

# Reservoir characterization of the thick IVF Cypress Sandstone in Noble Field, Illinois, for nonconventional CO<sub>2</sub>-EOR

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# Outline

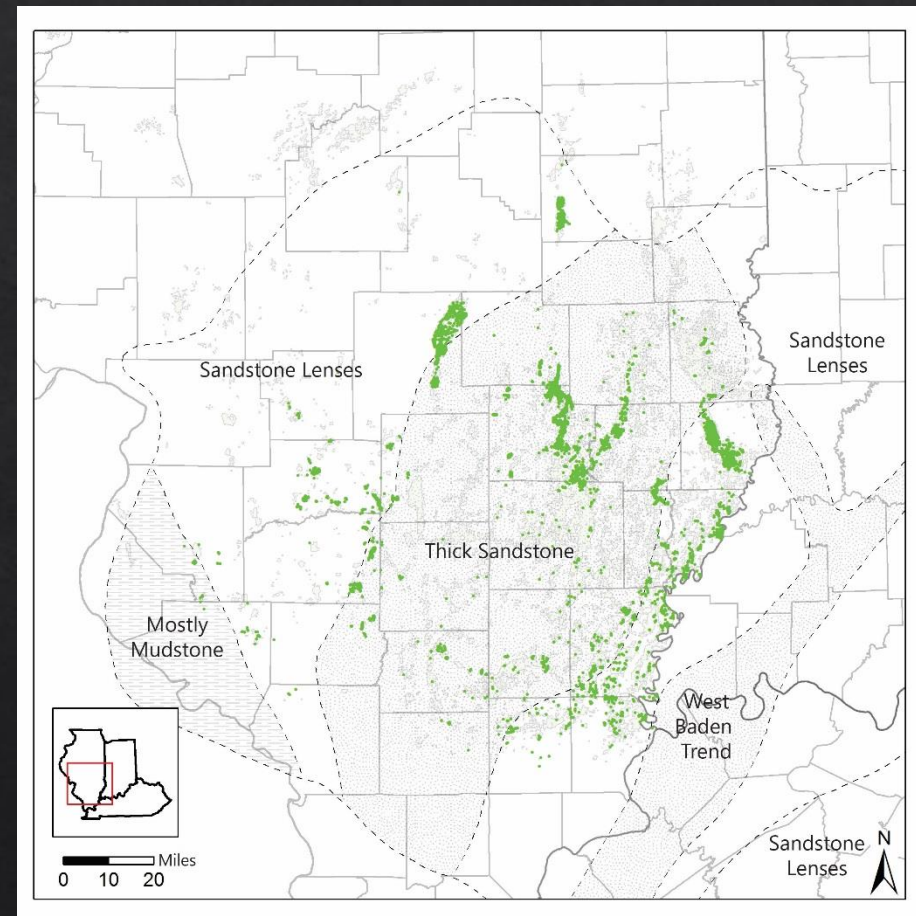
- ◇ Background
- ◇ Noble Field
  - ◇ Geology
  - ◇ Geocellular Modeling
  - ◇ Preliminary Findings
- ◇ Implications and Future Work

# Background: Motivation for study

- ◇ Oil zones in the top of thick sandstones are a target for CO<sub>2</sub>-EOR and geologic storage
  - ◇ EOR: Conventional reservoir and possible residual oil zone (ROZ)
  - ◇ Storage: Vast capacity in aquifer
- ◇ Objectives: 4-year study to...
  - ◇ Develop a method to economically recover incremental oil while storing CO<sub>2</sub> in the underlying aquifer
  - ◇ Identify ROZs by looking for direct and indirect indicators
    - ◇ Direct: Oil saturation profiles from core or log analysis
    - ◇ Indirect: Tilted oil/water contact, relatively fresh water, different oil composition
  - ◇ Determine potential for net carbon negative oil production

# Background: Cypress Ss Provinces

- ◇ Multiple Cypress Sandstone provinces in the Illinois Basin
- ◇ Production commonly from sandstone lenses
- ◇ Oil zones in thick Cypress Ss
  - ◇ Mobile oil above thick (100+ feet) saline aquifer
  - ◇ Fining upward/increasing permeability with depth (?)
- ◇ Potential residual oil zones
  - ◇ Naturally waterflooded over geologic time

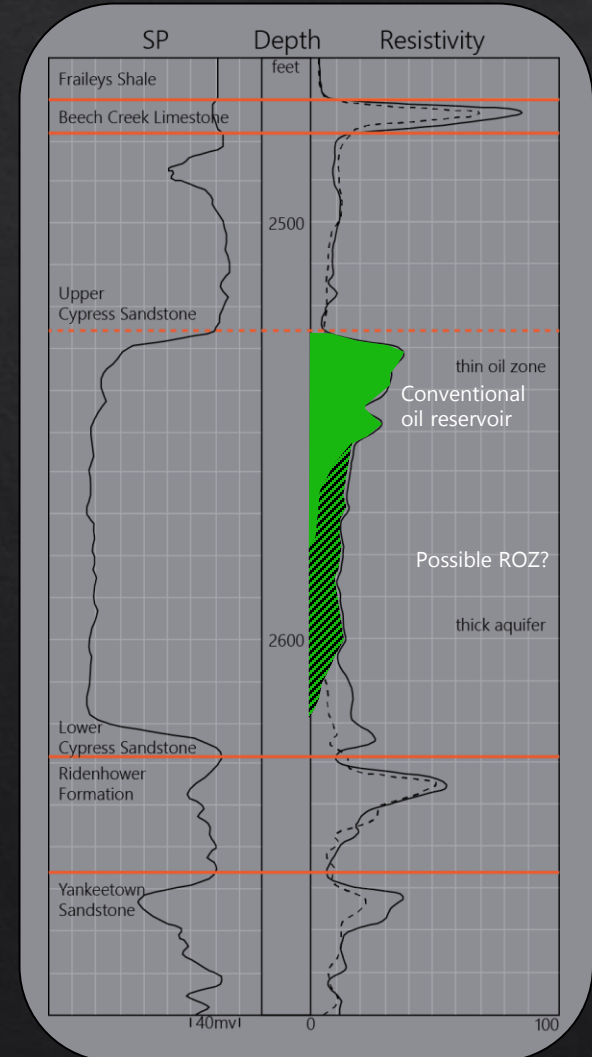


Cypress Sandstone provinces with Cypress producing wells in Illinois shown in green



# Background: Thick Cypress Reservoirs

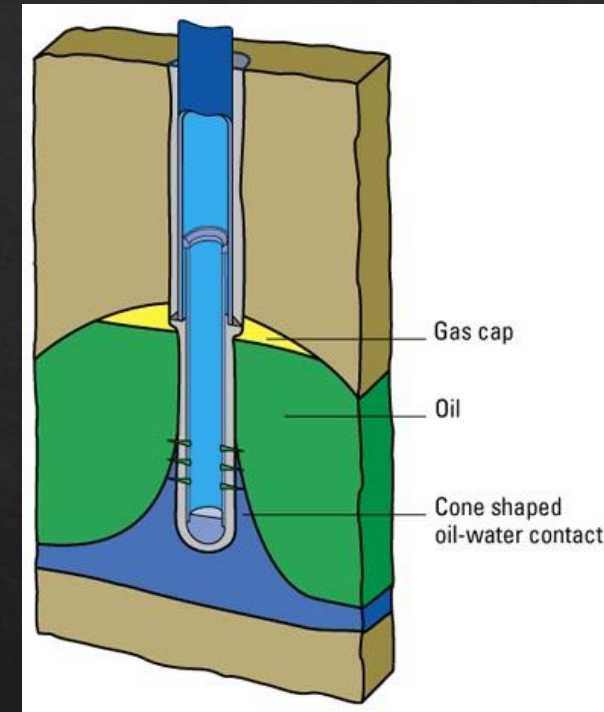
- ◆ Nonconventional CO<sub>2</sub>-EOR
  - ◆ Bypassed resource due to production difficulty
  - ◆ Potential ROZ and high net CO<sub>2</sub> utilization
  - ◆ Saline storage potential of 3.5 to 40.2 Tcf (0.2 to 2.3 Gt)\* of CO<sub>2</sub> in the Illinois Basin (DOE/MGSC, 2012)



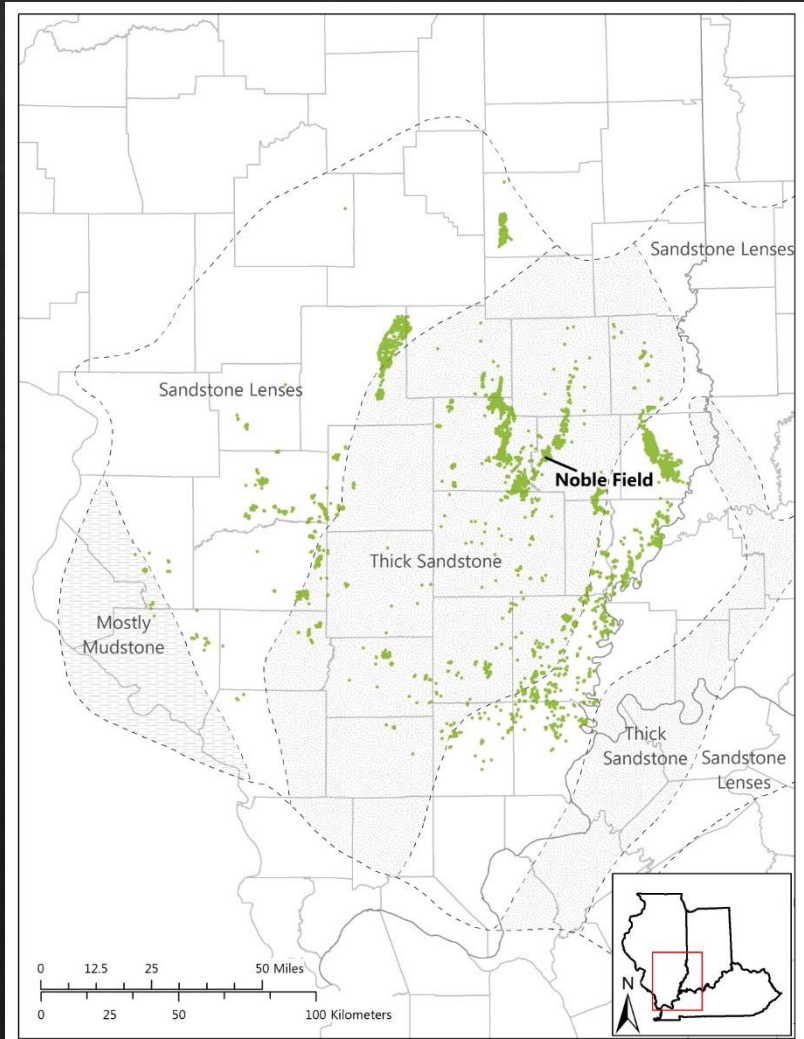
\*Using storage efficiency (*E*) factors of 0.4% and 5.5%, respectively, which represent the  $P_{10}$  and  $P_{90}$  estimates.

# Background: Historical Field Development

- ◊ Vertical wells, natural open-hole completions
- ◊ Low oil recoveries due to excessive water coning
- ◊ Generally primary production only; some "waterflooding" (disposal of produced water)
- ◊ Polymer injection to block water (undocumented)
- ◊ Horizontal wells drilled in the last few decades
- ◊ No substantive long-term EOR attempts
- ◊ Few areas of the Basin where thick Cypress Sandstone is a prolific producer; Noble Field is the best example



# Noble Field Location



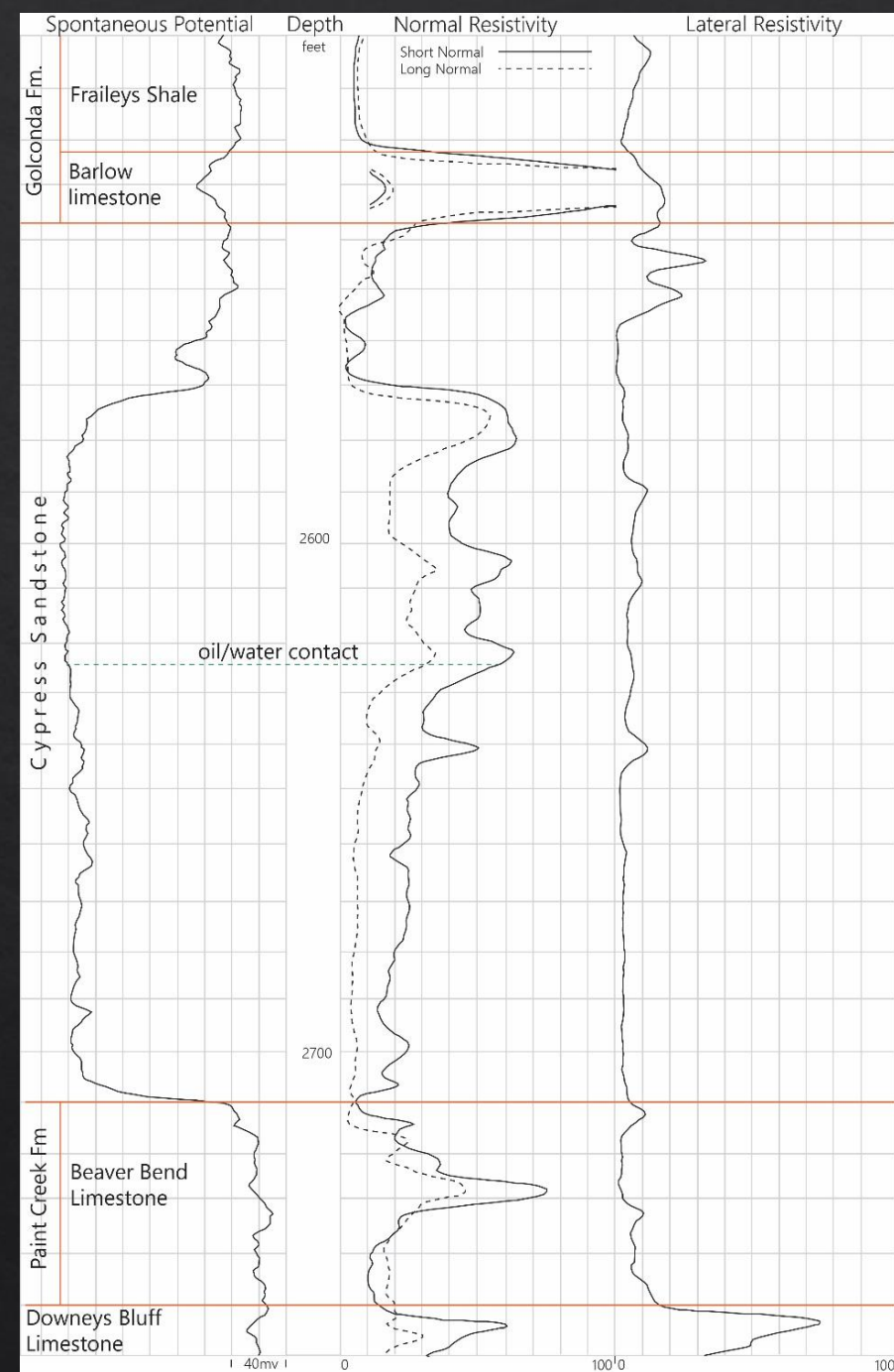
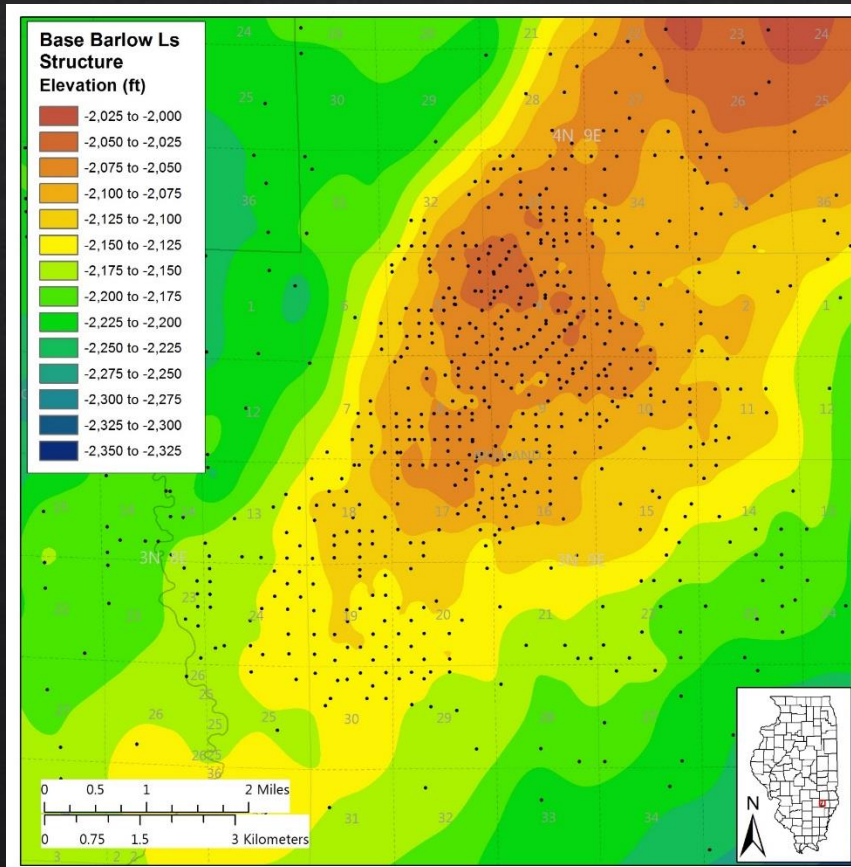
- ◇ Discovered in 1937 by Pure Oil
- ◇ Part of Clay City Consolidated Field
- ◇ 5 main producing formations
  - ◇ All are Mississippian in age
- ◇ Produced >45 MMBO
- ◇ Thick Cypress Sandstone is a major producer

Green = Cypress Sandstone production in Illinois



# Geologic Setting

- ◇ Cypress up to ~175 feet thick
- ◇ Field is located on SW plunging nose of the Clay City Anticline

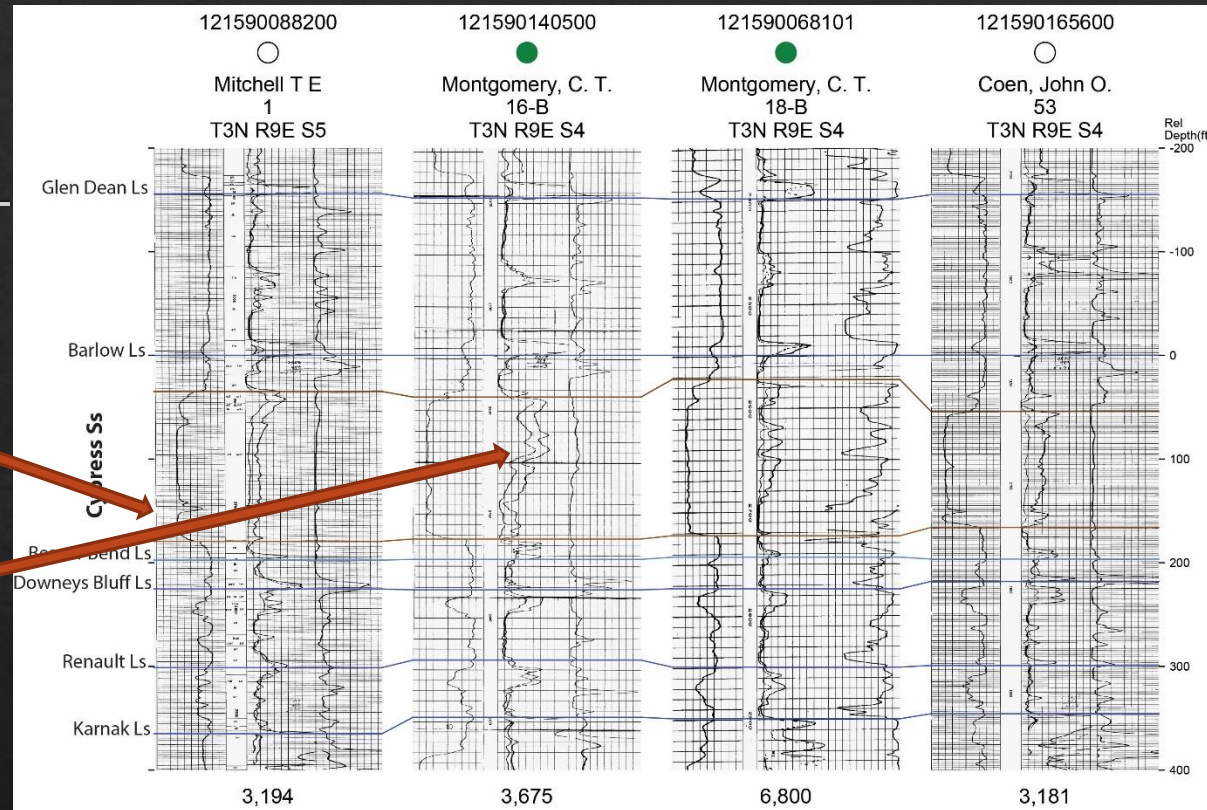


Type log: C.T. Montgomery B-15, API 121590140400



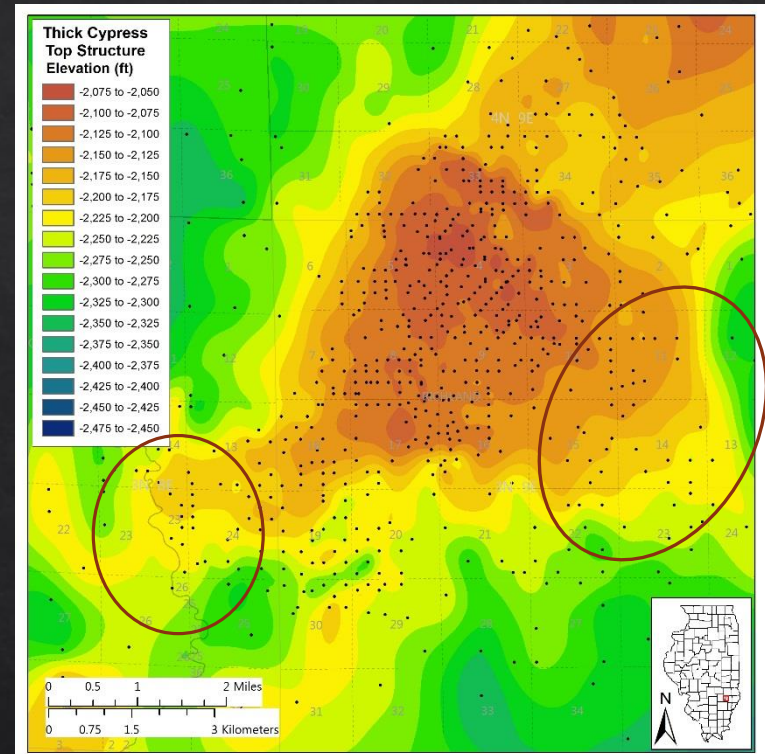
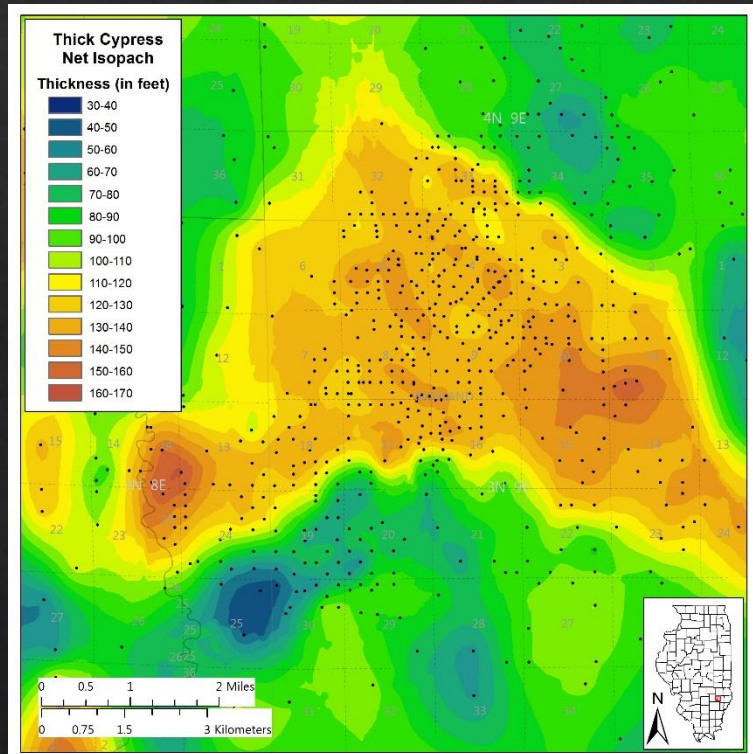
# Cross Section Correlations

- ◆ Well defined, blocky appearance on SP logs
- ◆ Laterally continuous — easy correlation
- ◆ Few internal baffles
  - ◆ Some continuous shale breaks
  - ◆ Persistent calcite-cemented zones
- ◆ Base of sandstone can truncate underlying units



East-west log cross section

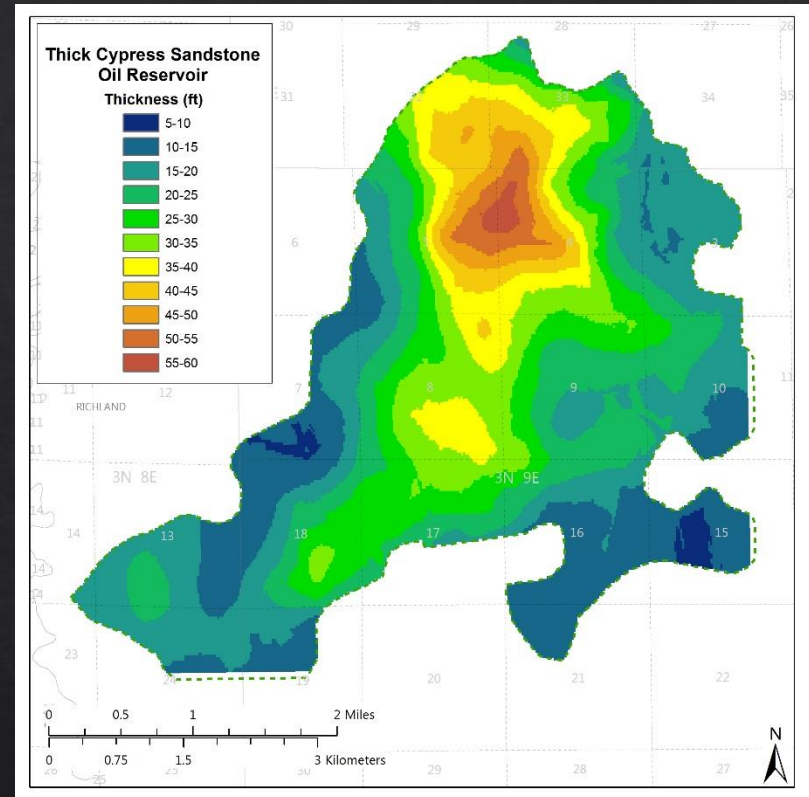
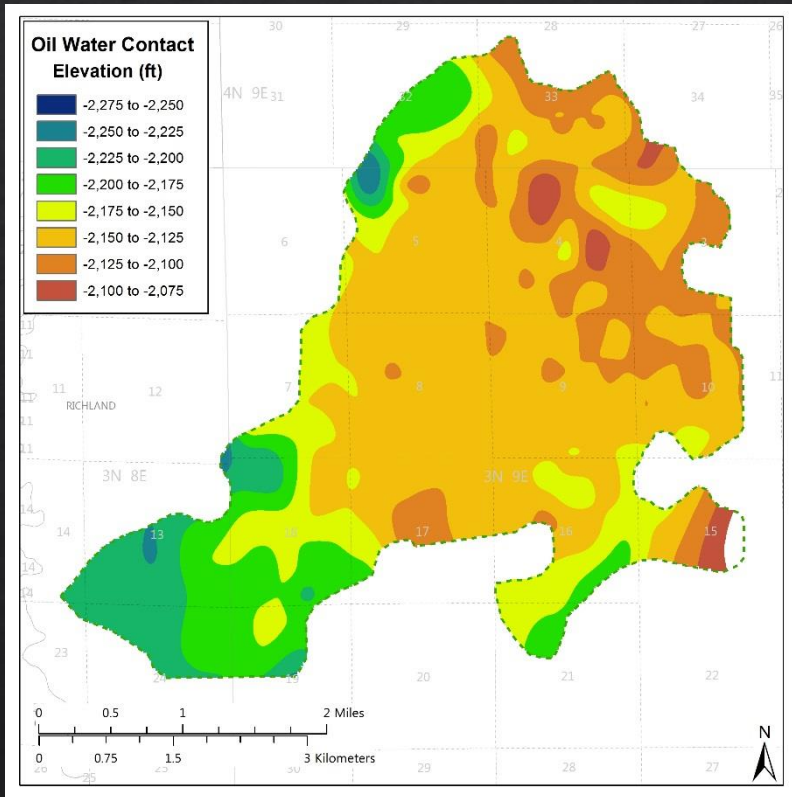
# Cypress Sandstone Geometry



- ◇ Isopach shows intersecting NW-SE and NE-SW trending sandstone bodies
  - ◇ Thickest sandstone occurs on the flanks of the Clay City Anticline
- ◇ Structure on top of sandstone shows effects of differential compaction

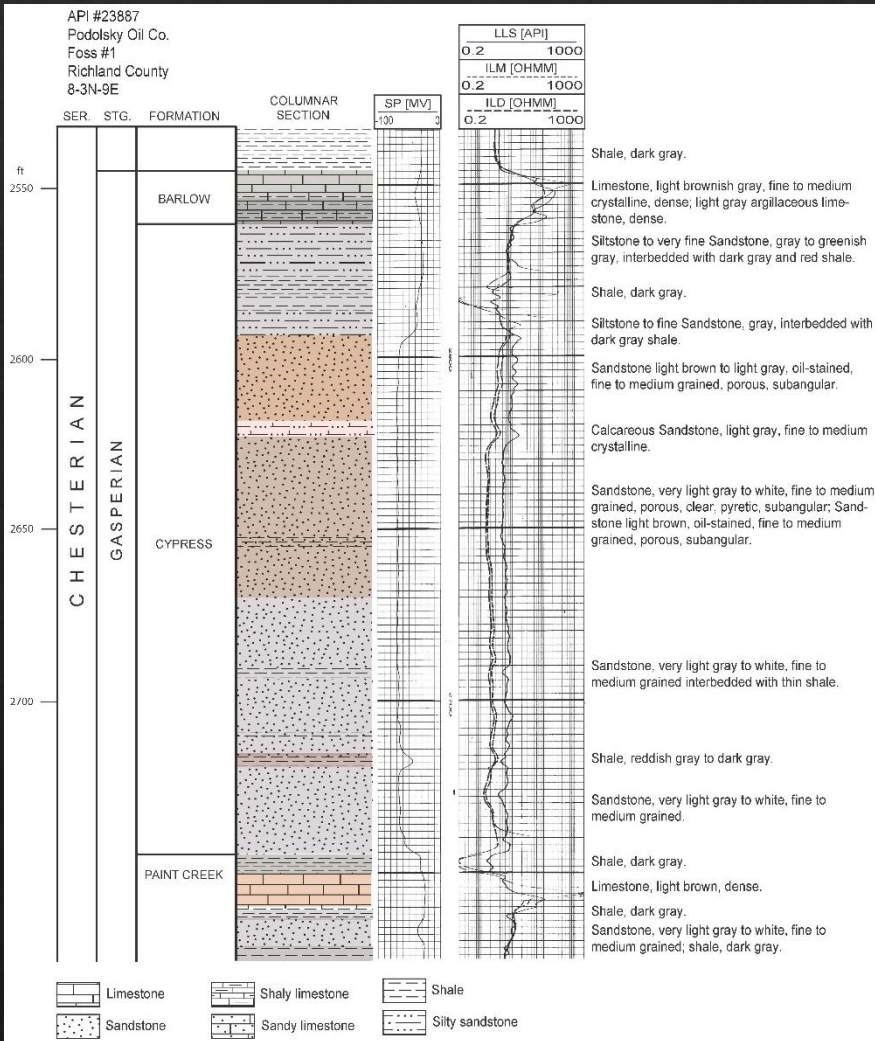


# Cypress Sandstone Oil Reservoir



- ◇ Tilted oil/water contact (OWC) indicates possible ROZ
- ◇ Isopach of reservoir above OWC shows down-structure oil
- ◇ Preliminary OOIP of Cypress Ss ~100 MMBO without ROZ
  - ◇ ~24 MMBO Cypress production = Recovery efficiency of ~24%

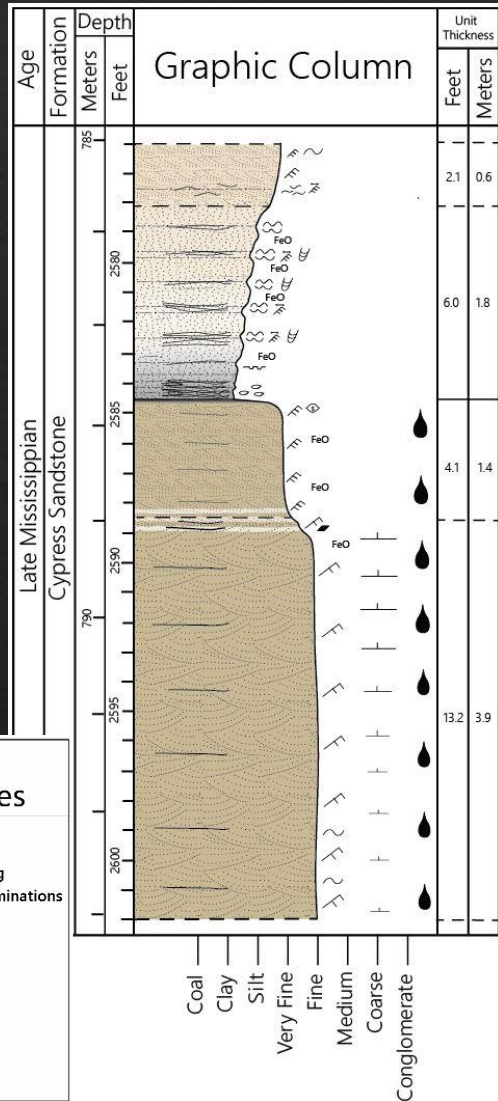
# Sedimentology



- ◆ Examining sample sets in and near Noble Field
  - ◆ Fine- to medium-grained sandstone; not consistently fining upward
- ◆ Describing characteristics of internal baffles
  - ◆ Laterally persistent, fossiliferous shale interbeds
  - ◆ Dense, calcite-cemented sandstone intervals



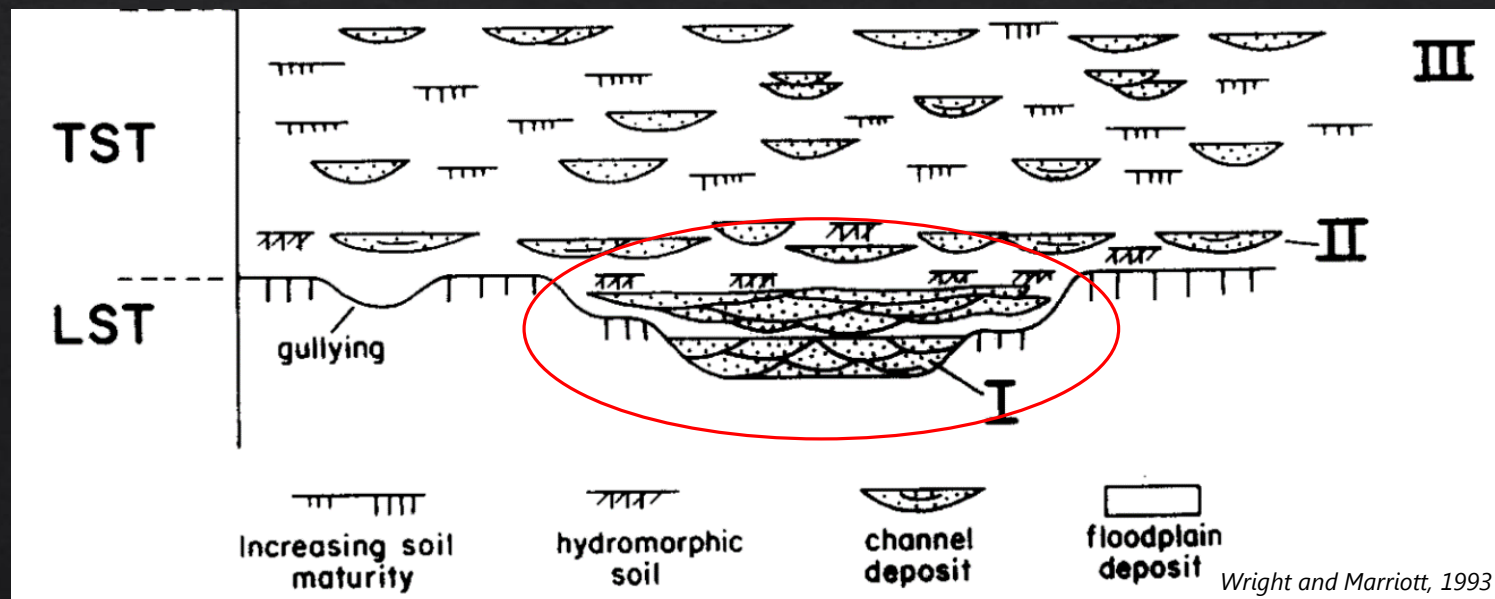
# Sedimentology



- ◇ Describing available cores and conducting facies analysis
  - ◇ Fluvial cross-bedded sandstones grade upward into heterolithic, estuarine deposits
- ◇ Sampling cores for porosity, permeability, and mineralogy
  - ◇ Developing diagenetic history
  - ◇ Determining depositional and diagenetic controls on reservoir quality

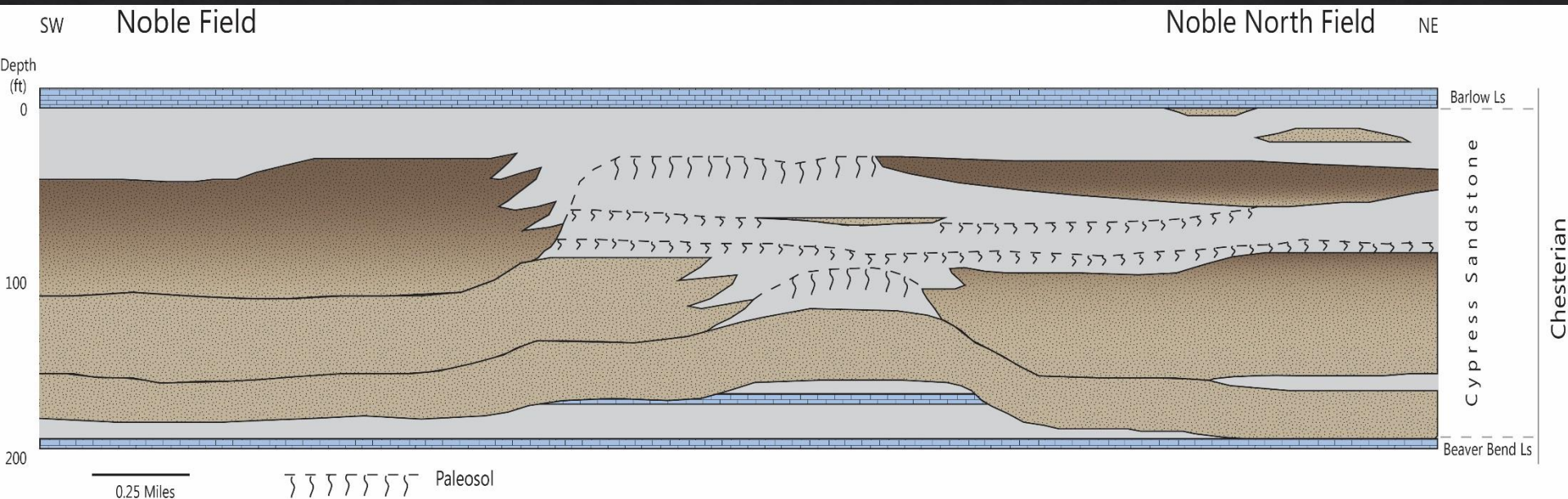
# Depositional Environment

- ◆ The Cypress Sandstone at Noble Field is likely part of a lowstand (LST) incised valley fill environment
  - ◆ Multistory sandstone built through parasequence-scale successive fluvial to estuarine depositional episodes
  - ◆ Amalgamated fluvial to estuarine channels are punctuated by marine incursions as indicated by fossil fragments



# Geological Model

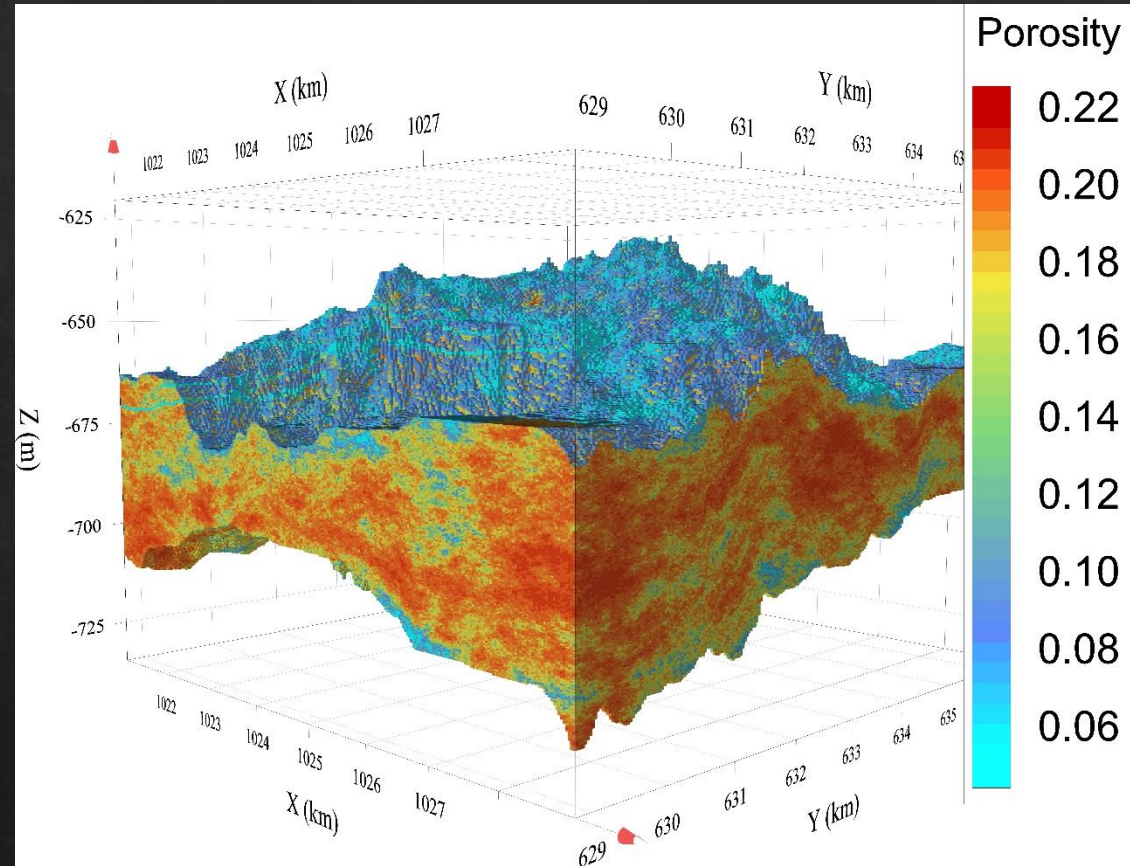
- ◇ Basal sandstone story blankets entire field and reportedly covers much of the nearby counties; indicates low accommodation
- ◇ Middle and upper sandstone stories amalgamate at Noble Field but are less persistent elsewhere
  - ◇ Top of thick Cypress Ss is convex upward where amalgamated
  - ◇ Differential compaction over amalgamated sandstones create stratigraphic traps





# Geocellular Model

- ◆ SP and neutron-density logs were used to incorporate depositional and diagenetic facies
  - ◆ Shaly, estuarine facies at the top of the model
  - ◆ Thin shale interbeds
  - ◆ Low porosity calcite-cemented sandstone zones





# Noble Field: Findings

- ◆ Cypress Sandstone contributed ~50% of cumulative production
- ◆ Combination of structural and stratigraphic controls on oil trapping
- ◆ Oil column up to ~60 feet thick with potential for underlying ROZ
  - ◆ Oil/water contact is tilted towards the south
- ◆ Multistory fluvial/estuarine sandstone bodies make up the thick Cypress Sandstone
- ◆ Geocellular model captures anisotropy and sand/shale heterogeneity but needs further refining to include diagenetic features

# Implications and Future Work

- ◆ Noble Field has thickest known oil column and <25% recovery efficiency—potential for ROZ and successful CO<sub>2</sub>-EOR
- ◆ Reservoir simulations to determine the most effective CO<sub>2</sub>-EOR and storage method
  - ◆ Scenarios weighted towards oil production and storage
  - ◆ Potential to produce net carbon negative oil (NCNO)
- ◆ Regional resource estimate using lessons learned from Noble Field
  - ◆ Better understanding of the geology of the thick Cypress Sandstone
- ◆ Regional mapping of the thick Cypress Sandstone
  - ◆ Identification of locations with oil reservoirs analogous to Noble Field
- ◆ Refine algorithm for identifying ROZs
  - ◆ Petrophysical methods supported by cased-hole pulsed-neutron logging, measuring saturation in fresh core, measuring oil and water composition

# Acknowledgements

- ◆ Research herein was supported by the US Department of Energy contract number DE-FE0024431
- ◆ Through a university grant program, IHS Petra software was used for the geologic modeling and Geovariances Isatis software was used for geocellular modeling
- ◆ For project information, including reports and presentations, please visit:  
<http://www.isgs.illinois.edu/research/oil-gas/doe>

## References

*Wright, V. P., & Marriott, S. B. (1993). The sequence stratigraphy of fluvial depositional systems: the role of floodplain sediment storage. Sedimentary Geology, 86, 203–210.*