Unconventional Natural Gas Assessment for the Cordova Embayment in Northeastern British Columbia

Upstream Development Division
Tenure and Geoscience Branch

Oil and Gas Report 2015-1

BRITISH COLUMBIA
Ministry of Natural Gas Development

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Back Cover Description: Gas processing facility along the Alaska Highway south of Fort Nelson. BC. BC Oil and Gas Commission.

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FOREWORD

British Columbia Ministry of Natural Gas Development

The role of the British Columbia Ministry of Natural Gas Development is to guide the responsible development, and ensure maximum economic benefits to British Columbians, from the province's natural gas resources and the province's next new major industrial sector—that of liquefied natural gas (LNG).

The Ministry facilitates B.C.'s thriving, safe, environmentally responsible and competitive natural gas sector to create jobs and economic growth. In developing natural gas policies, legislation and guidelines, the Ministry consults with other ministries and levels of government, energy companies, First Nations, communities, environmental and industry organizations, and the public. A key component of the Ministry's mandate is to develop tenure, royalty and regulatory policy for British Columbia's natural gas industry, thereby promoting the effective and environmentally responsible management of the province's natural gas resources.

The Ministry is also mandated to carry out resource assessments of petroleum resources within the Province of British Columbia, and, is responsible for the British Columbia Oil and Gas Commission.

British Columbia Oil and Gas Commission

The BC Oil and Gas Commission (Commission) is the provincial regulatory agency with responsibilities for regulating oil and gas activities in British Columbia, including exploration, development, pipeline transportation and reclamation.

The Commission's core services include reviewing and assessing applications for industry activity, consulting with First Nations, cooperating with partner agencies, and ensuring industry complies with provincial legislation and all regulatory requirements. The public interest is protected by ensuring public safety, respecting those affected by oil and gas activities, conserving the environment, and ensuring equitable participation in production.

For general information about the Commission, please visit www.bcogc.ca or phone 250-794-5200.

Executive Summary

The marketable unconventional shale gas potential within the Cordova Embayment in British Columbia has been evaluated by the British Columbia Ministry of Natural Gas Development and the British Columbia Oil and Gas Commission. The volume of marketable natural gas for shale formations within the Cordova Embayment is estimated to be 249.2 billion m^3 (8.8 trillion cubic feet (Tcf)).

Introduction

The Cordova Embayment in British Columbia covers an area of approximately 2,400 km^2 (Figure 1). It is located in the extreme northeastern corner of the Province, extending northwards into the Northwest Territories, and is separated from the Horn River Basin on the west by the Presqu'ile Barrier reef complex (i.e., the Slave Point and Keg River reefal carbonates), which in the Middle Devonian extended from Alberta, through British Columbia, and into the Yukon and Northwest Territories.

Although at a much earlier stage of evaluation by industry than the Horn River Basin, the Devonian shale plays of the Cordova Embayment are known to produce shale gas.
As of August, 2015 , twenty one (21) wells in the Cordova Embayment produced approximately 1.1 $x10^9$ m^3 (~37.6 Bcf) of cumulative gas from the Muskwa – Otter Park and Evie shales; with most of the production on record obtained from block G on map Sheet 94-P-10 (Balogun, 2014).

The Cordova Embayment is crossed by a significant network of gas pipelines and other infrastructure that were utilized during development of the overlying Jean Marie Formation in the Helmet field. This may lower the costs of developing local shale gas relative to shale basins that are more isolated from infrastructure.

For this study, the British Columbia Ministry of Natural Gas Development (BC MNGD) assessed in-place and marketable volumes of natural gas contained within the Mid-Upper Devonian Evie, Otter Park and Muskwa formations. Data used for this study is based on non-confidential industry core and well data that has been submitted to the BC Oil and Gas Commission (BC OGC).

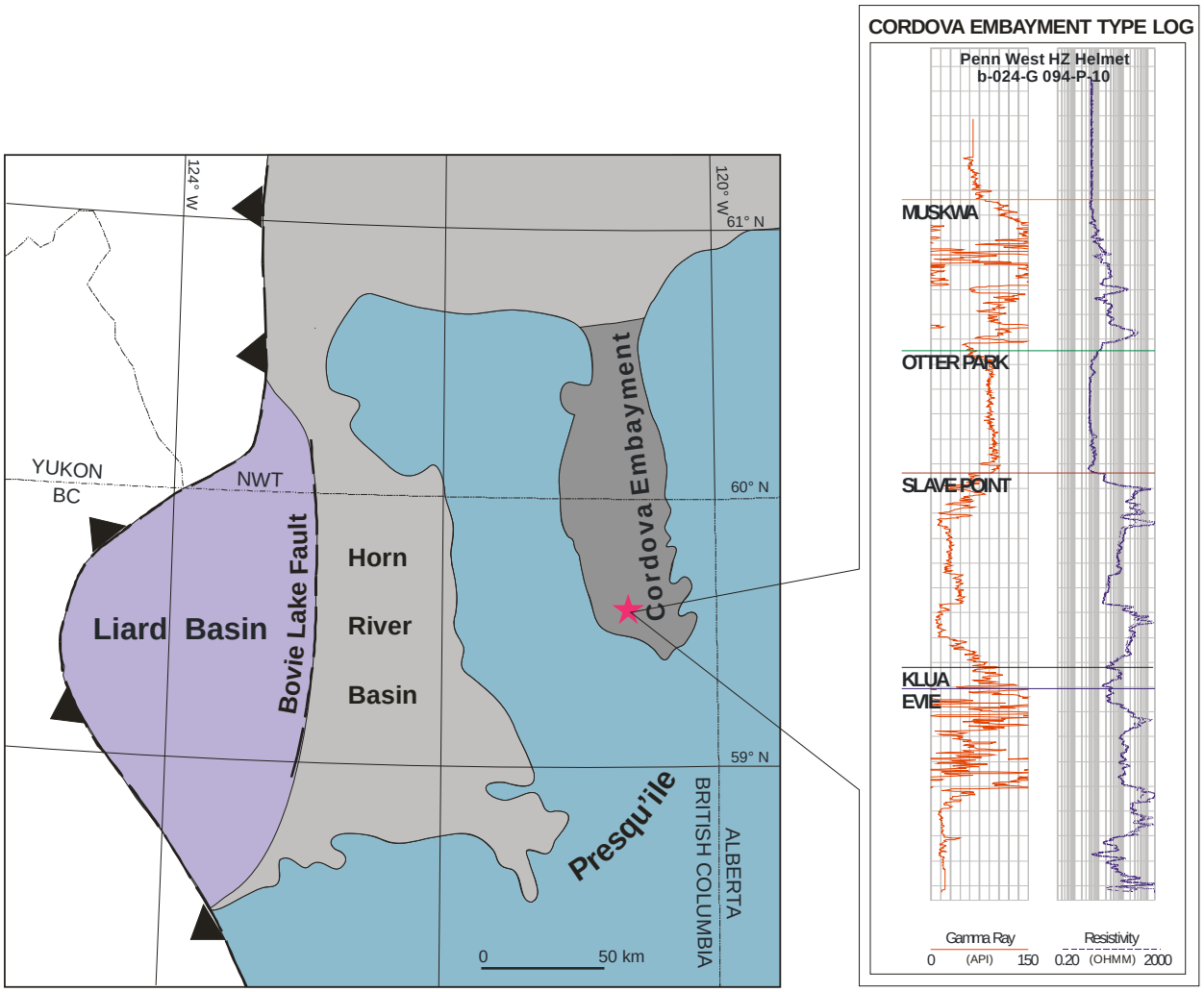

Figure 1. Location of the Cordova Embayment with respect to the Horn River and Liard basins of northeastern British Columbia (outlines of the Liard Basin, Horn River Basin and Cordova Embayment modified from Drees, 1994 and Morrow, 2012). Also shown is the Cordova Embayment Type Log and well location for Penn West HZ Helmet B-024-G-094-P-10.

Geological Setting and Description

During the Middle Devonian, shale's were preferentially deposited in paleo-geographic depressions of the Horn River Basin (HRB) and the Cordova Embayment. The HRB and Cordova Embayment were surrounded by a shallow carbonate platform. Organic shale deposition within the Cordova Embayment is the result of two transgressive-regressive cycles; hence, their boundaries are defined by the thinning and pinching out of these shale deposits at the edges of the carbonate platforms on which they onlap.

While it is believed that middle to upper Devonian shale deposition in the HRB and the Cordova Embayment was synchronous, some notable differences exist in the stratigraphic architecture of the basins. These are:

a. The floor of the Cordova Embayment is much shallower than that of the HRB and the total section of shale contained within it is significantly thinner. And,

b. The Cordova Embayment is almost completely surrounded by the Devonian Presqu'ile barrier reef complex, with only a narrow channel open to the north. In contrast, the HRB is far less confined and was likely unbounded to the north and west (Drees, 1994).

Because of relatively scarce data for shales in the Cordova Embayment, a number of assumptions were made for some reservoir parameters (including using properties of the HRB shales as analogs).

A geological summary of the shale formations assessed in this report is provided below (see Figure 2 for a schematic of the Cordova Embayment stratigraphic section):

Evie Shale

The Evie consists of dark grey to black, radioactive, organic-rich and pyritic shale. It is also siliceous and somewhat calcareous. This unit is characterized on well logs by relatively high gamma-ray readings and high resistivity. It is overlain by the Klua Shale, which is generally of lower radioactivity and resistivity than the Evie. The Evie Shale reaches a maximum thickness of 58 m within the southern extent of the Cordova Embayment. The Evie Shale overlies carbonate rocks of the Lower Keg River Formation and abuts the barrier reef complex of the Upper Keg River along the edge of the basin.

Otter Park Shale

The Otter Park Shale reaches a maximum thickness of over 75 m in the centre of the Cordova Embayment, where it consists of medium to dark grey, calcareous shale with lower radioactivity and resistivity on well logs than the Evie and Muskwa Shales. The Otter Park pinches-out to 0 m along the edge of the Embayment.

Muskwa Shale

The Muskwa consists of grey to black, radioactive, organic-rich, pyritic, siliceous shale and is characterized on well logs by high gamma ray readings and high resistivity. It has a gradational contact with the overlying silt-rich shales of the Fort Simpson Formation. In the Cordova Embayment, the Muskwa reaches a maximum thickness of approximately 58 m in the centre of the basin and thins to about 20 m along the edges of the Embayment, from where it extends over the top of the barrier reef and is present through the rest of northeastern British Columbia. It is stratigraphically equivalent to the Duvernay Shale, which extends over much of Alberta.

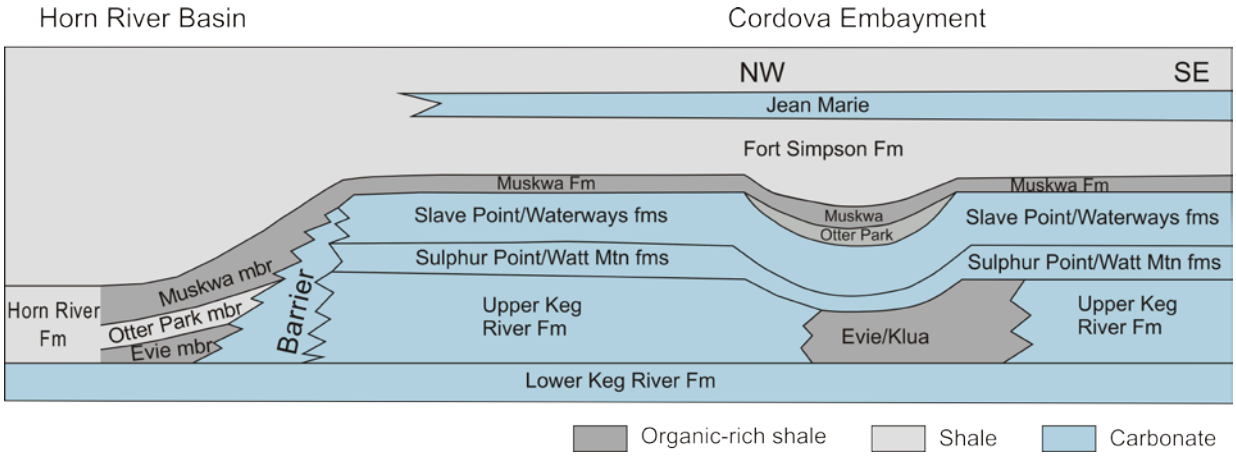

Figure 2. Middle to Late Devonian stratigraphic units within the Cordova Embayment and the adjacent Horn River and Liard basin (modified from Ferri and Griffiths, 2014).

Methods

The methods used in this study are similar to those utilized in the 2013 study of the unconventional petroleum resources of the Montney Formation of British Columbia and Alberta; jointly published by the British Columbia Oil and Gas Commission, Alberta Energy Regulator, British Columbia Ministry of Natural Gas Development, and the National Energy Board (NEB, BCOGC, BCMNGD, AER, 2013). In-place and marketable volumes of gas[1] (i.e. for free and adsorbed gas fractions) were calculated using volumetric equations where the variables were determined from map grids of geological data, and, assumed statistical distributions based on best estimates[2]. This allowed the model to reflect spatial changes in the characteristics of the reservoir. Statistical distributions were then applied to some of the variables in the equations after which Monte Carlo simulations[3] estimated low, expected and high values[4].

The model outputs a set of in-place and marketable volumes for gas on a grid format based on the British Columbia drilling spacing unit (grid dimension of 1415.5 m by 1856.0 m, at the latitude of the Cordova Embayment).

Assessment Results

Free and adsorbed gas estimates were obtained for each shale unit and, thereafter, summed to obtain the total gas-in-place (GIP) and total marketable resource for the Cordova Embayment. The estimate of ultimate GIP for the Cordova Embayment is between 17 194 10^8 m^3 (60.7 Tcf (trillion cubic feet)) and 21 028 10^8 m^3 (74.2 Tcf), with an expected volume of 19 037 10^8 m^3

[1] The terms “In-place” as used in this report refers to the total of free (within pore space) and adsorbed (on outer surface) gas within a shale reservoir. Marketable resources refer to the technically recoverable gas volume after taking into account surface losses, and, deducting the transportation fuel and gas impurities from the In-place gas volume.

[2] Where reservoir data for the Cordova Embayment was unavailable, data from the Horn River Basin was utilized.

[3] A Monte Carlo simulation is a computerized mathematical technique where random numbers are picked from a statistical distribution over several trial runs; in order to determine a range of possibilities and to reflect uncertainty/risk in an estimate.

[4] The terms “low”, “expected” and “high” used in this report correspond with the P10, P50 and P90 values from the Monte Carlo simulation. P10 and P90 values correspond to low and high risk scenarios, respectively.

(67.2 Tcf). The basin's marketable resource estimate is between 22 115 10^7 m^3 (7.8 Tcf) and 27 241 10^7 m^3 (9.7 Tcf), with an expected volume of 24 883 10^7 m^3 (8.8 Tcf).

Table 1. Estimate of total gas-in-place for shale in the Cordova Embayment by assessment zone.

Natural Gas Billion m^3 (Trillion cubic feet)	Free GIP			Adsorbed GIP			Basin Total GIP		
	P10	P50	P90	P10	**P50**	P90	P10	**P50**	P90
Muskwa	476.9 (16.8)	**527.3 (18.6)**	581.6 (20.5)	156.6 (5.5)	**173.0 (6.1)**	191.7 (6.8)	633.4 (22.4)	**700.3 (24.7)**	773.3 (27.3)
Otter Park	335.3 (11.8)	**374.3 (13.2)**	414.3 (14.6)	118.7 (4.2)	**132.2 (4.7)**	147.3 (5.2)	453.9 (16.0)	**506.6 (17.9)**	561.5 (19.8)
Evie	498.9 (17.6)	**550.2 (19.4)**	606.6 (21.4)	133.1 (4.7)	**146.7 (5.2)**	161.4 (5.7)	632.0 (22.3)	**696.9 (24.6)**	768.0 (27.1)
Total	1311.1 (46.3)	**1451.8 (51.3)**	1602.5 (56.6)	408.3 (14.4)	**451.9 (16.0)**	500.4 (17.7)	1719.4 (60.7)	**1903.7 (67.2)**	2103.0 (74.3)

Table 2. Estimate of marketable resource for the Cordova Embayment shale by assessment zone.

Natural Gas Billion m^3 (Trillion cubic feet)	Free Marketable Resource			Adsorbed Marketable Resource			Basin Total Marketable Resource		
	P10	**P50**	P90	P10	**P50**	P90	P10	**P50**	P90
Muskwa	58.3 (2.1)	**54.9 (2.3)**	71.9 (2.5)	23.5 (0.8)	**26.1 (0.9)**	29.2 (1.0)	81.8 (2.9)	**90.9 (3.2)**	101.1 (3.6)
Otter Park	41.1 (1.5)	**45.9 (1.6)**	51.0 (1.8)	17.8 (0.6)	**20.1 (0.7)**	22.4 (0.8)	58.9 (2.1)	**68.2 (2.4)**	73.3 (2.6)
Evie	60.3 (2.1)	**66.8 (2.4)**	73.6 (2.6)	20.1 (0.7)	**22.4 (0.8)**	24.4 (0.9)	80.4 (2.8)	**89.2 (3.2)**	98.0 (3.5)
Total	159.7 (5.6)	**177.6 (6.3)**	196.5 (6.9)	61.5 (2.2)	**68.5 (2.4)**	75.9 (2.7)	221.2 (7.8)	**248.3 (8.8)**	272.4 (9.6)

As of August 30, 2015, approximately 1.1 x10^9 m^3 (37.6 Bcf, billion cubic feet) of unconventional gas has been produced from Cordova Embayment shale formations in British Columbia (i.e. Muskwa, Otter Park and Evie shales). Taking into account the current cumulative unconventional natural gas production from the Cordova Embayment, approximately 24 820 10^7 m^3 (8.76 Tcf), or, 99.6% of the expected marketable gas, remains. This does not take into account future improvements in drilling, production, or completion technologies which could further add to the recoverable resource base. In this study, the expected marketable natural gas estimate represents approximately thirteen percent (13%) of the expected total GIP.

Observations

With respect to data entered into the model, assumptions were based on best estimates for some reservoir properties, especially for areas of the basin where there are currently no wells penetrating the prospective formations (mainly in the northern and northeastern areas of the Cordova Embayment). Consequently, there is a lower level of confidence in the estimated resources for these areas and, as such, the estimates of ultimate recovery of these areas may change over time as more exploration occurs and the BC MNGD and BC OGC gain a better understanding of the geological setting of the zones. The ratio of P10 to P90 for total gas-in-place estimated in this study (~1.2) is marginally smaller than what is observed in the Horn River Basin (~1.4); with the latter reflecting a statistically wider 'spread' of the parameter distributions used for the Horn River basin assessment (BC MEM, NEB, 2011).

In June, 2013, the U.S. Energy Information Administration (EIA) estimated expected GIP and marketable gas for the Cordova Embayment as 22 937 10^8 m^3 (81 Tcf) and 5 663 10^8 m^3 (20 Tcf), respectively (Kuuskraa et. al., 2013). GIP and marketable resource estimates provided in this study are exclusively for the portion of the Cordova Embayment in BC, and, does not include the portion of the Cordova Embayment in the Northwest Territories.

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