Abstract

Residual Oil Zones (ROZs) are volumes of rock in which oil accumulated and was later naturally displaced by encroaching water, leaving residual oil saturation in the range of 20 to 40%. Carbon dioxide enhanced oil recovery (CO2-EOR) is used to recover oil from known thick carbonate ROZs in the Permian Basin. In other basins, ROZs are not recognized or are ill-defined. Due to the technical and economic limitations of recovering oil at residual saturation to water, there have been few attempts at ROZ production. Therefore, a challenge in ROZ resource assessment is identifying ROZs and quantifying the oil in place. In addition to the economic benefit of oil production via CO2-EOR, ROZs have the potential for associated CO2 storage. In the Illinois Basin, an ROZ play has been identified in the Mississippian Cypress Sandstone. The results of the resource assessment of the Cypress ROZ play will be presented.

Background and Study Area

Cypress Sandstone (Upper Mississippian) of the Illinois Basin

- Multiple depositional facies (Below)
- Oil production (green dots) dominantly from sandstone lenses
- Thick Cypress Sandstone reservoirs are an under-produced resource
  - Thin main pay zones (MPZs) above thick (100+ feet) brine aquifers
  - Water coning issues hamper oil production attempts

- Thin MPZs have potential underlying residual oil zones (ROZs)
  - Porous and permeable fairway may have been naturally waterflooded
  - EOR potential in MPZ + ROZ with high net CO2 utilization
  - Saline storage potential of 3.5 to 40.2 Tcf (0.2 to 2.3 Gt) of CO2 in the Illinois Basin (DOE/NETL, 2012)

Residual Oil Zones (ROZs)

- Formed as a result of natural waterflooding over geologic time
  - Brownfield: Has MPZ
  - Greenfield: No MPZ
- Same characteristics as swept portions of a mature waterflood
- Permian Basin examples
  - 15% to 35% So
  - 10% to 20% can be recovered by CO2-EOR
- Scale and saturations could be different in the Cypress Sandstone of the Illinois Basin

Motivation

Determine the potential resource for net carbon negative oil production via CO2-EOR and geologic storage in a siliciclastic ROZ

Objectives of this four-year study include:

- Characterizing geology of CO2-EOR target Cypress Sandstone
- Identifying ROZs via direct and indirect oil indicators
- Developing a CO2-EOR and storage strategy for the regional resource based on detailed case studies
Methodology: ROZ Identification and Mapping

Understanding petroleum migration into (e.g., Lewan et al., 2002) and reservoir characteristics of the Cypress Sandstone in the Illinois Basin (e.g., Webb et al., 2016) provide the framework for identifying potential ROZs.

Results: ROZ Fairway and Prospects

Applied well log analysis to quantitatively determine the thickness and saturation values of residual oil.

Followed Trentham and Melzer’s (2016) “cookbook” approach to document and reinterpret existing data to identify oil indicators used to explore for ROZs:
• Production or perforations
• Oil shows
• Core oil saturation
• Drill stem tests

Identification of oil indicators, especially in areas with no associated production and within the thick sandstone fairway, guided the selection of wells for further analyses.

Above - The Cypress Sandstone ROZ fairway (shaded in brown) is defined as the area of the Basin that, based on regional mapping and data analysis, has potential to contain ROZ prospects. Map developed based on:
• Isopach map to define porous and permeable facies
• Isopach and structure maps guided spider map of potential oil migration pathways
• Occurrence of oil indicators from well data (~18,000 wells with oil indicators) and well log analysis

Below - The Cypress Sandstone ROZ fairway (shaded in brown) is defined as the area of the Basin that, based on regional mapping and data analysis, has potential to contain ROZ prospects. Map developed based on:
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Within the ROZ fairway, discreet ROZ prospects were defined (Above Right)
• Prospects were delineated by grouping wells with Cypress oil indicators with wells in which well log analysis indicated a ROZ
• Structure and thickness maps were used to delineate the boundaries of each potential prospect, where appropriate; some prospects lack clearly defined structural closure
• Regional isopach map was used for volumetric calculations within each defined prospect (Right)
Conclusions:
Cypress Sandstone Resource Assessment
• Preliminary estimate of oil in place for all ROZ prospects
  ◦ Oil in place may or may not be technically recoverable
  ◦ ROZ fairway likely contains oil beyond the boundaries of the prospects defined here
  ◦ ROZ S_{oil} = 16%  R_{oil} SOR = 23%  R_{oil} SOR = 30%
  | 1.3 billion bbl | 1.8 billion bbl | 2.4 billion bbl |
• Based on well log analysis, the median So within Cypress ROZs is 23%, with +/- one standard deviation of 16% and 30%
• MGSC (2005) estimated the total original oil in place for Cypress Sandstone main pay zones in the Illinois Basin to be 2.65 billion barrels
  ◦ Identified ROZ prospects may contribute an additional 49% to 91% to oil in place values for the Cypress Sandstone

References

Future Work: Continued Research on Illinois Basin ROZs
ROZ validation and screening for other ROZ and stacked CO_{2}-EOR and associated storage opportunities
• Conduct additional well log analyses to improve confidence in:
  ◦ Spatial distribution of Cypress ROZ fairway and prospects
  ◦ ROZ thickness, porosity, and saturation
  ◦ Volumetric estimates of oil in place
• Apply CO_{2}-EOR and storage factors based on reservoir simulations and published results to determine economic viability of the ROZ Prospect to validate thickness and saturation estimations
• Expand analyses to include other Illinois Basin formations with potential to host ROZs (Right)

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• For project information, including reports and presentations, please visit:
  www.isgs.illinois.edu/research/erd/nco2eor

Contributors
The four year study of the Cypress Sandstone involved contributions from a number of ISGS staff:
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