CSPG Canada's Energy Geoscientists
TOURMALINE OIL CORP.
CORE CONFERENCE
16-17 May 2019 • AER Core Research Centre • Calgary, AB
Celebrating 50 Years

Evolving landscapes of the Upper Cretaceous, and potential reservoir development

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Summary

The Princess core, NE-35-19-12W4, was drilled through the entirety of the Belly River Group. The Group comprises three very contrasting Formations: the Foremost Fm., dominated by a series of coarsening upward shoreface cycles; the Oldman Fm., which has been interpreted as braided fluvial in character; and the Dinosaur Park Fm., with stacked meandering fluvial and overbank deposits.

Selected cored intervals from the latter two Formations will be on display to allow comparisons to be made between the reservoir sandstone beds from contrasting fluvial depositional settings. In addition the sedimentology of each Formation will be interpreted to "paint a picture" of the different settings. The influence of low gradients and climatic variations on depositional character will also be addressed.

Introduction

The late Cretaceous Western Canada Sedimentary Basin was the site for deposition of regionally extensive non marine and marine clastic sequences. Within the Belly River Group, the Oldman Formation and overlying Dinosaur Park Formation have been intersected in the Princess core, drilled close to Dinosaur Provincial Park. The core provides an excellent opportunity to compare the expresion of the stratigraphy in a cored section with field exposoures along the South Saskatchewan River in eastern Alberta, and in Dinosaur Provincial Park.The two formations have been interpreted as being separated by a regional disconformity.

A coal exploration well, Princess NE-35-19-12W was drilled through the entirety of the Belly River Group. When examined in detail, the two younger Formations, namely the Oldman and Dinosaur Park Formations (Hamblin 1996; Eberth and Hamblin 1992) exhibit a wide array of depositional characteristics. While the small scale sedimentary structures can be interpreted through depositional processes, the changes in fluvial architecture have been linked to changes in relative sea level (Noad 1991; Shanley and McCabe 1993).

It should be noted that hydrocarbons have been successfully produced from all three Formations making up the Group, most successfully gas from the Comrey Sandstone interval of the Oldman Formation.

Theory

The core on display covers the majority of the Oldman and Dinosaur Park Formations. Facies exposed in the core include the following:

Facies code	*Description*	*Interpretation*
Str	Trough cross-bedded sandstone; grey, fine grained to very fine grained; occasional intraformational mudclast lag	Dunes in fluvial setting at base of channel
Slas	Fine to medium grained sandstone with planar cross-beds dipping at 5 to 25 degrees	Lateral accretion surfaces formed in point bar deposits; may be bank attached or in channel
Srip	Rippled sandstone, usually overlying Str; ripples often poicked out by carbonaceous drapes	Bar tops or point bar tops
Spar	Parallel laminated sandstone, picked out by carbonaceous material, usually overlying Str	Deposited in tranquil backwaters in fluvial setting, possibly with seasonal influence
Swav	Wavy laminated siltstone	Bar top deposits
Mpal	Massive, beige mudstone with occasional root traces with haloes; sometimes contorted bedding is visible; large traces such as Taenidium may be seen	Palaeosol
Move	Grey mudstone with scattered carbonaceous fragments	Overbank fines

There is a clear change in depositional facies through the core, with changes in the character and stacking of the sandstone dominated facies. These changes can be related to changes in relative sea level, and then used in a predictive sense to select targets for hydrocarbon exploration.

The channel deposits of the Oldman Formation are interpreted as representing deposition in an overall braided river system with channels typically around 50 m to 100 m in width. The wide variations in channel morphology and stacking through the Oldman Formation interval can be interpreted in terms of relative sea change, climatic variations and regional tectonic influences. When accommodation space is low, during relative lowstand, channels amalgamate and form sheet-like deposits. The best example of this is the Comrey Sandstone, which is interpreted as a sequence boundary. When accommodation space is high, more overbank deposits will be preserved and the channel sandbodies will be smaller and more isolated.

The Dinosaur Park Formation is dominated by sandstone beds showing interpreted lateral accretion surfaces, indicating an overall meandering channel setting. The upper interval shows a transition from meandering channels to palaeosols, suggesting a lowering of relative sea level and possible change in climate. The palaesols are overlain by the Lethbridge Coal Zone and ultimately by the marine Bearpaw Shales, representing an overall transgression from the Comrey Sandstone of the Oldman Formation.

Interpreted depositional settings

The facies associations and associated fossils have been used to reconstruct the palaeoenvironments extant at the time of deposition of the Upper Belly River Group. The gradient was very low (as demonstrated by the bone beds seen in the Park (Currie and Koppelhaus eds. 2005), similar to Bangladesh today. The climate was variable but generally warm and humid. The channel style ranged from possibly braided to meandering, although some of the stacked trough cross-bedded sandstone beds in the Oldman Formation may represent the basal portion of meandering channels, where the upper portion of LAS has later been removed by erosion due to liomited accommodation space.

The fauna was dominated by dinosaurs, with at least 40 species recorded from the studied stratigraphic interval. However there was a diverse fauna and flora apart form the large vertebrates. Some of these animals occupied the floodplain (insects leaving Taenidium traces) and ponds (garfish, snails, pond plants), as well as the fluvial channels crossing the floodplain.

Implications for reservoir development

Required reservoir properties:

Thick sandstone	• Stacked channels relating to somewhat limited accommodation space • Deeper channels may be affected by more humid climate
Laterally extensive sandstone	• Low gradient • Ideally deposited on sequence boundary but with little incision • Extensive sandy point bars in a meandering setting could be deposited autogenically
Clean, porous sandstone	• High energy flow to winnow out fines • Low clay content • Presence or absence of extraformational clasts and associated minerals that may reduce poroperm values
Limited baffles	• LAS versus IHS • Few shale breaks, which may be facilitated by limited accommodation space

Conclusions

Using the core data, supported by detailed outcrop studies at Sandy Point, Ferry Crossing and and in Dinosaur Provincial Park, it has proved possible to put together a sequence stratigraphic framework based on changes in fluvial architecture throughout the Belly River Group succession. This model represents the fluvial evolution over this stratigraphic interval.

The changes in relative sea level impact the depositional character, reservoir properties and lateral extent of the various reservoir sandstone beds. The erected framework can be used to predict these changes in the subsurface. It is hoped that this work provides a blueprint for building fluvial sequence stratigraphic models in other localities.

Acknowledgements

I would like to acknowledge Dr. David Eberth, my inspirational Masters thesis supervisor, and for the many discussions that we had on these fascinating rocks; Dr. Charlie Bristow, for all his support during my Masters; and Dr. Jenni Scott, who always has time to talk over these Formations and their complexities. I would also like to thank the staff at Dinosaur Provincial Park for their unfailing enthusiasm whenever I visit the park.

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Figures

Figure 1.
View of outcropping Oldman and Dinosaur Park Formation deposits. The contact sits atop the grassy bench in the middle of the photograph: Sandy Point, AB

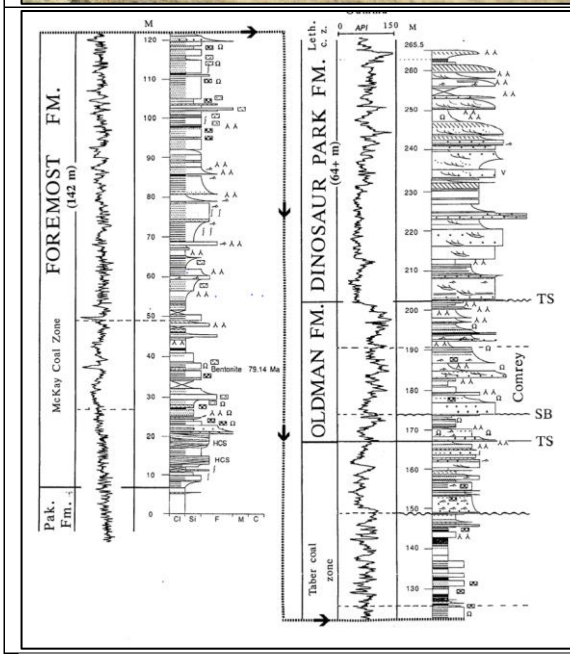

Figure 5.
Gamma ray and sedimentological log of Princess core (Eberth and Hamblin 1992)

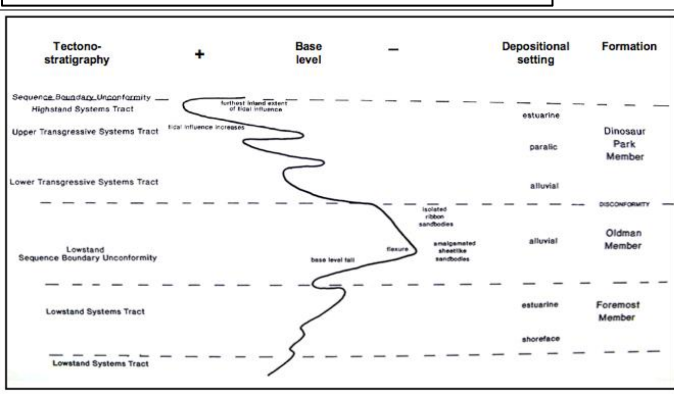

Figure 6.
Sequence stratigraphic interpretation of Belly River Group (Eberth & Ryan 1992) and Noad (1993).

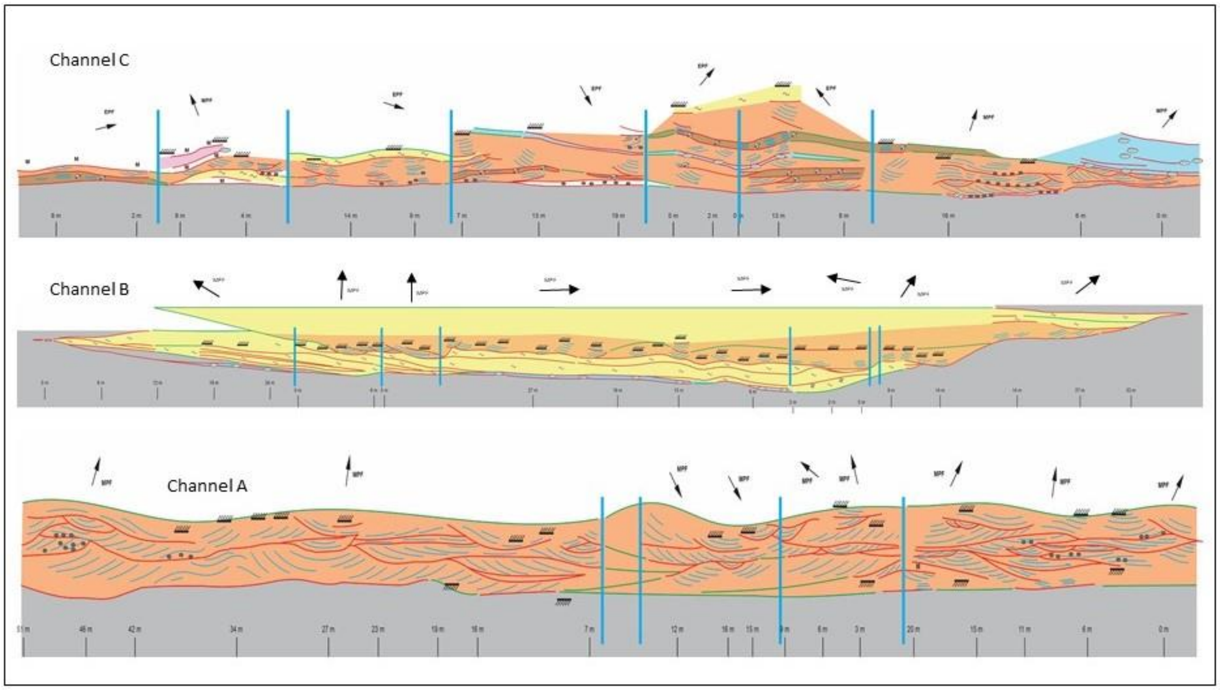

Figure 3
Channels of the Upper Oldman Formation:
Channel A is 23 m below the contact with the overlying Dinosaur Park Formation, and is around 11 m in thickness. It is dominated by trough cross-bedded sandstone (in orange).
Channel B is 23 m below the contact with the overlying Dinosaur Park Formation, and comprises two isolated channels around 3 m in thickness. It is dominated by dipping lateral accretion surfaces with rippled beds (in yellow).
Channel C is 4 m below the contact with the overlying Dinosaur Park Formation, and is around 6 m in thickness. It features dipping lateral accretion surfaces with carbonaceous, trough cross-bedded sands and unionid-rich intervals (in blue).
The channels are encased in overbank mudstones (in grey)

Figure 4
Photomosaic of Princess core showing identified facies and the four featured core intervals on display.