Shale Units of the Horn River Formation, Horn River Basin and Cordova Embayment, Northeast British Columbia

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Introduction

The Horn River Basin (HRB) and Cordova Embayment (CE) of northeastern British Columbia are bordered by the reef-fringed carbonate platforms of the Middle Devonian Upper Keg River, Sulphur Point, and Slave Point formations. Basinal shales laterally-equivalent to these carbonate units comprise the Evie, Otter Park, and Muskwa members of the Horn River Formation (Figure 1). These shales, particularly those of the Evie and Muskwa members that have high silica and organic contents are the target of a developing shale gas play.

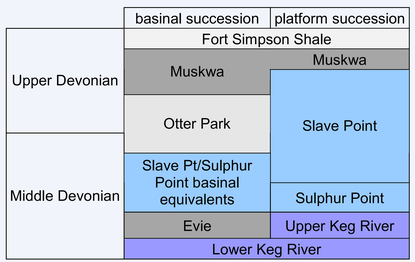


Figure 1: Middle and basal Upper Devonian units of the Horn River Basin (HRB) and Cordova Embayment (CE).

Shale Gas Activity

- Exploration activity for these shales in this lightly developed region has developed dramatically over the past two years (Adams *et al*, 2007)
- Total bonus paid for rights to the Horn River Shales exceeded $400 million in 2007
- Experimental schemes, which allow an operator to hold well data confidential for 3 years, have been granted to several companies within the HRB and CE
- 48 wells have been licensed or drilled to test these targets since 2004
- Few results are available, but the recompletion of a vertical well in d-60-I/94-O-9 in the HRB resulted in a gas flow of 13 e^3m^3/d, and EOG recently announced gas flow of 140 e^3m^3/d from their horizontal well in a-26-G/94-O-9

The purpose of this display is to highlight the main shale units that are the focus of shale gas activity in the HRB and CE, using available core, core analysis data, and geophysical well logs. A brief overview of the basinal stratigraphy is provided, supplemented by cross sections.

Although continuous non-confidential cores of the shale units are rare, several cores (mainly the result of missed core points!) do exist. Six cored wells have been selected for this core display. Analytical data, including total organic content (TOC), vitrinite reflectance, Rock Eval, porosity, permeability, mineralogy and other physical properties, are available for these cores and other wells in the region (Walsh and McPhail, 2007).

Basinal Shale Units

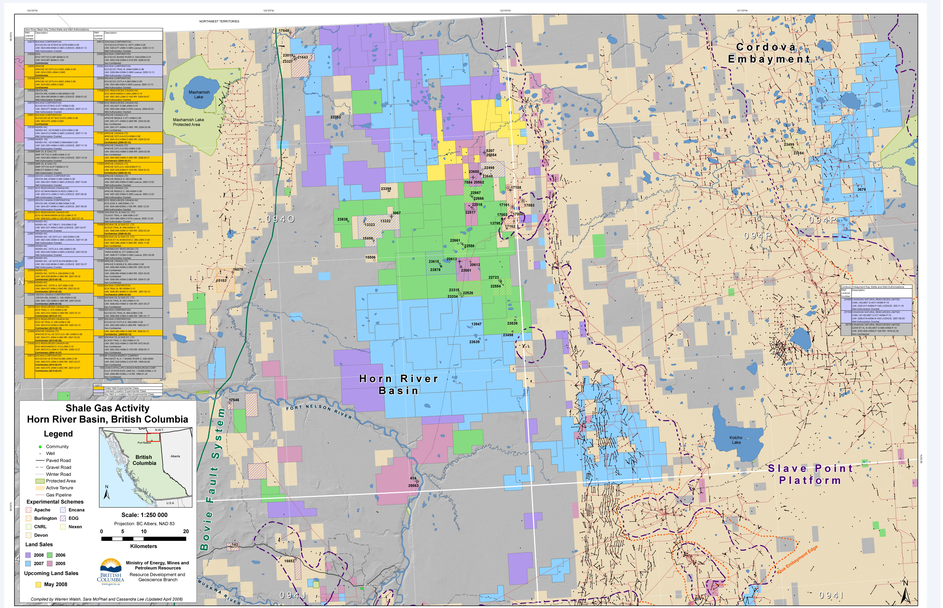
The basinal stratigraphy consists of the Evie, Otter Park and Muskwa members. However, basinal equivalents of the Slave Point and Sulphur Point can also be recognized in the basinal succession between the Evie and Otter Park (Morrow et al., 2002). All of these terms have been inconsistently used in the past, and here we primarily follow the usage of Gray and Kassube (1963), Meijer Drees (1994, figure 10.11) and Oldale and Munday (1994, figure 11.8a), modified to include the Slave Point and Sulphur Point equivalents (also commonly referred to as the Middle Devonian Carbonate or MDC). Others have used the term Klua for the Evie (e.g. Morrow et al., 2002).

Evie Member

- Lower package of highly radioactive shales in the Horn River Formation
- Overlies carbonates of the Lower Keg River
- Dark grey to black, organic-rich, pyritic, variably calcareous, siliceous shale
- High gamma ray readings and high resistivity on logs
- Uppermost part of the unit includes more argillaceous shales, and generally has lower radioactivity and resistivity
- CE: generally 40-50 m thick
- HRB: over 75 m thick immediately west of the Upper Keg River to Slave Point platform margin and it thins west to less than 20 m thick in the vicinity of the Bovie Lake Structure

Evie representation in this core display

UWI and [WA]	Location	Evie Thickness		Description
		Total	Cored	
d-6-H/94-P-10 [WA 3679]	CE	55 m	lower 14 m	• dark, organic-rich siliceous shale with some calcareous laminae
b-97-A/94-O-3 [WA 12681]	southern HRB	19 m	entire formation	• lower interval of highly radioactive organic-rich siliceous shale • middle unit of argillaceous shale • upper interval of highly radioactive organic-rich siliceous shale
a-47-G/94-P-4 [WA 5225]	southern HRB	68 m	upper 18 m	• dark, organic-rich calcareous shale • more siliceous at the base, and grades upwards to a siliceous argillaceous shale



Basinal Slave Point and Sulphur Point Equivalents

- Argillaceous limestones and interbedded shales
- CE: well developed, on the order of 60 m thick, and the Slave Point and Sulphur Point equivalents can each be distinguished (Morrow et al., 2002)
- HRB: a regionally traceable limestone unit that thins westwards from 15 m adjacent to the Upper Keg River to Slave Point platform margin to 5 m thick near the Bovie Lake structure

Otter Park Member

- Middle, less radioactive part of the Horn River Formation
- Maximum thickness exceeds 270 m in the southeast corner of the HRB, where it consists of medium to dark grey calcareous shale
- Logs exhibit lower radioactivity and resistivity than the Evie and Muskwa members
- Thins depositionally to the north and west, and includes more highly radioactive siliceous black shale beds in this direction

Otter Park representation in this core display

UWI and [WA]	Location	Otter Park Thickness		Description
		Total	Cored	
b-97-A/94-O-3 [WA 12681]	southern HRB	45 m	lower 1m	• dark grey, calcareous, shale • slightly grittier than the underlying Evie

Muskwa Member

- Upper, highly radioactive part of the Horn River Formation
- Grey to black, organic-rich, pyritic, siliceous shale
- High gamma ray readings and high resistivity on logs
- Gradational contact with the overlying argillaceous shales of the Fort Simpson Formation
- CE: 50 -70 m thick
- HRB: 30 m thick adjacent to the Upper Keg River to Slave Point platform margin. Thickens westward to over 60 m near Bovie Lake Structure. Thins considerably where the Otter Park thickness reaches its maximum in the southeast corner of the HRB

Muskwa representation in this core display

UWI and [WA]	Location	Muskwa Thickness		Description
		Total	Cored	
a-9-F/94-P-3 [WA 714]	Western margin of the HRB	10 m	lower 4 m	• dark grey, variably calcareous shale
b-49-G/94-P-10 [WA 1279]	Slave Point Platform southwest of the CE	17 m	upper 6 m	• dark grey, non-calcareous shale. • TOC values decrease upward, reflecting the gradational upper contact with the Fort Simpson
c-28-D/94-O-1 [WA 414]	Southern HRB	60 m	middle 4 m	• dark grey calcareous shale

Oil and Gas Exploration Activity Report 2006

- Exploration and development activity by the oil and gas industry is a major force in the provincial economy
- In 2006, drilling activity in British Columbia reached the second highest level ever recorded
- Raw natural gas production reached over three billion cubic feet per day and conventional oil production was 28,200 barrels per day
- The established remaining raw gas reserves estimate of 16.4 trillion cubic feet is the highest level in the history of the province and represents a four per cent increase over 2005 year-end reserves
- The Province has taken specific measures to ensure these opportunities are managed in an environmentally and socially responsible manner

Gas Shale Potential: Core and Cuttings Analysis

- Compilation of non-confidential analysis from core and cuttings samples that have been submitted
- Includes a variety of data that have applications to major shale gas plays in Northeast British Columbia including the Devonian shales of the Horn River Basin, Triassic Doig and Montney shales in the Peace River Arch and Cretaceous shales from the outer foothills and plains

References

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Gray, F.F., and Kassube, J.R. (1963): Geology and stratigraphy of Clarke Lake gas field, British Columbia; *American Association of Petroleum Geologists Bulletin*, volume 47, pages 467-483.

Meijer Drees, N.J. (1994): Chapter 10 Devonian Elk Point Group of the Western Canada Sedimentary Basin; *in* Geological Atlas of the Western Canada Sedimentary Basin, Mossop, G., and Shetsen, I., Compilers, *Canadian Society of Petroleum Geologists* and *Alberta Research Council*, pages 128-147.

Morrow, D.W., Zhao, M., Stasiuk, L.D. (2002): The gas-bearing Devonian Presqu'ile Dolomite of the Cordova Embayment region of British Columbia, Canada: Dolomitization and the stratigraphic template; *American Association of Petroleum Geologists Bulletin*, volume 86, pages 1609-1638.

Oldale, H.S., and Munday, R.J. (1994): Devonian Beaverhill Lake Group of the Western Canada Sedimentary Basin; *in* Geological Atlas of the Western Canada Sedimentary Basin, Mossop, G., and Shetsen, I., Compilers, *Canadian Society of Petroleum Geologists* and *Alberta Research Council*, pages 148-163.

Walsh, W. and McPhail, S. (2007): Shale Gas Potential: Core and Cuttings Analysis, Northeast British Columbia; Ministry of Energy, Mines and Petroleum Resources, Petroleum Geology Open File 2007-01.

Devonian Shales of the Horn River Basin and Cordova Embayment, Northeast British Columbia

BRITISH COLUMBIA
www.gov.bc.ca

SW

NE

←35661.8 m→ ←260.9 m→ ←45195.1 m→ ←20418.1 m→ ←47148.6 m→ ←26558.1 m→

UWI: 202/b-097-A/094-O-03/00
WA: 12681
2165.0

UWI: 200/c-028-D/094-O-01/00
WA: 00414
2320.7

UWI: 200/d-028-D/094-O-01/00
WA: 20563
2193.5

UWI: 200/a-047-G/094-P-04/00
WA: 05225
2456.0

UWI: 200/a-009-F/094-P-03/00
WA: 00714
2123.3

UWI: 200/b-049-G/094-P-07/00
WA: 01279
1934.6

UWI: 200/d-006-H/094-P-10/00
WA: 03679
2055.0

MUSKWA

OTTER PARK

EVIE

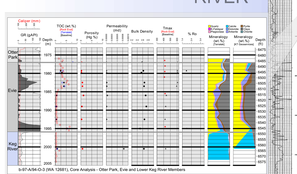
KEG RIVER

SLAVE POINT/ SULPHUR POINT/ KEG RIVER

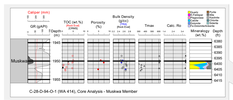
SLAVE POINT

WATT MOUNTAIN

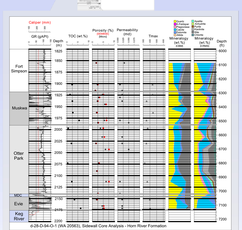
SULPHUR POINT



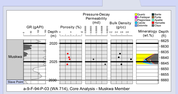
b-97-A/94-O-3 (WA 12681), Core Analysis - Otter Park, Evie and Lower Keg River Members



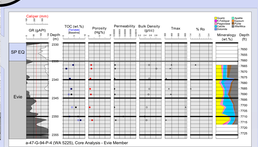
C-28-D-94-O-1 (WA 414), Core Analysis - Muskwa Member



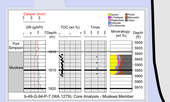
d-28-D-94-O-1 (WA 20563), Sidewall Core Analysis - Horn River Formation



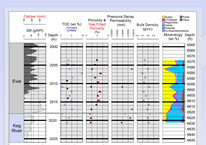
a-9-F-94-P-03 (WA 714), Core Analysis - Muskwa Member



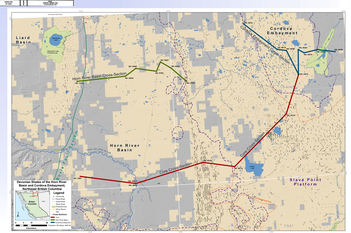
a-47-G-94-P-4 (WA 5225), Core Analysis - Evie Member



b-49-G-94-P-7 (WA 1279), Core Analysis - Muskwa Member



d-6-H-94-P-10 (WA 3679), Core Analysis - Evie and Lower Keg River Members



Cordova Embayment Stratigraphic Cross-Section

W

←27142.2 m→

←5989.2 m→

←16975.1 m→

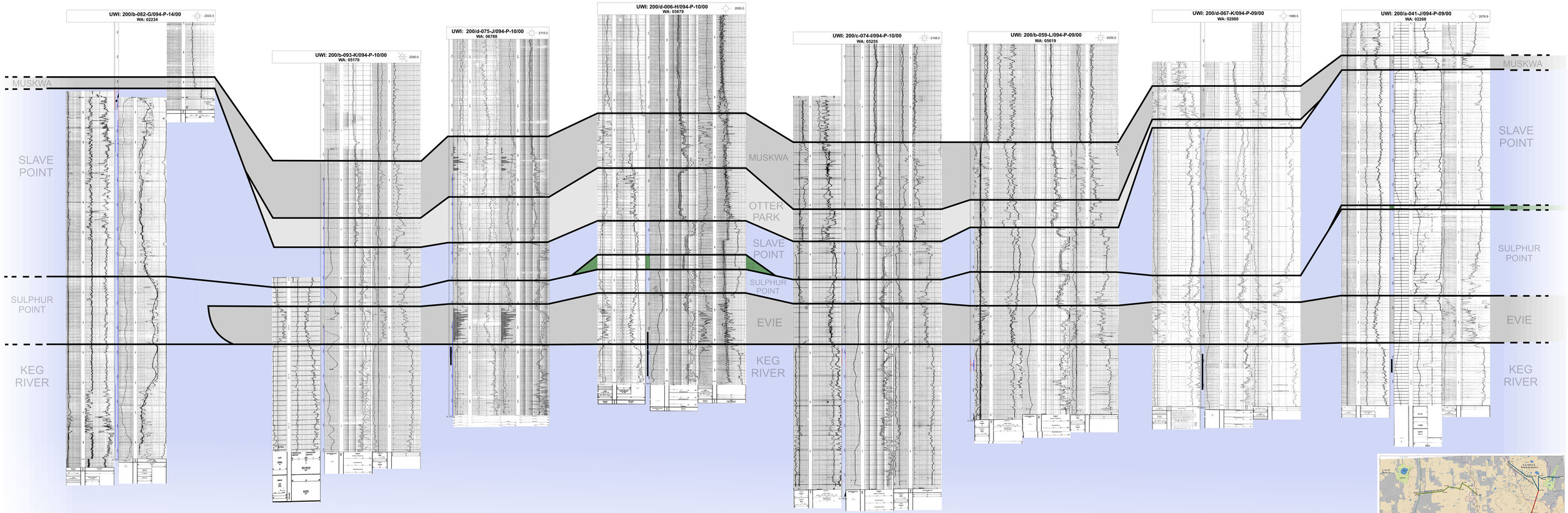
←15829.2 m→

←4371.8 m→

←8590.7 m→

←11520.6 m→

E



Horn River Basin Stratigraphic Cross-Section

W

E

←30636.7 m→

←8317.5 m→

←1321.1 m→

←6483.8 m→

←7886.8 m→

←13028.5 m→

UWI: 200/d-046-H/094-O-11/00
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4673.7

UWI: 200/c-062-H/094-O-10/00
WA: 05554
3100.0

UWI: 200/d-013-L/094-O-09/00
WA: 04665
2961.0

UWI: 200/b-094-G/094-O-09/00
WA: 07584
2620.0

UWI: 200/d-060-I/094-O-09/00
WA: 05207
2593.0

UWI: 200/d-001-I/094-O-09/00
WA: 04722
2445.0

UWI: 200/b-017-F/094-P-12/00
WA: 07050
2149.0

MUSKWA

OTTER PARK

MDC

EVIE

KEG RIVER

MUSKWA

OTTER PARK

EVIE

KEG RIVER

MUSKWA

SLAVE POINT/ SULPHUR POINT/ KEG RIVER