Horseshoe Canyon / Royal Tyrrell Museum Field Trip

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GEOLOGY OF THE HORSESHOE CANYON FORMATION

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WCSB Petroleum Systems

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Red Deer River Valley: Modern and Ancient Depositional Systems

Milovan Fustic
Geological Survey of Canada

Coal and Coalbed Methane in the Horseshoe Canyon Formation

D. L. Marchioni and W.J. McDougall
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INTRODUCTION

The Red Deer River valley between Dorothy and Big Valley provides a 100 km linear belt of exposure where the Horseshoe Canyon Formation can be viewed. At times, the exposures are almost continuous for distances of tens of kilometres especially in the southerly portions of this belt. Although nowhere is the formation exposed in its entirety because the stratigraphic thickness exceeds the topographic exposures, a virtually complete composite section can be measured at relatively easily accessible localities along the exposure belt. These exposures offer a rare opportunity to study a fairly thick sequence over a long distance by more or less complete outcrop. The presence of a number a large tributary coulees offer three dimensional views of the stratigraphic packages and facies making up the formation. Figure 1 provides a map of the Calgary-Drumheller region and section localities we will visit.

A note of caution is given to anyone exploring the badlands. The dry climate and generally high summer temperatures can be dangerous to unconditioned individuals. Always maintain an adequate fluid intake to prevent dehydration and wear protective clothing. The area has abundant prickly-pear cactus and these always are a danger for travellers in the badlands. Badland environments have a weathering style that creates a large number of pot holes and sink holes some of which can be very deep and of a large size. Travellers must keep a constant lookout for these features. In those areas where coal mining has in the past occurred, there is a danger around any of the old adits and these should not be entered. As well, there are still coal burns under way in some of the mine areas and these should be avoided. During wet weather, the rock exposures become exceedingly slippery because of the swelling-clay content of the sediments. It is recommended that you stay out of the badlands during wet periods. The prairies are noted for sudden changes in weather and a sharp eye should be kept for thunder storms that can be quite violent and approach quickly. Most of the exposures along the valley occur on private lands or leased lands and the permission of the landowner should always be obtained before venturing on to the property. One should take care to leave the area in much the same condition as one found it. The Province of Alberta has legislation controlling all historical resources in the province including archaeological artifacts and fossils. All objects in these categories belong to the crown unless disposed of by the crown. In practice, if any excavation is required to free a fossil or object from its stratigraphic context then a permit is required. We urge you to report all interesting finds so they can be evaluated for their scientific value. Provincial Parks restrict collection of anything including rocks, plants, fossils, and animals without a permit. It is a good idea and habit if you wish to look at outcrop in these parks, to inform the park supervisor what you are up to. Additionally, the federal government has legislation for the export of cultural properties including fossils and permits are required to remove them from the country. If you stop beside a highway, you should constantly be aware of traffic that is often traveling at a high speed.

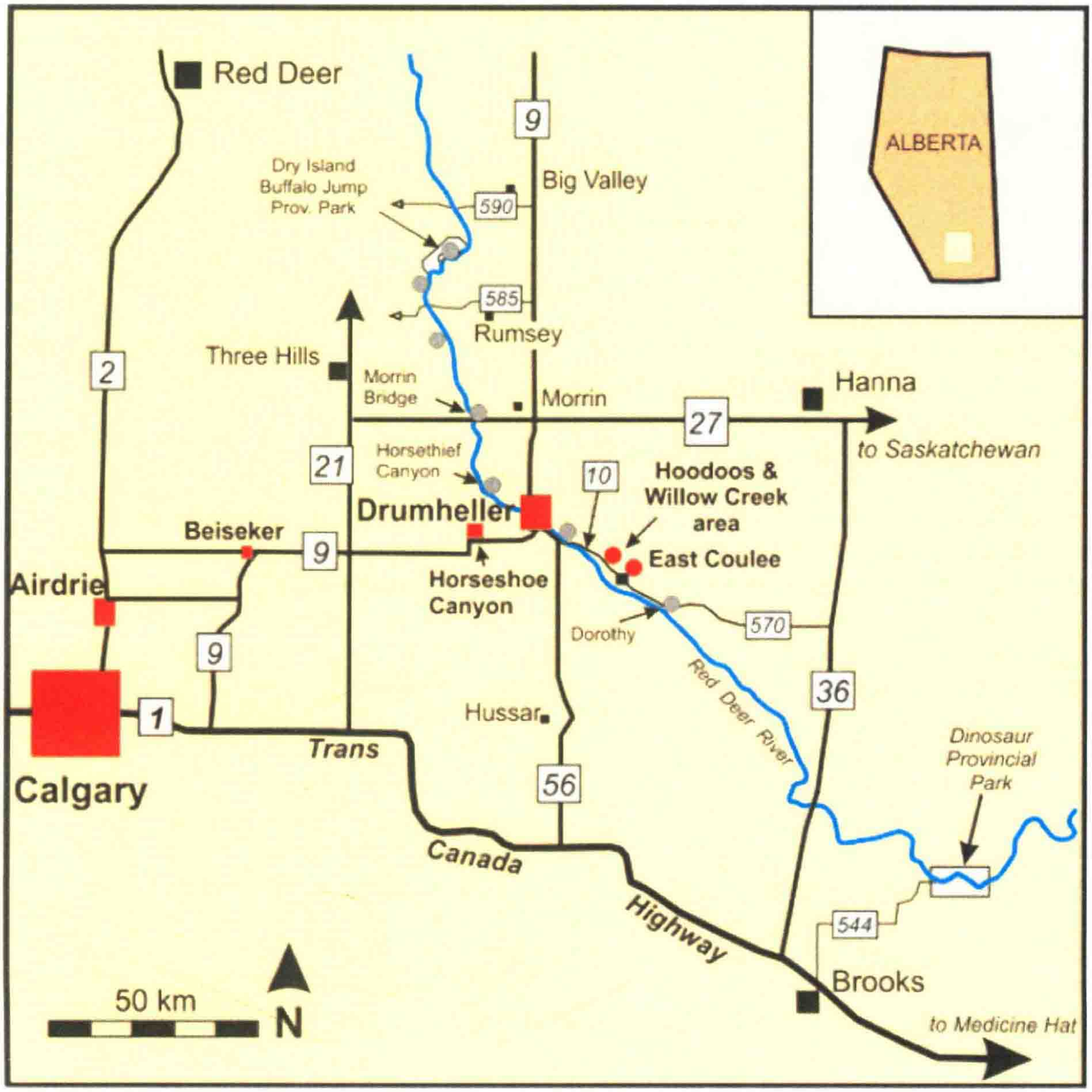

Figure 1: Map of the proposed field trip area (map supplied by Dave Eberth).

HISTORY AND REGIONAL SETTING

The Horseshoe Canyon Formation was originally described as part of the Edmonton Formation. Subsequently, the Edmonton Formation was raised to group status when it was subdivided into a number of formations one of which is the Horseshoe Canyon Formation. The zone marked by Edmonton Group exposures lies within what is termed central Alberta. The land surface is generally flat to gently rolling. Exceptions to this generalization exist of course especially where the Red Deer River and its tributaries have incised into this surface.

Soils covering the area are black, dark-brown and brown chernozemes. The bedrock exposures span two phytogeographic zones: namely Aspen Parkland and Mixed-grass Prairie. The Aspen Parkland occurs in the wetter climatic zone found in the northern part of the area and can be described as a mosaic of prairie patches interspersed with Aspen groves (*Populus tremuloides*). The Mixed-grass Prairie is dominated by a *Bouteloua gracilis-Koeleria cristata* community. Local variation in topography, aspect, microclimate and slope are reflected in minor plant communities within the two major phytogeographic zones. The Red Deer River valley is a major migratory pathway for a diverse variety of birds. The spring, summer and fall are particularly busy times with a reduced variety of residents during the winter. Mammals are common in the valley and adjacent areas with herds of mule deer, whitetail deer, fox, coyote, skunks, porcupines, Richardson ground squirrel, jackrabbit, cottontail rabbit, and a wide variety of other animals. Recent reports of mountain lions, black bear and moose indicate that they wander into the area periodically.

The archaeological record in central Alberta goes back approximately 11000 years. Human populations first arrived in Alberta at a time when mammoths, horses, and camels were still roaming the western Canadian steppes. Sites yielding evidence of these early settlers are rare and are principally documented by scattered surface finds of distinctive artifacts. Much of sequential knowledge of human occupation is derived from the changing styles of artifacts through time, especially the styles of projectile points. Three overall periods have been defined: An Early Prehistoric (Paleo-Indian) period lasting from 11,500 to 7000 years ago characterized by a big-game hunting adaptation utilizing large stone points on spears; a Middle Prehistoric period lasting from 7000 to 1500 years ago that used smaller stone points on scaled-down spears propelled by means of a spear thrower; and a Late Prehistoric period having specialized big-game hunting on the open plains with elaboration of the bison drive. This last period has been recognized in the Red Deer River valley area with the establishment of Dry Island Buffalo Jump Provincial Park north of Drumheller. Throughout the three periods of development, the buffalo or bison (*Bison bison* spp.) remained the basic element in the hunting economy. Other fairly common evidence of early occupation includes medicine wheels, cairns and teepee rings. These are scattered throughout the region often located on high points or valley rims. An example is the Rumsey Cairn, located on a prominent hill south of Rumsey near the Red Deer River. It consists of a large circular stone cairn with a partial outer circle of stones. Its precise function is not yet known, but apparently some human remains were associated with it.

On September 11, 1754, the first white man entered what was to become the province of Alberta in the person of Anthony Henday. Between 1759 and 1790 the area was revisited many times by fur traders attempting to establish new sources of trade. In 1792, Peter Fidler, during such a trading journey, was the first to do survey work and accurately located many of the rivers and mountains of central Alberta. He was able to produce a map of the region and on February 12, 1793 near the mouth to Three Hills Creek he made the first discovery of coal on the Canadian prairies. By 1800, knowledge was available about most of the major geographic features including rivers and high areas of the Red Deer River valley corridor. Between 1800 and 1850 there was a consolidation of the fur trade in the province and the first missionaries had entered the region. John Palliser led a government sponsored expedition into the area to evaluate the land and resources between 1857 and 1859. The members of the expedition looked at the geology and flora and produced a number of maps. James Hector, a member of this party reported coal, ironstone, silicified wood and marine shells in the Red Deer River valley. The Royal Canadian Mounted Police entered Alberta in 1874 to restore order following a number of years of tribal unrest and a deteriorating social system in part due to American whisky traders. The Dominion surveying of the west was started in 1874 and continued at a hectic pace well into the 1880's. In 1883, the Canadian Pacific Railway made it into Alberta and this event served as an impetus for the later waves of immigration that entered the province. James B. Tyrrell explored the valley in 1884 and made his observations on the mineral deposits and vertebrate fossils. The first ranchers reached the area in the late 1880's initiating a period of rapid growth. In 1910, the first railway from the Stettler area had reached Munson, a small community north of Drumheller, and this was quickly followed by the first coal mine opening in the Drumheller area in 1911-1912. Many other mines opened in quick succession turning the region into a major mining area for the next 50 years. Well over 120 mines have operated along the length of the river valley and adjoining tributaries. In 1914, the Canadian Northern Railway line from Saskatoon to Calgary was completed, further speeding up the development of the region. It was not until 1950 that oil was discovered in the Drumheller oilfield. The Royal Tyrrell Museum of Palaeontology opened in 1985 initiating an upswing in tourism into the valley.

GEOLOGIC SETTING

During the Late Cretaceous, the western interior basin was a dynamic setting for sedimentation. It was probably a generally low-lying region in which sediment was being trapped. The ultimate source of much this sediment was to the west where the Rocky Mountains were actively being uplifted. Periodically, marine transgressions swept across the basin leaving a record of interfingered marine and terrestrial sequences. The scene then was of an intracratonic seaway bordered to the west by a rapidly rising orogenic belt and rivers flowing eastward from the mountains out onto a relatively flat piedmont forming large delta fan complexes in the seaway. Associated with the orogenic uplift were numerous volcanic centres supplying large amounts of ash to the sedimentary sequences throughout much of the Late Cretaceous. The western margin of the basin was subsiding more rapidly than the eastern one so the greatest accumulated thickness of sediments occurs on the western margin of the basin.

The rising orogenic belt probably had an effect on the palaeoclimates of the region as did the presence of the interior seaway. Based on currently available data from sedimentology, palaeontology and geochemistry, climates, although regionally variable to a limited extent, were warm temperate with moderate to high amounts of moisture, at least seasonally. This climate allowed the formation of the extensive organic accumulations today seen as coal beds. Within the alluvial and deltaic environments plant life was abundant which, in turn, supported an interesting array of animal species.

As the intensity of orogenic activity increased to the west, the zone of disruption moved to the east and eventually involved younger sedimentary sequences. A structural feature referred to as the Alberta syncline was formed and the area under discussion lies on the east limb of this north-south trending feature. There is a gradual dip to the strata of 25 to 30 feet per mile to the west. Although the strata appear almost flat lying, this regional dip lets one move up section between the south and north ends of the linear belt of exposures along the Red Deer River valley. The tectonic forces that formed the Alberta Syncline also created a joint pattern within the sediments.

The final series of events which have influenced the area was the long episodes of erosion that the region has undergone. Perhaps the most important aspect of the erosion was the glaciation that the area underwent. Much of the badland exposures are capped by loosely-consolidated types of till or glacial lake sediments. The ice sheets crossing the area removed undetermined amounts of the Edmonton Group sediments and in places deformed these sediments forming severely tilted beds. One example of this deformation can be seen at the mouth of Willow Creek high on the exposure on the east side of the creek.

THE EDMONTON GROUP

The Edmonton Group as defined by Gibson (1977) records the persistent though punctuated eastward progradation of a clastic wedge derived from the newly arising Rocky Mountains, and the withdrawal of the `Bearpaw Sea' from southern Alberta. The age of the Edmonton Group is fairly uniform throughout southern Alberta, ranging from late Campanian to earliest Paleocene at its top. Edmonton Group lithofacies comprise fossiliferous interbedded sandstones, siltstones, claystones, coal and a variety of diagenetic products (ironstone and smectitic clays). In the Red Deer River valley, the unit is about 350-400 m thick, thins to the east, conformably overlies the Bearpaw Formation (a predominantly fine-grained marine unit), and is unconformably overlain by the Paleocene age Paskapoo Formation (a mixed shale and sandstone nonmarine unit). Cretaceous-Paleocene boundary sequences are well preserved at a number of localities north of Drumheller..

The Edmonton Group consists of three formations (Figure 1): in ascending order, the Horseshoe Canyon, Battle, and Scollard formations (Gibson, 1977; Eberth and Braman, 2012). The Horseshoe Canyon Formation makes up 2/3 of the entire Edmonton Group thickness in the Red Deer River valley and can be divided into 7 members that reflect gradational facies changes related to delta and coastal plain progradation and climatic changes. The Whitemud Member and Battle Formation together comprise approximately 15 m of section in the Red Deer River valley and represent a time of (relatively) reduced clastic sedimentation, high subsidence and extreme volcanic activity. The Scollard Formation marks a return to "normal" progradation such as that initiated during deposition of the Horseshoe Canyon Formation. The Cretaceous-Paleocene boundary occurs in the middle of the Scollard Formation.

Previous Work

This section of the guide is intended as a precis of the large volume of research that has been undertaken on the interval and as such includes only the briefest notation on individual papers. Further information can be obtained by looking within the referenced papers.

The term "Edmonton" was first used by Selwyn (1874) in reference to coal-bearing strata outcropping around the city of Edmonton. Tyrrell (1887) first described the Upper Cretaceous-Tertiary rocks in the Red Deer River area, referring the succession to the "Edmonton Series". Brown (1914) documented results of his explorations prospecting for fossil vertebrates over a region extending from New Mexico to the Red Deer River valley area. He stated that "this river presents one of the finest sections for the study of Mesozoic and Eocene rocks to be seen on the continent". It should be noted that at that time "Eocene" included both the Paleocene and Eocene epochs in terms of modern concepts. Allan (1918) studied sections along the North Saskatchewan River and Red Deer River and established the structure of the area and confirmed the sequence of units. Allan (1922) provided a detail description of the Drumheller coal field including the first detail descriptions of sections in the area. Warren (1926), Russell (1929), Dyer (1930), and Tozer (1956) have all included information about the invertebrates found in the Edmonton Group. Allan and Rutherford (1934), in a regional study of central Alberta, provided information on the thickness of the Edmonton Group, discussed its stratigraphic position and reconfirmed the abundant quantities of ash present in the group. Rutherford (1939) provided the first detailed geologic map for the Red Deer River corridor. Allan and Sanderson (1945) provided a detail report on the geology, economic geology, and palaeontology of the Edmonton Group in the study area. In it, they subdivide the group into three parts. Sternberg (1947, 1949) reported on his studies of vertebrate fossils in the valley and included some of his observations on the geology of the Edmonton Group. He recognized a clear break between the dinosaur faunas below and above the Kneehills Tuff. Bell (1949, 1965) reported on a number of fossil leaves found in the Edmonton Group and Aulenbach (2009) has updated information on these floras. Elliott (1960) provided a generalized section through the Edmonton Group and provided some subsurface sections. Ower (1960) discussed the stratigraphy of the Edmonton Group in central Alberta and correlated the surface sections with subsurface sections. He subdivided the Edmonton Group into five parts. Campbell (1962) attempted to refine both the lower and upper boundaries of the Edmonton Group. Beginning in 1966 and continuing in a substantial series of papers summarized in Srivastava (1970) has documented the palynomorphs of the Edmonton Group. Russell and Chamney (1967) found that dinosaurs and microfossils occur as distinct assemblages within the Edmonton Group. Irish (1967) produced a detail map of the Drumheller area. Ramanujam and Stewart (1969) identified four species of fossil wood from the Rosedale area. Shepheard and Hills (1970) worked out the detailed sedimentology and stratigraphy for the Bearpaw-Horseshoe Canyon transition and lower part of the Horseshoe Canyon Formation. They provided the best environmental determination achieved to that time and provided a clear indication of the complexity seen within the formation. Irish (1970) gave formational status to the Whitemud and Battle formations and proposed the Horseshoe Canyon Formation for the interval between the Bearpaw and the Whitemud formations. He considered that these three formations composed the Edmonton Group and agreed with Carrigy (1970) as the placement of the lower boundary of the Paskapoo. He established the Scollard Member as the lowest member of the Paskapoo Formation. Carrigy (1971) completed a regional study of upper Cretaceous strata and illustrated the lateral correlations for the interval. Campbell (1974, 1975) discusses the coal resources in the Edmonton Group of areas to the east and northeast of the Red Deer River valley. Rahmani and Lerbekmo (1975) reported on a regional study of heavy minerals including samples from the Edmonton Group and concluded that there was a northwest source for the sediments. Holter *et al.* (1976) completed a study on the geology and coal resources of the Horseshoe Canyon Formation. Gibson (1977) completed the most complete study of the entire Edmonton Group based on the outcrops along the Red Deer River valley. He established most of the nomenclature that is utilized in the present report and provided details on the large number of sections studied along the valley. In his report, the coal seams were utilized for stratigraphic control. Nurkowski and Rahmani (1984) subdivided the upper Horseshoe Canyon Formation into two informal stratigraphic units and attributed both units to accumulation within a meandering river environment. Bromley *et al.* (1984) reported on marine borings occurring on the top of the lowest coal in the Horseshoe Canyon Formation. Nurkowski and Ramani (1984) described the details of the uppermost Horseshoe Canyon subdividing it into two units. Lerbekmo and Coulter (1985) worked out the magnetostratigraphy of the continental sequence in the Red Deer River valley. Lerbekmo (1985) has provided magnetostratigraphic and biostratigraphic correlations between the Red Deer River valley and areas in southeast Saskatchewan. Rahmani (1988) provided a detailed treatment of the transitional sequence between the Bearpaw and Horseshoe Canyon formations and developed sedimentation models to explain the observed sequence. Ainsworth 1994 and Ainsworth and Pattison (1994) described the lower Horseshoe Canyon in terms of sequence stratigraphy recognizing a new geometry to the systems tracts in lower Horseshoe Canyon Formation. Hamblin (2004) in a comprehensive study of the formation provided a more complete picture of the changes through the unit and related his observation to sequence stratigraphic concepts. Vakarelov et al. (2012) describe the wave-dominated, tide-influenced shoreline systems in the lower Horseshoe Canyon. Quinney et al. reconstruct the palaeoenvironments and palaeoclimates of the Horseshoe Canyon Formation based on soils preserved in the section. Eberth and Braman (2012) formally subdivided the Horseshoe Canyon Formation into 7 members and included the Whitemud as one of them. Srivastava and Braman (2013) revisited and revised the palynology of the Red Deer Valley sequence earlier reported on by Srivastava (1970). Eberth et al. (2013) discussed the dinosaur biostratigraphy of the formation. Ainsworth et al. (2015) describe the form of the regressive, tide-influenced shoreline exposures in the lower Horseshoe Canyon Formation.

There have been a large number of field guidebooks produced over the years including Austin (1959), Wright-Broughton *et al.* (1970), Ollerenshaw and Hills (1978), Rahmani and Hills (1982), Harvey *et al.* (1982), Walker (1982), Rahmani (1983), Braman *et al.* (1984), Saunders and Pemberton (1986), Braman and Eberth (1987), Braman (1988), Ainsworth (1992), Eberth and Ryan (1992)Eberth and Braman (1993), Braman et al. (1995), Eberth and Straight (1998), Eberth and Lavigne (2002), and Eberth (2004). This list is not intended to be all inclusive but should serve as an introduction to the geology and localities for the Horseshoe Canyon Formation.

Coal occurring at a number of horizons throughout the formation has been extensively mined in the area in the past and this has spurred much of the previous research on the area. No mines are currently active in the valley. Another resource of this sequence that has spurred on exploration is the fossil vertebrates especially the dinosaurs. This region is one of the two great dinosaur burial sites in the province of Alberta where present-day erosion is exposing large numbers of bones, the other being Dinosaur Provincial Park north of Brooks.

THE HORSESHOE CANYON FORMATION

The Horseshoe Canyon Formation is about 250 m thick in the Red Deer River valley. However, the full stratigraphic extent is nowhere completely exposed. The Horseshoe Canyon Formation has received a great deal of attention from stratigraphic and economic geologists due to its coal seams, which were the basis of a boom economy in the first half of this century.

The rocks comprising the formation are for the most part flat-lying interbedded silty sandstones, siltstones, claystones and carbonaceous shales, coals, and diagenetic ironstones and altered volcanic ashes. Twelve separate coal seams occur throughout the sequence and provide a reliable means for correlating discontinuous exposures over relatively short distances in the Red Deer River valley. Attempts at regional correlation of coal seams have proved unreliable (Hughes, 1984). The Horseshoe Canyon Formation has been subdivided into 7 members (Eberth and Braman, 2012). Figure 2 provides some of the historical subdivisions of the formation while Figure 3 details the stratigraphic and coal nomenclature used within the Horseshoe Canyon and Scollard formations.

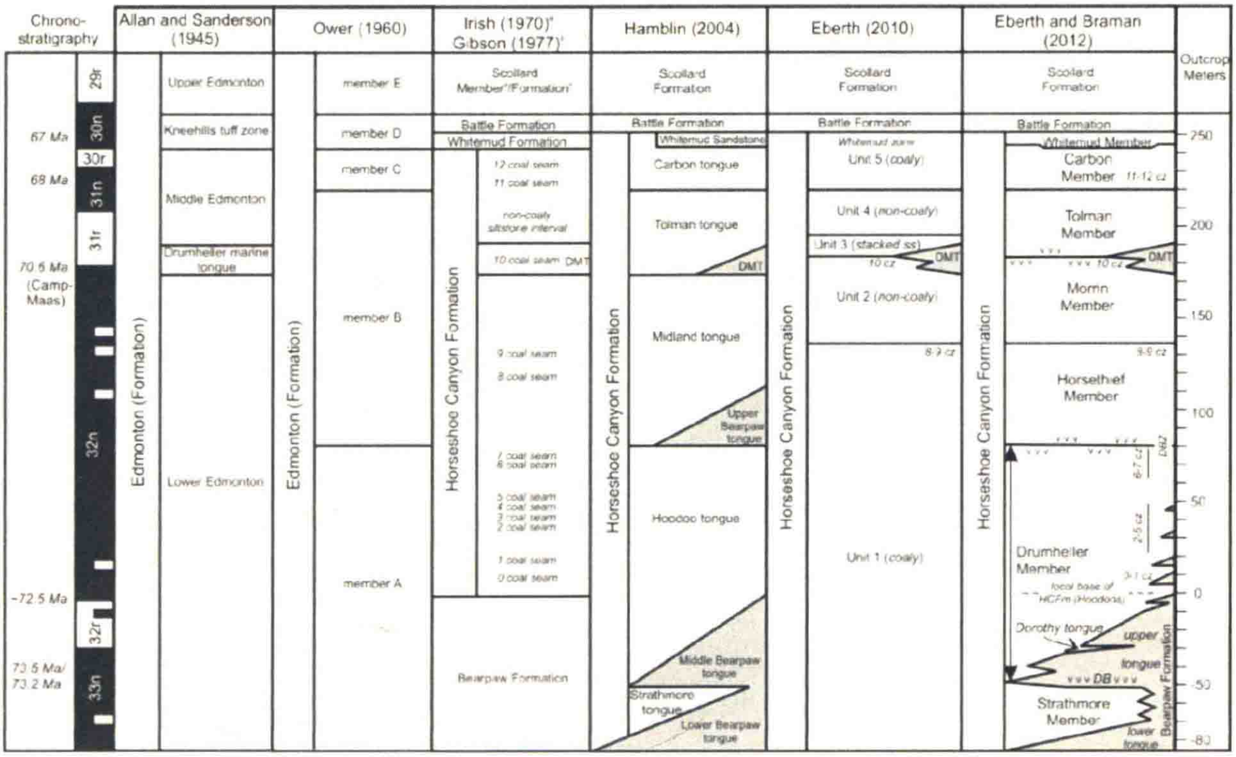

Figure 2: History of stratigraphic nomenclature applied to the Horseshoe Canyon-Scollard formation interval (figure supplied by Dave Eberth).

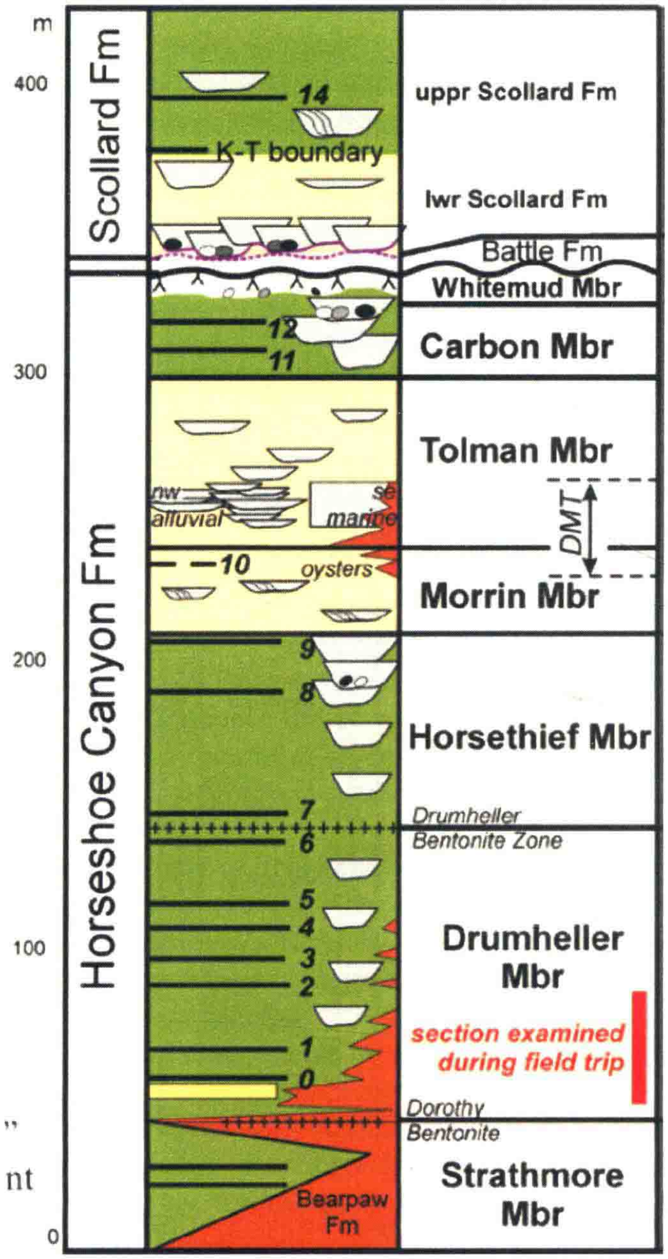

Figure 3: Stratigraphic and coal nomenclature applied to the Horseshoe Canyon to Scollard formation interval along the Red Deer River (diagram supplied by Dave Eberth).

Strathmore Member

The Strathmore Member is coastal deposit that has only been mainly studied in the subsurface with only limited exposures known. In the type well located near Strathmore, Alberta, it is 41 m thick and thins to the east and south between lower and upper tongues of the marine

Bearpaw Formation (Eberth and Braman, 2012). To the north and west where the upper tongue of the Bearpaw terminates, the unit can not be separated from the nonmarine Drumheller Member. In core, the unit consists of very-fine to fine-grained sandstone, muddy, silty, and carbonaceous mudstones, and carbonaceous shale to coal. The environment of deposition was nonmarine to shallow-marine areas along a shoreline. The age of the unit is upper Campanian with a suggested age ~73.2-74.0 Ma (Eberth and Braman, 2012).

Drumheller Member

The Drumheller Member records the initial phase of progradation in a coastal setting. The unit is 80 to 200 m thick and is coal rich and thins eastward. The unit is well exposed between Drumheller and East Coulee area and we will be seeing the member at the second stop during the field trip. The base of the member is well exposed between East Coulee and the Hoodoos area and is placed at the base of a prominent ~10 m sandstone. The underlying Bearpaw Formation consists of brown weathering shales that may have increasing numbers of sandstone layers in it upper portion. The member contains 8 numbered coals (see following section where coal deposits are discussed) with the lower 5 capped by marine flooding surfaces. Lithologically, the unit consists of isolated coal beds or coal swarms, lenticular paleochannel sandstones, tabular sandstones with trace fossils, and a variety of nonmarine and marine mudstones and paleosols. Bivalve-rich bars and in situ fossil trees are present along with isolated wood fossils whereas fossil vertebrates are rare in the unit. Above coal #5, only nonmarine sediments are noted. The depositional setting is a coastal plain to delta setting which was periodically flooded by marine waters. The suggested age of the unit is ~71.5-73.2 Ma (Eberth and Braman, 2012) and, if the age of the Campanian-Maastrichtian boundary of Gradstein et al. (2012) at 72.1 Ma is accepted, then the boundary would occur within the member in contrast with Lerbekmo and Braman (2002) who would place the boundary somewhat higher agreeing with Gradstein et al. (2004). The top of the member is placed at the Drumheller Bentonite Zone (Eberth and Braman, 2012).

Horsethief Member

The Horsethief Member is a coal-rich interval that is 50-90 m thick. It is well exposed between Midland Provincial Park (the Royal Tyrrell Museum is set within the park) to north of Morrin Bridge. We will be observing the unit at the third stop during the field trip. The top of the member is placed at or just above the coal #8-9 zone. The unit is similar in appearance to the Drumheller Member and includes organic-rich shales and coals, lenticular paleochannel sandstones, and a variety of overbank mudstones (Eberth and Braman, 2002). Beds within the member have less lateral continuity than seen within the underlying unit suggesting that the member was deposited in a more up-dip coastal plain setting. Again, the unit thins to the east. Vertebrate fossils are abundant within the unit. The age of the unit is estimated to be ~71.0-71.5 Ma (Eberth and Braman, 2012).

Morrin Member

The Morrin Member is well-exposed from Horsethief Canyon to north of Morrin Bridge and has a thickness of 35 to 100 m. The unit is mostly non-coaly and represents a near-shore coastal environment. The top of the member is placed at the maximum flooding surface of the Drumheller Marine Tongue, a bivalve-rich interval within the Horseshoe Canyon Formation. This flooding surface occurs just above the #10 coal seam. Very-fine to fine-grained sandstones, greenish mudstones and rare thin carbonaceous shale and coals characterize the unit. Marine invertebrates and vertebrate fossils are common within the unit. The Campanian-Maastrichtian boundary would sit within the member according the Lerbekmo and Braman (2002) and Gradstein et al. (2002) but not according to the published date of Gradstein et al. (2014). The age of the unit is suggested ~70.4-71.0 Ma (Eberth and Braman, 2012). Eberth and Deino (2005) have published a date of 70.4 Ma obtained slightly above coal #10.

Tolman Member

The Tolman Member is a noncoaly coastal to alluvial unit that has a thickness of 25-50 m. Its upper contact is marked by a colour change from a greenish cast to a grey cast of the coal-rich Carbon Member. The lower portion contains the upper part of the Drumheller Marine Tongue. It is well exposed between Morrin Bridge and Tolman Bridge. The member consists of green to greenish-grey, silty to sandy mustone and very-fine to fine-grained sandstones. It is thought that the interval represents a drier climatic regime. The unit has abundant invertebrates in the lower portion and abundant vertebrates. The age is suggested as ~68.4-70.4 Ma (Eberth and Braman, 2012).

Carbon Member

The Carbon Member is a coal-rich unit that is 24-40 m thick. The top of the unit is placed at the first occurrence of deeply-weathered, white sandstones of the Whitemud Member although it is not always easy to pick the contact (Eberth and Braman, 2012). Paleochannel sandstones tend to be thicker and more abundant than in Morrin and Tolman members. The unit is entirely nonmarine and represents wetter conditions than observed in Tolman Member. The unit occurs from areas north of Morrin Bridge to the McKenzie Bridge. Fine- to medium-grained sandstone, rooted grey mudstones, organic shales and coals (#11 and 12 coals) characterize the unit. Locally, lenses and strings of extraformational pebbles and cobbles are present. The suggested age of the unit is ~67.5-68.4 Ma (Eberth and Braman, 2012). Vertebrate fossils are extremely rare in the unit.

Whitemud Member

The Whitemud Member represents a deeply-weathered and altered sandstone and mudstone unit. The unit outcrops from north of Morrin Bridge to the area of the McKenzie Bridge. The top contact is with the dark-purple mudstones of the Battle Formation. This surface represents an unconformity and at times the Battle cuts down into the Whitemud or completely through it. Mudstones of the Battle often are eroded moving downslope and partly to completely obscuring the Whitemud. The member consists of white-weathering, bentonite-rich sandstone, siltstone, and claystone with a thickness of 1.5 to 6 m. The unit is unfossiliferous and has a suggested age of 67.0-

67.5 Ma (Eberth and Braman, 2012).

HORSESHOE CANYON COAL

Coals are a prominent feature of the Horseshoe Canyon Formation. In the past, numerous mines operated along the Red Deer River and its tributaries (Campbell, 1964). All of these mines have now shut down with the closest producing mine located at Sheerness, 70 km east of Drumheller. The Sheerness mine is a strip mine with the production feeding an onsite power generating plant. All of the coal-fired generating plants in Alberta are tentatively scheduled to be phased out in the near future so this mine may only be operating for a short time more.

Coal Stratigraphy

Allan (1922) introduced the numerical coal seam nomenclature currently being used for the Horseshoe Canyon-Scollard interval. Although I could not find reference to it, my suspicion is that this nomenclature was informally introduced by the mining operators prior to Allan's publication. The numerical sequence starts at the base of the Horseshoe Canyon Formation and progresses upwards into the overlying Scollard Formation. The thickest seam in the Horseshoe Canyon Formation was formerly known as the "Deep Seam" or "Drumheller Seam" and was designated the #1 seam. Subsequently, a seam was noticed below this seam that was relatively thin and it was referred as the #0 seam. The Drumheller Member contains seams #0, #1, #2, #3, #4, #5 (Top Seam or Newcastle Seam), #6 and #7 (Vulcan or Daly Seam), the Horsethief Member seams #8 and #9, the Morrin Member seam #10 (Marker Seam), and the Carbon Member seams #11 (Carbon Seam) and #12 (Thompson Seam). The Scollard Formation has seam #13 (Nevis Seam) and #14 (Ardley Seam). Only coals #1, #2, #5, and #7 were extensively mined in the Drumheller area (Allan, 1922) with the following seam descriptions taken from this publication and from unpublished field notes.

<u>Coal Seam #0</u>

The seam is 35 to 50 cm thick with the lowest 20 cm being argillaceous. The coal is about 1 m above the massive basal sandstone at Willow Creek and has a red-coloured underclay at it base. It is sharply overlain by a grey shale that has marine palynomorphs. The coal was not considered economical during the mining of the valley deposits. It thins to the east.

<u>Coal Seam #1</u>

The seam was the lowest coal worked during mining in the valley and occurs 12 m above the #0 coal at Willow Creek. Allan (1922) indicated that the seam was 1.2 to2.1 m thick in the mined areas. At Willow Creek the coal is about 1 m thick with a 2 to 20 cm ash layer in the middle of the coal. Numerous gypsum crystals are associated with the coal.

<u>Coal Seam #2</u>

The seam varies in thickness from 0.5 m to 1m and at Willow Creek it is 0.5 m thick occurring 4 m above the #1 coal. In the past, mines have worked this seam from areas where it is thickest. Rusty coal and joint planes with gypsum crystals are common features of the seam.

<u>Coal Seam #3</u>

The seam is usually less than 0.3 m thick and at Willow Creek it 2-3 cm thick and sharply overlain by 2 m white sandstone. It was 8 m above the #2 coal. The seam was economical so was not mined in the past.

Coal Seam #4

The seam is generally less than 0.3 m thick and was uneconomical but is laterally extensive and so can be used for correlation purposes. At Willow Creek it is 4.5 m above coal #3. This is the uppermost coal exposed near the mouth of Willow Creek although coal #5 is exposed farther up the Willow Creek valley.

Coal Seam #5

The seam was mined in the past and is 1 to 1.6 m thick in the region. Because of the regional dip to the beds, the seam disappears below outcrop level near Drumheller town. The coal from this seam is described as having a bright luster.

Coal Seam #6

The thickness of this seam varies from 15 to 90 cm thick. It is the seam that crops out at the base of the hill below the Royal Tyrrell Museum. Allan (1922) makes the comment that it can scarcely be called a coal as it contains little coal and at many spots is entirely black carbonaceous shale. It is a useful marker in the area.

Coal Seam #7

The thickness of the seam is highly variable ranging from 0.3 to 2 m in thickness although where thickest it has a thick shale parting within it. In the past, it was mined at one locality and at the Royal Tyrrell Museum it occurs just below the base of the building.

Coal Seam #8

The seam varies in thickness from a small fraction of a metre to 1.2 m and serves as a good marker bed. At places the seam splits into three parts with shale intervals between the coal layers. The seam is present near the museum towards the top of the exposure and is present in Horsethief Canyon towards the base of the section.

Coal Seam #9

The seam varies in thickness from 0.2 to 1 m and is a useful marker. It has been mined but not extensively. The seam occurs near the top of the exposure in vicinity of the Royal Tyrrell Museum and in Horsethief Canyon.

Coal Seam #10

This uneconomical seam is always less than 0.5 m thick. It occurs within the Drumheller Marine Tongue interval. A radiometric date was obtained by Eberth and Deino () of 70.4 Ma from an ash located just above the coal. In places, it is no more than a carbonaceous shale. It is present at Horsethief Canyon towards the top of the exposure.

Coal Seam #11

The seam varies in thickness from 0.3 to 2 m and has been mined at a number of localities. The seam is exposed near the base of visible exposures at Horseshoe Canyon.

Coal Seam #12

This is the uppermost coal in the Horseshoe Canyon Formation and can be observed in Horseshoe Canyon. It varies in thickness from 0.3 to 1 m.

Coal Characteristics

Horseshoe Canyon Formation coals fall in subbituminous C to B category depending on location. The following was gathered from a number of publications but it should be noted that the author of present guide has no experience with the characterizing of coal. The following tabulates (Table 1) published analysis of samples of Horseshoe Canyon coals either from the Drumheller area or from the Sheerness Mine to the east of Drumheller.

Table 1: Tabulation of some of the published coal analysis for the Horseshoe Canyon Formation.

		Stanfield & Lang, 1944	Smith, 1989	Nurkowski, 1984	Stanfield et al., 1925	Parkash et al., 1984	Chakrabartty and du Plessis, 1885
Proximate							
	Moisture	18%	20%	19.70%	16.60%	25.60%	25.60%
	Ash	6.60%	15.00%	13.90%	6.00%	10.90%	12.20%
	Volatile Matter	31.20%	44%	43.90%	31.80%	43.20%	41.90%
	Fixed Carbon	44.20%	56%	55.90%	43.60%	56.80%	58.10%
Ultimate							
	Carbon	57.60%	75%	74.50%		73.70%	73.70%
	Hydrogen	5.70%	5.00%	5.10%		4.60%	4.60%
	Sulphur	0.40%	1.50%	1.50%		1.70%	1.68%
	Nitrogen	1.20%	0.50%	0.47%		0.80%	0.81%
	Oxygen	28.50%	18%	18.30%		19.20%	
	Calorific Value			23.04 kJ/g			28.1 kJ/g
	Mean Max. Reflectance		0.36-0.47			0.47	
Petrography							
	Huminite					92.70%	92.70%
	Liptinite					5.30%	5.30%
	Semifusinite					1.20%	1.20%
	Fusinite					0.80%	0.80%

Coalbed Methane

Romax ≈ 0.67 lignite

Coalbed methane has become an important resource target in Alberta over the last two decades. The Horseshoe Canyon Formation has been one of the important targets in this exploration. Data presented here comes from a briefing note from the National Energy Board of Canada. The play area is to the west of Drumheller and the coal seams targeted vary from depth of 200 m to 1000 m. The Horseshoe Canyon coals contain very little water so there is no need to dewater the formation and gas production occurs rapidly with the production rate maximizing within a few months. Production depends primarily on permeability within the coals which varies from 5 to 40 milliDarcy. Initially, production was focused on high permeability areas but has more recently shifted to also include lower permeability areas. Four wells per section have been determined as optimal for development. Estimates of gas-in-place are about 36 trillion cubic feet with 10-12 trillion cubic feet recoverable. The average well productivity is 77 million cubic feet per day initially. Development todate has centred on the areas of Beiseker and Rockyford.

ROAD TRIP: CALGARY TO DRUMHELLER

The drive to Drumheller usually takes about one hour and forty-five minutes depending on traffic conditions in Calgary (always busy), construction and route selected. The following comments are made on leaving Calgary on Highway 2 north and then turning east near Crossfield by Highway 572 joining Highway 9 at Beiseker which is then followed to the first stop at Horseshoe Canyon (Figure 1).

Calgary

Fort Calgary was the name given by Lieutenant-Colonel J.F. Macleod (Northwest Mounted Police) to a newly built fort on the Bow River in 1876. "Calgary" was his ancestral estate on the Isle of Mull, Scotland. In Gaelic the name means "clear running water." The Hudson's Bay Company opened a trading station nearby in the same year and by 1883 Calgary had its first post office. The Canadian Pacific Railroad reached Calgary in 1884, stimulating the rapid expansion of the city and surrounding area that continues today.

Calgary to Airdrie

Driving north out of Calgary, we follow an under-fit glacial river valley that is now occupied by a south-flowing creek. The underlying bedrock is the Paskapoo Formation (Paleocene, 60 Ma). The Paskapoo's patchy buff-coloured outcrops of sandstone and shale yielded building stone that was used to build many of Calgary's early buildings. It also yields fossil leaf floras, nonmarine mollusks, mammal tracks, fish fossils, and many sites yield mammal fossils.

Airdrie

Airdrie is Alberta's newest city although the community was established in 1889. It was named after a community north of Glasgow, Scotland. The community was established near a spring rather than a river as most cities in the province have been. It is one of the fastest growing cities in Canada serving as a bedroom community to the much larger centre to the south. A short distance north is the turnoff on highway 572.