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 CO_2-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

Jennings, J.B., 1987, Capillary pressure techniques: Application to exploration and development geology: AAPG Bulletin, v. 71/10, p. 1196-1206.

Stone, D.S., 1967, Theory of Paleozoic oil and gas accumulation in the Big Horn Basin, Wyoming: AAPG Bulletin, v. 51/10, p. 2056-2114.

Ver Ploeg, A.J., 1985, Tectonic map of the Bighorn Basin, Wyoming, showing oil and gas development through May, 1985: Wyoming State Geological Survey, Laramie, WY, Open File Report OFR 85-11.

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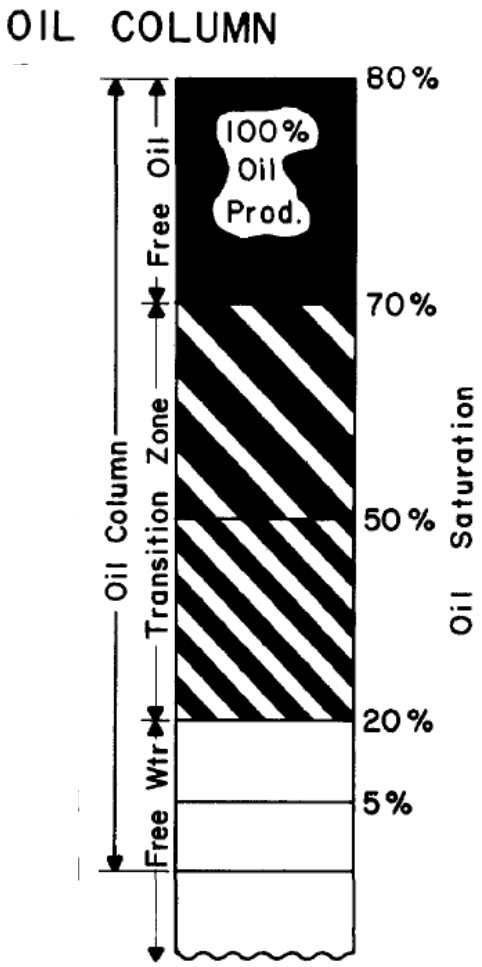
- Wyoming State Government.

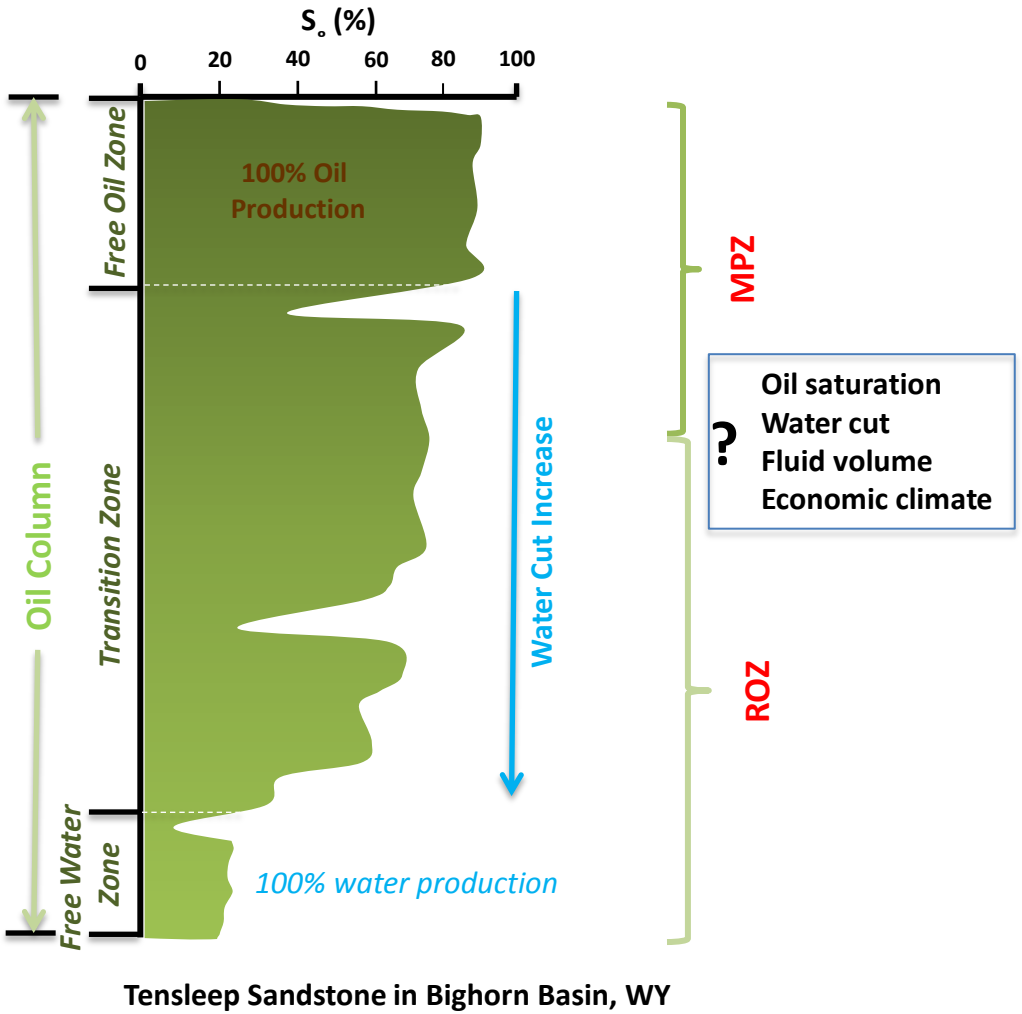
Outlines

- 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)

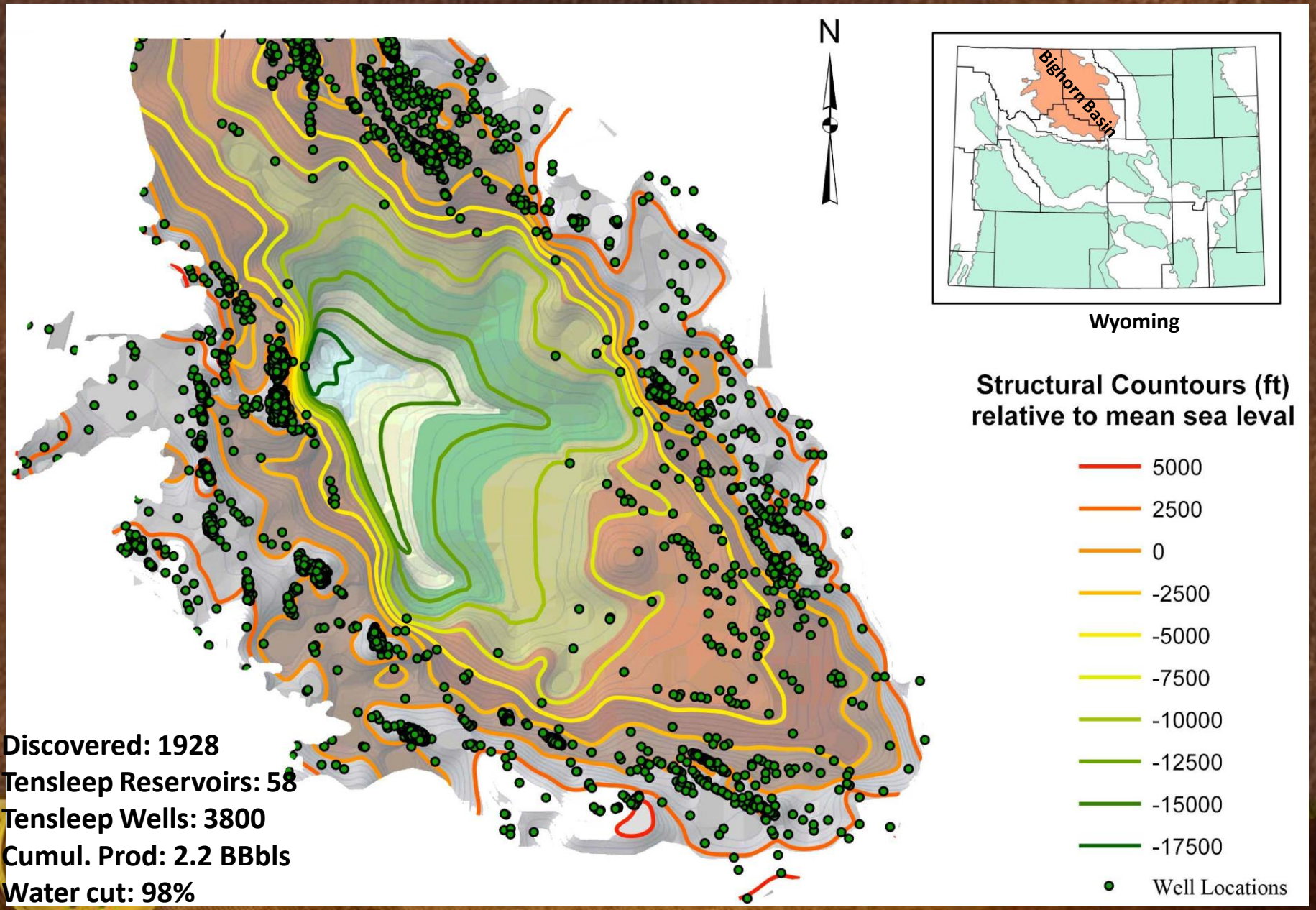


Jennings, 1987



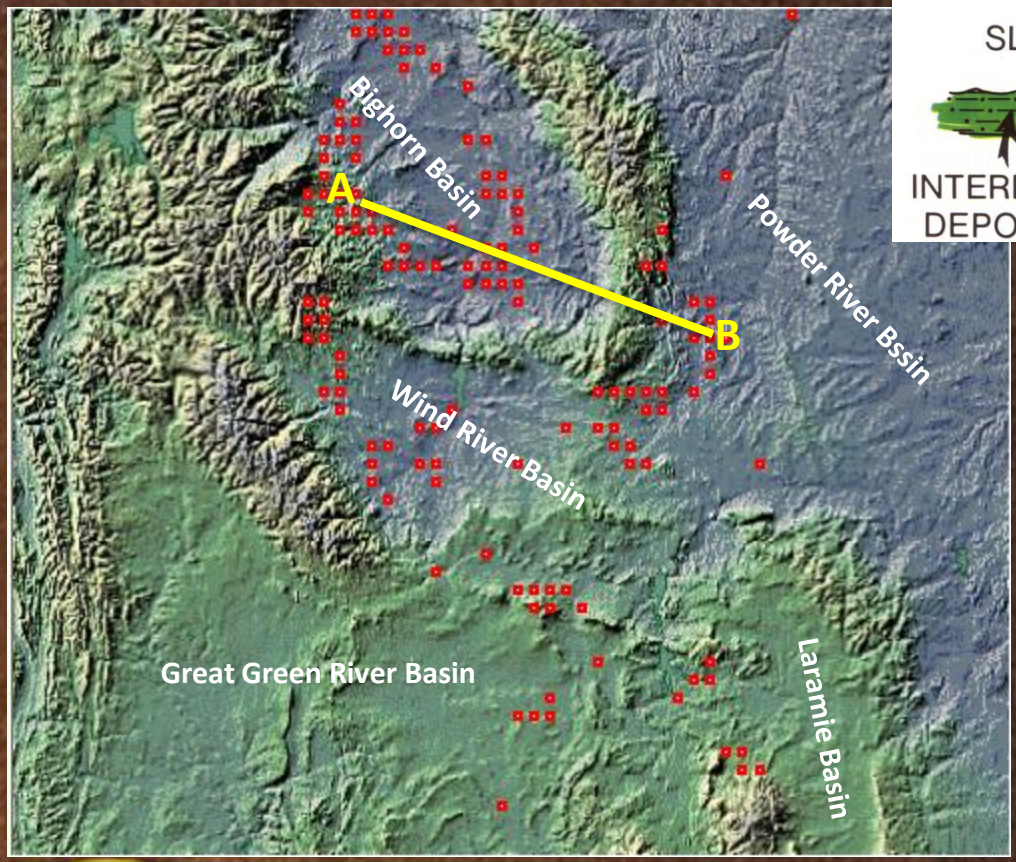
Tensleep Sandstone in Bighorn Basin, WY

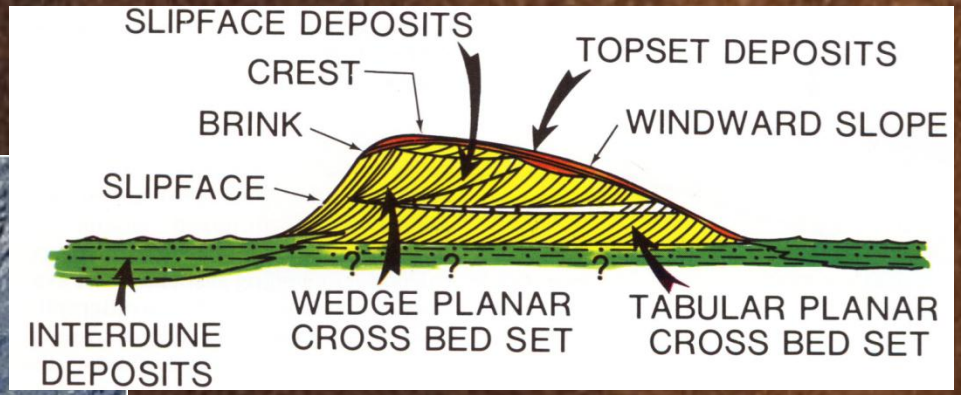
Bighorn Basin, Wyoming

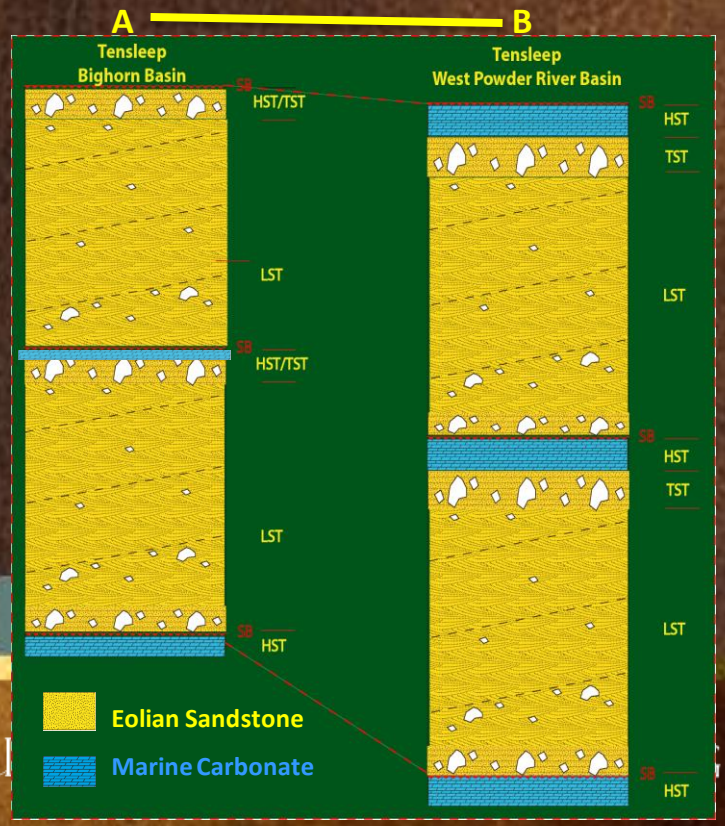


Discovered: 1928
Tensleep Reservoirs: 58
Tensleep Wells: 3800
Cumul. Prod: 2.2 BBbls
Water cut: 98%

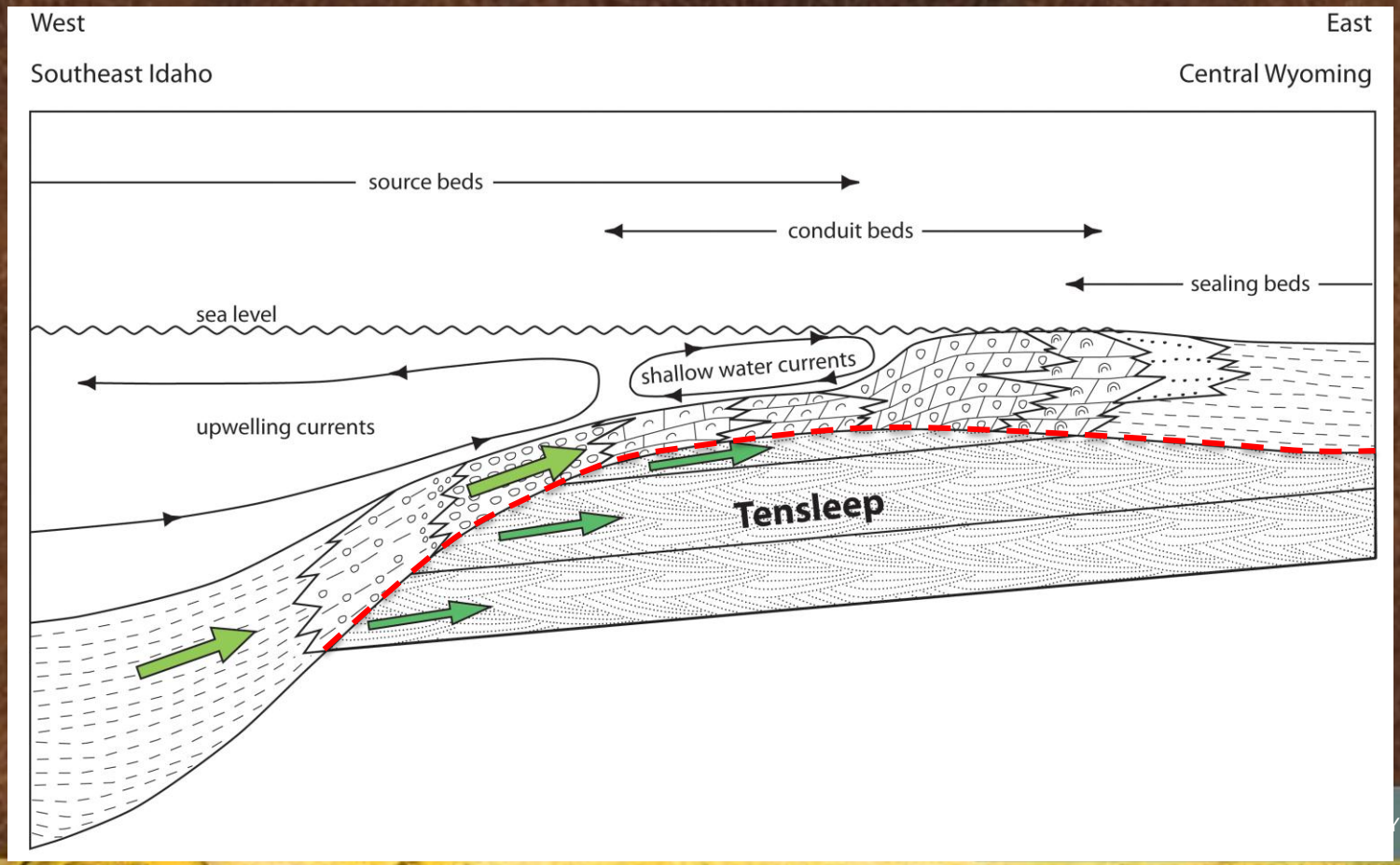
Tensleep Sandstone

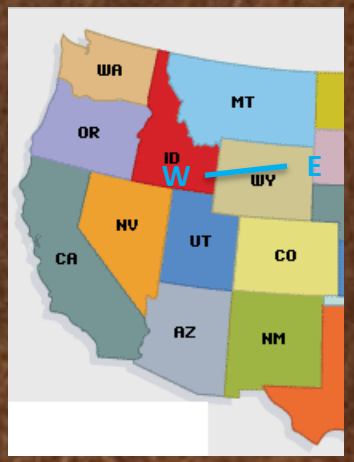






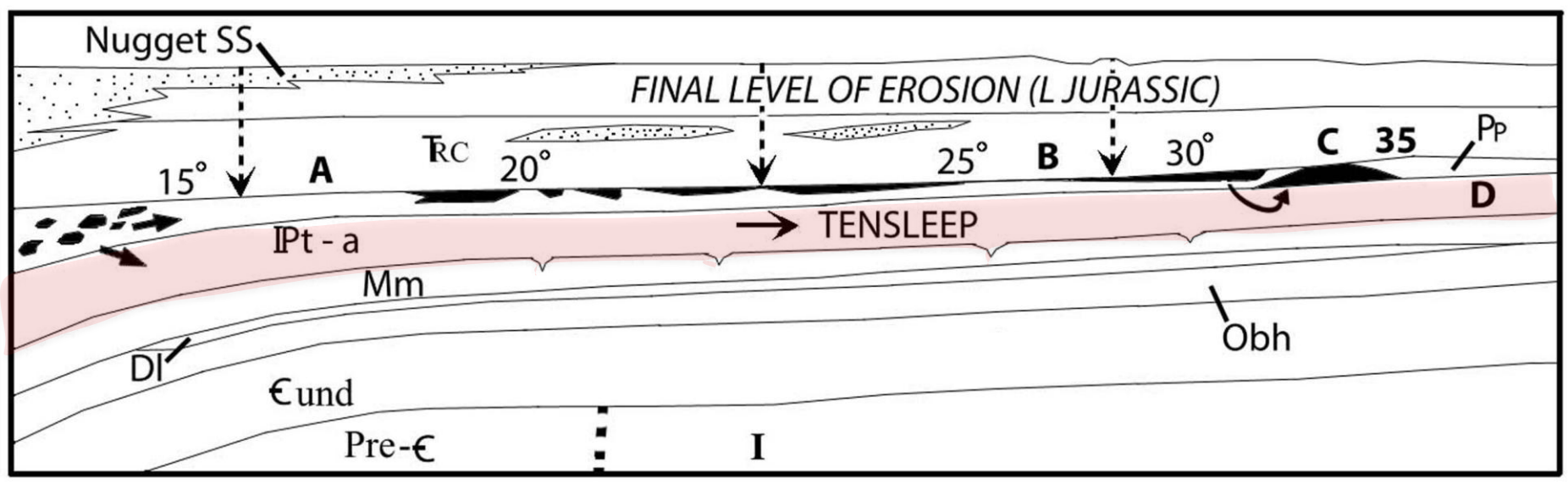
Oil Migrated into Phosphoria and Tensleep by end of Triassic Time





Modified from Stone, 1967

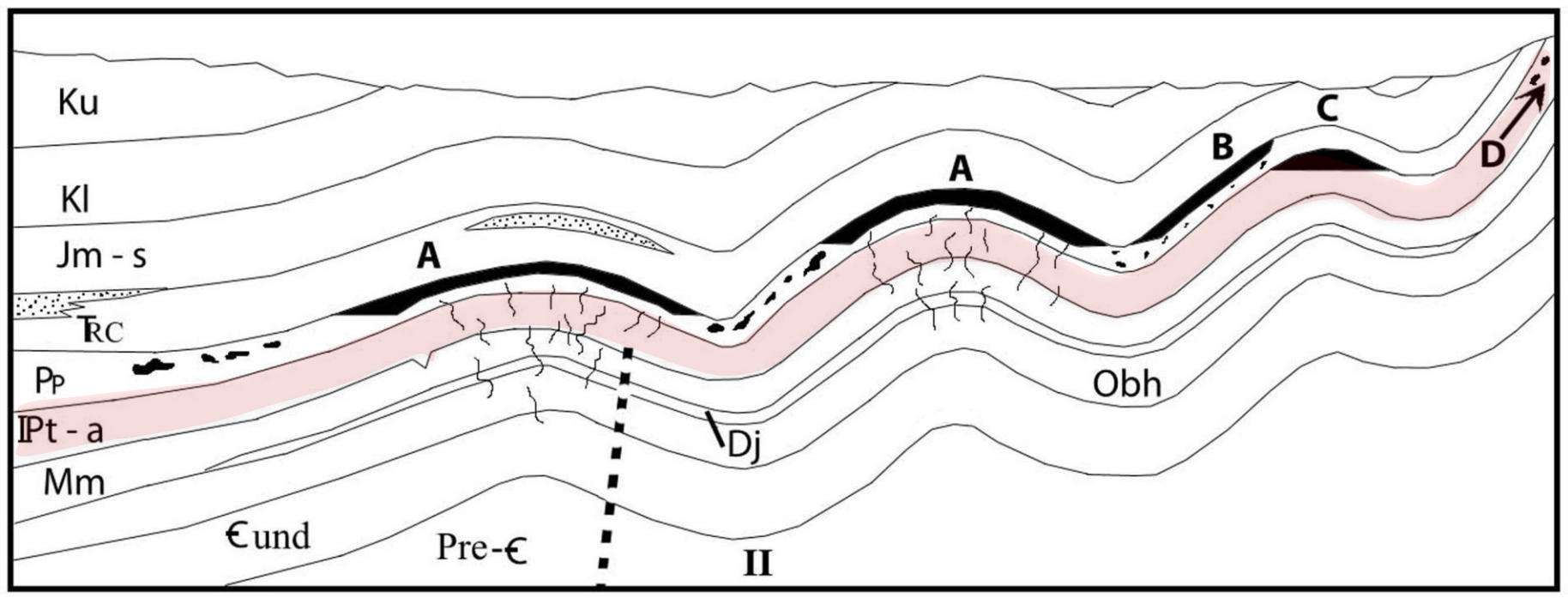
Development of Tensleep Reservoirs, Bighorn Basin



End of Triassic

Oil migrated into Phosphoria and Tensleep stratigraphic traps.

Development of Tensleep Reservoirs, Bighorn Basin



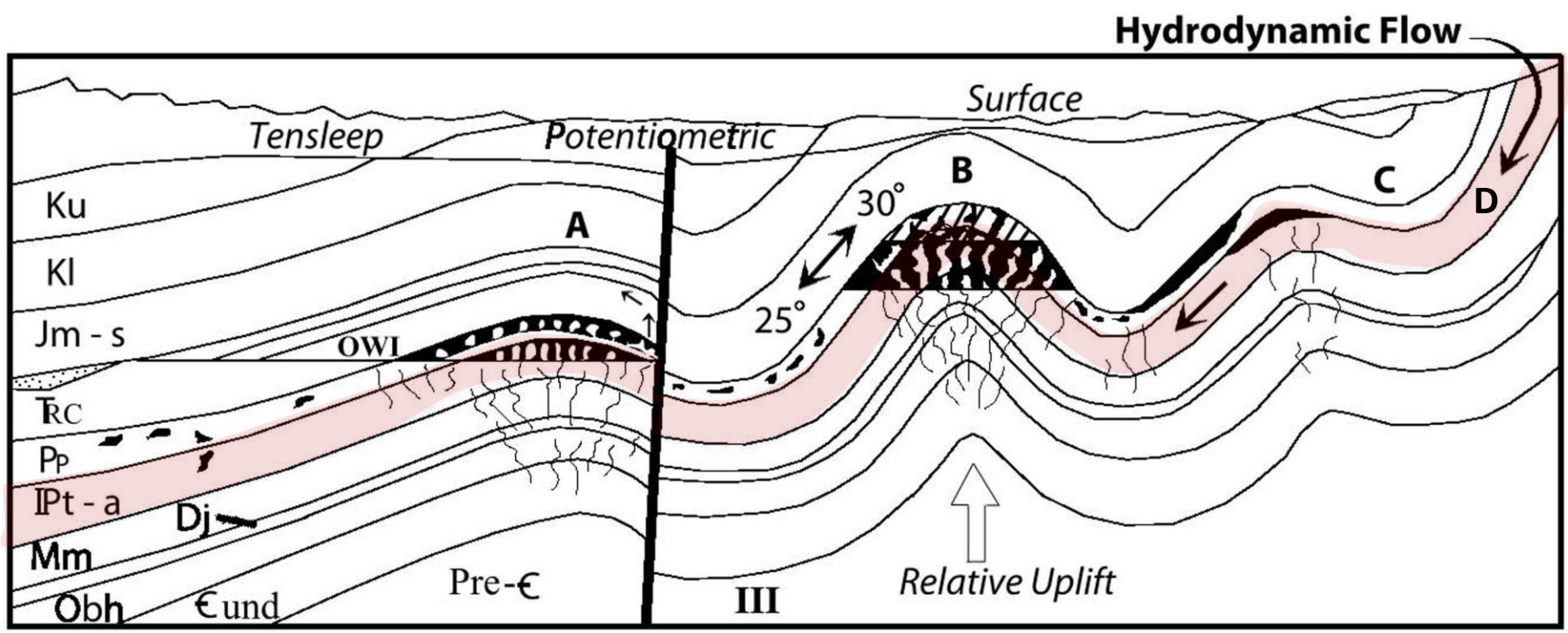
End of Paleocene

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.

Development of Tensleep Reservoirs, Bighorn Basin

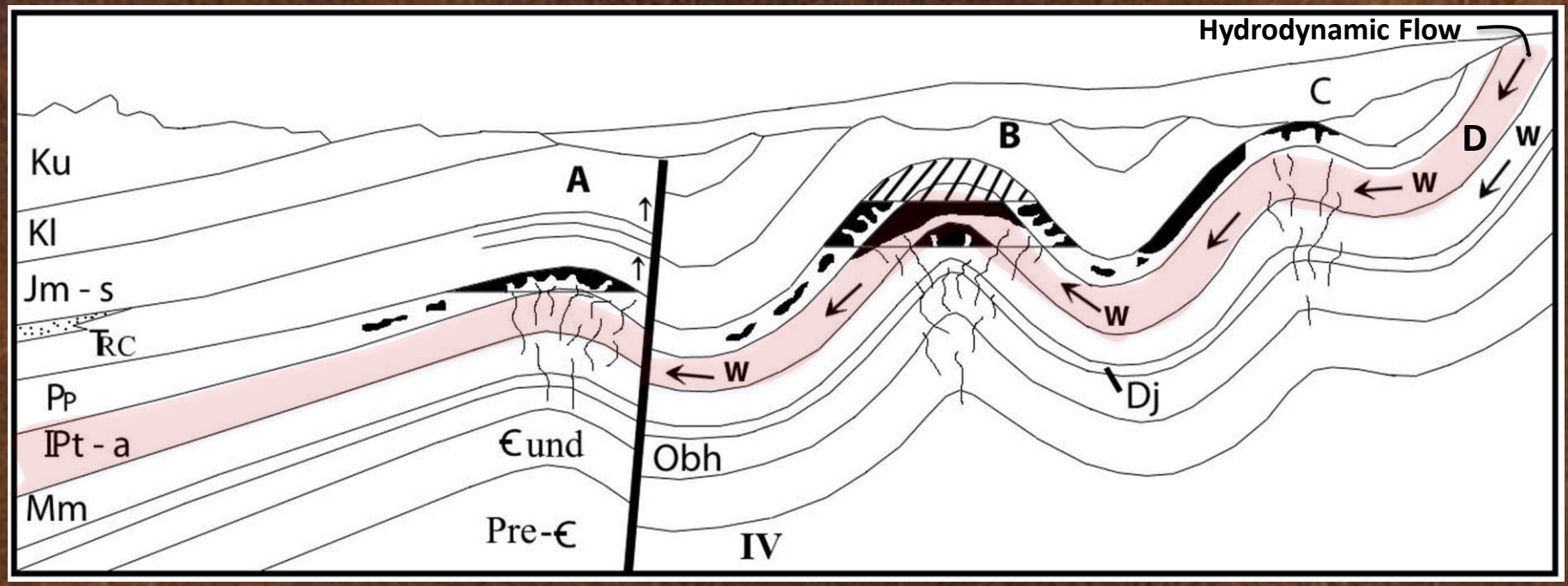


End of Eocene

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.

Development of Tensleep Reservoirs, Bighorn Basin

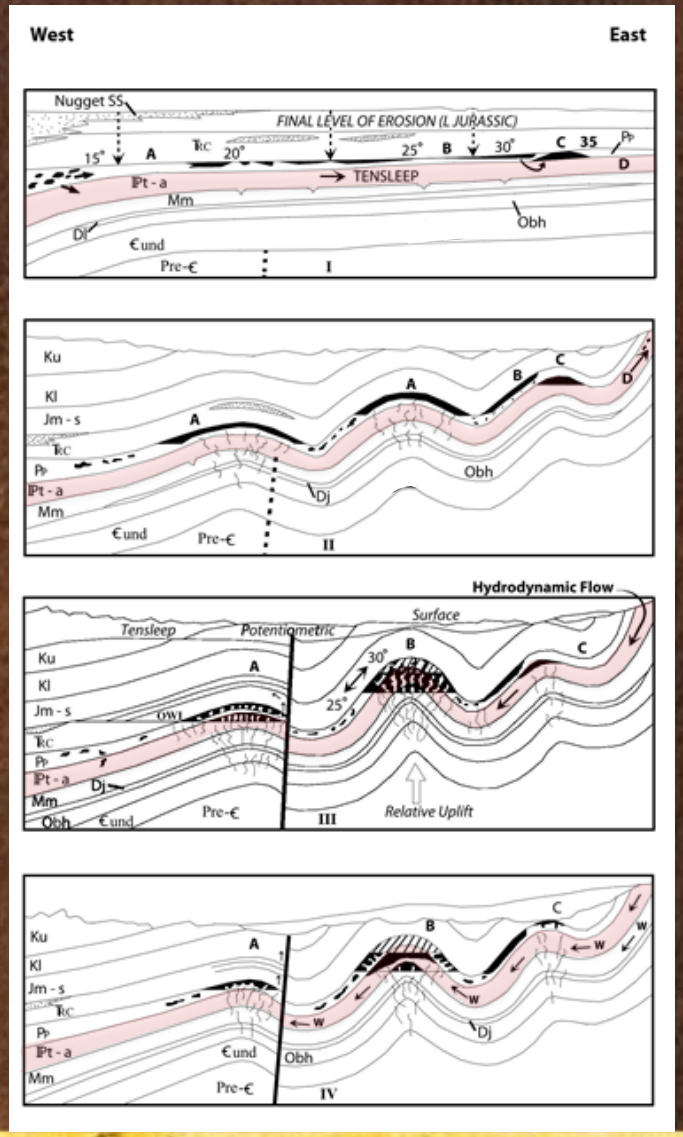


Recent

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

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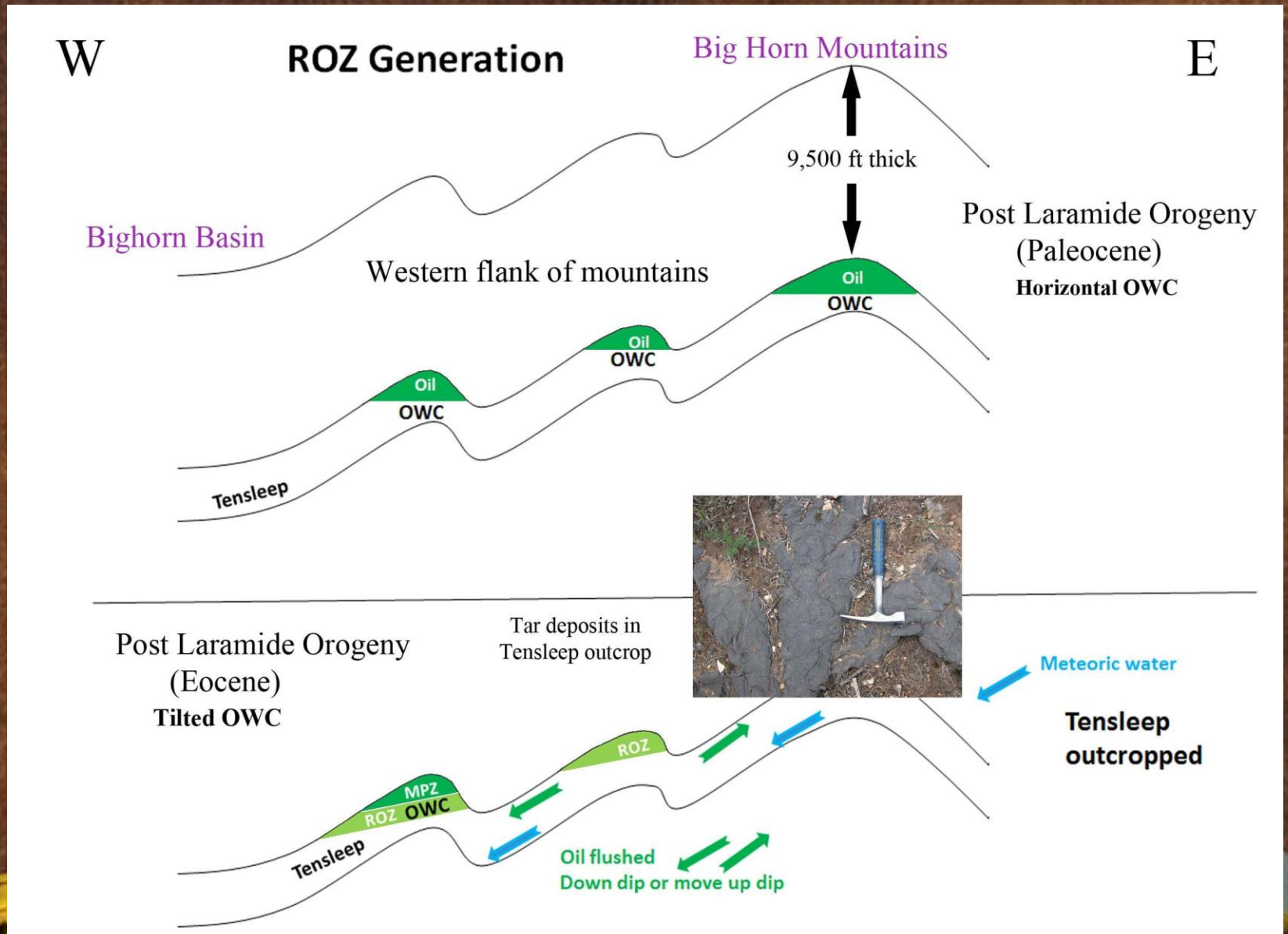
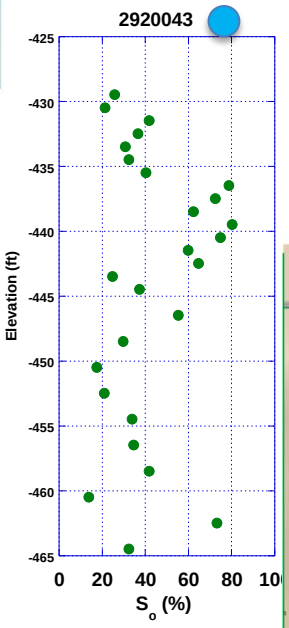
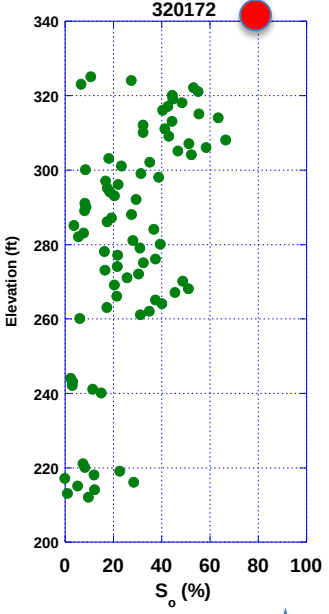
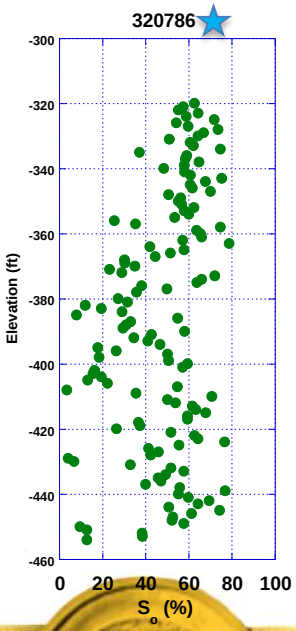

W
ROZ Generation
Big Horn Mountains
E
9,500 ft thick
Bighorn Basin
Western flank of mountains
Post Laramide Orogeny
(Paleocene)
Horizontal OWC
Oil
OWC
Oil
OWC
Oil
OWC
Tensleep
Post Laramide Orogeny
(Eocene)
Tilted OWC
Tar deposits in
Tensleep outcrop
Meteoric water
Tensleep
outcropped
ROZ
MPZ
ROZ
OWC
Tensleep
Oil flushed
Down dip or move up dip

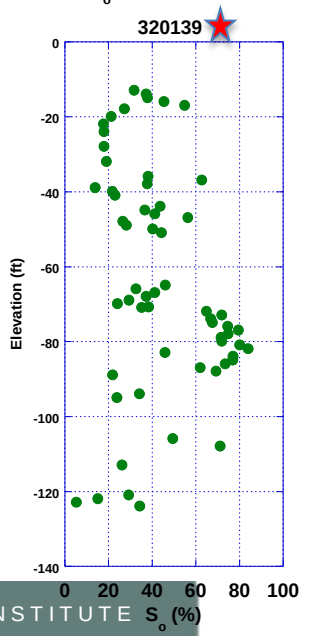
ROZ Distribution

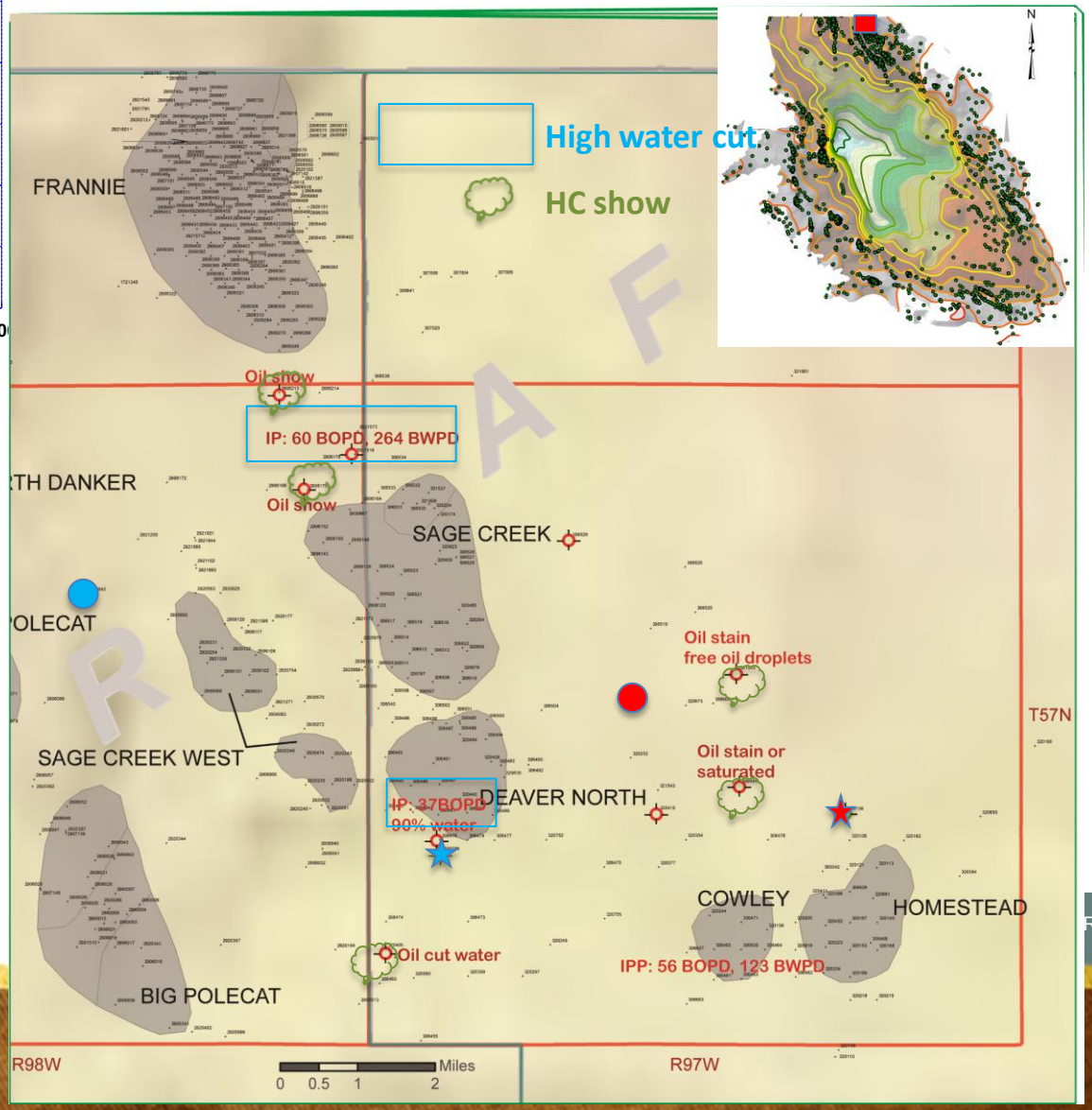
Frannie-Sage Creek-Homestead area





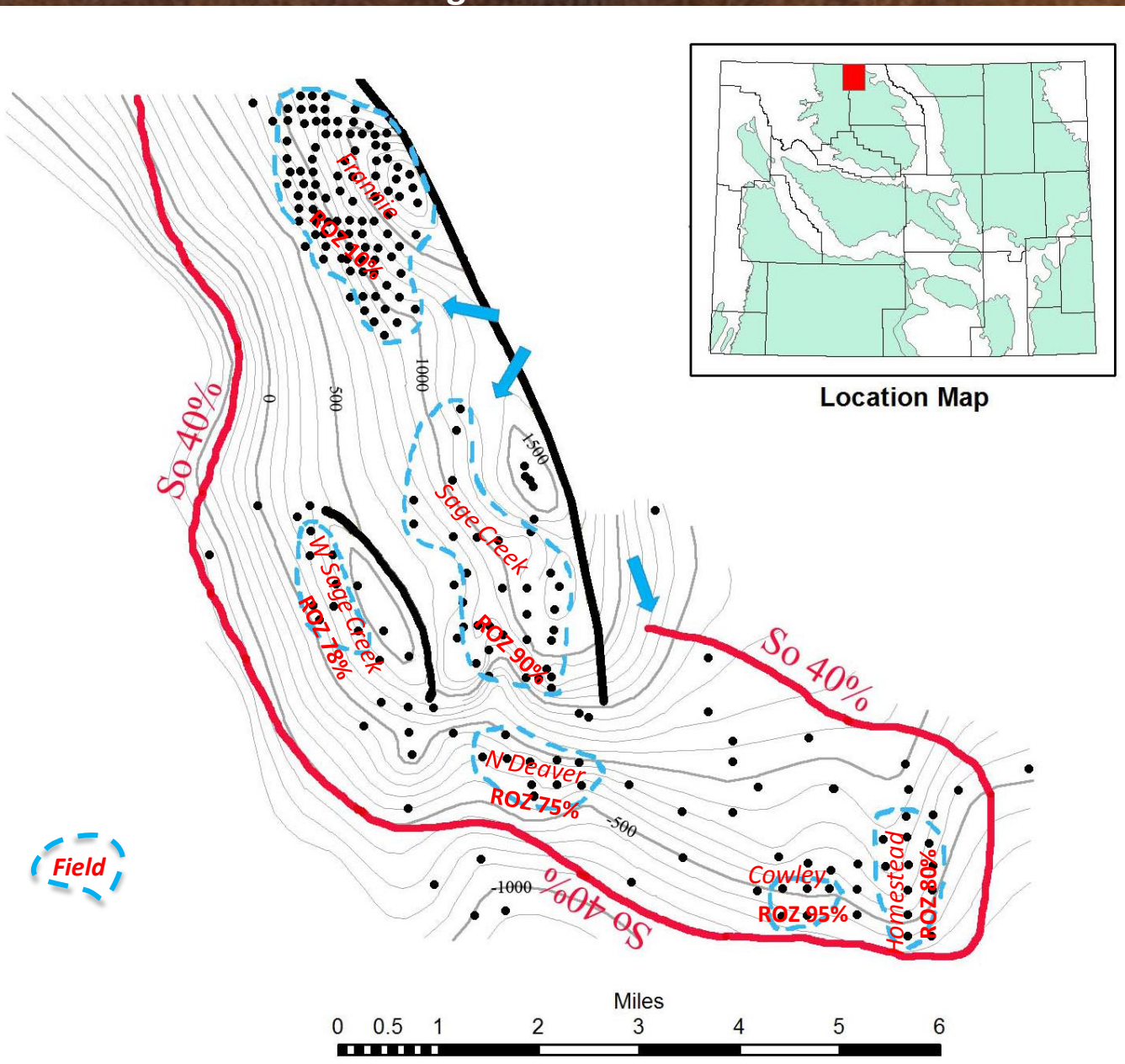






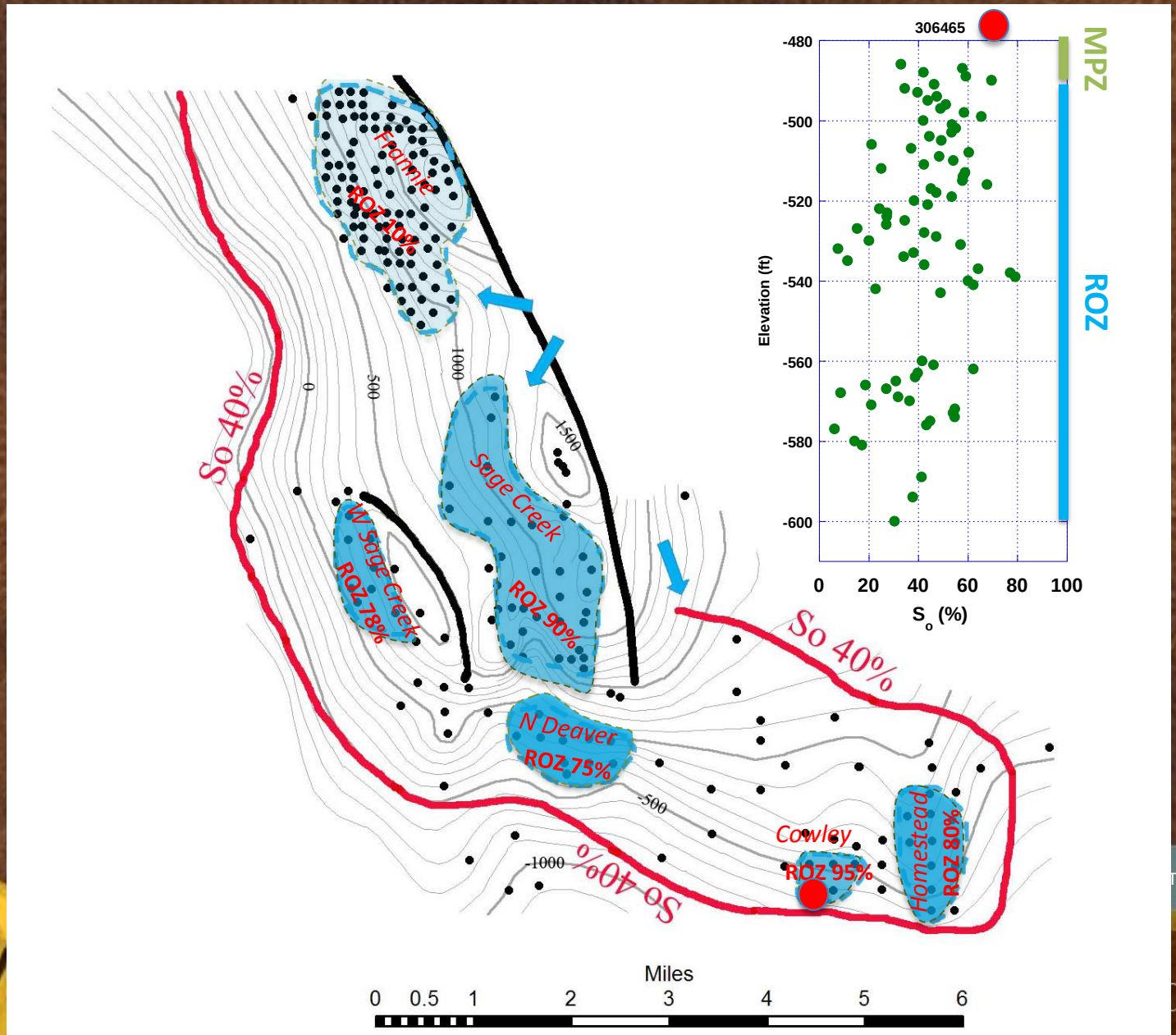
ROZ Identified around Reservoirs

Frannie-Sage Creek-Homestead area



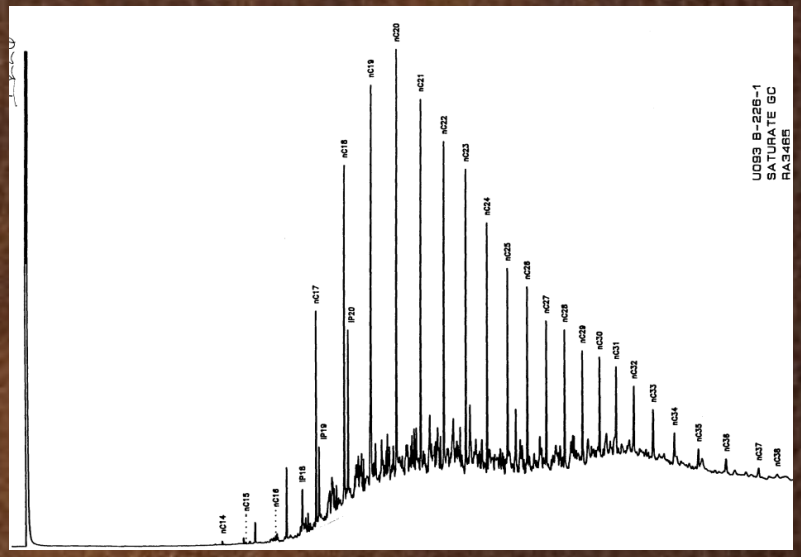
ROZ Identified below MPZ (Brown Field)

Frannie-Sage Creek-Homestead area

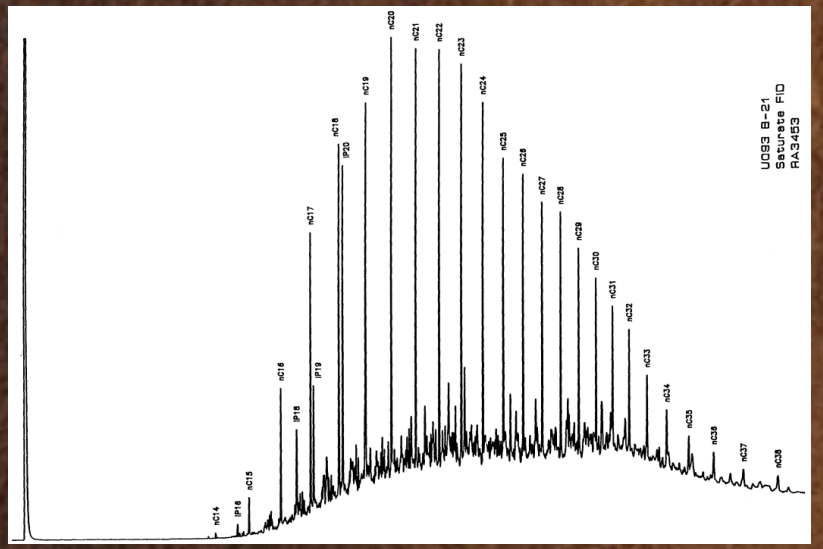


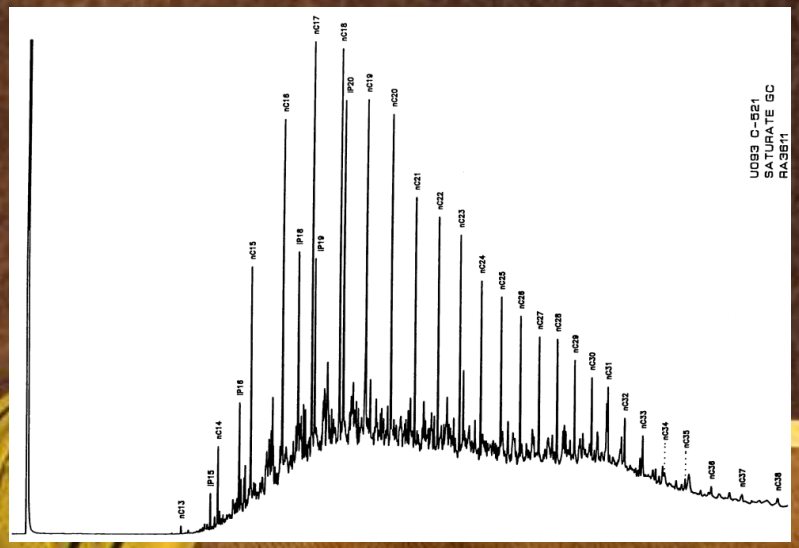
Oil Properties are similar in ROZ and MPZ

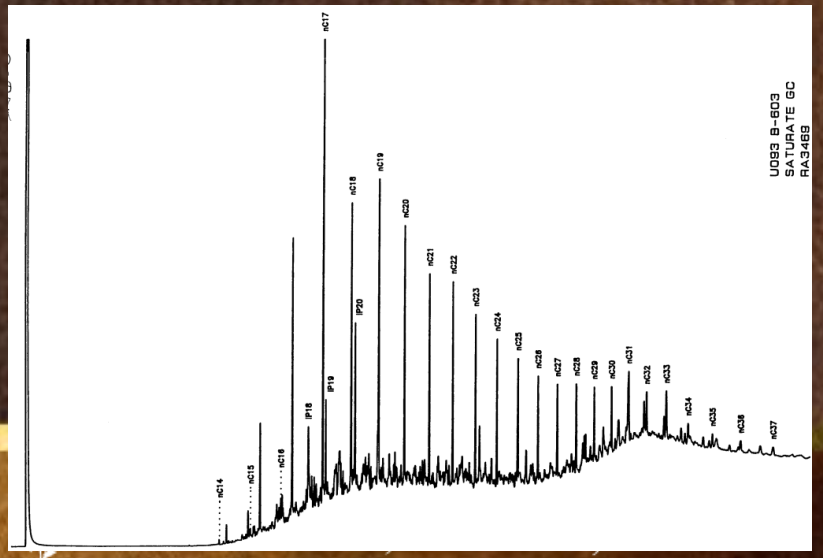
Reservoir Oil



Oil from Non-producing Wells

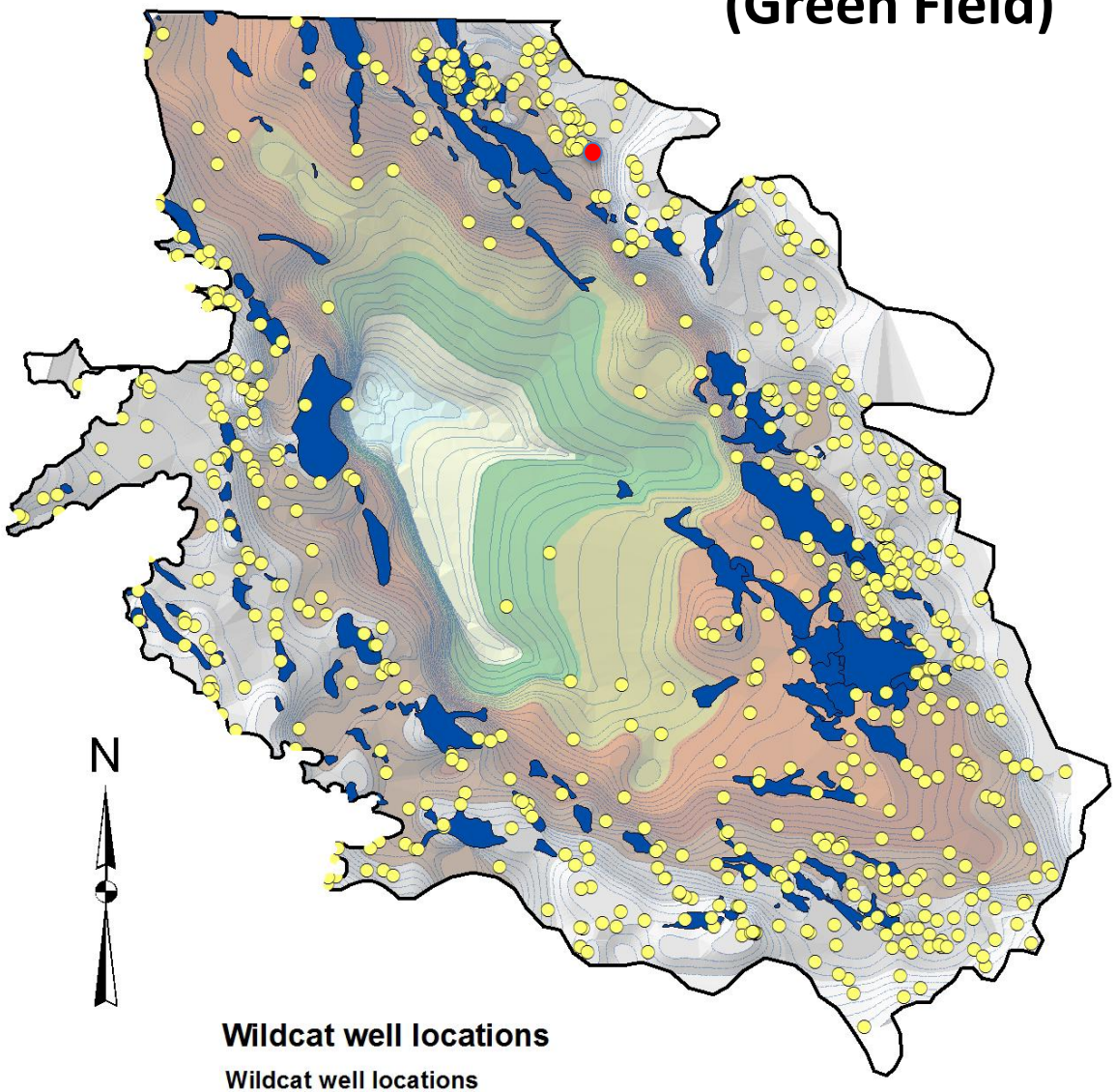


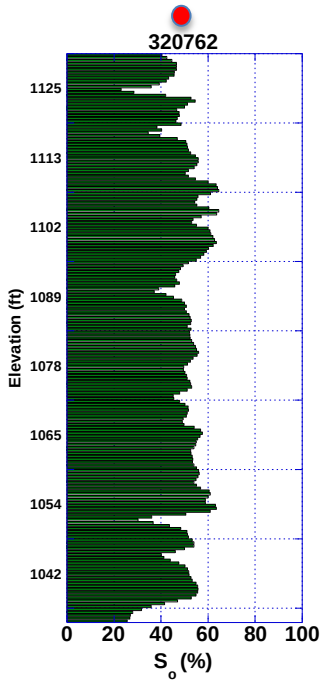


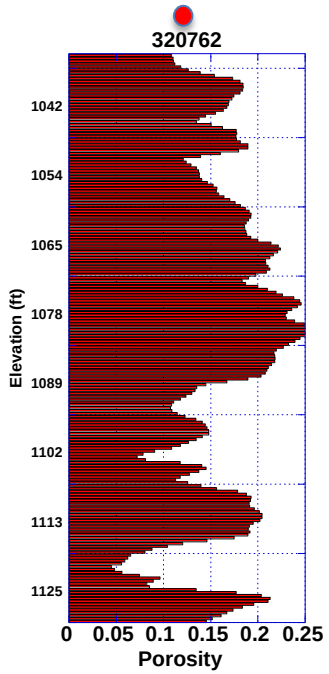


GC Analysis

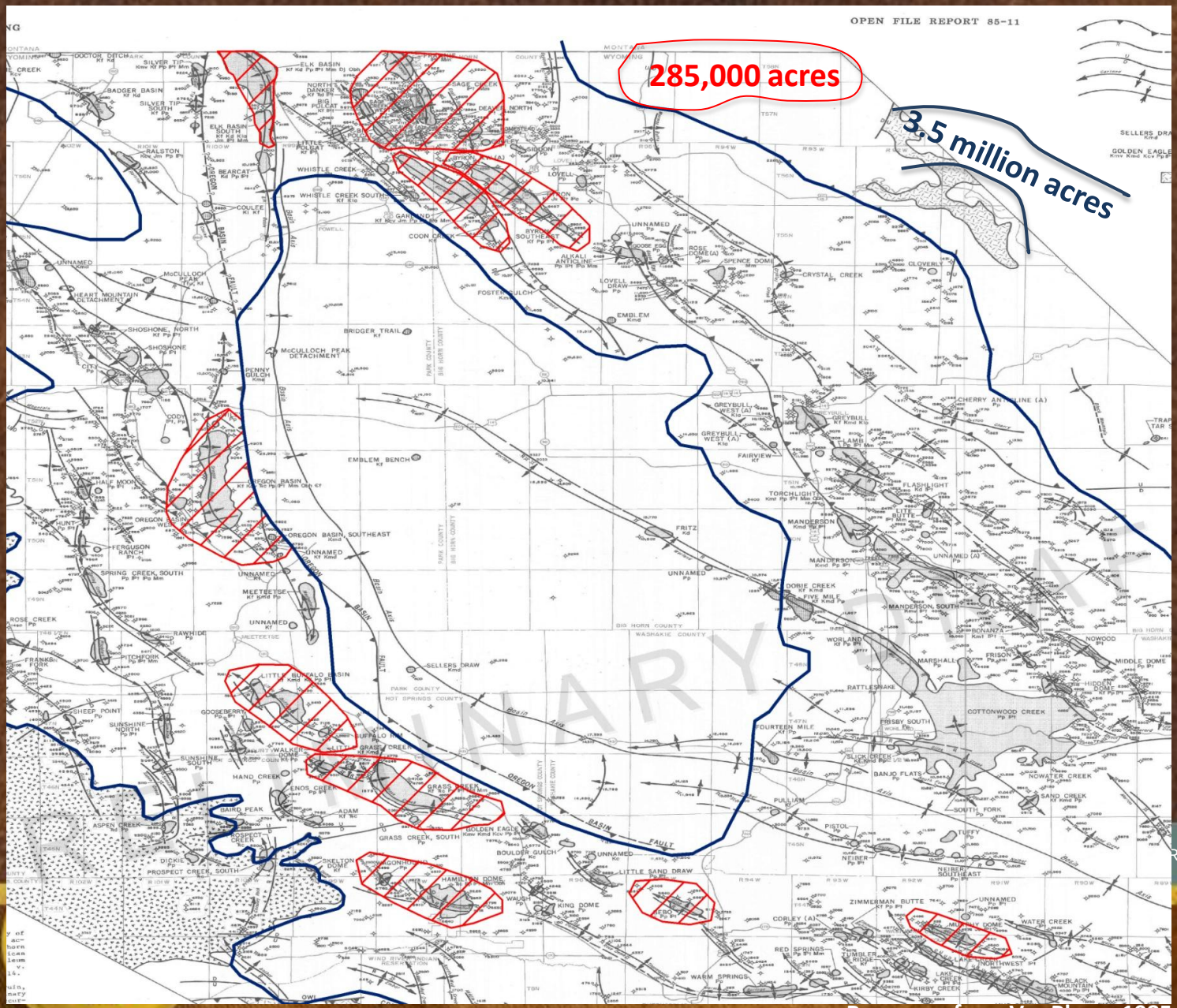
Wells with High Oil Saturation in Non-commercial Structure (Green Field)







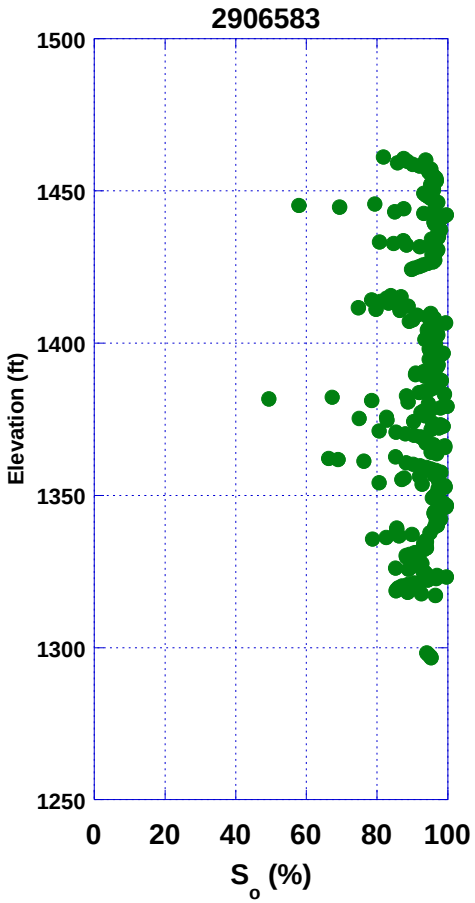
Proved and Predicted ROZ Occurrence in Bighorn Basin



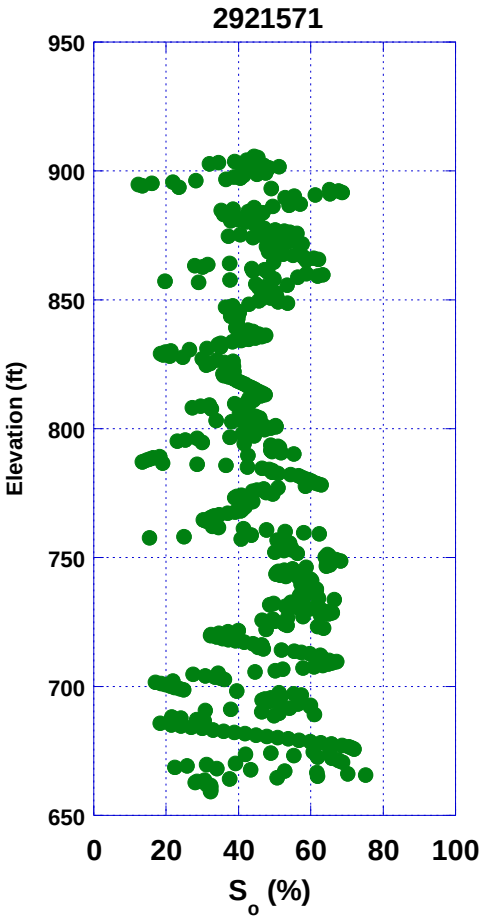
Based on:
ARI Report (2006)
EORI study

Base map from Ver Ploeg, 1985

Oil Saturation After Water Flooding

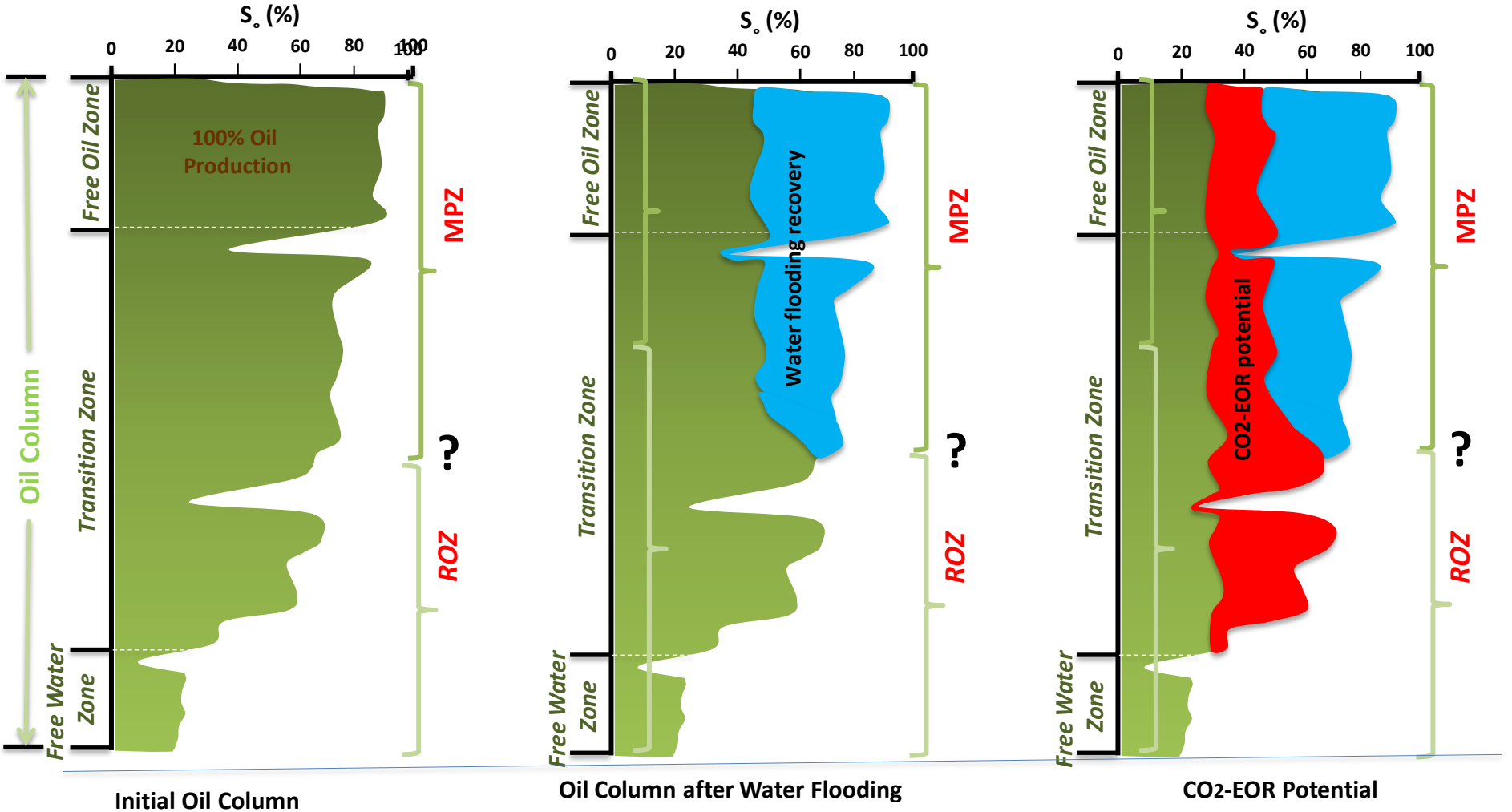


Initial Oil Saturation
1950



Oil Saturation after Water Flooding
1988

CO_2-EOR Potential



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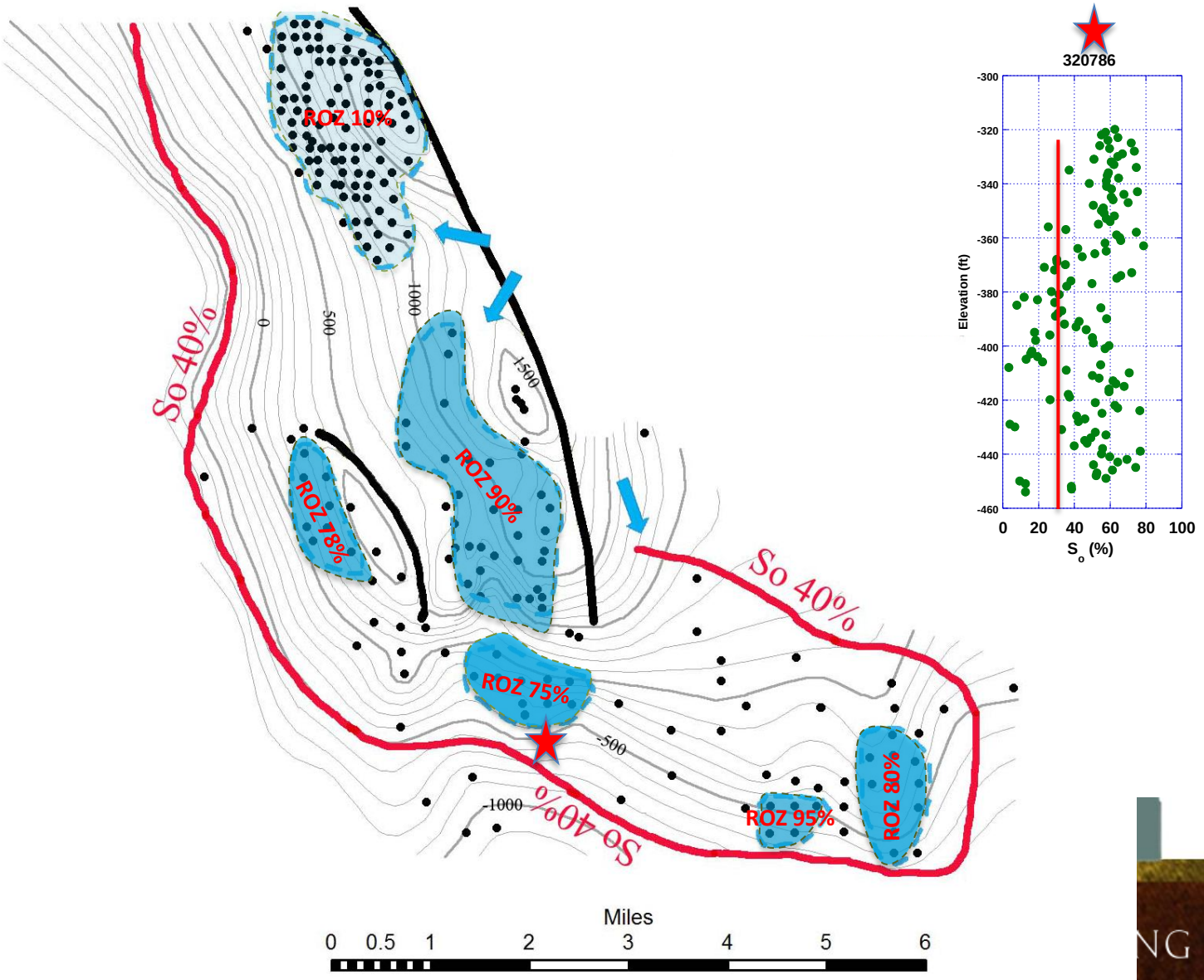
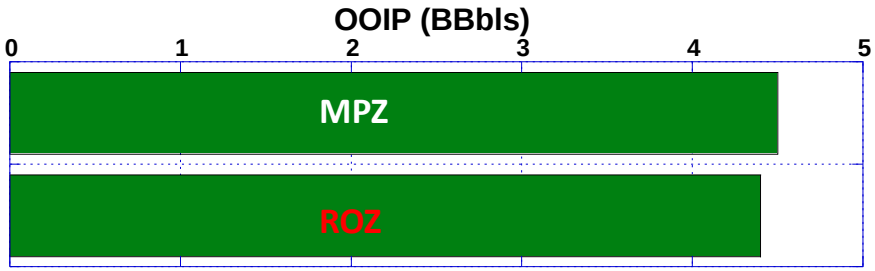
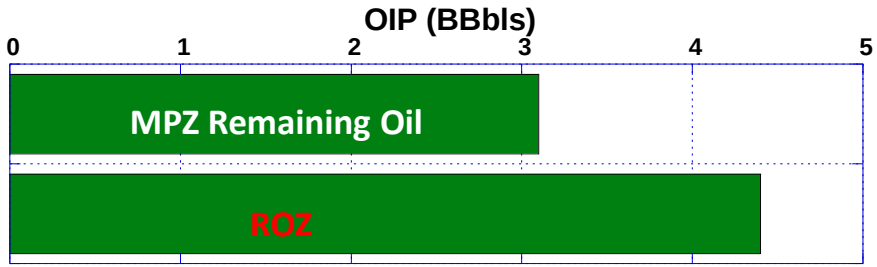
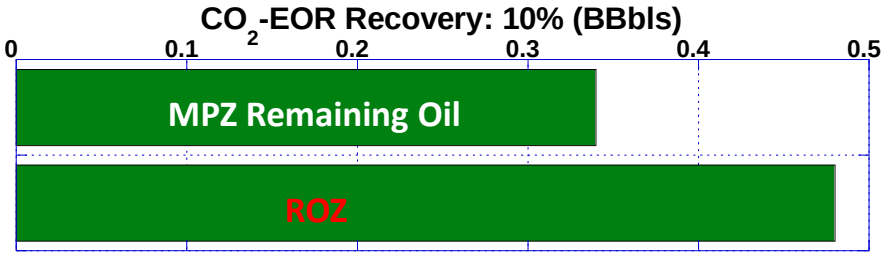
CO2-EOR Potential of ROZ

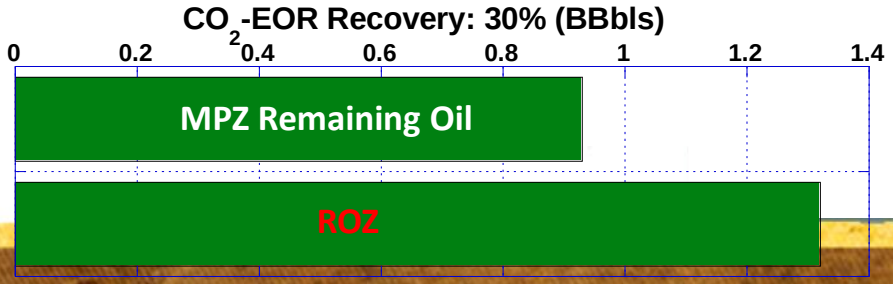


ROZ Potential of Tensleep Reservoirs









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.