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# The Dinosaur Park - Bearpaw Formation Transition in the Cypress Hills Region of Southwestern Saskatchewan, Canada

*Meagan M. Gilbert*
*Department of Geological Sciences, University of Saskatchewan; m.gilbert@usask.ca*

## Summary

The Upper Cretaceous Dinosaur Park Formation (DPF) is a south- and eastward-thinning fluvial to marginal marine clastic-wedge in the Western Canadian Sedimentary Basin. The DPF is overlain by the Bearpaw Formation (BF), a fully marine clastic succession representing the final major transgression of the epicontinental Western Interior Seaway (WIS) across western North America. In southwestern Saskatchewan, the DPF is comprised of marginal marine coal, carbonaceous shale, and heterolithic siltstone and sandstone grading vertically into marine sandstone and shale of the Bearpaw Formation. Due to Saskatchewan's proximity to the paleocoastline, 5$^{th}$ order transgressive cycles resulted in the deposition of multiple coal seams (Lethbridge Coal Zone; LCZ) in the upper two-thirds of the DPF in the study area. The estimated total volume of coal is $48\times10^9$ m$^3$, with a gas potential of $46\times10^9$ m$^3$ (Frank, 2005).

The focus of this study is to characterize the facies and facies associations of the DPF, the newly erected Manâtakâw Member, and the lower BF in the Cypress Hills region of southwestern Saskatchewan utilizing core, outcrop, and geophysical well log data. This study provides a comprehensive sequence stratigraphic overview of the DPF-BF transition in Saskatchewan and the potential for coalbed methane exploration.

## Introduction

The Dinosaur Park and Bearpaw Formations in Alberta, and its equivalents in Montana, have been the focus of several sedimentologic and stratigraphic studies due to exceptional outcrop exposure and extensive subsurface data (e.g., McLean, 1971; Wood, 1985, 1989; Eberth and Hamblin, 1993; Tsujita, 1995; Catuneanu et al., 1997; Hamblin, 1997; Rogers et al., 2016). The Dinosaur Park-Bearpaw (DPF-BF) transition, which is exposed in the Cypress Hills of southwestern Saskatchewan, has received little attention. There, it records a transgressive shoreline controlled by contemporary tectonics in the Canadian Cordillera. The interplay of accommodation space, sediment supply, and shoreline morphology resulted in major environmental changes in Alberta and Saskatchewan. An investigation of the DPF-BF transition based on outcrop and subsurface data provides insight into depositional trends and evolving

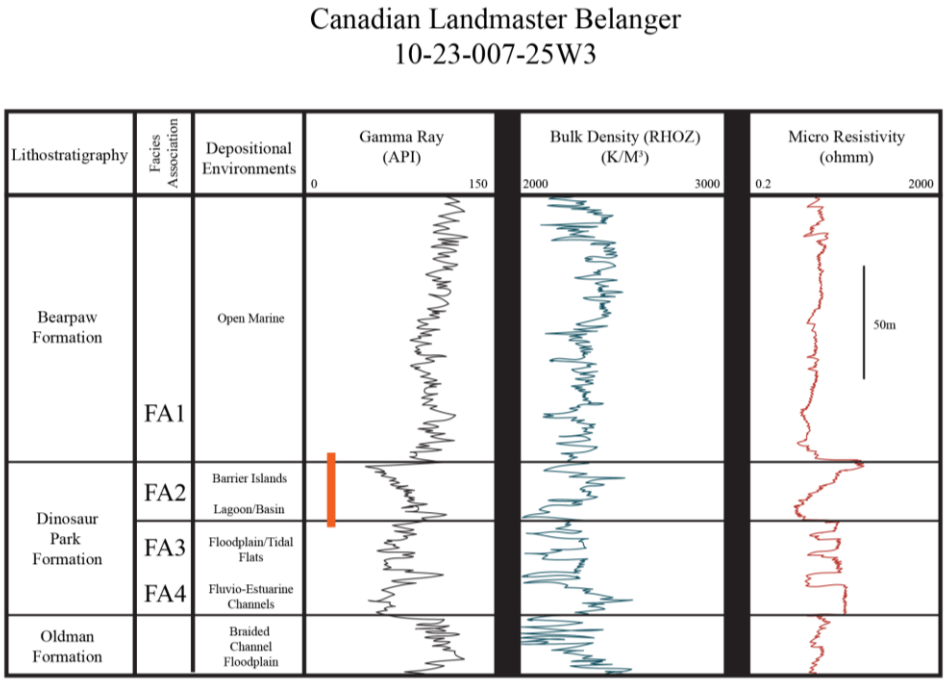


**Figure 1**. Representative well log highlighting stratigraphy, facies associations, and depositional environments of the Belly River Group in the subsurface of southwestern Saskatchewan (Canadian Landmaster Belanger – 10-23-007-25W3). This well illustrates the typical gamma ray – bulk density – resistivity log signatures of the Belly River Group. Dashed line of the Foremost Formation indicates its sporadic occurrence throughout the study area. Red line indicates available core that was logged for this study.

paleogeography of marginal marine coastlines in both the Cypress Hills and across the Western Canada Sedimentary Basin.

Detailed facies analysis indicates the upper DPF was deposited in a low-relief coastal plain with a wave-dominated, tidally influenced, fluvially modified shoreline (Fig. 1). Marginal-marine facies, interpreted as lagoons, tidal flats and estuaries, are bioturbated, showing a typical brackish-water trace-fossil assemblage, including *Asterosoma* isp., *Chondrites* isp., *Cylindrichnus concentricus*., *Teichichnus rectus*, and *Skolithos* isp. Fine-grained sandstone was deposited in an estuarine mouth-bar and barrier-island complex that protected the coast from wave reworking. As the seaway transgressed across the coast, fully marine wave-dominated parasequences replaced those of the coastal plain. Typical trace fossils include *Asterosoma* isp., *Chondrites* isp., *Diplocraterion* isp., *Nereites missouriensis*, *Phycosiphon incertum, Planolites* isp., *Rhizocorallium* isp., and *Zoophycos* isp., and are characteristic of nearshore, wave-dominated coastlines (Gilbert et al., 2019). This study provides critical insight into the evolution of depositional environments in the Late Cretaceous of southwestern Saskatchewan and a framework for further geologic and paleontologic studies ongoing in the region.

## Methods

The main study area extends from the United States border north to township 8 and from the Alberta border to range 21W3, encompassing most of the Saskatchewan extent of the Cypress Hills. Where possible, a minimum of one well per township was used, resulting in

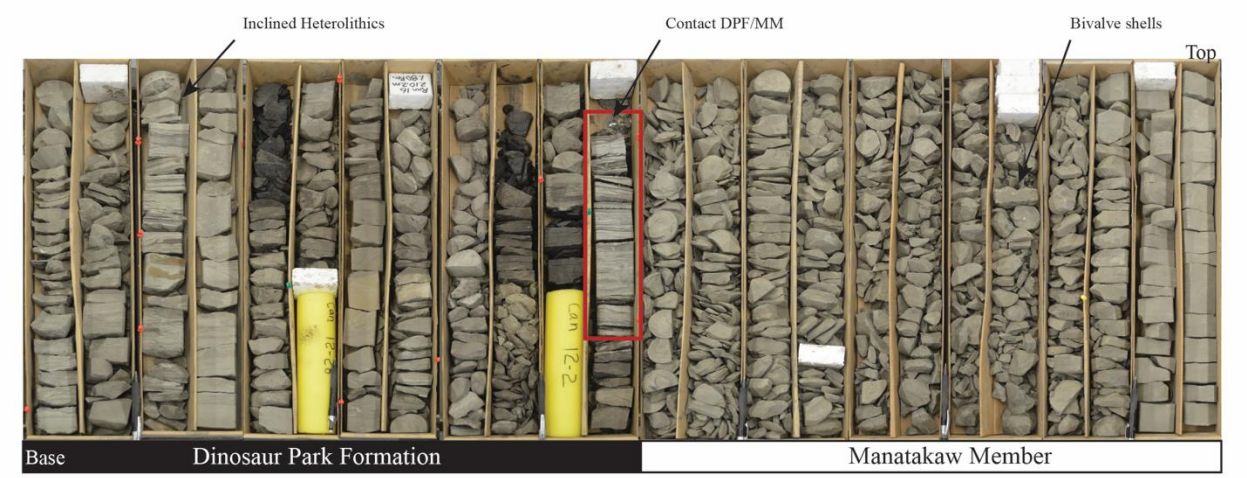


**Figure 2**. Representative core log from Nexen Battle Creek 07-02-004-27W3. Note the Inclined heterolithic stratification of at the top of the Dinosaur Park Formation. Red box indicates marginal marine facies with a preserved brackish water trace fossil assemblage. These deposits are immediately overlain by facies of the Manâtakâw Member. Note the presence of small bivalve shells in lagoon facies.

a database of 258 wells. Seven subsurface cores and outcrop exposures were included to provide a more robust dataset of depositional patterns across the basin. The gamma-density-resistivity suite of logs was used to pick the tops in the study area. This suite of logs is the most reliable for picking coals, which are a defining feature of the Dinosaur Park Formation in the Cypress Hills.

## Examples

Fifteen (15) discrete lithofacies are recognized throughout the Dinosaur Park-Bearpaw transition. These facies include fluvio-estuarine channels and their associated floodplains, marginal marine coastal plain, estuaries, lagoons, barrier islands, and wave dominated shallow marine deposits (Fig. 2). The lower DPF is characterized by fluvio-estuarine channels with discrete tidal structures deposited during Lowstand conditions (LST). The upper DPF is marked by onset of transgression of the WIS (Kauffman and Caldwell, 1993) in a Late Lowstand - Early Transgressive Systems Tract (Late LST - Early TST). Early transgressive deposits display signifiacant coal seam development and mudstone dominated facies. Marginal marine facies contain wave, tide, and fluvial sedimentary structures, underscoring the dynamic environmental conditions that persisted at the time of deposition. Fluvial processes are dominant in the lower DPF, but become subordinate to tide and wave affects with increased landward migration of the Western Interior Seaway. Marginal marine facies consisting of lagoon/estuary fill and barrier island sandstones cap the top of the DPF, and have been elevated to member status.

The new Manâtakâw Member of the Dinosaur Park Formation is named for the traditional Plains Cree word for the Cypress Hills. The base of the Manâtakâw Member is placed at the top of a consistent rightward gamma ray deflection that coincides with a bulk density deflection to the left.

This marks the lower boundary of estuarine basin and lagoon mudstone and shale. The upper contact is placed at the top of barrier island sandstone that correspond to a sharp gamma ray deflection to the left and a bulk density indication for sandstone. Facies of the Manâtakâw Member form coarsening upward successions that terminate against DPF and BF sediments between R27 and R28W3, but extend laterally to the north and south outside the study area. Termination of lagoon and barrier island deposits reflects decreasing accommodation to the west against the paleotopographic “highlands” of the Sweetgrass Arch. The lack of this member in the western portion of the study area, combined with the presence of conformable marine shales overlying heterolithic deposits of the DPF, indicates the region underwent rapid transgression at some point during the 2$^{nd}$ order Bearpaw Cycle.

The Vidora shallow gas pool is derived from the Dinosaur Park Formation and its associated upper member, and is sourced in part from the coals of the LCZ (Frank, 2005). Previous studies have indicated a mean gas content of 0.97 $m^3$ of gas per cubic meter of coal (Coal Gas Technologies Ltd., 2004a, 2004b). Seams are thickest around R25 and R26W3, and thin to the east and southeast in conjunction with thinning of the DPF clastic wedge.

## Conclusions

The DPF records a dramatic shift in basin evolution, with isopach maps indicating paleovalley incision between the underlying Oldman Formation and DPF contact. This required a significant fall in base level and was initiated by tectonism. Stacked meandering paleochannels attributed to a LST dominate the base of the formation. With the onset of late LST - Early TST, channel deposits are replaced by coals and floodplain heterolithic sediments. As transgression continued, estuaries, lagoons, and barrier islands of the newly erected Manâtakâw Member backstepped across coastal plain deposits of the DPF. An abrupt rise in sea level drowns the coast, resulting in marine shales of the Bearpaw Formation immediately overlying coastal plain deposits of the DPF west of R27 and R28W3. This indicates that the WIS underwent sudden, dramatic transgressive shifts that flooded substantial portions of the paleocoastline. Coal deposition resulted from small scale 5$^{th}$ order transgressive-regressive cycles, and underlies approximately 150 townships in the Cypress Hills region, roughly 13 300 $km^3$.

Detailed facies analysis reveals the Dinosaur Park - Bearpaw Formation contact in southwestern Saskatchewan as the base of a transgressive, barrier island - estuarine complex. The morphology of the coastline was largely controlled by storm surges and wave action, and influenced by mesotidal effects. Though meandering fluvial channels were active at the time of deposition, fluvial processes had subordinate control on sedimentation and shoreline morphology.

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