PS The Impact of Post-Oil Emplacement Tectonics of the Delaware Mountain Group, with an Emphasis on Residual Oil Zone Potential*

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Abstract

The Impact of post oil emplacement tectonics in developing traps/fields in the Cherry Canyon Formation of the Delaware Mountain Group is well understood. Unfortunately, the presence of intervals, which produce only water, but with similar oil saturation to producing fields, have also been documented. Many of these pseudo-fields are actually the locations of the traps charged with oil and gas prior to late stage tectonism. These pseudo-fields are now potential residual oil zone (ROZ) enhanced oil recovery (EOR) "Greenfields". During early Cherry Canyon time, the depocenter of the Delaware Basin was located along the southwest margin of the basin, north of the Apache and Davis Mountains. The slope of the basin floor at that time was on average a 10 dip to the southwest through this AOI. The Laramide and the Basin and Range tectonics have resulted in +/- 5000' of uplift to the west and a "tilt" of the basin to the east. This resulted in a re-equilibration of oil, gas, and water in the submarine fan complex channel in the Delaware Mountain Group.

We obtained digital well logs along with well and production data for 200 wells from a commercial well database. Using a commercial software package, a petrophysical model was built to test the Greenfield hypothesis. Correlations of the Organic Rich Sequences (ORS) permitted the generation of gross and net isopachs of the channel sands. These maps determined the location of present day reservoirs, as well as identifying Paleo-Traps with Residual Oil Zone CO_2 Enhanced Oil Recovery opportunities. Using the Haversine formula and law of sines, calculations on the spatial distance between surface-hole locations and depending on that distance, the pre-tectonic measured depth of the Cherry Canyon Formation was derived. A map of the pre-Laramide tectonic structure of the Cherry Canyon was then created. Based on that study and other work in the area, the hypothesis that late tectonism has resulted in the re-equilibration of traps within the sand channel complexes and that an emphasis on CO_2 EOR in the ROZ in lower Cherry Canyon Formation is plausible.

Using four cores and petrophysical logs from the lower Cherry Canyon Formation, ORS or organic-rich Siltstones, were identified and found to be highly correlatable across northeastern Culberson and northwestern Reeves counties. This study also found that the thickness and reservoir quality of sands in the lower Cherry Canyon were highly variable. The study focused on the distribution of calcite cement in the reservoir

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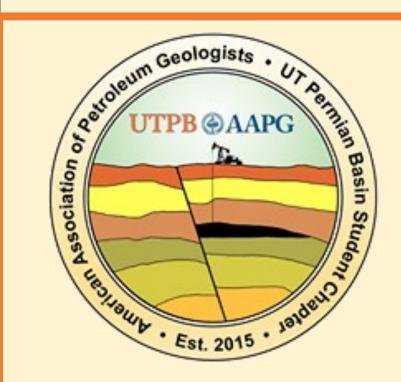
sandstones and determined that the calcite cements had only minor impact on reservoir quality. The four sand intervals studied represented the pay intervals in the West Ford (4100), West Geraldine, and Ford Geraldine Fields.

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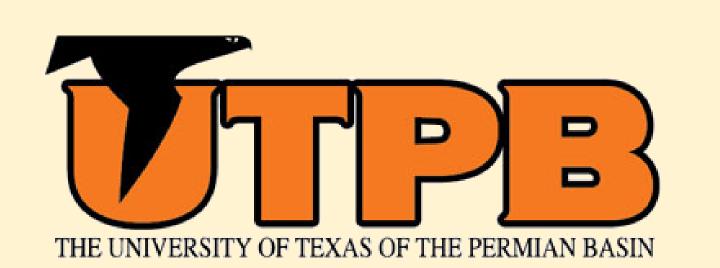
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During early Cherry Canyon time, the depocenter of the Delaware Basin was located along the southwest margin of the basin, north of the Apache and Davis Mountains. The slope of the basin floor at that time was on average a 1° dip to the southwest through this AOI. The Laramide, and the Basin and Range tectonics have resulted in +/- 5000' of uplift to the west and a "tilt" of the basin to the east. This resulted in a re-equilibration of oil, gas, and water in the submarine fan complex channel in the Delaware Mountain Group.

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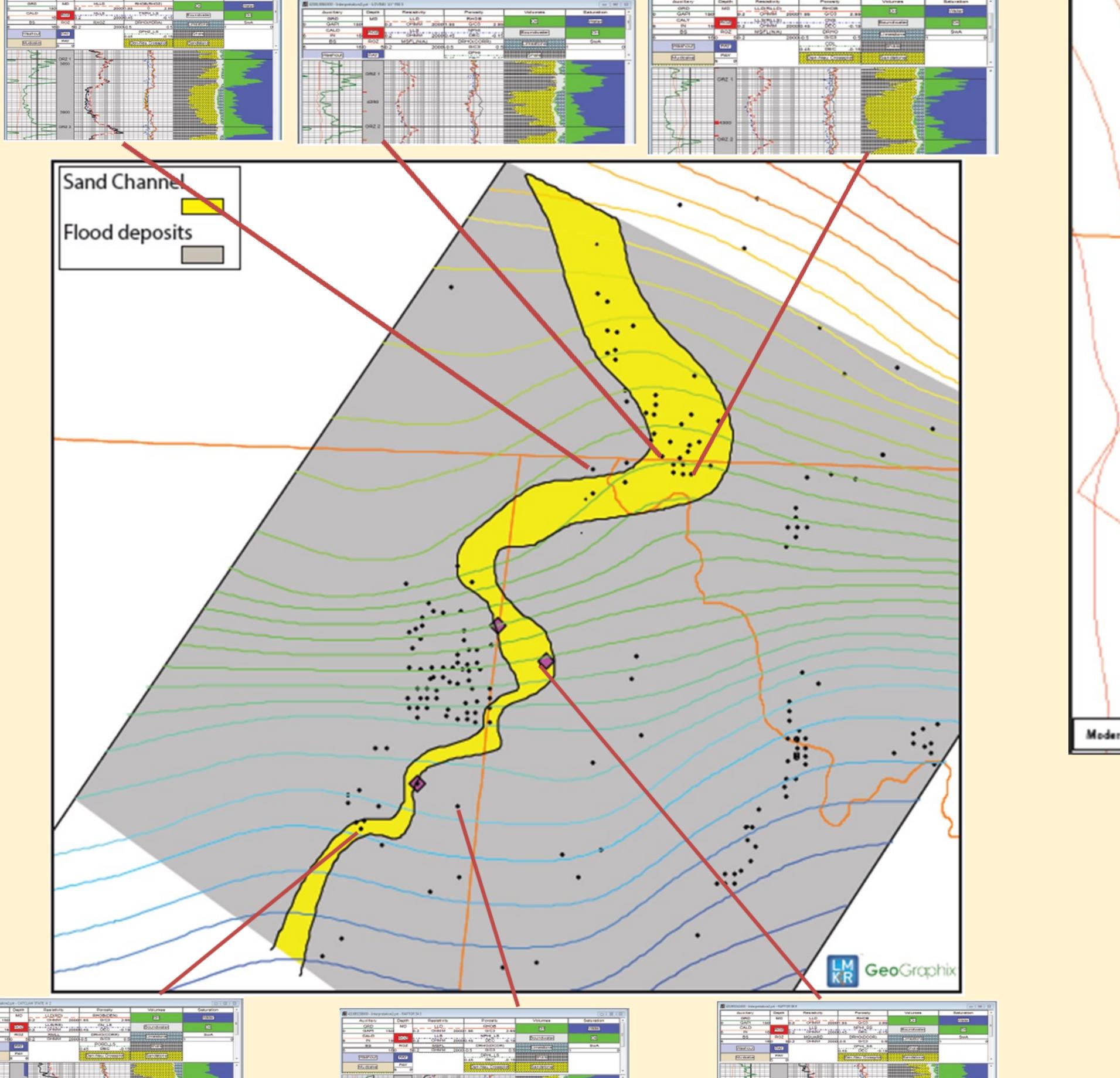
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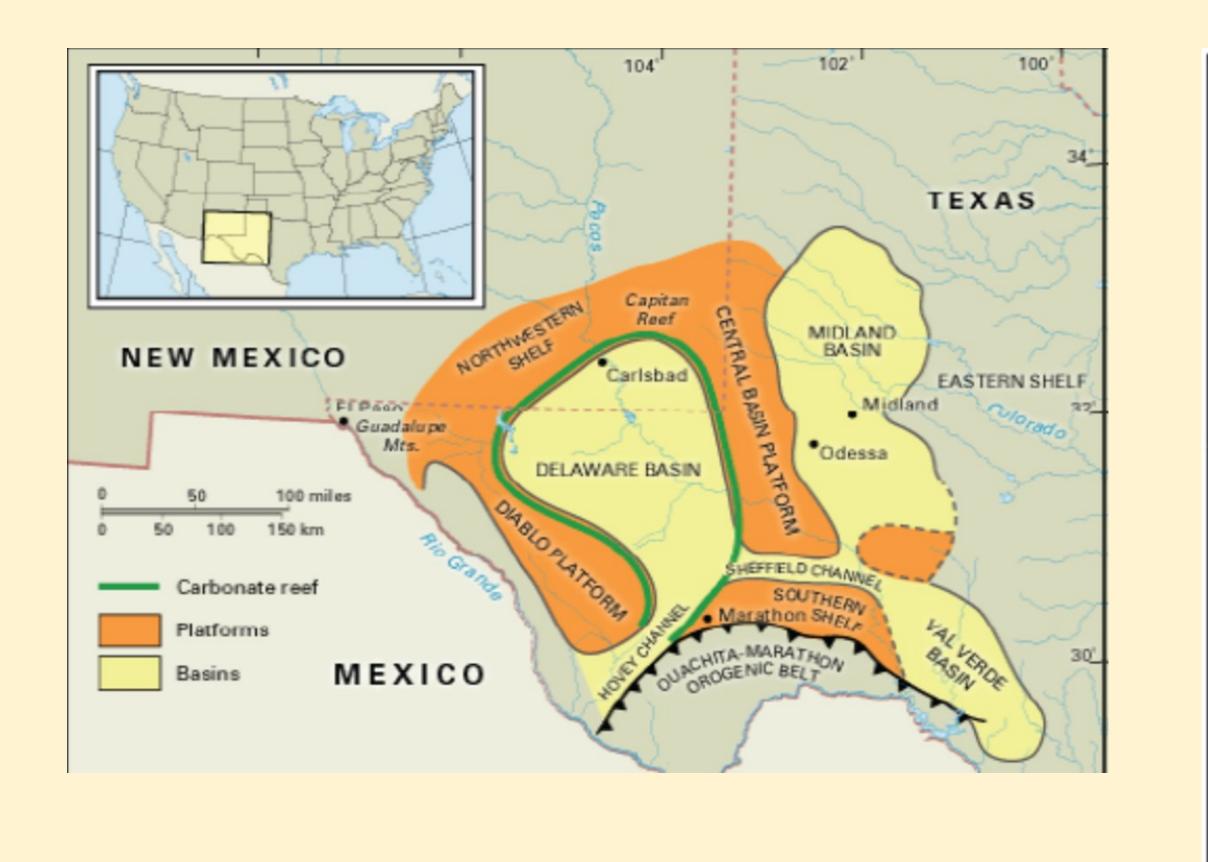
BACKGROUND

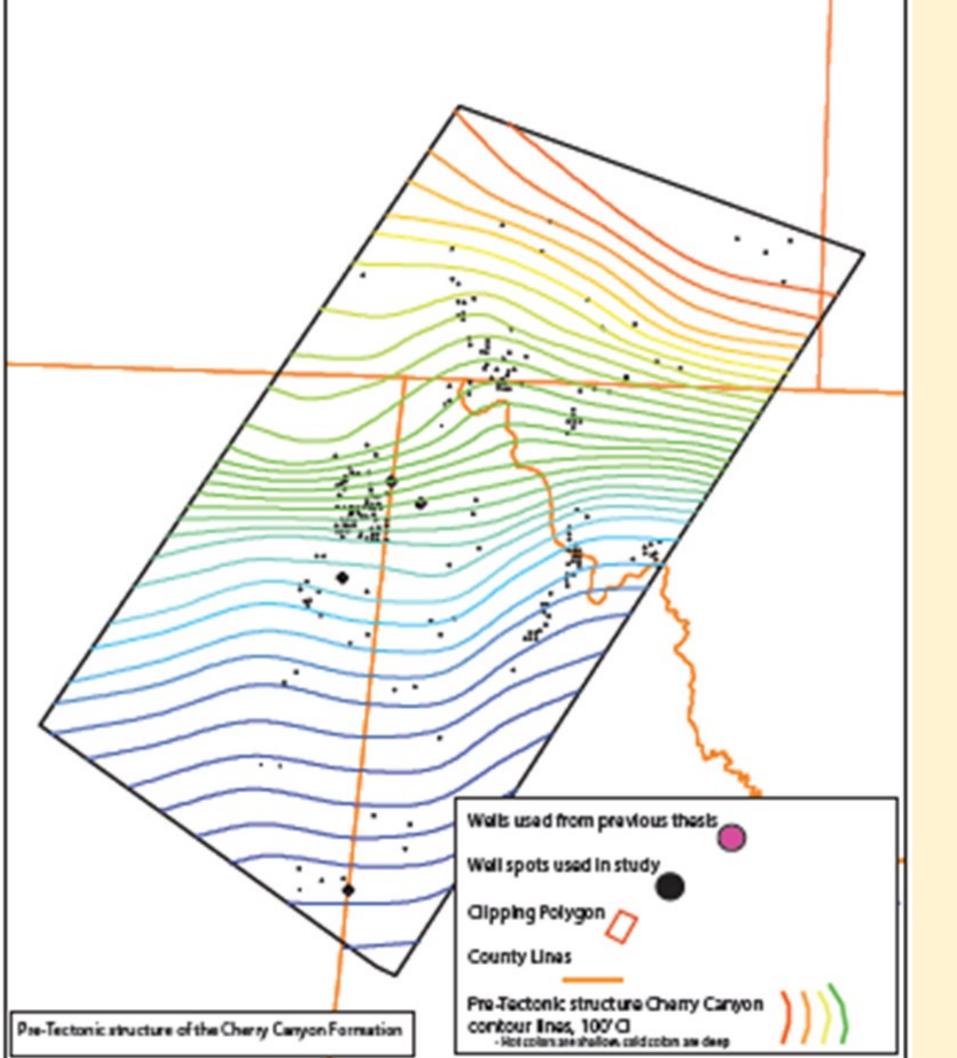
With previous studies completed on the Residual Oil Zone (ROZ) along with known ROZ fields being produced with Enhanced Oil Recovery (EOR) techniques on the Central Basin Platform of the Permian Basin, these workflows and current techniques could be applied to the basin formations. There is reason to believe that basinal sandstone and carbonate deposits could have the same producing capabilities via ROZ using EOR concepts. Regional geology and tectonic understanding of the Permian Basin is pivotal for EOR projects and the foundation of this study. Predicting the ancestral oil traps in the basin where hydrocarbons have migrated as a result of post-tectonic readjustment and into the current targets via tectonic displacement and Mother Nature's water flood, applying an EOR program to the asset is a viable option.

ROZs have as their analog, oil fields that possess mobile oil (main pay zones or MPZs), originally flowed oil naturally and then were secondarily water flooded until oil production neared zero. The "waterflood (swept) intervals" still have 20 – 40% residual oil in the pore space. The swept zones can be revived using CO₂ EOR. In fact, the Permian Basin (PB) now produces about 200,000 barrels of oil per from CO₂ floods. On average an additional recovery of 10 − 20% of the original oil in place in a field is possible using CO₂. This is oil that would not be recoverable without the aid of an injectant that liberates the oil. (R., Trentham, S., L. Melzer, D., Vance, 2012)

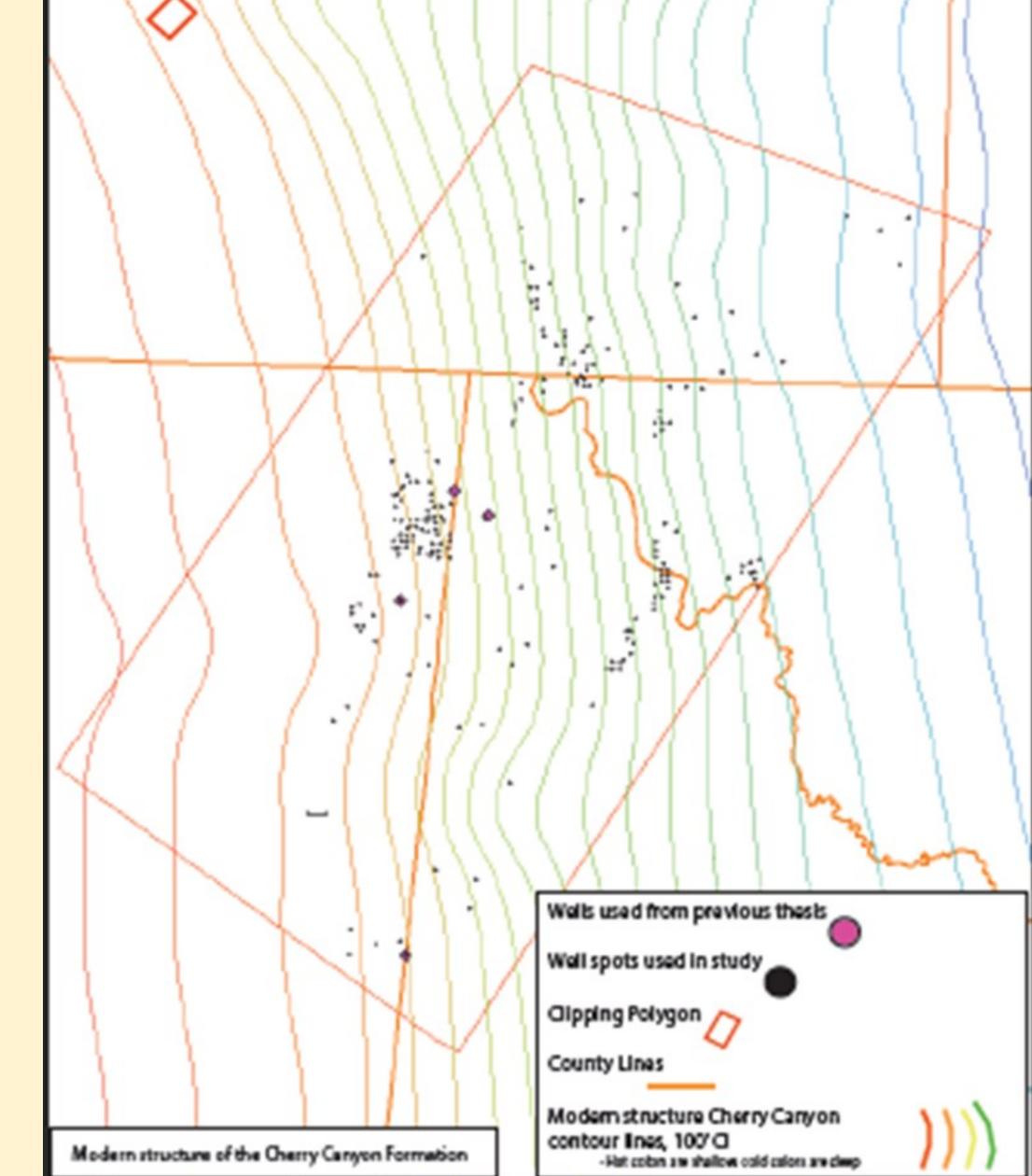
Asquith and Thomerson (1994) studied reservoirs with interesting hydrocarbon/water saturations in the Bell and Brushy Canyon, the formations that stratigraphically bound the targeted interval in this study, the Cherry Canyon. "The siltstone and very fine-grained sandstone reservoirs of the Permian Delaware Mountain Group often contain several zones that have shows of both oil and gas. When these zones are tested some are oilproductive with some water and others produce only water" (Asquith, G. B., Thomerson, M. D., 1994). Their work has a deeper focus on which reservoirs are more likely to have movable hydrocarbon for conventional drilling and which reservoirs will need the EOR techniques applied in order to produce the hydrocarbon. The significance of their study is concept of using more advanced petrophysical modeling to further identify potential ROZ's.

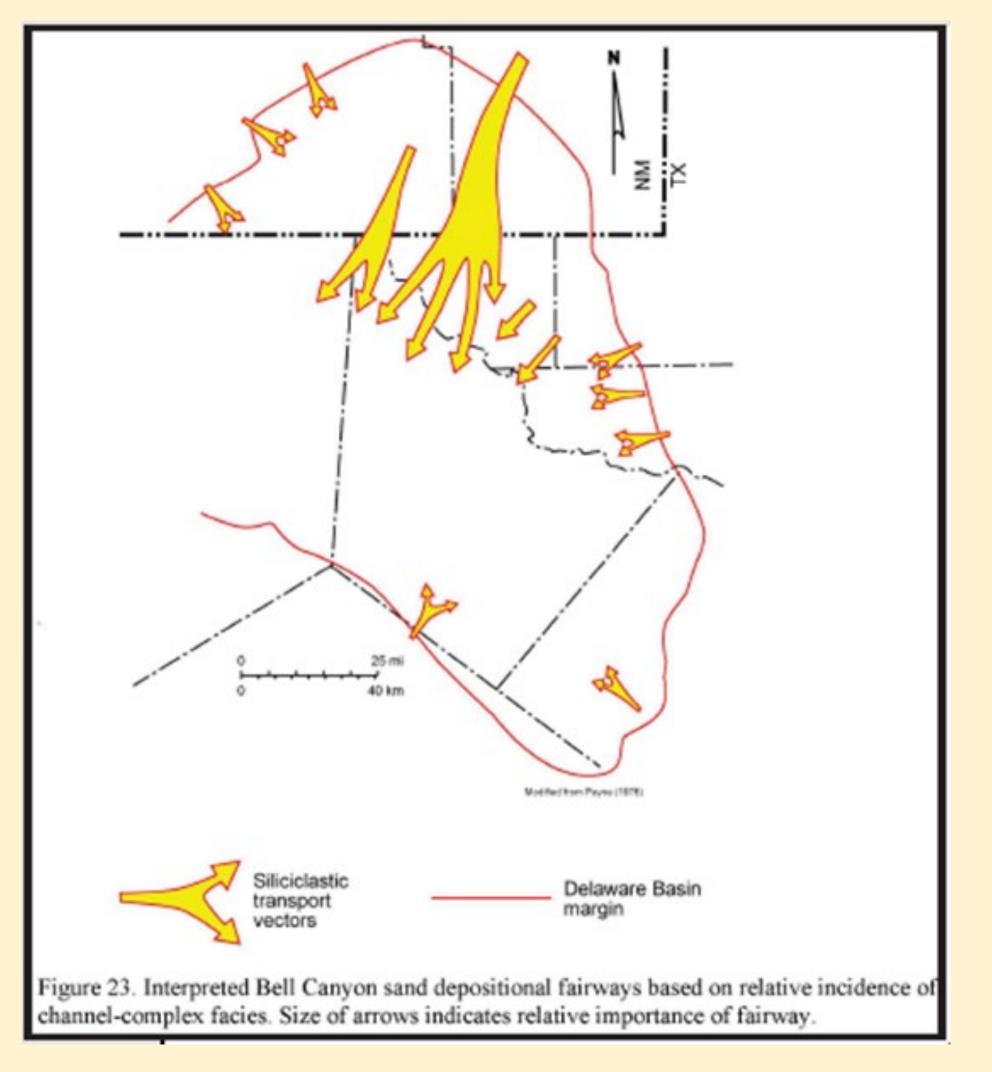






RESULTS





METHODS

Digital well logs along with well and production data for 200 wells were obtained from a commercial well database. Using a commercial software package, a petrophysical model was built to test the Greenfield hypothesis. Correlations of the Organic Rich Sequences (ORS) permitted the generation of gross and net isopachs of the channel sands. These maps determined the location of present day reservoirs, as well as identifying Paleo-Traps with Residual Oil Zone CO₂ Enhanced Oil Recovery opportunities. Using the Haversine formula and law of sines, calculations on the spatial distance between surface-hole locations and depending on that distance, the pre-tectonic measured depth of the Chery Canyon Formation was derived. A map of the pre-Laramide tectonic structure of the Cherry Canyon was then created. Based on that study and other work in the area, the hypothesis that late tectonism has resulted in the re-equilibration of traps within the sand channel complexes and that an emphasis on CO₂ EOR in the ROZ in lower Cherry Canyon Formation is plausible.

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Using specific log scale cut offs from 200 wells and the digital curves in a petrophysical model, channel deposits and flood deposits were distinguished. Between two distinct sea level high stands, Organic Rich Zones (ORZs) were deposited and bound the sand channels with impermeable rock. Using this understanding of the formation, sand channels could be identified and calculated into an isopach structure map. With the geometry of the channel mapped, and a tectonic understanding of the basin, the success of predicting ancestral oil traps increases in the area of interest. With the current ROZ reservoirs down dip of the reservoirs considered main pay today, there is convincing evidence to develop an EOR project. By injecting CO₂ into the wells that have the down dip ROZs it will sweep the reservoir produce closer to 100% of hydrocarbon from the channel.

OBJECTIVES

There is reason to believe that basinal sandstone and carbonate deposits could have the same producing capabilities via ROZ using EOR concepts. Regional geology and tectonic understanding of the Permian Basin is pivotal for EOR projects and the foundation of this study. Predicting the ancestral oil traps in the basin that have had the hydrocarbon migrated out and into the current targets via tectonic displacement and Mother Nature's water flood, applying an EOR program to the asset is a viable option.

CONCLUSIONS

The results from this study support the efforts of applying EOR techniques to basinal reservoirs in the Delaware Mountain Group of the Delaware Basin. With further work contributing to this study such as seismic interpretation to enhance the resolution of the geometry of the channels, full closure of the reservoirs could be identified and both current conventional and unconventional reservoirs could be produced. Using the proper cutoff's and petrophysical modeling, an operator could enhance their asset by identifying the ancestral traps and by implementing an EOR investment, produce up to 30% more hydrocarbon utilizing CO₂.

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