Case Study of a Large Conventional Oil Pool Discovery in a Mature Basin: the Upper Mannville of the Western Canada Sedimentary Basin

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Altura Energy Inc
Talk Outline

PART 1:
• Upper Mannville regional picture
• Overview of Leduc-Woodbend (LWB) area
• Discuss largest conventional oil pool discoveries in the basin
• Why was this pool undiscovered for so long?

PART 2:
• Pool parameters and key characteristics
• Pool exploitation process
  o Drilling and Completion practices
  o Production results
  o Economics
  o Development plan
• Conclusions
• 172Bn bbls or 10% of world’s total proved oil reserves (3rd largest)
• 4.2MM bbls/d production (6th largest)
• Greater than 700k wells
WCSB Stratigraphic Column
Upper Mannville
Key Characteristics

• Full spectrum of depositional environments:
  o Coastal plain to deltaic and marginal marine to fully marine
• Progradation northward across the foreland basin
• Extensive coastal plain deposits in the south to fully marine shales in the north
• Climate was warm and humid with extensive coal deposits to the south
• Sediment load derived from volcanic and tectonic events to the west in the ancestral Canadian and American Rockies
• Sands typically immature and lithic containing volcanic and feldspathic components; complex mineralogy with moderate to abundant amount of clays and cements
Upper Mannville Paleogeography

From Leckie and Smith, AAPG Mem 55
Upper Mannville
Regional Cross Section

From Newitt 2017
Falher, Rex & Clearwater members
Paleogeography

Spirit River (Falher) deep basin gas fairway

Clearwater oil targets

Provost-Lloydminster heavy oil belt

From Masters, AAPG Mem 38
Leduc-Woodbend Field
Well Control prior to 1947

Leduc #1 5-22-50-26W4 RR Feb 1947 (LWB D2A pool discovery)

Leduc #2 1-16-50-26W4 RR Nov 1947 (LWB D3A pool discovery)

Leduc-Calmar #2 5-25-49-26W4 RR Feb 1950 (LWB D2B pool discovery)

Rex oil pool outline
Well Control Today

LWB D2B pool (Nisku)
OOIP 151mmbbls
CTD 23mmbbls

LWB D3A pool (Leduc)
OOIP 385mmbbls
CTD 252mmbbls

LWB D2A pool (Nisku)
OOIP 294mmbbls
CTD 97mmbbls

LWB U Mann pool
OOIP 1160mmbbls
CTD 0.4mmbbls
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<th>Area</th>
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WCSB Pool Discovery History

Top 40 Pool Discoveries >300mm bbls OOIP by Decade

Number of Pools

- 1910s
- 1920s
- 1930s
- 1940s
- 1950s
- 1960s
- 1970s
- 1980s
- 1990s
- 2000s
- 2010s
Oil pool statistics

Pool size distribution

Pool by Period

Percent Exploratory wells

- Cretaceous
- Triassic
- Miss
- Devonian
How did the LWB oil pool remain undiscovered for so long?

1. Poor quality logs
   - very little quantitative information available from Electric logs and Gamma-Neutron logs
   - poor logs makes for a relatively quiet area with very few competitors

2. Difficult correlation relationships (coastal plain sequence)

3. Subtle log characteristics

4. Lack of production or drill stem test shows due to tight nature of rock
Most wells in the area drilled prior to 1960 (e.g., 13-24 & 12-23)

Electric logs and Gamma-Neutron logs were the only logs run in the 1940s and 1950s.

Many geologists today uncomfortable interpreting or even bother looking at pre-1960s logs.

Coal
Pay zone

13-24-49-26W4
12-23-49-26W4
Correlation Challenges

• Being a Coastal Plain environment there are no recognizable shale markers or flooding surfaces
• Thick coals are the only correlatable units but only in limited areas
• Two examples below are six km apart:
Subtle Log Characteristics

• After initial Devonian targets drilled a second phase of drilling from 1970s to the 2000s

• Clean, high perm Lower Mannville sands were the main target of drilling during second phase

• Lower perm Upper Mannville targets were again ignored because of their subtle log characteristics
Subtle Log Characteristics

- Neutron-Density separation
- Low to moderate resistivity pay zones
- High gamma readings in sands
- Poor SP development due to low permeability
Lack of Production or Shows

• Prior to 2016, only 3 vertical wells out of almost 900 had production within the pool; 1 gas well and 2 oil wells with all three producing non commercial quantities of hydrocarbons

• All 3 wells originally targeted deeper zones and were recompleted in the Upper Mannville

• The only hint of oil productivity was chip sample analysis with oil staining and fluorescence being key
PART 2: LWB Rex member oil pool

POOL PARAMETERS

Depth: 1300-1400m
Porosity: 9-15%
Permeability: unknown but likely 1-10mD (no core in pool)
Areal size: approximately 200 sections
Average net pay: 6m, range 2-12m
Water saturation: 30-50%
OOIP: 1.0-1.2Bn bbls
Oil quality: 17 API, 100-200cP, 2.8%S
Pressure: 10mPa or about 7.7kPa/m
Oil column: 120m with no known gas cap
GOR: varies from 200-3000 scf/bbl
Drive: solution gas
Depositional environment: delta/distributary channels
Rex member Facies Type Logs

a) **Channel facies**: medium-coarse grained sands, typically 15-25m thick, 1-2km wide; vary from straight to highly sinuous

b) **Non channel facies**: silt to fine grained sands interbedded with non-marine shales and thin coals

c) **Delta facies**: fine-medium grained sands; widespread when present
Provenance

• part of the volcano-feldspathic lithofacies within the Upper Mannville

• Texturally immature; likely plutonic or volcanic sources from the south and west; derived from a magmatic arc terrane in Idaho, Washington and BC

• Abundant feldspar and lithic rock fragments; existence of feldspar is important as it controls porosity type

• High percentage of lithic grains severely compacts or alters the framework grains which contributes to poorer permeability

From Potocki and Hutcheon, AAPG Mem 55
Rock-type Ternary Diagram
Mineralogy data from XRD

- Bulk mineralogy dominated by plagioclase and quartz

- Clay content varies from 15-40%

-composed mainly of kaolinite, illite and mixed layer illite/montmorillonite

Data from ProGeo Labs
Chip Sample Overview

1375m Rex Sand 1-16-48-26W4
Petrography – porosity examples

Intragranular porosity

Secondary porosity developed due to better cementation of sample grains

Ferroan dolomite cement

Ferroan dolomite

Intrgranular porosity
Petrography – grain type examples

Quartz

Plagioclase feldspar

Chert

Rock fragment
Petrography – cement examples

- Siderite
- Chlorite
- Dolomite
- Kaolinite
Core Data

- Two cores in the Rex sand nearby, both from distributary channels (13-2-46-25W4 and 13-11-47-27W4)

- Volcano-feldspathic sands quickly decrease in porosity with depth due to lithic material; results in lower permeability in Rex sand vs Lower Mannville sands at LWB
Petrophysical Data

02/10-15-49-26W4

Mineralogy

Porosity

Sw

Permeability

Grain Density

Porosity

6%

70%

1mD

VDOL
0
VLS
0
VSS
0

6%

70%

0.1
1000
0.1
1000
0.1
1000
0.1
1000

1.95
-0.05
0.45
-0.15
0.45
-0.15
0.2
-0.3

1
1
1
1
1
1
1
1

Sw

PAYFLAG
19
RESFLAG
20
PHIND
19
PHIE_D
25
RHOMAC
31
PERM_CALC
100

0
0
0
0
0
0
0

1mD
**Oil Quality Data**

- Moderate degree of biodegradation, 16-17 API, 100-200cP, 2.8% sulphur
- Likely from a Nordegg carbonate source as shown by family 1 on plot
- Nordegg oils tend to be low API due to lower thermal maturities near their subcrop edge (approximately 5 Twps to the west) and high sulphur oils due to the sulphur-rich kerogen
- Moderate amounts of light ends which suggests some mixing with other oils; likely from Exshaw

Data from Geomark Research
Seismic Data

- Reservoir is too thin to be resolved but used for structural control when drilling
- In areas of poor well control have used a Rex isochron to identify thicks
Drilling and Completions

• 1300m vertical depth, 2000-2300m horizontal length

• Horizontal section drills very easily (8 days spud to rig release)
  o Single trip bit runs, no dulling
  o ROPs of >120m/hr when rotating
  o Horizontal section drilled in 2 days

• Intermediate section challenges
  o Poor build rates from KOP to 30° inclination
  o Thick coal section immediately above the Rex sand

• Cemented closeable frac sleeves, all sleeves re-opened after the last frac is complete

• 45m sleeve spacing, have reduced some wells to 30m sleeve spacing

• 15t per interval, 16/30 natural sand

• Fluid system is a crosslinked borate to achieve high proppant concentration at low pump rate
Production Plot

Leduc-Woodbend ERH Wells Monthly Producing Day Rate

boepd

Month

102/13-14
100/03-02
102/13-24
102/08-36
102/14-24
102/14-24
LWB 1.5 ERH AVG boepd
70% Liquids 1.5 ERH Type Curve

0 50 100 150 200 250 300 350 400 450

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
Economics and Inventory of Locations

- Good economics on both freehold and crown lands
- Inventory of over 150 1-mile equivalent wells based on 4 wells/section
- Depending on pace of development that translates into 10-15 years of drilling inventory

### LWB Type Curve Economics
1.5-Mile Hz MSF (2/3 Crown, 1/3 Freehold) \(^{(1)}\)

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<th>McDaniel Q3 2019</th>
<th>$US55/Bbl WTI Flat</th>
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<td>DCET Capital</td>
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<td>1st Month IP Rate</td>
<td>330 Boe/d</td>
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<td>1st Year Average Rate</td>
<td>155 Boe/d</td>
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<td>2P EUR (^{(2)})</td>
<td>200 Mboe</td>
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<td>NPV10BT</td>
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<td>Payout (yrs)</td>
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<td>Liquids Weighting</td>
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Pool Development Plan

- Multi-well batteries and water disposal wells in both the north and south areas

- Extensive company owned and third party gas infrastructure

- Well established service base in the area with year round access

- Waterflood pilot project in sec 15 49-26W4
Conclusions

- Upper Mannville a significant hydrocarbon target in the WCSB
  - A common conventional oil and gas producer with multiple pools
  - Contains 9 of the top 40 conventional oil pool discoveries
- A relatively immature, bypassed target
  - Difficult to map and interpret based on subtle log response
  - Poorly understood; limited regional industry trend maps or cross sections available
  - New ideas applied to abundant old data
- Multi-stage frac horizontal wells have allowed economic rates of production from this and other low permeability zones
  - This technology has lead to large oil and gas pool discoveries and extensions
  - In the deep basin producers are realizing massive productivity gains within the gas window
- LWB Rex oil pool in this mature basin is an example of the combination of hard work, skill and luck
Acknowledgements

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www.alturaenergy.ca