Abstract

The Western Canada Sedimentary Basin has a complex depositional and structural history and hosts many hydrocarbon deposits in numerous horizons and play types. The Basin has been explored and exploited for over a century and has over 600,000 wellbore penetrations. Some of the producing horizons have been exploited more than others, with the Albian aged Upper Mannville (UM) zone being one of the least exploited units. In the southern portion of the basin, the UM was dominantly deposited in a coastal plain environment, making it difficult to map and predict due to the inconsistent and unpredictable log-based marker horizons. In addition, the reservoirs have subtle log characteristics due to the lithic nature of the sands. This talk will provide some background on how the pool of interest was discovered and the technical details of the pool itself.

The Altura Energy Inc. (ATU) discovery well was drilled in July 2016 with the drilling of the horizontal well 13-15-48-26W4 located 20 miles southwest of Edmonton, Alberta in the Leduc-Woodbend (LWB) Field. This field was the site of the first large commercial oil pool discovery (Frasnian aged Leduc Formation) in the Basin by Imperial Oil in 1947 and heralded the birth of the modern oil and gas industry in Western Canada. Hundreds of wells were drilled in the field in the 1940s and 1950s and by 2016 there were approximately 2400 wells in the field. The 13-15 well was drilled to a depth of 1350 m TVD based on the
geological mapping of many of these old wells with almost 900 of them penetrating the UM sand, all with missed pay indications. In the LWB area, the UM transitions from a channelized coastal plain environment into a marginal marine environment to the north. This provides the perfect setup to trap hydrocarbons updip against the sand pinchout edge. In this area, the sand body maps as a large wave dominated delta system roughly 200 square miles in size. This oil pool has remained undetected for so long because of a combination of subtle log characteristics, poor correlation relationships for mapping purposes and a relatively inactive area for competitors. The key to successfully exploiting this zone is the implementation of horizontal drilling and multistage hydraulic fracturing.

Key reservoir details will be presented and discussed but most notable is that the pool is approximately 1100 million barrels OOIP, making it one of the largest conventional oil pool discoveries in the Western Canadian Sedimentary Basin in the last 20 years. ATU has tied up just over sixty sections of land in the pool through Crown land sales and freehold leasing. Development has occurred methodically, with four horizontal wells drilled to date. Drilling has been successfully accomplished with the use of existing well control to pick both bottom hole locations and landing depths. Seismic usage has been ineffective as the sand is too thin to resolve. Horizontal wellbore lengths vary from 1 to 1.5 miles and the wells are hydraulic fractured with 20 tonnes of sand per stage and 30-45 stages per well. Individual well performance will be shown and initial indications show optimal pool development of 4 to 8 wells per section which will provide many future locations for the company.

References Cited


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

Rob Pinckston
Altura Energy Inc
PART 1:
• Introduction to the Western Canada Sedimentary Basin (WCSB) including the 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
WCSB Distribution of Oil Pools

- 172Bn bbls or 10% of world’s total proved oil reserves (3rd largest)
- 4.2MM bbls/d production (6th largest)
- Greater than 600k wells
WCSB Stratigraphic Column
Upper Mannville
Key Characteristics

- Full spectrum of depositional environments:
  - 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 the Geological Atlas of the WCSB
Falher, Rex & Clearwater members
Paleogeography

- Spirit River (Falher) deep basin gas fairway
- New Clearwater oil targets
- Provost-Lloydminster heavy oil belt

From Masters, AAPG Mem 38
Central Alberta Upper Mannville Overview

Proprietary Slide Removed
Well Control prior to 1947

Proprietary Slide Removed
Well Control Today

Proprietary Slide Removed
<table>
<thead>
<tr>
<th>Overall Rank</th>
<th>Area</th>
<th>Pool Name</th>
<th>Twp-Rge</th>
<th>Province</th>
<th>Formation</th>
<th>Disc Date (vt/hz)</th>
<th>OOIP (mmbbls)</th>
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<td>1952</td>
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<td>80-83, 8W6</td>
<td>Alberta</td>
<td>U Charlie Lake</td>
<td>1983/2013</td>
<td>700</td>
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<td>Cardium G etc</td>
<td>Alberta</td>
<td>Cardium</td>
<td>1961</td>
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WCSB Pool Discovery History

Top 40 Pool Discoveries >400mm bbls OOIP by Decade
• The term ‘discovery’ has been blurred because of technology
• Were the ‘discoveries’ of the 2000s and 2010s truly discoveries?
  o Most pools had uneconomic vertical producers
  o In some cases it’s not clear if the first vertical producers actually targeted the zone
  o The first horizontal well within each of those pools were typically the first commercial/economic success
• Resource triangle shows that the most recent pool discoveries exist further down on the triangle

Oil Resource Triangle

High Perm, pre 2000s pools (darcies)

Bitumen

Low Perm, 2000s & 2010s pools (millidarcies)

Oil Shale, Source beds (micro/nanodarcies)
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 (eg 13-24 & 12-23)

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

Many geologists today uncomfortable interpreting or even bother looking at pre 1960s logs
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 four miles 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

Rex sand

- 60-75 api
- 12 pu separation
- 20mv SP
- >10 ohms
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 fluorescence being key
## PART 2: LWB Rex member oil pool

### POOL PARAMETERS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td><strong>Depth</strong></td>
<td>4200-4600 ft</td>
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<tr>
<td><strong>Porosity</strong></td>
<td>9-15%</td>
</tr>
<tr>
<td><strong>Permeability</strong></td>
<td>unknown but likely 1-10mD (no core in pool)</td>
</tr>
<tr>
<td><strong>Areal size</strong></td>
<td>approximately 200 sections</td>
</tr>
<tr>
<td><strong>Average net pay</strong></td>
<td>20 ft, range 6-40 ft</td>
</tr>
<tr>
<td><strong>Water saturation</strong></td>
<td>30-50%</td>
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<tr>
<td><strong>OOIP</strong></td>
<td>1.0-1.2Bn bbls</td>
</tr>
<tr>
<td><strong>Oil quality</strong></td>
<td>17 API, 100-200cP, 2.8%S</td>
</tr>
<tr>
<td><strong>Pressure</strong></td>
<td>1600 psi or about 0.37 psi/ft</td>
</tr>
<tr>
<td><strong>Oil column</strong></td>
<td>400 ft with no known gas cap</td>
</tr>
<tr>
<td><strong>GOR</strong></td>
<td>varies from 200-1000 scf/bbl</td>
</tr>
<tr>
<td><strong>Drive</strong></td>
<td>solution gas</td>
</tr>
<tr>
<td><strong>Depositional environment</strong></td>
<td>delta/distributary channels</td>
</tr>
</tbody>
</table>
• OOIP 1.1Bn bbls
• Exploitable OOIP (>4m net pay) 900MM bbls
• OOIP on Altura lands 500MM bbls

Net Pay cut offs:
Rt >10 ohms, phi >6%

Old vertical oil producers
Altura discovery well (July 2016)

Old vertical gas producer

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Rex member Facies Type Logs

a) **Channel facies**: medium-coarse grained sands, typically 50-80ft thick, 0.5-1.5mile 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
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
Petrography – porosity examples

Intragranular porosity

Secondary porosity developed due to partial solution of grains

Ferroan dolomite cement

Ferroan dolomite
Petrography – grain type examples

- Quartz
- Plagioclase feldspar
- Chert
- Rock fragment
- Porosity
- Dolomite
- Polycrystalline quartz
Petrography – cement examples

- **Siderite**
- **Chlorite**
- **Kaolinite**
- **Dolomite**
Core Data

- The only core in the area is from a distributary channel (13-2) about 15 miles south of the pool.

- 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.
<table>
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<tr>
<th>Grain Density</th>
<th>Porosity</th>
<th>Mineralogy</th>
<th>Permeability</th>
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<tbody>
<tr>
<td>VDOL</td>
<td>VLS</td>
<td>VSSL</td>
<td>PAYFLAG</td>
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<td>1</td>
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<td>1</td>
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</table>

**02/10-15-49-26W4**

- **VCLGR**: 1
- **VCLND**: 1
- **SP**: 1
- **HCALD**: 1
- **GR**: 150

- **AF20**: 0.1
- **DRHO**: 1.0
- **VCOAL**: 0.1
- **PAYFLAG**: 20
- **PHIND**: 1
- **PHIE**: 0.3
- **PHIE_D**: 0.3
- **RHOMAND**: 0.3
- **RHOMAC**: 3
- **SW**: 0.01
- **PERM_CALC**: 100

- **MINERALS**
- **POROSITY**
- **GAS PERMEABILITY**

- **Porosity** 6%
- **Permeability** 1mD
- **Sw** 70%
Log Data Cross Plots

Pickett Plot

- 6% cutoff
- 30%
- 60%
- 100%

Deep Resistivity

Density Porosity

Neutron-Density Cross Plot

- 20%
- 40%
- 60%
- 80%

Neutron Porosity

- 50% Vclay cutoff

Bulk Density
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
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
• 4300ft vertical depth, 11,500ft measured depth
• 6500 – 8200ft horizontal length
• 10 days spud to rig release
• Horizontal section drills very easily
  o Single trip bit runs, no dulling
  o ROPs of >300ft/hr when rotating
  o Horizontal section drilled in <3 days
• Intermediate section challenges
  o Poor build rates from KOP to 30° inclination
  o Thick coal section immediately above the Rex sand
Completions

- Cemented frac sleeves, open – frac – close sequence. All sleeves re-opened after the last frac is complete
- 150ft sleeve spacing, evaluating reducing to 100ft sleeve spacing
- Frac is pumped down the annulus of 2 3/8 inch coiled tubing and the 4 ½ inch production casing
- 16/30 natural sand
- 33,000 lbs per interval on the last well, previously 44,000 lbs per interval
- Fluid system is a crosslinked borate to achieve high proppant concentration at low pump rate

4 ½ inch closable frac sleeves
Production and Facilities

• Have evaluated a variety of artificial lift systems
  o Jet pump
  o Insert pump with pump jack
  o Electric Submersible Pumps (ESP)
  o Progressive Cavity Pumps (PCP)

• Prefer PCP’s due to wide production operating range, ability to handle solids and ease of operating in a viscous oil environment

• Constructing a multi-well battery in 2018/2019 capable of handling approximately 6000bfpd (3000bopd)
  o Clean oil hauled to sales points
  o Water removed and disposed into Viking and Ellerslie formations
  o Solution gas processed at a downstream gas plant
Field Operations

13-15-48-26W4 wellsite

13-15-48-26W4 fracking operation
Production Plot

LWB Monthly Calendar Day Production

Production Month

boepd

100/02-02-049-26W4/0
100/03-02-049-26W4/0
102/12-15-049-26W4/0
102/13-14-049-26W4/0
100/13-15-048-26W4/0
Economics and Inventory of Locations

- Robust economics on both freehold and crown lands

- Inventory of about 200 1 mile equivalent wells based on 4 wells/section

- Depending on pace of development that translates into 10-15 years of drilling inventory

<table>
<thead>
<tr>
<th>LWB 1.5 Mile Crown Hz MSF Type Curve AB MRF Economics</th>
<th>Price Forecast</th>
<th>McDaniels Q2 2018</th>
<th>$US65/bbl WTI Flat</th>
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<td>1st Month IP</td>
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<td>1st Year Average</td>
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<td>IRR</td>
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<td>Recycle Ratio</td>
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<td>Liquids Weighting</td>
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<td>Breakeven Oil Price (2)</td>
<td>WTI US$ 42.55/bbl</td>
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Pool Development Plan

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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; no 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 low permeability zone
  - This technology has led to large oil and gas pool discoveries and extensions
  - In the deep basin producers are realizing massive productivity gains within the gas window
- Discovery of the LWB Rex oil pool in a mature basin is an example of combined hard work, skill and luck
Acknowledgements

• I would like to thank Altura Energy for allowing me to present this data

• The entire Altura team (David Burghardt, Travis Stephenson, Jeff Mazurak, Craig Stayura, Tavis Carlson, Leah Robbins and Jessieca Lucero) has been instrumental in developing this asset.

• Also our Board of Directors (Darren Gee, Brian Lavergne, John McAleer, Robert Maitland and David Burghardt) has given us excellent guidance throughout.

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www.alturaenergy.ca