Feasibility Study of Tensleep ROZ Potential, Bighorn Bain

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Main Pay Zone (MPZ), Transition Zone (TZ) & Residual Oil Zone (ROZ)
Topics

• Permian Basin Analogs
• Oil migration, accumulation, and late adjustment in Bighorn Basin Tensleep reservoirs
• Tensleep ROZ in Bighorn Basin
  – Thickness
  – Oil saturation
  – Reservoir properties
  – Oil quality
• CO$_2$-flooding potential in ROZ
• Next step
ACTIVE ROZ CO$_2$-EOR PROJECTS IN PERMIAN BASIN

MIDDLE SAN ANDRES PALEOGEOGRAPHY
with Location of Industry Documented ROZ Zones/Fields*

* Adapted from Sagnak (2006), Chevron Presentation at the 12/06 CO$_2$ Flooding Conference
Technically Recoverable Resources by CO₂-EOR from 5 Permian Basin Oil Plays

Northern Shelf Permian Basin (San Andres)
North Central Basin Platform (San Andres/Grayburg)
South Central Basin Platform (San Andrew/Grayburg)
Horseshoe Atoll (Canyon)
East New Mexico (San Andres)

11.9 Billion BO is technically recoverable from TZ/ROZ in the five Permian Basin oil plays

Plotted based on Trentham's data, 2010
ROZ Oil Saturation

Goldsmith & Seminole San Andres Unit

1934 & 1936: Field discovery
1963 & 1969: Water flooding
>90% water-cut before CO₂ flooding
Reservoir Property Consistent

Matrix Identification Plot, Goldsmith San Andres Unit

Quartz
Calcite
Dolomite

Thurmond. 2010
Technical Evaluation – Core Fluorescence

Goldsmith San Andres Unit

Thurmond. 2010
Oil Production Increase by Including ROZ CO$_2$-EOR

Goldsmith San Andres Unit

Seminole San Andres Unit

Thurmond, 2010

2010 CO$_2$ Flooding Conference
ROZ & MPZ Have Consistent Properties in Permian Basin

Concluded by Thurmond for Goldsmith San Andres Unit, 2010

- Core oil saturation is consistent.
- Reservoir quality is consistent.
- Bulk oil composition is consistent.
- Chemical process behavior is consistent.
Topics

• Permian Basin Analogs

• **Oil migration, accumulation, and late adjustment in Bighorn Basin Tensleep reservoirs**

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• **CO$_2$-flooding potential in ROZ**

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Late Permian Paleogeographic map
(Phosphoria Period)

Miller et al., 1991
Oil Migrated into Tensleep Through Unconformity

Modified from Stone, 1967
Most of the Tensleep anticlines formed during Paleocene-Eocene pulses (Stone, 1967).
9500' thick Post-Tensleep Strata

After Laramide

Bighorn Basin

Bighorn Mountain

Tensleep

Oil

ROZ Generation

Meteoric water

Flushing rate

Oil flushed downdip

Oil

Tensleep outcropped
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Bighorn Basin

McCook, 1956

Next Slide

Trapper Canyon Tar Sands

Zapp, 1956
Tensleep reservoirs located in lower portion of east Bighorn Basin flank
Updip traps are non-reservoirs
NW-SE Cross Section

- Perf Zone:
  - 105'
  - 110'
  - 170'
  - 26'
  - 177'

- Frannie Perf zone: 82'

- Sage Creek Perf zone: 47'

- Homestead Perf zone: 42'
NE-SW Cross Section

Sage Creek

Perf Zone: 47’
Core Photos, Non-productive well

320410
C L Zwemer 1
57N-97W-21
Bighorn Basin
ROZ Thickness and Properties

Frannie

Perf Zone

Tensleep

2906350
1947
77,062 Bbls

2906366
1947
433,085 Bbls

2920382
1973
Non-productive

Porosity (%)

Elevation (ft)

Permeability (md)

Frannie

Perf Zone

Tensleep

2920382
1973
Non-productive
GC Analysis

Reservoir Oil

From Non-productive Wells
Crude Gravity

Big Polecot
26.4° API

22° API
ROZ CO\textsubscript{2}-EOR Potential

- ARI estimated ROZ OIP in 13 Bighorn Basin Tensleep Productive reservoirs: \textbf{4.4 BBbls}
  - These 13 Tensleep reservoirs with cumulative production: from \textbf{345.4 to 6.2 MMBbls}

**13 Bighorn Basin Tensleep Reservoirs**

<table>
<thead>
<tr>
<th></th>
<th>MPZ OOIP (BBbls)</th>
<th>MPZ Remaining OOIP (BBbls)</th>
<th>TZ/ROZ OIP (BBbls)</th>
<th>Total Reserve for CO\textsubscript{2}-EOR (BBbls)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. CO\textsubscript{2}-miscible fields: 8</td>
<td>4.5</td>
<td>3.1</td>
<td>4.4</td>
<td>7.5</td>
</tr>
<tr>
<td>2. CO\textsubscript{2}-immiscible fields: 5</td>
<td></td>
<td></td>
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<tr>
<td>CO\textsubscript{2}-EOR recovery: 11%</td>
<td></td>
<td>0.34</td>
<td>0.48</td>
<td>0.82</td>
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<tr>
<td>CO\textsubscript{2}-EOR recovery: 30%</td>
<td></td>
<td>0.93</td>
<td>1.32</td>
<td>2.25</td>
</tr>
</tbody>
</table>

- ROZ CO\textsubscript{2} flooding potential will be estimated with future study
Next Step

• Choose a workable field
  – Big Tensleep field with thick ROZ.
  – Collaborated with the operator.
  – HC show records and oil analysis.

• Determine oil saturation, petrophysics, and crude quality
  – Core measurements.
  – Log analysis.
  – Deepen and core through ROZ.
  – Production test in ROZ.
  – Obtain oil/fluid samples.

• Calculate CO₂ flooding potential for both ROZ and MPZ

• Propose CO₂ flooding designs
  – Pilot operations.
  – WAG, CO₂ only, or gravity stable.
How much oil needed for all the people with their own cars?