

Shale units of the Horn River Formation, Horn River Basin and Cordova Embayment, Northeastern British Columbia

Sara McPhail, Warren Walsh and Cassandra Lee
British Columbia Ministry of Energy, Mines and Petroleum Resources

Patrick A. Monahan, Monahan Petroleum Consulting/Penn West Energy Trust

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 (Appendix A). 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 HRB and CE.

	basinal succession	platform succession
Upper Devonian	Fort Simpson Shale	
	Muskwa	Muskwa
	Otter Park	Slave Point
Middle Devonian	Slave Pt/Sulphur Point basinal equivalents	
	Evie	Upper Keg River
	Lower Keg River	

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 Shale 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, and 48 wells have been licensed or drilled to test these targets since 2004 (Appendix A). 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 e3m3/, and EOG recently announced gas flow of 140 e3m3/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 a cross section (Appendix B).

Although continuous non-confidential cores of the shale units are rare, several cores (mainly the result of missed core points!) do exist. 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). Six cored wells have been selected for this core display and analytical data for these cores is presented in Table 1 and Appendix C. Additional analytical data is summarized for two wells with sidewall cores that were collected from the entire Horn River Formation (Appendix D).

Table 1: Summary of Horn River Formation shale cores illustrated in this display

Well location		c-28-D/ 94-O-1	b-97-A/ 94-O-3	a-9-F/ 94-P-3	a-47-G/ 94-P-4	b-49-G/ 94-P-7	d-6-H/ 94-P-10		
WA		414	12681	714	5225	1279	3679		
Cored Interval (m)		1949.1-1953.1	#1: 1974.0-1992.0 #2: 1992.0-2002.4	2022.6-2034.4	2336.0-2354.0	1810.4-1816.5	2003.4-2021.6		
Core Thickness (m)		3.9	#1: 17.6 #2: 9.9	11.8	18.0	6.1	17.7		
Cored Units		Muskwa	Otter Park, Evie, Lower Keg River	Muskwa, Slave Point	Evie	Muskwa	Evie, Lower Keg River		
Core analysis depth interval	(ft)	6393-6406	6476.3-6568.2	6636.5-6646	7664-7717	5941-5960	6573.6-6629.3		
	(m)	1948.6-1952.5	1974-2002	2022.8-2025.7	2336-2352.2	1810.8-1816.6	2003.6-2020.6		
Core Analysis Data	Units	Muskwa	Otter Park	Evie	Muskwa	Evie	Muskwa	Evie	
	TOC (%)	0.20-4.99	1.6-7.97	0.3-6.56	n/a	1.38-8	0.15-1.8	0.76-9.57	
	Porosity (%)	4.77-7.36	0.39	0.23-1.19	3.56-4.45	0.49-5.1	n/a	2.22-6.79	
	Key Mineralogy* (wt. %)	Qtz	7-76.9	63.3-71.1	21.2-78.9	26-81	14-63.2	18-33	7-67
		Calc	0-88	2.7-15.3	0-8.2	0-14	5.3-54	0	0-9
		Dol.	0-44	0-3.3	0-20.5	0-14	1.6-33	0-8	0-42
		Clay	8.9-25.7	8.7-12.6	10-54.7	13-38	7.5-57.1	34-54	1-22
Pyr.		1.1-3.1	4.2-4.4	3.5-23.3	3-15	2-19	6-41	0-5	

*Qtz = quartz, Calc = calcite, Dol = dolomite, Pyr = pyrite.

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 be also 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. Others have used the term Klua for the Evie (e.g. Morrow et al., 2002).

Evie Member

The Evie Member forms the lower package of highly radioactive shales in the Horn River Formation, and consists of dark grey to black, organic-rich, pyritic, variably calcareous, siliceous shale. This unit is characterized on logs by high gamma ray readings and high resistivity. The uppermost part of the unit includes more argillaceous shales, and generally has lower radioactivity and resistivity. In the CE, the Evie is generally 40 m thick. On the eastern margin of the CE, where the Slave Point and Sulphur Point carbonate platform has prograded over the Upper Keg River platform margin, the Evie extends beneath Slave Point and Sulphur Point platform carbonates. In the HRB the Evie is over 75 m thick immediately west of the Upper Keg River to Slave Point platform margin and it thins west to less than 40 m thick in the vicinity of the Bovie Lake Structure. The Evie overlies carbonates of the Lower Keg River.

In this core display, the Evie is represented by cores of the d-6-H/94-P-10 well in the CE and b-97-A/94-O-3 and a-47-G/94-P-4 wells at the southern regions of the HRB. In the d-6-H well, the lowermost 14 m of the Evie is cored, and consists of dark, organic-rich siliceous shale with some calcareous laminae. In the a-47-G well, 18 m of the upper part of the Evie is cored and consists of dark, organic-rich calcareous shale that is more siliceous at the base, and grades upwards to a siliceous argillaceous shale. In the b-97-A well, the entire Evie is cored and consists of a lower interval of highly radioactive organic-rich siliceous shale, a middle unit of argillaceous shale, and an upper interval of highly radioactive organic-rich siliceous shale. The upper siliceous shale in this well may be the basinal equivalent of the Slave Point and Sulphur Point formations.

Basinal Slave Point and Sulphur Point equivalents.

Basinal equivalents of the Slave Point and Sulphur Point Formations consist of argillaceous limestones and interbedded shales. These are best developed in the CE, where they are in the order of 60 m thick, and the Slave Point and Sulphur Point equivalents can each be distinguished (Morrow et al., 2002). In the 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 is interpreted to represent the basinal equivalent of the Slave Point and Sulphur Point.

Otter Park Member

The Otter Park Member is the middle, less radioactive part of the Horn River Formation. It reaches a maximum thickness of over 270 m in the southeast corner of the HRB, where it consists of medium to dark grey calcareous shale. It is characterized on logs by lower

radioactivity and resistivity than the Evie and Muskwa Members. However, the unit thins depositionally to the north and west, and includes more highly radioactive siliceous black shale beds in this direction.

The upper part of the core in the b-97-A well can be correlated with the basal part of the Otter Park and there it consists of dark grey, calcareous, shale that is slightly grittier than the underlying Evie.

Muskwa Member

The Muskwa constitutes the upper, highly radioactive part of the Horn River Formation. It consists of grey to black, organic-rich, pyritic, siliceous shale, and is characterized on logs by high gamma ray readings and high resistivity. It has a gradational contact with the overlying argillaceous shales of the Fort Simpson Formation. In the CE, it is between 50 and 70 m thick. In the HRB, it is 30 m thick adjacent to the Upper Keg River to Slave Point platform margin and thickens westward to over 60 m in the vicinity of the Bovie Lake Structure. However, it thins considerably where the Otter Park thickness reaches its maximum in the southeast corner of the HRB. Unlike the underlying basinal shales units, the Muskwa is not restricted to the CE and HRB, but thins and extends over the Slave Point Formation in the adjacent carbonate platforms.

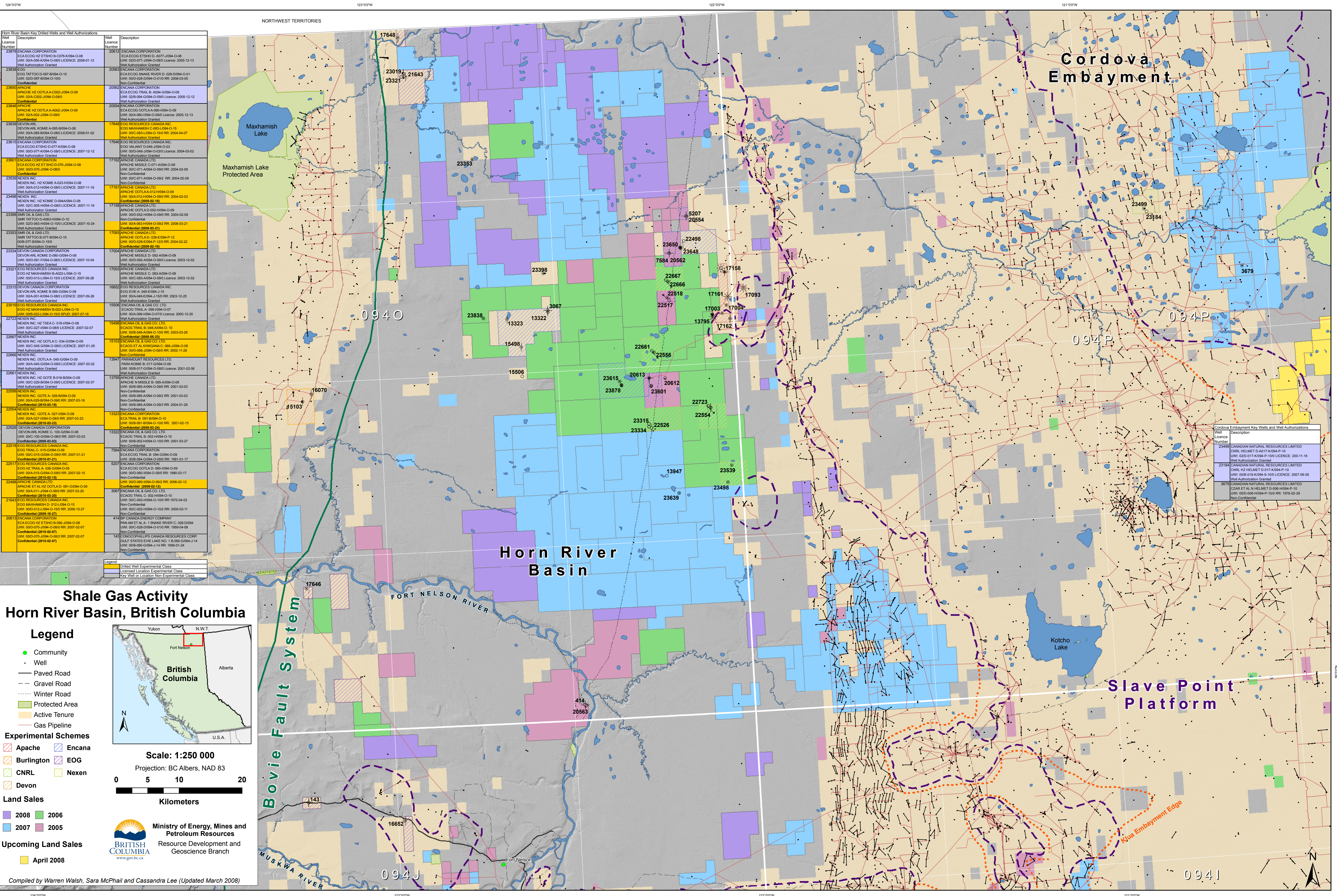
In this display, the Muskwa is represented by the cores of the a-9-F/94-P-3 and the b-49-G/94-P-10 wells, where thin Muskwa sections overlie the Slave Point Formation, and the core of the c-28-D/94-O-1 well, where it occurs in a basinal setting. In the a-9-F well, the Muskwa is 10 m thick, and the lower 7 m is represented in core. This consists of a dark grey, variably calcareous shale. In the b-49-G well, the Muskwa is 15 m thick, and the uppermost 6 m was cored. This interval consists of medium to dark grey, non-calcareous shale. TOC values decrease upward, reflecting the gradational upper contact with the Fort Simpson. In the c-28-D well, the Muskwa is 60 m thick and the 4 m thick core consists of dark grey calcareous shale.

References

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- 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.

Appendix A

Activity Map of the Horn River Basin and Cordova Embayment



Well License Number	Description	Well License Number	Description
23878	ENCANA CORPORATION ECA EOGG HZ ETSHO D-077-J094-O-08 UWI: 00A-005-0094-O-080 LICENCE: 2008-01-12 Well Authorization Granted	20612	ENCANA CORPORATION ECA EOGG ETSHO D-077-J094-O-08 UWI: 00A-005-0094-O-080 LICENCE: 2005-12-13 Well Authorization Granted
23839	ENCANA CORPORATION EOG TATTOO D-097-B094-O-10 UWI: 00D-007-0094-O-100 Confidential	20560	ENCANA CORPORATION ECA EOGG SNAKE RIVER D-028-D094-O-01 UWI: 00D-028-D094-O-010 RRR: 2006-03-05 Non-Confidential
23850	APACHE APACHE HZ OOTLA A-002-J094-O-09 UWI: 00A-002-0094-O-090 Confidential	20562	ENCANA CORPORATION ECA EOGG TRAIL B-004-J094-O-09 UWI: 00B-004-0094-O-090 LICENCE: 2005-12-12 Well Authorization Granted
23849	APACHE APACHE HZ OOTLA A-002-J094-O-09 UWI: 00A-002-0094-O-090 Confidential	20559	ENCANA CORPORATION ECA EOGG OOTLA A-000-J094-O-09 UWI: 00A-000-0094-O-090 LICENCE: 2005-12-13 Well Authorization Granted
23839	DEVON ARL DEVON ARL KOMIE A-085-B094-O-08 UWI: 00A-085-0094-O-080 LICENCE: 2008-01-02 Well Authorization Granted	17648	EOG RESOURCES CANADA INC. EOG MAXHAMISH B-022-J094-O-15 UWI: 00B-022-J094-O-150 RRR: 2004-04-07 Well Authorization Granted
23815	ENCANA CORPORATION ECA EOGG ETSHO D-077-J094-O-08 UWI: 00D-007-0094-O-080 LICENCE: 2007-12-12 Well Authorization Granted	17648	EOG RESOURCES CANADA INC. EOG MAXHAMISH C-083-J094-O-15 UWI: 00C-083-0094-O-150 RRR: 2004-04-07 Well Authorization Granted
23801	ENCANA CORPORATION ECA EOGG HZ ETSHO D-077-J094-O-08 UWI: 00D-007-0094-O-080 Confidential	17162	APACHE CANADA LTD. APACHE MISSILE C-071-A094-O-09 UWI: 00C-071-A094-O-090 RRR: 2004-02-09 Non-Confidential
23539	NEXEN INC. NEXEN INC. HZ KOMIE A-023-H094-O-08 UWI: 00A-023-H094-O-080 LICENCE: 2007-11-19 Well Authorization Granted	17162	APACHE CANADA LTD. APACHE MISSILE C-071-A094-O-09 UWI: 00C-071-A094-O-090 RRR: 2004-02-09 Non-Confidential
23498	NEXEN INC. NEXEN INC. HZ KOMIE A-023-H094-O-08 UWI: 00A-023-H094-O-080 LICENCE: 2007-11-19 Well Authorization Granted	17158	APACHE CANADA LTD. APACHE MISSILE C-071-A094-O-09 UWI: 00C-071-A094-O-090 RRR: 2004-02-09 Non-Confidential
23388	SMR OIL & GAS LTD. SMR TATTOO D-097-B094-O-10 UWI: 00D-007-0094-O-100 Confidential (2009-02-21)	17000	APACHE CANADA LTD. APACHE MISSILE C-071-A094-O-09 UWI: 00C-071-A094-O-090 RRR: 2004-02-09 Non-Confidential
23383	SMR OIL & GAS LTD. SMR TATTOO D-097-B094-O-10 UWI: 00D-007-0094-O-100 Confidential (2009-02-21)	17000	APACHE CANADA LTD. APACHE MISSILE C-071-A094-O-09 UWI: 00C-071-A094-O-090 RRR: 2004-02-09 Non-Confidential
23334	DEVON CANADA CORPORATION DEVON ARL KOMIE B-099-G094-O-08 UWI: 00B-099-G094-O-080 LICENCE: 2007-10-04 Well Authorization Granted	17000	APACHE CANADA LTD. APACHE MISSILE C-071-A094-O-09 UWI: 00C-071-A094-O-090 RRR: 2004-02-09 Non-Confidential
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23067	NEXEN INC. NEXEN INC. HZ OOTLA C-034-G094-O-09 UWI: 00C-034-G094-O-090 LICENCE: 2007-01-29 Well Authorization Granted	15103	ENCANA OIL & GAS CO. LTD. ECAO TRAIL B-048-A094-O-10 UWI: 00B-048-A094-O-100 RRR: 2003-03-26 Confidential (2009-02-21)
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22559	NEXEN INC. NEXEN INC. GOTTE A-023-B094-O-09 UWI: 00A-023-B094-O-090 RRR: 2007-03-16 Confidential (2010-03-16)	13322	ENCANA OIL & GAS CO. LTD. ECAO TRAIL B-048-A094-O-10 UWI: 00B-048-A094-O-100 RRR: 2004-01-29 Non-Confidential
22544	NEXEN INC. NEXEN INC. GOTTE A-023-B094-O-09 UWI: 00A-023-B094-O-090 RRR: 2007-03-16 Confidential (2010-03-16)	13322	ENCANA OIL & GAS CO. LTD. ECAO TRAIL B-048-A094-O-10 UWI: 00B-048-A094-O-100 RRR: 2004-01-29 Non-Confidential
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22517	EOG RESOURCES CANADA INC. EOG TRAIL C-015-G094-O-09 UWI: 00C-015-G094-O-090 RRR: 2007-01-21 Confidential (2010-01-21)	13322	ENCANA OIL & GAS CO. LTD. ECAO TRAIL B-048-A094-O-10 UWI: 00B-048-A094-O-100 RRR: 2004-01-29 Non-Confidential
22488	APACHE CANADA LTD. APACHE HZ OOTLA D-091-G094-O-09 UWI: 00D-091-G094-O-090 RRR: 2007-03-20 Confidential (2010-03-20)	13322	ENCANA OIL & GAS CO. LTD. ECAO TRAIL B-048-A094-O-10 UWI: 00B-048-A094-O-100 RRR: 2004-01-29 Non-Confidential
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		141	CONCORP/PLPS CANADA RESOURCES CORP. SULF STATES ENE LANE NO. 18-B-090-G094-O-14 UWI: 00B-090-G094-O-140 RRR: 1995-01-24 Non-Confidential

Well License Number	Description
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23184	CANADIAN NATURAL RESOURCES LIMITED CNRL HZ HELMET D-017-K094-P-10 UWI: 00B-017-K094-P-100 LICENCE: 2007-09-05 Well Authorization Granted
3679	CANADIAN NATURAL RESOURCES LIMITED CNRL ET AL HELMET D-008-H094-P-10 UWI: 00D-008-H094-P-100 RRR: 1975-03-29 Non-Confidential

Shale Gas Activity Horn River Basin, British Columbia

Legend

- Community
- Well
- Paved Road
- Gravel Road
- Winter Road
- Protected Area
- Active Tenure
- Gas Pipeline

Experimental Schemes

- Apache
- Burlington
- CNRL
- Devon
- Encana
- EOG
- Nexen

Land Sales

- 2008
- 2007
- 2006
- 2005

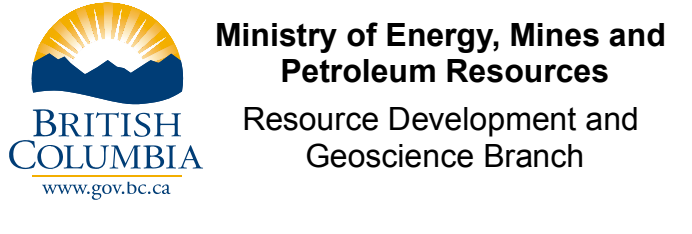
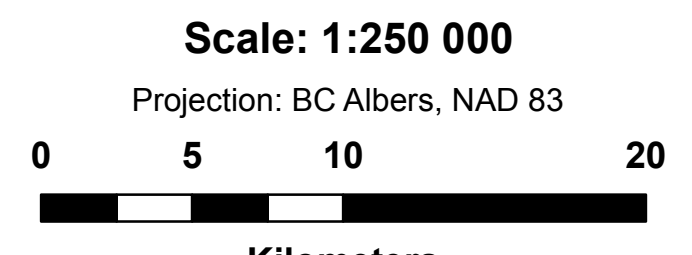
Upcoming Land Sales

- April 2008

Scale: 1:250 000
Projection: BC Albers, NAD 83

Ministry of Energy, Mines and Petroleum Resources
Resource Development and Geoscience Branch

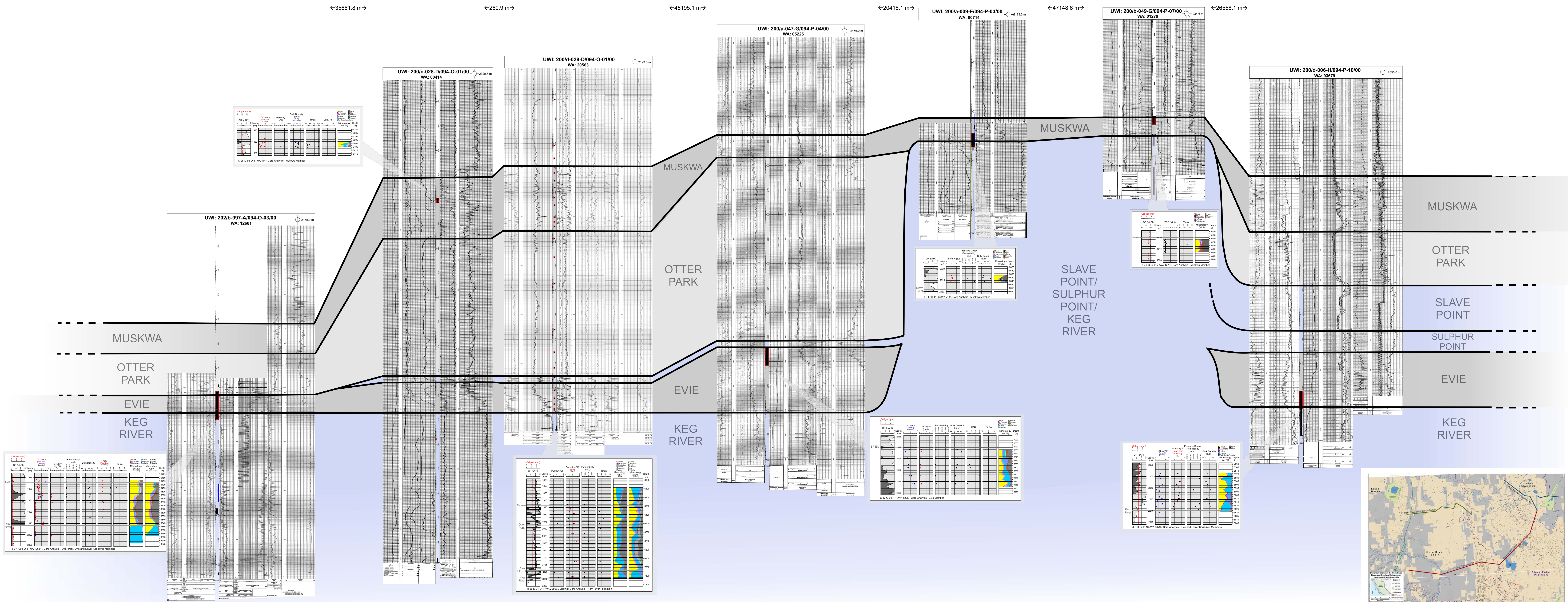
Compiled by Warren Walsh, Sara McPhail and Cassandra Lee (Updated March 2008)



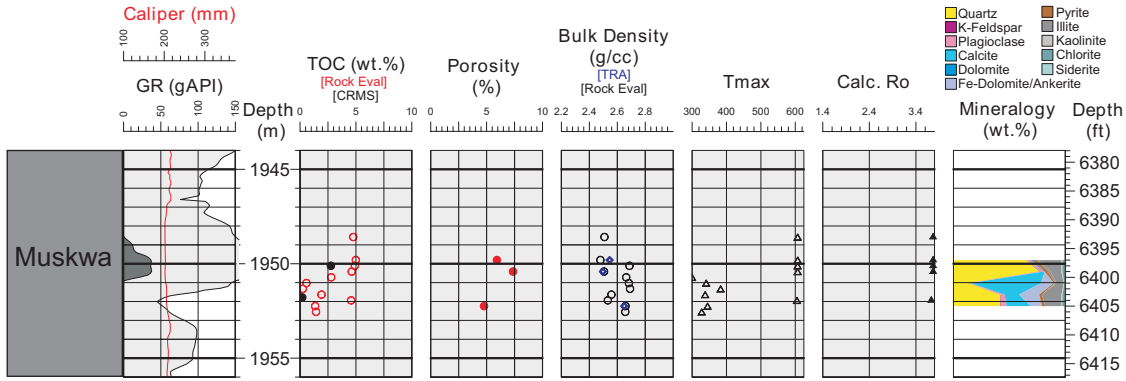
Appendix B

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

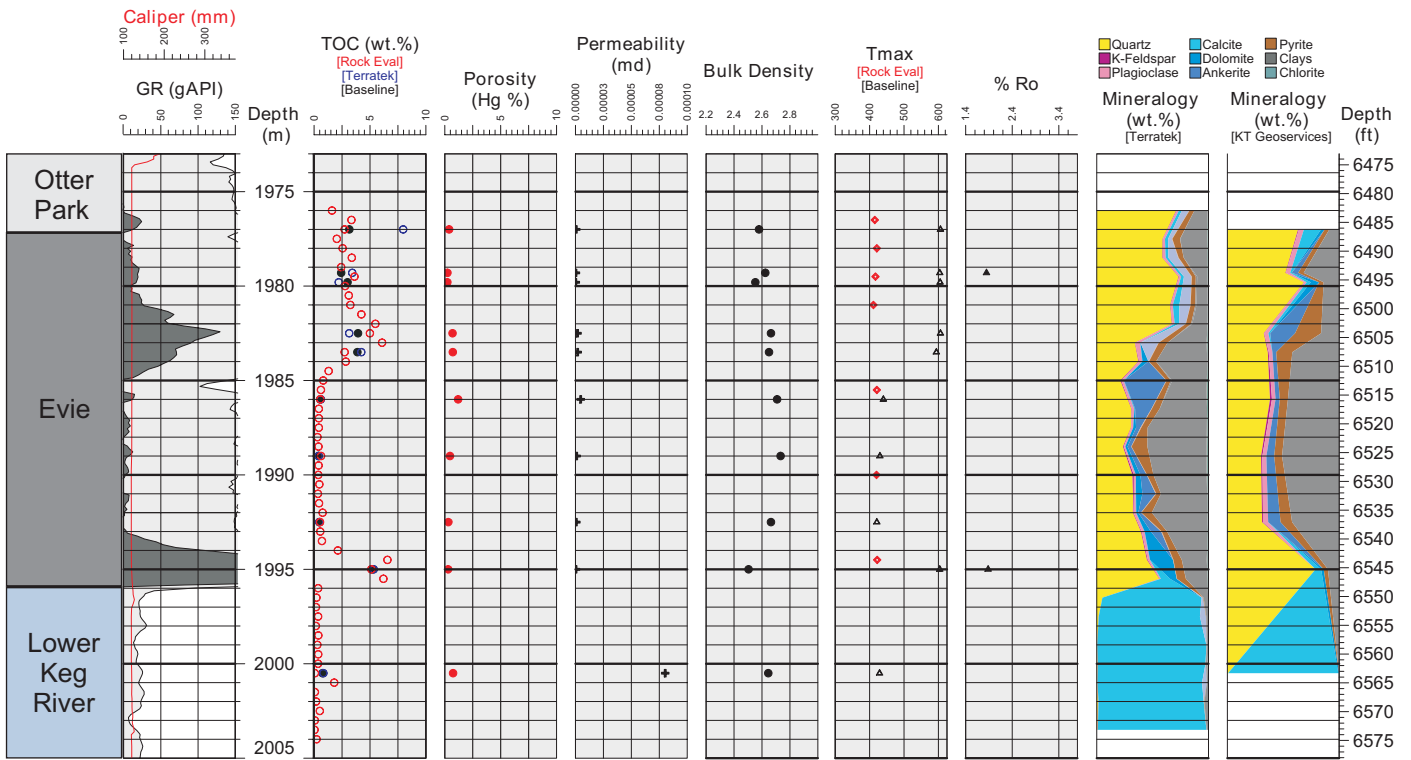
Devonian Shales of the Horn River Basin and Cordova Embayment, Northeast British Columbia



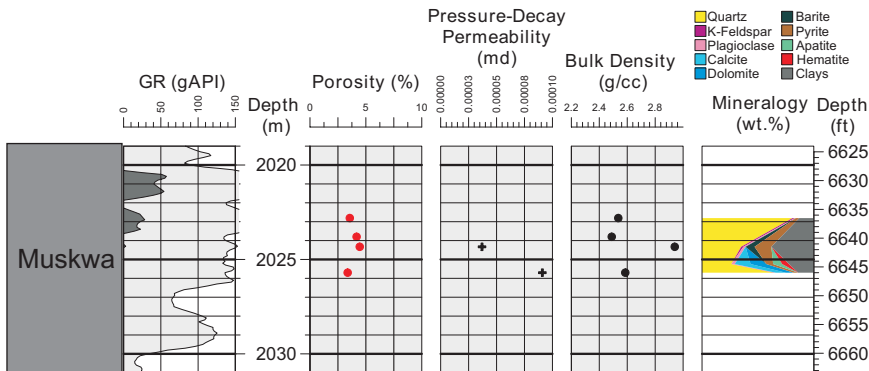
Appendix C: Core analysis data for core display wells



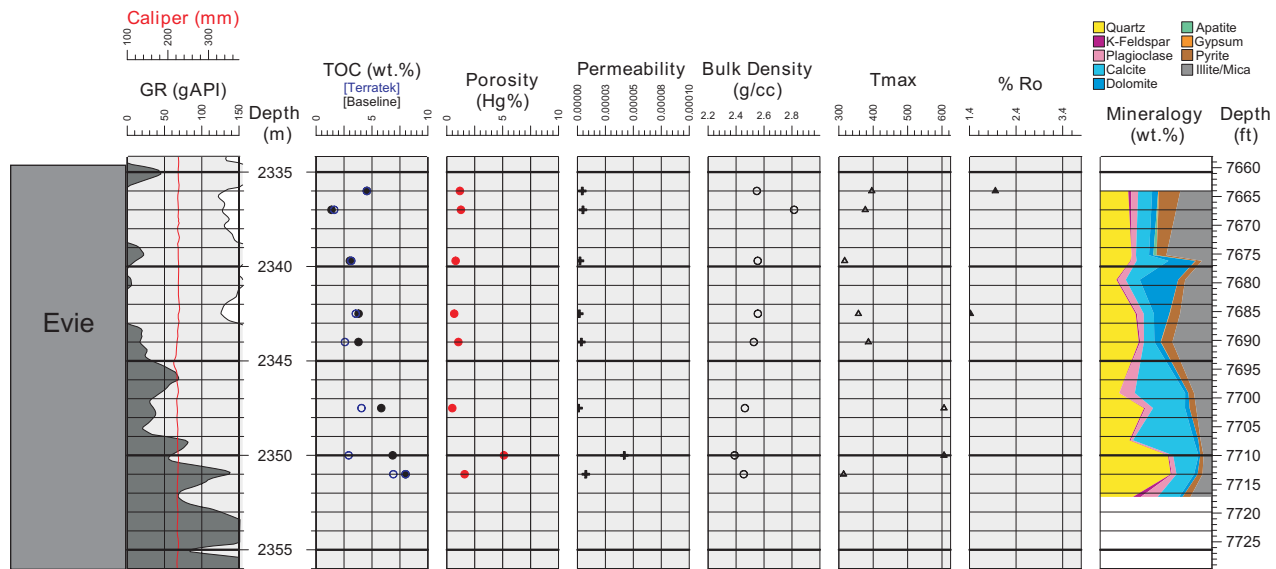
C-28-D/94-O-1 (WA 414), Core Analysis - Muskwa Member



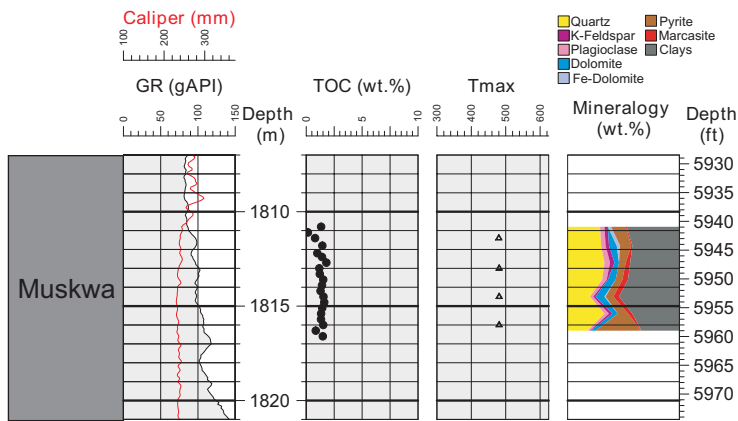
b-97-A/94-O-3 (WA 12681), Core Analysis - Otter Park, Evie, and Lower Keg River members



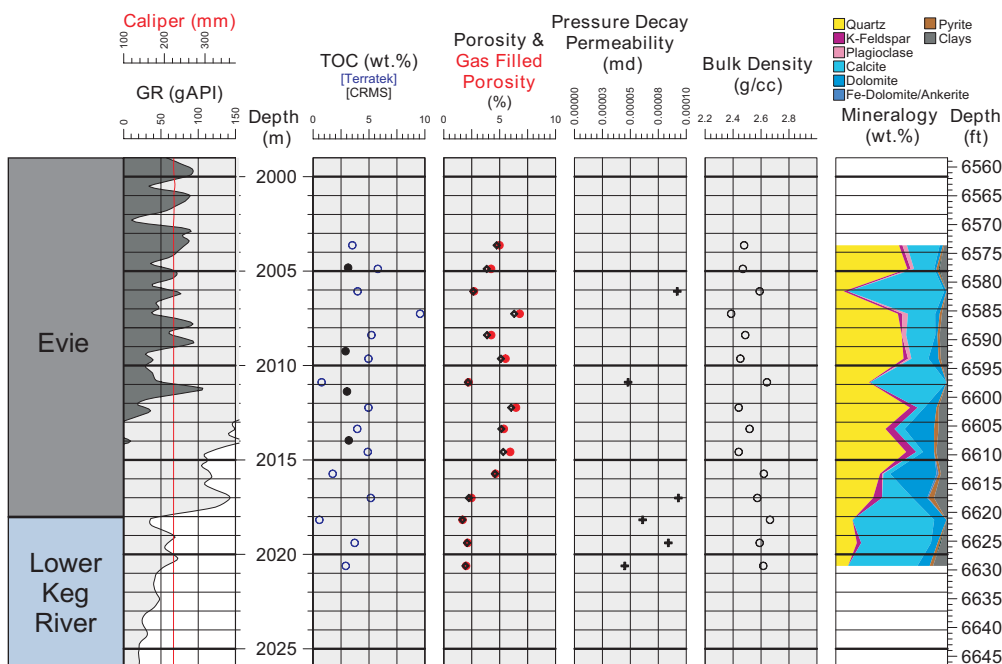
a-9-F/94-P-03 (WA 714), Core Analysis - Muskwa Member



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



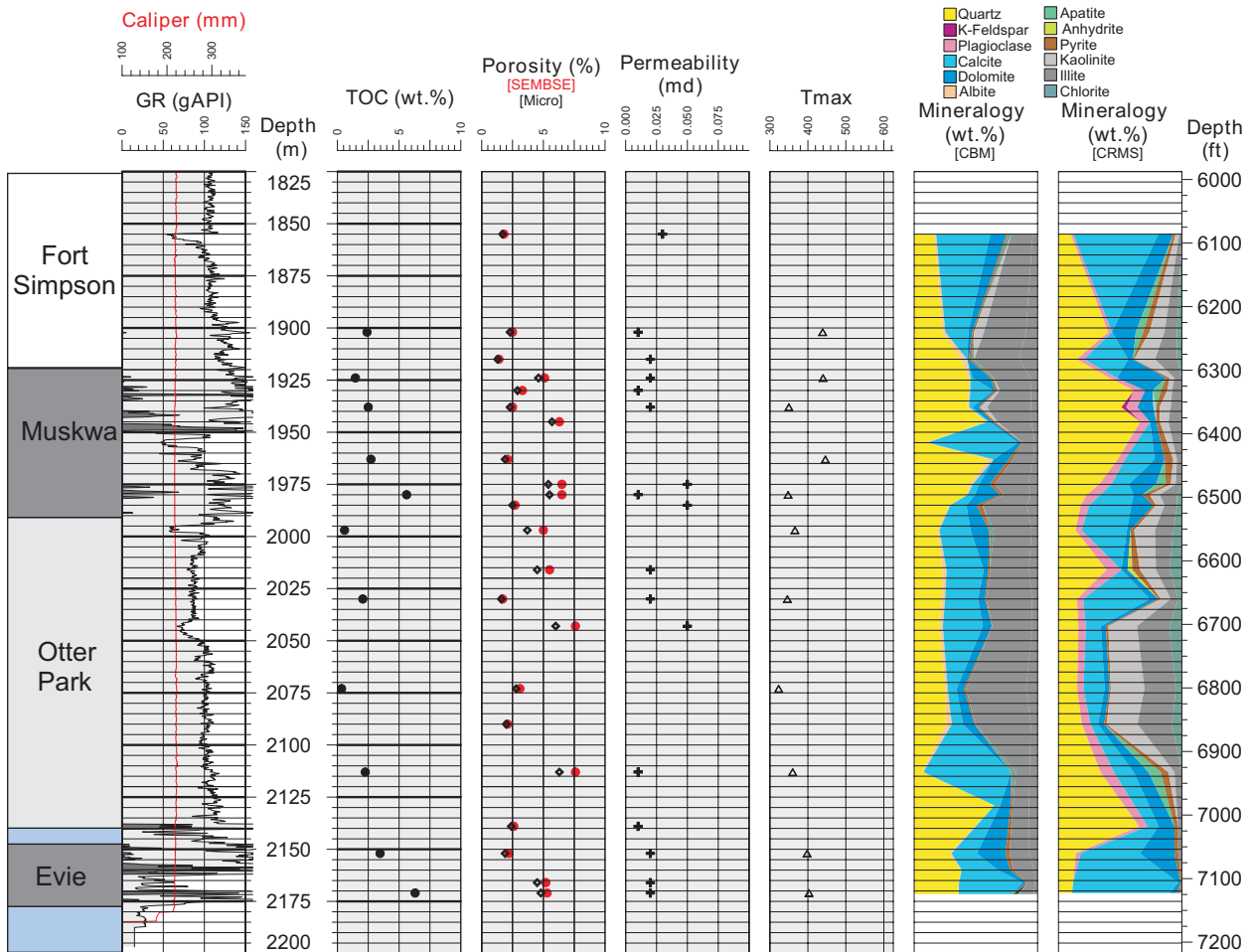
b-49-G/94-P-7 (WA 1279), Core Analysis - Muskwa Member



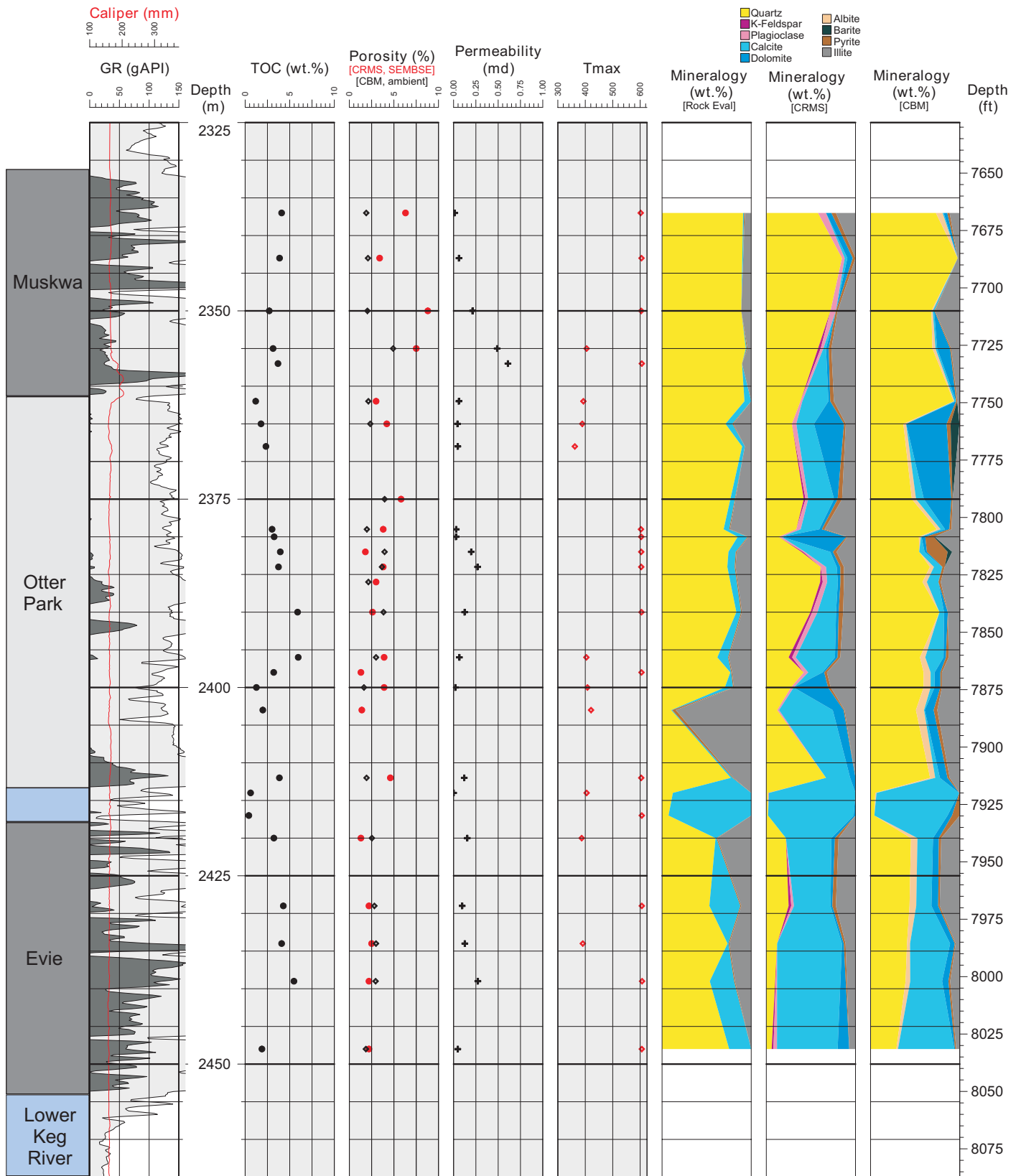
d-6-H/94-P-10 (WA 3679), Core Analysis - Evie and Lower Keg River Members

Appendix D: Core Analysis Data for sidewall core wells – summary tables and logs

Well Location		d-28-D/94-O-1			d-60-I/94-O-9			
WA		20563			5207			
Cored Units		Fort Simpson, Muskwa, Otter Park, Evie			Muskwa, Otter Park, Sulphur/Slave Point, Evie			
Core Analysis Depth Interval	6086-7124	6086-7124			7667-8031			
	(m)	1855-2171.5			2337-2448			
Core Analysis Data	Unit	Muskwa	Otter Park	Evie	Muskwa	Otter Park	Evie	
	TOC (%)	1.46-5.61	0.34-2.26	3.46-6.30	2.7-4.09	1.18-5.95	1.88-5.47	
	Porosity (%)	1.9-6.5	1.6-7.6	1.9-5.3	1.9-8.8	1.3-4.6	1.3-2.99	
	Key Mineralogy (wt%)	Quartz	18-67	6.9-69.83	11-66	58-98	10-88	6-73
		Calcite	0-75.31	0-75.89	9-85	0-3	0-59	1-72
		Dolomite	1.59-40	3-15.61	2-28	0-14.51	0-73	2-13
Clay		0-49.17	0-63.88	0-24.45	0-28	0-82	0-36	



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



d-60-I/94-O-9 (WA 5207), sidewall core analysis - Horn River Formations