Abstract

Pennel Southeast and Little Beaver East Prospect (the first economic resource play), now known as the Cedar Hills-East and Lookout Buttes fields, are located on the southeast flank of the Cedar Creek Anticline which at the time this prospect was generated (1988) had produced more than 350 million barrels of oil from 15 separate fields. Oil reservoirs include the Red River, Stony Mountain, Interlake, Duperow, Lodgepole and Mission Canyon formations. The Ordovician Red River B Zone, which is the most prolific of these reservoirs, has responded well to water flooding. The oil trapping mechanisms in the Red River B Zone have never been fully explained and very little Red River B Zone oil is trapped by four-way structural closure. Due to the complex nature of these Red River traps along the anticline, the oil-water contacts on the downdip east side of the fields were not defined. This fact was well documented by an active drilling program we initiated during the early 1980's when more than thirty producing wells were completed downdip of existing production at the Cabin Creek and Pennel fields. The downdip extension of production beyond the field boundaries suggests that a re-evaluation of the known limits of all the Cedar Creek Fields would be worthwhile. Pennel Southeast and Little Beaver East Prospects were defined simply by studying the well data on the east dip of the Cedar Creek Anticline. A cluster of by-passed and producing wells defined a large, undeveloped oil column downdip from the existing limits of Pennel - Lookout Butte and Little Beaver East fields with a 216 million barrel horizontal target using water flood support.

To date in these prospects 789 wells have been drilled and 190 million barrels of oil have been produced. The Codell Sandstone play was generated in 2005 looking for a resource that would compare favorably to the very successful Bakken carbonate play taking place in Richland County, Montana. The Codell had produced modestly in vertical wells in and south of the Silo Field in Laramie County, Wyoming setting up a focus area. To add to the intrigue a mud log was located that showed the Codell Sandstone was over pressured and attempted to blow out during the drilling of a J Sand test. Due to mineralogy and bound water, resistivity mapping would not define the resource. The resource boundaries were simply defined by a large cluster of good oil shows. This resource contains 1.65 billion barrels of oil in place and a recoverable 165 million barrel target was postulated. Currently there are 76 producing Codell wells, with 1,660 Codell locations permitted in the Wyoming portion of the play.

Steve Kirkwood, Kirkwood Oil and Gas, LLC – Wesco Operating
Cedar Hills – East Lookout Butte Play
Late 1980s
Target – Red River Formation B-Zone

Hecla Island, Lake Winnipeg, Manitoba
# Density-Neutron (CHSU Larkin 14-18NH15)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness</td>
<td>9 ft.</td>
</tr>
<tr>
<td>Porosity</td>
<td>17%</td>
</tr>
<tr>
<td>Permeability</td>
<td>10 md.</td>
</tr>
<tr>
<td>Water Saturation</td>
<td>30%</td>
</tr>
</tbody>
</table>

![Graph showing density-neutron data with labeled stratigraphic units](image-url)
Cedar Creek Anticline; Initial Well Development

- Historic Downdip Production
- 1980s Downdip Extension
- Burlington Resources Horizontals – Late 1980s
Cedar Creek Anticline (1989)
65,000 BO
28% Oil
167,000 BW
38,000 BO  
182,000 BW

17% Oil

42 BO  
1,150 BW

4% Oil
Fertile Prairie – 1989
Bowman County, North Dakota
Little Beaver East – 1989
Bowman County, North Dakota

Structure or Local Stratigraphic Closure Required for Entrapment

- 306’ G&MCO
  - 36’ M

- 600’ M
  - 380’ SGCW
  - 61K

- 306’ G&MCO
  - 36’ M

- 900’ O
  - 80’ W
  - 103K

- 130’ HOCM
  - 85’ O&WCM
  - 85’ HM&OCW
  - 130K

- 191’ WCM

- 180’ SG&WCM
  - 65’ SMCW
  - 65K

- 180’ M
  - 879’ SGCW
  - 82K

- 6.8 BO
  - 4.7 BW
  - 200K

- 400’ M
  - 380’ SGCW
  - 61K

- 651’ SMCW
  - 65K
B-B’ Cross Section, Little Beaver East

Movable oil indicated on Resistivity Logs across the Red River Lower B Zone may be drained by a horizontal B zone porosity well if natural fractures are present connecting the lower B Zone to the matrix porosity B Zone (Conduit)

Movable Oil Present in the Red River A Zone may be drained by a horizontal B Zone well if natural fractures are present connecting A & B Zones

B-Zone Conduit
Cedar Creek Anticline 1989

VOLUMETRICS OF UNDERDEVELOPED EAST PENNEL FIELD - LITTLE BEAVER EAST FIELD

≈ 6 Townships within oil column
≈ 216,000,000 BO recoverable at 250,000 BO per 160 acres

D. C. DUDLEY & ASSOCIATES
1774 Lincoln Street Suite 904 Denver, Colorado 80203 (303) 864-0800

REGIONAL MAP SOUTHERN CEDAR CREEK ANTICLINE
STRUCTURE CONTOUR MAP TOP RED RIVER FORMATION C.I. = 100'
Cedar Creek Anticline 2015

<table>
<thead>
<tr>
<th>1989 Estimates</th>
<th>2015 Realities</th>
</tr>
</thead>
<tbody>
<tr>
<td>~216 MMBO Recoverable</td>
<td>~190 MMBO so far...</td>
</tr>
<tr>
<td>Large Oil Column</td>
<td>Present</td>
</tr>
</tbody>
</table>

- Structure of Local Stratigraphic Closure Required for Entrapment
- Stratigraphic - Hydrodynamic Barrier
Current Decline Curves with Current Cumulatives

CEDAR HILLS and EAST LOOKOUT BUTTE WELLS PRODUCING

- Development Initiated
- Down Dip Edge Vertical Extension
- Prospect Development
- Waterflood

4 Wells
30 Wells
580 Wells

80 BOPD
600 BOPD
60,000 BOPD
17,000 BOPD

190 MMBO Cumulative
Codell Play
2005
Cheyenne Prospect, Laramie County, WY
Target: Codell Sandstone

<table>
<thead>
<tr>
<th>Era</th>
<th>Period</th>
<th>Subsurface Denver Basin</th>
<th>Source rock interval</th>
<th>Producing units</th>
</tr>
</thead>
<tbody>
<tr>
<td>CENOZOIC</td>
<td>TERTIARY</td>
<td>Oligocene</td>
<td>White River Fm</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Eocene</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Paleocene</td>
<td>Denver-Dawson Fm</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Arkansas Fm</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Laramie Fm</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pine Hills Fm</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CENOZOIC</td>
<td>CRETACEOUS</td>
<td>Upper</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MESOZOIC</td>
<td>CRETACEOUS</td>
<td>Lower</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>JURASSIC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TRIASSIC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PERMIAN</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PALEOZOIC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Cheyenne Prospect; Laramie County, WY

LEGEND
- APO DENIED
- DISPOSAL WELL
- EXPENDED PERMIT
- INJECTOR
- OIL WELL
- PLUGGED & ABANDONED - OIL WELL
- PLUGGED & ABANDONED - GAS WELL
- WELL LOCATION
- SHUT IN
- ABANDONED LOCATION

- SURFACE LOCATION
- BOTTOM HOLE
- POOR OIL SHOWS
- FAIR OIL SHOWS
- GOOD OIL SHOWS
- CODEL PERFORATED
- CODEL OR FORT HAYS PRODUCER

- RP DOES NOT PENETRATE CODEL
- HQ NO GEOLOGIC SAMPLE DATA FOR WELL
- NL NOT LOGGED
- T3 THICKNESS - CODEL SS
- TB SUBSEA - TOP OF CODEL SS

- SCALE: 1" = 6000 FT
- DATE: 7/18/18
- DRAWN BY  

KIRKWOOD Oil & Gas, LLC

CHEYENNE PROSPECT Laramie County, WY

CITY OF CHEYENNE
Cheyenne Prospect; Laramie County, WY

- Source Rock
- Ft. Hays Limestone
- Codell Sandstone
- J Sand

DST

GTS
338' GCO, 125 G&OCM
FSIP 5144 # (.58)

DST
1550' G, 110' GCM
926 CC GCM & Tr O
FSIP 118 #

DST
3,853' G, 95' SOCM
700 CCO & 800 CCM
FSIP 1344 #
Cheyenne Prospect; Laramie County, WY
### Reservoir Analog

<table>
<thead>
<tr>
<th>Reservoir</th>
<th>Codell Sandstone – DJ Basin</th>
<th>Bakken - Richland Co., MT Elm Coulee (Comparison)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Porosity</td>
<td>10.5%</td>
<td>12%</td>
</tr>
<tr>
<td>Permeability</td>
<td>0.44 MD</td>
<td>0.06 MD</td>
</tr>
<tr>
<td>Oil Saturation</td>
<td>60%</td>
<td>80%</td>
</tr>
<tr>
<td>FVF</td>
<td>1.15</td>
<td>1.4</td>
</tr>
<tr>
<td>Thickness</td>
<td>27’</td>
<td>10’</td>
</tr>
<tr>
<td>Pressure</td>
<td>Overpressure indicated</td>
<td>Overpressure</td>
</tr>
<tr>
<td>Gravity</td>
<td>35° Sweet</td>
<td>42° Sweet</td>
</tr>
<tr>
<td>Recovery Factor</td>
<td>10%</td>
<td>10%</td>
</tr>
<tr>
<td>Drilling Depth (Vertical)</td>
<td>8900’</td>
<td>9500’</td>
</tr>
</tbody>
</table>
Cheyenne Prospect; Laramie County, WY

LEGEND

- APO DENIED
- DISPOSAL WELL
- EXPINED PERMIT
- INJECTOR
- OIL WELL
- PLUGGED & ABANDONED - OIL WELL
- PLUGGED & ABANDONED - GAS WELL
- WELL LOCATION
- SHUT IN
- ABANDONED LOCATION

- SURFACE LOCATION
- BOTTOM HOLE
- POOR OIL SHOWS
- FAIR OIL SHOWS
- GOOD OIL SHOWS
- CODELL PERFORATED

- SURFACE LOCATION
- BOTTOM HOLE
- CODELL OR FORT HAYS PRODUCER

1.65 MMBO IN PLACE

Kirkwood Oil & Gas llc

CHEYENNE PROSPECT
Laramie County, WY

Scale: 1" = 6000'
Cheyenne Prospect;
Laramie County, WY

Codell Discovery Well: SM 1-30H Tomahawk
Decline Curves with Cumulatives - Codell
POST GENERATION HISTORY AND LESSONS LEARNED
“NO GREAT DISCOVERY WAS EVER MADE WITHOUT A BOLD GUESS” – Isaac Newton