ROZ Potential of Tensleep Reservoirs, Bighorn Basin*

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Abstract

The residual oil zone (ROZ) is the reservoir interval below the oil-water contact, and is typically not perforated for primary and secondary production. ROZs have been successfully identified and produced in the Permian Basin based on screening criteria including tectonic movements, hydrocarbon migration and accumulation, oil composition, and reservoir properties. Tensleep reservoirs in the Bighorn Basin have potential to contain thick ROZs based on evaluation of these same screening criteria. During the primary and secondary production period, most of the oil in the residual oil zone is not touched. After intensive water flooding, the oil saturation in the main pay zone (MPZ) of Tensleep reservoirs is reduced to that in the ROZ. CO₂-EOR is a promising technique for recovering the remaining oil from these mature reservoirs. The EOR potential in Tensleep reservoirs will significantly increase by adding the ROZ reserves to the remaining potential in the MPZ. If the ROZ potential can be proven in the Bighorn Basin Tensleep reservoirs as predicted, rich ROZ potential could also exist in Tensleep reservoirs in other basins and possibly other productive horizons as well.
Abstract

The residual oil (ROZ) is the reservoir interval below the oil-water contact, and is typically oil-saturated for primary and secondary production. ROZ is the area where oil accumulates in the reservoir, which can include tertiary recovery methods such as gas or water injection. ROZ reservoirs are considered to be high-quality reservoirs due to their high oil saturation and potential for enhanced oil recovery. ROZ reservoirs are typically ideal for secondary or tertiary recovery methods, including steam injection, cyclic steam stimulation, or Miscible displacement processes. ROZ reservoirs in the Bighorn Basin have potential to be developed through various recovery methods, including primary recovery, secondary recovery, and tertiary recovery methods. ROZ reservoirs can be further classified into primary or secondary production phases, and the oil in the residual oil zone is still mobile. After increased water recovery, the oil viscosity in the main pay zone (MPZ) of a ROZ reservoir is reduced to that in the ROZ. CO2-GOR is a promising mechanism for recovering the remaining oil from these reservoirs. The oil and gas industry has been exploring various methods to enhance oil production from ROZ reservoirs in the Bighorn Basin and possibly other producing basins as well.

Thick ROZ developed in Tensleep reservoirs of Bighorn Basin

Tensleep oil in Bighorn Basin was generated from the oil-rich Phosphoria source rock in the west, and migrated into Tensleep stratigraphic traps before the Laramide tectonic movement (modified from Bone, 1967).

Since the Tensleep Sandstone was exposed to surface, meteoric water has percolated into the permeable sandstones, flushing a portion of oil downdip, forming tilted oil-water contact. Contour lines in the diagram below roughly match the depths of OWC in a Tensleep reservoir, Bighorn Basin.

During the Laramide movement, a series of anticlines and domes were generated through folding. Most of the oil was re-migrated into structural traps. The oil should be accumulated in the top of traps with horizontal oil-water contact before the Tensleep Sandstone was outcoured due to erosion along escarpments of the Laramide Mountains.

During adjustment of OWC from horizontal to tilted downdip, thick ROZ is potential to generate in the updip portion of the reservoir.

Reservoir Oil

ROZ Potential of Tensleep reservoirs, Bighorn Basin

Replacement of anhydrite nodules by calcite in the downdip portion of the main pay zone indicates the current mean pay zone was once located below oil-water contact (OWC). The OWC has been adjusted with meteoric water flushing from horizontal to tilted, and the OWC has moved deeper downdip, but shallower updip.

GC Analysis

Reservoir Oil

From Non-productive Wells

Oil properties within ROZ are similar to those in the main pay zones, indicating that degradation of crude oil is not significant in ROZ due to water washing.
**Emergence of Residual Oil Zones (ROZ) in Permian Basin**

**Texas and New Mexico**

- **ROZ with high oil saturation and permeable sandstones:**
  - in well below perforation intervals (320452)
  - in wells out of reservoir boundaries (320410, 320767)

**Tensleep reservoir with tilted OWC and thick ROZ**

- After intensive waterflooding in the Tensleep reservoirs, the remaining oil saturation in main pay zones has reduced to the same level in ROZ. Oil in ROZ is also similar to that in main pay zones.
- Potential for CO₂-EOR will be significantly increase if ROZ is included in the performance.

**Technically recoverable resources by CO₂-EOR from 5 Permian Basin oil plays**

- **Northern Shelf Permian Basin**
  - Marathon Texas and New Mexico
- **South Central Basin Platform**
  - Horseshoe Atoll
  - WASSON FIELD (3)
- **Northern Central Basin Platform**
  - Marine Carbonate Shelf
- **Middle San Andres Paleogeography**
  - Shelf Margin
  - Del Mar Basin
- **Shelf Margin**
  - Central Basin Platform
  - Hobbs Platform
  - Overthrust Belt

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*Adapted from Sagnak (2006), Chevron Presentation at the 12/06 CO₂ Flooding Conference*