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Alberta Energy and Utilities Board
Alberta Geological Survey

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## Abstract

The Ardley Coal Zone forms part of the Scollard Formation of the Alberta Plains and contains one of Alberta's main coal resources. Information on the Ardley Coal Zone is often reported using Foothills coal seam terminology such as Val d'Or and Mynheer seams, implying correlation with the Coalspur Coal Zone of the Foothills area. However, cross-sections show that individual seams come and go, although some could be correlated with confidence over distances of over 50 km. Very detailed correlations of coal seams based on magneto-stratigraphy, palynology and petrography is available for the coal seams near the eastern outcrop edge of the Ardley Bend/Scollard Canyon area. In this area the traditional terminology of Lower Ardley (#13) and Ardley (#14) coal seams has been useful.

The use of a unified numeric terminology is possible for the Ardley Coal Zone in the subsurface, enabling regional correlation. In the western part of the basin, this terminology can be tied to the Foothills coal seam terminology of the Coal Valley area. The best coal seam for correlation purposes is the Lower Ardley (Seam 650; also designated as #13, Nevis and Mynheer Coal seams), the base of which marks the Cretaceous/Tertiary boundary. However, many other coal seams (such as seam 100 and 150) are also correlatable over large areas. A diagnostic palynoflora, embraced by the lower part of the *Aquilapollenites spinulosus* Zone, has been found to be characteristic of the Val d'Or Coal Seam (seam 75). The conditions suitable for peat deposition, which formed the Ardley Coal Zone, lasted at least 1 Ma, as indicated by U-Pb dating of zircons in bentonites. Regional cross sections constructed for this study provide a detailed picture of the wedge of sediment of this stratigraphic zone between the Cretaceous/Tertiary boundary and the unconformity at the base of the Paskapoo Formation.

# 1 Introduction

The Ardley Coal Zone forms part of the Scollard Formation of the Alberta Plains and contains one of Alberta's main coal resources. Information on the Ardley Coal Zone of the Plains is often reported using Foothills coal seam terminology, such as Val d'Or and Mynheer seams, implying correlation with the Coalspur Coal Zone of the Foothills area (Dawson et al., 2000). Cross-sections in Richardson et al. (1988) show that individual seams come and go, although some could be correlated with confidence over distances of over 50 km. The focus of this report will be on the Alberta Plains, the stratigraphy associated with the coals of the upper Scollard Formation and their extension westward. Very detailed correlations of coal seams based on magnetostratigraphy, palynology and petrography are available for the coal seams near the eastern outcrop edge of the Ardley Bend/Scollard Canyon area. In this area the traditional terminology of Lower Ardley (#13) and Ardley (#14) coal seams (Allan and Sanderson, 1945) has been useful. These named coals have been tied to the subsurface (Figure 1, cross-section line B–B') where a numeric terminology introduced by Richardson et al. (1988) can be applied to regional correlations. In the western part of the basin the numeric terminology can be tied to the Foothills coal terminology of the Coal Valley area (Jerzykiewicz, 1997; Figure 1, cross-section lines C–C,' E–E').

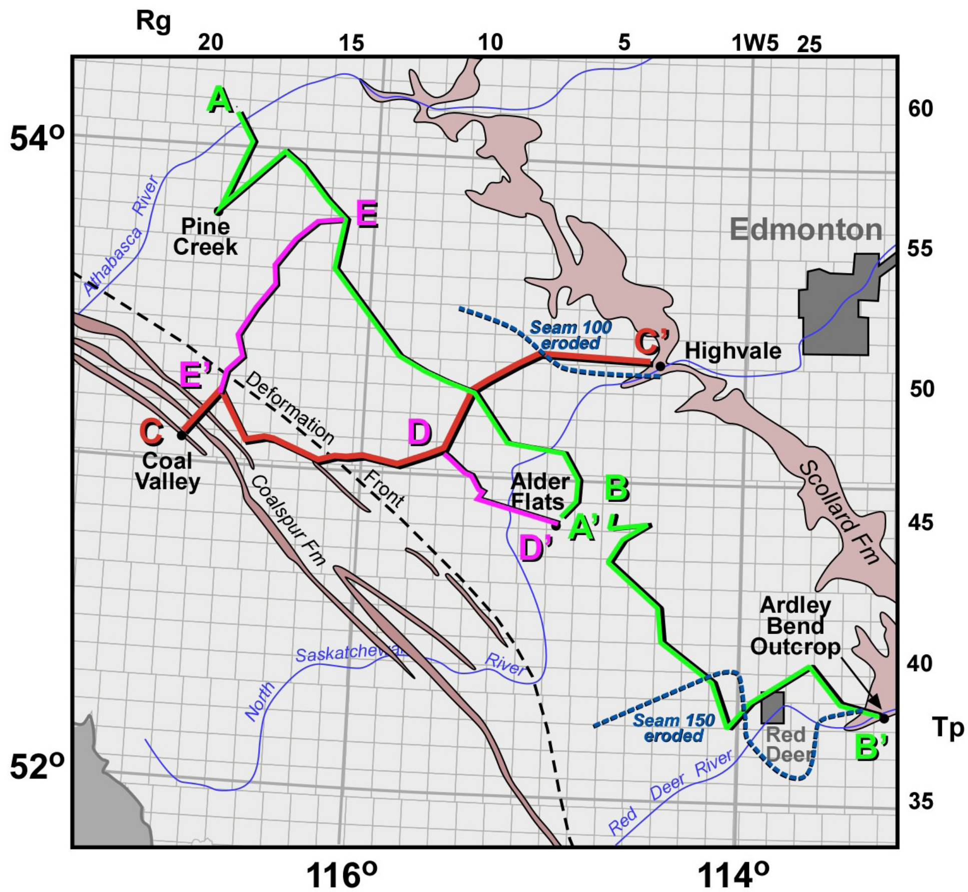


Figure 1. Map of study area with location of cross-sections and outcrop extent of Scollard and Coalspur formations (from Hamilton et al., 1999). The erosional edge of coal seams 100 and 150 is from Holter et al. (1975).

This report presents the regional Ardley Coal Zone correlations, which are supported by palynological and U-Pb age determinations and are displayed in five cross-sections. The locations of the cross-sections are shown on Figure 1. The cross-sections were drawn along the main Ardley fairway of thick coal and, where possible, include coalbed methane (CBM) exploration wells. The CBM exploration wells are often cored, which allows the collection of samples for palynology and/or dating. The wells are spaced approximately 10 km (1 township apart).

## 2 Methodology

Coal seams and marker horizons (such as the top of the Battle Formation) were identified on geophysical logs. Digital logs (LAS files) and picks were then imported in GeoGraphics™ software for cross-section construction. Coals were correlated along these cross-sections and given numbers according to the Richardson et al. (1988) terminology. This correlation implies continuity of coal seams to some extent. However, the real continuity of the coal seams with the same number cannot be proven without additional work on a more precise definition of fluvial channels and areas of peat formation. Until such time, the numbering indicates a rough age equivalency and possible continuity of the coal seams.

Shale and coal samples were collected from outcrop and core for palynological analysis with results presented in applied research reports (Sweet, 2003; 2004). In addition, three bentonite samples were collected in the Coal Valley area of the Foothills for age dating purposes. Small multi-grain zircon fractions were selected from these samples for U-Pb geochronology and analytical procedures similar to those outlined by Heaman et al. (2002) were employed.

## 3 The Stratigraphy of the Ardley Coal Zone

The stratigraphic nomenclature and various coal zone names of the Cretaceous and Tertiary interval, which includes the Ardley Coal Zone, is shown in Figure 2. Definition of the Ardley Coal Zone has evolved since the work of Dr. John Allan in the 1920s (Allan, 1924) and 1940s (Allan and Sanderson, 1945). More recent contributions by AGS include resource assessment reports of this coal zone by Campbell (1967), Holter et al. (1975), Chu (1978) and Richardson et al. (1988). The regional assessments of Alberta's CBM by AGS in the early 90s (Rottenfusser et al., 1991) and again in 2002 (Beaton et al., 2002) included the Ardley Coal Zone.

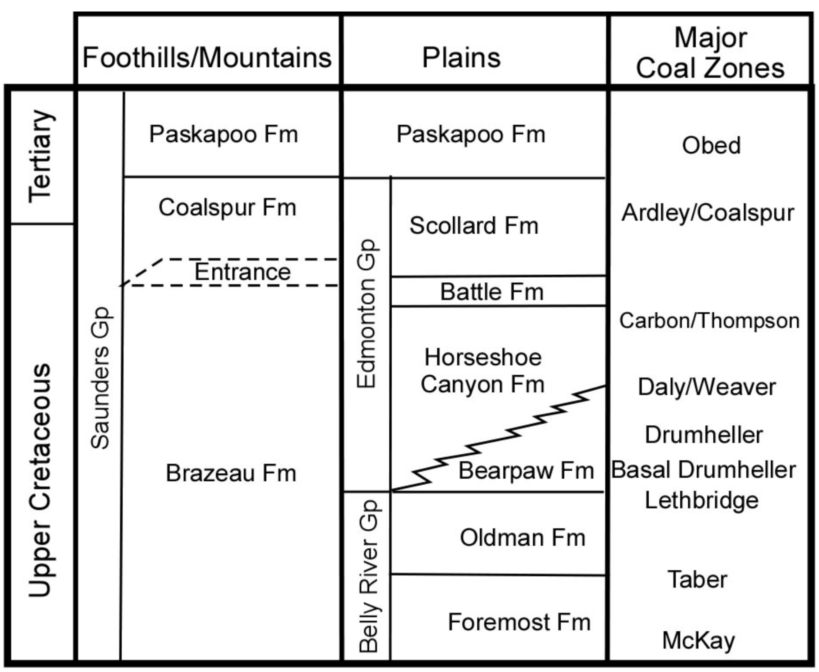


Figure 2. Stratigraphic nomenclature and coal zone terminology of the Cretaceous and Tertiary strata, which include the Ardley Coal Zone

The Ardley Coal Zone forms part of the Scollard Formation and the understanding of this stratigraphic interval evolved from the work by Elliott (1960), Irish (1970) and Carrigy (1971). A detailed study of the upper Cretaceous and Tertiary coal-bearing strata of the Red Deer River valley, including the Ardley Coal Zone, was carried out by Gibson (1977).

The Ardley Coal Zone is of Paleocene age and defines the upper part of the Scollard Formation (Gibson, 1977). The Scollard Formation is situated above the Battle Formation and below the Paskapoo Formation (Figure 2). These three units will be summarized in the following section. Because strata on the plains dip towards the mountains, Ardley coals are only exposed along the eastern and northern edges of the Scollard Formation subcrop (Hamilton et al., 1999: see also Figure 1). West of the Deformation Front, strata correlative to the Scollard Formation are referred to as the Coalspur Formation whose upper part, like that of the Scollard Formation, is coal-bearing and of Paleocene age. To the south, upper Scollard coals thin and, in the Calgary area, even thin coals are infrequent, if at all present (Lerbekmo and Sweet, 2000).

The Ardley Coal Zone is associated with alluvial plain/fluvial sediments (Richardson et al., 1988). The alluvial plain environment is characterized by widespread swamps and very low gradients. The moderately low ash content and the laterally persistent and relatively thick nature of many of these coal seams suggest the development of widespread swamps isolated from clastic deposition for long periods of time.

## 3.1 Battle Formation

The Battle Formation was defined by Irish and Harvard (1968) and is one of the most distinctive and easily recognized stratigraphic units in the region. It can be traced in adjacent outcrop and subsurface areas because of its typical lithology, colour and weathering characteristics. It also has a characteristic signature on most petrophysical logs (Ower, 1960; Elliott, 1960). The formation is relatively thin (generally between 3 and 11 m) and consists of bentonitic mudstone (with pedogenic characteristics indicating paleo-soil horizons) and volcanic ash. It is 10 m thick in the eastern part of the study area. The volcanic ash horizons (i.e., Kneehills Tuff of Allan and Sanderson, 1945) give the high gamma signature that makes the Battle Formation a good marker horizon. The tuff is not confined to any particular level in the formation and up to 3 different tuff beds have been observed.

Catuneanu and Sweet (1999, p. 696) presented palynological evidence for an extensive late Maastrichtian hiatus between the Battle and the underlying Horseshoe Canyon Formation, but found no recordable evidence for a time gap between the Scollard and Battle formations (as previously suggested by Russell, 1983).

In the western parts of the basin the Battle Formation loses its character and its age equivalent can only be inferred from shale below a prominent coarse channel sand (locally conglomeratic), known as the Entrance Conglomerate. These conglomerates are possibly eroding into the equivalents of the Battle Formation. Another interpretation is that the Entrance Conglomerate is part of a coarse facies shed into a subsiding foredeep in a more or less sheet-like configuration and that correlative sandstones extend eastward as the basal sandstones of the Scollard Formation (see Catuneanu and Sweet, 1999, p. 696).

## 3.2 Scollard Formation

The Scollard Formation was defined by Gibson (1977) and consists of sandstone, siltstone, mudstone, thin, discontinuous bentonites, and thick coal seams (Ardley Coal Zone). The upper contact with the Paskapoo Formation is clearly unconformable, as postulated by Allan and Sanderson (1945) and confirmed by Lerbekmo et al. (1990) on the basis of magnetostratigraphy and palynology.

The Cretaceous-Tertiary boundary, determined at the base of the Lower Ardley (also called Nevis) coal seam by Lerbekmo et al. (1987), divides the formation into two parts. The Paleocene upper part is coal-bearing and defines the Ardley Coal Zone, while the Maastrichtian lower part is barren of coal. In the study area, the Scollard Formation dips to the SW at 25 metres/10 km. The Scollard Formation of the plains is correlative to the Coalspur Formation in the foothills, which parallels the Scollard in its Paleocene upper part being coal-bearing and its Maastrichtian lower part being barren of coal (Jerzykiewicz and Sweet, 1986).

### 3.3 Paskapoo Formation

The Paskapoo Series was introduced by Tyrrell (1887) for sandstone units above the Edmonton Series as exposed along the Red Deer River near Red Deer. Its stratigraphy has more recently been refined by Gibson (1977), Demchuk and Hills (1991) and Jerzykiewicz (1997). The lower boundary of the Paskapoo Formation is defined as the erosional base of the first prominent sandstone above the Ardley Coal Zone and is an unconformity as described earlier. This definition can also be applied to correlative rocks on the west side of the Deformation Front, where its base is taken to be at the first major sandstone above the Val d'Or coal (Jerzykiewicz, 1997). The Paskapoo Formation is of middle and late Paleocene age.

## 4 Nomenclature of lower Paleocene Coals

Research on the Ardley coals dates back to the 1920s (Allan, 1924; Allan and Sanderson, 1945). Two prominent coal seams are generally recognized in the Ardley Coal Zone in outcrops along the Red Deer River, the Nevis (or #13) Seam and the Ardley (or #14) Seam from nomenclature proposed by Allan and Sanderson (1945; see also Gibson, 1977). Outcrop of these coal seams is shown in Figure 3. Richardson et al. (1988) focused on the coals to a depth of 400 m (using 1408 oil and gas wells and 98 Alberta Research Council coal exploration drillholes) and introduced a numeric coal seam correlation system, which numbers seams top-down ranging from 100 to 700. This numeric correlation scheme was adopted for the present study. In this correlation scheme the main Ardley coal seam (#14) is Seam 400/500/600.

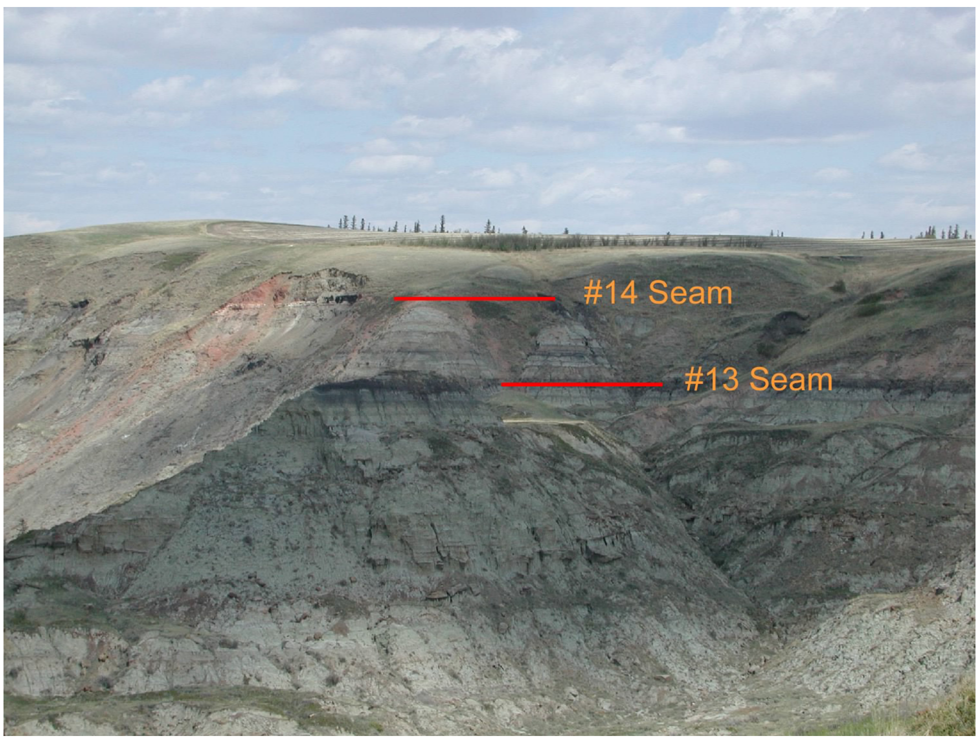


Figure 3. Outcrop of coal seams #13 (Lower Ardley/Nevis) and #14 (Main Ardley) near Dry Island Buffalo Jump Provincial Park.

The Nevis Coal Seam designation (Seam #13) was introduced by Allan (1924, p. 39) for a seam that was mined near Nevis and was supposedly located 15 m below the Ardley (#14) Seam. However, Allan and Sanderson (1945, p. 73 and Map 8) and Campbell (1967, his figure 3) show that this mine site (Section 2 & 3, TP 39, R22W4) was exploiting the Carbon/Thompson coal (part of the Maastrichtian Upper Horseshoe Canyon Formation, see Gibson, 1977; Lerbekmo and Braman, 2005). Consequently, it appears usage of the term 'Nevis Seam' for the coal exposed along the Red Deer Valley with the Cretaceous-Tertiary boundary at its base (Allan and Sanderson, 1945; Gibson, 1977; Lerbekmo et al., 1987) is a misnomer. A better name for this Cretaceous-Tertiary boundary coal is 'Lower Ardley' as suggested by Campbell (1967) and Holter et al. (1975). This coal seam can be designated Seam 650 using the Richardson et al. (1988) numeric classification scheme (see Figure 4).

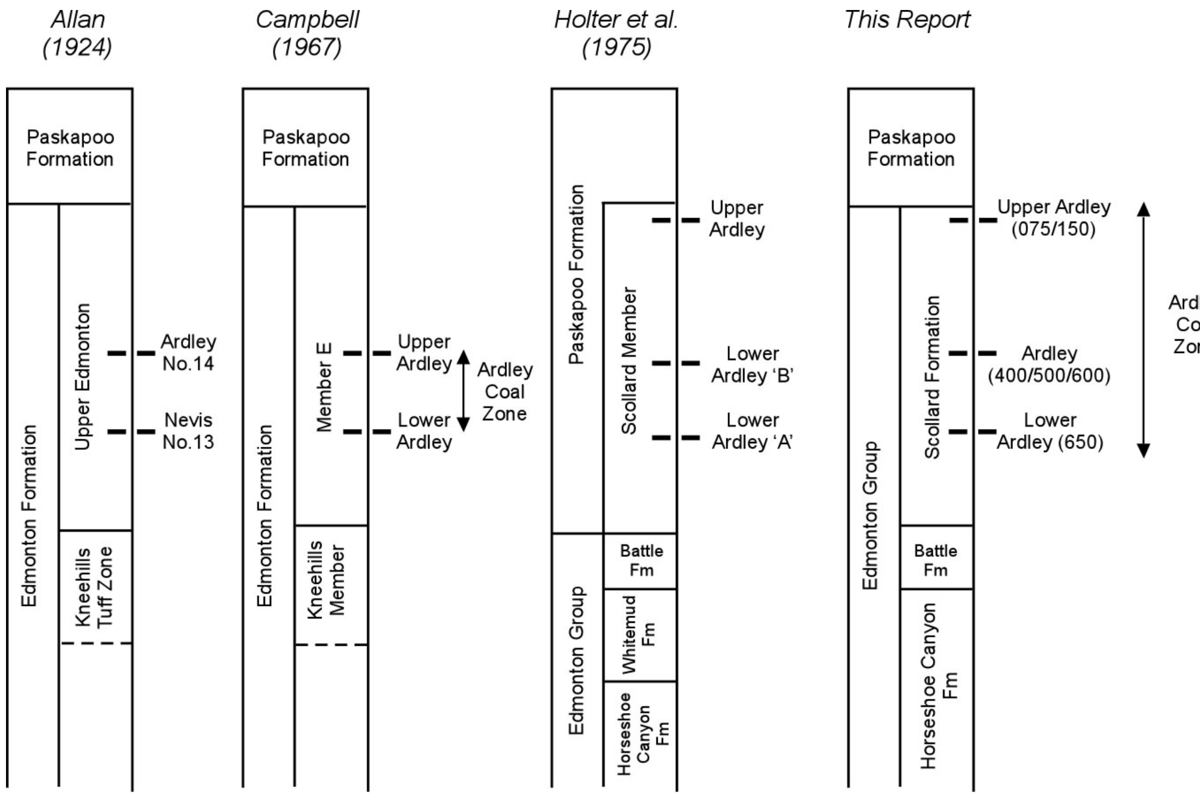


Figure 4. Coal seam terminology of the Ardley Coal Zone and terminology used in this report (right column). The stratigraphy in the right column is after Gibson (1977) and Hamblin (2004).

Palynology indicates that the Cretaceous-Tertiary boundary is located at the base of the Ardley coal zone in the Wabamun Lake area (at the base of what is locally called Coal Seam #6) and that it is located in a shaly interval 17 m below the Lower Main Seam at the Genesee mine site (Sweet, 1986a and b). The latter observation indicates that the equivalent of Seam 650 (Lower Ardley) is not present in the Genesee area.

Holter et al. (1975), following Ower (1960), also recognized a coal called 'Upper Ardley Coal Seam' in the Pigeon Lake and Lacombe areas (Figure 4). The Upper Ardley Coal Seam is exposed in the Genesee open pit coal mine near Warburg, where it is sometimes designated as the 'Cloud Seam' (Kalkreuth and Langenberg, 2002). Ower (1960) introduced a Three Hills Coal Seam, because he concluded that the coal mined near Three Hills was stratigraphically higher than the Upper Ardley Seam. However, Campbell (1967) and Holter et al. (1975) proved that the coal mined near Three Hills is the main Ardley (#14) Coal Seam. One can see how local seam terminology can lead to confusion in correlation.

A more extended but partially parallel coal seam nomenclature is based on coals west of the Deformation Front in the Alberta Foothills (Dawson et al., 2000; Engler, 1986; Jerzykiewicz 1997; Figure 5). Here the Cretaceous-Tertiary boundary coal is known as the Mynheer Seam.

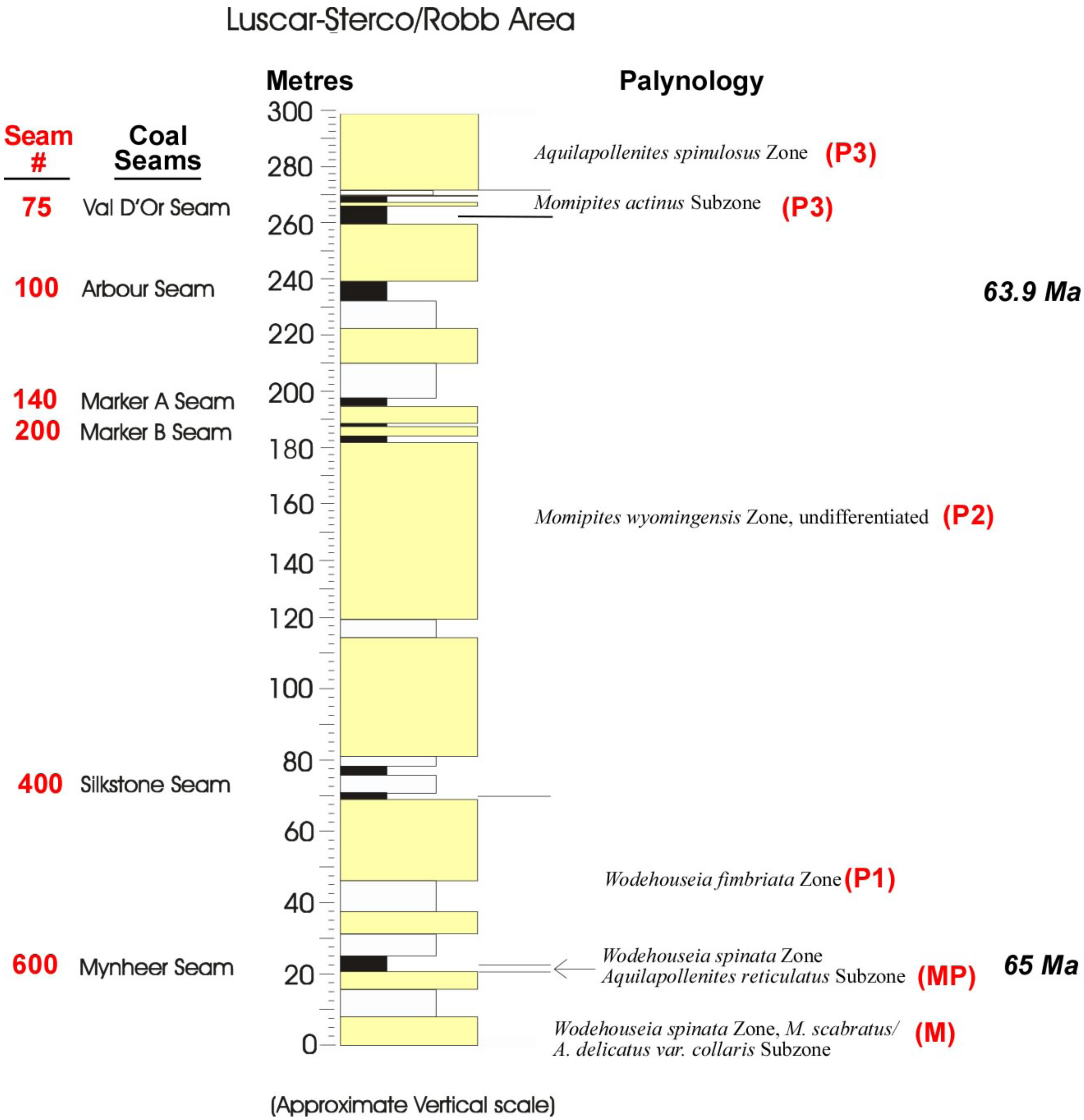


Figure 5. Simplified stratigraphic column for the Coal Valley area, with palynological zones, coal seam names and ages. M=Maastrichtian, MP=Maastrichtian/Paleocene, P1, P2 and P3 are palynological zones of the Paleocene from Nichols and Ott (1978).

## 5 Palynology

A truncation event of most miospore species characteristic of the *Wodehouseia spinata* Zone, *Myritipites scabratus/Aquilapollenites delicatus var. collaris* Subzone identifies the end of the Cretaceous Period in terrestrial rocks of mid-continental North America (Sweet and Braman, 1992). This truncation event provides a reliable basin-wide datum. It has been located at the base of the Lower Ardley coal in the Red Deer Valley (#650 seam), at the base of the Mynheer coal in the foothills (Jerzykiewicz and Sweet, 1986; Lerbekmo et al. 1987; Sweet and Braman, 1992), at the base of Coal Seam #6 in the Wabamun Lake area (Sweet, 2003) and in a shaly interval about 17 m below the Lower Main Seam at the Genesee mine site (Sweet, 1986a).

Earliest Paleocene strata in Western Canada are encompassed by the *Wodehouseia spinata* Zone, *Aquilapollenites reticulatus* Subzone (Braman and Sweet, 1999) in recognition of the conspicuous presence of a restricted number of typically Late Maastrichtian species. This subzone includes the Lower Ardley (Nevis/#13/#650) coal and about 2 m of immediately overlying strata in the Red Deer Valley, the lower Mynheer and 0.6 m of the upper Mynheer in the Coal Valley mine, and Coal seams #5 and #6 of the Wabamun Lake area (Braman and Sweet, 1999; Sweet, 2003). The top of this subzone is marked by the earliest occurrence of *Wodehouseia fimbriata*, which more or less coincides with the youngest occurrences of the name-bearing species of the *W. spinata* Zone, *A. reticulatus* Subzone. The subzone has not been recognized at Genesee (Sweet, 1986a) and in the Suncor-Cygnet 9-34-38-28W4 well (Sweet, 2004).

Demchuk (1990) did not separately differentiate the *W. spinata* Zone, *A. reticulatus* Subzone but included it within his *Wodehouseia fimbriata* Zone. Herein, the *Wodehouseia fimbriata* Zone is restricted in vertical extent to the range of Wodehouseia *fimbriata*. In the Red Deer Valley *Wodehouseia fimbriata* ranges from about 3 m above the Cretaceous-Tertiary boundary up into the lower 0.3 m of the thick Ardley coal (#14), in the interval below a prominent 0.2 m-thick bentonite (Lerbekmo et al., 1996); in the Coal Valley mine it ranges from within the upper Mynheer through to the basal part of the upper Silkstone coal (Sweet, 2003); in the Wabamun Lake area it occurs in the interval between Coal seams #5 and #4 and into the base of Coal Seam #4 (at about #400); and at Genesee over about a 5 m interval from near the approximate position of the Cretaceous-Tertiary boundary up to just below one of the Lower Ardley seams (possibly #650).

The next younger *Momipites wyomingensis* Zone of Demchuk (1990) spans the interval above the basal seam of the Ardley coal (above the stratigraphically highest record of *W. fimbriata* in the base of the Ardley) through to the base of the Paskapoo Formation in the Red Deer Valley (Demchuk, 1990). In Coal Valley, it includes the interval from the top part of the upper Silkstone coal (400) through to the base of the Val d'Or Coal seam (75); and in the Wabamun Lake area, the section above the basal part of Coal Seam #4 (Sweet, 2003).

Above the *Momipites wyomingensis* Zone, the informal *Aquilapollenites spinulosus* Zone, *Momipites actinus* subzone of Lerbekmo and Sweet (2000) encompasses Coal sub-seams A through I of the Val d'Or Coal Seam (#75). The upper limit of the *A. spinulosus* Zone, *M. actinus* subzone is placed below the first occurrence of *A. spinulosus.* Its usefulness is in uniquely identifying the main part of the Val d'Or Coal Seam. *Aquilapollenites spinulosus* occurs just above Coal A in the Coal Valley mine which places the rider seams A1 and A2 of the Val d'Or Coal Seam within the undifferentiated portion of the Middle Paleocene *Aquilapollenites spinulosus* Zone of Demchuk (1990), which continues into the overlying Paskapoo Formation. The *A. spinulosus* Zone has also been identified near the top of the coal-bearing portion of the Pine Creek area (BHP Pine Creek 02/11-6-56-19W5 borehole, starting at 746.4 m, see below). The *A. spinulosus* Zone, *M. actinus* subzone has not been observed in Red Deer Valley and associated sections.

## 6 Dating

The Cretaceous-Tertiary boundary has been dated in the Red Deer Valley (base of Lower Ardley Seam) by Baadsgaard et al. (1988) at 64.4 +/- 1.2 Ma using various methods. More recently, the boundary has been considered to be either 65 Ma (Swisher et al., 1993) or 65.5 Ma (Gradstein et al., 2004). There are several bentonites exposed in outcrops of the Upper Coalspur Formation, which contain zircons, that can be used for dating these volcanic rocks. A 3 m thick bentonite at the base of the Arbour Coal Seam (the 'Arbour Bentonite,' see Jerzykiewicz and Langenberg, 1983) was sampled from the Coalspur highway road cut (at UTM NAD27 Zone 11, 499 075 m E and 5892 425 m N). In addition, the Arbour Bentonite was sampled in a coal exploration drillhole where this bentonite is 2 m thick (sample ME-05-Gravel-3A at 10 m depth at UTM NAD27 Zone 11, 495 000 m E and 5888 900 m N). In this same drillhole, another, deeper bentonite (2 m thick) was sampled at 21 m depth (sample ME-05-Gravel-3B). Small multi-grain zircon fractions were selected from each sample for U-Pb geochronology and analytical procedures similar to those outlined by Heaman et al. (2002) were employed.

Abundant colourless zircon was recovered from the Arbour Bentonite (highway outcrop) sample. The recovered zircon occurs as subhedral to euhedral prisms with 2:1 aspect ratios or as long narrow prisms with aspect ratios up to 10:1. Four multi-grain (7–15 crystals) zircon fractions were selected from this Arbour bentonite sample and the U-Pb results are presented in Table 1 and on a concordia diagram in Figure 6a. All four fractions have similar geochemistry and $^{206}Pb/^{238}U$ ages that vary between 63.6 and 64.2 Ma. The weighted average $^{206}Pb/^{238}U$ age of 63.9 +/- 0.5 Ma (Figure 6b and Table 1) is considered a good estimate for the depositional age of the Coalspur highway Arbour Bentonite. This age is identical to the weighted average $^{206}Pb/^{238}U$ age of 63.9 +/- 0.3 Ma (Figure 6b and Table 1) obtained for two small multi-grain zircon fractions from the drillhole Arbour Bentonite (sample ME-05-Gravel-3A). The weighted average age for all five fractions from these two samples is 63.9+/-0.3 Ma and is interpreted to represent a maximum age for the deposition of the Arbour Coal Seam above this bentonite. The lower intercept age obtained by calculating a regression line for three small multi-grain zircon fractions from the deeper bentonite sampled (sample ME-05-Gravel-3B) yields an age of 64.1 +/- 0.9 Ma (Figure 6c).

The date of 63.9 Ma for the Arbour Bentonite may throw some light on the age of the Cretaceous-Tertiary boundary. The top of magnetic Polarity Chron C29n (Ogg, 1995), which is above Polarity Chron C29r, has now been located a few metres below the Arbour Coal seam (Lerbekmo, personal communication, 2006). The Arbour Coal Seam (Seam 100, equivalent to Upper Ardley) is about 220 m above the Cretaceous-Tertiary boundary (Figure 5). According to Ogg (1995), Chron C29n lasted 0.75 million years and the Tertiary part of Chron C29r may have lasted 0.25 million years (assuming that the boundary is at Polarity Chron C29r.7, see Ogg, 1995, p. 251). Adding up these two ages, one arrives at a total time of 1 million years for the interval between the Cretaceous-Tertiary boundary and the Arbour Coal Seam. Consequently, our dating of the Arbour Bentonite (63.9 Ma) agrees with an age of the Cretaceous-Tertiary boundary of about 65 Ma (and not with the 65.5 Ma age suggested by Gradstein et al., 2004). These dates indicate that the conditions suitable for peat deposition, which formed the Ardley Coal Zone, lasted at least 1 Ma (the Arbour Coal Seam correlates with the Upper Ardley Seam 100, see Figure 5).

## 7 Cross-Sections

Five cross-sections are presented, the locations of which are shown in Figure 1. All cross-sections are presented as stratigraphic cross-sections with the base of the Ardley Coal Zone as datum.

### 7.1 AA'

Cross-section AA' (Figure 7 and Enclosure 1) connects the Pine Creek area (north of Edson) with the Alder Flats (Buck Lake) area. It illustrates the prominent development of Seam 150 (with clear signature)

**Table 1. U-Pb results for zircon fractions from bentonites**

| Sample # | Description | Weight (mg) | U (ppm) | Th (ppm) | Pb (ppm) | Th/U | TCPb (pg) | 206Pb/ 204Pb | $^{206}$Pb/ $^{238}$U | $^{207}$Pb/ $^{235}$U | $^{207}$Pb/ $^{206}$Pb | $^{206}$Pb/ $^{238}$U | $^{207}$Pb/ $^{235}$U | $^{207}$Pb/ $^{206}$Pb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Outcrop Arbour-1 | 7 col long zircon prisms, best in 10NM | 11.0 | 384.8 | 131.1 | 4.6 | 0.341 | 8 | 318 | 0.01002±2 | 0.06183±90 | 0.04477±62 | 64.2±0.1 | 61±0.9 | |
| Outcrop Arbour-2 | 8 long zircon prisms, 2nd best in 10NM | 13.0 | 633.5 | 214.9 | 7.5 | 0.339 | 18 | 305 | 0.00991±1 | 0.06030±65 | 0.04414±46 | 63.6±0.1 | 59±0.6 | |
| Outcrop Arbour-3 | 10 long zircon prisms, 3rd best in 10NM | 16.0 | 831.4 | 269.0 | 9.6 | 0.324 | 23 | 374 | 0.00994±1 | 0.06519±40 | 0.04759±28 | 63.7±0.1 | 64±0.4 | |
| Outcrop Arbour-4 | 15 smaller col euhedral equant to 2:1 zircon prisms in 10NM | 23.0 | 803.1 | 217.7 | 8.3 | 0.271 | 10 | 1189 | 0.00997±1 | 0.06569±15 | 0.04779±10 | 64.0±0.1 | 65±0.1 | |
| | | | | | | | | | | | | | | |
| ME-05-Gravel-3A (10-11.6m)-1 | 22 col equant tiny zircons in ↓MI | 10 | 710 | 1431 | 7.4 | 2.02 | 5 | 856 | 0.00994±1 | 0.06338±49 | 0.04622±34 | 63.8±0.1 | 62.4±0.5 | 9.4±17.4 |
| ME-05-Gravel-3A (10-11.6m)-2 | 22 col 3:1 tiny zircons prisms in ↓MI | 12 | 558 | 9 | 8.8 | 0.02 | 8 | 839 | 0.01512±2 | 0.16087±59 | 0.07715±25 | 96.8±0.1 | 151.5±0.5 | 1125.0±6.5 |
| ME-05-Gravel-3A (10-11.6m)-3 | 14 col equant larger zircons in ↓MI | 28 | 411 | 117 | 4.5 | 0.29 | 14 | 550 | 0.00997±1 | 0.06549±50 | 0.04764±34 | 64.0±0.1 | 64.4±0.5 | 81.2±17.1 |
| | | | | | | | | | | | | | | |
| ME-05-Gravel-3B (21-23m)-1 | 22 col 3:1 tiny prisms in ↓MI | 19 | 544 | 84 | 5.9 | 0.15 | 8 | 860 | 0.01031±1 | 0.06872±21 | 0.04833±14 | 66.1±0.1 | 67.5±0.2 | 115.7±6.7 |
| ME-05-Gravel-3B (21-23m)-2 | 27 col 3:1 zircon prisms (2nd best) in ↓MI | 14 | 555 | 271 | 6.4 | 0.49 | 14 | 361 | 0.00986±1 | 0.06365±43 | 0.04682±30 | 63.3±0.1 | 62.7±0.4 | 40.0±15.4 |
| ME-05-Gravel-3B (21-23m)-3 | 29 col 3:1 zircon prisms in ↓MI | 8.1 | 784 | 221 | 10.3 | 0.28 | 17 | 269 | 0.01057±2 | 0.07086±102 | 0.04861±67 | 67.8±0.1 | 69.5±1.0 | 128.9±31.9 |

col: colourless
10NM: non-magnetic split from a Frantz Isodynamic Separator at a 10 degree side tilt
↓MI: Heavy mineral fraction that sank in Methyline Iodide
best: least fractures and impurities in zircons
TCPb: Total Common Pb in analysis in pg (picograms)

All errors in this table reported at 1 sigma.

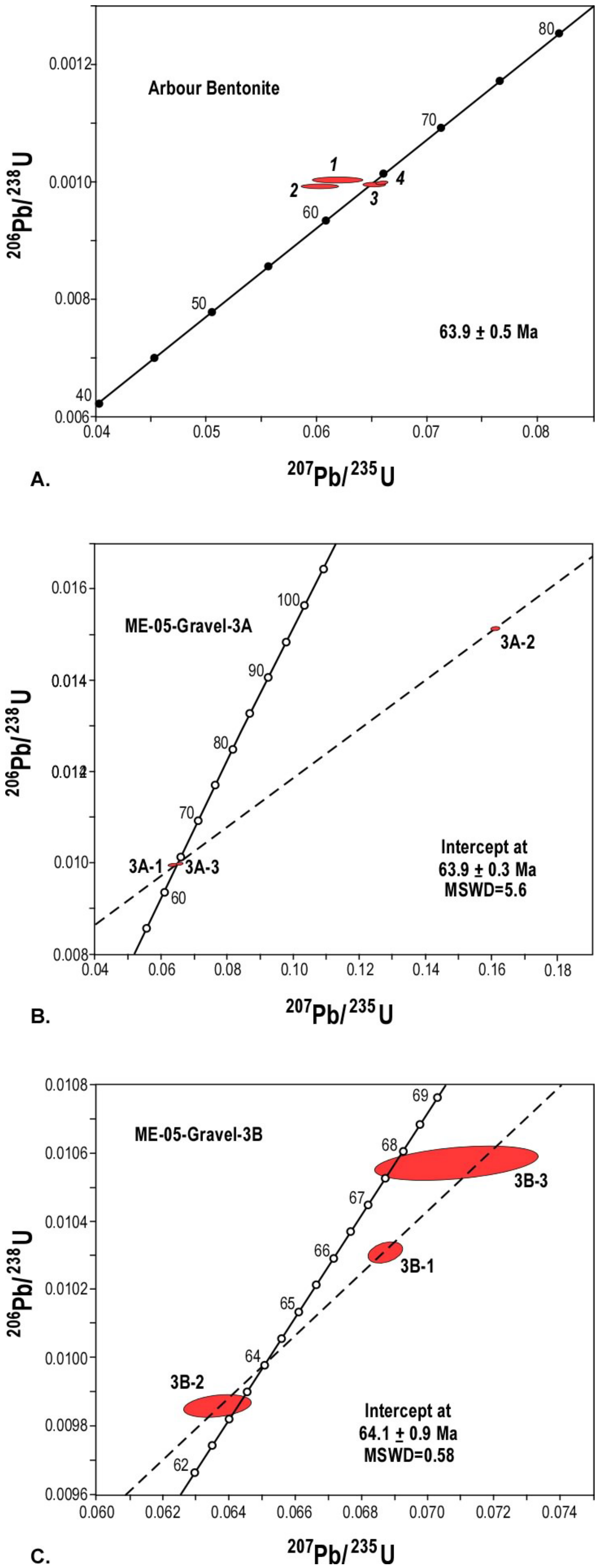


Figure 6. Isochrons of U-Pb dating of zircons. A. Data of the Arbour bentonite outcrop. B. Data of the Arbour bentonite in the borehole. C. Data of bentonite 10 m below the Arbour Seam in borehole.

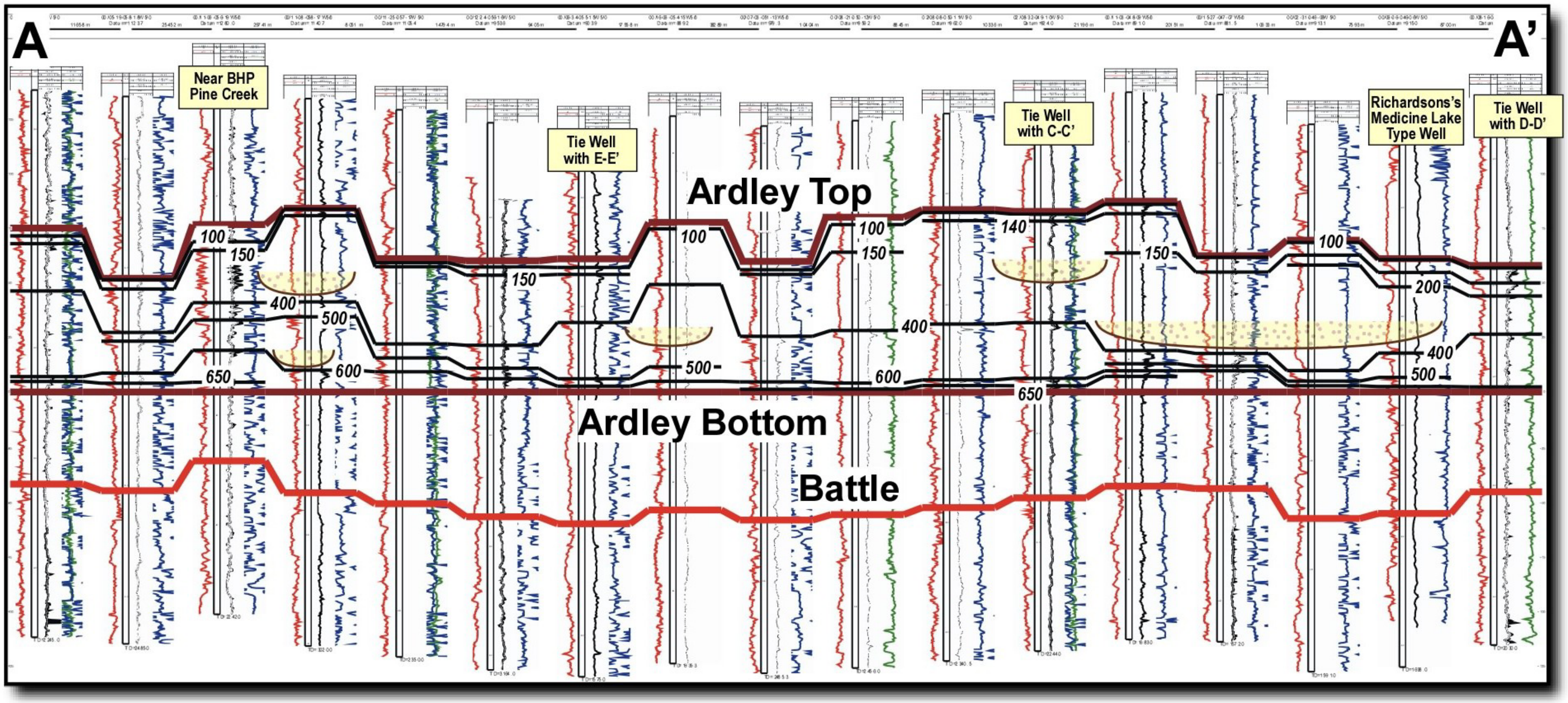


Figure 7. Cross-section AA' (large version is Enclosure 1). For location see Figure 1.

in the Alder Flat area. There are thick channel sands between seams 150 and 400, which may have eroded seams 200 (locally present) and 300 (not identified along this cross-section).

Palynology indicates that the *Wodehouseia fimbriata* Zone (P1) is missing in the Pine Creek core (from well BHP 02/11-6-56-19W5). The *Momipites actinus* informal subzone is present around Seam 100 (Figure 8) and above this seam, indicating that the equivalence of Seam 75 in the Foothills (Val d'Or Coal Seam) is present in a shaly and sandy facies. Consequently, this clearly shows that the usage of Foothills terminology is confusing the description of the Ardley Coal Zone in this area and that the label of Seam 100 for this coal seam is preferable.

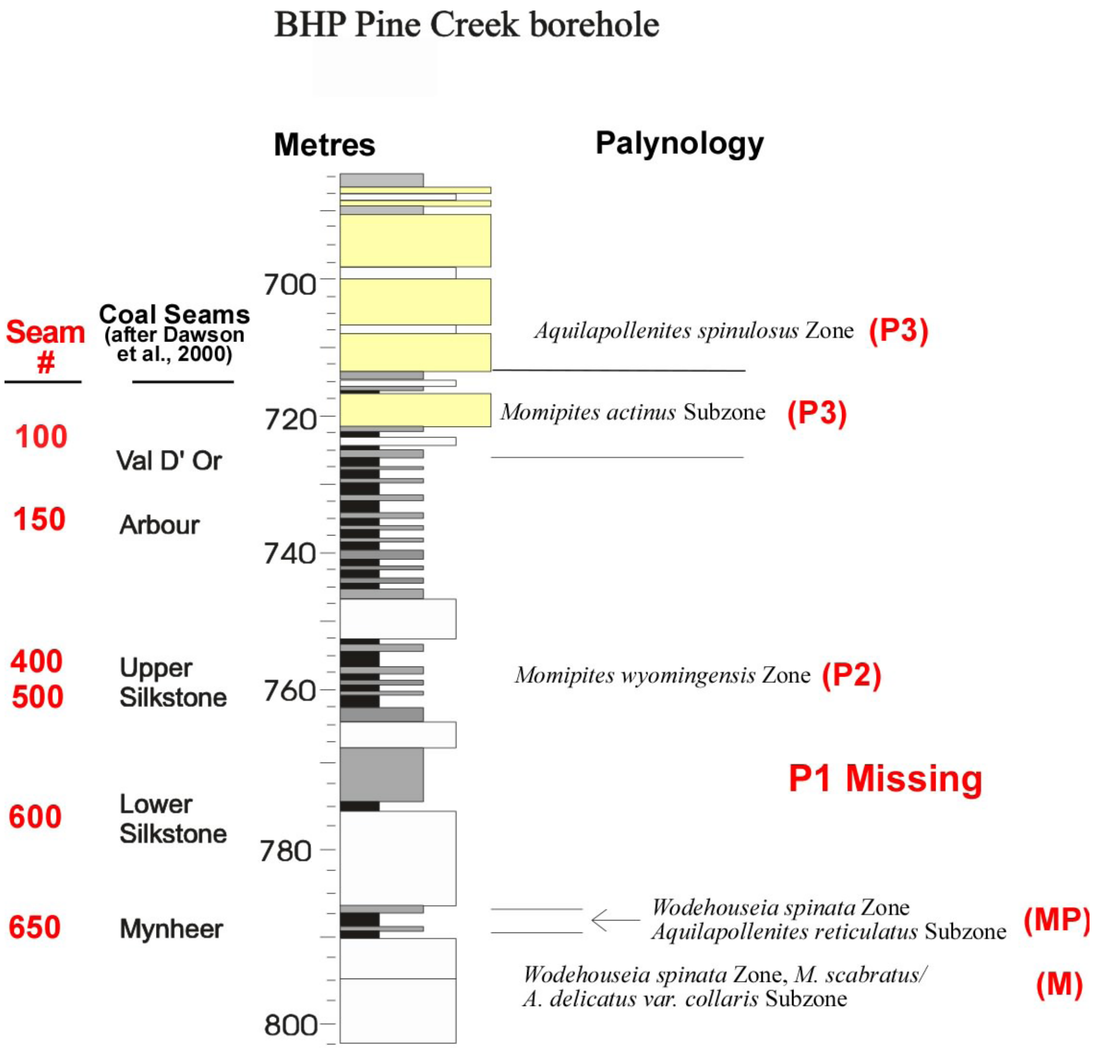


Figure 8. Litholog of core from well BHP Pine Creek 02/11-6-56-19W5, with palynological zones and seam names.

Equivalences of the Lower Ardley and Mynheer seams (seam 650) can be recognized near the base of the Ardley Coal Zone.

### 7.2 BB'

Cross-section BB' (Figure 9 and Enclosure 2) connects the Alder Flats area with the Red Deer and Ardley Bend area, where the Ardley Coal Zone is exposed in its type section. The positions of the Ardley

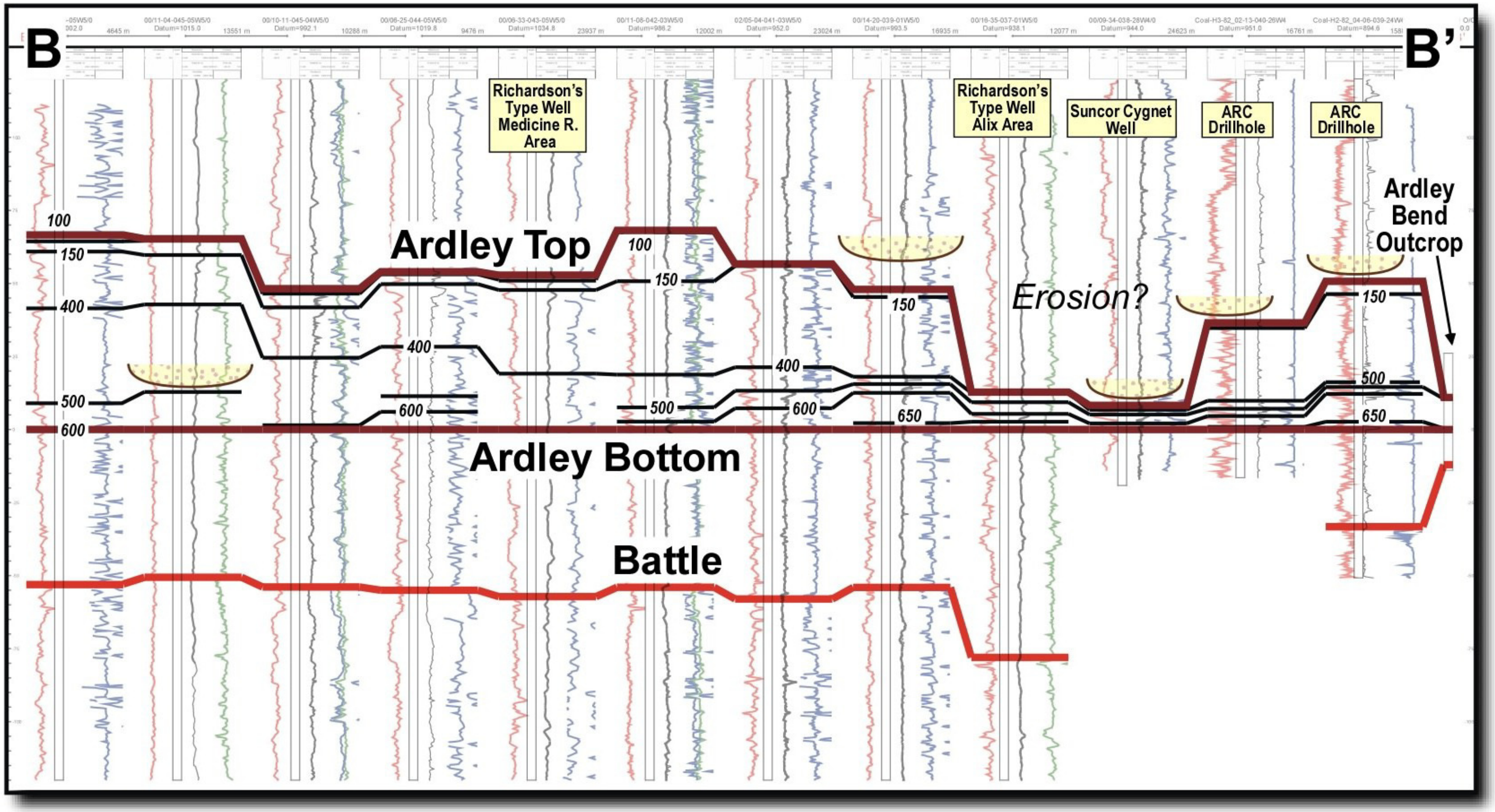


Figure 9. Cross-section BB' (large version is Enclosure 2). For location see Figure 1.

(Seam 400) and Lower Ardley (Seam 650) in the Ardley Bend outcrop are based on Campbell (1967). Wells 16-35-37-1W5 (Richardson et al., 1988, Alix area type well) and 9-34-38-28W4 (Suncor-Cygnet CBM well) show that there was significant erosion of the Upper Ardley (Seam 150). This is the sub-Paskapoo unconformity of Lerbekmo et al. (1990), which was also observed by Holter et al. (1975) by the absence of the Upper Ardley Coal Seam (seams 100 and 150). The erosional edge on Figure 1 is from Holter et al. (1975) and was also observed by two additional cross-sections southwest of Red Deer (not presented here).

Well 6-33-43-5W5 (Richardson et al., 1988, Medicine River area type well) shows that the Main Ardley (seams 500 and 600) and the Lower Ardley (Seam 650) are not present everywhere. Whether this represents nondeposition or erosion is uncertain.

### 7.3 CC'

Cross-section CC' (Figure 10 and Enclosure 3) correlates the Coal Valley area of the Foothills with the Wabamun Lake area (Highvale Coal mine). It shows that the equivalents of the Val d'Or (Seam 75) and Arbour (Seam 100) are not present in the Wabamun area. This is supported by the palynology, which shows that the *Momipites actinus* subzone (P3) is not present at this site (Figure 11). The Val d'Or (Seam 75) disappears around TP 47, R14W5 and the Arbour (Seam 100) disappears around TP 50, R9W5. These disappearances are related to the Paskapoo unconformity (Lerbekmo et al., 1990). Seam 400 (equivalent to Lower Silkstone) has reasonable continuity and may be represented by Seam #1 of the Highvale mine. Seams 200 and 300 (Upper Silkstone) are more discontinuous than the other seams.

### 7.4 DD'

Cross-section DD' (Figure 12 and Enclosure 4) ties the Alder Flats area through the BHP Pembina well (14-15-46-10W5) with cross-section CC.' It shows how Seam 150, which has a characteristic signature along cross-section AA,' cannot be recognized along cross-section CC.' A slightly higher seam was designated Seam 140. The discontinuous nature of Seam 150 can be partly explained by some significant channel deposits in this interval. The cross-section also shows a significant sandstone split between seams 600 and 650.

### 7.5 EE'

Cross-section EE' (Figure 13 and Enclosure 5) correlates the Foothills with the northern part of cross-section AA' (near the Pine Creek area). It shows how Seam 150 loses it characteristic signature towards the West and how Seam 75 (Val d'Or Seam) disappears into the Basin. This disappearance is related to the Paskapoo unconformity and is supported by palynology, as discussed previously.

## 8 Conclusions

Outcrop to subsurface correlations have been established. It is concluded that the use of a unified numeric terminology is possible for the Ardley Coal Zone. It appears that the Lower Ardley (Seam 650) is the best coal seam for correlation purposes. It is only absent in an area west of Red Deer and in the Genesee Coal Mine area. However, many other coal seams (such as seams 100 and 150) are also correlatable over large areas. The conditions suitable for peat deposition, which formed the Ardley Coal Zone, lasted at least 1 million years. The recognition of local unconformities may allow the establishment of more detailed geological histories in local areas.

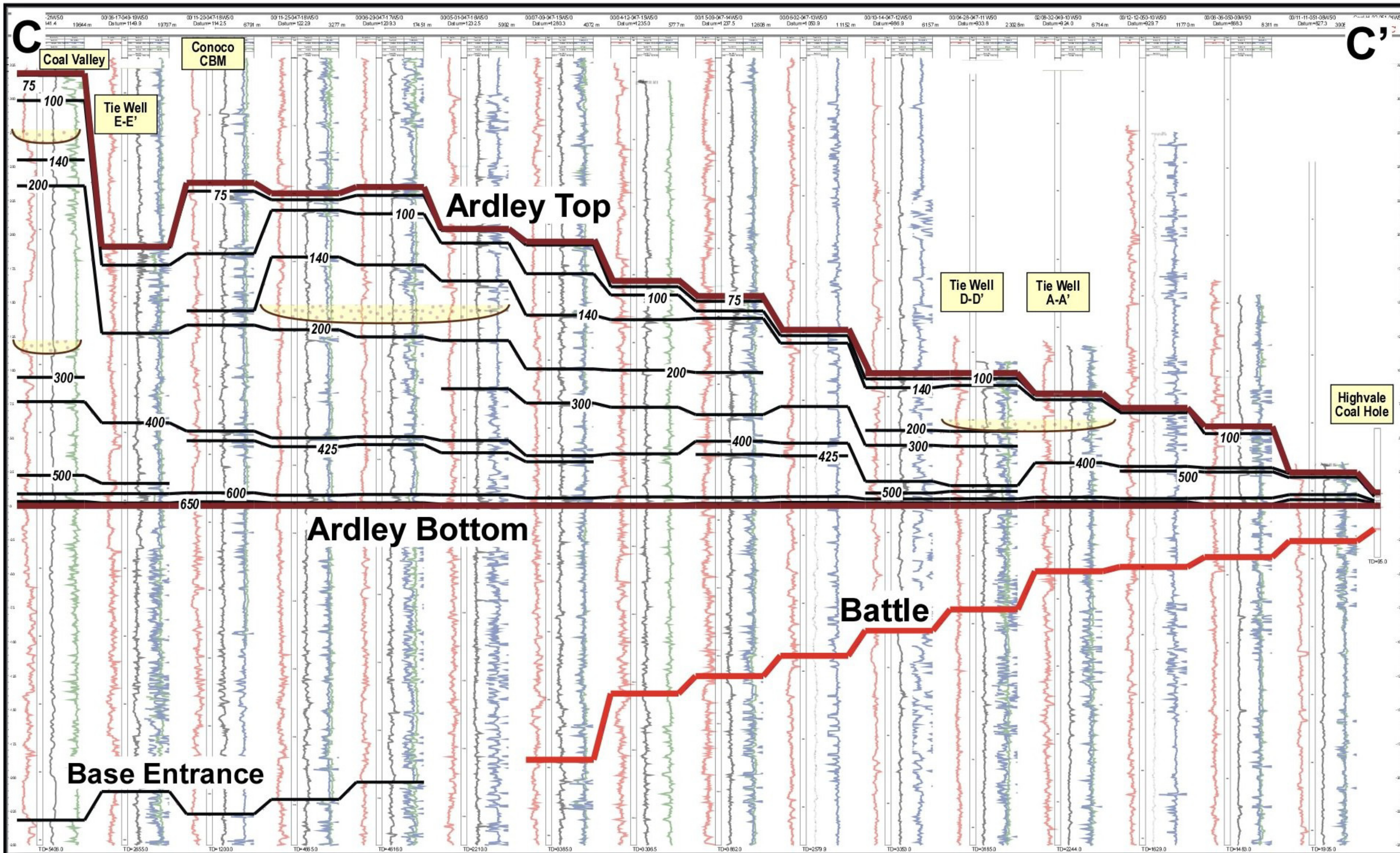


Figure 10. Cross-section CC' (large version is Enclosure 3). For location see Figure 1.

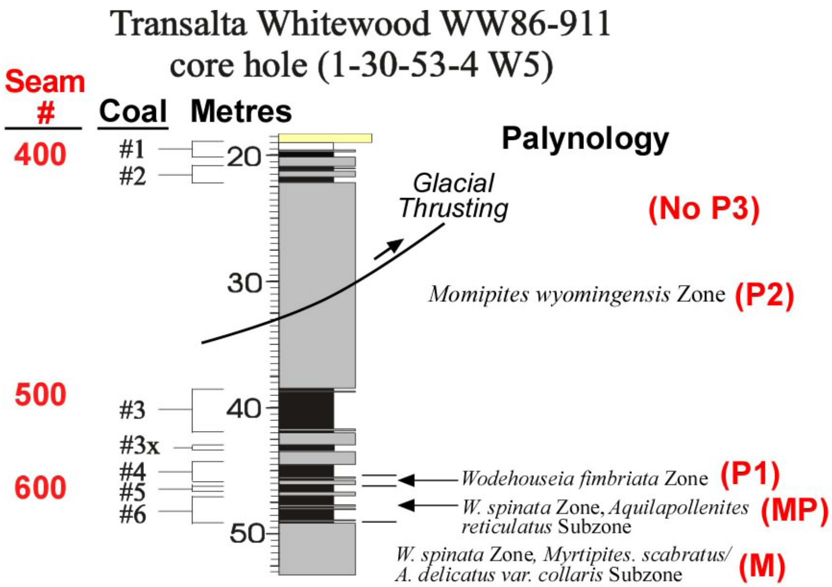


Figure 11. Litholog of core from coal hole at the Whitewood mine at 1-30-53-4W5, with palynological zones and seam names.

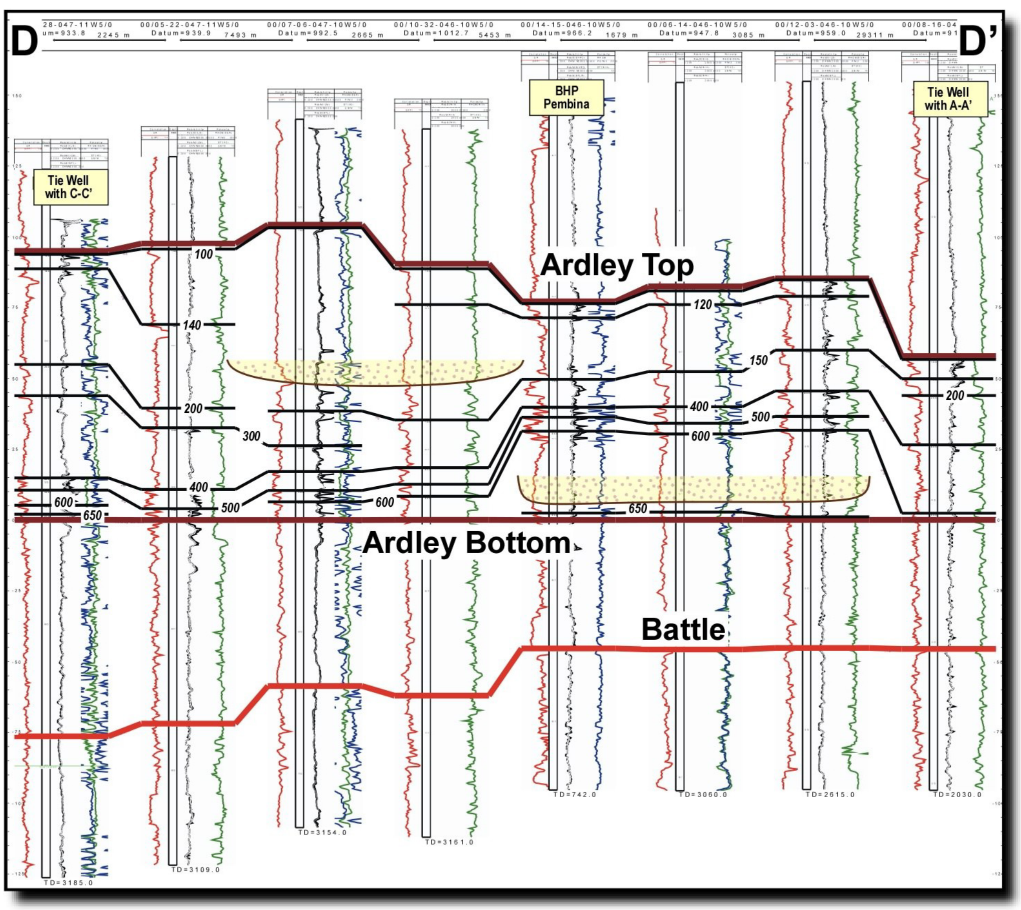


Figure 12. Cross-section DD' (large version is Enclosure 4). For location see Figure 1.

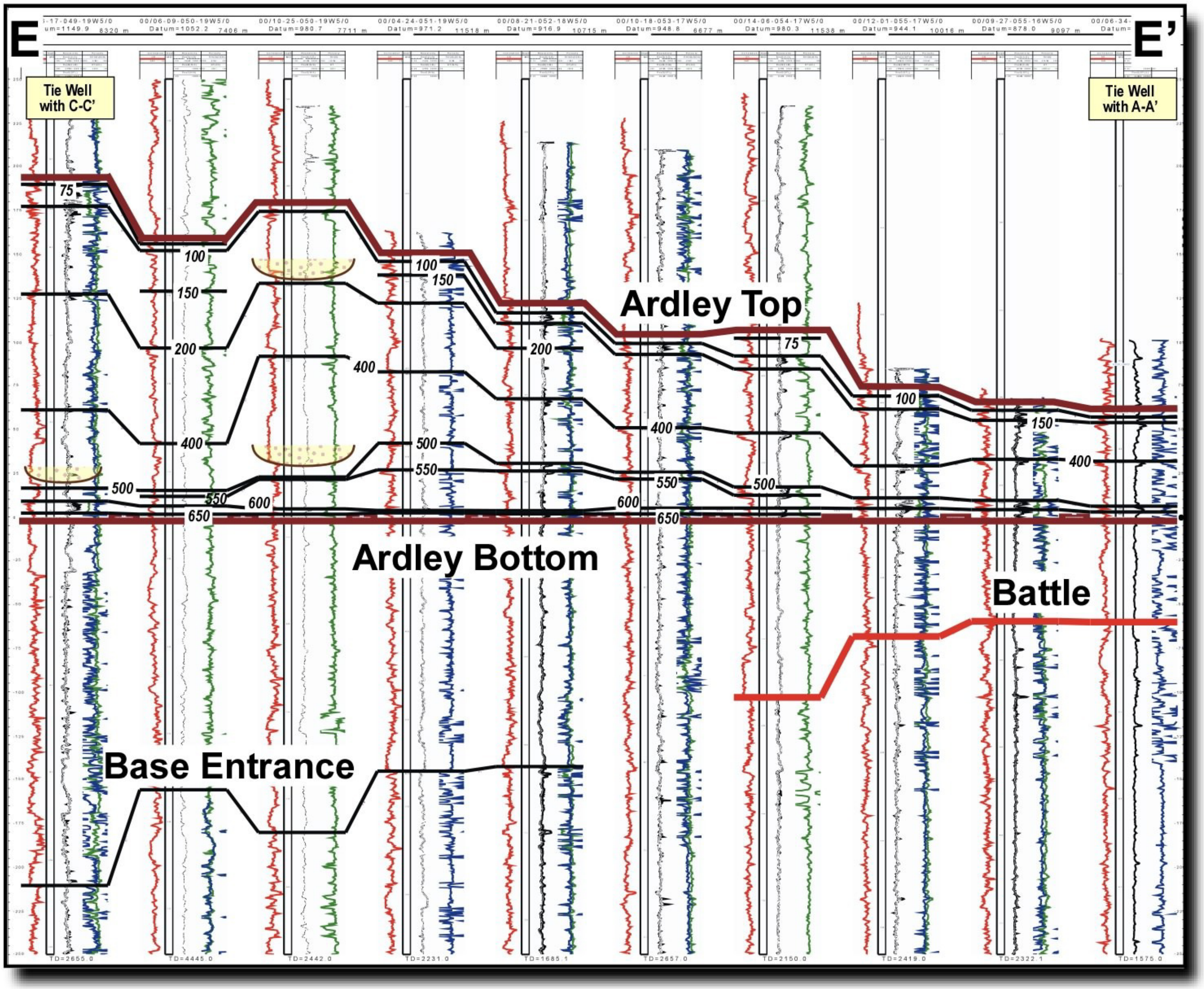


Figure 13. Cross-section EE' (large version is Enclosure 5). For location see Figure 1.

## 9 References


Allan, J.A. (1924): Carbon, Big Valley, and Ardley coal areas survey; Fifth annual report of the Scientific and Industrial Research Council of Alberta, p. 37–45.

Allan, J.A. and Sanderson, J.O.G. (1945): Geology of the Red Deer and Rosebud sheets, Alberta; Alberta Research Council, Alberta Geological Survey, Report 13, 115 p.

Baadsgaard, H., Lerbekmo, J.F. and McDougall, I. (1988): A radiometric age for the Cretaceous-Tertiary boundary based upon K-Ar, Rb-Sr, and U-Pb ages of bentonites from Alberta, Saskatchewan, and Montana; Canadian Journal of Earth Sciences, v. 25, p. 1088–1097.

Beaton, A., Pana, C., Chen, D., Wynne, D. and Langenberg, C.W. (2002): Coalbed-methane potential of Upper Cretaceous-Tertiary strata, Alberta Plains; Alberta Energy and Utilities Board, EUB/AGS Earth Sciences Report 2002-06, 76 p.

Braman, D.R. and Sweet, A.R. (1999): Terrestrial palynomorph biostratigraphy of the Cypress Hills, Wood Mountain and Turtle Mountain areas (Late Cretaceous-Paleocene), Western Canada; Canadian Journal of Earth Sciences, v. 36, p. 725–741.

Campbell, J.D. (1967): Ardley Coal Zone in the Alberta Plains: Central Red Deer River area; Alberta Research Council, Alberta Geological Survey, Earth Sciences Report 1967-01, 28 p.

Carrigy, M.A. (1971): Lithostratigraphy of the Uppermost Cretaceous (Lance) and Paleocene strata of the Alberta Plains; Alberta Research Council, Alberta Geological Survey, Bulletin 27, 161 p.

Catuneanu, O. and Sweet, A.R. (1999): Maastrichtian-Paleocene foreland basin stratigraphies, Western Canada: a reciprocal sequence architecture; Canadian Journal of Earth Sciences, v. 36, p. 685–703.

Chu, M. (1978): Geology and coal resources of the Wapiti Formation of north central Alberta; Alberta Research Council, Alberta Geological Survey, Open File Report 1978-12, 25 p.

Dawson, F.M., Marchioni, D.L., Anderson, T.C. and McDougall, W.J. (2000): An assessment of coalbed methane exploration projects in Canada; Geological Survey of Canada, Bulletin 549, 217 p.

Demchuk, T.D. (1990): Palynostratigrahic zonation of Paleocene strata in central and south-central Alberta Plains; Canadian Journal of Earth Sciences, v. 27, p. 1263–1269.

Demchuk, T.D. and Hills, L.V. (1991): A re-examination of the Paskapoo Formation in the central Alberta Plains: the designation of three new members; Bulletin of Canadian Petroleum Geology, v. 39, p. 270–282.

Elliott, R.H.J. (1960): Subsurface correlations of the Edmonton Formation; Journal of the Alberta Society of Petroleum Geologists, v. 8, p. 324–337.

Engler, R.F. (1986): The Coalspur beds: regional variations and correlations; Canadian Institute of Mining and Metallurgy Bulletin, v. 79, no. 891, p. 61–66.

Gibson, D.W. (1977): Upper Cretaceous and Tertiary coal-bearing strata in the Drumheller-Ardley region, Red Deer River Valley, Alberta; Geological Survey of Canada, Paper 76-35, 41 p.

Gradstein, F.M., Ogg, J.G. and Smith, A.G. (2004): A Geologic Time Scale 2004; Cambridge University Press, New York, 610 p.

Hamblin, A.P. (2004): The Horseshoe Canyon Formation in southern Alberta: Surface and subsurface stratigraphic architecture, sedimentology, and resource potential; Geological Survey of Canada, Bulletin 578, 180p.

Hamilton, W.N., Price, M.C. and Langenberg, C.W. (1999): Geological Map of Alberta; Alberta Energy and Utilities Board, EUB/AGS Map 236, scale 1:1 000 000.

Heaman, L.M., Erdmer, P. and Owen, J.V. (2002). U-Pb geochronologic constraints on the crustal evolution of the Long Range Inlier, Newfoundland; Canadian Journal of Earth Sciences, v. 39, p. 845–865.

Holter, M.E., Yurko, J.R. and Chu, M. (1975): Geology and coal reserves of the Ardley Coal Zone of central Alberta; Alberta Research Council, Alberta Geological Survey, Earth Sciences Report 1975-07, 41 p.

Irish, E.J.W. (1970): The Edmonton Group of south-central Alberta; Bulletin of Canadian Petroleum Geology, v. 18, p. 125–155.

Irish, E.J.W. and Harvard, C.J. (1968): The Whitemud and Battle formations ("Kneehills Tuff zone"), a stratigraphic marker; Geological Survey of Canada, Paper 67-63, 20 p.

Jerzykiewicz, T. (1997): Stratigraphic framework of the uppermost Cretaceous to Paleocene strata of the Alberta Basin; Geological Survey of Canada, Bulletin 510, 121 p.

Jerzykiewicz, T. and Langenberg, C.W. (1983): Structure, stratigraphy and sedimentary facies of the Paleocene and lower Cretaceous coal-bearing strata in the Coalspur and Grande Cache areas, Alberta; Canadian Society of Petroleum Geology, Conference on the Mesozoic of Middle North America, Calgary, May 8-11, 1983, Field Trip Guidebook No. 9, 63p.

Jerzykiewicz, T. and Sweet, A.R. (1986): The Cretaceous-Tertiary boundary in the central Alberta Foothills, 1: Stratigraphy; Canadian Journal of Earth Sciences, v. 23, p. 1356–1374.

Kalkreuth, W. and Langenberg, C.W. (2002): Petrography of Ardley Coals, Alberta—Implications for CBM Potential; Alberta Energy and Utilities Board, EUB/AGS Special Report 055, 46 p.

Lerbekmo, J.F. and Braman, D.R. (2005): Magnetostratigraphic and palynostratigraphic correlation of the late Campanian to early Maastrichtian strata of the Bearpaw and Horseshoe Canyon formations between the CPOG Strathmore corehole and the Red Deer Valley section, Alberta, Canada; Bulletin of Canadian Petroleum Geology, v. 53, p. 154–164.

Lerbekmo, J.F. and Sweet, A.R. (2000): Magnetostratigraphy and biostratigraphy of the continental Paleocene in the Calgary area, southwestern Alberta; Bulletin of Canadian Petroleum Geology, v. 48, p. 285–306.

Lerbekmo, J.F., Evans, M.E. and Hoye, G.S. (1990): Magnetostratigraphic evidence bearing on the magnitude of the sub-Paskapoo disconformity in the Scollard Canyon-Ardley area of the Red Deer Valley, Alberta; Bulletin of Canadian Petroleum Geology, v. 38, p. 197–202.

Lerbekmo, J.F., Sweet, A.R. and Duke, M.J.M. (1996): A normal polarity subchron which embraces the K/T boundary: a measure of sedimentary continuity across the boundary and sychroneity of boundary events; *in* Cretaceous-Tertiary Event and other Catastrophes in Earth History, G. Ryder, D. Fastovsky and S. Gartner (ed.), Geological Society of America, Special Paper 307, p. 465–476.

Lerbekmo, J.F., Sweet, A.R. and St. Louis, R.M. (1987): The relationship of the iridium anomaly and palynological floral events at three Cretaceous-Tertiary boundary locations in Western Canada; Geological Society of America, Bulletin, v. 99, p. 325–330.

Nichols, D.J. and Ott, H.L. (1978): Biostratigraphy and evolution of the *Momipites-Caryapollinites* lineage in the early Tertiary in the Eind River Basin, Wyoming. Palynology, v.2, p.93-112.

Ogg, J.G (1995): Magnetic polarity time scale of the Phanerozoic, Volume 1; *in*, Global Earth Physics: A Handbook of Physical Constants, T. J. Ahrens (ed.), American Geophysical Union, Washington, p. 240–270.

Ower, J.R. (1960): The Edmonton Formation; Journal of the Alberta Society of Petroleum Geologists, v. 8, p. 309–338.

Richardson, R.J.H, Strobl, R.S., Macdonald, D.E., Nurkowski, J.R., McCabe, P.J. and Bosman, A. (1988): An evaluation of the coal resources of the Ardley Coal Zone, to a depth of 400 m, in the Alberta Plains area; Alberta Research Council, Alberta Geological Survey, Open File Report 1988-02, 96 p.

Rottenfusser, B., Langenberg, W., Mandryk, G., Richardson, R., Fildes, B., Olic, J., Stewart, S., Eccles, R., Evans, C., Spelrem, M., Sprecher, B., Brulotte, M., Gentzis, T., Wynne, D. and Yuan, L.P. (1991): Regional evaluation of the coalbed methane potential in the Plains and Foothills of Alberta, stratigraphy and rank study; Alberta Research Council, Alberta Geological Survey, Special Report 7, 126 p.

Russell, L.S. (1983): Evidence for an unconformity at the Scollard-Battle contact, Upper Cretaceous strata, Alberta; Canadian Journal of Earth Sciences, v. 20, p. 1219–1231.

Sweet, A.R. (1986a): Applied research report on 13 samples of core from a coal testhole, GC-85-7, locality C-121100 near Genesee, Alberta (NTS 83G/8; NW1/4 Sec.9, Twp. 50, Rge. 2W5); Geological Survey of Canada, Report AS-86-4, 6 p.

Sweet, A.R. (1986b): Applied research report on 53 samples of the Scollard Formation from the Transalta WW86-911 core testhole located in the Whitewood mine, Wabamun Lake, Alberta (LSD 1, Sec. 30, Twp. 53, Rge. 4W5); Geological Survey of Canada, Report AS-86-10, 16 p.

Sweet, A.R. (2003): Applied research report on 208 subsurface core and outcrop samples of latest Maastrichtian and Paleocene age (NTS 82P5/6), west-central Alberta; Geological Survey of Canada, Report 04-ARS-2003, 7 p.

Sweet, A.R. (2004): Applied research report on 13 Paleocene samples from the Suncor et al. Cygnet 9-34-38-28 well, Upper Scollard Formation, west-central Alberta (9-34-38-28W4, NTS 83A/5); Geological Survey of Canada, Report 05-ARS-2004, 5 p.

Sweet, A.R. and Braman, D.R. (1992): The K-T boundary and contiguous strata in western Canada: interactions between paleoenvironments and palynological assemblages; Cretaceous Research, v. 13, p. 31–79.

Swisher, C.C. III, Dingus, L. and Butler, R.F. (1993): $^{40}Ar/^{39}Ar$ dating and magnetostratigraphic correlation of the terrestrial Cretaceous-Paleogene boundary and Puercan Mammel Age, Hell Creek – Tullock formations, eastern Montana; Canadian Journal of Earth Sciences, v. 30, p. 1981–1996.

Tyrrell, J.B. (1887): Report on a part of northern Alberta, and portions of adjacent districts of Assiniboia and Saskatchewan; Geological Survey of Canada, 1886 Annual Report, new series, v.II, Part E, p. 1-176.

## Enclosures 1-5 (Cross-Sections AA', BB', CC', DD' and EE')


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25452 m
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KB = 1280.0
29741 m
00/11-08-058-17W5/0
KB = 1140.7
8051 m
00/11-25-057-17W5/0
KB = 1105.4
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02/08-08-050-11W5/0
KB = 962.0
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KB = 881.5
10633 m
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KB = 913.1
7593 m
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KB = 915.0
8700 m
00/08-16-045-07W5/0
KB = 914.3
Near BHP-Pine Creek
Tie Well with E-E'
Tie Well with C-C'
Richardson's Medicine Lake Type well
Alder Flats Tie with D-D'
Ardley Coal Zone Top
Ardley Coal Zone Bottom
BATTLE
150
125
100
75
50
25
0
-25
-50
-75
-100
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Richardson's Type Well
Medicine R. Area
Richardson's Type Well
Alix Area
Suncor Cygnet
Well
A R C
Coal Hole
A R C
Coal Hole
Ardley-CZ Top
Ardley CZ-Bot
BATTLE
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75
50
25
0
-25
-50
-75
-100
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39081 m
Coal-H_02-051-04W5
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Coal Valley
Tie Well with E - E'
Conoco CBM
Tie Well with D - D'
Tie Well with A - A'
High Vale Coal Hole
Highvale Coal Mine
Ardley Coal Zone Top
Ardley Coal Zone Bottom
TD=5406.0
TD=2655.0
TD=1200.0
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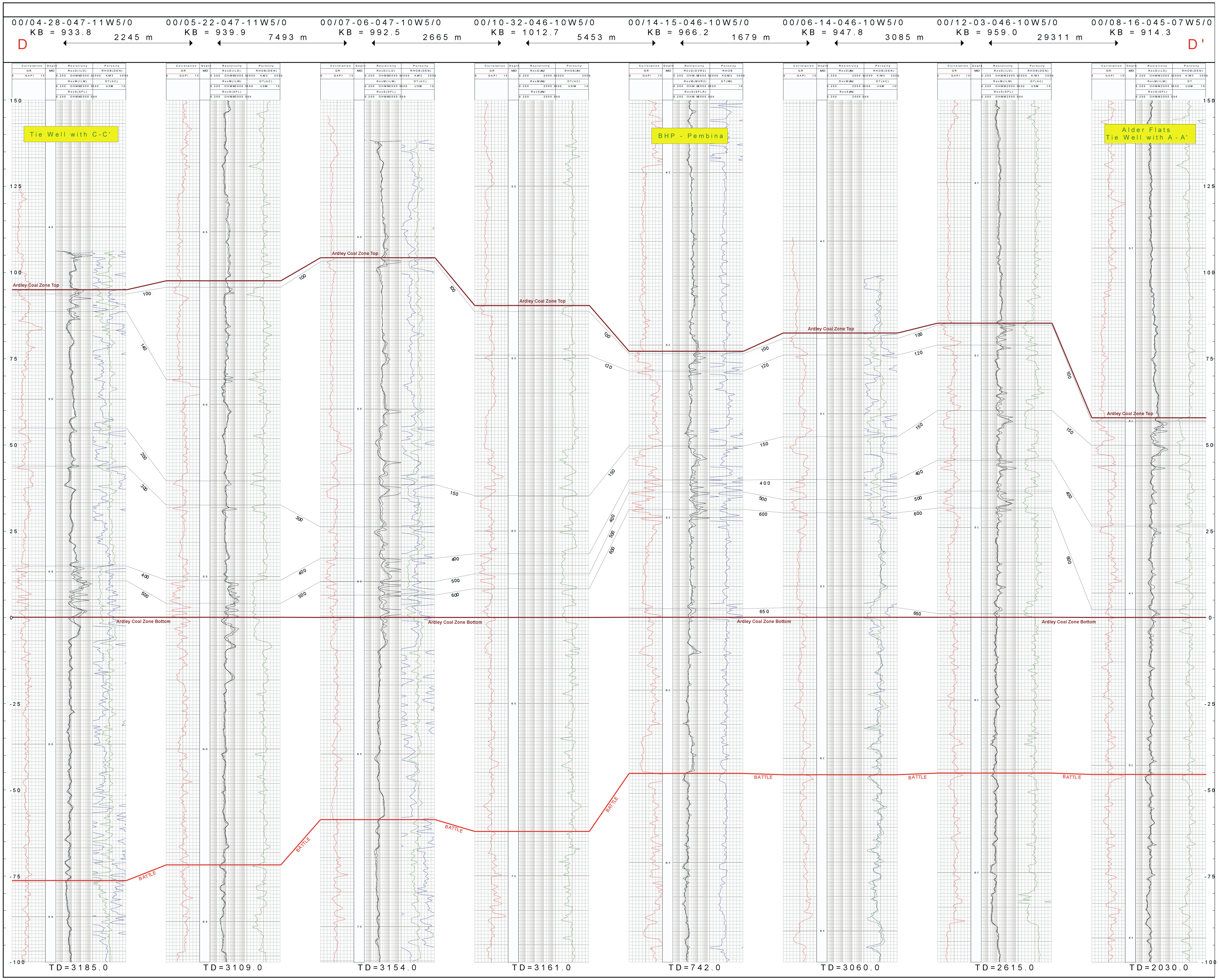

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D
D'
2245 m
7493 m
2665 m
5453 m
1679 m
3085 m
29311 m
Tie Well with C-C'
BHP - Pembina
Alder Flats
Tie Well with A-A'
Ardley Coal Zone Top
Ardley Coal Zone Bottom
BATTLE
TD=3185.0
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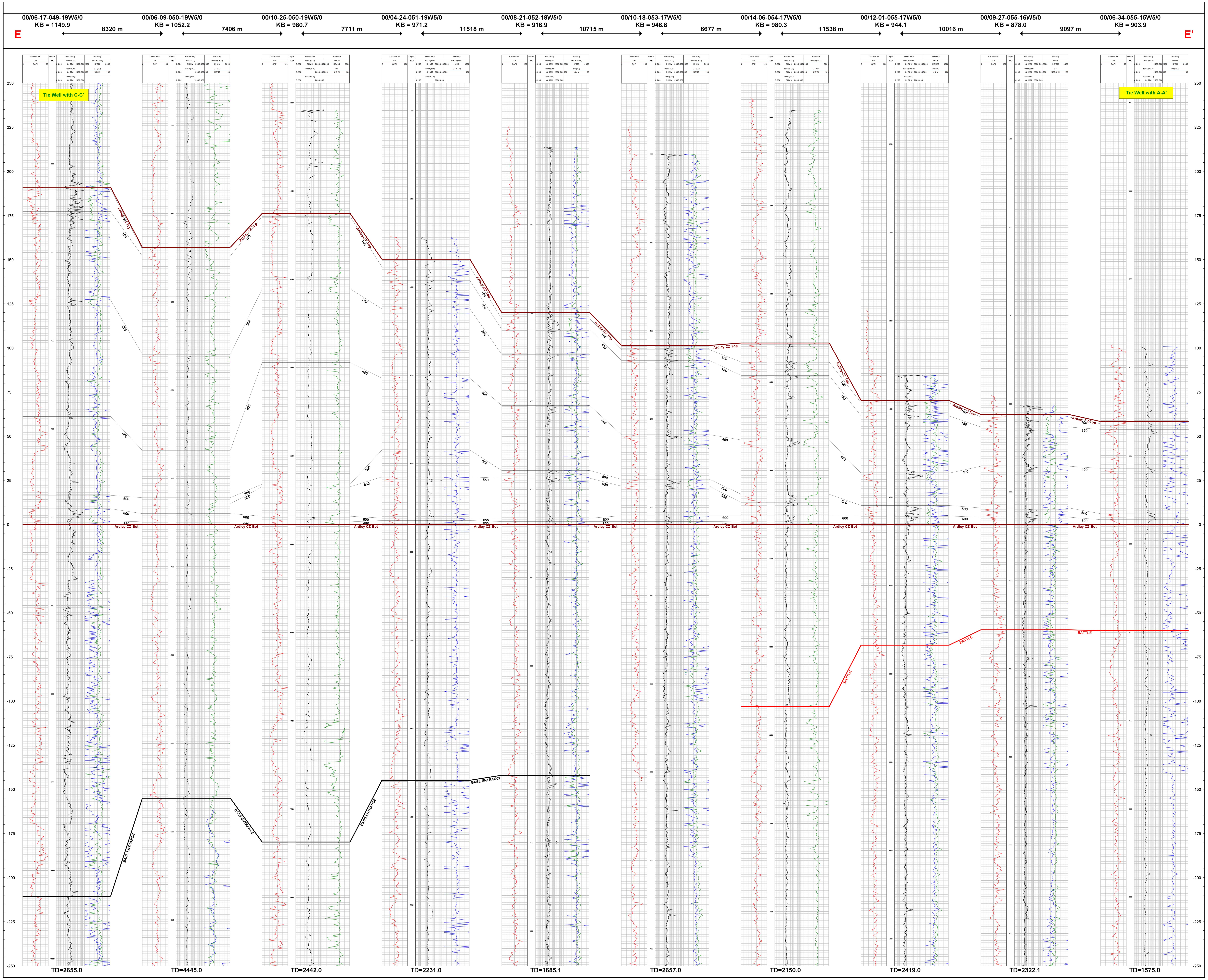
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KB = 980.7
00/04-24-051-19W5/0
KB = 971.2
00/08-21-052-18W5/0
KB = 916.9
00/10-18-053-17W5/0
KB = 948.8
00/14-06-054-17W5/0
KB = 980.3
00/12-01-055-17W5/0
KB = 944.1
00/09-27-055-16W5/0
KB = 878.0
00/06-34-055-15W5/0
KB = 903.9
8320 m
7406 m
7711 m
11518 m
10715 m
6677 m
11538 m
10016 m
9097 m
Tie Well with C-C'
Tie Well with A-A'
Ardley CZ Top
Ardley CZ-Bot
BATTLE
BASE ENTRANCE
TD=2655.0
TD=4445.0
TD=2442.0
TD=2231.0
TD=1685.1
TD=2657.0
TD=2150.0
TD=2419.0
TD=2322.1
TD=1575.0