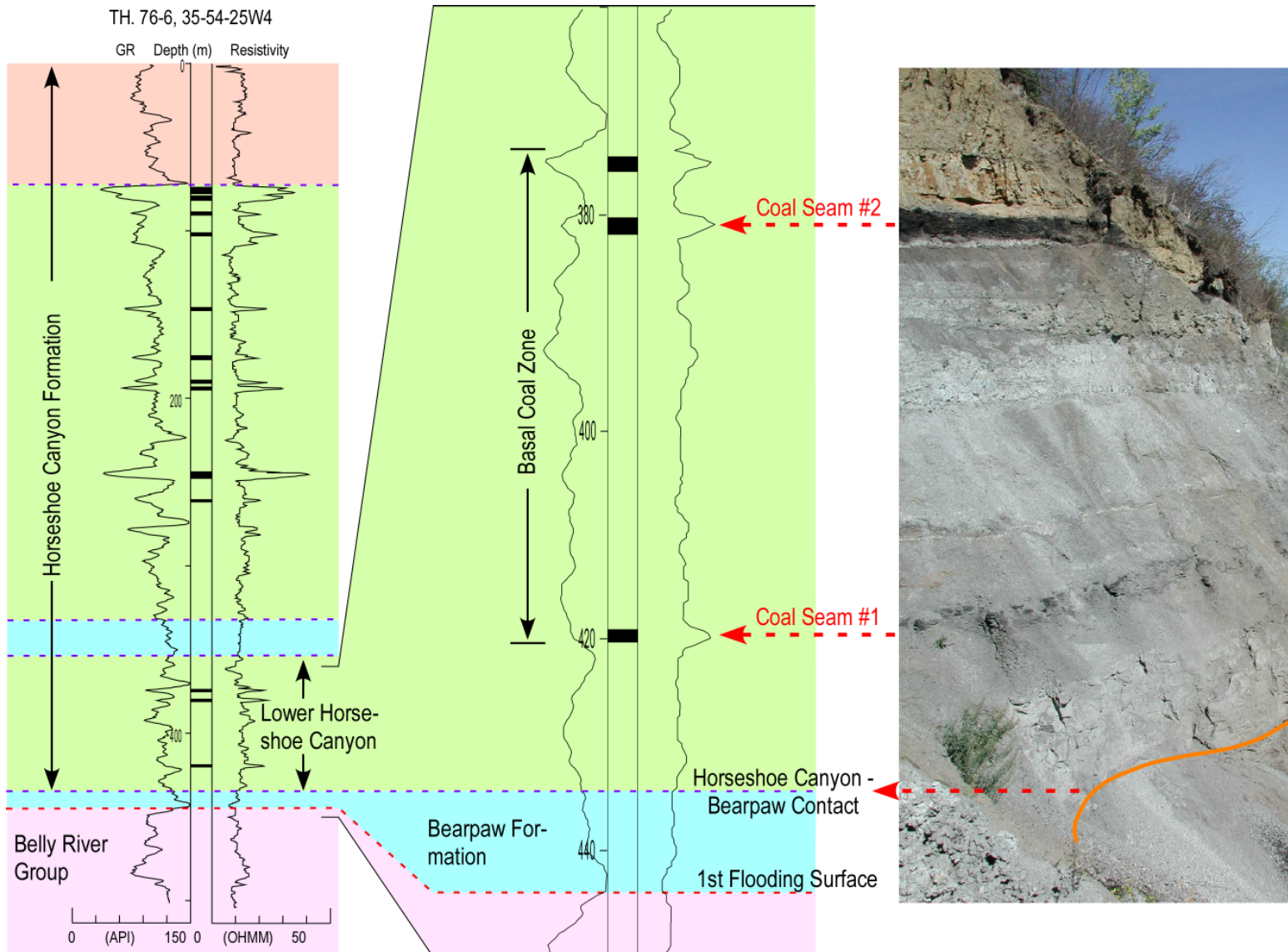


Figure 13. Correlation between the Riverbend outcrop east of Edmonton (right, refer to Figure 9) and well TH. 76-6, 35-54-25W4 north of Edmonton (left, see Figure 6 for location) in cross-section D-D' (refer to Figure 14). Middle: Expanded logs of the Bearpaw and Lower Horseshoe Canyon formations.

D

D'

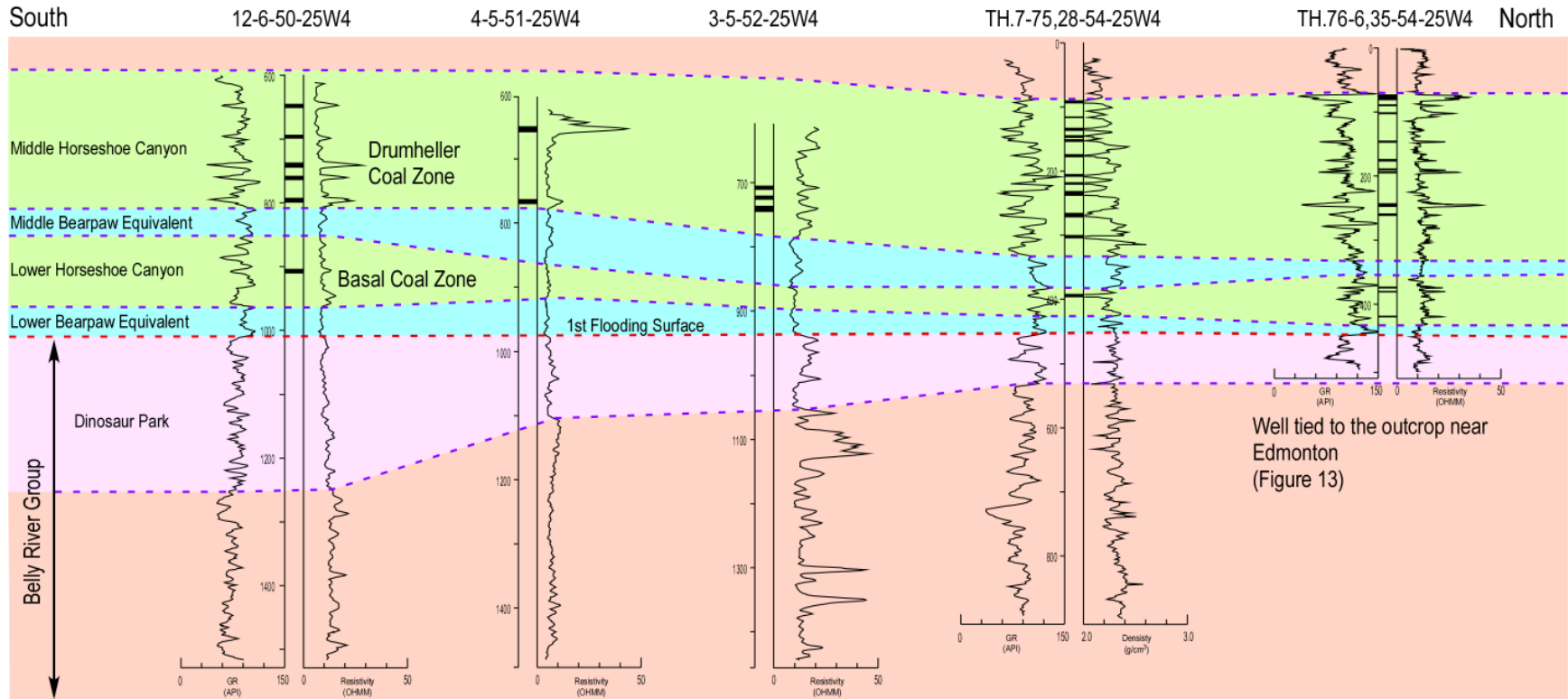


Figure 14. Cross-section D-D' across Edmonton showing the Horseshoe Canyon-Bearpaw transition and associated coal zones. Correlation datum, dashed red line, the First Flooding Surface at the base of the Bearpaw Formation. Blue colour, Bearpaw equivalent. Green colour, coal zone. Black bar in the column between log traces, coal seam. Pink and light brown colour, fluvial dominated deposits.

4 Summary

The Horseshoe Canyon Formation contains about 40% of the total CBM gas resources of the Upper Cretaceous-Tertiary succession, the major coal-bearing interval in the Alberta Plains. About 58% of the Horseshoe Canyon gas resources occur within the Drumheller and the Basal coal zones.

This study describes the Horseshoe Canyon–Bearpaw transition and correlates associated coal zones across the central and southern Alberta Plains. Outcrops and associated subsurface strata of the Horseshoe Canyon Formation in the Edmonton area are correlated and described.

Three Bearpaw marine tongues are interfingered with the Lower and Middle Horseshoe Canyon Formation. At least five major flooding surfaces are present in the Horseshoe Canyon – Bearpaw transitional zone. The 1st FS can be traced to west-central Alberta. Each of the Bearpaw marine tongues is bound by a flooding surface at the base and a coal-bearing succession on the top. The Lower and Middle Bearpaw marine tongues consist of two distinctive marine regressive (coarsening-up) sequences of strata barren of coal, whereas the Upper Bearpaw Marine Tongue consists of one coarsening-upward sequence.

Two coal zones are developed in the Lower and Middle Horseshoe Canyon Formation. The Basal Coal Zone is present between the Lower and Middle Bearpaw tongues. The Drumheller Coal Zone is present above the Middle Bearpaw Tongue and is divided by the Upper Bearpaw Tongue into the Lower and Upper Drumheller coal zones.

The gradual shifting of facies between the Bearpaw marine tongues and Horseshoe Canyon nonmarine deposits were controlled by relative fluctuations of sea level, which was in turn controlled by the activities of the basin floor and eustasy during deposition. In contrast, frequent facies changes at particular locations may have been affected by local basement discontinuities.

Ten coal seams are developed in the Edmonton area. Seams #1, #2 and #3 are correlated with the Basal Coal Zone in the Drumheller area. Seams #4, #5 and #6 are correlated with the Lower Drumheller Coal Zone in the Drumheller area. Seams #7 and #8 are equivalent to those in the Upper Drumheller Coal Zone in the Drumheller area. Coal seams #9 and #10 were not examined, but appear to be correlative to the Daly/Weaver Coal Zone.

In the Edmonton area, coal seams are mainly of sub-bituminous rank and highly fractured and cleated. Strike of the face cleats is N40-45°E, perpendicular to the Rocky Mountain Thrust Belt, and strike of the butt cleats is N50°-45°W, parallel to the Rocky Mountain Thrust Belt.

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