Using well log analyses to identify ROZs for CO_2-EOR; an example in the Cypress Sandstone

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Project Description

Carbon dioxide enhanced oil recovery (CO_2-EOR) has been used to economically produce oil from thick residual oil zones (ROZs) in the Permian Basin. To identify and characterize historically overlooked ROZs in other basins, analysis of existing well logs may be a cost effective preliminary screening tool. However, traditional open-hole well log analyses focus on higher oil saturations common in main pay zones (MPZs), with specific analyses focused on irreducible saturation and movable hydrocarbons. This study presents a procedure that uses a combination of established well log analysis methods to identify lower oil saturations typical of ROZs.

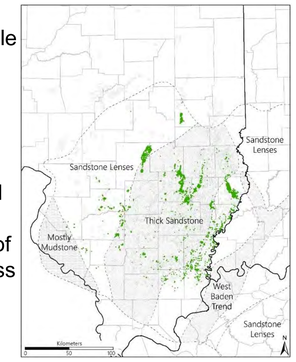
Archie, ratio, and dual-water methods were used to calculate oil saturation, and a combination of the moveable hydrocarbon index, bulk volume water, and apparent water resistivity were used to aid in picking the top and base of the MPZs and ROZs within example wells in the Cypress Sandstone in the Illinois Basin. Results indicate ROZs approximately 25–30 ft (~8-9 m) thick and 30–50 ft (~9-15 m) thick at the Noble and Kenner West Oil Fields, respectively. Residual oil saturation at both fields is around 20%–30%. Logs were analyzed elsewhere within the fairway of thick fluvial Cypress Sandstone to identify other areas that have the potential to contain ROZs and estimate the extent of the ROZ fairway. The results demonstrate that well log analyses based on a robust understanding of geologic variability can be used to detect low oil saturations found in siliciclastic ROZs and may be applicable in analogous basins.

Motivation

- Existing well logs in the Illinois Basin could represent a very large dataset to identify and characterize historically overlooked ROZs
  - Parameters for initial conditions
  - Estimation of residual oil saturation/OOIP
  - Ultimate oil water contact

Background

- Detailed studies at Noble and Kenner West oil fields
  - Geologic characterization
  - Production history
  - Validate with pulsed neutron
- Expand search to rest of interpreted thick Cypress Fairway



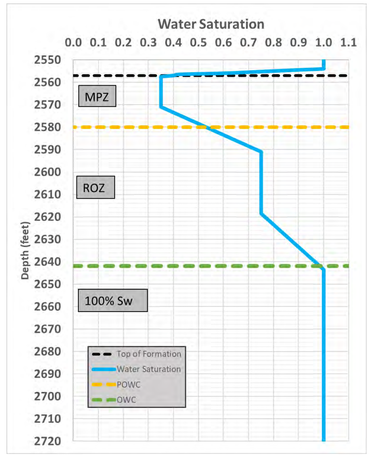
Interpreted fairway of thick cypress sandstone. Cypress oil production shown in green. Modified from Nelson et al., 2002

Water Saturation

- Water saturation (Sw) will vary with depth according to predicable behavior
- Sw was calculated from logs using Archie, Dual Water, and Ratio methods
- Cementation exponent used to match Rwa= known Rw and Sw=100% known water saturated intervals

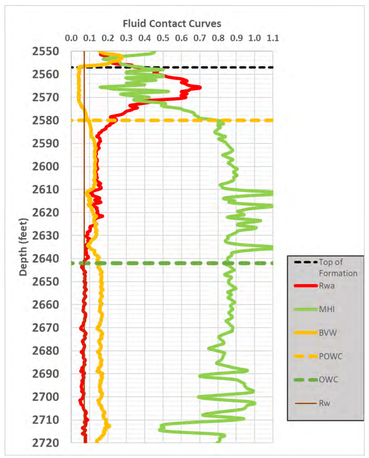
Fluid Contact Curves

- Apparent water resistivity (Rwa), moveable hydrocarbon index (MHI), and bulk volume water (BVW) were also calculated to validate POWC and OWC
- Each has unique properties within the main pay zone (MPZ), ROZ, and 100% Sw base that can be used to validate water saturation curves



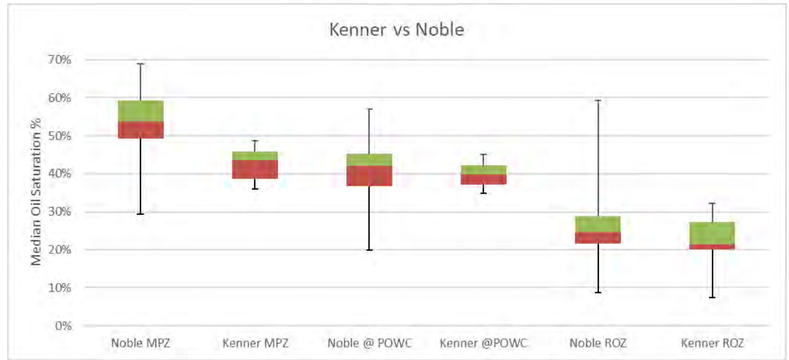
Left: Ideal water saturation profile. Low water saturation in MPZ higher in ROZ, 100% in water saturated base. Intervals separated by POWC and OWC

Right: fluid contact curves used to validate POWC and OWC. Rwa is very high in the MPZ, lower in the ROZ, and at Rw (0.07) in base. MHI is <0.7 where mobile oil is present and >0.7 where it is not. BVW stabilizes at irreducible water saturation according to grain size



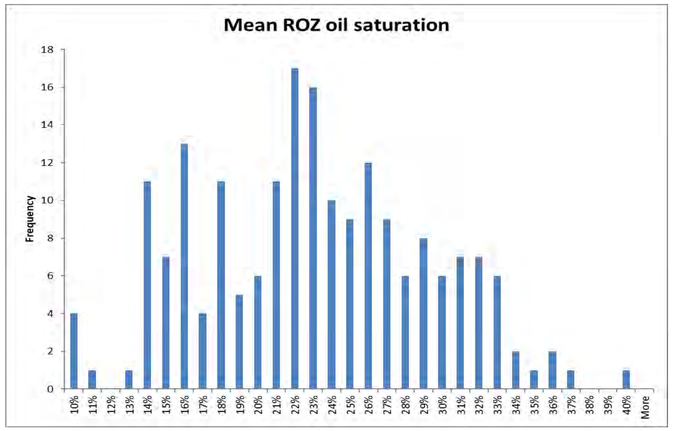
Application to Noble and Kenner West

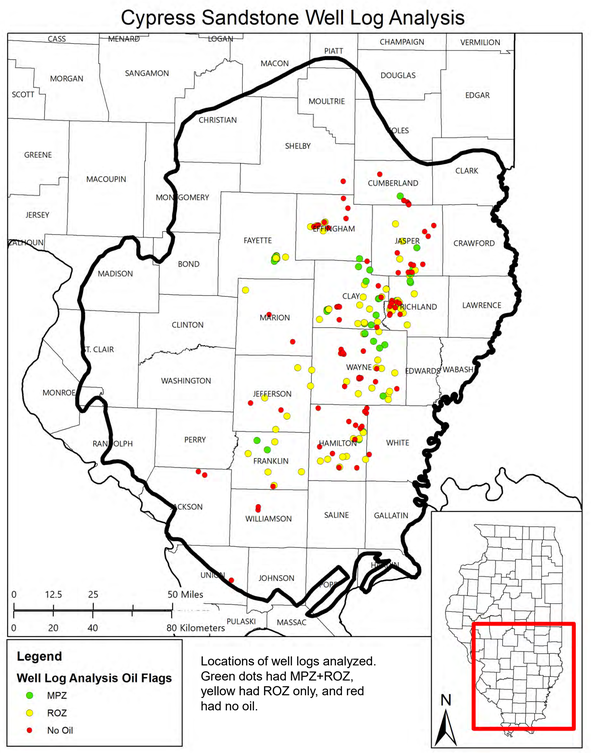
- Analyzed 94 wells at Noble and 9 wells at Kenner West.
- Both fields have similar properties (porosity, clay content) and historical production from thin main pay zone (<30 ft) above thick (~100 ft) aquifer
- 4 pulsed neutron logs at Noble to validate water saturation profiles
- Residual oil saturation at both fields between 20-30%
- Cementation exponents at both fields converged at 1.85



Regional Application

- Analyzed ~280 wells around the basin
  - Estimated Rw from published regional trends (Meents et al., 1952 and Demir, 1995)
  - Cementation exponent
  - Picked POWC/OWC
  - Calculated mean and median residual oil saturations
  - Compared to historical records of nearby wells
    - Oil shows, drill stem tests, core reports
- Findings
  - MPZ+ROZ identified in 110 wells (right)
  - ROZ without MPZ identified in 86 additional wells
  - Variability in residual oil saturation (below)





Conclusions

- Well logs can be used to detect low oil saturations found in siliciclastic ROZs and estimate residual oil saturation
- Considerations
  - Occurrence of ROZs controlled by local structures
  - Best for brownfields with abundant data
  - Archie is sensitive to m and Rw
  - Thin ROZs can masked by overlying seals
  - Shale must be accounted for
- Applicable in analogous basins but must be tailored to local rock and fluid properties
- Historical records or data from new wells necessary to validate findings

References

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