

Recognition and Exploitation of Residual Oil Zones Coming of Age

L. Stephen Melzer, Melzer Consulting
Robert C. Trenham, The University of Texas of the Permian Basin

June 11, 2015

Recognition and Exploitation of Residual Oil Zones Coming of Age

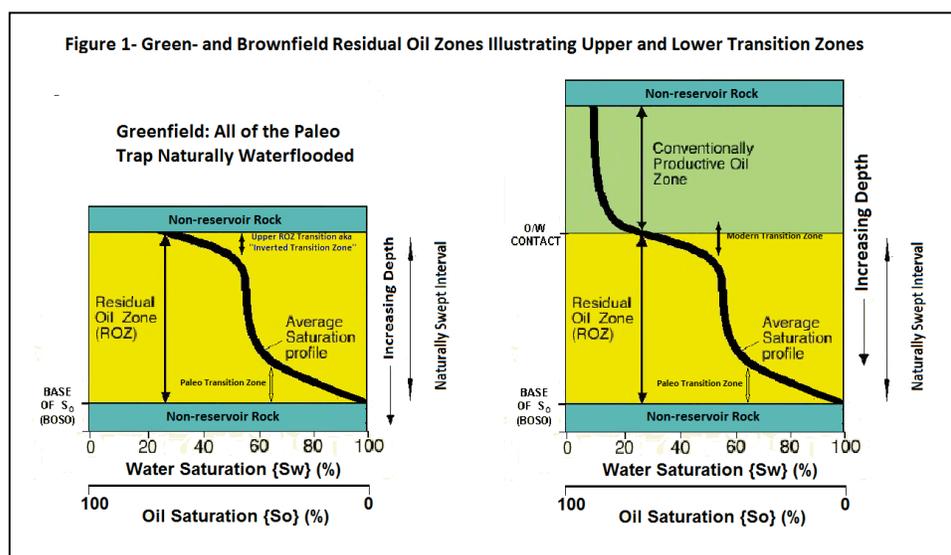
L. Stephen Melzer¹ and Robert C. Trentham²

Studies sponsored by the Research Partnership to Secure Energy for America (RPSEA) and the U.S. Department of Energy (USDOE) have opened the door to a whole new set of opportunities for commercial development of residual oil zones (ROZs) throughout the world. The historical understanding of the zones beneath the oil/water contacts in reservoirs had been relegated to the category of transition zones wherein capillary pressure and surface tension controlled the bottom of a reservoir; where there exists a mixed oil and water zone of several feet to tens of feet.

Recent research has shown that the zones below many oilfields are not only hundreds of feet thick but often possess an interval of nearly constant residual oil saturation sandwiched between the upward transition to mobile oil (main payzone or MPZ) and a lower transition to zero oil saturation below (Figure 1). These residual oil zones are also commonly observed to possess 20-50% oil saturation but with only mobile water. The research is also showing that they are present in extensive regions between oilfields.

With these ROZ observations as the basis, three types or origins of ROZs have been identified. All of these can be thought of as natural waterflood of a paleo oil entrapment. All come after the subsidence, oil generation and oil migration stage of a basin. They can owe their presence to a post entrapment 1) tilt of the paleo trap which can be a local or basinwide event, 2) leakage or breach of the seal above the reservoir, or 3) tectonic event on one side of a basin that creates an outcrop of the reservoir formation(s) and caused a lateral movement of meteorically derived water through the basin to outcrops on the downdip side of the basin. This last type is being studied extensively today in the Permian Basin San Andres formation and in the Tensleep formation in the Bighorn Basin of Wyoming.

The Permian Basin work sponsored by RPSEA has just completed a four-county study of the area between oil fields in what has been dubbed “greenfields” (see Figure 1). The areas have no well infrastructure in place since all of the wells drilled there were dry



¹ Engineering Consultant, Melzer Consulting, Midland Texas

² Senior Lecturer, Geology and Director, Center for Energy and Economic Diversification, The University of Texas of the Permian Basin

holes. The RPSEA sponsored work has identified 76 billion barrels of high quality target ROZ reservoirs where the oil saturations exceed 25% and the formation porosity exceeds 8%. ROZ resources have to be produced by processes that alter the properties of the oil to render it mobile. The 4-county region encompasses approximately 4100 square miles and includes 12 ROZ CO₂ EOR projects.

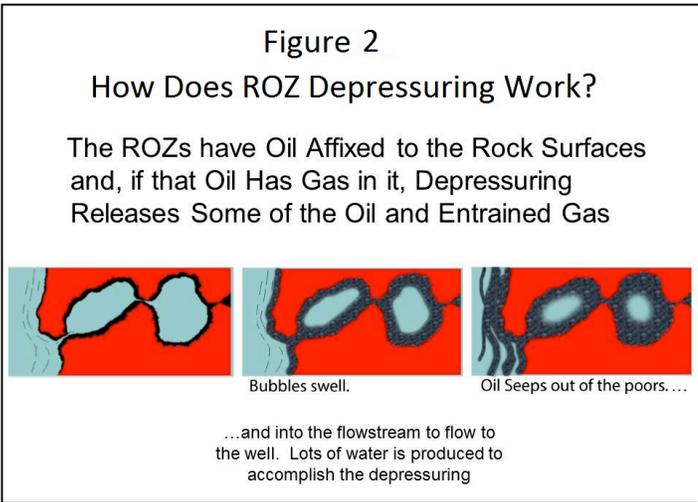
Today, the Permian Basin plays host to a total of 15 individual CO₂ EOR projects exploiting the ROZ. By conservative measures, these newly implemented projects are producing well over 12,000 bopd of formerly immobile ROZ oil. All but two of these projects involve deepening the wells in an oilfield into the ROZ (brownfields) but two have recently been completed in Greenfield areas. The Tall Cotton project in Gaines County, put into operation late last year by Kinder Morgan CO₂ Company, is especially notable in its potential size. Today, the project consists of nine injectors and fourteen producers on a forty-acre 5-spot configuration. While industry is leading the deployments, the ROZ science work sponsored by RPSEA clearly has provided much of the scientific platform for the ongoing commercial work. Time will tell what the enhanced oil recovery potential will be but the research sponsors can claim a major role in the implementation of the greenfield projects.

One of the characteristics of ROZs, especially the upper portions, is that when drilling through the formation, the oil and gas 'shows' from those intervals of immobile oil are equally as enticing as oil shows from the main payzones. Some drilling includes coring but even this often gives false indicators of mobile oil. As a result, many vertical well completions have been tried making very large volumes of sulfur water with non-commercial volumes of oil.

Very recently, some operators have utilized the evolving technologies of horizontal drilling and staged hydrofracturing completions to attempt to establish commercial production in these intervals. There are several examples of 1-mile long laterals with peak production levels of 250 bopd or more and projected ultimate recoveries of 250,000 barrels of oil or more. Total well costs are such that the economics are working at \$60 oil prices if water disposal costs can be controlled. The typical initial water production rate is 1500 to 2000 barrels per day and accompanied with no oil for 30-40 days. After that period oil cuts rise to 10-25% as the well matures.

The production concept is not yet widely recognized as the industry's grasp of residual oil zones and their origins is not widespread and understanding of the mostly oil wet ROZs is still immature. Some believe the oil is coming from the mobile portion of the fluids in the transition zone. However, time should prove that the oil is actually residual oil that has sufficient gas in solution to cause the immobile oil of the ROZ to break out as the pressures decay, analogous to the solution gas drive mechanism long witnessed and modeled in the mobile oil portions of reservoirs. Figure 2 is an attempt to demonstrate the principles of this process we have tentatively dubbed depressuring EOR (DEOR) or depressuring the upper ROZ (DUROZ).

All of the above understanding of the origins and distributions of ROZs and



emergent commercialization of the ROZ has occurred in the Permian Basin's San Andres dolomite formation. The ROZ researchers are beginning to believe that such discoveries are in no way exclusive to the Permian Basin but will soon see deployment in a variety of basins throughout the world. In fact, it is highly likely that most of the so-called dewatering plays around the U.S. are not connecting up mobile oil compartments in reservoirs but are, in fact, an ROZ depressuring play, at least in part.

Finally, it is interesting to reflect on the amazing explosion of new ideas and production occurring in the U.S. today. It is clearly a product of a number of factors but the availability of research sponsoring organizations such as RPSEA and USDOE are very significant. Just as important are private mineral ownership, the availability of capital, and the wealth of entrepreneurs in the oil and gas producing and service sectors willing to experiment on new things. Taken collectively, they have all combined to be the accelerant for the innovation being witnessed today. Producing the residual oil zones by CO₂ EOR and DEOR/DUROZ are two excellent examples.