PSROZ Potential of Tensleep Reservoirs, Bighorn Basin*

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Abstract

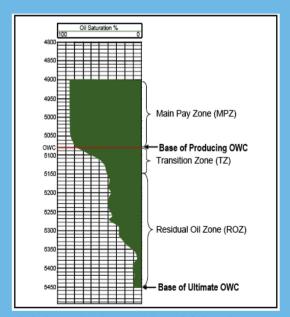
The residual oil zone (ROZ) is the reservoir interval below the oil-water contact, and is typically not perforated for primary and secondary production. ROZs have been successfully identified and produced in the Permian Basin based on screening criteria including tectonic movements, hydrocarbon migration 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.

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^{*}Adapted from poster presentation at AAPG Rocky Mountain Section meeting, Cheyenne, Wyoming, USA, June 25-29, 2011.

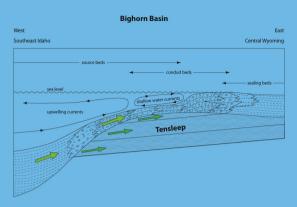
Abstract

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 proved 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.

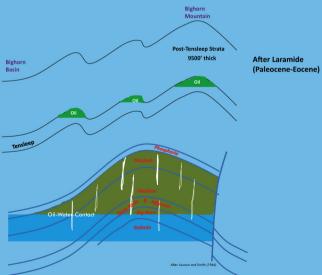


Residual oil zones (ROZ): reservoir intervals below oil-water contact, typically not perforated for primary and secondary production (from ARI, 2006).

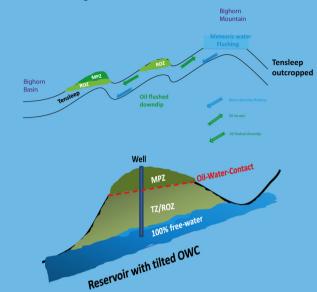
Thick ROZ developed in Tensleep reservoirs of Bighorn Basin



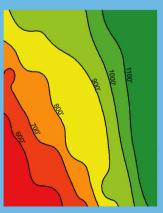
Tensleep oil in Bighorn Basin was generated from the oil-rich Phosphoria source rocks in the west, and migrated into Tensleep stratigraphic traps before the Laramide orogenic movement (modified from Stone, 1967).



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 outcropped due to erosion along top of the Bighorn Mountain.

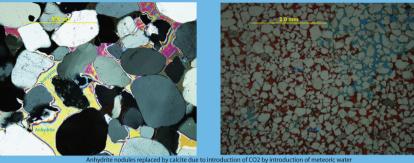


Since the Tensleep Sandstone was exposed to surface, meteoric water has percolated into the permeable sandstones, flushing a portion of oil downdip, forming tilted oil-water-contact. Contour lines in the diagram below roughly match the depths of OWC in a Tensleep reservoir, Bighorn Basin.



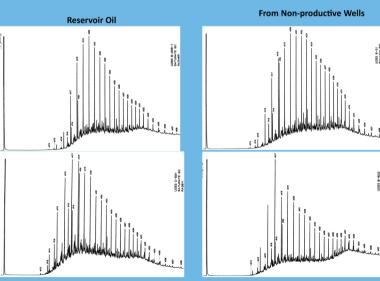
During adjustment of OWC from horizontal to tilted downdip, thick ROZ is potential to generate in the updip portion of the reservoir.

ROZ Potential of Tensleep reservoirs, Bighorn Basin



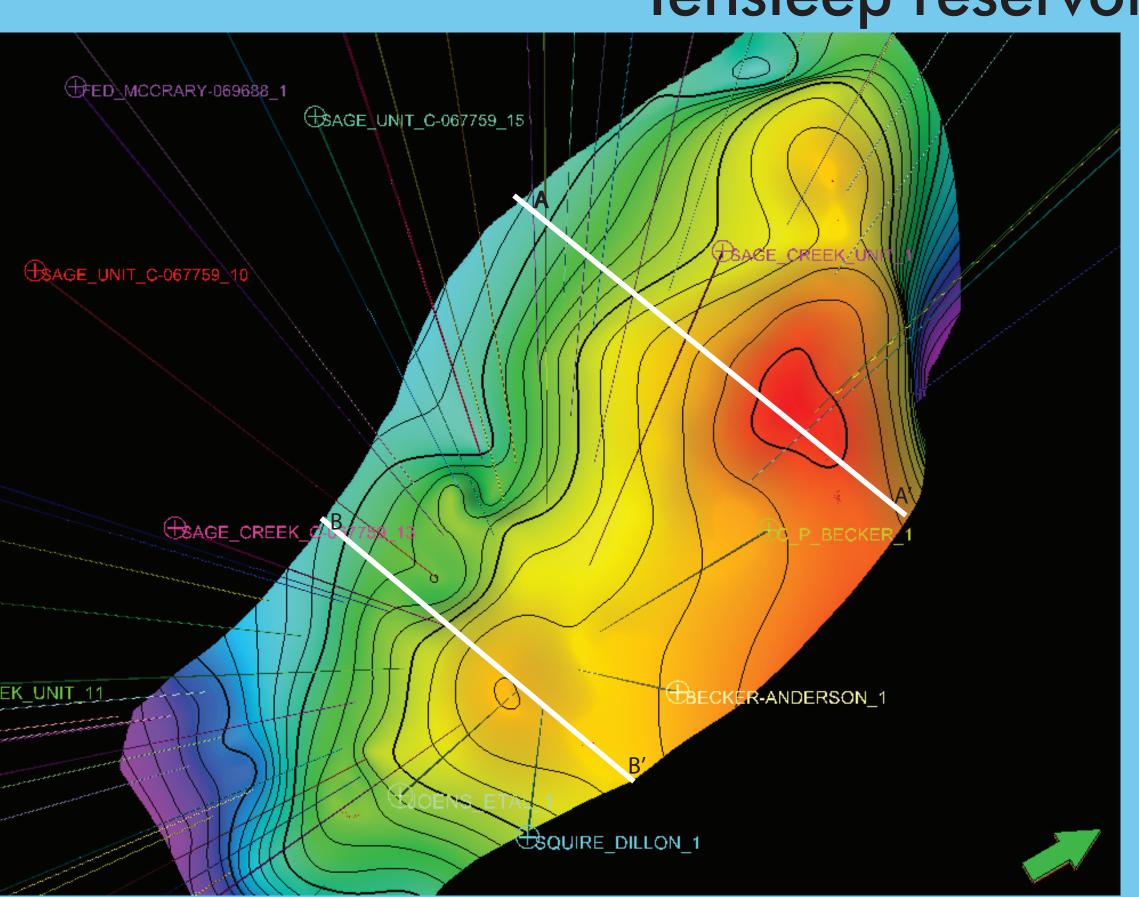
Replacement of anhydrite nodules by calcite in the downdip portion of the main pay zone indicates the current main pay zone was once located below oil-water-contact (OWC). The OWC has been adjusted with meteoric water flushing from horizontal to tilted, and the OWC has moved deeper downdip, but shallower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

GC Analysis



Oil properties within ROZ are similiar to those in the main pay zones, indicating that degradation of crude oil is not significant in ROZ due to water washing.

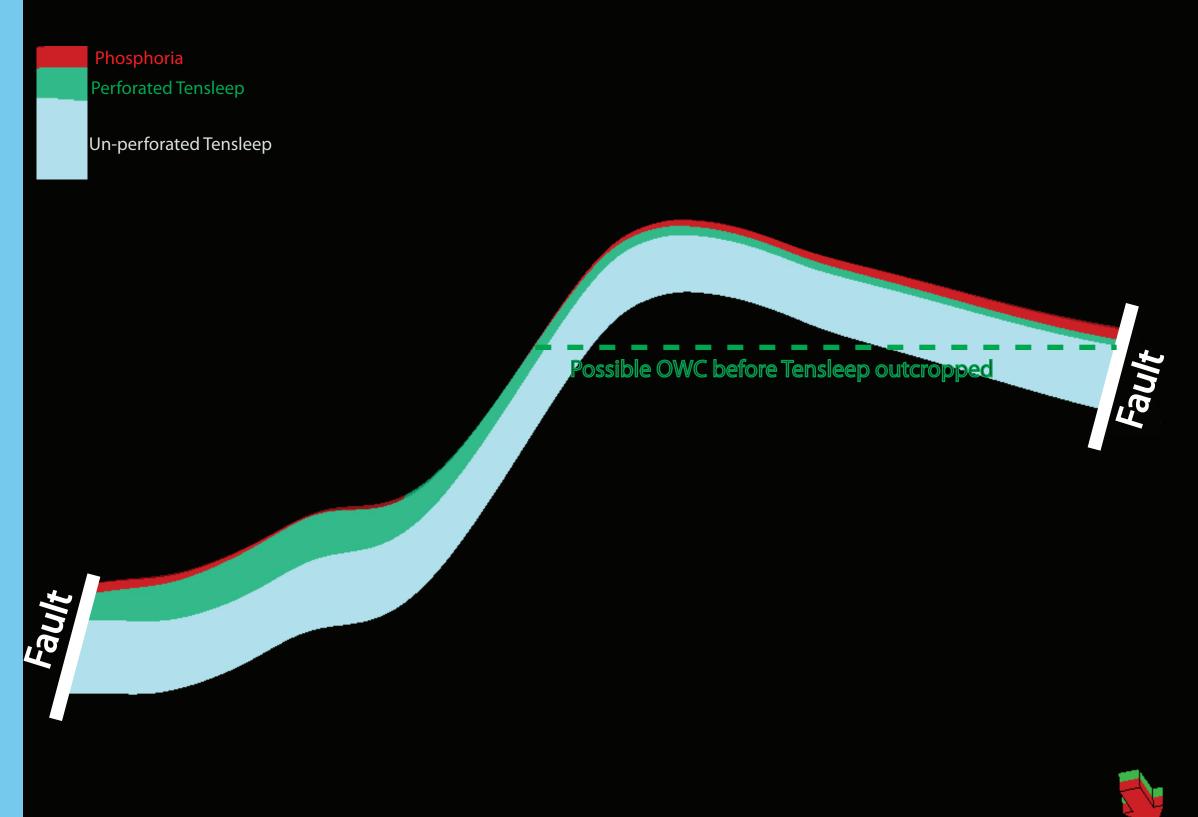
Tensleep reservoir with tilted OWC and thick ROZ

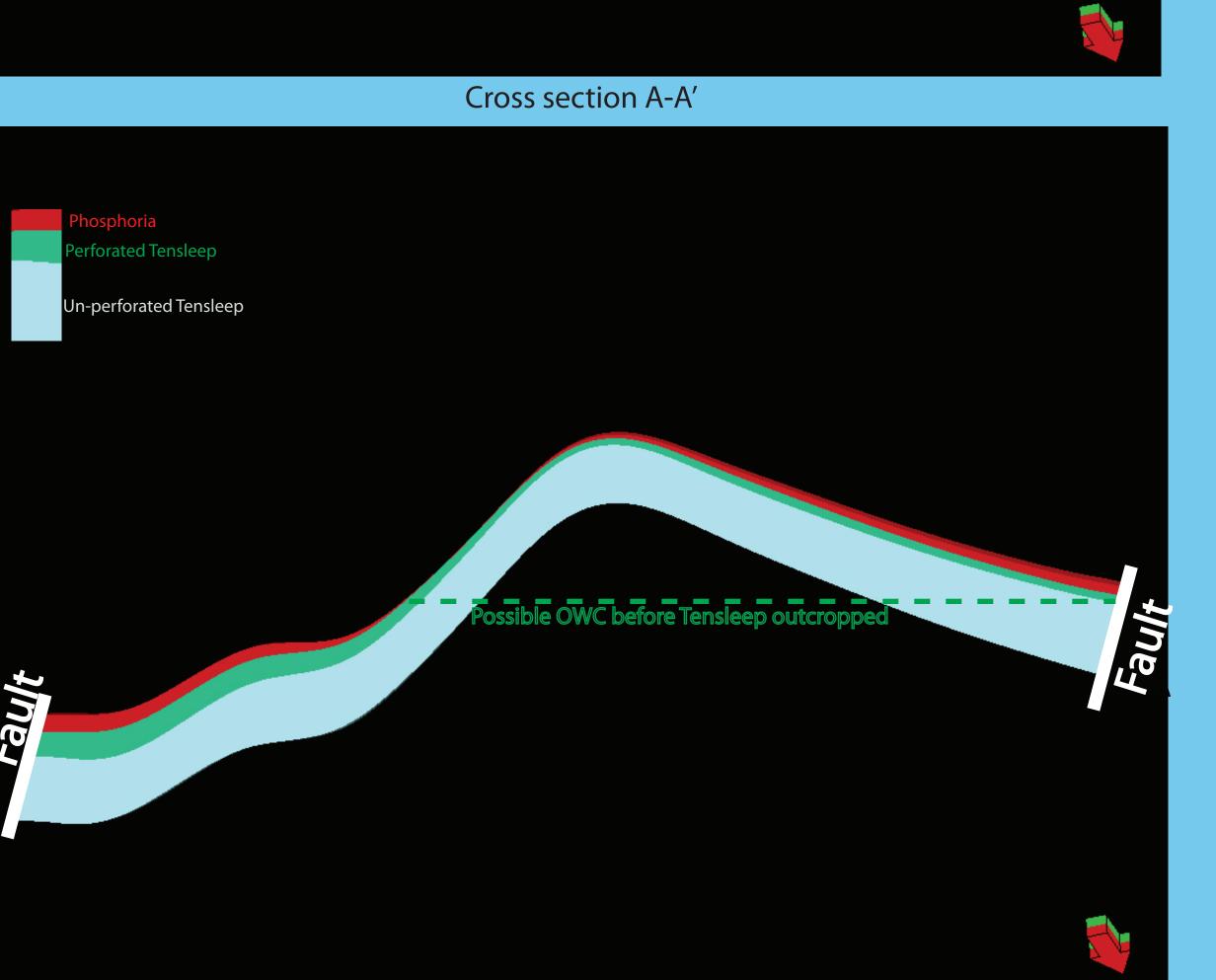


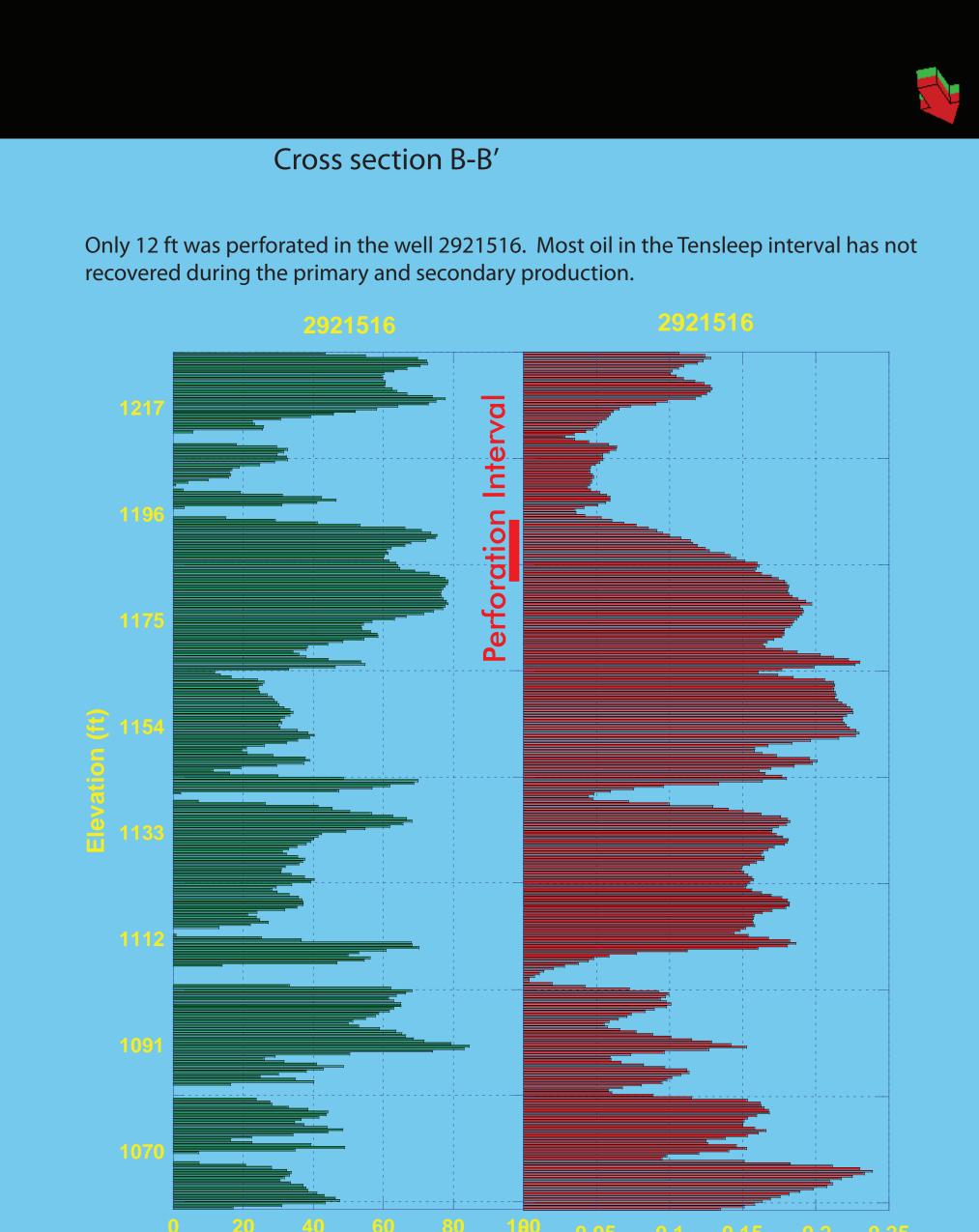
Tensleep Structure Map

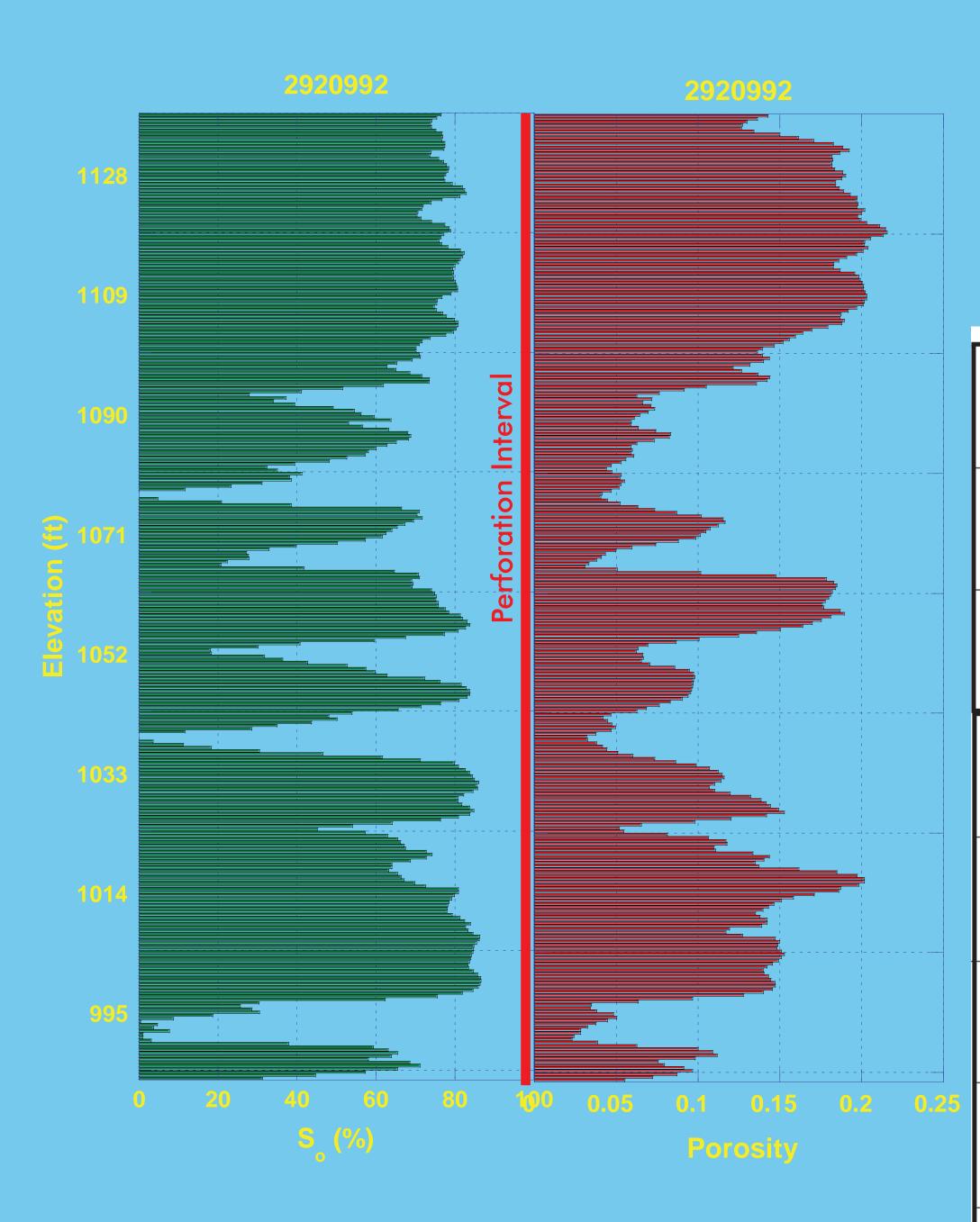
East view showing perforated and un-perforated zones

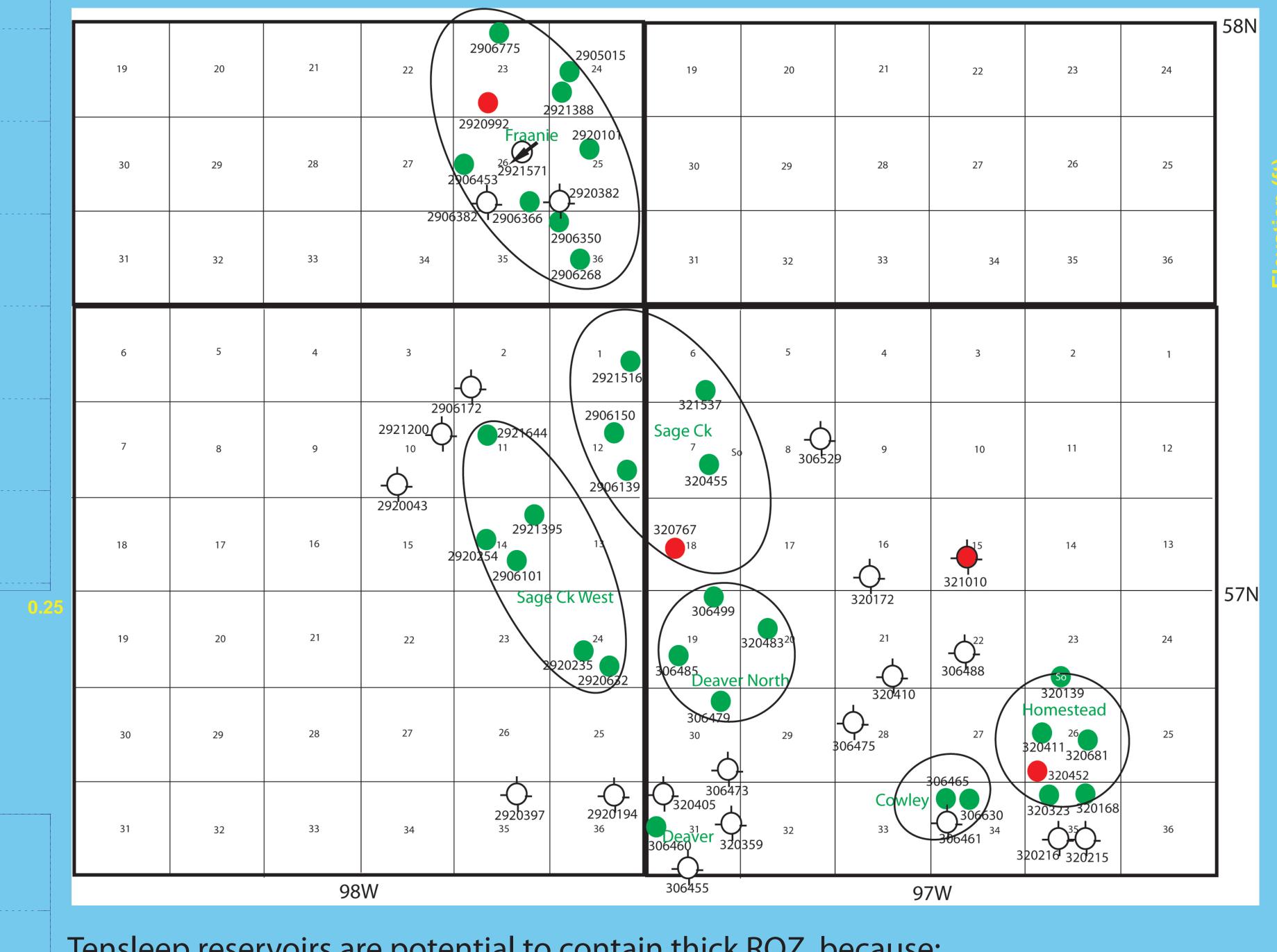
Although the well 320485 was perforated for a long interval, oil saturation is still above 60% in most of the permeable sandstones below perforation bottom (ROZ).







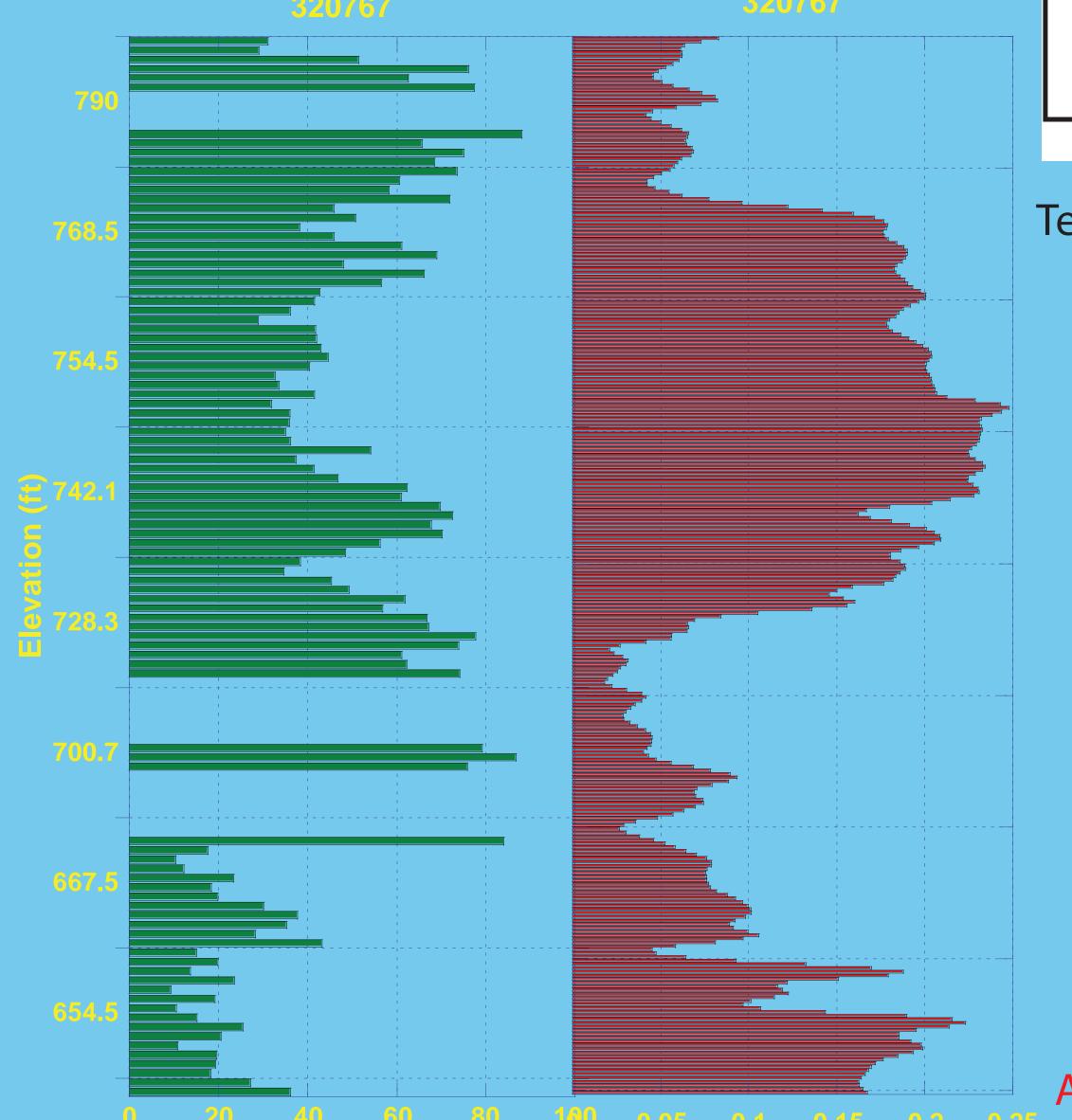




ROZ with high oil saturation and permeable sandstones:

in well below perforation intervals (320452)

in wells out of reservoir boundaries (320410, 320767)



Tensleep reservoirs are potential to contain thick ROZ, because:

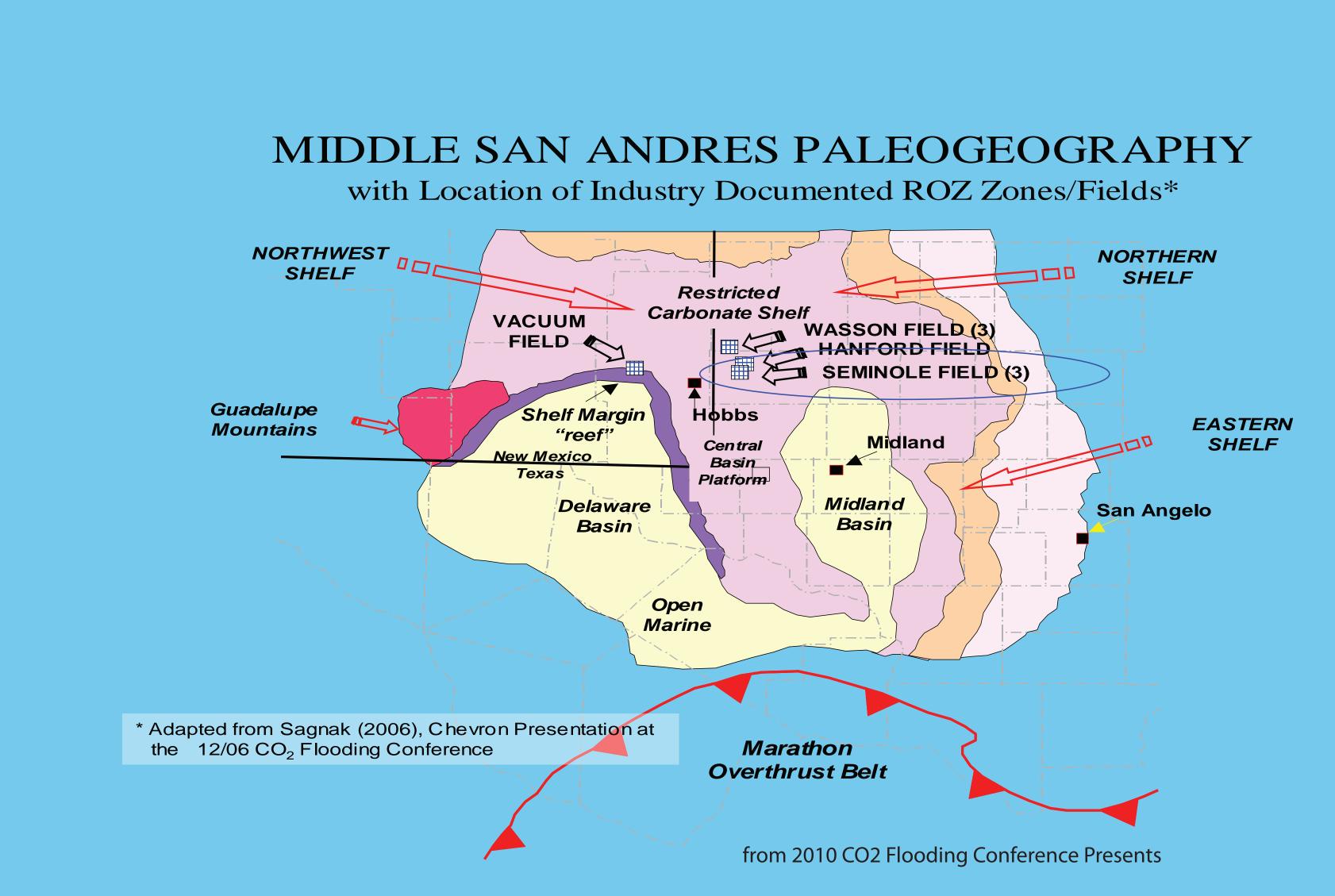
- 1. Oil has re-migrating several times since it migrated from west Phosphoria source rocks
- a. Migrated into stratigraphic traps from Phosphoria source rock.
- b. Re-migrated into structural traps with horizontal OWC after Laramie Orogeny.
- c. Re-distributed by meteoric water flushing after the Tensleep Sandstone was outcropped.

So, previous oil-bearing zones and pre-existing oil pools might be washed by meteoric water, leaving residual oil which cannot be produced during the primary and secondary recoveries.

- 2. Heavy Tensleep oil tends to generate thick ROZ.
- 3. Recent change of OWC and heavy oil favor less oil degradation, maintaining the quality of oil in ROZs is similiar to that in main pay zones.

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





Emergence of Residual Oil Zones (ROZ) in Permian Basin

Texas and New Mexico



