A Nonconventional CO$_2$-EOR Target in the Illinois Basin: Oil Reservoirs of the Thick Cypress Sandstone

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Nathan Webb, Scott Frailey, and Hannes Leetaru
Illinois State Geological Survey

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Presentation Outline

• Benefit to DOE Program
• Program and Project Overview
• Methodology
• Expected Outcomes
• Organization Chart and Communication Plan
• Project Tasks
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Benefit to DOE Program: Goal and Area of Interest

• Goal: Develop technologies to improve reservoir storage efficiency while ensuring containment effectiveness

• Area of Interest: 1A - Opportunities, Knowledge Advancements, and Technology Improvements for CO$_2$ Storage in Non-Conventional CO$_2$-EOR Targets – Residual Oil Zones (ROZs)
Benefit to DOE Program: Benefits Statement

• Field development guidelines will be developed to maximize economic oil recovery and CO$_2$ storage efficiency.

• It is projected that CO$_2$-EOR is an effective means of recovering additional oil from a formation that has historically low primary production and no waterflooding or EOR attempts. The formation is expected to have a high CO$_2$ storage (i.e. net utilization) compared to conventional CO$_2$-EOR.

• Through the application of these techniques, guidelines can be recommended for CO$_2$-EOR development (e.g., well patterns, spacing, and orientations as well as CO$_2$ injection profiles) of the thick Cypress (and similar formations) with the end result of maximized incremental recovery and CO$_2$ storage.
Program and Project Overview: Goals

DOE Program

• Develop technologies to improve reservoir storage efficiency while ensuring containment effectiveness
• Develop and advance technologies to significantly improve the effectiveness and reduce the cost of implementing carbon storage
• Adapt and apply existing technologies that can be utilized in the next five years while developing innovative and advanced technologies that will be deployed in the next decade and beyond

ncCO2-EOR TC ILB

• Identify and quantify nonconventional CO₂ storage and EOR opportunities in the thick Cypress Sandstone in the Illinois Basin
  • Economics/NCNO
  • Field development strategies
  • Near term deployment
Program and Project Overview: Objectives

DOE Program

• Detailed characterization
• ROZ fairway locations; CO₂ storage and EOR resource
• Field and lab tests
• Development methods for increasing CO₂ storage and improving oil recovery

ncCO₂-EOR TC ILB

• Correlate oil production to key geologic/reservoir properties
• Map CO₂ storage and EOR resource fairway (e.g. oil recovery)
• Obtain and analyze new core, logs, and fluid samples
• Develop screening and selection criteria; full field development strategies; economics and NCNO
Methodology

Background: Cypress Sandstone

- Prolific oil producing zone
- Overlain by an effective seal system
  - Shale (Fraileys Sh)
  - Limestone (Beech Creek Ls)
  - Shaley sandstone (upper Cypress Ss)
- Sandstone lenses vs. thick sandstone
Methodology

Background: Thick Cypress Ss

• Thin Oil Zones in Thick Aquifer Sandstones
  • Residual and mobile oil above thick water zone
  • Fining upward (grain size) sequence / increasing permeability with depth
  • Difficult to produce economically due to water coning and water management

• Nonconventional CO₂-EOR
  • Largely bypassed resource due to historical production difficulty
  • Sandstones 30+ meters thick and mostly aquifer
  • Saline storage potential of 0.2 to 2.3 Gt of CO₂ (DOE/MGSC, 2012)
Methodology
Study area selection

Choose a study area with:

- Reservoir data
  - Necessary for building geologic model and populating geocellular model
- Production history
  - Necessary for establishing typical decline curve for Thick Cypress
- Active drilling
  - Necessary for taking new geophysical logs and core
Methodology
Data synthesis and analysis

- Assemble comprehensive oil field database:
  - Production history and completion data
  - Petrophysical data
  - Mineralogical data
  - Core analysis data
  - Fluid composition data
  - Cores, core photos, and core descriptions
Methodology
Geology and Reservoir Characterization

• Develop geologic conceptual model:

  • Sandstone body geometries will be mapped, facies will be classified, and petrophysical and mineralogical properties will be characterized
  • Sequence stratigraphic, depositional, and diagenetic histories will be interpreted
Methodology
Geocellular Modeling

• Build geocellular model that reflects:
  • Petrophysical properties
  • Depositional environment
  • Trends observed in mapping

• Verify model against geologic conceptual model
  • Vetted by geologic staff
Methodology
Fluid Analysis and Geochemical Modeling

• Fluid Analysis
  • Samples of oil and brine will be collected from the Cypress Sandstone in or near the study area
  • Samples will be analyzed for attributes including: composition, minimum miscibility pressure

• Geochemical Modeling
  • Fluid properties will be modeled to identify potential oil/brine/CO₂ interactions
  • Relative permeability will be determined
  • Reactions with reservoir mineralogy will be investigated
Methodology
Reservoir Simulation

• Simulate injection scenarios using calibrated reservoir models
  • Identify injection scenarios that lead to improvement in CO$_2$ sweep efficiency
  • Improve understanding of CO$_2$ storage and water management plans
Methodology

Resource estimate and economics

• Define location of ncCO2-EOR fairways
  • Size of the oil resource and CO₂ storage capacity
    • Revised regional maps
    • Reservoir simulation results

• Analyze economics CO₂-EOR implementation
  • Feasibility of CO₂-EOR
  • Emphasis on Net Carbon Negative Oil

Figure from US DOE, 2012
Expected Outcomes

• Identification of effects of geologic attributes on CO$_2$ storage and EOR in thin oil zone/thick aquifer formations
  • New and existing data synthesis and analysis
  • New interpretation of depositional and diagenetic controls on reservoir, oil production, and storage behavior

• Rigorous geology-based, site-specific geocellular models
  • Include geologic heterogeneity; reflect depositional and diagenetic history
  • Modeling process that emphasizes site specific geologic attributes
Expected Outcomes (continued)

• Full-field development scenarios based on economic analysis and interpretation of reservoir simulation results
• New resource assessment and regional fairway maps of CO$_2$ storage and EOR
• New assessment of economic viability of CO$_2$-EOR in the thick Cypress with considerations for NCNO
Organization Chart and Communication Plan

- Project management team
- Weekly update meetings
- Monthly project plan review meetings
- Subtask leaders
  - Monthly meetings with PI
  - Monthly meetings with staff while task is active
Project Tasks

1. Project Management and Planning
2. Geology and Reservoir Characterization
3. Geocellular and Reservoir Modeling
4. CO$_2$-EOR and Storage Development Strategies
Task 1. Project Management and Planning

- Largest proportion of effort focuses on geologic characterization task
- Balance of effort roughly split between modeling and development strategies tasks
Task 2.
Geology and Reservoir Characterization

2.1 Oilfield Selection
   • Review past Illinois Basin studies
   • Aggregate, digitize, analyze available data

2.2 Petrophysics
   • Collection of new core and geophysical logs
   • Analyses of available and newly acquired data

2.3 Geologic Modeling
   • Description and analyses of core and outcrop
   • Mineralogy and petrography of samples
   • Correlations of geophysical logs
   • Mapping local and regional geology
   • Interpretation of depositional environment
Task 3.
Geocellular and Reservoir Modeling

3.1 Production & Injection Data Analysis
   • Analyze decline curves
   • Define historical successes and failures

3.2 Fluid Analysis and Geochemical Modeling
   • Sample and analyze reservoir fluids
   • Model potential interactions with core

3.3 Geocellular Modeling
   • Construct variogram from geostatistical analysis
   • Build 3D geocellular model

3.4 Reservoir Modeling
   • Set up reservoir modeling files
4.1 Field Development Guidelines

• Simulate:
  • Injection profiles and conformance
  • Well patterns and spacing
  • Vertical vs. horizontal wells

4.2 CO₂-EOR & Storage Resource Assessment

• Calculate volumetrics from regional maps
• Estimate resource using simulation results

4.3 Economics

• Demonstrate viability of economic production with CO₂ storage in underlying aquifer
• Determine threshold of NCNO production
Project Deliverables

• Project management plan
• Quarterly progress reports (quarterly)
• Topical reports
  • Geology of Thick Cypress (October, 2016)
  • Guidelines to Develop Thin Oil Zones in the Thick Cypress in the Illinois Basin (December, 2016)
  • CO₂ Storage, EOR, and Economics of the Thick Cypress in the Illinois Basin (August, 2017)
• Final report (October, 2017)
• Website (ongoing)
# Risk Matrix

<table>
<thead>
<tr>
<th>Risk</th>
<th>Description</th>
<th>Likelihood (0-3)</th>
<th>Severity (0-3)</th>
<th>Strategy</th>
<th>Mitigation plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data acquisition</td>
<td>Delays in acquiring data can delay the project</td>
<td>1</td>
<td>2</td>
<td>Most data is available at ISGS</td>
<td>Begin assembling and digitizing data immediately</td>
</tr>
<tr>
<td>Hiring delays</td>
<td>Delays in hiring key personnel can delay the project</td>
<td>1</td>
<td>2</td>
<td>Most of the staff included on project are current ISGS employees</td>
<td>Eliminate need to hire by utilizing current ISGS staff</td>
</tr>
<tr>
<td>Loss of personnel</td>
<td>Interdependencies of tasks require technical deliverables to be completed on time; thus, loss of key staff performing technical tasks may impede progress</td>
<td>2</td>
<td>2</td>
<td>Multiple current ISGS staff on the project are capable of performing the same tasks</td>
<td>Keep technical staff appraised of progress on each task. Distribute critical tasks to two or more staff members</td>
</tr>
<tr>
<td>Inability to partner with operator</td>
<td>An operator partner will be needed to facilitate the collection of new geophysical and core data on the thick Cypress; inability to identify such a partner may delay the project</td>
<td>2</td>
<td>2</td>
<td>While not ideal, the thick Cypress is present in shallow areas of the basin at depths that could be cored by ISGS</td>
<td>Make parallel preparations to take core independently of operator</td>
</tr>
</tbody>
</table>
## Proposed Schedule

<table>
<thead>
<tr>
<th>Task 1.0 – Project management and planning</th>
<th>Begin</th>
<th>End</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milestone: Project management plan</td>
<td>0</td>
<td>3</td>
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<tr>
<td>Milestone: Kickoff meeting</td>
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<tr>
<td>Task 2.0 – Geology and Reservoir Characterization</td>
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<tr>
<td>Subtask 2.1 – Literature Review and Oilfield Selection</td>
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<td>Subtask 2.2 – Petrophysical Analysis</td>
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<td>Subtask 2.3 – Geologic Model Development</td>
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<td>Milestone: Final selection of oilfields for study</td>
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<td>Milestone: Oilfield data synthesis and analysis</td>
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<tr>
<td>Milestone: Complete Petrophysical analysis and geologic modeling of the thick Cypress</td>
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<td>Task 3.0 – Geocellular and Reservoir Modeling</td>
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<td>Subtask 3.1 – Historical Production and Injection Data Analysis</td>
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<td>Subtask 3.2 – Illinois Basin Crude Oil-brine-CO2 Fluid Property Characterization</td>
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<td>Subtask 3.3 – Geocellular Modeling of Interwell Reservoir Characteristics</td>
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<td>Subtask 3.4 – Reservoir Modeling</td>
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<tr>
<td>Task 4.0 – CO2 EOR and Storage Development Strategies</td>
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<tr>
<td>Subtask 4.1 – Development Strategy Optimization</td>
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<tr>
<td>Subtask 4.2 – CO2 EOR and Storage Resource Assessment</td>
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<tr>
<td>Subtask 4.3 – Economic Analysis</td>
<td>18</td>
<td>36</td>
</tr>
<tr>
<td>Milestone: Complete guidelines to develop thin oil zones and store CO2 in the thick Cypress</td>
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<tr>
<td>Milestone: Complete estimate of CO2 EOR and Storage potential and Economic analysis of</td>
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<tr>
<td>Milestone: Document project results</td>
<td>36</td>
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Summary

• Three year geologic and reservoir study of the thick Cypress Sandstone in the Illinois Basin
• Site specific oilfield study using newly acquired core, core analyses, and geophysical logs
• CO$_2$ storage and EOR resource assessment of the thick Cypress Sandstone
• Full-field development guidelines for economic CO$_2$ storage and EOR
References

• Frailey, S. M., R. J. Finley, and J. A. Rupp, 2013, Illinois basin, Midwest carbon dioxide EOR challenges may be surmountable: Oil and Gas Journal.


