Residual Oil Zone Potential of Tensleep Sandstone in the Bighorn Basin, Wyoming*

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Abstract

Residual oil zones (ROZ) are oil-bearing intervals below main pay zones (MPZ) in existing reservoirs or in oil-bearing rocks within non-commercial traps. The oil resources in ROZ have not been produced during primary and secondary production due to high water cut and unfavorable economic climate. According to core measurement and well log analysis, Tensleep reservoirs in the Bighorn Basin, Wyoming, contain thick ROZ with oil saturation as high as 80%. ROZ potential in the Bighorn basin has been evaluated using basin tectonic movement, hydrocarbon migration and accumulation, oil composition, and reservoir properties. Oil in the Tensleep reservoirs of the Bighorn Basin was originally sourced from the Phosphoria Formation in the west and migrated into the Tensleep Sandstone in stratigraphic traps before the Laramide Orogeny. After the Laramide movement, the Tensleep oil re-migrated into structural traps on the basin flanks. Expulsion of the Tensleep Sandstone on the surrounding mountain areas due to erosion caused the meteoric water to flush downward, changing oil distribution in the Tensleep reservoirs. Re-distribution of oil during the recent period left massive oil in ROZ below the MPZ and areas surrounding the existing reservoirs, as well as in the non-developed oil-bearing structures. Permeability heterogeneity of the Tensleep reservoirs and heavy oil also contribute to thick ROZ. Some of the oil in Tensleep ROZ is mobile based on drilling stem tests and its composition is similar to that of MPZ oil.

After decades of water flooding, the remaining oil saturation in the MPZ of Tensleep reservoirs has been reduced to that in the ROZ or even lower, and the average water cut in currently produced oil from MPZ is over 98%. Development history of ROZ in the Permian Basin reservoirs has demonstrated that CO₂-EOR is a promising technique for recovering oil from ROZ in the mature Tensleep reservoirs and undeveloped oil-bearing structures. It is estimated that the unconventional EOR resources in Tensleep reservoirs will double the EOR reserve in the Bighorn Basin, and the recovery of oil from ROZ will revolutionize the concept of oil recovery.
References


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Outlines

• Main pay zone (MPZ) & residual oil zone (ROZ).

• Oil migration and accumulation in Tensleep Sandstone in Bighorn Basin, Wyoming.

• ROZ distribution in Tensleep Sandstone.

• CO$_2$-EOR potential of ROZ.
Main Pay Zone & Residual Oil Zone (ROZ)

Tensleep Sandstone in Bighorn Basin, WY

Jennings, 1987

ENHANCED OIL RECOVERY INSTITUTE

UNIVERSITY OF WYOMING
Discovered: 1928
Tensleep Reservoirs: 58
Tensleep Wells: 3800
Cumul. Prod: 2.2 BBbls
Water cut: 98%
Oil Migrated into Phosphoria and Tensleep by end of Triassic Time

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

End of Triassic
Oil migrated into Phosphoria and Tensleep stratigraphic traps.
Development of Tensleep Reservoirs, Bighorn Basin

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.
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 tilted or level OWC.
Recent

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

- End of Triassic
- End of Paleocene
- End of Eocene
- Recent
ROZ Distribution
Frannie-Sage Creek-Homestead area
ROZ Identified around Reservoirs
Frannie-Sage Creek-Homestead area
ROZ Identified below MPZ (Brown Field)
Frannie-Sage Creek-Homestead area
Oil Properties are similar in ROZ and MPZ

- Reservoir Oil
- Oil from Non-producing Wells

GC Analysis
Wells with High Oil Saturation in Non-commercial Structure (Green Field)
Proved and Predicted ROZ Occurrence in Bighorn Basin

Based on:
- EORI study

Base map from Ver Ploeg, 1985

285,000 acres

3.5 million acres
Oil Saturation After Water Flooding

**Initial Oil Saturation 1950**

**Oil Saturation after Water Flooding 1988**
CO₂-EOR Potential

Initial Oil Column

Oil Column after Water Flooding

CO₂-EOR Potential
CO2-EOR Potential of ROZ
ROZ Potential of Tensleep Reservoirs

Data from 13 Tensleep reservoirs evaluated by ARI, 2006)
Conclusions

• Complicated history of oil migration and accumulation is potential to generate massive ROZ.

• ROZ is developed not only below MPZ, but also between existing fields.

• ROZ is potential to contribute a significant portion of reserve for CO$_2$-EOR and other advanced EOR.

• ROZ is a new target for enhanced oil recovery in mature basins.