ROZ Potential of Tensleep Sandstone in Bighorn Basin, Wyoming

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- Steve Melzer, Melzer CO₂ Consulting.
- Merit Energy Company.
Main Pay Zone (MPZ) and Residual Oil Zone (ROZ)

Permian Basin

Melzer et al., 2006
Outlines

• Residual Oil Zone (ROZ) in Tensleep Sandstone, Bighorn Basin.

• Generation, migration, and accumulation of Tensleep oil.

• Estimation of ROZ resources.
Proved and Predicted ROZ Occurrence in Bighorn Basin

Base map from Ploeg, 1985

Based on:
EORI study

<table>
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<tr>
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<th>Estimated OOIP (BBbls)</th>
<th>CO2-EOR Potential (BBbls)</th>
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<tbody>
<tr>
<td>MPZ</td>
<td>4.5</td>
<td>0.5</td>
</tr>
<tr>
<td>TZ/ROZ</td>
<td>4.4</td>
<td>1.1</td>
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</table>
ROZ vs MPZ

**Frannie**
- Oil Shows
- Good Oil Show in Lower Tensleep
- ROZ
- MPZ

**Sage Creek**
- Reported Oil Stain
- MPZ
- ROZ

**Homestead**
- 44.3% So
- ROZ
- MPZ
- ~40% So
Average ROZ Distribution
Frannie-Sage Creek-Homestead area
Tensleep Hydrocarbon Show in Non-productive Wells

Base map by Alan Ploeg, 1985

HC show in formation test and pipe recovery

HC show in cores
Oil Properties are Similar in ROZ and MPZ

Reservoir Oil

Oil from Non-productive Wells

GC Analysis
Operator’s Comments

• Chris Mullen: Perforation interval in most Tensleep reservoirs depends on the economic cut offs, where there is too much water. Perforation too deep will quickly cause water coning.

• Eugene Wadleigh: We knew a lot of oil in the Tensleep Sandstone, Bighorn Basin had not been developed for the primary production.

• Gene George: A lot of oil has not been developed also in the Minnelusa sandstones from current production.

• Aufricht in Core Lab: Zones in Tensleep and Minnelusa with 80% So still show extremely high water cuts.
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Evidence of Phosphoria Oil in Tensleep and Minnelusa

- Trace elements exhibit similar patterns in the Phosphoria black beds and in the crude oil farther to the east (Sheldon, 1967).

- Good agreement in both aromatic-type analysis and infrared measurements on molecular distillation fractions between hydrocarbon extracts from a Phosphoria core and oil produced from the Tensleep in a Wind River basin well (Stone, 1967).
Structural Contour map of Permian Rocks at the End of the Early Cretaceous Epoch.

Sheldon, 1967
Oil Migrated into Phosphoria and Tensleep by end of Jurassic Time

Modified from Stone, 1967
Development of Tensleep Reservoirs, Bighorn Basin

End of Triassic
Oil migrated into Phosphoria and Tensleep stratigraphic traps.

Stone, 1967

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End of Paleocene

Laramide folding, creating fractures and faults. Previous hydrocarbon accumulations re-migrated into structural traps during the Paleocene and Eocene time. Reservoirs with horizontal OWC at that time.

Stone, 1967
End of Eocene

Intensified folding, fracturing, faulting, and differential uplift and hydrodynamic flow causing adjustment of oil accumulations and redistribution through faults and regional tilting.

Reservoirs forming level or tilted OWC.
Development of present hydrodynamic environment, and influx of meteoric water into Tensleep Sandstone.
Many reservoirs with tilted OWC.

Stone, 1967
Development of Tensleep Reservoirs, Bighorn Basin

End of Triassic

End of Paleocene

End of Eocene

Recent

Stone, 1967
TDS Difference in one Structure Caused by Hydrodynamics

TDS:
- 3712 in NFB
- 2185 in SFB
Before oil migrated into Madison

After oil migrated into Madison

Meteoric water flushing
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Methodology to Estimate ROZ Resources

- ROZ Resource = Initial OOIP of entire Tensleep section – Cumulative production - Remaining oil in MPZ.
  - Initial OOIP for the entire Tensleep section can be calculated using core measurements and well logs.
  - Remaining oil saturation in MPZ in current stage can be estimated based on the relative new wells and reports (40%).
  - Oil saturation in natural-water washed non-productive wells is about 40%.
  - A portion of original ROZ oil may be recovered during primary and secondary production from MPZ.
Oil Saturation After Water Flooding

Oil Saturation in Non-productive Wells
(Average Oil Saturation of the 4 Wells 40%)

Oil Saturation after Water Flooding 1988
(average So 45%)

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Available Data and Challenges

- Porosity logs (174)
- Core (56)
- Wells suitable for analysis (93)

- Rw’s – variable within Tensleep (0.5 – 2)
- Archies’ a (0.81), m(2), & n(2)
- Saturation calculations – one well at a time
- So calculated from well logs calibrated with core
- Log quality – highly variable
General Area

Location map & structural cross section
Vertical exaggeration ~5x (NE Bighorn Basin)

Frannie
Sage Creek
Deaver
Homestead
Cowley

15 Miles
6 Miles

Change XS
Log Data

Tensleep pay zone (8% porosity cut off)

Log Analysis (Top of Tensleep as datum)

Cored intervals

Net to gross ~50%

15 Miles
Correlated Tensleep pay zones (>8%)

-Note missing upper Tensleep-

(Top of Phosphoria as datum)
Study Area

Porosity modeling
Vertical exaggeration ~5x

Homestead
Deaver
Sage Creek
Cowley
Homestead

E N H A N C E D  O I L  R E C O V E R Y  I N S T I T U T E
Estimated ROZ Resource

Study area ~36 square miles
Cumulative production ~ 32 mmbls
Remaining oil in MPZ ~ 45 mmbls
OIP in ROZ ~ 796 mmbls
Log Analysis

Location map & Log data
Datum = Phosphoria

Log Phi/Core Phi

$R^2 = 0.7263$
Benefits & Uncertainties

- **Benefits:**
  - Let operators realize the significance of ROZ potential for EOR.
  - Estimation of total residual oil for EOR in both MPZ and ROZ.
  - Knowledge of residual oil ratio between MPZ and ROZ.
  - Easy for reservoir simulation.

- **Uncertainties:**
  - Portion of ROZ oil recovered during primary and secondary production is unknown without new data.
Summaries

• Tensleep Sandstone In BHB has extensive and rich residual oil.

• ROZ distribution is the result of tectonic movement, multiple oil migration and accumulation, and hydrodynamic effect.

• Massive ROZ resources are a significant potential target for advanced EOR.