A Nonconventional CO₂-EOR Target in the Illinois Basin: Oil Reservoirs of the Thick Cypress Sandstone

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Reporting Period End Date: 12/31/2018
Report Term: Quarterly
Signature of Submitting Official:
Nathan D. Webb: ____________________________
2. ACCOMPLISHMENTS

What was done? What was learned?

Major accomplishments include:

- Ambient-condition core flood experiments using surrogate fluids to determine the irreducible water saturation ($S_{wirr}$) and residual saturation ($S_{or}$) of Cypress Sandstone and analogous Pennsylvanian core plugs have been completed. Results from experiments show a mean $S_{or}$ value of 32% and mean $S_{wirr}$ value of 21% for all samples (porosity range of 12 to 25%).

What are the major goals of the project and what was accomplished under these goals?

The major goals of the project include identifying and quantifying nonconventional carbon dioxide (CO$_2$) storage and enhanced oil recovery (EOR) opportunities in the thick Cypress Sandstone in the Illinois Basin through geologic reservoir characterization, three-dimensional geocellular modeling, fluid properties and interaction modeling, and reservoir simulation. A study of the economics of potential storage and EOR programs in the thick Cypress will be made with considerations for production of net carbon negative oil. Field development strategies will be recommended with emphasis on near-term deployment.

Accomplishments towards these goals are listed below by task as outlined in the SOPO.

Task 1.0–Project Management and Planning (on schedule)

- Progress on completion of tasks, subtasks, deliverables, and milestones is tracked using Microsoft Project to ensure timely completion. Overall, this project is on schedule.
- Principal investigator (PI) Nathan Webb and co-PI Scott Frailey, along with Nathan Grigsby, met weekly to discuss project management.
- There were regular meetings with the PI and subtask leaders for active subtasks.

Task 2.0–Geology and Reservoir Characterization (on schedule)

Subtask 2.1–Literature Review and Oilfield Selection

- Subtask concluded on 6/30/2015.

Subtask 2.2–Petrophysical Analysis

- Subtask concluded 10/31/2017.
Nathan Grigsby and Scott Frailey continued work on a publication titled “Methodology for using well logs to identify residual oil zones: An example from Noble Field, Illinois.” This method provides a screening tool to assess ROZ potential using existing well logs.

Subtask 2.3–Geologic Model Development


- Kalin Howell, Nathan Webb, and collaborators from the University of Illinois Geology department continued work on a manuscript titled “The Sedimentology of a Large Fine-Grained Carboniferous River: Facies, Palaeohydraulics, and Implications for Reservoir Heterogeneity”

Task 3.0–Geocellular and Reservoir Modeling (on schedule)

Subtask 3.1–Historical Production and Injection Data Analysis


Subtask 3.2–Illinois Basin Crude Oil/Brine-CO₂ Fluid Property Characterization

- Dmytro Lukhtai concluded ambient-condition core flood experiments which use surrogate fluids to determine the irreducible water saturation (S_{wirr}) and residual saturation (S_{or}) of Cypress Sandstone and analogous Pennsylvanian core plugs. These experiments validate well log techniques (Archie equation) of saturation determination.
  - Results from experiments (Table 1) show a mean S_{or} value of 32% and mean S_{wirr} value of 21% for all samples (porosity range of 12 to 25%). It is assumed that a natural Cypress ROZ would exhibit similar S_{or} values. In general, the data with help resolve the disagreement between core flood and well log analysis-derived values of S_{or}.
  - Samples have been selected for capillary pressure analysis to compliment this dataset.

Subtask 3.3–Geocellular Modeling of Interwell Reservoir Characteristics


Subtask 3.4–Reservoir Modeling

Task 4.0–CO₂ EOR and Storage Development Strategies (on schedule)

Subtask 4.1–Field Development Strategies

- Roland Okwen is making final adjustments to complete the history matching of the Noble Field model.

Subtask 4.2–CO₂ EOR and Storage Resource Assessment

- Nathan Webb and Nathan Grigsby are analyzing additional data to provide higher confidence of ROZ prospect dimensions and saturations in order to revise the CO₂-EOR and storage estimates for the final version of the CO₂ Storage and EOR Resource Assessment of the Cypress Sandstone Residual Oil Zone Play in the Illinois Basin.

Subtask 4.3–Economic Analysis

- Scott Frailey selected development scenarios from the results of the pattern model simulations to use in the revised Noble static model simulations. These scenarios will be used to for the economic analyses to identify economically feasible CO₂-EOR and storage strategies for the Cypress ROZ in the ILB.

<table>
<thead>
<tr>
<th></th>
<th>$S_{wirr}$</th>
<th>$S_{or}$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cypress</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>22%</td>
<td>28%</td>
</tr>
<tr>
<td>Median</td>
<td>22%</td>
<td>32%</td>
</tr>
<tr>
<td><strong>Penn</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>21%</td>
<td>37%</td>
</tr>
<tr>
<td>Median</td>
<td>21%</td>
<td>41%</td>
</tr>
<tr>
<td><strong>All</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>21%</td>
<td>32%</td>
</tr>
<tr>
<td>Median</td>
<td>21%</td>
<td>33%</td>
</tr>
</tbody>
</table>

What opportunities for training and professional development has the project provided?

Three undergraduate students and one recent MS graduate have been involved in research on the project during the quarter. Under advisement of project staff and University of Illinois
professors, each student is developing skills in a particular discipline, such as routine and advanced core analysis, thin section petrography, and stratigraphy and sedimentology. The students are learning various techniques for their respective disciplines, and they are meeting and sharing findings with each other to better understand their roles in the larger framework of the project and to gain experience in presenting their research.

*How have the results been disseminated to communities of interest?*

- The project website ([http://isgs.illinois.edu/research/ERD/NCO2EOR](http://isgs.illinois.edu/research/ERD/NCO2EOR)) hosts a project summary, staff bios, and downloadable reports and presentations to disseminate project information and findings to the public and other interested parties.
- Draft manuscripts include:
  - Grigsby, N.P, and S.M Frailey, Methodology for using well logs to identify residual oil zones: An example from Noble Field, Illinois.


What do you plan to do during the next reporting period to accomplish the goals?

Task 1.0–Project Management and Planning (on schedule)

- Progress on completion of tasks, subtasks, deliverables, and milestones will continue to be tracked using Microsoft Project to ensure timely completion.
- The PI and co-PIs will continue to meet weekly to discuss project management.
- Regular meetings with the PI and subtask leaders will continue for active subtasks.
- Work will conclude with the availability of core visualization portfolios on the ILOIL website.

Task 2.0–Geology and Reservoir Characterization (on schedule)

Subtask 2.1–Literature Review and Oilfield Selection

- Subtask concluded on 6/30/2015.

Subtask 2.2–Petrophysical Analysis

- Subtask concluded 10/31/2017.
- Nathan Grigsby and Scott Frailey will continue to work on a paper tentatively titled “Methodology for using well logs to identify residual oil zones: An example from Noble Field, Illinois.”

Subtask 2.3–Geologic Model Development

- Kalin Howell, Nathan Webb, and collaborators from the University of Illinois Geology department will continue work on a manuscript that discusses the geologic model of the Cypress Sandstone and implications for reservoir properties titled “The Sedimentology of
a Large Fine-Grained Carboniferous River: Facies, Palaeohydraulics, and Implications for Reservoir Heterogeneity”

Task 3.0–Geocellular and Reservoir Modeling (on schedule)

Subtask 3.1–Historical Production and Injection Data Analysis


Subtask 3.2–Illinois Basin Crude Oil/Brine-CO₂ Fluid Property Characterization

- SOR core-flood experiments using analog fluids will continue to provide important calibration data for well log analyses.

Subtask 3.3–Geocellular Modeling of Interwell Reservoir Characteristics


Subtask 3.4–Reservoir Modeling


Task 4.0–CO₂ EOR and Storage Development Strategies (on schedule)

Subtask 4.1–Field Development Strategies

- Roland Okwen will complete final simulations of the history-matched Noble Field model to optimize field development strategies based on the results of pattern modeling simulations.

Subtask 4.2–CO₂ EOR and Storage Resource Assessment

- Nathan Webb, Nathan Grigsby, Scott Frailey, and Chris Korose will finalize the regional play analyses of the Cypress ROZ.

Subtask 4.3–Economic Analysis

- Scott Frailey will conclude the final economic analysis once the final results of the simulated CO₂-EOR scenarios are available.
## Project Milestone Log

<table>
<thead>
<tr>
<th>Task</th>
<th>Calendar Year</th>
<th>Milestone Title/Description</th>
<th>Planned Completion Date</th>
<th>Actual Completion Date</th>
<th>Verification Method</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>1</td>
<td>Project Management Plan</td>
<td>12/31/2014</td>
<td>12/15/2014</td>
<td>PMP File</td>
<td>100% Complete</td>
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<tr>
<td>1.0</td>
<td>1</td>
<td>Kickoff Meeting</td>
<td>12/31/2014</td>
<td>12/4/2014</td>
<td>Presentation File</td>
<td>100% Complete</td>
</tr>
<tr>
<td>2.0</td>
<td>2</td>
<td>Final selection of oilfields for study</td>
<td>3/31/2015</td>
<td>3/20/2015</td>
<td>Agreement between ISGS and DOE project manager to proceed with specific areas of study</td>
<td>100% Complete</td>
</tr>
<tr>
<td>2.0</td>
<td>2</td>
<td>Oilfield data synthesis and analysis</td>
<td>10/31/2015</td>
<td>10/21/2015</td>
<td>Wells/leases grouped into classes representing relative degree of productivity</td>
<td>100% Complete</td>
</tr>
<tr>
<td>2.0</td>
<td>3</td>
<td>Analogous Lower Pennsylvanian study areas selected</td>
<td>4/30/2016</td>
<td>4/29/2016</td>
<td>Agreement between ISGS and DOE project manager to proceed with specific areas of study</td>
<td>100% Complete</td>
</tr>
<tr>
<td>2.0, 3.0</td>
<td>3</td>
<td>Complete petrophysical analysis, geologic and geocellular modeling of the thick Cypress</td>
<td>10/31/2016</td>
<td>10/31/2016</td>
<td>Completion of draft topical report on geology of the thick Cypress in the ILB</td>
<td>100% Complete</td>
</tr>
<tr>
<td>2.0</td>
<td>4</td>
<td>Complete new coring near outcrop belt</td>
<td>9/30/2017</td>
<td>9/21/2017</td>
<td>Send DOE confirmation that core has been obtained and is in ISGS warehouse</td>
<td>100% Complete</td>
</tr>
<tr>
<td>4.0</td>
<td>3</td>
<td>Complete guidelines to develop thin oil zones and store CO₂ in the thick Cypress</td>
<td>12/31/2017</td>
<td>1/31/2018</td>
<td>Completion of draft topical report on guidelines to develop thin oil zones in the thick Cypress</td>
<td>100% Complete</td>
</tr>
<tr>
<td>4.0</td>
<td>4</td>
<td>Complete estimates of CO₂-EOR and storage potential and economic analysis of implementing program</td>
<td>8/31/2018</td>
<td>8/31/2018</td>
<td>Completion of draft topical report on CO₂-EOR, storage, and economics of the thick Cypress in the ILB</td>
<td>100% Complete</td>
</tr>
<tr>
<td>All</td>
<td>4</td>
<td>Document project results</td>
<td>4/30/2019</td>
<td></td>
<td>Complete final report</td>
<td>In progress</td>
</tr>
</tbody>
</table>
3. PRODUCTS

What has the project produced?

a. Publications, conference papers, and presentations

Presentations and manuscripts listed on pages 5-6.

b. Website(s) or other Internet site(s)

The project website is located at http://www.isgs.illinois.edu/research/erd/nco2eor.

4. PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

Nothing to report.

5. IMPACT

Nothing to report.

6. CHANGES/PROBLEMS

Changes in approach and reasons for change

There have been no changes in approach on this project.

Actual or anticipated problems or delays and actions or plans to resolve them

There are currently no anticipated problems or delays in the project.

Changes that have a significant impact on expenditures

As no changes have been made or are anticipated, none are expected to impact expenditures.

Significant changes in use or care of human subjects, vertebrate animals, and/or Biohazards

Not applicable.

Change of primary performance site location from that originally proposed

Not applicable.

7. Special Reporting Requirements

Nothing to report.
# 8. Budgetary Information

## Financial Reporting Table

<table>
<thead>
<tr>
<th>Baseline Reporting</th>
<th>Budget Period 1</th>
<th>Budget Period 2</th>
<th>Total</th>
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<tr>
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<td>11/01/14 - 10/31/17</td>
<td>11/01/17 - 4/30/19</td>
<td></td>
</tr>
<tr>
<td>FY15 Q1</td>
<td>FY15 Q2</td>
<td>FY15 Q3</td>
<td>FY15 Q4</td>
</tr>
<tr>
<td>Baseline Federal Share</td>
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<td>192,267</td>
<td>192,265</td>
</tr>
<tr>
<td>Total Baseline Cumulative Cost</td>
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<td>238,601</td>
<td>238,599</td>
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<tr>
<td>Actual Federal Share</td>
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<td>112,827</td>
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<tr>
<td>Actual non-Federal Share</td>
<td>29,328</td>
<td>48,918</td>
<td>47,155</td>
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<tr>
<td>Total Actual Cumulative Cost</td>
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<tr>
<td>Variance Federal Share</td>
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<td>79,438</td>
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<tr>
<td>Variance non-Federal Share</td>
<td>1,561</td>
<td>2,584</td>
<td>821</td>
</tr>
<tr>
<td>Total Variance Cumulative Cost</td>
<td>184,167</td>
<td>107,050</td>
<td>78,617</td>
</tr>
</tbody>
</table>