Identification and Evaluation of New Resource Oil Plays in Northeastern British Columbia

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Introduction

Horizontal drilling and multiple-stage hydraulic fracturing (multi-frac) stimulation technologies have greatly augmented gas and liquids resources and reserves in the unconventional reservoirs of British Columbia (BC) over the past several years. However, little new unconventional oil potential has been identified, even though substantial conventional oil pools have been producing for decades. To address this issue, Geoscience BC commissioned a study to determine the potential for new tight oil exploration and exploitation fairways, accessible through modern drilling and completions technologies.

Clarkson and Pedersen (2011) analyzed the spectrum of known unconventional oil plays, and assigned them to three categories:

- Tight oil plays—clastic or carbonate rock reservoirs with low permeability, requiring horizontal drilling and multi-frac stimulation to produce oil at economic rates. The middle Bakken Formation sandstone of the Williston Basin and portions of the Montney Formation in Alberta and BC are good examples.
- Halo oil plays—lower permeability fringes flanking conventional clastic and carbonate rock reservoirs, which can be developed with horizontal multi-frac wellbores to enlarge the original play area. Halo oil plays may extend vertically from a conventional pool, as well as laterally. The Cardium Formation in west-central Alberta is the best Canadian example.
- Shale oil plays—oil accumulations hosted by true shales and/or mudrocks. These are relatively rare, and there is a body of work suggesting that pore networks in true shales can produce liquids-rich gas, but not actual oil (Dembicki, 2014). The Second White Specks Formation of west-central and southern Alberta has been suggested as an example of a shale oil play, but detailed work suggests that associated tight sandstone beds with extensive natural fracturing are responsible for much of the production. Appraisal of other potential shale oil reservoirs, such as the Duvernay Formation and Gordondale Member ("Nordegg" Member), has failed to produce oil at economic rates to date.

Petrel Robertson Consulting Ltd., Trican Geological Solutions Ltd. and CGG Consulting Calgary have undertaken an assessment of new resource oil potential in northeastern BC, guided by the Clarkson and Pedersen (2011) classification. The Montney Formation was excluded from the project, as its tight oil potential has been the subject of considerable work to date (e.g., Ferri et al., 2013).

Progress Summary

Twenty-one potential resource oil plays were identified in northeastern BC and they were classified according to their overall productive potential, based upon the team's extensive knowledge of BC conventional and unconventional petroleum geology (Table 1). Existing analytical data were compiled to support play analysis, grouping the information into the following categories:

- source rock analysis, including thermal maturity, organic richness and hydrocarbon composition parameters;
- adsorption/desorption tests;
- X-ray diffraction (XRD) and X-ray fluorescence (XRF);
- scanning electron microscopy (SEM);
- standard petrographic (thin section) analysis; and
- geomechanical testing.

Keywords: *British Columbia, resource oil, tight oil, halo oil, reservoir engineering, Maxhamish field, geochemistry, geomechanics, hydrogeology, resource assessment*

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Table 1. Listing of resource oil plays being addressed in this study, northeastern British Columbia (BC).

Group, formation, member	Play type	Producing	Potential	New data	Comments
Muskwa	Shale	Oil (Alberta); gas (Horn River)	Local	?	Worked extensively in Alberta. Primarily in gas window in BC, but may be oil-bearing in specific areas.
Jean Marie	Tight carbonate	Gas, minor oil	Local	No	Extensively developed as tight gas play. Seeking areas of oil potential—likely related to maturity of Muskwa Fm.
Kakisa	Tight carbonate	Minor gas	Local	Yes	Seeking areas of oil potential—likely related to maturity of Muskwa Fm.
Kotcho	Tight carbonate	No	Local	Yes	Seeking areas of oil potential—likely related to maturity of Muskwa Fm.
Tetcho	Tight carbonate	Minor gas and oil	Local	Yes	Seeking areas of oil potential—likely related to maturity of Muskwa Fm.
Besa River/Exshaw	Shale/tight carbonate	Gas, oil tested	Moderate	Yes	Seeking areas with potential productivity in oil window.
Banff	Tight sandstone	Minor gas	Low	?	Secondary target, limited data.
Rundle	Halo(?)/tight sandstone	Oil and gas	High(?)	?	Need to understand Desan area and subcrop edge potential in general.
Golata	Shale	No	Low	Yes	Peace River Embayment area—organic richness appears low.
Stoddart (Kiskatinaw)	Tight sandstone	Yes	Low	?	Limited and structurally/stratigraphically isolated reservoirs—limited potential.
Belloy	Tight sandstone	Yes	Low	?	Limited and structurally/stratigraphically isolated reservoirs—limited potential.
Doig	Halo(?)/tight sandstone, shale	Yes	Moderate	No	Extensive existing data in both Doig phosphate and sandstone.
Toad/Grayling	Tight sandstone	No	High	Yes	Horn River and Liard basins; potential possibly in conjunction with overlying Chinkeh Fm.
Halfway	Halo sandstone	Yes	Low	No	Oil pools generally very mature, with discrete structural/stratigraphic boundaries—limited potential.
Charlie Lake	Halo/tight sandstone	Yes	Low	No	Little potential around existing conventional pools; assess potential for Worsley-type play.
Baldonnel	Halo/tight carbonate	Yes	Low	No	Existing production appears conventional with downdip water and limited halo potential.
"Nordegg"/Gordondale	Shale	Minor oil (Alberta)	Moderate	Yes	Good source rock, abundant existing data; little success in horizontal/multiple-stage hydraulic fracturing development to date.
Rock Creek	Tight sandstone	No	Low	No	Conceptual play, appears to have low potential, but just above Nordegg source rock.
Chinkeh	Tight sandstone	Oil and gas	High	Yes	Extensive oil resource downdip of Chinkeh oil pool.
Bluesky	Tight sandstone	Oil and gas	Low	No	Existing pools are conventional; stratigraphic work to identify tight oil potential.
Buckinghorse	Shale/tight sandstone	Gas	Moderate	Yes	Seeking areas with potential productivity in oil window.

Table 2. Source rock analysis data generated for samples from the Chinkeh and Toad/Grayling formations in core from the GSENR (ECA) Maxhamish D-48-B/94-O-11 well (universal well identifier 200D048B094O1100, BC Oil and Gas Commission, 2016), northeastern British Columbia. Abbreviations: HI, hydrogen index; OI, oxygen index; PC, pyrolyzed carbon; PI, production index; S1, free hydrocarbons present in sample; S2, hydrocarbons formed during pyrolysis; S3, $C0_2$ yield during breakdown of kerogen; T_{max}, temperature at maximum release of hydrocarbons; TOC, total organic carbon.

Sample ID	Formation	Sample type	Depth (m)	T_{max} (°C)	S1 (mg/g)	S2 (mg/g)	S3 (mg/g)	PC (%)	PI	S2/S3	S1/TOC	TOC (%)	HI	OI	T_{max} data quality
1466.06	Upper Chinkeh	Core	1466.06	450	0.64	1.74	0.47	0.20	0.27	3.70	0.43	1.50	116	31	Good
1467.11	Upper Chinkeh	Core	1467.11	451	0.55	2.05	0.49	0.22	0.21	4.18	0.39	1.41	145	35	Good
1468.05	Upper Chinkeh	Core	1468.05	453	0.49	1.80	0.69	0.19	0.21	2.61	0.33	1.48	122	46	Good
1468.97	Upper Chinkeh	Core	1468.97	455	0.45	1.50	0.52	0.16	0.23	2.88	0.35	1.29	116	40	Good
1470.08	Upper Chinkeh	Core	1470.08	453	0.41	1.40	0.52	0.15	0.23	2.69	0.34	1.21	115	43	Good
1470.96	Upper Chinkeh	Core	1470.96	451	0.75	0.74	0.69	0.12	0.50	1.07	0.91	0.82	90	84	Okay
1472.08	Top porosity Chinkeh	Core	1472.08	434	1.24	0.84	0.56	0.17	0.60	1.50	1.57	0.79	106	70	Poor
1472.96	Top porosity Chinkeh	Core	1472.96	449	1.26	1.15	0.68	0.20	0.52	1.69	1.12	1.13	101	60	Good
1474.18	Top porosity Chinkeh	Core	1474.18	458	1.22	0.71	0.42	0.16	0.63	1.69	1.44	0.85	82	49	Okay
1475.01	Top porosity Chinkeh	Core	1475.01	459	1.29	0.72	0.47	0.17	0.64	1.53	1.93	0.67	107	71	Okay
1475.51	Toad/Grayling	Core	1475.51	455	2.41	0.76	0.45	0.26	0.76	1.69	2.65	0.91	83	49	Okay
1475.92	Toad/Grayling	Core	1475.92		2.06	0.61	0.81	0.22	0.77	0.75	3.68	0.56	108	145	No good
1476.08	Toad/Grayling	Core	1476.08	455	0.62	0.45	0.61	0.09	0.58	0.74	1.29	0.48	94	127	Okay
1476.47	Toad/Grayling	Core	1476.47	446	0.89	1.51	0.36	0.20	0.37	4.19	0.73	1.22	123	29	Good
1476.74	Toad/Grayling	Core	1476.74	457	0.47	0.61	0.60	0.09	0.44	1.02	0.87	0.54	112	110	Okay
1477.05	Toad/Grayling	Core	1477.05	454	0.12	0.39	0.58	0.04	0.24	0.67	0.18	0.65	60	89	Okay
1478.03	Toad/Grayling	Core	1478.03	460	0.07	0.26	0.46	0.03	0.21	0.57	0.19	0.36	72	127	Poor
1478.95	Toad/Grayling	Core	1478.95	463	0.08	0.28	0.51	0.03	0.22	0.55	0.22	0.36	78	144	Poor
1480.05	Toad/Grayling	Core	1480.05	471	0.09	0.31	0.52	0.03	0.23	0.60	0.20	0.44	69	116	Poor
1481.03	Toad/Grayling	Core	1481.03	464	0.08	0.30	0.65	0.03	0.21	0.46	0.19	0.42	71	154	Poor
1482.03	Toad/Grayling	Core	1482.03	483	0.09	0.29	0.60	0.03	0.24	0.48	0.21	0.42	68	141	Poor
1483.04	Toad/Grayling	Core	1483.04	479	0.10	0.30	0.60	0.03	0.25	0.50	0.24	0.41	73	145	Poor
1483.50	Toad/Grayling	Core	1483.50	476	0.11	0.34	0.93	0.04	0.24	0.37	0.14	0.76	44	121	Poor

Table 3. Mineralogical data generated by X-ray diffraction analysis for samples from the Chinkeh and Toad/Grayling formations in core from the GSENR (ECA) Maxhamish D-48-B/94-O-11 well (universal well identifier 200D048B094O1100, BC Oil and Gas Commission, 2016), northeastern British Columbia. Abbreviations: T_{max}, temperature at maximum release of hydrocarbons; TOC, total organic carbon; tr, trace.

							Feldspar		Carbonate rocks			Clays		Sulphides	
Sample ID	Formation	Sample type	Depth (m)	T_{max} (°C)	TOC (%)	Quartz (%)	Albite (%)	Microcline (%)	Calcite (%)	Dolomite, Fe-dolomite (%)	Siderite (%)	Illite/mica (%)	Chlorite (%)	Pyrite (%)	Apatite (%)
1466.06	Upper Chinkeh	Core	1466.06	450	1.50	46.2	7.3	2.4	0.7	9.0		26.3	4.6	3.4	0.1
1467.11	Upper Chinkeh	Core	1467.11	451	1.41	52.3	5.2	1.9		15.7		19.9	4.3	0.6	0.1
1468.05	Upper Chinkeh	Core	1468.05	453	1.48	44.1	6.4	2.5	0.8	8.3		30.1	6.3	1.6	0.1
1468.97	Upper Chinkeh	Core	1468.97	455	1.29	56.1	6.2	2.2	0.5	5.8		23.8	4.0	1.4	
1470.08	Upper Chinkeh	Core	1470.08	453	1.21	55.2	7.2	2.1		8.3		21.0	5.1	1.1	
1470.96	Upper Chinkeh	Core	1470.96	451	0.82	68.9	6.6	1.8		6.9		10.9	4.0	0.8	
1472.08	Top porosity Chinkeh	Core	1472.08	434	0.79	69.9	5.5	1.9		3.4		14.2	3.9	0.8	0.3
1472.96	Top porosity Chinkeh	Core	1472.96	449	1.13	66.5	7.3	1.8		7.5		10.4	5.3	0.8	0.5
1474.18	Top porosity Chinkeh	Core	1474.18	458	0.85	88.4	3.8	1.5	1.2	1.0		0.8	2.3	0.2	0.8
1475.01	Top porosity Chinkeh	Core	1475.01	459	0.67	88.1	5.6	1.1	0.2	0.5		1.2	1.9	0.5	0.8
1475.51	Toad/Grayling	Core	1475.51	455	0.91	89.7	2.3	1.6	2.8	0.1		1.3	1.6	0.1	0.5
1475.92	Toad/Grayling	Core	1475.92		0.56	74.7	4.8	1.8	4.9	0.5	10.2	1.9	1.3		
1476.08	Toad/Grayling	Core	1476.08	455	0.48	85.6	5.8	2.0	1.7	0.7		1.5	2.6		tr
1476.47	Toad/Grayling	Core	1476.47	446	1.22	73.3	8.1	3.2	0.1	5.4		3.8	5.1	1.0	
1476.74	Toad/Grayling	Core	1476.74	457	0.54	76.0	7.6	2.7	0.2	6.1		3.1	3.9	0.4	
1477.05	Toad/Grayling	Core	1477.05	454	0.65	37.2	7.7	3.8		2.8		35.2	11.7	1.7	
1478.03	Toad/Grayling	Core	1478.03	460	0.36	34.0	4.0	4.0	0.6	1.0	0.1	41.2	13.7	1.5	
1478.95	Toad/Grayling	Core	1478.95	463	0.36	57.4	5.5	2.4	1.9	2.8		18.9	10.5	0.6	
1480.05	Toad/Grayling	Core	1480.05	471	0.44	45.7	4.5	3.5	1.1	1.1		31.4	11.8	1.0	
1481.03	Toad/Grayling	Core	1481.03	464	0.42	31.0	4.1	4.0	1.0	0.8	0.7	43.8	13.3	1.2	
1482.03	Toad/Grayling	Core	1482.03	483	0.42	59.5	5.6	2.1	2.1	3.1		16.8	10.2	0.5	
1483.04	Toad/Grayling	Core	1483.04	479	0.41	51.1	5.3	2.6	1.5	1.3		26.8	10.7	0.7	
1483.50	Toad/Grayling	Core	1483.50	476	0.76	46.8	5.2	3.3	1.3	1.3	0.1	30.5	11.0	0.6	

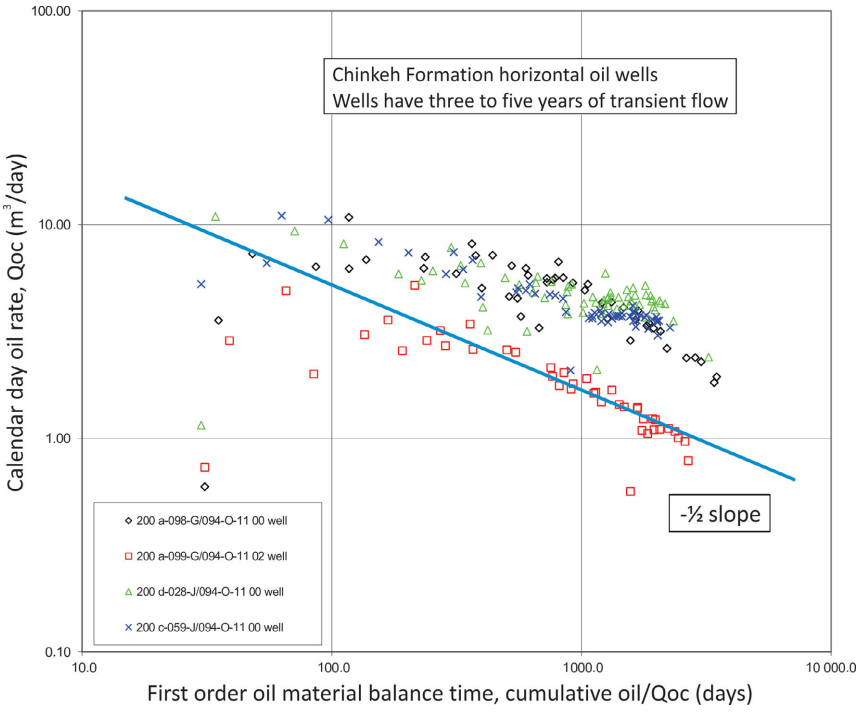

Figure 1. Oil production rate versus first order material balance time for four horizontal wells completed in the Chinkeh Formation on the western flank of the gas pool in the Maxhamish field, northeastern British Columbia. Three of the four wells have a slope less than the reference ½ slope which indicates transient flow, meaning that the wells are not seeing production interference from offset wells or from geological barriers, for at least 3–5 years. In other words, the oil in place contacted by each well is continually increasing throughout transient flow, indicating potentially large untapped oil resources.

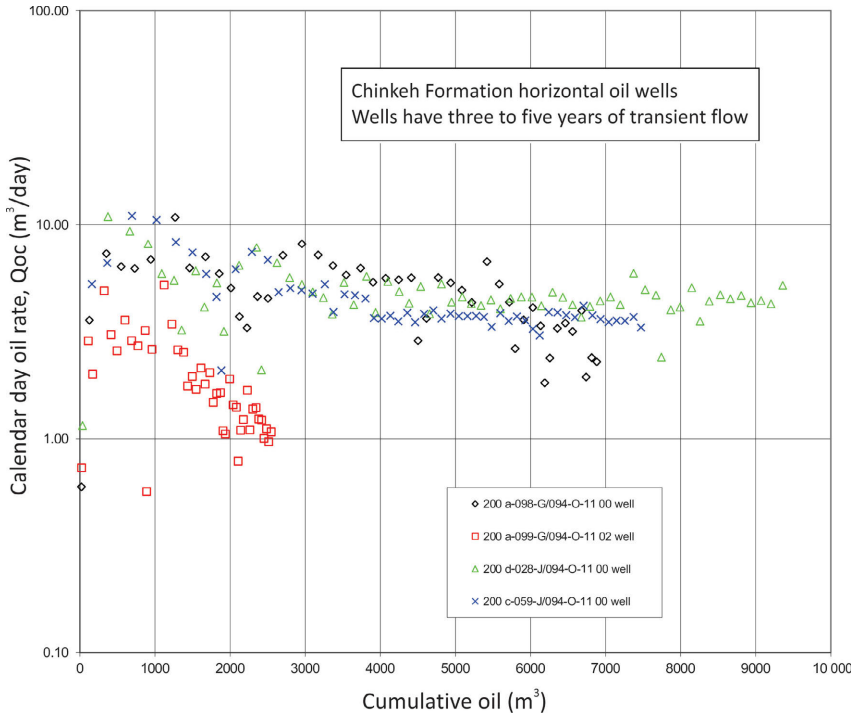

Figure 2. Oil production rate versus cumulative oil production for the same four horizontal wells in Figure 1, completed in the Chinkeh Formation on the western flank of the Maxhamish gas pool, northeastern British Columbia. On this graph, the so-called harmonic plot, three of the four wells show no sharp decrease in oil rate with increasing cumulative production. This provides additional corroboration that the wells are in long-term transient flow.

Data were gathered from the technical literature, government survey reports and analytical files submitted to the BC Oil and Gas Commission (BCOGC) by operators, yielding results from 752 wells. Between one and five stratigraphic units were analyzed in each well. Creating a comprehensive compilation was a much larger task than originally contemplated, but was essential to play characterization and to guide acquisition of new datasets. The BCOGC facilitated this work by providing partial compilations and access to data files. Some analytical work completed in the past, when BCOGC did not require submission of reports, is not available and therefore not included in the compilation.

Comparing existing analytical data against the spectrum of resource oil plays, new laboratory sampling of cores and analytical testing was identified to fill gaps in existing datasets. Trican Geological Solutions Ltd. (Trican) undertook the sampling work, and by the end of September 2016 had sampled, described and photographed cores from 12 wells, and had completed much of the analytical work for those wells. Table 2 illustrates results of source rock analysis on samples from the Chinkeh and Toad/Grayling formations in the core from the GSENR (ECA) Maxhamish D-48-B/94-O-11 well (universal well identifier 200D048B094O1100, BC Oil and Gas Commission, 2016), and Table 3 displays mineralogical compositions derived from XRD work on the same samples. After completing the compilation of existing data and consultation on results of Trican's work to date, the team will select additional core for sampling and analytical testing. Drill cuttings may also be sampled to fill critical dataset vacancies.

CGG Consulting Calgary is undertaking reservoir engineering analysis of potential resource oil plays with two primary goals: characterizing the fracability of potential reservoirs, and identifying fairways where existing oil production data suggest the presence of substantial oil resources occurring in low-permeability halo accumulations. Analysis of oil production from horizontal and vertical wells in the Chinkeh Formation on the western (downdip) flank of the gas pool in the Maxhamish field shows long-term transient flow from many wells, indicating potential for regionally extensive low-permeability oil accumulations (Figures 1, 2). Future productive behaviour of tight oil prospects, like the Chinkeh Formation, will be modelled once all data are compiled.

Deliverables

For each resource oil play, final project reporting will include

- reservoir mapping and facies characterization, related to existing conventional pools, where applicable;
- reservoir quality assessment, incorporating mineralogical data and porosity/permeability characteristics;
- assessment of geochemistry (source rock analysis), hydrogeology and fluid distributions
  - identification of abnormally pressured fairways, where present and supported by pressure and production data;
- assessment of geomechanical properties and resulting productive potential; and
- summary of resource potential characterization, including volumetric resource estimates and estimates of producible potential, guided by existing production and reservoir engineering analysis.

The study will wrap up with discussion and recommendations regarding exploration for and appraisal of the highest potential resource oil plays.

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References

BC Oil and Gas Commission (2016): Well lookup and reports; BC Oil and Gas Commission, web application, URL <http://www.bcogc.ca/online-services> [December 2016].

Clarkson, C.R. and Pedersen, P.K. (2011): Production analysis of Western Canadian unconventional light oil plays; Society of Petroleum Engineers, Canadian Unconventional Resources Conference, November 15–17, 2011, Calgary, Alberta, SPE-149005-MS, 23 p.

Dembicki, H. (2014): Challenges to black oil production from shales; American Association of Petroleum Geologists/Datapages, Inc., Search and Discovery Article #80355, 22 p.

Ferri, F., Hayes, M. and Nelson, A. (2013): Liquids potential of the Lower to Middle Triassic Montney and Doig formations, British Columbia; *in* Geoscience Reports 2013, BC Ministry of Natural Gas Development, p. 1–11.